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KALGOORLIE REGOLITH TERRAIN MAP COMMENTARY SHEET SH51 WESTERN AUSTRALIA 1:1000 000 Regolith Series

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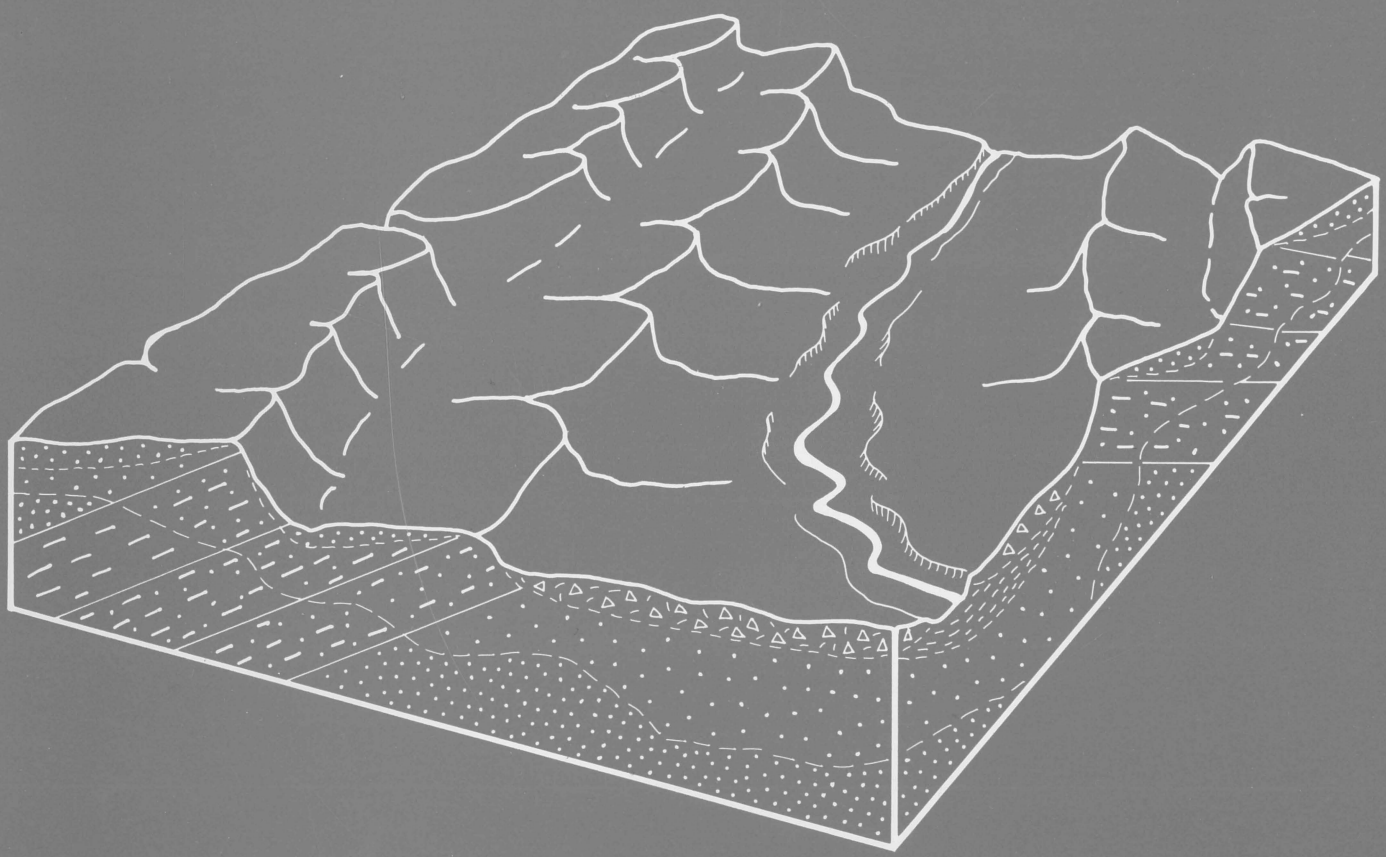

Record 1992/8

by R A Chan, M A Craig, M S Hazell and C D Ollier

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To accompany the map Regolith Terrains of the Kalgoorlie Area, and associated RTMAP database

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Geoscience for Australia's Future

DEPARTMENT OF PRIMARY INDUSTRIES AND ENERGY

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PREFACE

These notes and the accompanying 1:1 000 000 map, *Regolith Terrains Of the Kalgoorlie Area*, and RTMAP database are part of a Bureau of Mineral Resources, Geology and Geophysics' (BMR's) program to determine the distribution, properties and nature of the Australian regolith. This information will be of value to mineral exploration and the development of land use strategies. Regolith terrain mapping has been devised and is being further developed by BMR regolith geologists in order to achieve this goal.

In 1983 BMR initiated a Regolith program that produced an overview 1:5 000 000 scale regolith terrain map of the whole of Australia (Chan et al, 1986). Since the advent of the National Geoscience Mapping Accord in 1990, regolith terrain mapping is part of a multidisciplinary approach and BMR mapping is carried out at 1: 250 000 within Mapping Accord project areas.

The Kalgoorlie 1: 1 000 000 Regolith Terrain Map is available as a published first edition colour hardcopy. The regolith terrain unit and province boundaries have been scanned at 1: 1 000 000 scale into BMR's Intergraph computer assisted drafting/mapping (CAD/CAM) system, and these boundaries are being transferred progressively to Geographic Information System (GIS) format.

Kalgoorlie map unit data from the RTMAP database are available for sale as:

*Digital files
*Printed reports

At present, regolith maps are being digitised at the compilation scale of 1:100 000. Hard copy maps are available at either 1:100 000 or 1:250 000.The RTMAP data from each sheet is also available in either hard copy or digital form. When the digital map data is imported into the BMR GIS, and linked to RTMAP, thematic maps can then be produced in both hard copy and digital format.

Colin Pain
Manager, BMR Regolith Group

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1. INTRODUCTION

1.1 Scope

These notes accompany the 1: 1 000 000 scale regolith map, Regolith Terrains of the Kalgoorlie Area and the associated RTMAP database, and describe the approach, results and interpretation of BMR's regolith mapping in this area of Western Australia.

The Kalgoorlie 1: 1 000 000 sheet area is the second area in Australia to have 1: 1 000 000 scale regolith terrain mapping, the first being the Hamilton sheet area in western Victoria (Ollier and Joyce, 1986). The Kalgoorlie sheet area is the first area to have its data entered into a relational database- RTMAP, specifically developed by BMR's regolith group to accommodate such regolith terrain data (Pain et al, 1991; Lenz, 1991). The Kalgoorlie sheet area was selected by BMR because of the mineralisation history and potential within this part of the Yilgarn Block, and its extensive and deep regolith mantle (Chan, 1988).

1.2 Location

The area mapped is the Kalgoorlie 1: 1 000 000 scale sheet area (28° to 32° S, 120° to 126° E) and consists of sixteen 1: 250 000 map sheets (Figure 1).

1.3 Definitions and Rationale

The term regolith was introduced by Merrill in 1897 and has been variably defined since (see Pain et al, 1991). Regolith is composed of all earth materials above fresh bedrock. It primarily includes deep weathered materials and sediments, but also includes soils, and indurated materials (for example, ferricrete) which may occur as surface duricrusts or as hard layers within the generally unconsolidated regolith mantle. In other words regolith is bedrock which has been altered by processes at or near the surface including weathering, erosion, transportation, and terrestrial sedimentation.

Previous BMR publications document and explain the need to study the regolith and our approach to this study (Chan et al, 1986; Ollier and Joyce, 1986; Chan et al, 1988; Chan, 1988; Pain et al, 1991).

The Regolith Terrain Unit is the basic mapping unit and is defined most recently by Pain et al (1991) as:

> "A land area characterised by similar landform and regolith attributes; it refers to an area of land of any size that can be isolated at the scale of mapping."

The map shows mapping units, and thus each unit on the map will in reality be a composite of various regolith types and landforms. This is because there is a fundamental difference between regolith terrain classification units and regolith terrain mapping units. Pain et al (1991) explain this difference:

> "The arrangement of regolith terrain units in a classification is based on logical and hierarchical relationships between the different kinds of regolith terrains. However, such an arrangement has little in common with the spatial arrangement of these units in a landscape. The arrangement of regolith terrain units in a landscape depends on the geomorphic development and character of the area."

KALGOORLIE 1:1 000 000 SHEET AREA

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28 °00 ' S

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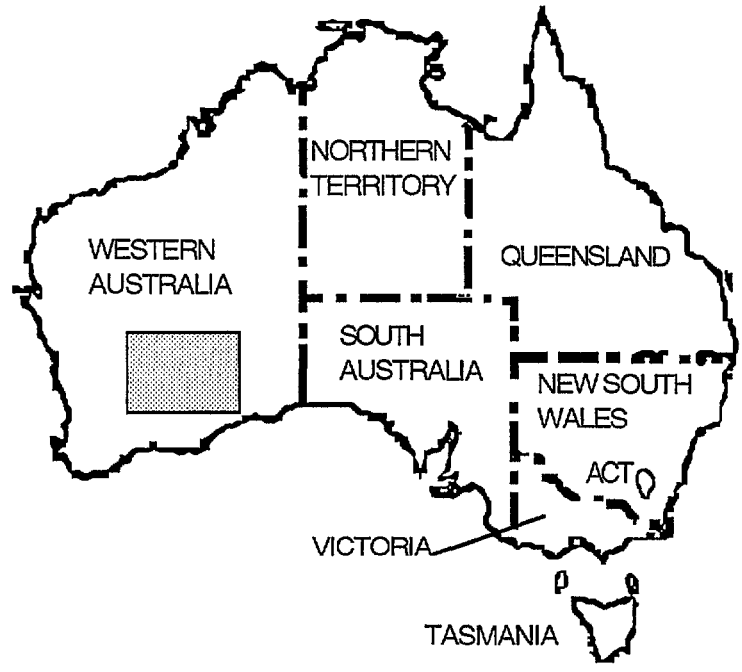

Figure 1. Location diagram for the Kalgoorlie 1: 1 000 000 sheet with component 1: 250 000 sheet areas

Pain et al (1991) define these types of units:

> "*Classification units* consist of regolith terrain units which are defined in terms of various regolith / terrain characteristics They are ideal or conceptual units which can be precisely defined.
>
> *Mapping units* are real regolith terrain units that can be conveniently mapped, and their definition will therefore depend to some extent on the scale of the map. The more detailed the scale, the more pure the regolith terrain units will be. A mapping unit will almost always include regolith terrain units that do not belong to the appropriate classification unit. These different units occur in areas that are to small too appear on the map, for example, narrow sedimentary areas in floodplains in dominantly deep weathered terrain."

When using the map, it must be remembered that it shows mapping units. This means that the regolith at a particular point in the field will not necessarily be that which is shown on the map for the surrounding area within that regolith terrain unit. The regolith at a particular point may only be a minor regolith type, perhaps mentioned in the database but not highlighted as part of the mapping unit description on the map. The same applies to landforms. The map should be used only as a guide to the dominant regolith types in any one area, not to identify a particular regolith type or profile of regolith types and associated landform at any given point.

1.4 Previous Work

Jutson (1914,1934) produced an account of the geomorphology of the Yilgarn Block. However, very limited regional regolith mapping has been undertaken within the Yilgarn Block with the exception of Churchward's map of 1977, at 1: 250 000 scale and the Geological Survey of Western Australia's preliminary 1: 100 000 regolith mapping of the Kalgoorlie and Dunnsville sheets. Regional geological maps of the Officer Basin (Jackson & van de Graaff, 1981) and the Eucla Basin (Lowry, 1970) provide useful insight about the regolith.
Before BMR's regolith mapping, available regolith information, especially in the Yilgarn Block, was limited, and mentioned mostly as asides to a more dominant bedrock theme. Regolith terrain units from the 1: 5 000 000 scale compilation of Australia (Chan, et al, 1986) provided a framework for existing data prior to fieldwork and more detailed compilation of regolith terrain units at 1: 1 000 000 scale.

1.5 Methodology

Regolith terrain mapping methodology is still developing and is being adapted to progressively larger scales of mapping. Initially, for the 1: 5 000 000 scale mapping, the methodology involved dominantly research of literature and maps, with variable input from remotely sensed images, and did not involve any fieldwork. This map was intended to provide an overview of the regolith at continental scale within a minimal time frame. Essentially this methodology resulted in synthesis and updating of relevant published data. As a result gaps and errors in the regional data were identified, but the objective of gaining a continental overview of regolith terrains was achieved.

The methodology for the 1: 1 000 000 scale regolith terrain mapping incorporates new regolith data and new ideas relating to regolith and landscape evolution based on fieldwork. So far three 1: 1 000 000 sheet areas have been mapped and results produced as: a preliminary map of Hamiliton in western Victoria; a preliminary map, followed by this first edition colour map, of Kalgoorlie; and part compilation of the Clermont sheet area in central-east Queensland.

Kalgoorlie regolith terrain units are defined from the recognition of distinct patterns of recurring terrain elements with characteristic regolith associations based largely on analysis of remotely sensed data, and interpreted using geomorphological principles. Regolith terrain unit boundaries were compiled on 1: 500 000 scale rectified Landsat-5 Multispectral Scanner (MSS) hardcopy imagery (bands 4, 5, 7), other than in the region surrounding Kalgoorlie township where 1: 250 000 scale rectified Landsat-5 Thematic Mapper (TM) hardcopy imagery (bands 1,4,7) was used. Some boundaries were revised using NOAA Advanced Very High Resolution Radiometer (AVHRR) imagery and Nimbus-7 Coastal Zone Colour Scanner (CZCS) imagery, particularly in areas not visited, and those which were indistinct on Landsat MSS imagery such as fire-burn areas in the south-west of the Officer Basin and the western part of the Eucla Basin (Chan, 1988).

Fieldwork was used to validate interpretations of regolith terrain features based on analysis of remotely sensed data and publications research. However, ground coverage was limited. Fieldwork was restricted to the Yilgarn Block half of the map sheet as this region is covered by thick regolith and has many opencut mines and drillhole information; little previous regional regolith mapping had been done in this area prior to the commencement of this project in 1985. Information about regolith at depth was gained from inspection of opencut mines, costeans and scrapes, as well as natural breakaways. Fieldwork was carried out by C.D. Ollier, D.L. Gibson, M.A. Craig, and R.A. Chan.

Information was obtained from both literature and map reviews for the whole area, but particularly for areas not visited in the field. The main discipline areas for these reviews were geology, geomorphology, soils, topography, vegetation, and land systems. All known relevant published data and information used to describe regolith terrain units is presented and referenced in the RTMAP database.

In summary, the Kalgoorlie regolith terrain mapping is a major regional assessment of regolith terrains based on the interpretation of remotely sensed data in conjunction with field and published data. Because of inadequate and inconsistent coverage of fieldwork the Kalgoorlie map will suffer from inaccuracies. It is not intended to be a detailed picture of regolith in the area, but more as a guide to regolith/terrain distribution and associations.

At present, regolith terrain mapping is being carried out within BMR's National Geoscience Mapping Accord project areas at 1: 250 000 scale with compilation at 1: 100 000 scale. Extensive reconnaissance fieldwork is an integral part of this latest approach to regolith terrain mapping, as is systematic air-photo interpretation, drainage analysis, and the use of additional remotely sensed data sets, such as radiometrics.

2. SETTING

2.1 Bedrock Geology

The Kalgoorlie 1: 1 000 000 sheet area covers a number of geological provinces and major structural elements (see Major Structural Elements diagram on accompanying map). The western half of the map area is underlain by NNW trending Archaean granitoid-greenstone sequences of the Eastern Goldfields and Southern Cross tectonic provinces of the Yilgarn Block. The northeastern quadrant of the map covers the Late Proterozoic to Cretaceous, mainly clastic, sedimentary rocks of the Officer Basin and the onlapping Eucla Basin. The southeastern quadrant is underlain by NNE trending Early to Middle Proterozoic metamorphic and granitic rocks of the Albany-Fraser Province and further east the Cretaceous to Tertiary carbonate and clastic sequences of the Eucla Basin. Further detailed mapping of parts of the Yilgarn at 1:100 000 is now underway as part of of the National Geoscience Mapping Accord (NGMA)

The Kalgoorlie area is particularly rich in gold and nickel associated with the Norseman-Wiluna Belt of the Yilgarn Block, and has a long history of gold mining. The Norseman-Wiluna Belt trends NNW within the Eastern Goldfields Province of the Yilgarn Block. Greenstones within this belt are anomalously enriched in volcanic-hosted gold and komatiite-associated nickel-copper. Furthermore, volcanogenic copper-zinc ores occur in the felsic volcanics zone along the eastern half of the Norseman-Wiluna Belt (Groves and Batt 1983). Older greenstones on either side of the Norseman-Wiluna Belt contain gold deposits hosted by banded iron formation (BIF). Thick complex regolith generally obscures the bedrock mineralisation in the Yilgarn Block, but it hosts alluvial concentrates (including deep leads) and supergene enrichments derived from the primary bedrock mineralisation beneath the regolith (Chan 1988).

2.2 Physiography

Regional relief decreases from highs of around 500m in the north and 450m in the west to around 100m in the southeast of the map area (see Regional Relief and Palaeodrainage diagram on the accompanying map). This reflects the regional NW-SE topographic gradient. Local relief is less than 10 m in much of the area and exceeds 20 m in only a few parts. This subdued relief is reflected in extensive flat to undulating plains broken by dunes, depressions, rises (particularly in the eastern half of the map area), and ridges, hills, plateaux (mainly in the western half). Numerous playa lakes, many of them large (up to several kilometres wide and tens of kilometres long), form chains generally trending towards the southeast and occupying the lower areas.

Generalised physiographic regions have been defined by Jennings and Mabbutt (1986) as part of their continent-wide physiographic review. The Kalgoorlie 1: 1 000 000 sheet area falls within their Yilgarn, Sandplain and Nullarbor (physiographic) Provinces.

The landforms in the western half of the map area relate to the Yilgarn Block and Albany Fraser Province geological domains. Dominant landforms within the Yilgarn Block are sandplains, plateaux and iron indurated breakaways, granitic and alluvial plains,NNW-SSE striking ridges of mainly metamorhpic rocks (greenstones), granitic/gneissic hills and rises with extensive debris fans particularly in the north, and large salt lakes and dunes along broad valleys. In the southern central portion of the map, landforms associated with the northern part of the Albany-Fraser Province are sandplains and stripped plains on gneiss, with low hills of granite and metamorphic rocks, and small salt lakes along shallow valleys.

In the eastern half of the map area the landforms relate to the Officer and the Eucla Basins. In the Officer Basin sandplains with small salt lakes and residual rises and hills surround

and separate dunefields with east-west longitudinal dunes of the Great Victoria Desert Dunefield: the dunefield in the northeast of the map area is broken by low tablelands and ridges. Landforms in the Eucla Basin, in the southeast of the map area, consist of flat plains along the north and west basin margins with shallow closed depressions in the north. The marginal plains enclose a flat to gently undulating limestone karst plain with closed depressions and caves. Joint controlled low ridges or rises occurr on the southern edge of the map area.

These physiographic regions broadly relate to the regolith terrain provinces described in section 3.2.4, which in turn are based on mapping units described in chapter 4 and appendix A2.

2.3 Vegetation

Vegetation has been a useful mapping tool because cultural interference within the mapping area is limited. A comparison of the *Pre-European Natural Vegetation Map of Australia* and the *Present Vegetation Map of Australia* (AUSLIG,1990) shows that, other than changes in vegetation in the far southwest corner of the map area due to logging associated with mining, there is practically no change from the natural vegetation. Thus vegetation has been used as a guide to natural soil associations and toposequences, and thereby as a guide to associated landforms and substrate regolith. The following summary description of the vegetation is based on the *Vegetation Survey of Western Australia* by Beard over parts of four 1: 1 000 000 map sheet areas: Great Victoria Desert (Beard,1974), Nullarbor (Beard, 1975), Murchison (Beard, 1976), and Swan (Beard, 1981).

The vegetation of the Kalgoorlie 1: 1 000 000 map area can be broadly divided into four areas:

* the northwest, as far east as Laverton and south almost to Menzies within the Yilgarn Block;
* the southwest, which can be subdivided into the largely granitic terrains in the west and the greenstones and associated terrains elsewhere within the Yilgarn Block;
* the southeast, covering mainly the Eucla Basin;
* the northeast, covering the Great Victoria Desert which includes the Officer Basin and parts of the Yilgarn and the Albany-Fraser Blocks.

These divisions are due to differences in bedrock and regolith (especially soils), and rainfall. Vegetation changes associated with toposequences occur in most areas with the topographically lowest areas, occupied by the playa lakes systems, usually having an association of saltbush and bluebush.

In the northwest, ridges are usually covered by scrubby acacias whilst on the plains low mulga woodlands with scattered eucalypts are the main vegetation types. The best growth on the plains is associated with red loamy soils. Towards the south mulga becomes mixed with cypress pines, sheoaks and eucalypts.

In the southwest, scrubby mulga and sheoaks are dominant on the more resistant strata which form rocky strike ridges, whereas, eucalypts occur on less abrupt and more deeply weathered greenstone strike ridges and on the plains in between. There is a general association of saltbush and bluebush understory with areas of calcareous soils; the understory changes independantly of the overwood. On the granite terrains in the west, the vegetation consists of scrub heath on the high sandplain remnants grading to progressively

larger tree species downslope (through acacia and casurina to mallee and then other eucalypts, and then finally tall salmon gum woodland in the valleys).

Southeastwards in the Eucla Basin the vegetation changes from thickly wooded succulent steppe (eucalypts, mulga, sheoak and saltbush) on the borders of the Eucla Basin to the open saltbush plain with trees in dongas which is characteristic of the calcareous bedrock areas of the Nullarbor Plain.

In the northeast, in the sand dune and sandplain country of the Great Victoria Desert, the main vegetation types consist of marble gum, mallee and spinifex. The sand dunes are usually devoid of vegetation.

2.4 Soils

The regolith profile almost always has soil as the top layer. Occasionally soil is the total regolith component and thus rests directly on fresh bedrock. Old soils (palaeosols) are a subsurface or exhumed surface layer. Soil formation is related to parent material, topography, vegetation, climate and time; parent material may be either an *in situ* weathered substrate or transported material. Topography affects depth and chemical composition of the soil depending on whether the soil is receiving material from upslope or losing it downslope. Vegetation and soil formation are commonly intimately related. Climate affects vegetation, weathering, erosion rates and subsurface movement of materials. Soils being the surface expression of regolith are therefore relevant indicators for regolith terrain mapping.

The following summary description of soils is a very general overview based on the *Atlas of Australian Soils* (Northcote, 1968), *Geology of the Officer Basin* (Jackson & van de Graff, 1981) and *Vegetation Survey of Western Australia* by Beard (1974, 1975, 1976 and 1981).

The granitic terrains of the Yilgarn Block in the western part of the map area consist of undulating upland sand plains divided by broad valleys. Soils are generally highly leached sandy yellow earths and sandy loams commonly underlain by a zone of hardened saprolite or a red brown hardpan. Breakaways are a common feature of these terrains separating plateaux or upland plains from the broad open valleys. Red and yellow duplex soils occur below the breakaways, gradually thickening downslope. Grey brown calcareous soils and some duplex soils occur in the valleys. Coarse sandy or gravelly soils are found around remnant granite tors and on outwash fans in low-land areas.

In the greenstone terrains of the Yilgarn Block soils are mainly skeletal along the ridges, thickening downslope. Shallow calcareous loams and earths of the mid and lower slopes grade to cracking clay soils and neutral red earths in the intervening plains and valleys. Pediments abutting greenstone ridges frequently have a red brown hardpan at shallow depth.

Within the Albany-Fraser Province undulating lands are broken by narrow rocky ridges. Along the ridges soils are generally shallow stony sands and loams. In the lower areas soils are deeper and more clayey.

In sandy areas of the Officer Basin dune sands and sandplains are red, structureless and composed of the same material. In the interdune corridors soils consist generally of red earthy sands frequently developed on a truncated profile. Interdune soils are occassionally overlain by the red dune sands. In some areas dunes also overlie duricrust residuals. Ridges consisting of the Yilgarn Block greenstone outliers are very rocky with little soil. On flatter ground surrounding the greenstone ridges there is typically a red loam. Outlying

Yilgarn Block granites usually weather identically to the Officer Basin sediments resulting in sandy soils and duricrusted mesas.

On the Bunda Plateau, in the Eucla Basin, soils on the broad rises are typically shallow (30-40cm deep) calcareous loams and earths mixed with limestone rubble. On the intervening broad flats soils are deeper (more than 90cm) brown calcareous earths. Calcrete is commonly present at shallow depths. It is believed that the shallow soil on the rises is the result of deflation in the Pleistocene. On the north and western flanks of the Eucla Basin, on the Nyanga and Carlisle Plains, the main soil is a deep brown calcareous earth which locally may be sandy.

Extending through most areas, and occupying the lowest areas topographically are the playa lake systems. The playa lake channels are mostly devoid of true soils, however, gypseous and saline loams, highly calcareous earths and occasional yellow duplex soils occur in the fringing areas. Dunes and lunettes are common and deposits of halite, gypsum, lime and alunite may occur.

2.5 1: 5 000 000 Regolith Terrains

The 1: 5 000 000 scale *Regolith Terrain Map of Australia* (Chan, et al, 1986) provides a continent-wide overview of regolith and associated landforms based largely on pre-existing knowledge. Within the Kalgoorlie 1: 1 000 000 sheet area eleven regolith terrain units have been mapped: Sandstone, Kalgoorlie, Lake Hope and Mount Fisher within the Yilgarn Block map portion; Zanthus within the Albany-Fraser Province; Great Victoria 1 and 2, Neale and Carnegie within the Officer Basin; and Nullarbor and Carlisle within the Eucla Basin (Figure 2).

There is a broad similarity between these 1: 5 000 000 scale regolith terrain units and some of the 1: 1 000 000 scale regolith terrain provinces (see the Regolith Terrain Provinces diagram on the accompanying map). Because of the more detailed scale of mapping and incorporation of new data, the fifty-eight regolith terrain units from the 1: 1 000 000 scale mapping give a more comprehensive guide to the distribution of the regolith and associated terrain.

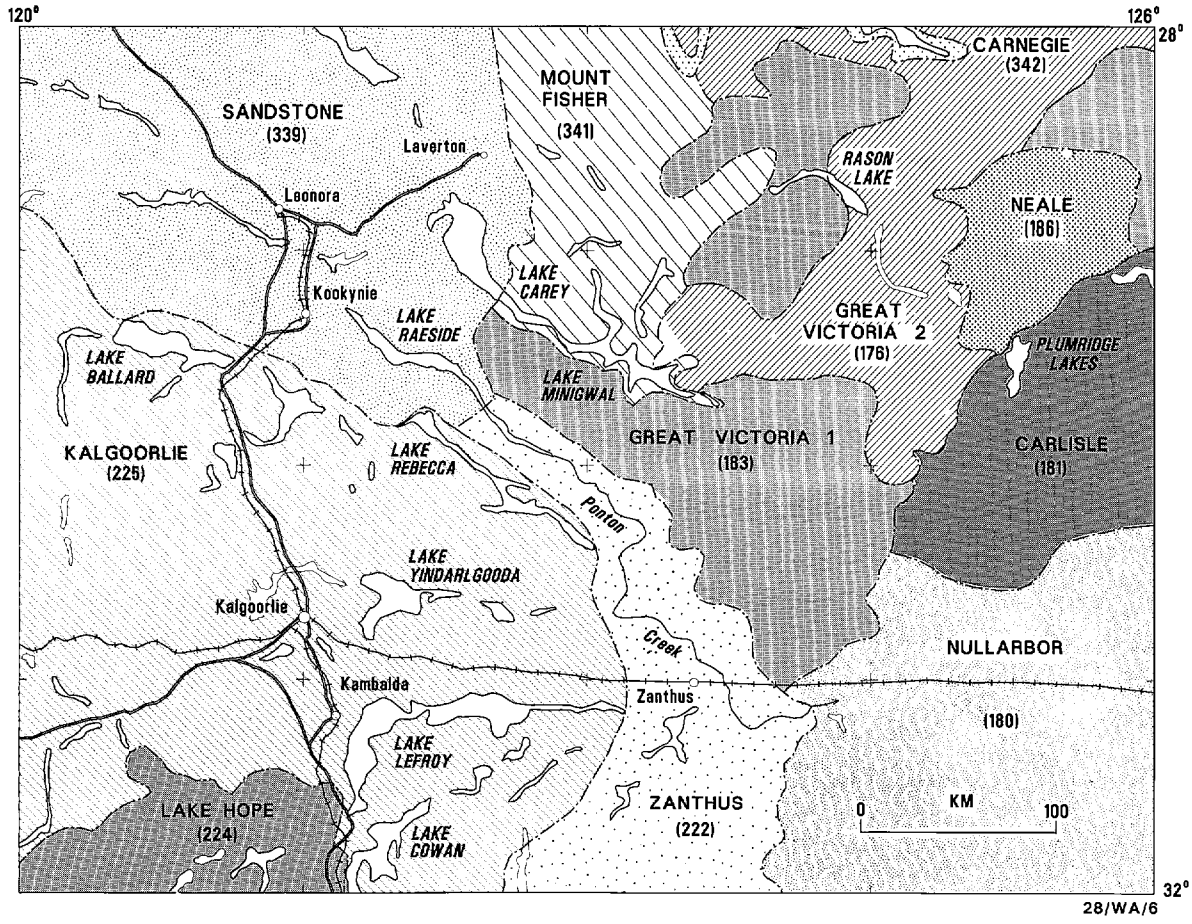

Figure 2. Regolith terrain units from the 1: 5 000 000 scale regolith terrain map of Australia (non-hachured areas are playa lakes).

3. THE KALGOORLIE REGOLITH TERRAIN MAP

3.1 Map Face

3.1.1 Regolith Terrains

The map face shows the distribution of regolith terrain units: these units provide the framework for attribute data in the accompanying RTMAP database. The fifty-eight regolith terrain units are classified into sixteen broad regolith terrain associations depicted in the map legend. Each association has a unique two component letter symbol, eg, Sp, which reflects the two components of the mapping unit, namely, the regolith (capital letter) and the terrain (lower case letter). Regolith terrain units, (eg, Dp3), within a particular category (Dp) are identified by specific numeric suffixes. The regolith terrain unit legend was developed by R.A.Chan with 1: 1 000 000 scale regolith terrain mapping of the whole of Australia in mind. The Kalgoorlie regolith terrain unit legend is a subset of this total classification.

There are three broad regolith groupings: deep weathered materials, ie >2 m thickness, (Deep Weathering Dominated Terrains-D); sediments (Sediment Dominated Terrains-S); and minimal (<2 m thickness) or no regolith (Bedrock Dominated Terrains-B). Where sediments overlie deep weathered materials the letter symbol identifies the sediments, and a dot pattern indicates underlying deep weathered materials. Each broad regolith category is subdivided according to the relative extent of distribution of the upper regolith substrate into extensive mantle (>80% coverage) and interrupted mantle (50%-80% coverage) subcategories. These categories are useful in understanding regolith genesis, and are of potential use to mineral exploration.

Each regolith terrain category defines one broad terrain: some of these terrain categories approximate pure classification units, as defined within the landform table hierarchy of the RTMAP database, for example, Dp (erosional plain), and occur within the extensive regolith mantle subcategories; others are mixed classification units, which are more typical of mapping units, for example, Du (undulating plain with outcrops and sediments), and occur within the Interrupted mantle subcategories. Sediment Dominated Terrains are divided into continental and coastal sediments but only continental sediment types occur on the Kalgoorlie map.

The colour scheme developed for this regolith terrain classification reflects the broad regolith categories: browns for Extensive Deep Weathering Mantle, oranges for Interrupted Deep Weathering Mantle, greens for Extensive Continental Sediment Mantle, blues for Extensive Coastal Sediment Mantle (not on Kalgoorlie map), yellows for Interrupted Sediment Mantle, purples for Extensive Outcrop Or Minimal Regolith Mantle, and pinks for Interrupted Outcrop Or Minimal Regolith Mantle. A random red dot pattern overprint depicts areas of sediments which are underlain by deep weathering profiles.

Regolith terrain units are grouped into regolith terrain provinces as shown by thicker black boundaries. Regolith terrain provinces are groupings of spatially related regolith terrain units and tend to reflect underlying geological provinces. A separate diagram on the map displays regolith terrain provinces and highlights their association with major structural elements.

3.1.2 Mineral Occurrences

Mineral occurrences (used here as a general term to include anything from minor showings to major deposits) are shown on the map to indicate any co-incidence with regolith terrain units (see chapter 6).

Mineral localities are symbolised by type. There is no indication of size or relative importance. The mineral occurrences legend lists mineral associations and categorises them as either regolith or bedrock occurrences; it also indicates the number of occurrences within each occurrence type. Related commodities, for example, various gold associations, have similar symbols. Regolith occurrences are emphasised by larger, though similar, solid red symbols.

The map shows a generalised representative coverage of mineral localities as there are far too many localities to show every individual one on the map. Over 5 000 mineral deposits, however, have been digitised for the Kalgoorlie regolith terrain mapping and are held in BMR's MINLOC database. Details explaining this dataset are in two map notes: Mineral Localities; and Sources of Deposit/Occurrence Data.

3.2 Diagrams

3.2.1 Indurated Regolith

This diagram displays information derived from the RTMAP database. The diagram shows complex associations of a variety of indurated materials cemented by iron, silica, and carbonate, covering nearly all the map area. The legend distinguishes between major and minor occurrence associations.

Indurated materials occcur as surface duricrusts or nodules, or as subsurface consolidated layers or nodules within the regolith. These materials result from the absolute or relative accumulation of cementing agents. Known cementing agents include: iron, silica, carbonate, gypsum, aluminous oxides and hydroxides, and clays. Materials vary in hardness according to their degree and type of induration. Three classes are defined by Pain et al (1991): completely cemented, that is >90% of material has been cemented (ferricretes, silcretes etc.); moderately cemented, that is 70%-90% cemented (includes many mottled zones of weathering profiles); and partially cemented, that is <70% cemented (includes hardpans).

3.2.2 Regional Relief and Palaeodrainage

This diagram provides a backdrop of regional relief to the palaeodrainage information that was mainly compiled from published sources. Palaeodrainage associated with playa lakes was, however, refined as a result of the Kalgoorlie regolith terrain mapping. Depressions in the regional relief broadly correlate with this playa lakes system. Palaeodrainage in the Officer Basin and the Eucla Basin is also shown and coincides with certain landforms: undulations in the duricrust and sand plains of the Officer Basin, and dongas and ridges in the Eucla Basin.

The variable density and limited extent of palaeodrainage is due to the degree of preservation of associated landforms, bedrock lithologic variation and the style of regolith induration. The style and detail of mapping from which this published information was derived also introduces limitations.

3.2.3 Major Structural Elements

This diagram shows the geological domains of the bedrock geology. These domains, with their different surface bedrock lithologies, influence landscape and regolith evolution. This can be seen by comparing the Major Structural Elements diagram with the Regolith Terrain Provinces diagram.

Four major structural elements occur within the Kalgoorlie map area: the Yilgarn Block, the Albany-Fraser Province, the Officer Basin, and the Eucla Basin. The Yilgarn Block is subdivided into tectonic provinces, two of which occur within the map area: Eastern Goldfields Tectonic Province and Southern Cross Tectonic Province.

3.2.4 Regolith Terrain Provinces

Thirty regolith terrain provinces have been identified and named (each province is named after a topographic feature within the province area), and are displayed in this diagram. A particular regolith terrain province comprises a unique assembly of regolith terrain units. The legend lists, in order of size, component regolith terrain units for each regolith terrain province. Some regolith terrain provinces contain only one regolith terrain unit, but most contain multiple regolith terrain units. Moreover, a particular regolith terrain unit may fall within more than one regolith terrain province.

The legend groups regolith terrain provinces according to major structural element associations (see section 3.2.3). There are ten associations which are of three types: Dominant Associations (regolith terrain provinces clearly reflect a particular solid geological structural domain or part thereof), Transitional Associations (regolith terrain provinces reflect a transitional zone between two or more such domains), and No Association (regolith terrain provinces cut across various structural domains).

Regolith terrain provinces summarise the distribution of individual regolith terrain units and allow comparison, at an appropriate scale, with the underlying solid geology, thereby facilitating an understanding of the regional geologic-geomorphic evolution. In contrast, map legend terrain units are categorised by similar regolith and landscape formation processes. These categories may cut across solid geology associations (for example, Si and Ss). The different ways of portraying the same basic regolith terrain unit data are complementary and can be interwoven to portray a more complete picture of regolith terrain evolution.

3.3 Photographs

Four photographs with descriptions are included in the map surrounds to pictorially display examples of regolith terrain units which are representative of three major structural elements. They are from west to east (left to right) across the map: the Yilgarn Block (one photograph each for Granitic terrain, and Greenstone terrain); the Officer Basin; and the Eucla Basin.

4. MAPPING UNITS

In this section brief summary descriptions of the distribution and broad characteristics of the Kalgoorlie 1:1 000 000 scale regolith terrain units are given according to the sixteen categories of the map legend classification. Appendix A2 gives details of core attributes from the RTMAP database for each of the fifty eight regolith terrain units. For complete descriptions of all attribute data the map user should refer to the RTMAP database.

4.1 Extensive Deep Weathering Mantle (Dp, Dr, Ds)

Regolith is dominantly deep weathered (bedrock and/or sediments), covering more than 80% of the surface area of each mapping unit. Regolith is greater than 2 m deep and may in some cases extend to a depth of several hundred metres.

4.1.1 Erosional Plains (Dp)

There are four regolith terrain units in this category and are within the Carlisle Plain and the Nyanga Plain regolith terrain provinces in the Eucla Basin. Flat plains (erosional, karst, and sand) dominate with large (to 20 km diameter) shallow (to 30 m) depressions in the north. Shallow to deep calcareous soils overlie variable calcrete (pisolitic, sheet, rubbly, nodular, massive) and clay layers on partly weathered bedrock. Within the Nyanga Plain Province the thickness of calcrete and clay is about 5 m but can extend to 8 m. Within the Carlisle Plain Province the calcrete is commonly pisolitic and 2 m thick. Bedrock is dominantly calcarenite, but includes sandstone, particularly in the north, and limestone.

Calcrete layers such as these are sometimes referred to as kankar (for example, Lowry 1970). The calcareous clay of the Nyanga Plain is believed to be largely residual. However, there has been some reworking of clay by wind before it lithified to form calcrete The soil and calcrete of the Carlisle Plain appears to have formed after a period of deflation and to be younger than the calcrete of the Nyanga Plain (Lowry, 1970).

4.1.2 Ridges, Hills, Rises (Dr)

There are five regolith terrain units in this category and they fall within twelve regolith terrain provinces which occur dominantly within the Yilgarn Block (Granitic terrain - Donkey Rocks, Emu Rocks, Kurrajong Range, Niagara Creek, Mulgabiddy Creek; Greenstone terrain - Coowarna Rocks, Kalalgoorlie, Leonora) and the Officer Basin (Ethel Hill, Minnie Hill, Pitcher Range, Bartlett Bluff, Mulgabiddy Creek). One terrain province occurs over the northern extension of the Albany-Fraser Province (Bartlett Bluff). Landforms consist of rises (including branching ridges of Dr1), erosional plain, etchplain, escarpments, and the ubiquitous breakaway. Relief extends to 50 m and averages 20 m. Deep weathered bedrock dominates, commonly with pallid and/or mottled zones overlain variously by sandy soils, siliceous hardpan (Wiluna Hardpan), silcrete (over 3 m thick), ferruginous nodules (2 m to 8 m thick), colluvium (with sheet calcrete in places) and alluvium. Other features include ferruginous and siliceous skins and silicified bedrock at depth. Depth of weathering ranges from 20 m to 250 m. Bedrock varies widely and includes metamorphic, igneous and sedimentary rocks.

Regolith terrain unit Dr1 consists of the deep weathered silcrete-capped granitic ridges with a dendritic pattern. The unit could be interpreted as a now inverted palaeodrainage system which flowed NW. Se1 incorporates probable relict fans that eroded from Dr1, whereas Sf1 consists of active fans presently eroding from Dr1.

4.1.3 Sand Covered Plateaux (Ds)

The only regolith terrain unit in this category occurs in three regolith terrain provinces (Boorabbin, Donkey Rocks, Kalgoorlie), but primarily within the Boorabbin Province which straddles the Swan-Avon palaeodrainage divide (see Regional Relief and Palaeodrainage diagram on the accompanying map). All three provinces lie within the Yilgarn Block. The terrain is composed of undulating plateaux with relief of less than 9 m, edged in places by abrupt breakaways nearing heights of 20 m. The plateaux are mainly surrounded by Du in the south and Si in the north, with Sp in between. Deep yellow sands over 5 m thick with clay glaebules and ferruginous nodules overlie in places at least 50m of saprolite. Mottling occurs in the saprolite and in places ferricrete occurs on the breakaways. Bedrock is dominantly granite but includes metasedimentary and metavolcanic rocks.

Much controversy has related to the origin of these yellow sands (see Section 5.1.2), which are now thought to be residual material (grus) derived from the dissolution of kaolin from the underlying granitic saprolite. Parts of the upper layer of the sand sheet have been locally transported by cut and fill, as evidenced by stone lines.

4.2 Interrupted Deep Weathering Mantle (Db, Du)

Regolith is formed by the deep weathering of bedrock and/or sediment and covers about 50% to 80% of the surface area of each mapping unit. The depth of regolith is greater than 2 m and may in some cases extend to a depth of several hundred metres.

4.2.1 Duricrusted Buttes/Mesas/Interfluves, and Sediments (Db)

Two regolith terrain units in this category occur within four regolith terrain provinces (Cowarna Rocks, Edjudina Range, Kalgoorlie, Leonora) within the Greenstone terrain of the Yilgarn Block. The terrain is composed of remnant landforms, with relief to 20 m, and preserved due to widespread duricrusting. Landforms consist of rises, etchplains (with buttes, mesas, interfluves and breakaways), and depositional plains. Deep weathered bedrock, generally over 50 m thick, is preserved by a duricrust on high areas and is overlain by sediments on low rises and intervening plains. Indurated regolith forms ferricrete cappings, ferruginous gravels, deep weathered ferruginous profiles, and calcrete and siliceous hardpans associated with colluvium. Bedrocks include a range of greenstone related rocks and also include banded iron formation within Db2, as well as some felsic extrusives within Db1.

4.2.2 Deep weathered Plains with Outcrops and Sediments (Du)

The seven regolith terrain units within this category occur in three regolith terrain provinces within the Granitic terrain of the Yilgarn Block (Binneringie, Boorabbin, Cave Hill) and in three regolith terrain provinces within the Greenstone terrain of the Yilgarn Block (Bremer Range, Cowarna Range, Kalgoorlie). All Du regolith terrain units cluster in the south-western portion of the Yilgarn Block within the map area. The terrains range from a complex mixture of landforms (erosional landforms, etchplains, rises, depositional plains, drainage depressions and colluvial fans) to relatively simple erosional plains. Relief is variable and from more than 50 m for the erosional landforms to 25 m for the tors within the etchplain, and to less than 2 m in some drainage depressions. The regolith complexity reflects the landform complexity. The regolith consists of various mixtures of deep weathered bedrock more than 50 m thick eg, in Figure 3; relatively shallow residual regolith (commonly less than 0.5 m thick) associated with subcrop, outcrop, and colluvial and alluvial sediments. Indurated regolith (sometimes over 5 m thick) mainly in the form of ferruginous nodules and calcrete (over 2 m thick), mantles the rises and is associated with

colluvium especially in Du4 (Figure 4). Calcareous nodules and ferricrete (Figure 3) also occur.

Regolith stripping is a significant process within these terrains. Stripping is particularly evident in Du2 in the Cave Hill Province where many granite tors and large domes are exposed (Figure 5). This area of stripping is the erosive zone (to 50 km wide) between the higher sand covered plateaux of Ds1 in the Boorabbin Province and the lower base level of the playa complex of Sp1 in the Lake Lefroy Province. As a result Du2, and in a similar way but to a lesser extent Du1, is expanding at the expense of Ds1 due to the lower base level of Sp1.

4.3 Extensive Continental Sediment Mantle (Sd, Ss, Se, Sf, Sv, Sp)

Regolith is dominantly terrestrial sediments, covering more than 80% of the surface area of each mapping unit. Commonly sediments are underlain by a few hundred metres of deep weathered bedrock. A dot pattern is used to show this on the map.

4.3.1 Continental Dunefields (Sd)

Two regolith terrain units occur within this category in the map area. Sd1 is more extensive and occurs in four regolith terrain provinces (Ethel Hill, Minnie Hill, Pitcher Range, Neale Plateau) within the Officer Basin in the northeast of the map area; Sd2 is localised in one regolith terrain province (Streich Mound) which is transitional between the Officer Basin, the Albany-Fraser Province and the Yilgarn Block. The terrain consists of 5m to 15 m high E-W sand dunes of the Great Victoria Desert; landforms consist of dunefields, sandplains, and rises. Regolith consists of quartz dune sands and red earthy sands (less than 3 m thick) in interdune corridors overlying 50m to rarely >100 m of deep weathered, commonly ferruginised or silicified, bedrock. Indurated regolith in Sd1 also includes ferricrete, silcrete and calcrete. Bedrock is mainly adamellite and migmatite in Sd1 and sandstone in Sd2.

4.3.2 Sand Covered Plains (Ss)

Five regolith terrain units are within this category and occur in four regolith terrain provinces: 1 Kurrajong Range - in the NW of the map area in the Yilgarn Block; 2. Neale Plateau - in the Officer Basin; 3. Moon Rock - transitional between the the Eucla Basin and the Albany-Fraser Province; and 4. Streich Mound - transitional between the Officer Basin, the Albany-Fraser Province and the Yilgarn Block. The terrain consists of flat to gently undulating sand plains with rises and some dunefields. Relief is usually less than 5 m but may approach 15 m. The regolith consists of sheets of quartz sand (2 to 4 m thick) and some gravel covered rises variously overlying siliceous hardpan (less than 2 m thick), calcrete (sandy/sheet/nodular), alluvium and colluvium (sometimes with ferricrete and silcrete pebbles), all overlying thick (>100 m) saprolite which is commonly silicified/ferruginised. Bedrock is mainly sedimentary, but also includes metamorphic and igneous rocks.

Figure 3: Massive ferricrete over deep weathered mottled bedrock: Gulch Pit, near Sand King Mine; about 20 km NW of Ora Banda. [Regolith terrain unit Du4 in Kalgoorlie regolith terrain province.]

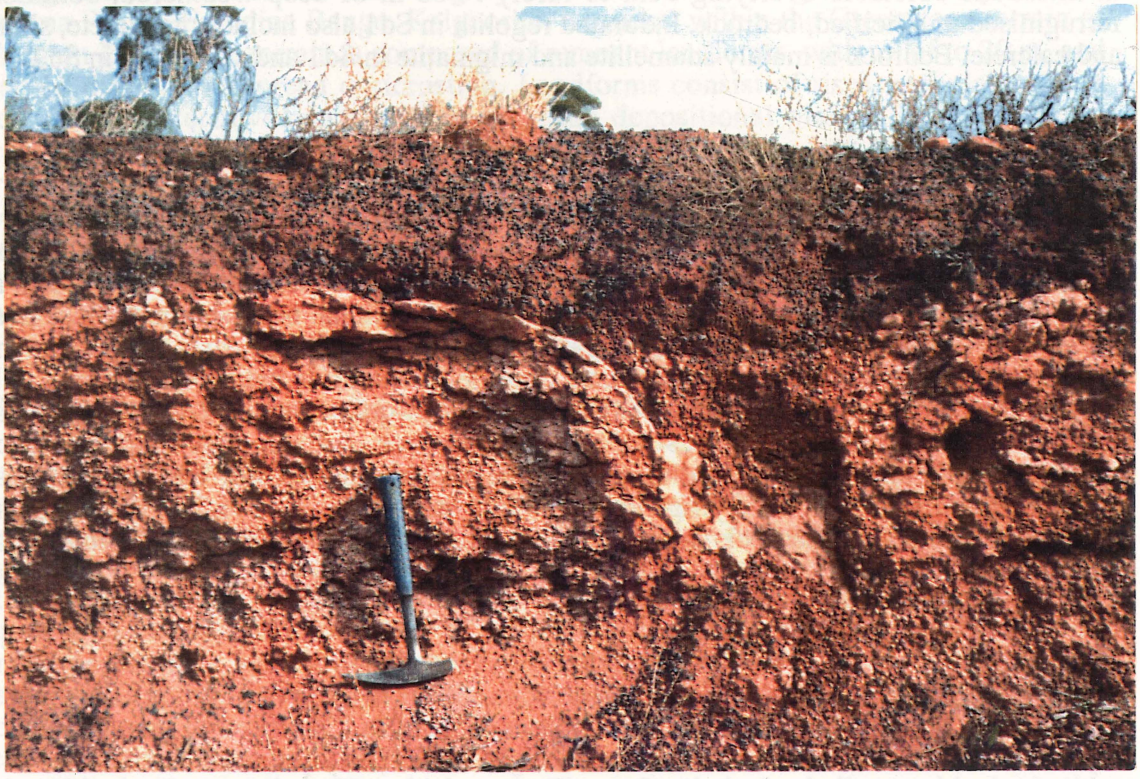

Figure 4: Ferruginous nodules in red soil over calcrete: near Golden Ridge, about 20km SE of Kalgoorlie. [Regolith terrain unit Du4 in Kalgoorlie regolith terrain province.]

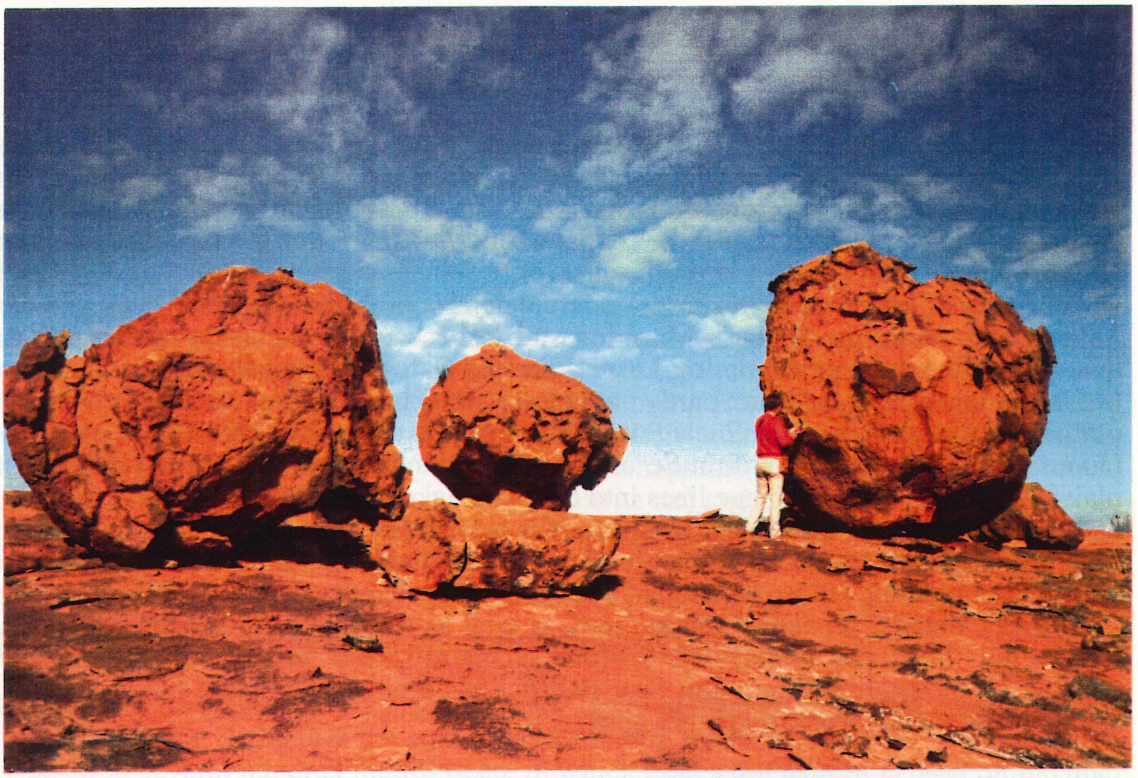

Figure 5: Granite dome stripped of regolith with granite tors showing polygonal weathering: Bullabulling Dome, about 3km WSW of Coolgardie. [Regolith terrain unit Du2 within Cave Hill regolith terrain province.]

Figure 6: Complex deep weathered bedrock: Bottle Creek Mine, about 6km south of Copperfield. [Regolith terrain unit Sf3 in Edjudina Range regolith province.]

4.3.3 Depositional Plains (Se)

This category includes five regolith terrain units which are dispersed over four regolith terrain provinces: two provinces in the Granitic terrain of the Yilgarn Block - Moon Rock and Niagara Creek); one transitional between the Eucla Basin and the Albany-Fraser Province (and to a lesser degree the Yilgarn Block)- Fraser Range; and one transitional between the Officer Basin, the Albany-Fraser Province and the Yilgarn Block - Bartlett Bluff. Se1 and Se2 occur in the northwestern quadrant of the map area between and along Lakes Carey, Raeside, Ballard, Marmion and Rebecca. Se4 occurs in the northeastern quadrant of the map area rimming Lakes Raeside, Carey, Minigwal and Rason. Se3 and Se5 occur together in the south partly along Lake Rivers and Harris Lake. Se5 coincides in part with the extension of the Eucla Basin sequence into the Lefroy Palaeoriver embayment (Jones 1990). The terrain within Se units is flat to undulating and sloping depositional plains commonly with drainage lines into the playa lakes. Landforms include depositional and alluvial plains, and colluvial fans. Relief is mainly less than 5 m but may approach 20 m in Se5. Regolith consists dominantly of colluvial and alluvial sediments over 15 m thick variously containing siliceous hardpan and duricrust, calcrete (nodular and sheet, less than 2 m thick), detrital ferricrete and silcrete, as well as residual deep calcareous earths in terrain unit Se5. The underlying bedrock is mainly deep weathered with shallower weathering in regolith terrain unit Se5. Bedrock is dominantly granitic but also includes sedimentary, metamorphic and other igneous rocks.

4.3.4 Fans (Sf)

Three regolith terrain units fall into this category and extend over six regolith terrain provinces within the Yilgarn Block: two provinces (Kurrajong Range, and Niagara Rocks) in the Granitic terrain and four provinces (Cowarna Rocks, Edjudina Rnge, Kalgoorlie and Leonora) in the Greenstone terrain. Landforms are discrete or composite alluvial/colluvial fans and have less than 5 m relief. Regolith terrain units are distinguished by the provenance of these sediments (granites, greenstones, banded iron formation and ferricrete). Associated with these 15 to 50m thick fan sediments are surface gravels (commonly ferruginous), siliceous hardpan, and in places sheet or nodular calcrete; all overlie deep weathered bedrock for example, figure 6. Bedrock includes granite, greenstones, and banded iron formation and so indicate localised provenance for the fans.

4.3.5 Valley Complex (Sv)

There are three valley complex regolith terrain units, one in each of three regolith terrain provinces: one province (Cave Hill) in the Granitic terrain and one (Kalgoorlie) in the Greenstone terrain of the Yilgarn Block, and one (Lake Lefroy) occurring in both the Officer Basin and the Yilgarn Block. The terrain characteristically comprises elongated depressions which range from broad (3km to 5 km wide) saucer-shaped valleys (Sv2), to palaeovalleys with mound and karst topography (Sv1), to valley plains with present day drainage lines (Sv3). Relief is usually less than 3 m but may be up to 20 m. Regolith is dominantly alluvium (valley or drainage line floors) and colluvium (valley sides and floors). In Sv3 these sediments contain or are overlain by calcrete or calcareous nodules. Valley sediments overlie more than 15 m of weathered (commonly deep) granite and greenstone bedrocks.

There is a noticable variation between these regolith terrain units in their present geomorphic activity relating to deposition: from fairly active in Sv2 which is in the erosive zone of the Cave Hill Province (see 4.2.2), to less active in the flatter and wider valley plains of Sv3, to inactive in the palaeovalley of Sv1.

4.3.6 Playa Complex (Sp)

Though there is only one regolith terrain unit within one regolith terrain province (Lake Lefroy) in this category, it is an important and extensive unit and indicates a palaeodrainage system with broad valleys (from a few to 30 km wide) which cuts across all major structural elements in the map area (see Regional Relief and Palaeodrainage diagram on the accompanying map). The terrain is a playa plain with up to 10 m relief. The dominant landform, as the name implies, is the playa lakes system. Associated and surrounding landforms are kopi and sand dunes, lunettes and fringing depositional flats. The regolith consists of evaporites and lacustrine sediments in lakes, aeolian sediments in dunes and lunettes, and alluvial and colluvial sediments on fringing flats. These sediments overlie a great variety of bedrocks reflecting the regional geology, and are variously but commonly weathered to a considerable depth (over 100 and perhaps 200 m or more depth). Indurated regolith includes variable subsurface (notably ferricrete) and pavement (notably calcrete) duricrust.Lunettes and dunes are inevitably at the eastern ends of the playa lakes due to the dominant west to east wind direction.

4.4 Interrupted Continental Sediment Mantle (Si, Sr)

The regolith is dominantly terrestrial sediments, covering from 50% to 80% surface area of each mapping unit. Sediments are commonly underlain by deep weathered bedrock which may be up to several hundred metres deep, in which case a dot pattern is used on the map face.

4.4.1 Sediment Plains with Outcrops and Deep Weathering Residuals (Si)

There are six regolith terrain units in this category spread over seven regolith terrain provinces: four provinces (Donkey Rocks, Emu Rocks, Moon Rocks & Walling Rock) within the Granitic terrain of the Yilgarn Block; two (Cowarna Rocks, Kalgoorlie) within the Greenstone terrain of the Yilgarn Block; and one province (Murdonna Hill) is transitional between the Albany-Fraser Province and the Yilgarn Block. The terrain is mainly flat to undulating plains (relief less than 5 m) with scattered outcrops, pediments and breakaways, and drainage lines. Landform types include depositional plains, sandplains, erosional landforms and minor dunefields; relief is generally less than 5 m. Regolith comprises mainly colluvium and alluvium, and minor aeolian deposits, with intervening areas of residual materials (up to and over 15 m thick) and outcrops with associated skeletal soils and scree. Indurated regolith variously includes calcrete in calcareous soils, calcrete in colluvium, residual ferricrete gravel, ferricrete and silcrete duricrusts, and siliceous hardpan. Sediments and residual deposits overlie deep weathered bedrock. The depth of weathered bedrock exceeds 50 m. Bedrock is largely granitic but includes other igneous rocks, metamorphic rocks, and minor sedimentary rocks.

4.4.2 Relict Sediment Plains with Duricrusted Residuals (Sr)

The five regolith terrain units within this category are spread over seven regolith terrain provinces: three provinces (Ethel Hill, Minnie Hill, Pitcher Range) in the Officer Basin; two (Donkey Rocks, Moon Rocks) in the Granitic terrain of the Yilgarn Block; one (Mulgabiddy Creek) transitional between the Officer Basin and the Yilgarn Block; and one (Murdonna Hill) transitional between the Albany-Fraser Province and the Yilgarn Block. The terrain ranges from flat to undulating sediment plains, commonly with low duricrusted residuals, to broken sand plains with scattered higher areas of duricrust plains and intervening corridors of sand plain. The relief varies from less than 2 m on the plains up to 50 m for breakaways, duricrusted rises, and scattered sand dunes. The regolith comprises areas of colluvium, ferruginous gravels, aeolian sand (sheet and dunes), residual soils on deflated rises, and minor alluvium along present drainage lines: all overlie deep weathered

and sometimes ferruginised/silicified (notably sandstone in Sr5) bedrock. The depth of weathering is greater than 50 m. Sediments are up to and over 5 m thick; ferricrete is greater than 5 m thick along breakaways. The colluvium may in part be reworked aeolian sand (and conversely the aeolian sand may be reworked colluvium), or deep calcareous soils with calcareous nodules (Sr2) or scree on slopes around deflated rises. Residual and reworked red soils, mainly on rises, contain ferruginous nodules. Areas of wind modified sands and earthy soils are occasionally underlain by siliceous hardpan (Sr3).

4.5 Extensive Outcrop or Minimal Regolith Mantle (Bp, Bs)

Outcrop or minimal regolith is dominant, covering more than 80% of the surface area of each mapping unit. Where present, the depth of regolith is less than 2 m.

4.5.1 Structural Plains (Bp)

There is only one regolith terrain unit which entirely makes up one regolith terrain province (Nuullarbor Plain) within the Eucla Basin. Bp1 is the extensive limestone plain of the well known Nullarbor Plain. It is in part an etchplain and a karst plain, flat to gently undulating with large shallow depressions (dongas) in the north. Relief is to 6 m and occasionally 9 m. Regolith is less than 0.5 metre of calcareous residual soils on low rises, and 1 to 3 m of colluvial calcareous clay in depressions. Limestone and calcrete cobbles, and bedrock pavements are common. The bedrock consists of calcarenite, limestone and sandstone and has solution cavities; commonly there is a subsurface horizontal zone of fracturing.

According to Lowry (1970) it seems probable that the Nullarbor Plain was once covered by a similar thickness of clay and calcrete as is presently on the Nyanga Plain, and subsequently it has been removed by wind erosion. The calcrete was probably dissolved and reprecipitated as clay sized particles, and so deflation could then progressively remove the calcrete as well as the clay.

4.5.2 Linear Structural Ridges (Bs)

There are three regolith terrain units in this category, one in each of three regolith terrain provinces: one province (Hampton Tableland) in the Eucla Basin; one (Binneringie) in the Granitic terrain of the the Yilgarn Block; and one (Fraser Range) transitional between the Eucla Basin and the Albany-Fraser Province. The terrain consists of structural ridges which range from joint controlled low ridges (4 to 6 m relief in Bs3), to 50 m high ridges of rounded quartzite hills (Bs2), to 120 m high prominant rocky ridges commonly associated with resistant structurally controlled igneous (dykes) and metamorphic bedrock. The regolith mantle varies from none (relatively fresh bedrock pavements such as quartzite), to shallow stony soils (Bs1) or residual loams with sheet and nodular calcrete and limestone fragments (Bs3), to minor colluvium and alluvium and possibly aeolian loam. Regolith is generally less than 2 m thick but may be greater than 5 m in places where the bedrock is weathered (Bs2).

The Hampton Tableland, similar to the Nullarbor Plain (4.5.1), was probably once covered with a similar thickness of clay with calcrete as is presently on the Nyanga Plain. The clay with calcrete has since been removed by wind erosion (Lowry, 1970).

4.6 Interrupted Outcrop or Minimal Regolith Mantle (Bh)

Outcrop or minimal regolith are dominant, covering from 50% to 80% surface area of each mapping unit. Where present, the depth of regolith is less than 2 m.

4.6.1 Outcrops with Pockets of Deep Weathering and Sediments (Bh)

Five regolith terrain units are in six regolith terrain provinces: two regolith terrain units (Bh1 and Bh2) are spread over five provinces (Cowarna Range, Edjudina Range, Kalgoorlie, Kambalda, Leonora) within the Greenstone terrain of the Yilgarn Block; and three regolith terrain units occur in one province (Fraser Range) which is transitional between the Eucla Basin and the Albany-Fraser Province. The terrain consists of strike ridges and ranges of hills separated by valleys, flats and plains. Landform types include hills, low hills, pediment, erosional plain, and depositional plain. Relief varies from less than 5 m (Bh3, Bh4, and Bh5) to 80 m in Bh2, and to 150 m in Bh1. Regolith comprises colluvial aprons around bedrock outcrops, colluvium on flats, alluvium in valleys and along drainage lines, ferricrete veneers over calcrete nodules in calcareous soils (Bh1), and residual and aeolian loam with calcrete (Bh3). Bedrocks are dominantly greenstones (Bh1 and Bh2) and metamorphics (Bh3, Bh4 and Bh5), and vary from relatively fresh outcrops on ridges to deep weathered pockets which may be covered by sediments in intervening low areas. The regolith depth is mainly less than 2 m on ridges but is of unknown, though probably considerable, thickness elsewhere.

5. REGOLITH AND LANDSCAPE EVOLUTION

This account of the regolith and landscape evolution of the Kalgoorlie 1: 1 000 000 sheet area includes previous literature and draws on information from the Kalgoorlie regolith terrain map, especially within the Yilgarn Block and associated field mapping reported in Ollier et al, (1988). The other major structural elements of the bedrock geology ie. the Albany-Fraser Province, the Officer Basin and the Eucla Basin provide a convenient regional framework for comment about regolith beyond the Yilgarn Block.

5.1 The Yilgarn Block

5.1.1 Summary of the Geologic-Geomorphic Evolution of the Yilgarn Block

From the scattered and varied accounts of the regolith within the Kalgoorlie 1: 1 000 000 sheet area, the geologic-geomorphic evolution of the Yilgarn Block since Permian glaciation is summarised as follows:

1. Permian glaciation of already planated bedrock;
2. Mesozoic deep weathering, with minor planation;
3. Establishment of a drainage pattern with major valleys several kilometres wide (playa lakes palaeodrainag); regolith terrain unit Dr1 may represent inverted NW flowing palaeodrainage which would be presumably older than playa lakes palaeodrainage
4. The break-up of Gondwanaland;
5. Incision of valleys and deposition of Eocene terrestrial sediments;
6. Upper Eocene marine incursion penetrating 300 km up valleys, and associated marine sediments;
7. Tectonic activity largely resulting in an epeirogenic uplift of about 300 m;
8. Cainozoic landscape evolution involving renewed weathering, and duricrust formation; progressive landscape inversion
9. Climatic change from a warm and moist climate in the Mesozoic and Cainozoic, through increasing dryness in the upper Cainozoic, to a Quaternary period of aridity involving salt weathering, aeolian deposits, limited drainage and the formation of remnant lake systems.

5.1.2 Carbonates, Sands and Other Covers

Greenstone outcrops in the Kalgoorlie region commonly have clay-rich calcareous soils. Carbonates also occur in redistributed forms as nodules, laminae or massive calcrete with evidence in some places of several additive and mobile phases. The carbonate could be derived by weathering then moved in solution and precipitated. The carbonate has sometimes been regarded as an aeolian addition. Such a view fails to explain the restriction of the calcareous soils to greenstone outcrops. Minor carbonate is associated with some

granitic terrain but those deposits are most likely the result of groundwater redistribution. One proposed source for the carbonate is the Nullarbor Plain, though this requires an improbable reversal of the known palaeowind directions. Perhaps there is only a local aeolian carbonate component to these soils.

On granites in the southwest of the map area, a carpet of yellow non-calcareous sand is widespread (unit Ds1) and, like the calcareous soils, is thought by some writers to have an aeolian origin but again such a view fails to account for the major coincidence of sandplain with granite. Carroll (1939) interpreted two different sandplain soils in the Yilgarn, both essentially *in-situ*, one related to metamorphic bedrock and the other to granitic bedrock. This interpreted difference was based on the analysis of heavy mineral suites. Prider (1966) also suggested the sandplains formed *in-situ*. Contrary to this interpretation, in the York-Quairading area, Mulcahy (1959) and Mulcahy & Hingston (1961) suggested that the sandplain material was released by weathering from lateritic, ferruginous or mottled zones and then transported. Brewer and Bettenay (1973) thought only the uppermost layers were transported. Still more varied views are expressed by Bettenay (1984). Butt (1985) and Ollier et al. (1988) suggest that despite some possible reworking of the upper parts of the sandplains, an *in situ* origin is probable for the bulk of the regolith profile.

Evaporitic, aeolian, colluvial and alluvial surficial materials are deposited in and near wind eroded plains, playa lakes and associated flats (unit Sp1) which are the remnants of ancient drainage lines (Ollier et al. 1988). The alluvium is of variable thickness, colour and composition, and occurs along modern channels and Bettenay (1962) reports the essential features. Ollier et al. (1988) report lacustrine deposits of gypsum, halite, clay, silt, sand and solonchak soils occuring in the salt lakes and clay pans. Kopi dunes and carbonate-rich gilgai with wavelengths of up to a few metres are also reported north of Menzies.

5.1.3 Palaeodrainage

Palaeodrainage lines are shown on the Regional Relief and Palaeodrainage diagram on the Kalgoorlie map.The dashed line represents the Swan-Avon palaeodivide. The thicker purple lines are essentially refinements of the playa lake palaeodrainage lines by van de Graaff, Crowe, Bunting & Jackson (1977). The thinner purple lines represent the Officer Basin palaeodrainage. Both span a period of drainage development from late Cretaceous to early Tertiary. Another set of green lines connect dongas and ridges of the Eucla Basin and span a period of drainage development from late Teriary to Quaternary In addition to the palaeodrainage shown on the diagram an apparent dendritic pattern shown by the deep weathered silcrete-capped granitic ridges of the regolith terrain unit Dr1 could be interpreted as inverted formerly NW flowing palaeodrainage older than the playa lakes palaeodrainage. On the other hand the silcrete may only be an edge effect and the apparent dendritic pattern only a coincidence.

Several views have been expressed about the Tertiary palaeodrainage of central Western Australia in general, and about the Kalgoorlie region in particular. Jutson (1934, part X) favoured the view that the salt lake basins were formed by wind. van de Graaff et al. (1977) described the integrated, dendritic nature of the lake systems in considerable detail and supported the view, held much earlier by Gregory (1914), that the lakes represented the remains of a large river system. Such views are clearly corroborated by examining satellite imagery, digital terrain models, or aerial photographs of the region. In the Kalgoorlie area the ancient valleys drained towards the Nullarbor Plain (Ollier et al, 1988). Cope (1975) describes how tectonic movement along the Jarrahwood Axis has warped the older valleys.

Cross-sections of ancient valleys are exposed in the Princess Royal open-cut mine in the Norseman area . The lowest level sediment in the valley is terrestrial, and contains leaves, fruits and pollen indicating an Eocene age of about 40 million years. These are overlain by marine sediments containing sponge spicules and sharks' teeth, also about 40 million years old. Evidently a marine incursion caused by a rise in sea level extended from the south for

hundreds of kilometres up the valleys, apparently without overflowing onto the surrounding plain. By 40 million years ago the valleys were not only in existence, but they were incised in a very flat plain. The plain is older than Eocene. Reasonably, these conclusions can be extended to the Kalgoorlie area (Playford et al, 1975; Ollier et al, 1988).

Sediments filling these valleys have been weathered, but not sufficiently to destroy the organic remains preserved in coal deposits at the base of the sediments. The valleys are cut into a deep weathered profile which can be divided into an oxidised upper zone and a reduced lower zone. The oxidised zone is so intensely altered that it seems preservation of fossil fruit, leaves and pollen is unlikely. It seems much more probable that the valleys were eroded into an already deep weathered plain. Since the valley fill is about 40 million years old the weathering of the valley sides must be older, possibly Mesozoic. Age assessments using Alunite in the weathered rocks from central Western Australia gave a minimum potassium/argon date of about 60 million years (Bird et al, 1990).

King (1989, p. 23) has pointed out that there is a great deal of secondary enrichment of gold around Kalgoorlie goldfields. In the Golden Mile mining area adjacent to Kalgoorlie township, many shoots were abandoned at about 30 m due to impoverishment. The general secondary enrichment may well be associated with this early phase of weathering.

5.1.4 Ferricrete and landscape evolution

Until a revised landscape model was published by Ollier et al. (1988), the generally accepted model of landscape evolution for the Kalgoorlie region was one proposed by Jutson (1914, 1934). In Jutson's model, an eroding, old, extensive lateritised plateau is progressively replaced by a younger plateau without laterite. Although Jutson's work was widely accepted, there have been some recent shifts from that traditional acceptance (see Bettenay & Hingston, 1964; Bettenay, 1984). Ollier et al. (1988) proposed substantial revision of the landscape evolutionary model for the region, and treated regolith formation as an integral part of the geological history since the Permian.

In the Kalgoorlie region the regolith is partially stripped from some areas and completely stripped from others making an etchplain (Finkl, 1979). West of Widgiemooltha, flat to low domed granitic outcrops are widely scattered and completely stripped of regolith. The unloading sheets on Bullabulling granitic dome are interpreted by Ollier et al. (1988) as the likely result of stripping of overlying regolith. Cave Hill, SW of Widgemooltha, and other nearby granitic rises are regarded as domes or even inselbergs showing total removal of regolith. Evidence of partial stripping of the regolith is found at numerous *in-situ* weathered granite subcrops and outcrops where the grus (*in-situ* weathered granite) is commonly present around the base of the exposures. Except for the granites already mentioned and some greenstone strike ridges and basic dykes, the Kalgoorlie area is generally only partly stripped of saprolite.

The Old Plateau suggested by Jutson implies a relatively flat surface but the Kalgoorlie landscape contains hills which rise above it. Examples are listed by Ollier et al. (1988, p311) who reference Jutson's knowledge of these above-plateau hills. However, more recently the idea of a flat plateau, implied by Jutson's diagrams, has dominated the literature.

Jutson's model implies that laterite (ferricrete) and the Old Plateau are related phenomena and that dissection of the Old Plateau led to the formation of a New Plateau devoid of laterite (ferricrete). There is some evidence to show that ferricrete is unconformable over various substrates in the Kalgoorlie area and may not be the horizontal landscape feature it is so commonly assumed to be. Ferricrete initial slopes are recorded by Ollier et al. (1988) to be about 5^{o}, for example at Sons of Gwalia Mine near Leonora and 8 km north of Jaurdi Homestead, and in other parts of the Yilgarn by Playford (1954) and Bettenay & Hingston (1964).

Western Australian laterites (ferricretes) and weathering profiles were well documented by Walther (1915) and his work is now regarded as one of the classic accounts. Walther's lateritic profile shows ferricrete at the surface over a mottled zone with a pallid zone underneath overlying fresh bedrock. Examples of such profiles, partial and complete, are recorded in the Kalgoorlie area by Ollier et al. (1988).

Breakaways with ferricrete are preserved at various levels within the landscape (see Honman, 1917; Jutson 1934; Ollier et al., 1988). Modern alternative views about their level of origin within the landscape suggest that they are mostly formed low in the landscape and are related to drainage lines and footslopes (Moss, 1965; Young, 1976). Therefore, contrary to the traditional view, ferricretes would not form as a sheet-like feature on plateau surfaces. Unconformities beneath ferricretes are suspected to be common (Ollier & Galloway, 1990). Work by Churchward & Bettenay (1973), Milnes, Bourman & Northcote (1985), and Milnes & Bourman (1985) report similar views. Ollier et al. (1988) suspect that in the Kalgoorlie area unconformities beneath ferricretes are much more common than they could prove, but detecting any separate surficial layers after a period of ferricrete development is often difficult. Convincing unconformities beneath ferricrete in the Kalgoorlie region are recognised by stone-lines of quartz gravels. A close genetic relationship between the ferricrete and the lower parts of the weathering profile in these instances seems most unlikely.

Some hypotheses of ferricrete formation are based on its association with underlying weathered materials which are depleted in iron. Since the lower material is iron-poor and the upper material iron-rich, some investigators infer that the iron has somehow moved upwards in solution, aided by groundwater fluctuation, capillary action or other possible methods.

Another series of hypotheses suggest that lateral movement of iron is important, and that it is mostly precipitated on lower slopes and in valley bottoms (Ollier & Galloway, 1990; Ollier, 1991). If this is followed by inversion of relief (see Figure 7) the familiar situation is produced with ferricrete on plateau tops. The distribution of ferricrete in plan may resemble a drainage pattern and there may be associated fluvial gravels. The concept of ferricrete in valleys, followed by inversion of relief to locate the ferricrete on hilltops was extended to many other parts of the world (Ollier & Galloway,1990). It has also been suggested that repeated formation of ferricrete and inversion of relief is possible, a mechanism invoked in Madagascar (Maignien, 1966), and Australia (Ollier et al, 1988). This is a widespread method of landscape evolution to be contrasted with the more traditional models of Davis, Penck, or Jutson.

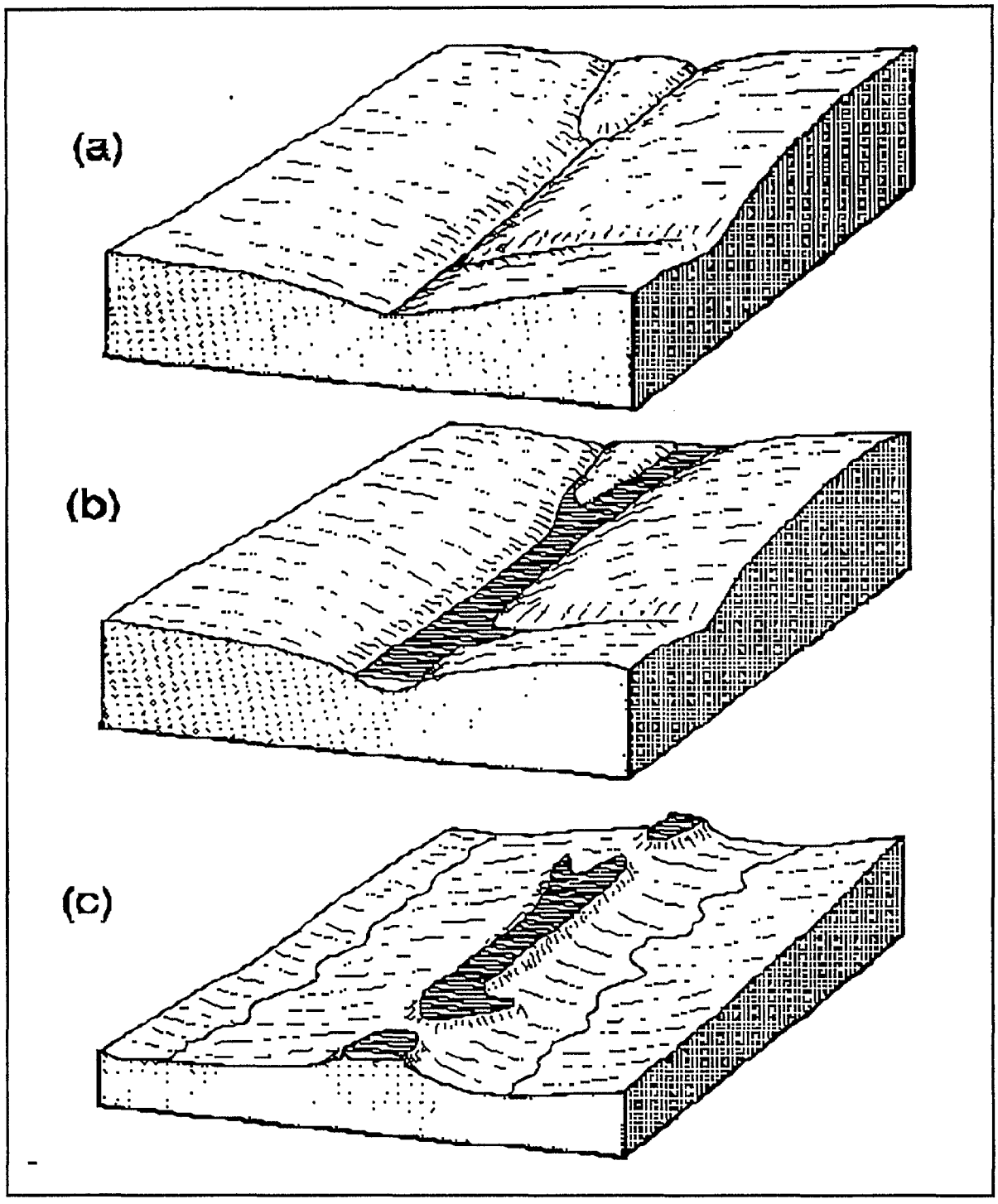

Figure 7. Typical development of relief inversion: (a) original valley; (b) ferricrete and ferruginous mottled zone development in lower valley sides and floors; (c) Old ferricrete capped ridges

5.2 The Officer Basin

5.2.1 Summary of the Geologic-Geomorphic Evolution of the Officer Basin

1. Permian glaciation of bedrock;
2. Mesozoic deep weathering, with minor planation;
3. Establishment of drainage patterns with major valleys several kilometres wide (Playa Lakes Palaeodrainage);
4. The break-up of Gondwanaland;
5 Cainozoic landscape evolution involving renewed weathering, and duricrust formation;
6. Climatic change from a warm and moist climate in the Mesozoic and Cainozoic to a period of aridity involving salt weathering, aeolian deposits, limited drainage and the formation of remnant lake systems.

5.2.2 Regolith, Paleodrainage and Landscape Evolution

The Officer Basin is situated between the Yilgarn Block and the Musgrave Block. The landsurface is dominated by an early Tertiary duricrusted peneplain (Jackson and van de Graaff, 1981) containing a well preserved dendritic palaeodrainage system (see Regional Relief and Palaeodrainage diagram on the accompanying map). Since the demise of the palaeodrainage system, salt lakes and sand dunes, predominate because of the change to a drier environment: the Great Victoria Desert is a large component of the Officer basin within the kalgoorlie sheet area. Extensive soil cover, weathering profiles (Walther type), dissected mesas and extensive and thick valley calcretes, ferricrete, silcrete, aeolian sand and colluvium are some examples of regolith variation within the Officer Basin. Jackson and van de Graaff (1981) report that lateritic weathering almost completely obscures the nature of bedrock exposures making reliable photo-identification of lithologies impossible.

Mesas, buttes and breakaways are common Officer Basin landforms and frequently have aprons of, or are surrounded by, stony scree slopes and pediments. Deep weathering profiles are usually evident beneath the duricrust caps where differential erosion has hastened and sometimes magnified breakaway development. Jackson and van de Graaff (1981) note that ferruginisation and silicification of bedrock occurs throughout the whole of the basin region: ferruginous weathering being best developed in the north and east of the Officer Basin on more clay-rich bedrock; whereas the siliceous weathering profiles are more commonly developed elsewhere, particularly in the south, over Permian or older bedrock, as indicated on the Kalgoorlie map.

According to Jackson and van de Graaff (1981), a lateritic (ferruginous) and siliceous duricrust developed beneath an undulating surface that formed during the Late Cretaceous to Early Tertiary. The landscape evolutionary model used by Jackson and van de Graaff was the simple Jutson model of Old and New Plateau. The linking of separate duricrusted surfaces to form one entire continuous surface is no more valid for the Officer Basin than it was for the Yilgarn Block. Jackson (pers. comm.) now believes that the inversion of relief hypothesis can account satisfactorily for much of the geomorphology and regolith of the Officer Basin.

5.3 The Eucla Basin

5.3 1 Summary of the Geologic-Geomorphic Evolution of the Eucla Basin

The following history is an integrated summary of the geologic-geomorphic evolution of the Eucla Basin based on data from Hocking (1990) and Lowry (1970).

1. Pre-Cretaceous erosion (possibly fluvial) causing development of irregular topography in the SW area of the basin. The area was subsequently buried by Cretaceous sediments. Topography in the northern part of the basin was much more subdued;

2. Lower Cretaceous irregular basin subsidence with terrestrial and shallow marine sediments accumulating until the Upper Cretaceous. There is little evidence of erosion from the Crtaceous through to the Middle Eocene when deposition and downwarping recommenced;

3. Eocene downwarping and sedimentation within the basin. At the end of the Eocene seas retreated and weathering and erosion recommenced;

4. Lower Miocene marine transgression due probably to further downwarping of the Eucla Basin;

5. Middle to Upper Miocene emergence of the Bunda Plateau (Nullarbor Plain) which is essentially the major landscape feature of the present topography;

6. Late Cainozoic continued weathering, erosion, regolith development and landscape evolution:

    a. Middle-Upper Miocene recrystallisation of near-surface limestones reported due to weathering

    b. Pliocene formation of residual soils and oolitic calcrete

    c. Lower Pleistocene development of:

        1. Rivers flowing onto the Nullarbor Plain;
        2. Intermittent formation of residual soil and calcrete through to Recent time;

    d. Middle Pleistocene end to the deflation of clays from the Nullarbor Plain; (possibly some deflation also occurred on the Hampton Tableland and the Nyanga Plain).

    e. Middle Pleistocene start of accummulation of dune sands, salt lakes, clay pans and associated dunes (lunettes); formation of karstic features: dongas, caves and collapse structures.

5.3.1 Regolith and palaeodrainage

The Eucla Basin consists of five major physiographic regions and extends from Western Australia into South Australia. Two thirds of the basin sits within Western Australia with the bulk being onshore. The five major regions are: the Bunda plateau (more popularly known as the Nullarbor Plain); a scarp known in different places as The Hampton Range, Baxter Cliffs and Wylie Scarp; two coastal plains (in SW- the Israelite Plain and further east the Roe Plains; and the continental shelf - the Eucla shelf. The Bunda Plateau (more popularly known as the Nullabor Plain) is the only major region occurring of the Kalgoorlie map. Lowry (1970) defines a number of sub-environments onshore within the Bunda Plateau and only four of those are within the Kalgoorlie maps sheet area. They are: the Nullabor, Nyanga and Carlisle Plains and the Hampton Tableland. These sub-environments are reflected in the Eucla Basin regolith terrain provinces and accordingly have been given the same names

Hard cemented deposits of calcium carbonate (calcrete), referred to as kankar by Lowry (1970), are found within soil profiles and form an important and extensive component of the regolith in the Eucla Basin. Lowry (1970) recognised and described in detail at least six different kankar occurrences. Gypsum is also ubiquitous in the Eucla Basin soils, particularly the Nyanga Plain soils. Some possible sulphate sources are mentioned by Lowry (1970) and he suggests that accession via rainwater is sufficient to explain known volumes and distributions and hence removes the need to postulate former (Tertiary) marine evaporites as its source. Possible origins of the kankar are also mentioned but no firm conclusions are drawn.

Colluvium, principally consists of clay, quartz silt, and sand and scattered fragments of kankar and limestone. It is described in detail by Lowry (1970) who suggests it occurs in at least five onshore Eucla Basin sub-environments.

Lowry (1970). reports a scarcity of alluvium associated with palaeodrainage systems which once flowed across the Nullarbor and Nyanga Plains. However outside the Kalgoorlie map area, intermittent streams on the Hampton and Wylie scarpslopes, and on the steeper slopes of depressions on the Carlisle Plain, do show alluvium.

Lacustrine clays, sands and salts (gypsum and halite) in playas occur towards the northern edge of the Eucla Basin. The thickness of the deposits is unknown (Lowry, 1970). Little sedimentological detail is known. In Lowry's view, the northern lakes do not appear to fit the dismembered ancient drainage model proposed by Bettenay (1962) and, earlier by Gibson (1909) for the salt lakes west of the Eucla Basin. The proposed origin of lake salt ranges from accession from west of the Eucla to being the result of local weathering.

Little or no laterite (ferricrete) is recorded in the Eucla Basin within the Kalgoorlie map sheet area. Ouside the map sheet, subsurface ferruginous pisoliths are reported in sands in the far southwest of the basin in the vicinity of Israelite Bay. Some lateritisation (?) of the Plantagenet Group in the Israelite Bay area is reported by Lowry (1970). Silicification and recrystallisation of limestones is also noted by Lowry (1970) and is regarded generally to be related to surface weathering, although a detailed explanation of the relationship is not offered.

6. MINERAL OCCURRENCE CORRELATIONS

6.1 Background

Known mineral occurrences have been plotted onto the Kalgoorlie regolith terrain map. Correlation between the regolith terrain units and minerals localities (see terrain unit/commodities correlation Table 1) may be useful in helping to predict new prospective areas by extrapolation.

The mineral occurrences on theKalgoorlie regolith terrain map represent over 5 000 individual occurrences taken from BMR's MINLOC (Mineral Location) database. The occurrences were derived from a number of sources: published 1: 100 000 Geology maps by the Geological Survey of Western Australia; 1: 50 000 geological mapping by Hallberg (1985); compilation sheets (at scales from 1: 31 000 to 1: 63 000) for the first edition 1: 250 000 geological mapping conducted from 1963 to 1977 by the Geological Survey of Western Australia and BMR; and a small number of recent discoveries supplied by Geological Survey of Western Australia geologists and by company geologists. Unfortunately the bulk of discoveries post-dating the above maps have not yet been added to the Minloc data set. The mineral occurrences marked on the map indicate location and type of commodity only and are not meant to represent the size of the deposits. Discrepancies between the number of occurrences on the map face and the number of occurrences in Table 1 are due to additional data having been added to MINLOC since the compilation of the map.

We have divided the mineral occurrences into two categories: Regolith related and Bedrock related. Regolith related occurrences include secondary and detrital mineralisation within the regolith: lateritic nickel and gold deposits; alluvial gold; secondary uranium in calcrete; and concentrations of secondary minerals, manganese, magnesite, alunite and rare earth minerals associated with the Mt Weld Carbonatite. Bedrock occurrences include those where the main occurrence is primary mineralisation in the bedrock.

Given the increased interest and awareness of the regolith more mineral occurrences are now being recognised as being regolith related. Unfortunately many old maps do not make the distinction between regolith related and bedrock related occurrences, except in the case of alluvials and some deep leads and more recently lateritic nickel. We have restricted ourselves in most cases to using only that information available on the source maps. With certain occurrences we have been able to cross correlate with other information to determine an occurrences relationship with the regolith. We have been very conservative in designating regolith related occurrences and it is most probable that many more occurrences in the bedrock categories are actually regolith related.

The relatively small scale of the Kalgoorlie regolith terrain mapping only allows general correlations between regolith terrain units and mineral localities to be drawn. Any inferences from these correlations must take this scale factor into account. More detailed mapping would allow mineral occurrences to be related more accurately to their regolith/geomorphic setting. The correlations presented here will hopefully offer a different perspective to defining prospective ground, and so help point to the discovery of new mineral deposits.

6.2 Method and Accuracy

Plots of the more than 5 000 digitised mineral occurrences from the Kalgoorlie map area were obtained from MINLOC at 1: 250 000 scale. Outlines of the regolith terrain unit boundaries at the same scale were then overlain and the number of occurrences within each regolith terrain unit determined. There are some possible errors where occurrences are very close to or on regolith terrain unit boundaries. This is due to a difference in compilation scales: the Kalgoorlie regolith terrain map was compiled at 1: 500 000 while the mineral occurrences were compiled at 1: 100 000 or in some instances at larger scales. Therefore slight errors in positioning regolith terrain unit boundaries, insignificant at the 1: 1 000 000 scale of the final map, are noticeable at 1: 250 000 and may lead to some mineral occurrences being assigned to the wrong regolith terrain unit. The number of occurrences affected in this way is thought to be very small.

The accuracy of the mineral occurrence locations ranges between 50 and 100 and it must be remembered that the Kalgoorlie map mineral locations are no more accurate than the original source maps.

There is also a bias in the MINLOC mineral occurrence data due to over half of the occurrences having been taken off the 1: 50 000 maps by Hallberg (1985) in the Laverton-Leonora area. Hallberg's maps cover an area almost equal to two 1: 250 000 sheet areas. Hallberg mapped almost every shaft, pit or opencut in this area: every one of these was digitised as a mineral occurrence into MINLOC and then used in this correlation exercise. The regolith terrain units that occur in Hallberg's map area therefore have a higher level of correlation with mineral occurrences than those that do not occur within this area. This disparity does not invalidate the correlations because the regolith terrain units that have high correlations inside the Hallberg mapped area also have high correlation rates outside Hallberg's map area. The additional occurrences from Hallberg's maps serve to emphasise those regolith terrain units that have high correlation rates.

6.3 Comments

The data in Table 1 serve as only a guide to the prospectivity of the various regolith terrain units. There are two reasons for this. Firstly, as noted above, the data are incomplete. Secondly, it is highly likely that many of the occurrences shown as being bedrock hosted are in fact regolith hosted.

Having noted the inadequacies of the present data set, we can also note that regolith maps do have the potential to assist in mineral exploration. There is a need for more work on both regional associations of regolith and mineral occurrences, and specific occurrences of mineralisation within the regolith.

	DEEP WEATHERING TERRAINS					INTERRUPTED DEEP WEATHERING TERRAINS					SEDIMENT DOMINATED TERRAINS											INTERRUPTED SEDIMENT TERRAINS							BEDROCK TERRAIN		INTERRUPTED BEDROCK TERRAIN		
	Dp	Dr			Ds	Db		Du			Sd	Ss	Se			Sf			Sv		Sp	Si				Sr			Bp	Bs	Bh		
	[1-4]	[1-5]			[1]	[1-2]		[1-7]			[1-2]	[1-5]	[1-5]			[1-3]			[1-3]		[1]	[1-6]				[1-5]			[1]	[1-3]	[1-5]		COMMODITY
COMMODITY		1	2	3	1	1	2	1	4	7	2	1	1	3	4	1	2	3	1	3	1	1	3	4	6	1	2	3	1		1	2	TOTALS
Alluvial Au		3		10		47			27								3	1			2		6								36	5	142
Lateritic Au						3																									3		5
Deep Lead Au						1											1						1										3
Au		449	5	934	6	1064	9	3	336				116		73	5	185	17		23	78	1	96	7	1	1		1			1148	162	4720
Au, Cu				1																	1										7		9
Au, Cu, Ag																		1															1
Au, Bi																					1												1
Au, W						1															1												2
Ni, Co/Ni - Laterite						1			2																						3		6
Ni						8		1	3			2					1				7										19		41
Ni, Au																															2		2
Ni, Cu				1																													1
Cu		10		2		3			3						1							1									23	1	44
Zn, Cu, Ag, Pb				1																													1
Pb, Ag																		1															1
Pb		1																															1
Bi				1																													1
Mo		3								1																							4
Sn, Ta																					3												3
Ta																					1												1
Li/Feldspar Pegmatite					1				1								1			1											3		7
U (Calcrete hosted)																			3		1												4
U (Sandstone hosted)											3																						3
Fe (BIF)						1	1																										2
Mn																	1															1	2
Cr															1																		1
Ba														1																			1
Rare Earths (Mt Weld)													1																				1
Magnesite						1							1																		2		4
Vermiculite/Asbestos						1																											1
Brown Coal																					1						1						2
Alunite						1																											1
Fullers Earth								1																									1
TOTALS by TERRAIN	0	468	5	950	7	1131	10	5	372	1	3	2	118	1	75	5	192	20	3	24	96	2	103	7	1	1	1	1	0	0	1246	169	5019

Table 1. Regolith terrain unit / commodity correlation chart. Shaded areas are regolith related.

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APPENDICIES

A1. REGOLITH TERRAIN DATABASE (RTMAP)

A1.1 Structure and attributes

The Regolith Terrain Mapping database (RTMAP) was designed jointly by BMR's Regolith Group within the Minerals and Landuse Program and BMR's Information Systems Branch for the storage and retrieval of data for regolith terrain mapping. The database uses the ORACLE relational database management system.

As a first step in the development of the RTMAP database, the descriptions of many regolith and terrain attributes had to be structured into distinct and well defined categories suitable for use in a relational database. This aim has by no means been completely achieved. The development process is on-going and will require the input of all people involved in regolith studies, both within and outside BMR, to obtain a system that is acceptable to the wider regolith mapping community.

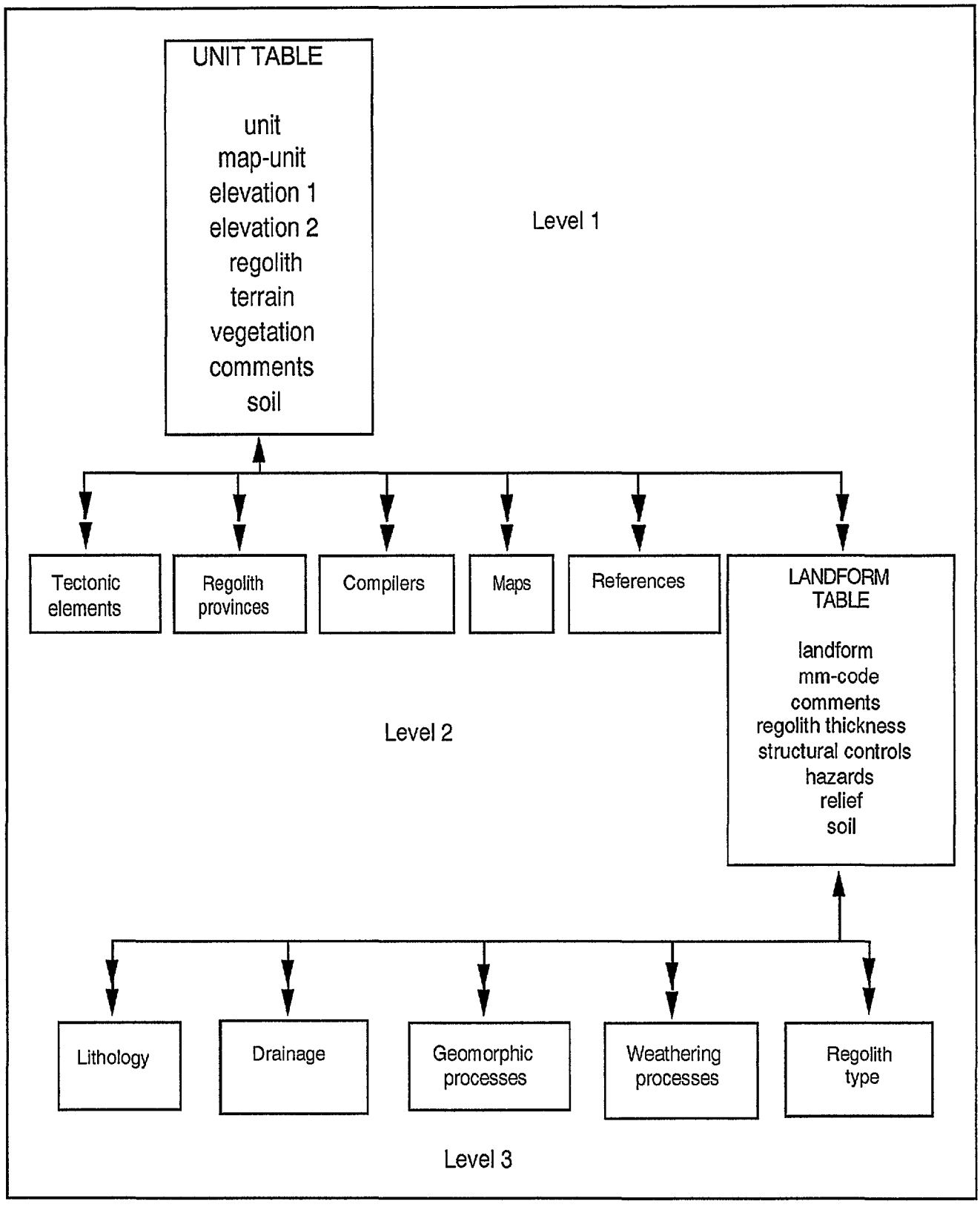
The RTMAP database was designed for both spatial (mapping unit) data and point (field site) data, with field site data being synthesised to form part of mapping unit data. The RTMAP database will be used in conjunction with the ARC/INFO geographic information system for interactive interpretation of data sets and the production of derivative thematic maps tailored to suit specific requirements of clients.

The two main entities in the RTMAP database are the Unit table and the Site table. These tables represent the spatial (regolith terrain mapping units) and point (field site) data components respectively. Thirty three other tables make up the rest of the database. Some are of these tables are for entry of data whereas others, called lookup tables, contain lists of predefined valid attributes. The diagrams in sections A1.2 and A1.3 are simplified logical relationship diagrams showing the relationships between mapping unit and site data respectively.

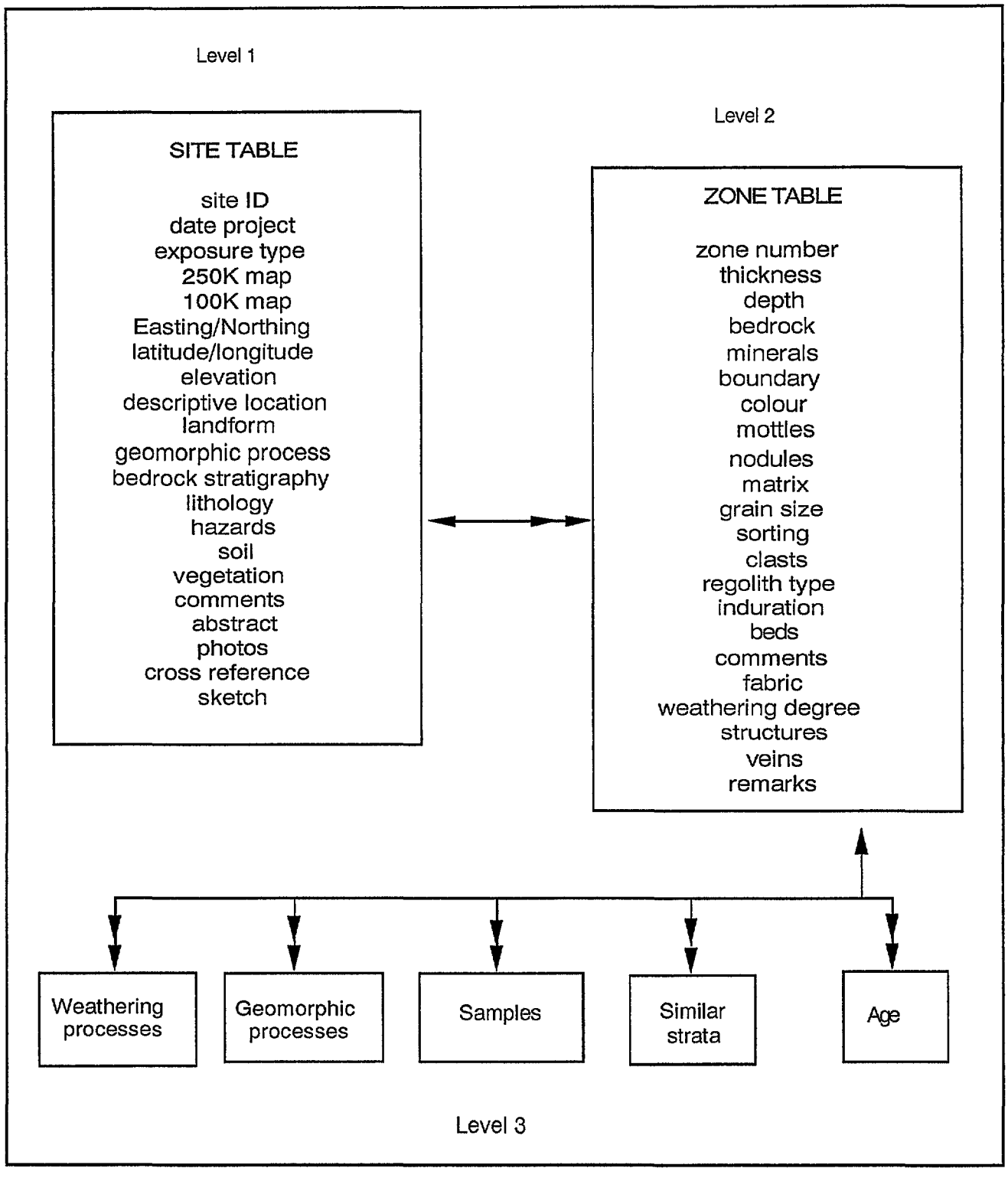
The diagrams in sections A1.2 and A1.3 show three levels of tables. These levels can be thought of as levels of detail: the first, most general level contains the main table; the second level contains more specific information relating to the first level; and the third level contains still more detailed information on certain of the attributes in level two. For those interested in the complete details of the RTMAP database, Lenz (1991) describes the structure and methods to: enter data; query RTMAP; and produce basic reports.

The diagram in section A1.2 shows at Level 1 a Unit Table which consists mainly of lengthy, descriptive free text fields describing the regolith terrain unit as a whole. A Landform table is at Level 2 and describes the different landforms, of which there may be many, within a mapping unit. The other tables at Level 2 have the same many to one relationship to the Unit table. Tables at Level 3 describe in detail attributes of each landform. Tables at Level 2 and 3 allow entry of predefined valid attributes from associated lookup tables.

At level 1 in the diagram of section A1.3 is a Site table which contains general descriptions specific to each field site. At Level 2, a Zone table describes zones that may be present at a site. Finally, at Level 3 there is more detailed information relating to each of the zones at a particular site. The tables in sections A1.4 and A1.5 list in detail the database tables and their attributes along with brief explanations of the type of data found in each attribute. More complete information on the attributes within the RTMAP database and the methodology of compiling the RTMAP data can be obtained from Pain et al (1991).



A1.2. Simplified logical relationships of mapping unit data in the RTMAP database. Double headed arrows indicate many to one relationships between tables.



A1.3. Simplified logical relationships of field site data in the RTMAP database. Double headed arrows indicate many to one relationships between tables

A1.4. Regolith terrain unit tables from the RTMAP database.

Table Names	Attributes	Description
Unit	Unit ID	Unique identifying number for regolith terrain units in RTMAP and serves to link the tables together.
	Map Unit	Unique number that corresponds to a polygon (or polygons) on the map face and links the map in the GIS to the RTMAP database.
	Elevation	The highest and lowest elevations above sea level within the regolith terrain unit.
	Terrain	Description of the terrain within the regolith terrain unit as a whole.
	Regolith	Description of the regolith within the regolith terrain unit as a whole.
	Vegetation	Description of the vegetation within the regolith terrain unit as a whole
	General comments	General comments that cannot be entered elsewhere.
	Soil comments	Summary information on soils within the regolith terrain unit if more detailed information is not available at the Landform level.
Tectonic Elements		List of Tectonic elements in which the regolith terrain unit is found. Tectonic elements are taken from Palfreyman (1984).
Regolith Terrain Province		The Regolith Terrain Provinces in which the regolith terrain unit is found.
Compilers		The compiler's name, affiliation and the date of compilation.
Map References		Details of maps used in compiling the regolith terrain unit.
References		Bibliographic References.
Landform Unit	Landform	Type of landform
	Relief	Average local relief of the landform.
	Structural Controls	Structural control of the landform, if any.
	Environmental Hazards	Environmental hazards within the landform.
	Regolith Thickness	General indication of the maximum thickness of the regolith in the landform.
	Soil comments	Information on the soils at landform scale, if known.
Lithology	Lithology	Bedrock lithology.
	Lithology details	Further description of the lithology.
	Stratigraphy and Age	Stratigraphic relationship of the bedrock, if known.
Drainage	Drainage Pattern	Type of drainage pattern.
	Drainage character	Dry, intermittent or perennial.
	Drainage type	Antecedent, captured, diverted, normal, reversed, superimposed or underground.
	Spacing	Spacing of the stream channels.
Geomorphic Processes	Geomorphic Process	Type of geomorphic process.
	Major/Subordinate	Major or subordinate process.
	Active/Relict	Active or relict process.
Weathering Processes	Weathering Process	Type of weathering process, and also as for Geomorphic processes if it is major/subordinate, or active/relict.

Table Names	Attributes	Description
Regolith Type	Regolith Type	The type of regolith.
	Major/Subordinate	The regolith regolith type is of major/subordinate occurrence in the Landform.
	Degree of weathering	Degree of weathering of the regolith.
	Induration	Type of induration of the regolith.
	Thickness	Thickness of each specific regolith type.
	Informal Age	Age of the regolith type if it has been dated or an inferred age can be obtained from other work.
	Age details	How the age was obtained and its accuracy.
	Regolith Profile	Descriptive field recording the total known gross profile character of the regolith type.
	Regolith Distribution	Descriptive field recording the 3 dimensional landscape position of the regolith type.

A1.5. Regolith terrain field site tables from the RTMAP database.

Table Names	Attributes	Description
Site	Site ID	Unique identifier for each field site description; also links the tables together.
	Date	Date of data collection in the field.
	Project	Name of project.
	Exposure type	Type of exposure from which the data was collected.
	Map1	The 1: 250 000 scale map on which the field description falls.
	Map2	The 1: 100 000 scale map on which the field description falls.
	Latitude	Latitude in degrees and decimal minutes.
	Longitude	Longitude in degrees and decimal minutes.
	East	AMG Easting.
	North	AMG Northing.
	Elevation	Height above sea level of the field site.
	Slope	Angle of slope at the field site.
	Aspect	Aspect of the site.
	Descriptive location	Further descriptive location of the site.
	Landform	Landform at the site.
	Geomorphic Process	Geomorphic process operating at the site.
	Bedrock Stratigraphy	Stratigraphy of the bedrock.
	Bedrock lithology	Lithology of the bedrock.
	Environmental Hazards	Environmental hazards at the site.
	Soil	Description of the soils at the site.
	Vegetation	Description of vegetation at the site.
	Comments	Free text field for comments about the site as a whole.
	Abstract	Summary description of the site, including the zones.
	Photos	Number of photos taken at the site.
	Cross references	Reference to similar sites.
	Sketch	Notes if a sketch of the site has been made.
Zones	Zone Number	Indentifying number for each zone at a site, increasing from the surface down.
	Thickness	Average thickness of the zone.
	Depth	Depth to lower boundary of the zone.
	Bedrock	Notes if bedrock is immediately below this zone.
	Mineralisation	Any noteworthy mineralisation.
	Boundary	Character of the lower boundary.
	Colour	Free text description of the colour.
	Mottling	Comments on mottling, size, contrast and abundance.
	Nodules	Comments on nodules, size, contrast, abundance and strength.
	Matrix	Free text field for a description of the matrix.
	Grainsize	The grain size of particles in the zone.
	Sorting	Amount of sorting.
	Clasts	Free text description of the characteristics of the > 2 mm fraction.
	Regolith type	Classifies the zone as a regolith type.
	Induration	Degree and type of induration.
	Bedding thickness	Thickness of any bedding within a zone.
	Internal Bedding	Internal structure of any bedding.
	Bedding comments	Free text field for any comments on the bedding.

Table Names	Attributes	Description
Zones(cont)	Fabric	Comments on the fabric of the zone, including orientation of particles and any indications of flow direction.
	Weathering	Degree of weathering of the zone.
	Weathering structures	Free text field for comments about weathering characteristics.
	Veins	Comments on veins present.
	Remarks	Any further comments about the zone.
Weathering Processes		Weathering processes responsible for formation of the zone.
Geomorphic Processes		Geomorphic processes responsible for the formation of the zone.
Samples	Sample number	Identifying number of the sample.
	Sample description	Comments or description of the sample.
Similar Strata		Notes zones at other sites that have similar characteristics.
Age Determination		Age of the zone in millions of years, if dated.

A2. THE KALGOORLIE DATA

The Kalgoorlie data needed reformatting to fit the RTMAP database format because it was compiled prior to the development of the RTMAP database. The 1: 1 000 000 scale meant that certain attributes had to be extensively generalised or passed over due to the coarseness of the original data. The original data compilation was done by R.A. Chan, M.A. Craig and D.L. Gibson. It was subsequently modified with the addition of more up to date information by R.A. Chan, M.A. Craig and M.S. Hazell.

Data attributes for all fifty eight regolith terrain units have been entered into the RTMAP database. Section A2.1 lists the codes, in hierarchical order, for the regolith and induration types. Section A2.2 lists core data attributes extracted from the RTMAP database. The first two columns of the table consist of general unit level descriptions of the regolith followed by the the terrain. The next column lists the landform types, of which there may be many for each general regolith and terrain description. Below each landform type is the known thickness of the regolith and the relief in each landform. Next to each landform in the last two columns, are the lithologies and the specific regolith and induration types that are found in each landform within a particular regolith terrain unit.

Field site data obtained during field mapping for the Kalgoorlie 1: 1 000 000 map have not been entered into the RTMAP database. The data were collected before the RTMAP database had been developed and the resources are presently not available to change the data into a suitable format for the RTMAP database.

A2.1. Explanation for the regolith and induration codes used in section A2.2

WMU00	weathered material (unknown origin)
WIR00	in situ weathered rocks
WIR10	deep weathered bedrock
WIR11	saprolite
WIR12	structured saprolite
WIR13	mottled zone
WIR14	pallid zone
WIR20	residual material
WIR21	lag
WIR22	residual sand
WIR23	residual clay
WIR24	soil on bedrock
WIS00	shallow soil on fresh bedrock
UOS00	sand (unknown origin)
UOC00	clay (unknown origin)
SDT00	terrestrial sediments
SDA00	alluvial sediments
SDA10	channel deposits
SDA20	overbank deposits
SDC00	colluvial sediments
SDC01	scree
SDC02	landslide deposit
SDC03	mudflow deposit
SDC04	creep deposit
SDC05	sheet flow deposit
SDE00	aeolian sediment
SDE01	aeolian sand
SDE02	loess
SDE03	parna
SDS00	coastal sediments
SDS01	beach sediments
SDS02	estuarine sediments
SDL00	lacustrine sediments
SDM00	marine sediment
SDG00	glacial sediments
SDF00	fill
VOL00	volcanic material
VOL01	lava flow
VOL02	ash
EVA00	evaporite
EVA01	halite
EVA02	gypsum
IND00	indurated material
IND10	bauxitic induration
IND20	calcareous induration
IND30	clay induration
IND40	ferruginous induration
IND50	gypsiferous induration
IND60	siliceous induration
IND70	humic induration
IDU00	duricrust
IDS00	completely cemented duricrust (crete)
IDS10	alcrete (bauxite)

IDS20	calcrete
IDS40	ferricrete
IDS41	massive ferricrete
IDS42	nodular ferricrete
IDS50	gypcrete
IDS60	silcrete
IDM00	moderately cemented duricrust
IDM20	calcareous duricrust
IDM40	ferruginous duricrust
IDM60	siliceous duricrust
IDP00	partially cemented duricrust (hardpan)
IDP10	bauxitic hardpan
IDP30	clay hardpan
IDP40	ferruginous hardpan
IDP60	siliceous hardpan
IDP70	humic hardpan
INO00	nodules
INO10	bauxitic nodules
INO20	calcareous nodules
INO30	clay nodules
INO40	ferruginous nodules
INO60	siliceous nodules

A2.2 A listing of core attributes from the 58 Kalgoorlie regolith terrain units in the RTMAP database.

The listing is firstly alphabetical according to the regolith terrain unit classifier, and then numerical. General unit level descriptions of regolith and terrain are followed by the landforms that occur in each regolith terrain unit. Underneath each landform is the average known thickness of regolith and the relief within the landform. The lithologies (* denotes each lithology) and regolith type codes appear in the next columns. The first regolith type column denotes the primary regolith type. If there is induration of the regolith and the primary type of regolith prior to it being indurated is known, then the code denoting the type of induration appears in the second regolith type column. Commonly however, the identity of the parent regolith material is totally obscured by the induration. In these cases the type of induration is designated as the regolith type and that code appears in the first regolith type column and the second column is left empty. Explanations for the regolith and induration codes are listed in section A2.1 above.

A2.2 A listing of core attributes from the 58 Kalgoorlie Regolith Terrain Units (RTUs) in the RTMAP database.

Unit	Regolith description	Terrain description	Landforms Regolith thickness Landform relief	Bedrock lithology	Regolith, Induration codes
Bh1	Bedrock outcrop on ridges & hills. Intervening colluvium; ferricrete gravel veneers over calcrete nodules in calcareous soils; alluvium; residual gravels; calcrete; siliceous red-brown hardpan in north; deeply weathered bedrock.	Undulating plains & strike ridges; broken slopes & ridges, rocky ranges & hills, flat to undulating valley plains & pediments; hills & ridges underlain by green-stone, plains by sedimentary rocks.	pediment unknown thickness <9m hills (90-300m) unknown thickness <150m depositional plain unknown thickness <9m	*granite *metamorphic mafic rock *metasediment *metamorphic ultramafic rock *quartz feldspar porphyry *mafic igneous intrusive *metamorphic mafic rock *metasediment *metamorphic ultramafic rock *metasediment *sandstone	INO20, IDS20, IDS40, INO40, SDA00, WIR00, IDS20, IDS40, INO20, INO40, SDC00, SDA00, IDP60, IDS20, IDS40, INO20, INO40,

Unit	Regolith description	Terrain description	Landforms Regolith thickness Landform relief	Bedrock lithology	Regolith, Induration codes
Bh2	Minor colluvial & alluvial deposits surrounding siliceous & ferruginous bedrock outcrops.	Prominent rocky ranges & hills with intervening slopes & valleys.	low hills (30-90m) unknown thickness <80m	*metamorphic mafic rock *quartzite *metasediment *metamorphic ultramafic rock *banded iron formation *sandstone	SDA00, SDC00, WIR00, IDM40 WIR00, IDM60
Bh3	Colluvial deposits adjacent to numerous rocky bedrock exposures; alluvium in presently active drainage lines, & residual & aeolian loam with calcrete in intervening areas.	Low hills & ridges separated by colluvial flats, grading to undulating plains.	pediment unknown thickness 3-5m low hills (30-90m) unknown thickness up to 50m depositional plain unknown thickness 3-5m	*granulite *granulite *granulite	SDC00, SDC00, SDE00, IDS20

Unit	Regolith description	Terrain description	Landforms Regolith thickness Landform relief	Bedrock lithology	Regolith, Induration codes
Bh4	Colluvial, alluvial & aeolian loamy textured sediments as aprons around gabbro outcrops with some alluvium along present-day drainages; calcrete.	Low hills & ridges separated by colluvial flats grading to undulating plains.	erosional plain (<9m) unknown thickness <5m	*metagabbro *granulite	SDT00, IND20 WIR00, SDA00, IND20
Bh5	Colluvium adjacent to bedrock outcrops; minor alluvium; some deeply weathered bedrock.	Rises & ridges separated in the south by alluvial flats grading to undulating plains.	erosional landforms > 5m thick <5m occasionally 20m	*amphibolite *gneiss *granulite *metasediment	SDC00, IDS20 SDA00, IDS20 WIR00,
Bp1	Rises with <0.5m residual calcareous loams & earths on bedrock; abundant large limestone frags; some calcrete nodules. 1-3m colluvial calcareous clay in depressions on bedrock; limestone & calcrete cobbles; rare limestone outcrop; often gilgai structure.	Flat to gently undulating plain with rises & depressions. Parallel chains of elongated or circular hummocky clay flats in sth. Large shallow depressions (dongas) & numerous small scattered claypans in nth. Some rock holes & blow holes.	etchplain < 0.5m thick 6m occasionally 9m karst > 2m thick 3m max in northern dongas.	*sandstone *calcarenite *limestone	WIR21, IDS20 WIR21, WIR24, SDC00, WIR21, IDS20 WIR21,

Unit	Regolith description	Terrain description	Landforms Regolith thickness Landform relief	Bedrock lithology	Regolith, Induration codes
Bs1	Shallow, often stony soils on bedrock; minor colluvium and alluvium.	Prominent linear rocky ridges. Trending east north east in west, north east in east.	hills (90-300m) unknown thickness 120m	*mafic/ultramafic intrusive *mafic/ultramafic intrusive *metagabbro *gneiss *granulite	WIR24, SDA10, SDC00,
Bs2	Some weathered bedrock; minor colluvium & alluvium deposits; numerous quartzite exposures.	Low hills or ranges consisting of rounded hill forms.	hills (90-300m) unknown thickness 50m	*metasediment	SDA00, SDC00, WIR00,
Bs3	Shallow residual loams containing sheet and nodular calcrete and limestone fragments on bedrock ridges. Colluvial clay with limestone and calcrete fragments fill depressions in bedrock. Thin patchy cover of ?aeolian loam.	Alternating broad low, often stony, parallel joint-controlled, tree covered ridges and shallow grassy clay flats; numerous small depressions.	erosional plain (<9m) unknown thickness 4-6m	*limestone	SDC05, WIR24, IDS20, SDE00, WIR21,

Unit	Regolith description	Terrain description	Landforms Regolith thickness Landform relief	Bedrock lithology	Regolith, Induration codes
Db1	Numerous duricrusted outcrops (mainly ferricrete, minor silcrete), often overlying a deep weathered partly ferruginous profile; residual sediment on low rises & alluvial fill in valleys; colluvium with calcrete next to greenstone outcrops.	Slopes, rises & plains: Mesas, pediments, broken slopes, ridges, low breakaways and plains.	rises (9-30m) unknown thickness 2 - 20m depositional plain unknown thickness <9m	*felsic igneous extrusive *metamorphic mafic rock *hornfels *sandstone *metamorphic mafic rock *metasediment	WIR10, IDS40 SDC00, IDS20 WIR10, IDS60 WIR20, SDA00,
Db2	Deeply weathered bedrock; ferruginous duricrust & gravel, colluvial deposits with red-brown siliceous (Wiluna) hardpan.	Mesas, broken slopes, with scarps & breakaways.	etchplain > 50m thick <9m	*ultramafic igneous intrusive *mafic igneous extrusive *metasediment *banded iron formation	IDM40, SDC00, IDP60 SDC00, IDM40 WIR00, IDM40

Unit	Regolith description	Terrain description	Landforms Regolith thickness Landform relief	Bedrock lithology	Regolith, Induration codes
Dp1	Calcareous residual soils over authigenic layer of calcrete pisoliths (0.5-2.0m thick) loose in sand, packed or cemented. Clayey soils in depressions. Aeolian calcareous sand over gypsum near northwest lakes.	Flat plain; large (20Km) shallow (30m) northern depressions; sand dunes (2-6m high). Claypans often in centre of depressions.	erosional plain (<9m) < 0.5m thick <5m karst unknown thickness <30m sand plain unknown thickness 2-6m	*calcarenite *sandstone *sandstone *calcarenite *sandstone *sandstone *calcarenite *sandstone *sandstone	IDS20, WIR23, UOS00,
Dp2	Shallow residual calcareous loams & clayey calcareous earths with nodular & 5m thick oolitic sheet calcrete over indurated & recrystallised limestone. Rubbly calcrete set in clay over calcareous & gysiferous clay.	Featureless flat plain with 15m deep occasional depressions <5Km wide. Low parallel ridges in southeast. Numerous small clay pans, & gilgai on sloping floors of large depressions.	erosional plain (<9m) > 5m thick generally <2m	*calcarenite *calcarenite *limestone *sandstone	IDS20, SDC05, IDS20 UOC00, IDS20 UOS00, IDS20

Unit	Regolith description	Terrain description	Landforms Regolith thickness Landform relief	Bedrock lithology	Regolith, Induration codes
Dp3	Residual deep calcreous earths with nodular, rubbly, pisolitic & laminar limestone over <1.5m of platy & pisolitic calcrete in clay. Underlain by massive oolitic calcrete in clay (see Dp2), & weathered limestone at greater depth.	Flat plain well wooded (data limited).	erosional plain (<9m) > 2m thick <5m	*calcarenite *calcarenite *sandstone	IDS20, IDS20, WIR23, IDS40
Dp4	Deep (?residual) calcareous earths containing sheet & nodualar calcrete, with patchy loamy (?aeolian) surface soils overlying limestone bedrock.	Plain, with deep soils on SW edge of flat plain.	erosional plain (<9m) unknown thickness 6-9m	*calcarenite *calcarenite	IDS20, INO20,

Unit	Regolith description	Terrain description	Landforms Regolith thickness Landform relief	Bedrock lithology	Regolith, Induration codes
Dr1	Areas of saprolite including pallid zones, siliceous & ferruginous skins to granitic saprolite on hill & ridge tops; silcrete ridge caps & some minor ferricrete. Gritty sands, earthy sands, & extensive to discontinuous siliceous hardpans.	Branching ridges with breakaways and small rocky rises.	rises (9-30m) > 15m thick <20m	*felsic igneous intrusive *quartz porphry *metamorphic mafic rock *gneiss *migmatite *sandstone	IDP60, WIR10, IDM40 WIR10, IDM60 IDS40, IDS60,
Dr2	Weathered granitic bedrock; colluvium, qtz & feldspar grain dominated, from granite outcrops; minor undifferentiated colluvium & alluvium; red-brown siliceous (Wiluna) hardpan in northern areas, possibly calcrete in southern areas.	Ridges and rises.	rises (9-30m) unknown thickness up to 30m	*adamellite *granitoid rock *metasediment	WIR10, IDP60, SDC00, SDC00,

Unit	Regolith description	Terrain description	Landforms Regolith thickness Landform relief	Bedrock lithology	Regolith, Induration codes
Dr3	Deeply weathered bedrock; colluvium with sheet calcrete & alluvium around outcrops; red-brown siliceous hard-pan (Wiluna Hardpan) in areas north of 30 deg S	Broken slopes & ridges, & gently undulating to low hilly pediments.	low hills (30-90m) > 50m thick <50m	*granite *ultramafic igneous intrusive *felsic igneous extrusive *metamorphic mafic rock *sandstone	IDP60, SDA00, SDC00, IDS20 WIR00,
Dr4	Ferruginous nodular/pisolitic ferricrete (2-8m thick) over mottled & pallid weathering zones; ferruginous scree/colluv-ium around topo highs; overlie deeply weathered (50-250m) often silicified acidic bedrock.	Scattered remnants of undulating duricrust plains with small breakaways & rises & mounds; scarplands consisting of mesas, buttes, breakaways, & hillocks in the north & west; associated scree aprons.	etchplain > 50m thick <9m escarpment > 50m thick 5-20m	*granite *migmatite *sedimentary rocks, chemical/biogenic *sandstone *granite *sandstone	SDC00, IND40 IDM60, IDS42, INO40, SDC00, IND40 WIR10, IDM60
Dr5	Silcrete (<3m preserved) pavements & rubble, shallow soils & residual silicified soils over deeply weathered (>20m) in-situ kaolinisedbedrock; weathered outcrops; lateritic duricrust (or ferruginized silcrete); scree & colluvium or alluvium.	Scarpland-breakaways with cuestas, mesas, buttes & stony hillocks; steep coalescing stony talus slopes incised by ephemeral creeks.	escarpment > 50m thick approx 20m	*granite *tonalite *migmatite *metasediment *sedimentary rocks, chemical/biogenic *sandstone *sandstone	IDS60, IDU00, IND40 SDT00, WIR10,

Unit	Regolith description	Terrain description	Landforms Regolith thickness Landform relief	Bedrock lithology	Regolith, Induration codes
Ds1	Yellow earthy residual & colluvial sand, with both quartz grains & clay glaebules, containing ferruginous nodules in places, overlying & derived from deeply weathered mottled granitic rocks. Some ferruginous duricrusts at breakaways.	Gently sloping to undulating upland sandplains or plateaus, edged in places by abrupt low erosional scarps.	plateau > 50m thick <9m on plateau, scarp <20m	*granite *granite *metabasalt *metasediment	SDC00, INO40 WIR10, IDM40 WIR22, INO40
Du1	Scattered areas of quartzo-feldspathic sand over deep weathered granitoid bedrock & yellow sandplain remnants (Ds1) on higher terrain. Dissected by valleys with alluvium & colluvium.	Hills, granitoid domes, plateau remnants, slopes and valleys. Collectively represent the eroding rim between the sand plateau & the playa complex.	erosional landforms unknown thickness >50m drainage depression unknown thickness < 5m	*granite *granite *granite *metabasalt *gneiss *granite *granite *granite *metabasalt *gneiss	WIR11, WIR22, WIR22, INO40 SDC00, WIR11, SDA00,

Unit	Regolith description	Terrain description	Landforms Regolith thickness Landform relief	Bedrock lithology	Regolith, Induration codes
Du2	Residual quartzo-feldspathic sand over granitoid bedrock on interfluves. Colluvium & alluvium in valleys over weathered bedrock. Skeletal soils on granite domes. Remnant yellow colluvial sand & ferruginous gravels on higher interfluves.	Undulating plain consisting of broad interfluves with broken slopes & pediments, & minor headwater tributaries. Numerous granitic tors & bosses on broken slopes. Remnant sand covered plateaus on higher interfluves.	etchplain unknown thickness <9m but up to 25m on tors drainage depression unknown thickness 2m	*granodiorite *granite *granite *mafic/ultramafic intrusive *mafic/ultramafic intrusive *metabasalt *metasediment *metamorphic ultramafic rock *granite *granite	WIR00, WIR22, WIR22, INO40 WIR24, SDC00, INO20 WIR00, SDA00,
Du3	Residual material derived from deeply weathered greenstones. Minor colluvium & calcareous & ferruginous nodules. Very limited alluvium along a few intermittant streams. Residual quartzo-felds-pathic sand over deeply weathered granite.	Gently undulating plains with some gilgai areas. Occasional rises & ridges.	etchplain unknown thickness <9m occasionally up to 20m	*granite *pegmatite *metamorphic mafic rock *metasediment *metamorphic ultramafic rock *Granite	WIR20, INO20 IND40, SDA00, SDC00, WIR22,

Unit	Regolith description	Terrain description	Landforms Regolith thickness Landform relief	Bedrock lithology	Regolith, Induration codes
Du4	Ferruginous lag over sheet calcrete mantling rises. Ferruginous gravel (scree) over colluvium on slopes. Intervening valley sediments. Minor ferricrete & sand plateau remnants. Underlying deeply weathered bedrock.	Gently undulating plains with low rises & interfluves, & colluvial fans & tributary valleys.	rises (9-30m) > 50m thick up to 15m colluvial fan > 50m thick < 5m Drainage depression > 50m thick < 2m	*metamorphic mafic rock *metasediment *metamorphic ultramafic rock *metamorphic rock *Granite *metamorphic rock	IDS20, SDT00, INO40 WIR11, WIR21, INO40 SDT00, IDS40 WIR11, IDM40 WIR11, INO60 WIR11, INO40 SDC01, INO40 SDT00, IDS40 SDT00, INO40 WIR10, IDM40 WIR10, WIR10, INO60 WIR10, INO40 SDC00, SDT00, IDS40 SDT00, INO40 WIR11, IDM40 WIR11, WIR11, INO40 WIR11, INO60 SDA00

Unit	Regolith description	Terrain description	Landforms Regolith thickness Landform relief	Bedrock lithology	Regolith, Induration codes
Du5	Skeletal soils & residual granite derived weathered material associated with outcrops & subcrops; surrounded by Fe-induration or colluvium overlies deeply weathered bedrock. Minor areas of dunes. Calcareous nodules present in colluvium.	Flat to gently undulating plain interrupted by flat to low domed bedrock exposures.	etchplain unknown thickness <4m rises (9-30m) < 0.5m thick outcrops <30m depositional plain unknown thickness <4m	*granite *granite *sandstone *granite	IND40, WMU00, WIR00, WIS00, SDC00, INO20 WMU00, SDE01,
Du6	Bedrock residual material with intervening colluvium over deeply weathered bedrock. Deep calcareous soils with calcareous nodules, shallow calcareous soils. Scattered areas of reworked red soil with ferruginous pisoliths	Gently undulating plain.	erosional plain (<9m) unknown thickness 4m	*granite *metamorphic mafic rock *metasediment *metasediment *sedimentary rocks, chemical/biogenic	SDC00, INO20 WIR20, WMU00, INO40,

Unit	Regolith description	Terrain description	Landforms Regolith thickness Landform relief	Bedrock lithology	Regolith, Induration codes
Du7	Deeply weathered granite; colluvial weathering residuals, & alluvial deposits, in some places containing Ferruginous-pisoliths; small areas of Fe-duricrust. Similar to Du5 except Du7 has more alluvial deposits, & soil differences.	Undulating plain with present-day drainage & isolated clusters of low rises.	erosional plain (<9m) > 15m thick <2m	*granitoid rock *syenite *metasediment *banded iron formation	SDA00, INO40 SDC00, INO40 WIR00, IDM40 WIR20, INO40
Sd1	Aeolian red-brown & minor yellow qtz dunes sometimes over ?residual red earthy sand of interdune corridors: cf Sd2 but contaminated by ferruginous & colluvial components, & derived from muddier sst; calcrete in east. Deep weathered bedrock.	Sandplain with numerous seif dunes & interdune corridors; dunes oriented east-west & merge with west oriented dunes. Dunes vary from 5-15m high & up to 10km long.	dunefield > 50m thick 5-15m (averaged) sand plain > 50m thick 5m erosional landforms > 50m thick likely <5m	*adamellite *migmatite *sandstone *adamellite *migmatite *adamellite *sandstone	SDC00, SDE01, SDC00, UOS00, WIR00, IDS40 WIR00, IDS00 WIR00, IDS60 WIR10, SDC00, WIR00, IDS40 WIR00, IDS00 WIR00, IDS60

Unit	Regolith description	Terrain description	Landforms Regolith thickness Landform relief	Bedrock lithology	Regolith, Induration codes
Sd2	Aeolian red-brown & minor yellow quartz dune sand sometimes cover ?residual red earthy sands (<3m deep) of interdune corridors; over deeply (100m) weathered & often silicified/ferruginous arenaceous bedrock, interdune clays, gypsum.	Sandplain with seif dunes & interdune corridors (Great Victoria Desert). Dominant E-W oriented dunes have merging angles facing W. Dune heights 5-15m & up to 10Km long.	sand plain > 50m thick <5m dunefield > 50m thick 5-15m longitudinal dune field > 50m thick 5-15m, Streich Mound 50m	*granite *sandstone *quartzite *sandstone *sandstone	UOS00, WIR00, IND40 WIR00, IND60 EVA02, SDC05, SDE01, WIR21, WIR00, IND40 WIR00, IND60 SDE01, SDE01,
Se1	Mixed colluvial & alluvial deposits derived from eroding granitic outcrops; extensive red-brown siliceous (Wiluna) hardpan; some deep red soils & brown loams with gravelly ferricrete; deeply weathered bedrock.	Undulating surfaces, broken slopes & ridges; gently undulating plains.	depositional plain > 15m thick <5m	*granite	IDP60, SDT00, WIR00, IDS20, IDS42,

Unit	Regolith description	Terrain description	Landforms Regolith thickness Landform relief	Bedrock lithology	Regolith, Induration codes
Se2	Colluvium, including reworked Tertiary sandplain, & alluvium; calcrete; minor siliceous duricrust; deeply weathered bedrock.	Undulating plains & broad interfluves.	depositional plain > 15m thick <5m	*granite	SDT00, IDS20 SDT00, IDM60 WIR00,
Se3	Colluvial, alluvial & aeolian loam with calcrete; alluvium along present-day drainage lines; deeply weathered bedrock.	Flat to undulating plains with many present-day drainage lines.	alluvial plain unknown thickness <2m	*granite *granulite	SDA00, SDT00, WIR00,
Se4	Colluvial gravel/sand/silt/clay which may contain red-brown (Wiluna) hardpan, detrital ferricrete/silcrete & Fe mottles; likely sheet calcrete in west; minor alluvium; grades to playa lake deposits; underlain by deeply weathered acid rocks.	Gentle slopes & flats occasionally cut by ephemeral channels; mainly in corridors adjacent to playa lakes in NW unit occurences; often at the foot of breakaways in the east.	colluvial fan > 15m thick <5m likely depositional plain > 15m thick <5m likely	*granite *sandstone *sandstone *granite *tonalite *serpentinite *mafic igneous extrusive *sandstone	SDC05, IND20 WIR00, WIR21, IDP60, IDS20, WIR00, WIR21, IDP60, IDS20, SDA00,

Unit	Regolith description	Terrain description	Landforms Regolith thickness Landform relief	Bedrock lithology	Regolith, Induration codes
Se5	Areas of superimposed or abutting alluvium, colluvium & residual deep calcareous earths with loamy to sandy soils;nodular/sheet calcrete (<2m) to east & possibly parna-derived (playa) calcareous earths to west; over shallow weathered bedrock	Gently undulating low lying plains & valleys.	depositional plain unknown thickness 20m	*granite *gneiss *granulite *calcarenite	SDT00, WIR00, IND20 IDS20,
Sf1	Alluvial & colluvial sediments: fine gravel to clay size, possibly up to 50m thick, derived from eroded granite. Sediments contain red-brown siliceous (Wiluna) hardpan, & calcrete nodules; surface gravels; weathered granite.	Alluvial outwash fans, slopes & plains with numerous braided ephemeral watercourses.	alluvial fan > 15m thick <5m	*granite	SDT00, IDM60 SDT00, INO20 WIR00, WIR21,

Unit	Regolith description	Terrain description	Landforms Regolith thickness Landform relief	Bedrock lithology	Regolith, Induration codes
Sf2	Mixed colluvial and alluvial deposits, mainly loams derived from green-stones; surface gravels sometimes ferricete gravels; red-brown sili-ceous (Wiluna) weathered bedrock at depth.	Slopes generated by outwash fans.	colluvial fan > 15m thick <5m	*granite *metamorphic mafic rock *metasediment	SDT00, IDP60 WIR00, WIR20,
Sf3	Colluvial & alluvial deposits containing ferricrete gravel, sheet calcrete under ferruginous gravels & red brown siliceous (Wiluna) hardpan derived from nearby areas of Fe-duricrust or banded iron formation; over deeply weathered bedrock.	Slopes adjacent to ridges of banded iron formation & plateaux of ferruginous duricrust.	colluvial fan > 15m thick <5m	*granodiorite *granite *diorite *mafic/ultramafic intrusive *metabasalt *metasediment *banded iron formation	SDA00, IDS20 SDA00, INO40 SDA00, IDP60 SDC00, IDS20 SDC00, INO40 SDC00, IDP60 WIR00,
Si1	Sandy to loamy alluvium & colluvium; nodular calcrete in soils, espec-ially in southern part of the area; scree & pedi-ments around granite out-crops; some aeolian deposits; deeply weathered bedrock.	Sandy outwash plains with gravelly pediments & low breakaways & broad valley sides. Small granitic hills & remnant sand plains.	depositional plain unknown thickness <2m	*granite	SDT00, WIR00, IDS20, SDE01,

Unit	Regolith description	Terrain description	Landforms Regolith thickness Landform relief	Bedrock lithology	Regolith, Induration codes
Si2	Residual ferricrete gravel, granite derived colluvium, colluvially reworked sandplains; undifferentiated loamy colluvial & alluvial deposits, Fe duricrust, (Wiluna) hardpan; deeply weathered granite bedrock	Undulating plain with small granite rises.	sand plain > 15m thick <5m erosional plain (<9m) > 15m thick <5m	*granite *granite	SDT00, IDP60 WIR22, WIR00, IDM40 SDC00, WIR20, INO40
Si3	Mixtures of colluvial, alluvial & residual deposits, some with calcrete, ferruginous & calcareous nodules; overlying deeply weathered bedrock; minor mottled zones &ferricrete.	Flat to gently undulating valley plains with present-day drainage, & low rises.	depositional plain unknown thickness <4m	*granite *mafic/ultramafic intrusive *intermediate igneous extrusive *metasediment *banded iron formation *mixed siliciclastic/chem	SDT00, IND40 SDT00, IND20 WIR00, IDS40
Si4	Red-brown loam with calcrete; colluvium, including arkosic material derived from granite, alluvium, residual ferricrete gravel; deeply weathered bedrock.	Flat to undulating plains with low interfluves.	depositional plain unknown thickness <4m	*granodiorite *granodiorite *metasediment	SDA00, WIR00, IDS20, SDC00, WIR21,

Unit	Regolith description	Terrain description	Landforms Regolith thickness Landform relief	Bedrock lithology	Regolith, Induration codes
Si5	Colluvial & alluvial deposits over deeply weathered bedrock; minor ferruginous/siliceous duricrust, ferruginous gravel in sand; calcrete in places with colluvium; scattered outcrop.	Undulating plains with low drainage divides & present-day drainage lines.	depositional plain unknown thickness <5m	*granite *ultramafic igneous intrusive *gneiss *migmatite *sandstone	SDA00, SDC00, WIR00, IDM40, IDM60, IDS20, WIR21,
Si6	Colluvium, alluvium, aeolian veneers; Fe & siliceous duricrusts, hardpan; deeply weathered bedrock.	Gently undulating plain with breakaways & dendritic drainage systems.	erosional plain (<9m) unknown thickness <5m dunefield > 2m thick <5m	*granite *mafic igneous extrusive *granulite *metasediment *banded iron formation *sandstone *granite *sandstone	SDA00, SDC00, IDM20 WIR00, IDM40, IDM60, IDP60, SDE01, SDE00,

Unit	Regolith description	Terrain description	Landforms Regolith thickness Landform relief	Bedrock lithology	Regolith, Induration codes
Sp1	Evaporite interbedded with clay & sand in playas. Sand,silt & gypsum in stabilized dunes adjacent to playas. Associated colluvial & alluvial deposits between & fringing playas. Variable subsurface & pavement duricrust. Deep weathered bedrock	Partially infilled palaeodrainage valleys with playas (often with saline lakes), claypans, kopi dunes & sand dunes & lunettes (preferentially on eastern side of playas), & fringing flats.	playa plain unknown thickness up to 10m	*granite *mafic/ultramafic intrusive *mafic igneous extrusive *regional metamorphic rock *metasediment *metasediment *banded iron formation *calcarenite *sedimentary rocks, chemical/biogenic *siliciclastic sedimentary rocks *siliciclastic sedimentary rocks *sandstone	EVA01, EVA02, SDL00, WMU00, IDU00, SDA00, SDC00, SDE01, SDE03,
Sr1	Areas of colluvium (reworked aeolian sand & red-brown clay & loam); areas of Fe-gravels in sand and loam matrix; areas of red, brown & yellow aeolian sand; alluvium along present drainage; over deeply weathered bedrock.	Undulating valley plains.	alluvial plain > 15m thick <2m	*granodiorite *granite *mafic igneous intrusive *migmatite	SDA00, SDE01, WIR00, IDP60, IDS20,

Unit	Regolith description	Terrain description	Landforms Regolith thickness Landform relief	Bedrock lithology	Regolith, Induration codes
Sr2	Reworked red soil with ferruginous pisoliths, intervening corridors of colluvium with deep calcareous soils with calc-areous nodules. Deeply weathered substrate.	Flat to gently undulating plain.	depositional plain unknown thickness 4 m	*granite *metamorphic mafic rock *metasediment *metasediment *sandstone	INO40, WMU00, SDC00, INO20
Sr3	Wind modified red-brown quartz sands & earthy soils of mixed origin underlain by siliceous red-brown (Wiluna) Hardpan; residual soils from deflated laterite/ silcrete; over deeply weathered & duricrusted bedrock.	Undulating sandplain with low duricrusted residuals & scattered dendritic ephemeral stream channels; minor sand dunes.	sand plain unknown thickness variable up to 50m	*granite *migmatite *sandstone	IDP60, WIR00, IND40 WIR00, WIR00, IND60 WIR22,
Sr4	Aeolian red-brown quartz sand of dunes, over or adjacent to ?residual red earthy sands of dune corridors; rises of deflated (in part) residual red earth with Fe pisoliths & colluvial scree slopes; over deeply weathered Permian bedrock.	Scattered remnants of undulating duricrust plains with small breakaways & rises with scree aprons inter-fingering with dunefields.	etchplain > 50m thick <9m dunefield > 50m thick <15m	*sandstone *sandstone	WIR00, IDM40 WIR00, IDM60 SDC01, SDE01, WIR00, IDM40 WIR00, IDM60

Unit	Regolith description	Terrain description	Landforms Regolith thickness Landform relief	Bedrock lithology	Regolith, Induration codes
Sr5	?Reorganized (in-situ) & reworked aeolian, shallow (<1m) patchy red quartz sheet sand; over deeply weathered partly ferruginized/silicified sandstone bedrock. Small smoothly rounded scattered ferricrete/ pisolith strewn rises.	Irregular corridors of sandplains; Small scattered higher areas of duricrust plains & a few scattered sand dunes. General form is a broken gently undulating sandplain.	sand plain > 15m thick <5m dunefield > 15m thick 10m average etchplain > 15m thick <9m rises (9-30m) > 15m thick <30m escarpment > 15m thick <30m	*sandstone *sandstone *sandstone *gneiss *sandstone *sandstone	SDT00, SDE01, WIR00, IND40 WIR00, IND60 WIR10, IDS40,

Unit	Regolith description	Terrain description	Landforms Regolith thickness Landform relief	Bedrock lithology	Regolith, Induration codes
Ss1	Red, brown & yellow aeolian & fluvial sand, some colluvium in NW. Sediments contain red-brown siliceous (Wiluna) hardpan <2m thick from mid to lower slope surfaces; gravel covered ridges. Thick bedrock saprolite.	Aeolian & fluvial plain with some longitudinal dunes.	sand plain > 15m thick <5m longitudinal dune field > 15m thick 5m erosional landforms > 15m thick <5m	*granite *granite *granite *metamorphic mafic rock *metamorphic ultramafic rock	SDA00, SDE01, WIR10, WIR10, SDE01, WIR10, SDA10, SDC00, IDP60
Ss2	?Reorganized (in-situ) & reworked (aeolian) red quartz sands over sandy calcrete over colluvium/ alluvium with ferricrete/ silcrete pebbles, & mottles; underlain by deeply weathered sand-stone, partly calcareous & ferruginous.	Flat sandy plains with areas of broad flats & low rises.	erosional plain (<9m) > 15m thick <5m sand plain > 15m thick <5m	*metasediment *sandstone *sandstone	IDS20, SDT00, WIR00, IDM40 WIR00, IDS60 IDS20, SDE01, WIR00, IDM40 WIR00, IDS60

Unit	Regolith description	Terrain description	Landforms Regolith thickness Landform relief	Bedrock lithology	Regolith, Induration codes
Ss3	Reorganised (in-situ) & reworked (aeolian) red-brown & minor yellow well sorted quartz to clayey sand, forming sheets 2-4m thick; over deeply (>100m) weathered often silicified and/or ferruginized bedrock.	Gently undulating to flat sand plain with some dune-fields (Great Victoria Desert).	sand plain > 50m thick <5m dunefield > 50m thick 5-15m	*mafic igneous extrusive *calcarenite *limestone *sandstone *sandstone *calcarenite *limestone *sandstone	WIR00, SDC05, WIR21, SDE01, WIR00, SDC05,
Ss4	Aeolian red quartz sand over residual sand/silt/ clay containing sheet & nodular calcrete; overlie Eucla Basin bedrock.	Widely distributed sandplains.	sand plain unknown thickness <2m	*calcarenite *sandstone	SDE01, WIR20, IDS20
Ss5	Patchy aeolian sands overlying alluvial & col-luvial material. Sheet & nodular calcrete with the eastern association with Eucla Basin; underlain by deeply weathered granites in west & sandstones in the centre.	Gently undulating plain with small shallow depressions & low gentle rises; some longitudinal seif dunes on the western edge of the unit. Patchy sand sheet in the east.	etchplain > 15m thick <6m	*granite *metamorphic rock *granulite *calcarenite *limestone *sandstone	IDU00, SDE01, WIR00, SDT00,

Unit	Regolith description	Terrain description	Landforms Regolith thickness Landform relief	Bedrock lithology	Regolith, Induration codes
Sv1	Pedogenic valley calcrete, uraniferous in places, overlying colluvium & alluvium; deeply weathered bedrock.	Valley floor, with mound & karst topography.	alluvial landforms unknown thickness ?3m	*granite *mafic/ultramafic intrusive	IDS20, SDA00, IND20 SDC00, IND20 WIR00,
Sv2	Sheetwash & talus colluvium on valley sides, alluvium in channels in valley bottoms. Overlies deeply weathered granitic bedrock. Some calcareous nodules, mainly in alluvium.	Broad saucer shaped valleys, 3-5 Km wide, gradually widening downstream towards playa complex.	drainage depression unknown thickness 10-20m edges of unit	*granite *granite	SDA10, INO20 SDC01, SDC05, WIR00,
Sv3	Younger alluvium, overlying valley-fill loam containing calcrete (?alluvial & colluvial deposits), overlying deep weathered rock	Flat to gently undulating valley plains with present-day drainage systems.	alluvial plain > 15m thick <2m	*granite *metamorphic felsic rock *metamorphic mafic rock	SDA00, SDT00, INO20 WIR00,

Other Regolith Group publications:

1. Ollier, C.D. 1984: Glossary of Morphotectonics, BMR Record 1984/24.

2. Chan, R.A., Craig, M.A., D'Addario, G.W., Gibson, D.L., Ollier, C.D. and Taylor, G. 1986: The Regolith Terrain Map of Australia 1:5 000 000, BMR Record 1986/27.

3. Ollier, C.D. and Joyce E.B., 1986: Regolith Terrain Units of the Hamilton 1:1 000 000 Sheet Area, Western Victoria, BMR Record 1986/33.

4. Chan, R.A., Ollier, C.D. and Gibson, D.L., 1988: Regolith Terrain Data, Kalgoorlie 1:1 000 000 sheet SH-51, Western Australia, BMR Record 1988/3.

5. Pain, C.F., Chan, R.A., Craig, M.A. Hazell, M., Kamprad, J., and Wilford, J., 1991: RTMAP BMR Regolith Database Handbook, BMR Record 1191/29.

AUSTRALIA

BMR GEOLOGY AND GEOPHYSICS AUSTRALIA

REGOLITH TERRAINS OF THE KALGOORLIE AREA

By R.A. Chan, BMR

1991

Scale 1:1 000 000

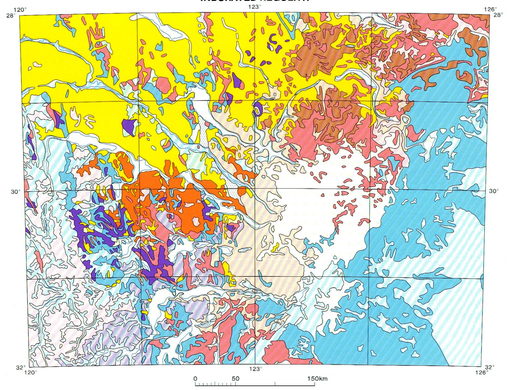
0 20 40 60 80 100 kilometres

LAMBERT CONFORMAL CONIC PROJECTION WITH TWO STANDARD PARALLELS (28°40' and 31°20')

AUSTRALIA 1:1 000 000 REGOLITH

WESTERN AUSTRALIA SH–51

INDURATED REGOLITH



MAJOR OCCURRENCES

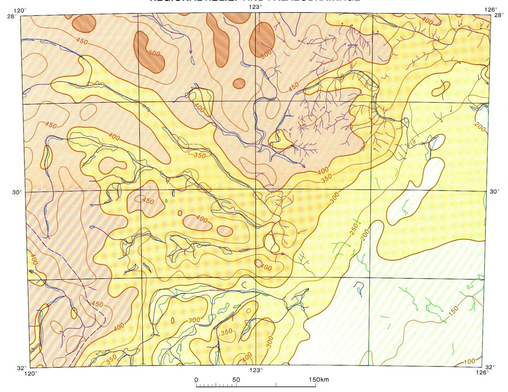
- *CALCRETE (east), CALCAREOUS NODULES (west) — may include ferruginous and siliceous nodules*
- *FERRICRETE and/or FERRUGINOUS NODULES and/or FERRUGINOUS INDURATED MOTTLES — may include calcrete, calcareous nodules, siliceous hardpan and/or nodules*
- *SILICEOUS HARDPAN — may include silcrete, ferricrete, siliceous and/or ferruginous and/or calcareous nodules*
- *CALCRETE, FERRUGINOUS NODULES*
- *SILICEOUS HARDPAN, FERRUGINOUS NODULES*
- *CALCRETE, FERRICRETE, SILCRETE*

Minor Occurrences

- *Calcrete (east and northwest), Calcareous nodules (southwest)*
- *Ferricrete and/or ferruginous nodules and/or ferruginous indurated mottles*
- *Siliceous hardpan*
- *Possible indurated regolith at depth*
- *Calcrete and/or calcareous nodules, ferruginous nodules*
- *Calcrete, siliceous hardpan*
- *Calcrete, ferricrete, siliceous hardpan– may include siliceous and/or ferruginous and/or calcareous nodules*
- *Non-indurated regolith*

NOTE: Order of combined occurrences (eg *CALCRETE , FERRUGINOUS NODULES*) does not imply dominance

REGIONAL RELIEF AND PALAEODRAINAGE



PRESENT–DAY RELIEF

0 100 200 300 400 500 600 metres asl

Contour interval: 50 metres

LATE CRETACEOUS TO EARLY TERTIARY PALAEODRAINAGE

(Variability in palaeodrainage density reflects preservation, variability in bedrock lithology, style and detail of mapping)

- *Major palaeodrainage lines associated with playa lake system (Regolith Terrain Units* **Sp1** *and* **Sv1***)*
- *Tributary and minor palaeodrainage lines associated with undulating duricrust and sand plains of the Officer Basin*
- *Palaeodrainage divide*

LATE TERTIARY TO QUATERNARY PALAEODRAINAGE

- *Palaeodrainage associated with dongas and ridges of the Eucla Basin*

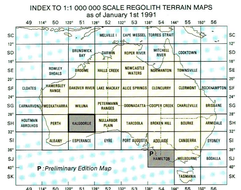
SOURCES: Topographic contours derived from altitudes of gravity stations:
Wellman, P. et al (1988) — Land and Sea-bottom Relief. 1:10M map.
BMR Earth Science Atlas

Officer Basin palaeodrainage:
Jackson, M.J. & van de Graaff, W.J.E. (1981) — Geology of the Officer Basin, Western Australia.
BMR Bulletin 206

Eucla Basin palaeodrainage:
Lowry, D.C. (1970) — Geology of the Western Australian part of the Eucla Basin.
GSWA Bulletin 122

REFERENCE: Van de Graaff, W.J.E. et al (1977) — Relict Early Cainozoic drainages in arid Western Australia.
Z. Geomorph. N.F. 21,4

INDEX TO 1:1 000 000 SCALE REGOLITH TERRAIN MAPS
as of January 1st 1991



Field work 1985 by C. D. Ollier, D. L. Gibson, M. A. Craig, R. A. Chan, BMR
Landsat Interpretation 1985–86 by R. A. Chan, BMR

Compiled 1985–1987 by R.A. Chan, A.S. Mikolajczak, BMR
Revised 1989–1990 by R.A. Chan
Mineral locality compilation and digitising 1989–1990 by M.S. Hazell, BMR
Cartography by F. Moffat, J.F. Stirzaker, J.N. Mason, BMR
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This map is accompanied by data within the RTMAP data base, and the 1:1 000 000 Regolith Terrains Explanatory Notes

It is recommended that this map be referred to as:
Chan, R.A., 1991 —
Regolith Terrains of the Kalgoorlie Area, First Edition, (1:1 000 000 scale map)
Bureau of Mineral Resources, Canberra

MINERAL LOCALITIES

Mineral localities on this map show only the occurrence of mineralisation, and no indication of the size of the occurrence is intended or inferred. The occurrences have been divided into regolith and non-regolith (dominantly bedrock) categories and then broadly grouped by mineral association. The set of localities on the map should not be considered complete as some occurrences have been omitted due to the need for generalisation and others due to doubts about source accuracy. Where ambiguities occurred, the most recent and accurate information available was used. More than 5000 mineral localities were digitised and a small number plotted by hand. Most of the localities were digitised as points, however the boundaries of 85 polygonal occurrences were also digitised. The digital data, which includes Location (latitude, longitude), Mineral/Element Type and Deposit Name (where known) for each occurrence, is held in BMR's MINLOC data base. It is envisaged that further geological and production data will be added in the future. Information about the availability of this and other data in MINLOC may be obtained from BMR's Mr Brian Elliot on (06) 249 9502

SOURCES OF DEPOSIT/OCCURRENCE DATA

LOCATION DATA (Ordered by number of locations)

Hallberg, J.A., 1985 — Geology and Mineral Deposits of the Leonora-Laverton Area, Northeastern Yilgarn Block, Western Australia. 1:50 000 scale map; GSWA

GSWA/BMR, 1963–1977 — Unpublished compilation sheets from the 1:250 000 series Geology maps covering the Yilgarn Block. Scales of compilation sheets vary from 1:31 000 to 1:63 000

GSWA, 1988–1989 — 1st Edition 1:100 000 Geology maps

GSWA, 1989 — Preliminary 1:100 000 Geology maps

GSWA, information supplied by Geologists

Delta Gold NL, information supplied by Geologists

ADDITIONAL DATA

Mann, A.W., 1984 — Redistribution of gold in the oxidised zone of some Western Australian deposits. In GOLD MINING METALLURGY AND GEOLOGY. Kalgoorlie Regional Conference, AUSIMM

BMR MINDEP: Mineral Deposits Data Base

Wilson, A.F., 1983 — The economic significance of non-hydrothermal transport of gold, and the accretion of large gold nuggets in laterite and other weathering profiles in Australia. *In* SPECIAL PUBLICATION No7. The Geological Society of South Africa

The following map data is available in digital form and may be ordered from the Chief Cartographer, BMR– Ph (06) 245 1295, Fax (06) 247 2728

- Regolith Terrain Unit boundaries
- Regolith Terrain Province boundaries

MINERAL OCCURRENCES

REGOLITH OCCURRENCES

SYMBOL	TYPE OF OCCURRENCE	OCCURRENCES IN SHEET AREA
●	GOLD– *Alluvial*	142
●	GOLD– *Laterite*	5
●	GOLD– *Deeplead*	3
▲	NICKEL; NICKEL, COBALT – *Lateritic*	6
✳	URANIUM *(Calcrete hosted)*	4
◆	SEMI–PRECIOUS GEMSTONES *Includes: Chrysoprase, Opal*	7
■	MANGANESE	2
◆	MAGNESITE	1
▼	ALUNITE	1
▲	FULLER'S EARTH *(Attapulgite)*	1
▬	RARE EARTHS *(Carbonatite) Includes: Niobium, Yttrium, Thorium, Apatite*	1

BEDROCK OCCURRENCES

SYMBOL	TYPE OF OCCURRENCE	OCCURRENCES IN SHEET AREA
●	GOLD	4720
	Includes: Gold Copper	9
	Gold, Copper, Silver	1
	Gold, Bismuth	1
	Gold, Tungsten	1
●	NICKEL	30
	Includes: Nickel	2
	Nickel, Gold	1
	Nickel, Copper	
●	BASEMETALS	44
	Includes: Copper	1
	Zinc, Copper, Silver, Lead	1
	Lead	1
	Bismuth	7
▪	LITHIUM/FELDSPAR *(Pegmatite)*	3
▪	URANIUM *(Sandstone hosted)*	3
▪	MOLYBDENITE	2
▪	IRON *(BIF)*	1
▪	BROWN COAL	1
▪	CHROMIUM	1
▪	ASBESTOS, VERMICULITE	

REGOLITH TERRAINS

Full descriptions of Regolith Terrain Units (eg **Dp3**) are provided in the accompanying RTMAP data base

DEEP WEATHERING DOMINATED TERRAINS

EXTENSIVE DEEP WEATHERING MANTLE

- **Dp 1–4** *Erosional plain*
- **Dr 1–5** *Ridges/hills/rises*
- **Ds 1** *Sand covered plateau*

INTERRUPTED DEEP WEATHERING MANTLE

- **Db 1–2** *Duricrusted buttes/mesas/interfluves and intervening sediments*
- **Du 1–7** *Undulating deeply weathered plain with scattered outcrops (hills/tors) and/or sediments*

SEDIMENT DOMINATED TERRAINS

EXTENSIVE CONTINENTAL SEDIMENT MANTLE

- **Sd 1–2** *Continental dunefield*
- **Ss 1–5** *Sand covered plain*
- **Se 1–5** *Depositional plain*
- **Sf 1–3** *Fans*
- **Sv 1–3** *Valley complex*
- **Sp 1** *Playa complex*

INTERRUPTED CONTINENTAL SEDIMENT MANTLE

- **Si 1–6** *Sediment plains interrupted by bedrock (outcrops/pediments) and/or deep weathering residuals (breakaways/hills/rises)*
- **Sr 1–5** *Relict sediment plain with duricrust residuals and scree*

BEDROCK DOMINATED TERRAINS

EXTENSIVE OUTCROP OR MINIMAL REGOLITH MANTLE

- **Bp 1** *Structural plain*
- **Bs 1–3** *Linear structural ridges*

INTERRUPTED OUTCROP OR MINIMAL REGOLITH MANTLE

- **Bk 1–5** *Outcrop (hills/ridges) with pockets of deep weathering and intervening valleys/flats*

Sediments overlying deeply weathered profile

- *Regolith Terrain Unit boundary*
- *Regolith Terrain Province boundary*
- *Playa lake, claypan*
- *Ephemeral stream*
- *Bore or well*
- *Water storage: tank or dam*
- *Sand dunes*
- *Highway*
- *Secondary road*
- *Minor road, track*
- *Railway with siding*
- *Homestead*
- *Elevation in metres*

Flat-topped deeply weathered granite ridges with silcrete capping and granitic scree slopes. Indicative of Regolith Terrain Unit **Dr1** within Kurnajong Range Regolith Terrain Province in granite-gneiss domain of the Yilgarn Block

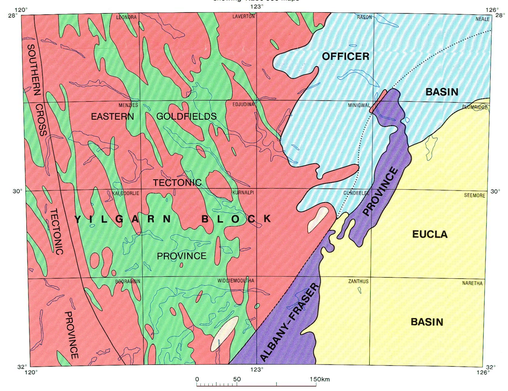
Basalt and chert ridges separated by undulating deeply weathered felsic volcanic plains with sediment cover. Indicative of Regolith Terrain Unit **Bh1** within Leonora Regolith Terrain Province in greenstone domain of the Yilgarn Block

Breached duricrust plain forming mesas with palaeodrainage lines indicated by denser vegetation. Indicative of Regolith Terrain Unit **Br4** within Pitcher Range Regolith Terrain Province in the Officer Basin

Flat limestone plain with shallow rises and depressions and minimal calcareous soils. Indicative of Regolith Terrain Unit **Dp1** within Nullarbor Regolith Terrain Province in the Eucla Basin

MAJOR STRUCTURAL ELEMENTS

showing 1:250 000 maps



- Cretaceous to Tertiary — **EUCLA BASIN**
- Late Proterozoic to Cretaceous — **OFFICER BASIN**
- *Sedimentary rocks*
- Early to Middle Proterozoic — **ALBANY–FRASER PROVINCE:** *Metamorphic and granitic rocks*
- **YILGARN BLOCK**
- Archaean — Cratonic cover: *sedimentary rocks*
- *Dominantly granitic and gneissic rocks*
- *Dominantly greenstones, volcanics and sedimentary rocks; minor basic intrusives*

- *Playa lakes*
- *Approximate boundary between basement elements*
- *Approximate boundary between basement elements beneath basin cover*

SOURCES

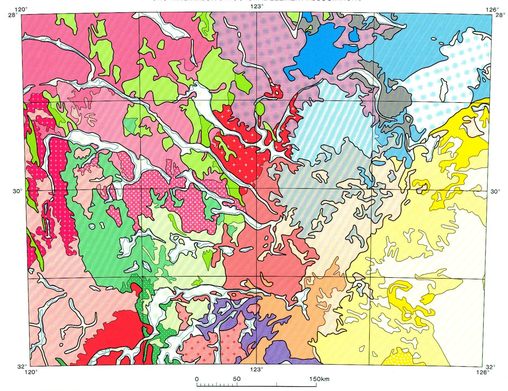
Boundary between Albany–Fraser Province and Yilgarn Block:
After— Whitaker, A. (in press). Interpretation of Regional Aeromagnetics, Kalgoorlie 1:1 M map, BMR

Tectonic province divisions within Yilgarn Block:
After— Gee, R.D. & others (1981). Crustal development in the Yilgarn block, Western Australia. *Spec. Publs. Geol. Soc. Aust. 7*

Other major structural element boundaries:
After— GSWA (1988). Geological map of Western Australia, Centennial edition, 1:2.5 M map

REGOLITH TERRAIN PROVINCES

SHOWING MAJOR STRUCTURAL ELEMENT ASSOCIATIONS



DOMINANT ASSOCIATIONS

EUCLA BASIN

- Ca P *Carlisle Plain* (**Dp1**)
- Ha T *Hampton Tableland* (**Ds3**)
- Nu P *Nullarbor Plain* (**Bp1**)
- Ny P *Nyanga Plain* (**Dp2,Dp3,Dp4**)

OFFICER BASIN

- Et H *Ethel Hill* (**Dr4,Sd1,Sr4**)
- Mi H *Minnie Hill* (**Dr4,Sd1,Sr4**)
- Pi R *Pitcher Range* (**Dr4,Sd1,Sr4,Sr5**)

OFFICER BASIN (overlying Albany–Fraser Province basement)

- Ne P *Neale Plateau* (**Sd1,Sx2**)

YILGARN BLOCK (Granitic terrain)

- Bin *Binneringie* (**Bx2,Dx5,Dx6,Dx7**)
- Boo *Boorabbin* (**Dx1,Dx1**)
- Ca H *Cave Hill* (**Dx2,Sv2**)
- Do R *Donkey Rocks* (**Dr2,Ds1,Si2,Sr1**)
- Em R *Emu Rocks* (**Dr2,Si5,Si6**)
- Ku R *Kurrajong Range* (**Dr1,Sf1,Ss1**)
- Mo R *Moon Rock* (**Se2,Se4,Si6,Sr1,Sr3**)
- Ni C *Niagara Creek* (**Dr1,Ss1,Sf1**)
- Wa R *Walling Rock* (**Si1**)

YILGARN BLOCK (Greenstone terrain)

- Br R *Bremer Range* (**Du3**)
- Co R *Cowarna Rocks* (**Bh1,Db1,Dr3,De4,Sf2,Si3**)
- Ed R *Edjudina Range* (**Bh2,Db1,Db2,Sf2,Sf3**)
- Kal *Kalgoorlie* (**Bh1,Ds1,Dr3,Ds1,De4,Sf2,Si3,Si4,Sv3**)
- Kam *Kambalda* (**Bh1**)
- Leo *Leonora* (**Bh1,Bh2,Db1,Dr1,Dr3,Sf2**)

TRANSITIONAL ASSOCIATIONS

EUCLA BASIN/ALBANY–FRASER PROVINCE

- Fr R *Fraser Range* (**Bh3,Bh4,Bh5,Bs1,Sx3,Sx5**)
- Moo *Moonyoora* (**Sx3,Sx4,Sx5**)

OFFICER BASIN/ALBANY–FRASER PROVINCE/YILGARN BLOCK

- Ba B *Bartlett Bluff* (**Dr4,Dr5,Se4**)
- St M *Streich Mound* (**Sd2,Sx3**)

OFFICER BASIN/YILGARN BLOCK

- Mu C *Mulgabiddy Creek* (**Dr4,Dr5,Sr3**)

ALBANY–FRASER PROVINCE /YILGARN BLOCK

- Mu H *Murdonna Hill* (**Si6,Sr2**)

NO ASSOCIATION

- Le *Lake Lefroy* (**Sp1,Sv1**)

- *Province Boundary*
- *Province/Major Structural Element Boundary*

Bracketed letter symbols denote typical Regolith Terrain Units within each Regolith Terrain Province

REGOLITH TERRAINS OF THE KALGOORLIE AREA
SHEET SH–51
FIRST EDITION 1991