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CYPLUS

CAPE YORK PENINSULA
LAND USE STRATEGY

NATURAL RESOURCES ANALYSIS PROGRAM
(NRAP)

REGOLITH-TERRAIN MAPPING OF CAPE YORK PENINSULA

C.F. Pain and J.R. Wilford
Australian Geological Survey Organisation
and
J.C. Dohrenwend
United States Geological Survey
1995

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Final report on project:

NR12 - REGOLITH-TERRAIN MAPPING

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Note:

Due to the timing of publication, reports on other CYPLUS projects may not be fully cited in the REFERENCES section. However, they should be able to be located by author, agency or subject.

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CAPE YORK PENINSULA LAND USE STRATEGY
STAGE I

PREFACE TO PROJECT REPORTS

Cape York Peninsula Land Use Strategy (CYPLUS) is an initiative to provide a basis for public participation in planning for the ecologically sustainable development of Cape York Peninsula. It is jointly funded by the Queensland and Commonwealth Governments and is being carried out in three stages:

- Stage I - information gathering;
- Stage II - development of principles, policies and processes; and
- Stage III - implementation and review.

The project dealt with in this report is a part of Stage I of CYPLUS. The main components of Stage I of CYPLUS consist of two data collection programs, the development of a Geographic Information System (GIS) and the establishment of processes for public participation.

The data collection and collation work was conducted within two broad programs, the Natural Resources Analysis Program (NRAP) and the Land Use Program (LUP). The project reported on here forms part of one of these programs.

The objectives of NRAP were to collect and interpret base data on the natural resources of Cape York Peninsula to provide input to:

- evaluation of the potential of those resources for a range of activities related to the use and management of land in line with economic, environmental and social values; and
- formulation of the land use policies, principles and processes of CYPLUS.

Projects examining both physical and biological resources were included in NRAP together with Geographic Information System (GIS) projects. NRAP projects are listed in the following Table.

Physical Resource/GIS Projects	Biological Resource Projects
Bedrock geological data - digitising and integration (NR05)	Vegetation mapping (NR01)
Airborne geophysical survey (NR15)	Marine plant (seagrass/mangrove) distribution (NR06)
Coastal environment geoscience survey (NR14)	Insect fauna survey (NR17)
Mineral resource inventory (NR04)	Fish fauna survey (NR10)
Water resource investigation (groundwater) (NR16)	Terrestrial vertebrate fauna survey (NR03)
Regolith terrain mapping (NR12)	Wetland fauna survey (NR09)

Physical Resource/GIS Projects	Biological Resource Projects
Environmental region analysis (NR11)	Fauna distribution modelling (NR19)
CYPLUS data into NRIC database FINDAR (NR20)	Golden-shouldered parrot conservation management (NR21)
Queensland GIS development and maintenance (NR08)*	
GIS creation/maintenance (NR07)*	

* These projects are accumulating and storing all Stage I data that is submitted in GIS compatible formats.

Research priorities for the LUP were set through the public participation process with the objectives of:

- collecting information on a wide range of social, cultural, economic and environmental issues relevant to Cape York Peninsula; and
- highlighting interactions between people, land (resource use) and nature sectors.

Projects were undertaken within these sector areas and are listed in the following Table.

People Projects	Land Projects	Nature Projects
Population	Current land use	Surface water resources
Transport services and infrastructure	Land tenure	Fire
Values, needs and aspirations	Indigenous management of land and sea	Feral and pest animals
Services and infrastructure	Pastoral industry	Weeds
Economic assessment	Primary industries (non-pastoral, non-forestry)	Land degradation and soil erosion
Secondary and tertiary industries	Forest resources	Conservation and natural heritage assessment
Traditional activities	Commercial and non commercial fisheries	Conservation and National Park management
Current administrative structures	Mineral resource potential and mining industry	
	Tourism industry	

TABLE OF CONTENTS

TABLES

SUMMARY

Regolith in the CYPLUS area in North Queensland consists of both *in situ* weathered bedrock and transported materials. *In situ* weathered bedrock includes:

Deep weathering profiles with bauxitic or ferruginous duricrusts, mottled zones, and pallid zones, found on remnant land surfaces.

Residual sand over moderately weathered saprolite in areas of relatively low geomorphic activity.

Thin soils lying directly on slightly weathered or unweathered bedrock on steeper slopes and unstable areas.

Transported regolith includes:

Large areas of alluvium in fans in the east, and a small area of slightly dissected fan alluvium in the south west

Narrow strips of alluvium, with occasional terraces, along the major rivers

Coastal sediments (beach ridges and estuarine sediments)

Small areas of colluvium in footslopes below steeper hill slopes

Iron cementing forms immature ferricrete in a few locations. Siliceous cementing is more widespread, both in present valley floors, and as silcrete in partially eroded alluvium that now caps small remnants of old land surfaces.

1. INTRODUCTION

This Final Report forms part of the Cape York Peninsula Land Use Strategy (CYPLUS) Project NR12, Regolith-Terrain Mapping. Some of the results presented here were obtained as part of the National Geoscience Mapping Accord (NGMA) North Queensland Project. 1:250 000 regolith landform maps and map commentaries will be published as part of the NGMA project. the map and commentary for EBAGOOLA have already been published (Pain et al. 1994a, 1994b).

When the project started the mapping units were called "Regolith-Terrain Units". However, as a result of deliberations by a joint AGSO/CSIRO Regolith Terminology Working Group, the name was changed to Regolith-Landform Units.

This report provides a brief statement of the methodology, results and significance of the CYPLUS Regolith-Landform map. The area is divided into regolith-landform units which were mapped using a combination of 1:80 000 panchromatic aerial photography (1970), 1:50 000 colour aerial photography (1990), Landsat TM image data, airborne magnetic and gamma-ray spectrometric image data, and field work carried out over the period 1992-1994 by the Australian Geological Survey Organisation (AGSO).

The philosophy behind the map is first presented. The report then discusses the regolith, first its characteristics, and then in relation to landscape position. Significance of the results is briefly discussed. A brief glossary is at the end of the record, and is followed by a detailed Data Dictionary that defines attributes for the fields attached to each regolith landform unit in the CYPLUS digital map coverage.

2. REGOLITH

2.1. Definitions of Regolith

There are a number of definitions of regolith to be found in various journals and books. The word itself was introduced by Merrill (1897) and has been in use since then. The term comes from the Greek *rhegos* = blanket and *lithos* = stone. In other words, the blanket over the rock.

Three similar definitions, which give the general idea of what we mean by the term *regolith*, are presented here.

- A general term for the layer or mantle of fragmented and unconsolidated rock material, whether residual or transported, that nearly everywhere forms the surface of the land and overlies or covers bedrock (Chan *et al.* 1986).

- The mantle of materials, including weathered rocks and sediments, altered or formed by land surface processes (Speight and Isbell 1990).

- The weathered and/or transported material, the upper part of which is called soil, overlying or covering bedrock.

Regolith includes rock debris of all kinds, including weathered rock in place, alluvium, colluvium, aeolian deposits, volcanic ash, and glacial till. It is commonly called "soil" by engineers, but here *soil* is restricted to organically influenced regolith which is at the surface. These points have been emphasised in earlier work by AGSO (then BMR) (Ollier and Joyce 1986, Chan 1988, Chan *et al.* 1988).

The underlying zone of rocks formed or altered by deep-seated crustal processes is the bedrock. Regolith and bedrock are thus characterised by different processes, rather than different materials. Regolith is bedrock which has been altered by processes at or near the surface including weathering, erosion, transportation, and terrestrial sedimentation. This includes induration of regolith by cementation to form, for example, duricrusts. Thus some regolith is not unconsolidated, but is very hard.

2.2. The Importance of Regolith

The regolith is important for several reasons:

1. It is of intrinsic scientific importance, especially in Australia, where more than 80% of the continent is covered in thick regolith. Moreover, much of the later geological history of the continent is recorded in the regolith.

2. Some regolith materials are of economic importance, such as bauxite, uraniferous calcrete, opal, and kaolin, and in other cases the regolith hosts economically important minerals such as gold, diamonds, tin, groundwater and road gravel.

3. Over large areas the regolith is a barrier between mineral explorers and their targets. A greater understanding of the regolith would allow mineral explorers to better plan ways to overcome this problem.

4. The regolith is the parent material for the soils on which agricultural and other land uses depend. An understanding of the regolith allows a better understanding of soil patterns, and also allows better prediction of soil characteristics in areas without detailed soil information.

5. The engineering properties of regolith are important for many civil works programs such as road building.

6. Information about regolith materials can be used to estimate erosion hazards and some kinds of land degradation. Part of our work for CYPLUS involves the production of a map of potential soil loss by water erosion.

3. REGOLITH-LANDFORM MAPPING

3.1. Regolith-Landform Units

The regolith-landform unit is the basic mapping unit, and is defined by Pain et al. (1991) as an area of land possessing similar landform and regolith attributes. A regolith-landform unit refers to an area of land of any size that can be isolated at the scale of mapping. Units are mapped primarily on the basis of landforms and then described in terms of the relationships between landforms and regolith. Often the landforms and regolith will be related both spatially and genetically. These relationships can be expressed as regolith toposequences, which, like soil catenas, show the location of regolith materials associated with particular parts of the landscape. The difference between a regolith toposequence and a soil catena is that the former is likely to be deeper and more complex.

It is important to note that regolith-landform maps show mapping units that are a composite of various regolith types and landforms. This follows from the fundamental difference between regolith and landform classification units, and regolith-landform mapping units. The arrangement of regolith materials in a classification is based on logical and hierarchical relationships between the different kinds of regolith. The same is true of landforms, which are classified separately from regolith. However, such arrangement in a classification has little in common with the spatial arrangement of these materials or landforms in a landscape. The arrangement of regolith-landform units in a landscape depends on the geomorphic character and development of an area. The difference between classification and mapping units is contained in the following definitions:

> *Classification units* consist of regolith or landform units which are defined in terms of various regolith or landform characteristics. They are ideal or conceptual units which can be precisely defined.
>
> *Mapping units* are real regolith-landform units that can be conveniently mapped, and their delimitation will therefore depend to some extent on the scale of the map. The more detailed the scale, the higher the purity of the regolith-landform units will be. A mapping unit will almost always include regolith units that do not belong to the appropriate classification unit. These different units occur in areas that are too small to appear on the map. An example of this are narrow areas of alluvium in floodplains within areas of dominantly highly weathered saprolite.

Regolith-landform units, therefore, do not define areas of uniform regolith materials, and regolith-landform maps cannot be interpreted in the same way as geology maps. 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-landform unit. The regolith at a particular point may be only a minor regolith type, perhaps mentioned in the database but not highlighted as part of the unit description on the map. The same applies to landforms. The regolith toposequence concept, embodied in the descriptions contained in this record, allows the map to be used as a guide to the dominant regolith types that occur in particular landscape positions in each mapping unit. The map should not be used to identify a particular regolith type at any given point. This also means that in order to use a regolith-landform map, the user must have at least some familiarity with regolith and landforms. Definitions of regolith and landform types are included as appendices to this record.

Aerial photographs at a scale of 1:80 000 and Landsat Thematic Mapper image data printed at 1:100 000 scale were the main means of compiling the CYPLUS regolith landform map. These two data sources provided information on landforms and landscape patterns. Landsat Thematic Mapper image data were used in combination with airborne gamma-ray spectrometric image data to assist in defining some regolith-landform units and in locating unit boundaries that are not obvious either from interpretation of aerial photographs or from field observation. However, although this method of map compilation is extremely powerful, only 2 1:250 000 sheets in the CYPLUS area (EBAGOOLA and HANN RIVER) have high resolution (50m) airborne gamma-ray spectrometric image data available. The rest of the CYPLUS area is covered with gamma-ray spectrometric imagery with a groundresolution of 1km. The integration of Landsat TM imagery with airborne gamma-ray spectrometric imagery, and the interpretation of airborne gamma-ray spectrometrics for regolith, are presented in Wilford (1992).

4. THE CYPLUS REGOLITH DATA SET

4.1. What it Contains

The digital regolith-landform map of the CYPLUS area consists of polygons that define regolith-landform mapping units (see above). Each polygon has a number of attributes attached as fields in an INFO table. Definitions are included in this report in the section Data Dictionary. Other attributes are available for most polygons, but at the time of writing (July 1994) the RTMAP database for the CYPLUS area has not been fully checked. These additional attributes will become available at a later date.

Attributes usually recorded for each regolith-landform unit are given in Table 1. Note that not all attributes are recorded for each unit, and not all are attached to polygons in Arc/Info. The attributes recorded depend on the nature of the unit, and the amount of data collected for the unit. In particular, units that were not visited in the field generally have very little data entered in RTMAP. Table 2 is a sample RTMAP data record. In order to save space only part of the record is given here.

Table 1. Attributes usually recorded for each regolith-landform mapping unit.

Information relating to whole unit	Information relating to each landform type within a unit	Information relating to each regolith type within a landform unit
Unit ID*		
Elevation range		
Regolith comments		
Landform comments		
1:250 000 map sheets		
Compiler		
Landform types (ranked)*	Structural control	
	General regolith thickness*	
	Environmental hazards*	
	Bedrock types	
	Drainage patterns	
	Drainage density	
	Geomorphic processes*	
	Weathering processes	
	Regolith types (ranked)*	Thickness*
		Degree of weathering*
		Position in profile*
		Distribution in landscape*
		Age
		Induration*

* Attributes included with the CYPLUS Arc/Info regolith landform coverage.

Table 2. Sample Regolith Terrain Mapping Unit Data

UNIT ID: 90

GENERAL MAP UNIT DESCRIPTION

Elevation of Unit: from 1m to 80m
Regolith Description.: Alluvial deposits of varying thickness over weathered bedrock.
Terrain Description..: Gently sloping plains with dendritic to anabranching drainage. Some parts are slightly incised, but for the most part this is an actively depositing landscape unit.
Vegetation...........:
General Unit Comments:
Soil.................:
250K Maps: EBAGOOLA, COEN
Tectonic Elements: Coen Block, Laura Basin

LANDFORM DESCRIPTIONS

LANDFORM..: alluvial plain
Rank: 1
Relief................: very low relief
Structural control....: no structural control
Max regolith thickness: unknown
General Comments......:

ENVIRONMENTAL HAZARDS: no recognised hazards

BEDROCK LITHOLOGY

DRAINAGE:
Pattern...: absent or very rare >2500 m
Rank: 1
Character.............: intermittent
Spacing...............: closely spaced, 250-400m
Type..................: normal

GEOMORPHIC PROCESSES
1 A channelled stream flow
2 A over-bank stream flow
3 A sheet flow, sheet or surface wash

REGOLITH DESCRIPTIONS

Regolith type.: alluvial sediments
Rank: 1
Thickness............: unknown
Degree of weathering.: slightly weathered
Age..................: to
Age details..........:
Regolith Profile.....: Alluvial sediments of unknown thickness over ?weathered bedrock
Regolith Distribution: Easterly two thirds of unit, in all landscape positions.
Induration...........:

Regolith type.: fanglomerate
Rank: 2
Thickness............: < 2.0 m
Degree of weathering.: slightly weathered
Age..................: to
Age details..........:
Regolith Profile.....: overlying alluvium
Regolith Distribution: along edges of unit where streams enter from adjacent hills.
Induration...........:

Compiled: 10-SEP-92, Peljo, M. 26-NOV-93, Pain, C.F.

4.2. Field Sites

Regolith information for each unit was derived largely from reconnaissance field work. The approach used in field work was to study enough sites in a given landscape or landform type to determine the range of regolith materials present, and their position in the landscape. With this information regolith toposequences were produced for each landform type. Information usually collected at each field site, and subsequently entered into RTMAP, is listed in Table 3.

Table 3. Information collected about each field site.

Information relating to whole site	Information relating to each zone within a site
Site ID	
Exposure type	
Map number and name	
Grid reference	
Elevation	
Descriptive location	
Landform	
Geomorphic processes	
Bedrock information	
Hazards	
Soil	
Vegetation	
Summary description of site	
Other comments	
Photographs taken of site	
Sketch Y/N	
Zones (from surface)	Zone number
	Zone thickness
	Depth to lower boundary
	Nature of lower boundary
	Colour
	Mottles
	Induration/nodules
	Grain size and sorting
	Coarse fragments
	Matrix
	Regolith type
	Bedding
	Degree of weathering
	Geomorphic processes
	Weathering processes
	Other comments

4.3. Limitations of the Data

There are two main limitations in the data set. Both limitations relate to the large area covered in a short period, and the uneven coverage of field observations.

1. Because the whole of the CYPLUS area was surveyed in only two field seasons, some areas were not visited at all, and others were visited only briefly. This circumstance meant that some of the area was mapped mainly from aerial photographs and satellite imagery. This in turn means that often only partial data are available for regolith landform units.

2. For a number of reasons, field coverage was uneven. Figure 1 shows three levels of field observations. Most field time was spent in area A, which is readily accessible, and is the core area of the NGMA North Queensland Project. It consists of the COEN, EBAGOOLA and HANN RIVER 1:250 000 sheet areas. 1:50 000 aerial photography and airborne geophysics are also available for EBAGOOLA and HANN RIVER. Area B is less accessible, and was covered by a few traverses. Area C was not visited in the field, and map compilation was from aerial photographs and satellite imagery only. Therefore, of the three areas, data from area A is most reliable and data from area C is least reliable.

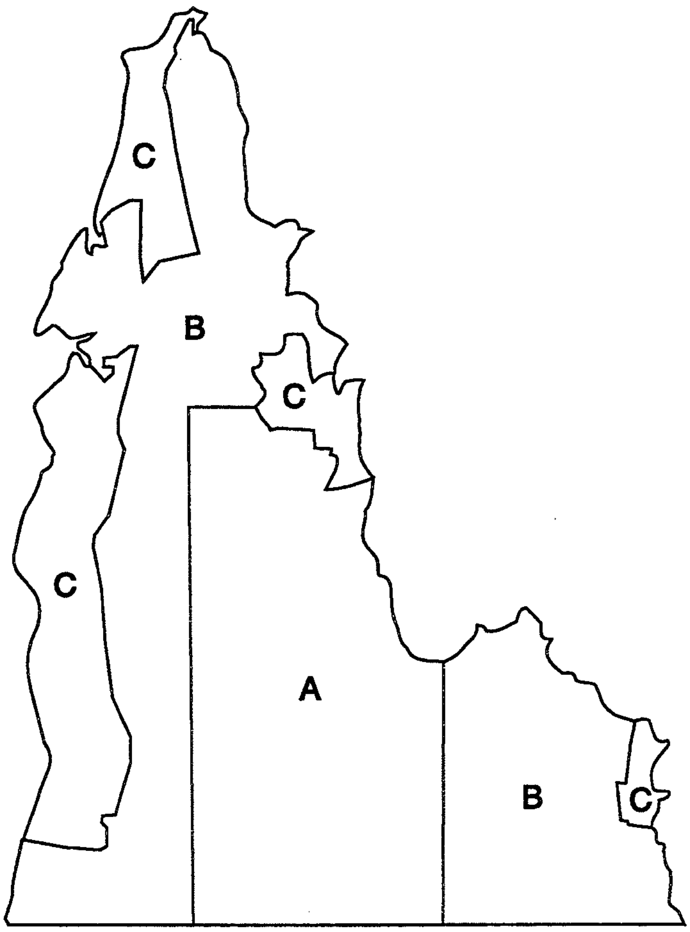

Figure 1. Reliability diagram for the CYPLUS regolith landform map.

A. Many traverses, 1:50 000 and 1:80 000 aerial photographs, airborne geophysical imagery, satellite imagery.

B. Few traverses, 1:80 000 aerial photographs, satellite imagery.

C. No traverses, 1:80 000 aerial photographs, satellite imagery.

5. MAIN REGOLITH TYPES

This section briefly presents information about the main regolith types that occur in the CYPLUS area. The regolith types are described, and their relationship to landforms and landscape position is noted. Table 4 lists the main regolith types found in the CYPLUS area, and gives their areas. Table 5 does the same for the main landform types.

Table 4. Areas of Regolith Types in the CYPLUS Study Area

Regolith Type	Area (km^2)
Alluvial sediments	30614.3
Channel deposits	19626.1
Overbank deposits	1592.4
Colluvial sediments	218.3
Scree deposits	34.9
Sheet flow deposits	52.0
Fanglomerate	1063.1
Aeolian sediments	2.5
Aeolian sand	1572.3
Lacustrine sediments	312.8
Coastal sediments	227.7
Beach sediments	1739.9
Estuarine sediments	4214.5
Coral	17.0
Volcanic ash	4.9
Saprolite	61.9
Slightly weathered saprolite	10803.8
Moderately weathered saprolite	25136.3
Highly weathered saprolite	7967.5
Very highly weathered saprolite	2637.4
Completely weathered bedrock	443.0
Residual sand	15946.5
Residual clay	891.3
Soil on bedrock	7398.0

5.1. Residual Material

Residual material is derived from the weathering of bedrock, and remains in place after more mobile weathering products have been removed by chemical weathering, solution, and movement in soil and ground water. There is loss of volume from the weathered mass, and there may have been local disturbance, particularly by bioturbation.

Table 5. Areas of Landform Types in the CYPLUS Study Area

Landform	Area (km^2)
Alluvial plain	13384.6
Flood plain	22612.4
Meander plain	54.3
Alluvial terraces	1492.3
Stagnant alluvial plain	973.3
Alluvial swamp	275.9
Beach ridge	8741.5
Chenier plain	838.9
Coral reef	17.0
Tidal flat	3055.7
Coastal dunes	1098.8
Coastal plain	208.2
Dunefield	457.8
Erosional plain	24636.0
Pediment	1431.7
Rises	22408.0
Low hills	12729.8
Hills	6323.7
Mountains	2994.1
Escarpments	1539.4
Badlands	7.9
Drainage depressions	2936.4
Fans	86.7
Alluvial fans	4955.4
Colluvial fans	1329.0
Plateaus	5851.5
Volcanic cones	4.8

5.1.1. Soil on Bedrock

Soil on bedrock is mapped in areas where fresh or weakly weathered bedrock lies within 2 m of the surface. Soils on other regolith materials such as saprolite were not mapped separately. Material mapped as soil on bedrock typically consists of a shallow lithosol or skeletal soil. Such areas are found on sandstone, siltstone and metamorphic bedrock, although small areas also occur on granite and volcanics.

This regolith type consists of a skeletal sandy or stony soil generally less than 0.5 m thick directly overlying fresh or weakly weathered bedrock. Angular blocks of fresh or weakly weathered bedrock lie on the surface as well as occurring within the soil itself. Associated landforms include hills, low hills and ridges as well as small areas of plateau surface, particularly on sandstone. Steep slopes are a common feature of areas with soils on bedrock.

5.1.2. Residual Sand

Residual sand, predominantly quartz, is derived from the in place weathering and removal of finer material by solution or suspension in sub surface water (Pain et al. 1991). Thin residual sand veneers the surface of much of the weathered bedrock in the CYPLUS area. However, it is mapped as residual sand only where it is more than 0.5 m thick. Residual sand commonly contains iron nodules which may be scattered throughout the profile; however these nodules are typically concentrated in the lower parts. It is found over highly weathered saprolite, moderately weathered saprolite, and ferricrete and bauxite.

The development of large areas of residual sand up to or exceeding 1m in depth derives in part from the activity of termites and tree fall. The residual sand, being loose, also tends to be permeable, especially in its lower levels. However, the surface can be quite impermeable, especially if there is a high organic matter content in the top few centimetres.

Preliminary research into the interpretation of gamma-ray spectrometric imagery for regolith mapping (Wilford 1992) facilitated the mapping of quartz-rich residual sand in the EBAGOOLA and HANN RIVER 1:250 000 map sheet areas. Quartz-rich residual sand more than 0.5 m thick appears as very dark tones (low in potassium, thorium and uranium) on RGB-composite gamma-ray spectrometric images and is easily distinguished from areas of brighter tones which typically indicate either shallow soils on crystalline bedrock or relatively young alluvium derived from these rocks.

West of the Coen Inlier on sedimentary bedrock of the Carpentaria Basin, residual sand is generally best developed on sandy intervals within these shallow marine/fluvial deposits. The residual sand overlies moderately weathered saprolite, and the boundary between these two regolith types is usually quite distinct. With the exception of a few small areas near the Coen Inlier, residual sand in this area lies on erosional plains.

East of the Coen Inlier, residual sand overlies moderately weathered saprolite on sedimentary bedrock of the Laura Basin. The regolith cover in this area is very similar to that on the west side of the Inlier.

Within the Coen Inlier itself, residual sand is confined largely to granitic bedrock where it occurs for the most part in two general geomorphic settings: (1) on rises above low erosional scarps; and (2) below and some distance from these same low scarps. In both settings the residual sand overlies saprolite. These areas represent the oldest parts of the granitic landscape, and therefore they are underlain by the most highly weathered saprolite. Above the scarps, the residual sand and saprolite cover remnants of the pre-scarp land surface, whereas below the scarps they have developed on a time-transgressive surface formed as a result of scarp retreat, and thus they are thickest on that part of the surface furthermost from the scarp (Figure 2).

On the western side of the Inlier, residual sand also overlies metamorphic rocks. However, because metamorphic rocks rarely weather to sand sized material, this sand may represent the deeply weathered remnants of a former cover of Mesozoic sedimentary deposits most of which have been eroded away.

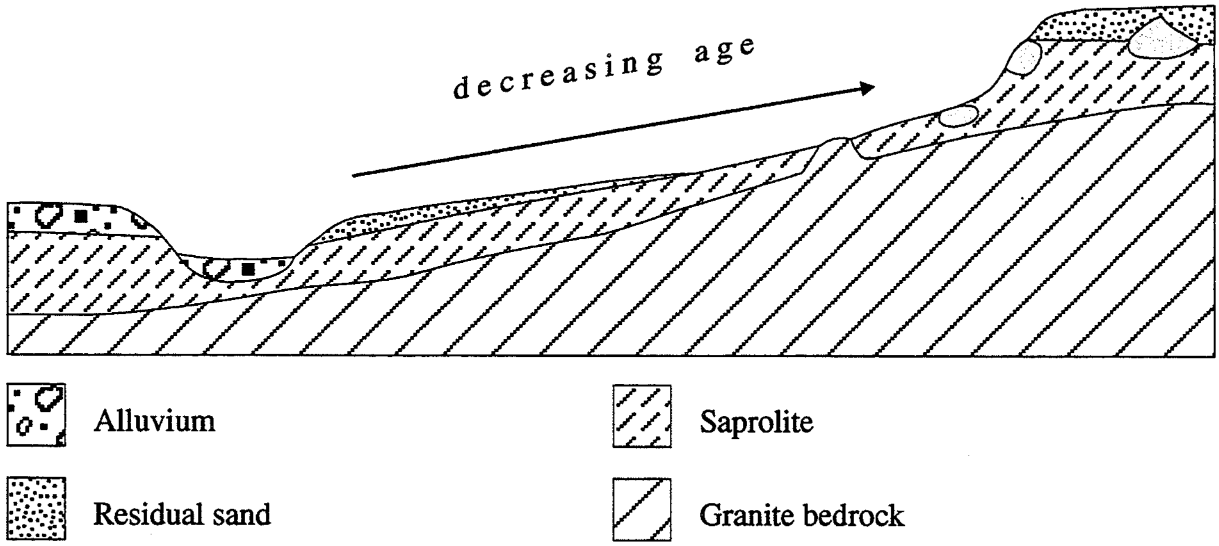

Figure 2. Section showing distribution of residual sand on granite, and the nature of the time-transgressive surface.

5.1.3. Residual Clay

Residual clay is bedrock weathered in place, with losses of material mainly by solution. There has been some local rearrangement of materials in this regolith type. The clay minerals present (predominantly montmorillonite) have expanding clay lattices, and lead to the formation of gilgai micro relief, deep cracking of the upper part of the regolith profile, and a self mulching layer. The highly seasonal climate emphasises these features.

Residual clay appears to be confined largely to a particularly clay-rich unit in the Cretaceous Rolling Downs Group. For the most part it is found on erosional plains or low rises where, apart from the Gilgai relief, it is reasonably stable. However, on some locally steep slopes, such as those around the Embley Range, this material is prone to land sliding.

A small area of residual clay is developed on basalts on the COOKTOWN 1:250 000 map sheet area.

5.1.4. Bauxite and Ferricrete

A number of low mesas and extensive relict erosional plains, particularly on the western side of the area, are veneered by a cover of bauxitic nodules over a mottled zone of completely weathered saprolite. The regolith consists of a few centimetres of residual sand and silt over a layer of well developed bauxitic nodules up to 10 m thick. This in turn overlies a mottled zone on saprolite developed on sedimentary bedrock. The mapped areas are locally bounded by low erosion scarps. Some of these relict surfaces include small unmapped areas of moderately weathered saprolite, some of which are strongly silicified.

The bauxite at Weipa and Andoom is well documented (e.g. Schaap 1990), and there is no need to describe it further here. However, it is worth noting the presence of much thinner (<2 m) covers of bauxite in a number of parts of the CYPLUS area. These areas of thinner bauxite are important in the HOLROYD and EBAGOOLA 1:250 000 map sheet areas, in the south, and in isolated mesas and plateaus between the major bauxite deposits and the Coen inlier. In many cases a kaolin layer is present either under the bauxite, or under the mottled zone that underlies the bauxite. At Weipa this kaolin layer is an economic resource, and it is also an important aquifer, supplying water for the township of Weipa. Elsewhere, for example on Batavia Downs and Merluna stations, springs emerging from a pallid zone below bauxite provide a small source of permanent water.

Ferricrete occurs in a wide variety of landscape positions (Pain and Ollier 1992). However, these occurrences tend to be very restricted, and are very different from the widespread occurrences of "laterite" that are found elsewhere on the Australian continent.

5.2. Saprolite

Saprolite is defined as moderately to completely weathered bedrock which has been weathered in place without volume alteration. Primary rock fabric is usually apparent. Saprolite is divided into slightly, moderately, highly, and very highly weathered saprolite on the basis of the degree of preservation of rock fabric and the abundance of earth material. Detailed definitions are given in Pain et al. (1991).

5.2.1. Slightly Weathered Saprolite

Slightly weathered saprolite is found in only a few places, mainly on steep slopes in the Coen Inlier. One such area lies west of the Great Escarpment, above Lockhart River. Another large area is on sandstones north of Heathlands. There are also areas of slightly weathered saprolite in the steep hill country between Cooktown and Cape Melville.

5.2.2. Moderately Weathered Saprolite

Moderately weathered saprolite occurs in three principal areas:

1. In the west, erosional plains developed on gently dipping to flat lying strata of the Rolling Downs Group are covered by moderately weathered saprolite. This regolith consists of a thin layer of residual sand, sometimes with iron pisoliths, developed on moderately to highly weathered light grey fine sandstone and siltstone. Total depth of weathering is not known, but moderately weathered regolith is generally less than 5 m thick before it grades into slightly weathered saprolite which may be as much as several tens of metres thick. This slightly weathered saprolite is not mapped because it is always covered with other regolith materials. Locally, this map unit contains included areas of deeper residual sand and small areas of deep weathering on low hills where silicified mottled zones overlie the saprolite.

Rounded quartz gravels and cobbles veneer the crests of some of these hills. These latter occurrences probably represent the degraded remnants of an older higher landscape. Valley floors contain thin alluvial sequences, and siliceous hardpans commonly cement both the alluvium and the adjacent weathered bedrock. These hardpans are commonly known as creek rock. The thickness of the saprolite is closely related to lithology. On metamorphic rocks and on the sandstones of the Gilbert River Formation it is quite thin (1-5m), whereas on the Rolling Downs Group it may be relatively thick (>10 m).

1. On metamorphic rocks, this regolith type consists of a thin soil formed on moderately to highly weathered saprolite developed on rises and low hills. Total regolith cover is generally thin, ranging from 1 to 5 m.

2. Along the Great Escarpment, a thin soil on moderately weathered saprolite covers slopes up to 25°. Corestones and tors are common. This regolith type also occurs along most of the smaller erosional scarps developed on granite in the sheet area, but these occurrences are generally too small to show at a scale of 1:250 000.

5.2.3. Highly Weathered Saprolite

Highly weathered saprolite is mapped mainly on granite and metamorphic rocks, although some small areas also occur on sandstones of the Rolling Downs Group. On granite, this regolith type consists of a thin sandy soil over weathered granite with many unweathered mineral grains. Corestones and tors are common, especially on lower valley slopes. Other regolith types occur locally within this map unit. For example, almost all valley floors have a narrow belt of shallow alluvium, usually less than 10 m wide and 2 m thick. Valley floor regolith, both alluvium and saprolite, is sometimes silicified to form a siliceous hardpan. The predominant landforms are rises. Regolith derived from metamorphic rocks consists of a shallow soil over moderately to highly weathered saprolite. The saprolite normally shows original metamorphic structures quite clearly, although the material is soft and primary minerals are typically altered to clay. The principal landform types are rises and low hills with steep slopes developed on the more resistant quartzites and gentle slopes developed on the less resistant saprolite. Also included within this map unit are areas of shallow coarse angular to sub-angular alluvium along valley floors and thin colluvial mantles on some lower valley slopes. Ferruginous induration of the valley floor regolith is common. Regolith thicknesses in all areas are generally less than 10 m.

5.2.4. Very Highly Weathered Saprolite

Very highly weathered saprolite occurs mainly on granitic rocks of the Coen and Yambo Inliers, and in the area south of Cooktown. This material consists of sand in a clay matrix. In some areas, for example north of Coen, quartz veins from the original unweathered granite persist through to within a few tens of centimetres of the surface. Core stones are common, and some tors are also present.

5.2.5. Completely Weathered Saprolite

Completely weathered saprolite does not occur at the surface anywhere in the CYPLUS area. However, it does underlie some surface regolith materials. Two types of completely weathered saprolite occur in the area:

1. A number of small areas underlain by metamorphic rocks have a ferruginous mottled layer on the surface. Locally, this layer is strongly indurated and contains some iron nodules and pisoliths. It overlies completely weathered saprolite, and the total thickness of the regolith ranges from 5 - 15m.
2. Completely weathered saprolite underlies bauxite nodules on erosional plains and low plateau surfaces in the west and north west.

5.3. Coastal Deposits

Coastal sediments occur more-or-less along the whole coast line of the CYPLUS area. However, they are most important along the west coast south of Weipa, in the north on both sides of the Peninsula, and in bay heads such as Lockhart River and Princess Charlotte Bay in the east.

5.3.1. Modern Beach

The modern beach forms a more-or-less continuous strip of beach sand and the associated foredune along the coast of the CYPLUS area. Its composition varies from place to place depending on the nature of the sand being brought to the coast by rivers. Its form and width also varies depending on the nature of the areas behind the beach.

5.3.2 Beach Sediments

Beach deposits form beach ridges and chenier plains along much of the coast. These deposits are primarily sand and are derived from the alluvium of rivers which rise in the hills in the centre of the Peninsula as well as to the south of the CYPLUS area. Two ages of beach deposits can be distinguished on the basis of location and composition. Older beach deposits are characterised by strongly leached quartz sands. Soils are deep, sandy, and uniform-textured with a grey-brown organic stained A_1 horizon. These older deposits form a truncated beach strand-line up to 15 km inland from the present coast. This strand-line includes Pleistocene beach ridges along the west coast of Cape York Peninsula (Smart 1976). Younger (Holocene?) beach ridges lie within 4 km of the shoreline and consist of quartz, mica and shelly material. Soils on these younger deposits have poor horizon differentiation and are characterised by sandy uniform-textured profiles with weak organic stained A horizons.
Gamma-ray spectrometric image data indicates that on EBAGOOLA the younger deposits contain potassium-rich minerals whereas these minerals have been weathered and leached from the older deposits.

5.3.3. Estuarine Sediments

Estuarine sediments underlie broad flats in several parts of the coast, including the Jardine River mouth, the southern end of Temple Bay, Lockhart River and Princess Charlotte Bay. They consist of fine sand, silt, mud and minor evaporitic salts forming clay flats and salt pans. Three types of estuarine deposits have been mapped. One is frequently covered by tides and consists mainly of black organic mud. A second is slightly higher in elevation, less frequently inundated by tides, and consists of dark grey to greyish brown cracking clays, saline alkali soils and black organic mud. A third consists of mangrove-covered areas, both tidal and supratidal. The largest area of tidal sediments lies at the head of Princess Charlotte Bay.

5.3.4. Coral Cays

Coral cays are restricted to islands off the eastern side of the Peninsula. They consist of coral sand, usually only a few metres thick, and often within a metre or so of high tide level.

5.3.5. Coastal Sand Dunes

Several large areas of coastal dunes occur along the eastern side of the Peninsula. They are all composed of mainly silica sand, and have dune forms aligned with the prevailing winds from the south east. There are several ages of dune, ranging from Pleistocene to Holocene, with some dunes still active and therefore modern.

5.4. Alluvial Sediments

5.4.1. Alluvial Deposits

In many areas the difference between channel and over bank deposits is not obvious because of a lack of distinct channels. In general the regolith consists of channel deposits either at the surface or overlain by finer over bank deposits. This fining upwards sequence is typical of alluvial deposits in a large number of areas. The alluvium is rarely more than a few metres thick. In the south west, alluvium forms large low angle fans and broad flood plains. These areas consist of numerous anastomosing channels and intervening flood plains. Typical regolith is a coarse channel deposit, mainly sand, which is overlain in the flood plain areas by finer sediments. Similar, although smaller, areas of alluvium surround Princess Charlotte Bay, in the south east, forming the down stream parts of the Normanby system.

Channel deposits occur in both active and abandoned stream channels. Some of the main rivers, such as the Mitchell and the Palmer, have well rounded gravels and cobbles in their channels. Channel alluvium is mapped along all major west-flowing streams. They are predominantly sandy, and gamma-ray spectrometric image data indicates that the sand is derived mainly from the granitic bedrock of the Coen Inlier (Wilford 1992). Within the Inlier, deposits within smaller channels are generally less than 1 m thick and bedrock is exposed in most channel floors. West of the Inlier, channel alluvium in the main rivers is also relatively thin, although thicknesses are not so readily documented. In many places, channel deposits are cemented by silica to form a siliceous hardpan, locally known as "creek rock". This hardpan commonly extends into the weathered bedrock adjacent to the channels.

Over bank deposits are deposited outside the perimeter of the active channel during flooding. These deposits tend to be finer than adjacent channel deposits, consisting of fine sandy alluvium a few metres deep, which overlies coarser channel deposits. However, because alluvium in the CYPLUS area is overwhelmingly dominated by sand-sized material, it is often very difficult to make a distinction between overbank and channel deposits.

5.4.2. Alluvial Swamps

Seasonally flooded alluvial swamps are found along some of the major rivers, especially the Archer, Holroyd and Coleman. These swamps are formed when sediment carried by the trunk stream of the major river is deposited in tributary mouths. The lower parts of the blocked tributaries, thus dammed, become swamps, and locations of deposition of sediments derived from the tributary catchment.

5.4.3. Alluvial Terrace Deposits

Areas of older fluvial deposits occur in the upper reaches of some of the main rivers, especially the Holroyd and Coleman Rivers on the west, and the Kennedy and Normanby Rivers, which flows into Princess Charlotte Bay. The deposits generally consist of about 1 m of alluvial sand grading down to well rounded quartz gravels and cobbles. The lower contact is sharp, and the alluvium rests on saprolite.

5.4.4. Dissected Tertiary Fans

A belt of slightly dissected alluvial fans of Tertiary age (coinciding more-or-less with the Wyaaba Beds) lies between the Archer and Mitchell Rivers. These materials, consisting mainly of sand, were deposited from rivers on low angle fans. They have now been dissected by the main rivers that traverse them, and by the broad shallow valleys discussed in the next section.

5.4.5. Broad Shallow Valleys

Much of the area to the west, especially on the depositional surface south of the Archer River, contains a network of broad but very shallow valleys. Most of these valleys are several hundred metres wide, but often are only 1 or 2 metres in relief from divide to valley floor. Regolith consists of fine sand and clay, apparently derived from the local area. They are most common on the Tertiary fans, but also occur elsewhere.

5.4.6. Shallow depressions

Shallow closed depressions, locally known as "melon holes" are also common on the Tertiary dissected fans. They range in width from a few tens of metres to more than 1km. Regolith is very similar to that in the broad shallow valleys. They may owe their origin, in part at least, to removal of material in solution.

5.5. Colluvial Deposits

Colluvial deposits, generally less than 5 m thick, occur in footslope locations, and consist mainly of sheet flow deposits and fanglomerates overlain by stony soils. Usually they are massive but in places weak bedding suggests sheet wash deposition. Near valley floors, these deposits typically inter finger with alluvium.

Colluvial deposits are mapped only in areas adjacent to steeper ridges and hills. These upland areas are the source of abundant coarse angular material. Colluvium also occurs in small unmapped areas on granite and sandstone bedrock. In these latter areas, it is not easily recognised because of its grain size similarity to residual sand.

6. DISCUSSION

Space in this report does not allow a full discussion of all aspects of the work. Many of the results will be included in explanatory notes that will accompany regolith-landform maps to be published by AGSO at a scale of 1:250 000. In addition, a volume of papers summarising the findings of the NGMA North Queensland Project is being prepared for publication at the end of the project. However, some aspects of the work are either of significance to the objectives of CYPLUS, or are sufficiently interesting in themselves to warrant a brief discussion here.

6.1. Layering of Regolith Materials

The interpretation of layers of regolith material must take into account an understanding of geomorphology and weathering. For example, some people talk of the stratigraphy of regolith materials as if horizons in a regolith profile could be treated like strata in a sedimentary succession. Regolith studies are not as simple as the study of successive sedimentary strata.

For layers of sedimentary materials, the simple rules of stratigraphy apply.

a) A weathering profile must be younger than the original material that is weathered.

b) A material overlying a weathering profile must be younger than the weathering profile.

c) If a weathering profile cuts across several sedimentary layers, the profile is younger than the youngest material it crosses.

Within the weathering profile, simple stratigraphic laws do not apply.

a) Weathering profiles with quite different morphologies can develop in different parts of the landscape at the same time. Thus, a profile consisting of residual sand on saprolite developed on gentle slopes on granite is the same age as a profile without residual sand on steeper slopes elsewhere in the same landscape.

b) Soil horizons that formed parallel to the present land surface are generally younger than the formation of that slope.

c) Soil horizons that parallel the present land surface are younger than any deep weathering of the parent material. For example, soils formed on the Great Escarpment, or on the scarps around the Embley Range, are younger than the deep weathering profiles on which they are formed.

d) A deep profile may form progressively over a long time as weathering processes work their way down into the unweathered parent material. The upper part is therefore older than the lower part.

Treating regolith profiles as stacks of "strata" is even more dubious when it realised that some materials come in laterally. There will also be lateral variations in materials of the same age, akin to facies variations in a sedimentary layer. Moreover, interpretation of regolith profiles as pure vertical sequences has been used as evidence for general landscape lowering. This can do violence to concepts of landscape evolution. Lateral movement and accumulation of the products of weathering in low parts of the landscape is the rule rather than the exception.

6.2. Geomorphic processes

Data on one or more geomorphic processes are usually attached to each regolith-landform unit. For sedimentary materials the geomorphic processes responsible for the materials and associated landforms are usually clear. However, for *in situ* regolith materials on erosional landscapes, the responsible geomorphic processes may not be so obvious. Never-the-less, we can make some generalisations.

6.2.1. Alluvial Processes

Alluvial deposition is responsible for the large fans in the south eastern part of the area, the somewhat smaller alluvial fans around Princess Charlotte Bay, and the alluvial plains of the Lockhart and Nesbit Rivers. Elsewhere, alluvial deposition is not very important, and rivers such as the Archer and the Wenlock are mainly transportational channels, with very little alluvium. Fluvial erosion is most obvious along roads, where gullies are started as a result of runoff from the road surfaces and associated disturbed areas. Natural gully erosion appears to be restricted to a few valley floor locations.

6.2.2. Colluvial Processes

Colluvial processes occur on most slopes, and are dominated by surface wash. Surface wash is most effective where ground cover is low, and is probably most active in recently burnt areas during the first few rain storms of each wet season. Colluvial deposition from surface wash is responsible for a few small areas of colluvial fans and footslopes. Soil creep almost certainly is active on many of the steeper slopes in the area, but evidence for such processes is difficult to observe. However, lag deposits on hill slopes south of Coen, for example, are probably derived by creep. Evidence for soil flows or land sliding is present on the slopes of the Embley range, where slabs of sandstone have been tilted back against the slope, and low ridges indicate the movement of the upper metre or so of the regolith.

Shrinking and swelling of soil clays has produced gilgai forms in some places.

6.2.3. Sub-surface Solution

Sub-surface solution and removal of material by water movement is important in all landscapes, but evidence for such processes is hard to find. The melon holes that are so abundant in parts of the landscape of the study area are probably a result of sub-surface solution and removal of materials. In addition, the various hard pans and duricrusts that are found through the area are clear evidence that at least iron and silica are moved in solution from one part of the landscape to another. In this regard, both ferricrete and silcrete are locally very important parts of the regolith. Another obvious regolith material is the siliceous hardpan or "creek rock", that is found in many valley floors both in and outside the study area. This hardpan is a result of partial cementing of material by silica. It occurs in valley floors beneath and adjacent to channels. The cemented material is mainly alluvium, but in smaller channels weathered bedrock adjacent to the channel alluvium is also cemented. It can be quite young; we have a radiocarbon age of just over 1000 years for charcoal from within hardpan material. The origin of the hardpan seems to lie in the movement of silica in solution to the lowest parts of the landscape during wet seasons, and precipitation of the silica as the valley floors dry up during dry seasons.

6.2.4. Coastal Processes

Coastal processes are responsible for some important areas of coastal regolith materials in the CYPLUS area. These are being studied in detail in CYPLUS NRAP Project NR14, Coastal Environment Geoscience Survey. Here we need only note that wave-built forms and associated tidal flats are important on both sides of the Peninsula, and that wind blown sand forms important areas of dunes mainly on the east coast.

7. REGOLITH-LANDFORM EVOLUTION

7.1. Landform Features

A number of landform features contain important clues for the development of landforms and regolith in the CYPLUS area. These are discussed briefly before a general outline of regolith-landform evolution in the area is presented.

7.1.1. Scarps

The most important geomorphic boundary in the CYPLUS area is the Great Escarpment, a feature which, with a few gaps, runs from just south of Cape York all the way to Victoria (Ollier 1982; Ollier & Stevens 1989). As elsewhere, it separates old landforms and regolith on the western side from younger landforms and regolith on the eastern side. On Cape York Peninsula the Great Escarpment is up to 200 m high. For much of its length it coincides with the Great Divide. Places where the Great Divide is west of the Great Escarpment are often associated with evidence for drainage diversion, for example the Stewart River west of Coen.

Elsewhere small streams have been captured. A particularly good example occurs east of the former mining settlement of Ebagoola, where a stream flows for about 5 km north before abruptly turning and plunging over the scarp. The former course is clearly marked by a dry valley. This particular capture must have occurred fairly recently because the stream has not yet eroded a bedrock channel, flowing instead along joints in the granite.

West of the Great Escarpment there are smaller less continuous scarps. These erosion breaks occur around the headwaters of some drainage basins, around low cuestas and mesas, and parallel to some streams. Examples are the scarp around the Embley Range, the "jump-up" that marks the eastern boundary of the bauxite area east of Weipa, and the scarp south of Merapah. In many cases these scarps form important boundaries between different regolith types, with generally older regolith materials above and younger materials below.

7.1.2. Drainage

A number of west-flowing streams, including the Archer, Holroyd and Coleman Rivers, rise within the Coen Inlier near the Great Escarpment at elevations of about 200 - 250 m and flow in gorges cut through the higher metamorphic ridges (up to 400 m elevation) on the western side of the uplands. The Pascoe River, at the northern end of the Coen Inlier, also rises close to the Great Escarpment on a low relief surface, and then flows through a much higher range of hills. This superimposed drainage indicates inheritance from a higher surface.

The Pascoe River is a good example of a river that has been disrupted either by capture or, more likely, reversal. After flowing north west for some distance, it turns first to the north and then to the east, to flow into the sea north of Portland Roads. There is a very clear former river coarse, now dry, above the Pascoe River where it turns north. It seems clear that the northwesterly-flowing headwaters of the Pascoe River once flowed into the Wenlock River. Another obvious disruption of drainage is the Stewart River. The headwaters of the Stewart were once part of the westerly flowing Holroyd drainage system. Their diversion into the Stewart is indicated by an abrupt change of channel direction near where the Stewart flows in rapids over the Great Escarpment. This diversion is also indicated by the presence of high level gravels at this bend and by low, poorly drained areas on and west of the Great Divide at the present headwaters of the Holroyd River.

Clear evidence for inversion of relief can be found in a number of places in the CYPLUS area. At one extreme, this evidence consists of narrow sinuous ridges with a capping of quartz alluvial silcrete. On one of these ridges, between Strathburn and Strathhaven, the central depression of the palaeo-valley floor is still preserved. At the other extreme, active stream channels occupy narrow linear mesas surrounded by erosion breaks. A good example is found west of the Strathburn fault scarp, and north of the Coleman River. Another is east of Merapah, where an active channel tributary to the Archer River becomes separated from the surrounding streams by low scarps in its upstream reaches. Further upstream it becomes a series of ponds on a narrow mesa. Thus one channel moves from normal to inverted.

7.2. Mesozoic Sedimentation and Uplift

Formation of the Carpentaria and Laura Basins during Middle to Late Jurassic and Early Cretaceous time (Smart et al. 1980), covered the Palaeozoic and Proterozoic rocks of the Coen Inlier with a veneer of coarse terrestrial to fine marine sediment (Blewett & others 1992). The emergence of these basin sediments in the Late Cretaceous marks the beginning of landform and regolith evolution in EBAGOOLA. The sediments probably covered most, if not all, of the Coen Inlier (see below), and post-Mesozoic erosion subsequently uncovered the basement to form the Inlier.

7.3. Post Mesozoic Morphotectonics and Erosion

The Mesozoic Carpentaria Basin was subsequently cut by Tertiary or younger N to NNW-trending faults. Regional uplift of the inlier and modest down warping of the Carpentaria Basin would appear to be the primary driving forces behind regional erosion and aggradation.

Substantial erosion and surface lowering in the area following emergence at the end of the Cretaceous is evidenced by the landform features described above. Superimposition of drainage reflects an early drainage pattern inherited from the post-Palaeozoic cover. This inheritance strongly suggests that the Mesozoic cover extended over a large part if not all of the Coen Inlier.

Erosion following emergence left the basement rocks high in the landscape, forming the uplands of the Coen Inlier. Initial drainage directions were to the west and north west from a divide east of the present Great Divide. Indeed, it is likely that rivers at that time, before continental breakup, had their headwaters east of the present coastline, because the continental edge was then much further to the east.

The breakup of the north eastern part of the Australian continent and the opening of the Coral Sea had a profound effect on landforms on Cape York Peninsula. Such effects are well known from studies of a number of passive continental margins (eg. Ollier 1985), and most have their origins in pre-separation rifting. In the study area, separation began with tectonism which created rift grabens in the troughs east of the present land area (Mutter & Karner 1980, see also Ollier and Stevens 1989). Major geomorphic affects probably began at this time. Down warping to the east of the peninsula formed the present Great Divide, which runs from north to south along the eastern edge of the Coen Inlier, as well as to the north and south. This down warping had two major results. First, the head-water streams of the formerly west flowing rivers were reversed, to flow towards the newly formed depression and then ocean to the east. The Stewart and Pascoe Rivers are good examples of this. Some of the sediment supply to the lower reaches of major rivers such as the Holroyd was cut off, and this may have resulted in some down cutting along their valleys. This down-cutting appears to have initiated small scarps along some rivers within the Coen Inlier. These scarps have subsequently retreated up to 10 km from their place of initiation. The low scarp between Ebagoola and the Holroyd River is a good example. Second, the new easterly flowing steams were steeper than those flowing to the west, and increased energy and resulting erosion in both the river channels and on adjacent hill slopes led to the formation of the Great Escarpment. Subsequent retreat of the Great Escarpment formed the lowlands to the east, some of which are now covered with a thin (10 m) layer of alluvium. Scarp retreat has also caused river capture in a few places.

West of the Coen Inlier, on erosional plains formed on Mesozoic sediments, there is clear evidence for erosion of several tens of metres of material, and inversion of relief. Valley floor materials, both alluvium and adjacent weathered bedrock, were cemented by silica to form silcrete. Subsequent erosion has left this very resistant silcrete as a cap on the higher parts of the landscape. The best examples are between Strathburn and Strathhaven homesteads, where long narrow sinuous ridges with a central depression mark former stream courses. These remnants have resulted from scarp retreat initiated along rivers such as the Coleman and the Holroyd. Further north, both west and east of Pretender Creek, plateaus with a deep bauxitic weathering profile on Rolling Downs Group sediments provide further evidence of the retreat of low scarps across the landscape. This picture is continued on both sides of the Archer River, near Merapah and Merluna.

The youngest igneous event recorded in the CYPLUS area was extrusion of the Silver Plains Nephelinite (3.72 ± 0.06 Ma - Sutherland 1991). This small lava mound had very little effect except for local drainage diversion.

There are thus a wide variety of different kinds of surfaces, with different ages and stability.

8. REGOLITH-LANDFORM MAPS IN LAND EVALUATION

As noted in the section on mapping methodologies, regolith-landform maps are compiled on the basis of landforms, as defined in the data dictionary. Landform types are then associated with regolith types, and a description of the regolith-landform units is thus built up. This procedure means that the regolith-landform map can be used as landform or as regolith maps.

Landforms are fundamental to land evaluation because they are related to many other facets of the physical landscape. We have already noted that regolith distribution is directly related to landforms. This does not mean that each landform type has a unique assemblage of regolith types. It does mean that, with careful observation of the regolith toposequences in a regolith-landform unit, we can predict the kinds of regolith materials that will occur in different landscape positions. The same is true of soils, which are also closely related to landscape position. Another point is that regolith is the parent material for soils, so this underlines the close relationship between soil and landscape position. Indeed, the age and degree of weathering of the soil parent material may account for soil differences on a broader scale, including soil fertility differences from place to place.

Some regolith materials are of economic importance, the most obvious in the CYPLUS area being bauxite and kaolin. Other regolith materials of potential economic value are sands and gravels that could be used for concrete aggregate, and materials (including sand and gravel) which can be used for road building.

Although we have made no direct observations or measurements, engineering properties of the regolith are obviously important. With suitable work, the landform-regolith map can be used to predict engineering properties of regolith for such purposes as route finding and road building.

There is some significance for groundwater in the distribution and characteristics of the regolith. At Weipa the kaolin layer is an important aquifer, supplying water for the township. Elsewhere, for example on Batavia Downs and Merluna stations, springs emerging from a pallid zone below bauxite provide a small source of permanent water.

We have listed here only some of the possible uses of regolith and landform-regolith information. The potential usefulness of landform-regolith information arises from the fact that many kinds of landuse are constrained by the same qualities of land. This means that the land needs to be mapped only once to provide the framework for planning many different potential land uses. Such uses may include, for example, agriculture, road construction, conservation or tourism.

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11. GLOSSARY

This glossary contains definitions of a few of the more important words used in this record to describe regolith materials. It is included because many of the words are used in various ways in different publications. The definitions listed here are the standard AGSO definitions. The Data Dictionary which follows this Glossary contains definitions of the attributes attached to each regolith landform unit in the CYPLUS regolith landform map.

Bedrock is used to mean the rock from which the regolith is derived. It includes both basement and sedimentary basin rocks. Some confusion may arise in the case of younger sedimentary materials. In general, where sediments, usually terrestrial, are directly related to present-day landforms, they are considered to be regolith rather than bedrock.

Bioturbation refers to disturbance of regolith by the action of plants and animals. In North Queensland the most common kinds of bioturbation are caused by termites and tree fall.

Corestones are fragments, sometimes quite large, of the original bedrock surrounded by weathered material. The frequency, shape and distribution of corestones is important in definitions of degree of weathering (see below). Not all weathered material contains corestones.

Gilgai is surface microrelief associated with soils containing shrink-swell clays. It consists of mounds and depressions showing various degrees of order, sometimes separated by a subplanar or slightly undulating surface (McDonald and others 1990).

Pisoliths are spherical nodules with an internal structure consisting mainly of concentric skins.

Mottled zone refers to material, usually strongly weathered, in which iron segregation results in the development of ferrugenous mottles, commonly reddish in colour. Size of mottles can range from millimetres to tens of centimetres. The latter are sometimes called mega mottles. The mottled zone is frequently near the top of a deeply weathered regolith profile, lying above the pallid zone.

Pallid zone refers to kaolinised zone usually found in the lower part of a weathering profile. This zone is generally light grey to white in colour, and may or may not retain original rock structure.

Regolith toposequences. Often landforms and regolith types will be related both spatially and genetically. These relationships can be expressed as regolith toposequences, which, like soil catenas, show the location of regolith materials associated with particular parts of the landscape.

Self mulching layers form at the surface from wetting and drying of clay materials. They are commonly associated with gilgai.

12. REGOLITH-LANDFORM UNITS - DATA DICTIONARY

The definitions here are taken directly from Pain et al. (1991), with some additions. Pain et al (1991) followed standard definitions where possible, especially those in McDonald *et al.* (1990). Where appropriate, other sources have been given. We assume that users are either familiar with most of the terms we use here, or that they have access to appropriate textbooks. Field names are given in square brackets [ ]. There are two points about these definitions:

1. This document contains defitintions for all the types in each attribute. Not all of them will be present in any one map area.

2. We include only those attributes which are routinely attached to units in an ARC/INFO coverage. RTMAP at AGSO contains information on many more attibutes.

12.1. Unit Identification [U_ID]

This is a unique automatically created sequential number cued by data entry. It is the number which identifies the regolith terrain unit in RTMAP, and it links all the tables together.

12.2. Landform Types [LANDFORM]

Landforms are an expression of the evolution of the landscape in which they occur. They are a culmination of processes, both past and present, acting on that landscape. Landforms are also highly visible in the landscape, and can be recognised from topographic maps and from various kinds of imagery, both airborne and spaceborne.

The landform units listed here are equivalent to the landform patterns of Speight (1990). According to Speight, landform patterns are areas more than 600 m across, and are made up of landform elements. In RTMAP we use the concept of landform units and landform elements in much the same way. At a scale of 1:250 000 we are mapping landform units, and the landform elements are too small to map.

The listing is grouped together into related landform types under general headings, to give a hierarchical classification. Most of the landform units listed in this table are defined by Speight. Other definitions are either from AGSO Regolith Geologists, or from sources noted.

AL00 Alluvial Landforms

Complex landform pattern on valley floors. This landform pattern has active, inactive or relict erosion and aggradation by channelled and over-bank stream flow.

AL10 Alluvial plain

Level landform pattern with extremely low relief. The shallow to deep alluvial stream channels are sparse to widely spaced, forming a unidirectional integrated network. There may be frequently active erosion and aggradation by channelled and over-bank stream flow, or the landforms may be relict from these processes.

AL11 Flood plain

Alluvial plain characterised by frequently active erosion and aggradation by channelled or over-bank stream flow. Unless otherwise specified, "frequently active" is to mean that flow has an Average Recurrence Interval of 50 years or less.

AL12 Anastomotic plain

Flood plain with slowly migrating deep alluvial channels, usually moderately spaced, forming a divergent to unidirectional integrated reticulated network. There is frequently active aggradation by over bank and channelled stream flow.

AL13 Bar plain

Flood plain with numerous rapidly migrating shallow alluvial channels forming a unidirectional integrated reticulated network. There is frequently active aggradation and erosion by channelled stream flow.

AL14 Covered plain

Flood plain with slowly migrating deep alluvial channels, usually widely spaced and forming a unidirectional integrated non-tributary network. There is frequently active aggradation by over-bank stream flow.

AL15 Meander plain

Flood plain with widely spaced, rapidly migrating, moderately deep alluvial stream channels which form a unidirectional integrated non-tributary network. There is frequently active aggradation and erosion by channelled stream flow with subordinate aggradation by over-bank stream flow.

AL16 Floodout

Flat inclined radially away from a point on the margin or at the end of a stream channel, aggraded by over-bank stream flow, or by channelled stream flow associated with channels developed within the over-bank part.

AL20 Alluvial terrace

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

AL30 Stagnant alluvial plain

Alluvial plain on which erosion and aggradation by channelled and over-bank stream flow is slightly active or inactive because of reduced water supply, without apparent incision or channel enlargement that would lower the level of stream action.

AL40 Terraced land

Landform pattern including one or more terraces and often a flood plain. Relief is low or very low (9 - 90m). Terrace plains or terrace flats occur at stated heights above the top of the stream bank.

AL50 Alluvial swamp

Almost level, closed or almost closed depression with a seasonal or permanent water table at or above the surface, commonly aggraded by overbank stream flow and sometimes biological (peat) accumulation.

CO00 Coastal lands

Level to gently undulating landform pattern of extremely low relief eroded or aggraded by waves, tides, overbank or channel flow, or wind. The landform pattern may be either active or relict.

CO01 Beach ridge plain

Level to gently undulating landform pattern of extremely low relief on which stream channels are absent or very rare; it consists of relict parallel linear ridges built up by waves and modified by wind.

CO02 Chenier plain

Level to gently undulating landform pattern of extremely low relief on which stream channels are very rare. The pattern consists of relict, parallel linear ridges built by waves, separated by and built over flats aggraded by tides or over bank stream flow.

CO03 Coral reef

Continuously active or relict landform pattern built up to the sea-level of the present day or of a former time by corals and other organisms. It is mainly level, with moderately inclined to precipitous slopes below sea level. Stream channels are generally absent, but there may occasionally be fixed deep erosional tidal stream channels forming a disintegrated non-tributary pattern.

CO04 Marine plain

Plain eroded or aggraded by waves, tides, or submarine currents, and aggraded by deposition of material from suspension and solution in sea water, elevated above sea level by earth movements or eustacy, and little modified by subaerial agents such as stream flow or wind.

CO05 Tidal flat

Level landform pattern with extremely low relief and slowly migrating deep alluvial stream channels which form dendritic tributary patterns; it is aggraded by frequently active tides.

CO06 Coastal dunes

Level to rolling landform pattern of very low to extremely low relief without stream channels, built up or locally excavated, eroded or aggraded by wind. This landform pattern occurs in usually restricted coastal locations.

CO07 Coastal plain

Level landform pattern with extremely low relief either with or without stream channels, built up by coastal, usually tidal, processes.

CO08 Beach

Short, low, very wide slope, gently or moderately inclined, built up or eroded by waves, forming the shore of a lake or sea.

DE00 Delta

Flood plain projecting into a sea or lake, with slowly migrating deep alluvial channels, usually moderately spaced, typically forming a divergent distributary network. This landform is aggraded by frequently active over-bank and channelled stream flow that is modified by tides.

DU00 Dune field

Level to rolling landform pattern of very low to extremely low relief without stream channels, built up or locally excavated, eroded or aggraded by wind.

DU01 Longitudinal Dune field

Dune field characterised by long narrow sand dunes and wide flat swales. The dunes are oriented parallel with the direction of the prevailing wind, and in cross section one slope is typically steeper than the other.

ER00 Erosional landforms

Landform pattern of very low to high relief and very gentle to steep slopes. The pattern is eroded by continuously active to slightly active or inactive geomorphic processes.

ER10 Erosional plain

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

ER11 Pediment

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

ER12 Pediplain

Level to very gently inclined landform pattern with extremely low relief and no stream channels, eroded by slightly active sheet flow and wind. Largely relict from more effective erosion by stream flow in incipient channels as on a pediment.

ER13 Peneplain

Level to gently undulating landform pattern with extremely low relief and sparse slowly migrating alluvial stream channels which form a non-directional integrated tributary pattern. It is eroded by slightly active sheet flow, creep, and channelled and over bank stream flow.

ER14 Etchplain

Level to undulating or, rarely, rolling landform pattern of extremely low relief, formed by deep weathering and then erosion of the resulting weathered regolith. Removal of the weathered material may be either partial or complete (see also Ollier 1984).

ER20 Rises

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

ER30 Low hills

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

ER40 Hills

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

ER50 Mountains

Landform pattern of very high relief (> 300 m) with moderate to precipitous slopes and fixed erosional stream channels which are closely to very widely spaced and form a dendritic of diverging integrated tributary network. There is continuously active erosion by collapse, landslide, sheet flow, creep, and channelled stream flow.

ER60 Escarpment

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

ER70 Badlands

Landform pattern of low to extremely low relief (< 90 m) and steep to precipitous slopes, typically with numerous fixed erosional stream channels which form a dendritic to parallel integrated tributary network. There is continuously active erosion by collapse, landslide, sheetflow, creep and channelled stream flow.

ER80 Drainage depression

Depression cut into a surface by erosional processes. This term should be used only in cases where a single depression or valley is incised into a plateau or other surface, and where the scale of mapping does not allow the depression to be subdivided into its component parts (e.g. rises, floodplain).

FA00 Fan

Level (< 1% slope) to moderately inclined complex landform pattern of extremely low relief with a generally fan-shaped plan form. The channels form a centrifugal to divergent, integrated, reticulated to distributary pattern.

FA01 Alluvial fan

Level (< 1% slope) to very gently inclined complex landform pattern of extremely low relief with a generally fan-shaped plan form. The rapidly migrating alluvial stream channels are shallow to moderately deep, locally numerous, but elsewhere widely spaced. The channels form a centrifugal to divergent, integrated, reticulated to distributary pattern. The landform pattern includes areas that are bar plains, being aggraded or eroded by frequently active channelled stream flow, and other areas comprising terraces or stagnant alluvial plains with slopes that are greater than usual, formed by channelled stream flow but now relict. Incision in the up-slope area may give rise to an erosional stream bed between scarps.

FA02 Colluvial fan

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

FA03 Sheet-flood fan

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

KA00 Karst

Landform pattern of unspecified relief and slope (for specification use terms such as "Karst rolling hills") typically with fixed deep erosional stream channels forming a non-directional disintegrated tributary pattern and many closed depressions without stream channels. It is eroded by continuously active solution and rarely active collapse, the products being removed through underground channels.

MA00 Made land

Landform pattern typically of very low or extremely low relief and with slopes in the classes level and very steep. Sparse, fixed deep artificial steam channels form a non-directional interrupted tributary pattern. The landform pattern is eroded and aggraded, and locally built up or excavated, by rarely active human agency.

ME00 Meteor crater

Rare landform pattern comprising a circular closed depression with a raised margin, it is typically of low to high relief and has a large range of slope values, without stream channels, or with a peripheral integrated pattern of centrifugal tributary streams. The pattern is excavated, heaved up and built up by a meteor impact and now relict.

PL00 Plain

Level to undulating or, rarely, rolling landform pattern of extremely low relief (< 9 m). Some types of plains are described under alluvial landforms, and some are also described under erosional landforms.

PL01 Depositional plain

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

PL02 Lacustrine plain

Level landform pattern with extremely low relief formerly occupied by a lake but now partly or completely dry. It is relict after aggradation by waves and by deposition of material from suspension and solution in standing water. The landform pattern is usually bounded by wave-formed cliffs, rock platforms, beaches, berms and lunettes that may be included or excluded.

PL03 Playa plain

Level landform pattern with extremely low relief, typically without stream channels, aggraded by rarely active sheet flow and modified by wind, waves, and soil phenomena. Playa plains are sediment sinks and are the lowest parts of the landscape.

PL04 Sand plain

Level landform pattern with extremely low relief, typically without stream channels, aggraded by active wind deposition and rarely active sheet flow.

PT00 Plateau

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

PT01 Plateau edge

The bounding edge of a plateau where it is a low scarp or cliff. This landform type is used mainly for site descriptions.

PT02 Plateau surface

Level to rolling landform pattern of plains, rises or low hills.

VO00 Volcano

Typically very high and very steep landform pattern without stream channels, or with erosional stream channels forming a centrifugal or radial tributary pattern. The landform is built up by volcanism, and modified by erosional agents.

VO01 Caldera

Rare landform pattern typically of very high relief and steep to precipitous slopes. It is without stream channels or has fixed erosional channels forming a centripetal integrated tributary pattern. The landform has subsided or was excavated as a result of volcanism.

VO02 Cone (volcanic)

Typically low to high relief and very steep landform pattern without stream channels, or with erosional rills forming a radial tributary pattern. The landform is built up by volcanism, and slightly modified by erosional agents.

VO03 Lava plain

Level to undulating landform pattern of very low to extremely low relief typically with widely spaced fixed stream channels which form a non-directional integrated or interrupted tributary pattern. The landform pattern is aggraded by volcanism (lava flow) that is generally relict; it is subject to erosion by continuously active sheet flow, creep, and channelled stream flow.

VO04 Ash plain

Level to undulating landform pattern of very low to extremely low relief typically with widely spaced fixed stream channels which form an integrated or interrupted tributary pattern. The landform pattern is aggraded by volcanism (ash fall) that is generally relict; it is subject to erosion by continuously active sheet flow, creep, and channelled stream flow.

VO05 Lava flow

Level to undulating landform pattern of very low to extremely low relief typically linear in plan form. The landform pattern is aggraded by volcanism (lava flow) that is generally relict, and confined to a single flow.

VO05 Lava plateau

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

12.3. Regolith Thickness [LREGT_TKNS]

Regolith thickness over an entire regolith-landform unit is impossible to determine. This field is for a general indication of the maximum observed thickness of regolith in a regolith-landform unit. The actual regolith thickness may be much greater than the observed regolith thickness.

0	unknown
1	< 0.5 m
2	< 2 m
3	> 2 m
4	> 5 m
5	> 15 m
6	> 50 m

12.4. Environmental Hazard Definitions [HAZARD]

Evidence of environmental hazards can be observed in the field, and assessments of hazard liability can be made. The hazards listed here are those that are either directly related to the regolith and landforms (e.g. landslides), or their impacts are restricted to particular landscape types that are identified as part of a regolith landform map (e.g. floods). Readers who want more information about environmental hazards should, as a beginning point, refer to Heathcote and Thom (1979) or Blong and Johnson (1986).

NH No recognised hazards

AV Snow avalanche

Rapid movement of snow down mountain slopes.

CO Coastal erosion

Erosion of coastal land by waves and wind. This may be brought about by several factors including human disturbance of the foredune, and various effects of climatic change such as rising sea level, and increased storminess.

CP Coastal progradation

Deposition on coastal areas by waves and wind. This may be brought about by several factors including human disturbance causing coastal erosion in some areas and deposition in others. Other factors include the various effects of climatic change such as rising sea level, and increased storminess.

FF Flash flood

Rapid rise of water level in rivers, sometimes with overbank flow, resulting from high intensity rain storms. These events are common in lower rainfall areas, and may occur downstream of the location of rainfall.

FL Flood

Rise of water in rivers followed by overbank flow, resulting from prolonged heavy rainfall. Flood waters may affect areas outside the area of rainfall.

LA Landslide

Rapid mass movement of regolith material down hillslopes.

RO Rockfall

Fall of rock from vertical or near vertical cliffs.

SA Salinity

Accumulation of salts at the surface or within the near-surface soil. This can arise from a number of causes ranging from a rise in water table levels in irrigated areas to emergence of subsurface water in lower footslope areas.

SC Solution cavities

In some circumstances, particularly on calcareous rock types, solution processes within the underlying rock can lead to the development of hollows and possibly collapse.

SD Sand drift

Movement of sand by wind erosion, transport and deposition.

SO Soil erosion

Loss of soil by erosion processes, including surface wash and rill erosion, as well as wind erosion.

ST Storm surge

Unusually high temporary sea levels resulting from storms that force sea water on to the land through a combination of strong onshore winds, high tides, and lowered barometric pressure.

SU Subsidence

Sinking of the ground surface, either slowly or by more rapid collapse, due, for example, underground caves in limestone, mines, and removal of water from subsurface aquafers.

TS Tsunami

Ocean waves generated by either volcanic or seismic activity, usually on the sea floor. Tsunami are sometimes erroneously called tidal waves.

VE Volcanic activity

Effects resulting from volcanic eruption.

GU Gully erosion

Linear erosion caused by channel flow and head ward retreat. It may be caused by human activities such as vegetation clearing, or may be part of the natural geomorphic cycle.

GI Gilgai

Effects caused by shrinking and swelling of soil. It can affect houses and other structures, and also play a part in initiation of landsclides.

12.5. Geomorphic Process Definitions [GPROCESS]

In the database, geomorphic processes are those which form or modify landform units. They can refer to either present or past activity. This means that processes occurring now as well as those responsible for the evolution of a regolith terrain unit can be entered into the database. An active/relict (A/R) code is used to distinguish the two.

Brief definitions are included here. For more detailed descriptions of these processes the user is referred to a textbook on geomorphology, such as Chorley et al. (1984). Other suitable references are given at various points.

GR00 Gravity

Any geomorphic process that acts mainly as a result of gravity. For more details see Selby (1982).

GR01 Vertical collapse

Collapse of large fragments of rock and/or soil, commonly from cliff faces. The collapsed materials accumulate where they fall, and may be acted on by other processes.

GR02 Particle fall

More-or-less free fall of small particles of rock and/or soil from or near vertical faces.

GR03 Creep

Slow movement of rock and/or soil particles down slope under the influence of gravity. Creep operates at rates of a few millimetres per year, with wetting and drying, shrinking and swelling, and freezing and thawing all contributing to the down slope movement of material.

GR04 Landslide

Translational movement of material along a shearplane under the influence of gravity. The moving material may be either a single coherent mass, or it may consist of a number of sliding fragments. In this type of movement, the material generally maintains its orientation relative to the land surface. The resulting deposit contains unbroken blocks or rafts of material.

GR05 Mudflow

Turbulent movement of material down slope under the influence of gravity. In this type of movement the moving mass tumbles, rolls and flows down slope. The resulting deposit is a mixture of material of all sizes, with no obvious orientation or indication of original structure.

WT00 Water

The movement and deposition of material through the agency of water. For more details see Morisawa (1985).

WT01 Channelled stream flow

Erosion, transport and deposition of material in stream channels. These commonly give well sorted deposits which are confined to river channels, either modern or relict (channel deposits).

WT02 Over-bank stream flow

Erosion, transport and deposition of material on flood plains and other areas adjacent to rivers by water which has flowed out of a confined channel (over-bank deposits).

WT03 Sheet flow, sheet wash, surface wash

Erosion, transport and deposition of material by sheets of water flowing over the ground surface. This unconfined flow occurs on hill slopes and on low angle landform units. It commonly removes fine material, leaving coarser material behind as a lag deposit.

WT04 Waves

Erosion, transport and deposition of material by wave action either on the sea coast or along lake edges. For more details on coastal processes see Davies (1980).

WT05 Tides

Erosion, transport and deposition of material by movement of tidal currents.

WT06 Detrital deposition in still water

Deposition of detrital material from a body of standing water onto the floor of the basin. In terrestrial landscapes this occurs in lakes. Sources of detrital material include channel flow into the lake, and wave action along lake edges.

WT07 Rill/gully erosion

Linear erosion by water, producing steep sided channels. Rills are less than 0.3m deep and gullies are more than 0.3m deep.

WT08 Subsurface solution/piping

Action by water beneath the surface, mainly by removal of material in solution. Such chemical denudation is important in all landscapes. In places removal by solution can form cavities, which can in turn become integrated subsurface drainage tunnel systems. The collapse of these systems produces pipe/shaft forms.

IC00 Ice

Erosion, transport and deposition of material by moving ice. For more details see Davies (1969).

IC01 Frost

Freezing and thawing of water, which leads to shattering and movement of rock fragments, and disturbance of soil material. Processes include solifluction, and the development of patterned ground.

IC02 Glacial erosion

Erosion and transport of material by glacial ice, giving rise to distinctive landforms such as U-shaped valleys and cirques.

IC03 Glacial deposition

Deposition of material from melting ice. The deposits are referred to by the general term moraine.

WI00 Wind

Erosion, transport and deposition of material by wind. For more details see Mabbutt (1977).

WI01 Wind erosion (deflation)

Erosion of material by the action of wind. This may involve entrainment of sand and dust particles, and their movement to other locations. It also includes the action of sand corrasion to produce ventifacts.

WI02 Sand deposition (wind)

Deposition of sand by wind to form various landform types including dunes and sand sheets.

WI03 Dust deposition (wind)

Deposition of dust being transported by wind in the atmosphere as suspended load. This process is responsible for deposition of loess. Where the dust is composed of clay pellets, it forms a special kind of loess, sometimes called parna in Australia.

DI00 Diastrophism; earth movements

Diastrophic movements are those which result directly or indirectly in relative or absolute changes of position, level or attitude of rocks forming the earth's crust. This includes uplift and faulting.

VO00 Volcanism

Volcanism refers to the group of processes generated by volcanic activity on the land surface (see Ollier 1988).

VO01 Lava flow

The flow of molten rock across the land surface.

VO02 Ash flow

The flow of volcanic ash material across the land surface. This includes nuée ardentes. The resulting deposits are sometimes called ignimbrites.

VO03 Ash fall

The fall of volcanic ash on to the land surface, typically leading to mantles of volcanic ash (tephra) over all parts of the landscape.

BI00 Biological agents

Formation or changes in the shape of landforms by animals or plants, for example, the development of coral reefs.

HU00 Human agents

Formation or changes in the shape of landforms by human activity.

MT00 Impact by meteors

Formation or changes in the shape of landforms by meteorite impact, typically to produce craters.

12.6. Regolith Type [REGOLITH]

Landform classification has reached the stage where, although there may be minor disagreements, most people generally agree on the major groupings. However, regolith classification is an entirely different matter. There is still disagreement about what regolith is, and this disagreement extends to the use of different terms to describe regolith types. A good example is the use of the words *laterite* and *ferricrete*.

In developing a classification of regolith we must keep in mind its purpose. We are mapping regolith-landform units at a publication scale of 1:250,000, although field mapping is at 1:100,000. This rules out, in most cases, mapping specific regolith materials such as the mottled zone of a laterite profile. Regolith-landform units will contain groupings of specific regolith materials. Often these groupings will be related both spatially and genetically, in the same way as the soils in a toposequence are related. The difference between a regolith "toposequence" and a soil toposequence is that the former is likely to be deeper and more complex. A group of regolith types will be a three dimensional entity which frequently contains a wide variety of specific materials.

The list presented here contains the basic regolith types, derived in part from Speight and Isbell (1990). It will expand, particularly with the addition of categories of regolith profiles, as data come both from our field mapping program and from workers outside the BMR.

WMU00 Weathered material (origin unknown)

This category covers those materials that are weathered, and so are regolith, but contain no features that allow them to be characterised as being either in situ or transported.

WIR00 In situ weathered rock

Rock masses that have suffered chemical, mineral and physical changes on exposure to land surface processes, resulting in a loss of up to 85% of the rock strength (Speight and Isbell 1990). Weathered rocks have thus been altered by weathering processes such that they are broken into smaller fragments and/or changed in composition. The degree of weathering can vary from slight to complete (see under Degree of Weathering).

A number of terms are in general use for naming all or parts of a weathering profile. Some definitions are given here, with preferred terms for use in RTMAP indicated. An undisturbed deep weathering profile consists of an upper soil layer and a lower *in situ* weathered layer. The former is developed from the material below, but may have been disturbed. It is best classed as residual material. The latter is undisturbed, and is called saprolite.

WIR10 Saprolite

The term *saprolite* (Becker 1895) is used in RTMAP to refer to all those parts of a weathering profile which have been formed strictly *in situ*, with interstitial grain relationships being undisturbed. This contrasts with residual material, which has been disturbed (see below, WIR20). Saprolite is altered from the original rock by mainly chemical alteration and loss without any change in volume. This is sometimes referred to as constant volume alteration. Saprolite is often equivelent to the C horizon in pedology. Some workers confine the use of the term to weathered material below the zone of pedological alteration (or pedoplasmation - Flach *et al* 1968).

The various layers or zones in deep weathered regolith are often assumed to be genetically related. In some cases this may be true, but there are so many exceptions reported in the literature that we have chosen to leave out all genetic conotations in our definitions. Moreover, the various layers do not always occur in the same sequence, making genetic implications suspect in many cases.

The term *lateritic profile* is sometimes used to refer to a particular type of deep weathered regolith which has ferruginous upper layers, and kaolinised lower layers.

WIR11 Slightly weathered saprolite

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

WIR12 Moderately weathered saprolite

Moderately weathered rock has strong iron staining, and up to 50 % earth material. Corestones, if present, are rectangular and interlocked. Most feldspars have decayed, and there are microfractures throughout. Moderately weathered rock can be broken by a kick (with boots on), but not by hand.

WIR13 Highly weathered saprolite

Highly weathered rock has strong iron staining, and more than 50% earth material. Core stones, if present, are free and rounded. Nearly all feldspars are decayed, and there are numerous microfractures. The material can be broken apart in the hands with difficulty.

WIR14 Very highly weathered saprolite

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

WIR15 Completely weathered in situ rock

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

WIR20 Residual material

Material derived from weathering of rock and remaining in place after part of the weathered material has been removed. It results from loss of volume from the weathered mass.

WIR21 Lag

A deposit, commonly thin, of fragments larger than sand size, spread over the land surface. Its most common origin is as the coarse material left behind after fine material has been transported away by wind or, less commonly, sheet flow.

WIR22 Residual sand

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

WIR23 Residual clay

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

WIR24 Soil on bedrock

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

UOS00 Sand (unknown origin)

Some sand deposits, particularly in inland locations, cannot be attributed to any particular origin. Such deposits are placed in this category.

UOC00 Clay (unknown origin)

Some clay deposits cannot be attributed to any particular origin. Such deposits are placed in this category.

SDT00 Sediments (terrestrial)

Materials deposited on the land surface by terrestrial geomorphic processes.

SDA00 Alluvial sediments

Materials deposited on the land surface from transport by flowing water confined to a channel or valley floor.

SDA10 Channel deposits

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

SDA20 Overbank deposits

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

SDC00 Colluvial sediments

Sediment mass deposited from transport down a slope by gravity. Compared with alluvium, colluvium lacks bedding structure, is more variable in grain size, and contains mainly material derived locally.

SDC01 Scree

Scree, sometimes called talus, is colluvium deposited after falling or rolling from cliffed or precipitous slopes, consisting of loose rock fragments of gravel size or larger.

SDC02 Landslide deposit

Colluvium rapidly displaced down slope by failure of a mass of earth or rock. If the mass was not already part of the regolith the landslide incorporates it into the regolith. Original rock structures are fragmented and tilted by the action of the landslide.

SDC03 Mudflow deposit

Colluvium rapidly displaced down slope mixed with water to form a dense fluid. The material is more thoroughly disaggregated than that of a landslide deposit, but lacks the bedding and sorting of grain sizes seen in alluvium.

SDC04 Creep deposit

Normally a thin layer of rocky or earthy colluvium which moves very slowly down slope. In some circumstances it may be recognised by, for example, bending of rock bands down slope, but in other cases can only be inferred.

SDC05 Sheet flow deposit

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

SDC06 Fanglomerate

Colluvium deposited from sheet flows, mudflows and/or channel flow on colluvial fans. The material is usually poorly sorted and unbedded or poorly bedded.

SDE00 Aeolian sediment

Sediment deposited from transport by wind.

SDE01 Aeolian sand

Wind blown sediment of sand size, often taking the form of dunes, with characteristic bedding structures.

SDE02 Loess

Aeolian sediment of silt size, often deposited over the landscape as a blanket.

SDE03 Parna

Aeolian sediment of clay size, commonly transported as flakes of larger size, up to sand size.

SDS00 Coastal sediments

Sediments deposited in the coastal zone by coastal processes.

SDS01 Beach sediments

Sediment mass deposited from transport by waves or tides at the shore of a sea or lake.

SDS02 Estuarine sediments

Sediments deposited in an estuary or lagoon, from transport by tidal currents.

SDS03 Coral

Mainly carbonaceous material deposited by coral-building organisms in near shore and reef environments. It may still be in growth position, or it may be disturbed and reworked.

SDG00 Glacial sediments

Sediment deposited from transport by moving ice. It is neither bedded nor sorted. It has a matrix of clay or silt enclosing larger particles of unweathered rock ranging up to large boulders.

SDL00 Lacustrine sediments

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

SDM00 Marine sediment

Sediments deposited from transport by waves and from solution and suspension in sea water. Marine sediments may occur in the regolith where the sea has withdrawn from an area during the Quaternary Period.

SDP00 Peat

Organic deposits consisting of undecomposed to completely decomposed plant remains, usually found in swampy depressions.

SDF00 Fill

Artificial sediment mass formed by earth moving works. Fill is sometimes compacted to the status of a very weak rock, but typically remains an earth mass.

VOL00 Volcanic material

Material derived from igneous activity at the surface.

VOL01 Lava

Igneous rocks solidified after eruption on to the land surface.

VOL02 Volcanic Ash (tephra)

Material deposited on the land surface after ejection from a volcano. It often contains a proportion of highly weatherable glass, and mantles the landscape.

EVA00 Evaporite

Sediment formed by the precipitation of solutes from water bodies on the land surface, typically as lacustrine sediments.

EVA01 Halite

Evaporite consisting of sodium chloride.

EVA02 Gypsum

Evaporite consisting of hydrated calcium sulphate.

A.Induration [INDURATION]

IN00 Indurated material

Regolith material that has been hardened and/or cemented to some degree. This category is further subdivided according to the dominant indurating material, as follows:

IB00 Bauxitic induration
IK00 Calcareous induration
IC00 Clay induration
IF40 Ferruginous induration
IG50 Gypsiferous induration
IS60 Siliceous induration
IH00 Humic iduration

DU00 Duricrust

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

DC00 Completely cemented duricrust (crete)

Smooth textured duricrust where >90% of the material has been cemented. The suffix "crete" is used for these materials.

DC10 Alcrete (bauxite)

Completely cemented duricrust cemented mainly by aluminium compounds.

DC20 Calcrete

Completely cemented duricrust cemented mainly by calcium carbonate.

DC40 Ferricrete

Completely cemented duricrust cemented mainly by iron. It is not necessarily associated with deep weathering profiles or laterite (see Pain and Ollier, 1992).

DC41 Massive ferricrete

Ferricrete which has little or no internal differentiation.

DC42 Nodular ferricrete

Ferricrete which is differentiated internally and gives the appearance of cemented nodules.

DC50 Gypcrete

Completely cemented duricrust cemented mainly by gypsum.

DC60 Silcrete

Completely cemented duricrust cemented mainly by silica.

DC61 Silcrete sheet

Silcrete which has formed as a sheet within the regolith, and is more-or-less continuous in outcrop.

DC62 Silcrete pods

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

DM00 Moderately cemented duricrust

Duricrust where the material is 70 - 90% cemented. It often has a grainy texture and may be mottled. These materials can be further subdivided as follows:

DM20 Calcareous
DM40 Ferruginous
DM60 Siliceous

DP00 Partially cemented duricrust

Duricrust with less than 70% cemented material, often with an open texture, for which the term hardpan is used. This category can be further subdivided:

DP10 Bauxitic hardpan
DP30 Clay hardpan
DP40 Ferruginous hardpan
DP60 Siliceous hardpan
DP70 Humic hardpan

NO00 Nodules

Nodules are irregular to spherical units of regolith material that occur enclosed within the regolith, as lag, or in duricrusts. They generally have rounded edges. They are distinct because of a greater concentration of some constituent, a difference in internal fabric or a distinct boundary with the surrounding material. We use the term as more or less equivalent to the *glaebule* of Brewer (1964). It does not include fragments of weathered rock, or coarse sedimentary particles unless they have been modified. For example, a fragment of rock weathered and coated with a cutan would fit our definition.

There are many possible subdivisions of this category, such as pisoliths and concretions. These may be included in revisions. The following subdivisions of this category are included at this time:

NO10 bauxitic nodules
NO20 calcareous nodules
NO30 clay nodules
NO40 ferruginous nodules
NO60 siliceous nodules

12.8. Degree of Weathering [REGT_WEATH]

For each regolith type listed above it is necessary to assess the degree of weathering. Speight and Isbell (1990) have developed a schema for *in situ* rocks. We have modified this slightly, and have included practical tests from Ollier (1965). We have extended Speight and Isbell's schema to cover transported materials.

0 Unknown

This category is used during reconnaissance mapping when an RTU has been recognised on imagery or maps, but has not been visited in the field.

1 Unweathered

Regolith with no visible signs of weathering. Normally this class will be confined to sedimentary regolith types because, by definition, fresh bedrock is not regolith.

2 Slightly weathered

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

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

3 Moderately weathered

Moderately weathered rock has strong iron staining, and up to 50 % earth material. Corestones, if present, are rectangular and interlocked. Most feldspars have decayed, and there are microfractures throughout. Moderately weathered rock can be broken by a kick (with boots on), but not by hand.

Moderately weathered sediments have strong iron staining, and up to 50 % earth material. Labile particles up to gravel size are completely weathered. Larger particles have thick weathering skins. Most feldspars in larger particles have decayed.

4 Highly weathered

Highly weathered rock has strong iron staining, and more than 50% earth material. Core stones, if present, are free and rounded. Nearly all feldspars are decayed, and there are numerous microfractures. The material can be broken apart in the hands with difficulty.

Highly weathered sediment has strong iron staining, and more than 50% earth material. All except the largest particles are weathered right through. Boulders have thick weathering skins.

5 Very highly weathered

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

Very highly weathered sediment is thoroughly decomposed, but still retains the shapes of the original sediment particles, as well as laminations and bedding. It is composed completely of earth material.

6 Completely weathered

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

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

12.9. Thickness [REGT_TKNS]

This thickness field is for specific regolith types. The field LREGT_TKNS referes to general regolith thickness in the landform unit as a whole.

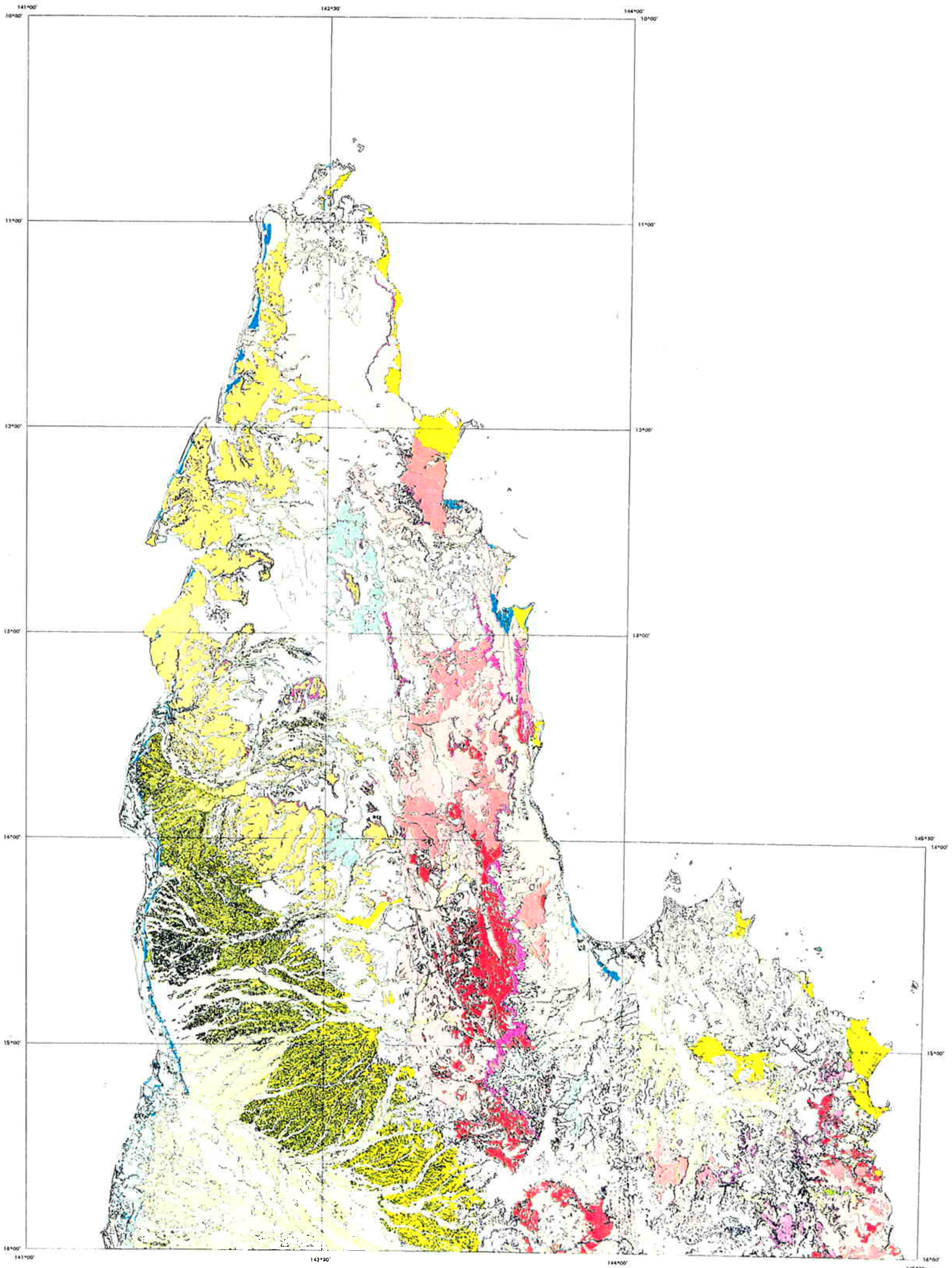
0	unknown
1	< 0.5 m
2	< 2 m
3	> 2 m
4	> 5 m
5	> 15 m
6	> 50 m

12.10. Position in Profile [REGT_PROF]

This is a descriptive field for recording the total known gross profile characteristics of the regolith, including any truncation or covering that may have occurred. It places the regolith type in its stratigraphic context, if appropriate.

12.11. Distribution in Landscape [REGT_DIST]

This is a descriptive field for comments on the 3 dimensional landscape position of the regolith type. It is used to describe any toposequence relationships observed in the regolith type.



CYPLUS

CYPLUS is a joint initiative between the Queensland and Commonwealth Governments

REGOLITH-LANDFORM

EDITION 1

IN SITU WEATHERED ROCK

Residual Material

- Soil on bedrock
- Residual sand over highly weathered saprolite
- Residual sand over ferricrete and very highly weathered saprolite
- Residual clay on fine grained Cretaceous sandstone
- Residual clay on weathered basalt
- Bauxite and ferricrete over completely weathered saprolite

Saprolite

- Slightly weathered saprolite
- Moderately weathered saprolite on pre-Mesozoic basement
- Moderately weathered saprolite on Mesozoic sandstones and siltstones
- Moderately weathered saprolite on Early Tertiary & Mesozoic sandstones
- Moderately weathered saprolite on erosional scarps
- Moderately weathered saprolite on volcanic cones & hills
- Highly weathered saprolite
- Very highly weathered saprolite

DEPOSITIONAL MATERIAL

Coastal Sediments

- Modern beach
- Younger beach sediments
- Older beach sediments and beach ridges
- Tidal sediments, including some areas of mangroves
- Supratidal sediments
- Mangrove areas with estuarine sediments
- Coral Cay

Coastal Dunes

- Active coastal sand dunes
- Inactive coastal sand dunes

Alluvial Sediments

- Active river channel deposits (gravels, sand minor clay)
- Active alluvial deposits on floodplains and alluvial plains
- Less active alluvial deposits on floodplains and alluvial plains
- Active alluvial plain - overbank deposits
- Alluvial swamps and lacustrine sediments
- Minor river channels, broad shallow valleys
- Alluvial terrace deposits
- Dissected fluvial sediments
- Dissected Tertiary fans with very low relief - mainly fine sand
- Shallow depressions, and solution pits (melon holes)
- Relict alluvial plain partially covered by more recent alluvial sediments

Colluvial Sediments

- Colluvial sediments, footslopes

SCALE 1:2,500,000

0 50 100 150 200 250 Kilometres

UNIVERSAL TRANSVERSE MERCATOR PROJECTION

Australian Map Grid Zone 54

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