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SUPPLEMENTARY NOTES AND REGOLITH MAP FOR THE ENIGMA PROSPECT (WOLLUBAR), KALGOORLIE, WESTERN AUSTRALIA

M.A. Craig, M.J. Lintern and D.J. Gray

CRC LEME OPEN FILE REPORT 111

June 2001

(CRC LEME Restricted Report 33R/
CSIRO Division of Exploration and Mining Report 339R, 1997.
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CRC LEME is an unincorporated joint venture between The Australian National University,
University of Canberra, Australian Geological Survey Organisation and CSIRO Exploration and Mining
Headquarters: CRC LEME c/o CSIRO Exploration and Mining, Private Bag No 5, PO Wembley, Western Australia, 6913.

RESEARCH ARISING FROM CSIRO/AMIRA YILGARN REGOLITH GEOCHEMISTRY PROJECTS 1987-1996

In 1987, CSIRO commenced a series of multi-client research projects in regolith geology and geochemistry which were sponsored by companies in the Australian mining industry, through the Australian Mineral Industries Research Association Limited (AMIRA). The initial research program, "Exploration for concealed gold deposits, Yilgarn Block, Western Australia" had the aim of developing improved geological, geochemical and geophysical methods for mineral exploration that would facilitate the location of blind, buried or deeply weathered gold deposits. The program commenced with the following projects:

P240: Laterite geochemistry for detecting concealed mineral deposits (1987-1991). Leader: Dr R.E. Smith.
Its scope was development of methods for sampling and interpretation of multi-element laterite geochemistry data and application of multi-element techniques to gold and polymetallic mineral exploration in weathered terrain. The project emphasised viewing laterite geochemical dispersion patterns in their regolith-landform context at local and district scales. It was supported by 30 companies.

P241: Gold and associated elements in the regolith - dispersion processes and implications for exploration (1987-1991). Leader: Dr C.R.M. Butt.
The project investigated the distribution of ore and indicator elements in the regolith. It included studies of the mineralogical and geochemical characteristics of weathered ore deposits and wall rocks, and the chemical controls on element dispersion and concentration during regolith evolution. This was to increase the effectiveness of geochemical exploration in weathered terrain through improved understanding of weathering processes. It was supported by 26 companies.

These projects represented 'an opportunity for the mineral industry to participate in a multi-disciplinary program of geoscience research aimed at developing new geological, geochemical and geophysical methods for exploration in deeply weathered Archaean terrains'. This initiative recognised the unique opportunities, created by exploration and open-cut mining, to conduct detailed studies of the weathered zone, with particular emphasis on the near-surface expression of gold mineralisation. The skills of existing and specially recruited research staff from the Floreat Park and North Ryde laboratories (of the then Divisions of Minerals and Geochemistry, and Mineral Physics and Mineralogy, subsequently Exploration Geoscience and later Exploration and Mining) were integrated to form a task force with expertise in geology, mineralogy, geochemistry and geophysics. Several staff participated in more than one project. Following completion of the original projects, two continuation projects were developed.

P240A: Geochemical exploration in complex lateritic environments of the Yilgarn Craton, Western Australia (1991-1993). Leaders: Drs R.E. Smith and R.R. Anand.
The approach of viewing geochemical dispersion within a well-controlled and well-understood regolith-landform and bedrock framework at detailed and district scales continued. In this extension, focus was particularly on areas of transported cover and on more complex lateritic environments typified by the Kalgoorlie regional study. This was supported by 17 companies.

P241A: Gold and associated elements in the regolith - dispersion processes and implications for exploration (1991-1993). Leader: Dr. C.R.M. Butt.
The significance of gold mobilisation under present-day conditions, particularly the important relationship with pedogenic carbonate, was investigated further. In addition, attention was focussed on the recognition of primary lithologies from their weathered equivalents. This project was supported by 14 companies.

Most reports related to the above research projects were published as CRC LEME Open File Reports Series (Nos 1-74), with an index (Report 75), by June 1999. Publication now continues with release of reports from further projects.

P252: Geochemical exploration for platinum group elements in weathered terrain. Leader: Dr C.R.M. Butt.
This project was designed to gather information on the geochemical behaviour of the platinum group elements under weathering conditions using both laboratory and field studies, to determine their dispersion in the regolith and to apply this to concepts for use in exploration. The research was commenced in 1988 by CSIRO Exploration Geoscience and the University of Wales (Cardiff). The Final Report was completed in December 1992. It was supported by 9 companies.

P409: Geochemical exploration in areas of transported overburden, Yilgarn Craton and environs, WA.
Leaders: Drs C.R.M. Butt and R.E. Smith.
About 50% or more of prospective terrain in the Yilgarn is obscured by substantial thicknesses of transported overburden that varies in age from Permian to Recent. Some of this cover has undergone substantial weathering. Exploration problems in these covered areas were the focus of Project 409. The research was commenced in June 1993 by CSIRO Exploration and Mining but was subsequently incorporated into the activities of CRC LEME in July 1995 and was concluded in July 1996. It was supported by 22 companies.

Although the confidentiality periods of Projects P252 and P409 expired in 1994 and 1998, respectively, the reports have not been released previously. CRC LEME acknowledges the Australian Mineral Industries Research Association and CSIRO Division of Exploration and Mining for authority to publish these reports. It is intended that publication of the reports will be a substantial additional factor in transferring technology to aid the Australian mineral industry.

This report (CRC LEME Open File Report 111) is a second impression (second printing) of CSIRO, Division of Exploration and Mining Restricted Report 339R, first issued in 1997/02, which formed part of the CSIRO/AMIRA Project P409.

Copies of this publication can be obtained from:
The Publication Officer, c/- CRC LEME, CSIRO Exploration and Mining, Private Bag 5, Wembley, WA 6913, Australia. Information on other publications in this series may be obtained from the above or from http://leme.anu.edu.au/

Cataloguing-in-Publication:
Craig, M.A.
Supplementary notes and regolith map for the Enigma Prospect (Wollubar), Kalgoorlie, Western Australia.
ISBN 0 643 06736 1
1. Soils - Western Australia 2. Sediments (geology) - Western Australia
I. Lintern, M.J. II. Gray, D.J. III. Title
CRC LEME Open File Report 111.
ISSN 1329-4768

PREFACE

The CRCLEME-AMIRA Project 409 "Exploration in areas of transported overburden, Yilgarn Craton and environs" has, as its principal objective, development of geochemical methods for mineral exploration in areas with substantial transported overburden, through investigations of the processes of geochemical dispersion from concealed mineralization. An earlier report (EM Report 98R), entitled "Progress statement for the Kalgoorlie study area, Enigma prospect (Wollubar), Western Australia", focussed on soil geochemistry. Subsequently, district-scale regolith-landform mapping (1:50000 scale) has been undertaken to determine the geomorphological setting of the Enigma prospect. This should more readily enable comparisons between this site and equivalents in the region.

The procedures by which the map has been compiled are briefly described and a copy of the map itself is included. This report and Report EM 98R are complementary and should be read in conjunction with one another.

C.R.M. Butt
R.E. Smith
Project Leaders
January 1997

1. INTRODUCTION

This report supplements that previously issued (Lintern and Gray, 1995) by providing a regolith landform map and explanatory notes for the Wollubar-Enigma district. The mapping was undertaken in order to establish the geomorphological setting of the detailed geochemical studies described in the earlier report. These two reports are complementary. The area was visited in May 1996 in order to calibrate aerial photographic patterns and supplementary Landsat Thematic Mapper image patterns, to assist in the overall framework interpretation for the area. Due to the limited time available, the map is not fully rectified.

2. METHODS

For regolith landform map construction, 1:86000 RC9 black and white aerial photographs were used. Approximately 130 locations were visited and observations recorded to assist with regolith interpretations and map construction. The data were used to construct regolith landform units from calibrated photopatterns and used to modulate data interpreted from satellite imagery. Compilations were performed at photoscale by scanning aerial photographs with overlays attached without the intricate removal of radial distortion. All photographs with overlays were edge-matched then compiled into one composite sheet. The regolith polygons were scanned and imported into ARC/Info to allow the automatic diagram layout and automatic legend planning.

3. INTERPRETATION

The dominant regolith landform unit for the Enigma (Wollubar) area is depositional which comprises 77% of the total mapped area (TMA) with colluvial sediments providing nearly 42% of the TMA (Figure 1, Table 1). Erosional areas comprise 20% of the TMA; the dominant erosional regolith landform unit is "moderately weathered bedrock" and represents 15% of the TMA. Relict area comprise 3.4% of the TMA.

Table 1: Principal regolith landform regimes.

REGOLITH LANDFORM UNIT	% OF TOTAL MAPPED AREA (TMA)
RELICT	3.4
EROSIONAL	20
Highly weathered	1.5
Moderately weathered	15
Slightly weathered	3.7
DEPOSITIONAL	77
Alluvial sediments	22
Aeolian sands	1.4
Dunefield	2.5
Colluvial sediments	43
Lacustrine	8.4
TOTAL	100

WOLLUBAR INTERPRETED LANDSCAPE CLASSES

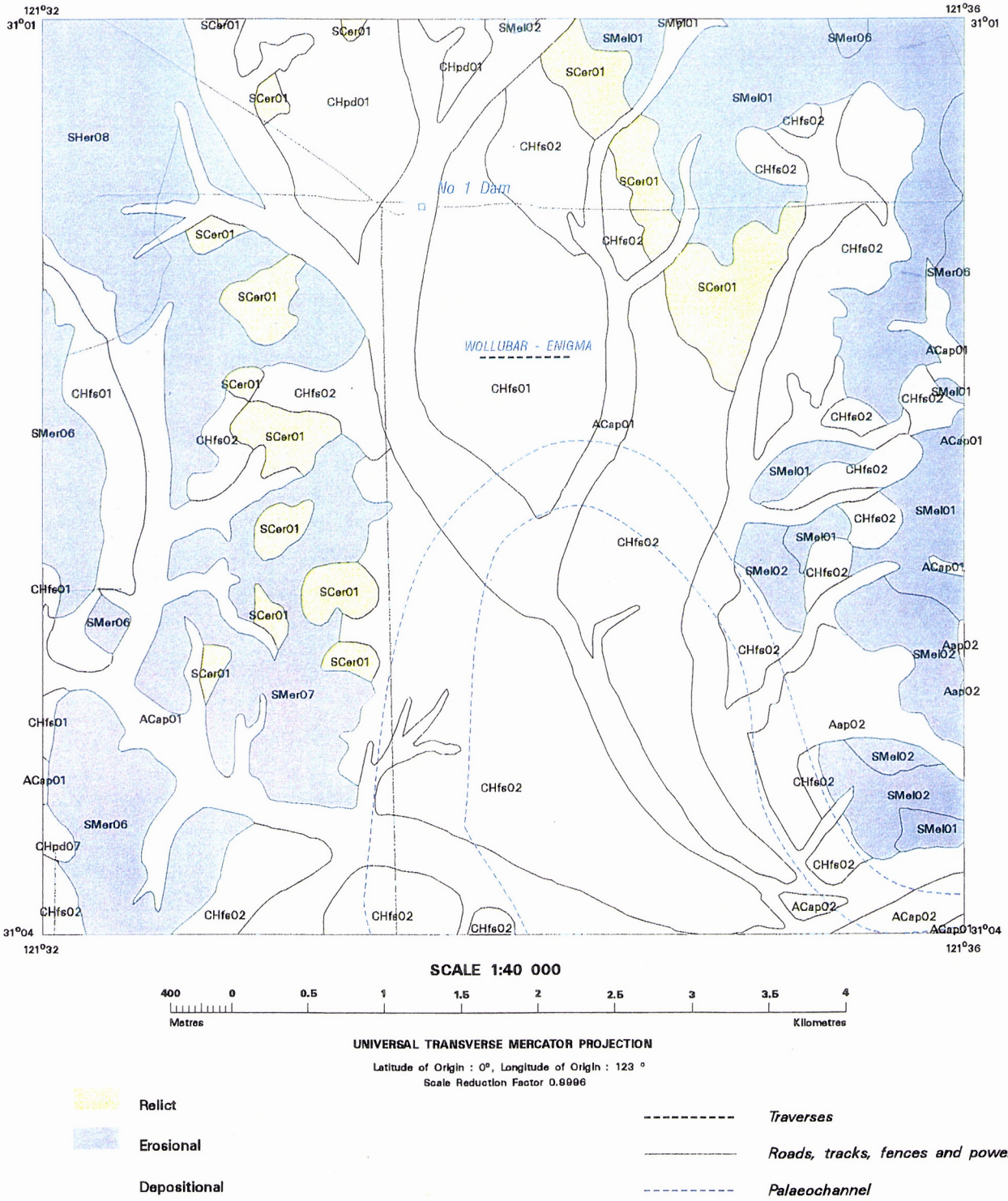


Figure 1: Simplified regolith diagram of the Wollubar-Enigma area. See back of report for full size detailed diagram.

An interpretation was made of the nature of the material expressed directly at the actual land surface (Table 2); this was possible for approximately 56% of the TMA at this level of investigation. These materials represent the source of regolith compositional information as determined by Landsat TM imagery. These surface materials do not indicate the full nature of regolith materials at depth. A complete explanation of the regolith materials and landforms comprising each unit is provided in the legend on the regolith landform map located at the back of this document.

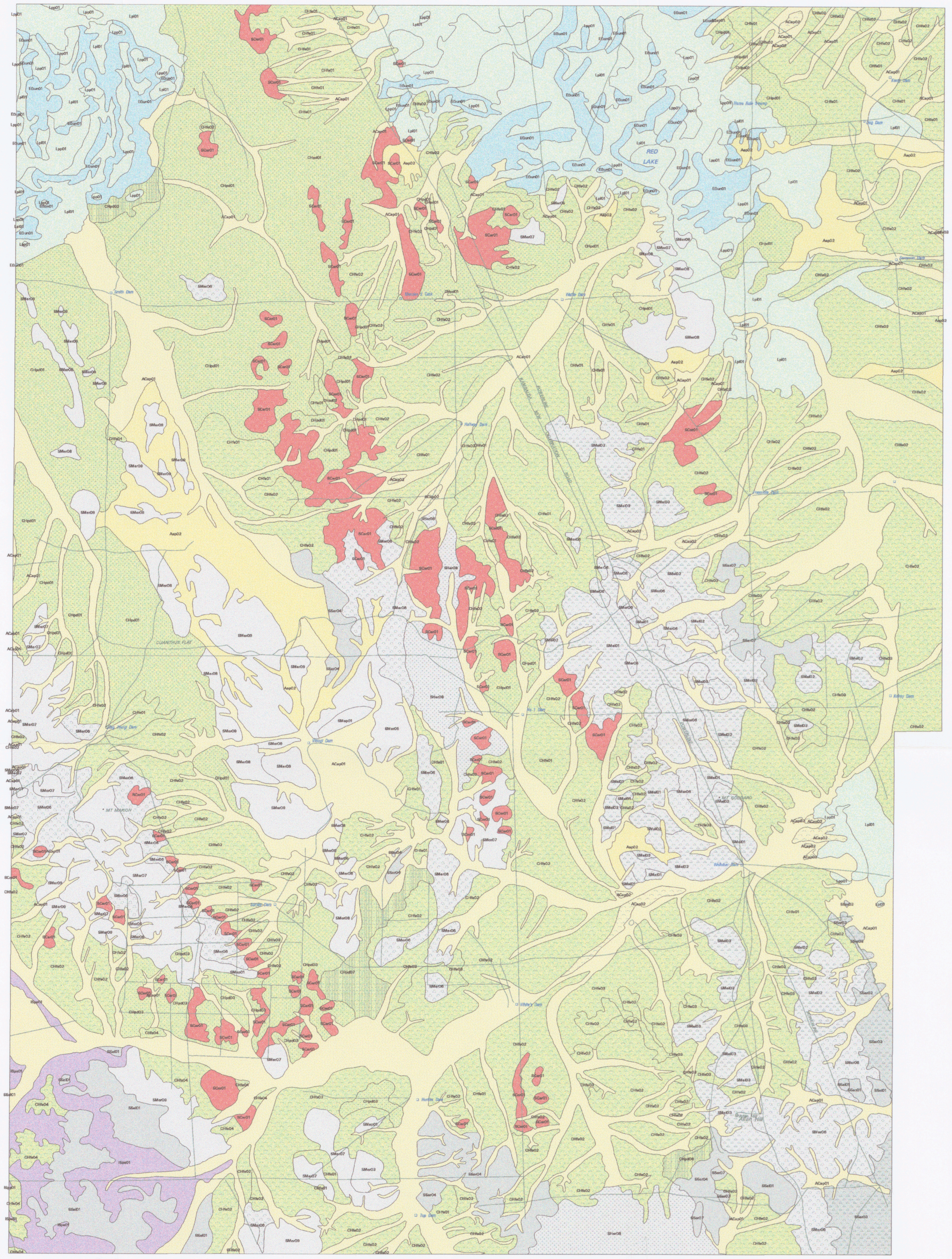
Table 2: Surface material, Enigma (Wollubar) area.

	UNIT	% of TOTAL MAPPED AREA
1.	Calcareous earths, soil carbonate, calcareous nodules	0.7
2.	Lag:-variable composition, but dominantly gravel-sized lithic fragments	4.9
3.	Lag gravels: dominantly quartzofeldspathic sand or granules, or mixtures	13
4.	Ferruginous fragments - mixed composition: lateritic residuum, duricrust, Fe segregations, Fe saprolite and Fe-stained hardpan	7.3
5.	Fine ferruginous gravel lags	29
6.	Black, slightly magnetic, haematite- maghemite-rich ferruginous gravels	1.3
7.	Unassigned	43
	Total map area	100

4. REFERENCES

Lintern, M.J., and Gray, D.J., 1995. Progress Statement for the Kalgoorlie Study Area - Enigma Prospect (Wollubar), Western Australia. (CSIRO/AMIRA Project 409: Yilgarn Transported Overburden). CSIRO Division of Exploration and Mining Restricted Report No. 98R. 36pp.

WOLLUBAR REGOLITH LANDFORMS SCHEMATIC DIAGRAM



Relict

SCer01 — *Completely weathered bedrock*
Completely weathered mafic/ultramafic bedrock sequences developed as rises (>9 m local relief) and having lateritic duricrusts (iron rich in places) occurring on sub-crestal to crestal regions with a matrix of shallow reddish to khaki very fine sandy clays. Completely weathered fe rich saprolite exposures (>3m thick), and fe nodular & granular lags.

Erosional

Highly weathered bedrock

SHer08 — Highly weathered metasedimentary rocks derived from pebbly sandstones, sandstone and siltstone forming erosional rises with pebbly and sandy quartzofeldspathic surface lags and pebbly sandy colluvium with some mixtures from local sources.

Moderately weathered bedrock

SMep01 — Moderately weathered mafic to ultra-mafic dykes and metamorphosed magnesium basalts forming an erosional plain with a shallow colluvial mantle.

SMer03 — Moderately weathered mafic schists, metabasalts, metadolerites and amphibolite forming erosional rises to undulating plain

SMer05 — Moderately weathered granitic bedrock (in some parts very weathered) forming erosional rises to undulating erosional plain with a thin mantle consisting of quartzofeldspathic fine to medium sands with some mixtures of ferruginous granules and iron bedrock fragments.

SMer06 — Moderately weathered mafic to ultramafic bedrock including metakomatite forming erosional rises and having a colluvial mantle consisting mostly of very fine sandy light clays, usually calcareous and may have a lag containing some carbonate nodules, iron granules and iron bedrock fragments.

SMer07 — Moderately weathered metamorphosed high magnesium basalt mostly forming erosional rises (>9m relief) with a surrounding and sometimes blanketing colluvial mantle of calcareous sheetflow sediments with iron bedrock and saprolite fragments and some iron granules as surface lag.

SMer08 — Moderately weathered intermediate shallow intrusives or volcanics forming erosional rises with colluvial mantle of calcareous quartzofeldspathic sands.

SMer09 — Moderately weathered metamorphosed felsic volcanic rock forming kaolinized erosional rises with slightly clayey quartzofeldspathic colluvial mantle.

SMel01 — Moderately weathered greenstone bedrock exposures forming low hills (30-90m local relief) with a mantle of colluvium containing bedrock fragments and also bedrock fragments sometimes present as surface lag.

SMel02 — Moderately weathered mafic schists, metabasalts and metadolerites forming erosional low hills (9-30 metres local relief).

SMel03 — Moderately weathered metamorphosed high magnesium basalts forming low hills (30-90m relief) with a medium to thin mantle of calcareous sheetflow colluvium with iron bedrock fragments as scattered surface lag.

Slightly weathered bedrock

SSec01 — Slightly weathered granitic bedrock exposures forming limited extent etched planer to slightly undulating platforms with little or no colluvial mantle remaining.

SSer03 — Slightly weathered, dominantly greenstone bedrock lithologies developed as bedrock rises sometimes granitic interbeds are present. Often occurring as the flanking region of the near crestal portion of bedrock rises Calcareous sandy, clayey colluvial mantle containg Fe lithic bedrock fragments and possibly some calcareous nodules.

SSer04 — Slightly sometimes moderately weathered metasedimentary sequences developed as bedrock rises (> 9 m local relief) with a colluvial mantle of clayey, silty sands through to sandy clays.

SSer07 — Slightly to moderately weathered (in part) bedrock rises consisting of acid to intermediate volcanic and volcaniclastic rocks. A thin mantle of quartzofeldspathic sand covers and undulating small erosional plains between rises.

SSel01 — Slightly weathered granitic bedrock exposures forming low hills (30-90m local relief) with little or no colluvial mantle present.

Depositional

Alluvial sediments

Alluvial sediments

Aap02 — Alluvial sediments with minor colluvium derived from nearby slopes. Calcareous sandy silty clays and clayey silty sands are exposed on an alluvial plain and smaller tracts between rises and low hills.

ACap01 — Alluvial channel sediments consisting of various combinations of quartz sands, clays, and silts.

ACap02 — Alluvial channel sediments consisting of calcareous sand, red to red-brown clays derived from mixed felsic and mafic source rocks, developed on broad shallow alluvial tracts. Granule to very scattered polymict lags consisting of 1-5cm quartz and 1-3cm lithic fragments with red-brown and bright black iron granules.

Transported Regolith

Aeolian sediments

Aeolian sand

ISps01 — Quartzofeldspathic sand with limonitic nodules developed from weathered granitic bedrock and reworked by aeolian action and to a lesser extent by sheetflow and fluvial action now formed into sandplains.

Depositional

Colluvial sediments

Sheet flow deposit

CHfs01 — Sheetflow deposits consisting of colluvial sediments derived from ultramafic bedrock exposures, and having a surface lags consisting of Fe granules over calcareous soils.

CHfs02 — Colluvial sediments as sheetflow deposits from ultramafic source rocks with ferruginous granular lag gravels, some calcareous nodules and some calcareous soils.

CHfs03 — Colluvial sediments as sheetflow deposits from ultramafic source rocks with few iron granular lags and calcareous soils and rarer iron fragments.

CHfs04 — Colluvial quartzofeldspathic sediments derived from weathered granitic bedrock forming variable thickness (< 1.5m) sheetflow deposits as sheetflow fans, or forming plains if coalesced.

CHpd01 — Calcareous sheetflow sediments consisting of red-brown sandy, light to medium textured clays to a depth of more than 70 cm and occurring on and inclined to gently undulating depositional plain. Some areas of quartzofeldspathic sandy lag at the surface and with less than 2pc of Fe granular lithic bedrock fragments derived from local greenstone.

CHpd02 — Sheetflow deposits consisting of highly calcareous khaki cloured very fine sany clays over calcareous nodules at about 20 cm depth.

CHpd03 — Sheetflow deposits consisting of highly calcareous silty clay loams, sometimes gritty, to a depth of overlying calcareous medium to heavy textured red-brown clays. Very rare calcareous nodules present at the surface, but mostly dominated by bright black Fe granular (1-4 mm) lag

CHpd07 — Colluvial sheetflow sediments consisting of calcareous sandy light to medium red-brown textured clays over brown cracking clays at about 6 metres in some locataions and probably mostly overlying weathered felsic bedrock

CHpd08 — Colluvial sheetflow sediments consisting of calcareous slightly sandy (medium), light brown, light textured clays through to medium and heavy textured clays to at least 75cm. Lags are rare to mostly absent with some calcrete nodules present in rills and flow lines.

Dunefield Sediments

Lunette Sediments

EGun01 — Lunettes and single dune forms consisting of combinations of some halite, quartz sands, silts and playa plains and lakes.

Lacustrine sediments

Lacustrine sediments

Lpl01 — Lacustrine sediments consisting of saline gypsiferous red-brown muds (ie clays and silt mixtures) forming mud flats on the edge of saline lakes and broad playa plains.

Lpp01 — Lacustrine sediments with some halite, and gypsiferous red-brown clays and silts forming salt lake beds and playa plains.

INDURATION MODIFIER

- Calcareous earths, soil carbonate, calcareous nodules
- Lag - variable composition but dominantly gravel-sized consisting of bedrock fragments
- Lag-gravels: dominantly sandy quartzofeldspathic, or quartzofeldspathic granules or mixtures
- Ferruginous fragments - mixed composition: lateritic residuum, duricrust, Fe segregations, Fe-saprolite and Fe-stained hardpan.
- Ferruginous fine gravel lags
- Black lightly magnetic haematite - maghematite rich ferruginous granules

DEPOSITIONAL LANDFORMS

ap	Alluvial plain
un	Lunette
fs	Sheet-flood fan
pd	Depositional plain
pp	Playa plain
pl	Lacustrine plain
ps	Sand plain

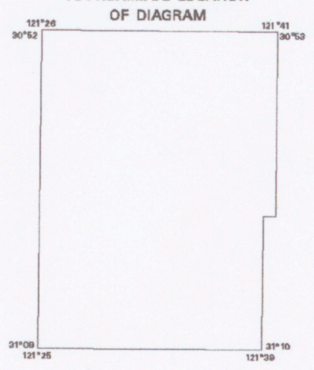
EROSIONAL LANDFORMS

ep	Erosional plain
ec	Etchplain
er	Rises
el	Low hills

Roads, tracks, fences and powerlines

MAP LOCALITY

APPROXIMATE LOCATION OF DIAGRAM



APPROXIMATE SCALE 1:50 000

1000 Metres 0 1 2 3 4 5 Kilometres

UNIVERSAL TRANSVERSE MERCATOR PROJECTION

Latitude of Origin : 0°, Longitude of Origin : 123 °
Scale Reduction Factor 0.9996

WARNING: This is not a rectified map, the scale is approximate and non-linear, spatial relationships are only approximate.

RESTRICTED CIRCULATION
This diagram has been prepared exclusively for sponsors of CRC LEME - AMIRA P409 (Yilgarn Transported Overburden) and is not to be given additional distribution or reproduced in any manner without the consent of the Director of the Cooperative Research Centre for Landscape Evolution and Mineral Exploration.

Compiled by M.A. Craig (CRC LEME/AGSO), 1996

Diagram composition by P Ursem and M.A. Craig (AGSO), 1996

This Diagram forms part of the following document:

Report number 98R
Progress statement for the Kalgoorlie Study
Area - Engima Prospect (Wollubar), Western Australia
M. J. Lintern and D. J. Gray

The regolith diagram is based on the interpretation of 1:86 000 RC9 panchromatic aerial photography (1967) of the Widgiemooltha and/or Kalgoorlie 250k sheet areas and selected field traverses. This diagram provides a broad overview of regolith landforms as a framework for more detailed local knowledge. Boundaries and polygon descriptions are generalised to show the main regolith and landform types. The diagram is not a true map. It is not fully spatially rectified. The scale is non linear and is only approximate. Relative spatial relationships are approximate.

Published by CRC LEME, Canberra, Australia.
Produced by, AGSO, Canberra, Australia.

Topographic information shown on this diagram has been derived from 1:86 000 RC9 panchromatic aerial photography 1967.

CRC LEME acknowledges the support provided for the production of this diagram by AMIRA.

CRC LEME is an unincorporated joint venture between the Australian National University, University of Canberra, Australian Geological Survey Organisation and CSIRO Exploration and Mining, established and supported under the Australian Government's Cooperative Research Centre Program.

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