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CSIRO
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Australian Mineral Industries Research Association Limited ACN 004 448 266

GEOCHEMICAL EXPLORATION IN COMPLEX LATERITIC ENVIRONMENTS OF THE YILGARN CRATON, WESTERN AUSTRALIA

P240A Final Report
Volume 4 - Maps

R.R. Anand, R.E. Smith, C. Phang, J.E. Wildman,
I.D.M. Robertson and T.J. Munday

CRC LEME OPEN FILE REPORT 58

November 1998

(CSIRO Division of Exploration Geoscience Report 442R, December 1993.
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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, PO Wembley, Western Australia, 6014

RESEARCH ARISING FROM CSIRO/AMIRA REGOLITH GEOCHEMISTRY PROJECTS 1987-1993

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" (1987-1993) 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 included 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. 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.

Although the confidentiality periods of the research reports have expired, the last in December 1994, they have not been made public until now. Publishing the reports through the CRC LEME Report Series is seen as an appropriate means of doing this. By making available the results of the research and the authors' interpretations, it is hoped that the reports will provide source data for future research and be useful for teaching. CRC LEME acknowledges the Australian Mineral Industries Research Association and CSIRO Division of Exploration and Mining for authorisation 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 58) is a First revision (second printing) of CSIRO, Division of Exploration Geoscience Restricted Report 442R, first issued in 1993, which formed part of the CSIRO/AMIRA Project P240A.

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CSIRO DIVISION OF EXPLORATION AND MINING
R.R. Anand et al., 1993 **Report 442R Appendix V**

KALGOORLIE-KURNALPI REGOLITH-LANDFORMS

SPECIAL EDITION 1993

RESIDUAL REGIME

- R1 — Black Fe-rich duricrust, lateritic duricrust (low in Fe), lateritic pisoliths and nodules, ferruginous saprolite fragments, acid to calcareous red clay soil; crests and low topographic highs
- R2 — Lateritic pisoliths and nodules and ferruginous saprolite fragments; backslopes

EROSIONAL REGIME

- E1 — Lag of ferruginous saprolite and ferruginous lithic fragments with minor lateritic nodules and pisoliths, acid to calcareous red clay soil, some hardpan in soils; crests, backslopes (upper and midslopes), gently undulating highs
- E2 — Lag of ferruginous granules, calcareous brown clay soil with carbonate nodules over non-calcareous red/orange clays and mottled zone; gently sloping terrain
- E3 — Saprolite and mottled zone exposed-breakaway scarps; pediments
- E4 — Saprolite as pale clays with carbonate nodules, black ferruginous granules and quartz; erosional plains
- E5 — Bedrock fragments and red, calcareous sandy clay soils; scree slopes
- E6 — Bedrock; low hills
- E7 — Ferruginous bedrock; low hills
- E8 — Bedrock; high hills
- E9 — Ferruginous bedrock; high hills

DEPOSITIONAL REGIME

- D1 — Acid to calcareous red sandy clay soil with polymictic ferruginous lag within major drainage basins and channels, ferruginous granules common in soils
- D2 — Calcareous soils - colluvium as sheetwash, ferruginous granules common in soils
- D3 — Black, highly magnetic, fine hematite-maghemite-rich ferruginous granules, non-calcareous red clays at surface, carbonates at 10-20cm, ferruginous granules common in soils; gently sloping plain
- D4 — Black, highly magnetic, fine hematite-maghemite-rich ferruginous granules, acid to calcareous red clay soils with ferruginous granules, colluvium/alluvium; gently sloping alluvial floor
- D5 — Acid to calcareous soils with ferruginous granules, alluvium; broad alluvial floor
- D6 — Orange to brown saline clays and muds; playa
- D7 — Gypsiferous sands with minor rounded quartz and lithic fragments; playa
- D8 — Calcareous sandy soil as dunes with associated pale orange clays within swales
- D9 — Elevated, undulating topography with valley slopes and floors, now inactive depositional regimes identifiable, lags, gravels, nodules, sands, loams, colluvial/alluvial gravels and dune fields

Regolith boundary
Principal road
Vehicle track
Railway
Watercourse
Mine
Windpump
Dam, Well
Bore
Trig Stn
Spot ht

Regolith 1993, Compiled 1993 by
M.A.Craig AGSO-CRCAMET and R.R.Anand CSIRO-CRCAMET

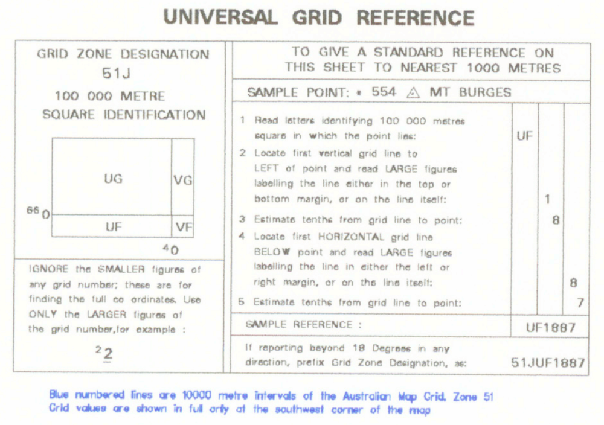
in collaboration with

J.R.Gozzard GSWA-CRCAMET, M.R.Dell University of Tasmania-CSIRO
C.Phang CSIRO-CRCAMET, J.D.King CSIRO
T.J.Munday Curtin University-CRCAMET

Map constructed by
T.Brennan, D.Dlugosz, D.Pillinger, and M.Peljo, AGSO
using Arc/Info software

It is recommended that this map is identified as:
Craig, M.A. and Anand, R.R. 1993 -
Kalgoorlie-Kurnalpi Regolith-Landforms 1:250,000 Special Edition
Australian Geological Survey Organisation

UNIVERSAL GRID REFERENCE



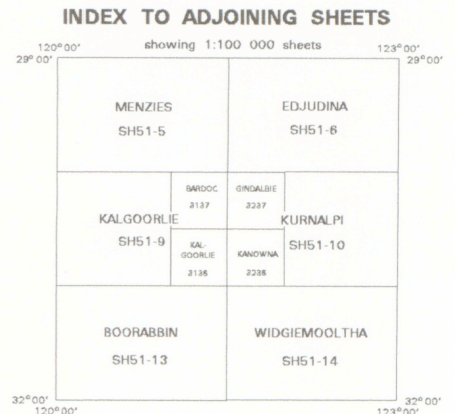
MAP LOCALITY

SCALE 1:250 000

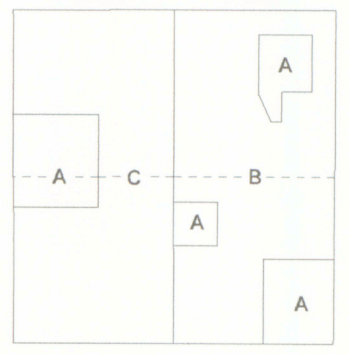
0 5 10 15 20 25 Kilometres

UNIVERSAL TRANSVERSE MERCATOR PROJECTION
Latitude of Origin : 0°, Longitude of Origin : 123°
Scale Reduction Factor 0.9996

INDEX TO ADJOINING SHEETS
showing 1:100 000 sheets



RELIABILITY DIAGRAM



A : Numerous detailed traverses with airphoto interpretation and satellite remote sensing (TM)
B : Numerous general traverses with airphoto interpretation and satellite remote sensing (TM)
C : General traverses with airphoto interpretation and satellite remote sensing (TM)

KALGOORLIE-KURNALPI
REGOLITH-LANDFORMS

SPECIAL EDITION
1993

CSIRO DIVISION OF EXPLORATION AND MINING
R.R. Anand et. al., 1993 **Report 442R, Appendix VI**

CSIRO AUSTRALIA

Breakaway scarp

Greenstone strike ridge trend line

Dune trend line

0 1 2 3 4 5 km

This map uses an uncontrolled photomosaic as its base; some minor distortion occurs.

310000E 320000E 330000E

6640000N

6630000N

6620000N

6610000N

Ora Banda
Cawes Find
Lady Evelyn
Grants Patch
Carbine
Matt Dam
Lady Bountiful
Mt Pleasant
Black Flag
Kintore

SURFACE DISTRIBUTION OF REGOLITH-LANDFORM UNITS FOR THE ORA BANDA DISTRICT

RESIDUAL REGIME

R1 Black Fe-rich duricrust, lateritic duricrust (low in Fe), lateritic pisoliths and nodules, ferruginous saprolite fragments, acid to calcareous red clay soil - crests and low topographic highs

EROSIONAL REGIME

E1 Lag of fragments of ferruginous saprolite and ferruginous lithic fragments with minor lateritic nodules and pisoliths, acid to calcareous red clay soil - crests, backslopes (upper and midslopes), gently undulating topographic highs

E3 Saprolite and mottled zone exposed - breakaway scarps, pediments

E6 Bedrock - low hills

E7 Ferruginous bedrock - low hills

E8 Bedrock - high hills

DEPOSITIONAL REGIME

D1a Acid to calcareous red clay soil with polymictic ferruginous lag within major drainage basins and channels

D2 Calcareous soils as sheetwash - colluvium

D3 Black, highly magnetic, fine polymictic hematite-maghemite- rich granules, non calcareous red clays at surface, carbonates at 10-20 cm - gently sloping plain

D4 Black, fine hematite-maghemite- rich ferruginous granules, acid to calcareous red clay soils, colluvium/alluvium - gently sloping alluvial floor

D5 Acid to calcareous soils - broad alluvial floor

D6 Orange to brown saline clays and muds, playa

D8 Calcareous sandy soil as dunes with associated pale orange clays within swales

Prefixes

f felsic g granite m mafic um ultramafic i intermediate s sediment

J.R. Gozzard January 1993

CSIRO DIVISION OF EXPLORATION AND MINING
R.R. Anand et. al., 1993 Report 442R, Appendix VII

CSIRO AUSTRALIA

360000E 370000E 380000E

6625000N 6615000N 6605000N

Harper Lagoon
Six Mile
SIX MILE
Grave Dam
QED Kanowna
Kanowna
Ballarat - Last Chance
Kanowna Belle
Kanowna Dam
Cone Dam
Sheep Dam
Half Way Dams
Carmelia Rd
Kurnalpi Rd
Yarri Rd

SURFACE DISTRIBUTION OF REGOLITH-LANDFORM UNITS FOR THE KANOWNA BELLE DISTRICT

RESIDUAL REGIME

R1 Black Fe-rich duricrust, lateritic duricrust (low in Fe), lateritic pisoliths and nodules, ferruginous saprolite fragments, acid to calcareous red clay soil - crests and low topographic highs

EROSIONAL REGIME

E1 Lag of fragments of ferruginous saprolite and ferruginous lithic fragments with minor lateritic nodules and pisoliths, acid to calcareous red clay soil - crests, backslopes (upper and midslopes), gently undulating topographic highs

E2 Calcareous brown clay soil with carbonate nodules over non-calcareous red/orange clays and mottled zone - gently sloping terrain

E3 Saprolite and mottled zone exposed - breakaway scarps, pediments

E4 Saprolite as pale clays with carbonate nodules, black ferruginous granules and quartz erosional plains

E5 Bedrock fragments and red calcareous sandy clay soils - scree slopes

E7 Ferruginous bedrock - low hills

E8 Bedrock - high hills

DEPOSITIONAL REGIME

D1a Acid to calcareous red clay soil with polymictic ferruginous lag within major drainage basins and channels

D1b Acid to calcareous red clay soil with common black polymictic ferruginous lag within minor drainage basins and channels

D2 Calcareous soils as sheetwash - colluvium

D4 Black, fine hematite-maghemite- rich ferruginous granules, acid to calcareous red clay soils, colluvium/alluvium - gently sloping alluvial floor

D5 Acid to calcareous soils - broad alluvial floor

D6 Orange to brown saline clays and muds, playa

D7 Gypsiferous sands with minor rounded quartz and lithic fragments, playa

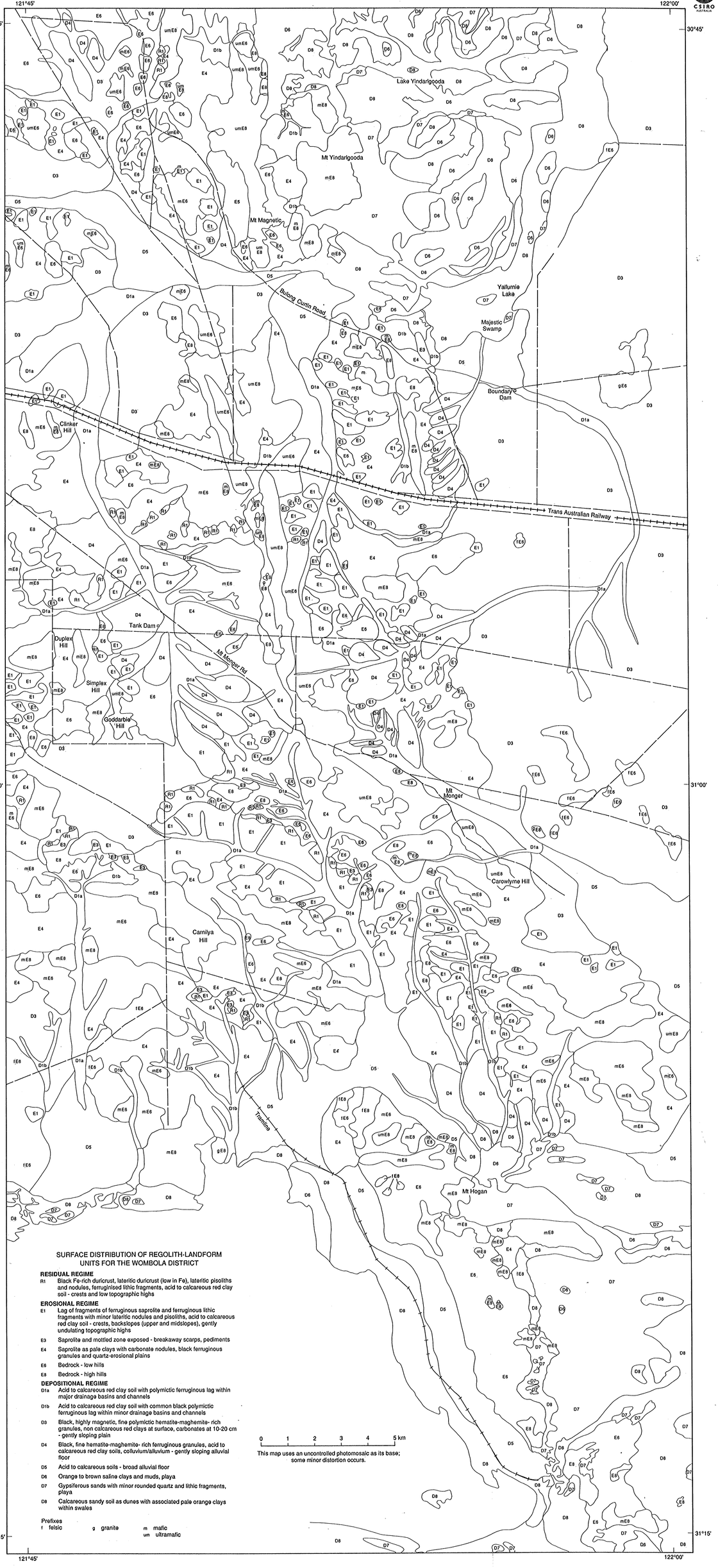
D8 Calcareous sandy soil as dunes with associated pale orange clays within swales

Prefixes
f felsic m mafic um ultramafic s sediment

Breakaways Mines Alluvial workings

0 1 2 3 4 5 km

This map uses an uncontrolled photomosaic as its base; some minor distortion occurs.



SURFACE DISTRIBUTION OF REGOLITH-LANDFORM UNITS FOR THE WOMBOLA DISTRICT

RESIDUAL REGIME

R1 Black Fe-rich duricrust, lateritic duricrust (low in Fe), lateritic pisoliths and nodules, ferruginised lithic fragments, acid to calcareous red clay soil - crests and low topographic highs

EROSIONAL REGIME

E1 Lag of fragments of ferruginous saprolite and ferruginous lithic fragments with minor lateritic nodules and pisoliths, acid to calcareous red clay soil - crests, backslopes (upper and midslopes), gently undulating topographic highs

E3 Saprolite and mottled zone exposed - breakaway scarps, pediments

E4 Saprolite as pale clays with carbonate nodules, black ferruginous granules and quartz-erosional plains

E6 Bedrock - low hills

E8 Bedrock - high hills

DEPOSITIONAL REGIME

D1a Acid to calcareous red clay soil with polymictic ferruginous lag within major drainage basins and channels

D1b Acid to calcareous red clay soil with common black polymictic ferruginous lag within minor drainage basins and channels

D3 Black, highly magnetic, fine polymictic hematite-maghemite- rich granules, non calcareous red clays at surface, carbonates at 10-20 cm - gently sloping plain

D4 Black, fine hematite-maghemite- rich ferruginous granules, acid to calcareous red clay soils, colluvium/alluvium - gently sloping alluvial floor

D5 Acid to calcareous soils - broad alluvial floor

D6 Orange to brown saline clays and muds, playa

D7 Gypsiferous sands with minor rounded quartz and lithic fragments, playa

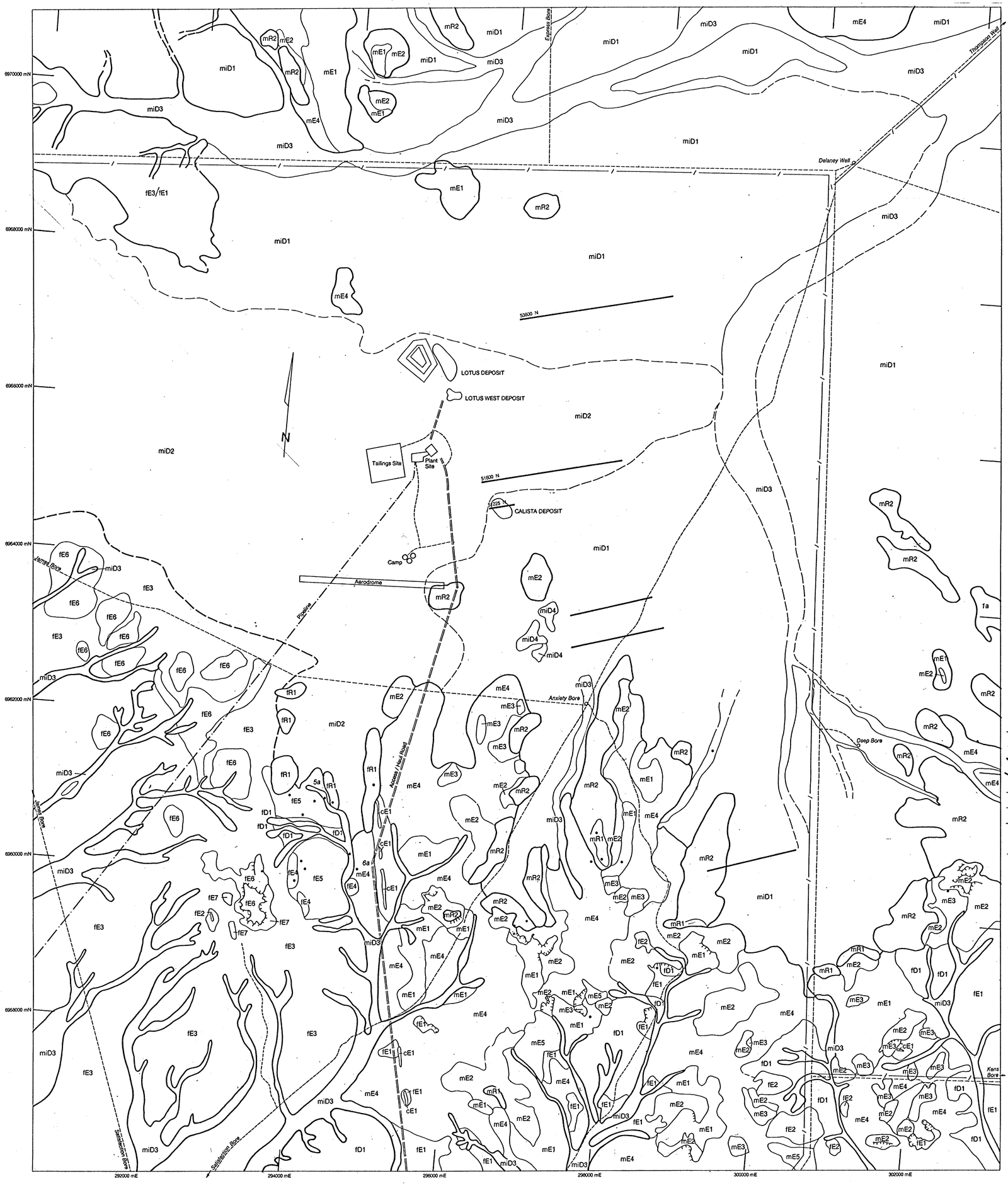
D8 Calcareous sandy soil as dunes with associated pale orange clays within swales

Prefixes

f felsic g granite m mafic um ultramafic

SURFACE DISTRIBUTION OF REGOLITH – LANDFORM UNITS

MT McCLURE



REFERENCE

RESIDUAL REGIME

Regolith developed from MAFIC BEDROCK
- mR1 — Black, magnetic, hematite-goethite-Maghemite rich, pisolitic and nodular iron rich duricrust, crests.
- mR2 — Reddish brown, kaolinite-goethite-hematite rich, loose lateritic pisoliths and nodules and nodular duricrust, blackslopes.

Regolith developed from FELSIC BEDROCK (Felsic volcanics)
- fR1 — Yellowish brown, kaolinite-goethite-hematite rich loose nodules on nodular duricrust, ridges.

EROSIONAL REGIME

Regolith developed from MAFIC BEDROCK
- mE1 — Black, massive, non-magnetic, goethite (lesser hematite) rich iron segregations: silicified saprolite, patches of hardpanized saprolite low hills and undulating tracts.
- mE2 — Light yellow-brown, non-magnetic, kaolinite-goethite rich ferruginous saprolite, breakaways, pediment slopes and bluffs bounded by breakaway.
- mE3 — Black, non-magnetic, hematite rich (lesser goethite) iron segregations, low hills and steep valleys.
- mE4 — Quartz and black, hematite rich (lesser goethite) iron segregations, low hills and undulating tracts.
- mE5 — Mafic (metamorphosed basalt, amphibolite) outcrop, rounded hills.

Regolith developed from FELSIC BEDROCK
- fE1 — Quartz sand on pale white saprolite, erosional plains.
- fE2 — Coarse blocky quartz lag surrounding quartz veins, ridges.
- fE3 — Quartz lag and micaceous quartz sand on gneiss, gentle slopes.
- fE4 — Ferruginous saprolite ridges developed from felsic volcanic rocks.
- fE5 — Iron segregations, quartz, silicified saprolite and patches of hardpanized saprolite developed from felsic volcanics, moderately steep slopes.
- fE6 — Gneiss saprock, low hills.
- fE7 — Gneiss outcrop, low hills.

CHERT
- cE1 — Chert ridges and surrounding lag of chert fragments.

DEPOSITIONAL REGIME

Colluvium-alluvium on MIXED LITHOLOGIES (Granites, Gneiss, basalt, ultramafics).
- miD1 — Mixed fine lag of quartz, lateritic pisoliths and nodules (without cutans), and red clayey sand. Lateritic residuum beneath 20m of hardpanized colluvium and alluvium.
- miD2 — Mixed fine gravelly lag of quartz, lateritic pisoliths and nodules (without cutans) and red clayey sand. Lateritic residuum is truncated, saprolite clays beneath 20-30m of hardpanized colluvium and alluvium and palaeochannel clays.
- miD3 — Lag of iron segregations, quartz, lateritic gravels (with and without cutans) and red clayey sand in minor and major tributaries.
- miD4 — Iron segregations, quartz and red clayey sand containing gypsum in local drainage sumps.

Colluvium on FELSIC BEDROCK
- fD1 — Iron segregations and quartz on red clayey sand (from upland mafic regions).

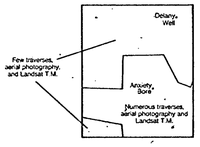
SYMBOLS

- Mapping unit boundaries
- Inferred mapping unit boundaries
- Transition between residual, erosional and depositional regimes (i.e. contacts between units from different regimes)
- Inferred transitions between residual, erosional and depositional regimes
- Fence line
- Roads and station tracks
- Water pipeline
- Station well
- Breakaway
- Sample and/or photograph locality
- R.A.B. line used for stratigraphic purposes

mi = mixed lithologies
m = mafic bedrock
f = felsic bedrock
c = chert
R = residual regime
E = erosional regime
D = depositional regime

LOCALITY MAP

RELIABILITY DIAGRAM



0 ½ 1 2km
SCALE: 1:25000

PLATE ONE

SURFACE DISTRIBUTION OF REGOLITH – LANDFORM UNITS FOR THE MT McCLURE DISTRICT