LAWLERS ORIENTATION STUDY

R.R. Anand, R.E. Smith, H.M. Churchward and J.L. Perdrix

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February 1999

LAWLERS ORIENTATION STUDY
Contribution to Field Guide,
Eastern Goldfields Trip,
1-2 November 1990

R.R. Anand, R.E. Smith, H.M. Churchward and J.L. Perdrix

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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:

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.

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.

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.

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.

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LAWLERS FIELD.STOPS

1 and 2 November 1990

10.00 AM

STOP 1 Brilliant area

An example of regolith in an erosional regime (Unit 2)
- low stony hills
- stripping of the lateritic profile
- lag of ferruginous cobbles (iron segregations)
- red clay soil
- pedogenic carbonate
- pockets of saprolite/bedrock

The ferruginous cobbles occur largely on erosional areas in the Lawlers district and appear to have been derived from the breakdown of iron segregation bodies. The iron segregations, several metres across, commonly occur within the ferruginous saprolite/saprolite horizons in a weathering profile. Ferruginous cobbles are black, generally non-magnetic and many of them are dominated by low Al-substituted goethite and hematite. The internal surfaces of many of the ferruginous cobbles show the goethite pseudomorphs after pyrite. Ferruginous cobbles are high in Fe (71% Fe₂O₃), Mn (3000 ppm), Zn (380 ppm), Cu (157 ppm), and Co (91 ppm) – mean values of 33 samples.

STOP 2 Agnew-McCaffery area

Comparison of the regolith between erosional (Unit 2) and residual regimes (Unit 1) of the Agnew - McCaffery area. The location comprises two minor valleys.

Residual regime - broad crest, backslope, valley floor (Northern Valley).

- Gravelly sandy loam to sandy clay loam soil over lateritic residuum.
- Lateritic gravels with yellowish brown cutans on broad crest and become finer downslope.
- Downslope, the gravels with dark brown to brownish black surfaces become increasingly more common.
- Hematite and maghemite are more abundant in lateritic lag gravels on broad crest.
  This suite of minerals also dominates the backslope and valley floor.
- Fe₂O₃ is the most abundant constituent with values greater than 75% in lateritic gravels. The small amounts of Al₂O₃ and SiO₂ are mainly present as kaolinite.
- The trace elements V, Mn, Cr, As, Pb, and Ga are more abundant in the lateritic gravels than in lag of ferruginous saprolite.
- Goethites are highly Al-substituted (up to 30 mole %).

Erosional regime - breakaway, pediment slope, valley floor (Southern Valley).

- Gravelly sandy clay loam soil over saprolite.
- Subcropping saprolite/ferruginous saprolite (Unit 2) on the breakaway and upper pediments and alluvium/colluvium dominating the valley floor.
- The pediments below the breakaway are mantled by a coarse lag containing yellowish brown ferruginous saprolite/mottled saprolite.
- These lags become finer downslope, they are mixture of clasts with yellowish brown surfaces and others that are black. Cutans are generally not present.
Goethite is the dominant mineral. Al-substitution in the goethite from the lags of the erosional regime is systematically lower (13-18 mole %) than goethites from the residual regime. Kaolinite is relatively more abundant in ferruginous saprolite than in lateritic gravels.

- $\text{Fe}_2\text{O}_3$ averages about 55% in lag of ferruginous saprolite/mottled saprolite.
- Cu and Ni are more abundant in lag of ferruginous saprolite/mottled saprolite than in lateritic gravels.

LUNCH 12.45 PM

2.00 PM

STOP 3  Turrett Pit

Colluvial outwash plain (Unit 6), colluvium on lateritic residuum.

Laterite relationships and regolith stratigraphy from mine pit walls.

Units of the weathering profile (Southern half of the Western wall).

Top

- Gravelly colluvium (hardpanized and containing lateritic detritus).
- Lateritic residuum with iron segregations.
- Massive iron segregation bodies (note breakdown of iron segregations into small 5 to 10-mm nodules); many iron segregations and nodules show goethite pseudomorphs after pyrite).
- Ferruginous saprolite/collapsed ferruginous saprolite.
- Saprolite, saprock.

Bottom

Also (northern half)
- Colluvium on packed duricrust (black pisoliths in sandy matrix).
- Colluvium on red clay (some hardpanized).

STOP 4  Agnew gravel pit

Residual regime - backslopes, crest

- Lateritic nodules, pisoliths.
- Nodular/pisolitic duricrust (some hardpanized).
- Pockets of Fe-rich pebbly duricrust.

Erosional regime - breakaway, pediment slopes.

- Lag of ferruginous saprolite/mottled saprolite, iron segregations.

Lateritic duricrust and lateritic gravels are dominated by hematite, goethite, and maghemite with small amounts of kaolinite, gibbsite, quartz and, anatase. By contrast, iron segregations are dominated by goethite with small amounts of hematite.

5.00 PM

BARBECUE AT 5.45 PM
8.00 AM

STOP 5 Waroonga Pit

Colluvial outwash plain (Unit 6); thick colluvium on lateritic residuum.

Top
- Red colluvium.
- Hardpanized red colluvium containing lateritic detritus, with abundant partings (Si-rich) and Mn staining.
- Red clay with some ferruginous granules (note the sharp contact between hardpanized colluvium and red clay).
- Nodular duricrust (hematite rich-red nodules in a kaolinite-rich matrix).

Bottom

STOP 6 Brilliant area

- Fe-rich nodular/oolithic duricrust on crest and breakaway face.
- Ferruginous cobbles (iron segregations) on pediments.
- Local pockets of pedogenic carbonates.
- Saproline.

Iron-rich duricrusts are sporadically distributed throughout the Lawlers district and commonly occur on topographically-elevated areas. The most characteristic features of Fe-rich duricrusts are:

- the boundaries between nodules/ooliths and matrix are not well developed in sliced surfaces, despite the pebbly appearance of weathered surfaces;
- the matrix and nodule compositions are not significantly different and both are Fe-rich;
- the volume of matrix between the nodules is small;
- nodules generally lack cutans;
- weathered ilmenite grains and slightly-ferruginized charcoal fragments occur within pisoliths;
- characterized by high concentration of Fe and very low concentration of Si and Al;
- dominated by hematite, goethite, and maghemite;
- large range in values on Mn, Cr, V, Zn, Ni, Co, As, and Ga.

11.00 AM DEPART LAWLERS FOR KALGOORLIE.

LUNCH AT LEONORA

RETURN TO KALGOORLIE BY BUS.
PROJECT LEADER'S PREFACE
R. E. Smith
26 October 1990

Regolith relationships and the challenges to geochemical exploration in the Lawlers district represented a logical progression from the experiences which had arisen from the Mt. Gibson and Bottle Creek orientation studies, moving towards more complicated settings, namely those involving deep burial of laterite profiles. Thus, because of its scientific merit, the Lawlers district became one of the Laterite Geochemistry Project's four substantial district-scale orientation studies.

The research activities at Lawlers have been part of a three-way collaborative study: Forsayth Mining Ltd., the tenement holders, providing geological control and funds for research, GEOCHEMEX Australia carrying out the exploration geochemistry applications for Forsayth, and the Laterite Geochemistry Group providing the research component. Under the terms of the agreement, the flow of research results from this activity to the CSIRO/AMIRA Laterite Geochemistry Project P240 has been subject to a three-months period of confidentiality. The GEOCHEMEX laterite-based geochemical programme commenced in mid-1988 and the CSIRO research study in November 1988.

In mid-1989, scientists of the CSIRO WA Remote Sensing Group were invited to commence collaborative research with the Laterite Geochemistry Group on testing the application of remote sensing to regolith mapping within the Lawlers district. This collaboration is in full flight.

The attributes of the Lawlers district pertinent to geochemical exploration are listed below, as well as the components of the research study.
ATTRIBUTES OF THE LAWLERS DISTRICT

- Typifies important exploration problems, Norseman-Wiluna
- Mafic/ultramafic sequences
- Buried laterite profiles
- Orientation on concealed ore
- Opportunity for state-of-art geochemical exploration
- Substantial exploration regolith framework
- Rapidly-growing bedrock control
RESEARCH COMPONENTS, LAWLERS

- District-scale regolith framework
- Orientation, Au beneath +10 m lateritic hardpan
- Type study of iron segregations, etc.
- Feasibility of drilling for lateritic geochemistry
- Bedrock versus laterite composition (mafic and ultramafic sequence)
- Further classification of laterites
PROVISIONAL MAP SHOWING THE SURFACE DISTRIBUTION OF REGOLITH UNITS, LAWLER'S DISTRICT

Generalised from mapping by I.K. Butler, R.E. Smith, R.R. Anand and H.M. Churchward
Note: The map uses an uncontrolled photomosaic as its base; some minor distortion occurs.

(Refer also to Appendix III of Butler et al. 1990)

Depositional units
- Alluvium
  - 7b: Alluvium in upper tributaries
  - 7c: Alluvium in broadened valleys

Colluvium
- 6: Colluvium as sheetwash

Calcrete
- 8: Interpreted as valley form calcretes

Residual units
- Latric residue
  - 1: Loose latric particles and nodules
  - 3a: Nodular latric (Clio. 1)

Truncational units
- Mottled zone
  - 3b: Contains subsoil and block of mottled zone and saprolite after meta- and schistose rocks

Saprolite
- 11: Saprolitic outcrops and sediments, a mafic, b tuffic

Outcrop, rubble, boulders
- 5: Bedrock (sedimentary, intrusive, tectonic) beneath surface of regolith

Stony soil
- 2: Red brown soil, kersowe 1g and saprolite after meta- and schistose rocks, pedogenic calcrete

Areas of detailed mapping

Road

Track
Fig. MM. Generalized composite section for Lawlers district showing regolith/landform relationships and distribution (vertical and lateral) of lateritic units and associated ferruginous materials.
## Characteristics of Regolith Units: Lawlers District

<table>
<thead>
<tr>
<th>Type of Regime</th>
<th>Erosional Regimes</th>
<th>Residual Regime</th>
<th>Depositional Regimes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regolith Unit at Surface</td>
<td>2</td>
<td>3a 3b</td>
<td>5</td>
</tr>
<tr>
<td>LANDFORM</td>
<td>Low hills</td>
<td>Breakaway and pediment slopes</td>
<td>Convex hills</td>
</tr>
<tr>
<td>VEGETATION</td>
<td>Mulga</td>
<td>Mulga</td>
<td>Mulga</td>
</tr>
<tr>
<td>LAG</td>
<td>Coarse iron segregations, vein quartz</td>
<td>Lag of ferruginous saprolite, mottled saprolite, grit iron segregations</td>
<td>Fine quartz, feldspar</td>
</tr>
<tr>
<td>SOILS</td>
<td>Red sandy light clays</td>
<td>Red sandy clay loam</td>
<td>Clayey sand</td>
</tr>
<tr>
<td>ALLUVIUM</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>COLUVIUM</td>
<td>Shallow stony clay loam (1-2m)</td>
<td>Shallow clay loam with abundant lateritic debris (0.5-4m)</td>
<td>Minor</td>
</tr>
<tr>
<td>HARDPAN (developed in colluvium/alluvium)</td>
<td>-</td>
<td>Minor</td>
<td>-</td>
</tr>
<tr>
<td>CALCRETE</td>
<td>Pedogenic calcrite</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>LATERITIC RESIDUUM</td>
<td>-</td>
<td>-</td>
<td>Some duricrust on crests</td>
</tr>
<tr>
<td>FERRUGINOUS SAPROLITE/MOTTLED SAPROLITE</td>
<td>Present</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>SAPROLITE</td>
<td>Multicoloured clay rich saprolite with iron segregations, variable thickness</td>
<td>Granitic/felsic saprolite</td>
<td>-</td>
</tr>
<tr>
<td>BEDROCK</td>
<td>Mafic, ultramafics</td>
<td>Granitic/ felsic rocks</td>
<td>Mafic</td>
</tr>
</tbody>
</table>
Fig. 23A. Generalized regolith/landform model based upon the Agnew-McCaffery study area. Reproduced from 106R.

Fig. 23B. Schematic regolith cross-section showing trends in soil and regolith stratigraphy for the traverse shown in Fig. 23A. Reproduced from 106R.
Table 7. Regolith characteristics, Agnew-McCaffery Area

<table>
<thead>
<tr>
<th>SAMPLE SITES (See Fig. 23B)</th>
<th>a</th>
<th>b</th>
<th>c</th>
<th>d</th>
<th>e</th>
<th>f</th>
</tr>
</thead>
<tbody>
<tr>
<td>REGOLITH UNIT AT SURFACE</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1a</td>
<td>1b</td>
<td>1b</td>
</tr>
<tr>
<td>TYPE OF REGIME</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LANDFORM</td>
<td>Valley floor</td>
<td>Upper pediment</td>
<td>Breakaway scarp</td>
<td>Broad smooth crest</td>
<td>Smooth gentle slopes, &quot;back slopes&quot;</td>
<td>Valley floor</td>
</tr>
<tr>
<td>LAG</td>
<td>Lag of mixed origin (ferruginous pebbles/granules, lateritic nodules)</td>
<td>Lateritic lithic fragments</td>
<td>Lateritic lithic fragments</td>
<td>Lateritic lag</td>
<td>Lateritic lag</td>
<td>Lateritic lag</td>
</tr>
<tr>
<td>SOILS</td>
<td>Gravelly red fine sandy clay</td>
<td>Reddish-brown gravelly fine sandy loam</td>
<td>-</td>
<td>Gravelly reddish brown fine sandy loam</td>
<td>Gravelly reddish brown fine sandy loam</td>
<td>Gravelly brown fine sandy clay loam</td>
</tr>
<tr>
<td>COLLUVIUM</td>
<td>Gravelly colluvium</td>
<td>Gravelly colluvium</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Gravelly colluvium</td>
</tr>
<tr>
<td>HARDPAN</td>
<td>Present within 1 metre</td>
<td>Present within 1 metre</td>
<td>-</td>
<td>-</td>
<td>Some</td>
<td>Some</td>
</tr>
<tr>
<td>LATERITIC RESIDUUM</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Nodular duricrust</td>
<td>Nodular duricrust (?)</td>
<td>Nodular duricrust (?)</td>
</tr>
<tr>
<td>SAPROLITE</td>
<td>Ferruginous and clay-rich saprolite (?)</td>
<td>Ferruginous and clay-rich saprolite</td>
<td>Ferruginous and clay-rich saprolite</td>
<td>Ferruginous and clay-rich saprolite (?)</td>
<td>Ferruginous and clay-rich saprolite (?)</td>
<td>Ferruginous and clay-rich saprolite (?)</td>
</tr>
</tbody>
</table>

Reproduced from 106R.
Fig. 25. Distribution of goethite, hematite, maghemite, and kaolinite in lag gravels for the sample sites shown in Fig. 23B. Reproduced from 106R.
Fig. 26. Distribution of Al-substitution in goethite, hematite, and maghemite in lag gravels for the sample sites shown in Fig. 23B. Reproduced from 106R.
Table XX. The types of layer-silicate minerals present for the different regolith/landform situations along the studied traverse of Figs 23A and B in the Agnew-McCaffery study area.

<table>
<thead>
<tr>
<th>Regolith/landform unit:</th>
<th>Truncational regime</th>
<th>Residual regime</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>7a</td>
<td>2</td>
</tr>
<tr>
<td>Location:</td>
<td>Cracking clay</td>
<td>a</td>
</tr>
<tr>
<td>Landform setting:</td>
<td>Central drainage</td>
<td>Valley floor</td>
</tr>
<tr>
<td></td>
<td>with gilgai</td>
<td></td>
</tr>
<tr>
<td></td>
<td>meso-relief</td>
<td></td>
</tr>
<tr>
<td>Kaolinite:</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td>Smectite:</td>
<td>+++</td>
<td>++</td>
</tr>
<tr>
<td>Chlorite:</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>Inter-stratified:</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td>Illite:</td>
<td>+</td>
<td></td>
</tr>
</tbody>
</table>

Codes for abundances:
- Dominant: +++
- Sub-dominant: ++
- Minor: +

Modified from Table 8 in 106R.
Fig. PP. Diagrammatic cross-section along line 9900N in the North Pit study area showing relationships for the regolith and dispersion of Au in lateritic residuum.
Fig. 16. Geochemical data for regolith units intersected in drill hole 783, North Pit area. Au, Ag, As, and W.
INTERIM

Fig. 4.3/4.X. Detail block diagram showing field relationships and classification codes for several categories of lateritic materials and iron segregations. Reproduced from 60R.
Iron segregation.

Photomicrograph of polished section of iron segregation showing goethite pseudomorph after pyrrhotite.
Fig. 11a. Lateritic nodules and pisoliths from residual laterite (Hole 729, sample 07-0838). Reproduced from 22R.

Photomicrograph of polished section of lateritic nodule showing relict talc in goethite-rich matrix.
Identification of regolith units in drill spoil/open pit

The following criteria, taken conjointly, are believed sufficient to establish the characteristics of residual and transported regolith in a field situation, although ambiguous situations can arise.

**Hardpanized colluvium/colluvium**

- Red-brown, non-hardpanized colluvium may have variable colours
- Hard, brittle, irregular dull fracture faces, very fine porosity
- Abundant Mn staining
- Glassy, botryoidal opal in pores or along partings
- Soft carbonates along partings
- Exhibit coarse subhorizontal lamination
- Presence of large amounts of sandy/gritty clays
- Presence of polymictic gravels - exotic lithorelics, lateritic gravels without cutans

**Lateritic residuum**

- The nodules and pisoliths with yellowish brown/olive green cutans
- Presence of small fragments of lateritic duricrust in drill spoil

**Transported laterite**

- Large proportion of nodules/pisoliths which are fractured or the abundance of chipped cutans.
- Layers of well sorted and well rounded lateritic gravel
- Presence of cyclic bands of packed lateritic debris alternating with layers of colluvium/alluvium
Fig. NN. Diagrammatic cross-section along line 6 891 600N in the Meatoa Study area showing relationships for the regolith.
DURICRUST FORMATION AND DISMANTLING

Pluvial action

Fe-rich duricrust

Lateritic gravel

Lateritic weathering

Leaching of matrix & clays

Nodular duricrust

Collapse breccia

Mottled or ferruginized saprolite

Saprolite

Mafic bedrock

Colluvium alluvium

Gravelly, sandy, silty colluvium

with pisoliths, nodules, vein quartz, lithorelics

Vein quartz

Fig. XX. Schematic facies relationship diagram for the formation of the lateritic weathering mantle at Lawlers and its subsequent dismantling. (Other possible origins for Fe-rich duricrust are being researched.)

PARTIAL TRUNCATION

Lag: Ferruginous cobbles
quartz
lithorelics

Deflation

Weakening continuing

Lateritic weathering

Light clay soil with

Ferruginous cobbles
Lithorelics
Vein quartz
Calcrete mounds

Saprolite

Komatiites
High Mg basalts

-ferruginized
-silicified

Fig. YY. Schematic facies relationship diagram for the periods of erosion with post-lateritic weathering.
<table>
<thead>
<tr>
<th>REGOLITH</th>
<th>BODDINGTON</th>
<th>Mt. GIBSON</th>
<th>BOTTLE CREEK</th>
<th>LAWLERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardpan</td>
<td>-</td>
<td>Deep, discontinuous</td>
<td>Deep, continuous</td>
<td>Shallow, discontinuous</td>
</tr>
<tr>
<td>Calcareous clays</td>
<td>-</td>
<td>Common</td>
<td>Trace</td>
<td>Trace</td>
</tr>
<tr>
<td>Lateritic gravels</td>
<td>Extensive, discontinuous</td>
<td>Extensive, discontinuous</td>
<td>Extensive, discontinuous</td>
<td>Extensive, discontinuous</td>
</tr>
<tr>
<td>Lateritic duricrust</td>
<td>Extensive, discontinuous</td>
<td>Extensive, discontinuous</td>
<td>Patchy</td>
<td>Patchy</td>
</tr>
<tr>
<td>Mottled zone</td>
<td>Extensive</td>
<td>Extensive</td>
<td>Extensive</td>
<td>Very patchy</td>
</tr>
<tr>
<td>Ferruginous saprolite</td>
<td>-</td>
<td>-</td>
<td>Common</td>
<td>Extensive</td>
</tr>
<tr>
<td>Fe-rich duricrust</td>
<td>Very patchy</td>
<td>Patchy</td>
<td>Patchy</td>
<td>Patchy</td>
</tr>
<tr>
<td>Fe-segregations</td>
<td>-</td>
<td>Few</td>
<td>Moderate</td>
<td>Abundant</td>
</tr>
<tr>
<td>Gossans</td>
<td>-</td>
<td>Trace</td>
<td>Present</td>
<td>Present</td>
</tr>
</tbody>
</table>

Fig. LL. Comparison of the regolith between the four orientation study areas.
Acknowledgements

A number of the Tables and Figures in this Field Guide have been reproduced from CSIRO Restricted Reports, and abbreviated notations are used as follows:-

\[22R = \text{CSIRO Division of Exploration Geoscience Restricted Report 22R, Research into Laterite Geochemistry Lawlers District, Western Australia (Progress Report to Geochemex Australia and Forsayth Mining Ltd) by RR Anand, J Innes and RE Smith, 28 April, 1989, 42 + A12 pp.}\]

\[60R = \text{CSIRO Division of Exploration Geoscience Restricted Report 60R, Laterite Types and Associated Ferruginous Materials, Yilgarn Block, WA, terminology, classification, and atlas, by RR Anand, RE Smith, J Innes, HM Churchward, JL Perdrix and EC Grunsky, August 1989. This forms Chapter 3 of the Manual under preparation Laterite Geochemistry for Mineral Exploration, Compilers and Editors RE Smith and RR Anand.}\]

\[106R = \text{CSIRO Division of Exploration Geoscience Restricted Report 106R, Regolith/landform relationships and the Petrological, Mineralogical and Geochemical Characteristics of Lags, Lawlers District, Western Australia (Progress report to Forsayth Mining Ltd and Geochemex Australia) by RR Anand, HM Churchward and RE Smith, April 1990, 105 pp.}\]

The Project Leader and scientists within the Laterite Geochemistry Group acknowledge the substantial sponsorship by mining and exploration companies, through AMIRA, which has made possible this multidisciplinary approach to exploration research.
**BOX PLOT**

**LG206**
- $n = 33$
- Ferruginous cobbles

**CVALL**
- $n = 33$
- Colluvium

**LT220**
- $n = 8$
- Iron-rich duricrust

**LT12M**
- $n = 20$
- Lateritic residuum on mafic

**LT12U**
- $n = 13$
- Lateritic residuum on ultramafic

**SAPFM**
- $n = 15$
- Ferruginous saprolite on mafic

**SAPFU**
- $n = 11$
- Ferruginous saprolite on ultramafic

**ISALL**
- $n = 41$
- Iron segregations

---

**CSIRO**

**LAWLERS**

Mixed Sampling

$A1203 - ICP$ wt%

Leonora SH-51-01
BOX PLOT

LG206  n= 33
Ferruginous cobbles

CVALL  n= 33
Colluvium

LT220  n= 8
Iron-rich duricrust

LT12M  n= 20
Lateritic residuum on mafic

LT12U  n= 13
Lateritic residuum on ultramafic

SAPFM  n= 15
Ferruginous saprolite on mafic

SAPFU  n= 11
Ferruginous saprolite on ultramafic

ISALL  n= 41
Iron segregations

\[ \text{scale} \]

Median

95\% confidence limits on median

\( \times \) outliers

\( \ast \) extreme outliers

CSIRO

LAWLERS
Mixed Sampling
TiO2-ICP wt\%

Leonora SH-51-01

1130-2D-33-13
Ferruginous cobbles

Colluvium

Iron-rich duricrust

Lateritic residuum on mafic

Lateritic residuum on ultramafic

Ferruginous saprolite on mafic

Ferruginous saprolite on ultramafic

Iron segregations

median

95% confidence limits on median

× outliers

× extreme outliers

CSIRO

LAWLERS
Mixed Sampling
Mn-ICP ppm

Leonora SH-51-01

4000 ppm
BOX PLOT

LG206
n= 10

Ferruginous cobbles

CVALL
n= 33

Colluvium

LT220
n= 8

Iron-rich duricrust

LT12M
n= 19

Lateritic residuum on mafic

LT12U
n= 13

Lateritic residuum on ultramafic

SAPFM
n= 15

Ferruginous saprolite on mafic

SAPFU
n= 11

Ferruginous saprolite on ultramafic

ISALL
n= 21

Iron segregations

scale

0.00 0.50 1.00 1.50 2.00

median

95% confidence limits on median

× outliers

× extreme outliers

CSIRO

LAWLERS
Mixed Sampling
Cr203-ICP wt%  

Leonora SH-51-01 
ilo 1990 October