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# INTRODUCTION AND BOTTLE CREEK ORIENTATION STUDY - CONTRIBUTION TO FIELD GUIDE, EASTERN GOLDFIELDS TRIP

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

**CRC LEME OPEN FILE REPORT 60**

December 1998

(CSIRO Division of Exploration Geoscience, Unnumbered 1990.
Second impression 1998

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 Centres Program.

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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:

**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 60) is a Second impression (second printing) of CSIRO, Division of Exploration Geoscience Restricted Report Unnumbered, first issued in 1990, which formed part of the CSIRO/AMIRA Project P240.

**Copies of this publication can be obtained from:**
The Publication Officer, c/- CRC LEME, CSIRO Exploration and Mining, PMB, Wembley, WA 6014, Australia. Information on other publications in this series may be obtained from the above or from http://leme.anu.edu.au/
**Cataloguing-in-Publication:**
Anand, R.R.
Introduction and Bottle Creek Orientation Study - Contribution to Field Guide, Eastern Goldfields Trip
ISBN 0 642 28261 7
1.Gold - Western Australia 2. Laterite 3. Geochemistry
I. Anand, R.R., II. Title
CRC LEME Open File Report 60.
ISSN 1329-4768

## LATERITE GEOCHEMISTRY PROJECT

The project emphasises a regolith/landform approach to geochemical exploration. The main components of the project are:

- Orientation studies
  - Mt. Gibson
  - Bottle Creek
  - Boddington
  - Lawlers
  - Beasley Creek
  - Callion
  -
  -

- Laterite classification scheme
- Siting and bonding of elements
- Dispersion processes
- Anomaly recognition methods
- Knowledge of regional variations
- Representative models, syntheses
- Feasibility tests

These components are integrated to provide practical approaches to exploration in lateritic terrain.

R. E. Smith
Project Leader
26 October 1990

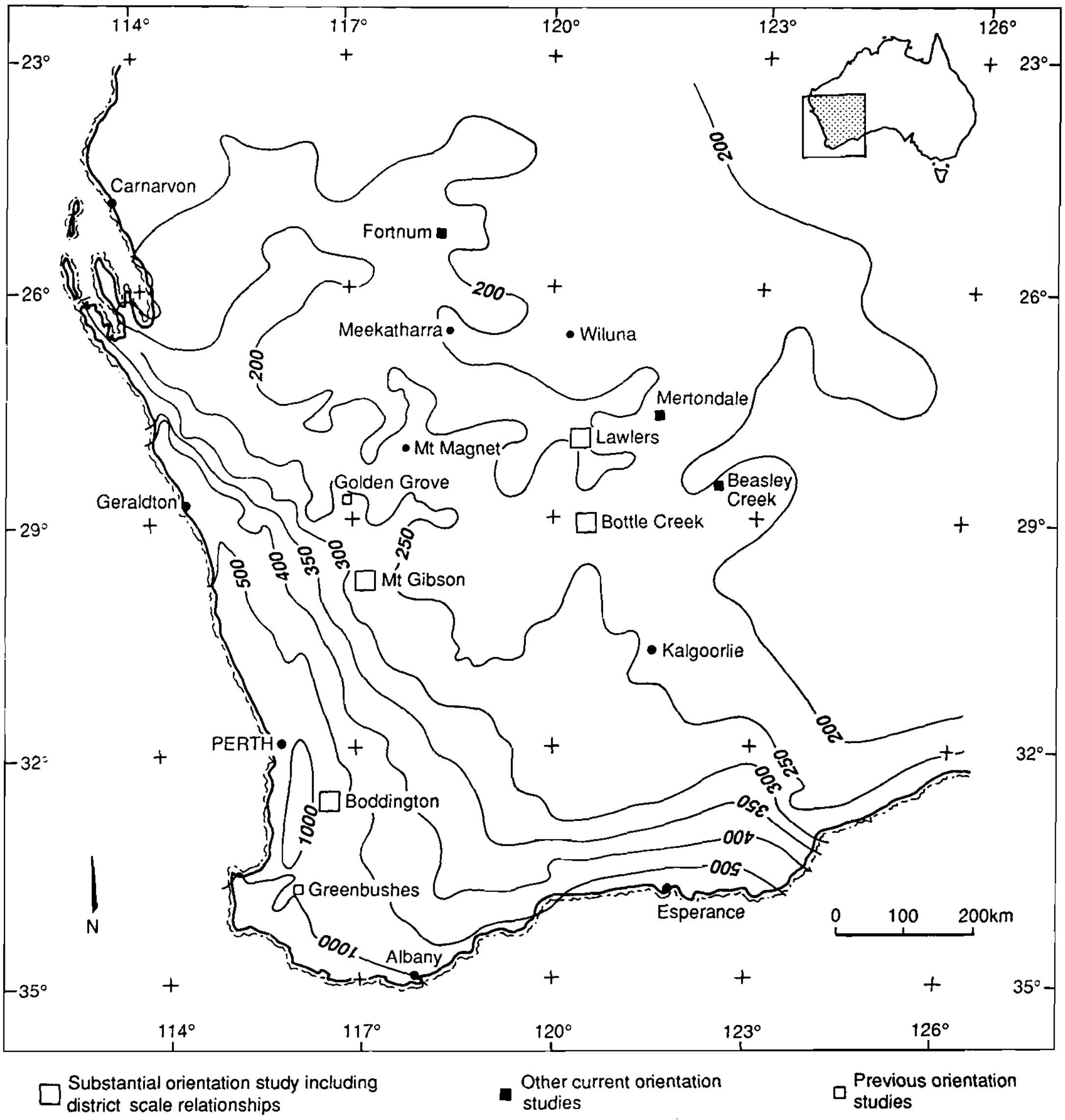



**Fig. 3.1. Orientation areas of the Laterite Geochemistry Project. Reproduced from 60R.**

Substantial orientation studies have been chosen, distributed across the present-day rainfall gradient. In each of these, the geochemical dispersion patterns are established and placed within the regolith/landform setting at both the local and district scales, with the area of each being some 500 $km^2$.

The orientation studies become the fundamental building blocks for other component themes of the project, such as, the laterite classification scheme, and dispersion processes. Together with other orientation studies, they also provide the well-controlled reference data sets which are the foundations of the project's research into multivariate data interpretational methods.

# INTERIM

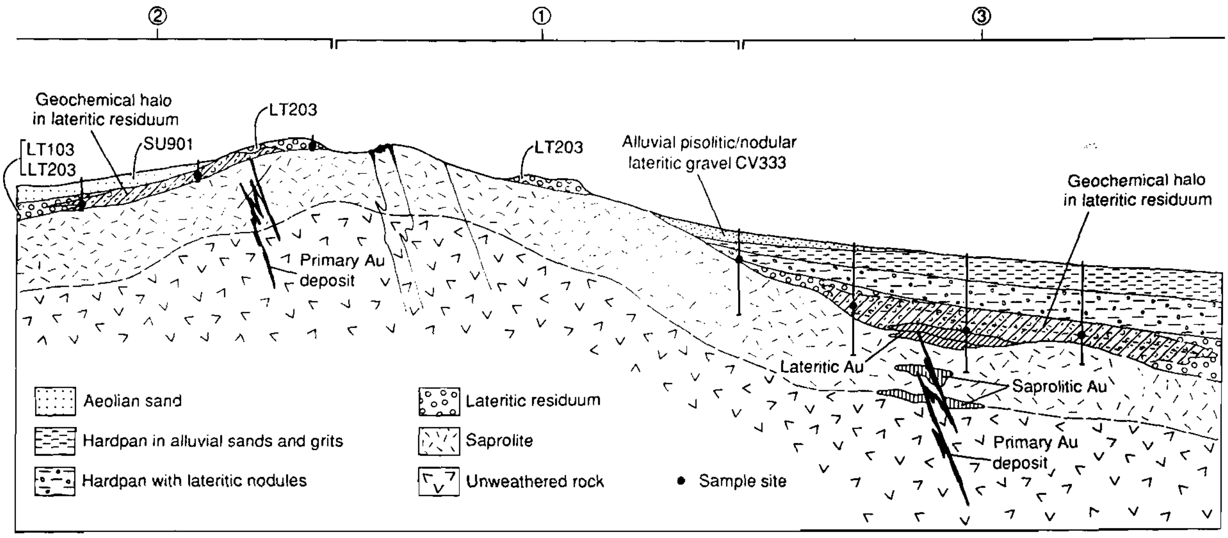



Fig. 4.3.Y. Section across an upland/lowland situation typifying some of the non-outcropping areas in the Yilgarn Block. Classification codes are shown for some selected regolith materials. Reproduced from 60R.

# BOTTLE CREEK AREA

### Schedule of stops

8.00 a.m.

**STOP 1** Erosional regime - walk from mine road to line 14,800N turn west towards breakaway.
Note variability in topography, outcrops, and lags on erosional surfaces.
Lags of quartz, saprock, ferruginous lithic fragments, iron segregations feruginous saprolite and calcrete.
Elements of the regolith/landform mapping units 3, 5, and 6 should be present.

**STOP 2** Stable regime from crest (above a low breakaway) down a long gentle backslope.
Continue the walk along line 14,800N. Stop on crest, midslope and lower slope positions.
On crest note coarse fragments of duricrust of various types also some nodules/pisoliths with yellow-brown cutans (skins).
Midslope note finer lag which is dark brown to black also few if any pisoliths and little if any quartz.
Lower slope fine lag. Note contrast with silts of the narrow alluvial track (mapping unit 9a nearby). Move on to next stop along 14,800N.

**STOP 3** Stable regime EMU location. Exposure of deep nodular/pisolitic lateritic residuum in EMU test pit.
- (i) Note deep hardpanization of lateritic residuum
- (ii) trends downwards from lateritic residuum to mottled zone
- (iii) types of iron segregations
  - (a) pisolitic/nodular, Fe-rich, magnetic
  - (b) yellow brown to red brown mottled to incipiently pisolitic
  - (c) gossanous types

Commentary by G. F. Taylor on gossans and lithogeochemistry
If sufficient time, continue along exposures of regolith north of EMU test pit noting lateritic residuum,lens-shaped iron segregations, "fragmentary duricrusts", gossanous materials and trends in depth to weathered rock.

**STOP 4** Towards north end of VB pit
Gossan and lithogeochemistry - G. F. Taylor

12.30 p.m.

Lunch

1.30 p.m.

**STOP 5** BOAGS mine pit
Greenstone sequence well exposed.
Channel deposit, at north end of decline.
Fine nodular, very gravelly lateritic residuum mid-way along eastern face of decline.
Pisolitic/nodular lateritic residuum at south end of entrance to the main pit.
Iron segregations will be noted in the face.
Gossans will be discussed - G. Taylor.

3.00-3.30 p.m.

Depart Bottle Creek by bus

# 1.0 PROJECT LEADER'S PREFACE

R. E. Smith 26 October 1990

## 1.1 General

Fundamental building blocks of the CSIRO/AMIRA Laterite Geochemistry Project are four substantial multidisciplinary geochemical orientation studies: Mt. Gibson, Bottle Creek, Lawlers, and Boddington. In each case geochemical dispersion arising from concealed Au deposits is studied by establishing an understanding of the regolith, landform and bedrock relationships, not only of the immediate ore environments but also of the district within which the deposits lie.

The Bottle Creek Au deposits were discovered in 1983 by the Electrolytic Zinc Company of Australia Limited and are amongst the few 'greenfield' discoveries which resulted from the 1980s gold boom (1979 to 1988). Discovery of these deposits resulted from a sequence of exploration activities by the company including strategic planning, geological concepts of ore genesis, and the use of multi-element geochemistry of lateritic pisoliths and nodules collected from the ground surface, initially at 1 km-spacing, using an innovative electromagnet (Legge *et al.*, 199 ).

Bottle Creek was chosen for an orientation study within the Laterite Geochemistry Project, because of the importance of multi-element geochemistry in the discovery, because of the extent of prospective greenstone sequences which are largely concealed by laterite, alluvium and colluvium, and to provide comparisons and contrasts with the project's other orientation areas.

The Bottle Creek area is also the focus of some other research activity within the CSIRO/AMIRA Yilgarn Research Programme: gossan and saprolite profiles are being studied within the Weathering Process Project (P241) and the application of remote sensing to mineral exploration within the WA Remote Sensing Project (P243). In addition, study of unweathered bedrock from the ore environments has been carried out (Binns, 19 ).

The above factors coupled with support by the tenement holders, EZ/Norgold/Geopeko, the funding provided by the sponsoring companies through AMIRA, and the exposures provided by open pit mining as the study progressed has provided the excellent research opportunities upon which this study is based.

## 1.2 Objectives of the Bottle Creek orientation study

The objectives are to carry out a geochemical orientation study about the Au deposits, focussed upon the surficial regolith units within a well-controlled regolith/landform framework.

## 1.3 Attributes of the Bottle Creek district

The following attributes were important in choosing Bottle Creek for an orientation study:

- various ferruginous nodules and pisoliths characterize the landscape;
- the laterite profiles show varied degrees of truncation, and burial;
- the area contained significant Au deposits, discovery of which used multi-element geochemistry of lateritic pisoliths/nodules; and
- the area was little distributed at commencement of the study.

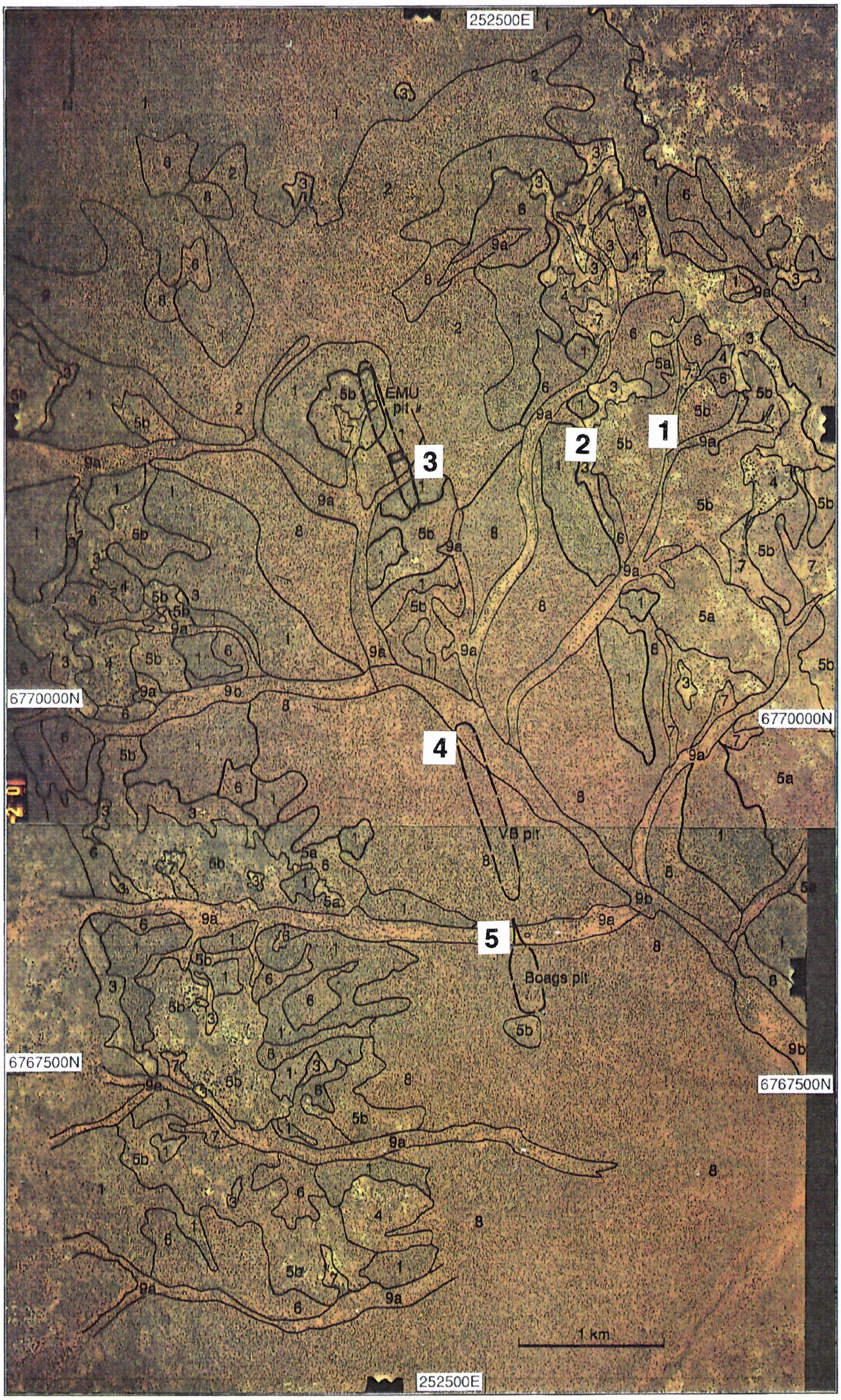
## 1.4 Components of research at Bottle Creek

Multi-disciplinary research carried out within the Laterite Geochemistry Project has the following components:

- District-scale regolith/landform framework;
- Regolith/landform relationships of the mine environments;
- Regolith stratigraphy at local and district scales;
- Classification of pertinent regolith units;
- Nodule, clast and pisolith types, classification, origin;
- Orientation geochemistry focussed upon regolith units above saprolite;
- Siting and bonding of elements of interest within geochemical anomalies;
- Surficial dispersion processes;
- Reference data sets tied to specific regolith units;
- Multivariate data interpretation;
- Generalized models of regolith evolution and geochemical dispersion.

This report presents the research carried out by the Laterite Geochemistry Group covering many of the components listed above including regolith/landform relationships at district and local scales, and presents the findings on geochemical dispersion within that framework.

| Land form regime | Mapping Unit | *Abbreviated characteristics* |
| --- | --- | --- |
| Stable | | |
| | 1 | Lateritic crests and slopes |
| | 2 | Local valley floors and lower slopes |
| Erosional | | |
| | 3 | Pale saprolite outcrops |
| | 4 | Pediments with pedogenic carbonate |
| | 5a | Low hills, red earths, calcareous earths |
| | 5b | Low rises, calcareous earths, shallow acid earths |
| | 6 | Pediments with pedisediment, acid red earths |
| | 7 | Minor calcareous alluvial tracts |
| Depositional | | |
| | 8 | Alluvial plains |
| | 9a | Alluvium, minor tributaries |
| | 9b | Alluvium, medium-sized tributaries |




A regolith-landform map of the upper Bottle Creek catchment. Aerial photograpohs 6/120 and 7/137, 15.3.80, Kevron Aerial Surveys, published with permission of North Ldt.

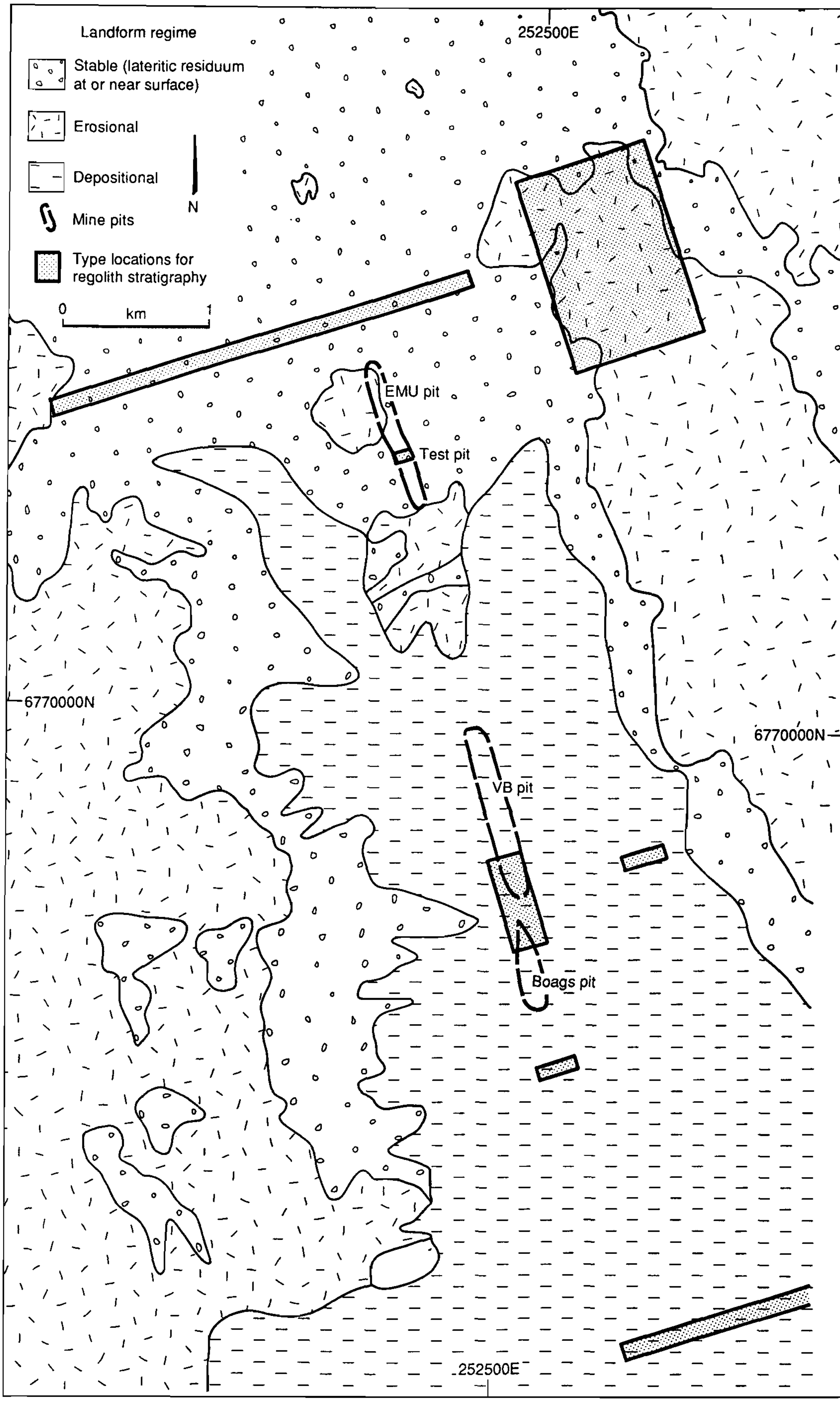
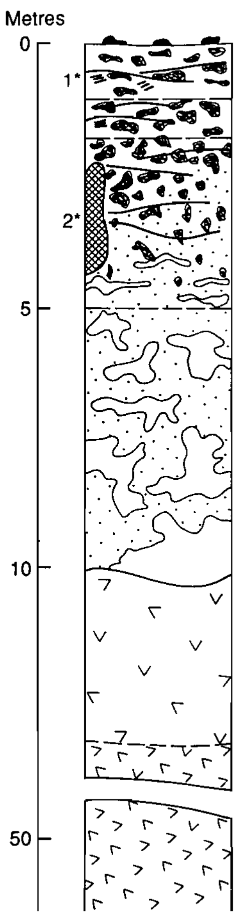



Fig. XX. Map showing the type locations for the regolith stratigraphy in the Upper Bottle Creek Catchment area. Note that the narrow alluvial tracts are not shown on this diagram so as to emphasize the broader regolith units.

| Bottle Creek regolith stratigraphy | Type location: Stable regime (mid to lower gentle slope) |
|---|---|
| | Emu Test Pit: 15050N 9400E Mine grid |




| Depth | Graphical column | Regolith unit | Description of regolith units, facies |
|---|---|---|---|
| | | Lag | *Ferruginous clasts, some lateritic nodules, pisoliths. Yellow cutans are rare. (LG203, LG104)* |
| 0 | | Soil | *Acid red earth in colluvium. (SU100)* |
| | | Colluvium | *Red-brown sandy loam with ferruginous clasts. (CV106HP)* |
| | | Lateritic residuum - hardpanized | *Lateritic pisoliths/nodules set in a brown to red-brown clayey matrix with yellowish grey mottling. Pisoliths/nodules form up to 40% of residuum at top, decreasing to rare at 5m. Superimposed is a white, coarse (10 cm scale) reticulate tree root mottling. (LT203, LT203HP, LT241)* |
| 5 | | Mottled zone | *Brown and yellowish brown subrounded to irregular mottles on a 10 cm scale set in a pale brown to yellow-grey clay-rich matrix. The pale material dominates.* |
| 10 | | Saprolite | *Pale brown-grey clay-rich.* |
| | | Saprock | *Pale brownish-grey, brittle with coarse rock fabrics visible* |
| 50 | | Bedrock (not exposed) | |

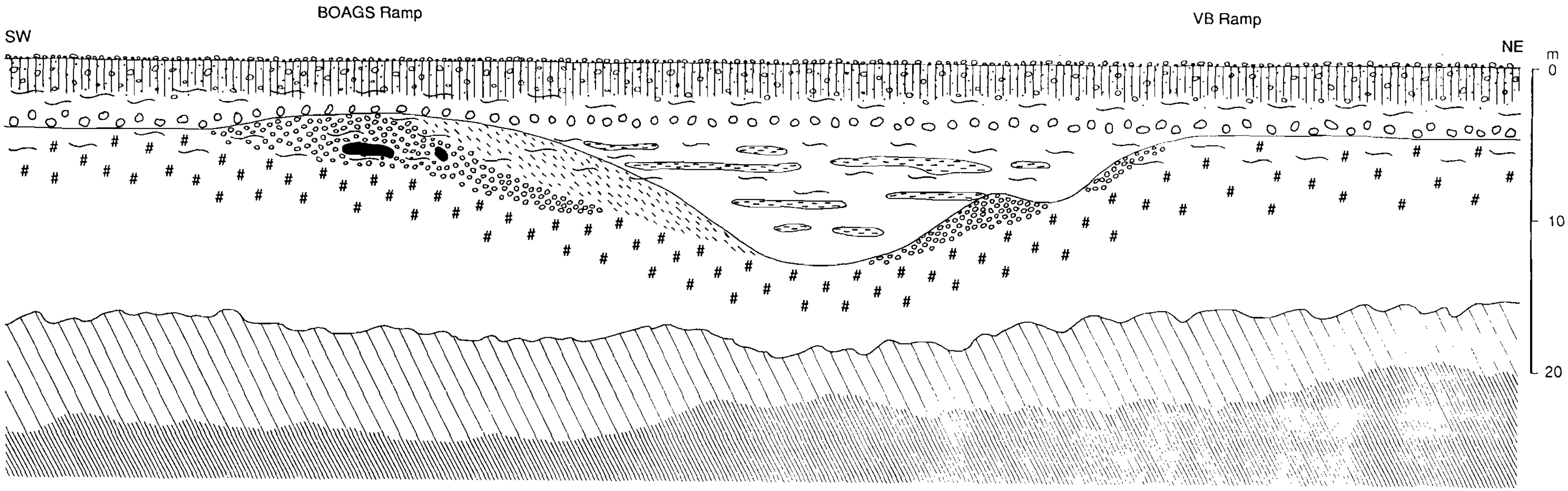
1* Hardpanization:
*Laminar and curviplanar conspicuous due to cementation, dominantly by silica. Mn staining (≶) in soil and in colluvium. Hardpanization also conspicuous in upper part of lateritic residuum.*

2* *Irregularly distributed competent masses up to several m across within lateritic residuum:*

- *Fe-rich pebbly duricrust. (LT228)*
- *Hard mottled (LT241) and vermiform (LT231) duricrust*
- *Gossans and gossanous pods comparable to LT229 and IS101*

Australian Map Grid Coordinates:

Fig. AA. Regolith stratigraphy for stable regime at EMU test pit.




Lag: Ferruginous pebbles (LG203) and minor ferruginous cobbles (LG206), ferruginized rock fragments (JG231) and quartz.

Colluvium: Red colluvial gravelly clay (CV104). Trace amounts of lithic fragments including quartz.

Stone line: Coarse lithic ferruginous fragments in a sandy granular matrix.

*Channel deposits: Crudely stratified alluvium; ill defined coarse laminae of* ferruginous cobbles and granules, (AV305).

Lateritic residuum: Fine and coarse nodules in yellow brown clayey matrix; weakly indurated (LT203).

: Fine nodular, very gravelly mass in firm to friable yellow brown matrix (LT204).

*Mottled zone: Clay, coarsely mottled yellow brown, red and olive grey.*

Pallid saprolite: Pale brownish grey clay

Saprock: Pale grey brown brittle weathered rock.

Fresh rock

Soil: Acid red earths

Hardpan: Hard brittle; rough fracture faces; coarse irregular laminae, very fine sugary silica and black manganese staining.

Iron segregations: an array of black to brown nodular and pisolitic bodies, some are magnetic.

0 100 200 m

Fig. BB. Cross-section showing regolith stratigraphy of depositional regime from BOAGS to VB pits.

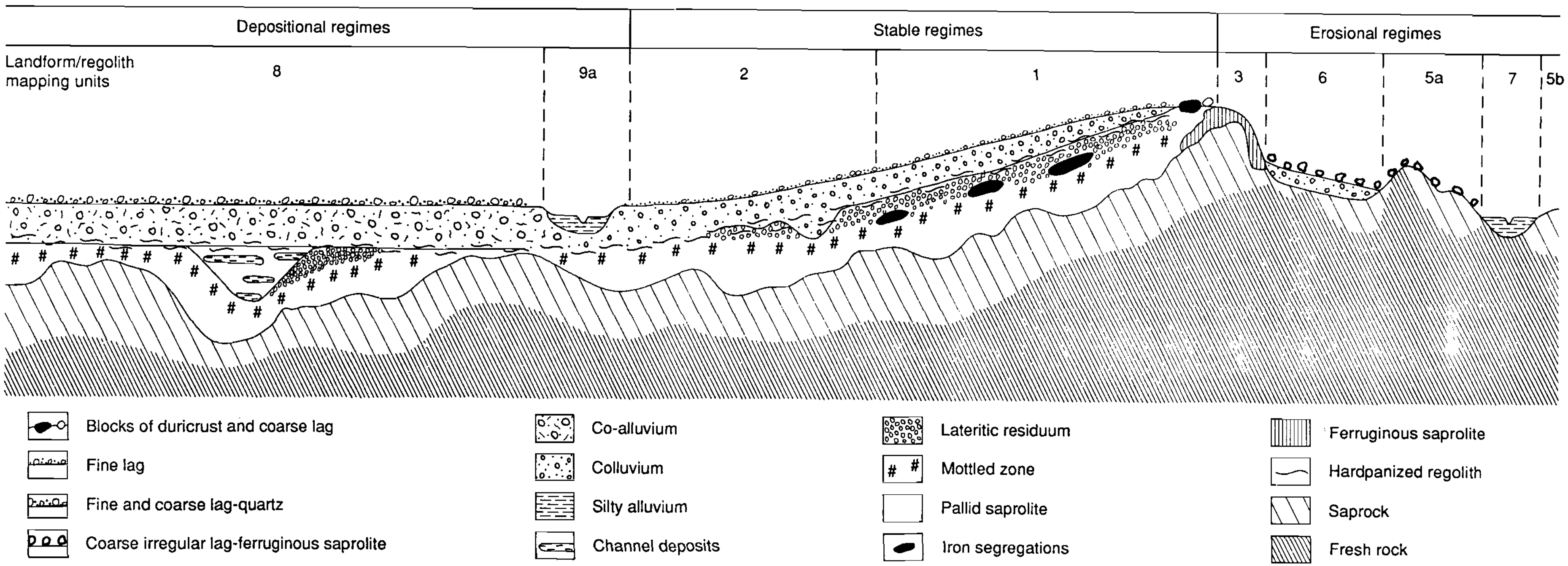



**Fig. CC. Notional east-west cross-section for Bottle Creek showing regolith and landforms.**

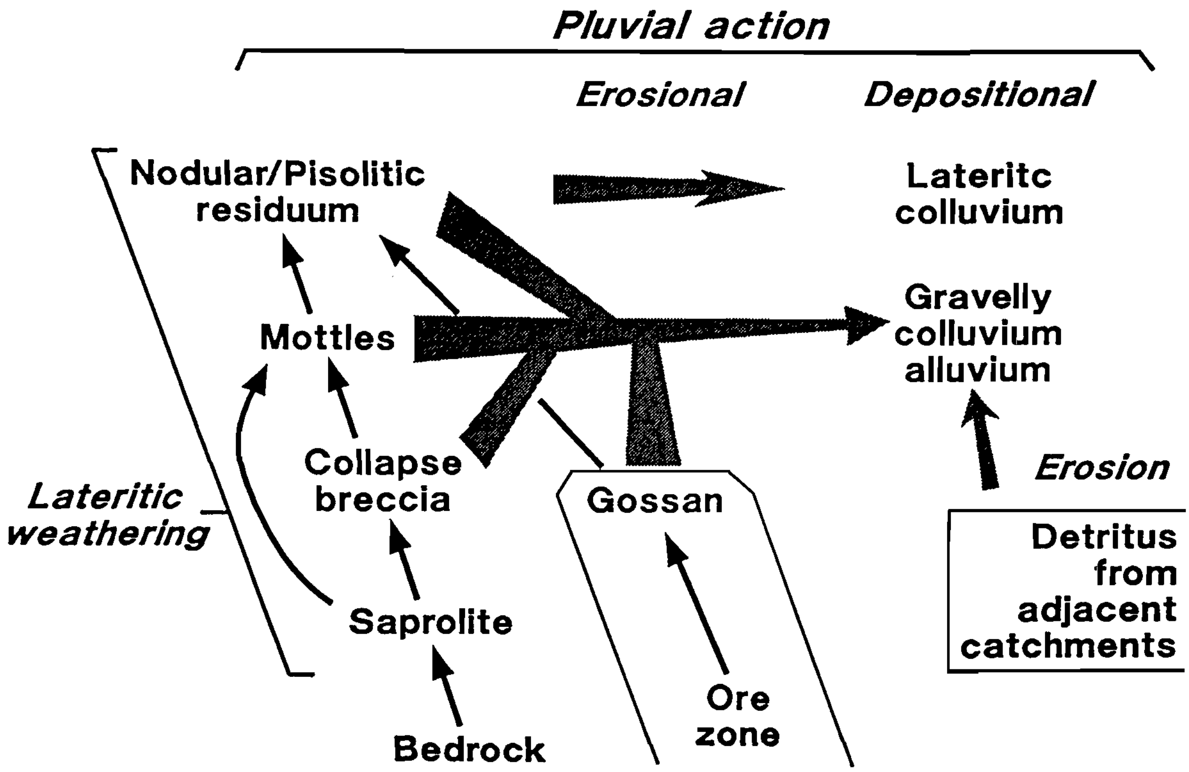



Fig. WW. Schematic facies relationship diagram for the formation of the lateritic weathering mantle at Bottle Creek and its subsequent dismantling.

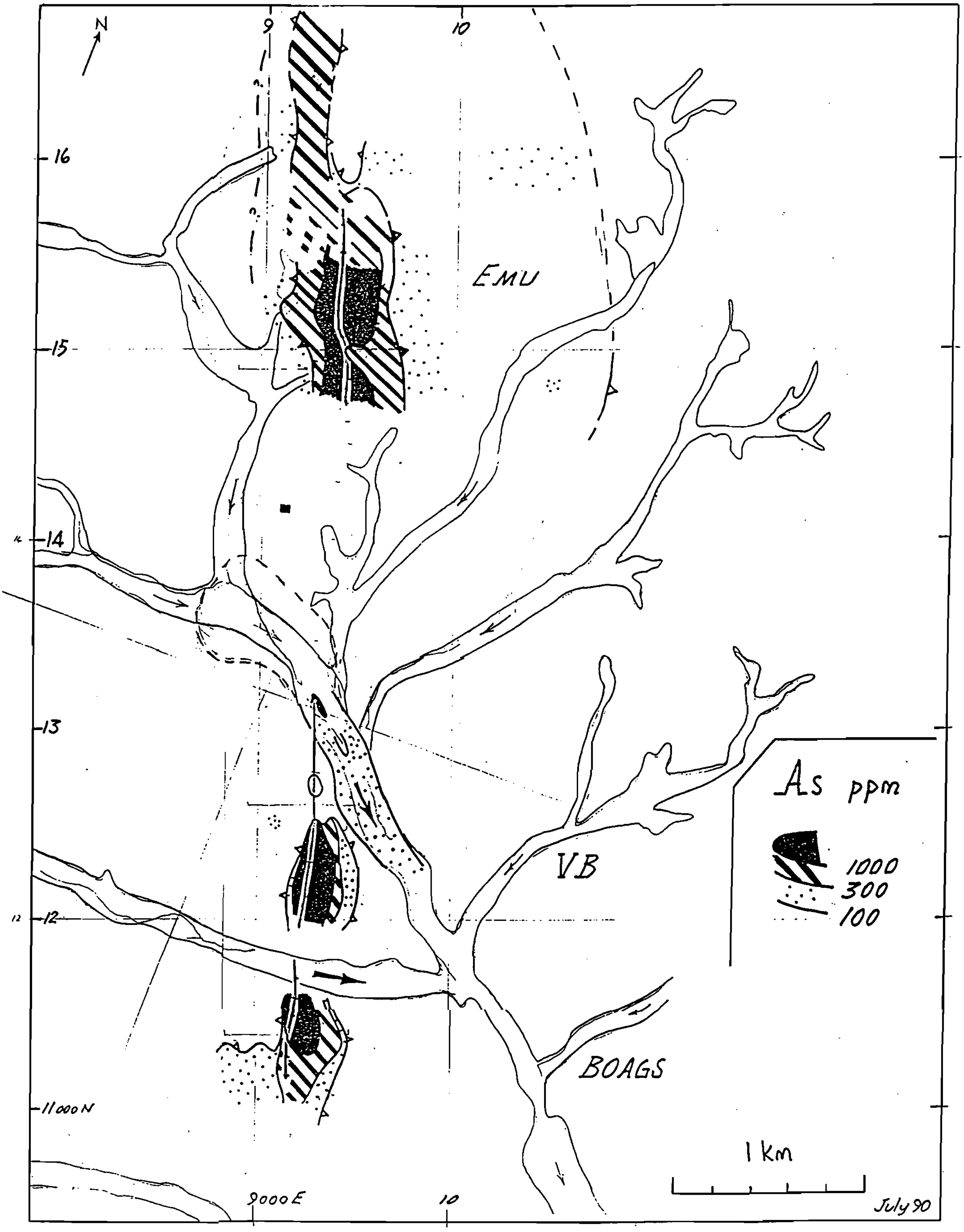



Fig. VV. Interim map showing the distribution of As in lateritic residuum about Bottle Creek Au deposits, based upon the research sampling.

## 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 = 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.

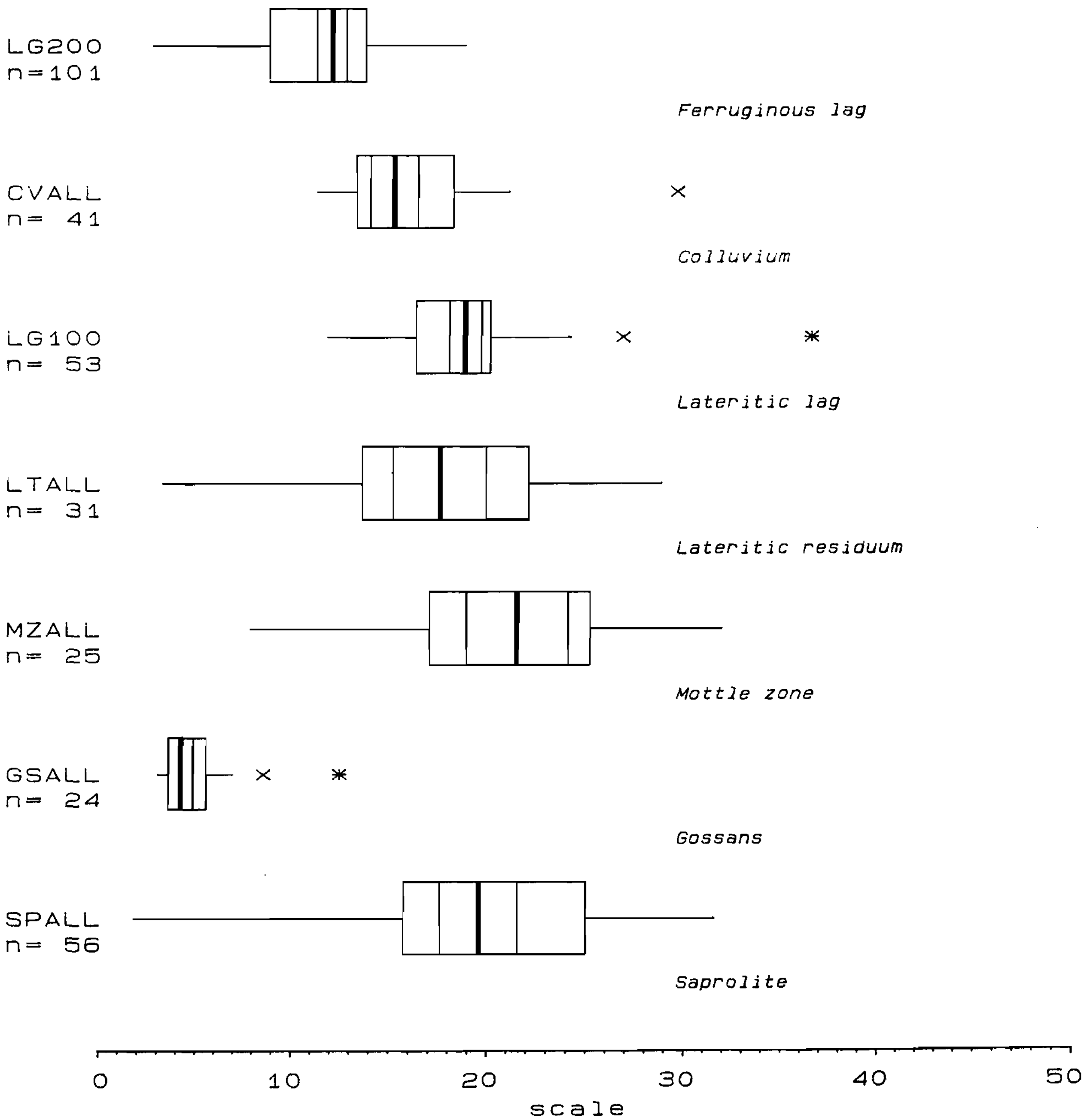
60R = CSIRO Division of Exploration Geoscience Restricted Report 60R, Laterite Types and Associated Ferruginous Materials, Yilgarn Block, WA, terminology, classification, and atlas, by RR Anand, RE Smith, J Innes, HM Churchward, JL Perdrix and EC Grunsky, August 1989. This forms Chapter 3 of the Manual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

106R = 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 multidisiplinary approach to exploration research.

Eastern Goldfields Trip-1990

# BOX PLOT




median

95% confidence limits on median

× outliers

⁎ extreme outliers

| CSIRO | |
|---|---|
| Al203-ICP wt%<br>Profile<br>Bottle Creek | |
| Menzies | SH-51-05 |
| JLP | 1990 July 23 |

Eastern Goldfields Trip-1990

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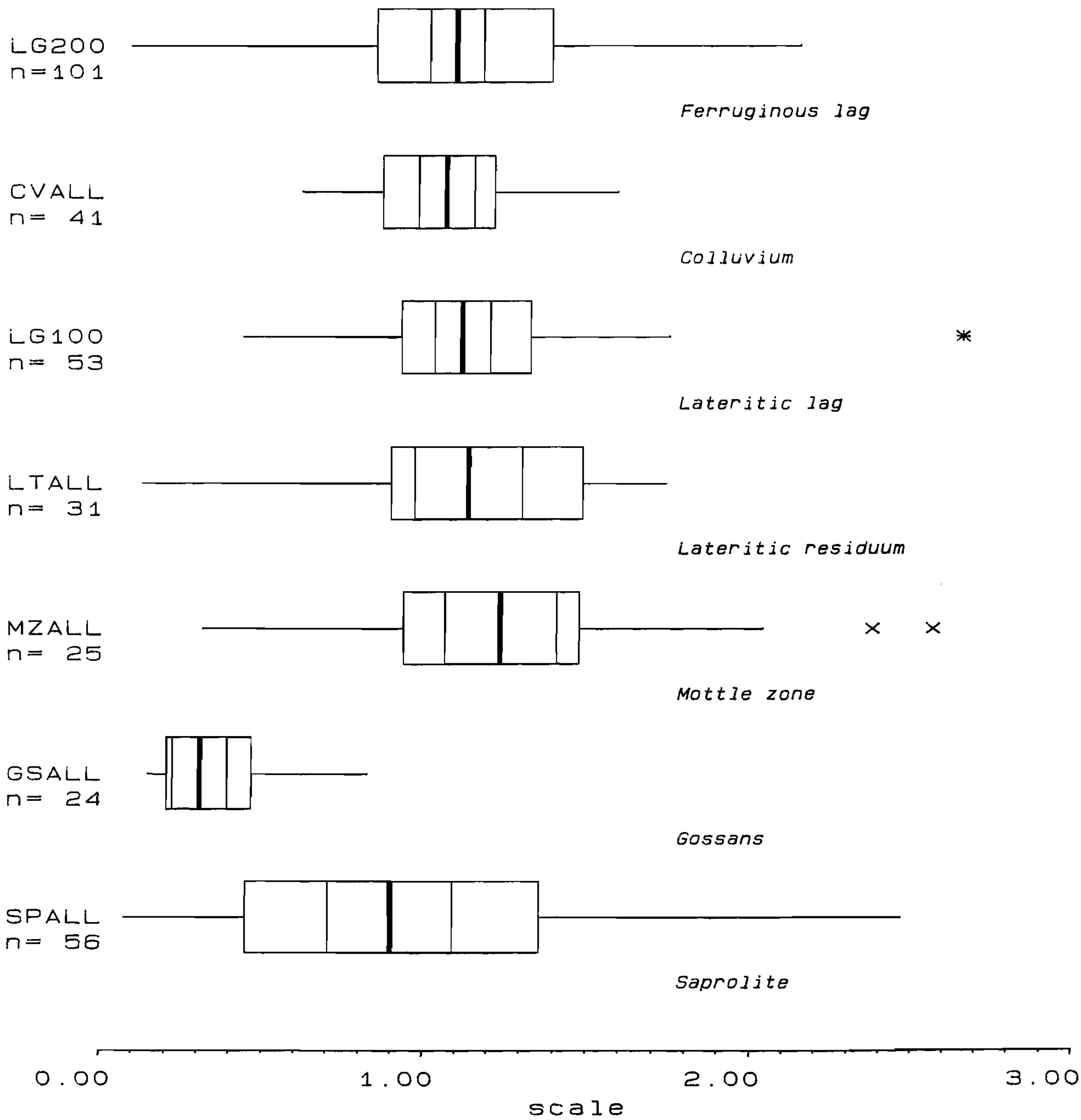


median

95% confidence limits on median

× outliers

✳ extreme outliers

| CSIRO | |
|---|---|
| TiO2-ICP wt% Profile Bottle Creek | |
| Menzies | SH-51-05 |
| JLP | 1990 July 23 |

Eastern Goldfields Trip-1990

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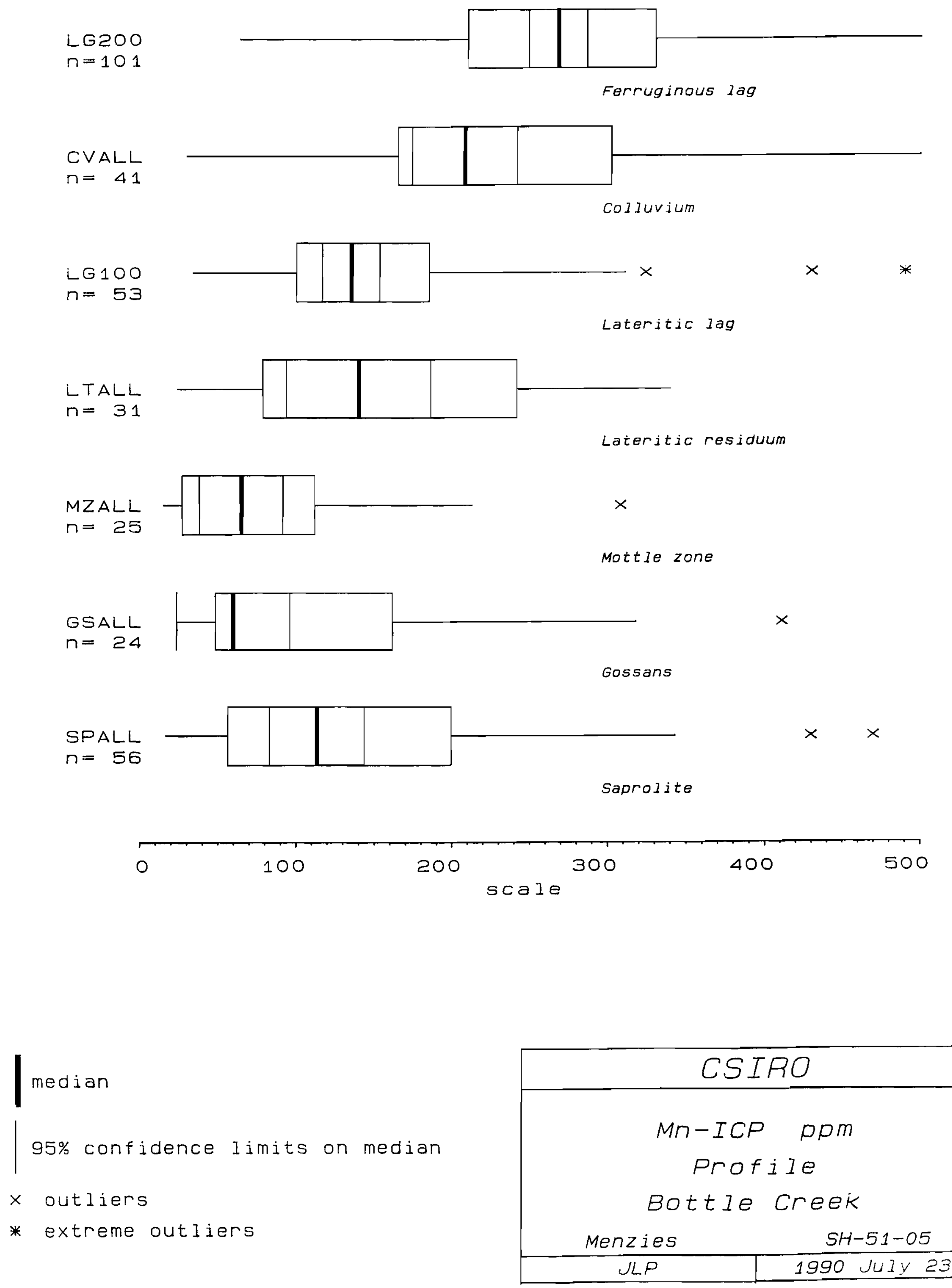

Eastern Goldfields Trip-1990

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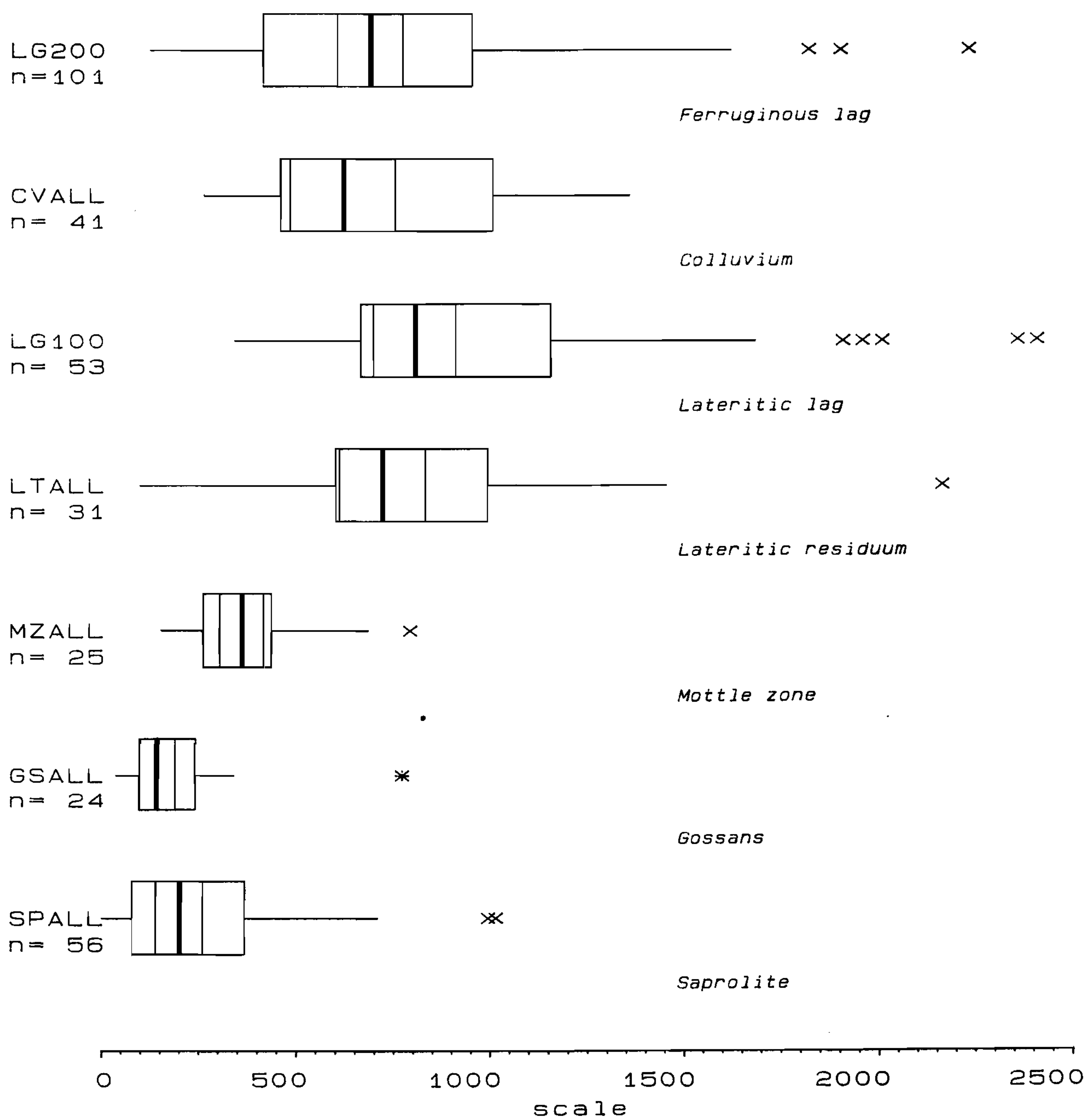


median

95% confidence limits on median

× outliers

✱ extreme outliers

| CSIRO | |
|---|---|
| Cr-ICP ppm<br>Profile<br>Bottle Creek | |
| Menzies | SH-51-05 |
| JLP | 1990 July 23 |

Eastern Goldfields Trip-1990

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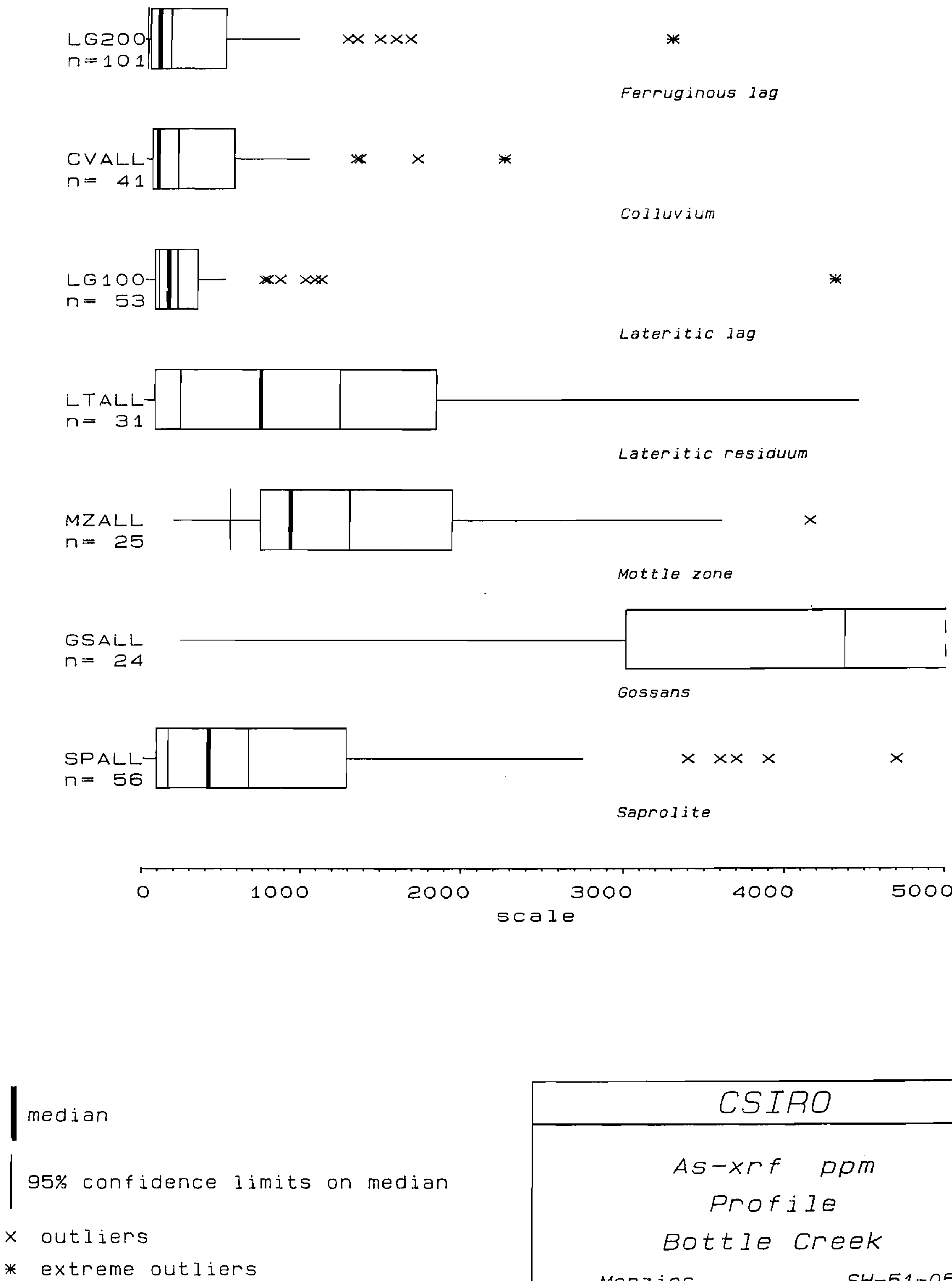


| CSIRO | |
|---|---|
| As-xrf ppm<br>Profile<br>Bottle Creek | |
| Menzies | SH-51-05 |
| JLP | 1990 July 23 |

Eastern Goldfields Trip-1990

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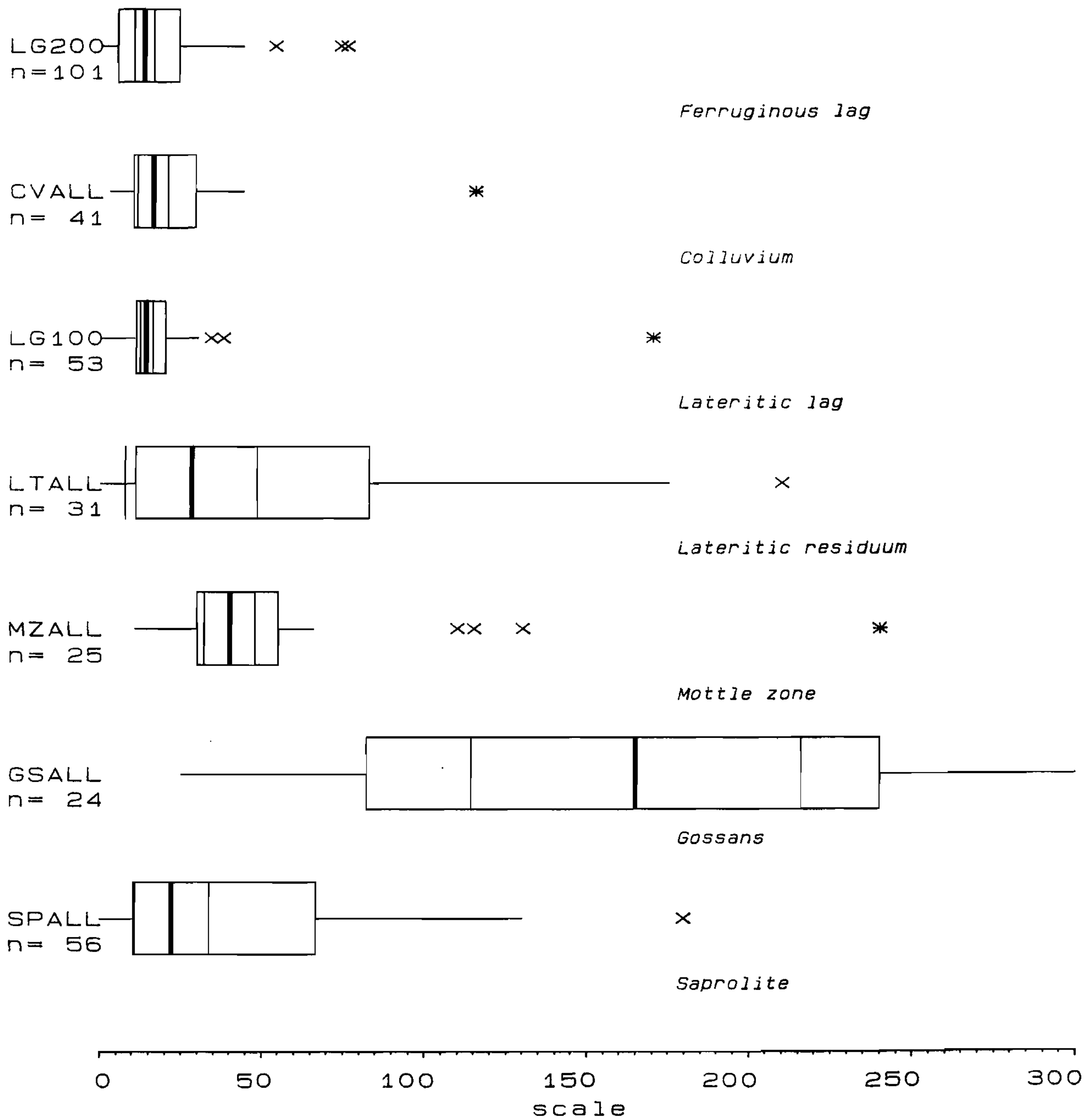


median

95% confidence limits on median

× outliers

✳ extreme outliers

| CSIRO | |
|---|---|
| Sb-xrf ppm<br>Profile<br>Bottle Creek | |
| Menzies | SH-51-05 |
| JLP | 1990 July 23 |

Eastern Goldfields Trip-1990

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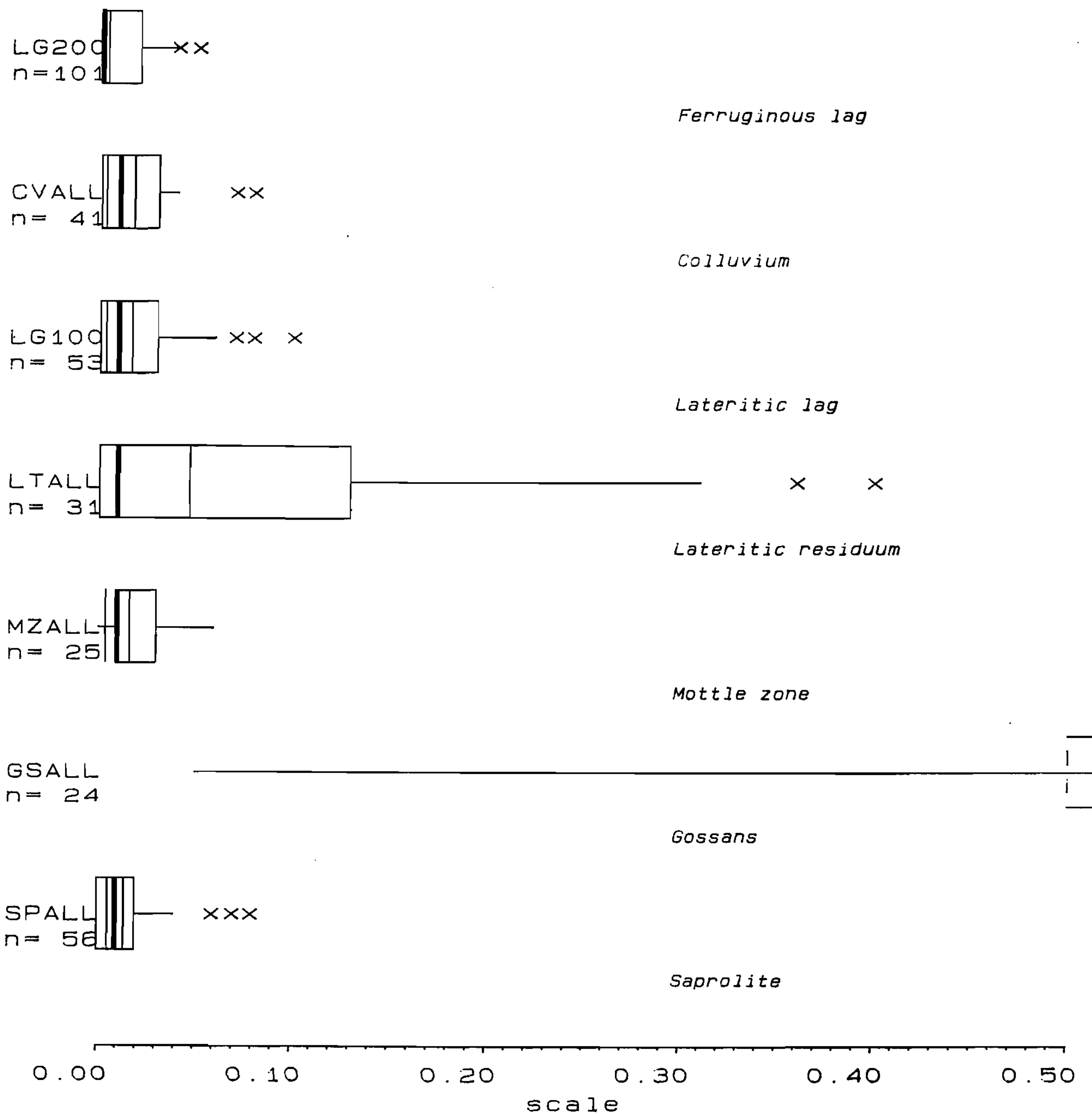


median

95% confidence limits on median

× outliers

* extreme outliers

| CSIRO | |
|---|---|
| Au-AAS ppm<br>Profile<br>Bottle Creek | |
| Menzies | SH-51-05 |
| JLP | 1990 July 23 |