PRELIMINARY INTERPRETATION OF REGOLITH-LANDFORMS IN THE BOOBEROI TO QUANDIALLA TRANSECT AREA, CENTRAL WEST NEW SOUTH WALES.

Michael Holzapfel and C. Leah Moore

Dryland Salinity Hazard Mitigation Program, CRC LEME,
Division of Science and Design, University of Canberra, ACT 2601

INTRODUCTION

Landholders in the Booberoi to Quandialla (B-Q) Transect area, central west NSW (Figure 1), have been concerned about an emerging dryland salinity problem since the late 1990's (Wooldridge *pers. comm.* 2002, Muller *pers. comm.* 2002). The presence of salt tolerant indicator species, waterlogging of soils and salinised land are becoming increasingly prevalent. The B-Q Transect lies within the Bland Creek catchment, a broad plain receiving sediments from rises and low hills located to the west, south and east. Stream flow across low angle alluvial fans and alluvial plains is intermittent, with most of the flow diverted into groundwater storage or lost to evaporation. Streams rarely flow into Lake Cowal to the north. As part of an approach to assist with hazard mitigation and land management, a preliminary interpretation of regolith-landforms was completed in the Back Creek and Quandialla areas. Compilation of these observations will result in the production of two detailed regolith-landform maps (1:10,000 scale). A more regional interpretation of regolith-landforms will culminate in the production of a regolith-landform map covering the B-Q Transect (1:100,000 scale; Holzapfel & Moore 2002). In this study, the compilation of information from available spatial imagery (aerial photographs, topographic maps, a map illustrating reconstructed palaeotopography, a digital elevation model, a depth to basement map, Landsat imagery) and geophysical data (e.g. gamma-ray spectrometric data) complements a field-based regolith-landform analysis for the B-Q Transect. The preliminary evaluation of this information provides the context for ongoing regolith-landform mapping and geophysical interpretation of subsurface regolith configuration.

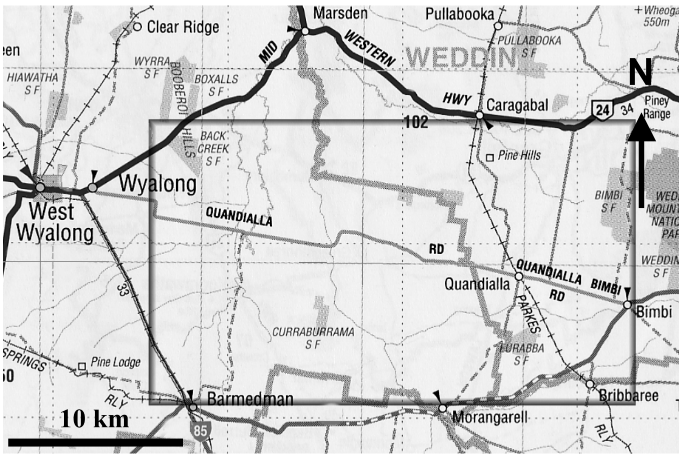

Figure 1: Location of the B-Q Transect area and major population centers including West Wyalong, Quandialla and Bribbaree (from HEMA 2001).

LOCATION, PHYSIOGRAPHY AND NATIVE VEGETATION

The B-Q Transect is located between the towns of Bribbaree and Bimbi in the east and West Wyalong in the west, in central west NSW (Figure 1). To the north lies the small town of Caragabal and to the south lies the settlement of Morangarell. Surface water flow into the Bland Creek catchment arises from three different directions: the Yiddah and Gagies Creeks flow from the west; the Barmedman, Duck and Bland Creeks flow from the south; and the Burrangong, Bribbaree and Caragabal Creeks flow from the east. All streams draining into the Bland Creek catchment are ephemeral. Salt loads from these drainage systems are deposited into the catchment. Upland areas are located to the east (Weddin Mountains), west (Yiddah Hills) and south (Barmedman Hills) of the B-Q Transect (Figure 1). Due to extensive grazing and cropping, the native vegetation has been extensively modified. Exceptions to this are stands of native vegetation preserved in National Parks and State Forests on rocky hills. Partially modified native vegetation assemblages are present along riparian zones, laneways and stock routes.

REGIONAL GEOLOGY

Basement rocks include: Late Ordovician metasediments; Siluro-Devonian granitoids; volcanic rocks; siliciclastic sediments; and, Late Devonian sediments. Due to the paucity of exposed bedrock and a consequent reliance on geophysical data, the interpreted basement geology maps for the northern and southern parts of the B-Q Transect have different lithological boundaries (Bacchin *et al.* 1999, Duggan &

In: Roach I.C. ed. 2002. *Regolith and Landscapes in Eastern Australia*, pp. 68-73. CRC LEME.

Lyons 2000, Raymond & Duggan *et al.* 2000, Raymond & Wallace 2000). Major structural features in the area are the NW trending Gilmore/Booberoi Fault Zone to the west and the NE trending Parkes Fault Zone to the east of the B-Q Transect (Bacchin *et al.* 1999, Raymond & Duggan *et al.* 2000).

REGOLITH MAPS

The regional (1:86,000 scale) GILMORE Project regolith-landform map (Gibson & Chan 2000), that partially covers the western portion of the B-Q Transect, resolves broad differences in alluvium in the study area. Typically, regolith-landform units fall into three groups: alluvial fans; plains; and channels. More recent regolith-landform mapping of the Forbes area at broader scale (1:250,000; Chan & Gibson 1999) provides regional context for regolith-landform mapping in the northern B-Q Transect but again has few regolith-landform units covering the subdued Bland Creek catchment area. The soil-landscape map of the Forbes area (1:250,000 scale; King 1998) provides generalised descriptions indicating changes between soil-landscapes that are commonly linked with geology. Descriptions also include vegetation cover, an indication of typical land use, descriptions of regional soil character and possible soil hazards.

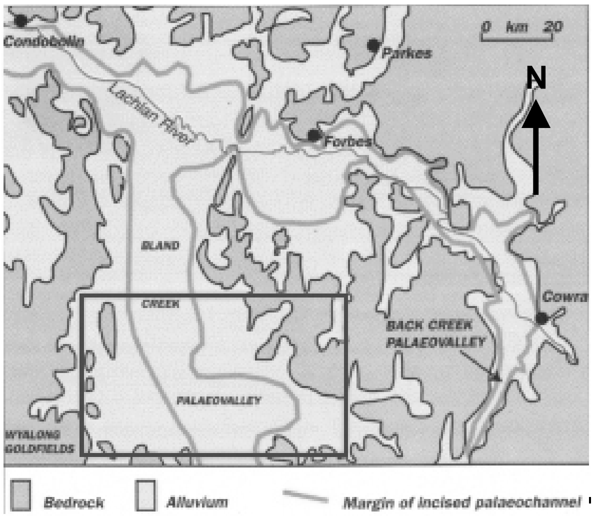

Figure 2: Bedrock and alluvial terrain and margins of the Bland Creek Palaeochannel, part of the regional groundwater-flow-system in the Bland Creek catchment (from White 2000).

HYDROLOGY

Both local- to intermediate- and regional-scale hydrological systems are observed within the Bland Creek catchment. Paleochannels have been identified in the West Wyalong area since the late 19th century when 'deep leads' were exploited for gold (Lawrie *et al.* 1999). Aeromagnetic surveys over the area have delineated maghemite-filled palaeochannels that drained to the east from rises west of West Wyalong (de Souza Kovacs 2000, Leslie *et al.* 2000, Mackey *et al.* 2000). On a local- to intermediate-scale the preferred groundwater flow and recharge pathways include buried and partially exhumed palaeochannels and sandy regolith on the flanks of rises. The local to intermediate hydrological systems more commonly contain potable water and are 'perched' above the regional groundwater-flow-system (Block *pers. comm.* 2002). A regional feature in the Bland Creek catchment is the Bland Creek Palaeovalley, a wide N-S trending depression filled with in excess of 150 m of transported sediments (Raymond & Gibson *et al.* 2000) (Figure 2). Recent drilling has identified five sedimentation cycles defined on the basis of morphology and mineralogy that are interpreted to be deposited in response to climate and vegetation change (Gibson & Tan *et al.* 2002) (Table 1). Buried depocentres in the regional groundwater-flow-system remain in approximately the same positions as current drainage depressions indicating slow infill by low angle alluvial fans as well as gradual sedimentation onto alluvial plains (Raymond & Gibson *et al.* 2000, Lawrie *et al.* 2000, Gibson & Tan *et al.* 2002).

Table 1: Summary of regolith units (informal, undated) distinguished from drill hole analysis as part of the Gilmore Project (from Gibson & Tan *et al.* 2002).

Unit	Description and Interpretation
E	Basal sands and gravels. Indicative of winnowed channel deposits
D	Red to grey mottled muds with minor floating quartz grains. Indicative of low angle fans and debris flows.
C	Sands and silts including maghemite gravels. Indicative of low angle fans and channel deposits.
B	Clay-rich muds. Indicative of paludal to lacustrine environments.
A	Thin interbedded layers of mud and sand with minor gravel, including maghemite gravel. Indicative of low angle fans, channel deposits and debris flows.

PIEZOMETER AND DRILL-HOLE INFORMATION

Drill-hole logs of varying quality are being compiled to constrain the three-dimensional configuration of regolith units in the Bland Creek catchment. The highest quality information is from GILMORE Project drilling (Gibson & Tan *et al.* 2002) and State Government stratigraphic bores. Company drill hole information collected since the early 1980's reflects a poor understanding of the benefits of regolith classification and characterisation (Tan *pers. comm.* 2002). Piezometer information and anecdotal evidence points to strong lateral variations in groundwater quality. These variations are the result of changes in regolith-lithology forming perched water tables in the buried sedimentary pile (Gibson *pers. comm.* 2002).

Coarse, well-sorted sands deposited as part of shallow (5-30 m deep) palaeochannel systems act as the main aquifers with clay layers laid down as overbank deposits, lake or swamp deposits acting as the aquitards. The deeper regional groundwater table is interpreted to be at approximately 100 m at the intersection of the northern margin of the B-Q Transect and Barmedman Creek (Block *pers. comm.* 2002). Anecdotal evidence suggests that the deeper groundwater typically has higher salt contents.

AIRBORNE ELECTROMAGNETIC INDUCTION SURVEY

An airborne electromagnetic (AEM) induction survey (GILMORE Project) has been used to reconstruct the palaeo-land surface in the western Bland Creek catchment. It has helped distinguish high conductivity lenses, corresponding to high clay contents in drill logs (Gibson & Tan *et al.* 2002) interpreted to represent lake or swamp sediments. Changes in the palaeo-land surface morphology have been used to distinguish bedrock ridges, linked palaeochannels and palaeo-lake features at a range of depths (Lawrie *et al.* 2000, Gibson & Tan *et al.* 2002a, Gibson & Wilford *et al.* 2002b, Wilford *et al.* 2002).

METHODS AND RESULTS

Gamma Spectrometric Image Interpretation

A colour-enhanced regional gamma spectrometric image (K-red, Th-green, U-blue) (Lawrie 2000) was analysed to facilitate regolith differentiation in the field. Gamma-Ray Spectrometry has proven useful in conjunction with field mapping for determining preferred colluvial and alluvial sediment dispersion pathways in the Bland Creek catchment. Granite uplands are visible due to the high potassium content and the sandstones are spectrometrically less evident, or have a subdued uranium response. The current pattern of transported alluvium, when compared with reconstructions of the Bland Creek Palaeovalley, show that the drainage pathways have remained relatively unchanged. Sediment is typically sourced from the east, west and south. Saddles between low-rises and watersheds have high thorium counts correlating with an increase in surface iron-rich lags (Chan & Gibson 1999). Palaeochannels and regions of clay-rich sands are also evident from combined gamma-ray signals in the centre of the B-Q Transect. These define near-surface and partially exhumed palaeochannels trending west and northwest. Field surveys confirm the presence of a number of subdued rises composed of well-sorted quartzose sands and clayey sands, typically < 150 m wide in these areas.

Landsat Image Interpretation

Landsat ETM+ imagery was used to undertake preliminary reconnaissance of regolith materials using a range of spectral band combinations to highlight stressed or invigorated vegetation, moisture and areas of high reflectance from bare earth (Table 2). Due to intensive pasture modification, cropping of wheat, canola and other cereals, and widespread grazing on modified pastures, most regolith-landform boundaries were partially obscured by modified vegetation cover. ETM+ bands 2,4,6 (BGR) exhibited the most promising information with well-drained sandy soils, including partially exhumed palaeochannels, highlighted in pink to light purple. Riparian vegetation was displayed in green and heavy clays with high moisture contents were highlighted in blue. A vegetation contrast was also visible with healthier vegetation present on the lower-lying clay-rich soils and more sparse vegetation on drier free-draining sandy soils. Stressed vegetation was represented in yellow and may indicate future areas of land salinisation. One difficulty encountered using Landsat ETM+ imagery included strong seasonal effects between imagery swaths. The heavy,

Table 2: Band combinations used in preliminary regolith-landform investigation (Lourens *et al.* 1999).

Bands (B,G,R)	Response
1,2,3	Colour photo look-alike.
3,4,5	Pseudo natural (vegetation appears green).
7,5,4	Crop and vegetation variability (false colour – vegetation appears red).
5,7,4	Crop and vegetation variability (false colour – vegetation appears red).
3,5,4	Crop and vegetation variability (false colour – vegetation appears red).
2,3,4	Vegetation (colour infrared composite).
1,2,5	Cultural features.
2,4,6	Stressed vegetation (yellow areas may show future dry land salinity problems).
4,5,7	Infrared composite.

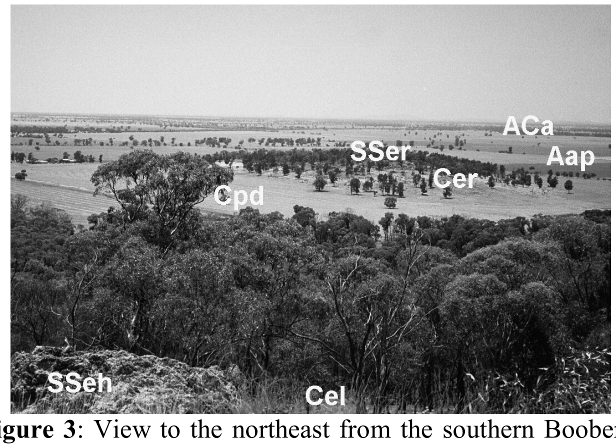

Figure 3: View to the northeast from the southern Booberoi Hills. Regolith-landform units have been classified using the scheme of Pain *et al.* (in prep).

moisture-rich clays highlighted by bands 2,4,6 (BGR) also correspond with high total count Gamma-Ray spectrometric signals and the exhumed palaeochannels and sandy soils can be correlated with high total counts and high potassium (K) counts.

Regolith-Landforms

Regolith-landforms were characterised according to the regolith-landform classification scheme of Pain *et al.* (in prep.) that recognises regolith materials as *in situ*, colluvial or alluvial and classifies landform as well. Modifiers used include the typical land use and distribution of native vegetation on a regolith-landform unit, and physical dimensions and gradients of landscape features (Figure 3).

Slightly Weathered Bedrock Regolith-Landforms:

Slightly weathered bedrock is separated into bedrock outcrops with greater than 2 m relief or less than 2 m above the surrounding surface cover. Outcrop is typically weathered granite and metasediment. These rocky areas typically preserve remnant stands of native vegetation with minimal pasture modification. They are mostly located on erosional rises, low hills and hills with the largest rocky outcrops on hillcrests.

Colluvial Regolith-Landforms:

Colluvial slopes are typically found on the flanks of bedrock rises, low hills and hills located on the periphery of the B-Q Transect and on isolated hills within the B-Q Transect. Colluvial erosional landforms are localised in areas of higher relief and are open to densely vegetated (native) with minimal pasture modification. Colluvial depositional plains are typically located in saddles between hills or at the slope break adjacent to alluvial plains. The colluvial plains are intensively cropped and grazed.

Alluvial Regolith-Landforms:

Alluvial fans are typically low-angle and are mostly located on the western and eastern margins of the B-Q Transect. They are associated with the lower parts of alluvial channels draining colluvial rises and have built out onto the adjacent alluvial plains. Land use is typically cereal cropping and modified pasture for grazing. Alluvial flood plains are typically very low-angle to flat and are located in the centre of the B-Q Transect adjacent to major drainage channels of the Barmedman and Bland Creeks. Alluvial plains are broader, low-angle features that extend further from the main drainage channels. Alluvial drainage depressions may be up to 5-10 m wide and less than 1 m deep. They are located on alluvial fans and plains and form incipient channel systems. Broad lowland alluvial channels are typically 20-40 m wide and up to 5 m deep. These form complex anastomosing channel systems and meander in response to the low gradient.

DISCUSSION AND CONCLUSIONS

There is a paucity of existing surficial regolith-landform information at a desirable scale (less than 1:50,000) for the Bland Creek catchment. Existing maps provide regional context but not information at detailed scales. For farm-scale land management decision-making these maps are of limited use.

Field observations confirm that the characteristics of palaeochannels change from west to east of the B-Q Transect. Palaeochannels in the east lack maghemite gravels and have less pisoliths, they are typically wider and contain well-sorted sands (Figure 4). The preliminary interpretation of regolith-landforms has been successful in highlighting major aquifers for local and intermediate groundwater flow-systems with partially exposed palaeochannel systems being the primary recharge areas and buried palaeochannels the primary conduits for fluid flow. Increasing salt stores are occurring through evaporation of intermittent floodwaters, primarily sourced from floodplains, back plains and broad meandering creek systems. Palaeochannels further away from current drainage systems are less affected by rising salt loads and have fresher water quality, similar to waters in sandy granitic regolith and colluvium located on hill flanks.

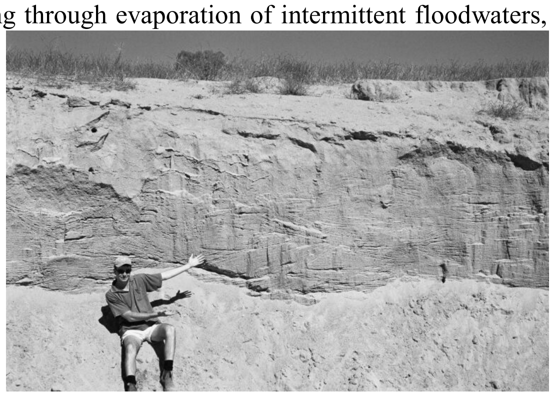

Figure 4: Cross section through the upper portion of a palaeochannel located in a sand quarry south of the Eurabba State Forest. Cross-bedding and scour-fill structures are visible.

Evidence from preliminary interpretation of regolith-landforms and drill hole data show that, as well as lateral variation of regolith units, there is considerable variation with depth. Use of alternative techniques to provide information on the three-dimensional configuration of regolith-landforms will complement regolith-landform mapping in this area of subdued relief. Geophysical techniques currently being investigated include seismic refraction surveys, transient electromagnetic (TEM) induction surveys and resistivity surveys. Regolith-landform maps are effective tools for development of Land Management Units (LMUs). The method involves correlating regolith-landform distribution with a land capability classification. Dividing a property into LMUs on the basis of surficial regolith-landform characteristics, current land use patterns and other available data allows land managers to plan ongoing land use and mitigate against emerging hazards (e.g. land salinisation) in a more strategic manner than is currently practiced. Saline sites are not evenly distributed with regard to landscape position—initial evidence points to buried or partially exhumed palaeochannels being preferred pathways for shallow fluid flow. Fluid flow and the risk of dryland salinity increase when palaeochannels intersect current drainage channels. Floodplains and poorly draining swamps adjacent to the major drainage channels are also potential dryland salinity sites.

The approach to regolith-landform mapping must be integrated and should include the widest possible use of remotely sensed imagery (e.g. DEM models, aerial photographs, satellite imagery), geophysical data (e.g. gamma-ray spectrometry, aeromagnetic imagery) and drill hole information. The three-dimensional integration of regolith-landform mapping with other techniques is critical in determining the interaction, distribution and movement of groundwater in the Bland Creek catchment as buried palaeochannels are the preferred fluid pathways. The distribution of these palaeochannels will influence the location of future land salinisation.

REFERENCES

BACCHIN M., DUGGAN M., GLEN R., GUNN P., LAWRIE K., LYONS P., MACKAY T., RAPHAEL N., RAYMOND O., ROBSON D. & SHERWIN L. 1999. *Cootamundra, Interpreted Geology 1:250,000 Scale Map*. Australian Geological Survey Organisation, Canberra / New South Wales Department of Mineral Resources.

BARRETT B., HEINSON G., HATCH M. & TELFER A. 2002. Geophysical Methods in Saline Groundwater Studies: Locating Perched Water Tables and Fresh-Water Lenses. *Exploration Geophysics* **33**, 115-121.

CHAN R. & GIBSON D. 1999. *Forbes Regolith Map (1:250,000 scale)*. Australian Geological Survey Organisation, Canberra / New South Wales Department of Mineral Resources.

DE SOUZA KOVACS N. 2000. *Regolith Stratigraphy and Landform Architecture, Barmedman District, Central Western NSW: Influence of Mineral Systems.* Unpublished Honours Thesis, University of Canberra, Canberra, 163 p.

DUGGAN M. & LYONS P. 2000. *Wyalong (First Edition).* 1:100,000 Geological Map 8330. Australian Geological Survey Organisation, Canberra / New South Wales Department of Mineral Resources.

GIBSON D. & CHAN R. 2000. *Regolith-Landform Map (1:86,000 Scale) GILMORE Project Area.* CRC LEME, Australian Geological Survey Organisation, Canberra.

GIBSON D.L., WILFORD J., TAN K.P., & LAWRIE K.C. 2002. Palaeogeography, A Predictive Tool in Environmental Studies – Applications to the Margins of the Murray Basin. *Victoria Undercover*, 2002.

GIBSON D., TAN K. & WILFORD J. 2002. Sedimentary Systems in the Bland Basin, An Upstream Extension of the Murray Basin. *Geological Society of Australia* **Abstracts 67**, p. 413.

HEMA 2001. *Australian Touring Atlas.* Hema Maps 69 p.

HOLZAPFEL M. J. & MOORE C.L. 2002. Dryland Salinity and Regolith-Landform Distribution in The Booberoi to Quandialla Transect, Central West NSW. *Geological Society of Australia* **Abstracts 67**, p. 417.

KING D.P. 1998. Soil Landscapes of the Forbes 1:250,000 Sheet, Department of Land and Water Conservation, Sydney.

LAWRIE K.C., CHAN R., GIBSON D.L., DE SOUZA KOVACS N. 1999. Alluvial Gold Potential in Buried Palaeochannels in the Wyalong District, Lachlan Fold Belt, New South Wales. *AGSO Research Newsletter* **30**, 1-5.

LAWRIE K.C., MUNDAY T.J., DENT D.L., BRODIE R.C., WILFORD J., REILEY N.S., CHAN R.A., & BARKER P. 2000. A Geological Systems Approach to Understanding the Processes Involved in Land and Water Salinisation, the GILMORE Project Area, Central-West New South Wales. *AGSO Research Newsletter*, May 2000, 12-21.

LESLIE C., JONES L., PAPP E., WAKE-DYSTER K., DEEN T. & GOHL K. 2000. High-Resolution Seismic Imagery of Palaeochannels Near West Wyalong, New South Wales. *Exploration Geophysics* **31**, 383-388.

LOURENS U., KILBY M. & WALTER K. 1999. Introduction to Remote Sensing and Feature Recognition. Agrecon, *University of Canberra Short Course Notes*.

MACKEY T., LAWRIE K.C., WILKES P., MUNDAY T.J., DE SOUZA KOVACS N., CHAN R.A., GIBSON D.L., CHARTRES C., & EVANS R.W. 2000. Palaeochannels Near West Wyalong, New South Wales: A Case Study in Delineation and Modelling Using Aeromagnetics. *Exploration Geophysics* **31**, 1-7.

PAIN C., CHAN R., CRAIG M., GIBSON D., URSEM P. & WILFORD J. in prep. RTMAP Regolith Database Field Book and Users Guide (Second Edition). CRC LEME **Report 138**.

RAYMOND O.L., DUGGAN M.B., GLEN R.A., LEYS M., LYONS P., SCOTT M.M., SHERWIN L., & WALLACE D.A. 2000. *Forbes (SI55-7) Simplified Basement Geology 1:250,000 Scale Map (First Edition)*. Australian Geological Survey Organisation, Canberra / New South Wales Department of Mineral Resources, Orange.

RAYMOND O.L., GIBSON D.L. & CHAN R.A. 2000. *Forbes (SI55-7) Depth to Slightly Weathered Bedrock 1:250,000 Scale Map (First Edition)*. Australian Geological Survey Organisation, Canberra / New South Wales Department of Land and Water Conservation, Forbes / Geological Survey of New South Wales.

RAYMOND O.L. & WALLACE D.A. 2000. *Marsden (First Edition) 1:100,000 Geological Map 8430*. Australian Geological Survey Organisation, Canberra / New South Wales Department Of Mineral Resources.

RAYMOND O. L., DUGGAN M. B., LYONS P., SCOTT M. M., SHERWIN L., WALLACE D. A., KRYNEN J. P., YOUNG G. C., WYBORN D., GLEN R. A., PERCIVAL I. G. & LEYS M. 2000. *Forbes (Second Edition) 1:250,000 Geological Map (SI55-7)*. Australian Geological Survey, Canberra And The NSW Geological Survey, Orange.

WHITE M.E. 2000. *Running Down, Water In A Changing Land*. Kangaroo Press. 228 p.

WILFORD J., GIBSON D.L., LAWRIE K.C. & TAN K.P. 2002. Extending Regolith-Landform Maps into the Third Dimension – Unravelling the Palaeogeography Story for Mineral Exploration and Environmental Applications. *Victoria Undercover*, 193-202.

Acknowledgments: We would like to thank Mr Kim Block (Timberscombe), Andrew Wooldridge (DLWC), Rob Muller (DLWC), Dr Colin Pain (GA/CRC LEME), Dave Gibson (GA/CRC LEME) and K.P Tan (GA/CRC LEME) for assistance over the course of this project and useful discussions quoted in this publication. I would also like to thank DSHMP and CRC LEME for financial and technical support. Gamma-Ray Spectrometric data courtesy of Geoscience Australia, 2000.