Cooperative Research Centre for Landscape Environments and Mineral Exploration

InterGeoRAP Consulting

OPEN FILE REPORT SERIES

# RESONANCE ACOUSTIC PROFILING TRIALS IN AUSTRALIA


*Report prepared by*
Valery Lazebnick, Boris Matveev and Bronislav Koulmametiev of
INTERGEORAP CONSULTING (St. Petersburg, Russia)

*Edited and compiled by*
*Matthias Cornelius*



**CRC LEME OPEN FILE REPORT 146**

**February 2003**

(CRC LEME Report 127R, 2000.
Second impression 2003)

CRC LEME is an unincorporated joint venture between CSIRO-Exploration & Mining, and Land & Water, The Australian National University, Curtin University of Technology, University of Adelaide, Geoscience Australia, Primary Industries and Resources SA, NSW Department of Mineral Resources and Minerals Council of Australia, established and supported under the Australian Government's Cooperative Research Centres Program.

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*Headquarters:* CRC LEME c/o CSIRO Exploration and Mining, PO Box 1130, Bentley WA 6102, Australia

CRC LEME, with industry sponsorship, hosted a visit to Australia by researchers from InterGeoRAP Consulting to conduct testing of the Resonance Acoustic Profiling technique. Fieldwork was completed by December 1999 and this report was issued in January 2000. Under an agreement between CRC LEME and InterGeoRAP Consulting, signed on 26 November 1999, the report of the trials remained confidential for a period of six months from completion, subject to change by the sponsors during the confidentiality period.

Neither CRC LEME nor InterGeoRAP Consulting received any requests to extend the confidentiality beyond the agreed period that has now expired (July 2000). The information contained in this report is therefore in the public domain.

CRC LEME was not responsible for conducting the field tests and measurements and accepts no responsibility for the accuracy of any results reported herein.


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## PREFACE

The InterGeoRap representative for Australia, Dr B Matveev, introduced Resonance Acoustic Profiling (RAP) to CRC LEME in early 1999. It was noted at the time that the RAP technique might have potential for 3D regolith mapping and mineral exploration. In September 1999, CRC LEME and InterGeoRAP decided to conduct a series of trials with the objective to test the RAP technology in the Australian environment under supervision of CRC LEME. Seven mining companies and AGSO participated in the trials. In addition to financial and logistical support, the sponsors were asked to provide a test site with interesting and well documented geological and regolith features.

The InterGeoRAP team arrived in Perth in early November 1999 and commenced trials in the Northern Territory and the northern part of Western Australia by mid November. Trials continued in the eastern and northern Goldfields and concluded in NSW in early December 1999; data processing was completed before Christmas. Late submission of some company geological data and late changes to geological cross sections did, however, delay completion of the project and production of this report.

CRC LEME was present at five trials and also assisted with data evaluation and report compilation. CRC LEME has not, however, conducted research or had prior knowledge of any sites except North – Eastern Yilgarn and Gilmore (Sites 4 and 8). At the request of sponsors, information pertaining to companies, locations and commodities has been excluded from this report.

In our view the trials have achieved their objective. InterGeoRAP has demonstrated their integrity and expertise, and proven the potential of their technology. The results show that RAP can be used to delineate features such as depth of weathering, depth of transported cover and depth of duricrust. RAP also appears to indicate water-table depth and show structural features extending from the bedrock into saprock and saprolite. It may also indicate features associated with certain types of mineralization to a depth of 150 to 250 m and the presence of cavities. These results were achieved even though the operators had little or no experience in deeply weathered and regolith-dominated terrains and did not have algorithms suited to the interpretation of regolith materials. There are, however, numerous features on the RAP sections that are unexplained or for which the explanation is equivocal. Further work is needed to investigate these features, to realize the full potential of the procedure and to determine its limitations, as outlined below.

A problem encountered during the data evaluation has been the correlation of RAP sections with some company geological logs and sections provided for the test sites.

- The RAP sections are objective and show interfaces between units based on different acoustic properties, whereas geological logs are subjective, based on colour, texture, mineralogy and appearance.
- RAP sections, because of close station intervals, give semi-continuous information, whereas geological sections are based on correlation between holes commonly widely spaced. Geological sections are thus themselves interpretative. In several instances, the regolith geology was poorly known and perhaps unsuitable for a test of this nature.

- Many of the calibration holes were inadequate. Ideally, they should have represented the significant materials at the sites and be of similar depth to the information being sought. In some instances, the holes were distant from the site and not representative of the materials and therefore did not provide the necessary information for optimal calibration.

Previous work has shown the RAP technique can be applied directly to the investigation of exploration targets, a conclusion also born out by some of these studies. However, for one major potential application in Australia, namely 3D mapping of regolith and associated mineralisation, further experimentation and testing of the technique are warranted in order to optimize its application.

A more detailed test program should, for example:

- Include characteristic sites representing various regolith environments and different styles and types of mineralization.
- Measure specific acoustic properties of various regolith materials and bedrock features.
- Be combined and correlated with other objective measures (PIMA, density).
- Include an experienced regolith geologist to characterize and document the regolith and geological settings.

Through the conduct of these trials, the InterGeoRAP team has demonstrated a technology that can make an important contribution to the advance of regolith mapping in the Australian environment. RAP has considerable potential as an alternative to extensive drilling in order to establish regolith stratigraphy and generate 3D models of the regolith and surface geology. In contrast to other geophysical techniques such as seismics and ground penetrating radar, RAP is unaffected by groundwater and its salinity, is relatively simple in its application and interpretation and has demonstrated a capability to delineate important regolith units. It is anticipated that a major application could be 3D regolith mapping, to determine the continuity of specific units at the prospect to deposit scale, to guide geochemical sampling programs and to aid the delineation of supergene mineral deposits.

C.R.M. Butt and M. Cornelius
Cooperative Research Centre for Landscape Evolution and Mineral Exploration
January 2000

## EXECUTIVE SUMMARY

InterGeoRAP Consulting is an independent geophysical firm established in St. Petersburg, Russia. They have developed a new ground acoustic technique – Resonance Acoustic Profiling (RAP) - that could potentially be suitable for mapping regolith and shallow bedrock units as well as certain subsurface features such as cavities. RAP has the potential to offer an alternative or form an addition to traditional geophysical techniques and drilling.

The technique was introduced to CRC LEME, which helped to arrange the RAP trials in Australia at properties of some sponsoring mining companies. The objectives of the trials include:

- Carrying out independent tests of the new technique.
- Evaluating the potential of the RAP technique for 3 dimensional mapping of regolith and shallow bedrock features.

The trials took place at well-explored areas chosen by the sponsoring companies and unknown to the RAP team. Representatives from CRC LEME accompanied the team on five of these field visits. The 23-day field trials were conducted in the Northern Territory, the Kimberley, five project areas in the Eastern and Northern Goldfields, and at AGSO's Gilmore Project in New South Wales.

This report includes both the RAP geophysical models and geological information provided to CRC LEME in confidence by sponsor companies. The geological information was not disclosed to the RAP team until the completion of the final data processing.

Best results were achieved for settings such as volcanic pipes and sub-vertical or steeply inclined bedrock structures. An established set of survey and processing algorithms, developed by InterGeoRAP in other parts of the world, allows optimal interpretation of these structures with minimum calibration requirements. The trials also demonstrated the ability of the RAP technique to clearly delineate major interfaces such as the boundaries between regolith and bedrock and alluvium and regolith. Encouraging results were also obtained for deep regolith profiles and may allow to delineate internal regolith features such as silicification, Fe oxide enrichment and collapsed zones within clayey units. More reliable interpretation of the acoustic properties of various regolith materials requires further calibration and better geological information to establish optimal survey and processing algorithms.

The RAP trials in Australia have confirmed the validity of the new technique under independent supervision of CRC LEME and the sponsoring companies, and have demonstrated the potential of RAP to play an important role in mineral exploration in Australia, both for supergene and bedrock-hosted mineral deposits. In addition, there may be applications in environmental, geotechnical and other geoscientific areas.

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# INTRODUCTION

## *General background*

InterGeoRAP Consulting was established in St. Petersburg in 1996. The firm employs a group of highly qualified geophysicists and software specialists, formerly involved in the state owned regional mining and exploration company SEVZAPGEOLOGIYA (Northwest Geology). SEVZAPGEOLOGIYA played a major role in the discovery of the Arkhangelsk Diamond Province in northwest Russia.

The founder and Managing Director of InterGeoRAP Consulting, Mr. Valery Lazebnik, is a former Chief Geophysicist with the Russian diamond monopoly Almazy Rossii Sakha (ALROSA). His 27-year professional career includes the discovery of the Ebeliakh diamond field and numerous diamondiferous bodies in sub Arctic Yakutia, participation in feasibility and pre-feasibility studies of the Udachnaya, Aikhal, Sytykan, Yubileinaya kimberlite pipes, as well as exploration for gold, uranium and other commodities. He also participated in geotechnical and environmental projects in many regions of the former USSR, Australia, South and West Africa.

InterGeoRAP Consulting has developed a new ground acoustic technique, **Resonance Acoustic Profiling (RAP),** together with software for processing and interpretation of ground and airborne magnetic data. The company also has the expertise to carry out ground and airborne geophysical surveys for radiometrics, EM and gravimetry and can provide remote sensing and GIS integration.

InterGeoRAP Consulting carries out field research and consulting assignments in Russia, CIS countries and overseas. Additional information on InterGeoPAP can be obtained at: http://www.iinet.net.au/~tchern

## *Technical background*

The RAP technique is based on recent theoretical progress in acoustics and new approaches to the interpretation of acoustic signals. Unlike traditional seismic methods, the RAP technique uses acoustic oscillations generated within various geological bodies by external shock and registers changes in their acoustic density (impedance).

The advantages of RAP are:

- Portable field equipment (~6 kg including batteries);
- 2-person field team (able to survey up to 6 line kilometres per day depending on station spacing and ground conditions)
- penetration down to 150-300 meters and good resolution;
- field calibration based on area specific geology;
- field quality control based on field visualisation of preliminary processed data using laptop computers;

RAP results are presented in a format compatible with other geological and geophysical data. The portability of the equipment and the speed of data acquisition and interpretation offer a cost-effective survey procedure.

RAP has been successfully applied to diamond exploration and environmental and geotechnical projects in Russia, the Ukraine and Africa. The technique has advantages in areas where conventional techniques such as EM and Ground Penetration Radar fail due to soil salinity or unfavourable hydrogeological conditions.

## *Objective of the RAP trials in Australia*

The RAP technique has to date only been applied outside Australia, mainly targeting features in fresh rock or sediment. The objectives of the trials in Australia were:

- To establish the integrity of the technique and InterGeoRAP by conducting independent trials, monitored by CRC LEME and the sponsoring companies.
- To determine whether it could be used to determine regolith stratigraphy and hence have application as a tool for 3D mapping of the regolith.

The co-sponsorship by seven mining companies and AGSO provides each sponsor with a data set from a wide range of geological settings and enables a better assessment of the capabilities of the RAP technique.

## *Organization of the trials*

Mr. Valery Lazebnik, Mr. Bronislav Koulmametiev and Dr. Boris Matveev conducted the 23-day field trials. The field program included:

- 7 days in the Northern Territory and Kimberley
- 12 days at five project areas in the Eastern and Northern Goldfields
- 4 days at Gilmore, NSW

The coordinator of the trials, CRC LEME, had attempted to include as many geological and geotechnical settings as possible; the selection of the test sites was, however, done by the sponsoring companies. Sponsors were asked by CRC LEME to select well-explored areas with distinct regolith and/or bedrock features. Sites and geology were unknown to the InterGeoRAP team and, in most cases, CRC LEME at the time of arrival at the respective sites. Representatives from CRC LEME accompanied the team on five of the eight field visits.

Surveys usually started with a field calibration at 1 or 2 drill holes to adjust the technique to area-specific geological conditions and to determine the appropriate sound velocities. Following calibration, the survey was carried out along lines selected by the sponsor.

At each test site, the RAP team completed preliminary processing of the survey data using a laptop computer and showed the results to the company representatives for a first impression and as confirmation of the validity of the field data. The data processing was completed in Perth.

Report preparation was done at CRC LEME's premises. Following completion of the data processing, the geological information provided in confidence by the sponsors to CRC LEME was appended to the RAP sections. At the request of the sponsors, specific locations of the sites have not been disclosed.

## SITE STUDIES

### *Area 1: Regolith profiles on ultramafic sequence, Northern Yilgarn*

*Site description*
RAP surveys were carried out at two exploration sites several kilometres apart that show different regolith profiles.

*Objective*
Investigate the regolith profile and the bedrock surface.

*Survey*
Both sites were traversed by two parallel 300m long east - west and two parallel and equally long north - south lines. In the report only one east – west and one north – south line is shown for each of the two sites (Figs. 1.1.1, 1.1.2 and 1.2.1, 1.2.2 respectively).

The calibration was carried out along a separate 100m line between two calibration drill holes located a few hundred metres from the first test site (Fig. 1.3).

The RAP measurements along the profiles were made at 5m spacing. The acoustic signal was recorded using a medium-frequency mode to optimize the resolution and quality for the regolith and upper part of the bedrock to a maximum depth of 50 to 75 m. A detailed RAP survey at 2.5 m spacing was carried out along a 50m section of the western part of Profile 1 at Site 1 (Fig. 1.4).

*Interpretation*
All RAP sections show saprolite-saprock and saprock-bedrock boundaries. In addition there is a prominent red-orange horizon in the upper part of the regolith, which appears to indicate the water-table. There are other irregular acoustic features within the regolith that cannot easily be correlated with the geological logs. The correlation between RAP data and geological information is best on Fig. 1.4b, where thin regolith units can be correlated with subtle acoustic features. There are several reasons for differences between the geological and the RAP profiles for the other sections:

- The calibration was carried out outside the test profiles; no geological information was provided for the test lines
- In order to achieve optimal resolution, survey settings and processing algorithms should be fine-tuned to the local regolith. This is beyond the scope of a pilot study.
- The water-table is a prominent acoustic boundary, overprinting other regolith features.

## *Area 2: Volcanic pipes, Northern Territory*

*Site description*

The RAP survey was carried out over two volcanic pipes intruded into Cambrian sandstone and mudstone. The pipes are deeply weathered and are covered by thin sand and gravel; the sedimentary hostrock is only weakly weathered. According to company information, Pipe 1 is about 20m in diameter and Pipe 2 approximately 100m in diameter.

*Objective*

Locate the pipes, investigate the regolith features associated with the pipes and characterize the depth extension of the pipes.

*Survey*

A 600m long east – west line and a 100m long north – south line traversed Pipe 1, although neither may have crossed the widest part of the pipe (Fig. 2.1.1 and 2.1.2). Pipe 2 was traversed by east – west and north - south profiles that are 350m and 375m long (Fig. 2.2.1 and 2.2.2).

The RAP measurements along the profiles were made at 5m spacing. The acoustic signal was recorded using low-frequency mode to maximise the depth of the RAP penetration, which in this terrain was approximately 200m. A relatively thin (1-2m) and damp sandy surface did not significantly reduce the depth of penetration.

The central part of the east - west profile across Pipe 1 (100m) was repeated using high-frequency mode to achieve a more detailed signature for the regolith profile above the pipe (Fig 2.1.3).

Different data filtering techniques were used for processing and are shown in two different presentations of the RAP sections. The processing has concentrated on emphasizing the effects of weathering.

*Interpretation*

The RAP profiles show strongly anomalous acoustic signals in the upper part of the pipes between approximately 10 and 90m depth. This signature is interpreted as due to deeper and more intense weathering of the volcanic rock in the upper part of the pipe compared to the host rock.

The lower parts of the pipes (90 to 200m depth) are delineated by a predominantly sub-vertical fabric in the processed acoustic signal (Fig. 2.1.3).

## *Area 3: Alluvial sediments, North-Eastern Kimberley*

*Site description*
The test site comprised two profiles across river terraces.

*Objective*
Show various alluvial units and the alluvium – bedrock boundary.

*Survey*
The RAP survey was carried out along two traverses:
Line 1 was 1130m long; RAP measurements were taken at 10m spacing (Fig. 3.1.1 and 3.1.2).
Line 2 was 1000m long and RAP measurements were taken at 5m spacing (Fig. 3.2.1 and 3.2.2).

The calibration was carried out at 5m spacing along a 100m long section of Line 1 that included three drill holes. A high-frequency mode was used for the test profiles.

*Interpretation*
The RAP sections clearly show the alluvium - bedrock boundary by changes both in acoustic density and in the texture of the visualised acoustic signal.

Stratigraphic units within the alluvium are less clear and there are significant differences between the RAP sections and the geological interpretation provided by the sponsor. The effectiveness of the survey could be improved by:

- Reducing spacing of the RAP measurements. At an average thickness of 5 to 6m for most alluvial units, the optimum spacing is approximately 2.5m.
- Improving calibration by reducing the distance between calibration holes and the spacing of measurements. More time is needed to experiment with calibration parameters.
- Further increasing frequency for better differentiation of lithological units within the shallow alluvium.
- Introducing objective parameters into the geological log for calibration holes, for example PIMA measurements.

## *Area 4: Regolith profile on a greenstone sequence and transported overburden, Northern Yilgarn*

*Site description*
Palaeochannel sediments up to 20m overlying a weathered greenstone sequence.

*Objective*
Delineate transported and residual regolith and show bedrock features.

*Survey*
The RAP survey was carried out along one 2.5km long east - west profile (Fig. 4.1 - 4.4). Acoustic signals were recorded at 5m spacing, using low-frequency mode to ensure deep penetration.

There are three different presentations for each RAP cross-section. Different filtering algorithms were used to optimize the presentation of the upper, middle and lower part of the traverse. The location of the single, deep calibration drill hole is shown in the figures. The geological boundaries in Fig. 4.2 are based on drilling. With the exception of 3 holes, drilling did not reach saprock or bedrock.

*Interpretation*
The RAP section correlates well with the geological information provided. Changes in acoustic properties quite clearly delineate the boundary between transported and residual material (Fig. 4.2). The saprolite - bedrock boundary is most obvious in Fig. 4.3. Structures in the bedrock such as sub-vertical and steeply dipping faults and shears, are visible in Fig. 4.4.

Unfortunately, there is insufficient geological information to verify all acoustic features and boundaries that appear on the section. A calibration using 2 or 3 deep drill holes could also improve the RAP model and lead to an even better correlation between geological and geophysical sections.

## *Area 5: Palaeochannel incised into conglomerate sequence beneath alluvial plain, North-Eastern Yilgarn*

*Site description*
The main feature of this site is a palaeochannel incised into conglomerates. Thick alluvial and aeolian sediment covers the channel and rock sequence

*Objectives*
Delineate the palaeochannel.
Outline transported and residual regolith.
Investigate bedrock structures.

*Survey*
The RAP survey was carried out along a 2km long east - west profile at 5m spacing (Fig. 5.1-5.3). Acoustic signals were recorded using low-frequency mode to ensure deep penetration.

The soil surface along the survey line proved to be very unfavourable for an acoustic study. Close-spaced exploration drilling and subsequent rehabilitation had destroyed the thin natural surface "crust" and turned the surface into loose unconsolidated sand. This resulted in a weak strength of the mechanically generated acoustic signal and very irregular recording conditions. Additional filtering and normalising of the primary data was necessary to partially overcome these problems.

*Interpretation*
The RAP cross-sections are shown in two different presentations using different data filtering algorithms. Despite the unfavourable recording conditions, the final RAP cross-sections correlate well with the geological information (Fig. 5.3).

The RAP section shows boundaries between the alluvium, palaeochannel sediments, saprolite and bedrock, and other minor geological features in the regolith. In the bedrock, the sections suggest some sub-vertical structures, possibly fault or shear zones, and other minor features.

### *Area 6: Regolith sequence on volcaniclastic sequence, Eastern Goldfields*

*Site description*
The RAP survey was carried out at two neighboring sites on a sequence of volcaniclastic sandstone and mafic schist, weathered to a depth of about 40 to 50m.

*Objectives*
Determine the thickness of the regolith.
Investigate the geological structure of the bedrock and the expression of the mineralization.

*Survey*
There were two survey sites. Site 1 was traversed by a 400m long east - west profile (Fig 6.1.1 and 6.1.2), Site 2 by a 750m long east – west profile (Fig 6.2.1, 6.2.2 and 6.2.3). The calibration was carried out between two calibration drill holes at each test profile.

The RAP measurements were made at 5m spacing along the profiles. The acoustic signals were recorded using low-frequency mode to record bedrock features to 150m depth.

*Interpretation*
Site 1 Two styles of presentation are shown. Regolith and lithological features, in particular the saprolite – saprock boundary, are highlighted in Fig. 6.1.1. Several steep east-dipping structures appear to be related to mineralization. The second presentation is a gray scale profile to highlight subvertical structures, and shows geological information and boundaries interpreted from the RAP section.

Site 2 Three different presentations are shown. Fig. 6.2.1 highlights subvertical features extending from fresh rock into the saprock and saprolite. Fig. 6.2.2 mainly shows a different RAP signature for the mottled zone and saprolite within the mineralized zone and the grayscale presentation, Fig. 6.2.3, also highlights steeply dipping to subvertical features. There are a number of smaller acoustic features both in the regolith and in the bedrock, inside and outside the mineralised zone. These features could represent small scale structural and lithological changes; some appear to indicate mineralization (e.g. yellow outline on Fig. 6.2.3).

The origin and characteristics of acoustic features that appear to be associated with regolith and bedrock in the mineralized zone need to be further investigated. If such features are unique to mineralized parts of the profile, it could be a useful tool for locating similar mineralization in this geological environment.

### *Area 7: Cavities in mine site, Eastern Goldfields*

*Site description*
The trial was carried out on a freshly blasted and excavated bedrock bench in an open pit.

*Objective*
Delineation of underground cavities.

*Survey*
The RAP survey was carried out along three lines at 1m spacing. Line 1 was 30m in length; lines 2 and 3 were both 40m long (Fig. 7.7). The acoustic signals were recorded using medium-frequency mode to obtain a good resolution down to approximately 60m depth beneath the bench on which the survey was done.

Line 1 was the calibration line, lines 2 and 3 were the actually test traverses. Unfortunately, no geological data were provided for the calibration line during the test. When CRC LEME received outlines of some of the cavities, it became apparent that all profiles were poorly positioned. The calibration line did not cross a cavity, but was located above a large cavity throughout its length. The test lines also failed to intersect the main cavity and merely covered part of it (Fig. 7.4 to 7.6).

*Interpretation*
The RAP sections clearly show several acoustic features but their interpretation without geological bedrock information is difficult. The following is a guide only:

| **Colour on RAP section** | **Possible bedrock characteristics** |
|---|---|
| Grey-green | Broken and fractured rock |
| Pink | Less fractured rock |
| Yellow | Unfractured rock |
| Blue | Inferred cavities |

There are large acoustic anomalies that approximately match the location and shape of the drilled cavities. Several other similar anomalies on the RAP sections appear to indicate additional cavities that have yet not been detected by drilling.

### *Area 8: Transported cover over bedrock, Gilmore, NSW*

*Site description*
The RAP survey was carried out along two lines that cross a palaeochannel outlined by airborne and ground geophysics and one deep drill hole.

*Objective*
Investigate stratigraphy of transported sediments.
Determine bedrock relief.

*Survey*
Line 1 (Yiaddah) is 500m long (Fig. 8.1.1 to 8.1.4), Line 2 (Wyalong) 1650m (Fig. 8.2.1 to 8.2.4). The RAP measurements along the profiles were made at 5m spacing.

Calibration was carried out at one drill hole located on Line 1.

*Interpretation*
Apart from the drill hole used for calibration, the only information provided were seismic sections for each traverse. Line 1 shows several major geological boundaries within the transported overburden and the residual part of the section. The paucity of deep drilling prevents a meaningful interpretation of the section, but there appear to be two boundaries: Transported - residual regolith and regolith - bedrock. In addition there are several features within the transported cover that appear to be lenses and units of fine and coarse-grained sediment.
Line 2 has no drill control so that no geological interpretation was attempted. The line indicates a reasonably flat and homogenous geology. The relatively flat bedrock surface can be identified along the contact of the 'ripple-like' texture that marks bedrock and the more nebulous texture of the saprolite zone.
NB Interpretations of the seismic lines (Fig. 8.1.2 and 8.2.2) have a non-linear vertical scale. They could therefore not be appended to the RAP sections.

## DISCUSSION AND CONCLUSION

With assistance from CRC LEME and the sponsoring companies, InterGeoRAP completed eight field trials in the period 14 November to 10 December 1999. Data collection and preliminary processing of data were completed in the field at each site without any setbacks. Final processing of the field data was completed in Perth and results were presented to CRC LEME by 20 December. Some delays were experienced due to late provision of geological data.

Very limited geological information was given to the InterGeoRAP team prior to the trials to prevent any possibility of data manipulation. However, although this arrangement was essential to ensure an objective appraisal of the technique, in some instances it impeded on the ability of the RAP team to achieve best possible adjustments and calibration of their instrumentation for the different geological settings. The main reason is that InterGeoRAP did not have an established set of algorithms relevant to the Australian regolith environment.

RAP records changes in acoustic properties, which may or may not be related to changes in mineralogy and petrography recorded in geological drill logs. Proper calibration helps to fine tune the technique to reflect the geological features and to establish algorithms, which can then be used for similar settings. The survey settings and processing algorithms best suited to reflect a geological setting can either be empirical or based on detailed geological logs used for calibration. Data processing generally produces several RAP presentations for the same cross-section that are based on specific survey settings and filtering techniques and can show different geological details.

Some of the survey parameters used during these trials were not optimal for a few of the areas and this somewhat reduced the quality of the final RAP sections. An example is Area 3 (Alluvial sediments in the North-Eastern Kimberley) where measurement spacing and distance between the calibration holes were inadequate. At other sites, the material provided for calibration was inadequate or did not necessarily represent the regolith conditions at the test site.

Despite these provisos, the results offer a clear indication that RAP can provide unique information about the stratigraphy of the regions. At most sites, it was able to provide a multi-layered regolith model that indicated many of the principle horizon/zone boundaries. RAP has also indicated structural and lithological features, within bedrock and extending into the regolith. In comparing RAP results and existing information, it should be noted that the close station intervals have resulted in more complete and more complex interpretation than those possible from drill sections.

There are some technical adaptations necessary for the RAP technology with regards to the Australian environment. The RAP survey across sand dunes and heavily disturbed sandy surface such as at Area 5 (Palaeochannel incised into conglomerate sequence beneath alluvial plain, North-Eastern Yilgarn), has been successful. It could, however, be further improved by using a non-mechanical means for emitting an acoustic signal into the ground and by accumulating and averaging the measurements to increase the strength of the signal and to filter out acoustic "noise". InterGeoRAP is aware of possible solutions to this problem and is currently developing instrumentation.

The potentially achievable quality of RAP data is demonstrated at Area 2 (Volcanic Pipes in the Northern Territory). InterGeoRAP has explored similar geological structures in Russia and in deeply weathered terrain in West and South Africa, and uses well-established survey and processing algorithms. The same is true for sub-vertical bedrock structures such as in Areas 4 and 6. Results for Areas 1 and 6 are also encouraging where RAP successfully subdivided the regolith cover into its transported and residual components. The survey at the second site in Area 6 demonstrates that RAP has the potential to outline target zones in order to limit follow-up drilling.

In conclusion, the trials demonstrated the potential and ability of the RAP technique effectively:

- delineate palaeochannels
- recognize boundaries between transported and residual material
- outline features within the regolith that could relate to differences in hardness (calcretisation, silicification), Fe content, mineralisation, etc.
- define bedrock structures
- test targets or anomalies as part of grass roots exploration

These trials were focused mainly on exploration applications but there are also a number of potential applications in geoscientific, environmental and geotechnical areas in mining and civil engineering. The RAP trial Area 7 (Cavities in a mine), although inconclusive, is an example of the potential for diverse application of this technique.

## ACKNOWLEDGEMENTS

The RAP trials in Australia were organised on the initiative of Dr. Charles Butt, Deputy Director, CRC LEME. InterGeoRAP Consulting would like to thank him as well as Dr. Matthias Cornelius, Project Leader, CRC LEME, and Mr. Phillip Schmaal, Business Manager, CRC LEME, for their help at all stages of the project. Figures were compiled and edited by Mr. Travis Naughton and Mr. Angelo Vartesi; their help is much appreciated.

InterGeoRAP gratefully acknowledges financial support from the sponsor companies, which made it possible for the RAP team to come to Australia. We are very grateful to all representatives of the sponsor companies, CRC LEME and AGSO for their assistance in the field tests and in the preparation of this report.

## LIST OF FIGURES