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Curnamona Audit and Gaps Analysis Report

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1. Executive summary

1.1 Background

The NSW and SA Geological Surveys and Geoscience Australia wish to re-invigorate mineral exploration in the Curnamona Province. One of the main avenues is to provide pre-competitive data and information using the existing platform of the Broken Hill Exploration Initiative (BHEI). However, information is required about the type and extent of data and level of knowledge that is currently available in order to help make informed decisions concerning future investment in the Curnamona Province.

CSIRO Exploration and Mining was commissioned by the Surveys to conduct an audit and gaps analysis of the Curnamona Province. Since the Surveys and CSIRO Exploration and Mining are all participants in the pmd*CRC, the study was undertaken through the pmd*CRC, under the Program 1: Terranes, and Project: C5. Curnamona Province – Audit and Gaps Analysis.

1.1.1 Aim of Study

The aim of the Curnamona Audit and Gaps Analysis was to evaluate current databases, information and knowledge relating to the Curnamona Province in order to assist government decision making about the allocation of resources to re-invigorate mineral exploration.

1.1.2 Key Drivers

1. Future investment must be in high impact initiatives that are focused to provide the maximum impact for mineral explorers.

2. The role of government is to provide pre-competitive data and information, beyond which point the exploration industry takes over.

3. The study must draw and build upon existing resources, and expertise in the pmd*CRC

1.1.3 Methodology

Existing data and information, including state and federal data sets and company data where appropriate, were catalogued and assessed. The opinions and ideas of industry and researchers were sought using self administered questionnaires. Discussions were also held with personnel in industry, academia and the Geological Surveys of NSW and SA, and Geoscience Australia. The data collected were synthesized to provide an analysis of knowledge and data gaps in the Curnamona Province.

1.2 Key Conclusions

- A voluminous amount of data exists for the Curnamona Province but in varying degrees in the three main domains: Broken Hill, Olary and Mt Painter. The Province is underpinned by arguably the greatest orebody in the world and one of the most comprehensive datasets of any mineral province worldwide. However, in spite of the volume and richness of data, there is not a correspondingly high level of data synthesis and geological understanding of the Province.

- A survey of industry (33 responses equivalent to a return rate of 45%) indicates that most companies would be encouraged to invest further in the Curnamona Province if DMR, GA and PIRSA provided, in order of priority:

    1. more detailed gravity
    2. stratigraphic drilling
    3. data synthesis
    4. depth to basement maps
    5. commercial incentives, especially faster turnover of ground

- Depth to basement and ‘cover’ are generally viewed as the major impediments to exploration success, followed some way behind by ground availability. Clearly a new discovery in the Curnamona would rekindle interest by the majors.

- Industry (especially juniors) rates the prospectivity of the Curnamona Province as high. Some majors have opted to explore ‘easier’ targets in other areas in Australia and overseas. Copper-gold potential is considered to be good but undervalued particularly for iron-oxide-copper-gold potential in the north of the Province. Potential for gold-only systems is considered to be low. Lead-zinc potential is considered to be good by virtue of the presence of the Broken Hill deposit.

- A survey of researchers (29 responses, equivalent to a return rate of 58%) predominantly from Australian universities actively involved in the Curnamona Province, indicates that researchers rank the level of geological knowledge of the Curnamona Province below that of the Mt Isa and Lachlan Fold Belt, but higher than the Yilgarn, Pilbara and Tanami areas.

- The major impediment to research in the Curnamona Province is funding. The lack of research funding reflects both the presence of cash-constrained juniors and the general exit of majors during the past few years. The high level of past research in the Curnamona Province is not considered an impediment.

- A majority of researchers believe that the most significant knowledge gaps in the Curnamona Province are, in order of priority:

    1. robust mineralization models
    2. synthesis of existing data sets
    3. alteration synthesis
    4. 3D structural models

- The vast majority of datasets are variously husbanded digital compilations available to the public (courtesy of the combined foresight of DMR, GA and PIRSA) but when viewed in detail contain inconsistencies that require minor changes to assist users.

- The BHEI2003 CD is the most comprehensive dataset to date, though the NSW GIS data are not available in MapInfo format. The main problem with the publicly available data is that attribute data are inconsistent across maps and data files. Explanations of abbreviations are not always included, or are difficult to find. Metadata is not detailed enough to trace the source and age of the mapping, or to establish relationships between attribute tables.

- Other sources of information such as university theses, company and other unpublished reports are not readily accessible, in part due to the closure of the old Mine Managers Association library in Broken Hill.

- There is a wealth of unpublished data available that, subject to confidentiality issues, could be collated and made available; e.g. of the 18 alteration studies in the Curnamona, only a handful are published and the remainder reside in company files.

- Similarly, numerous unpublished company-funded stratigraphic-structural studies represent a valuable resource that could significantly help integrate and evaluate regional models, improve the understanding of the evolution of the Curnamona province, and also provide a better context for new GIS data.

1.3 Key Recommendations

1.3.1. Regional Synthesis

It is recommended that a coordinated compilation, integration and synthesis of data be undertaken for the Curnamona Province. Such a study would aim to bring together a coherent tectonic and metamorphic evolution of the Province including robust structural and sedimentological framework, fluid flow, alteration, and mineralization. The synthesis would serve to elevate the general geological understanding of the Curnmamona Province.

1.3.2 Specific to Industry Requirements

It is recommended that steps be taken to address depth of cover and other major impediments to successful exploration, including:

1. more detailed gravity
2. stratigraphic drilling
3. depth to basement maps
4. commercial incentives, especially faster turnover of ground

1.3.3. Databases and Information

It is recommended that:

- The old MMA library (it is currently split up in Broken Hill) be reassembled and, where possible, updated by the inclusion of recent theses and unpublished materials.

- Companies be strongly encourage to add materials that have hitherto been classified as confidential to the library since these resources are potentially significant and important contributions to the science and understanding of the Curnamona Province. Contributions could be viewed as 'in kind' and counted as part of investment return from the BHEI.

- All materials should be scanned and made available on line to provide 24 hour remote access to all workers in the Curnamona Province, providing a means to fill the knowledge gap that is evident among them. The library resource (as well as the synthesis recommended above) would also help to minimize 'reinventing-the-wheel' that is a common impediment to research and exploration in the Curnamona Province.

- DMR, GA and PIRSA adopt and rigorously retain the same data-structure and data-dictionary for databases to facilitate data searches and compilations. Adequate and consistent metadata should be included in the published datasets to allow assessment of age and reliability of mapping/compilation.

- All map coverage be published with a consistent flat data structure (e.g. fully attributed stand-alone shape files) to facilitate uptake of new data into existing company databases by non-expert GIS users.

- Detailed structural data available on existing hardcopy maps should be validated and included in future GIS packages.

1.4 Other Findings

1.4.1 Survey Databases and Awareness of Other Work

- Researchers rated geology, geochemistry and gravity coverage more highly and radiometric coverage lower than industry, reflecting their different focus.

- The different regolith mapping schemes used in NSW and SA make correlation between maps difficult.

- Both industry and researchers are reasonably aware of activities of the DMR, PIRSA and GA in the Curnamona Province, mainly through Georef, survey publications and contact with Survey geologists. In contrast, the industry had limited awareness of the activities of the pmd*CRC and CRC LEMEII prior to the BHEI 2003, although a higher proportion of researchers were aware of their activities (surveyed after the BHEI 2003).

- Surprisingly, DIGS, SARIG and the GA website are not used as main sources of information by researchers.

1.4.2 Geological Synthesis

Regional Studies

- There is no universally accepted or agreed stratigraphic, structural and tectonic framework in use for the Curnamona Province. The structural-stratigraphic evolution of the Mt Painter-Mt Babbage inliers remains enigmatic and is not well correlated with the rest of the Curnamona Province.

- Of fifty six regional-type studies identified, around 1/3 are company-sponsored unpublished and remain confidential. They represent a potentially valuable resource.

Mineralization Models

- There are basic mineralisation models for all styles of mineralization in the Curnamona Province. Most base metal mineralization models focus on Broken Hill but Cu-Au models have a more regional genetic framework. NSW DMR classifications are based on descriptive lithological types without genetic connotations. By contrast PIRSA classifications have strong genetic links.

- Supergene and regolith metallogenic models are not well developed, and there is need for development.

1.4.3 Geology

Geological Mapping

- No digitized maps more detailed than 1:500 000 are available for the Mt Painter Inlier.

- In contrast, the coverage of geological mapping in the Broken Hill Block is excellent, and is developing in the Olary Block. The Broken Hill maps, however, could be updated by utilizing magnetic, hyperspectral and radiometric data.

- Only limited structural lineament data (e.g. faults, trends etc) are included in the GIS version of the detailed 1:50 000 and 1:25 000 scale map sheets. Where they do exist there are no structural attributes (e.g. fault type, dip, lineations).

- Only very limited amounts of structural readings are included (e.g. bedding, foliations, lineations), and these are consigned to a consistent deformation sequence. Exceptions to this are the new Olary-Billeroo and Outalpa 1:25 000 sheets.

Regolith Mapping

- There is a lack of detailed coverage over the Olary and Mt Painter inliers.

- Incompatible regolith mapping nomenclatures are used by CRCLEME and PIRSA, and cause artificial difficulties in interpretation.

Mineral Deposits

The South Australian database MINDEP could have more detailed metadata to aid the user and needs to be updated. Compared with South Australia, the mineral deposits database in NSW has little attribute data.

Mineral Occurrences

There are differences in coverage between GA and the BHEI GIS products, and the data for South Australia need to be updated with the GA data. Location accuracy is variable and it is noted that both the Queensland and WA Surveys have revisited mineral occurrences in Mt Isa and Yilgarn blocks, respectively to accurately measure locations using GPS. These programs were perceived by industry to be useful.

Petrology

Petrological rock and thin section descriptions are reasonably well covered over the Broken Hill Inlier, but scarce over the Olary Block and essentially non-existent over the Mt Painter Inlier. A large amount of petrological data resides in university theses, which are difficult to access.

1.4.4 Geochemistry

Geochemistry and Drill Hole Data

- Geochemistry and drillhole data comprise arguably the most extensive and valuable exploration resource available to Curnamona explorers; however, capture and validation of data remains a significant challenge for the Broken Hill Exploration Initiative.

- For the Curnamona, approximately 90% of NSW and 10% of SA geochemical data from exploration reports and academic research has been incorporated into Government databases.

- Geoscience Australia's OzChem database has very limited geochemical data coverage over the Curnamona; however, it contains data not captured in state GIS packages.

- There remains a significant lack of consistency and transparency of digital data in published GIS packages but this could be addressed by improving the quality of the metadata. For example, by having one comprehensive drillhole database (e.g. Intersect) that contains detailed headers and links to a geochemistry database with a comprehensive flat structure. The drill hole database could include columns for x y and z coordinates for all points (with projection details), so they can be plotted in 3D space without the need of complex database mergers with drillhole header information.

Water Bores

Water bore coverage is comprehensive but BHEI GIS packages do not contain water yield data. A slight coverage gap exists in the southern Broken Hill Block.

Isotopic Data

- Approximately 1500 isotopic analyses comprising δ34S, δ18O (+δD), δ11B, δ13C, 147Sm/144Nd, Rb87/Sr87 (+ Sr87/Sr86), 40Ar/39Ar (+ K-Ar) were identified but few have been consolidated into GIS databases.

- With the exception of ongoing Sm/Nd studies in the Olary Domain, most studies have been focused in the Broken Hill Domain, and especially on the Broken Hill line-of-lode with the majority of samples being generally poorly located.

- Isotopic work in the Mt Painter and Mt Babbage inliers is limited

Lead Isotopes

- Around 440 analyses, including all previously published data, are consolidated into CSIRO EM's database at North Ryde; and represents the most comprehensive Pb-isotope dataset for any mineral province in the world. The majority of analyses are concentrated on mineral deposits in the Broken Hill Domain with only 34 analyses available for the Olary Domain. One problem with the data is that only about half the samples are well located. The CSIRO database needs to be preserved in the event that the CSIRO isotope Lab is dismantled following the announcement to close North Ryde in July 2003.

- Double-spike analyses have greatly improved the precision and value of Pb-isotopic data and a robust Pb growth curve for the Curnamona Province is being developed.

Geochronology

- No single database includes all the available data and the two main databases (OZCHRON and BHEI 2003 GIS) have different structures. Location and other information about samples are inadequate in places. If databases were to be rationalized into one database, OZCHRON would probably be the best to keep up to date as it is more comprehensive.

- New data (post 2000) has not been entered into any database and there are around 30-50 age data "in press".

- On going issues relate to interpretation of results and the quality of some data (e.g. the types of zircons dated, whether they represent depositional age or metamorphic age).

- There are no major gaps in the geochronological coverage of the Curnamona, although as exploration continues to target new areas, new gaps in coverage will inevitably emerge.

- Many local geological issues exist (e.g. age difference of the Sundown Group and the Cartwright Creek Metasediments), that focused geochronological studies are continuing to address.

- Improved and newly developed techniques (e.g. Pb-Pb step leaching) mean that there will continue to be a demand for new, improved geochronological information.

Alteration

- A surprisingly large number of alteration studies were identified in this study. Of the 18 known studies on alteration systems in the Curnamona, 16 have focused on the Broken Hill ore system, and two regional studies have covered the Olary Domain in Cu-Au systems.

- Alteration studies on the Broken Hill Ore System demonstrate a consistent premetamorphic enrichment in K, Fe, Si, Mn, Rb and depletion in Na, Ca, and Sr, approaching the ore position.

- Potential exists for regional alteration mapping using new remote-sensing techniques such as ASTER and HyMap to compliment existing techniques using radiometrics, geology, and whole-rock geochemistry as demonstrated recently in the Olary Domain.

1.4.6 Geophysics

Electrical Conductivity Surveys

- Coverage is limited to tenement areas held by companies, and the Broken Hill Domain has the best coverage.

- There is no publicly available information on ground electrical surveys and DMR's Aerofind is the only public source of information on airborne electrical surveys; although comprehensive industry compilations are known to exist.

Airborne Magnetic and Radiometric Surveys

Airborne magnetic and radiometric coverage is generally good to excellent over Olary and Broken Hill Domains but is widely spaced over the Mt Painter Inlier.

Ground Gravity

Ground gravity is reasonably well covered over Olary and Broken Hill Blocks but mineral exploration companies view more detailed gravity as being a high priority for pre competitive data, not only as a direct detection tool but also to assist depth to basement and geological understanding. There is a gap in the data in the Mt Painter area where ground gravity data exists but is confidential.

Airborne Gravity Gradiometry

This relatively new technique was flown over part of the Broken Block in 2003. A simple inversion of the data into physical property units (g/cm3) has been performed. Integration of the data with ground gravity and the Pasminco 3D model is ongoing.

Seismic Survey

- Consideration is being given to extending seismic cover over the Olary Block where no seismic data exist, and connecting with coverage over Broken Hill.

- Existing deep seismic in the Broken Hill Block is difficult to correlate with surface geology and there exists an upper 3km gap in interpretation. Consideration is being given to collecting shallow seismic to assist in closing this gap.

1.4.7 Rock Properties

- This study revealed the existence of approximately 3440 samples mainly from the Broken Hill Domain, and a significant amount of company data currently held by a geophysical consultant The South Australian Curnamona is particularly data poor and under-represented compared with the Broken Hill Domain.

- There is clear scope to increase the measurements of rock properties in SA and to try to access company data, both from the consultant and open file reports.

1.4.8 Remote Sensing

ASTER

- Interpreted mineral maps generated from ASTER within the Broken Hill Block have generally provided supplementary AlOH, MgOH and regolith quartz maps to areas already with detailed 1:25 000 mapped geology.

- AlOH content and compositional maps indicate possible varied alteration histories within the Broken Hill Block's metasediments.

- Detailed comparisons between ASTER and HyMap are currently being undertaken by CSIRO-Sumitomo Metal Mining which will assess ASTER's interpreted AlOH compositional mapping.

HyMap Data

Preliminary results of surveys limited to the Broken Hill Domain show that HyMap is able to identify some geological units and alteration not revealed by previous outcrop mapping. Considerable processing and interpretation is still required to generate mineral maps and to provide these maps in usable formats.

Geoscan Data

Available data consists of a single survey over the Olary Domain, acquired in the early 1990s. However, Geoscan is outdated. Satellite borne ASTER imagery can potentially generate similar maps of mineral groups (e.g. FeOx, AlOH, MgOH), albeit at poorer spatial resolution (30 m cf 10 m). If greater accuracy in spatial and spectral resolution than ASTER is required, then surveying by HyMap or similar hyperspectral system is a recommended option.

AirSar (Airborne Synthetic Aperture Radar)

There has been very little work with respect to mineral exploration done to date, and only few datasets with restricted coverage exist.

OARS & TIPS

A single pilot study survey of OARS and TIPS was acquired over the Broken Hill Domain in 2002. Garnet rich units and garnet chemistry were unable to be detected with TIPS because of spatial resolution limitations of the line profiling TIPS instrument. The new ARES (Airborne Reflective Emissive Sensor) image scanner to be delivered by HyVista late 2004 is an opportunity to map prospective areas (i.e. garnet-rich alteration) in the Curnamona Province.

Landsat TM

Complete coverage exists of modern LandSat TM over the Curnamona Province.

Spectral Sampling

There is limited spectral sampling in the South Australian Curnamona; however the cost of new sampling and field measurements has to compare with possible airborne coverage. Thermal Infrared spectral measurements of relevant Curnamona samples, either using a portable thermal spectrometer or an airborne TIR sensor (i.e. ARES) under lab conditions, would also help assess the potential capability of the future HyVista ARES thermal scanner planned for deployment in 2004.

2. Acknowledgements

PIRSA, NSW DMR and GA are thanked for their support to undertake this project through pmd*CRC. Fruitful discussions have been held with a number of people from these agencies, in particular Stuart Robertson, Colin Conor, Kevin Capnerhurst, Barney Stevens, Richard Lane, Lesley Wyborn and Peter Lewis. We also acknowledge guidance provided by Lindsay Gilligan, Paul Heithersay, Russell Korsch and Chris Pigram; and assistance from CSIRO's Glass Earth initiative, led by Joan Esterle. The 62 respondents of the two surveys are also thanked for their time and consideration.

3. Glossary

AEM	Airborne Electro-Magnetic
AGG	Airborne Gravity Gradiometry
AirSar	Airborne Synthetic Aperture Radar
ARES	Airborne Reflective Emissive Sensor
ARGUS	
ASEG	Australian Society of Exploration Geophysicists
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
BHEI	Broken Hill Exploration Initiative
BHEI2000	Broken Hill Exploration Initiative 2000 GIS compilation
BHEI2002	Broken Hill Exploration Initiative 2002 GIS compilation
BHEI2003	Broken Hill Exploration Initiative 2003 GIS compilation
CRAE	CRA Exploration Pty Limited
CRCLEMEII	Co-operative Research Centre for Landscape Evolution and Mineral Exploration
CSIRO	Commonwealth Scientific and Industrial Research Organization
DMR	NSW Department of Mineral Resources
ENVI	Environment for Visualising Images
ERSDAC	Earth Remote Sensing Data Acquisition Centre
GA	Geoscience Australia
GeoScan	(full product name)
GIS	Geographical Information System
HyMap	Hyperspectral Mapper
HyVista	TM Company name
IOGC	Iron oxide copper gold
IP	Induced Polarization
LandSat TM	LandSat Thematic Mapper
microFTIR	micro- 'Fourier transform infrared'
NASA-JPL	North American Space Agency –Jet Propulsion Laboratory
OARS	Operational Airborne Research Sensor
OZCHEM	Geoscience Australia’s geochemical database
OZCHRON	Geoscience Australia’s geochronology database
OZROX	Geoscience Australia’s rock sample database
PIMA	Portable Infrared Mineral Analyser
PIRSA	Primary Industry and Resources of South Australia
Pmd*CRC	Predictive Mineral Discovery Co-operative Research Centre
SHRIMP	Sensitive High Resolution Ion Microprobe
SPOT	(SPOT Image is the company name that supports the SPOT Earth observation satellites)
SWIR	Short Wave Infra-red
TIPS	Thermal Infrared Profiling Sensor
TIR	Thermal Infra-red
USGS	United States Geological Survey
VNIR	Visible Near Infrared

4. Introduction

Background

The NSW and SA Geological Surveys in conjunction with Geoscience Australia ("the Surveys") wish to re-invigorate the Broken Hill Exploration Initiative (BHEI). Their combined expenditure on pre-competitive data since the start of the BHEI is nearly $20 million compared with the industry's expenditure on exploration of around $95 million (see Fig. 1 and Table 1). This ratio (1:4.76) of government to industry expenditure is slightly below that of the national average of 1:5. (P. Heithersay, pers. comm. 2003). Industry expenditure has declined significantly since 1998/99 and the industry players in the Curnamona Province have changed; for example, Pasminco has divested assets to Perilya, the take over of MIM by Xstrata and the withdrawal from direct exploration of major companies such as Rio Tinto. However, junior companies are continuing to explore and make new running. Exploration success has been mixed with the mining of the small Potosi Pb-Zn-Ag deposit near Broken Hill, new intercepts of high grade Pb-Zn and precious metals at the Pinnacles deposit and the discovery of the White Dam and Benagerie Ridge in Olary. Companies such as PlatSearch continue to test deep magnetic/gravity/structural targets.

The BHEI which commenced some 8 years ago seeks to increase mineral exploration in the Curnamona Province thereby leading to new discoveries, and ultimately benefiting the people of NSW and SA and Australia. One of the world's great orebodies occurs in Broken Hill and there is excellent potential for similar or other types of deposits to be found the Curnamona Province.

It is considered that one of the best ways to re-invigorate mineral exploration is to provide pre-competitive data and information. However, the main question is what kind of information and data is the most appropriate that is not only scientifically sound but also attractive for potential mineral explorers.

To this end an audit is required of what information, knowledge and data exist and whether there are gaps in this coverage that could be filled.

CSIRO Exploration and Mining was commissioned by the Surveys to conduct and audit and gaps analysis of the Curnamona Province. Since the NSW and SA Geological Surveys, Geoscience Australia and CSIRO Exploration and Mining are all participants in the pmd*CRC, the study was undertaken through the pmd*CRC, under the Project Title of C5. Curnamona Province –Audit and Gaps Analysis, and Program 1 Terranes. The C5 Project Leader is Tim McConachy, CSIRO Exploration and Mining and the Program Leader is Russell Korsch, pmd*CRC.

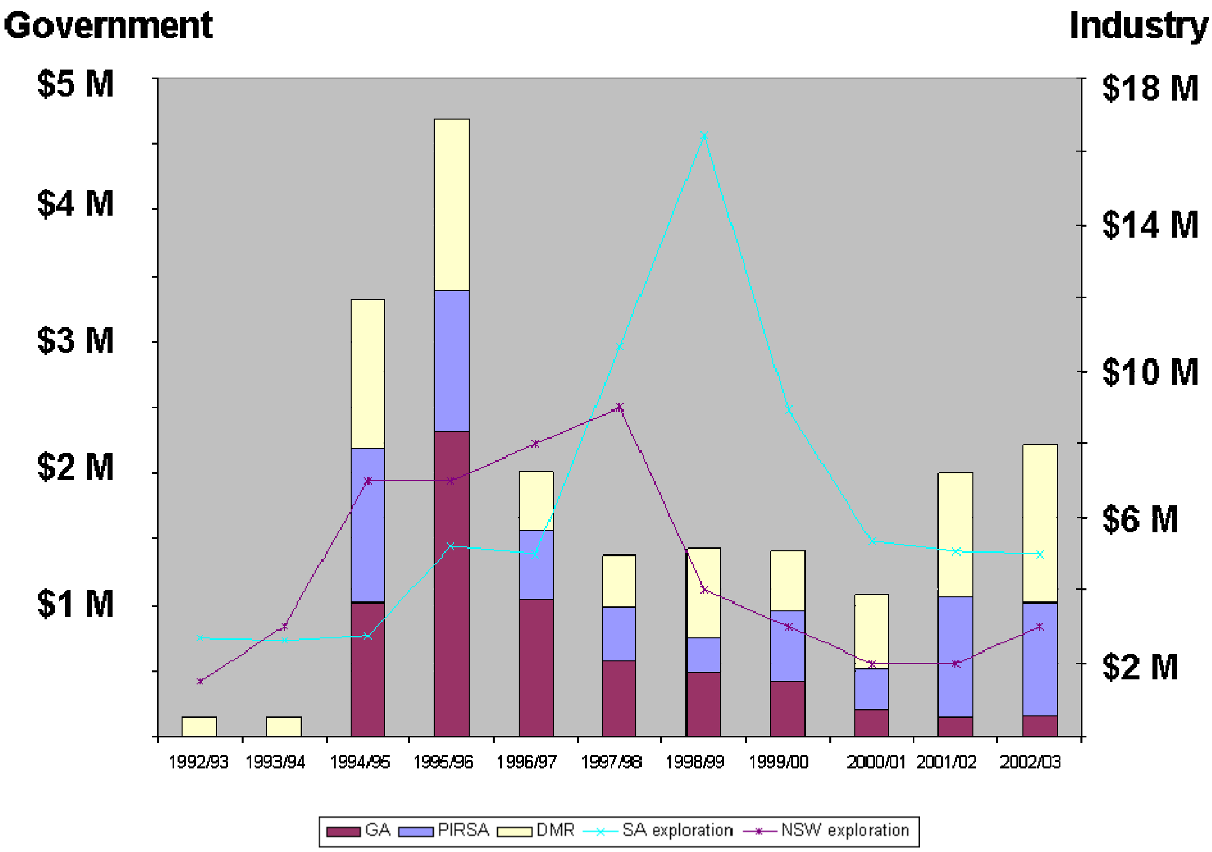


Figure 4.1. Government (BHEI) and Industry Expenditure in the Curnamona Province 1992/93-2002/03. (Source: Geoscience Australia, PIRSA and NSW DMR).

	BHEI	Industry	Total
GA	$6.36		$6.36
DMR	$7.39	$30.00	$37.39
PIRSA	$6.05	$64.31	$70.36
Total	$19.80	$94.31	$114.11

Table 4.1. Summary of Government and Industry Expenditure 1992/93-2002/03 (Aus$million) (Source: Geoscience Australia, PIRSA and NSW DMR).

Objectives

The aim of the audit and gaps analysis is to ultimately assist government on where and how it should allocate its resources in the future in the Curnamona Province to achieve its goal of re-invigorating mineral exploration and maximise potential for discovery.

Key Drivers

The key drivers for the invigoration of the BHEI are:

1. Investment in high impact initiatives. The BHEI will continue but where should resources be focussed to provide the maximum impact.

2. Data and information are provided by government on a pre-competitive basis. Beyond this point it becomes exploration.

3. Build upon and utilize existing resources and expertise in the pmd*CRC

Area of Interest

The Curnamona Province includes the Broken Hill Block, Olary Block Mount Painter Inlier and Mount Babbage Inlier and the areas between, as shown in Fig. 2. The area of interest does not include younger terrains on the fringe of the Curnamanona Province (e.g. Koonenberry in NSW and the Nackara Arc in SA), though overlap in data sets is frequently unavoidable.

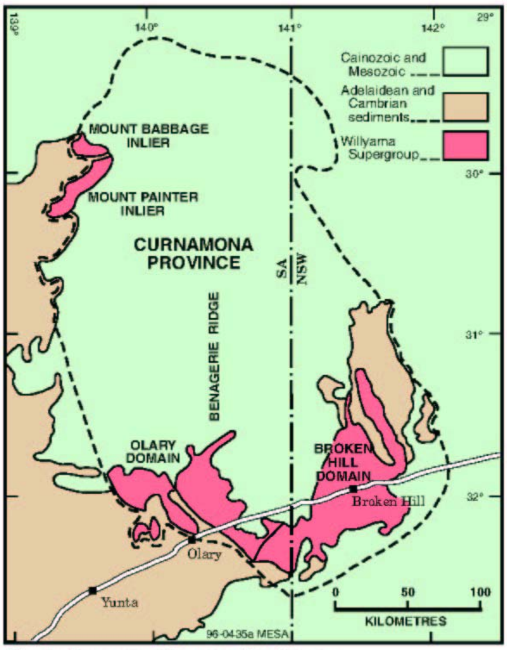


Fig. 1 Curnamona Province locality map

Figure 2. Curnamona Province (Scource: PIRSA)

Methodology

Approach

1. Catalogue existing data and information, including state and federal data sets and company data where appropriate.

2. Assess the existing data and information coverage. For example, where are the gaps in coverage, assess the integrity of data sets e.g.: surveys (what, where and how), magnetic, seismic, electromagnetic, gravity; age dating-coverage, stratigraphy, methods used, applicability; geochemical compilations (e.g., RAB, soil, groundwater, whole rock, alteration and isotope geochemistry); regolith coverage; depth to basement and "ease" of exploration; drilling coverage; open file reports and university theses; mineralization models, and coverage by “new” techniques assessing their potential applications (e.g., HyMap).

3. Analysis of knowledge gaps as well as the data gaps. Examples of knowledge gaps include the coverage of age dating in the Curnamona. Are there gaps in the current coverage, and, if so, how might they be filled? What structural models have been used and how useful are they?

4. Questionnaire- asking what the industry sees as its priority for pre-competitive data and technical impediments to exploration in the Curnamona area. Following the BHEI in July 2003, it was also decided to survey the views of researchers working in the Curnamona Province. Both survey results are presented and discussed in this report.

Possible spin offs envisaged from the audit and gaps analysis include revised assessments of the potential for new styles of mineralisation, and further advancement and understanding on the growing similarities between the metallogenic evolution of Curnamona and Mt Isa.

Metadata has been captured in Arcinfo and MapInfo and managed on CSIRO’s Twiki server. It has not been practicable to utilize XMML technology in this study to link datasets.

Timing

The project commenced on March 1, 2003 and concluded on December 31, 2003. The 10 month-long audit and gaps analysis comprised various fractions of the authors’ time.

Deliverables

In addition to this final report which also includes a CD version, 2-month progress reports have been delivered to the relevant parties. Preliminary results were presented at the Broken Hill Exploration Initiative in July 2003. A final oral presentation, including recommendations of where to invest future resources for maximum impact is scheduled for December.

5.1 Industry Survey

Conclusions

A survey concerning the Curnamona Province was emailed to 73 people in major and junior companies and industry consultants in Australia. Thirty three replies were received from mainly exploration manager- and CEO-level people, representing an excellent response rate of 45%. Twenty or 60% of responses were from companies and people actively engaged in exploration in the Curnamona Province.

The main results of the industry survey include:

1. The prospectivity of the Province is rated highly by juniors but less so by the majors who have a Pb-Zn (or Cu-Au) focus in other areas in Australia and overseas that afford ‘easier’ targets.

2. A discovery in the Curnamona, however, would rekindle waning corporate interest of the majors.

3. The Cu-Au potential in the Curnamona Province is considered to be good, and is undervalued particularly for its iron-oxide-copper-gold potential in the north of the Province. Potential for gold-only mineralisation is considered to be low.

4. Depth of cover was most frequently identified as the major impediment to exploration, followed some way behind by ground availability.

5. Level of past exploration, native title, sovereign risk and access to old drill core are seen as only minor impediments.

6. Other major impediments identified were:
    - poor geological understanding of province
    - lack of new exploration models
    - lack of synthesis or compilation of previous exploration
    - poorly located data, straddling two states
    - geological complexity
    - high cost of exploration

7. When asked what would encourage an increased interest in the Curnamona Province, over 60% of the responses from majors and juniors alike would like to see more detailed gravity, stratigraphic drilling and data synthesis; and over 40% would like to see depth to basement maps and commercial incentives , especially faster ground turnover.
8. There is a mixed awareness of available data in the Curnamona Province, with a certain amount of polarity of knowledge, depending on current exploration interest and focus. Overall, ratings of databases were lower for SA. This suggests that there are relatively few people who take an active, broader view of the Province.

9. Overall, exploration companies have good awareness of the activities of PIRSA, NSWDMR and GA; however, there is little awareness about pmd*CRC and CRCLEMEII activities in the Curnamona Province.

Recommendations

1. That the Surveys consider industry's response for them to supply more detailed gravity, stratigraphic drilling and data synthesis, including geological synthesis of the Province.

2. Depth of cover is major impediment to exploration and improved depth to basement maps are viewed as a critical.

3. Consider a range of commercial incentives for explorers. For example, count drilling dollars as twice normal expenditure for reporting requirements; acknowledging the higher cost of exploration in the Curnamona due to depth of cover

4. Consider ways of increasing ground turnover (e.g. tender system for ELs)

Methodology

Survey distribution

In June 2003, 82 surveys were emailed to major and junior companies and consultants. The recipients comprised exploration companies with active tenements in the Curnamona Province, gleaned from PIRSA and NSW DMR, companies involved in the pmd*CRC, and consultants known to the writers who are either currently active or had recent involvement in the Curnamona Province. Several recipients were companies that are currently headed by people with recent experience in the Curnamona Province, though not actively exploring there. Two email recipients were away and 7 'bounced', leaving a total of 73 surveys received. 33 (45%) surveys were returned. A good bottle of red wine was offered as an incentive to complete the survey. The winner, drawn at the BHEI in July, was Tim Green, Pasminco.

The survey sought information about

- the type of company and the position the respondent held;
- whether exploration/work was currently being undertaken in the Curnamona Province;
- if exploration was being conducted, what was being looked for; if not, the reasons for this;
- assessment of the prospectivity of the Curnamona Province;
- impediments to exploration in the Province;
- what would encourage exploration in the Province;
- database coverage for NSW and SA about such things as magnetics, gravity, drill hole data, regolith, summaries of past exploration etc
- knowledge of the work being undertaken in the Province by groups such as Geoscience Australia, NSW DMR, CRCLEMEII and pmd*CRC.

A copy of the survey is appended (Appendix 1).

Assessment of Data

Who responded?

A total of 33 respondents:

- 15 people from 10 major companies
- 12 people from 12 junior companies
- 6 consultants

1a. Who are you

		%
major	15	45
junior	12	36
consultant	6	18
total	*33*	*100*

Table 5.1. Breakdown of Industry Survey respondent by nature of company.

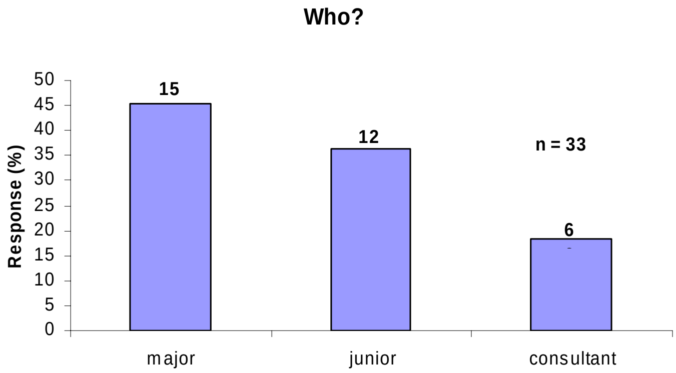


Figure 5.1. Breakdown of Industry Survey respondent by nature of company.

People self-classified themselves e.g. majors varied in size; one person who classified himself as working for an intermediate company was included as a major. People were invited to pass the survey on if there were others in their organization more suited to respond, or who could also provide input. Some responses represented a 'group' effort, and more than one response was received from 3 major companies.

What was their position?

31 out of 33 respondents noted their position, as shown in the following figures:

1b.What is your position	Total	*%*
CEO	8	*26*
Exploration manager	13	*42*
Senior geologist	5	*16*

other	5	*16*
total	31	

Table 5.2. Breakdown of Industry Survey respondent by position.

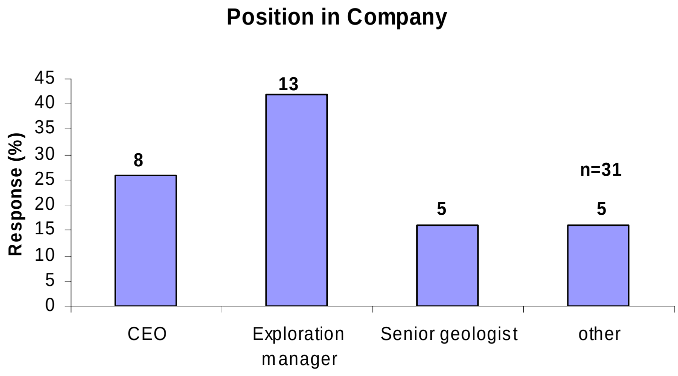


Figure 5.2. Breakdown of Industry Survey respondent by position.

The majority of respondents were exploration managers, and the majority of CEOs came from junior companies. ‘Other’ were internal consultant, business development manager, geochemist and chairman; and one had a title so specific as to identify the individual.

How many respondents are currently exploring in the Province?

20 respondents or 60% (representing 7 responses from 5 majors, 10 juniors and 3 consultants) are currently exploring in the region.

13 respondents or 40% (representing 8 responses from 6 majors, 2 juniors and 3 consultants) are not currently exploring.

The ‘extra’ response from majors is that two responses from people who worked for the same company gave conflicting answers to this question. One person had just finished working on tenements that had been farmed out, and therefore answered ‘no’, while the other viewed the farm out as still actively exploring, and answered ‘yes’.

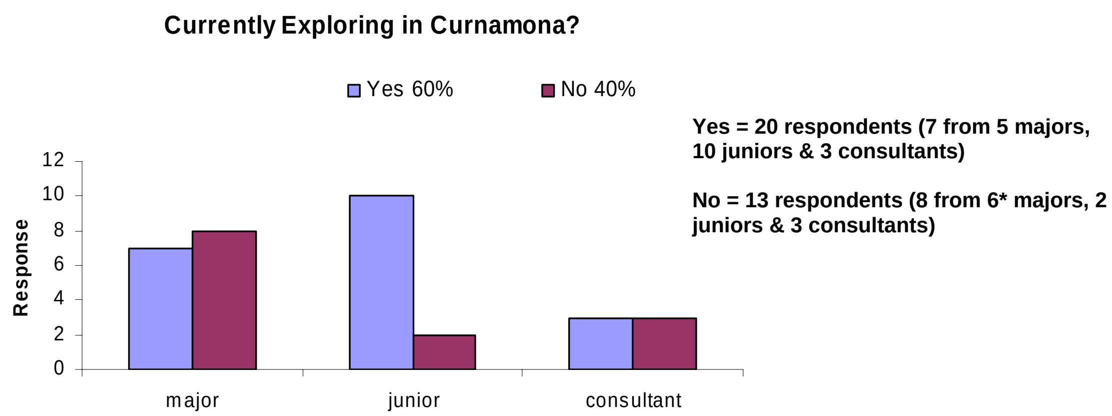


Figure 5.3. Breakdown of Industry Survey respondents by current exploration activity.

Focus of current exploration?

20/20 respondents noted what they are exploring for:

Pb-Zn	14
Cu-Au	16
U	4
Ni-PGE	2
Other	1

Table 5.4. Breakdown of Industry Survey respondents by exploration commodity.

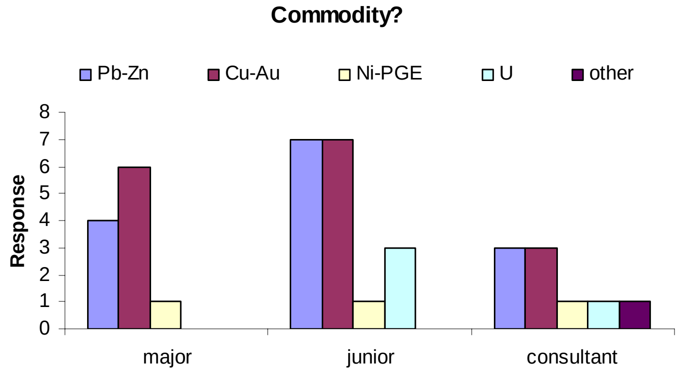


Figure 5.4. Breakdown of Industry Survey respondents by exploration commodity.

Not surprisingly, there is an emphasis on Pb-Zn and Cu-Au, with minor interest in Ni, PGE and U. One person noted the diamond potential of the Province was not known.

Reasons not exploring?

11/13 respondents noted why they are not exploring Reasons given by respondents from major and junior companies were:

- Lack of perceived potential (preference for Au only)
- Have worked in Province but now sold out
- Focus is elsewhere
- Province is over explored in part

Consultants indicated there was no work available, with example quotes shown below:

- *"… has been unsuccessful in identifying a world class base metal deposit. No opportunities are readily apparent. Other Pb-Zn terranes elsewhere in Australia provide better "first mover" opportunity"*

- *"'easy-to-find' major deposit is viewed as relatively low….but watching brief in case, …..prepared to re-enter"*

Assessment of prospectivity?

Assessment of prospectivity		%
excellent	11	*33*
good	17	*52*
limited	5	*15*
poor	0	*0*
total	33	*100*

Table 5.5. Breakdown of Industry Survey respondents by prospectivity assessment.

Assessment of prospectivity	excell.	good	ltd	poor
major	3	7	5	0
junior	5	7	0	0
consultant	3	3	0	0
total	11	17	5	0
%	*33*	*52*	*15*	*0*

Table 5.6. Breakdown of prospectivity assessment by type of respondent.

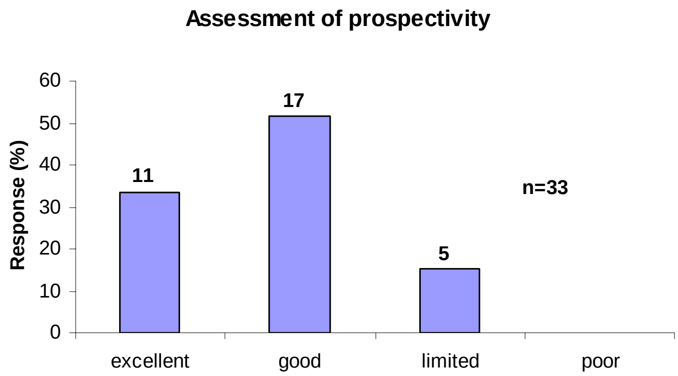


Figure 5.5. Breakdown of Industry Survey respondents by prospectivity assessment.

- 85% of all respondents assessed prospectivity of the region as good or excellent
- 15% of all respondents – all from major companies, 5 representing 4 companies – rated it as limited
- 23 respondents commented on their assessment
- Respondents from major and junior companies and consultants agree there is good potential but:
  - Depth of cover makes it hard to explore
  - There are limits to existing knowledge
  - Data compilation is limited
  - It is good for Cu-Au but not Au only. Good for Pb-Zn

Quotes on prospectivity from majors:

"The Broken Hill Block of the Curnamona has much opportunity for Cu-Au and PGE as these have not extensively explored in the past, and there is significant transported cover over much of the area"

"I rate the Curnamona as having very prospectivity fro a substantial discovery of Cu-Au mineralization. It has the right rocks, structural setting. Magnetic signatures, and known IOCG-style mineralization"

"1. Favourable geology
2. Good pedigree
3. Mature exploration
4. Deep cover in areas of interest"

"Whilst the area is undoubtedly mineralized and hosts at least one system of interest, there has been a lot of work done, and it is hard to see what can be done at low cost until some major new positive ideas emerge"

Quotes on prospectivity from juniors:

"The most prospective, under explored area in Australia"

"Proximity to Broken Hill and Roxby gives the area a good address. Geological understanding is limited due to excessive cover"

"Findability is an issue because of the extent and depth of cover"

"Under explored, not well understood geology due to widespread cover. Drilling has largely been shallow air core generating little true stratigraphic info"

Impediments to exploration in the Province?

Impediments to exploration	major	impediment %	minor	impediment %	Don't	know %
a. past exploration	4	*13*	25	*83*	1	*3*
b. depth of cover	21	*66*	11	*34*	0	*0*
c. ground availability	10	*33*	18	*60*	2	*7*
d. native title/sovereign risk	6	*18*	23	*70*	4	*12*
e. access to old drill core	3	*10*	19	*63*	8	*27*

Table 5.7. Industry Survey- assessment of impediments to exploration.

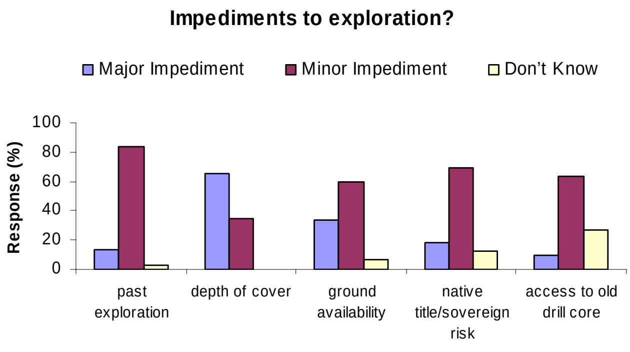


Figure 5.6. Industry Survey- assessment of impediments to exploration.

- Depth of cover was most frequently identified as the major impediment to exploration.
- Followed some way behind by ground availability

- Level of past exploration and native title and sovereign are seen as only minor impediments, though 2 junior companies commented on the large amount of time and money spent on dealing with Native Title issues.
- 12/15 ‘other’ impediments identified were rated as major, including
  - poor geological understanding of province;
  - lack of new exploration model;
  - lack of synthesis/compilation of previous exploration;
  - poorly located data;
  - data straddles two states; people stuck on stratabound model;
  - geological complexity of zone;
  - high cost

Twenty eight respondents made additional comments, generally in response to the prompt ‘What would make Curnamona more attractive to you?’ The following were most frequent:

- Better geological understanding of the area through better data synthesis (9 respondents)

“better use of old non digital data”

“depth to bedrock and detailed bedrock interpretation maps”

- Quality gravity coverage (7 respondents)

“200m flight line spacing airborne gravity”

- Greater turnover of ground (4 respondents)

“tender system to assist with more frequent ground turnover…reduce incidence of ‘real-estating”
“mandatory statutory reduction”

What would encourage your company to increase its interest in Province?

8.What would increase interest	total	%
a. mineralisation model	13	*39*
b. better data synthesis	21	*64*
c.increase geophysical cover	25	*76*
ci.gravity	23	*70*
cii.magnetics	7	*21*
ciii.radiometrics	4	*12*
d.depth to basement maps	14	*42*
e.stratigraphic drilling	26	*79*
f.seismic	7	*21*
g.prospectivity maps	4	*12*
h.integrated 3D/4D models	8	*24*
I. commercial incentives	14	*42*

Table 5.8. Industry Survey- assessment of factors increasing interest in exploration.

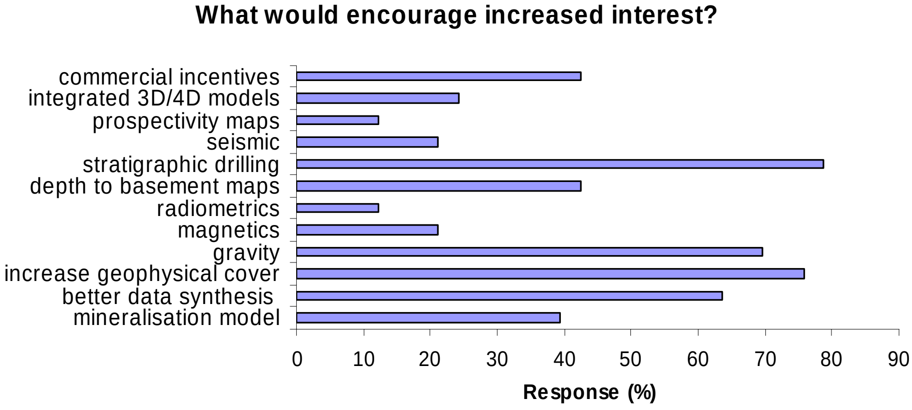


Figure 5.7. Industry Survey- assessment of factors increasing interest in exploration.

- Stratigraphic drilling, increased geophysical cover (specifically gravity) and better data synthesis were most frequently identified.
- No major differences between respondents from majors and juniors and consultants
- 14 respondents identified other things or provided additional comments about what would encourage their company to increase its interest in the province.

Comments covered a wide range of issues:

- Change of corporate strategy
- A new discovery
- Better geological understanding of covered areas
- Sedimentological comparison with N Aust Basins (gamma ray)
- Publish a geological framework like NW Qld study by Taylor & Wall
- Basement maps
- Airborne EM (palaeochannels)
- Better age dates (and validated locations, outcrop descriptions)
- Expensive area to explore, juniors need assistance
- Drill expenditure = x2 expenditure for Mines Dept commitments
- Increase tenement turnover
- Stratigraphic drill hole in McLennan's Syncline E of Hunters Dam
- Systematic mapping at 1:1000 to 1:500 scale of range of prospects
- List of all Native Title Heritage Sites

Rating of coverage of databases

NSW databases	excellent	**%**	good	%	adequate	%	poor	%	DK	%	Total
a.magnetics	14	*31*	10	*31*	2	*6*	0	0	6	*19*	32
b.gravity	3	*6*	10	*31*	3	*9*	7	*22*	9	*28*	32
c.radiometrics	4	*10*	15	*48*	1	*3*	1	*3*	10	*32*	31
d.drill hole data	1	*3*	7	*23*	6	*19*	6	*19*	11	*35*	31
e.geochemistry	1	*0*	2	*6*	9	*29*	7	*23*	12	*39*	31
f.depth-basement	0	*0*	1	*3*	13	*42*	3	*10*	14	*45*	31
g.regolith	1	*0*	7	*23*	5	*16*	3	*10*	15	*48*	31
h.geochronology	1	*0*	7	*23*	10	*32*	2	*6*	11	*35*	31
I.geology	7	*3*	10	*32*	4	*13*	1	*3*	9	*29*	31
j.summaries of past expl.	0	*3*	7	*23*	5	*16*	6	*19*	13	*42*	31

Table 5.9. Industry Survey- rating of database coverage in NSW.

SA databases	excellent	**%**	good	%	adequate	%	poor	%	DK	%	Total
a.magnetics	10	*30*	15	*45*	3	*9*	2	*6*	3	*9*	33
b.gravity	2	*6*	8	*24*	9	*27*	9	*27*	5	*15*	33
c.radiometrics	3	*10*	11	*35*	6	*19*	5	*16*	6	*19*	31
d.drill hole data	1	*3*	9	*27*	6	*18*	10	*30*	7	*21*	33
e.geochemistry	0	*0*	3	*9*	6	*18*	17	*52*	7	*21*	33
f.depth-basement	0	*0*	7	*21*	10	*30*	9	*27*	7	*21*	33
g.regolith	0	*0*	5	*16*	4	*13*	8	*25*	15	*47*	32
h.geochronology	0	*0*	5	*16*	9	*28*	9	*28*	9	*28*	32
I.geology	1	*3*	6	*18*	9	*27*	12	*36*	5	*15*	33
j.summaries of past expl.	1	*3*	8	*27*	9	*30*	3	*10*	9	*30*	30

Table 5.10. Industry Survey- rating of database coverage in South Australia.

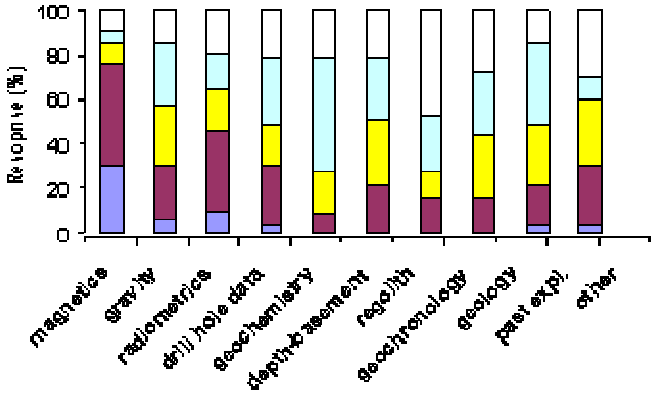


Figure 5.8. Industry Survey- rating of database coverage in NSW.

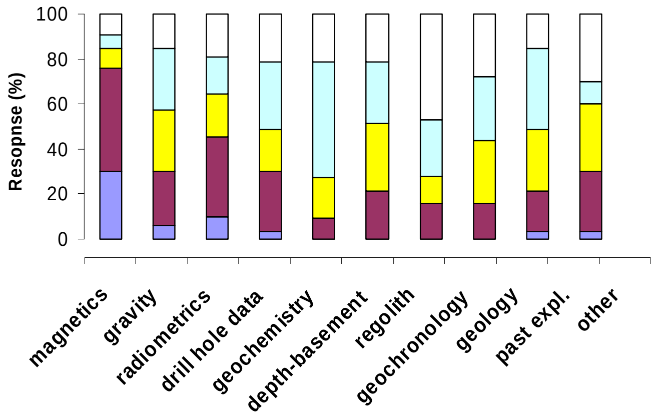


Figure 5.9. Industry Survey- rating of database coverage in South Australia.

There was a mixed range of knowledge depending on current exploration interest and focus.
For NSW:

- magnetics and radiometrics were rated as excellent or good by approx 60% of respondents
- drill-hole data and geochemistry were rated as poor by approx 20% respondents

For SA

- magnetics was rated as excellent or good by 75% of respondents, followed by radiometrics (45%).
- 50% of respondents rated geochemistry as poor by, 25% or more ---respondents rated geology, drill-hole data, geochronology, gravity, depth-basement and regolith as poor.
- Overall, ratings were lower for SA databases.
-

Awareness of organisations' work in the province?

9. Awareness of work	fully	%	s'what	%	DK	%
a. Geoscience Aust	6	*18*	19	*58*	8	*24*
b. NSW DMR	10	*30*	18	*55*	5	*15*
c. PIRSA	11	*33*	18	*55*	4	*12*
d. pmd*CRC	4	*12*	11	*33*	18	*55*
e. CRCLEME II	2	*6*	14	*42*	17	*52*
N=33						

Table 5.11. Industry Survey- rating of government agency awareness.

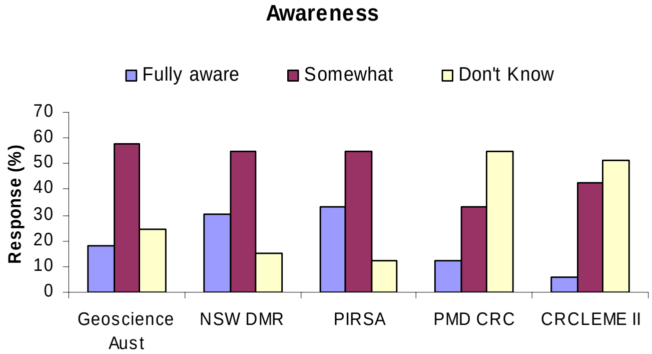


Figure 5.10. Industry Survey- rating of government agency awareness.

Although a large number of respondents were fully or somewhat informed about the work of Geoscience Australia, NSW DMR and PIRSA, more than 50% did not know of the work being done by pmd*CRC and CRCLEMEII.

General Comments

There were relatively few general comments as most had been put in other parts of the survey. Some reiterated earlier comments, others had new comments**.** Some example quotes include:

- *"Stop navel gazing, and get on with it!"*
- *"Research rarely finds orebodies and a better use of available funds would be to reduce the amount of "researching" that is being done and increase the amount of useful data collection, particularly as it relates to the third dimension, through drilling and detailed gravity."*
- *"Researching past exploration data and presenting this in a way that it can be easily used, as raw factual data, rather than interpretation, would be very useful"*

5.2 Researchers Survey

5.2.1. Conclusions and Recommendations

Conclusions

1. A survey of 50 academics about the Curnamona Province received 29 replies, an impressive response rate of 58%.

2. 83% of the respondees were actively involved in research in the Curnamona, mainly at Australian Universities with connections to the pmd*CRC and CRCLEMEII.

3. 60% of respondees held positions of lecturer, project leader or other senior positions, and 40% were post graduates engaged in a wide range of research studies, the main ones being geochronology (34%) and structure (31%) followed equally by ore genesis and alteration and fluid flow.

4. When asked to rank the level of geological knowledge of the Curnamona Province and to compare with other areas in Australia, around half of the respondents rated Curnamona Province below Mt Isa and the Lachlan Fold Belt. However, nearly 40% of respondents rated the general level of geological knowledge of Curnamona as adequate; and the Curnamona received generally a higher rating than the Yilgarn, Pilbara and Tanami areas. One theme of the comments received was there seemed to be a lot of data on Curnamona but understanding is poor.

5. At an international level, over ¾ of respondents rated interest in the Curnamona Province as medium to low. Many noted that the main interest has been in the Broken Hill deposit itself, and that there is little interest from overseas researchers outside the deposit.

6. Researchers reported two very consistent views about impediments to research. Over half considered that the lack of funding was a major impediment, but nearly 60% of respondents considered, somewhat ironically, that the high level of previous research was not an impediment to research.

7. Around 40% considered that access to land and shortage of students were minor impediments to research. However, about one third of all respondents did not consider that access to land, access to drill core, access to company data and confidentiality issues were impediments at all to research. Strong comments were received concerning the difficulty in doing truly cooperative research in the Curnamona due to others' "protecting territory" and the "dogmatic" attitudes.

8. Georef and Survey publications are the main sources of information followed in ranking by AJES, Economic Geology and 'Other' including Survey Geologists, Conference Abstracts, web sites generally, and other publications. SARIG, DIGS and GA Website are not commonly used sources of information for researchers.

9. Except for a higher rating for geology in NSW, researchers generally rated NSW and SA databases similarly. However, there is a slightly higher proportion of researches who are not familiar with NSW databases which possibly reflect their focussed research activities in SA. The different regolith mapping schemes used in NSW and SA make correlation between maps difficult.

10. Compared with industry responses from an earlier survey which asked the same question, significant differences were highlighted in the assessment of geology, with ~70-90% of researchers rating geology as adequate or above, compared with industry's response of 40-60%, and geochemistry rating of 60% as adequate or above compared with only 20-40% from industry. Researchers rated gravity databases much higher than industry (70-80% v 50% as adequate or better), whereas researchers rated the radiometric coverage lower with a significant proportion (40-50%) of researchers saying that they "don't know" about radiometric data bases.

11. Robust mineralisation models and synthesis of existing data sets were ranked by researchers as the two biggest knowledge gaps, followed by alteration synthesis and 3D structural models. Apart from a relatively lowly ranked depth to basement category, others such as time space framework, geochronology, regolith geology and metamorphic studies were generally clustered in a similar response range in terms of knowledge gaps.

12. In order to address knowledge gaps a major theme of the majority of responses was to have a coordinated compilation, integration and synthesis of data at the province scale. Such a study would assist in bringing together a coherent tectonic and metamorphic evolution of the province including robust structural framework, fluid flow, alteration and timing.

13. The majority of researchers are aware of GA, NSW DMR and PIRSA activities in the Curnamona Province but surprisingly they are less aware of the work being undertaken under the banner of pmd*CRC and CRCLEMEII.

14. The survey highlighted knowledge gaps surrounding issues such as :

- Volume and access to literature
- Large gaps in knowledge depending on workers experience in the Curnamona Province
- Journal editorial policy

These are real and perceived deterrents to advancing understanding and progress in the Curnamona Province but they can be fixed.

Recommendations

1. The clear message from researchers is that a major knowledge gap in the Curnamona Province would be addressed by coordinated compilation, integration and synthesis of data at the province scale. Such a study would assist in bringing together a coherent tectonic and metamorphic evolution of the province including robust structural framework, fluid flow, alteration and timing.

2. Consideration should be given to revamping the old MMA library which is currently split between Perilya and DMR, and, where possible, to update the library by the inclusion of the most recent theses and unpublished materials. All materials should be scanned and accessible via the web.

3. A major knowledge gap exists between experienced workers in the Curnamona and many academics who are simply not aware of past work and rely of published materials only. There is a wealth of unpublished data available, subject to confidentiality issues, that should be collated and made available. This would go a long way of addressing the reinventing the wheel issues that appear to restrain progress in the Curnamona Province.

5.2.2. Scope of Data

See Methodology

5.2.3. Methodology

Survey Distribution

The selection of researchers was based on the attendees list at the Broken Hill Exploration Initiative 2003 conference held in Broken Hill, July 2003, and people known to the authors who had either current or recent research interest in the Curnamona Province. Some 50 researchers were included in the survey. The vast majority surveyed were researchers in Australian Universities. The survey was emailed out on an individual basis between 9-15 October and the majority of responses were received by the 20th October. A good bottle of wine was offered as an incentive to complete the survey, and the winner, Dr Peter Betts of Monash University, was drawn by Dr Graham Carr, Deputy Chief, CSIRO Exploration and Mining on Melbourne Cup Day at CSIRO's North Ryde Laboratories.

The survey sought information about:

- the workplace and position held by respondent;
- whether research was currently being undertaken in the Curnamona Province;
- if exploration was being conducted, what was being studied; if not, the reasons for this;
- assessment of the general level of geological understanding of the Curnamona Province, and, for comparison, the Mt Isa, Yilgarn, Gawler, Lachlan Fold Belt, Tanami and Pilbara areas;
- the level of international interest in the Curnamona Province;
- impediments to exploration in the Province;
- their 5 main sources of information about the Province;
- database coverage for NSW and SA about such things as magnetics, gravity, radiometrics, geochemistry, drill hole data, depth to basement, regolith, geochronology, geology and summaries of past exploration;
- the gaps in knowledge about the Province and what types of study would best address these gaps;
- knowledge of the work being undertaken in the Province by groups such as Geoscience Australia, NSW DMR, CRCLEMEII and pmd*CRC.

A copy of the survey is appended (Appendix 2).

5.2.4. Assessment of Data

Who Responded

Of the 50 surveys emailed, 29 replies were received, an overall excellent response rate of 58%. In most instances all questions and parts of question were answered.

Who are you working for?

Table 5.2.1 Researchers Survey-Work Place

Institution	Number	%
CRCLEME	7	*24*
pmd*CRC	5	*17*
Australian University	20	*69*
SRC	3	*10*
Other	3	*10*
Total	39	*100*

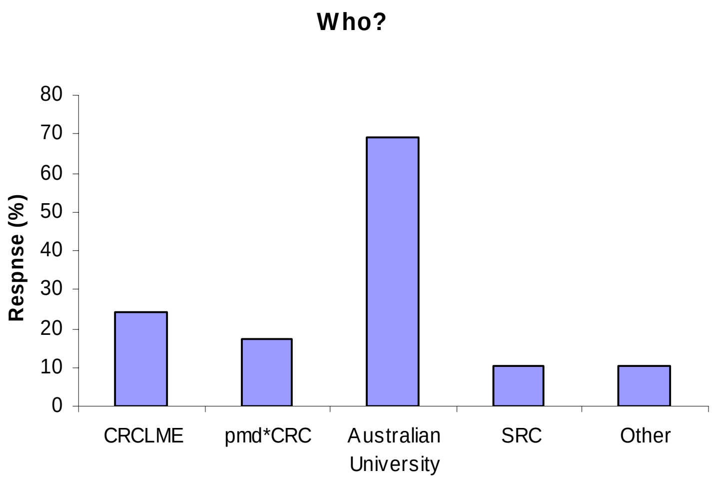


Figure 5.2.1 Researchers Survey-Work Place

The majority of responses came from researchers in Australian Universities (69%) with affiliations to either CRC LEME (24%) or pmd*CRC (17%). Just over 10% of responses were received from SRCs and from overseas institutions (3 responses each).

Position

Table 5.2.2 Researchers Survey-Position of Respondents

Position	**Number**	**%**
Post Grad	12	*41*
Lecturer	5	*17*
Project Leader	5	*17*
Other	7	*24*
total	29	*99*

About 60% of the respondents hold positions of lecturer, project leader or other positions such as Professorships in universities, CRCs or SRCs while around 40% of the respondents are post graduate students.

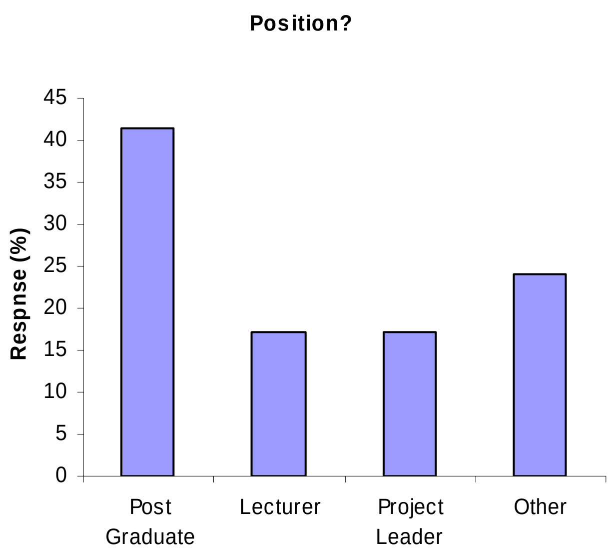


Figure 5.2.2 Researchers Survey-Position of Respondents

Currently Working in the Curnamona Province

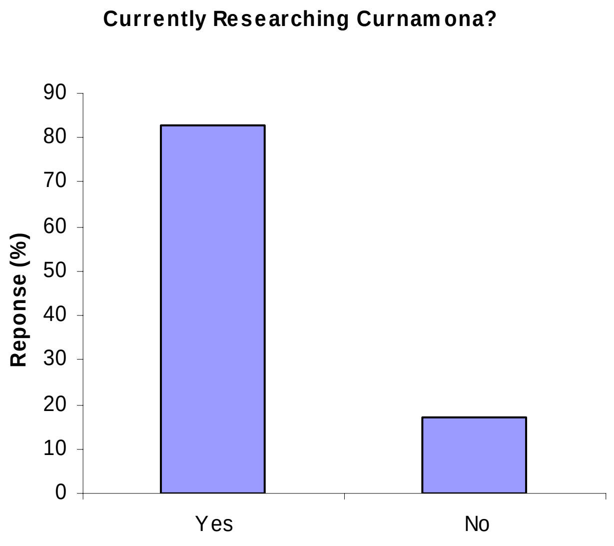


Figure 5.2.3 Researchers Survey-Currently active in Curnamona

Table 5.2.3 Researchers Survey-Current Research Topics

Research Topic	**Number**	**%**
Ore genesis	7	*24*
Structure	9	*31*
Stratigraphy	5	*17*
Metamorphism	7	*24*
Alteration and Fluid Flow	7	*24*
Regolith	6	*21*
3D/4D Regional Modelling	3	*10*
Geophysics	3	*10*
Remote sensing	5	*17*
Geochronology	10	*34*
Other	8	*28*

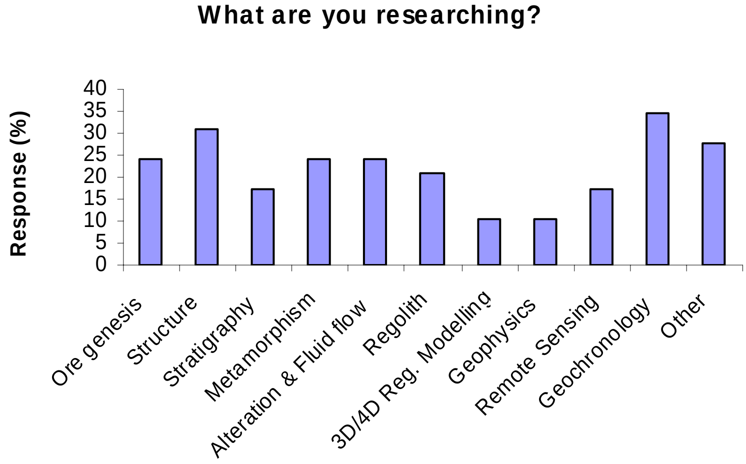


Figure 5.2.4 Researchers Survey-Current research topics

The majority of respondents (83%) are currently involved in research in the Curnamona Province, and they tend to work across a number of disciplines. The highest number of responses include studies of geochronology (34%) and structure (31%) followed equally by ore genesis and alteration and fluid flow. 'Other' topics that were mentioned by 28% of respondents included specific projects such as continental scale studies, volcanic and magmatic events, mineral studies, imaging spectroscopy and environmental and biogeochemistry.

General Level of Knowledge of Curnamona

Table 5.2.4 General Level of Knowledge of Curnamona & Comparison With Other Areas in Australia

%	Excellent	Good	Adequate	Poor	Don't Know
Curnamona	*7*	*28*	*38*	*28*	*0*
Mt Isa	*7*	*48*	*10*	*10*	*21*
Yilgarn	*7*	*31*	*17*	*7*	*38*
Gawler	*0*	*17*	*31*	*28*	*21*
Lachlan Fold Belt	*7*	*48*	*21*	*14*	*7*
Tanami	*3*	*0*	*21*	*45*	*34*
Pilbara	*7*	*14*	*38*	*10*	*31*

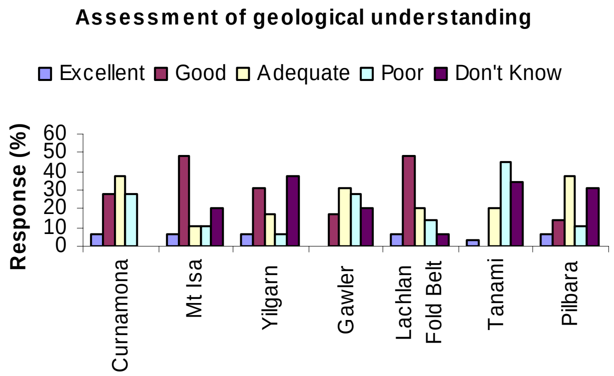


Figure 5.2.5 General Level of Knowledge of Curnamona & Comparison With Other Areas in Australia

Around half of the respondents rated the general level of geological knowledge of the Curnamona Province below that of Mt Isa and the Lachlan Fold Belt. However, 38% of respondents rated the general level of geological knowledge of Curnamona as adequate (though 2 respondents questioned the use of this term and preferred the term 'moderate'); and generally the Curnamona received a higher rating than the Yilgarn, Pilbara and Tanami, with Tanami receiving the overall lowest ranking in terms of the level of geological knowledge (46%). Approximately 1/3 of respondents said that they did not know about the state of knowledge of the Yilgarn, Pilbara and Tanami provinces. This lack of knowledge, doubtless reflects their current research interests.

Around half of the respondents also added specific comments. The two main themes from these comments were that there seemed to be a lot of data on Curnamona but understanding is poor, e.g., tectonic evolution and signatures of hydrothermal alteration of mineralising systems; and that the answer to the question is very subjective, mostly based on personal experience and opinion.

"The state of knowledge on the geological understanding of the Curnamona is very inhomogeneous"

International Interest

In terms of international interest in the Curnamona province, over ¾ of respondents rated it as medium to low. Half of the respondents added comments and the majority noted that the main interest has been in the Broken Hill deposit itself, and that there is very little interest from overseas researchers outside the deposit.

"It is only high (level of international interest) because of the Broken Hill deposit; otherwise it would be medium"

Broken Hill is of international interest, the rest is hardly noticed"

"Only given the Broken Hill deposit, the BHEI Conference has kept the interest levels above low."

Impediments to Research

Table 5.2.5 Researchers Survey-Impediments to Research

%	Major	Minor	Don't Know	Not an Impediment
Lack of funds	55	21	7	7
Access to land	3	38	14	34
Access to company data	14	24	24	34
Access to drill core	10	24	17	41
Confidentiality issues	14	17	24	38
Shortage of students	14	41	10	31

High level of previous research	*0*	*31*	*7*	*59*

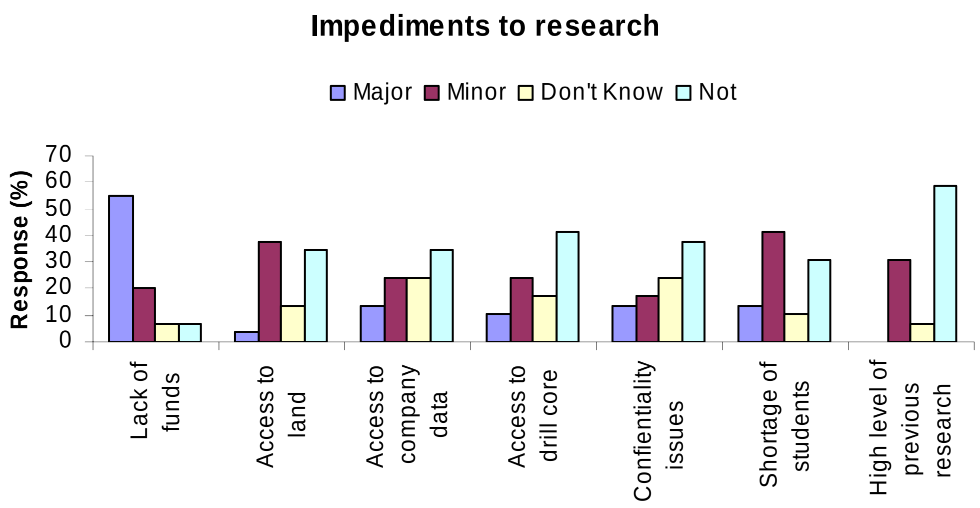


Figure 5.2.6 Researchers Survey-Impediments to Research

There were two very consistent views amongst researchers about impediments or lack of them to research. Over half (55%) considered that the lack of funding was a major impediment, and nearly 60% of the respondents considered that the high level of previous research was not an impediment to research. Around 40% considered that access to land and shortage of students were minor impediments. However, about one third of all respondents did not consider that access to land, access to drill core, access to company data and confidentiality issues were impediments at all to research.

Of the 8 respondents who made additional comments, two noted the lack of industry related funding, and the difficulty of obtaining ARC funds for any kind of "applied" research in the Curnamona province. Two other respondents commented that impediments to research revolved around the difficulty in doing truly cooperative research due to others' "protecting territory" and "dogmatic" attitude.

One response noted the access to previous work, especially company research and lost files from the MMA library was an impediment.

"It is disturbing to see how much "re invention" of the wheel there is as a result of either poor access or lack of knowledge of what has been done in the past"

This comment is interesting given the overwhelming response that past research was definitely not an impediment.

Sources of Information

Table 5.2.6 Researchers Survey-Sources of Information

Sources of Information	Number	%
SARIG	10	*34*
DIGS	8	*28*
GA Website	11	*38*
Georef	20	*69*
Econ Geol	16	*55*
AJES	18	*62*
Survey Publications	25	*86*
Consultants	8	*28*
Company Geologists	18	*62*
Other	15	*52*

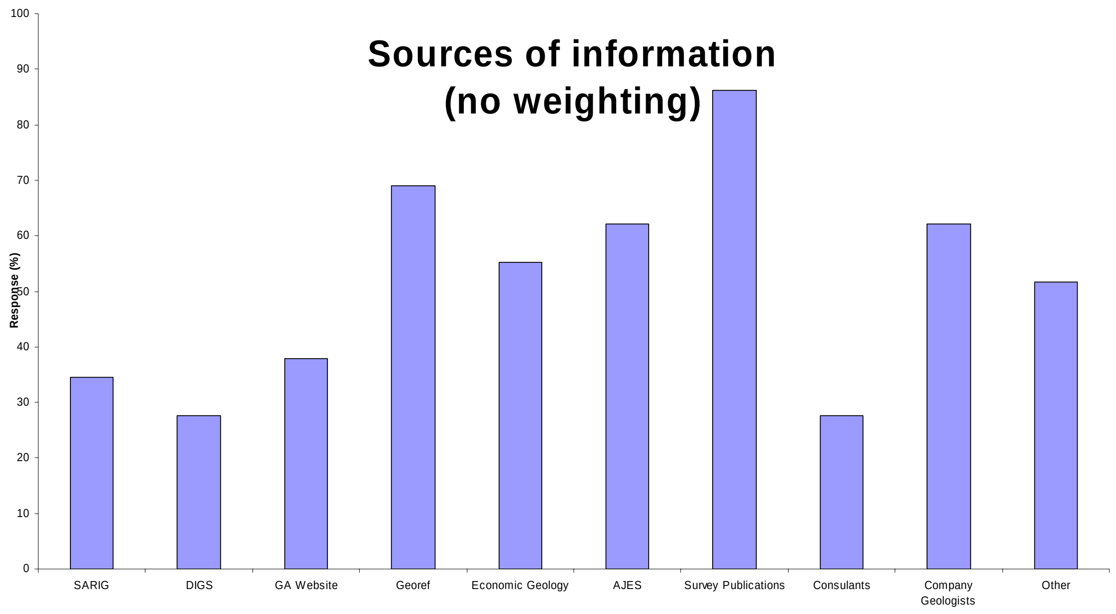


Figure 5.2.7 Researchers Survey-Sources of Information (no weighting)

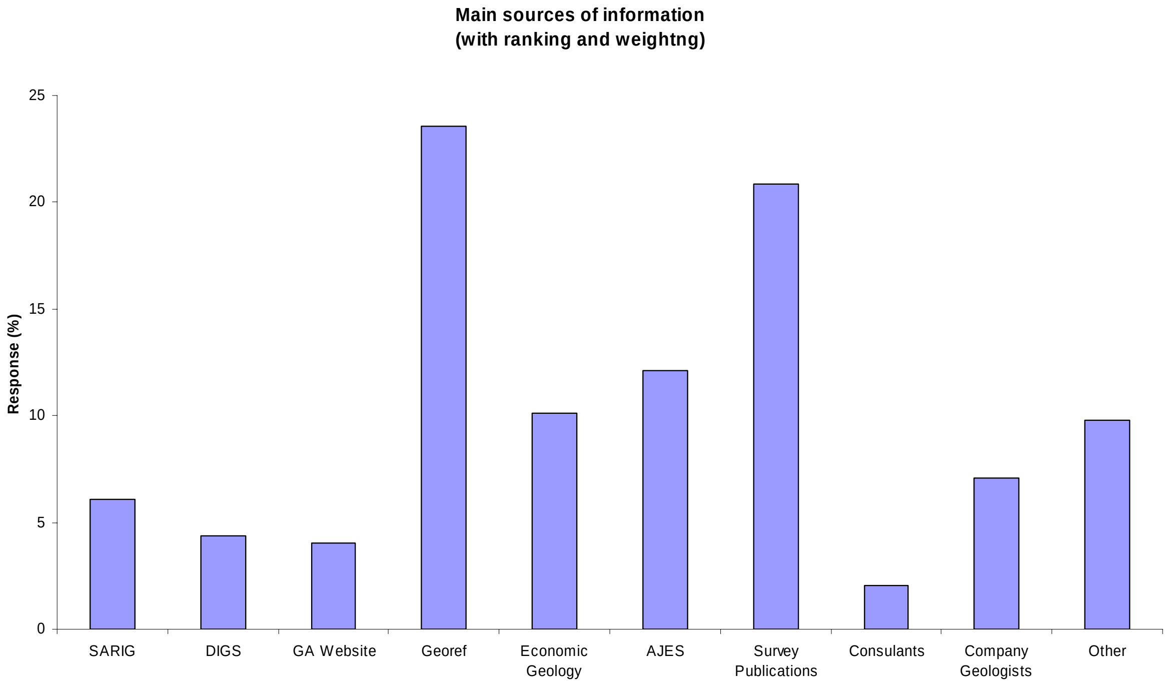


Figure 5.2.8 Researchers Survey-Sources of Information (with ranking & weighting)

Researchers were asked to rank their 5 main sources of information for the Curnamona from a list of 10. Around 70% responded appropriately to the question; with the other 30% responding but omitting a ranking.

Using all the responses and no ranking nor weighting as shown in the above table, Survey Publications (86%) and Georef (69%) scored most highly with company geologists and AJES being equal third.

The 70% of appropriate responses were weighted according to rank. For example, a weighting of 5 was given to their highest ranked source of information, 4 to their second choice, 3 to their third choice, 2 to their fourth choice and no weighting to their fifth choice. Two main sources of information were highlighted: Georef (24%) and Survey publications (21%) followed by AJES (12%), Economic Geology (10%) and "Other" (10%) in order of ranking. 'Other' sources of information included Survey Geologists, Conference Abstracts, web sites generally, and other publications not listed. Survey geologists were an often quoted 'other' source of information.

All respondents ranked consultants , SARIG, DIGS and GA Website low as their sources of information. For example, between 2 and 6% for the 5 top weighted ranking and between 28 and 38% for all the non ranked and non weighted responses.

Rating of Public Databases

Researchers were asked to rate the public databases in NSW and SA. This question was identical to the one asked of industry.

Table 5.2.7 Researchers Survey-Rating Of Public Data Bases

NSW databases	excellent	**%**	good	%	adequate	%	poor	%	DK	%
magnetics	6	*21*	12	*41*	6	*21*	0	0	5	*17*
gravity	1	*3*	17	*59*	5	*17*	1	*3*	5	*17*
radiometrics	3	*10*	5	*17*	6	*21*	0	*0*	14	*48*
drill hole data	1	*3*	6	*21*	6	*21*	2	*7*	14	*48*
geochemistry	1	*3*	9	*31*	8	*28*	4	*14*	7	*24*
depth-basement	0	*0*	6	*21*	4	*14*	4	*14*	15	*52*
regolith	2	*7*	8	*28*	6	*21*	3	*10*	10	*34*
geochronology	4	*14*	10	*34*	7	*24*	3	*10*	5	*17*
geology	6	*21*	10	*34*	10	*34*	1	*3*	2	*7*
summaries of past expl.	2	*7*	6	*21*	6	*21*	2	*7*	11	*38*

SA databases	excellent	**%**	good	%	adequate	%	poor	%	DK	%
magnetics	4	*14*	11	*38*	6	*21*	1	*3*	6	*21*
gravity	1	*3*	11	*38*	8	*28*	1	*3*	7	*24*
radiometrics	1	*3*	8	*28*	8	*28*	0	*0*	11	*38*
drill hole data	2	*7*	9	*31*	6	*21*	3	*10*	7	*24*
geochemistry	0	*0*	7	*24*	9	*31*	5	*17*	7	*24*
depth-basement	0	*0*	6	*21*	7	*24*	5	*17*	10	*34*
regolith	2	*7*	3	*10*	8	*28*	6	*21*	8	*28*
geochronology	1	*3*	8	*28*	9	*31*	4	*14*	6	*21*
geology	2	*7*	11	*38*	6	*21*	3	*10*	6	*21*
summaries of past expl.	0	*0*	9	*31*	6	*21*	0	*0*	13	*45*

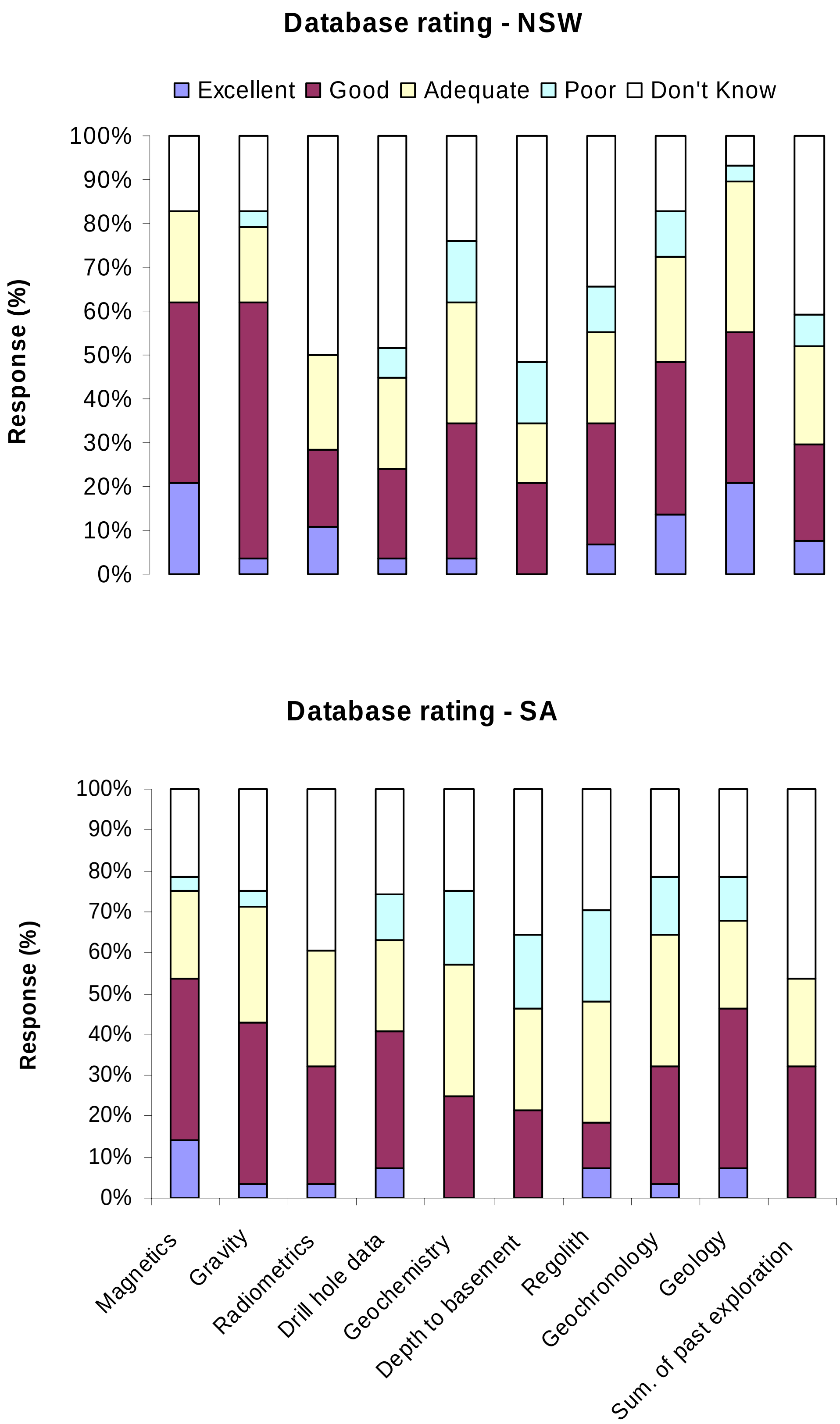


Figure 5.2.9 Researchers Survey-Rating of Public Databases.

In general the results for NSW and SA are similar, with magnetics and gravity being given an adequate to excellent rating. Except for a higher rating for geology in NSW, most of the other categories are similar. However, there is a slightly higher proportion of researches who are not familiar with NSW databases as these received a higher “don’t know’ response compared with SA.

Only a small number of responses included additional comments to this section. Two commented on the quality of radiometric coverage (patchy, poor resolution for detailed work), and the differing regolith mapping schemes used in NSW and SA making correlation between maps difficult.

Compared with industry responses, the researchers’ responses give similar ratings for magnetics, depth to basement and summary of past exploration. Researchers, however, give a superior rating to gravity, drill holes, geochemistry, regolith, geochronology and geology. Specifically, they revealed significant differences in their assessment of geology (~70-90% of researchers rate as adequate or above, compared with industry’s 40-60%), and geochemistry 60% as adequate or above compared with 20-40% in industry.

Overall, the researchers rate gravity databases much higher than industry (70-80% v 50% as adequate or better), whereas the researchers rate the radiometric coverage lower with a significant proportion (40-50%) of researchers saying that they don’t know about radiometric data bases.

Knowledge Gaps

Table 5.2.8 Researchers Survey-Ranking of Knowledge Gaps in Curnamona

Topic	**Number**	**%**
Robust mineralisation models	23	*79*
Synthesis of existing data	21	*72*
3D structural models	19	*66*
Time space frame work	20	*69*
Geochronology coverage	19	*66*
Depth to basement studies	14	*48*
Fluid Flow models	17	*59*
Interpretative regional geology	19	*66*
Metamorphic studies	19	*66*
Regolith 3D studies	17	*59*
Seismic interpretation	17	*59*
Stratigraphic framework	17	*59*
Alteration synthesis	20	*69*
Other	10	*34*

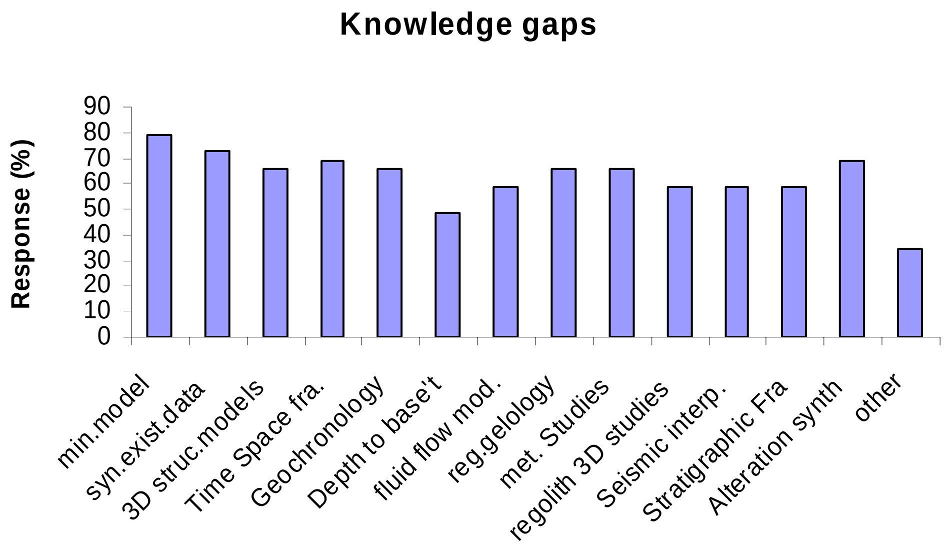


Figure 5.2.10 Researchers Survey-Ranking of Knowledge Gaps in Curnamona

Researchers were asked to rank in order of importance knowledge gaps in Curnamona from a list 16 categories, and then offer suggestions for the types of study that would best address their top 3 choices.

Robust mineralisation models (79%) and synthesis of existing data sets (72%) ranked highest of the knowledge gaps, followed by alteration synthesis and 3D structural models (both 69%). Apart from a relatively lowly ranked depth to basement category (48%) other categories such as time space framework, geochronology, regolith geology and metamorphic studies were generally clustered in the 59-66% response range.

Ten respondents made additional comments with a general theme that this section was difficult to do or answer because some points are necessary ingredients in others. Recurring themes are addressed in the next section.

Studies To Address Top 3 Knowledge Gaps

Not surprisingly, there were wide ranging, general to highly detailed suggestions to this question from the 21 responses received, reflecting current and possibly future specific interests of researchers. For example, “geochronological”, “further geochemistry” “use of geophysical and geochemical methods to assess the geology and mineralisation potential under cover sequences”, “spectral characterisation of alteration minerals” “detailed, prospect scale mapping, 3D modelling in areas of known mineralisation”, “study of magmatic and volcanic units, ore types, and alteration geochemistry” “studies on the remotely sensed signatures of mineralisation: magnetics, radiometrics and hyperspectral” and “quantitative structural analysis and stress analysis“ and “more regolith studies!” to name a handful.

A major theme, however, of the majority of responses was to address knowledge gaps by a coordinated compilation, integration and synthesis of data at the province scale. Such a study would assist in bringing together a coherent tectonic and metamorphic evolution of the province including robust structural framework, fluid flow, alteration and timing.

Awareness of Other Work

Table 5.2.9 Researchers Survey-Awareness of Other Work

	Fully Informed	%	**Somewhat Informed**	%	**Don't Know**	%
Geoscience Australia	7	*24*	18	*62*	2	*7*
Nsw DMR	11	*38*	13	*45*	3	*10*
PIRSA	12	*41*	14	*48*	1	*3*
pmc*CRC	7	*24*	9	*31*	11	*38*
CRCLEME II	10	*34*	11	*38*	7	*24*

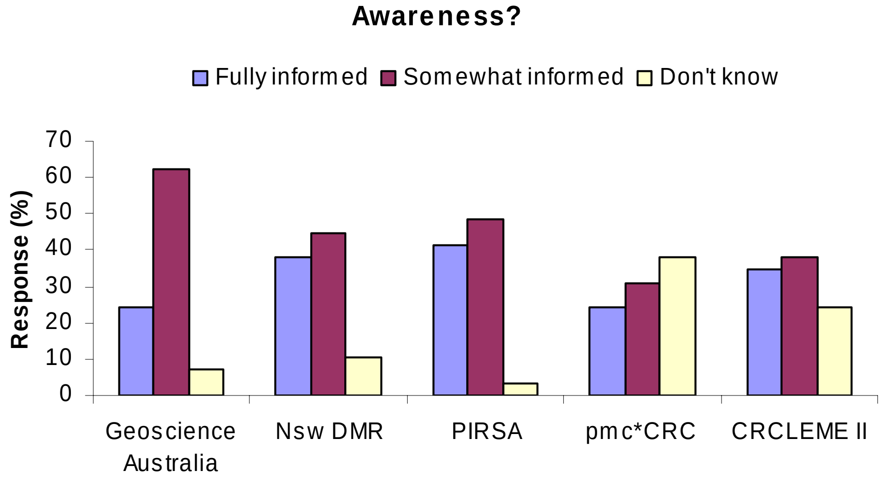


Figure 5.2.11 Researchers Survey-Awareness of Other Work

Researchers were asked to comment on their awareness of other work being undertaken by GA, NSW DMR, PIRSA , pmd*CRC and CRCLEMEII in the Curnamona Province, in the precisely the same way as asked in the industry survey. The vast majority are either somewhat or fully aware of GA, NSW DMR and PIRSA (83-89%) but are less aware of the work under the banner of pmd*CRC (55%) and CRCLEMEII (72%).

Compared with the industry responses, researchers are more aware of the work being undertaken by GA (86% v 72%) but about the same for NSWDMR and PIRSA. Researchers' awareness about CRCLEMEII is significantly higher than industry's (72% v 48%) and higher for pmp*CRC (55% v 45%). A big surprise, considering that the survey was done after the BHEI in July 2003 at which the vast majority of the researchers attended, was that a number of respondents (38% and 24%) did not know about the work being undertaken by pmd*CRC and CRCLEMEII. This result, however, is an improvement compared with industry's lack of knowledge of the work of pmd*CRC (55%) and CRCLEMEII (48%).

Other Comments

Of the 8 responses received, two re-emphasised the lack of funding for research in the Curnamona and the lack of major company interest.

One person expressed concern about duplication of research by not knowing what had done in the past:

"There is considerable 'reinvention of the wheel' as new researchers to the Curnamona Province commonly do not adequately discover, access and acknowledge the value of previous research"

Another emphasised a new approach:

"If research is to be successful at Curnamona, it needs anew research team with new ideas and a more pragmatic approach. Very little of the previous research has, in my opinion, helped understand why Broken is where it is. Discussions on the IOCG deposits has also been very naïve"

More specific recommendations included:

"The state should develop a set of type drill holes from companies that encourage researchers to conduct investigations in a 'geological framework' that will ensure research breaks new ground rather than resurrecting past ideas that have been based on 100 years of daily observations of mine staff"

Another suggested that

"less hydrogeochemistry and less remote sensing in areas where we know about rocks sticking out of the ground (i.e., stop splashing around in the shallow end of the pool"

Issues

See Discussion (Chapter 12)

6.1 Regional Studies

Conclusions

- There is no agreement on the structural history for the Curnamona Province.
- Unpublished company stratigraphic-structural works represent a valuable resource that could significantly aid the assessment of regional stratigraphic and structural models and improve the understanding of the evolution of the Curnamona Province.
- There is a need for an integrated, structural-stratigraphic synthesis of the Curnamona Province. This synthesis would be especially useful to new explorers in the region.

Recommendations

- Consider approaching Perilya or other relevant companies to obtain unpublished reports.
- Compile and digitise available hard-copy structural data, and put this into a consistent structural framework.
- Consider compiling an updated Curnamona structural-stratigraphic synthesis and incorporating this with public-release GIS datasets.

Scope of Data

This compilation has focused on recording regional-scale company, university and geological survey projects, which span at least an area of several tenements, or several map sheets. The assessment did not include any single map sheet, university thesis or tenement.

Methodology

A list of relevant studies was compiled with the assistance of DMR and PIRSA. These were assessed in terms of focus, integration of various data sets, and quality.

Assessment of the Data

An overview of the entire Curnamona Province is given in Robertson et al. (1998) and Robertson et al. (2002). Key regional studies for domains comprising the Curnamona Province are given below, and in the accompanying spreadsheet.

For the combined Olary/Broken Hill domains, the geology is summarised by Flint and Parker (1993). Rankin (1998b) produced an interpretation largely from detailed aeromagnetics.

In the Broken Hill Domain, the DMR (eg. Stevens, 1980; Stevens et al, 1988; Willis et al., 1983; Willis et al., 1989) has produced excellent lithostratigraphic maps and associated reports focussed on the stratigraphy (mineralisation is discussed separately). Structural studies at this scale (Hobbs et al., 1984, Laing, 1996; White et al., 1995) have generally agreed on two high-grade fold events with later "retrograde" shearing. Archibald et al. (2000) constructed an internally consistent 3D model based on the DMR stratigraphy and incorporating both Broken Hill line-of-lode and regional structural interpretations.

For the Olary Domain, geological syntheses have been completed by Ashley (2000); Ashley et al. (1997); Conor (2000; 2002) and Clarke et al. (1986). Laing (1995) compiled prior geological mapping, while Mills (1986) and Hills et al. (2003) used geophysical data to derive regional interpretations.

The geology of the Mount Painter-Mount Babbage Inliers is summarised by Teale (1998).

Issues

There continues to be a lack of agreement on the structural evolution of the Curnamona Province. This has become a major issue because:

- A structural compilation of the entire Curnamona Province has never been attempted until Laing et al. (1996).
- DMR geological mapping have relied heavily on company structural mapping and their own maps have structural data without context.
- PIRSA geological mapping has been sporadic, and initially relied on stratigraphic correlations from the Broken Hill Domain.
- GA, as part of the BHEI, attempted to bring the structural story together, however the project focused on a limited number of areas and was unable to deliver an integrated stratigraphic-structural model for the entire province.
- There is a lack of readily accessible (especially digital) structural data, and new structural projects are required to 'start from scratch'.

Thus there is no universally accepted structural framework in use for the Curnamona Province or sub-domains therein.

PIRSA have digital structural data recorded for their recent 1:100 000 map sheets; however structural data from DMR map sheets, company and academic structural databases have not been compiled. To do so would require interpretation into various "S_0, S_1, S_2, S_3, etc." fabrics which then need to be put into a consistent framework and within domains of consistent structural relationships. With the aid of field validation and geochronological constraints, this may allow the complex stratigraphic-structural history to be unravelled.

Company reports and associated digital data represent a potentially valuable resource in terms of assessing various regional stratigraphic – structural models.

Identified Gaps

- Unavailability of several company reports that are known to, or may, contribute to the understanding of the Curnamona Province.
- Lack of a coherent and generally agreed stratigraphic, structural and tectonic synthesis of the Olary and Broken Hill domains, as well as for the entire Curnamona Province.
- The structural-stratigraphic evolution of the Mount Painter-Mount Babbage inliers remains enigmatic and is not well correlated with the rest of the Curnamona Province.

Table 6.1.1 Major structural syntheses for the Curnamona Province.

Group	Figure area no.	Reference/Author(s)	Company	Confidential?	Type/ format*	Comments
Companies	2	Archibald NJ, 1978. Report by N.J. Archibald on the 1977-1978 phase of the Broken Hill Lode Project, co-ordinated by B.E. Hobbs, M.A. Etheridge and V.J. Wall.	Broken Hill MMA	?	U	Structural/stratigraphic synthesis of outcropping BH block.
	5	Archibald NJ, 1980. ? Unpublished report to Esso on the regional geology of the Olary Domain.	Esso	y	U	Olary regional compilation of stratigraphy and structure
	1, 2	Archibald, N J., Holden, D., Mason, R and Green, T., 2000. "A 3D Geological Model of the Broken Hill "Line of Lode" and Regional area"; unpubl.	Pasminco/ Perilya/ Fractal Graphics	y	D	3D digital geological model. Not yet validated and no supporting documentation.
	2	Brunker, R. 1970's. Regional stratigraphy and structure.	Rio Tinto (CRA)	y		Not seen. Mapping prior to DMR work.
	5	Davies, Brett and Anderson, B., date unknown. Regional compilation and tectonic interpretation of Olary domain.	Normandy	y	U	Abstract in BHEI, as Davies, B. and Anderson, H., 2000. Olarian Waves: Deformation, Fluids and Alteration in the western Willyama; in Peljo (comp) Broken Hill Exploration Initiative; AGSO Record 2000/10; 29-32.
	1	Hopwood, T H, 1976. The Geology of the Northern Leases and its relationship to the for North Broken Hill Orebody.	North BH to Pasminco to Perilya	y	U	Detailed study of North mine and leases. Valuable data, radical (at the time) interpretation. High-grade shears not recognised.
	2	Hopwood, T H, date unknown. Regional structural study, Broken Hill domain.	Aberfoyle	y	U	Serial regional cross-sections compiled in stratigraphic model. High-grade shears not recognised.
	3	Main, J., Laing, W, Barclay, TJR, et al, 1980 (approx)(BH Task Force, CRAE)	CRAE/ Pasminco/ Perilya	y	U	Not seen. Rumoured to be largely a stratigraphic template to define "Suite 4" regionally.

Group	Figure area no.	Reference/Author(s)	Company	Confidential?	Type/ format*	Comments
	2	Marjoribanks, R. W. and others, 1978. The structure of the Willyama Block. Report to North Broken Hill Ltd. MMA Rep 100279.	Broken Hill MMA	?	U	Not seen. Mapping prior to DMR work.
	2	Murphy, F. C., 1994. Interim report on Structural Interpretation of Aeromagnetic and Gravity Data for the Broken Hill Block; Pasminco Exploration report HW125, unpubl.	Pasminco/ Perilya	y	U	Interpretation of gravity and magnetic data over Broken Hill, into a series of thrust slices.
	4	Rankin, L., 1998a. Benagerie Ridge Magnetic Complex, South Australia: integrated geological interpretation of geophysical data. Report to Pasminco Exploration, 29p (unpubl).	Pasminco/ Perilya	y	U	Interpretation of gravity and magnetic data over Benagerie Ridge (unseen).
	3	Rankin, L., 1998b. Curnamona Craton/Broken Hill Block structural interpretation of geophysical data. Report to Pasminco Exploration, 29p (unpubl).	Pasminco/ Perilya	y	U	Major regional interpretation of gravity and magnetic data (unseen).
	1	Rothery, E, 2001. Tectonic shape of the Broken Hill lodes supported by their structural setting in a high-grade shear zone; AJES, 48, 201-220.	n	n	P	Thorough review of line-of-lode structural-stratigraphic relations.
	1	Schuler, M., Leyh, W, Larsen, D and Lobb, A, 1993. The Broken Hill Line of Lode Study (4 vols); Pasminco Exploration Report PX972, unpubl.	Pasminco/ Perilya	y	U	Synthesis and review of LOL data. Main attribute is serial cross-sections.
	2	Thomson, Bren, 1950's-60's. Regional stratigraphy and structure.	Rio Tinto (CRA)	y	U	Not seen. Mapping prior to DMR work.
	1, 2	White, S, 1995. Shearing within the Line of Lode: Implications for Regional Exploration; Pasminco Exploration Report PX1189, unpubl.	Pasminco/ Perilya	y	U	Assessment of Prograde and Retrograde shears along LOL

Group	Figure area no.	Reference/Author(s)	Company	Confidential?	Type/ format*	Comments
	2	White, S. H., Rothery, E, Lips, A. L. W. and Barclay, T. J. R., 1995. Broken Hill area, Australia, as a Proterozoic fold and thrust belt: implications for the Broken Hill base-metal deposit; Trans Instn Min Metall B, 104; B1-B17.	n	n	P	First descrption of prograde shears in BH. Later work (Gibson) contradicts some findings.
	5	Wright, J. V. and McConachy, G. W., 1998. Report on Geological Consulting June 1998: Curnamona Project Generation	Pasminco/ Perilya	y	U	Curnamona province project generation report and review, based on field traverses and core. Includes assessment of the Pas geochemical database by L Wyborn.
	6	Unknown; Mt Painter Inlier including Marathon Petroleum, North Flinders Mines, Pan Australia, Rio Tinto.	various	y	U	Several companies had large projects over the Mt. Painter Inlier which may have included regional work. Not sighted.
Adelaide Uni 1970s	1	Laing, W. P., 1977a. Structural and metamorphic geology of a critical area adjacent to the Broken Hill orebody, Willyama Complex, Australia. *PhD;* 232 pages.	n	n	T	State-of-the-art at the time, structural study with drill core, facings. High-grade shears not known but "slides" defined. Not accurate (too simplistic) in detail due to too few prograde and retrograde shears.
	1	Laing, W. P., 1977b. Structural and stratigraphic investigation of Zinc Corporation Ltd/NBHC Ltd mine area and southern extensions; CRAE Report 9119.	Rio Tinto/ Perilya	Y	U	"Line of lode" focus
	2	Laing, W P, 1996. Nappe interpretation, palaeogeography and metallogenic synthesis of the Broken Hill – Olary Block; *in* Ponzgratz, J and Davidson, G, eds: New Developments in Broken Hill Type Deposits; CODES Spec Pub 1; 21-51; University of Tasmania.	n	n	P	

Group	Figure area no.	Reference/Author(s)	Company	Confidential?	Type/ format*	Comments
	1	Laing, W P, Marjoribanks, R W and Rutland, R W R, 1978. Structure of the Broken Hill mine area and its significance for the genesis of the orebodies; Economic Geology, 73: 1112-1136.	n	n	P	"Line of lode" focus
	2	Marjoribanks, R W, Rutland, R W R, Glen, R A and Laing, W P, 1980. The Structure and Evolution of the Broken Hill Region, Australia; Precambrian Res, 13, 209-240.	n	n	P	Regional structural study with folds and facings defining coherent structural style (nappes). High-grade shears not defined. Not accurate (too simplistic) in detail due to too few prograde and retrograde shears.
	2	Vernon, R H, and Ransom, D M, 1971. Retrograde Schists of the Amphibolite Facies at Broken Hill, New South Wales; Jour Geol Soc Aust, 18 (3), 267-277.	n	n	P	Definition of retrograde (amphibolite-grade) schist zones near BH.
GA 1990s	2	Gibson, G. and 7 others, 1998. Re-evaluation of Crustal Structure of the Broken Hill Inlier through Structural Mapping and Seismic Profiling. AGSO Record 98/1, 55p.	n	n	P	
	2	Gibson, G, 2000. Tectonic Evolution of the Palaeoproterozoic Willyama Supergroup, Broken Hill: The Early Years; <u>in</u> Peljo (comp) Broken Hill Exploration Initiative; AGSO Record 2000/10; 45-47.	n	n	P	
	2	Gunn, P J, Milligan, P, Mackey, T, Liu, S, Murray, A, Maidment, D and Haren, R, 1997. Geophysical mapping using the national airborne and gravity datasets: an example focusing on Broken Hill; AGSO Jour Geol Geophys, 17(1), 127-136.	n	n	P	

Group	Figure area no.	Reference/Author(s)	Company	Confidential?	Type/ format*	Comments
	2	Haren, R, Liu, S, Gibson, G M, Maidment, D, and Gunn, P, 1997. Geological interpretation of high resolution airborne geophysical data in the Broken Hill region. Exploration Geophys. 28: 235-241.	n	n	P	Regional stratigraphic and structural study with folds defining coherent structural style (2 events). High-grade shears not defined.
DMR	2	Stevens, B. P. J. (ed.) 1980. A guide to the stratigraphy and mineralization of the Broken Hill Block, New South Wales; Geol. Surv. N.S.W.Records, 20 (1).	n	n	P	
(key refs only)	2	Stevens, B. P. J., and Stroud, W. J. (eds.) 1983. Rocks of the Broken Hill Block, their classification, nature, stratigraphic distribution and origin; Geol. Surv. N.S.W.Records, 21 (1).	n	n	P	
	2	Stevens, B.P.J., Barnes, R.G., Brown, R.E., Stroud, W.J. and Willis, I.L., 1988. The Willyama Supergroup in the Broken Hill and Euriowie Blocks, New South Wales. *Precambrian Research,* 40/41:297-327.	n	n	P	
	2	Willis, I. L., Brown, R. E. Stroud, W. J. and Stevens, B. P. J., 1983. The early Proterozoic Willyama Supergroup: stratigraphic subdivision and interpretation of high- to low-grade metamorphic rocks in the Broken Hill Block; Jour. Geol. Soc. Aust., 30, 195-224.	n	n	P	
	2	Willis, I. L., Stevens, B. P. J., Barnes, R. G., Bradley, G. M., Brown, R. E. and Stroud, W. J., 1989. Broken Hill Stratigraphic Map 1:100,000; Geol. Surv. N.S.W., Sydney.	n	n	P	

Group	Figure area no.	Reference/Author(s)	Company	Confidential?	Type/ format*	Comments
Monash 1960s-70s-80s	1	Hobbs, B E, 1966. The structural environment of the northern part of the Broken Hill orebody; Jour Geol Soc Aust 13, 315-338.	n	n	P	"Line of lode" focus
	2	Hobbs, B E, Archibald, N J, Etheridge, M A and Wall, V J, 1984. Tectonic history of the Broken Hill Block, Australia; in Kroner, A and Greiling, R (eds); Precambrian Tectonics Illustrated 24, 353-368; E. Schweizerbartische, Stuttgart.	n	n	P	
Monash Uni/ AGCRC 1990s-2000's		Ehlers K, Foster J, Nutman AP, and Giles D, 1996, New constraints on Broken Hill geology and mineralisation. in New developments in Broken Hill type deposits; in Ponzgratz, J and Davidson, G, eds: New Developments in Broken Hill Type Deposits; CODES Spec Pub 1; University of Tasmania.	n	n	P	Mainly geochronology
	5	Hills, Q. G., Betts, P.G. and Lister, G. S., 2003. Geophysical interpretation and modelling of the Olary Domain under cover: an inverted rift system; Aust. Jour. Earth Sci., 50, 633-644.	n	n	P	Interpretation using aeromagnetics and modelling
PIRSA	6	Coats, RP and Blisset, AH, 1971. Regional and economic geology of the Mount Painter province. South Australia Geological Survey Bull. 43	n	n	P	
(key refs only)	5	Conor, C.H.H., 2000. Definition of major sedimentary and igneous units of the Olary Domain, Curnamona Province. *MESA Journal,* 19:51-56.	n	n	P	

Group	Figure area no.	Reference/Author(s)	Company	Confidential?	Type/ format*	Comments
	5	Conor, C.H.H., 2002. Geology of the Olary Domain, Curnamona Province, South Australia. Field Guidebook 2002. *South Australia. Department of Primary Industries and Resources. Report Book,* 2002/015.	n	n	P	
	3	Flint, DJ and Parker, AJ., 1993. Willyama Inliers; in The Geology of South Australia, Volume 1, The Precambrian [JF Drexel, WV Preiss and AJ Parker (eds)]; South Australia Geological Survey Bull. 54; 82-93.	n	n	P	
	5	Laing, WP, 1995. Lithological geology of the Olary region. 1:100,000 scale. Geological Survey of South Australia.	n	n	P	PIRSA publication; compilation of mapping.
	5	Mills, A., 1986. An interpretation of regional geophysical data in the Olary region, South Australia. *South Australia. Department of Mines and Energy. Report Book,* 82/56.	n	n	P	
		Robertson, R.S., Preiss, W.V., Crooks, A.F., Hill, P.W. and Sheard, M.J., 1998. Review of the Proterozoic geology and mineral potential of the Curnamona Province in South Australia. *AGSO Journal of Australian Geology and Geophysics,* 17(3):169-182.	n	n	P	
		Robertson, R. S., Conor, C. H. H., Preiss, W. V., Crooks, A. F. and Sheard, M. J., 2002. Ch. 5; Curnamona Province in: Mineral Explorers Guide: PIRSA	n	n	P	

Group	Figure area no.	Reference/Author(s)	Company	Confidential?	Type/ format*	Comments
	6	Teale, GS., 1993. Geology of the Mount Painter and Mount Babbage Inliers; in The Geology of South Australia, Volume 1, The Precambrian [JF Drexel, WV Preiss and AJ Parker (eds)]; South Australia Geological Survey Bull. 54; 149-156.	n	n	P	
Uni of Melbourne/ UNSW	5	Ashley, P. M., Lawie, D. C., Conor, C. H. H. and Plimer, I. R., 1997. Geology of the Olary Domain, Curnamona Province, South Australia, and Field Guide to 1997 Excursion Stops. MESA Report Book 1997/17, 51p.	n	n	P	
	5	Ashley, P.M., 2000. Review of the geology and metallogenesis of the Olary Domain, South Australia. *AGSO Record,* 10/2000:4-7.	n	n	P	
	2	Binns, R.A., 1964. Zones of progressive regional metamorphism in the Willyama Complex, Broken Hill district, New South Wales. Journal of the Geological Society of Australia, 11: 283-330.	n	n	P	
	5	Clarke, G L, Burg, J P and Wilson, C J L, 1986. Stratigraphic and Structural Constraints on the Proterozoic Tectonic History of the Olary Block, South Australia; Precambrian Res, 34, 107-137.	n	n	P	
	5	Cook NDJ, Fanning CM, and Ashley PM, 1994, New geochronological results from the Willyama Supergroup, Olary Block, South Australia. in Australian Research on Ore Genesis Symposium, Adelaide, South Australia, December 12-14, 1994. Proceedings. Glenside, SA: Australian Mineral Foundation,	n	n	P	

Group	Figure area no.	Reference/Author(s)	Company	Confidential?	Type/ format*	Comments
	2	Doyle C and Cartwright I, 1999. Shear zones from Broken Hill Australia: deformation, conditions of formation and the role of fluids. *In* Last Conference of the Millenium. Specialist Group in Tectonics and Structural Geology Field Conference, Halls Gap, Vic., February 14-19, 1999. Geological Society of Australia. Abstracts,	n	n	P	
	1	Findlay, D, 1994. Boudinage, a reinterpretation of the structural control on the mineralisation at Broken Hill; AJES, 41, 387-390.	n	n	P	Short note on LOL boudinage and geometries.
	5	Plimer IR, 1996, The Olary Block, South Australia: an insight into mineralisation in the adjacent Broken Hill Block; in New developments in Broken Hill type deposits. Proceedings of a Workshop, Hobart, 8-9 July, 1996, edited by J. Pongratz and G. J. Davidson. Hobart: University of Tasmania. Centre for Ore Deposit and Exploration Studies.	n	n	P	
	7	Williams, P F, 1967 Structural Analysis of the Little Broken Hill Area, New South Wales; J Geol Soc Aust, 14 (2) 317-331.	n	n	P	Classical structural geology of Little B. H. area.

*D=digital U=unpublished report P=published T=thesis

6.2 Mineralisation models

Conclusions

- There are basic mineralisation models for all styles of mineralisation in the Curnamona Province.
- Most base metal mineralisation models focus on Broken Hill.
- Cu-Au models have a more regional genetic framework
- Supergene and regolith metallogenic models are not well developed
- Mineralisation models for supergene processes and regolith-related mineralisation are underdeveloped
- NSW DMR classifications are based on descriptive lithological types without genetic connotations. By contrast PIRSA classifications have strong genetic links.

Recommendations

- The models have many common elements, but lack overall consistency. Encouragement should be given to developing Curnamona-wide mineralisation models that account for spatial and temporal variance across the province.
- There are also only a few models that attempt to place mineralisation in the Curnamona Province into a regional (eastern Australia) and global (Paleoproterozoic) context.
- Models for mineralisation in the regolith and also supergene processes are under-developed. Exploration models are being developed but only indirectly consider metallogenesis.

Scope of Data

This section covers ***regional*** mineralisation models briefly. Models relating to the Broken Hill orebody are dealt with in Greenfield (pmd*CRC report in prep).

The Curnamona Province is dominated by the Broken Hill deposit, and not surprisingly base metal mineralisation models are also focussed on that deposit. However, there are more than 3500 small to very small stratiform, stratabound, vein and intrusive-related deposits of Pb, Ag, Zn, Cu, Au, W, Sn, U, Be, Pt and Ni in the Broken Hill domain alone, and hundreds of kilometres discontinuous strike length of quartz-gahnite rock and fine grained Mn garnet rock (“lode horizons”). More recently there has been growing interest in the Cu/Au potential of the Curnamona Province and several mineralisation models, with many common elements, have been developed for these metals. The Cu/Au, Fe oxide models tend to cover the whole of the Curnamona and have a more holistic approach to the metallogenic history of the province.

In terms of mineralisation in the regolith, new regolith mapping by CRC LEME across the province has led to an improved understanding of calcrete, silcrete and biogeochemical signatures and its significance for metallogenesis. Exploration models are also being developed for paleo-landscape related dispersion – particularly placer Au.

Classification schemes (see tables 6.2.1 – 6.2.3)

Descriptive schemes developed by the NSWGS (Barnes, 1986, 1988; Burton, 1994, 2000; Stevens et al., 2003) subdivide all described mineral occurrences (including non-metallic) into 6 groups and ~28 subgroups.

A more genetic-orientated scheme developed by PIRSA (eg Conor, 2003) is related directly to the recognised tectonic framework. Regional and local metasomatic alteration has also been identified (eg Ashley and Plimer, 1998, Kent et al., 2000) and has been directly linked to Cu-Au, Fe oxide and REE mineralisation styles.

Summary of regional mineralisation models:

Laing, 1996:

- Comprehensive metallogenic synthesis including maps of distribution of different ore-types over BH domain with reference to the whole Curnamona Province.
- Compared Olary and Broken Hill domains in terms of shelf and rift facies. "Metal deposit stratigraphy" developed for the Willyama Supergroup in the BH region.

Leyh and Conor, 2000

Based on a regional redox boundary through whole Curnamona:

1. Below redox boundary = Thackaringa (BH) and quartzofeldspathic suite to upper albite (Olary)
2. Above redox boundary = Broken Hill Group (BH), Bimba Suite (Olary)
    - Change from quartzofeldspathic, mainly albitic often strongly magnetic metasediments with abundant metavolcanics to overlying pelitic, locally graphitic metasediments

Iron formations below redox boundary:

- Coarsely layered quartz-magnetite ±barite
- Cu-Au mineralisation
- (Thackaringa Group)

Iron formations above redox boundary:

- Finely layered to laminated Mn-rich oxide silicate facies BIF±apatite,
- Pb-Zn-Ag mineralisation

Paragon Group mineralisation later reactivation of fundamental crustal lineaments linked to earlier rifting – recycled earlier stratiform mineralisation

Willis, 2000:

See Table 6.2.3. Based on tectonic evolution, with the following features:

- Pre-tectonic stratiform to stratabound sediment-hosted massive sulfide Pb-Zn-Ag (eg Broken Hill, Pinnacles)
- Pre- to early tectonic stratabound sulfide (eg Corruga, Black Prince, Bimba Horizon)
- Epigenetic syn- to late tectonic, stratabound vein, breccia and replacement deposits (eg Copper Blow, the Sisters, Diamond Jubilee)
- Epigenetic, post-tectonic, structurally-controlled late vein deposits (eg Mount Robe, Portia).
- Epigenetic, post-tectonic magmatic deposits, pegmatites, ultramafic intrusives (eg Triple Chance, Bijerkerno)
- Sedimentary U.

Anderson and McConachy 2001:
"Continuum" model similar to the petroleum-style basin analysis described by Wright et al. (1987) and expanded in Wright (1994).In this model, basin maturation, fluid migration and mineralisation follow a predictable sequence from hydrocarbons, to Pb-Zn basinal brines, followed by Cu and then Au in metamorphic and/or magmatic fluids. Ore deposition occurs in favourable physical/chemical "trap" sites.

- Ongoing metal bearing fluid transport along penetrative, long lived structures during periods of deformation, metamorphism and magmatic activity
- Base metal-rich deposits occur where reduced shale sequences provide both physical and chemical trap sites or seals for mineralising fluids
- Cu-Au mineralisation related to a major orogenic belt (and its collapse) stretching from Gawler Craton, through Curnamona Province to Mount Isa – Cloncurry province

Barratt, 2003:
Update of Anderson and McConachy (2001) and Willis (2000)
Precise geochronology (Page et al., 2000): 1600-1585 Ma

- Post and syn-deformation Mundi Mundi granites and leucogranites (BH)
- Bimbowrie Suite and Benagerie Ridge volcanics (Olary)
- Hiltaba granites Gawler Range Volcanics (Olympic Dam)

Polymetallic (Fe-Zn-Pb-Cu-Ag-Au) related to extension and syn-depositional basic and felsic magmatism associated with:

- (and probably deposited with) upper Thackaringa Group to basal Broken Hill group (up to the Ettlewood Calcsilicate Member)
- May also be associated with final stages of deposition of the BH Group

Cu-Au and Au mineralisation during deformation, peak-waning metamorphism and syn to post deformation magmatism:

- Epigenetic mineralisation in geochemical and structural traps
- Includes Fe-oxide related mineralisation
- Mainly in more oxidised units of the Thackaringa Group and vein mineralistaion

Cu-Ni-PGE-Au mineralisation associated with (ultra) mafic Adelaidean flood basalt extrusion.
Au(-Cu) with pyrite in dilatational site in reactivated shear zones and mafic dykes during Delamerian thermal event

Betts and Giles (2003 BHEI) place Curnamona mineralisation into a regional/global tectonic environment. They identify the Curnamona Province as lying at the intersection between two mineral belts:

1. Sediment-hosted Pb-Zn -Ag massive sulfide mineralisation
    a. BHT-type in back arc extension - Curnamona
    b. SHMS-type thermal subsidence of the lithosphere – Mount Isa Terrane
2. Fe-oxide, Cu-Au deposits: southern Gawler Craton through to Mount Isa Inlier

Numerical modelling:
Hobbs et al, 1998, 2000

- Thermal transport, deformation–fluid flow modeling
- High temperature, high pressure scenario

- Conceptual model simulates a half-graben sedimentary basin loaded by the Himalayan style nappe structures resulting in a much thicker crust
- Thermal model incorporates depth-related, Proterozoic aged, internal heat production, a Moho heat flux and a constant thermal conductivity.
- Regional peak granulite facies metamorphism generates partial melting, serving as fluid sources arising from devolatilisation and/or crystallisation of melts

Coupled deformation–fluid flow model suggests that under the influence of regional shortening and high topographic loading:

- Hydrofracturing in sedimentary rocks within the basin
- Releases fluids trapped in the basin
- Fluids focus into areas with high dilation (deformation-related volume increase)
- Discharge into foreland areas

Mount Painter and Mount Babbage:
The Palaeoproterozoic rocks contain a wide variety of mineralisation including U, REE, Th, Cu, Zn, Au, W, Ga and Mo, mostly as minor occurrences (Teale, 1993a). In the Mount Painter – Mount Gee area, the Radium Ridge Breccias are host to significant uranium resources,

The inliers are prospective for stratiform and volcanic-related base metal mineralisation within metasedimentary and metavolcanic units. In addition, the long history of intrusion and heating from the early Mesoproterozoic, through the Delamerian Orogeny to the late Palaeozoic makes the inliers highly prospective for hydrothermal vein, breccia and skarn Au, Cu, U and REE deposits.

Table 6.2.1 Major classification schemes for mineralisation styles in the Curnamona Province.

Ore deposit types in the Broken Hill Domain (after Barnes 1986, 1988)

Ore deposit type	Commodity	Characteristics	Other relevant references
Stratiform deposits			
Broken Hill type	Pb-Ag-Zn	Quartz-gahnite, garnet-quartz (also BIF, quartz-fluorite)	
Ettlewood type	Pb-Ag-Zn-Cu-W	Layered calc-silicate rock containing sulfides or base metals	
Corruga type	Pb-Ag-Zn-Cu-W	Irregular garnet-quartz-epidote-amphibole rock containing base metals sulfides or scheelite	
Sisters type	Fe-Cu-Co	Quartz-magnetite ±Fe sulfides	
Great Eastern type	Fe-Cu-Co	Granular quartz-Fe sulfides rock (±garnet)	
Big Hill type	Fe-Co	Pyrite (±colbalt) in plagioclase-quartz rock	
Parnell type*	Pb-Ag-Zn	Hosted by amphibolites and felsic gneisses	* addition by Laing, 1996
Stratabound deposits			
Silver King type	Pb-Ag-Zn-Cu-Au-W	Base metal-bearing grossly concordant quartz body, or base metals disseminated in amphibolite	
Hores type (subdivided by Laing, 1996 into "Hores type" – stratiform and "Freyers type" – stratabound)	W	Tungsten in quartz-muscovite-tourmaline pegmatite, or as disseminations within quartz-feldspar-biotite (±garnet) gneiss or tourmalinite	
Diamond Jubilee type	Cu-Au	Pyritic quartz lenses in migmatite	
Yanco Glen*	W	Tungsten hosted in magnetite and silicates disseminated in metasediments	* addition by Laing, 1996
Vein Multiple Veins and Stockworks			
Thackaringa type	Ag-Pb	Siderite quartz veins	
Copper-bearing siderite-quartz veins	Cu	Copper-bearing siderite-quartz veins	
Mount Robe type	Pb-Ag-Zn-Cu-F	Quartz-fluorite veins	
Lead-bearing quartz veins	Pb-Ag	Lead-bearing quartz veins	
Copper-bearing quartz veins	Cu	Copper-bearing quartz veins or copper disseminated in schist	
Pyrite-bearing quartz veins	Fe	Pyrite-bearing quartz veins, no base metals	
Gold-bearing quartz veins	Au-Cu, pyrite	Gold-bearing pyritic or cupriferous quartz veins	

Disseminations and massive, lenticular or irregular mineralisation related to intrusive rock types		
Waukeroo type	Sn	Cassiterite disseminated in pegmatite
Mulga Springs type	Pt-Cu-Ni	Platinoid-copper-nickel occurrences in ultrabasic intrusive rock
Iron Duke type	Fe, pyrite	Magnetite-pyrite occurrences in granitic intrusive rock, or as veins or pods in metasediments
Bakers type:	U-Th	Pegmatite and aplitic rocks containing radioactive minerals
Pegmatites	Pb-Cu	Pegmatites containing base metals or rutile
Miscellaneous		
Hematite breccias	Fe	Hematite breccias “veins” in faults
Base metal-bearing chlorite-garnet	Fe- Cu (Zn-Pb-Mn)	Base metal-bearing chlorite-garnet (±gahnite magnetite, muscovite) rocks
Ferruginous material	Fe	Ferruginous material including ferricretes
Gossans	Fe	Small gossans derived from pyrite, pyrrhotite with minor copper
Uranium in shear zones or disseminated in host rocks	U	Uranium in shear zones or disseminated in host rocks
Non-metallic		
Pegmatite		Pegmatite with feldspar, mica or beryl
Sillimanite, kyanite		Sillimanite, kyanite other refractory minerals

Table 6.2.2 Ore deposit types in the Olary Domain (after Conor, 2003)

Ore deposit type	Commodity	Characteristics	Other relevant references
Stratiform		Disseminated to massive, generally sediment-hosted with local evidence of felsic volcanism, possibly redox boundary control and association with evaporitic facies.	
Banded Iron formations	Fe-Mn	Small BIF and Mn silicates in Ethiudna Subgroup and Strathearn Group	
Bimba Formation	Fe-Zn (Pb)	Laminated sulfides with marble, calcsilicates and pelites	
Baritic Iron formations	Fe-Cu-Au	Baritic Iron formations mainly in upper Wiperaminga Group	
Stratabound		Disseminated sediment-hosted Fe-Cu-Zn-Co-W-U-F. Possibly redox boundary control and association with evaporitic facies in Wiperaminga Group, Ethiudna Subgroup and Bimba Formation.	
syn-tectonic mobilisation	Fe-Cu-Zn-Co-W-U-F	Local syn-tectonic mobilisation of Fe(Zn) sulfides in Bimba Formation and Strathearn Group.	
Epigenetic and Vein Replacement		Episodic structurally and lithologically controlled localisation of hydrothermally mobilised components. Formation during the Olarian and Delemarian Orogenies	Bierlein et al., 1995, 1996a, 1996b
Calcsilicate-hosted	Fe-Cu-Zn-	Calcsilicate-hosted sulfides ("stratabound skarn")	
Calcsilicate-, ironstone-, albitite- and psammopelite-hosted	Cu-Au(-Mo)	Calcsilicate-, ironstone-, albitite- and psammopelite-hosted replacements, stockworks, quartz-base metal sulfide (-carbonate) veins and stockworks	
Massive ironstones	Cu-Au	Massive ironstones formed by replacement of iron formations and associated rocks	
Shear zone-hosted U	U(-REE)	Localisation of U(-REE) in shear zones during late retrograde events	
Delemarian quartz veins	Au-Cu	Delemarian quartz veins in Adelaidean rocks	
Granite and pegamatite related (1600±20 Ma)		Magmatic derivation of mineralising fluids from the crystallisation of granitic melts	
veins, breccias and stockworks	U, Th, Ree	In veins, breccias and stockworks	
pegmatites	Feldspar, beryl, U, Th, Ree, Nb, phosphates, muscovite	In pegmatites	

Weathering-related		Derivation of gossans, supergene-enriched Cu(Co-Au) and other surficial ironstones during Tertiary to Recent weathering and diagenetic U and Au deposits formed by Tertiary to Recent ground water processes
Supergene-enrichment	Cu-Au-Co	Supergene-enrichment formed by oxidation of mineralisation
Redox controlled	U-Au	Redox control in Tertiary sediments immediately above the Palaeo-Mesoproterozoic rocks
Placer enrichment	Au	Possible – at Willyama unconformity on Benagerie Ridge

Table 6.2.3 Major deposit types for the Curnamona from Willis (2000):

MINERAL SYSTEM	COMMODITIES	COMMENTS
1. Pre-tectonic stratiform to stratabound sediment-hosted massive sulfide Pb-Zn-Ag.	Pb-Zn-Ag	- Broken Hill type massive sulfide Pb-Zn-Ag deposits, predominantly in the Broken Hill Group of the Broken Hill and Euriowie Blocks in NSW (eg Broken Hill Main Lode). - Laminated Pb-Zn sulfides in metasediments of the upper Bimba or lower Pelite suite in Olary Block (Hunters Dam type).
2. Pre- to early tectonic stratabound sulfide.	Fe, Pb-Zn-Ag. ±Cu, Cu-Co, ±W	- ?Redox front related Fe sulfides in stratabound/ stratiform horizons or disseminated in host intervals - Interpreted to form early post-deposition through redox and replacement processes (~1700-1640 Ma), with later metals overprints (~1590-1580 Ma). - Associated with regional disseminated to veined polymetallic sulfides of various types and ages, hosted in metasediments and/or metacarbonates (calc-silicate) (eg Bimba type Fe, Pb-Zn-Ag ±Cu-Co-Zn-Pb ±W, ?Ettlewood type).
3. Epigenetic syn- to latetectonic, stratabound vein, breccia and replacement deposits.	Cu, Cu-Au, Au, ±Co ±Mo	- Deposits structurally controlled and related to hydrothermal fluids and alteration (?magmatic and/or metamorphic). - Examples: Copper Blow, Waukeroo, Portia, Kalkaroo, White Dam, transgressive veining in pre-tectonic ironstones and calc-silicates (eg Bimba, Great Eastern ironstones, Sisters type iron formations). - Post high-grade metamorphism, syn to early post-D3, concomitant with regional alteration, magmatism and - deformation at ~1590-1580 Ma.
4. Epigenetic, post-tectonic, structurally-controlled late vein deposits.	Cu, Au, Pb-Ag (Zn)	- Wide range of generally quartz + sulfide ±carbonate veins in faults, shears, stockworks. - Include base metals and Au, Ag veins (eg Thackaringa type Ag-Pb). - Principally Delamerian (~500-450 Ma), but some possibly Adelaidean.
5. Epigenetic, post-tectonic magmatic deposits pegmatites, ultramafic intrusives).	Feldspar, Be, Sn, W, U, PGE-Au-base metals	Varied ages for pegmatites but dominantly ~?1600-1550 Ma. Mafic/ ultramafic intrusives ~800-850 Ma.
6. Sedimentary U.	U oxides.	Weathering related deposits (Cainozoic).

7.1 Geological Mapping

Conclusions

- No digitized maps more detailed than 1:500k are available for the Mt Painter Inlier.
- Unpublished detailed (1:12000) field mapping sheets by CRAE for the Broken Hill Domain are not readily available (possibly superceded)
- Only limited structural information (eg. faults, trends etc) is included in the GIS version of the detailed 1:50k and 1:25k scale map sheets. Where they exist there are no structural attributes (eg, fault type, dip, lineations)
- Only very limited amounts of structural readings are included (eg. Bedding, foliations, lineations). Exceptions to this are the new Olary – Billeroo and Outalpa 1:25K sheets.
- The main issue with the data is that attribute data is inconsistent across maps and explanations of abbreviations used are not always included, or difficult to find.
- Metadata is not detailed enough to trace the source and age of the mapping, or to establish relationships between attribute tables.

Recommendations

- Future mapping should prioritise the Mt Painter and eastern Olary Inliers over producing more detailed second-pass maps.
- Assess how much and to what quality structural data exists. If these data do not exist or are irretrievable, consideration should be given to a focussed field program to re-collect the data.
- Detailed structural data available on existing hardcopy maps should be included in the GIS products
- All map coverages should be published with a consistent flat data structure (eg. fully attributed stand-alone shape files) to facilitate uptake of new data into existing company databases by non-expert GIS users.
- Adequate metadata to allow assessment of age and reliability of the mapping should be included in the published datasets.

Scope of data

Digital geological mapping data in GIS and scanned formats were compiled from data packages published by PIRSA and DMR. The table below summarizes these maps and their contents, as well as known hardcopy maps. More detailed information about each dataset is contained in the accompanying GIS. Note that the scale is the maximum scale intended for use of the maps.

Coverage	Scale	Source	Themes	Attributes
Curnamona	1:500k	BHEI2003	solid geology structure	stratigraphic units faults, joints, geophysical trends
Curnamona	1:500k	BHEI2003	outcrop geology structure	stratigraphic units faults, joints, trends
Olary	1:100k	Olary2001	solid geology structure	stratigraphic units faults, folds, trends

Olary	1:100k	Olary2001	outcrop geology	stratigraphic units
Olary	1:50K	Olary2001, BHEI2003	outcrop lithology	lithologies, stratigraphic units
Olary – Billeroo, Outalpa	1:50K	BHEI2003	Solid geology, outcrop geology, structure	Very comprehensive including structure
Olary - Mingary	1:50K	BHEI2003	outcrop geology	lithology
Olary - Coppertop	detail	BHEI2003	Lithology, structure	lithology
Broken Hill	1:100k	BHEI2000, BHEI2003	solid geology structure	combined stratigraphy and lithology faults, dykes, marker beds
Broken Hill	1:100k	BHEI2002	solid geology	stratigraphy with detailed lithology
Broken Hill	1:100k	BHEI2000	regolith	landforms, regolith types
Broken Hill	1:50K	BHEI2003	metallogenic maps	(scanned images)
Broken Hill	1:25K	BHEI2003	outcrop lithology	lithology, stratigraphy
Broken Hill	1:25K	BHEI2003	solid lithology	lithology codes
Brewery Well (BH)	1:25K	BHEI2000	geology structure	lithologies shear zones, trends
Mt Painter	1:63K	PIRSA	Outcrop geology	Completed in late 1960's
Curnamona	1:250K	-	Outcrop geology	Completed in mid 1980's
Broken Hill	1:12000 (?)	NSW DMR	Geology, field mapping sheets	Unpublished CRAE mapping from the 1970's

Table 7.1.1. Summary of geological mapping available for the Curnamona Province.

Notes on individual datasets:

- *Olary 1:100k solid geology* contains two separate files for the geological line-work, which complement each other.
- There is another pivoted version for the eastern part of *Olary 1:50K outcrop lithology* published in BHEI2000 that combines each lithology across some sheets. The underlying data is the same. All sheets are compiled into one map in the BHEI2003 edition.
- Seven further 1:50k sheets linking Olary with the Broken Hill Domain are in preparation by PIRSA.
- The *Broken Hill 1:100k solid geology* published in BHEI2002 and BHEI2003 are similar but different in extent, detail and attribute data. The older BHEI2002 dataset is far more comprehensive. It is included again in the BHEI2003, but without legend files.
- In *Broken Hill 1:25k outcrop lithology* (23 sheets) and *solid geology* (3 sheets) the attributes to the coverage only include stratigraphic unit codes, the lithologies are defined in the legends only.
- There is another searched version for *Broken Hill 1:25k outcrop lithology* published in BHEI2002 that combines each lithology across all sheets. The underlying data is the same.
- The Brewery Well map contains some detailed mapping that updates the sheet in dataset 13.

Assessment of data

- The most detailed scale of digital geological maps that cover the entire Curnamona Province is 1:500,000. Below that the scales and types of more detailed mapping reflect the amount of exploration and mining activities that have occurred in each area.

- The Broken Hill Domain has the most detailed datasets available at 1:25,000 scale. It is also the only area where different themes of mapping (i.e. solid and outcrop geology, regolith and landform) are available.
- The Olary Domain was mapped at 1:50,000 scale over its better-exposed western area, with the more eastern sheets currently in various stages of production. No detailed maps are published for the Mt Painter Inlier. The Mt Painter area is still serviced by Ron Coate's 1:63000 mapping completed in the late 1960's.
- **The main gaps in the geological map coverage are the Mt Painter Inlier and the eastern part of the Olary Inlier**.
- Considering the structural complexity of the Curnamona Province, it is surprising that there is a near-complete lack of published structural data. Some of the larger scale maps have line themes that include faults, dykes and marker units, but even these do not contain information about fault types, dips or lineations. Trends are commonly included but don't specify the source (eg. magnetic, air photo etc.). No structural readings such as bedding or foliation planes were included in any of the maps.
- **The most important gap in the available geological themes is structural mapping.**
- All maps include a polygon coverage that contains the geological units either by lithology or stratigraphic unit. The attributes attached to the polygons vary across the datasets, ranging from comprehensive (eg. stratigraphic symbol, full unit name, contained lithologies, and age) to rudimentary (eg. Stratigraphic symbol only). In some maps the legend definition, which is part of a workspace, not the data, is the only source of explanation to the symbols listed as attributes. This information is easily lost when the data files are taken across into company exploration databases. Also there is generally no information on projections or the mapping age or source.
- The main issue with the data is that attribute data is inconsistent across maps and explanations of abbreviations used are not always included, or difficult to find.

The second issue with the data is that metadata is not detailed enough to trace the source and age of the mapping

7.2 Regolith Mapping

Conclusions

- Lack of detailed coverage over the Olary and Mt Painter inliers.
- Incompatible regolith mapping methods used by CRCLEME and PIRSA.

Recommendations

- Implement a consistent approach to regolith mapping.

Scope of data

- All regolith mapping in the region is attributed to the CRCLEME. Survey outlines and scales were supplied by GA.

Assessment of data

- Regolith mapping by CRCLEME has covered the Broken Hill Domain at a reasonable scale (1:100 000 and 8 1:25 000 scale regolith maps).
- Coverage of the remainder of the Curnamona Province is at 1:500 000 scale.
- 1:25 000 scale outcrop mapping in the Olary Domain is currently being undertaken by PIRSA, and includes regolith mapping. Regolith mapping by CRCLEME students is also currently being undertaken.
- Olary Domain geological mapping by Allistair Crooks in the mid 1990's included regolith mapping using the RED scheme (Residual-Erosional-Depositional). This approach was developed in Western Australia, where separation of 'RED' themes is more straightforward. The CRCLEME approach is more detailed, and not compatible with the RED scheme.

7.3 Mineral Deposits

Conclusions

- Little attribute data attached to deposits in NSW.

Recommendations

- Complete the NSW data to the same level of detail as the SA data.
- Verify locations between the two datasets.
- PIRSA should consider updating MINDEP and including more detailed metadata.

Scope of data

Coverage	Deposits	Source	Attributes
Curnamona (SA)	29	BHEI2003	Commodity, production, geology, references
Curnamona	31	GA ozmin	Name and age

Assessment of data

- The mineral deposit data included in the BHEI2003 database is limited to South Australia, but has very detailed attribute data attached to it, while the GA dataset shows more deposits, but has very little attribute data.
- Until 1993, Allistair Crooks was custodian of MINDEP, a PIRSA mineral deposits database. This needs to be updated and merged with “Selected Mineral Deposits” database.
- Where there are duplicates between the two datasets their locations rarely coincide. The shift varies from deposit to deposit, so a simple datum shift is not likely to be the cause.

7.4 Mineral Occurrences

Conclusions

- Differences in coverage between GA and the BHEI products.

Recommendations

- Update the SA data with the GA data.
- Occurrences should be checked with GPS.
- Verify locations between the two datasets.

Scope of data

Coverage	**Occurrences**	**Source**	**Attributes**	**Comments**
Curnamona (SA)	593	BHEI2003	Name, description, history	Comprehensive attribute tables are loaded separately
Curnamona (NSW)	3543	Curna2001	Name, commodity status	Comprehensive coverage over Broken Hill inlier, older projections shifts locations compared to Minloc database
Curnamona	1530	GA Minloc	Name, commodity status	Missing northern Broken Hill and some new ones on Copley 1:250k sheet

Table 7.4.1 Summary of mineral occurrence data.

Assessment of data

- Coverage is generally very good, in particular over the Broken Hill Inlier.
- Note that both the QLD and WA surveys have revisited and accurately located mineral locations in the Mt Isa and Yilgarn Provinces, which was perceived as very useful by industry.

7.5 Petrology

Conclusions

- Petrological rock and thin section descriptions are reasonably well covered over the Broken Hill Inlier, but scarce over the Olary and non-existent over the Mt Painter Inlier.
- A large amount of petrological data resides in university theses, which are difficult to access.

Recommendations

- Rather than focusing on a compilation of raw data, develop a comprehensive time-space framework that uses all available geochronology and geothermobarometry data.
- Create a Curnamona thesis reference collection, hotlinked to their study locations in GIS.

Scope of Data

Coverage	Samples	Source	Attributes	Comments
Broken Hill Domain	8261	BHEI2003	Sample information only	DMR rock sample collection Brief rock-type descriptions
Broken Hill Domain	47	BHEI2003	Sample information only	DMR outcrop photo collection Brief photo descriptions TIF format
Broken Hill Domain	23	BHEI2000	Rock name, description	GA structural outcrop photo collection Brief photo descriptions, scanned and hotlinked to their locations GIF format
Broken Hill and Olary Domain	464	BHEI2000	Rock name, description	GA Thin section descriptions Stored in 2 linked tables These have ‘disappeared ‘ from the later BHEI2003 dataset
Broken Hill Domain	14	BHEI2000	Hotlinks to scanned report	Thermobarometry samples. These were not included in the later BHEI2003 dataset

Assessment of the Data

- Petrological rock and thin section descriptions are reasonably well covered over the Broken Hill Inlier, but scarce over the Olary and non-existent over the Mt Painter Inlier.
- Apart from government survey collections and company reports, most primary petrological data reside within universities, particularly in theses. Access to University thin section collections, rock collections and theses are not systematic and require a personal approach. Some universities have online thesis collections; however in the majority of cases, to access petrological data, it is essential to know the title or author of the thesis that contains the data. In this respect, it would be useful for Curnamona explorers to have a BHEI thesis reference

collection, preferably with attributes such as author, title, degree, university, location of study, data types collected, hotlinked to their general locations in GIS. A recent compilation of 344 Curnamona thesis references is included in Appendix X.

8.1 Geochemistry and Drillhole data

Conclusions

- Geochemistry and drillhole data comprise the single most extensive and valuable exploration resource available to Curnamona explorers.
- For the Curnamona, approximately 90% of South Australia's, and 10% of NSW's geochemical data from exploration reports and academic research remains to be incorporated into Government databases.
- Geoscience Australia's OzChem database has very limited geochemical data coverage over the Curnamona, however most of this is unique data not captured on state GIS packages.
- There remains a significant lack of consistency and transparency of digital data in published GIS packages.
- Capture and validation of the geochemistry data remains a significant challenge for the Broken Hill Exploration Initiative.

Recommendations

- Compile a single comprehensive drillhole database (eg. Intersect) with detailed header and link to geochemistry. Include columns for x y and z coordinates for all points (with projection details), so they can be plotted in 3D space (eg. in mine planning software) without the need of complex database mergers with drillhole header information.
- Compile a single all-encompassing geochemistry database with a comprehensive flat structure.
- For future GIS packages, improve the quality of the metadata.

Scope of Data

Table 8.1.1 summarizes the geochemistry and drill hole data available for the Curnamona.

Methodology

In compiling the audit for BHEI geochemical data, the BEHI 2003 GIS package was used as a benchmark, representing the most up to date published GIS dataset available, and also the most comprehensive of any published GIS package of drillhole or geochemical data from the Curnamona Province.

This review is also based on meetings with staff from DMR, GA and PIRSA, as well as the following reports:

- Kevin Capnerhurst 1998. Progress report for BHEI Geoscience database. (Unpublished report).
- Tony Webster 2001. Broken Hill Mines data capture project, Preliminary scoping assessment. (Unpublished report).

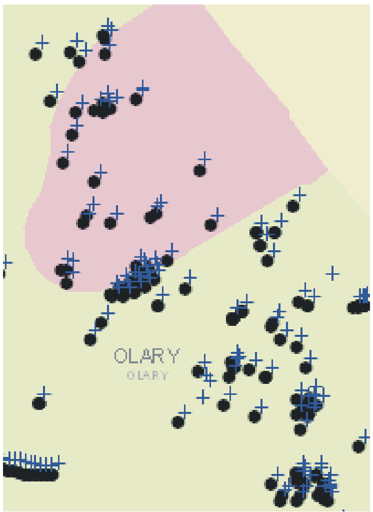
- John Stockfeld 2002. Validation of whole-rock geochemical data for the Broken Hill Mines area.(Unpublished report, July 26th, 2002)
- Clifford R. Stanley 1996, 1997(CD), Broken Hill /Cannington Lithogeochemical Study: Progress Report # 1, # 2, #3, #4.
- Steve. G. Walters, 2000. Broken Hill Type alteration halos- developing more user friendly lithogeochemical tools. Final Report to Pasminco.

Assessment of the Data

Geochemical data represent the largest amount of data contained in the BHEI 2003 database both for SA and NSW. The other GIS dataset compilations are similar versions of the same data or much smaller datasets. These include the GA Ozchem database, the SA Granites study and an Olary dataset within BHEI 2003. The latter show little overlap with the bigger sets. The presence of these smaller datasets without significant overlap suggests that there may be other data not found in this present compilation.

As with all the other themes, metadata is sparse. More explanation is needed for each of the columns in the database, particularly what other linked data is available by looking up reference numbers such as “RNO”, “FIELD_NO” or “COLLNUM”. There is no need to include this extra data, but the user should be able to know what data is available and how to ask for it.

The apparently ubiquitous problem with lack or information about projections used can be demonstrated in the mismatch of locations from data dumps of the same PIRSA database in 2001 and 2003 (see map and attribute list below). The difference between the locations is ~215m which is roughly the difference between GDA96 and AGD66. This affects both latitude/longitude and eastings/northings.



RSNUM	LONGITUD	LATITUDE	ZONE	EASTING	NORTHING
270	139.345639	-30.227928	54	340795	6654789
271	139.345639	-30.227928	54	340795	6654789
272	139.345639	-30.227928	54	340795	6654789
273	139.345639	-30.227928	54	340795	6654789

RSNUM	LONGITUD	LATITUDE	ZONE	EASTING	NORTHING
270	139.346930	-30.226440	54	340917	6654967
271	139.346930	-30.226440	54	340917	6654967
272	139.346930	-30.226440	54	340917	6654967
273	139.346930	-30.226440	54	340917	6654967

The other issue that is particularly important with geochemical data is its position in 3D space. It would be of great benefit to exploration analysis of the data if each data point had an elevation as well as eastings and northings. While some of this data can be desurveyed from borehole collars, surface data needs to be merged with topographic surveys. This type of data merging is beyond the capabilities of normal exploration GIS databases, but could be easily done within the powerful database management systems used by the government departments.

Further notes on NSW data

- For BHEI 2003 and other GIS packages, there is no Mapinfo version of NSW data.
- Digital capture of geochemical assay and dill hole location data is ~95% complete for open file RAB and Auger holes for the Broken Hill Domain to 1995, but does not include mine leases, as this information is still confidential. Geochemistry data linked to these RAB and Auger holes are bottom-of-hole samples. NSW unpublished database here comprises geochemistry and location data from ~100 000 samples mostly from CRAE programs completed in the early 1970's. An auger drilling program by Broken Hill South contains geochemistry and location data from ~40 000 samples. The data have not been interrogated in any detail, remaining unlevelled and without any stratigraphic units assigned.
- A Terra Search project finished in June 2002 collected all available RAB and Auger data (including assays) for the Broken Hill Domain. The majority of this data was from the Broken Hill South auger-drilling program mentioned above.
- No geochemical information has been captured since 1995, although the BHEI 2003 GIS has some limited post 1995 data.
- No assay data has been captured for diamond, RC/percussion or soil geochemistry. In addition, there are >14180 diamond drill holes not yet captured for the Broken Hill mine area. This is restricted by confidentiality issues.
- No assay downhole survey data have been incorporated in the GIS packages so far. Because most mine data remains confidential, this is not regarded as a priority.
- Only ~10% of available whole rock geochemistry has been validated and incorporated into GIS packages. A dataset containing all known whole rock samples for the Broken Hill Domain (17101 samples) is currently kept by Kevin Capnerhurst.

Further notes on PIRSA data

- All geochemistry and drill holes captured by PIRSA resides on the SA-geodata database. Of approximately 150 000 available geochemical samples (state-wide), only ~12% (~17 000 have been digitally captured). For the ~44 000 available drill holes, ~20% captured on SA-Geodata.
- ~90% (4294 of 4800) capture of diamond, deep RC/percussion and RAB.
- ~10% (3393 of ~39000) capture of shallow RAB, auger, RC/percussion.

Major Identified gaps

- No link to geological data for the NSW diamond and RC/percussion drillholes.
- Variability in attribute data and duplication, particularly in the prospect data.
- Most Pasminco data not compiled into BHEI products.
- Limited overlap between smaller datasets suggests that there may be more out there that could be captured.

Table 8.1.1 Summary of geochemical and drillhole data available for the Curnamona Province.

Source	**Data Type**	**Most Recent Dataset**	**Coverage**	**No. Geochem Samples**	**No. Data Points in GIS**	**Map No. in this report**	**Notes**
NSWDMR	Drill Holes (location data only)	BHEI 2003	Broken Hill Domain	0	2011	8.1.1	• RC, diamond drilling- no assay data captured since this information is still confidential • GDA94 • Stored on the 'Intersect' DMR database • Various companies, regional data • A subset file on BHEI 2003 contains the 337 drillholes that are deeper than 250m
	Whole Rock	Vax (CRAE)	Broken Hill Domain	10467	0	-	• From CRAE VAX computer • Includes 802 'regional' samples that remain unvalidated • of the mine sequence samples, 7392 have been assigned lithologies, 2892 assigned lithologies and stratigraphic units • Some overlap with Explore and NSWDMR database • Perilya have released this data to the public domain
	Whole Rock	Explore (Pasminco)	Broken Hill mine sequence	6544	0	-	• from 82 mine sequence drillholes • 1108 samples have been assigned lithologies and stratigraphic units • Perilya have released this data to the public domain • Data is globally less precise and sporadically less accurate than Megachem database (Stockfeld, 2002)
	Whole rock	Cliff Stanley (Pasminco/ BHP)	Broken Hill mine sequence	1300	0	-	• Broken Hill Line-of-lode drill core • Hand-picked samples for alteration study • Location of dataset unknown
	Whole Rock	BHEI 2003	Broken Hill Domain	2040	2040	8.1.3	• Broken Hill Domain, both mine and regional data • Contains both DMR and historical literature/thesis data • Represents the most comprehensive whole rock database in terms of assigned attributes
	Diamond drillhole	BHEI 2003	Broken Hill Domain	0	<2011	8.1.1	• Only location data captured, shown in Fig. 1 (2011 drillholes, including RC/percussion)
	RAB	BHEI 2003	Broken Hill Domain	94298	94298	8.1.2	
	Auger	BHEI 2003	Broken Hill Domain	62303	62303	8.1.2	• 606 samples contain no assay information (contained in 1 file)

Source	Data Type	Most Recent Dataset	Coverage	No. Geochem Samples	No. Data Points in GIS	Map No. in this report	Notes
	RC/ percussion	BHEI 2003	Broken Hill Domain	307	>307 <2318	8.1.2	• 307 samples accidentally included with North Broken Hill RAB and Auger results • only point data exists for other BHEI 2003 RC/percussion data (Fig. 1)
	Soil		Broken Hill Domain	0	0	-	• No NSW soil samples available, apart from Pasminco data (Fig. 5)
	Stream sediment	BHEI 2003	Broken Hill Domain	9135	6858	8.1.4	• Only 6858 data points shown in Fig. 4 since some samples contain multiple assay reports
	Water Bores	BHEI 2003	NSW Curnamona	0	1600	8.2	• Collar information, geology • GDA94, has metadata
PIRSA	Drill Holes (location data only)	BHEI 2003	SA Curnamona	0	12212	8.1.1	• Metadata linked to geochemistry
	Drill Holes (location data only)	Curnamona 2001	Curnamona	0	7424	8.1.1	• AGD66 • No projection details • Position mismatch with BHEI 2003 • Overlap with BHEI 2003, but contains some unique data
	Whole rock	BHEI 2003	Olary	352	352	8.1.3	• Unspecified overlap with Granites SA and BHEI 2003 outcrops
	Core sludge	BHEI 2003	SA Curnamona	29	29	8.1.3	
	Costean	BHEI 2003	SA Curnamona	115	115	8.1.3	
	Drill core	BHEI 2003	SA Curnamona	2010	2010	8.1.3	
	Drill cuttings	BHEI 2003	SA Curnamona	5873	5873	8.1.3	
	Mine samples	BHEI 2003	SA Curnamona	203	203	8.1.3	
	Outcrop	BHEI 2003	SA Curnamona	3700	3700	8.1.3	
	Soil	BHEI 2003	SA Curnamona	2375	2375	8.1.3	
	Stream sediment	BHEI 2003	SA Curnamona	223	223	8.1.3	
	Water Bores	BHEI 2003	SA Curnamona	0	7395	8.2	• Collar information, geological log • GDA94, no metadata, geological logs need to be related from

Source	Data Type	Most Recent Dataset	Coverage	No. Geochem Samples	No. Data Points in GIS	Map No. in this report	Notes
							separate table
Pasminco (Subset of BHEI2003 data)	Stream sediment	Pasminco	Broken Hill Domain	7961	7961	8.1.5	• PDF images with sample points for Pasminco data • Obtained from Tim Green (Pasminco) • Assay data exists but not disclosed to pmdCRC, however, some RAB and auger data appears on BHEI 2003 (Fig. 2)
	unspecified	Pasminco	Broken Hill Domain	795	795	8.1.5	
	Auger in DH collars	Pasminco	Broken Hill Domain	299	299	8.1.5	
	RAB in BH collars	Pasminco	Broken Hill Domain	3892	3892	8.1.5	
	Auger	Pasminco	Broken Hill Domain	44708	44708	8.1.5	
	Costean	Pasminco	Broken Hill Domain	18	0	8.1.5	
	RAB	Pasminco	Broken Hill Domain	20547	0	8.1.5	
	Rock chips	Pasminco	Broken Hill Domain	809	0	8.1.5	
	Soil	Pasminco	Broken Hill Domain	4858	0	8.1.5	
Granites SA	Whole rock	Granites SA GIS	Curnamona	1135	0	8.1.3	• Contains mysterious sample points in NSW which are not mentioned in the accompanying report • Minor overlap with SA-Geodata
Geoscience Australia	Whole rock	GA Ozchem	Curnamona	676	676	8.1.3	• Geographic projection defined • Some overlap with state data, however most of the dataset is unique

8.2 Water Bores

Conclusions

- Water bore coverage is comprehensive but does not contain water yield data.
- A slight coverage gap exists in the southern Broken Hill Domain.

Recommendations

- Include engineering (water yield) as well as geological data in future GIS releases.

Scope of data

Coverage	Bores	Source	Attributes	Comments
Curnamona (SA)	7395	BHEI2003	Collar information, geological log	GDA94, no metadata, geological logs need to be related from separate table
Curnamona (NSW)	1600	BHEI2003	Collar information, geology	GDA94, has metadata
Broken Hill Domain	33	CSIRO EM	Extensive major and trace elements	Angela Giblin's database

Table 8.2.1 Summary of water bore point data for the Curnamona Province.

Assessment of data

- The water bore database is comprehensive and looks complete including detailed lithological logging.
- Minor gaps in coverage include Curnamona, Callabonna, and Frome 1:250 000 sheets (mostly covered in playa lakes); as well as the Oakvale, Thackaringa, Cobham Lake and Wonnaminta 1:100 000 sheets.
- It is assumed that there is data available for the Manara and Urisino 1:250 000 sheets that were not included with the NSW BHEI2003 data.
- The main issue with the water bore data is the type of attributes extracted from the original databases. Both files contain downhole geological descriptions with no other information about the bore. Apparently these data exist but have not been included in the GIS packages.
- An earlier dataset (Curnamona GIS, PIRSA 2001) contained the same boreholes but also included water yield data, which could be useful for explorers.
- Recent research by GA has analysed stable isotopes (O, S) from sulphate in groundwater as a potential exploration tool (Kirste et al., 2003).
- There is an unpublished database of 33 water bore geochemical analyses stored at CSIRO North Ryde form the work of Angela Giblin.

8.3 Isotopic Data

Conclusions

- Approximately 1500 isotopic analyses have been identified.
- The following isotopic data types were assessed: $\delta^{34}S$, $\delta^{18}O$ (+δD), $\delta^{11}B$, $\delta^{13}C$, $^{147}Sm/^{144}Nd$, Rb^{87}/Sr^{87} (+ Sr^{87}/Sr^{86}), $^{40}Ar/^{39}Ar$ (+ K-Ar).
- Apart from Sm/Nd studies which are currently focused in the Olary Domain, most other data type studies have been focused in the Broken Hill Domain, and especially on the Broken Hill main lode.
- The majority of the samples were obtained from mineral deposits and are generally poorly located.
- The isotopic coverage in the Mt Painter and Mt Babbage inliers is limited.

Recommendations

- Collate and standardize the existing isotopic data into a GIS database.

Methodology

Apart from what is available on BHEI 2000 GIS (see below), no centrally accessible database is available for any of the isotopic data reviewed in this section, and the results were collated from literature review (see References).

A spatial distribution of $^{147}Sm/^{144}Nd$, Rb^{87}/Sr^{87} (+ Sr^{87}/Sr^{86}), $^{40}Ar/^{39}Ar$ (+ K-Ar) data is shown in Map X.

Scope of Data

The scope of available isotopic data were assessed for the following commonly studied ratios (U/Th/Pb and Pb/Pb are covered separately):

$\delta^{34}S$

A large, unvalidated set of 312 sulphur isotope analyses has been published for the Curnamona. The most recent compilations are found in Laing (1996) and Bierlein (1996a). The SO_2 has been extracted and analyzed from common sulphide minerals and barite, collected from various mineral deposits, including:

- Lawrence & Rafter (1962), Stanton & Rafter (1967), Both & Smith (1975), Spry (1987), 55 analyses from the Broken Hill main lode
- Dong et al. (1987), Parr (1992), 79 analyses from Broken Hill Type deposits within the Broken Hill Domain
- Bierlein (1996a), 127 analyses from 23 localities of stratabound and epigenetic mineralization in the Olary Domain

- Dong et al. (1987), 31 analyses from late epigenetic vein mineralization within the Broken Hill Domain.

An additional $\delta^{34}S$ dataset of 145 analyses on dissolved sulphate in groundwater samples from the Broken Hill Domain was collected and analysed by Kirste et al. (2003). These were used as an exploartion tool to decifer sources of sulphide mineralization.

$\delta^{18}O$ (+ δD)

A medium-sized, partially validated set of oxygen isotopic compositions from 210 analyses has been published for the Curnamona. These consist of five separate studies:

- Dong et al. (1987), 26 analyses from a variety of mineral deposits throughout the Broken Hill Domain,
- Cartwright (1999) and Doyle & Cartwright (2000), 142 analyses of metasedimentary and metavolcanic rocks throughout the Broken Hill Domain. Doyle & Cartwright (2000) focused on the isotopic contrast between sheared and unsheared rocks,
- Gallacher & Plimer (2000), An unknown number of analyses were obtained from fault zone calcites in the Broken Hill main lode.
- Melchiorre et al. (2001), 11 analyses from cerussite minerals and modern groundwater in the Broken Hill main lode and Pinnacles mine. These were applied to a low temperature thermometer to assess supergene enrichment processes, and included 8 δD analyses.
- Skirrow (BHEI 2000 CD), 31 analyses from a variety of rock types including albitites, amphibolites, calc-silicates and granites in the Olary Domain. These data are available on the BHEI 2000 CD-rom.

An additional $\delta^{18}O$ dataset of 100 analyses on dissolved sulphate in groundwater samples from the Broken Hill Domain was collected and analysed by Kirste et al. (2003). These were used as an exploartion tool to decifer sources of sulphide mineralization.

$\delta^{11}B$

A small, dispered, unvalidated set of Boron isotopic compositions from 52 samples have been published for the Curnamona. These are derived from essentially one study by Palmer & Slack (1989) and Slack et al. (1989; 1993). Boron isotopic compositions were analysed from tourmalines obtained mostly from mineral deposits and associated country rocks across the Broken Hill Domain.

$\delta^{13}C$

Published Carbon isotopic data includes:

- Dong et al. (1987), 7 analyses from the Broken Hill Domain- 5 from siderite and calcite in Thackaringa Veins, and 2 from calcite in the Broken Hill main lode,
- Gallacher & Plimer (2000), An unknown number of analyses were obtained from fault zone calcites in the Broken Hill main lode.
- Melchiorre et al. (2001), 10 analyses from cerussite in the Broken Hill main lode, applied to a low-temperature isotopic thermometer.

$^{147}Sm/^{144}Nd$

Published Sm/Nd data consist of 2 analyses from Ameroo Hill in the Olary Domain (Ashley et al., 1996) and 4 analyses from the Broken Hill Domain by McCulloch (1987). The Ozchem database contains 7 unpublished Sm-Nd dates by George Gibson, from felsic and mafic gneisses from across the Broken Hill Domain. Karen Barovich and Martin Hand from Adelaide University have an unpublished, validated database of ~50-60 Sm/Nd analyses from the Olary Domain, with most data attributes due to be published in 2004. Preliminary interpretations of these data can be found in Barovich (2003) and Hand et al. (2003).

Rb^{87}/Sr^{87} (+ Sr^{87}/Sr^{86})

Published Rb^{87}/Sr^{87} and Sr^{87}/Sr^{86} analyses are collated in the BHEI 2000 CD and include:

- Richards & Pidgeon (1963), 23 Rb-Sr age determinations on low-grade metamorphic micas from the Broken Hill Domain, giving Delamarian ages (~560 Ma),
- Compston (1966), 31 Rb-Sr whole-rock age determinations on a variety of rock types in the South Australian Curnamona. These are available on BHEI 2000 CD-rom,
- Page & Laing (1992), 5 Rb-Sr age determinations (including Sr-Sr compositions) on the Hores and Parnell gneisses in the Broken Hill Domain mine sequence,
- Pidgeon (1967), 31 Rb-Sr age determinations (including Sr-Sr compositions) on granites and high grade metamorphic rocks from the Broken Hill Domain mine sequence,
- Shaw (1968), 52 samples from the Broken Hill Domain mine sequence, measuring Rb-Sr and Sr-Sr isotopic compositions,
- Flint & Webb (1980), at least 13 Rb-Sr age determinations on granites and metamorphic rocks of the Outalpa Inlier in the Olary Domain, including Sr-Sr compositions,
- Etheridge & Cooper (1981), 21 samples analysed for Rb-Sr and Sr-Sr from the British Shear Zone in Broken Hill and adjacent Potosi Gneiss,
- Gallacher & Plimer (2000), An unknown number of analyses were obtained from fault zone calcites in the Broken Hill main lode.

$^{40}Ar/^{39}Ar$ (+ K-Ar)

Published $^{40}Ar/^{39}Ar$ and K-Ar studies are collated in the BHEI 2000 CD and include:

- Evernden & Richards (1961), 2 K-Ar measurements giving Delamarian ages (~515 Ma),
- Richards & Pidgeon (1963), 19 K-Ar measurements on retrograde biotite from samples of Broken Hill mine sequence gneisses giving Delamarian ages (~560 Ma),
- Binns & Miller (1963), 10 K-Ar age determinations on hornblende, muscovite and biotite from 7 samples of Broken Hill mine sequence gneisses,
- Harrison & McDougall (1981), 46 K-Ar measurements on hornblende, plagioclase, pyroxene, magnetite, muscovite and biotite from 23 samples of gneisses from throughout the Broken Hill Domain, and 16 $^{40}Ar/^{39}Ar$ age spectrum results,
- Bierlein et al. (1996), 13 $^{40}Ar/^{39}Ar$ age spectrum results on micas from sulphide-bearing veins in the Olary Domain.
- Gibson & Foster (BHEI 2000 CD), 25 $^{40}Ar/^{39}Ar$ age spectrum results on micas, hornblende and K-feldspar from regional country rocks in the Broken Hill Domain.

Assessment of the Data

- Only ~25% of total isotopic data applies to the Olary Domain- and virtually none for other parts of the South Australian Curnamona. The bulk of the data applies to the Broken Hill Domain.
- Of the Broken Hill Domain isotopic data, ~50% are from the Broken Hill main lode or associated mine sequence.

- Apart from Sm/Nd studies which are currently focused in the Olary Domain, all other data type studies have been focused in the Broken Hill Domain, and especially on the Broken Hill main lode.
- The majority of the data has been analysed from known mineral deposits throughout the Curnamona.

Issues

Apart from BHEI 2000 CD rom and the Ozchem database, the majority of the data is not centrally stored in a publically available database, and locality information is limited. However, because most of the sampling is from known mineral deposits, a lot of the locality data could be deduced.

8.4 Lead isotopes

Conclusions

- Probably the most comprehensive Pb-isotope dataset for any mineral province worldwide.
- A database of over 439 analyses is available from CSIRO, and includes all previously published data.
- Double-spiked analyses have greatly improved the precision and value of Pb-isotopic data.
- ~50% of the data is well located, the remainder is unknown to poorly located.
- Coverage is concentrated on mineral deposits in the Broken Hill Domain.
- There are only 34 analyses available for the Olary Domain.
- A robust growth curve for the Curnamona is still in the development stage.

Recommendations

- The CSIRO database needs to be preserved in the event that the CSIRO isotope Lab is dismantled.
- Further work to complete the growth curve for the Curnamona should be supported.
- Further work on double-spike analysis for deposit modelling is recommended.
- Further work using Pb-isotopes in elucidating Cu-Zn mineralization is recommended.

Scope of Data

The total number of data include 400 conventional Pb isotope analyses and 63 double spike Pb isotope analyses. Table 8.4.1 summarizes the available data:

Period	**No. samples**	**No. Locations**	**Accuracy of location**	**Notes**
Pre 2000:	276	~70	27% poorly located 18% well located 55% accuracy of location unknown	80% company data 20% research data
2000-2003:	Galena: 98 K fsp: 26	~35 ?~20 (~25 pending)	100% well located (GA collection)	Systematic coverage of ore deposit types K fsp from rocks with U-Pb zircon ages
2002-2003 double spike	63 samples	~20	100% well located	Broken Hill orebody, Pinnacles orebody, variety of other small deposits

Table 8.4.1. Summary of Pb isotope data available for the Curnamona Province.

All of these data are currently held by CSIRO (~90% analyses done at CSIRO North Ryde laboratories, 10% overseas). The data stored in CSIRO Pb Graph database (Access structure) and includes a confidential survey compiled by Rio Tinto.

Methodology

As a single accessible database exists in CSIRO for most Pb isotope data, assessment of location, coverage and quality has been done in-house at CSIRO North Ryde.

Important published papers and reports for the data are included in Table 8.4.2:

Barnes R.G., 1979, Some base metal deposits in the Mount Robe area, Broken Hill: their classification and relevance to lead isotope interpretation. *New South Wales. Geological Survey. Quarterly Notes*. 34, 5-14.
Bierlein, F.P., Haack, U., Forster, B. and Plimer, I.R., 1996, Lead isotope study on hydrothermal sulfide mineralisation in the Willyama Supergroup, Olary Block, South Australia. *Australian Journal of Earth Sciences*. 43(2) 177-187.
Carr G.R. and Sun S.-S. Lead isotope models applied to Broken Hill style terrains: syngenetic vs epigenetic metallogenesis. *in* Pongratz, J. and Davidson, G., (editors): *New Developments in Broken Hill Type Deposits*. CODES Special Publication 1, 77-86.
Cooper J.A., 1972, Lead isotope classification of the A.B.H. Consols and Browne's shaft veins at Broken Hill , N.S.W. *Australasian Institute of Mining and Metallurgy Proceedings*. 241, 91-93.
Gulson B.L., 1984, Uranium-lead and lead-lead investigations of minerals from the Broken Hill lodes and mine sequence rocks. *Economic GeoloIgy*. 79(3) 476-490.
Gulson B.L., Porritt, P.M., Mizon, K.J. and Barnes, R.G., 1985, Lead isotope signatures of stratiform and strata-bound mineralization in the Broken Hill Block, New South Wales, Australia. *Economic Geology*. 80(2) 488-496.
Parr, J.M. and Carr G.R., 2002, Hydrothermal History of the Curnamona Terrain Assessment of Pb Isotope and Metallogenic Associations Progress Report, *CSIRO Report No. 998R pmd*CRC report C1-002*, pp. 11.
Parr, J.M., Stevens, B.P.J. and Carr, G.R., 2003, Timing of multiple hydrothermal events in the Broken Hill terrain – evidence from lead isotopes. *in* Peljo M. (compiler) *Broken Hill Exploration Initiative 2000, conference abstracts* AGSO Record 2000/10, 126-129.
Reynolds, P.H.A., 1971, U-Th-Pb isotope study of rocks and ores from Broken Hill, Australia. *Earth and Planetary Science Letters*. 12, 215-223.
Russell, R.D., Farquhar, R.M. and Hawley, J.E. 1957, Isotopic analyses of lead from Broken Hill, Australia, with spectrographic analyses. *Transactions of the American Geophysical Union*. 38, 557-565.
Sun S.-S., Carr, G.R. and Page, R.W., 1996, A continued effort to improve lead-isotope model ages. *Australian Geological Survey Organisation Research Newsletter*. 24, 19-20.

Table 8.4.2. References relevant to Pb isotope data in the Curnamona Province.

Assessment of the Data

- Olary province has only 34 analyses and there are no analyses for the Mount Painter and Mount Babbage Inliers
- Cu-Au mineralisation is under-represented (problems here with U contents – getting initial ratios is difficult, but not impossible).
- A provisional Pb isotope growth curve for the Curnamona Province has been constructed using double spike data (Parr et al., in prep), however, magmatic rocks that already have well constrained U-Pb zircon ages (Rod Page) are being analysed to build a better constrained growth curve.

Issues

- Pmd*CRC project (Parr and Carr 2000-2003) has lead to a better understanding of timing of mineralising events relative to each other and to host rocks. The data are being routinely used in ore genesis modelling.
- Use of the double spike technique has greatly increased the analytical precision so that there is much better control in data variation and enhanced confidence in interpretation. Increased use of this method should allow better-constrained geological models.
- A new Pb isotope growth curve is being developed using host rock feldspars so that Pb isotope data for the Curnamona Province can be related to a Curnamona chronological framework. Completion of this work is required to relate Curnamona geological models to other Proterozoic terrains (eg Mount Isa).
- A major issue at the time of writing is the uncertain future of CSIRO Exploration and Mining Isotope Lab. It seems likely that this facility will be lost.

8.5 Geochronology

Conclusions

- No single database has all the available data in it.
- The two main databases (OZCHRON and BHEI 2003 GIS) have different structures.
- New data (post 2000) has not been entered into any database and there are ~30-50 age data “in press”.
- There exists some age data in abstracts and publications but often location data and information about the sample are inadequate.
- There are issues relating to interpretation of results and the quality of some data.
- There are no *major* gaps in the geochronological coverage of the Curnamona
- There are local geological issues that focussed geochronological studies can address
- Improved and newly developed techniques mean that there will continue to be a demand for new, improved geochronological information.

Recommendations

- Recommend that one database be formed. The OZCHRON database is comprehensive and most detailed, and is probably the one to keep up to date.

Scope of Data

Exact numbers of data points are unclear because they are in disparate databases and are repeated in others. Additional data are scattered in abstracts and have not been gleaned for this study (see also isotope section); these may provide a useful resource.

The coverage is fairly extensive over the Curnamona Province and new studies (eg Page; Teale and Fanning) are working in less well-sampled areas (Olary, Benagerie Ridge).

New SHRIMP data through a pmd*CRC project (2002-2003, Rod Page) has not been added to any database (~25 done, 10 in progress covering both BH and Olary). Rod Page intends entering them into OZCHRON (funding dependent). Graham Teale knows of at least 10 SHRIMP data points for Benagerie Ridge that are unpublished.

Other new geochronological data includes data published in papers and abstracts and is not captured by OZCHRON or the GIS packages (eg Elburg et al 2003: samples from Mount Painter analysed at Adelaide University).

Available databases

OZCHRON:

- Coverage is for the whole of Australia and all results are normalised to decay constants recommended by the IUGS Subcommission on Geochronology.
- According to Rod Page there should be much more data in OZCHRON.

SHRIMP	20

U-Pb whole rock	12
Rb-Sr	10
Sm-Nd	5(?)

Table 8.5.1. Geochronological data available on OZCHRON for the Curnamona Province

BHEI 2003 GIS:
The data are divided into two subsets: 379 data points from BHEI 2000 GIS and 127 "new" data points. The two datasets are in separate folders and have different metadata associated. Metadata from the BHEI 2000 GIS is less comprehensive than that for the later dataset.

BHEI 2003 GIS **new** geochron data		From BHEI 2000 GIS (included in BHEI 2003 GIS in \ga_data\geochron.tab)	
U-Pb	57	SHRIMP	121
Rb-Sr	39	U-Pb	31
Sm-Nd	31	Rb-Sr	97
		K-Ar	70
		Fission Track	6
		Ar-Ar	54
TOTAL	127	TOTAL	379

Table 8.5.2. Geochronological data available on BHEI 2003 GIS for the Curnamona Province

- The "new" data (127 points) are mostly in the Olary Domain, with 3 U-Pb data points in Mount Painter, Mundi Mundi Plain and NE of the Euriowie Block.
- There is some overlap between BHEI 2003 GIS and OZCHRON, but not completely. As a result there is no full database of geochronological data.

Methodology

OZCHRON
- Available from GA in ArcView, MapInfo, Access and text formats. Free download from http://www.ga.gov.au/rural/projects/20011023_32.jsp
- Information on the structure of the OZCHRON database is found in Edgecombe et al. (2002).

BHEI 2003 GIS:
- MapInfo and ArcView versions available.
- Important published papers and reports for the data include:

Conor, C.H.H. and Fanning, C.M., 2001, Geochronology of the Woman-in-White Amphibolite, Olary Domain. *MESA Journal*, 20, 41-43.
Cooper, J.A., and Ludwig, K.R., 1985, Inherited zircons in the Mundi Mundi Granite, Broken Hill , New South Wales. *Australian Journal of Earth Sciences*, 32(4) 467-470.
Ehlers K., Foster J., Nutman A.P., and Giles D., 1996, New constraints on Broken Hill geology and mineralisation. *in* Pongratz, J. and Davidson, G., (editors): *New Developments in Broken Hill Type Deposits*. CODES Special Publication 1, 73-76.
Elburg, M.A., Bons, P.D., Foden, J. and Brugger, J., 2003, A newly defined Late Ordovician magmatic-thermal event in the Mt Painter Province, northern Flinders ranges, South Australia: *Australian Journal of Earth Sciences,*

50(4), 611-632.

Fanning, M., Ashley, P., Cook, N., Teale, G. and Conor, C., 1998, A geochronological perspective of crustal evolution in the Curnamona Province. *Australian Geological Survey Organisation Record*. 1998/25, 30-35.

Gulson B.L., 1984, Uranium-lead and lead-lead investigations of minerals from the Broken Hill lodes and mine sequence rocks. *Economic GeoloIgy*. 79(3) 476-490.

Nutman, A.P. and Ehlers, K., 1998, Evidence for multiple Palaeoproterozoic thermal events and magmatism adjacent to the Broken Hill Pb-Zn-Ag orebody, Australia. *Precambrian Research*, 90(3-4) 203-238.

Page, R., 1994. Depositional age of volcanic precursors of the 'Potosi' gneiss, Broken Hill Group. *Bureau of Mineral Resources, Geology and Geophysics. Research Newsletter*, 14, 3-4.

Page, R.W. and Laing, W.P., 1990, Depositional age of the Broken Hill Group from volcanics stratigraphically equivalent to the Ag-Pb-Zn orebody. *In:* Gondwana: terranes and resources. Tenth Australian Geological Convention, Hobart. *Geological Society of Australia. Abstracts,* 25, 18-19.

Page, R.W., Laing, W.P. and Stevens, B.P.J., 1990, The Broken Hill orebody, Australia: depositional age and timing of high-grade metamorphism. *In:* Seventh International Conference on Geochronology, Cosmochronology and Isotope Geology, Canberra, Australia. *Geological Society of Australia. Abstracts,* 27, 75.

Page, R.W., Conor, C.H.H., Stevens, B.P.J., Gibson, G.M., Preiss, W.V. and Southgate, P.N., *in press* Broken Hill and Olary Domains in the Curnamona Province, Australia: correlation with Mount Isa and other north Australian Pb-Zn-Ag bearing successions. *Economic Geology.*

Page, R., Stevens. B., Gibson. G. and Conor, C.H.H., 2000. Geochronology of Willyama Supergroup rocks near Broken Hill. *Minfo: New South Wales Mining and Exploration Quarterly,* 68, 28-30.

Page, R.W., Stevens, B.P.J., and Gibson, G.M., 2000, New SHRIMP zircon results from Broken Hill : towards robust stratigraphic and event timing. *In:* Understanding planet earth: searching for a sustainable future. 15th Australian Geological Convention, *Geological Society of Australia. Abstracts,* 59, 375.

Page, R.W., Stevens, B.P.J. and Gibson, G.M., *in press* Geochronology of the sequence hosting the Broken Hill Pb-Zn-Ag orebody, Australia. *Economic Geology.*

Raetz, M., Krabbendam, M. and Donaghy, A.G., 2002, Compilation of U-Pb zircon data from the Willyama Supergroup, Broken Hill region, Australia: evidence for three tectonostratigraphic successions and four magmatic events? *Australian Journal Of Earth Sciences,* 49(6), 965-983.

Raetz, M., Krabbendam, M. and Giles, D., 2000, Three tectonostratigraphic cycles in the Broken Hill Terrane based on a review of SHRIMP 207Pb/206Pb zircon dates comparison with northern Australia. *In:* Understanding planet earth: searching for a sustainable future. 15th Australian Geological Convention. *Geological Society of Australia Abstracts,* 59, 403.

Skirrow, R.G., Ashley, P.M., Suzuki, K. and McNaughton, N.J., 2000, Timing of Cu-Au(-Mo) and regional sodic-calcic alteration in the Olary -Broken Hill region: molybdenite Re-Os and titanite U-Pb dating constraints. *In:* Understanding planet earth: searching for a sustainable future. 15th Australian Geological Convention. *Geological Society of Australia Abstracts,*59, 461.

Skirrow, R., Maas, R. and Ashley, P., 1999, New age constraints for Cu-Au(-Mo) mineralisation and regional alteration in the Olary -Broken Hill region. *Australian Geological Survey Organisation. Research Newsletter,* 31, 22-25.

Teale, G. and Fanning, C.M., 2000, The Portia-North Portia Cu-Au(-Mo) prospect, South Australia: timing of mineralisation, albitisation and origin of ore fluid. *In:* Porter, T.M. (editor), Hydrothermal Iron Oxide Copper-Gold and Related Deposits: A Global Perspective Conference. *Australian Mineral Foundation,* 137-147.

Assessment of the Data

OZCHRON

- Access version: This database does not convert well from Access 95 (lots of compiling errors). It is not very user friendly (may be result of poor translation?), for example all tables etc. are hidden when opening the database.
- MapInfo version (and ArcView?): needs to be opened in conjunction with OZRox to get all geological information.
- The following extracts from Edgecombe et al. (1999) explain the relational structure of the GA rock databases:

> *"OZCHRON is part of a system of databases set up for the National Geoscience Mapping Accord (NGMA). …The central component of these databases is the OZROX Field Geology Database which records all sample attribute data (e.g., location, stratigraphic formation, lithology, etc.). …*
> *The OZCHRON database comprises eight main tables for analytical and derived age information for four age determination methods, Rb-Sr, conventional U-Pb, SHRIMP U-Pb, and Sm-Nd. Each age determination can be related back to attribute and locational data in the OZROX database, or to information in other databases (e.g., whole rock geochemistry in the OZCHEM database). Authority or lookup tables are used by OZROX and OZCHRON to supply standard values for many fields."*

BHEI 2003 GIS

This is a comprehensive database that includes data from BHEI 2000 GIS that is confusingly in a directory called GA data. The structures of tables of "old" and "new" data are different, making direct comparison awkward.

Abstracts and papers

Variable amounts of information relating to location, sample type and analytical procedure.

Issues

According to Rod Page there are no huge gaps in coverage because the pmd*CRC project that has been running 2002-2003 is specifically designed to address any gaps in geochronological coverage. However completion of the project is currently uncertain (6 months to complete). Two papers are in press in Economic geology covering some of this work.

The nature of geochronological data is such that it is possible to interpret the data in many ways. The question therefore arises "Should data be made accessible even when it has not undergone scrutiny (eg unpublished)?" A lot of data is controversial in terms of interpretation (eg AGCRC data measures an "event" at 1650 Ma which Page argues is an artefact of using discordant data in their interpretations.

As techniques are improved (eg Pb isotope double spike) and others are developed (eg step leaching of garnets), a number of factors will effect geochronology and sites/samples will need to be redone or reassessed:

- the accuracy of results and therefore interpretations will improve
- a better constrained tectono-stratigraphic framework will lead to improved geological interpretations

Therefore, there will always be a demand for new, improved geochronological information.

Unpublished data

- In 2002-2003 Mark Fanning and Graham Teale have done a lot of U-Pb (SHRIMP) analyses around the Benagerie Ridge area (zircon, monazite and rutile) as well as up at

Mt Painter. They are planning to publish, but have ~10 dates in the Benagerie Ridge area alone which are not on any database.

- There are ~70 AGCRC SHRIMP data, mostly from Broken Hill. Some were published in Nutman and Ehlers (1998), but many are only in abstracts if published at all. The sample location is generally not well documented.

Published data

- Keeping track of new data in abstracts and papers is difficult especially as more universities become capable of doing their own isotopic analyses.
- Publications have variable amounts of information relating to location, sample type and analytical procedure. This means entering them into a central database may possibly compromise the database integrity.

8.6 Alteration

Conclusions

- Of the 18 known studies on alteration systems in the Curnamona, 16 have focused on the Broken Hill ore system (Broken Hill-type deposit), and two regional studies have covered the Olary Domain (Cu-Au systems).
- Alteration studies on the Broken Hill Ore System demonstrate a consistent premetamorphic enrichment in K, Fe, Si, Mn, Rb and depletion in Na, Ca, and Sr, approaching the ore position.
- Ashley & Skirrow (BHEI2000 GIS) have developed a regional spatial approach to alteration mapping using radiometrics, geology, and whole-rock geochemistry for the Olary Domain. This information is not available on the BHEI2003 GIS.
- There is potential for regional alteration mapping using remote-sensing techniques such as ASTER and HyMap to compliment existing techniques.

Recommendations

- Consider creating regional spatial alteration maps outside of the Olary Domain.
- Incorporate knowledge and data from the Broken Hill ore system studies into regional alteration studies for Broken Hill-type deposits.
- Continue to investigate the potential for alteration mapping using ASTER and HyMap.

Scope of Data

Author	No. Analyses	Rock types	Approaching ore:	
			Enriched in	Depleted in
Walker (1964)	4000 (trace elements)	Potosi, pelite, psammite, tholeiite	Pb. Zn, Ag, Cu, Cd	Sr
Ransom (1972)	21 (modal)	tholeiite to Potosi transition	K, Si, Na	Fe, Mg, Ca
Hodgson (1975)	thin sections	Wall rocks to ore	Ca, Mn, Fe	Na, K, Al, Si
Klingner & McConachy (1975)	1723 (XRF)	Potosi	K, Ca, Al	Na, Si
Plimer (1976) Elliot (1976)	112 (XRF)	Potosi, pelite	Rb, K, (sericite), Fe3+	Sr, Ca, Na, Mg
		thoeliite	Rb, K, Al, H_2O	Ca, Sr, Na, Ti
Elliot (1979)	347 (XRF)	Potosi, pelite, psammite, tholeiite	Mn, Fe3+, Pb, Zn	Na, Ca, Sr, Mg
Plimer (1979)	260 (XRF)	Potosi, pelite, psammite, tholeiite	K, Fe, Si, Mn, Pb, Rb, S, Ti	Na, Ca, Sr, Mg

Main et al. (1983)	4054 (XRF)	Mainly Potosi	Mn, (K, Fe, Ca, Mg, Rb, Ti, Al)	Na, Sr, (P, Ba)
Haydon et al. (1993), Wright et al. (1993)	1093 (XRF)	Potosi, pelite, psammite	K, Fe, Mn, Pb, Zn, Cu, As	Na, P
Stanley (1997)	1300 (XRF) 1400 (probe)	Pelite, psammite	K, Fe, Si, Mn, Pb, Zn	Na, Ca
Prendergast et al. (1998)	Fluid inclusions	Potosi, pelite, psammite	Fe, Mn, Mg	Na, K, Ca
Williams et al. (1998)	Fluid inclusions	Qtz-rich veins	K, Fe, Ca, Si, Mn, Pb, Zn, P, F, Na	
Stevens & Capnerhurst (1998)	2300 (XRF)	Mainly Potosi and thoeliite	Potosi: K	Potosi: Na
			Thoeliite: Si, P	Thoeliite: Fe3+, Mg, Ti
BHEI2000 GIS (Skirrow & Ashley, 2000) Olary Domain	352 (XRF), K/Th gamma	All rock types	Fe, Na/K, K	K
Kent et al. (2000) Olary Domain	20 (XRF), fluid inclusions	calc-silicate	Mn, Fe^{3+}, Ca, Cu	Na, Fe^{2+}, Mg, Rb
Walters (2000)	10000 (XRF)	Pelite, psammite	K, Fe, Si, Mn, Pb, Rb, Zn	Na, Ca, Sr, Mg
Leyh (2000)	petrographic	Pelite, psammite	K, Si, Fe, Mn, Mg	
			K, Fe, Si, Mg	
Evans (2002)	20 (XRF)	Pelite, psammite	Fe, Mn, Zn, Ca	K, Si, Rb

Table 8.6.1. Hydrothermal alteration studies on the Curnamona. All studies relate to the Broken Hill ore system except Skirrow and Ashley (2000) and Kent et al. (2000).

Methodology

Apart from the Geoscience Australia GIS products found in BHEI 2000 GIS, other material for this assessment has been sourced from literature (see References).

Assessment of the Data

- Alteration associated with the Broken Hill ore system is well documented in a number of geochemical studies shown in Table X. However, in the Broken Hill Domain, publicly available alteration studies outside of this ore system are scarce.
- The alteration studies on the Broken Hill Ore System have an overall consistent conclusion: the alteration halo displays enrichment in K, Fe, Si, Mn, Rb and depletion in Na, Ca, and Sr, approaching the ore position.
- PIRSA wish to create regional alteration maps based on geology and detailed radiometrics. A first step in this aim was Roger Skirrow and Paul Ashley's work on alteration associated with Cu-Au systems was undertaken between 1998-2000, focused on the Olary Domain. This included gamma-ray spectrometrics (K^2/Th) to assess potassic alteration zones, highlighting outcrops of altered rocks, and Na_2O/K_2O ratios from whole-

rock data to assess areas of albitization and potassic alteration. The results are presented in the BHEI 2000 GIS, but missing from BHEI2003 GIS.

- ASTER data is useful for defining alteration for OH groups such as sericite, but unlikely to detect potassic alteration or albitization. A more complete assessment of the potential of the ASTER data to define alteration is presented in Chapter X.

9.1 Electrical Conductivity Surveys

Conclusions

- Coverage is limited to tenement areas held by companies.
- The Broken Hill Domain has the best coverage.
- There is no publically available information on ground electrical surveys. DMR's Aerofind is the only public source of information on airborne electrical surveys.

Recommendations

- Recommend that one agency maintains comprehensive list of open-file company and government survey data for the Curnamona Province, or failing that;
- Recommend that all agencies adopt the same data-structure and data-dictionary to facilitate data searches and compilations.

Scope of the Data

Airborne Survey data that contained AEM data were sourced from:

- DMR Aerofind Data set, March 2003;
- PIRSA Compilation CD (for the Audit & Gaps Analysis, May, 2003).

The DMR and PIRSA data document open-file company AEM data sets. Airborne Electro-magnetic surveys have been acquired over the Curnamona between 1974 and 1996. A range of system technologies have been used in these acquisitions, however, the configuration of the AEM system or the geophysical contractor it is not always obvious in the database. The line-spacing of the data typically range between 200 and 400m with variable flying heights.

The only IP survey coverage available was from Pasminco, as point coverage only over the Broken Hill Domain (Figure X). Coverage is concentrated on the southwestern portion of this domain, including detailed work over the Broken Hill line of lode.

Methodology

All files used were clipped to be within the bounds of the study area. Separate files were created from the available airborne geophysical data sets detailing those surveys that included AEM measurements.

Issues

Data sets suffer the same issues as the airborne radiometrics data sets in that there is an inconsistent data structure and data-dictionary used by the agencies (Figure 9.1.1).

Assessment of the Data

Coverage is limited to tenement areas held by companies. As expected the Broken Hill Block has the best coverage.

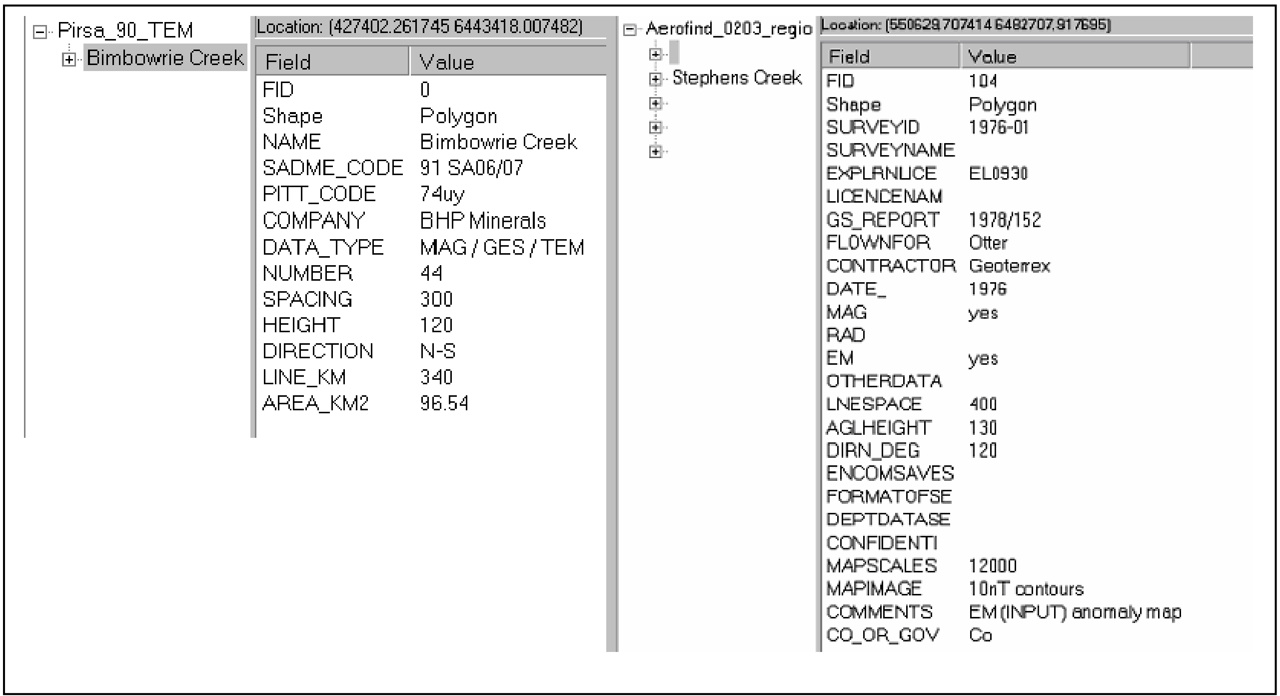


Figure 9.1.1: Comparison of the data base structures between PIRSA and DMR, AEM meta data.

9.2 Airborne Magnetic Surveys

Conclusions

- Airborne Magnetics coverage generally excellent over Olary and Broken Hill Blocks.
- Outcropping Willyama Supergroup in Mt Painter/Mt Babbage area possibly needs better coverage.

Recommendations

- Recommend that areas with greater than 400m line-spacing, be assessed to determine whether the geology or structural situation indicates more detailed data needs to be acquired.
- Recommend that one agency maintains comprehensive list of open-file company and government survey data for the Curnamona Province.; or failing that,
- Recommend that all agencies adopt the same data-structure and data-dictionary to facilitate data searches and compilations.

Scope of the data

Airborne Survey data that contained “Magnetics” were sourced from:

- NSW-DMR Aerofind Data set, March 2003;
- Geoscience Australia Airborne Geophysical Data Archive, May 23, 2003, (GA Record 2003/10);
- PIRSA Olary Geoscientific GIS Dataset 2001 CD; and, PIRSA Compilation CD (for the Audit & Gaps Analysis, May, 2003).

And these data sets were considered the most comprehensive and recent available from the survey organizations. The NSW-DMR and PIRSA data document state-survey and open-file company data sets. The first airborne magnetics data were collected over the Curnamona Province in September 1957 by the then BMR (now GA); and the most recent was acquired in 1999 as part of the South Australian Exploration Initiative. Hence there is at least two, if not three generations of magnetometer technology represented in the data sets. The line-spacing of the data sets ranges typically range between 3200m to 100m with variable flying heights.

This study has looked at the “foot-prints” and available meta-data of the surveys and no assessment has been made of the actual data. Various surveys have now been gridded, leveled and mosaicked into images, and no assessment has been made on these “products” either. Because the “heritage” of these images is typically not-known, let the users of these image products beware.

Methodology

All files used were clipped to be within the bounds of the study area.. Separate files were created detailing those surveys that included magnetic measurements from the original files.

To indicate the detail of the survey, the following schema based on line-spacing was used: ≤100m – solid, >100 ≤ 400m - cross-hatch and ≥ 400m - hatch. Transparent backgrounds were used; hence the resulting map shows the most-detailed coverage available over a particular area. Because some surveys had variable line-spacing (e.g., 100-200m), the most detailed line-spacing was used to denote that survey. Also for some surveys, the line-spacing was not obvious from the available information, and a guess was made based on best practice at that time.

Issues

Data sets suffer the same issues as the airborne radiometrics data sets in that there is an inconsistent data structure and data-dictionary used by the three agencies (Figure 9.4.1).

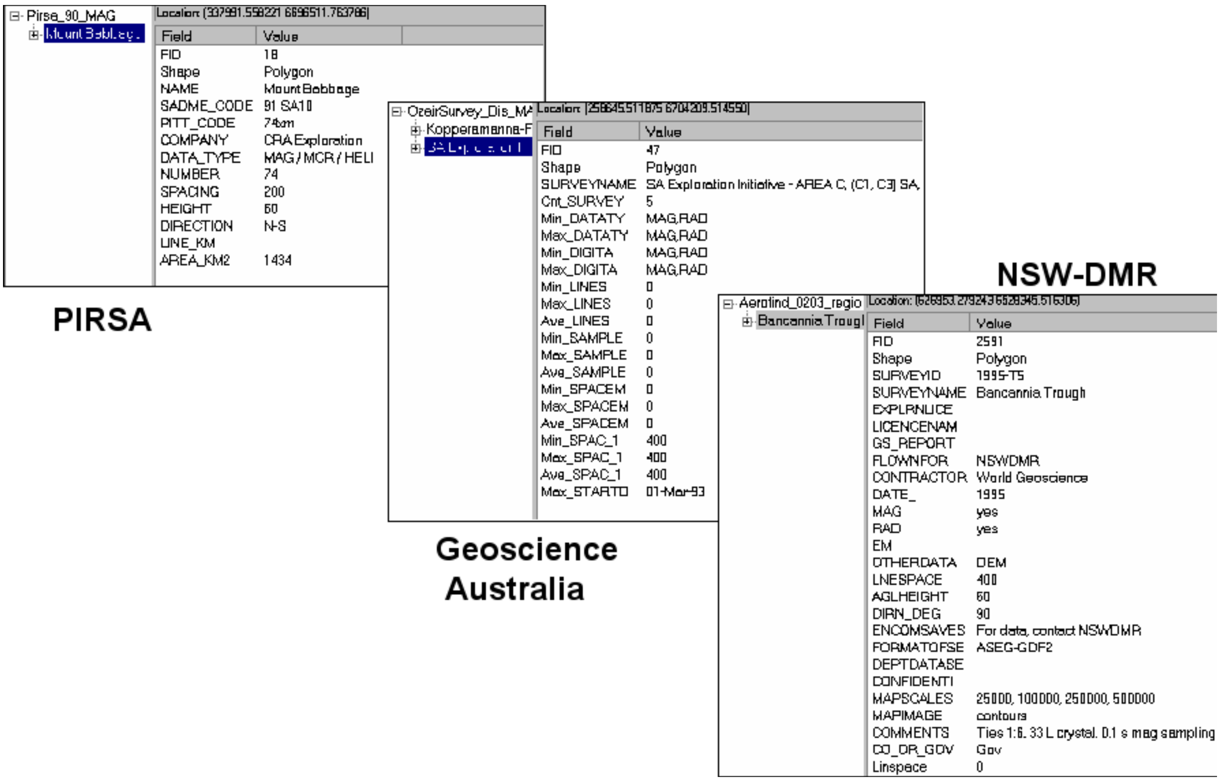


Figure 9.4.1: Different data structures used to describe the airborne geophysical datasets by the three agencies.

It is a problem that each agency maintains a different data structure and uses a different "data-dictionary". It would be ideal for one agency to accept responsibility for maintaining all the airborne geophysical data over the Curnamona , which could then be distributed via all three agencies.

Eighty-five percent of the study area is covered by airborne radiometrics data with a flight-line spacing better than 400m. Approximately fifteen percent is covered by data with between 400 and 6200m flight-line spacing. Most of the closely-spaced data in South Australia has a variable flight-line spacing between 100 and 400m.

Assessment of the Data

Coverage over the Broken Hill and the Olary Block areas by high quality magnetic data appears adequate. Only a small portion of the Mt Painter/Mt Babbage Willyama Supergroup is covered by closely-spaced data.

Some areas towards the margins of the study area are covered by wide-spaced data (typically ~3000m).

9.3 Airborne Radiometric Surveys

Conclusions

- Radiometrics coverage generally excellent over Olary and Broken Hill Blocks.
- Outcropping Willyama Supergroup in Mt Painter/Mt Babbage area possibly needs better coverage.

Recommendations

- Recommend that areas with greater than 400m line-spacing or no coverage at all, be assessed to determine whether the geology or structural situation indicates more detailed data need to be acquired over these areas.
- Recommend that one agency maintains comprehensive list of open-file company and government survey data for the Curnamona Province; or failing that
- Recommend that all agencies adopt the same data-structure and data-dictionary to facilitate data searches and compilations.

Scope of the Data

Airborne Survey data that contained "Radiometrics" were sourced from:

- NSW-DMR Aerofind Data set, March 2003;
- Geoscience Australia Airborne Geophysical Data Archive, May 23, 2003, (GA Record 2003/10);
- PIRSA Olary Geoscientific GIS Dataset 2001 CD; and, PIRSA Compilation CD (for the Audit & Gaps Analysis, May, 2003).

And these data sets were considered the most comprehensive and recent available from the survey organizations. The NSW-DMR and PIRSA data document both state-survey and open-file company data sets.

Methodology

All files used were clipped to be within the bounds of the study area. Because the original data documented airborne geophysical surveys, separate files were created detailing those surveys that included gamma-ray measurements.

To indicate the detail of the survey, the following schema based on line-spacing was used: ≤100m – solid, >100 ≤ 400m - cross-hatch and ≥ 400m - hatch. Transparent backgrounds were used; hence the resulting map shows the most-detailed coverage available over a particular area. Because some surveys had variable line-spacing (e.g., 100-200m), the most detailed line-spacing was used to denote that survey. Also for some surveys, the line-spacing was not obvious from the available information, and a guess was made based on best practice at that time.

Issues

Data sets suffer the same issues as the airborne magnetics data sets in that there is an inconsistent data structure and data-dictionary used by the three agencies (Figure 9.5.1).

A variety of terms, (e.g., “RAD”, “RAL”, “MCR”) is used to denote the type of radiometric survey flown. “RAL” is by Geoscience Australia and “MCR” by PIRSA to denote 256-channel gamma-ray data. Also, the use of “RAL” for 256-channel gamma-ray data by Geoscience Australia is at odds with the term recommended in their “Data Dictionary for GIS Products”, which is “Rad-256”.

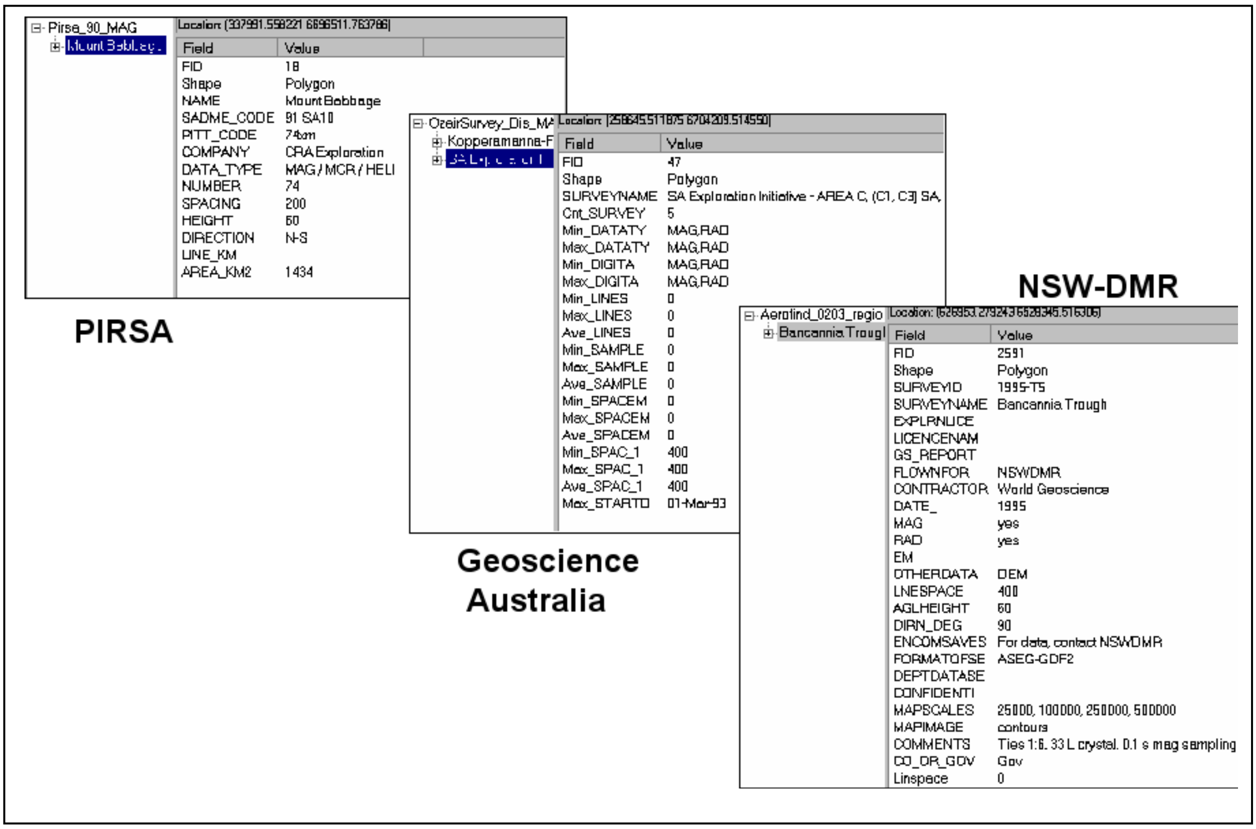


Figure 9.5.1: Different data structures used to describe the airborne geophysical datasets by the three agencies

Firstly it is not ideal that each agency maintains a different data structure and that each uses a different “data-dictionary”. Secondly, it would be prudent for one agency to accept responsibility for maintaining all the airborne geophysical data over the Curnamona, which could then be distributed via all three agencies.

Eight-five percent of the study area is cover by airborne radiometrics data with flight-line spacing better than 400m. Approximately ten percent is covered by data with between 400 and 3000m flight-line spacing; and another five percent with no radiometrics cover at all. These coverage gaps are shown on the accompanying map.

Information about crystal-size, and hence signal-to-noise, is not consistently apparent from the existing metadata. However some of this information can be gained from interrogating the GA geophysical archive.

Assessment of the Data

Coverage over the Broken Hill and the Olary Block areas by high quality radiometrics data appears adequate. Only a small portion of the Mt Painter/Mt Babbage Willyama Supergroup is covered by closely-spaced radiometrics.

There are a number of radiometric coverage gaps over the study area, which may or may not be a major issue. The two areas with line-spacing coverage greater than 400m should be assessed to determine whether the collection of more closely spaced is warranted.

Radiometrics are considered to be an under-utilized data set in the Curnamona region; however it is an effective tool for surface and regolith mapping.

9.5 Ground Gravity Stations

Conclusions

- Ground Gravity coverage is excellent and comprehensive over Olary and Broken Hill Blocks and immediate surrounds.
- There is a gap in the data in the Mt Painter area where ground gravity data exists but is confidential.

Recommendations

- Recommend that one agency maintains comprehensive list of Ground Gravity Stations for the Curnamona Province, or failing that;
- Recommend that all agencies adopt the same data-structure and data-dictionary to facilitate data searches and compilations.

Methodology

Gravity Station data were sourced from:

- Geoscience Australia: Australian National Gravity Database, May, 2003 Edition, (free download from www.ga.gov.au): # GA NSW 58,507 gravity stations – blue dots, # GA SA 66,426 gravity stations - blue dots on Figure X.
- Geoscience Australia: Broken Hill – Menindee Gravity Database, July 2003 (free download from www.ga.gov.au).
- PIRSA Compilation CD (for the Audit & Gaps Analysis, May, 2003): 27,292 gravity stations (7 km to 1 km spacing- red dots).
- NSW-DMR: The Broken Hill Geoscience Database Version 2, 16 October 2002**.** 60,672 gravity stations (down to 60m spacings- green dots).

The GA data sets were most comprehensive, and they included all stations contained on the "PIRSA Compilation CD". The NSW-DMR data set did contain unique data over the Broken Hill Block and its immediate surrounds.

The data were clipped to be within the bounds of the study area.

Issues

The data sets suffer the same issues as the airborne geophysical data in that there is an inconsistent data structure and data-dictionary used by the three agencies (Figure 9.6.1). Although this issue can be overcome readily by an experienced GIS user, it represents a serious hurdle to explorationists who are not experienced in GIS.

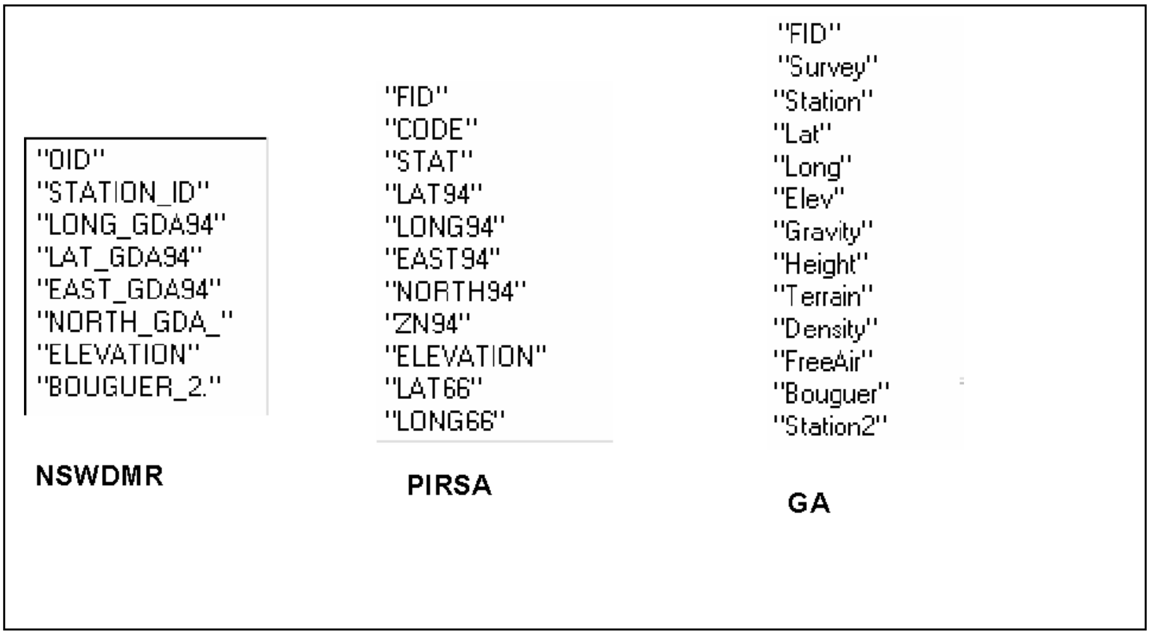


Figure 9.6.1. Comparison of data base structures for Gravity Station Data

On Figure 9.6.2, the GA "Survey" 197006 is shown as a "CODE" 7006 on the PIRSA data. Even more disturbing is the discrepancy in the (GDA 94) latitude and longitude of the station. Because these data are stored as latitude and longitude in decimal degrees, there is potential for error related to precision and rounding. Between the PIRSA and GA data sets we have seen variation typically in the fourth decimal place and beyond for a given location. However, at times the PIRSA dataset appears to be "rounded" at the third decimal place, which gives rise to occasional positional errors on the ground of up to 400m (see Figure 9.6.3). These errors seem to be more common for stations south-west of Olary. We are aware of ASCII export problems within Access™, whereby a user can inadvertently round and limit the number of exported decimal places; and this can be a trap for unwary players, especially when locations are stored in decimal degrees.

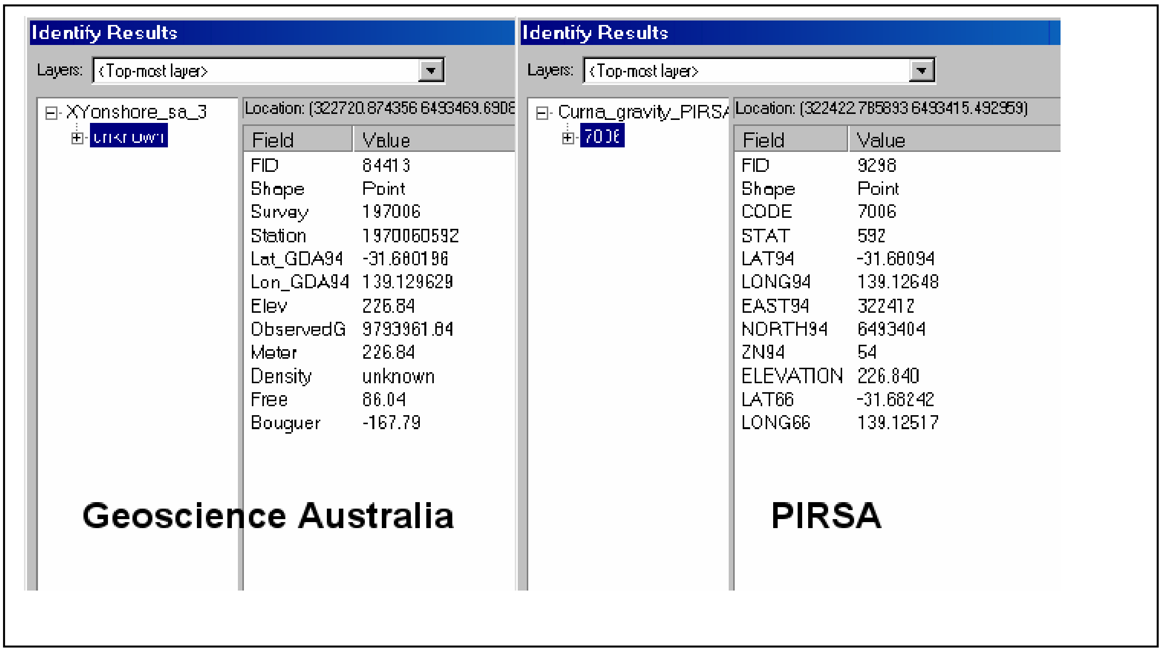


Figure 9.6.2 Differences in database structure and terminology between GA and PIRSA data for the same gravity station

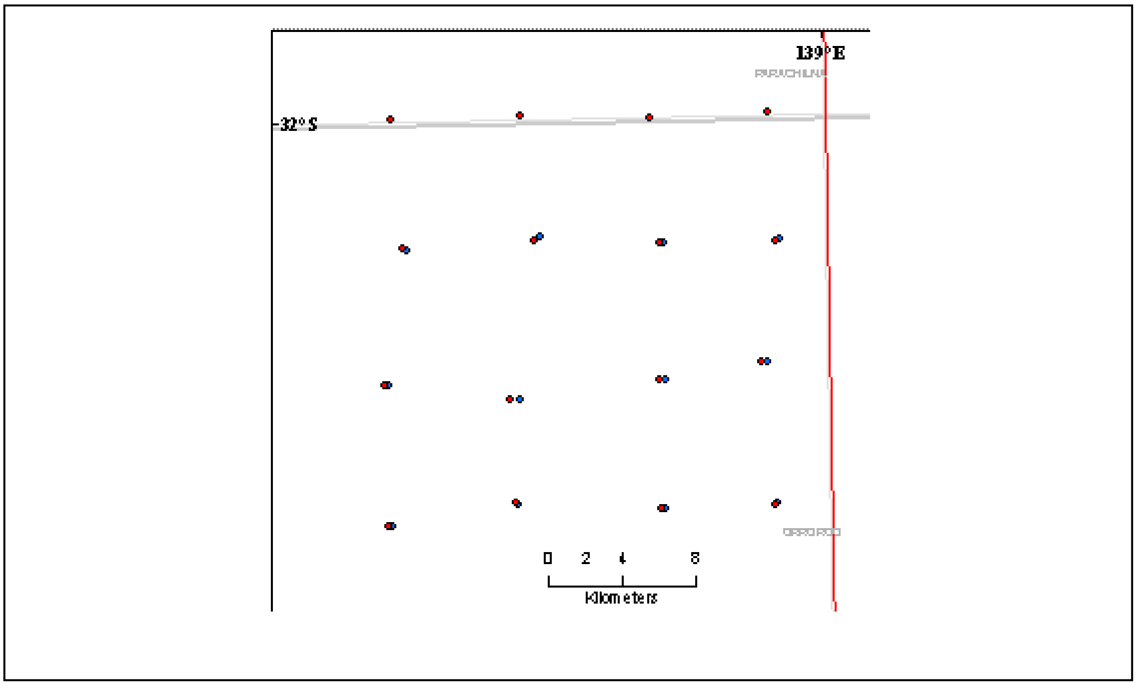


Figure: 9.6.3: Example of "aliasing" effect evident because of the "rounding" problem in decimal degree locations on the PIRSA data set. Red dots - PIRSA; Blue dots - GA

Assessment of the Data

- The Ground Gravity coverage over the Broken Hill and Olary Blocks, and the areas immediately to their north is exceptionally good.
- As a general statement the regularity and density of the stations in South Australian appears to be better than the distribution in NSW.

Positional discrepancies between PIRSA and GA data need to be addressed.

9.5 Airborne Gravity Gradiometry Survey

Conclusions

- Coverage is within the Broken Hill Domain only.
- A simple inversion of the data into physical property units (g/cm^3) has been performed.
- Integration of the data with ground gravity and the Pasminco 3D model is ongoing.

Recommendations

Nil.

Scope of Data

- A single survey using a FALCON™ AGG system was acquired in February 2003.
- The survey covered 1000 square km and included Broken Hill, little Broken Hill, the Pinnacles, Copper Blow and Galena Hill deposits (Figure 9.3.1).
- Line data was spaced at 200m intervals, flown at ~80 metres above ground.

Methodology

Information for this review was mostly sourced from Lane et al. (2003).

Assessment of the Data

- Data relevant for base metal, Fe-Cu-Au and Ni-Cu-Pt-Pl explorers.
- The coverage of rock property data available for Curnamona coincides with the AGG survey, so that relevant petrophysical data is available.
- A simple inversion of the data into g/cm^3 supports previous suggestions that the gravity high around Broken Hill could be related to material in the upper 2km of the subsurface, rather than a deeper source.
- The AGG data is in the process of being incorporated into the Pasminco 3D model by pmd*CRC staff.

Future work includes better estimates of noise levels in the data and integration with ground gravity data. To assist with data integration, Geoscience Australia has recently acquired more ground gravity data in the survey area to reduce the maximum station spacing from 7km to 2km.

9.6 Seismic Survey Data

Conclusions

- There is no seismic data over the Olary Domain.
- There is a lack of shallow seismic data over Proterozoic basement rocks.

Recommendations

- Consideration be given to conducting shallow seismic surveys over existing deep seismic traverses to allow better correlation between surface geology and seismic interpretation.
- Consideration be given to extending seismic cover over the Olary Block and connecting with coverage over Broken Hill (as planned by PIRSA).

Methodology

Seismic data were sourced from:

- DMR_BHEI2000_AV ; DMR_BHEI2002_AV
- PIRSA Compilation CD (for the Audit & Gaps Analysis, May, 2003).: MESA_Curnamona_MI

Assessment of the Data

Coverage is limited to some earlier shallow seismic surveys for petroleum 90 exploration in the sedimentary package that covers the central zone of the Curnamona Province, and to more recent traverses that transect the Broken Hill Block done as part of the AG-CRC deep crustal study of the Broken Hill Inlier.

Various workers have flagged a problem in extrapolating deep structures identified by the AG-CRC seismic survey to mapped surface structures.

10. Rock Properties

Conclusions

- The South Australian Curnamona is especially data poor and under-represented compared with the Broken Hill Domain.
- A significant amount of data resides in company databases, often with little benefit to the company, and may be obtainable.

Recommendations

- Pasminco and other relevant companies should be approached for their rock property data.
- Consideration should be given to collecting more data from the South Australian Curnamona.

Methodology

- BHEI 2000 GIS data and Maidment et al. (1999) data plotted into shape files (App. X), the remaining data exist as hard-copy appendices in the theses mentioned above.
- Major explorers may have data in databases that is unused and of little value to them. For example, Pasminco owns significant amount of geophysical rock property data, currently held by Prof. Don Emerson.

Scope of Data

The distribution of the following data is shown in Appendix X:

- BHEI 2000 GIS- 271 samples from 8 outcrop localities in the Broken Hill Domain measured for magnetic susceptibility, anisotropy of susceptibility, and remanence, were made on oriented drillcore.
- 1001 samples (825 drillcore and 176 outcrop samples) from 174 outcrops and 16 drillholes were measured for magnetic susceptibility, natural remanent magnetisation, anisotropy of magnetic susceptibility and density (Maidment et al., 1999). This dataset was analysed by Ruszkowski (1998).

The following data are obtainable from theses:

- 67 samples from 5 drillholes at Broken Hill, Rupee, and Little Broken Hill measured for density and porosity by Elliott (1979).
- 2103 Magnetic properties were compiled and analysed by Tucker (1983). His dataset included magnetic data collected by a number of students in the Broken Hill Domain (Jenke, 1972; Wood, 1972; Anderson, 1975; and Isles, 1983), and a dataset by Clark (1981) as well as some company data.

There is an unknown number of outcrop and drillhole magnetic susceptibility measurements collected by various companies that remain unpublished.

Assessment of the Data

- These data are important for inversion of geophysical surveys and numerical modelling.
- No data apparent for SA Curnamona; limited distribution of samples within Broken Hill Block (App. X).
- Total available data are not compiled into a single database.

11.1 ASTER data

Conclusions

- Interpreted mineral maps generated from ASTER within the Broken Hill Block have generally provided supplementary AlOH, MgOH and regolith quartz maps to areas already with detailed 1:25,000 mapped geology.
- AlOH content and compositional maps indicate possible varied alteration histories within the Broken Hill Block's metasediments.
- Detailed comparisons between ASTER and HyMap are currently being undertaken by CSIRO-Sumitomo Metal Mining which will assess ASTER's interpreted AlOH compositional mapping.

Recommendations

- Further sampling and spectral measurements will assist in assessing the relevance of the AlOH variation and possible alteration significance for the Olary Curnamona intrusives.
- Further detailed comparisons with geology (GIS) and possible spectral sampling is also required to fully assess the usefulness of the ASTER mineral map products within the Olary Block and other areas within SA's Curnamona.

Scope of Data

Over forty ASTER 60 x 60 km scenes (Figure 1) consisting each of 4 bands (including stereo band) within the visible-near infrared wavelength region (@ 15 m), 6 shortwave infrared bands (@ 30 m) and 5 thermal infrared bands (@ 90 m) have been acquired within the Curnamona Province from May 2000 till May 2003 (Hewson et al., 2003a, b). Some cloud cover is apparent although repeat acquisitions reduce this issue. Higher level products are available to order from either the USGS (http://edcimswww.cr.usgs.gov/pub/imswelcome/) or Japan's Earth Remote Sensing Data Acquisition Centre (ERSDAC) (http://www.gds.aster.ersdac.or.jp/gds_www2002/index_e.html) and based on the Level 1b radiance at the sensor standard product. DEMs are also available to order but involve lengthy delays (6 months +) unless software is available (PCI, ASTERDTM) to process the ASTER radiance data. Publications include Hewson (2003a, 2003b).

Methodology

The ASTER Curnamona Project, supported by PIRSA, produced seamless geological mineral group products including Al-OH (abundance and compositional variation), MgOH-carbonate, quartz content. This required the mosaicing of fifteen different dates of ASTER acquisition using empirically derived linear gain factors for the SWIR bands. Most of the processing was undertaken with ERMapper version 6.3, including the use of band ratios targeting mineral (group) signatures.

Assessment of the Data

Coverage of ASTER data within the Curnamona Province Study Area is almost complete although gaps in imagery (Figure 2) occur within portions of the Olary (10% missing) and Anabama (20%) 100K mapsheets. Also 10% high level cloud cover is apparent for ASTER scenes encompassing the Winnininnie and Yunta 100K sheets. Miscalibration of ASTER's SWIR bands, particularly bands 5 and 9 is significant (Cross Talk Effect) however this is mostly corrected for by application of ERSDAC's correction software (vers. 3.0). ASTER'S SWIR bands qualitatively mapped the concentration of AlOH, MgOH-rich units and quartz regolith cover within the Broken Hill Block. The mapping of the AlOH composition (e.g. phengite vs muscovite) was also possible however subsequent comparisons with HyMap indicated the presence of chlorite could reduce ASTER's effectiveness for this discrimination. The quartz regolith map over the Curnamona was effectively produced and mosaiced from ASTER's Level 2 surface emissivity product using simple band ratios. Generally this product is reasonable however horizontal striping noise is a problem for some scenes.

Issues

The AlOH "abundance" map approximately highlighted outcropping metasediments and granitic intrusives within the Broken Hill Block and SA's Curnamona/Olary areas within the limits afforded by 30 metre pixels and 6 band shortwave infrared bands available. Comparisons with the 1:25 000 DMR geology indicated however more highly weathered and generally narrow retrograde shear zones were not differentiated by the ASTER AlOH maps. Also the interpreted AlOH compositional maps derived from simple ratios of ASTER bands produced a qualitatively comparable image of the change in white mica chemistry (i.e. Al rich or poor) to Broken Hill field spectra and hyperspectral airborne (HyMap) results except in units rich in chlorite. An assessment of the AlOH content and compositional variation within the Olary/SA Curnamona Province is still awaiting interpretation of field spectra and comparison with previous mapping. Comparisons between ASTER AlOH products and resampled hyperspectral HyMap data indicated that ASTER produced credible results, assuming its limited spectral resolution (i.e. 6 bands).

Generally ASTER's quartz regolith map appears to compare well with GIS identified boundaries of outcrop and colluvium/alluvium. However the MgOH/carbonate ASTER product cannot distinguish MgOH group minerals from carbonate rich units because of the limited spectral resolution of ASTER's SWIR bands capable of measuring any 2.33-2.35 μm absorption features. Higher spectral resolution imagery capable of distinguishing MgOH and carbonate-rich units is available with airborne hyperspectral data such as HyMap.

11.2 HyMap Data

Conclusions

- Preliminary results show that HyMap is able to identify some geological units and alteration not revealed by previous outcrop mapping.
- Extent of survey limited to the Broken Hill Domain.
- Considerable processing and interpretation is still required to generate mineral maps and to provide these maps in usable formats.

Recommendations

- Improving the format (digital and hardcopy) for ease of use for explorationists.

Scope of Data

Airborne hyperspectral HyMap imagery was acquired over the major portion of the Broken Hill Domain by the DMR. Approximately 4,000 km^2 of data were collected with a 3m pixel size in 126 reflectance bands within the 400 nm to 2500 nm wavelength range. The data was acquired in March 2002 over 41 strips in a north-south flight direction, each strip being approximately 1.5 km wide. The total data set consists of 400 Gb in total including radiance at the sensor data and atmospherically corrected reflectance data. These data are available from the DMR. Geolocation data files were supplied to facilitate the registration of the data using on board inertial navigational system parameters. The launching of the public access of the HyMap data coincided with the 16th ASEG conference in Adelaide, February 2003 and its preliminary results within the Little Broken Hill Mining District were presented in the below ASEG publication and later at the Broken Hill exploration Initiative Meeting (Robson et al., 2003; Taylor, 2003):

Methodology

The large size of the data and the difficulty in mosaicing 41 HyMap image strips limited the initial and preliminary processing of this data to a small group of specialists from UNSW, HyVista or CSIRO. Products available from the HyMap data can potentially include regolith, lithological and alteration related imagery. The main processing methodology has involved either simple band ratios targetted on particular mineral(s) absorption features, or on subsets of the image data, such as at Little Broken Hill, where detailed spectral unmixing processing (i.e. via ENVI) can be undertaken. HyMap imagery can be acquired via HyVista Corporation (hvc@hyvista.com)

Assessment of the Data

Initial evaluation shows the HyMap data is of good quality. Difficulties arise due to the very large nature of the data set (each image file associated with individual flight lines is 2Gb+). Mosaicing the HyMap imagery can also present difficulties from cross track illumination effects arising from the variable solar angle conditions when data was acquired between 9.30 am to 4.00pm during the three days.

The coverage of the HyMap data is essentially restricted to the Broken Hill Domain of the Curnamona and only limited HyMap is present within the SA Curnamona including the Olary Domain.

Issues

Using band ratios mosaicing between flight strips has proved feasible and preliminary interpreted image products have been produced by HyVista for iron oxides, AlOH, chlorite/epidote, chlorite chemistry, green vegetation and dry vegetation. A full assessment of these products and the realistic stretch that can be meaningful applied to their image histograms is awaiting completion. An alternative image product of this data is available in the form of unmixed spectral endmembers such as those produced by Taylor (2003) although these are limited to small subset areas including Little Broken Hill. Limited field spectral sampling for either image product types can also be a handicap in understanding and optimizing the full potential of this data.

11.3 Geoscan Data

Conclusions

- Available data consists of a single survey over the Olary Domain.
- This multispectral Geoscan data was acquired in the early 1990s, prior to more advanced better calibrated satellite and airborne systems.

Recommendations

- No further interpretive work is recommended, since satellite borne ASTER imagery can potentially generate similar maps of mineral groups (e.g. FeOx, AlOH, MgOH), albeit at poorer spatial resolution (30 m cf 10m). If greater accuracy in spatial and spectral resolution than ASTER is required, surveying by HyMap or similar hyperspectral system would be a recommended option.

Scope of Data

Geoscan MkII remote sensing data within the Curnamona Province was acquired over the Olary area in January 1993. This airborne multispectral data consists of 24 band imagery from the visible, shortwave and thermal infrared wavelength regions. This data is restricted to a single 9 x 60 km swath over part of the Olary Block at a spatial pixel resolution of 10 metres.

Methodology

No known interpretation or report/publication has resulted from this imagery.

Assessment of the Data

Geoscan MkII was acquired before airborne hyperspectral imagery such as HyMap was available from 1997. Although Geoscan has proved useful elsewhere in discriminating anomalous areas of alteration and mineral groups, issues of calibration and reliable radiance measurements made interpretation of this data difficult. The thermal infrared imagery in particular is regarded of poor quality.

Issues

Given the calibration issues of the Geoscane MkII data and its poorer spectral resolution compared to HyMap for discriminating mineralogy, no further work is recommended on this data.

11.4 OARS & TIPS

Conclusions

- A single Pilot study survey of OARS and TIPS was aquired over the Broken Hill Domain
- Garnet rich units and garnet chemistry were unable to be detected with TIPS because of spatial resolution limitations of the line profiling TIPS instrument.

Recommendations

- Consideration be given to use the new ARES (Airborne Reflective Emissive Sensor) image scanner to be delivered by HyVista late 2004- this is an opportunity to map prospective areas (i.e. garnets-rich alteration) in the Curnamona Province.

Scope of Data

Airborne hyperspectral OARS (Operational Airborne Research Sensor) and TIPS (Thermal Infrared Profiling Sensor) profiling data was acquired in December 2000 over a 11 x 23 km area east of Broken Hill and encompassing the Little Broken Hill mine prospects and the Cleavedale Migmatite. The OARS data consists of line profile visible-near infrared –shortwave infrared spectral data acquired from 10 metre pixels sampled contiguously the ground along north westerly oriented flightlines at 100 m intervals. Similarly the TIPS data was acquired simultaneously from 10 metre pixels along such flightlines. High resolution radiometrics and aeromagnetics was also acquired during the flight at an altitude of 100 metres.

Methodology

The specialised nature of this remote sensing data required additional software as well ENVI routinues produced as part of the joint CSIRO-World Geoscience CERBERUS Project. The processing, interpretation and reporting of this data were undertaken as part of CSIRO's Glass Earth Project and NSW DMR (Hewson et al., 2001a, Hewson et al., 2001b). The shortwave infrared (OARS) and thermal infrared (TIPS) line profile data was processed using partial spectral unmixing techniques into endmember "abundances" representative of the dominant mineral components. These mineral endmember abundances associated with each flightline were subsequently gridded and interpolated into mineral maps assuming a 1:4 gridding ratio (i.e. 25 m grid).

Assessment of the Data

Although the OARS and TIPS sensors used in this project were prototypes for the future ARGUS system, reliable radiance data was obtained during the three days of acquisition. However the variable nature of the atmospheric conditions and ground surface temperatures did present some difficulty in the processing and mosaicing of the data. It appeared that these effects introduced some noise into the data although the main phyllosillicate and silicate mineralogies were identified by the OARS and TIPS data.

Issues

Spatial resolution issue (10 m pixel grided between 100m flight data) mapping garnet-rich units and their chemistry difference with TIPS.

11.5 AirSar (Airborne Synthetic Aperture Radar)

Conclusions

- Unique datasets with restricted coverage. Very little work with respect to mineral exploration done to date.

Recommendations

nil

Scope of Data

AirSar data were collected over the South Australian Olary and Mt Fitton area, and over the Fowlers Gap area in NSW in September 1993 as part of an Australian AirSAr Mission. These data were not processed by NASA for some years later (1995-1998). For more details on the data, see: http://airsar.jpl.nasa.gov .

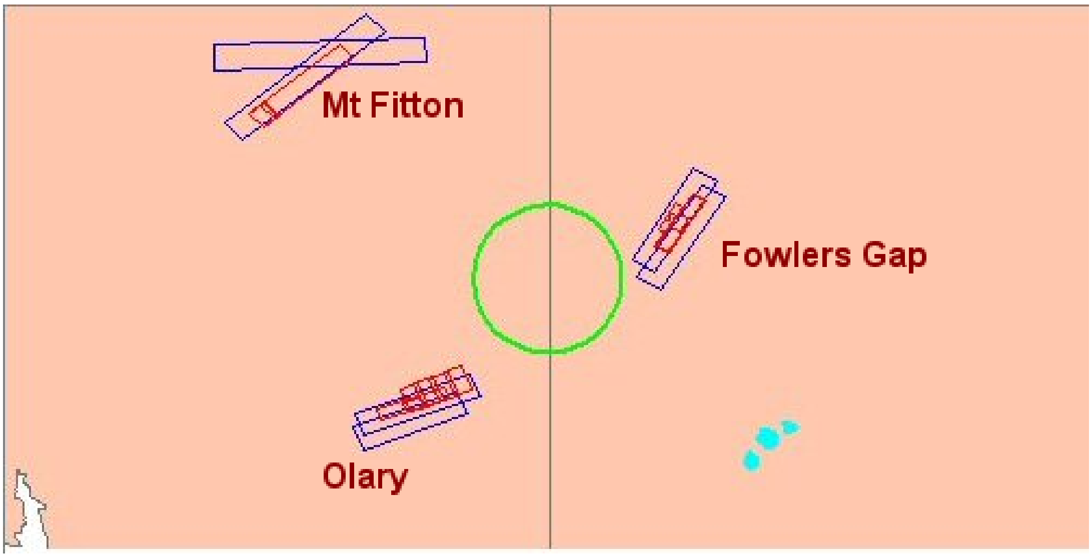


Figure 11.5.1: Locations of the Curnamona AirSar Surveys. (Extracted from NASA website, projection and scale indeterminate)

Methodology

Found location of data archives at the JPL/NASA site. Accuracy of swaths on the final compilation GIS is suspect and should only be considered approximate (especially the Fowlers Gap and Mt Fitton locations as they were taken from a very small scale NASA location map).

Assessment of the Data

These data are high quality and given the nature of the data set, they most likely have not been adequately assessed. Locations of Fowlers Gap and Mt Fitton surveys are questionable on compiled GIS.

Issues

Specialist software and knowledge is needed to interpret these data sets. Work done elsewhere suggests that in areas of shallow sand cover, the radar data may provide some indication of bedrock morphology. Detailed digital elevation models can also be created from these data sets.

11.6 Landsat TM

Conclusions

- There is complete coverage of modern LandSat TM over the Curnamona Province.

Recommendations

- No further large scale processing for geological interpretation is recommended for the Landsat data sets within the Curnamona. However any plans for monitoring environmental changes associated with mining or related regolith studies could encourage the evaluation of the entent of cloud free multi-temporal Landsat coverage available.

Scope of Data

Complete coverage of the Curnamona has been aquired by NASA's satellite borne Landsat 5 Thematic Mapper (TM) and the more recent Landsat 7 Enhanced Thematic Mapper (ETM+) sensors. Their coverage consists of 180 km x 180 km image scenes acquired at 16 day intervals. In particular Landsat 5 has acquired over 500 cloud free scenes within the Curnamona Province (-31^{o} S to –33 ^{o}S, 138.9 ^{o} E to 141.8 ^{o}E) over the March 1984 to present period while Landsat 7 has collected over 270 cloud free scenes since April 1999. Both Landsat 5 and 7 have collected reliable radiance data from four visible to near infrared (VNIR) and two shortwave infrared (SWIR) bands at 30 metres spatial resolution. Landsat 5 has one thermal infrared (TIR) band at 120 m resolution while Landsat 7 effectively acquires the same thermal imagery at 60 m. In addition Landsat 7 also collects a panchromatic image at 15 metres resolution within the visible wavelength region. Both data sets are easily accessible and ordered from the Australian Centre for Remote Sensing (ACRES) (http://acs.auslig.gov.au/intro.html).

Methodology

Landsat data can be easily processed using standard processing software such as ERMapper. It can be simply processed to produce imagery that discriminates broad lithological and regolith features using simple image processing techniques such as RGB band combinations, band ratios or pricipal component analysis. GIS integration of Landsat imagery with other geological, geophysical data sets and ortho-imagery is often undertaken.

Assessment of the Data

The quality of the Landsat TM data is mostly high although recently Landsat 7 has displayed high noise levels. Landsat's spatial resolution and individual scene coverage is considered useful for regolith discrimination however the spectral resolution generally limits its ability to separate or identify spectral features associated with different mineral groups. However the multi-temporal nature and high quality Landsat acquisitions since 1984 can provide a useful baseline for environmental changes within the Curnamona Province. In a similar way satellite borne SPOT also provides multispectral and multitemporal VNIR data sets as base images across the entire Curnamona Province but at a higher spatial resoution of 20 metres and also has a panchromatic image at 10 metres resolution.

Issues

Limited spectral and spatial resolution handicaps detailed geological and alteration mapping potential. The recently launched ASTER satellite sensor provides fourteen bands at similar or better spatial resolution. In particular, ASTER bands 1 to 4 are equivalent to Landsat band's 2 to 5. In addition, ASTER also has five shortwave infrared (SWIR) bands compared to Landsat's band 7 within the same 2.0 to 2.4 µm wavelength region. Similary ASTER has five thermal infrared (TIR) bands to Landsat's thermal band 6. These additional SWIR and TIR bands effectively indicates that ASTER supercedes Landsat for mineral (group) mapping capabilities assuming ASTER's data handling requirements and QC issues are in turn respected (see ASTER Chapter).

11.7 Spectral Sampling

Conclusions

- There is limited spectral sampling apparent in the South Australian Curnamona however the cost of new sampling and field measurements has to compare with possible airborne coverage.
- Thermal Infrared spectral measurements of relevant Curnamona samples, either using a portable thermal spectrometer or an airborne TIR sensor (i.e. ARES) under lab conditions, would also help assess the potential capability of the future HyVista ARES thermal scanner planned for deployment in 2004.

Recommendations

- A greater range of spectral measurements of rock outcrop, soil/regolith and vegetation would be useful for the present remote sensing data sets under examination (e.g. HyMap and ASTER) although the full extent of spectral sample measurements outside CSIRO is uncertain.
- The acquisition of more visible-shortwave spectral measurements of field samples already collected could assist in testing the viability of future planned HyMap surveys over areas of the Curnamona outside of the Broken Hill Domain.

Scope of Data

Spectral measurements in the Curnamona of either rock outcrop and soil/regolith samples for subsequent spectral and field measurements, or from direct measurements in the field have provided useful comparisons with airborne sensor (e.g. OARS & TIPS, HyMap) and satellite borne (e.g. ASTER) remote sensing data sets. The coverage is concentrated within the Broken Hill Domain and limited in the Olary Domain. The spectral measurements consist of mostly PIMA (1.3 to 2.5 µm SWIR) and ASD (0.35 to 2.5 µm Visible-SWIR) wavelength regions although some thermal infrared (8 to 13 µm TIR) spectral measurements have been also been acquired. Many of these spectral measurements have been acquired as part of calibration and/or geological ground truthing by CSIRO Exploration and Mining personnel (Figure X) or by staff or students at the University of NSW (G. Taylor, pers. comm.). Limited spectral measurements have also been acquired of different vegetation cover with some measurements acquired at the Fowlers Gap Arid Zone Research Station, 110 km north of Broken Hill (Megan Lewis, U. of Adelaide).

Methodology

Spectral measurements, measured either in the field or laboratory, are converted to reflectances for visible to shortwave infrared wavelengths or emissivities within thermal wavelengths using specialised proprietary software provided with the particular spectrometer. ENVI software is often used to visualise and interpret the converted reflectance or emissivity data against library spectra provided by NASA-JPL, USGS or John Hopkins University.

Assessment of the Data

Laboratory measured spectra of field outcrop or regolith/soil samples are generally of superior quality than field measured spectra due to the highly variable and temporal atmospheric conditions. The limited portability of the microFTIR thermal infared spectrometer and significant noise effects from the atmosphere have particulary encouraged laboratory measurements of field samples. The small field of view afforded by these spectrometers (generally cm's at best) of rock or soil samples is a limitation on their comparison in physical units with remote sensing data sets, particularly for large pixel imagery (e.g. ASTER's 30 & 90 metre SWIR and TIR bands). However interpreted trends in AlOH chemistry, related to wavelength shifts in spectral signatures rather than to absolute reflectance appear reliable.

Issues

The limited number of sample localities used for spectral measurements within the Curnamona have handicapped a full appreciation of the remote sensing datasets.

12. Discussion

Discussion of individual datasets is presented in the relevant chapters. This chapter comprises discussion covering some important general observations and findings highlighted by the audit and gaps analysis.

12.1 Volume and Access of Literature

In the Curnamona Province, around 2040 published and unpublished papers (1934 up to June 2003), company reports, government reports and theses have been written during the past 120 years (Greenfield et al., 2003, Greenfield, pers. comm. 2003). To understand the present state of play in Curnamona it is prudent to appreciate the past; and this principle has underpinned the Curnamona audit and gaps analysis.

Table 12.1 and Figure 12.1 show the proliferation of literature commencing in the late 1960s with peaks during the early 1970s and again in the mid 1990s.

The 1970s peak occurred when the Broken Hill Mining Managers Association (MMA) sought to coordinate the rapidly expanding research studies on Broken Hill. The MMA funded the creation of the MMA library to house their burgeoning thesis and research collection. The University of NSW Broken Hill-based Robinson College, was involved in tertiary teaching and graduate and post graduate research in the Broken Hill area; and other universities such as Monash and New England and Macquarie were also actively involved. Indeed, it was a recommendation from the MMA that saw the NSW DMR initiate in 1975 the 1:25 000 scale mapping of the Broken Hill Block.

The MMA comprised line-of-lode operating and associate companies such as the Zinc Corporation, Ltd, New Broken Hill Consolidated, North Broken Hill and CRA Exploration Pty Limited. In addition to funding company geologists to undertake post graduate studies on aspects of local geology and geophysics, these companies also engaged in other significant in-house research that has remained largely confidential. Examples of in house research/work include the mapping of the whole Broken Hill Block by R.L. Brunker in the early 1970s for CRA Exploration Pty Limited. Although these companies left the Curnamona scene, in-house confidential research continued through the 1990s by others such as Pasminco, Aberfoyle and MIM. But the maintenance of the MMA library was left to just one company, Pasminco who ‘inherited’ it from Rio Tinto.

Following divestment by Pasminco of its Broken Hill assets, much of the MMA Library is now with Peryila but some of it found its way to the NSWDMR office in Broken Hill in the form of copies of reports and theses. It is a valuable resource as it contains reports and theses which are difficult to access through other channels (Webster, 2003; B.J. Stevens, pers.comm., 2003).

Table 12.1 Summary of Curnamona Literature(1890- June 2003)
(after Greenfield et al., 2003)

Item	Number
Government reports	307
Company reports	613
Research Papers	774
Theses	255
Total	1932
	2040*

(*at Dec 2003)

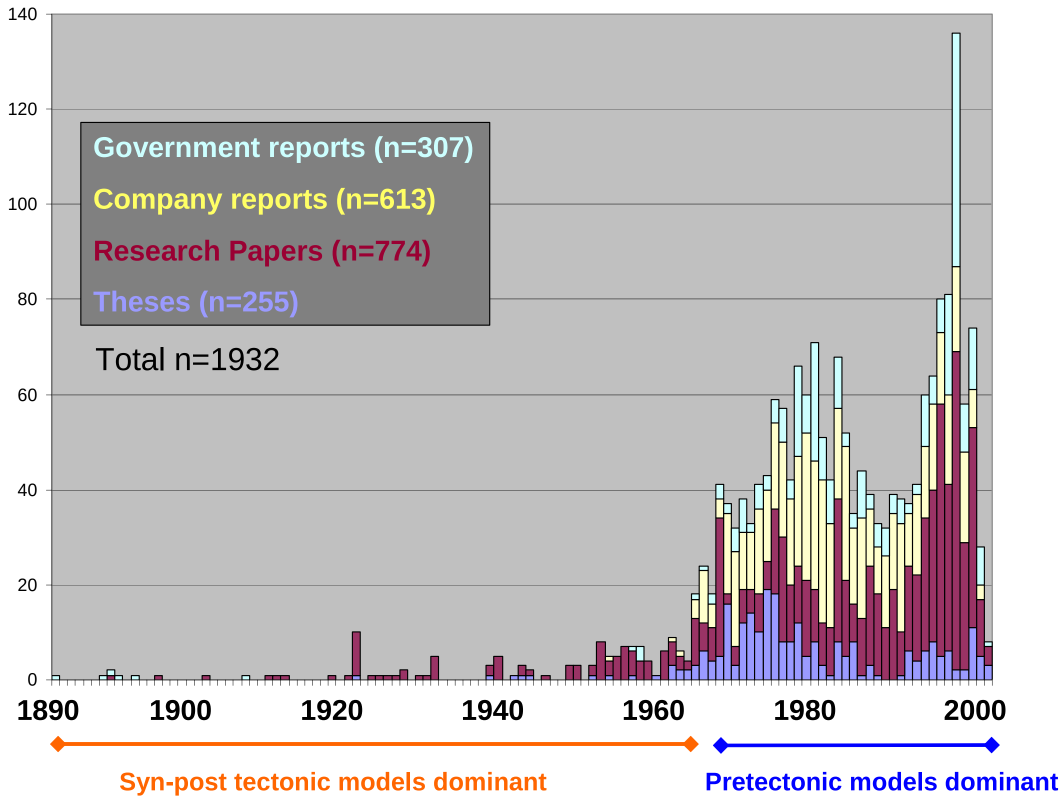


Figure 12.1 Summary of literature in Curnamona (1890-June 2003)
(After Greenfield et al., 2003)

12.2 Knowledge Gap Between Workers

As stated above, the MMA companies no longer exist but numerous geologists who worked with them have had continuing involvement with the Curnamona Province. Not surprisingly, these workers have retained earlier in-house knowledge as well as retaining a comprehensive overview of most past work, both published and unpublished.

The audit and gaps analysis has highlighted a significant knowledge gap amongst workers in the Curnamona Province. This knowledge gap is reflected by some experienced company and government geologists who have long associations in the Broken Hill and Olary Blocks, and have a good to excellent working knowledge of past and current work both unpublished and confidential reports; and some less experienced workers who are not as familiar with past work, especially in-house company research, and company-sponsored university research.

This knowledge gap is considered to be responsible for much confusion, misunderstanding and 're-inventing of the wheel' that accompanies some exploration and research projects in the Curnamona Province. An example of this knowledge gap is 18 alteration studies undertaken in the Curnamona, 16 of which concern the Broken Hill ore deposit involving around 17 000 analyses, described in Chapter 8 of this report. Apart from two published studies by Plimer (1976, 1979) and an in-house study by Klingner and McConachy (1975) referred to in Main et al. (1983) the other 12 studies have not been published. A large line-of-lode alteration study commissioned by Pasminco and BHPBilliton in 1996 (Stanely (1997) and summarised by Walters (2000)), and now owned by Perilya has been made available to the pmd*CRC for research studies. The report, however, is not widely available but enough people know about it so that it has become 'public fact' without being a 'public document'. It is example of the blurring of confidentiality issues surrounding Broken Hill.

In spite of the large number previous alteration studies, a view held among many workers is that alteration is not well documented nor understood and therefore needs to addressed. It is therefore important to get these company studies into the public domain.

12.3 Journal Editorial Policy

A key performance measurement for advancement in academia is the number of papers published in journals and the number of times papers are referred to by other researchers, the citation index. The editorial guidelines of some 'higher ranked' journals have a tendency to restrict references to journal papers of similar refereed standards. This has the effect of eliminating references such as theses, conference abstracts, and other non-refereed or lightly-refereed material. Therefore, even though an author may have knowledge of past work, it may be difficult to reference in certain journals, with a result that authors may be unfairly criticised by workers for omission of acknowledgment of past work. Therefore knowledge gaps may be inadvertently created by editorial constraints.

Moreover, by solely relying on journals and references therein, unpublished or lightly refereed work will be bypassed. In the worst case, a researcher may not be aware of unpublished work such as university theses.

12.4 Research Topics

The purpose of this study was not to create a comprehensive list of possible gaps in data and knowledge that could be filled by research topics. This had been partly the aim of the pmd*CRC C1 Terrane project which commenced in 2002. A survey was sent by pmd*CRC to around 30 industry representatives in September 2001 during the development phase of C1. The aim of the survey was to obtain industry input as a key driver in framing the Curnamona Project. Around 15 replies were received; and the results were fed into the project development process. The survey was followed by 2 project development team meetings in Sydney, from which the C1 initial project emerged (T. Lees, pers. comm., 2003).

Unfortunately the raw results are not available. However, the questions were framed in terms of points raised, discussion and output from the first meeting. The questionnaire asked to put a

High, Medium or Low ranking on the importance of each issue. Scores were tallied on a 3, 2, 1 basis, and the average for each given. Three main categories of potential research topics were highlighted:

High

1. Timing of ore deposition unknown; ore-deposit scale architecture
2. Alteration:
   –Distribution of assemblages and zoning
   –Timing of alteration(s) especially with respect to metamorphism
3. Ore deposition processes
4. Ore parageneses over the entire deposit

Medium

1. Tectonic setting /architecture and evolution of the Curnamona province
2. Ore deposit conceptual model (syn/diagenetic vs metamorphic/skarn)

Low

1. Pb isotopes of deposits and regional geology2. High grade shear zones not mapped and are undated
3. Geochemistry of the ore fluid
   –Poorly constrained
   –Magnetite stability important (cf Cannington)
   –Control on garnet chemistry (Mn/Fe/Ca)
4. What is the host rock package and is it important?

Many of the above themes were also registered in this study in both surveys of industry and researchers described in Chapters 5.1 and 5.2, although not in the same order of priority. This is probably due to a number of reasons including how the question was framed, the change of industry personnel between then and June 2002, and the purpose of the questionnaire. However, the gaps in knowledge are as valid now as before and so are the implications for understanding ore deposition and preservation.

There are many links in research topics such as the apparent low levels of Pb and Zn in the albitite rich rocks in the Broken Hill Block and their potential metal source of the Broken Hill mineralization. If Broken Hill line-of-lode rocks are shelf sediments, then what is the implication of this shallow marine setting for the proposed genesis of submarine hydrothermal mineralization. It is beyond the scope of this study to investigate these lines of research. At least for the Broken Hill ore system, they are being developed in another study (Greenfield, in prep.)

Numerous minor gaps exist in age dating throughout the Curnamona Province but this study has found no major gaps. Examples of local gaps include the unambiguous age dating of the Sundown Group and Cartwright Creek metasediments, and the Thorndale Group Gneiss and the Redan Gneiss in the lower part of the Broken Hill sequence. Whether the Redan Gneiss is basement to the Willyama Supergroup remains unclear.

Issues also surround whether zircons are metamorphic or represent depositional zircon. Clearly as exploration continues more gaps will emerge that will provide new dates and re interpretation of these new data.

There were a large range of suggestions from industry and others for government to conduct activities such as ultra detailed geological mapping to updating the 1:25 000 Broken Hill mapping using the available geophysical datasets. Magnetics, for example, would redefine current geological boundaries.

12.5 Province Synthesis

A main theme highlighted by this study has been the recurring suggestion from both industry and research workers for the need of data synthesis and integration at Province level. Synthesis or variations on this theme were highlighted in a number of places in the Industry Survey: as one of the impediments to exploration, was the third ranked activity that would increase exploration interest in the Province and was mentioned as 'comments' using phrases like:

"Poor geological understanding of Province"
"Better geological understanding of covered areas"
"Lack of synthesis/compilation of previous exploration"
"Better use of non digital data"

As a knowledge gap in the Curnamona Province, researchers ranked 'synthesis of existing data' a clear second after 'robust mineralisation models'

Workers seem to be almost swamped by the amount of data in the Curnamona Province and recognise the need to bring the all the data together in a coordinated integrated project that addresses structure, geology, alteration, mineralisation, thus improves the knowledge of the Province and help to answer how and why ore deposits are there.

12.6 Depth of Cover and Depth to Basement

Industry considered that depth of cover to be a major impediment to exploration in the Curnamona Province, ranking it number one by double the margin to the second ranked major impediment of ground availability. Depth to basement maps were in the first 5 categories of products that would increase industry interest in the Curnamona. In contrast, although admittedly in answer to a different question, researchers ranked depth to basement lowest in terms of knowledge gaps in the Province. This difference undoubtedly reflects the primary concerns of explorers at the practical level, as budgets can be consumed quickly by testing areas of deep cover or depth to basement.

The concern of depth of cover by industry was also complemented by other answers in the Industry Survey; and more detailed gravity and stratigraphic drilling were ranked very highly by industry as activities to encourage further exploration.

12.7 Digital Metadata

A large amount of data has been compiled digitally and made available publicly, probably more than in any other region in Australia. The study was unable to confirm that all paper data has been captured but it seems unlikely given the anticipated large volume.

Capturing paper data digitally is important, but even more critical is consistency and transparency of digital data that is going out to the public. The end-users are generally exploration geologists with limited GIS skills, and little time and patience to dig for data.

From the users' perspective there is a need for:

- All database files (ie. ArcView shape files or Mapinfo tables) need to be fully self-explanatory, even at the cost of some data repetition, so that they can easily be integrated into existing company data structures.
- All point data should have coordinates for elevation as well as eastings and northings (these can be easily calculated in the master databases), so they can be plotted and analysed in 3D. This would mean that complex cross-referencing of geochemical data points with borehole collar information is no longer required.
- Database structures, that are the subsets of attributes from the master database, released to the public need to be standardised. For example, if a geologist has integrated this years geochemistry data into an exploration database, he wants to be able to go to the department next year asking for new geochemistry data so that he can add this new data in a simple copy and paste operation. At the moment this task is impossible.
- Publish all data dictionaries on the internet, so this information is always available.
- Use a single standardised datum and projection and provide the metadata for this.

The biggest gap looking at the databases is not in the data coverage or themes, but in the information and knowledge layers that allow exploration decisions to be made. This is particularly important if the aim is to attract new players into the region. Main themes include:

- Mapped outcrop structure (there is an interpretation element in this as someone will make the decision about what is bedding, S1,S2 etc)
- Fault interpretation with attributed dip and dip direction, estimated throw, observed kinematic indicators, and interpreted movement type for each deformation event.
- Time-space evolution diagrams
- Stratigraphic columns (including information about how the formations were defined)
- Cross-sections of the main regional maps showing the gross geometry (with explanations as to models used).

Considering the good coverage of the region with detailed geophysical surveys, there is a dearth of regional scale interpretations of these data

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