



New National Geoscience Datasets in Australia: Geology, Geophysics and Geochemistry

In 2006, the Australian Government announced a new Energy Security Initiative, which led to the establishment, among others, of the Onshore Energy Security Program (OESP) at Geoscience Australia. This Program, which has a budget of A\$58.9 million over 5 years, is deploying several data acquisition programs (seismic, radiometric, magneto-telluric, airborne electromagnetic, and geochemical) to attract investment in exploration for onshore petroleum, geothermal, uranium and thorium energy resources in Australia (Johnson 2006).

Three new, national-scale geoscience initiatives are under way in Australia with the aim to provide energy and mineral explorers with state-of-the-art pre-competitive data and information about the continent's potential resources. (1) A digital geological map provides a seamless and consistent coverage of geological units at 1:1,000,000 scale. It is underpinned by a national stratigraphic index database to ensure uniform and consistent unit description and classification and nomenclature usage. (2) An

Australia-wide airborne geophysical survey that has been used to level all of Australia's public-domain radioelement data to a common datum. This enables interpreters to make accurate comparisons between radiometric signatures in different parts of the continent. (3) A low-density geochemical survey aims to provide a national geochemical data layer using consistent sampling medium and methods, as well as consistent sample preparation and analysis. Large-scale geochemical patterns thus revealed are hoped to point to new areas of exploration potential. The two latter projects are funded under the Australian Government's Onshore Energy Security Program. Together, these three national geoscience datasets will help make Australia a more attractive destination for energy and mineral exploration investments.

The purpose of this paper is to bring the international exploration community up to date with three new national-scale geoscience datasets. These are intended to enhance

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the global attractiveness of Australia as an investment destination for energy and mineral explorers by lowering geological risk. The three new datasets that are the focus of this presentation are:

- a seamless 1:1,000,000 scale digital surface geology map of Australia;
- an Australia-wide airborne geophysical survey (magnetics and radiometrics) that has been used to level all of Australia's public-domain radiometric data to a common datum; and
- a low-density, internally consistent, surficial geochemistry coverage of greater than 90% of Australia.

The first of these datasets (geological map of Australia) has been ongoing since 2001, whilst the two others (airborne geophysics and geochemistry) were initiated as part of the OESP funding.

Digital Geological Map of Australia *Compilation*

The compilation of a seamless, digital, surface geology map of Australia at 1:1,000,000 scale (Fig. 1) was commenced in 2001. The new data are the most detailed, informative and consistent national geology coverage available. They provide invaluable baseline datasets for large scale regional and national evaluation of resource potential, environmental issues, and land use. The aim of the project was to provide a more detailed and better attributed digital dataset of the surface geology of Australia to replace the 1:2,500,000

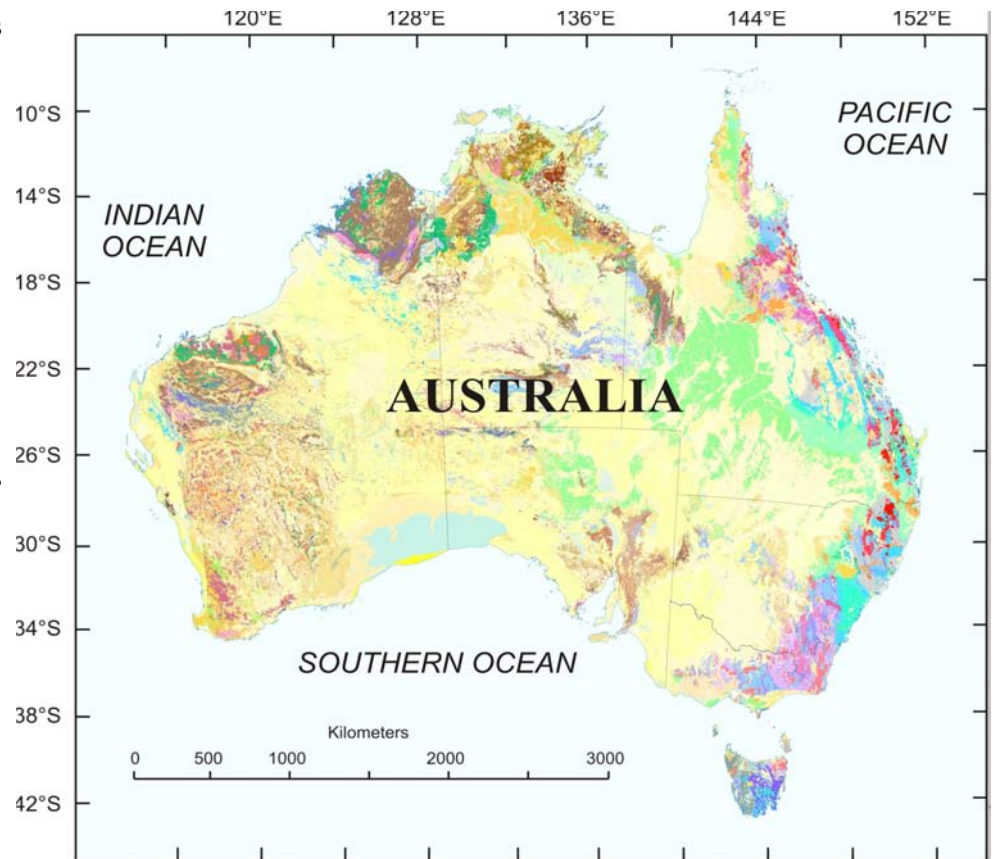


Figure 1. Overview of the new digital surface geology dataset of Australia

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scale dataset published in 1998. The project has been conducted in collaboration with all Australian State and Northern Territory geoscience agencies who provided their most recent map data for the national compilation. Individual state portions of the national dataset have been released as they were completed, starting with Tasmania and Victoria in 2004 (https://www.ga.gov.au/products/servlet/controller?event=PRODUCT_SELECTION&keyword=%22surface+geology22). Updated editions of some of the earlier released states (Tasmania, Victoria, Queensland and New South Wales) have also been produced as compilation standards have evolved during the national project. The national coverage will be completed in November 2008 with the release of the Western Australian data. Updated editions of the dataset will be released on an irregular basis.

Initially, the plan was to compile the map from the existing regional geological maps of between 1:500,000 to 1:2,000,000 scale. However, it became clear early in the project that these regional maps were typically fairly old (1970's and 1980's) and that the geological information on them was of poor quality considering the geological mapping programs undertaken by the Federal, State and Northern Territory geoscience agencies in the last 20 years. In particular, these regional maps did not include the new generation of digital geological maps at 1:100,000 and 1:250,000 scales produced in the 1990's with the aid of new high-resolution aeromagnetic and gamma-ray spectrometric images, satellite imagery and new geochronological (especially U-Pb zircon) data (Jaques *et al.* 1997). As a result, much of the new Australian geology coverage has been compiled from the most recent 1:250,000 scale mapping, and even 1:100,000 or 1:50,000 scale in some areas where the 1:250,000 maps were out of date. Although compiled from detailed geological maps, the national data have been simplified for use at 1:1,000,000 scale and have a spatial accuracy of between 200 m and 1 km depending on the quality of the original source data.

An important and time-consuming task for the compilation team was matching the geological information between maps which could be up to 40 years apart in age. Considerable time was invested in resolving stratigraphic mismatches across map tile and political boundaries. At times, satellite imagery and geophysical data, such as gamma-ray spectrometry and magnetics, were also used to resolve edge-matching discrepancies and to reposition poorly located geological data on older maps.

Standardisation of unit classification and descriptions was particularly important for the unconsolidated regolith

materials, which cover a large proportion of the Australian continent. Regolith mapping has advanced considerably over the last few decades, particularly with the advent of remote sensing imagery, and a simple standard scheme for regolith unit compilation, based largely on the classification of Grimes (1983), was used for the new national map.

The new dataset contains comprehensive descriptions of several thousand geological units (Fig. 2). These unit

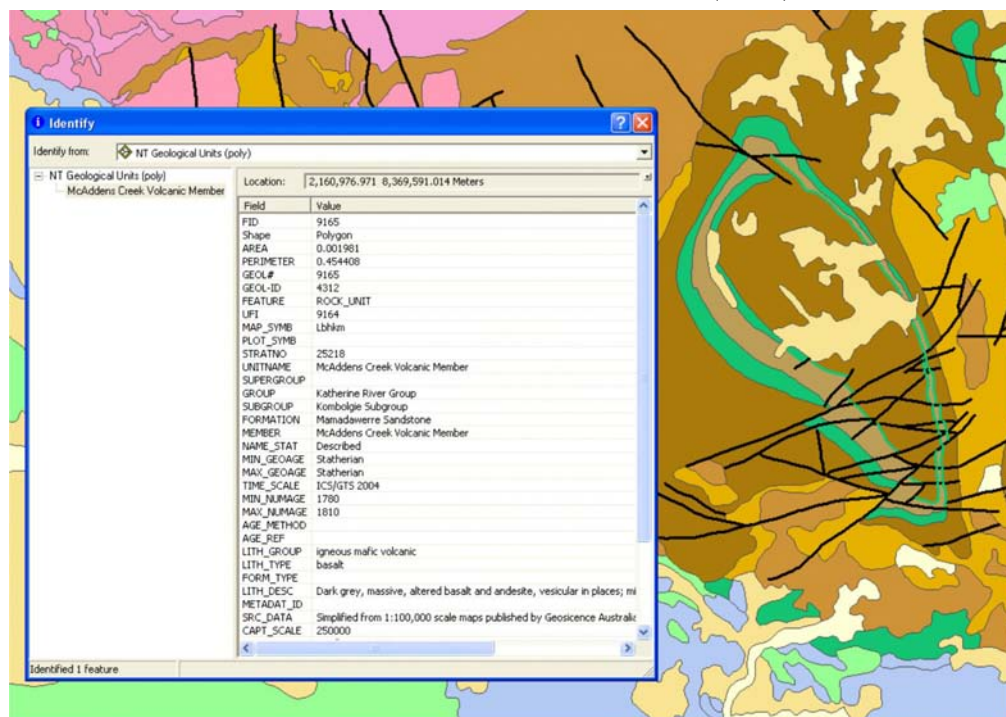


Figure 2. An example of attribute data for a geological unit in the 1:1,000,000 scale surface geology of Australia dataset.

descriptions include a unique stratigraphic name and number which provides a link to the Australian Stratigraphic Units Database (<http://www.ga.gov.au/oracle/stratnames/index.jsp>), which is the authoritative repository of Australian geological unit descriptions. Other digital attributes include a stratigraphic parent-child hierarchy, a text description of the unit, maximum and minimum ages, and lithology classifications. Faults and stratigraphic boundaries are also coded in the data. The data also come with comprehensive metadata describing the origins of the source data.

Data Delivery

The new data are designed primarily as a digital tool for GIS applications. There are no plans to issue a printed map – a paper map of Australia at 1:1,000,000 scale would be almost 4 m tall. Currently the data are available through download from the Geoscience Australia website (www.ga.gov.au) in ESRI export file and shapefile formats. The data are also available to view on the OneGeology portal website (portal.onegeology.org) where the map can be displayed as a Web Map Service (WMS) together with the national geological coverages of many other nations. Geoscience Australia will be moving towards providing the

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data as a Web Feature Service (WFS) using the GeoSciML data standard (GeoScience Markup Language; Simons *et al.* 2008) in the near future.

Australia-wide Airborne Geophysical Survey

Australian Governments have systematically surveyed the Australian continent for over 40 years using airborne geophysical surveys. The airborne survey coverage of the continent is now 100% for airborne magnetic surveys and about 75% for airborne gamma-ray spectrometric surveys (Fig. 3). The gamma-ray spectrometric surveys are used to derive estimates of the concentrations of potassium (K), equivalent uranium (eU) and equivalent thorium (eTh) at the Earth's surface. All the public-domain magnetic survey data have been digitally merged into a single continental scale compilation (Tarlowski *et al.* 1992, 1996; Minty *et al.* 2003). However, the individual surveys that comprise Australia's national gamma-ray spectrometric radioelement database are not all registered to the same datum. Older survey results are presented in units of counts/sec, which depend on factors such as survey flying height and detector volume. Even recent surveys can have a significant mismatch along common borders due to limitations in spectrometer calibration and data processing procedures, as well as environmental effects that result in temporal changes in the gamma-radiation fluence rate at the Earth's surface. These problems limit the usefulness of the national radioelement database as it is difficult to compare radiometric signatures observed in different parts of the continent.

Geophysical Data Acquisition

Geoscience Australia has recently undertaken an Australia-Wide Airborne Geophysical Survey (AWAGS), funded under the Australian Government's Onshore Energy Security Program, to serve as a radioelement baseline for all current and future airborne gamma-ray spectrometric surveys in Australia. The survey data were acquired in 2007 at a nominal terrain clearance of 80 m above ground level along north-south flight lines spaced 75 km apart and east-west tie lines spaced 400 km apart (Fig. 4). The survey

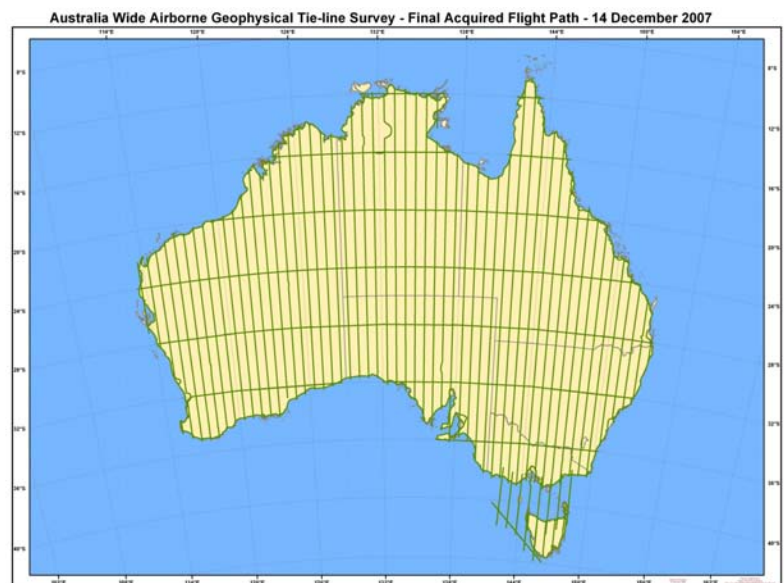


Figure 4. Nominal flight path pattern for the AWAGS airborne geophysical survey.

data were acquired and processed according to international standards, and the final estimates of radioelement concentrations along the AWAGS lines are consistent with the International Atomic Energy Agency's (IAEA) radioelement datum.

Levelling the Radiometric Database

The AWAGS survey has been used to adjust the hundreds of surveys that comprise the national radioelement database to a common datum. This was achieved by estimating, for each survey in the national database, correction factors that, once applied, minimize both the differences in radioelement estimates between surveys (where these surveys overlap) and the differences between the surveys and the AWAGS traverses. This effectively levels the surveys to the IAEA datum to produce a consistent and coherent national gamma-ray spectrometric coverage of the continent.

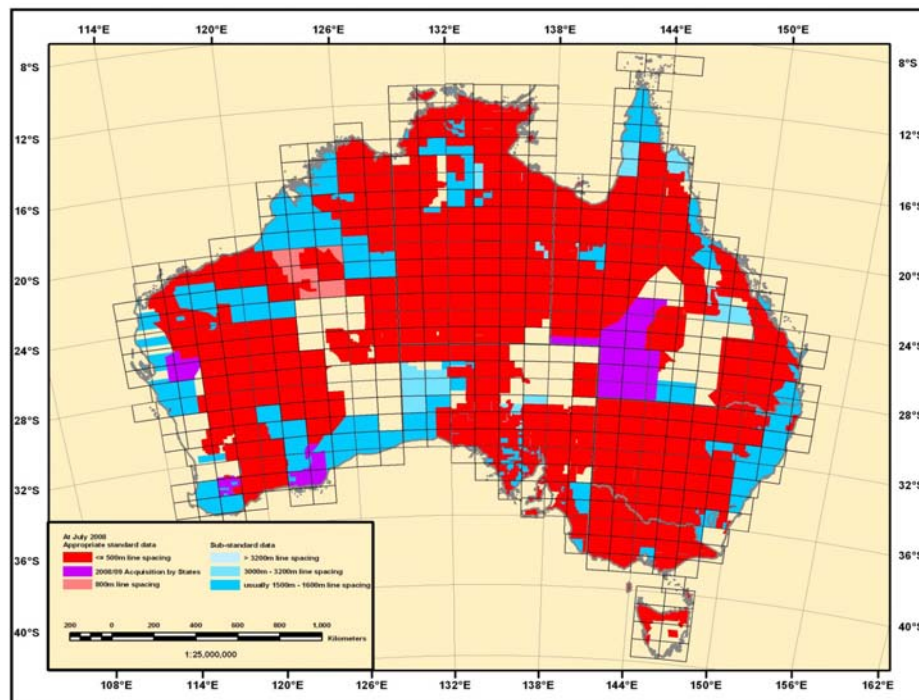


Figure 3. National coverage of airborne gamma-ray data acquired by Geoscience Australia and the State and the Northern Territory geoscience agencies as of July 2008.

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The Radiometric Map of Australia

The levelled database has been used to produce the first “Radiometric Map of Australia” – levelled and merged composite potassium (% K), uranium (ppm eU) and thorium (ppm eTh) grids over Australia at 100 m resolution. A ternary image (K-red, eU-blue, eTh-green) derived from this database is shown in Figure 5. Interpreters can now use the normalised database to reliably relate geochemical



Figure 5. Ternary image of potassium (red), uranium (blue) and thorium (green) radioelement estimates across Australia after levelling surveys with AWAGS data.

patterns observed in one area to similar patterns observed elsewhere, and better appreciate the significance of broad-scale variations in radioelement concentrations.

There are several applications that will benefit from the updated database:

- uranium and thorium exploration through the ability to make quantitative comparisons between radiometric signatures in different survey areas;
- heat flow studies and assessment of geothermal energy resources;
- the derivation of a radiation risk map of Australia for natural sources of radiation;
- research in land-use modelling, sustainability, agricultural and forest productivity, radiation risk, mineral exploration, regional geology, regolith and soils; and
- direct comparisons with geochemical data.

Geochemical Mapping

The National Geochemical Survey of Australia (NGSA) project aims to provide pre-competitive data and knowledge to support exploration for energy resources in Australia. In particular, it will improve the existing knowledge of the concentrations and distributions of energy-related elements such as uranium (U) and thorium (Th) at the national scale. The project is underpinned by a series of pilot geochemical surveys carried out in recent years by Geoscience Australia and the Cooperative Research Centre for Landscape

Environments and Mineral Exploration (CRC LEME) to test robust and cost-effective protocols for sample collection, preparation and analysis. Examples of these are the Riverina (Caritat *et al.* 2005; Caritat *et al.* 2007), the Gawler (Caritat *et al.* 2008) and the Thomson (Caritat & Lech 2007; Lech & Caritat 2007) pilot geochemical surveys. Selected results from these pilot projects have been presented by Caritat *et al.* (2008). The current national project, described below, is being conducted in collaboration with the State and the Northern Territory geoscience agencies.

Rationale

The national geochemical survey was initiated because of the realisation that there is no complete geochemical coverage available for Australia and because such a data layer is an important complement to national-scale geological and geophysical datasets.

The current distribution of geochemical data available through the national repository (OZCHEM database) is shown in Figure 6. The map shows that there are vast areas of the country (>60%) that lack any geochemical information. Also, where geochemical data are available,

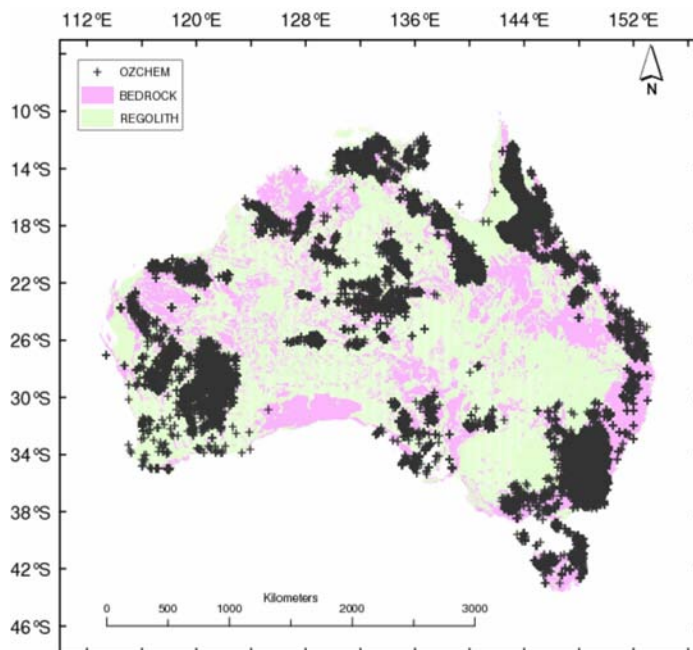


Figure 6. Distribution of whole rock geochemical data in Australia (plus signs) extracted from the OZCHEM national database as of June 2006, overlain on bedrock (pink) and regolith (green) coverage.

they are often not comparable as a result of:

- inconsistent sampling material (e.g. rocks of various types and/or degree of alteration, mineralisation or weathering);
- inconsistent sample preparation methods (e.g. total analyses versus partial digests with weak chemicals);
- large differences in instrumentation used, leading to variable lower limits of detection between datasets (e.g. older versus state-of-the-art instruments);

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- lack of metadata on data quality (e.g. instrument calibration, bias, precision, sample type description, etc.); and
- variable suite of elements analysed (e.g. sometimes very limited suite such as gold (Au) only or gold plus copper (Au + Cu)).

Similarly, the current airborne gamma-ray spectrometric (radiometric) survey coverage available at a resolution deemed appropriate for exploration does not provide a complete national picture of the distribution of radiogenic elements potassium (K), uranium (U) or thorium (Th) (see Fig. 3). This situation is being remedied by the new AWAGS project discussed above, which, together with NGSAs, will result in a significantly improved understanding of the distribution of K, U and Th in Australia. Some regional geochemical surveys have been carried out in parts of Australia (e.g., Morris *et al.* 1998; Cornelius *et al.* 2008), but no national coverage exists. Since the inception of the concept of regional geochemical surveys in the 1960s, they have proven to be a reliable tool for mineral exploration.

Objectives

The objectives of the NGSAs project are to:

- collect transported regolith samples at the outlet of large catchments covering >90% of Australia using an ultra low sampling density approach;
- prepare and analyse the samples to extract the

maximum amount of geochemical information (60+ elements) using internally consistent, state-of-the-art techniques;

- populate the national geochemical database with the resulting new data; and
- compile an atlas of geochemical maps for use by the mineral exploration industry to identify areas of interest in terms of energy-related resources and other mineral commodities, which can then be the focus of targeted exploration efforts.

Strategy

A sampling method has been adapted to Australian landscape and climate conditions. It has been field-tested in the Riverina, Gawler and Thomson pilot projects. The cost of a national survey is kept reasonably low by applying an ultra low sampling density approach (1 site/1,000 km² to 1 site/10,000 km²).

The strategy adopted for the national geochemical survey is described below.

Sampling media: Catchment outlet sediments (similar to floodplain sediments in most cases), sampled at two depths (0-10 cm below the surface as well as a 10 cm interval at a depth of between around 60 and 90 cm).

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Sampling sites: 1,390 catchments covering 91% (or about seven million km²) of Australia across all States and Territories have been targeted for sampling (Fig. 7). Most catchments will be sampled near their outlet, while those exhibiting internal or poorly defined drainage will be sampled at, or as close as possible to, their lowest point. Catchments smaller than 1,000 km² (mostly coastal) and small islands are not included in the survey. The resulting distribution of catchment outlet sites targeted for sampling is shown in Figure 8 and translates to an average sampling density of around 1 site/5,500 km².

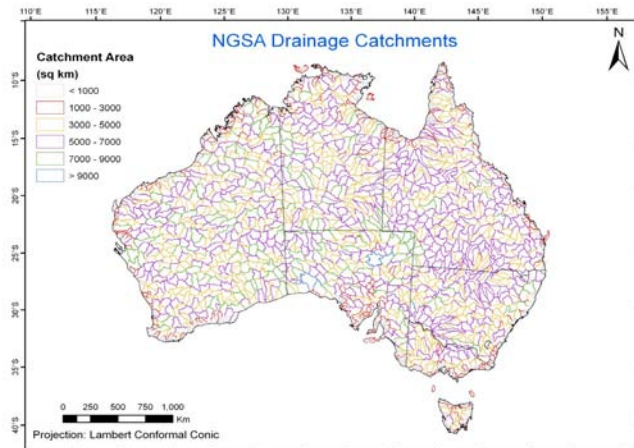


Figure 7. Distribution of catchments for the National Geochemical Survey of Australia.

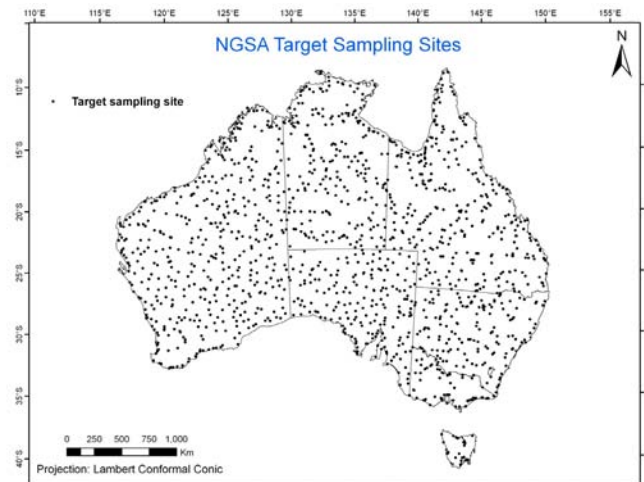


Figure 8. Distribution of target sampling sites for the National Geochemical Survey of Australia.

Sample collection: A detailed Field Manual has been compiled (Lech *et al.* 2007) and all sampling equipment and consumables have been centrally purchased. Sample collection is carried out by the State and the Northern Territory geoscience agencies following a hands-on, in-field training period. At each locality a detailed site description, field pH, and dry and moist soil Munsell® colours are recorded and several digital photographs are taken. All information is recorded digitally to facilitate subsequent uploading into databases.

Sample preparation: Samples are dried, rotary/riffle split and sieved to <2 mm and <75 μm fractions. The <2 mm fraction is mechanically ground for some analyses, while the finer fraction is not. A bulk split of each sample is archived for future investigations.

Sample analysis: Sample analysis has started for 60+ elements using mainly XRF and collision cell ICP-MS at Geoscience Australia. The ICP-MS analyses are carried out on a total digest (HF + HNO₃) of fragments of the XRF beads (Pyke 2000). Other parameters to be recorded routinely at Geoscience Australia are pH 1:5 (soil:water ratio), electrical conductivity 1:5 (soil:water ratio), and laser particle size distribution. Analyses for selected elements not available at Geoscience Australia (e.g. gold (Au), fluorine (F), selenium (Se), and platinum group elements (PGEs)) will take place externally. Additional digests/analyses (e.g. after aqua regia digestion, infrared spectroscopy) are being considered.

Quality assessment/quality control: Sample numbers have been randomised to minimise regional bias, help separate false from true anomalies and obtain meaningful estimates of the variance of duplicates. Field duplicates, analytical duplicates, in-house standards and certified reference materials are introduced at regular intervals in the analytical streams.

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Data analysis: Graphical and statistical data analysis will be carried out at various scales (regional, States/Northern Territory, and National). Non-parametric univariate and multi-variate analysis along with the production of geochemical maps will be carried out.

Timeline: Following planning in the first half of 2007, fieldwork, including initial training, began in mid-2007 and is expected to continue until early 2009 (allowing for the wet season prohibiting field work in northern Australia for six months each year, and for time to obtain access permission in some area). Figure 9 shows the catchments sampled to 30 June 2008. Sample preparation started in early 2008 and will continue until late 2009. Sample analysis started mid-2008 and will continue until mid-2010. Data analysis and reporting are planned to take place in 2010 and early 2011. The project concludes on 30 June 2011.

Data Delivery

By 2011, the NGSa project will deliver a National Geochemical Atlas of Australia available online. In addition, reports on the geochemistry of all States and the Northern Territory will be released, as will reports on energy related commodities, implications for geothermal resources, comparison with airborne radiometric surveys and for regions which are the focus of OESP projects. The national geochemical database will be populated with the new data.

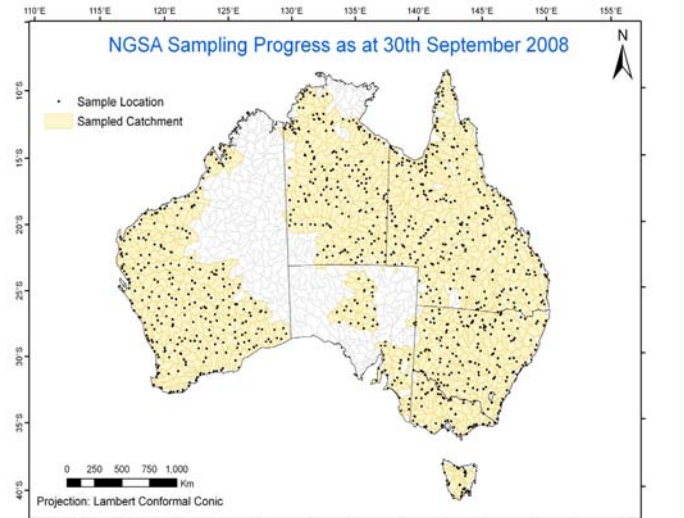


Figure 9. Distribution of catchments sampled for the National Geochemical Survey of Australia, as of 30 September 2008 (1032 catchments, or 74%, completed).

The NGSa will lead to increased knowledge of the concentrations and distributions of geochemical elements in the near-surface environment at the national scale. Further, NGSa results should support increased exploration activity for energy related resources in Australia, particularly using national geochemical survey data to select specific areas

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for further exploration investment. Finally, it is hoped that the NGSa will be one of several contributors to success in mineral exploration in Australia. Spin-off benefits in environmental management, land use policy development and geohealth assessment are also expected.

Conclusion

Three new national geoscience initiatives are under way in Australia. A new digital geological map, an airborne geophysical tie line survey to level the radiometric database, and a surficial geochemical survey will provide invaluable pre-competitive data and information to the energy and minerals exploration industry. Within the next few years, as results all come on line, it is hoped that industry, government and academia stakeholders will make use of these three new datasets, individually, but more importantly, also in combination to support their decision-making processes. The potential to reach a new understanding of geological processes active at the continental-scale is now clearly on the horizon in Australia.

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