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Continental geochemical survey opens up fresh avenues for mineral exploration and natural resource management in Australia

A new continental-scale geochemical atlas and dataset for Australia were officially released into the public domain at the end of June 2011. The National Geochemical Survey of Australia (NGSA) project, which started in 2007 under the Australian Government's Onshore Energy Security Program at Geoscience Australia, aimed at filling a huge knowledge gap relating to the geochemical composition of surface and near-surface materials in Australia. Better understanding the concentration levels and spatial distributions of chemical elements in the regolith has profound implications for energy and mineral exploration, as well as for natural resource management.

In this world first project, a uniform regolith medium was sampled at an ultra-low density over nearly the entire continent, and subsamples from two depths and two grain-size fractions were analysed using up to three different (total, strong and weak) chemical digestions. This procedure yielded an internally consistent and comprehensive geochemical dataset for 68 chemical elements (plus additional bulk properties). From its inception, the emphasis of the project has been on quality control and documentation of procedures and results, and this has resulted in eight reports (including an atlas containing over 500 geochemical maps) and a large geochemical dataset representing the significant deliverables of this ambitious and innovative project. The NGSA project was carried out in collaboration with the geoscience agencies from every State and the Northern Territory under National Geoscience Agreements.

Technicalities

From 2007 to 2009, the National Geochemical Survey of Australia (NGSA) project collected sediment samples from 1315 sites located in 1186 catchments (~10 % of which were sampled in duplicate) from across Australia. The total area covered by the survey is 6.174 million km^2, or ~81% of Australia. The resulting average sampling density is 1 site per ~5200 km^2.

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Figure 1. Helicopter access was required at a number of remote sites accessed by the NGSA field teams between 2007 and 2009 (Photo: Joseph Tang, Geological Survey of Queensland).

Catchment outlet sediments, in most cases similar to overbank sediments, were chosen as the sampling medium, with a near-surface sample (Top Outlet Sediment, TOS, from 0-10 cm below the surface) and a bottom sample (Bottom Outlet Sediment, BOS, between on average 60-80 cm below the surface) being collected at each site. In order to minimise the effect of natural sort-scale compositional variability of soils, the TOS sample was collected from material mixed from a ~1 m^2 shallow (10 cm) pit, and the BOS sample was a composite of material originating from generally three or more auger holes drilled within a 100 m^2 area. The sample sites were selected to be near outlets or spill points of large catchments, so that overbank sediments there could reasonably be assumed to represent well-mixed, fine-grained composite samples of all major rock and soil types present in the catchment. Finally, sampling sites were selected to be well away (and preferably upstream) from major human activities or infrastructure, such as mines, urbanisation, or roads, in order to provide background, i.e., as devoid of human influence as practically possible, chemical compositions.

A number of parameters were recorded in the field, including GPS coordinates, and dry and moist Munsell® colour and field pH of the soil. The sampling sites were described and photographed, with all field data captured digitally for easy subsequent upload into databases. In the laboratory, the samples were air-dried, homogenised and split into an archive sample for future investigations and an analytical sample for immediate analysis. The latter was further split into a bulk subsample, a dry-sieved <2 mm grain size fraction subsample and a dry-sieved <75 μm grain size fraction subsample. The bulk subsample was analysed for electrical conductivity of 1:5 (soil:water) slurries (EC1:5), pH of 1:5 (soil:water) slurries (pH1:5) and grain size analysis using a laser particle size analyser.

Figure 2. Auger holes drilled to collect BOS samples at a site in the Northern Territory. Note that several auger holes were sampled at each site and combined into the BOS samples to minimise the effect of natural local compositional variability (Photo: Andrew Wygralak, Northern Territory Geological Survey).

During 2009 to 2010, the coarse (<2 mm) and fine (<75 μm) fractions were analysed using a variety of analytical methods to determine (1) Total element content, (2) Aqua Regia soluble element content, and (3) Mobile Metal Ion (MMI™) element content (the latter done only on the TOS coarse subsamples). Total element content was determined using a combination of X-Ray Fluorescence (XRF) on fused beads made with lithium borate flux, Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) after total digestion of XRF bead fragments in hydrofluoric and nitric acids (both for determining multiple elements); Fire Assay (FA) for Platinum Group Elements (PGEs) gold, platinum and palladium; Ion Specific Electrode (ISE) after alkaline fusion for fluoride; and hydrochloric and nitric acids digestion followed by ICP-MS analysis for selenium. Gold concentrations were also determined after Aqua Regia and MMI digestion.

A total of 68 chemical elements were determined by at least one of the above methods, including low level gold, platinum and palladium, and rare earth elements (all 14

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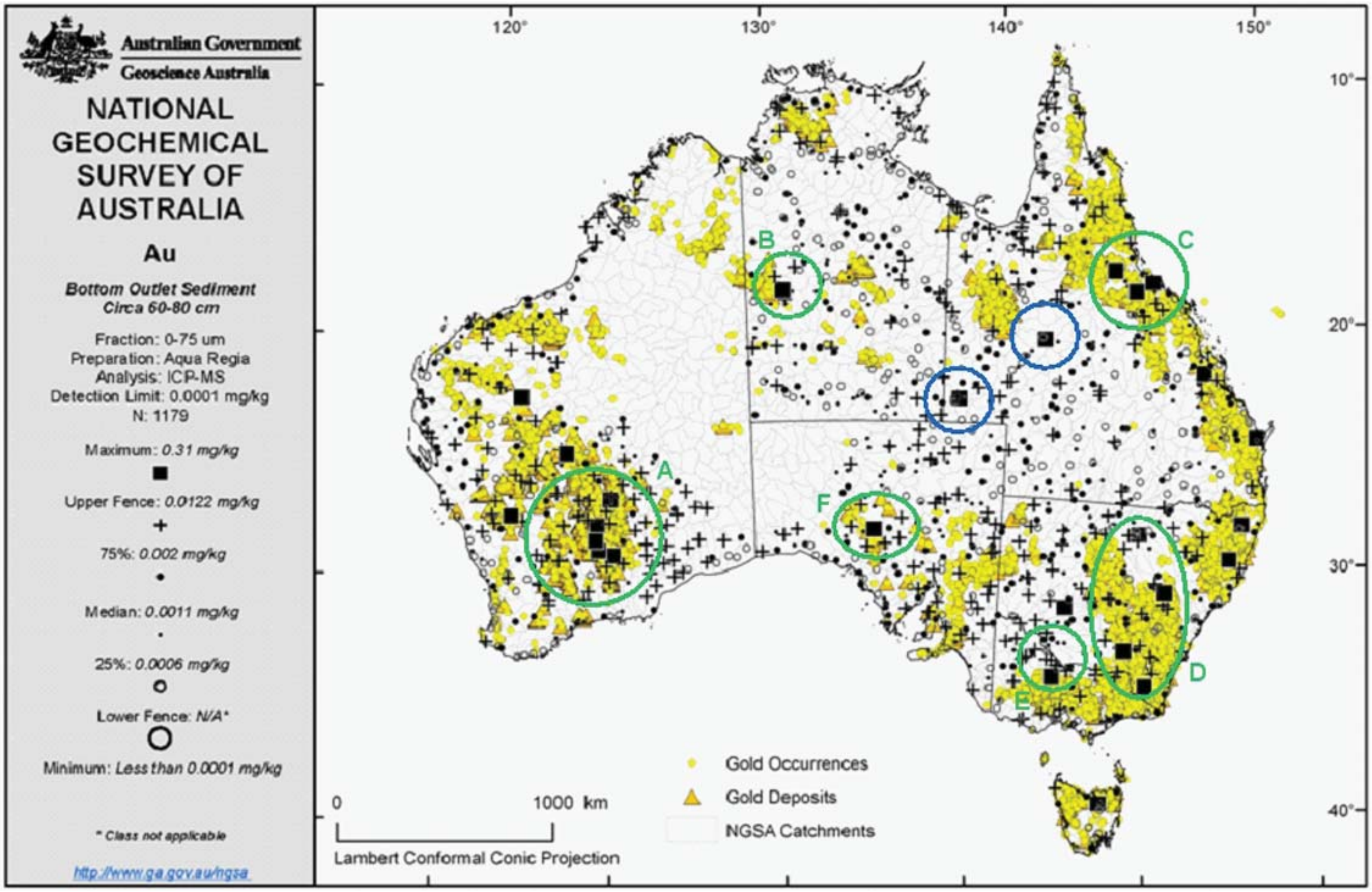

Figure 3. Distribution of gold concentrations determined by the NGSA project in BOS fine samples after aqua regia digestion (solid and open black symbols as per scale on left side of map), overlain on known gold occurrences (grey dots) and deposits (grey triangles). Ellipses marked "A" to "F" illustrate the coincidence of elevated geochemical concentration in catchments with known gold occurrences and/or deposits. Unmarked ellipses are examples of elevated aqua regia gold values in areas with no known gold occurrences and deposits.

stable lanthanides plus scandium and yttrium). Thus, with two depths sampled, two grain size fractions separated, and three analytical methods applied, up to nine concentration determinations were obtained for any given element at each sampling site. These geochemical data plus the bulk properties were collated in a 700,000+ cell spreadsheet and graphically represented as a series of maps. The latter is available in a geochemical atlas (Caritat & Cooper, 2011) downloadable from the project website (www.ga.gov.au/ngsa).

The geochemical atlas (Caritat & Cooper, 2011) is a compilation of 529 geochemical maps from the NGSA project. These constitute the first continental-scale series of geochemical maps based on internally consistent, state-of-the-art data pertaining to the same sampling medium collected, prepared and analysed in a uniform and well documented manner and over a relatively short time period (four years).

Applications

The maps and data delivered by the NGSA project have significant potential to aid reducing risk in energy and mineral exploration in Australia when used in conjunction with other geoscience datasets and tools. A preliminary investigation (Caritat *et al.* 2011) suggests that many of today's known deposits and occurrences for energy related elements (uranium and thorium) as well as common metal (e.g., gold, copper, lead, zinc) and rare earth element (e.g., cerium) commodities are located in catchments with elevated concentrations in these elements as revealed by NGSA results. Additionally, and encouragingly, several catchments with no known deposits and occurrences can easily be identified as anomalous above local background and are obvious places to focus more detailed follow-up exploration effort. Initial feedback from the industry suggests that some of these areas indeed hold promise for future discovery.

The radiometric map of uranium (Minty *et al.* 2010) could also gain from NGSA results because for the first time we have available a nation-wide sample base that can be used to ground-truth the radiometric data. NGSA results indicate that airborne based uranium equivalent concentrations (eU) are generally lower than the geochemically determined uranium concentrations. The eU values are estimated from

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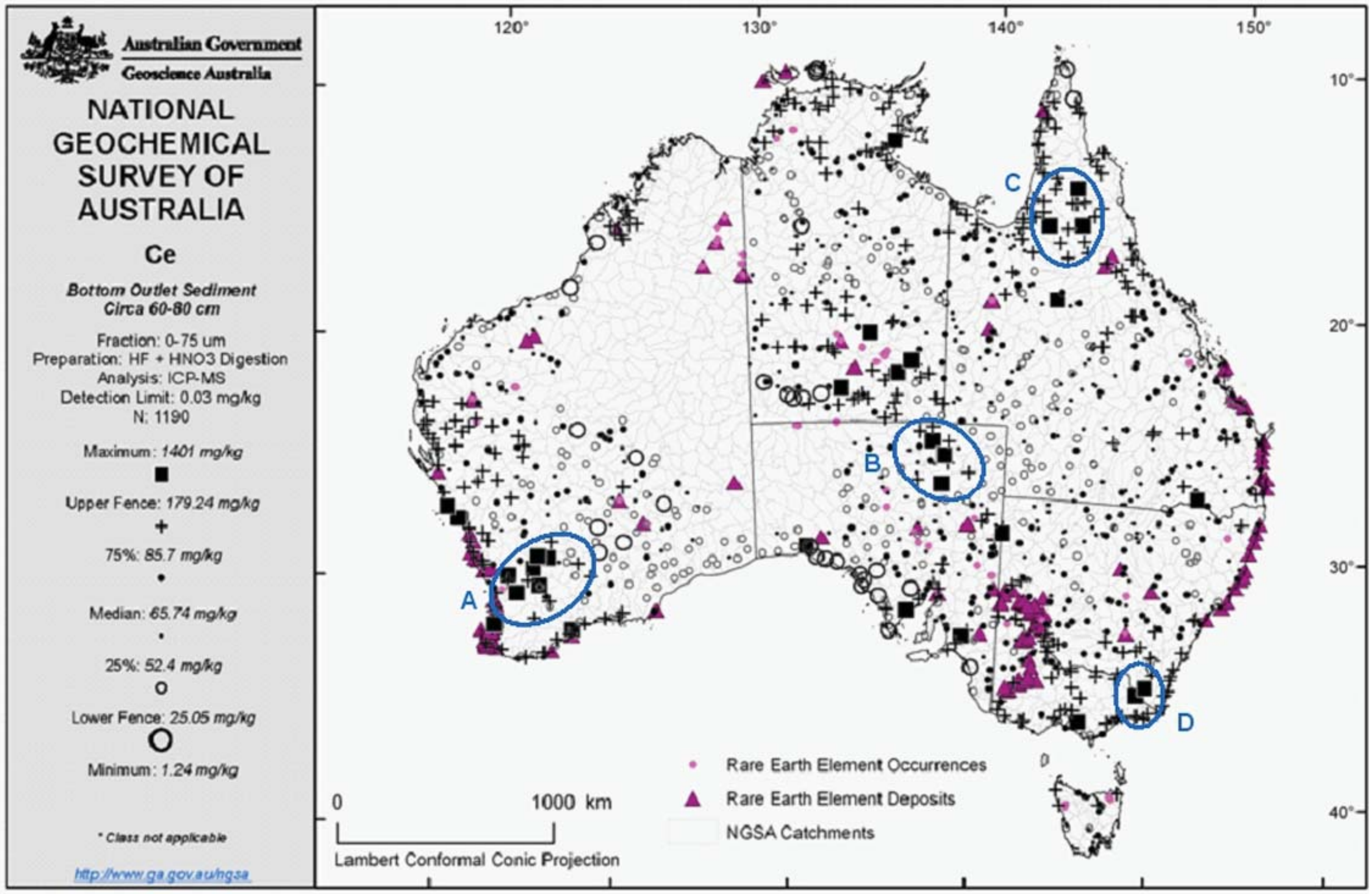

Figure 4. Distribution of cerium concentrations determined by the NGSA project in BOS fine samples (solid and open black symbols as per scale on left side of map), overlain on known REEs occurrences (grey dots) and deposits (grey triangles). Ellipses marked "A" to "D" are examples of elevated cerium values in areas with no known REEs occurrences and deposits.

the gamma radiation emitted by bismuth-214, assuming equilibrium in the uranium decay chain above that isotope. It is known, however, that this decay chain can be plagued with disequilibrium problems whereby one or several of the daughter products (e.g., radium or radon isotopes) can be mobilised away, or accumulate into particular landscape and regolith settings. This can render the eU values unreliable or noisy. Based on the NGSA data, calculation of a correction factor for uranium distribution is under way (Wilford *et al.* 2011).

Another field of application for the NGSA data is in the environmental disciplines, where the wide spatial coverage and comprehensive geochemical element database will enable better decision making relating to landuse decisions, geohealth (i.e., identifying areas where potential excesses or deficiencies of nutrients or toxicants in soils may be expected), dust source fingerprinting and the shaping of knowledge-based soil management strategies, to name a few.

References

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Patrice de Caritat
Geoscience Australia
Email: Patrice.deCaritat@ga.gov.au