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Continental-scale geochemical surveys and mineral prospectivity: Comparison of a trivariate and a multivariate approach

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A B S T R A C T

The National Geochemical Survey of Australia (NGSA) provides an internally consistent, state-of-the-art, continental-scale geochemical dataset that can be used to assess areas of Australia more elevated in commodity metals and/or pathfinder elements than others. But do regions elevated in such elements correspond to known mineralized provinces, and what is the best method for detecting and thus potentially predicting those? Here, using base metal associations as an example, I compare a trivariate rank-based index and a multivariate-based Principal Component Analysis method. The analysis suggests that the simpler rank-based index better discriminates catchments endowed with known base metal mineralization from barren ones and could be used as a first-pass prospectivity tool.

1. Introduction

Modern exploration for mineral resources has relied on geochemical methods since the early days of 'mineral prospecting' in the first half of the XXth century (e.g., Hawkes and Webb, 1962; Levinson, 1974; Beus and Grigorian, 1977; Rose et al., 1979). Former Soviet Union and Scandinavian geologists led the way in developing sampling and analytical methods for the first systematic geochemical surveys. Over recent decades, a large number of geochemical surveys have been carried out at low (~1 site/1000 km^2) to ultra-low (~1 site/10,000 km^2) sampling densities revealing increasingly large geochemical features (Xie and Yin, 1993; Garrett et al., 2008). These have been shown to faithfully represent geochemical patterns revealed in greater detail by higher density surveys of the same areas (e.g., Smith and Reimann, 2008; Birke et al., 2015).

As regions of low and elevated element content are revealed by such surveys, it is relevant to investigate statistically if and how these relate to mineral systems (Wyborn et al., 1994; Reimann et al., 2016). Statistical and visualization methods ranging from univariate analysis to complex machine learning algorithms and geographic information systems have been used to analyze geochemical data, including for prospectivity analysis purposes (e.g., Grunsky, 2010; Zuo et al., 2016; Cracknell and Caritat, 2017). The purpose of such studies is to identify which regions could be prioritized for further strategic investigation and investment. Here I will use low-density geochemical data from the National Geochemical Survey of Australia (NGSA; Caritat and Cooper, 2011, 2016) to investigate if base metal mineral endowment can be recognized at the continental scale. I choose to compare a relatively simple statistical analysis to a more complex multivariate approach.

2. The National Geochemical Survey of Australia

The NGSA project (2007–11) aimed at providing pre-competitive data and knowledge to support exploration for energy resources in Australia (www.ga.gov.au/ngsa). In particular, it improved existing knowledge of the concentrations and distributions of energy related elements such as U and Th at the national scale.

The project was underpinned by a series of pilot geochemical surveys carried out in previous years by Geoscience Australia and the Cooperative Research Centre for Landscape Environments and Mineral Exploration (CRC LEME). These developed and tested robust and cost-effective protocols for sample collection, preparation and analysis (see below). Selected results from these pilot projects were summarized in Caritat et al. (2008a).

The NGSA project was conducted in collaboration with all the State and Northern Territory (NT) geoscience agencies. It was initiated be-

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Table 1
Summary statistics of AR soluble Ag, Pb and Zn concentrations in NGSA samples (in mg/kg). Tc: TOS coarse; Tf: TOS fine; Bc: BOS coarse; Bf: BOS fine; Min: Minimum; Med: Median; Max: Maximum; Skew: Skewness; Kurt: Kurtosis.

	Type	N	Min	Med	Max	Skew	Kurt
Ag	Tc	1189	< 0.002	0.012	1.08	14	223
	Tf	1175	< 0.002	0.017	5.42	31	1006
	Bc	1190	< 0.002	0.011	3.28	26	754
	Bf	1175	< 0.002	0.017	0.65	9	147
Pb	Tc	1189	< 0.01	7.25	1090	28	856
	Tf	1175	0.01	10.5	1520	30	989
	Bc	1190	< 0.01	7.39	789	29	923
	Bf	1175	0.01	10.5	146	6	75
Zn	Tc	1189	< 0.1	26.5	262	2	13
	Tf	1175	< 0.1	37.1	8910	33	1106
	Bc	1190	< 0.1	26.5	330	3	28
	Bf	1175	< 0.1	38.1	1950	24	724

cause a geochemical coverage for Australia was identified as a gap, which when filled would complement the national-scale geological and geophysical datasets (Caritat et al., 2008b).

3. Material and methods

Catchment outlet sediments were collected from 1186 catchments (or 1315 sites, including field duplicates), which together cover over 6.174 million km^2 or ~81% of Australia at the average density of 1 site/5200 km^2. Approximately 200 catchments in South Australia and Western Australia could not be sampled during this project due to access limitations. Collaboration with State and NT geoscience agencies was critical for the completion of the project, particularly regarding the sampling phase.

Sampling procedures, sample preparation, and sample analysis protocols, as well as data quality assessment have been presented in detail in a series of reports (see Caritat and Cooper, 2016, for a full bibliography) and are thus only briefly described below. The geochemical atlas (Caritat and Cooper, 2011) presented 529 maps illustrating the geographical distribution of the concentration of chemical elements and properties as acquired by the NGSA project.

In brief the relevant points here are that catchment outlet sediments (similar to overbank/floodplain sediments) were collected from two depths (0–10 cm for Top Outlet Sediment or TOS and ~60–80 cm for Bottom Outlet Sediment or BOS) near the lower point of those large catchments; after air drying a coarse (< 2 mm) and a fine (< 75 μm) fraction were separated, yielding four sample types (TOS coarse or Tc;

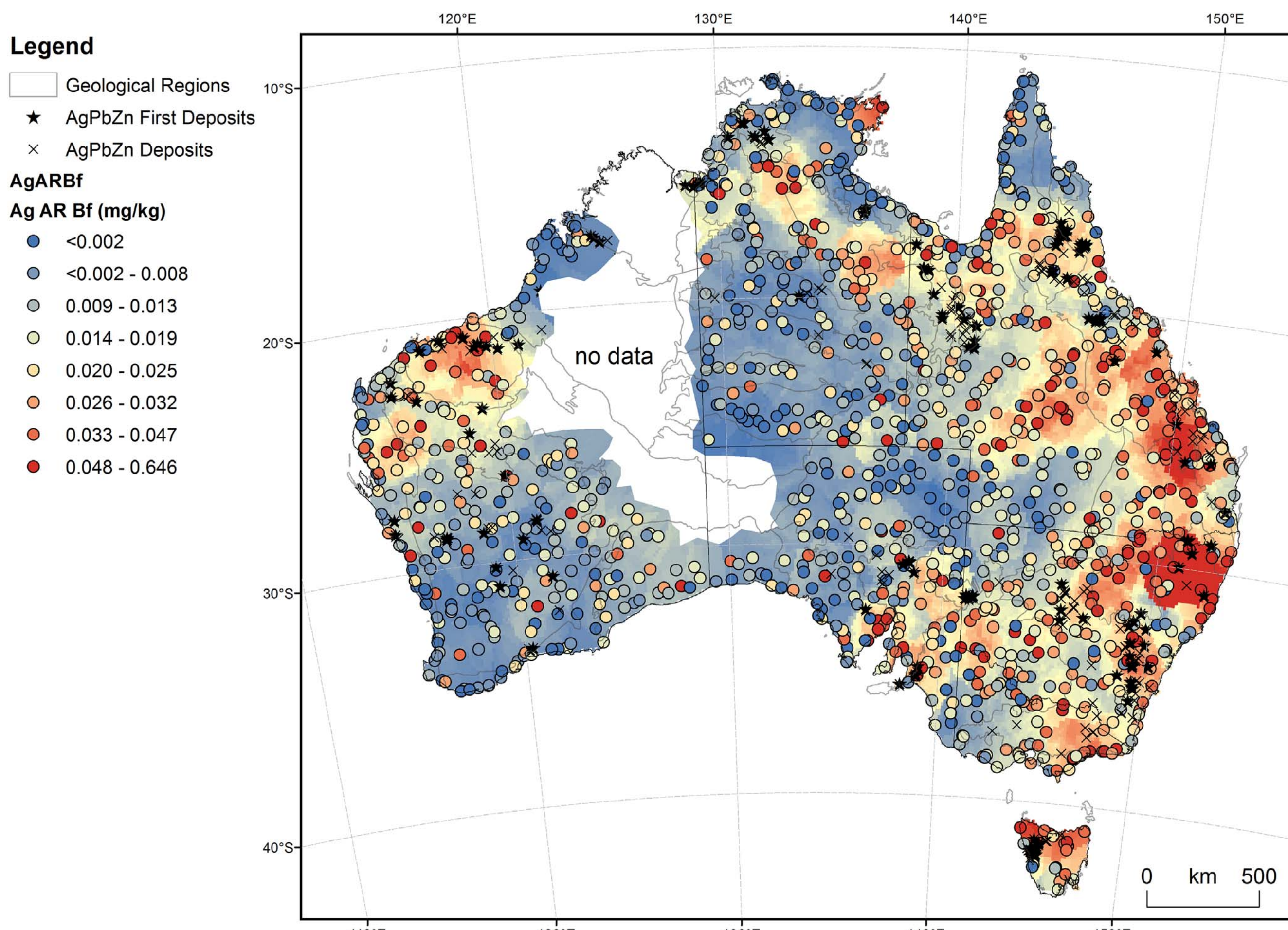

Fig. 1. Kriged raster map of AR soluble Ag concentrations (mg/kg) in Australian catchment outlet sediments (bottom outlet sediment, < 75 μm fraction) based on eight quantile classes with Ag-Pb-Zn deposits overlain (see text). Same color ramp is used for the sample symbols and the underlying raster.