Establishing a geochemical baseline in an area of critical mineral occurences: Murray Basin, Victoria

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Introduction

Establishing an environmental geochemical baseline in areas of proposed resource development is critical (Darnley et al, 1995; Lee & Helsel, 2005; Raiber et al, 2013). Geochemical baselines can be used by government, industry and Traditional Custodians to benchmark and understand environmental condition prior to development. Mineral sand occurrences containing globally significant quantities of rare earth elements (REE), titanium (Ti) and zirconium (Zr) occur in northwest Victoria, and are the target of multiple recently approved mines (Mason, 2016; DEECA, 2024; Geoscience Australia, 2024). The Geological Survey of Victoria (GSV), in collaboration with the Commonwealth Scientific and Industrial Research Organisation (CSIRO), is undertaking a geochemical baseline study over an area of 57,000km² in northwest Victoria (Fig. 1). The aim of this study was to sample and analyse the geochemistry of:

Soil

Groundwater

Lake sediment and salt crystal

Vegetation

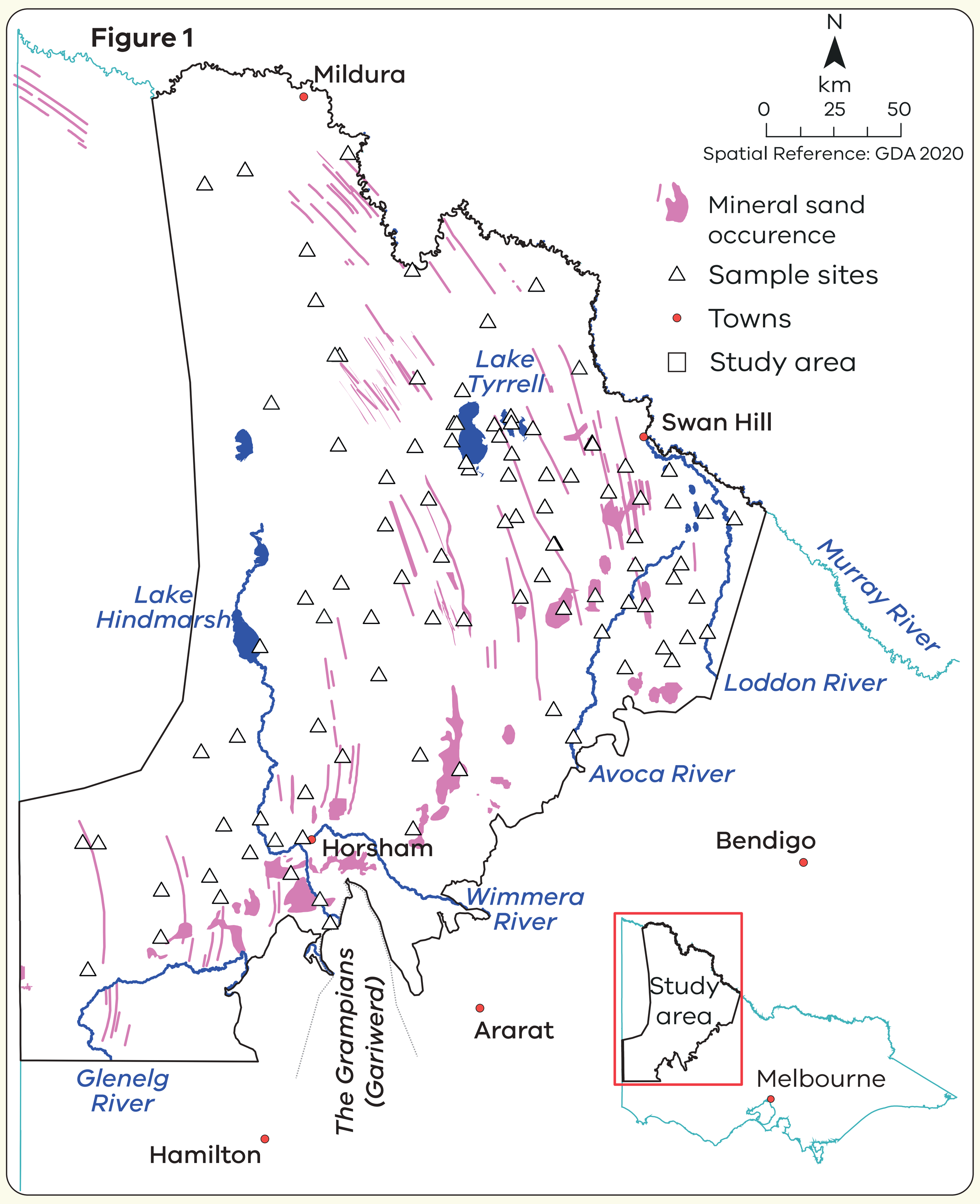

Figure 1

Methods

- 104 near surface soil samples were collected at a target depth between 5 to 25 cm.
- The sub-2 mm portion underwent a partial digest and a total digest, and 67 elements were analysed via inductively coupled plasma (ICP) mass spectrometry (MS) and ICP optical emission spectrometry (OES).
- 95 lake sediment, 20 salt lake crystal and 190 vegetation samples will be collected in early 2026 and analysed via ICP MS/OES.
- 163 groundwater samples were collected using a flow-through bailer at least 5 m below the water table.
- The following were measured in groundwater samples, as per the methodology in Gray et al (2016):

Major, minor, trace elements inc. Ti, Zr, REE	Stable isotopes δ^2H, $\delta^{18}O$, $\delta^{13}C$	Radioisotope tracers ^3H, ^{14}C	Natural radiation Pb, Ra, Th, U
All samples	All GW samples	15 GW samples	6 GW samples

Results and discussion

Groundwater

Groundwater is mostly saline (>10,000 mg/L) and measured salinities in the Parilla Sand are up to 300,000 mg/L. Groundwater in the deeper Duddo Limestone (median = 1,170 mg/L) and Renmark Group (median = 10,700 mg/L) is generally fresher. Only 11 groundwater samples had salinity within the aesthetic guideline for human consumption (600 mg/L, NHMRC, 2011).

Groundwater is predominantly Na-Cl type and little variation in groundwater major ion geochemistry is observed between aquifers. This is consistent with high amounts of evapotranspiration and mixing between water from the different aquifers.

Titanium and zirconium concentrations in groundwater are mostly below detection, as is expected given the low solubility and mobility of these elements. The highest concentration of Ti (14 µg/L) and Zr (3.2 µg/L) occur in the Parilla Sand east of Lake Tyrrell.

Groundwater concentrations of REE are greatest in the Parilla Sand (median = 2.15 µg/L), particularly in the region surrounding Lake Tyrrell (max = 4230 µg/L; Fig. 2, 3). Light REE (La, Ce, Pr, Nd, Sm, Eu & Gd) concentrations are elevated relative to heavy REE (Tb, Dy, Ho, Er, Tm, Yb & Lu). Concentrations of the REE are typically greatest in acidic groundwater with pH <6 (Fig. 3). This is also observed for other metals including Co, Li, Ga and Ni.

There is no clear correlation between groundwater Ti, Zr and REE concentrations and mapped mineral sand occurences (Fig. 1).

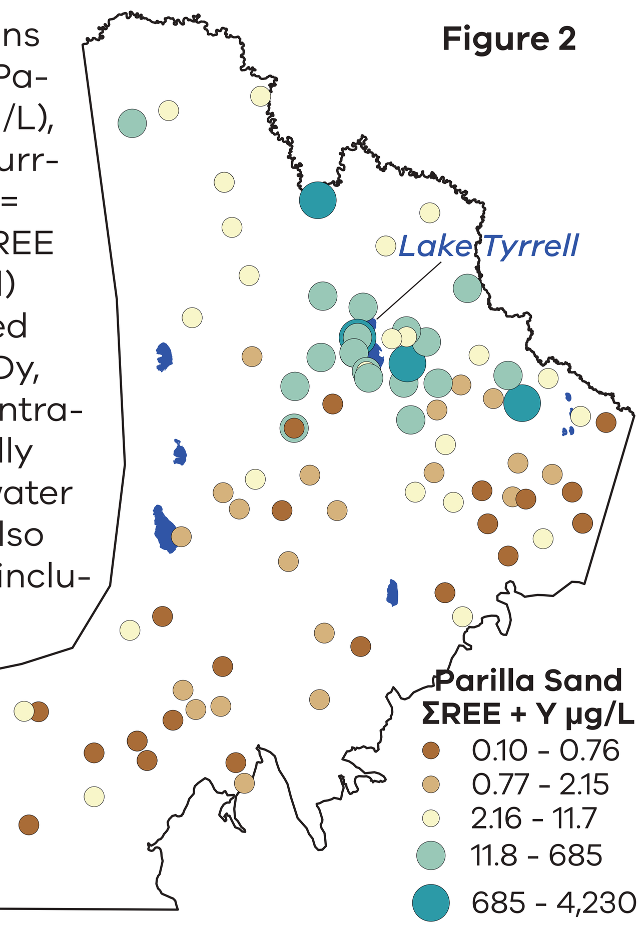

Figure 2

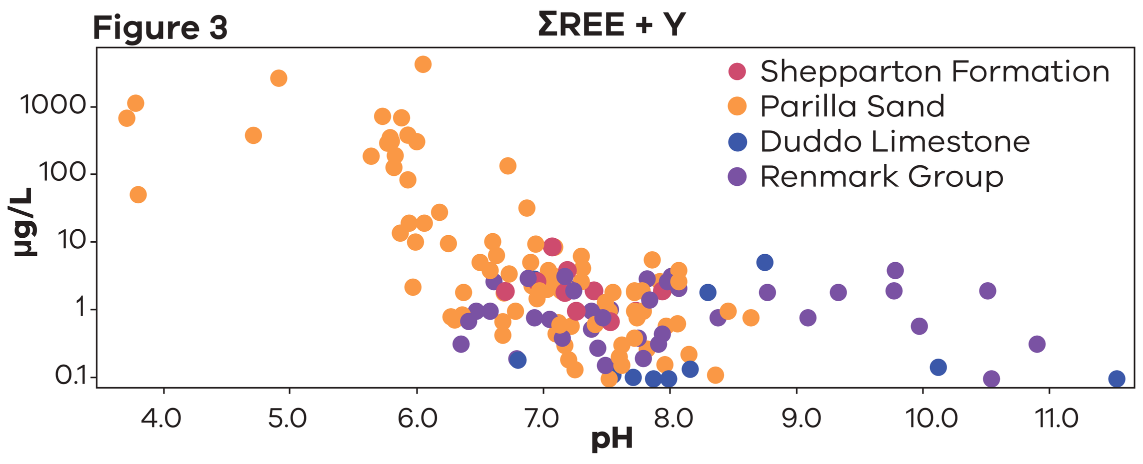

Figure 3

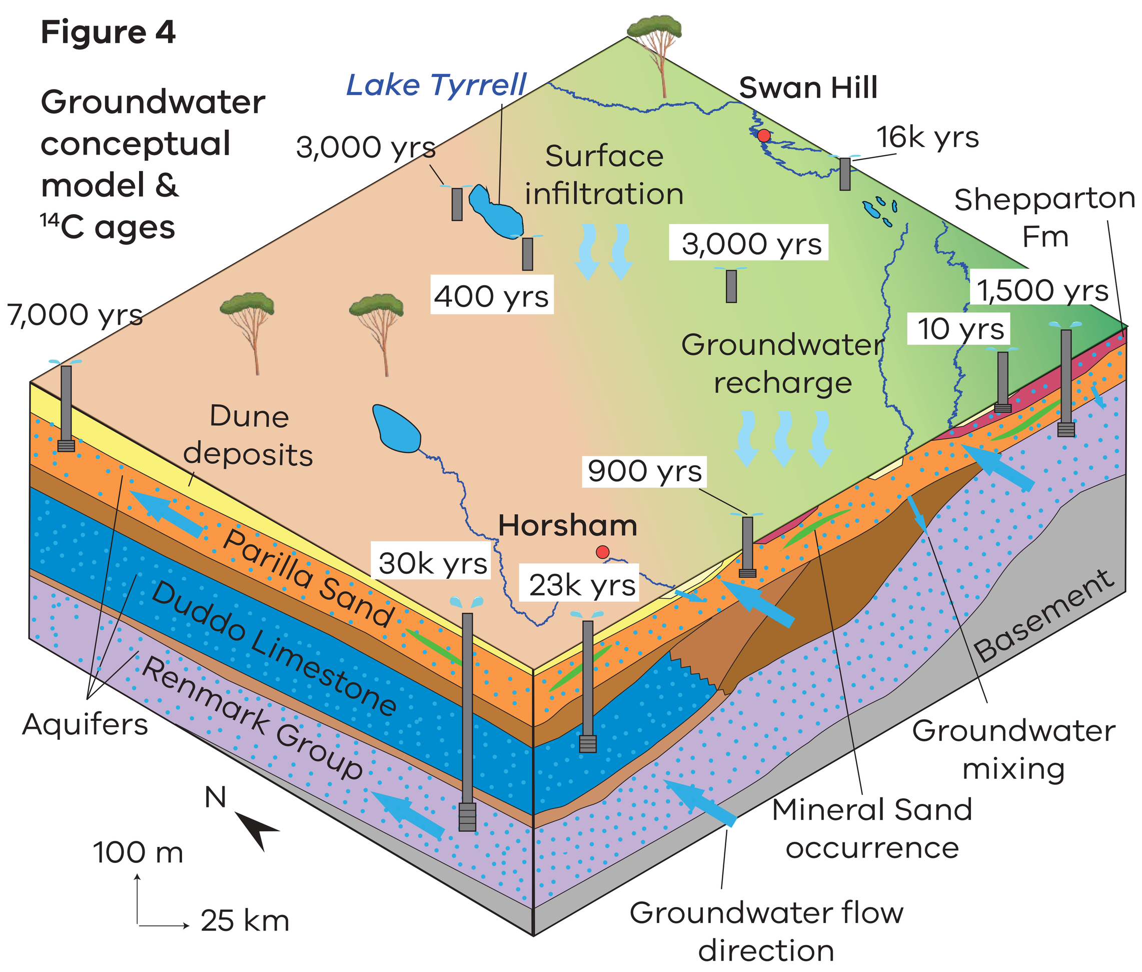

Figure 4

Radiocarbon activities in groundwater ($a^{14}C$) range from 100 - 2.2 pMC, consistent with ages from <10 to >30k years. Groundwater ^{14}C ages <1000 years in the southern Murray Basin and at the southern end of Lake Tyrrell are consistent with recent groundwater recharge and/or surface water infiltration.

Soil

Four recurring patterns occur in the soil concentration data (Fig.5). The origin of the soil parent material has a primary control on soil chemistry.

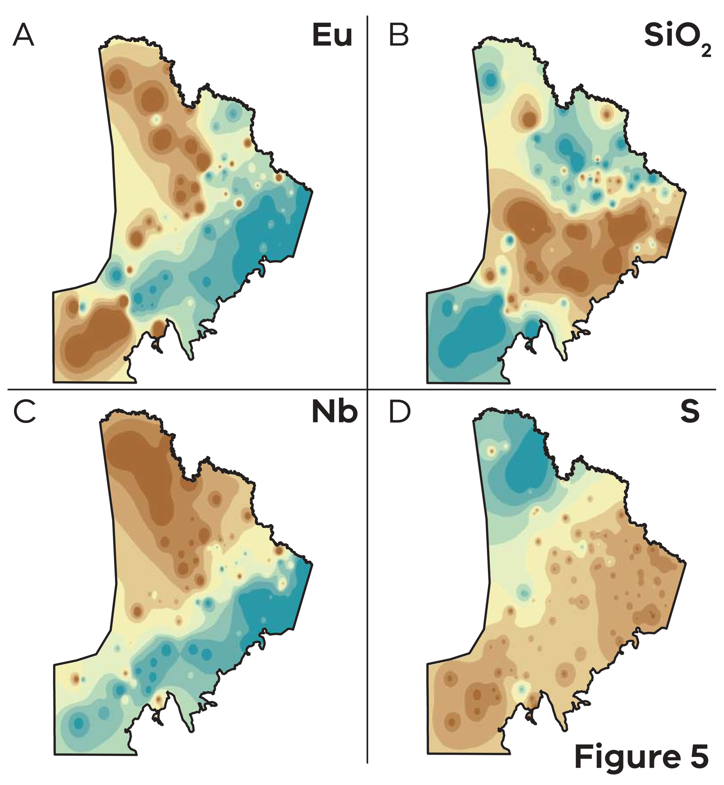

Figure 5

Soils in the northern study area are developed on calcareous dune deposits resulting in higher CaO and Sr concentrations.

Soils in the southern study area are developed on exposed basement rocks that change from non-marine sedimentary rocks in the Glenelg Zone to marine and igneous rocks eastward.

Elements such as SiO_2 (Fig. 5B) are higher in Glenelg Zone soils, while TiO_2 and REE (Fig. 6) are higher in soils to the east.

Soil geochemistry is observed to vary spatially with river location. Element concenrations vary across the trace of the Wimmera River, consistent with variation between alluvial deposists from the river catchment and soil parent material sourced from the Glenelg Zone to the west.

Avon, Avoca and Loddon rivers (Fig. 1) deliver alluvial sediments enriched in TiO_2 and REE in the Stawell and Bendigo zones (Fig. 6).

Titanium concentrations range from 0.04 – 1.0 wt %, Zr 33 – 703 mg/kg and ΣREE + Y +Ti + Zr 490 – 10113 mg/kg (Fig. 6). These values fall within the range detected in previous Australian studies (de Caritat & Cooper, 2016).

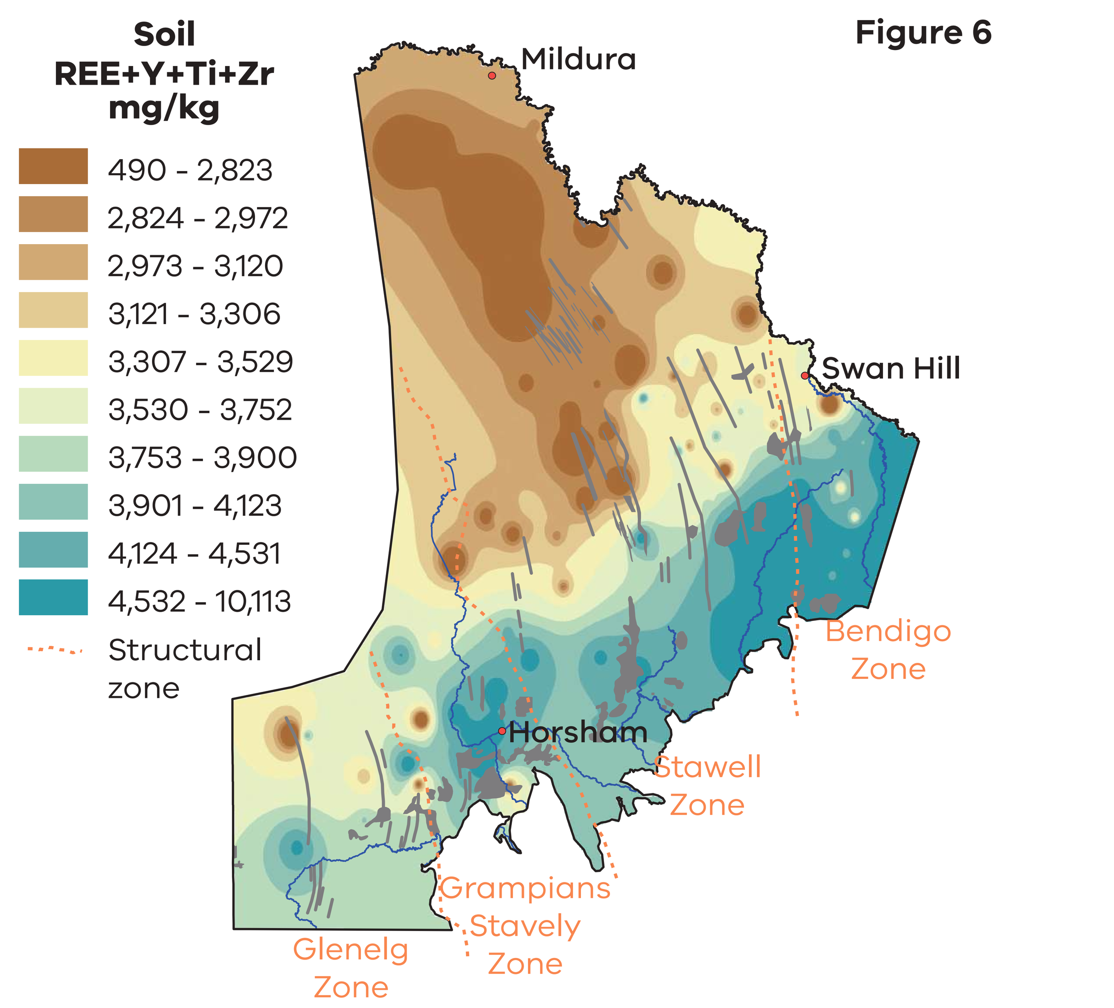

Figure 6

Future opportunities

- Use this study as a basis for future monitoring and evaluation
- Broadening baseline geochemistry surveys across Victoria.
- Create additional collaboration opportunities within the state and across borders to adjoining baseline studies to trace geochemical trends and associated processes outside of the study area.
- Integration of groundwater, soil, vegetation, lake sediment and salt crystal geochemistry to develop a holistic understanding of geochemistry in the landscape.

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