Samarium–neodymium isotope map of Western Australia

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Abstract

The Geological Survey of Western Australia (GSWA) released its first statewide samarium–neodymium (Sm–Nd) isotope map under the Accelerated Geoscience Program in 2021 (Lu et al., 2021). Such isotope maps have previously been used to characterize lithospheric architecture through time, and to help understand crustal evolution and mineral system distributions, and play an increasingly important role in predictive exploration targeting (Champion and Cassidy, 2007; McCuaig and Hronsky, 2014; Mole et al., 2015; Champion and Huston, 2016; Wu et al., 2022). Here we present a revised Sm–Nd isotope map of Western Australia that updates previously released data with analyses of 230 new samples, for a total of 2224 analyses (Figs 1, 2).

These Sm–Nd isotope maps (Fig. 2) are based on whole-rock Sm–Nd data for felsic igneous rocks, which provide a window into the age and compositional variation of the middle and lower continental crust where most felsic magmas are generated (Champion and Huston, 2016). Although mafic igneous and sedimentary rocks were not used in constructing the isotope maps, Sm–Nd data for those samples are also included in the data table along with data for felsic igneous rocks.

The isotope calculations are based on a chondritic uniform reservoir (CHUR) model with modern-day CHUR values of $^{147}Sm/^{144}Nd$ = 0.1960 and $^{143}Nd/^{144}Nd$ = 0.512630 (Bouvier et al., 2008), a depleted mantle (DM) model with modern-day DM values of $^{147}Sm/^{144}Nd$ = 0.2136 and $^{143}Nd/^{144}Nd$ = 0.513163, and an assumed $^{147}Sm/^{144}Nd$ value of 0.11 for average continental crust (Champion and Huston, 2016). The isotope maps were created using the Natural Neighbour interpolation tool in ArcGIS Spatial Analyst following Champion and Huston (2016), and are presented as both classified (natural breaks classification, Fig. 2a,c) and stretched (Histogram Equalize type, Fig. 2b,d) raster datasets.

The maps show two-stage depleted mantle model ages (T_{DM}^2, proxy for the average age of the crustal source of the igneous rocks) and crustal residence time (T_{CR}, the difference between T_{DM}^2 and magmatic crystallization age, i.e. the length of time the source of the igneous rocks has resided in the crust prior to melting). Strong isotope gradients are typically associated with major crustal boundaries and are potentially important for localizing mineral systems (Martin et al., 2021). However, map colours in areas with no or few samples reflect interpolated values and may have little or no relationship with underlying crust.

Some isotope gradients may not be as pronounced in the statewide map as they might be on more detailed maps of individual regions. It is therefore recommended that users download the isotope data and create their own contour maps for particular areas, to enhance the isotope gradients in those areas. An example is provided for the Archean Yilgarn Craton (Fig. 3), which provides a more detailed image of the architecture of the Kalgoorlie–Kurnalpi region, a world-class Archean gold province (Witt et al., 2020). It shows that old T_{DM}^2 values (>2900 Ma) are common across the Yilgarn Craton, but only occur on the western and eastern margin of the Kurnalpi Terrane, supporting the interpretation that the Kalgoorlie–Kurnalpi region developed as a rift above Youanmi-like substrate with rifting centred in the Kurnalpi Terrane (e.g. Smithies et al., 2018; Mole et al., 2019; Witt et al., 2020).

Insights into crustal evolution can be gained by visualizing the variation with age of $\varepsilon_{Nd(i)}$, T_{DM}^2 and T_{CR} for both mafic and felsic igneous rocks (Fig. 4). From c. 3730 to 2500 Ma, mafic and felsic igneous

rocks show overlapping $\varepsilon_{Nd(i)}$, $T_{DM}{}^2$ and T_{CR}, which is in contrast to times younger than 2000 Ma, when mafic rocks generally yield higher $\varepsilon_{Nd(i)}$, and lower $T_{DM}{}^2$ and T_{CR} than felsic rocks in any given time. Felsic rocks older than 2500 Ma record sources requiring episodic juvenile mantle input at c. 3730, 3600, 3480–3420, 3300–3200, 3100, 2950, 2800 and 2700 Ma, as well as reworking of existing crust with $T_{DM}{}^2$ up to c. 3960 Ma (Fig. 4a). The data for post-2000 Ma igneous rocks, however, suggest crustal reworking is the dominant mechanism forming felsic rocks younger than 2000 Ma in Western Australia. The increasing T_{CR} for both mafic and felsic rocks from c. 3730 to 500 Ma is consistent with secular crustal maturation observed in other isotope systems, such as zircon oxygen isotopes (Fig. 4c; Valley et al., 2005; Lu et al., 2022).

There are few mafic or felsic igneous rocks between 2500 and 2000 Ma (Fig. 4). However, xenocrystic zircons of this age are common and have mainly heavy $\delta^{18}O$ values, implying that felsic magmatism during this interval involved significant reworking of supracrustal materials, and that those magmatic rocks were mostly emplaced at depth and not exposed at the surface (Lu et al., 2022). This may indicate that the early Paleoproterozoic may have been dominated by orogenic compression, which trapped magmas at deep crustal levels (Loucks, 2021).

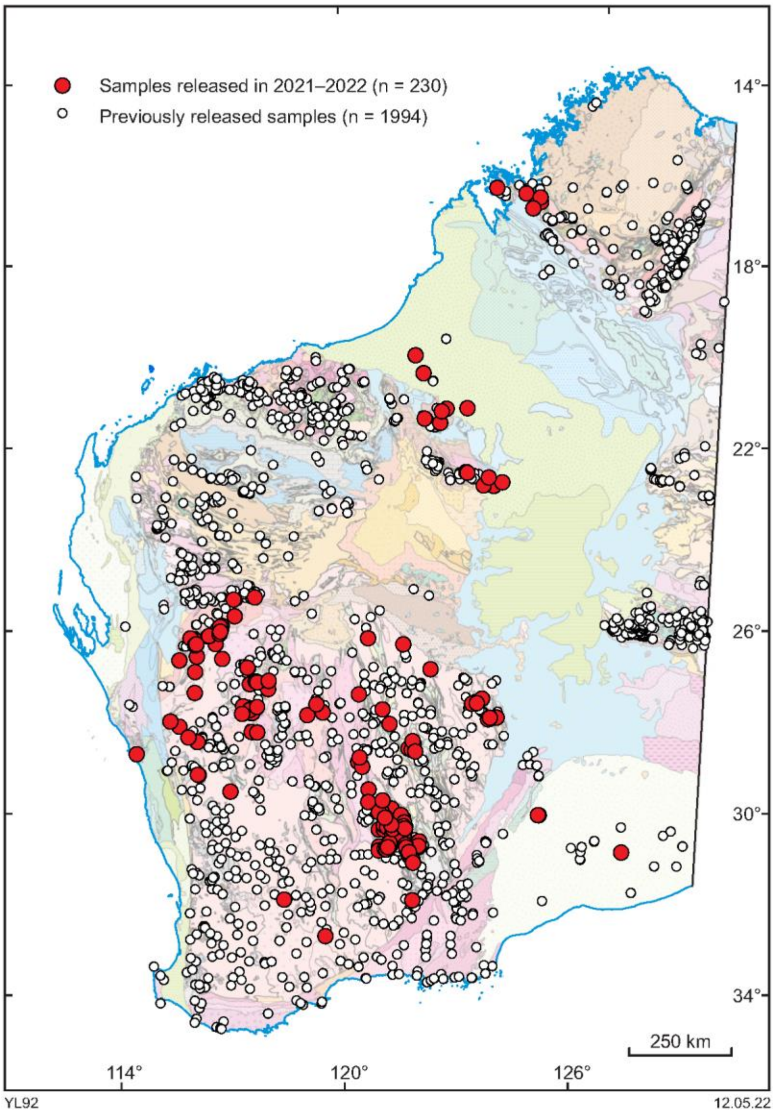

Figure 1. **Locations of new and previously released Sm–Nd isotope samples, shown on the 1:2.5 million interpreted bedrock geology map**

The Sm–Nd isotope samples and associated data were compiled as part of a collaboration between GSWA and Geoscience Australia (GA). Acquisition of GSWA's Sm–Nd isotope data was funded by the Exploration Incentive Scheme (EIS), and involved collaboration with several university research laboratories.

How to access

The data layer is best accessed using GeoVIEW.WA. This online interactive mapping system allows data to be viewed and searched together with other datasets, including GSWA and GA geochronology data, geological maps, and mineral exploration datasets. The Samarium–neodymium isotope map digital data are also available as a free download from the Data and Software Centre via Datasets — Statewide spatial datasets — Geochronology & Isotope Geology — Samarium–neodymium isotope map, as ESRI shape files and MapInfo TAB files. These datasets are subject to ongoing updates as new data are generated.

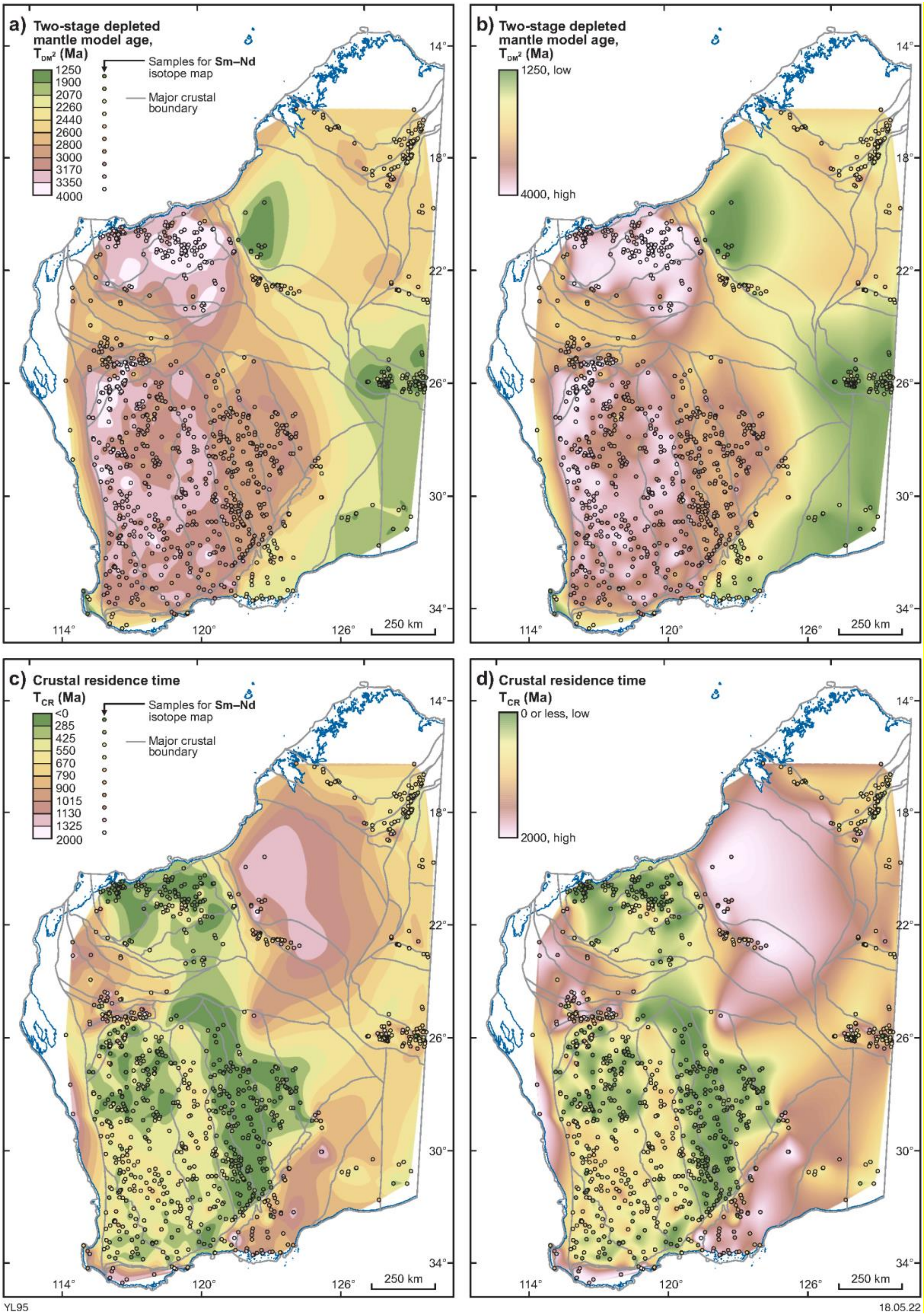

Figure 2. **Sm–Nd isotope maps for whole-rock samples of felsic igneous rocks in Western Australia. T_{DM}^2 and T_{CR} maps are presented as classified (a and c) and stretched (b and d) raster images. Symbols show the locations of Sm–Nd samples used for isotope mapping. Major crustal boundaries (gray lines) are from Martin et al. (2021)**

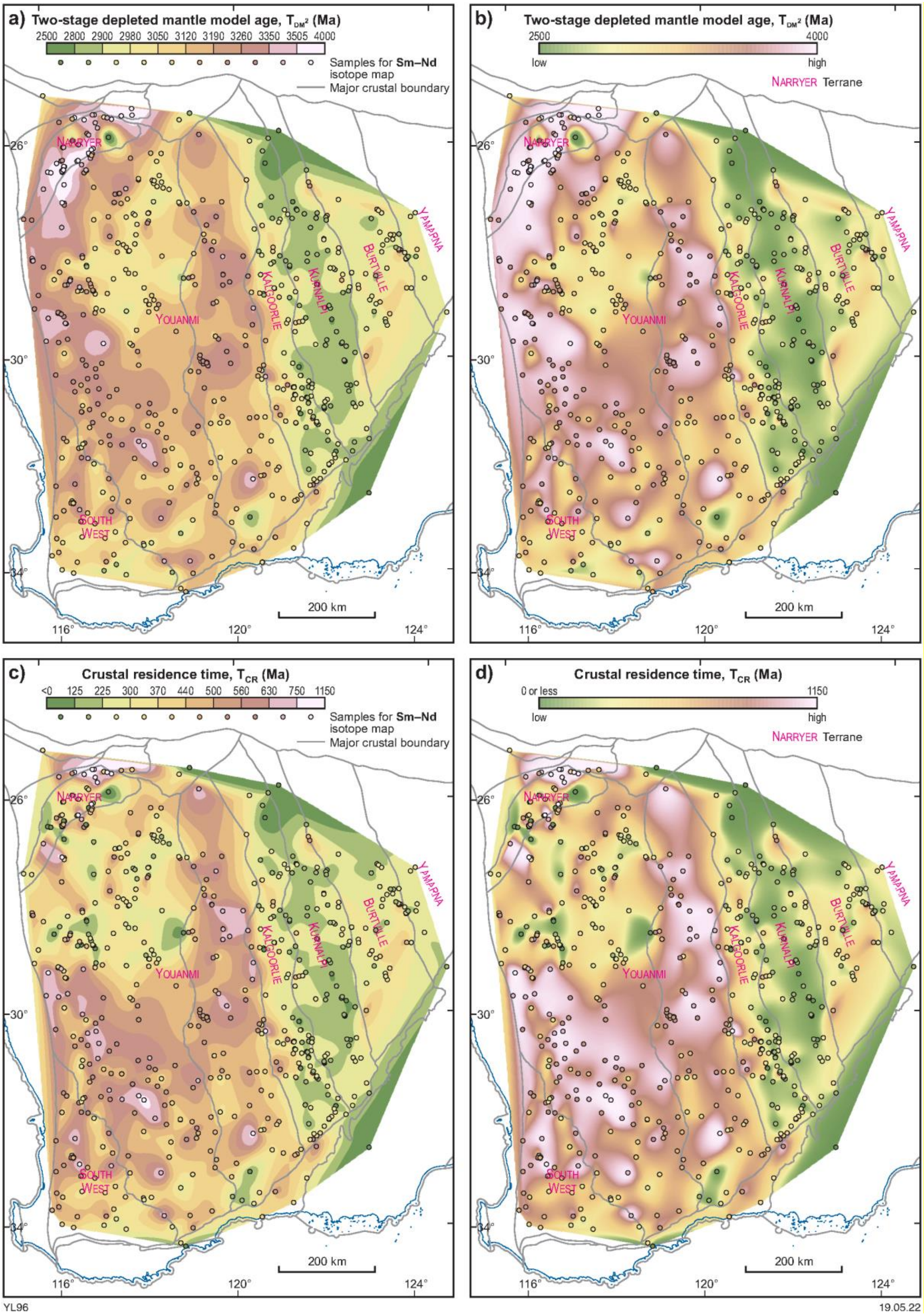

Figure 3. Sm–Nd isotope maps for whole-rock samples of felsic igneous rocks in Yilgarn Craton. T_{DM}^2 and T_{CR} maps are presented as classified (a and c) and stretched (b and d) raster images. Symbols show the locations of Sm–Nd samples used for isotope mapping. Major crustal boundaries (gray lines) are from Martin et al. (2021). Only samples older than 2600 Ma are used here to reveal the Archean crustal architecture of the craton

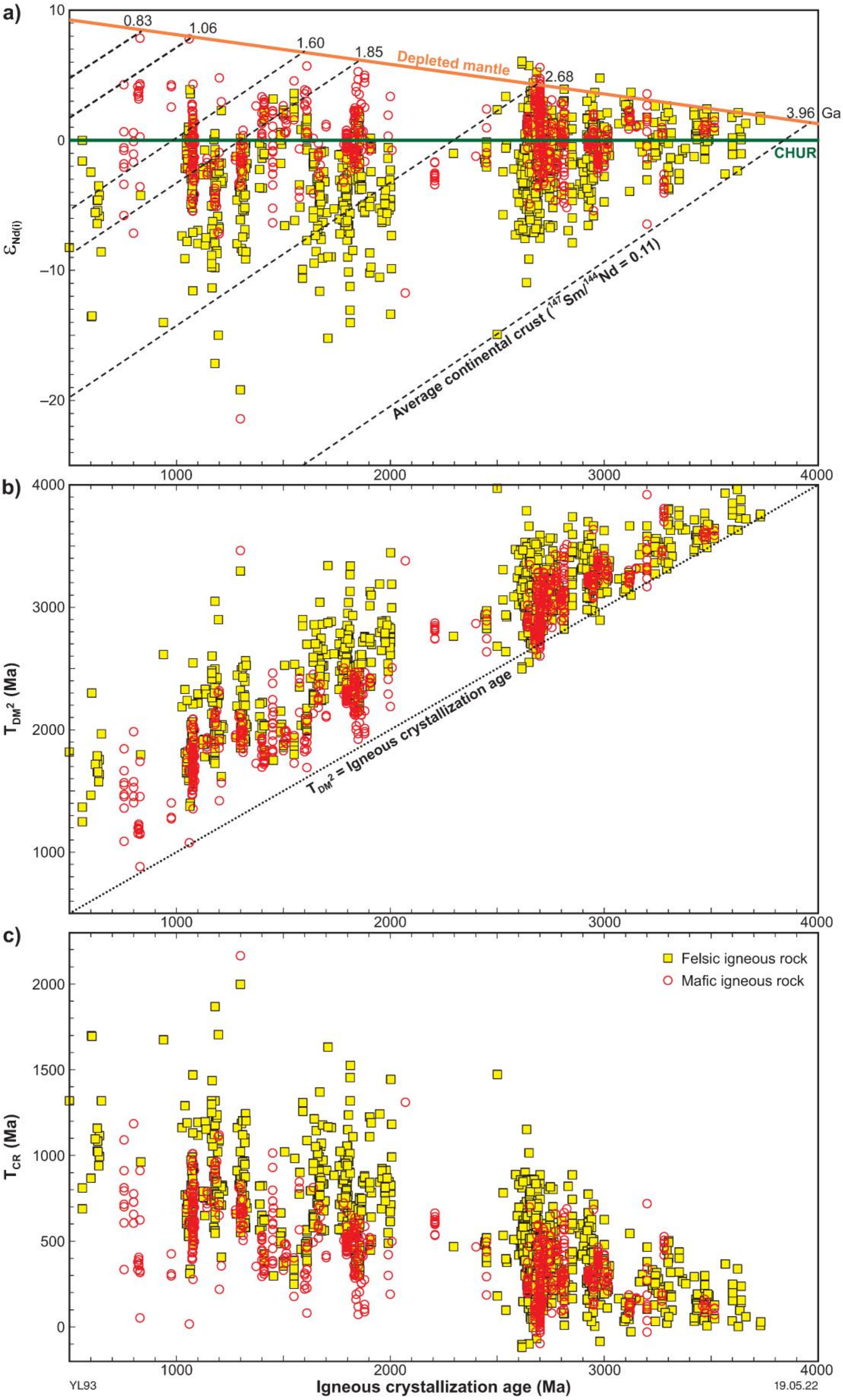

Figure 4. **Values of $\varepsilon_{Nd(i)}$ (a), T_{DM}^2 (b), and T_{CR} (c) vs Igneous crystallization age for felsic and mafic igneous rocks in Western Australia. Samples on or close to the Depleted mantle line in (a) or the T_{DM}^2 = Igneous crystallization age line in (b) indicate juvenile mantle input**

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EXPLORATION INCENTIVE SCHEME

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