RECORD 2021/6

# YILGARN GRANITE PROJECT — NOTES TO ACCOMPANY 2021 DATA RELEASE

by
JR Lowrey, RH Smithies and DC Champion

Government of **Western Australia**
Department of **Mines, Industry Regulation and Safety**

**Geological Survey of Western Australia**

Government of **Western Australia**
Department of **Mines, Industry Regulation and Safety**

RECORD 2021/6

# YILGARN GRANITE PROJECT — NOTES TO ACCOMPANY 2021 DATA RELEASE

by
JR Lowrey, RH Smithies and DC Champion*

* Geoscience Australia, 1010 Jerrabomberra Ave, Symonston ACT 2609, Australia

PERTH 2021

**Geological Survey of Western Australia**

**MINISTER FOR MINES AND PETROLEUM**
**Hon Bill Johnston MLA**

**DIRECTOR GENERAL, DEPARTMENT OF MINES, INDUSTRY REGULATION AND SAFETY**
**Richard Sellers**

**EXECUTIVE DIRECTOR, GEOLOGICAL SURVEY AND RESOURCE STRATEGY**
**Jeff Haworth**

**REFERENCE**
**The recommended reference for this publication is:**
Lowrey, JR, Smithies, RH, and Champion, DC 2021, Yilgarn Granite Project: notes to accompany 2021 data release: Geological Survey of Western Australia, Record 2021/6, 4p.

**ISBN** 978-1-74168-929-7
**ISSN** 2204-4345

Grid references in this publication refer to the Geocentric Datum of Australia 1994 (GDA94). Locations mentioned in the text are referenced using Map Grid Australia (MGA) coordinates, Zone 50. All locations are quoted to at least the nearest 100 m.



**Published 2021 by the Geological Survey of Western Australia**
This Record is published in digital format (PDF) and is available online at <www.dmirs.wa.gov.au/GSWApublications>.



**Further details of geoscience products are available from:**
Information Centre
Department of Mines, Industry Regulation and Safety
100 Plain Street
EAST PERTH WESTERN AUSTRALIA 6004
Telephone: +61 8 9222 3459 Email: publications@dmirs.wa.gov.au
**www.dmirs.wa.gov.au/GSWApublications**

**Cover image:** Wave and wind sculpted stromatolites at Flagpole Landing, Hamelin Pool in the world heritage site of Shark Bay, Western Australia (photo courtesy of Heidi Allen, DMIRS)

# Contents



## Figure



## Appendix

*Available with the PDF online as an accompanying digital resource*

Yilgarn Granite Project geochemical dataset

# Yilgarn Granite Project — notes to accompany 2021 data release

by

**JR Lowrey, RH Smithies and DC Champion***

## Abstract

The Yilgarn Granite Project is an initiative under the State Government Exploration Incentive Scheme (EIS) that aims to provide complete and detailed coverage of the Yilgarn Craton in terms of modern, high-quality, major and trace element data (including Li) on felsic intrusive rocks, and at the same time, expand the coverage of whole-rock Sm–Nd isotope data. We hope also to identify, within this new dataset, potential proxies for crustal source composition, melting conditions and for fertility in terms of producing precious and strategic mineral deposits. As data is accumulated, the project will provide interpretation (digital data, GIS layers, Reports) that attempts to place these data within the context of crustal-scale structure, source regions and economic mineral fertility.

The vast majority of the data generated during the first year of this project were derived from re-analysing archived materials, mainly from Geoscience Australia's (GA) Yilgarn Craton granite collection (now housed with GSWA), using the best whole-rock chemical assay methods commercially available. For most reported elements, detection levels have lowered by an order of magnitude or more compared to the original methods used. This Record and the accompanying dataset will be updated and re-released annually, and it is expected that future releases will contain significant numbers of newly collected granitic samples from outcrop and drillcores across the Yilgarn Craton.

The locations of geochemical samples contained in the dataset are shown in Figure 1 and the dataset (Appendix) itself is fully attributed with the sample details required for a range of uses, potentially beyond the scope of the project. Separate Records will present interpretations of these data in line with the aims of the Yilgarn granite geochemistry project.

**KEYWORDS**: Archean, granite, whole-rock geochemistry, Yilgarn Craton

# Sample selection and analytical techniques

## Dataset content

The dataset presented here (n = 1033; Appendix) contains only those samples collected or re-analysed specifically for the Yilgarn Granite Project. Other data produced by the Geological Survey of Western Australia (GSWA) and various universities and research organizations are available in published literature or in publicly available online datasets. The dataset includes whole-rock major and trace element data primarily covering granitic (or meta-granitic) lithologies including high-level (subvolcanic) felsic intrusive rocks (commonly referred to as 'felsic porphyry'). It also includes some mafic igneous rocks, such as lamprophyres and quartz-gabbroic rocks, where a co-magmatic relationship with felsic derivatives can be established or realistically inferred. To date, 882 samples from GA's granite dataset have been re-analysed and the remaining estimated 1600 samples will be re-analysed within the next phases of this project. Also reported, are entirely new geochemical data for 151 samples, including 93 samples collected from diamond drillcores and outcrops for current GSWA projects, 37 samples from the GSWA sample archive, and 21 samples from the Curtin University sample archive. A list of cores that were sampled is provided in the Appendix (under the spreadsheet labelled 'DDH details'). This list includes details relating to the location, length and average or initial orientation of the drillholes. Where orientation details are unavailable, the drillhole is assumed to be vertical. The sampling interval (length/depth in the relevant core) is noted for all drillcore samples.

Each sample is accompanied by a geological description ('Sample description and details'). These are largely uncorrected or unedited notes made at the time of sampling.

Most samples in GA's Yilgarn granite dataset have ferric and ferrous proportions of iron reported. Ferrous iron ($Fe^{2+}$; reported as FeO) was determined by titration and then used to calculate $Fe^{3+}$ by the difference from total Fe as measured by X-ray fluorescence spectrometry (XRF). For all new samples, ferrous and ferric iron proportions were not determined and all iron (total) is reported in the ferric state, denoted as $Fe_2O_3T$. All major element concentrations and totals are calculated and reported both considering and ignoring analytical loss on ignition (LOI), the prefix 'a' (e.g. $aSiO_2$) denoting a concentration recalculated volatile free.

* Geoscience Australia, 1010 Jerrabomberra Ave, Symonston ACT 2609, Australia

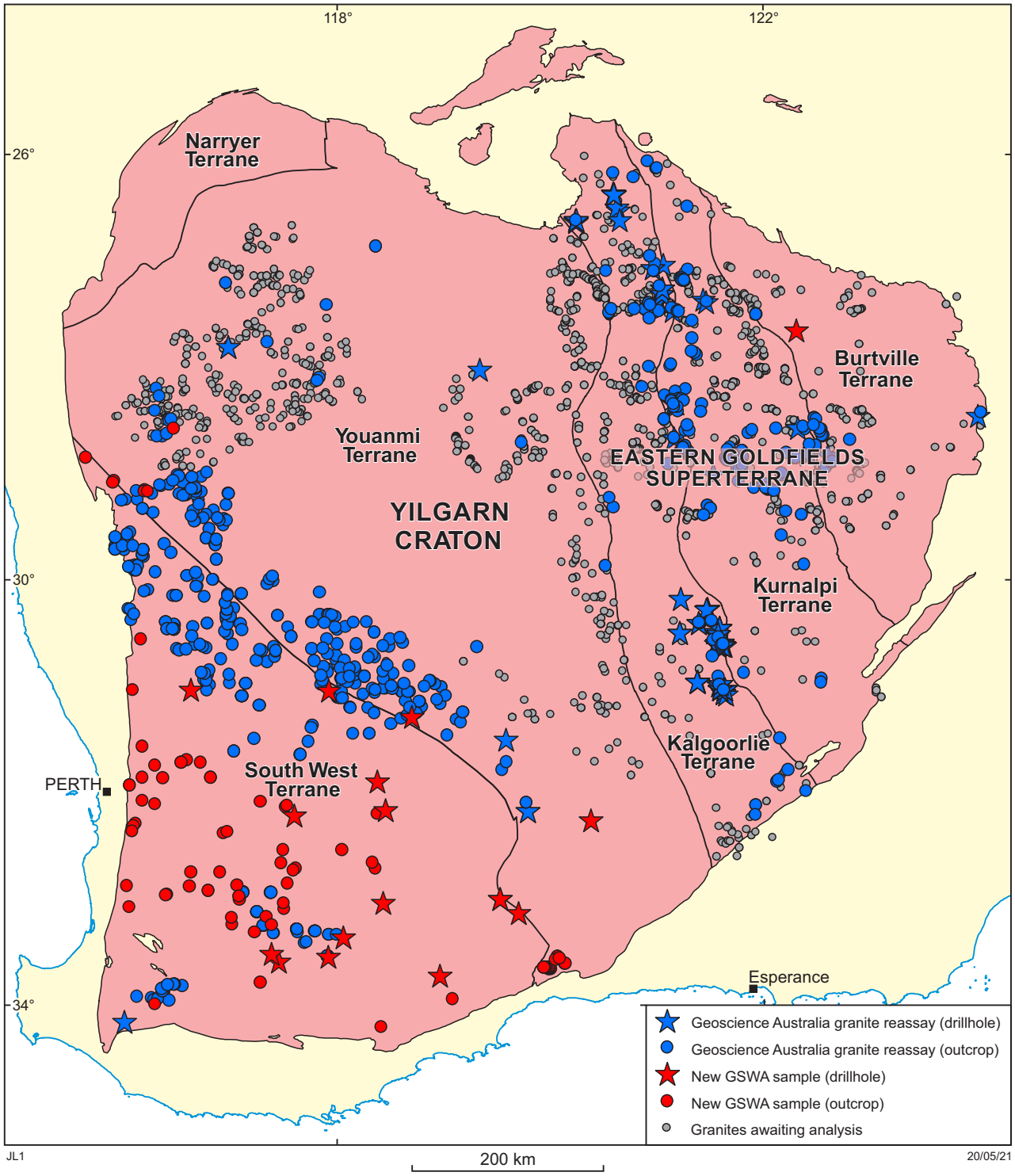


Figure 1. Yilgarn Granite Project area overview and sample localities: a) location map of the study area; b) aeromagnetic image of the Yilgarn Craton showing the locations of samples used for this study. Note that many sites represent the location given for several samples

No other derived values (e.g. ratios) are provided except for Mg# (molecular Mg/[Mg/Fe]; with Fe calculated as $Fe^{2+}$) and the Aluminum Saturation Index (ASI; molecular Al/[Ca+Na+K]).

## Chemical classification of the data

Most samples in GA's Yilgarn granite dataset were previously classified into High-Ca granites, Low-Ca granites, High-high field strength element (HFSE) granites and mafic granites using compositional criteria established by Champion and Sheraton (1997) and Champion and Cassidy (2002). The classification of these samples has not been changed and is presented in the Appendix in the column labelled 'Granite Class'. Many samples remained unclassified, for various reasons including ambiguous or 'transitional' compositional features, and will be reinvestigated at a later stage of this project.

The same classification procedures and scheme used by Champion and Sheraton (1997) and Champion and Cassidy (2002) were also applied to most new samples. In doing this, a specific group of analyses was identified, with usually high concentrations of $TiO_2$, $P_2O_5$, Total Fe, rare earth elements (REE) and HFSE, broadly transitional between Low-Ca and High-HFSE granites, and is referred to here as 'Low-Ca P-rich granite'. Many samples initially classified as mafic granite fit the chemical definition for sanukitoid, and are classified as such. Sanukitoid is defined as a hornblende-bearing rock (or rock series) which, at ~60 wt% $SiO_2$ has a Mg# >60, Cr and Ni concentrations each >100 ppm and Sr and Ba concentrations >400–500 ppm. Hornblende-bearing intrusions that satisfy many, but not most (or all) of these criteria are referred to here as 'probable sanukitoid'. A secondary classification scheme based on $K_2O/Na_2O$ ratio (<0.6 = strongly sodic; 0.6–1.0 = sodic; >1.0 = potassic) and Sr/Y ratio (≤30 = low Sr/Y; >30 = high Sr/Y) is also applied to the High- and Low-Ca granites (after Smithies et al., 2018). Strongly sodic granites are derived from sources with a broadly 'basaltic' composition, whereas potassic granites are derived from crustal source compositions more evolved than basalt (i.e. they have a recycled, or 'crustal' source component) and/or reflect lower degrees of partial melting and/or higher degrees of fractionation. The Sr/Y ratio can be used as a broad proxy for the depth of melting based on the effect that any plagioclase (Sr-rich) and garnet and hornblende (Y-rich) remaining in the source after melting has on this ratio (e.g. deep, garnet-rich source yield melts with high Sr/Y). Water saturated melting, source enrichment and fractionation/cumulate processes can all complicate any pressure-related interpretations based on Sr/Y ratios.

## Analytical methodology

Trace element concentrations for all 1066 analyses reported here were measured at a single commercial laboratory (Australian Laboratory Services [ALS] Global Pty Ltd) employing a single set of analytical procedures, outlined below. This approach minimizes the potential for any variation in the dataset potentially attributable to variations in analytical procedure. Major element and LOI assays for new samples were also measured at ALS, whereas for the re-analysis of GA's granite collection, it was decided that since the existing major element concentrations were determined using comparable methods and of similar quality to those being offered by commercial laboratories, this component of the analysis suite would not be repeated.

New samples collected for the purpose of this study were taken by GSWA geologists from drillcore and outcrops. Samples were visibly inspected and any weathering or excessive vein material was removed. Each sample was crushed by GSWA using a plate jaw crusher and splitter and milled by ALS using a low-Cr steel mill to produce a pulp with a nominal particle size of 90% <75 µm. A quartz-feldspar aggregate material containing below detection level concentrations of transition and precious metals was milled between each sample to scrub any remaining pulp residue from the previous sample. Representative pulp aliquots were analysed for 14 elements (of which we report 11) as major and minor components, mass LOI and 60 elements as trace elements. Major and minor elements were determined by mixing a 0.66 g aliquot of sample with lithium borate flux ($LiBO_2$, $LiB_4O_7$ and $LiNO_3$) in a 1:10 ratio, and then fusing the mixture at 1025 °C and pouring it into a platinum mold. The resulting disk was analysed by XRF (ALS method ME-XRF26). LOI was determined by thermogravimetric analysis (ALS method ME-GRA05). For resistive trace elements (Cr, V, Cs, Rb, Ba, Sr, Th, U, Nb, Zr, Hf, Y, La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb and Lu), an aliquot of the sample was mixed with lithium borate flux and fused, then digested in acid and analysed by inductively coupled plasma mass spectroscopy (ICP-MS; ALS method ME-MS81). For the remaining trace elements (Ag, As, Be, Bi, Cd, Co, Cu, Ge, In, Li, Mo, Ni, Pb, Re, Sb, Sc, Se, Te, Tl, Zn), i.e. predominantly transition metals, a 0.25g aliquot of sample was digested with a mixture of concentrated acids ($HClO_4$, $HNO_3$, HF), heated at 185 °C until incipient dryness, then leached with 50% HCl and diluted to volume with weak HCl, then analysed by ICP-MS and inductively coupled plasma atomic emission spectroscopy (ICP-AES; ALS method ME-MS61L).

Gold concentrations were measured for 809 samples by digesting a 25 g aliquot of pulverized sample in aqua regia ($HClO_4$ and $HNO_3$ mixed in a 3:1 ratio) then analysis by ICP-MS (ALS method Au-ST43). This technique has a lower detection limit of 0.1 ppb, an order of magnitude lower than commercially available fire assay techniques (1 ppb) which were found to be of limited usefulness in characterizing low-level Au concentrations in granites of the south west Yilgarn Craton, where 82% of samples contained <1 ppb Au and 94% of samples contained <10 ppb (based on 192 samples; Smithies et al., 2018).

Data quality was monitored by 'blind' insertion of sample duplicates (i.e. a second aliquot of pulp or finely crushed material) at a rate of 1 per 10 unknown samples, as well as GSWA internal reference materials and certified reference materials (OREAS 24b; <www.ore.com.au>), also inserted at a rate of 1 per 10 unknown samples. ALS also conducted repeat analyses of samples, variably certified reference materials and blanks. An assessment of accuracy and precision was made using data for 28 analyses of OREAS 24b, determined during the analysis of samples for the geochemical barcoding project itself. For analytes where the concentration is at least 10 times the lower level of detection (all analytes except Ag, Cd, Cl, In, Re, Sb, Te, Tl, W), a measure of accuracy is provided by the agreement between the average determined value and the certified

value according to half absolute relative difference (HARD); that is, (analysis1 – analysis2)/(analysis1 + analysis2) (Stanley and Lawie, 2007). The average of measured major and minor element concentrations for agree to within 2 HARD% of their certified values. The average of measured trace element concentrations agree to within 5 HARD% of their certified values, except for Be, Bi, Sn and W (7, 9, 7 and 10 HARD% respectively). In terms of precision, the relative standard deviation (RSD), or covariance, for analysis of OREAS 24b is ≤4% RSD for major and minor elements and ≤10% RSD for most trace elements. The exceptions are Bi, Sb and Sn (50%, 11% and 17% RSD respectively). Similar levels of agreement were found for GSWA reference materials (granodiorite GRD-1 and basalt BB1) and between duplicate pair samples. All blank values were less than three times the lower level of detection.

The precision for Au is based on seven analyses of OREAS 24b, with an average of 2.1 ppb and standard deviation of 0.2 ppb (10% RSD).

# References

Champion, DC and Cassidy, K, 2002, Granites of the northern Eastern Goldfields: their distribution, age, geochemistry, petrogenesis, relationship with mineralisation, and implications for tectonic environment, *in* Cassidy, K, Champion, D, McNaughton, N, Fletcher, I, Whitaker, A, Bastrakova, I and Budd, A 2002, Characterization and metallogenic significance of Archaean granitoids of the Yilgarn Craton, Western Australia: Minerals and Energy Resources Institute of Western Australia, Report 222.

Champion, DC and Sheraton, JW 1997, Geochemistry and Nd isotope systematics of Archaean granites of the Eastern Goldfields, Yilgarn Craton, Australia: implications for crustal growth processes: Precambrian Research, v. 83, p. 109–132.

Smithies, RH, Lu, Y, Gessner, K, Wingate, MTD and Champion, DC 2018, Geochemistry of Archean granitic rocks in the South West Terrane of the Yilgarn Craton: Geological Survey of Western Australia, Record 2018/10, 13p.

Stanley, CR and Lawie D 2007, Average relative error in geochemical determination: clarification, calculation, and a plea for constituency: Exploration and Mining Geology, v. 16, p. 267–275.

RECORD 2021/6

YILGARN GRANITE PROJECT – NOTES TO ACCOMPANY 2021 DATA RELEASE

Lowrey et al.

This Record is published in digital format (PDF) and is available as a free download from the DMIRS website at <www.dmirs.wa.gov.au/GSWApublications>.

Further details of geoscience products are available from:

Information Centre
Department of Mines, Industry Regulation and Safety
100 Plain Street
EAST PERTH  WESTERN AUSTRALIA  6004
Phone: +61 8 9222 3459  Email: publications@dmirs.wa.gov.au
www.dmirs.wa.gov.au/GSWApublications