

DIAMOND PROSPECTIVITY OF WESTERN AUSTRALIA

Mark T. Hutchison^{1,2}

¹ Geological Survey of Western Australia, Perth, WA, Australia
mark.hutchison@dmirs.wa.gov.au
² Trigon GeoServices Ltd., Las Vegas, NV, United States
mth@trigon-gs.com

THE BACKGROUND

Most of Western Australia (WA) is prospective for diamonds;

- Exposed Archean rocks - 696 000 km²
- Paleoproterozoic rocks - 439 000 km²
- Pre-1.6 Ga rocks comprise ca. 45% of the State
- Considerable remaining portions are also underlain by thick mantle lithosphere (Kennett et al., 2013)

Numerous diamondiferous lamproite and kimberlite fields known:

- Oldest proven diamondiferous body is ca 1868 Ma (Brockman Creek kimberlite in the Pilbara; White, 2000)
- Youngest diamondiferous body is ca. 17 Ma (Walgidee Hills lamproite, Noonkanbah field, West Kimberley; Phillips et al, 2012)

Produces diamonds:

- Produced ca. 11% of global rough diamond production by weight in 2015 - fourth in the world
- Ellendale mine closed in 2015, responsible for a large proportion of the world's fancy yellow production,
- Argyle mine continues production, responsible for a large proportion of the world's fancy red and pink production

THE STUDY

- Summarise methods and results of WA diamond exploration
- Assess the effectiveness of prior diamond exploration
- Identify under-explored prospective areas
- Quantitatively model diamond prospectivity at a regional scale (Hutchison, 2017)

THE METHODS

Data collection (compiled in GSWA, 2017):

- 4200 Statutory Company Reports assessed
- A further three independent databases integrated
- 88,529 diamond exploration samples compiled and assessed
- 30,224 good quality mineral compositional analyses compiled (80% determined to be genuine indicator minerals)
- Locations compiled of 523 discrete in-situ bodies with diamond potential (Map Plate; kimberlites, lamproites, ultramafic lamprophyres and carbonatites; 114 confirmed diamondiferous)
- 127 age determinations from 63 bodies establish geochronology

Regional subdivision:

- State divided into 6 tectonic domains constituting cratons and non-craton areas for assessing mineral chemical trends
- Further subdivided into 67 onshore units based on similar age, tectonic setting and lithology for prospectivity modelling (Map Plate)

Prospectivity modelling modified from Hutchison (2013):

- Units ranked based on lithological age ranges (Figure 1). Highest score applies where all rocks predate the oldest kimberlite (2128 Ma, at Turkey Well; Jourdan et al., 2012)
- Units ranked based on sampling success. Reconnaissance sampled areas (average under 1 sample per 100 km²) with good sample recovery (over 1/3 of samples yield visually-identified indicators) score highest (Figure 2).
- Units ranked according to mantle lithosphere thickness. Areas at the edges of thick mantle lithosphere score highest (Figure 3)
- Rankings are combined yielding 13-levels of attractiveness for future diamond exploration (Map Plate)

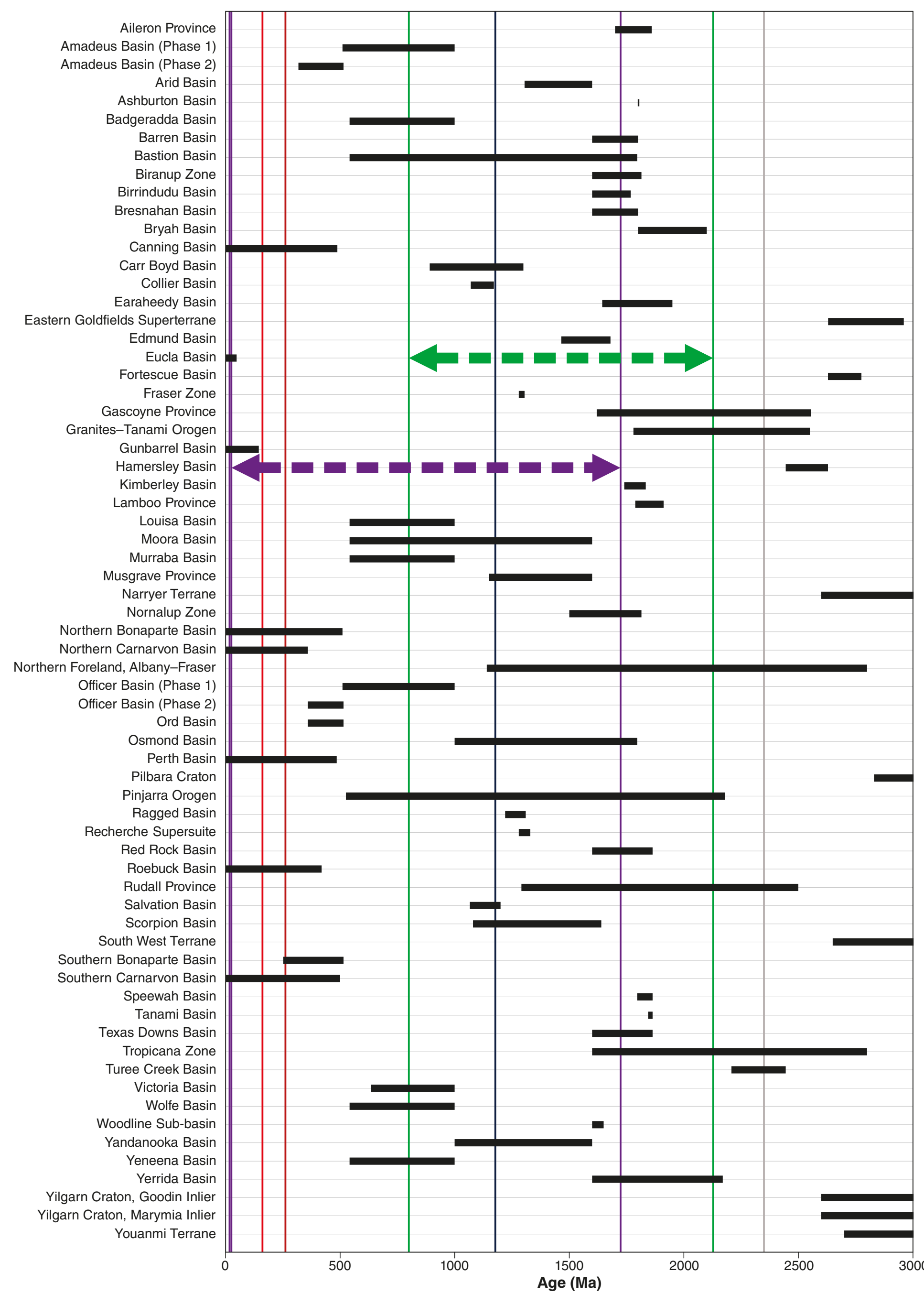


Figure 1. Ranges of ages of rocks present in geological regions of WA in the context of diamond-prospective rocks
Vertical lines: kimberlite age ranges - green; lamproites - purple; Ponton Creek carbonatite - grey; Argyle AK1 lamproite - black; Ed1 ultramafic lamprophyre - brown; Wandagee M142 - red.

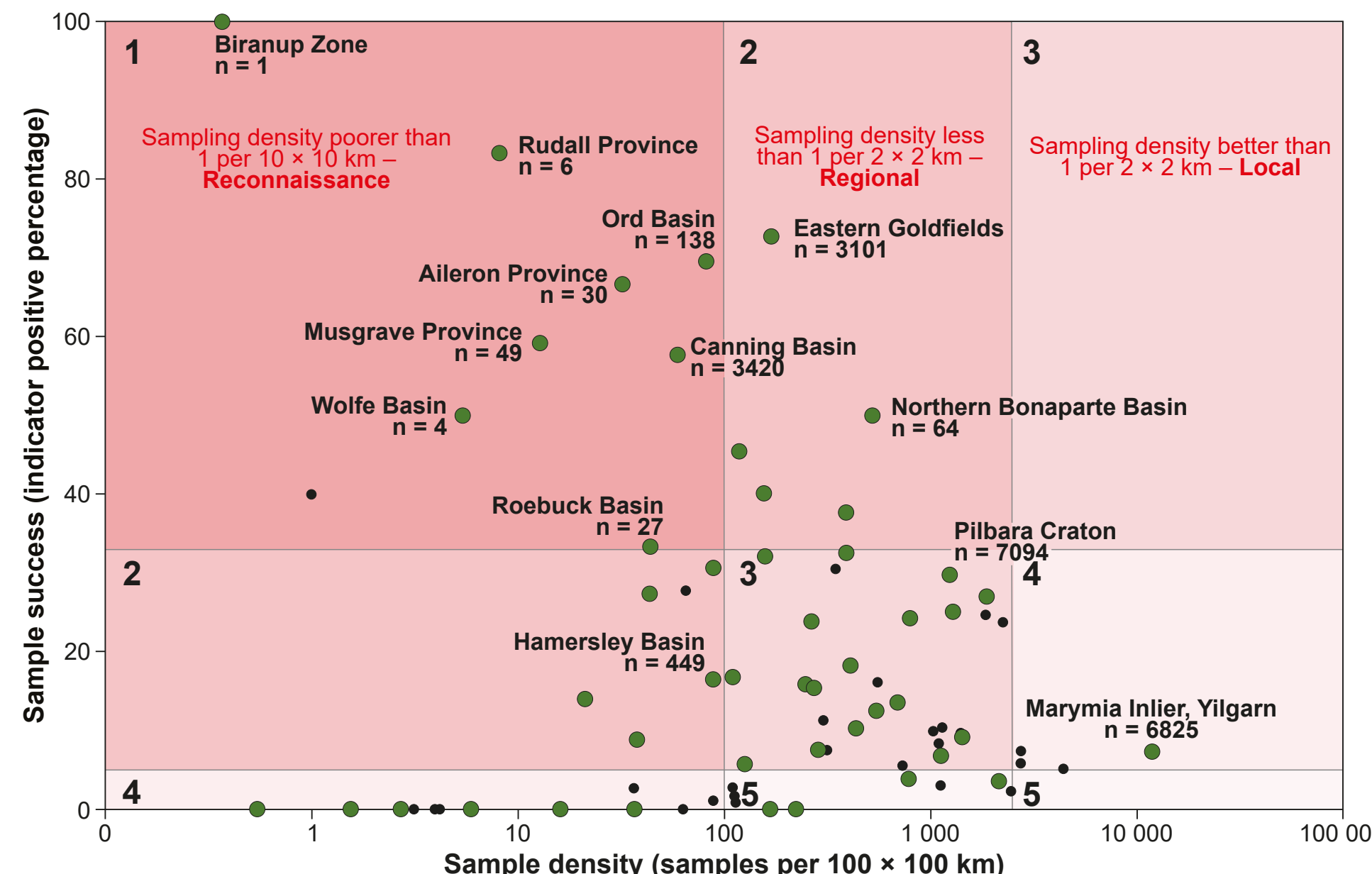


Figure 2. Sampling success versus sampling density for diamond exploration samples from WA geological regions

Blue numbers represent prospectivity scores assigned to regions plotting within shaded areas of the chart. Northern Territory (NT) data (black dots) are provided for comparison (Hutchison, 2012) showing that NT diamond exploration has covered a similar sampling density range but with fewer high success regions.

Figure 3. Map of lithosphere thickness

Estimated depth to the lithosphere / asthenosphere boundary, adapted from Kennett et al. (2013). Blue colouration describes the mantle lithosphere thickness incrementally from 70 km (light blue) to 240 km (dark blue) in 10 km increments. Boundaries of WA cratonic regions at surface, following Martin et al. (2016), are indicated as described in the key. White-bordered polygons describe areas of differing diamond prospectivity based on lithosphere characteristics with 1 being most favourable and 6 being the least.

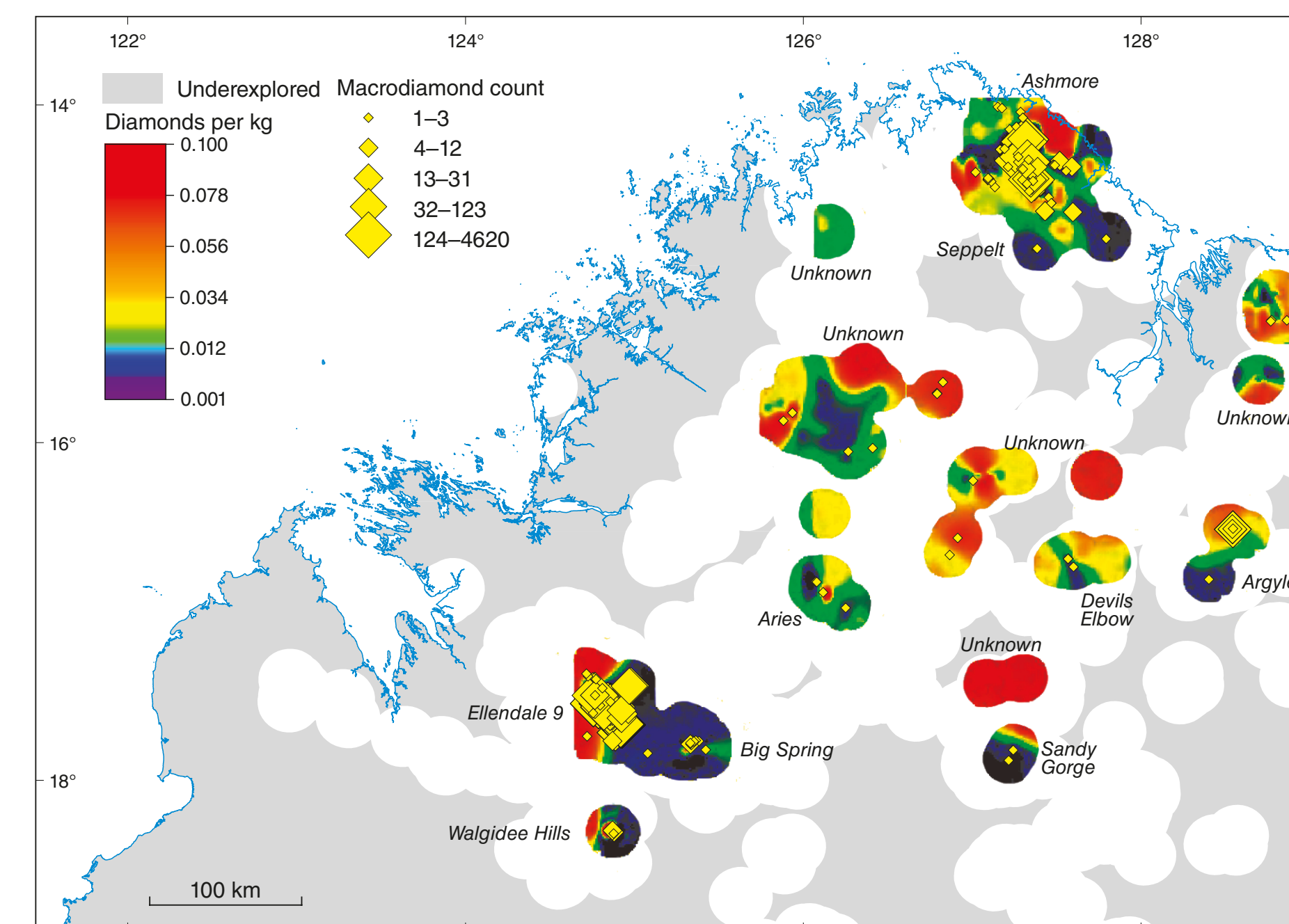
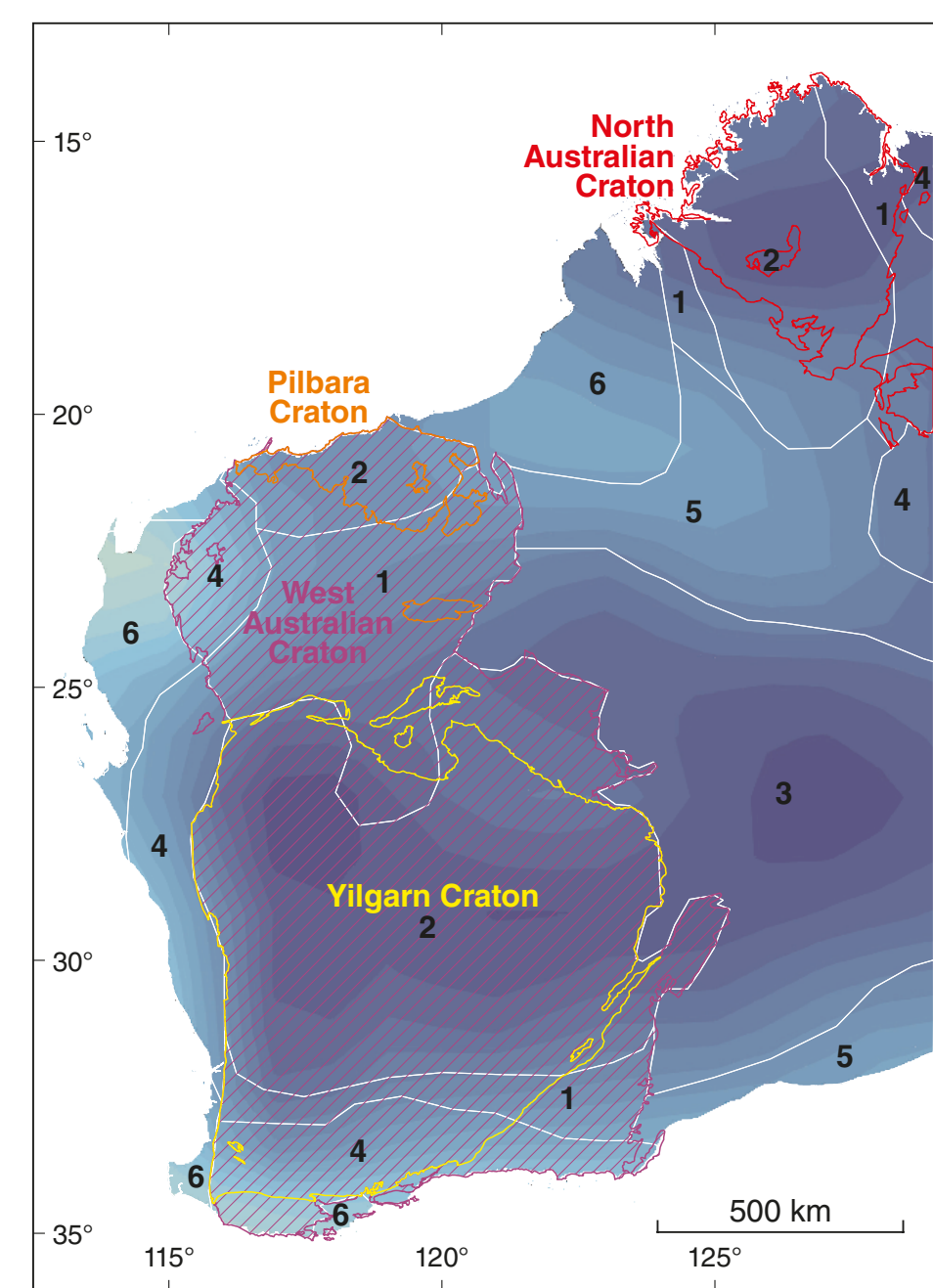


Figure 4. Distribution of diamond concentration in the North Australian Craton of WA.
Diamond concentration (diamond counts per kg) contoured with macrodiamonds indicated. All areas in excess of 20 km from a diamond exploration sample are shown in shading, providing an indication of where the diamond concentration map is limited by no data. Diamond concentrations with no known sources are indicated.

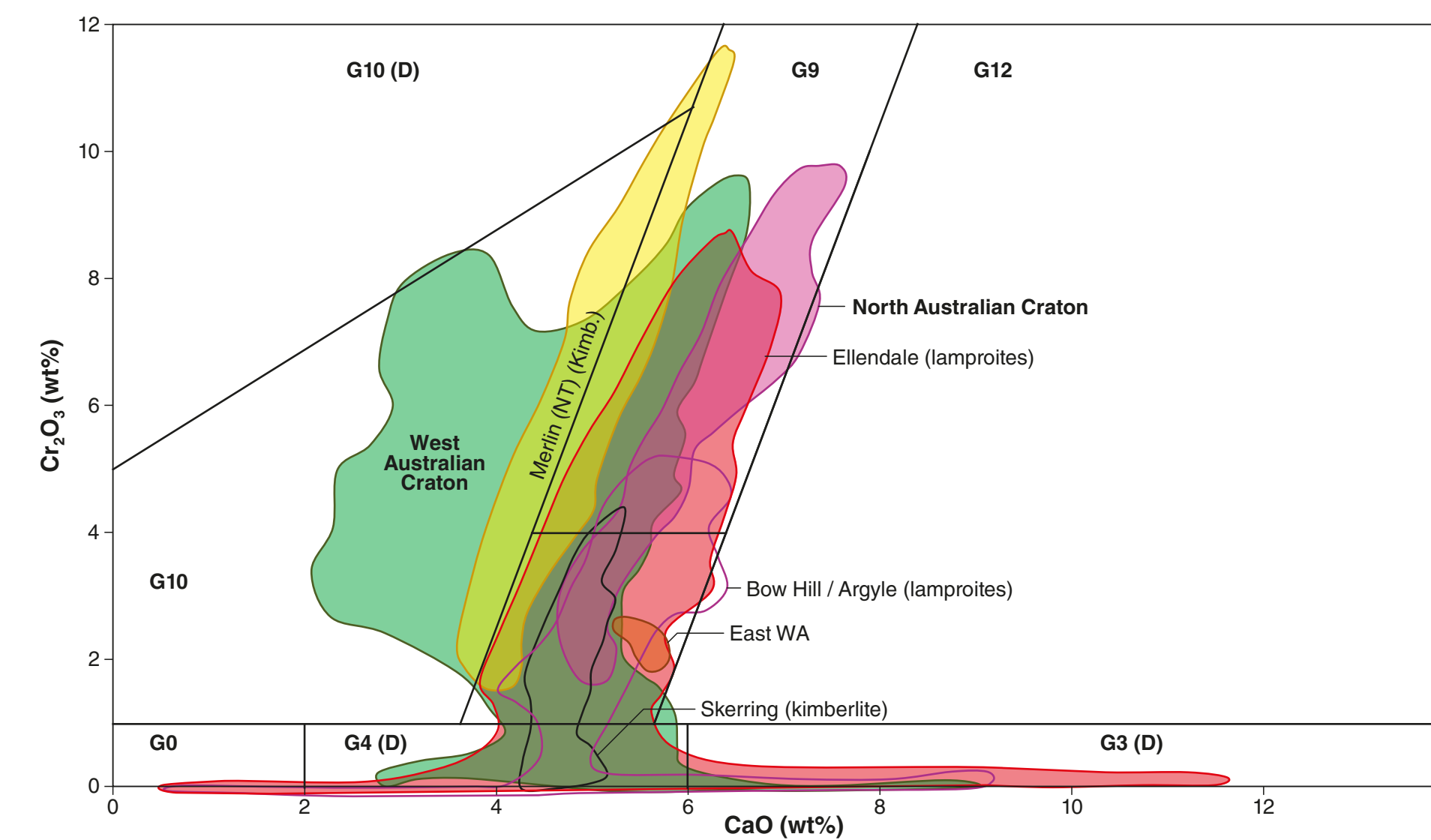


Figure 5. Chemical composition of pyrope-almandine-grossular garnets in terms of CaO and Cr₂O₃. Representative compositional fields encompassing ca. 90% of analyses from each region. Classification follows Grütter et al., 2004. Merlin analyses from Reddick (1999); Bow Hill, Skerrington and Argyle analyses from Ramsay (1992).

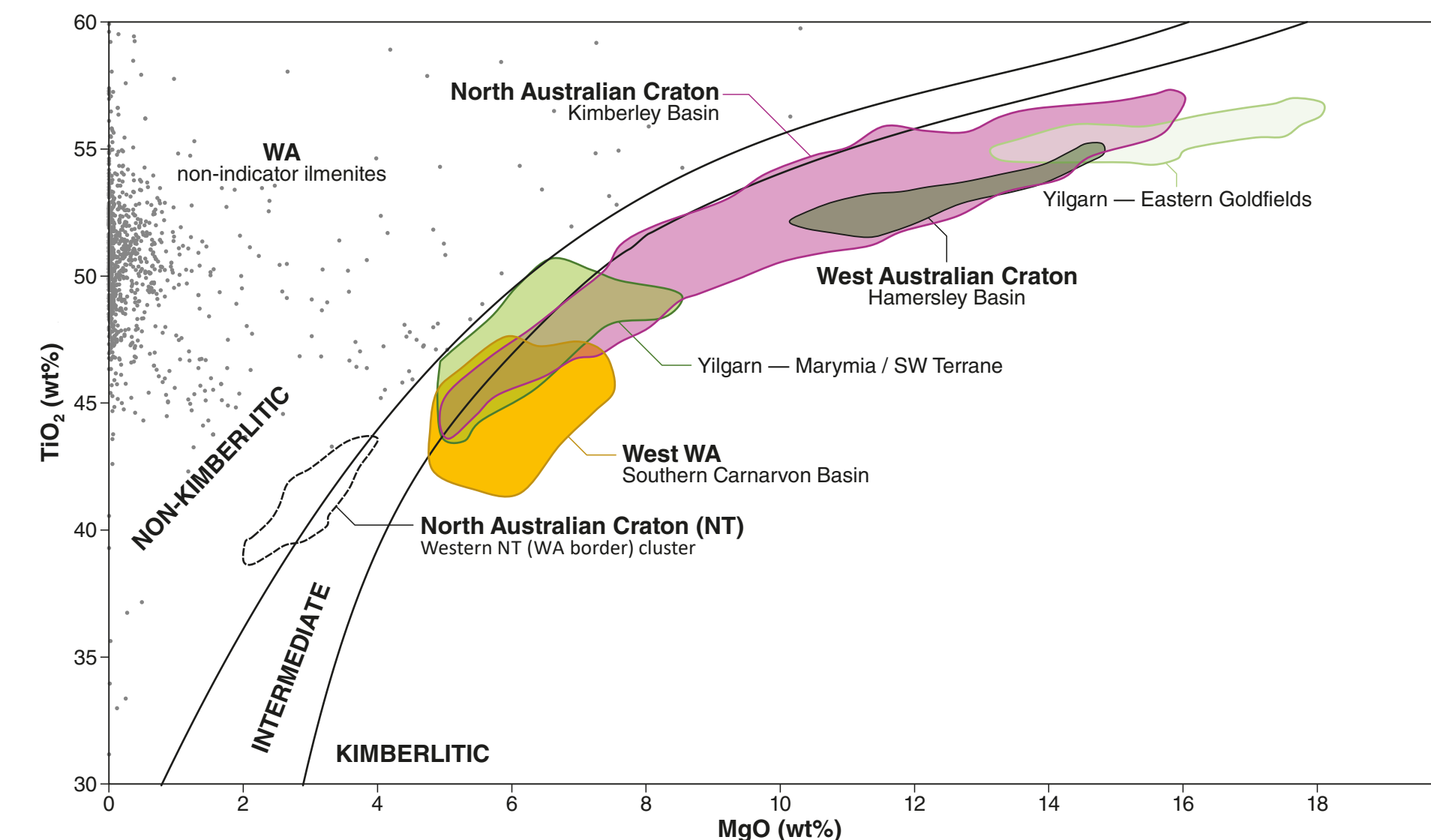


Figure 6. Chemical composition of ilmenites in terms of TiO₂ and MgO
Hand-drawn fields encompass 90% of data excluding outliers. Classification follows Wyatt et al (2004). NT compositions from Hutchison (2013).

Map Plate: Diamond prospectivity of Western Australia.

Geological sub-divisions are ranked for prospectivity in the context of mantle structure, the age of surface rocks, the extent of sample coverage and recovery of visually-determined indicators. Ranking follows the key, with 1 being the most prospective area. In-situ bodies are shown by stars. Shaded areas describe locations in excess of 20 km from sampling sites, indicating un-explored areas. Larger circles indicate sites of recovery of visually-determined indicator minerals with colours in the key. Diamond and chromite distinguish themselves as the most robust and hence commonly-recovered indicator minerals. Much of WA is under-explored with prospective areas in the NAC and particularly the WAC.

RESULTS - PROSPECTIVITY ANALYSIS

Empirical observations:

- Indicator mineral occurrences and in-situ bodies with diamond potential are largely within the North and West Australian Cratons
- Clusters correlate with areas of significant changes in mantle thickness reflecting structures favourable for diamond emplacement.
- Mineral chemical criteria distinguish the Pilbara Craton and further south within the WAC as most prospective. The Yilgarn Craton is variably prospective, locally highly so.
- Localities with unresolved anomalous diamond prospectivity are identified, including offshore at the Fohn field, headless diamond anomalies in the central and east NAC, prospective indicator minerals north of Ellendale, and the Hamersley Basin

Prospectivity ranking:

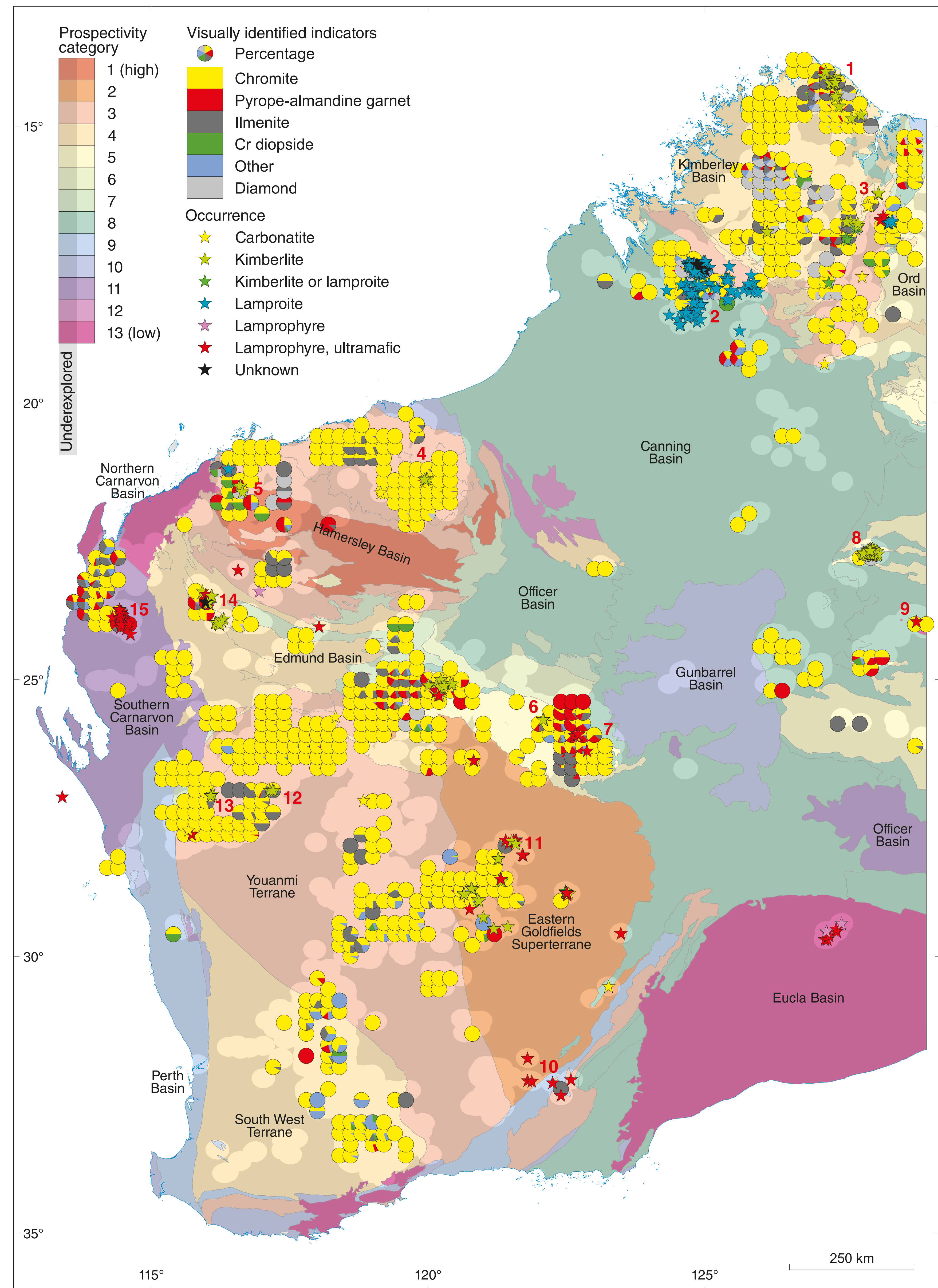
- The NAC, location of WAs diamond mines, scores well.
- Partly because of under-sampling combined with good indicator recovery, results point to parts of the WAC being more prospective.
- Most notable are the Hamersley Basin (ranked 1), Eastern Goldfields Superterrane and the Goodin Inlier of the Yilgarn Craton (ranked 2).
- Challenges to exploration take the form of accessibility, lateritisation, particularly ferricretisation and magnetic country rocks

CONCLUSIONS

- Despite prolific diamond exploration, Western Australia is considerably under-explored - 68% of the State's onshore areas lie over 20 km from a known diamond exploration sample site.
- As kimberlite and lamproite emplacements span 2 500 Ma, there are significant opportunities for diamond-affinity rocks being present near surface even within the large, under-explored sedimentary basins overlying thick mantle lithosphere.
- Results of exploration reveal diamonds and indicator minerals with unknown sources, highly prospective localities and regions
- The case for renewed diamond exploration is directed by highly ranked regions.

REFERENCES

GSWA (2017) Diamond exploration and prospectivity of Western Australia, 2017. Geological Survey of Western Australia Diamond Exploration Package ISBN 978-1-74168-707-1
Grütter HS, Gurney JJ, Menzies AH, Winter F (2004) An updated classification scheme for mantle-derived garnet, for use by diamond explorers. Lithos 77: 841-857
Hutchison MT (2013) Diamond Exploration and Regional Prospectivity of the Northern Territory of Australia. In: Pearson DG et al. (eds) Proceedings of the 10th International Kimberlite Conference, Volume 2, Special Issue of the Journal of the Geological Society of India, pp 257-280
Hutchison MT (2017) Diamond exploration and prospectivity of Western Australia. Geological Survey of Western Australia Report, 179, 95 p
Jourdan F, Thern E, Wilde SA and Frewer L 2012. 40Ar/39Ar dating of unusual minerals (tourmaline, K-richite, yimengite, wadeite and peridite) and applicability to the geological record. Geophysical Research Abstracts, v.14, EGU2012-6858.
Kennett BLN, Fichtner A, Fishwick S, Yoshizawa K (2013) Australian Seismological Reference Model (AuSREM): mantle component. Geophysical Journal International 192: 871-887
Phillips D, Clarke W, Jacques AL (2012) New 40Ar/39Ar ages for the West Kimberley lamproites and implications for Australian plate geodynamics. 10 IKC Ext. Abs. Bangalore, India: 10IKC-104
Ramsay, RH 1992, Geochemistry of diamond indicator minerals. PhD thesis, Department of Geology and Geophysics, University of Western Australia, Perth, 221p and 3 appendices.
Reddick TH 1999, Merlin Kimberlite Field Batten Province, Northern Territory: Department of Geology and Geophysics, University of Western Australia, Perth, MSc thesis (unpublished) 221p and 3 appendices.
White B (2000) The geochronology and thermochronology of the Brockman Creek 01. Melita and Melita 02 kimberlite.



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

www.dmirs.wa.gov.au



Geological Survey of
Western Australia

