Critical minerals at Geoscience Australia: National-scale high purity silica mineral systems study

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Introduction

Critical minerals are the minerals and elements essential for modern technologies, economies, and national security. However, the supply chains of these minerals may be vulnerable to disruption such that the study of these minerals, from source to product, is of primary importance.

The global transition to net-zero emissions is driving accelerated consumption of critical minerals, particularly due to the increase in demand for technologies such as solar photovoltaics (PV) and semiconductors (Department of Industry, Science and Resources [DISR] 2023). In parallel, the phasing out of, for example, traditional machinery and manufacturing processes reliant on hydrocarbon resources (Skirrow *et al* 2013, Ali *et al* 2017, Bruce *et al* 2021, International Energy Agency [IEA] 2021, 2023) is further adding to the global demand. High purity quartz (HPQ) forms just one of these critical minerals and is the primary raw material for the production of high purity silica (HPS) and silicon (Si) for use in products ranging from solar PVs to semiconductors.

There are 31 minerals currently classified as critical (DISR 2023). This diversity of critical minerals is promoting a new focus on i) the exploration for new styles of mineralisation that might host sufficient volumes of critical minerals, and ii) the re-examination of existing minerals systems knowledge in order to assist mineral explorers discover new resources to support the increasing demand.

The main global suppliers of HPQ are the United States, Canada, Norway, Brazil, Russia, and India (Pan *et al* 2022). In Australia, there has been a paucity of exploration and development of HPQ mineral deposits despite the fact that Australia has potentially significant HPQ occurrences; Simcoa Operations Pty Ltd (**Figure 1**) is the only operator currently mining HPQ and manufacturing silicon in Australia (Simcoa 2020).

Australia is well positioned to incentivise the exploration, discovery and supply of raw materials and thus significantly expand onshore silicon production capacity (PricewaterhouseCoopers 2022). Research presented herein highlights the opportunity Australia has to make a positive contribution in meeting the global demand for the HPQ required for high-technology applications and the transition to a net zero economy.

Australian Critical Minerals Research and Development Hub

The *Australian Critical Minerals Research and Development Hub* ('the Hub') is a $50.5 million Federal Government-funded initiative spanning four years until June 2026, with Tranche 1 and 2 project funding already allocated. Geoscience Australia (GA), along with the Australian Nuclear Science and Technology Organisation (ANSTO)

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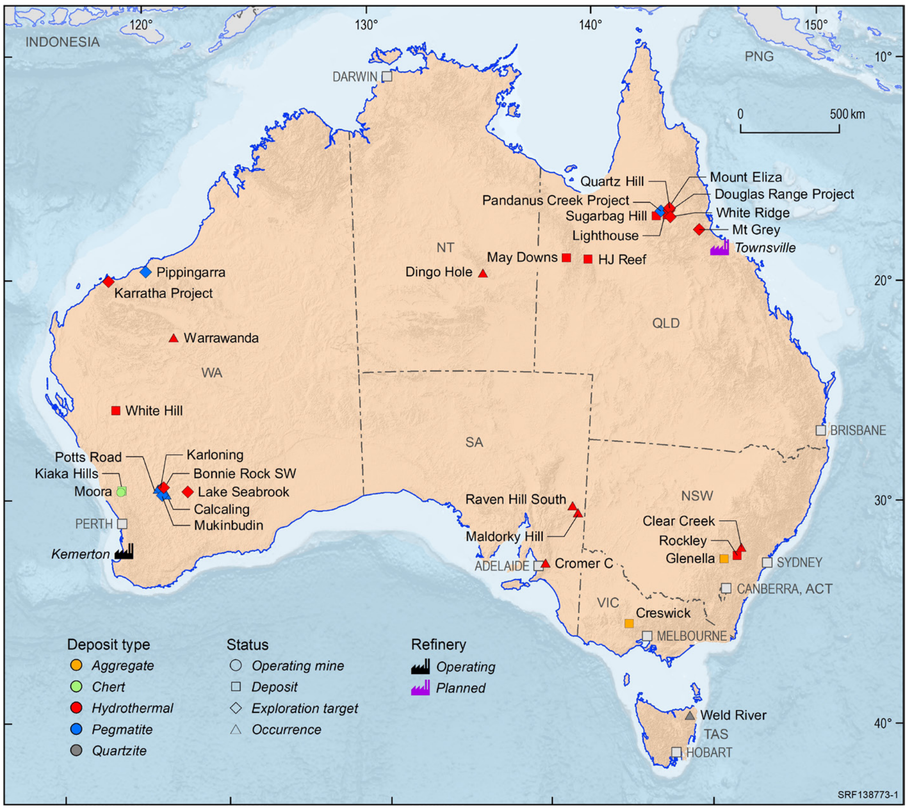

Figure 1. Map of Australia highlighting known high purity quartz (HPQ) operations, deposits and occurrences.

and the Commonwealth Scientific and Industrial Research Organisation (CSIRO), are working collaboratively to scale-up and commercialise Australia's critical minerals potential by aligning research and development to priority technical challenges and Australia's strategic priorities. The Hub also works closely with the Critical Minerals Office at the DISR, while also collaborating with industry, universities and the research community. The overarching aim of the Hub, in line with Australia's Critical Minerals Strategy 2023–2030, is to address technical challenges and drive collaborative research across the critical minerals value chain needed to support clean energy and Australia's net zero policy agenda.

The Hub's research program supports collaborative projects conducted by the three science agencies (GA, ANSTO, CSIRO), which are designed to deliver the technical breakthroughs needed to leverage Australia's opportunities in the critical minerals sector. There are seven Hub-funded research projects, including three announced in January 2024 as part of Tranche 2.

High Purity Quartz (HPQ) mineral systems study

As part of the Hub's research programs, GA is undertaking the development of a detailed examination of Australia's HPS mineral potential, with a focus on the raw material, HPQ. The study will develop the first-ever national-scale, geologically consistent mineral system model for HPQ. The goal of study is to identify and prioritise regions of Australia that have the greatest potential to supply raw feed stock material suitable to support the production of silicon. The program aims to stimulate exploration and support the development of a downstream silicon industry in Australia.

Background

The most common raw material used in the production of silicon metal is quartz, the second most abundant mineral in the Earth's crust. However, despite the mineral's abundance, the deposits of HPQ are rare and additional efforts are required to make economic discoveries of the mineral.

High purity quartz mineralisation includes mineral deposits composed of the mineral quartz, such as hydrothermal quartz veins and pegmatites. High purity silica refers to all potential sources of silica as a raw material and can include silicate-rich rocks such as silcretes. Both HPQ and HPS can be a source material for silicon production, but the majority of the global raw material is from HPQ.

The growing interest in quartz exploration is principally due to the recognition that silicon demand is increasing, and that the raw material supply chain must be secured. Accordingly, silicon is classified as a critical mineral in Australia (DISR 2023), as well as in the European Union (Grohol and Veeh 2023), United Kingdom (Department for Business, Energy and Industrial Strategy 2022), Japan (Nakano 2021), India (Ministry of Mines 2023), and South Korea (Australian Trade and Investment Commission 2023). High purity quartz has been identified in a variety of silica-rich hard rock sources globally, including pegmatites (Ibrahim *et al* 2015, Larsen *et al* 2000, Müller *et al,* Swanson and Veal 2010), hydrothermal quartz (Afahnwie *et al* 2022, Wang *et al* 2022, Xia *et al* 2023), sedimentary sources (Phillips and Hughes 1996, Abeysinghe 2003, Davies *et al* 2015), and quartzite (Müller *et al* 2007, Fedorov *et al* 2019, Wanvik 2019, Hancock 2022).

Processing and refining requirements for silicon production dictate the minimum standards required of the raw HPQ feedstock. These are: (i) very low level of impurities, (ii) application-dependent particle size, and (iii) melting behaviour that is acceptable for downstream manufacturers (PricewaterhouseCoopers 2022). The refining of HPQ to produce silicon requires gravel to cobble sized feedstock (30 mm–100 mm). Silica sand is currently unsuitable for the production of silicon as the particle size is too small for the silicon smelting process (PricewaterhouseCoopers 2022); however, it can be used for other HPQ applications, for example glass-making and foundry industries, if it meets the requisite purity.

Figure 1 highlights known HPQ operations, deposits and occurrences in Australia. Accurately and precisely defining the state of HPQ exploration and mining in Australia has been difficult due to the lack of publicly accessible reporting by companies. Quartz is currently categorised as an industrial commodity, therefore details such as production volumes, grade, resource and reserve estimates and life-of-mine are not required to be publicly reported, making it difficult to assess at a national-scale. In addition, most companies involved in the HPQ industry are privately owned and operated, and therefore not required to release public statements about exploration, potential resources, reserves or grade on the Australian Securities Exchange (ASX). However, with the growing interest in renewable energy and the associated demand for critical minerals in Australia and globally, HPQ exploration and discoveries are increasingly being reported in public forums (such as the ASX or company websites).

Nevertheless, despite the lack of reporting, there is an appetite for explorers to re-examine existing deposits or exploration areas as an opportunity to develop a new or additional product in parallel with traditional exploration for minerals such as copper and gold.

Australia is a country endowed with natural resources and is well positioned to incentivise the discovery and supply of raw HPQ needed to develop onshore silicon production capacity (PricewaterhouseCoopers 2022). This could significantly contribute to meeting the global demand for HPQ and HPS required for high-technology applications.

Conclusion

The demand for HPQ is forecast to increase, primarily driven by the solar PV and semiconductor industries. The Australian Silicon Action Plan (PricewaterhouseCoopers 2022) highlights that in order to meet solar energy requirements, the global demand for raw quartz feedstock will increase by nearly a factor of 40 by 2050. However, as is the case with other critical minerals, the supply chain is volatile due to the geopolitics of global trade, economic factors and availability of alternative materials (Ali *et al* 2017, Bruce *et al* 2021). As of 2022, China manufactured over 80% of the key elements for solar panel production, including polysilicon, ingots, wafers, cells, and modules (IEA 2022). The predominance of a centralised manufacturing industry highlights the need for diversification throughout the entire silicon supply chain, from mining through to manufacturing.

Although still in its initial stage, GA's national-scale HPS mineral systems study, to be delivered in June 2026 as part of the *Australian Critical Minerals Research and Development Hub*, aims to identify mineral systems and regions that have the greatest potential to supply raw feed stock to support the production of silicon, thus stimulating exploration and the development of a downstream silicon industry in Australia.

Australia is host to a range of geological settings and silica source rocks, including pegmatites, hydrothermal quartz veins, sedimentary accumulations, and quartzite, all of which have been identified internationally as applicable for HPQ – herein provides an opportunity to understand, re-examine and explore mineral systems most prospective for HPQ in Australia.

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