Graphite reconnaissance, Minas Gerais – Bahia region, Brazil, March 2024

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BRITISH GEOLOGICAL SURVEY

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Foreword

This report summarises the visit to Brazil from 14 to 21 March 2024 by Dr David Currie, minerals scientist at the British Geological Survey (BGS), as part of a BGS research collaboration on Brazilian graphite resources.

The main purpose of this visit was to build a field-based knowledge-exchange collaboration on graphite mineralisation between BGS and the Brazilian Geological Survey (SGB) and to assist SGB with the collection and analysis of graphite-bearing samples. This visit lasted two weeks and included Dr Kathryn Goodenough and Jonathan Ford. It consisted of several days of meetings with SGB and the 'Lithium and development: challenges and opportunities for Minas Gerais' workshop in Belo Horizonte prior to graphite reconnaissance fieldwork. The trip also involved a visit to the Companhia Brasileira de Lítio (CBL) underground mine with SGB staff, Dr Goodenough, PhD student Sofia Chinaglia and her supervisor, Dr Andrew Miles of Leicester University.

The work formed part of the NEE7891S (NC) Regional International Geoscience project, which focused on understanding the geology of lithium and graphite mineralisation in Brazil.

Acknowledgements

The authors of this report would like to thank Carlos Ribeiro, main geologist at CBL, for their assistance and support in preparation for and during the visit. We would also like to thank Dr Holly Elliott for reviewing this report.

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1 Introduction

The development of supply chains for both critical and battery raw materials is crucial to achieving global decarbonisation and net zero. The current Brazilian government, led by Luiz Inácio Lula da Silva, is dedicated to fostering growth in the mining sector and emphasising its role in achieving a just and sustainable energy transition on a global scale. The Geological Survey of Brazil (Serviço Geológico do Brasil; SGB) understands the advantageous position of the country, being continent-scale and having vast natural resources, and is enthusiastic about showcasing Brazil's varied geology.

The British Geological Survey (BGS) works closely with the UK Government to build collaborative international partnerships relating to critical minerals and to deliver the UK's critical minerals strategy. A Memorandum of Understanding was signed between SGB and BGS in March 2024 to collaborate and share skillsets across all areas of geoscience.

Graphite is widely recognised as a critical mineral, largely because of its importance in the anodes of lithium-ion batteries. Brazil is the world's fourth-largest producer of graphite and has active mines in several states (Idoine et al., 2025; Silva et al., 2024). Most of those mines, including the Salto da Divisa and Pedra Azul mines owned by Nacional de Grafite Ltd., are in northern Minas Gerais state, within the Bahia–Minas Graphite Province (BMGP), which is Brazil's largest and considered one of the world's foremost natural graphite provinces. The largest mine in the BMGP is Salto da Divisa, which has an estimated graphite resource of approximately 230 million tonnes at grades of approximately 25 per cent (Silva et al., 2024), certified by ISO 9001:2015 (DNV, 2021).

Investment in Brazil's graphite sector is expected to increase in the coming years. Considering Brazil's potential to become a world leader in graphite production and refining, gaining a better understanding of graphite mineralisation could lead to processing improvements and ultimately result in increased graphite production, helping Brazil to achieve this potential. This project seeks to characterise Brazil's graphite mineralisation and its genesis by conducting detailed petrographic and mineralogical investigations of the raw material both at BGS's and SGB's research facilities.

A small team consisting of David Currie (BGS) and Joanna Chaves Souto Araujo, Francisco Teixeira Vilela and Debora Rabelo Matos (all SGB) (the field team; Figure 1) visited many field localities between 14 and 21 March 2024. The aim was to identify and sample graphite-bearing materials and collect sufficient samples to then conduct petrographic analyses. A visit to the UK by Francisco Vilela in August 2024 has since allowed for knowledge exchange relating to the petrography and mineralogy of the samples collected.

Globally, graphite deposits of economic interest are grouped into two broad categories: amorphous (microcrystalline) and crystalline (flake, vein/lump or chip). Flake graphite occurs as isolated, flat, plate-like particles with hexagonal edges, often found in medium- to higher-grade regional metamorphic rocks such as schists and gneisses, respectively. Vein graphite, also known as lump graphite, forms in veins or fractures within metamorphic and igneous rocks, and is characterised by its high purity and crystalline nature. Amorphous graphite is primarily extracted from heat-affected coal beds and appears as fine- to nanoscale particles (Robinson Jr et al., 2017).

The size and grade of graphite flakes are important parameters for the commercial viability and end uses of the mineral. Reduction in flake size will lead to a reduction in product price (Jara et al., 2019). Reduction of grade will result in the graphite being used in less specialised and lower priced end-use applications (Jara et al., 2019; Kim et al., 2003; Mitchell, 1992). Minimising the degree of crushing and milling and understanding the liberation characteristics and impurities of graphite is therefore crucial (Chehreh Chelgani et al., 2016; Sandmann et al., 2014).

Figure 1 Graphite field team at the summit of Pedra da Conceição, Pedra Azul. From left to right: David Currie, Debora Rabelo Matos, Joanna Chaves Souto Araujo and Francisco Teixeira Vilela. BGS © UKRI 2025

2 Visit itinerary

Following completion of the ‘Lithium and development: challenges and opportunities for Minas Gerais’ event in Belo Horizonte, the field team departed for Araçuaí. Table 1 documents the basic outline of work and the travel itinerary for the week.

Table 1 Itinerary for visit to Brazil, March 2024.

Date	Activity
Day 1: 14 March 2024	Travel from Belo Horizonte to Araçuaí (about 600 km; 12 hours)
Day 2: 15 March 2024	Morning: travel from Araçuaí to Pedra Azul (about 170 km; 4 hours) Afternoon: hike to Pedra da Conceição, Pedra Azul
Day 3: 16 March 2024	Fieldwork on graphite outcrops around the Pedra Azul area and onward travel to Almenara (about 100 km; 3 hours)
Day 4: 17 March 2024	Fieldwork on graphite outcrops around the Almenara area
Day 5: 18 March 2024	Onward travel to Jordânia (about 80 km; 3 hours) followed by fieldwork on graphite outcrops in the Jordânia area
Day 6: 19 March 2024	Travel to Almenara to pick up previously collected samples and then travel onwards to Araçuaí (about 300 km; 7 hours) with fieldwork on graphite outcrops whilst travelling
Day 7: 20 March 2024	Visit CBL’s Cachoeira underground mine
Day 8: 21 March 2024	Travel from Araçuaí to Belo Horizonte (about 600 km; 12 hours)

3 Graphite in Brazil

3.1 HISTORY OF GRAPHITE MINING IN BRAZIL

Graphite mining in Brazil has a long and varied history. The extraction and utilisation of graphite began in the early 20th century. Initially, the country focused on exploiting its natural resources for domestic consumption in a variety of industrial uses such as lubricants, furnace lining in the iron and steel industry, and pencils. In the mid-20th century, Brazil saw a surge in graphite exploration activities, particularly in the states of Minas Gerais, Bahia, Ceará and Tocantins. This period marked the transition from small-scale mining operations to more organised and extensive mining projects. By the late 20th century, Brazil had established itself as a key exporter of graphite, particularly benefiting from the growing demand from the iron and steel industry for high-quality flake graphite for industrial furnaces and crucibles.

Moving into the 21st century, advancements in mining technology and increased global demand for graphite, driven by its applications in industries such as steel manufacturing, batteries and electronics, has propelled Brazil into becoming a consistent top-five producer of graphite year on year (Idoine et al., 2025; Sousa and Matos, 2020). In 2023, Brazil was the world's fourth-largest producer of graphite and had active mines in several states (Idoine et al., 2025; Silva et al., 2024). Most of those mines, including the Salto da Divisa and Pedra Azul mines owned by Nacional de Grafite Ltd., are in northern Minas Gerais and are part of the BMGP.

Global demand for graphite is expected to double by 2030 and increase five-fold by 2050, driven by its use in lithium-ion battery technology, grid-scale energy storage and consumer electronics, alongside its prevalence in steel making and other large-scale industrial applications (IEA, 2024).

The Brazilian government has consistently supported the mining sector through policies aimed at attracting foreign investment, enhancing infrastructure and fostering sustainable mining practices. This supportive environment has enabled the graphite industry to thrive, even amid fluctuating global markets (Idoine et al., 2024; Silva et al., 2024).

3.2 GEOLOGY OF GRAPHITE OCCURRENCES IN BRAZIL

Brazil's geological landscape is highly conducive to graphite formation. The country boasts significant deposits of both flake and amorphous graphite, which are both primarily found in Precambrian metamorphic rocks. Key graphite-bearing formations are typically associated with high-grade metamorphic terranes where carbon-rich organic materials have been subjected to intense heat and pressure over millions of years (Silva et al., 2024). The primary regions for graphite occurrence in Brazil are in the states of Ceará, Tocantins, Minas Gerais and Bahia.

Sections 3.2.1 and 3.2.2 give a brief description of the Ceará and Tocantins deposits, whilst the rest of this report will focus on the BMGP.

3.2.1 Ceará

In Ceará state, the occurrences of graphite in the Aracoiába–Baturité district have been known since the late 1940s and were primarily exploited as lubricant for WW2 tanks and vehicles. Little interest was paid to these deposits until the start of the 21st century, when large deposits of disseminated graphite were identified by mineral exploration companies. Graphite deposits in the Aracoiaba–Baturité district are hosted by Neoproterozoic graphitic gneiss (disseminated ore) and epigenetic veins.

Disseminated graphite, with 1.5 to 7 per cent carbon, forms large lenticular bodies along the Cheréco–Erom and Fazenda Alvorada–Itans belts, two north-north-west trending metamorphic belts that extend for 8 to 10 km. Massive graphite veins, grading 20 to 40 per cent carbon, occur in structural traps such as faults and folds and are linked to remobilisation by fluids from the Pedra Aguda pluton. Carbon isotope values ($\delta^{13}C$ from around -27 per mil to -20 per mil) confirm an organic origin. Hosted in the Baturité Subunit, these deposits reflect a Neoproterozoic slope-to-abyssal palaeogeography, resembling the khondalite belts of India and China and marking a possible ancient oceanic suture zone (Pereira and Fragomeni, 2013).

3.2.2 Tocantins

Tocantins state hosts both flake and amorphous graphite resources. Graphite occurs in metasedimentary and metavolcanic rocks within Palaeoproterozoic greenstone belts, notably near Palmeiropolis. Hosted in schists and amphibolites, the graphite likely formed under medium- to high-grade metamorphism, with potential for both disseminated and structurally controlled vein-type mineralisation (Fuck et al., 2014). These deposits may be linked to granitoid intrusions and fault systems (Botelho et al., 2006; Fuck et al., 2014).

3.3 GRAPHITE OCCURRENCES IN MINAS GERAIS

Minas Gerais hosts Brazil's largest flake graphite reserves and is the country's biggest graphite producer. The most important graphite deposits in Minas Gerais are in the BMGP in the north of the state, close to the border with Bahia state. The other large deposit occurs close to Itapecerica, in the central-western part of Minas Gerais.

In the BMGP, graphite deposits are essentially related to metamorphic rocks of sedimentary origin found in two Proterozoic units:

- greenschist facies Macaúbas Group (900 to 660 million years old (Ma)), where graphite is hosted in graphite-rich schists
- amphibolite to granulite facies Jequitinhonha Complex (580 to 545 Ma), where graphite is hosted in aluminium-rich paragneiss, with sillimanite, graphite, quartzite and lenses of calc-silicate rocks metamorphosed to upper amphibolite or granulite facies (Pacheco et al., 2021; Pedrosa-Soares et al., 2011a)

The Jequitinhonha Complex has been interpreted as part of the distal passive margin of the precursor basin of the Araçuaí Orogen, with the sedimentation of the protoliths probably occurring during the Cryogenian period (720 to 635 Ma) (Dias et al., 2016; Gonçalves-Dias et al., 2011; Pedrosa-Soares et al., 2011b). In both units, graphite is more commonly found disseminated in host rock and less frequently occurs as massive vein-type graphite (Belém, 2006).

Previous work on the graphite-rich schists of the Macaúbas Group found graphite is flake to jumbo in size and has, on average, long axes lengths ranging between 0.10 and 0.30 mm, widths between 0.08 and 0.25 mm and thicknesses between 0.01 and 0.05 mm (Belém, 2006). In the graphite-rich gneisses of the Jequitinhonha Complex, graphite appears as flake to super jumbo in size with lengths varying between 0.30 mm and 1 cm, widths between 0.15 and 0.90 mm and thickness between 0.03 and 0.25 mm (Belém, 2006).

The three largest operating mines in the BMPG — Mina de Salto da Divisa, Mina Maiquinique and Mina de Pedra Azul — extract graphite from the Jequitinhonha Complex. The size of graphite grains across the BMPG sits between flake and super jumbo, with possible application in a range of sectors including industrial, energy storage, electronics, nuclear, aerospace and other advanced and specialised sectors (Jara et al., 2019).

4 Fieldwork

4.1 FIELDWORK DAY ONE: BELO HORIZONTE TO ARAÇUAÍ

The first day of fieldwork was a travel day between Belo Horizonte and Araçuaí. This is an approximately 600 km drive on paved roads. The field team stopped in several towns along the route and at the Paraúna River Dam panoramic view (Figure 2). This view allowed for geologist Francisco Vilela to contextualise the regional geology and discuss the pre-, syn- and post-Araçuaí orogenic events, which are summarised in Section 4.1.1.

4.1.1 Araçuaí Orogen

The Araçuaí Orogen, located in south-eastern Brazil, is a classic example of a confined Neoproterozoic to Cambrian orogen formed during the assembly of West Gondwana. Its tectonic evolution is divided into three main stages: pre-, syn- and post-tectonic, each reflecting distinct geodynamic processes (Alkmim et al., 2017). Together, these stages reflect a complete Wilson cycle, from rifting to collision and collapse, and are mirrored in the West Congo Belt across the Atlantic, highlighting the Araçuaí Orogen's role in the broader tectonic evolution of Gondwana (Pedrosa-Soares et al., 2001)

During the pre-tectonic stage (about 900 to 630 Ma), the region experienced continental rifting that led to the formation of the Macaúbas Basin, a passive margin setting along the São Francisco–Congo craton (Alkmim et al., 2017; Pedrosa-Soares et al., 2011a). This stage is marked by the deposition of thick sedimentary sequences, including glaciogenic units, and the intrusion of mafic dykes and anorogenic granites such as the Pedro Lessa dykes (about 906 Ma) and the Salto da Divisa granite (about 875 Ma), indicating crustal extension and thinning (Schannor et al., 2021).

The syn-tectonic stage (around 630 to 580 Ma) began with the closure of the Macaúbas Basin and the onset of continental collision. This phase was characterised by crustal thickening, high-pressure metamorphism and the emplacement of syncollisional S-type granites (G2 suite, 582 to 560 Ma) derived from partial melting of metasedimentary rocks (Pedrosa-Soares et al., 2011b). Structural deformation and regional metamorphism reached amphibolite facies conditions, with peak pressures of 7 to 9 kbar and temperatures of 580 to 620°C (Schannor et al., 2021).

In the post-tectonic stage (about 580 to 500 Ma), the orogen underwent extensional collapse and exhumation of deep crustal rocks. This was accompanied by the intrusion of post-collisional leucogranites (G3 suite) and the development of post-orogenic basins (Pedrosa-Soares et al., 2011b). Cooling and erosion shaped the modern landscape, exposing migmatitic cores and granitoid batholiths (Schannor et al., 2021) .

Figure 2 Paraúna River Dam panoramic view. BGS © UKRI 2025

4.2 FIELDWORK DAY TWO: ARAÇUAÍ TO PEDRA AZUL

The morning and early afternoon of day two was taken up with travelling from Araçuaí to Pedra Azul. Following check-in, the team regrouped and hiked to the Pedra da Conceição viewpoint, which provides a 360° view of the Pedra Azul area (Figure 3).

Figure 3 Pedra da Conceição viewpoint, Pedra Azul area. BGS © UKRI 2025

4.3 FIELDWORK DAY THREE: PEDRA AZUL TO ALMENARA

The team began by visiting an outcrop on the access road to the Nacional de Grafite mine, located between Pedra Azul and Divisópolis (Figure 4). The site had previously been sampled by SGB colleagues, but samples FV-R-024D and E were taken as well as a 30 kg bulk sample for future work at SGB (Table 2).

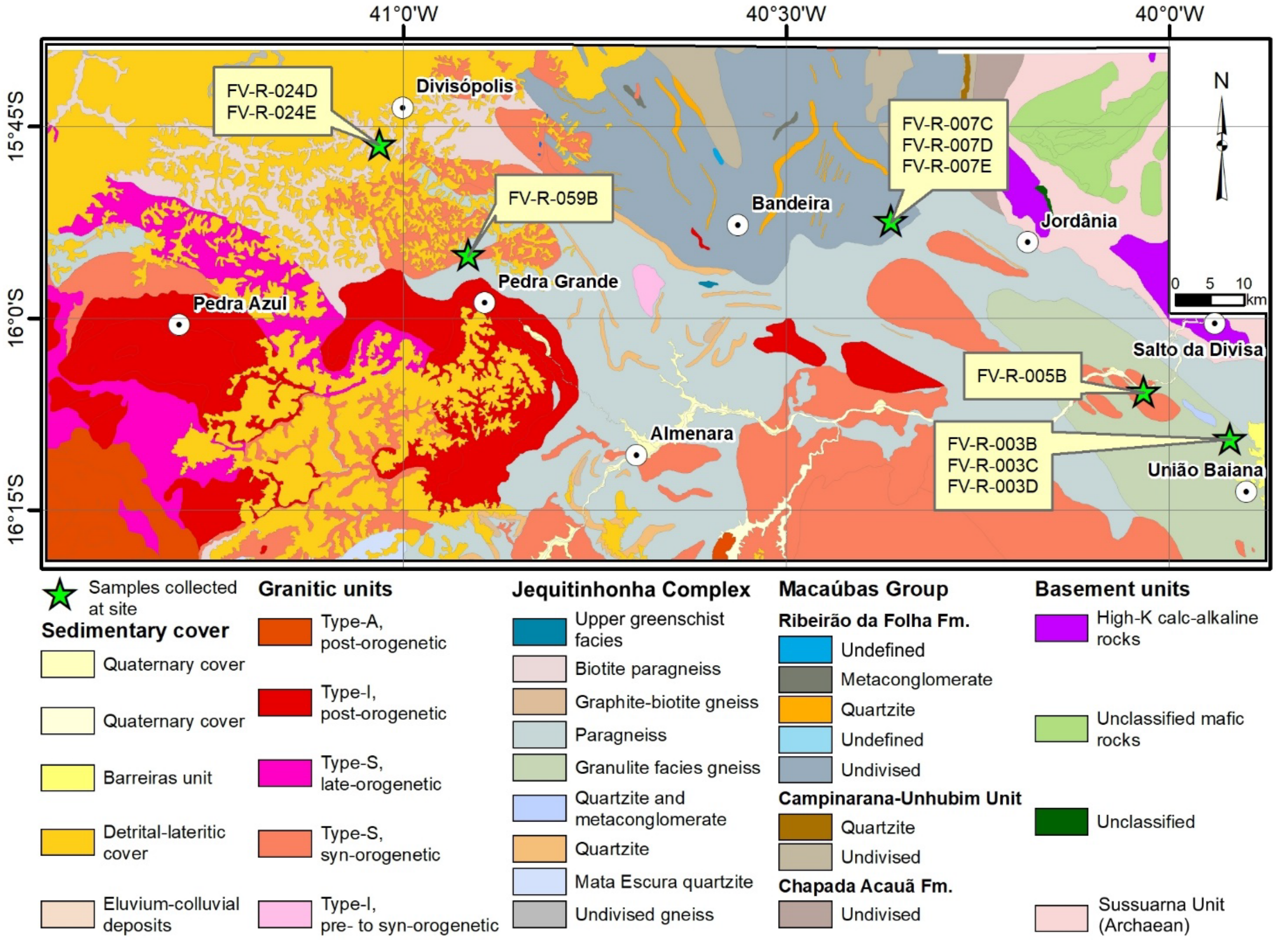

Figure 4 Geological map of the field area with sample locations provided. Map prepared by F T Vilela using SGB data and simplified from Silva et al. (2020). © SGB 2025

The locality visited is a weathered, red ochre-coloured paragneiss outcrop extending approximately 50 m along the roadside (Figure 5a). Gneissose banding of cream or white quartzofeldspathic layers and grey, graphite-rich biotite layers are present at centimetre to millimetre scale (Figure 5b). The graphite appears to be a fine, disseminated, crystalline flake variety and flattens to form shiny, smooth surfaces if compressed by a hammer blade (Figures 5b, c and d). Garnet is locally observed ranging in size from 1 to 3 mm, though no garnet samples were taken. Graphite is more concentrated in the biotite-rich layers.

Table 2 List of samples collected during this fieldwork that have been sent for thin sectioning by SGB.

BGS sample name	SGB sample name	Latitude (S)	Longitude (W)	Elevation (m)	Description
BR24/02	FV-R-024D	15°46.326'	041°01.785'	728	Biotite-graphite gneiss
BR24/03	FV-R-024E	15°46.326'	041°01.785'	728	Graphite gneiss
BR24/04	FV-R-059B	15°54.990'	040°54.846'	579	Graphite-migmatite contact
BR24/08	FV-R-003B	16°09.361'	039°55.184'	189	Graphite gneiss
BR24/09	FV-R-003C	16°09.361'	039°55.184'	189	Migmatite
BR24/10	FV-R-003D	16°09.361'	039°55.184'	189	Mafic section of gneiss
BR24/11	FV-R-005B	16°05.640'	040°01.946'	147	Migmatite and graphite gneiss contact
BR24/12-1	FV-R-007C	15°52.588'	040°21.677'	528	Graphite gneiss
BR24/12-2	FV-R-007D	15°52.588'	040°21.677'	528	Graphite gneiss
BR24/12-3	FV-R-007E	15°52.588'	040°21.677'	528	Garnet-cordierite-graphite gneiss

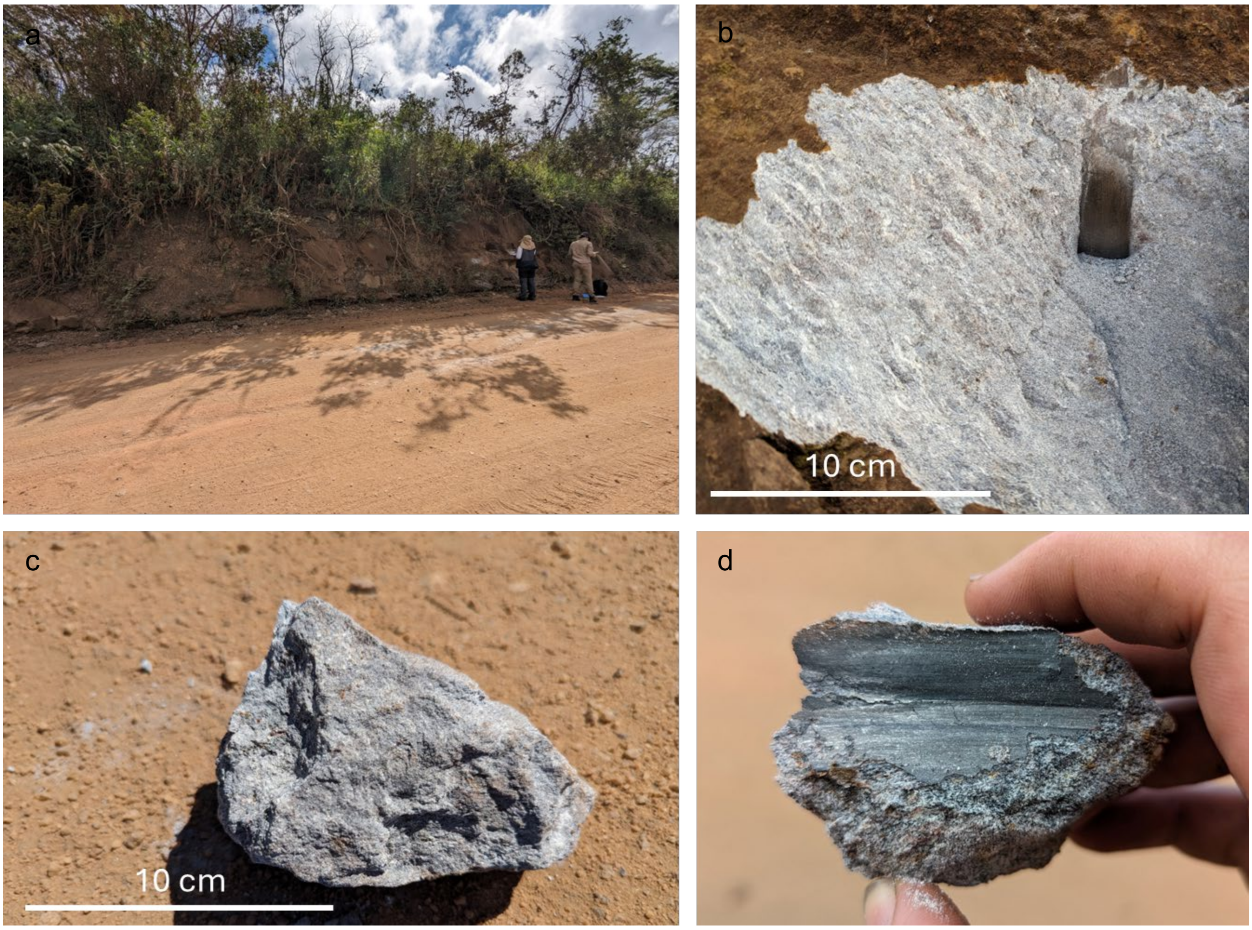

Figure 5 Photographs of outcrop and hand samples between Pedra Azul and Divisópolis. a) Weathered, red-ochre paragneiss outcrop extending for around 50 m along the roadside; b) Gneissose banding of cream or white quartzofeldspathic layers and grey, graphite-rich biotite layers. The dark grey mark in the outcrop was created by a hammer pick, resulting in the flattening and alignment of graphite flakes; c) Hand sample of graphite-rich gneiss; d) Example of the shiny surface of the graphite. BGS © UKRI 2025

The day continued by travelling further towards Divisópolis along dirt tracks with varied conditions, but mostly poor. We arrived at the second location around midday.

At the second location, the outcrop contains a graphite-rich, millimetre-scale lens of sericitised mylonitic schist with a vertical schistosity (Figure 6). The outcrop is heavily weathered and friable. The graphite appears to be a fine, disseminated, crystalline flake variety, occasionally forming small, millimetre-scale lenses that appear to be composed only of graphite. On the edges of the graphite-rich portion, there is a sericite schist with minimal graphite mineralisation. The contact appears to be gradual, with a decrease in the amount of graphite. Schistosity: 340/90.

Samples collected (see Table 2 for location and sample description):

- BR24/02 (BGS ID) or FV-R-024D (SGB ID)
- BR24/03 (BGS ID) or FV-R-024E (SGB ID)

Figure 6 Left: outcrop of graphite-rich lenses of the sericitised mylonitic schist. Right: closer look at the weathered nature of the outcrop with fine layers of graphite-rich material in centre of image. BGS © UKRI 2025.

The final location of the day was an outcrop in a dirt road cut extending approximately 30 m in length and 3 m in height. It exposes saprolite of migmatitic paragneiss with white, black and grey banding, typically around 10 cm in width, with pervasive weathering (Figure 7). The white bands (leucosomes) likely consist of quartz and kaolinite; the red bands are alteration of mafic material and contain graphite; the grey bands are almost exclusively graphite and may contain some quartz and feldspar.

The leucosomes appear as irregular bands and pockets of coarse-grained quartz and feldspar. Graphite concentrates around pockets of the leucosomes and thick platelets of graphite are associated with biotite within the leucosomes. Intense folding is evident and often disharmonic, with recumbent or plunging, inclined, open to tight folds at outcrop scale. Folding can also appear isoclinal, with a pinched appearance. Graphite appears to concentrate around the external rims of the folded leucosomes. Banding: 232/50.

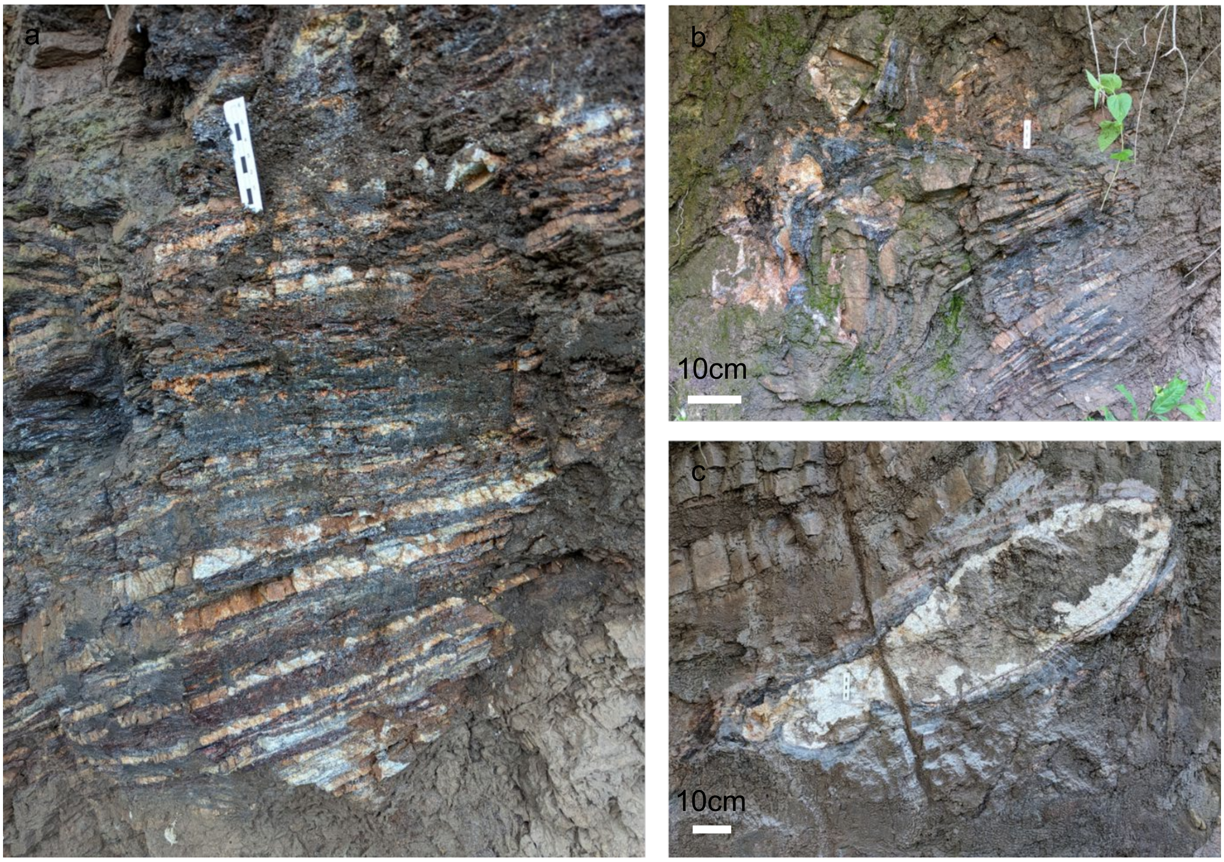

Figure 7 a) Example of relatively fresh exposure of graphite gneiss with quartzofeldspathic to kaolinised pale bands and graphite-rich grey bands. Weathered material is still pervasive as ochre-stained material; b) Example of intensely folded gneiss above the more regular banded occurrence; c) Example of larger-scale quartzofeldspathic to kaolinised leucosomal feature with graphite-rich rim.

Samples collected (see Table 2 for location and sample description):

- BR24/04 (graphitic band) or FV-R-059B (SGB ID)
- BR24/05 (graphite at contact of leucosome)
- BR24/06 (felsic pod of leucosome)
- BR24/07 (graphite below leucosome) or FV-R-059 (SGB ID)

4.4 FIELDWORK DAY FOUR: ALMENARA REGION

We began the day by travelling to the Oklahoma Farm graphite occurrence, only a few kilometres north-west of Nacional de Grafite's Salto da Divisia mine. The site had previously been subject to trenching and around 1500 m of exploration drilling on a 50 × 50 m grid. The outcrop was in a steep, sloping section of farm pasture that led down to a small stream. The slope was subject to extensive gully erosion (Figure 8).

This gully outcrop comprises graphite-rich, saprolitic paragneiss, very similar in appearance to that studied during the previous day's fieldwork (Figure 7). Bands consist of felsic (quart and, feldspar), mafic (biotite) and grey (graphite) constituents. Several leucosome pods, ranging from several centimetres to tens of metres and which appear to be part of a larger scale, boudinage-style occurrence, are present. Minor amounts of graphite appear in these felsic boudins. Pervasive weathering of all banding is common.

We discussed the entire outcrop as potentially being the same gneiss that is being extracted within the Nacional de Grafite mine, based on the orientation of banding and proximity to the mine site. Banding: 052/44.

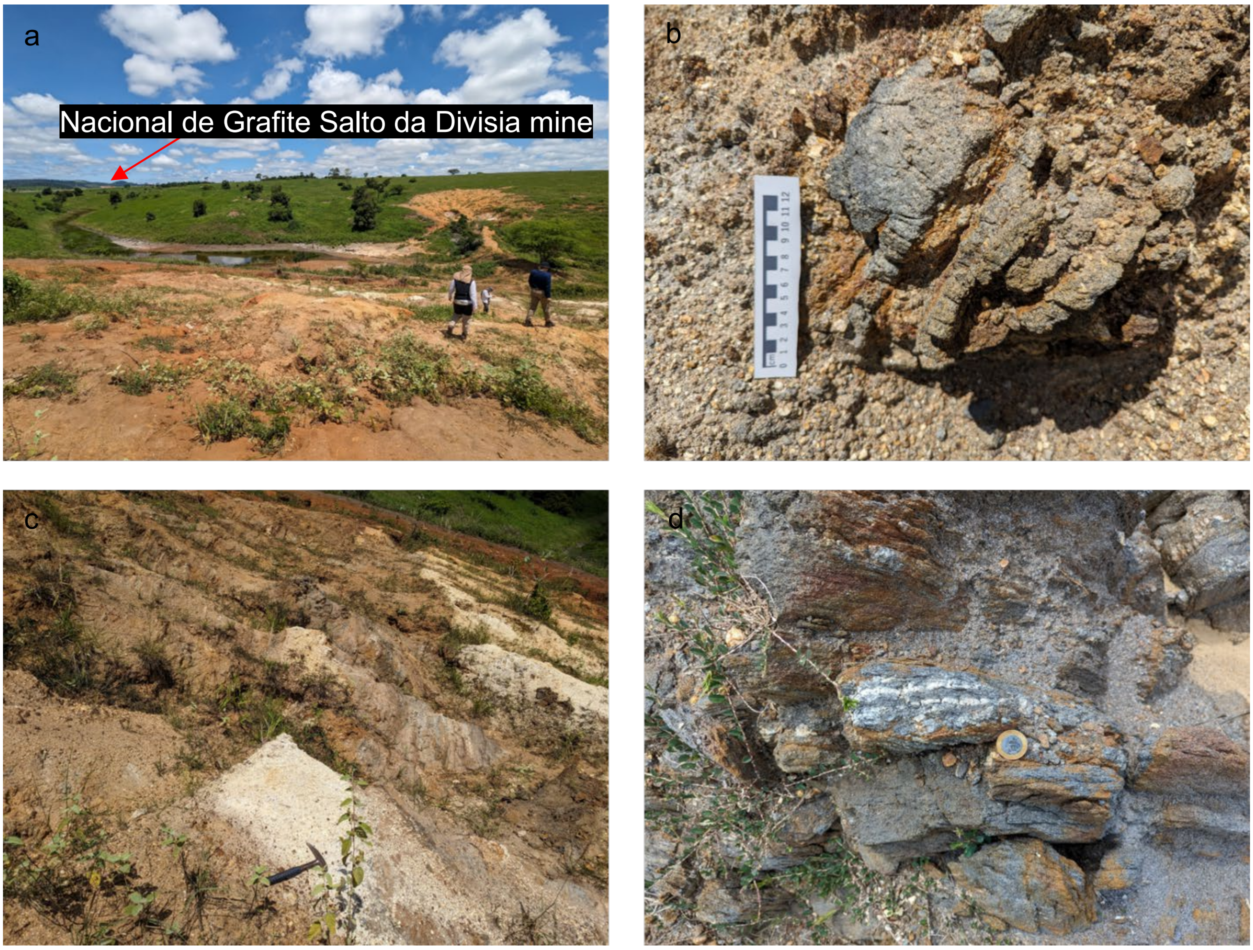

Figure 8 a) The field team walking down into the stream bottom with Nacional de Grafite's Salto da Divisia mine in the distance. The weathered nature of the outcrop is evident, with gully erosion in the middle right of the image; b) Mafic section of paragneiss; c) This image was taken parallel to the gneissic banding and shows the distinction between the graphite-rich grey bands and the more boudin-like pinch-and-swell of the quartzofeldspathic leucosomal band in the foreground, adjacent to the hammer; d) Typical exposure of grey, graphite-rich bands and pale, quartzofeldspathic bands. BGS © UKRI 2025.

Samples collected (see Table 2 for location and sample description):

- BR24/08 (graphite) or FV-R-003B (SGB ID)
- BR24/09 (felsic band) or FV-R-003C (SGB ID)
- BR24/10 (mafic band) or FV-R-003D (SGB ID)

The final location of the day was a road cut on the way back to Almenara. A 30 kg bulk sample of weathered graphite-bearing material was collected for future SGB analysis.

The road cut and road surface (a dirt road with exposure under the dust) expose graphite-rich paragneiss (Figure 9). We noted gneissose banding similar to that at the previous two outcrops. The outcrop on the road surface was intensely folded, with a mixture of open and tight forms.

Sample collected (see Table 2 for location and sample description):

- BR24/11 or FV05

Figure 9 a) Road outcrop mostly along a vertical face in the shade and on the inside bend of the road in front of the pick-up truck; b) Scenery on the road back to Almenara; c) An example of paragneiss outcrop on the road surface with intensely folded graphite-rich and quartzofeldspathic bands. BGS © UKRI 2025.

4.5 FIELDWORK DAY FIVE: ALMENARA TO JORDÂNIA

We set off early from Almenara towards Jordânia. On the map, this journey appears to be only 80 km but it took almost three hours due to poor road conditions. We checked into our hotel in central Jordânia and set off for our field location, the Pedro Perdido graphite occurrence. Again, this journey appears short by map, but the roads were especially difficult on this stretch. We arrived at the outcrop by 13:00 and were accompanied by a local guide with mining experience in this area.

The exposure and graphite occurrence are owned by Samaca Ferros Ltda and Viva Companhia de Mineração S.A. mining companies and have been worked previously. The local guide directed us to the top of the mountain, where a 100 × 5 m high wall of weathered, graphite-rich paragneiss is exposed (Figure 10). We were advised to wear padded gaiters here to mitigate potential contact with snakes.

This outcrop is a graphite-rich paragneiss with bands less than 1 m wide of felsic, mafic and graphitic lithologies, with quartzofeldspathic boudins and veins up to 20 cm wide at random intervals. The entire outcrop is heavily weathered and material can be scraped off easily using a flat-bladed, pick-type instrument. Occasional occurrences of garnet, cordierite and a green mineral that may be a pyroxene phase or epidote were found at this location (Figure 10). Banding: 300/82; 296/80; 304/86.

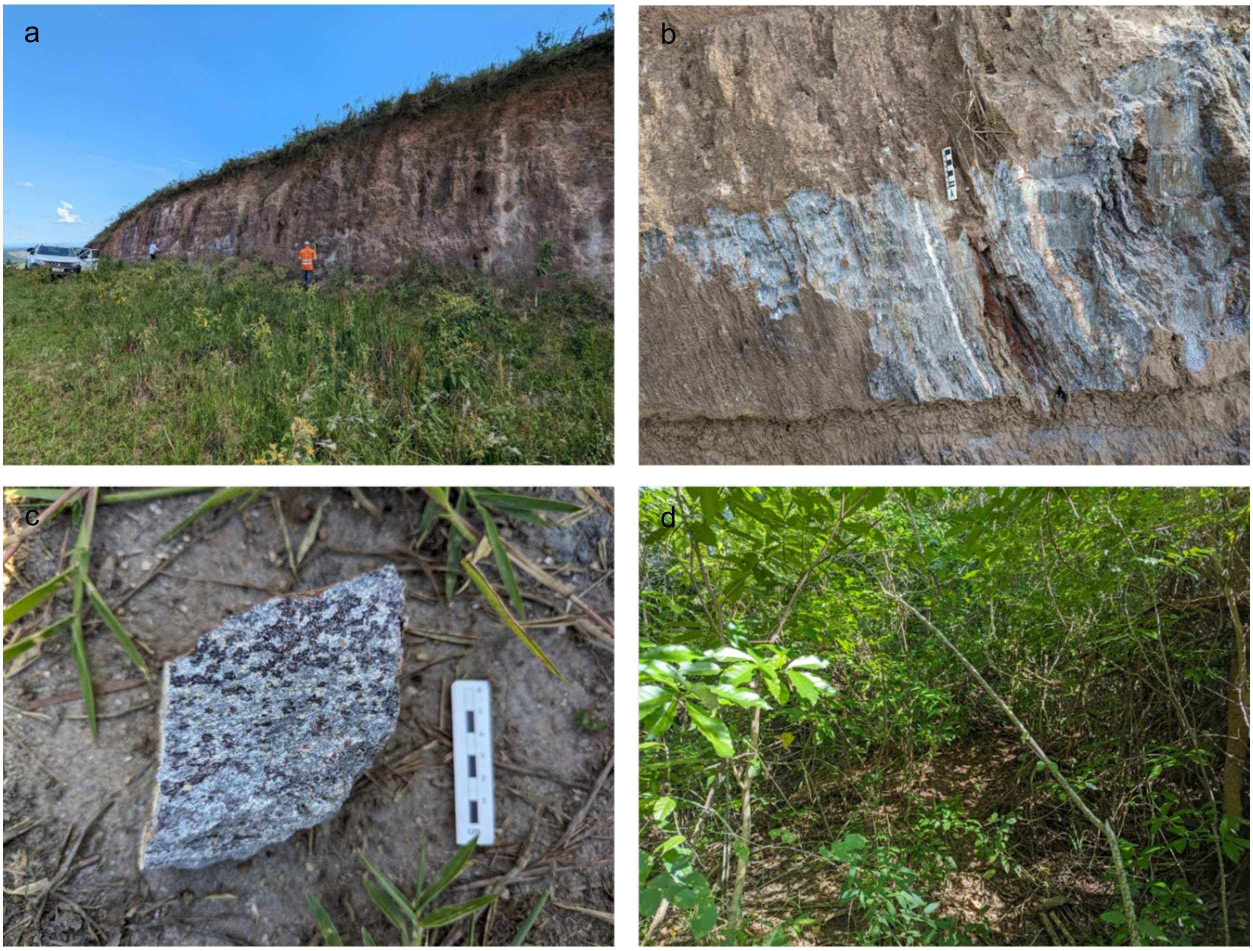

Figure 10 a) Extent of the weathered, graphite-rich paragneiss outcrop along the hill top; b) The scraped surface of the outcrop exposing almost vertical banding of gneiss with grey, graphite-rich bands and paler, quartzofeldspathic bands; c) Example of garnet-bearing gneiss; d) Dense forest covering the location of the underground gallery opened by Viva Companhia de Mineração S.A. several years earlier. BGS © UKRI 2025.

Sample collected (see Table 2 for location and sample description):

- BR24/12 or FV07

Following sampling at BR24/12 we, along with our local guide, attempted to find an underground gallery opened by Viva Companhia de Mineração S.A. several years earlier. However, the forest around us became dense and steeply inclined; chances of finding the gallery were close to zero, even with GPS coordinates of the approximate location (Figure 10d).

4.6 FIELDWORK DAY SIX: JORDÂNIA TO ARAÇUAÍ VIA JEQUITINHONHA

This was mostly a travel day going from Jordânia to Araçuaí via Jequitinhonha. Stops were built in where graphite had been reported by other SGB staff on previous mapping trips across the Jequitinhonha region. When returning to Araçuaí, we travelled on the northern side of the Jequitinhonha River between Almenara and Jequitinhonha in search of a potential graphite exposure. However, we were met with a completely washed-out road that ended the fieldwork (Figure 11c) and we continued on to Araçuaí to meet with other SGB staff, Kathryn Goodenough, Andrew Miles and Sofia Chinaglia, who were on a lithium reconnaissance field trip in the Araçuaí region.

The outcrop comprises exposures of graphitic material on the road scraped by grading machinery (Figure 11). We are not convinced that this graphite was in situ, although it had been reported several years previously in the area by SGB staff not on this fieldwork.

Sample collected (see Table 2 for location and sample description):

- BR24/13

Figure 11 a) Polished road surface with minor exposure of graphite; b) Road grader in action; c) Failed stick bridge and washed-out river that halted our travel and ultimately ended the fieldwork; d) Jequitinhonha River BGS © UKRI 2025.

4.7 FIELDWORD DAY SEVEN: CACHOEIRA LITHIUM MINE VISIT, ARAÇUAÍ REGION

We met with the lithium-focused team the previous night in Araçuaí and, on day seven, we went to visit the Brazilian Lithium Company (Companhia Brasileira de Lítio, CBL)'s Cachoeira lithium pegmatite mine (Figure 12).

CBL was founded in 1985 and the mine has been in operation since 1991. It is an underground, spodumene-rich pegmatite mine and is the only mine outside China to produce and refine lithium to more than 99.5 per cent lithium carbonate (Li_2CO_3) battery grade (Figure 12c). The chemical processing plant is located approximately 180 km away in Divisa Alegre, Minas Gerais.

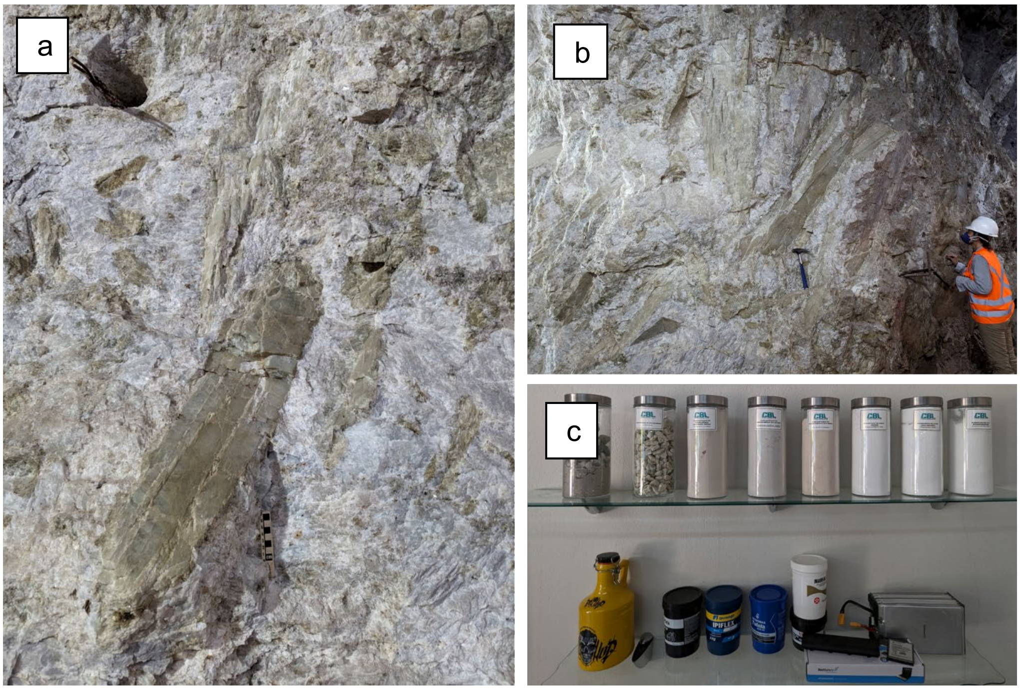

Figure 12 a) and b) Examples of the scale of spodumene mineralisation at the CBL mine with individual spodumene crystals reaching over 1 m in length; c) Examples of products from the CBL refinery. BGS © UKRI 2025.

4.8 FIELDWORK DAY EIGHT: ARAÇUAÍ TO BELO HORIZONTE

Our final day was spent travelling back from Araçuaí to Belo Horizonte. This journey is around 600 km and takes up to 12 hours to complete. We visited the Mesoproterozoic-aged Sopa Brumadinho Formation (Lavra–Lavrinha/small, mined area) near Diamantina to see an exposure of a diamondiferous conglomerate famous in Brazilian geology because the source of the diamonds has never been fully understood (Figure 13). The site is also used as a field location for many undergraduate geology training programmes due to the abundance of outcrops and examples of sedimentary processes in the geological record (Kuchenbecker et al., 2016).

Figure 13 Sofia Changlia beside an outcrop of the diamoniferous conglomerate Sopa Brumadinho Formation. BGS © UKRI 2025

4.9 GRAPHITE SAMPLES

Thin sectioning is being carried out by SGB staff. Table 2 documents the sample details.

5 Conclusions

The graphite reconnaissance fieldwork carried out across the Minas Gerais and Bahia region allowed us to collect a diverse sample set that will form the backbone of a collaborative approach to graphite characterisation between BGS and SGB. Of the twenty-eight samples collected, ten were suitable for thin sectioning, whilst others can be used for bulk rock geochemistry.

The visits to the graphite-bearing outcrops across the Minas Gerais and Bahia region provided a first-hand account of the geological background of the graphite we want to better understand. Graphite appears to be concentrated in micaceous bands of paragneiss that has been metamorphosed to amphibolite facies grade. Felsic bands appear to be composed of quartz and a mixture of plagioclase and K-feldspar with occasional graphite, whilst mafic bands appear more biotite- and amphibole-rich with more abundant graphite mineralisation.

Boudins of felsic material are pervasive across the area, highlighting that the metamorphic belt has been subject to intense ductile deformation. There is a clear competency contrast between more readily deformed graphite-rich bands and more competent felsic bands. In some areas, graphite-rich bands appear extensively sheared.

The material we collected will be processed and characterised by optical and scanning electron microscopy at BGS by David Currie and Francisco Vilela by the end of 2025. X-ray diffraction and thermogravimetric mass spectrometry analysis may also be carried out at BGS in what will become a standardised and systematic approach to graphite reconnaissance work.

Francisco Vilela travelled to the BGS Keyworth site in August 2024 to work alongside David Currie to characterise the graphite-bearing samples and gain a better insight into the workflow and hardware we use to undertake such analyses. By doing so, they will become a key link in the collaboration between BGS and SGB for sharing our combined knowledge and technical expertise. A peer-reviewed scientific journal paper on the graphite characterisation work carried out by Currie and Vilela will be submitted in 2025.

RECOMMENDATIONS FOR FUTURE WORK

- Continuation of the collaboration between BGS and SGB, which could be extended to carry out reconnaissance for graphite and other critical raw materials in other parts of Brazil
- Greater engagement with local communities and acknowledgement of the value of local knowledge
- Engagement with mineral industry stakeholders and international organisations that are actively supporting graphite and critical raw material development in Brazil

The collaboration between BGS and SGB is probably the main achievement of this work, with the strengths and experience of the teams contributing to highly effective graphite reconnaissance fieldwork and potentially many other projects on critical raw materials in the future.

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