

Essential Minerals for the Green Revolution – 4 Graphite From a pencil to the electric car!

Did you know that you have a sample of graphite in your pocket or in your pencil case? A “lead” pencil contains graphite mixed with clay. (The Greek for “to write” is *graphein*, from which graphite takes its name). Some electronic equipment and most rechargeable batteries also contain graphite, so it is never very far from you. Graphite is a form of carbon and is one of the softest minerals known, which is why it can be used to make a mark on paper– in contrast to another form of carbon, namely diamond which is the hardest.

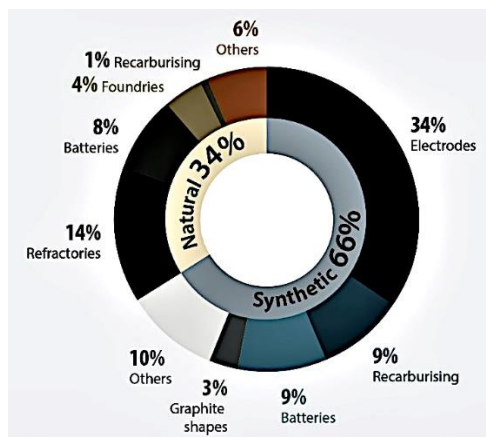


Graphite from a mine in New Hampshire USA
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Graphite is a very good conductor of electricity and heat and has been used for many years in batteries, as well as in the electric arc method of steelmaking and in refractory materials. However, its use is increasing rapidly today – can you suggest why? (A typical electric car battery contains around 50kg of graphite).

Where does graphite come from? Natural graphite occurs in metamorphic rocks such as schists and gneisses. Many industries also use synthetic graphite, made from petroleum coke. Suggest why this source may not be a very “carbon-friendly” source. (It is produced as a by-product of the processing of petroleum - crude oil - and a lot of carbon dioxide is produced in the process).

The diagram shows some of the uses of each form of graphite.



Global uses of graphite 2021 (www.natural-resources.canada.ca) [recarburing means adding carbon to the surface of steel products to increase their hardness]

If worldwide production of oil decreases to meet carbon reduction targets, then there will be less synthetic graphite produced and therefore more dependence on mining and recycling. Production in 2022 was already about 5 times higher than in 2018.



A new graphite mine in Madagascar
(<https://source.benchmarkminerals.com/>)

The table below shows the main World reserves of natural graphite and the mine production figures in tonnes (T). Study the table and then answer the following questions (**Our suggested answers are under “Context” below**):

- List the top 5 countries with the biggest reserves of graphite, in order.
- Use an atlas to help you to group the countries according to their continent (Most of Turkey’s graphite deposits are in the Asian parts of the country. Count Russia separately, as it spreads across Asia and Europe).
- Which continent has the biggest reserves of graphite?
- Which continents are missing from the list?
- Suggest why production of graphite in Russia has stayed the same between 2021 and 2022, while Ukraine’s production has decreased.
- A news item from the industry claims, “Africa could overtake China as the world’s largest producer of natural graphite for lithium-ion batteries as soon as 2026” (Benchmark). What evidence in the table would support this claim?

Country	Mine production (tonnes)		Reserves
	2021	2022	
United States	—	—	*
Austria	500	500	*
Brazil	82,000	87,000	74,000,000
Canada	12,000	15,000	*
China	820,000	850,000	52,000,000
Germany	250	250	*
India	7,000	8,300	8,000,000
Korea, North	8,100	8,100	2,000,000
Korea, Republic of	10,500	17,000	1,800,000
Madagascar	70,000	110,000	26,000,000
Mexico	2,100	1,900	3,100,000
Mozambique	72,000	170,000	25,000,000
Norway	6,290	10,000	600,000
Russia	15,000	15,000	14,000,000
Sri Lanka	3,000	3,000	1,500,000
Tanzania	—	8,000	18,000,000
Turkey	2,700	2,900	90,000,000
Ukraine	10,000	3,000	*
Uzbekistan	110	—	7,600,000
Vietnam	5,000	5,000	*
World total (rounded)	1,130,000	1,300,000	330,000,000

(Source: US Geological Survey, January 2023. * = figures not available. World total includes smaller reserves and estimated reserves from other countries)

The back up

Title: Essential Minerals for the Green Revolution
– 4 Graphite

Subtitle: From a pencil to the electric car!

Topic: An investigation into the sources of graphite as worldwide demand rises, with the introduction of new technology for motor vehicles, such as lithium-ion batteries

Age range of pupils: 12 years and above

Time needed to complete activity: 30 minutes

Pupil learning outcomes: Pupils can:

- explain why so much more graphite is needed as new technologies are employed to counter the rise in carbon emissions;
- evaluate different possible sources of graphite;
- explain why there is no alternative to mining to meet current and future demands for graphite.

Context: This activity could be used in a lesson on the need to identify and exploit graphite minerals in vital applications in many different fields, especially, lithium-ion batteries. Worldwide demand for graphite and related elements is rising rapidly as new technologies are embraced. Suggested answers to the questions on page 1 are:

1. 5 top countries: *Turkey, Brazil, China, Madagascar, Mozambique.*
2. Continental groupings: Africa: *Madagascar, Mozambique, Tanzania.* Asia: *China, India, North Korea, Republic of Korea, Sri Lanka, Turkey, Uzbekistan, Vietnam.* Europe: *Austria,*

Germany, Norway, Ukraine. North America: *Canada, Mexico, USA.* (Canada and USA do have reserves but data were not available for the table and mining is only recently increasing. South America: *Brazil.* Russia,

3. Biggest reserves: *Asia.*
4. “Missing” continents: *Australasia and Antarctica.* *Australia and New Zealand do have graphite resources but they are probably small. Any graphite which may be discovered in Antarctica would not be mined under the terms of the Antarctic Treaty.*
5. *Russia’s invasion of Ukraine in 2022 led to many countries ceasing to trade with Russia. Ukraine’s output ceased at first but then began again later in 2022.*
6. *Madagascar’s output of graphite increased by 57% and Mozambique’s by 136% in just one year between 2021 and 2022. Tanzania only started production in 2022.*

Following up the activity:

Pupils could plot a) the reserves, b) the mine production for 2022 onto a World map in the form of a bar graph for each of the main countries.

Underlying principles:

- Worldwide demand for graphite is increasing rapidly with the growth of new technologies.
- Existing technologies also require more graphite as world population increases.
- Manufacture of synthetic graphite is carbon intensive and depends on oil production: if this decreases over time, then more natural graphite will need to be mined.

- Some graphite can be recycled, but this is mostly suitable for brake linings and refractory materials rather than for batteries.
- Development of graphite mines in African countries mostly depends on investment from other countries, e.g. Canada and Australia.
- Mining of natural graphite can cause dust emissions, and the purification of battery-grade graphite uses reagents such as sodium hydroxide and hydrofluoric acid, which may be harmful to both human health and the environment.

Thinking skill development:

Establishing the worldwide demand for graphite and the need to extend the mining of it involves construction. Metacognition is involved when the international impact of mining is discussed. Applying thinking to new contexts is a bridging skill.

Resource list:

- access to the table and graphics above
- an atlas, or the electronic equivalent per group of pupils

Useful links:

[Graphite \(Natural\) \(usgs.gov\)](https://source.benchmarkminerals.com/article/esg-of-graphite-how-do-synthetic-graphite-and-natural-graphite-compare)
<https://source.benchmarkminerals.com/article/esg-of-graphite-how-do-synthetic-graphite-and-natural-graphite-compare>

Source: Written by Peter Kennett of the Earthlearning idea team. Thanks to Ben Lepley of SLR Consulting Ltd for advice.

Note: This activity was as accurate as possible in summer 2023. Rapid developments are taking place in the technology of low and renewable energy.

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Essential Minerals for the Green Revolution

Earthlearningidea has compiled a series of activities on the minerals which are essential if modern technology is to be able to reduce the World's carbon footprint. Some are regarded as "critical" minerals and many of them are relatively "new" in terms of needing to be exploited.

This table will be updated as fresh activities are added.

All titles begin with: Essential Minerals for the Green Revolution...

Mineral	Title
Lithium	1 Lithium: an element which is pulling more than its weight in the world
Copper	2 Copper: an element for which the demand is increasing rapidly
Rare Earths	3 Rare Earth Elements: vital components in modern technology
Graphite	4 Graphite: from a pencil to the electric car!
Cobalt	5 Cobalt: mined by children
Tin, Tungsten, Tantalum	6 "The Three Ts": Tin, Tungsten and Tantalum
Gold	7 Gold: an essential mineral - or is it?
Critical minerals	8 Critical Minerals: Essential mineral - critical mineral: what is the difference?