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Graphite

Graphite is a crystalline form of the element carbon (atomic number 6). Graphite is grey to black, soft with hardness of 0.5 to 1.0, a low density - 2.09 to 2.26 - and a metallic lustre. In its ***natural*** state it occurs as black crystal flakes or as an amorphous mass and is the most stable form of carbon under normal conditions. It has important properties such as chemical inertness, thermal stability, high electrical conductivity, and lubricity (slipperiness) making it suitable for many industrial applications. Graphite is considered a critical and strategic mineral because of its essential application in the aerospace and energy sectors.

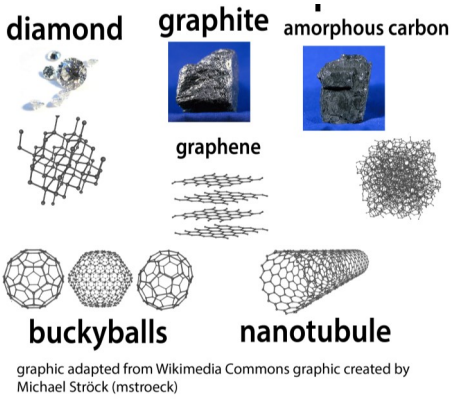
Graphite is also produced industrially by heating of hydrocarbon materials above 2500°C to drive off impurities and leaving a sheet like crystalline structure of atoms with a purity of over 99% carbon. The cost of producing ***synthetic*** graphite is significantly higher than for natural graphite but a market exists for both forms and commonly they are substituted for each other.

The chemical structure of graphite is carbon atoms arranged in a hexagonal form in one atom thick planar sheets. The individual layers are called graphene and within a one-millimeter graphite flake there are approximately 3 million stacked sheets of graphene. The bonding between the individual sheets is weak but under high temperature and pressure graphite converts into diamond (hardness 10) with the atomic structure changing into a tetrahedral form resulting in stronger covalent bonds.

Graphite has the highest melting point in nature at 3,550°C and as such traditional uses have been as a refractory material, high temperature lubricants, and foundry core in steel making. In recent years, its use in fuel cells, batteries and composites have substantially increased. According to the European Carbon and Graphite Association another driver is from nuclear reactors – no other material can meet the extremely high requirements with respect to chemical and thermal stability and conductivity.

Graphite has been found in ceramic paints in pottery from 3000BC. However, the first recorded mining of graphite was in the early 1500s in Cumbria, England. The locals had used it for marking sheep, but its real value was as a refractory material to line moulds for cannonballs, resulting in rounder, smoother balls that could be fired further, contributing to the strength of the English navy. By the 19th century, graphite's uses expanded greatly and its uses has grown ever since.

Historically graphite was called black lead or plumbago as it was similar in appearance to galena, a lead ore. In 1778 chemist Carl Wilhelm Scheele was able to determine that plubago contained no lead but carbon. It then took another 11 years, to 1789, before the name graphite was given. This was coined by geologist Abraham Gottlob Werner who derived this from Greek word for writing, graphein, reflecting the long use of graphite (mixed with clay) for the 'lead' in pencils.



Alltropes of carbon - only diamond, graphite and amorphous carbon occur naturally
碳的同素異形體 - 只有金剛石、石墨和無定形碳是天然存在的

石墨

石墨是碳元素（原子序數 6）的結晶形式。石墨呈灰色至黑色，柔軟，硬度為 0.5 至 1.0，密度低 - 2.09 至 2.26 - 並具有金屬光澤。在其自然狀態下，它以黑色晶體薄片或無定形塊的形式出現。它是正常條件下最穩定的碳排列形式。它具有化學惰性、熱穩定性、高導電性和潤滑性（光滑性）等重要特性，使其適用於許多工業應用。石墨被認為是一種關鍵的戰略礦物，因為它在航天和能源領域有著重要的應用。

石墨也可在工業上生產的，通過將碳氫化合物材料加熱到 2500°C 以上以去除雜質並留下碳純度超過 99% 的片狀原子晶體結構。生產合成石墨的成本明顯高於天然石墨，但兩者都有市場，通常它們可以相互替代。

石墨的化學結構是碳原子以六邊形形式排列在一個原子厚的平面片中。單個層被稱為石墨烯，在一毫米的石墨薄片內有大約 300 萬片石墨烯堆疊。單片之間的鍵合很弱，但在高溫高壓下石墨會轉化為金剛石/鑽石（硬度為 10），原子結構變為四面體，碳原子之間的鍵合是更強的共價鍵。

石墨在自然界中的熔點最高，為 3,550°C，因此傳統用途是用作耐火材料、高溫潤滑劑和煉鋼中的鑄造芯。近年來，它在燃料電池、電池和復合材料中的應用大幅增加。根據歐洲碳和石墨協會的說法，另一個驅動因素來自核反應堆 — 沒有其他材料可以滿足化學和熱穩定性以及導電性方面的極高要求。

早在公元前 3000 年，就在陶器的陶瓷塗料中發現了石墨。然而，第一次有記錄的石墨開採是在 1500 年代初的英格蘭坎布里亞郡。當地人用它來標記綿羊，但它的真正價值是作為一種耐火材料，用於製作砲彈的模具，使砲彈更圓、更光滑，可以射得更遠，從而增強了英國海軍的實力。到 19 世紀，石墨的用途大大擴展，此後其用途不斷增加。

歷史上，石墨被稱為黑鉛，因為它的外觀與鉛礦石方鉛礦相似。1778 年，化學家 Carl Wilhelm Scheele 能夠將石墨與其他柔軟的黑色礦物區分開來，1789 年，地質學家 Abraham Gottlob Werner 根據了源自希臘文字 “graphein”的 “graphite”一詞為其命名，反映了石墨（與粘土混合）長期用於鉛筆中的 “鉛” 。

石墨的地質和形態

當碳受熱和加壓時會形成石墨。因此，它是一種在變質岩和火成岩中發現的天然礦物元素。發現它的地質環境有3個，石墨礦類型由成礦環境決定。

1. 區域變質作用（鱗片石墨）— 在地球表面形成的大部分石墨形成於會

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Geology and Forms of Graphite

Graphite forms when carbon is subjected to heat and pressure. It is therefore a native mineral element found in metamorphic and igneous rocks. There are three geological settings in which it is found, and the graphite ore type is determined by the setting.

1. Regional Metamorphism (Flake Graphite) – Most of the graphite formed at the Earth's surface was formed at convergent plate boundaries where carbonaceous sediments were converted into marble, schist and gneiss while the carbon was converted into tiny crystal platelets and flakes of graphite which are disseminated in the rock and range in size between 40 microns (0.040mm) and 4cm, but generally are <1cm. Commercial deposits generally contain >200,000t of ore that grade >8% graphite. The foremost deposits are found in Brazil, Canada, China, India and Mozambique.
2. Coal Seam Metamorphism (Amorphous Graphite) – This type of graphite is the result of contact metamorphism of coal often by later intrusions of diabase or granite. Amorphous graphite is earthy and fine grained and occurs in seams that correspond to the original layer of coal. The term amorphous is incorrect as there is a crystalline structure as very fine flakes, <75 microns. Commercial deposits typically contain >1Mt of ore that is >75% carbon. Since the host rock is coal, the mined ore may contain non-graphitic carbonaceous material in addition to graphite, Large amorphous graphite deposits are found in Europe, China, Mexico and United States.
3. Hydrothermal Metamorphism (Lump or Chip Graphite) – Here, carbon compound in granite country rock are mobilized during hydrothermal metamorphism and deposited in veins . Because it is precipitated the graphite has a high degree of crystallinity and appears as massive fibrous and platy interlocking aggregates of coarse-grained graphite crystals. The only commercial deposits occur in Sri Lanka where families of veins are up to 3m thick consisting of 60% - 95% graphite. However, most deposits are small and likely do not exceed 100,000t.

Global natural graphite production has risen from ~900,000tpa in 2014 to approximately 1.0Mtpa - 1.2Mtpa. Of this flake graphite is estimated to be approximately 600,000t - 800,000t, amorphous graphite 300,000t and vein graphite around 4,000t. The leading world producers of flake graphite in 2020 are China (est 360,000t), Mozambique (120,000t) and Brazil (95,000t). Amorphous graphite in 2020 came mainly from China (est 290,000t). Mexico (9,000t) was the next highest producer.

World reserves of graphite in 2020 were estimated at 320Mt. Turkey (90Mt), China (73Mt), Brazil (70Mt) comprise over 70% of this. Madagascar (26Mt) and Mozambique (25Mt) also have significant reserves.

Mining and Processing

Natural graphite is mined from both open pit and underground methods although lump graphite is only mined underground where the additional cost of going underground is offset by the high grade of these deposits.

The quality of the deposit is reported as Total Graphitic Carbon (TGC) and for it to be commercially viable there are 'cut-off' grades which will vary according to the nature of the deposit. At the Triton Minerals Balama operation in Mozambique, one of the world's foremost graphite reserves, the TGC is 16.46%.

Beneficiation processes on site to concentrate the graphite vary from simple hand sorting and screening of high-grade ore at some amorphous graphite deposits, and at the Sri Lankan vein operations, to multistage crushing, screening, washing and flotation cycles. At Upulo, another Triton operation in Mozambique, beneficiation can increase the TGC from 6.6% to 97.5%.

聚板塊邊界，在那裡碳質沉積物轉化為大理石、片岩和片麻岩，而碳轉化為微小的晶片和石墨片，然後散佈在岩石的大小在 40 微米（0.040 毫米）到 4 厘米之間，但一般<1 厘米。商業礦床通常含有 >200,000 噸的礦石，其石墨品位 >8%。最重要的礦床位於巴西、加拿大、中國、印度和莫桑比克。

2. 煤層變質作用（無定形石墨或非晶石墨）— 這種類型的石墨是煤接觸變質作用的結果，通常是由輝綠岩或花崗岩的後期侵入造成的。無定形石墨呈泥土狀和細粒狀，出現在與原始煤層相對應的煤層中。稱為“無定形”是不正確的，因為它有非常細的晶體結構，小於 75 微米。商業礦床通常含有 >1 百萬噸的礦石，含碳量 >75%。由於主岩是煤，開采的礦石可能含有除石墨之外的非石墨碳質材料。在歐洲、中國、墨西哥和美國發現了大型無定形石墨礦床。
3. 熱液變質（塊狀石墨或脈狀石墨）—在這裡，花崗岩圍岩中的碳化合物在熱液變質過程中被遷移並沉積在脈中。因為它是沉澱的石墨具有高度的結晶度。石墨表現為粗粒結晶石墨晶體的塊狀纖維狀和板狀互鎖聚集體。唯一的商業礦床發生在斯里蘭卡，那裡的礦脈厚度達 3米，由 60% - 95% 的石墨組成。然而，大多數礦床規模較小，一般不超過 100,000 噸。

全球天然石墨產量已從 2014 年的約 90萬噸上升至每年約 100萬噸 - 120萬噸。其中鱗片石墨約 60萬噸 - 80萬噸噸，非晶石墨約 30萬噸噸，脈狀石墨約 4,000 噸。 2020年全球領先的鱗片石墨生產國是中國（估計36萬噸）、莫桑比克（12萬噸）和巴西（9.5萬噸）。 2020年非晶石墨主要來自中國（預計29萬噸）。墨西哥（9,000 噸）是第二大生產國。

2020 年世界石墨儲量估計為 3.2 億噸。土耳其（9 千萬噸）、中國（7.3 千萬噸）、巴西（7 千萬噸）佔其中的 70% 以上。馬達加斯加（2.6 千萬噸）和莫桑比克（2.5 千萬噸）也有大量的儲量。

開採與加工

天然石墨可通過露天和地下兩種方法開採，但脈狀石墨僅在地下開採，地下開采的額外成本被這些礦床的高品位抵消。

礦床的質量報告為總石墨碳 (Total Graphitic Carbon “TGC”)，為了使其在商業上可行，存在邊際品位，這些品位將根據礦床的性質而有所不同。Triton Minerals 在莫桑比克的 Balama 礦是世界上最重要的石墨儲量之一，其 TGC 為 16.46%。

現場濃縮石墨的選礦工藝各不相同，從一些高品位無定形石墨礦床對礦石進行簡單的手工分選和篩選，到斯里蘭卡礦脈作業中多重破碎、篩選、洗滌和浮選循環。Triton 在莫桑比克的另一個礦床 Upulo，選礦可以將 TGC 從 6.6% 提高到 97.5%。

之後精礦會被分級（分級或篩選）並確定碳含量。

石墨產品和定價

石墨產品由至少粒度分佈和純度界定。，沒有固定的行業規範。但在一些國家，如中國，政府已經制定了國家標準。從市場的角度來看，石墨產品的尺寸通常分類如*表 1*。

The concentrates are then classified (sized or screened) and the carbon contents determined.

Graphite Products and Pricing

Graphite products are specified, at a minimum, by particle size distribution and purity. However, there are no set industry specifications but, in some countries, such as in China, the government has established national standards. From a market viewpoint graphite products sizes are typically categorized as *Table 1.*

Purity (% Carbon) 純度 (%碳)	Size (Microns) 尺寸 (微米)	Product 產品	2020 Avg. Price (US$/t) 2020年平均價格 (美元/噸)
99—99.9	>300	Coarse / Large Flake	1,165—6,175
94—97	180—300		
90	180—300		
94—97	150—180	Medium Flake	500—520
90	150—180		
85—87	150—180		
94—97	<150	Fine Flake	500—520
90	<150		
80—85	<75	Amorphous	350
99.95		Synthetic	950—1,500

Table 1; Graphite product category

Customers may want a certain flake size distribution and carbon content. For example, Chinese manufacturers in the EV sector require 94% - 97% carbon - 100mesh flake graphite which they upgrade to 99.9% purity to make "spherical' graphite used in Li-ion batteries. The average selling price of spherical graphite was around US$3000/t which on coating with a disulphide, to improve electrical conductivity and helping to reduce the risk of electrostatic discharge, it is sold for between $7,000/t and US$12,000/t for high-end applications.

Market for Graphite Products and Outlook

Worldwide demand for natural and synthetic graphite is expected to continue increasing as more non-hydrocarbon energy applications, such as fuel cells, graphene, pebble bed nuclear reactors, and solar power, that use graphite are developed.

Batteries are the fastest growing market with demand forecast to grow 10 times from 2019 to 2030 according to Bloomberg, owing to growth in portable electronics and EVs. Roskill predict a 23% to 27% growth each year to 2028. Graphite is used in battery anodes with silicon oxide.

Expanded graphite is another market expected to grow, for applications such as for fire retardation, insulation, and heat transmission. Expanded graphite is used to produce graphite foil which acts to decrease heat loss or in fire stops around fire doors.

Sufficient graphite reserves exist to meet expected demand but according to 'Graphite Miners News' prices need to rise to incentivize new projects to attract funding.

客戶可能需要特定的薄片尺寸分佈和碳含量。例如，電動汽車行業的中國製造商需要 94% - 97% 的碳 -100 目片狀石墨，他們將其升級到 99.9% 的純度，以製造用於鋰離子電池的“球形”石墨。球形石墨的平均售價約為 3000 美元/噸，經過二硫化物塗層以提高導電性並有助於降低靜電放電風險後，用於高端應用的售價在每噸 7,000 美元至 12,000 美元之間 。

石墨產品市場及展望

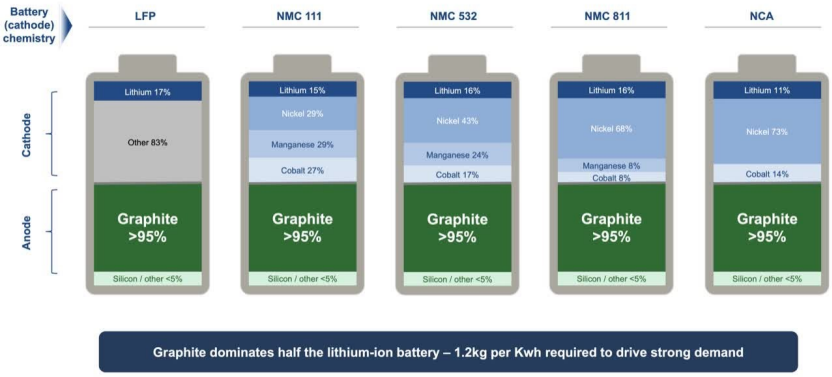
隨著更多使用石墨的非煙能源應用（例如燃料電池、石墨烯、球床核反應堆和太陽能）的開發，預計全球對天然和合成石墨的需求將繼續增長。

根據彭博社的數據，電池是增長最快的市場，由於便攜式電子產品和電動汽車的增長，其需求預計從 2019 年到 2030 年增長 10 倍。 Roskill 預測，到 2028 年，每年的增長率將達到 23% 至 27%。石墨與氧化矽一起用於電池陽極。

表1; 石墨產品分類

膨脹石墨是另一個有望增長的市場，用於阻燃、絕緣和傳熱等應用。膨脹石墨用於生產石墨箔，其作用是減少熱量損失或防火門周圍的防火。

現存有足夠的石墨儲備來滿足預期需求，但根據“石墨礦業新聞”的說法，價格需要上漲以激勵新項目吸引資金。



Ingredients in EV batteries (Source: Nouveau Monde Graphite)
電動汽車電池中的成分 (來源 ： Nouveau Monde Graphite)

Rockhound is a HK based company set up to serve the minerals industry in the Region. The company offers technical valuations and services in the natural resources sector.

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Elate Holdings Limited **誼礫控股有限公司(0076.HK)**

The Group's businesses primarily consist of (i) manufacture and sales of graphite products worldwide, (ii) manufacture and sales of electronic products in the United Kingdom, and (iii) development of multi-media production and movie making.

The Company has been engaged in the manufacture and sales of graphite products worldwide for more than a decade. The graphite business operations are considered as the Company's main path for profit growth. The customers include steel mills, lithium battery companies, refractory material companies and users of graphite products in China and around the world.

The Company's electronic manufacturing services are operated by its wholly-owned subsidiary Axiom Manufacturing Services Limited in the United Kingdom ("Axiom"). Axiom offers comprehensive contract manufacturing services, from design of electronic products to manufacturing, to the medical, national defense, transportation, aerospace, security, maritime and natural gas industries and other sectors. The electronic products of contract manufacturing and design are usually labeled with customers' brand names. Axiom's customers are mainly located in the UK.

The Company's cultural and multi-media business operations include motion picture production, television and online programming, and introduction of valuable foreign movies to Mainland China, etc. The production of the Company's first movie, "Pegasus", a black-humor feature film with an anti-war and anti-nuclear weapons theme, was completed in 2018.

中國石墨集團遞交香港上市申請 2021年6月1日 <FINET 財華社>

中國石墨集團於6月1日已向香港聯交所提交上市申請，並發出初步招股文件。

中國石墨集團於中國銷售鱗片石墨精礦及銷售球形石墨，主要從事石墨加工製成鱗片石墨精礦及球形石墨。根據弗若斯特沙利文報告，2019年，集團於中國鱗片石墨精礦行業銷售收入排名第五，市場份額約2.9%；及於中國球形石墨行業排名第六，市場份額約2.9%。

由於集團的鱗片石墨精礦碳含量高，集團相信其適合用於耐熱物料及製成球形石墨，其廣泛用作電子裝置及新能源汽車鋰離子電池的負極材料。集團亦銷售微型石墨粉及高純度石墨粉。

2019年，集團取得黑龍江北山礦場的採礦權，開採的未加工石墨僅供該集團自用而開採。根據獨立技術報告，北山礦場在石墨資源方面由約1400萬噸控制資源量及約100萬噸推定資源量組成，估計礦場年限約為21年。項目讓集團能夠獲取有保障及穩定的未加工石墨資源，及自垂直整合的協同效應獲得利益。

報告指出，集團的露天開採法更具成本效益、更環保及更安全。考慮到鋰離子電池全球需求增加，加上很多黑龍江石墨實際在山東加工成為市場趨勢，集團相信在黑龍江經營綜合石墨生產公司的業務模式仍具強大優勢。

2020年集團收益近1.69億元人民幣，同比增長36.4%；年內溢利近0.38億元，同比增長54.2%；毛利0.83億元人民幣，同比增長40.1%，其中來自銷售鱗片石墨精礦逾0.45億元，來自銷售球石墨及其副產品佔近0.35億元。經營活動淨現金流入逾0.24億元，增長118.3%。集資用途主要用於土地收購，建設，購買和安裝機器設備。

根據弗若斯特沙利文報告，鱗片石墨精礦銷售收益於2020年的估計近25.1億元人民幣，預期2025年增加至38.1億元。中國球形石墨的銷售收益於2020近22.2億元，複合年增長率約為20.7%，估計至2025年增至44.8億元，複合年增長率約為13.5%。

信部發布數據顯示，6月全國電池製造業主要產品中，鋰離子電池完成產量16.3億個，按年增長14.2%；鉛酸蓄電池產量2,045.2萬千伏安時，按年增長17.1%；原電池及原電池組(非扣式)產量36.2億個，按年增長15.3%。

Tanzania: graphite concentrate mines

02 Jun 2021 <Sahel Intelligence>

South Korean steel giant POSCO now owns a 15% stake in Black Rock Mining Limited, a mining company active on the Mahenge Liandu graphite project in Tanzania.

According to details released by Black Rock Mining on Tuesday, the South Korean company will hold a director position on the board of directors, as long as its stake in the mining company does not fall below 10% .

The Mahenge project has a production capacity of 7.4 million tonnes of graphite concentrate over a 26 year life.

Tirupati Graphite develops 'ground-breaking' graphene-aluminium (Al-Gr) composite (excerpt)

04 May 2021 <Graphene-info>

Tirupati Graphite has announced that its research center has developed a 'ground-breaking' graphene-aluminium (Al-Gr) composite, which reportedly exhibits significantly higher conductivity and strength properties over aluminium and could be used as a substitute for copper.

The specialist graphite and graphene producer said it was engaged with potential end users including a FTSE100 company for the composite's potential use replacing copper in thermal, power and propulsion systems, providing significant environmental advantages owing to reduced weight.

...

The graphene-aluminium composite retains aluminium's key properties including its light weight, whilst adding properties from graphene including increased thermal conductivity, electrical conductivity, and improved mechanical properties; the properties that generally make copper a preferred material in electrical and thermal conductivity-based applications, it said.

The composite has shown superior thermal conductivity and more than 95% of copper's electrical conductivity to date, which the company said it anticipates can be increased with further optimization of the material.