The City of London – a walk through geological time

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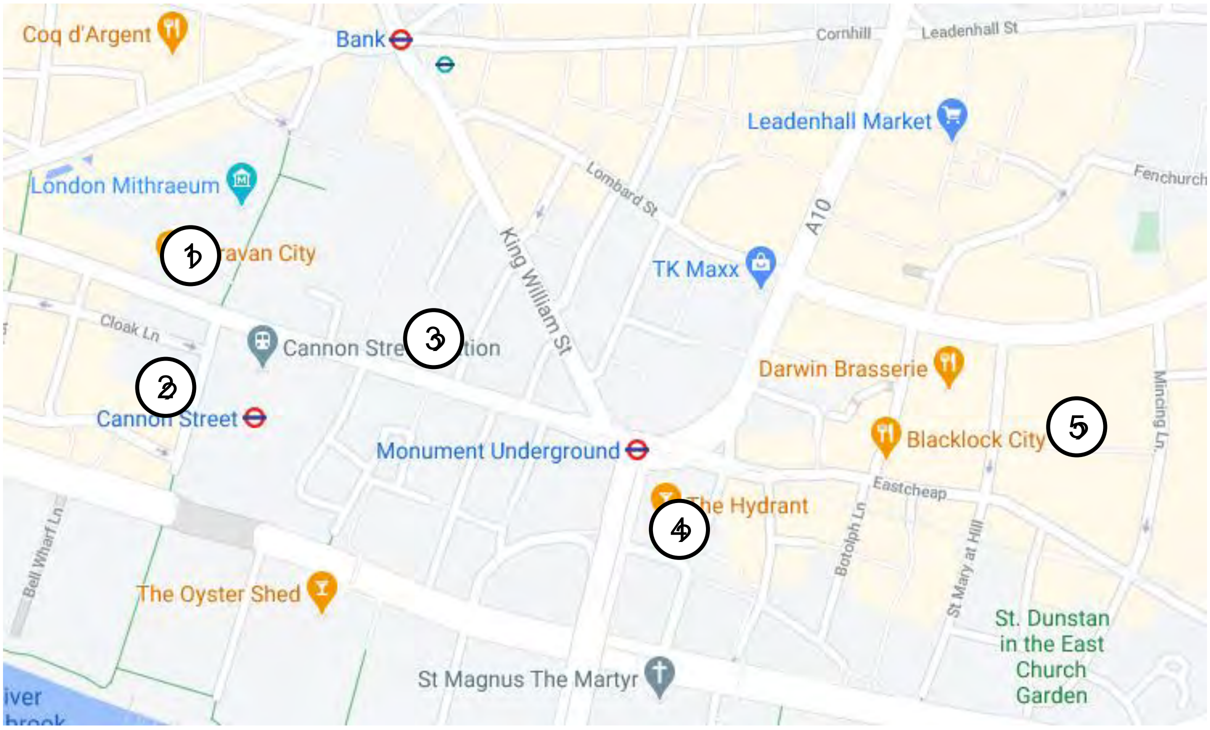
This walk is designed to take you through geological time, from some of the world's oldest rocks to some much more recent examples. Specifically, it tells a part of the story of one of the most important events in British history – the Caledonian Orogeny, where the British Isles were forged together by the collision of two continents.

The walk has five stops and, depending on the length of time spent at each stop, should take not more than 1 hour to complete.



Acknowledgments

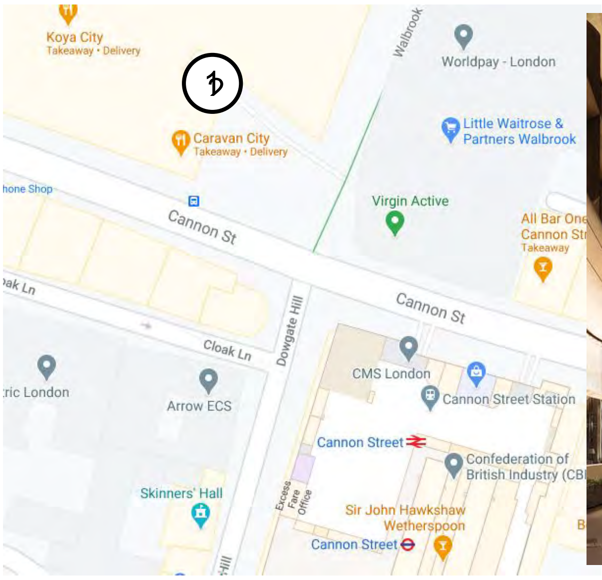
When planning this walk, I have relied upon the excellent *London Pavement Geology* website of Dave Wallis and Dr Ruth Siddall (http://londonpavementgeology.co.uk/). This is a compendium of information on building stones in London and elsewhere, as well as a helpful interactive map. The website also exists in app form, for iOS and Android, and I would strongly recommend this resource to the interested reader.

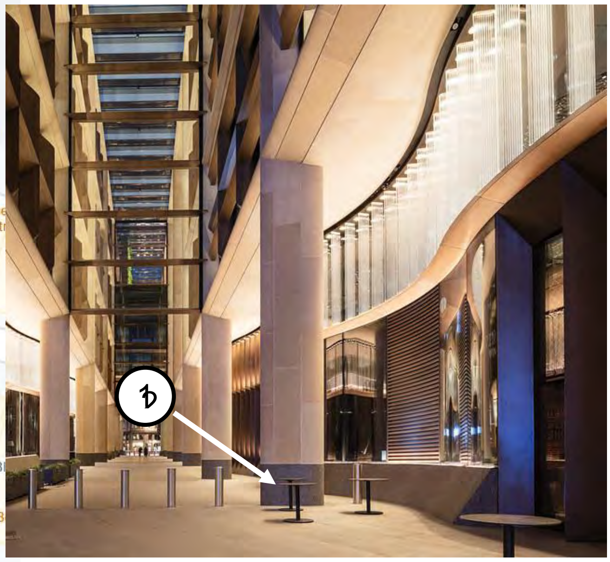
Ruth Siddall also has several guided Urban Geology walks available on her website (https://www.ucl.ac.uk/~ucfbrxs/Homepage/UrbanGeology.htm). I have found these guides to be immensely helpful in preparing this walk. On the occasions where this

walk intersects one of her guided walks I provide the relevant link, and strongly encourage the reader to consult these guides.

Locality 1: Bloomberg Arcade

From Cannon Street Station, head to the left across Cannon Street to the open arcade with restaurants and a water feature.



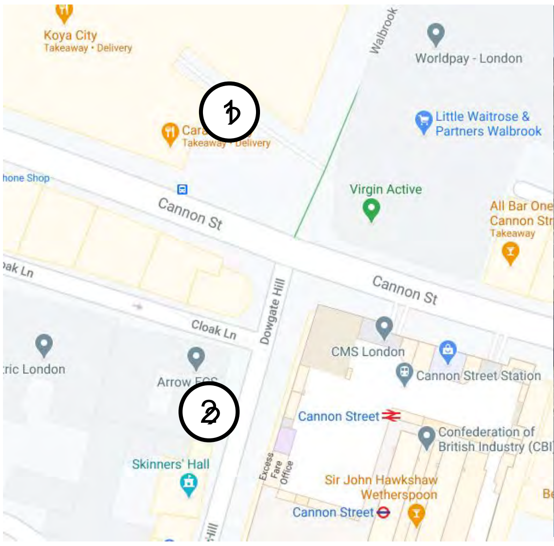


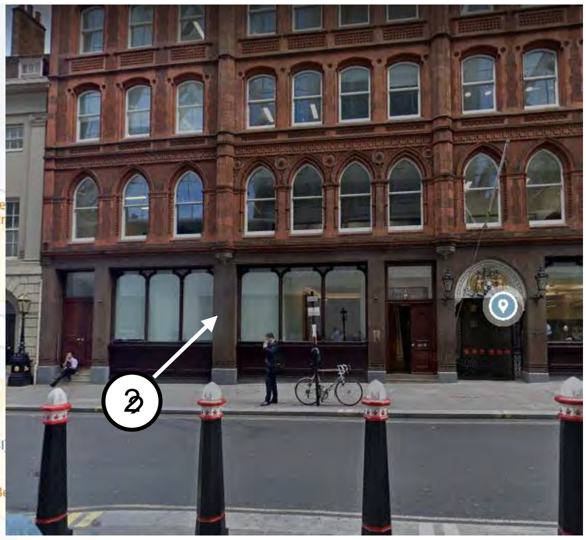
The Earth’s oldest rocks, having witnessed billions of years of plate tectonic activity, are notoriously hard to decipher but can provide evidence for the planet’s early processes. Most ancient rocks are crystalline – comprising a mosaic of interlocking crystals – as these igneous and metamorphic rocks are hardier and more abundant than sedimentary rocks, and thus more able to stand the test of time. Collectively, we refer to all ancient crystalline rocks which underlie more recent sedimentary and volcanic strata as the ‘basement’. Basement rocks form at depth within the crust, either through the crystallisation of magma (i.e. igneous rocks) or by high pressures and temperatures which cause rocks to form new crystals without melting (i.e. metamorphic rocks). Because they form deep underground, special tectonic events are required to expose the basement to the surface, such as faulting or exhumation (lifting up the land due to tectonic processes).

Although some ‘basement’ rocks have formed quite recently in Earth’s history, much of the Earth’s continental crust is extremely ancient. The brown coarse grained crystalline rocks comprising the base of the pillars of Bloomberg Arcade are from Southern India and are at least 1 billion years old (1000 million years) but may be as old as 2.5 billion years – over half the age of the Earth. The rock consists of several minerals, including quartz, feldspars, and pyroxene, and is classified as a *charnockite* – a metamorphic rock containing these minerals which formed by the solid re-crystallisation of rock at extremely high temperatures (>800°C) and pressures (4 to 12 kilobars – the equivalent pressure exerted by of a column of rock 1 m wide and 10 to 40 km high). Rocks of this kind underlie much of Southern India and many other continents, forming stable land masses called *cratons*.

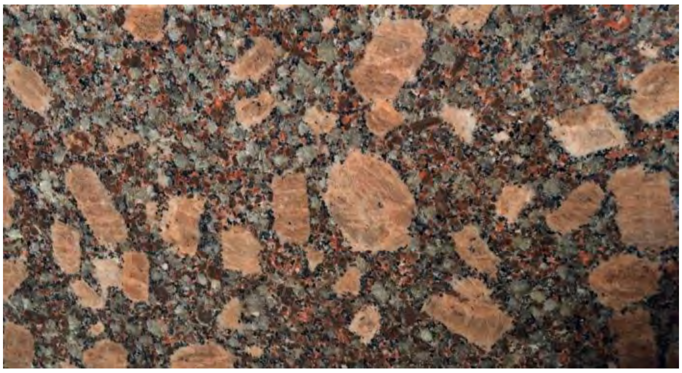
Locality 2: Tallow Chandlers' Hall, Dowgate Hill

Walk back towards Cannon Street Station. Dowgate Hill is the road to the right-hand side. Tallow Chandlers' Hall is on the opposite the side entrance to Cannon Street Underground station





The rock which forms the pillars here is Shap Granite, from the edge of the English Lake District. This rock formed during the early part of the Devonian period around 415 million years ago after the continents of Avalonia (which included Southern Britain) and Laurentia (including Scotland and N. America) finally collided during *the Caledonian Orogeny* (an 'orogeny' is a mountain-building event which occur when continents collide with other continents). The resultant heat associated with this collision caused the rocks at the bottom of the crust to melt to from magma. These buoyant magmas rose through the Earth's crust to pool in magma chambers several kilometres beneath the surface, where they slowly cooled to form coarse-grained granites. After millions of years of erosion, parts of these magma chambers are observed at the surface and today these Caledonian granites are widely used as decorative building stones and for aggregate. Shap Granite can also be found in the bollards outside St Paul's Cathedral.

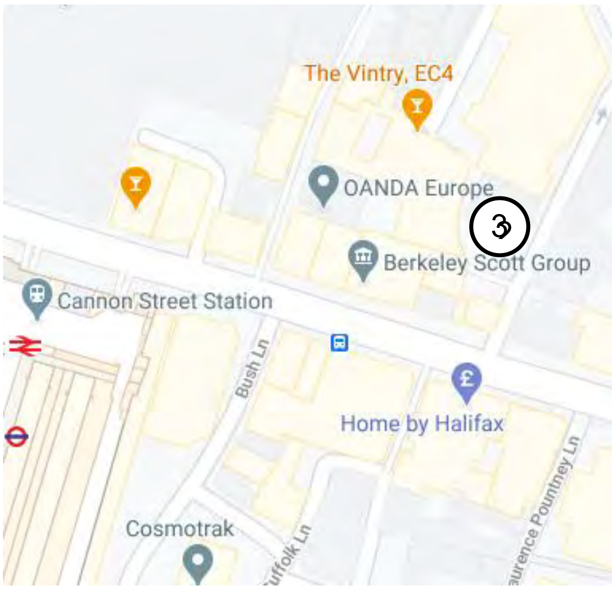


Shap Granite, with large pink potassium feldspar 'megacrysts'

One of the striking features of the Shap Granite is the centimetre-scale pink-brown potassium feldspar crystals distributed throughout the rock. These ‘megacrysts’ are quite common in granites. The classical explanation for their formation is that these crystals were the first to grow from the magma as it cooled, giving them more time to attain a larger size than the surrounding crystals. However, laboratory experiments have shown that in fact, these potassium feldspars crystallise *last*, after most of the smaller crystals surrounding them had already formed and the magma had nearly completely crystallised. It’s has been suggested that these large crystals grew by many successive cycles of heating and cooling of the granite close to its freezing point at around 650 to 700°C. Injections of hot magma into the cooling magma chamber could temporarily heat the nearly-solid magma enough to melt smaller crystals. Upon cooling, rather than re-grow these small crystals, the larger crystals grow larger. This process, called ‘Ostwald ripening’, is the same process which causes ice cream to become gritty and crunchy over time – repeated warming and cooling causes some ice crystals to grow larger.

Locality 3: Abchurch Yard

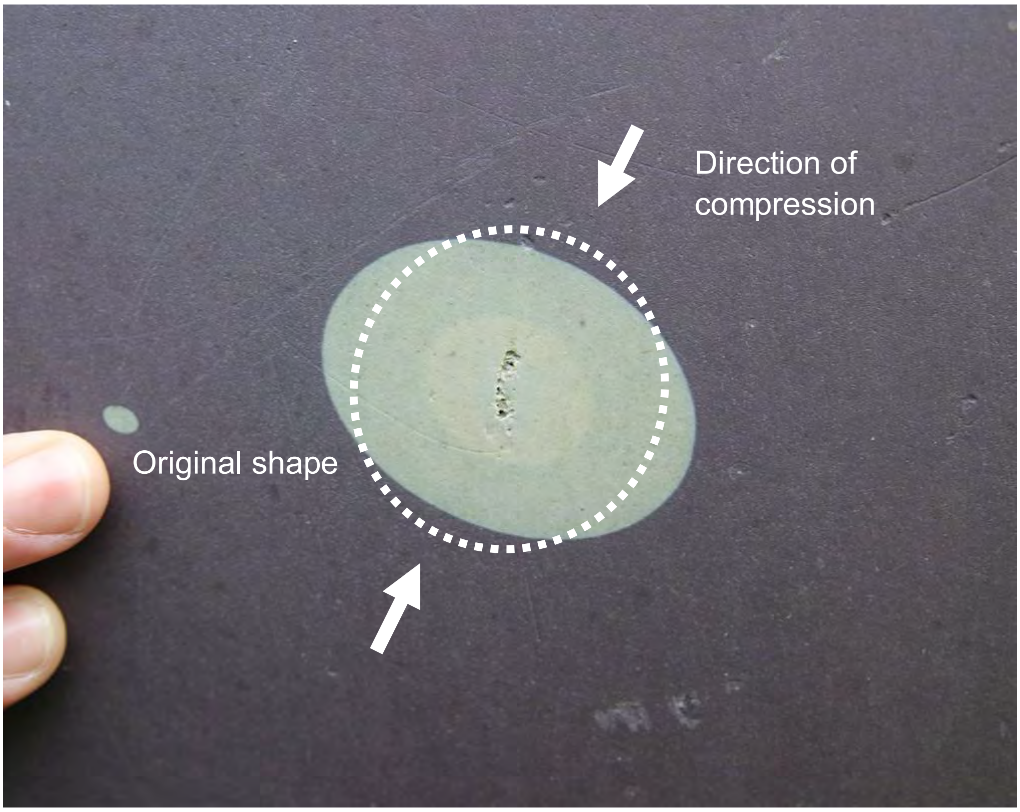
Continue down Cannon Street towards the City. Take a left on Abchurch Lane, and head left into Abchurch Yard



The purple paving slabs that make up much of the circular pattern on the floor of Abchurch Yard are the focus of this stop and are made of slate; a stone commonly used for roof tiles and paving slabs. Much of the slate quarried in the UK comes from Penrhyn and Dinorwic quarries in Snowdonia, Wales. The name 'Dinorwic' translates as 'Fort of the Ordowices', the Welsh tribe from which the Ordovician geological period takes its name. In fact, these rocks have their origin in the Cambrian period (~500 million years ago), where they were laid down as mudstone sediments in the deep waters of the Iapetus Ocean, which existed between the continents of Avalonia and Laurentia. In places, faint horizontal bands can be seen on the surface of the slate, which represent the original sedimentary layers.

During the Caledonian Orogeny, the Iapetus Ocean was closed, and these sediments were caught in the continental collision and subject to heat and pressure, where they were metamorphosed to form slate. Slate is a widely used paving stone because it cleaves into flat sheets, and these 'slaty cleavage' planes have their origin in compressional metamorphic processes. The heat and pressure cause flat microscopic minerals (e.g. micas) present in the original sediment to recrystallise perpendicular to the direction of squeezing. On a macroscopic scale, this forms the easy breaking surfaces which make slate a useful stone.

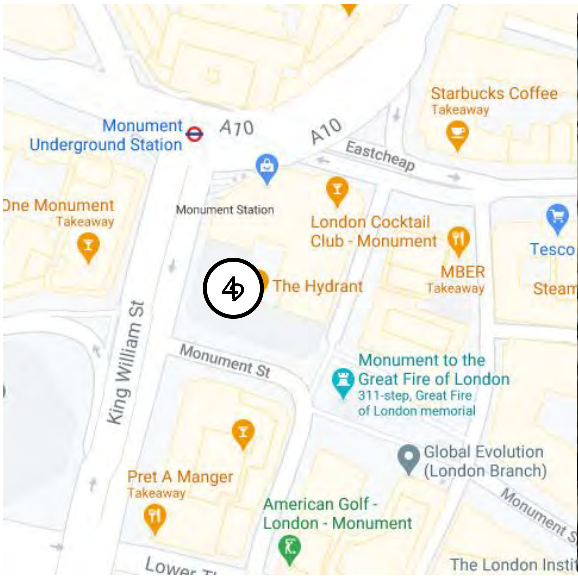
On further inspection, small oval green spots <1 to 2 cm in diameter can be seen marking the rock in several places. These pale spots record local chemical changes in the rock, where iron-rich minerals are 'reduced' by small amounts of organic matter (chemical reduction is the opposite process to 'oxidation' or rusting of iron). Little holes in the centre of reduction spots mark the original location of this organic material. These reduction spots were originally circular in cross section but have been significantly deformed into ellipsoid shapes by the strength of squeezing during the continental collision. The direction of this compression indicates the relative movement of the continents as they collided, meaning by studying the shape of these strain ellipses and the orientation of the slaty cleavage planes, geologists have been able to reconstruct the position and motion of the plates during the orogeny.



The shape of reduction spots (green) indicate the direction of continental collision, and help reconstruct the tectonic map during the Caledonian Orogeny.

Locality 4: The Monument and its surrounds

Continue along Cannon Street to the square surrounding the Monument – a large Doric column topped with golden fire



The Monument to the Great Fire of London, designed by Christopher Wren, and celebrated scientist Robert Hooke, is a famous City landmark and once the tallest building in London. The Monument commemorates the Great Fire of 1666, which began on Pudding Lane just to the east of the tower. As well as memorialising the fire, the Monument also doubled up as a scientific instrument. The central staircase contains a hollow core which extends through the monument from the top to a room below pavement level, from which a fixed point in the sky can be observed, allowing accurate celestial observations to be made (a zenith telescope) in additional to enclosed experiments with pendulums. Also, the steps of the tower are equally tall, meaning accurate changes in barometric pressure could be made.

The Monument and its surrounds contain some interesting building stones. Both the paving stones immediately surrounding the Monument and the walls of the glass-encased public lavatory block to the east are composed of Caithness Stone from Scotland, which formed in the aftermath of the Caledonian Orogeny. After the tectonic compression had ceased, the great mountains produced in the collision began to collapse due to gravitation instability. Large sedimentary basins began to form between the mountains, which eroded into lake and river systems forming in these basins. One example of this is the Orcadian basin in Northern Scotland, from which the Caithness Flagstones are derived. This Caithness Stone formed in a shallow lake around 370 million years ago during the Devonian period. Several fossil fish are preserved in some layers of the Caithness group, although few examples are apparent around the Monument. However, evidence for bioturbation (burrows and channels formed by small creatures) can be seen as positive relief bumps and lines on the surface of some paving stones.

These rocks form part of a group of strata referred to as the Old Red Sandstone; ‘old’ to distinguish it from the younger Triassic New Red Sandstone, and red in colour (notably lacking in the Caithness stones) due to oxidised iron coating the sediment grains. This group of rocks was important source of data for early palaeontologists and is the upper (overlying) part of James Hutton’s famous unconformity at Siccar Point.

The Caledonian Orogeny was followed by several other mountain building events both in Europe and around the world, which formed the supercontinent of Pangaea. By the Jurassic period (200 to 150 million years ago), Pangaea had begun to break up, leaving an extensive coastline fringed by shallowly submerged continental shelves. In the tropics (where much of present-day Europe was to be found) this led to an abundance of warm shallow seas teeming with marine life, the calcic remains of which formed large deposits of limestone throughout Europe.

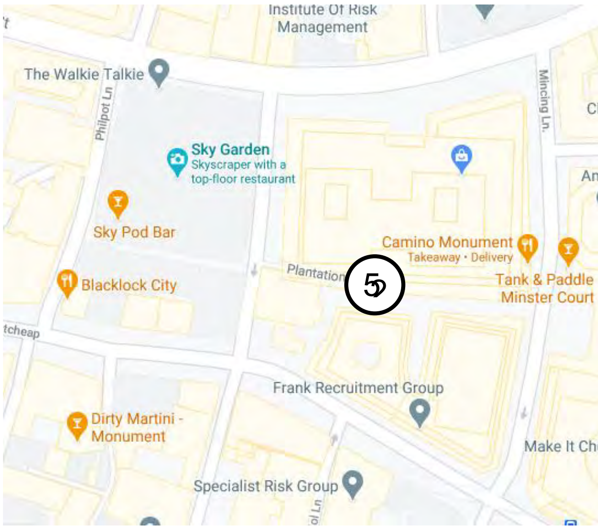
In Britain, an important Jurassic limestone is the Portland Stone from Dorset, of which the Monument is constructed. Portland Stone is one of the most popular building stones in Britain, forming the imposing walls of the Bank of England, Buckingham Palace, St Paul’s Cathedral to name only a few. A close inspection of the Monument with a hand lens will reveal that much of the rock is made up of tiny, rounded particles. These are called ‘ooids’, and form by an inorganic process of calcium carbonate precipitation directly from seawater onto a small clast or shell fragment, in a high energy marine environment (i.e. close to the shore). Additionally, large numbers of bivalve and oyster shell fragments can be observed, especially in the columns of the building to the south of Monument Square (near the Caithness-bedecked public lavatory). Although full of fossils, there are a limited number of marine species present in these rocks, possibly suggesting a locally high water salinity.

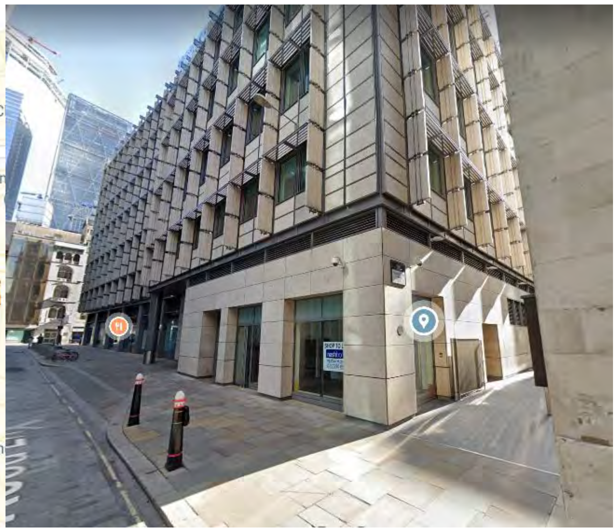
For more information on the rocks of the Monument, see Ruth Siddall's guide:

https://www.ucl.ac.uk/~ucfbrxs/Homepage/walks/Eastcheap.pdf

Locality 5: Plantation Lane

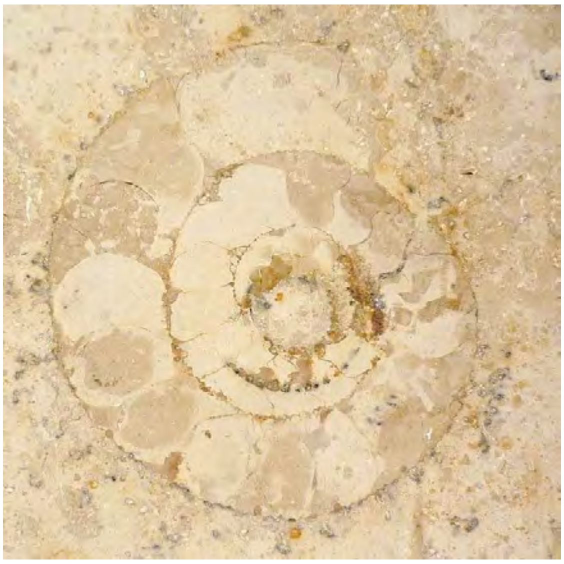
From the Monument, head up past Monument Underground Station, and right along Eastcheap. Turn left on Rood Lane, and enter the pedestrianised Plantation Lane to your right





The building on the north side of Plantation Lane is faced with another Jurassic limestone, this one called the Jura Marble from Germany south of Nurnberg. This limestone contains abundant fossils, including cephalopod ammonites and belemnites, sponges and corals, and it's worth lingering to spot a few.

Belemnites are a squid-like creature with a cone shell. The soft tissue, which included 10 tentacles, is rarely preserved including in the Jura Marble, but the rostrum is readily fossilised. Depending on the orientation in the rock, they can be seen as straight cones (as in the example below), or round coin shapes with a central point.

Ammonite (left) and belemnite (right) from the Jura Marble

Ammonites have coiled shells similar to nautiloids, although they are more closely related to octopus and cuttlefish than nautilus. Ammonites are distinguishable from other cephlapods with similar shells by their elaborate and complex suture lines - where the walls of the inner chambers, or ‘septa’, meet the outer shell. These can be seen here with careful inspection of some examples.

Once again, further information can be read in Ruth Siddall’s guide:

https://www.ucl.ac.uk/~ucfbrxs/Homepage/walks/Eastcheap.pdf