## Never in the field of urban geology have so many granites been looked at by so few!
## *A stroll along the Victoria Embankment from Charing Cross to Westminster & Blackfriars Bridge*

***Ruth Siddall & Di Clements***

This walk starts outside Charing Cross station and then turns down Villier's Street to the Thames Embankment. The walker then must take a choice (or retrace their steps). One may either follow the Embankment east along the River Thames to Blackfriars Bridge, taking in Victoria Embankment Gardens and Cleopatra's Needle on the way. Alternative, one may turn westwards towards Westminster and take in the RAF Memorial and the new Battle of Britain Memorial. A variety of London transport options can be picked up at the mainline and underground stations at either ends of the walk.
The inspiration for this walk is a field trip that Di Clements led, on behalf of the Geologists' Association, for the Department of Energy & Climate Change (DECC) on 18th September 2014 (Clements *pers*. *comm*.). Although the main focus of this walk is the embankment, we will also encounter a number of buildings and monument en route. As ever, information on architects and architecture is gleaned from Pevsner (Bradley & Pevsner, 1999; 2003) unless otherwise cited.

By far and away, the main rock we will encounter on this walk is granite. Granite comes in many varieties, but always has the same basic composition, being composed of the major rock forming minerals, quartz, orthoclase and plagioclase feldspar and mica, either the variety muscovite or biotite or both. The theme can vary based on the overall colour, mainly imparted by the feldspars and the grainsize of the rock. Granite can be composed of fine (<5 mm) to coarse-grained (>1 cm) crystals of the constituent minerals. They are usually at least medium grained and so the minerals can be seen with the naked eye, and certainly with the use of a hand lens. Granites may also be megacrystic, that is they contain large (>2 cm), well formed crystals of orthoclase feldspar, which stand out from a usually finer grained groundmass. These megacrysts may be aligned or randomly orientated throughout the rock.


*Victoria Embankment, underneath Hungerford Bridge.*

*Leave Charing Cross and walk out across the forecourt to the east and turn left into Villiers Street. Turn into Villiers Street which runs down to the river from the Strand. Named after George Villiers, 1st Duke of Buckingham, who's London home, York House was sited to the east of the street. Villiers Street is know to have existed since the early 17th Century, but there are no remains of that period here now. On the west side, the building work is dominated by modern architecture, which will be discussed below. On the east side, remnants of 19th century shops and warehouse still remain, now mainly cafés and pubs.*

**The Arches**

The entrance to The Arches shopping mall, beneath the station is part of the large building erected in 1990 called Embankment Place which envelopes the River-facing frontage of the Victorian station.

The black stone is a gabbro. Close inspection shows it not to be totally black in colour, but mottled with randomly orientated paler grey plagioclase feldspars, the size of grains of rice. This textures marks this stone out as coming from the Bushveld Complex of South Africa, the largest igneous intrusion on Earth. This is the variety known as **Belfast Black**. The town of Belfast (Emakhazeni) is located on the eastern part of this enormous intrusion. The stone is quarried at Wapadskloof, to the north of Belfast, from the Rustenberg Layered Suite of gabbros, and is one of the darkest coloured rocks quarried in this region. These are also ancient stones; the Bushveld Complex was intruded 2 billion years ago. The stone has been quarried since the early 1960s. The coarse-grained, bronzy stone is a charnockite. Charnockites are Precambrian rocks which are essentially pyroxene-bearing granites, and unusual composition with respect to Phanerozoic granites. The jury is out on the origin of charnockites, however what is clear is that they have had both igneous and metamorphic histories. Charnockites are associated with the cratons and despite being very much ignored in Geology 101 (most igneous and metamorphic text books pretty much ignore them) they are very commonly encountered on the high street, being handsome, decorative stones, capable of taking a high polish. Large, blotchy potassic feldspars are a feature of charnockites and they are often, as in this case, the blue-green variety microcline. Also present are quartz, orthopyroxene, amphibole and garnet. It is overall a dark grey-green colour, but is characterised by flashes of bronzy gold in the sunshine. This charnockite is almost certainly the variety **Verde Ubatuba** from near São Paulo in Brazil, a 565 million year old granitoid associated with the Neoproterozoic Brasiliano mountain building phases. The most famous 'outcrop' of this stone is the base of the famous statue of Christ which stands on a mountain top overlooking Rio de Janeiro (Price, 2007). It is slightly more accessible here on Villier's Street.

**1, Embankment Place**

Built in 1990 and designed by architects Terry Farrell & Partners, Embankment Place is a classic of post-modern architecture and is a London landmark, rising above Charing Cross Station like a giant proscenium arch. The entrance here on Villiers Street provides an opportunity for examining the granites used on the cladding at pavement level. The post-modernist movement brought a level of theatricality to buildings, with decorative features sometimes referencing other styles with ornamental details. This movement was responsible for the fashion in cladding buildings with exotic, and sometimes gaudy granites sourced from the Precambrian basements of India, Africa and Brazil. The monumental entrance to Price Waterhouse Cooper's offices are at 1, Embankment Place faces onto Villiers Street.

A polished stone block at the front bears the Price Waterhouse Coopers' logo. This is of a very black dolerite which takes a mirror-like polish. The origin is not confirmed but it is most probably **Nero Zimbabwe**, one of the most consistently black stones available on the market. As the name suggests, this comes from Zimbabwe. A vast region to the west and south west of the capital Harare is intruded by the Proterozoic (1.87 Ga) Mashonaland sill complex which has been widely quarried since the 1970s. Although there are variations in grainsize, the rock is remarkably homogenous, being composed of augite, hornblende, plagioclase feldspar and magnetite. The large quantities of magnetite present are largely responsible for the black colouration.

The massive columns have bases clad in 'rice-grain' **Belfast Black** as seen at The Arches above. Above these, and on the walls of the enormous porch are stripes of light grey and dark grey granite. The light grey stone

is **Sardinian Grey Granite**, also known as Grigio Sardo. This is so-called biotite monzogranite, containing larger crystals of greyish, sometimes slightly pinkish orthoclase feldspars in a medium grained matrix of white plagioclase, black biotite and grey quartz. Monzogranites contain approximately equal amounts of plagioclase and orthoclase. This stone is quarried from near the town of Buddoso in NW Sardinia and is derived from the eponymous Buddoso Pluton. Like the other granites of the Corso-Sardinian Batholith, the Buddoso Pluton was emplaced during the Variscan mountain-building event at c. 290 Ma (Barbey et al., 2008). Sardinian Grey Granite is also used, rough dressed, on the paving of the porch.

The third stone used is dark grey and has unfortunately suffered staining from water. Also unfortunate is the fact that the origin of this stone is unknown. It is a greenish grey in colour and coarse grained, composed of large, aligned feldspar phenocrysts in matrix of more feldspar, grey quartz and black biotite. Very obvious are the Carlsbad twins present in the large feldspars, revealed by one half of the crystals showing different levels of reflectivity than the other.

A row of black and white, polished, stone balls appeared along the frontage of 1 Embankment Place in October 2014 (below). The white balls are probably **Sardinian Grey Granite** and the black balls appear to be a porphyritic basalt, with polygonal euhedral phenocrysts of pyroxene and grey green olivines. This bears a strong resemblance to the Cretaceous basalts of the Shimaoshan Group, quarried in Fuding Province, SE China. This basalt, marketed as '**Black Pearl**' is not frequently seen polished, but it is used widely for paving and setts.

*1, Embankment Place with the newly installed granite balls (October 2014).*

*Walking further along Villier's Street, we reach the approach to Embankment Station (closed for major refurbishment at the time of writing). On the right hand side is Carrara House.*

**Carrara House**

There are no prizes for guessing the main building stone used on the façade of Carrara House, built in 1958-60 by architects J. Seymour Harris & Partners to house their own premises. Now dated, rather grubby Italian marble from the Alpi Apuane is used to clad the upper stories of the building. Carrara marble does

not do particularly well in northern climes, tending to discolour and even warp. The variety used here is white with grey streaks, which is fairly bog-standard Carrara marble known as **Bianco Carrara**. The grey streaks are coloured by variable amounts of pyrite. The lower storeys of this building and the entrance to the underpass beneath Embankment Place are clad with an ivory-coloured, relatively coarse-grained oolitic limestone. This stone was probably sourced from the Lusitanian Basin of Portugal where a large number of quarries work the Jurassic Valverde Formation producing stones that are marketed as **Mocha Crème** and Semi Rijo.

*Take an excursion to the right (east) into Victoria Embankment Gardens, past the decorative bandstand and follow the path around to the left to the York House Watergate, which is sunk below the level of the gardens and therefore the Embankment.*

**York House Watergate**

Victoria Embankment Gardens occupy the new land reclaimed by the embanking process and they were laid out by eminent Victorian landscape designers Alexander McKenzie and Joseph Meston. Of principal interest here is the York House Watergate, erected in 1626-7, designed to give access from the gardens of York House, home of George Villiers, 1$^{st}$ Duke of Buckingham, to the river. Now this is all that is left of this estate. It is not clear who the architect was. Pevsner records that Nicholas Stone, Balthazar Gerbier and, indeed, Inigo Jones are possible contenders. However we see an example of the early use of Portland Stone in London's architecture. This is a very weathered and pitted, but the presence of fossils identify it as **Portland Whitbed**. The York House Watergate is a useful landmark for visualising the pre-embankment Thames, marking the position and approximate elevation of the river bank in the early 17$^{th}$ Century.

The Gardens are well laid out and maintained and are worth taking a turn around both their exotic planting (banana trees) and a number of memorials of historical interest, but not of much geological interest. Worth a look is the monument to the Camel Corps with a bronze rider on a plinth of **Portland Stone** and Robert Burns, seated on a large plinth of salmon pink **Peterhead Granite**.

*Return to Villier's Street and take the road beneath Embankment Place and the railway. Note the columns clad in* ***Verde Ubatuba*** *supporting the roof. Turn left and cross the road.*

*We will now take a diversion to learn more about the building of the Victoria Embankment and the diversity of the main buildings material used; granite.*

**The Embankment**

The Victoria Embankment was constructed between 1865 and 1870 and stretches from Westminster to Blackfriars Bridge (Clifton & Porter 1988). The construction of the Thames Embankment was one of the greatest civil engineering projects of the Victorian age, controlling the river, preventing flooding and considerably reducing the flow of effluent into the river. The new strip of land created by embanking contained the Metropolitan Line, as well as sewers, below ground and made room for gardens and roadways on the surface. Prior to embanking, the tidal Thames left substantial beaches and shifting shoals in the river. The Times in 1864 lauded the fact that *'thirty-four acres of slime'* would be reclaimed by a *'wall of solid masonry, with a handsome parapet and bold granite mouldings*' (quoted in Oliver, 2000). Along with improved navigation along the river, the main driving force behind embanking the Thames was to improve London's sanitation, and with it put an end to outbreaks of cholera. John Snow's discovery during the 1854 epidemic that cholera was spread via drinking water contaminated with raw sewage was a major impetus for this project. However the final straw came with drought in the hot Summer of 1858 creating the 'Great Stink' emanating from the open sewer that the Thames had become. As the foul vapours infiltrated the Houses of Parliament, politicians decided enough was enough. Legislation via the rapidly passed Metropolis Local Management Amendment Act (1858) enabled work to commence under the Municipal Board of Works (MBW), masterminded by their chief engineer Joseph William Bazalgette (1819-1891). The scope of this immense project is described by Hughes (2013), Oliver (2000) and Porter & Clifton (1988).

**The Granites of the Embankment**

Plans were drawn up, contracts and contractors were put in place and the works started. Granite was the main construction material used in embanking. It was hard, strong and resistant to water erosion. It was also expensive and other materials, such as cast iron, were considered by the MBW (Oliver, 2000). Vast quantities of granite were needed for the works and suppliers were sourced in Great Britain and abroad. Despite this and the fact that the procurement of such large quantities of granite posed considerable problems for MBW's project managers, the word 'granite' gets around six mentions in the papers cited above. As ever the geological sources of building materials is much ignored in the literature. Oliver (2007) however does shed some light on the building materials, both in terms of quantity and variety. 500, 000 $m^3$ of granite were used in the construction if the embankment along with 110, 000 $m^3$ of concrete, 60, 000 $m^3$ of bricks, 14, 000 $m^3$ of timber and 750, 000 $m^3$ of earth to back fill the construction. This article also gives a clue to one of the main origins of stone used, Dalbeattie in Scotland. But, it is quite clear from observation of the stones used that Dalbeattie is not the only granite used. Nevertheless, one thing that is clear from simply looking at the Embankment is that the brief was for buff to pale grey coloured stone. Strongly coloured pink or dark grey granites were not used.

Evidence of granite sources can be found by searching the available literature on quarries and looking on what is produced in their literature on supplying the embankment. Luckily this was an engineering endeavour that quarries were proud to be associated with and this was recorded in the literature[1]. Sources are Hull (1872), Howe (1910), Watson (1911) and Elsden & Howe (1923) who record important building stones in use in the capital and elsewhere. However these books are not always reliable. Readers should be

[1] One quarry company that did *not* supply granite to the MBW, despite it raising shares in the early 1860s on the (false) grounds that it was to be the sole contractor to the Victoria Embankment, was the short-lived Lundy Granite Company, which was only in operation between 1863-8 (Rothwell & Ternstrom, 2008). However, interestingly, and in contrast, Watson (1911) claims that '*the marine wall, facing the river is largely composed of immense blocks of* [Lundy Granite]'.

wary that errors are transmitted between authors and original sources may not have been reliable. In all it's a minefield, and then you have to relate the literary sources to what is actually observed. And then we were told that that parts of the parapet of the Embankment was added in 1938 (John Williams *pers comm*.) … and that the whole caboodle was raised in 1975 (DECC *pers comm*.), probably coincident with the building of the Thames Barrier.

The most likely granite sources are described below although not all have (yet) been identified by the authors along the Embankment. Also be wary that as the granite is not polished here, you need to look hard to see textures and minerals that may be diagnostic of the source. It was clearly part of the overall design of the embankment that pale coloured granites, very similar in appearance, were used in its construction. As such they are very difficult to distinguish!

***Dalbeattie Granite***

Dalbeattie Granite is mentioned in most sources as having been used in the Embankment. The granite comes from the Criffel-Dalbeattie Pluton, a 391 Ma zoned intrusion with five types of granite present, distinguished by the variation of the amounts of muscovite with respect to biotite and the presence or absence of the mafic minerals hornblende and/or clinopyroxene (below, left).

A contemporary (and therefore probably reliable) source on the Dalbeattie granite is Bremner (1869). Bremner tells us that '*Mr Hugh Shearer of London was successful in obtaining the first contract for supplying granite for the Thames embankment, and opened several new quarries on the Munches estate, reopening at the same time four quarries which had formerly been worked by the Liverpool Dock Trustees. Such is the beauty and durability of the stone that it is said the engineers of the Board of Works prefer it to any other; and Mr Shearer and the partners he assumed about a year ago - the designation of the firm now being Messrs Shearer, Smith, & Co. - have supplied, and are still supplying, many thousands of tons of material for the great work referred to*.' Stone cutting was carried out at the quarries: '*The stones for the Thames embankment are forwarded by rail, dressed and ready for the builders'*. Several quarries are referred to within the intrusion, but they are not named in Bremner's text. Although the general area for one group is given as that around Munches House, to the NE of the town, the 'four quarries' that had been worked for the Liverpool Docks were probably those situated at Craignair to the west of the town. All quarries work a medium grained granite which contains biotite, white plagioclase, grey quartz, variable amounts of hornblende and, distinctively, pale pink orthoclase feldspar.

*Dalbeattie Granite: note the presence of pale pink feldspars.*

***Dancing Cairns Granite***

The only Aberdeenshire granite that appears to be recorded as being used on the Thames Embankment is that from Dancing Cairns Quarry (Elsden & Howe, 1923). This is a medium-grained two mica leucogranite containing quartz, white feldspar, biotite, muscovite. Also abundant are xenoliths of dark-coloured, fine-

grained, biotite-rich schist (Dalradian metasediments at sillimanite facies). The delightfully named Dancing Cairns Quarry is located at Bucksburn Howe in the city of Aberdeen. It is part of the Aberdeen Pluton, intruded during the Caledonian mountain building phase at c. 470 Ma and much paler than its more familiar counterpart from Rubislaw Quarry. I have not identified Dancing Cairns granite in the Victoria Embankment.

***Cornish Granite***

Cornish Granites are widely used on the Thames Embankment and are also, mercifully, recognisable. The intrusion of anatectic, S-type granite, forming the Late Variscan Cornubian Batholith, took place between 300-270 Ma. The granites which form a continuous mass at depth, were intruded into low metamorphic grade Devonian-Carboniferous clastic sediments of the Rhenohercynian trough. This includes the Dartmoor Plutons in Devon (see below) as well as the Land's End, Carnmenellis, St Austell and Bodmin Intrusions as well as some smaller stocks, of which Kit Hill was the most important quarry site. Hull (1872) writes that Cheesewring Granite being used in the Thames Embankment. Bristow (2013) tells us that granite from Lamorna (Land's End Pluton), Cheesewring (Bodmin) and Kit Hill were all used in the Embankment. The use of De Lank Granite also from the Bodmin Pluton is recorded by Stanier (1996). It is likely that stone from the other major granite quarries in operation at the time was also used.

Land's End Granite from the Lamorna Quarries, like most of the stone extracted from the Land's End Pluton, characteristically contains megacrysts of white feldspar, often >10 cm in length and up to 20 cm. These are set in a brown, quartz-rich matrix. Such granites are only encountered in the Land's End and St Austell Plutons. Granites from the Carnmenellis and Bodmin Pluton are pale grey to silver, two-mica granites containing brick-shaped feldspars and often slightly brownish quartz. Stones from both of these plutons are variably porphyritic with 'small megacrysts'. i.e. feldspar phenocrysts of ~ 2 cm length, which are often aligned. However, many varieties are non-porhyritic. The presence of tourmaline in veins and pegmatites is probably diagnostic of a Cheesewring source. The Kit Hill granite deserves a mention here as it is a much ignored intrusion. It is a small stock, almost a kilometre in diameter which occurs near Callington, a few kilometres to the east of the Bodmin Granite, not far from the Devon Border. Bristow (2013) describes the appearance of the granite as 'nothing exceptional'; it is a biotite granite, very similar to those quarried on Bodmin Moor and in the Carnmenellis Pluton. However it was extensively quarried as widely spaced joints enabled the extraction of large blocks. Kit Hill granite was much used as an engineering stone and was used for docks, bridges and lighthouses in the British Isles and even exported to Singapore.

As there is considerable similarity between Cornish granites, for the sake of this guide we will simplify the Cornish Granites into three basic types; 1. Non-porphyritic granite (below left), which may be derived from the Carnmenellis, Bodmin or Kit Hill intrusions; 2; Small-megacrystic granites (below middle) from the same sources and 3. Large megacrystic granites (below right) from Land's End (or potentially St Austell) plutons.

*Left: Non-porphyritic granite; Middle: Small megacrystic granite; Right: Large megacrystic granite. All images are at the same scale.*

***Dartmoor Granite***

According to Watson (1911), Granite from Swell Tor Quarry, two miles to the west of Princetown was used during 1864-7. He describes it to be a 'light grey, porphyritic stone'. Images in the British Geological Survey's National Building Stone collection has granite samples purportedly from Swell Tor with variable textures, from porphyritic, so-called 'blue granite' to compact, fine grained aplites. As such, it is probably indistinguishable from the type 2, small megacrystic granites described from Cornish sources above.

***Killiney Granite (Wicklow Granite)***

Elsden & Howe (1923) mention that an Irish granite from Wexford was used in the embanking project. More information is gleaned from Hull (1872) who writes that granite from Killiney Hill (Dalkey Quarry) was used in great quantities on the Embankment. KIlliney is closer to Wicklow, but the granite mass from which it was extracted, the Leinster Batholith, extends from near Dublin to Pollmounty in Co. Wexford, thus stones extracted are often called Wicklow-Wexford Granite.

The Leinster Batholith is a late Caledonian granite, intruded during the Devonian, which has considerable variability over its entire outcrop. That quarried at Dalkey is a pale grey, medium-grained stone which may be foliated. Hull (1972) describes the mineralogy to be quartz, orthoclase, plagioclase, muscovite, with subordinate amounts of biotite, tourmaline and fluorspar.

***Brittany Granite***

Local literature relating to the extraction of granite at L'Aber Ildut in westernmost Brittany, France proudly relates that it was a supplier of stone to London's Thames Embankment (Chauris, 1995). This stone, sold as Laber Granite, is also recorded as being used in this project by Howe (1910) and Elsden & Howe (1923). Brittany is an unexpected source of granite for the Embankment project. Indeed, French granites rarely occur in British Architecture. Porter & Clifton (1988) allude to the financial crisis of 1866 and associated granite supply problems, and it may be at this time that appropriate granites were contracted from abroad.

Laber Granite is quarried at several quarries around Brest and is one of a suite of Variscan Granites intruded into the Armorican Massif at c. 300 Ma, the same age and mountain building event which was responsible for the Cornish granites. In appearance, it is very similar to British Shap Granite from Cumbria, having large pink orthoclase megacrysts in a medium-grained, greyish groundmass composed of white plagioclase, quartz and biotite. Perhaps distinctive are numerous and sometimes large enclaves of dark grey doleritic rock. These are known as '*crapauds'* (toads) by local quarrymen. Disappointingly I have not as yet spotted this granite in use on the Thames Embankment. It may occur in the yet to be investigated stretch between Westminster and Hungerford Bridge. However, its most famous use is for the pedestal on which one of the sisters to Cleopatra's Needle stands, in the Place de la Concorde in Paris.

*So now forearmed with some knowledge of granites, we may now descend to the Embankment. However you will probably be thinking that all these granites look the same, and you would not be wrong. Distinguishing and identifying the granites on the embankment is no easy task. Also we are restricted in view to the granites used in the parapet only. A canoe would be required to examine the Embankment's retaining wall along the water. Only Dalbeattie and the south west English granites are securely identified in this walk and represent the majority of stones used on the Victoria Embankment.*

**The Victoria Embankment**

As you turn onto the Embankment and cross the road to the River, you are confronted with foot high, gold letters spelling out VICTORIA EMBANKMENT, which is reassurance that you are in the correct place. This is carved into Cornish two-mica 'small-megacrystic' granite. This granite is also used for almost every plinth supporting the lamp posts all along the Victoria Embankment. The paving along the Embankment is **York Stone**. According to Oliver (2007), 40,000 $m^2$ of York Stone were procured during the construction of the Embankment. York stone is derived from a large number of quarries in the Pennines, where thin sand beds within the Coal Measures are worked as flagstones. Typically York Stone is fine grained, thinly bedded, silty-sandstones containing quartz and muscovite. They often show ripples and other sedimentary structures

characteristic of their formation in braided river systems. When fresh, they are a golden brown, whereas when weathered they are a dull brown through grey to greenish in colour. They frequently show rings and swirls of iron oxides known as liesegang banding.

**Bazalgette Memorial**

A fine memorial to Sir Joseph Bazalgette is affixed to the wall, just west of Hungerford Bridge. This was designed by G. B. Simmonds in 1899-1901, 'A quattrocentro aedicule with portrait bust' (Bradley & Pevsner, 2003). This translates as being in the style of the early Italian Renaissance (15$^{th}$ Century). An aedicule is a framelike structure, like a doorway. The carving shows 'dolphins', sea serpents, a shovel and a pick axe. The inscription *flumini vincula posvit* translates as 'he enchained the river'. The carving is in **Carrara Marble**, with a light grey veining. This is a good quality monumental marble of the Blanco Carrara or Sicilian variety from the Alpi Apuane of Tuscany. The so-called Hettangian Marbles of this region are Mesozoic platform carbonates metamorphosed and deformed during the Alpine orogeny.

There are a variety of granites used as ashlar blacks in the wall behind the memorial. These include small megacrystic type Cornubian Granites, and some with pinkish micas, the variety lepidolite, which also suggests a Cornish source. However, most of the granite here appears to be Dalbeattie Granite with prominent biotite and hornblende, in a groundmass rich in white feldspars.

A block worthy of a second look is an ashlar of granite on the east corner of the wall, five blocks up from the bottom. This is a porphyritic granite with phenocrysts of white orthoclase feldspar in a coarse grained matrix of pink and white feldspars, biotite and hornblende. A geological history f the granite can be elucidated from looking at this block. This granite has been cut through first by a vein rich in mafic minerals, probably an altered shear zone, probably formed before the granite was completely solid. The phenocrysts have grown after this, in the solid state as they are seen both in the granite and in the grey shear. Finally an aplite – a fine grained granitic rock composed of quartz and feldspar – has cut through the rock.

The origin of this particular granite (above, field of view ~ 40 cm) is unfortunately unknown. The absence of muscovite suggest that this is not one of the Cornish Granites, despite its resemblance to the small megacrystic types.

*At this point the geowalker must make the decision to either turn left (east) and walk to Blackfriars Bridge) or right (west) and walk to Westminster. Similar granites and a selection of memorials can be seen in both directions. If you intend to retrace your steps and do both sections, take the shorter, Westminster route first, then retrace your steps to Hungerford Bridge before continuing on to Blackfriars.*

**1. Walking westwards towards Westminster**

The first section of this stretch of the Embankment is dominated by Cornish Granite. The Victoria Embankment sign and the stretch up to the Tattersall Castle pub ship is predominantly Cornish small megacrystic granite. Just beyond the ship are a few blocks of large megacrystic granite, possibly from the Land's End Pluton. Soon after, Dalbeattie Granite becomes the predominant stone used, up to the RAF Memorial.

**RAF Memorial**

The RAF Memorial is a square-section pillar of pale grey Portland Stone, surmounted by a golden eagle. It was designed by Sir Reginald Blomfield in 1923, the eagle is by sculptor William Reid Dick. The monument was initially erected to commemorate the airmen who lost their lives in WWI but further inscriptions have been added to include subsequent losses in other conflicts, most obviously for WWII on the plinth of the parapet. The variety of Portland Stone used here is **Portland Whitbed**, which contains variable amounts of fragmented fossil oysters. The blocks in the base have very obvious lags of oysters, lying parallel to what would have been the bedding in the limestone. Whitbed is the middle part of the Freestone Member of the Portland Limestone Formation. It is an oolitic limestone of late Jurassic age, which would have been deposited in a warm, shallow sea. Fossil content is variable, but this 'exposure' of Whitbed shows good evidence of the shellfish which would have flourished in this environment, *Liostrea expansa*.

**Victoria Embankment Parapet**

The parapet of the Embankment between the RAF Memorial and Westminster Pier is dominated by a compact medium to fine grained granite, which weathers to a pale, slightly orange – brown colour. Prominent and distinctive are well-formed (euhedral) crystals of silvery muscovite mica, with hexagonal shape and up to 5 mm in diameter. The granite also contains quartz, feldspar and black biotite, the latter defining a foliation. Texturally, this stone resembles neither the Cornish nor Dalbeattie granites we have already encountered. It could well be Irish Killiney Granite, but this cannot be verified. We will refer to it here as Muscovite Granite.

*'Muscovite Granite' Possibly from Killiney, Ireland. Note the prominent flakes of silver muscovite, ~ 3-5 mm diameter. Field of view ~ 25 cm.*

**Battle of Britain Memorial**

A large memorial, erected in 2005, commemorates the Battle of Britain, the first campaign fought entirely in the air. It took place in the Summer and Autumn of 1940. The conflict was so named by Winston Churchill during a speech in the Commons which actually took place *before* the battle. The line from Churchill's famous speech delivered whilst the Battle was in process on 20 August 1940 is engraved on the monument; '*Never in the field of human conflict was so much owed by so many to so few'.* This memorial

was the idea of the Battle of Britain Historical Society who raised funds and commissioned sculptor Paul Day and architects Donald Insall Associates to erect a monument on the Victoria Embankment on land donated by Westminster Council. The Monument utilised a pre-existing structure, 25 m long, which was a granite-built superstructure, part of the MBW's original design, that acted as an air vent from the Metropolitan Railway, which initially ran steam trains under the Embankment[2]. The original granite was salvaged; recut and cleaned at De Lank's granite works in St Breward near Bodmin and used in the construction of the new monument (Natural Stone Specialist, 2011). This is Dalbeattie Granite and a good opportunity to see this stone in its fresh state, enabling to imagine the bright, almost white appearance of much of the Embankment when it would have been new.


A new granite coping was sourced by the stone contractors Stonewest, according to their brochure, from Aberdeenshire, Scotland. Though unfortunately above my eye-level, the stone is a pale grey, weakly foliated, biotite granite of medium grain size, with pale brownish orthoclase feldspars. It is cut through by thin, pinkish granite veins. In terms of its source, there are few granite quarries still operating from Aberdeenshire, and this is almost certainly **Kemnay Granite** from Tom's Forest Quarry. The Kemnay Pluton is an ~ 460 Ma Caledonian syn-tectonic granite intruded into the Grampian Terrain (see Appleby et al., 2010).

**Westminster Pier**

At Westminster Pier, much of the Embankment parapet is obscured by ticket offices and hot dog vans. However, as the roadway ramps upwards to Westminster Bridge, this forces a substantial retaining wall to be built on the landward side of the pier. This is built of blacks of Cornish and Dalbeattie Granites. The Cornish granite includes the small megacrystic and non-porphyritic varieties. Many of these blocks contain slightly pinkish micas, this is the variety lepidolite, a lithium rich mica, characteristic of the Cornish granites. Also here is an abundance of Dalbeattie Granite. It is clear that there have been a number of cleaning trials undertaken in recent years on this wall – some areas are much whiter than others. In the cleanest patch, the typical texture of the Dalbeattie granite can be clearly seen with abundant pale pink orthoclase

[2] Pictures of the original structure over the ventilation shaft can seen at http://www.bbm.org.uk/thesite.htm

feldspars as well as white plagioclase and quartz. Biotite and stubby hornblendes constitute the mafic phases present.

**Potcullis House**

Portcullis House was built to house parliamentary offices for MPs as the Houses of Parliament across the road became increasingly overcrowded. It was designed by architects Michael Hopkins & Partners and completed in the year 2001. It also houses Westminster Station on the Jubilee Line. The stones used in Portcullis House are described in Thornton et al (2000). Although lots of metal and glass dominate the façade of this building, ribs of sandstone on plinths of granite are an important feature. The sandstone used is **Birchover Sandstone** from Ann Twyford's Quarry near the town of Birchover in Derbyshire. This is a buff, relatively iron-poor and quartz-rich sandstone from the Ashover Grit Member of the Marsden Formation. These are fluvial sandstone which are part of the upper Carboniferous Millstone Grit Group. The granite is from **Merrivale Granite** from Dartmoor and Portcullis House can claim some fame for being the last building to be built with dimension stone extracted from Merrivale. This is a coarse grained, porphyritic granite with a few megacrysts of white, potassic feldspars, the latter twinned and zoned. The matrix is of grey quartz and muscovite. Some feldspars are partially kaolinised and pale greenish or pinkish in colour.

*Portcullis House and Westminster Pier from the south bank of the Thames.*

**Houses of Parliament**

We cannot ignore the Houses of Parliament which dominate the skyline at Westminster Bridge. Much has been written on the exterior stones used here, so they will only be briefly described in this guide. Construction of the building began in the late 1830s under the supervision of architects Charles Barry and Augustus Pugin. Lott & Cooper (2005) & Elsden & Howe (1923) tell the not inconsiderable tale of the selection of stone for the Houses of Parliament. The stone was initially selected from Bolsover Quarry, which, it was assumed, had supplied the stone for Southwell Cathedral (however this was actually from Mansfield Woodhouse). On inspection, it was clear that Bolsover did not have the resources to supply the stone, although most of the stone was of good quality, it was poorly quarried without supervision, it was used when still green and many blocks ended up not being quarry laid, which caused them to deteriorate.

**Anston Stone** was selected instead. **Mansfield Woodhouse Limestone** was also used. Both stones are from the 'Magnesian Limestone' which is now called the Cadeby Formation. These are Permian dolomites which outcrop from Nottinghamshire to Northumberland. Anston Stone is from Turner's Quarry in South Yorkshire and Mansfield Woodhouse is from 'Parliament Quarry' in the eponymous village in Nottinghamshire.

*The walk can either be ended here, with transport links from Westminster Station, or alternatively, it takes only 10 minutes to walk back to Hungerford Bridge where the second stretch of the Embankment may be seen.*

***2. Walking eastwards towards Blackfriars***

*From the Bazalgette Memorial this section of the walk takes you east to Blackfriars Bridge. This section of the Embankment is punctuated by a number of piers for riverboats and moored ships and also by a series of edifices which I will refer to as 'turrets', blocks higher than the main parapet, which hold memorials to eminent Victorians. A highlight of this section of the walk is Cleopatra's Needle.*

**Embankment Pier**

At Embankment Pier, the cornerstone by the gift shop entrance to the pier has a prominent dark grey vein crossing it, mottled with white, feldspar phenocrysts. The host granite has pink and white feldspars, quartz, biotite and hornblende. It is the same biotite-granite used on the wall adjacent to the Bazalgette Memorial and described above. Unfortunately its origin is unknown.

Just beyond this is the turret with a bronze plaque dedicated to the memory of the composer, W. S. Gilbert. The same biotite-granite appears to be used here. It is a small megacrystic variety of granite, but again, absence of muscovite rules out a Cornish source. A few blocks show small, irregularly shaped xenoliths of a dark grey rock. It is not impossible that this could be a Brittany Granite, however I am far from being certain. Laber Granite, described above, and recorded by several sources as being used in the embankment has distinctly pink phenocrysts. However this may be a grey variety of this granite or derived from a related pluton. The western Variscan granites of Brittany are biotite rich and contain only very minor muscovite.

Cornish Granite and blocks of the medium to fine grained muscovite-rich granite, possibly from Killiney, Ireland (and described in the 'Westminster' section, above) is used in the parapet between Embankment Pier and Cleopatra's Needle.

**Cleopatra's Needle**

Cleopatra's Needle stands 21 m above the Thames. It was made c. 1460 BC for the pharaoh Thutmose III and erected at the sun temple of Heliopolis in Upper Egypt. It has nothing to do with any of the seven Egyptian queens called Cleopatra, who reigned in Egypt over a millennium later than the reign of Thutmose III. Cleopatra's Needle was brought to London in 1878, having being presented to the nation by the Viceroy of Egypt in 1819. It took some money, planning and nautical engineering to get the obelisk from Alexandria to the Thames. In 1877, a 28 m long floating cylinder was made to encase the obelisk and this was towed behind the steamship Olga. Things went more or less well until the convey hit October storms in the Bay of Biscay and the Cleopatra was detached from the Olga with some considerable loss of life (the sailors are commemorated on a bronze plaque on the plinth). Assumed lost, it was found four days later by Spanish fishermen and then rescued by a British steamship. Following repairs, it was eventually floated up the Thames on 21 January 1878. It was erected in its current location on 12 September 1878.

The Bronze Sphinxes are by C. H, Mabey and George Vulliamy (who also designed other metalwork along the Embankment, including the lamp posts with 'dolphins' twined around their bases, as well as the mooring rings and Egyptian or camel-themed benches[3]) and were put in place in 1882. The plinth of one of

[3] The current Egyptian and camel benches are reproductions based on the original 1870 designs and were installed in 1977.

the sphinxes shows shrapnel damage from a German WWI bomb, dropped on 4th September 1917. Like much of the superstructure associated with Cleopatra's Needle, the sphinxes sit on blocks of Cornish small megacrystic granite.

*The back of a sphinx and Cleopatra's Needle*

The steps down to the river were built during the embanking (1864-70) may be **Darley Dale Sandstone** According to Watson (1911) and Elsden & Howe (1923) this stone was used on the Embankment, although they do not give a location. Darley Dale is one of several sandstones carved from the Upper Carboniferous Ashover Grit Member of the Marsden Formation. These are subdivisions of the Millstone Grit Group in Derbyshire. Darley Dale, from the eponymous quarry is the equivalent of Birchover Sandstone (as used in Portcullis House at Westminster) and Stanton Moor Sandstone from Matlock (Lott, 2001).

Cleopatra's Needle itself is carved from the **Monumental Granite** of the Aswan Pluton, so-called because so many monuments were carved from it. Its greatest asset is that the granite is relatively joint free, which allowed these enormous obelisks to be cut as monolithic blocks. Klemm & Klemm (2001) have estimated that over one million tonnes of granite were quarried in antiquity. The stone is also known as *Granito Antico Rosso* or Aswan Rose Granite (see Price, 2007). In the weather-beaten obelisk, the pink colour of the feldspars is hard to see. However, even though all of the obelisk is above eye level, the very coarse grained nature of the granite is clear. It is composed of quartz, orthoclase, plagioclase, biotite and hornblende. The Aswan Pluton was intruded 606 million years ago. It is located south of the city of Aswan, with the main quarries close to the banks of the Nile, which aided transportation of the stone.

The next section of the parapet is composed of Cornish small megacrystic granite, Dalbeattie and the muscovite granite. At a small dog-leg in the embankment, the parapet turning through two right angles, a block of Dalbeattie Granite shows a nice vein, c. 8 cm wide and rich in hornblende. Dalbeattie Granite

becomes dominant as we approach Savoy Pier. However this now familiar triumvirate of granite continues to Waterloo Bridge.

**Waterloo Bridge**

Just before Waterloo Bridge is a turret built from blocks of Cornish small megacrystic granite and Dalbeattie Granite. This holds a bronze plaque commemorating novelist, Sir Walter Besant. Waterloo bridge its self is constructed from Portland Stone, but this usually familiar stone is not so recognisable here. The Bridge is faced with **Portland Whitbed** deposited in a particularly and unusually high energy environment and shows well developed cross bedding and many fragments of oyster shells and the reef-building algae *Solenopora* , fragments of which look a little like white cauliflower florets.

Just under Waterloo Bridge is a cornerstone which is a fine example of Cornish, coarse grained megacrystic granite. Just beyond this is a seating area underneath the Bridge, probably constructed during the 1970s. The steps and paving of this area are made of a dark purple slate, with riven rather than cleaved surfaces. A few grey-green reduction spots on the steps hint that this may be **Welsh Slate** from the Cambrian slate belt of North Wales (Llanberis Slate Formation), but this has not been verified.

*The slate-floored seating area, a bottle of Jägermeister provides scale.*

Beyond Westminster Bridge another turret marks one of the Thames Lifeboat Stations. This turret is built of blocks of Dalbeattie Granite and Cornish small megacrystic granite. Beyond the turret, the parapet is built predominantly from Dalbeattie Granite, however, a few blocks start to appear of a granite with prominent pink orthoclase feldspar phenocrysts. Other blocks contain large white megacrysts, 3-4 cm in length, some of these have rims of pink feldspar. These can be seen just before we walk past HMS Wellington. Once again, this granite has not been identified. It is similar to Cornish granites, but they do not contain pink feldspars.

Beyond HMS Wellington, a turret with a bronze plaque commemorates W. T. Stead (1849-1912), one of the first investigative journalists and later a newspaper editor. This turret is built of ashlars of a coarse grained, two-mica granite with white feldspars and a few scattered megacrysts up to 4 cm in length. This is almost certainly a Cornish Granite, perhaps from the Land's End Pluton.

**Temple Stairs Arch**

This archway, like a modern water-gate, was built in 1868 along with the Embankment. However a plaque installed in 1935 commemorates the silver jubilee of King George V. This stretch of the River is also known as King's Reach. The keystone has a carved head of Old Father Thames (or possibly Neptune) and fabulously carved rustication. The stone used here is a medium to coarse grained, grey granite packed with randomly orientated crystals of feldspar, grey brown quartz, biotite and muscovite. This is a non-porphyritic Cornish granite, very probably quarried from somewhere like Carnsew in the Carnmenellis Pluton.

*We pass the Griffins guarding the boundary with the City of London. These were brought here in 1963 from Lower Thames Street where they had stood outside the coal exchange. They were designed by Dewar, 1849.*

**Submarine War Memorial**

This monument was erected in 1922, designed by A. H. Ryan Tennison with bronzes by F. Brook Hitch, this memorial is covered in small bronze anchors which look exactly like coat hooks. These are in fact designed to hold wreathes placed on the monument on Remembrance Sunday. Here again we see the granite observed on the parapet by HMS Wellington, with sparse white feldspar megacrysts, rimmed with pink orthoclase. The granite also has pink orthoclase in its groundmass.

*The granite used on the Submarine Memorial, note the pink feldspar and the white feldspar megacrysts with a pink rim (top centre). Field of view is ~ 20 cm.*

The parapet from the Submarine War Memorial along to Blackfriars Bridge, past the HMS President (currently resplendent in a modern take on dazzle camouflage by artist Tobias Rehberger[4]), is predominantly built from Cornish granites. Beyond HMS President towards Blackfriars Bridge, the fine grained muscovite granite once more becomes the main stone used.

**City of London Map Sign**

The last stop on this walk is the City of London map sign on the approach to Blackfriars Bridge. This incorporates a map over a slab of limestone carved with the City's coat of arms. One has to crouch down to street level to properly examine this stone. It is packed with fossil fragments, primarily those of crinoids, also known as sea lilies. These creatures had stems and branching arms made of stacks of circular discs with a central hole, called ossicles. These can be seen in the slab on the boundary stone either as single ossicles

[4] For further information see http://www.1418now.org.uk/whats-on/dazzle-ships/

or as articulated sections of stems. This is a Lower Carboniferous limestone from Derbyshire, known commercially as **Hopton Wood Stone**. Geologically, it is a shallow marine limestone, belonging to the Bee Low Formation.

The paving up to Blackfriars Bridge is **York Stone** is recent restoration work and was supplied from Fagley Quarries near Bradford (see Siddall, 2014; Waterloo & City).

*This walk ends here. It is around a 20 minute walk back to Charing Cross Station or Waterloo (across the river), or alternatively Blackfriars station is located on the north side of the Bridge.*

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**Anston Stone** – Houses of Parliament

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**Hopton Wood Stone** – City of London Map sign, approach to Blackfriars Bridge

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**Verde Ubatuba** - 1, Embankment Place, Villier's Street.

**Welsh Slate** – seating under Waterloo Bridge

**York Stone** – Paving along the entire Embankment.

***Provenance of granites recorded as being used on the Victoria Embankment. Please note that these are not highlighted in the text above.***

**Cheesewring Granite** – Cornwall, England

**Dalbeattie Granite** – Dumfries & Galloway, Scotland

**Dancing Cairns Granite** – Aberdeen, Scotland

**Killiney Granite** – Leinster, Ireland

**Kit Hill Granite** – Cornwall, England

**Laber Granite** – Brittany, France

**Lamorna Granite** – Cornwall, England

**Swell Tour Granite** – Devon, England


*Joseph Bazalgette's Memorial, Hungerford Bridge.*

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