

From The Monument to the Tower of London: Urban geology around Eastcheap

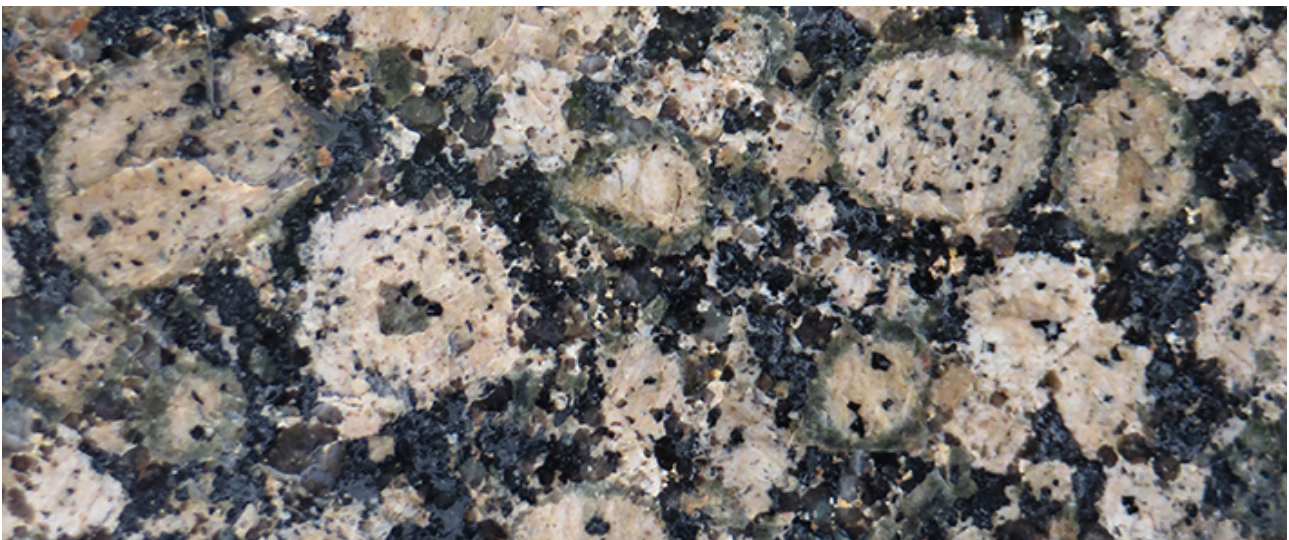
Ruth Siddall

This is probably my favourite urban geological walk around London, it is a fascinating area and there is lots to see, both geologically, architecturally and historically, and to be honest, the information here merely scrapes the surface, taking in only the most important buildings and the most impressive stones. The walk starts near the Monument, at the Fish Street Hill exit to Monument Underground and finishes at Trinity Square Gardens near Tower Hill station. It is a tour that takes in a huge amount of history, from the Fire of London, via war memorials to the Tower of London and with buildings constructed over the last 1000 years, it also takes in a broad history of building materials in London from the early Medieval Stones of the Tower to exotic metamorphic rocks used in the Disney castle-meets-gothic-chateau construction that is Minster Court. There are also some spectacular fossils and exotic minerals to be seen *en route* as well as a visit to the surface of the Moon ... Unless otherwise cited, architectural information contained herein is derived from Pevsner (Bradley & Pevsner, 1999).

Our first stop is immediately to the left of the tube exit.

Coral Bookmakers, Fish Street

The façade of the bookies is clad with polished, **Baltic Brown**, a variety of rapakivi granite. 'Rapakivi' is a Finnish word meaning 'rotten' or 'crumbly' rock, referring to the characteristically observed surface weathering of this stone. In geology, we use the phrase 'Rapakivi Granites' to refer to a suite of granites that have anorogenic affinities (that is, they were intruded during a period of crustal extension rather than collision) that were emplaced around 1.5 billion years ago into a 'Rapakivi Continent' that stretched from the Baltic Shield, down through North America, south to Texas. The Atlantic Ocean did not exist at the time and this region was, more or less, one huge landmass. The 'classic' rapakivi suite is intruded into southern Finland and adjoining Russia, with most stones (including Baltic Brown) being quarried from the enormous Vyborg (Wiborg) Batholith which straddles the border. Typically these rocks contain distinctive ovoids; circular megacrysts of potassic feldspar, often (but not always) with a rim of green plagioclase. Technically this variety of rapakivi granite, with ovoids, is called Wiborgite. Although not common, where they occur, these granites have been exploited as building stones. Baltic Brown is the most abundant variety quarried from the Vyborg Batholith and can be seen worldwide as a building stone.



Baltic Brown wiborgite: Note the pink ovoids of K-feldspar, rimmed by greenish plagioclase. There is also abundant quartz here, but it is easy to miss as it is almost black, the variety known by gemmologists as 'morion'.

Much has been written about the petrology and petrogenesis of the rapakivi granites mainly by the Finnish igneous petrologist Ilmari Haapala and his students, particularly Tapani Rämö of the University of Helsinki. A useful summary including their use as building stones, has been published by Müller (2007).

Walk down Fish Street Hill to The Monument. As you enter the square, an information and map sign, erected by the City of London Corporation is on your left hand side.

City of London Information Sign

These signs have been cropping up across the City of London. Obviously most people look at the map, but the stone plinths on which they stand are made of a beautiful fossiliferous limestone. This is a crinoidal limestone, with enormous fossil crinoids, with stems as big as fingers; some sections through these look like a set of false teeth for a small crocodile. These stone slabs are derived from Derbyshire where they are quarried from beds in a number of quarries. The main workings these days are operated by Mandale Stone Ltd who extract this stone from their 'Once-a-week' Quarry, formerly owned by the Dukes of Devonshire. The stone is known simply as **Derbyshire Fossil Marble**. It is of Lower Carboniferous age and is extracted from the Eyam and Monsal Dale Limestone Formations.



Crinoidal limestone on the City of London sign at The Monument.

The Monument

The Monument was constructed between 1671-77 to commemorate the Great Fire of London of 1666 which started close to this site on Pudding Lane on 2nd September, and raged across the City for the next three days. This Doric column was designed By Sir Christopher Wren and Dr Robert Hooke as a memorial to the Fire. It is 61 m high and 61 m away from the starting point of the Fire in Pudding Lane. Hooke, was a true polymath. Perhaps best known for Hooke's Law which applies to the extension of springs and his book on microscopy *Micrographia*, he is less well known for his architectural abilities. Hooke also made major contributions to the field of geology, being the first to realise that fossils were once living organisms and that they had become extinct due to some natural disaster.

The main building material is **Portland Stone**, the stone chosen by Christopher Wren and his fellow architects to rebuild London in a monumental style. Portland Stone has a long history of quarrying, but only came into mainstream use following the Great Fire (*see* Hackman, 2014). As the name suggests it is quarried from the Isle of Portland on the Dorset Coast from the uppermost strata of the Jurassic succession. There are a number of varieties of Portland Stone (and we shall encounter some of these on

this walk) but this is the most frequently used, called Whitbed. It is a pale grey limestone with scattered fossils, mainly the oyster shell species *Liostrrea*. Portland Stone is a strong limestone, so it is good for structural work. It is also a freestone, which means it has no preferred planes of weakness and is therefore suitable for intricate carving, as seen here.

Inside the column, the steps are made of a black limestone, reputedly **Pooilvaish Limestone** quarried from the southeast coast of the Isle of Man. However black limestones are sourced from many locations within the Lower Carboniferous strata of the British Isles, and differentiating them is notoriously difficult. Nevertheless tradition has said that Pooilvaish was used at the Monument, and the recent restoration of the structure has sourced the same stone from the current Manx quarry operators Pooil Vaaish Ltd. The stone is from the *Posidonomya* Beds of the Castleton Limestone. *Posidonomya* is a fossil bivalve with a concentrically-ribbed shell which occurs, albeit scarcely in this stone. Presence of this organism confirms that this is Pooilvaish Stone. A memorial stone commemorating the scientist Robert Hooke (1635-1703) is located in the yard east of the Monument. This too could well be Pooilvaish, having been installed at the same time as the restoration.

Caithness Stone is used for both paving the square surrounding the monument and also for the stone cobbles used in the gabions which have been used to build the 'Monument Pavilion' a toilet block designed and built in 2006 by Bere Architects. This stone is quarried from the northernmost tip of the Scottish mainland at Spittal. The Caithness Flagstone Group is part of the Devonian Old Red Sandstone, but here the environment of deposition was a muddy lake, nevertheless full of fish, which can be well preserved as fossils in the stone. I have scoured the paving here and sadly have not spotted any fish, however they can show up in paving stones and there are several good examples of fossil fish in the Caithness paving on the streets of Edinburgh (see McGowan & Challands, 2013).



The Monument Pavilion constructed with metal cages – ‘gabions’ – filled with Caithness Stone.

Cross over the Monument yard to Monument Place.

Monument Place, 24 Monument Street

This office redevelopment was completed in 2013, designed by David Walker Architects who were inspired by the Economist Building in St James’s (see Siddall & Hackman, 2015), and, as at The Economist, a fossil-

rich variety of Portland Stone has been used as cladding here. The variety used at Monument Place is called **Fancy Beach Whitbed** and it is crammed with fossil oyster shells (grey) and the cavities where other shell species have leached out. It also contains abundant fragments of one of the main reef-forming organisms of the Late Jurassic Portland seas, the alga *Solenopora portlandia*. This limestone, composed of shell debris would have indeed formed in a beach or very shallow marine setting. Imagine a shell beach that has been cemented together, and this is what we have here.



Fancy Beach Whitbed: grey streaks are oysters, cavities where other shells have leached away and white, banded florets are the alga Solenopora.

Leave the Monument yard and head up Pudding Lane and turn right onto Eastcheap. Walk on to the corner with Botolph Lane and cross over to the chocolate-coloured façade of no. 16 Eastcheap.

16, Eastcheap

The ground floor of this building has been clad with a granite that at first appears chocolate-brown, but on close examination, it is multi-coloured. The colour is mainly imparted by perthite feldspars, brown, but streaked with pink. Black biotite and hornblende are also present. The quartz is distinctive, being bluish and opaline in appearance, but this effect is promoted by deformation. Blue quartz is also often an indication that this is an old rock, and this is very true in this case. It is a 2.7 Ga granite from Millbank, South Dakota and is marketed under the names of **Dakota Mahogany**. Like Baltic Brown, this rock too has become very popular globally as a decorative stone and is commonly seen on many city streets.

Cross over and continue along Eastcheap turning left into Rood Lane. Then take the first right onto Plantation Place, immediately after the church of St Margaret Pattens.

Plantation Lane & Plantation Place

Plantation Lane is the passage from Rood Lane to Mincing Lane and Plantation Place is the building on the left (north) side of this passage. The building and walkway were designed and built by Arup Associates, in collaboration with artist Simon Patterson in 2004. There is stunning stonework and even geologically-themed art to be seen here.

The pale-brown stone used to clad the walls of Plantation Place are of a very fashionable stone called **Jura Marble**. Not a true marble, this stone is rich in fossils and some splendid examples of ammonites, nautiloids and belemnites are seen here. Once you get your eye in, they are everywhere. This is an Upper Jurassic

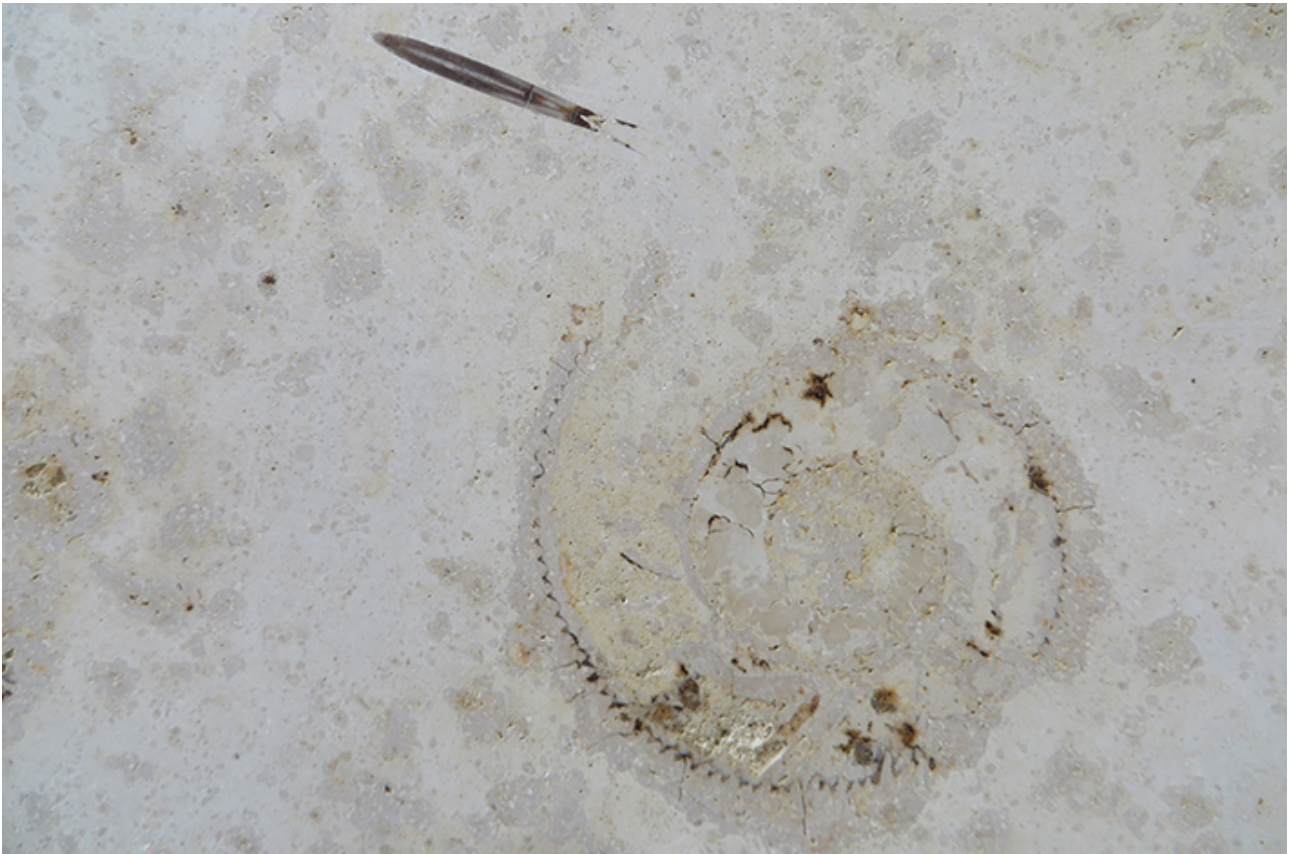
limestone sourced from the Southern Frankonian Alb of Bavaria. It comes from the Treuchtlingen Formation, representing a marine platform limestone with sporadic sponge reefs and bioherms. Sponges are also common fossil fragments seen here forming brown ring and cup-shaped structures.

The dark grey paving setts are **Pietra del Cardoso**, a sandstone derived from the Alpi Apuane region of Tuscany, Italy. It is Oligocene in age having derived from the erosion of the fledgling Alpine Mountain Range. It is quarried near the village of Cardoso from the enigmatically named Pseudomacigno Formation. This is in fact the metamorphosed portion of the sedimentary Macigno Formation. The metamorphism was not intense, but enough to make Pietra del Cardoso a tough, hardwearing stone that has a strong foliation making it easy to break into narrow setts as seen here (Carmignani et al., 2005).

Simon Patterson collaborated with Arup Associates to create an installation, integrated with the design of Plantation Lane, called 'Time and Tide' and completed in 2004 (see Brislin, 2005). The 'Time' aspect refers to the texts embedded in the paving; letters are Jura Marble in setts of Pietra del Cardoso. The words refer to the histories of the area, both real and imagined. The 'Tide' part of the artwork is a large glass panel, 41 m long and 6 m tall, featuring a photograph of the surface of a cratered area of the Moon. Arguably also of interest to the urban geologist, the cratered lunar highlands are composed of anorthosite (a rock composed of 90% plagioclase feldspar) and we will encounter a similar material later in this walk. Cratering on the moon happened around 4 billion years ago during a period known as the Late Heavy Bombardment (LHB). At this time the Solar System had formed, but lots of loose asteroids were still flying about. These were sucked into the gravitational fields of planets and large moons. Planets like Earth and Mars have subsequently been resurfaced by processes such as plate tectonics (on Earth) and volcanism (on Mars), but on the lunar highlands there has been no geological activity since the LHB. We know the timing thanks to rock samples which were brought back from the Apollo 15, 16 and 17 missions and subjected to radiometric dating.



Plantation Place and Simon Patterson's installation 'Time and Tide' (2004).



Jura Marble at Plantation Place: sections through a belemnite and an ammonite.

At the end of Plantation Lane we come onto Mincing Lane where we are faced with the pink and pinnacled façade of Minster Court.

Minster Court

This building is not the typical orthorhombic box that is the template for so many office buildings. Far from it, with its pinnacles and spires, it has been described as ‘postmodern gothic’ (McManus, 2014), and the Disney connection is real, it was used in the 1996 film of *101 Dalmatians* standing in as Cruella De Vil’s fur business headquarters. The building was designed by GMW Partnership and completed in 1991. The bronze horses at the front are by Althea Wynne and are named Dollar, Yen and Sterling.

The 1980s and 90s were the time that exotic granites were at the height of fashion in architecture. This building is clad with Brazilian **Rosa Torricoda**, a pink granite migmatite. This is a rock that has been frozen in the process of melting and this, along with deformation, accounts for its streaky texture. Buried to great depths in the Earth’s crust, this rock is transitional between a metamorphic and igneous rocks. It has a granitic composition and is composed of pink potassic feldspar, white plagioclase and grey quartz. The black mineral is the mica, biotite. This is a very old rock, quarried from the 2.75 billion year old Campo Belo Metamorphic Complex located in the São Francisco Craton of the state of Minas Gerais. Although metamorphosed at 2.75 Ga, the protoliths of these rocks are over 3 billion years old (Oliveira, 2001). This is just, the oldest rock that we will see on this trail (not counting the lunar highlands on Plantation Place).

Turn right down Mincing Lane and return to Eastcheap. At this junction the name changes to Great Tower Street. Cross over and turn left towards the Tower of London. Continue to Sripur Indian restaurant at 24, Great Tower Street.

24 Great Tower Street

24 Great Tower Street is partly occupied by the Indian restaurant Sripur. This is a granite clad construction, with the impressive doorway flanked by monolithic columns. These are not granite but a rock type called anorthosite. We have briefly encountered this rock theoretically on Plantation Place whilst contemplating the moonscape installed there. Composed of 90% calcium-rich plagioclase, anorthosites are not particularly common rocks on Earth and they are only quarried for building and decorative stone in a few locations. This stone is very decorative. At first it looks a dull brown, but look more closely and you will see that the crystals flash shades of peacock blues. This is a phenomena called 'schillerescence' that can be shown by many plagioclase feldspars, but is well-developed here. There are two potential commercial sources of these anorthosites containing blue schillerescence feldspar, Rogaland in Norway and Labrador in Canada. Indeed the gem-variety of these type of feldspars, extracted from these anorthosites, is known as labradorite. Neither of these stones have been on the market long, which suggest that these columns were put in place within the last 20 or so years. Texturally the stone here most resembles the variety from Norway which is (confusingly) called **Labrador Antique**. It is 930 million years old and is quarried from the Rogaland Igneous Province at Sirevag near Stavanger. In addition to the schillerescence, a distinctive texture is the bimodal grain size with larger grains, up to a centimetre or more across, surrounded by smaller grains of 3-5 mm.

The plinths on which these columns stand are of **Dark Shap Granite** and the rest of the building is clad with **Bon Accord Red**. These two stones are much more typical of 19th or early 20th Century architecture. Shap Granite, with its distinctive, brick-shaped, pink, K-feldspar phenocrysts is from Shap Fell in Cumbria and is just under 400 million years old. The groundmass is made up of orange K-feldspar, grey quartz, plagioclase and biotite. The coarse-grained red granite cladding is a variety called Bon Accord Red quarried near Uthamar on the Kalmar Coast of Sweden. It is composed of large crystals of brick-red K-feldspar with grey quartz and black biotite. This is a variety of rapakivi granite, intruded during the same magmatic phase as the Baltic Brown Wiborgite seen at our first location. This red granite lacks the ovoids and is the variety of rapakivi granite called pyterlite (named after the type location of Pyterlahti in Finland). It was intruded as part of a suite of granitoids in the Baltic region, known generically as the 'Coastal Reds' by stone workers. This variety comes from the Fieholm Granite, intruded at ~ 1.4 Ga. The name 'Bon Accord' is an allusion to the fact that these granites were shipped direct from the quarry to Aberdeen where they were cut, shaped and polished. 'Bon Accord' is Aberdeen's motto.



The beautiful igneous plutonic rocks at 24 Great Tower Street: left, Dark Shap Granite, field of view 12 cm; centre, Bon Accord Red FoV 12 cm; right, Labrador Antique, FoV 8cm.

Malta Memorial

Easy to walk past without a second glance, the square prism of the Malta Memorial stands on Byward Street, just in front of the church of All Hallows-by-the-Tower. This is a memorial commemorating the siege of Malta during the Second World War between 1940 and 1942 and it is constructed from stone brought from the Oligocene **Lower Coralline Limestone** of the Isle of Gozo in the Maltese archipelago. Described in

detail in Siddall (2014), this stone is packed with fossil sand dollars, flattened sea urchins of the species *Scutella subrotunda*. So common are these fossils in the upper part of the Lower Coralline Limestone the layer in which this block of stone was quarried is called the Scutella Beds. This block was quarried from near Xlendi in Gozo.

Walk down to the plaza in front of the Tower of London, a street known as Petty Wales.

The Tower of London

As one of London's most famous building complexes and one of London's oldest secular buildings I am far from the first to write about the building stones of the Tower of London. The main work on this subject is by Tim Tatton-Brown (Tatton-Brown 1991) with more recent work on stone conservation (see Price, 2007 and Sanderson & Garner, 2001). Tatton-Brown's write up is the result of a trip taken to the Tower in London in 1990, by everyone who was anyone in the world of building stone research at the time, including architectural historian Bridget Cherry, geologists Bernard Worssam and my former colleagues at UCL Desmond Donovan and Eric Robinson.

The oldest structure at the Tower of London is the Norman keep of the White Tower, constructed in the 11th Century. This is built of rubble masonry of Kentish Ragstone with ashlar quoins and other dressings, originally, in Caen Stone and now replaced (from the 18th Century onwards) with Portland Stone. If you visit the interior, the best place to see Caen Stone is in the Chapel of St John where it is used along with the somewhat darker Quarr Stone. 12th to 14th Century ashlar construction uses mainly Reigate Stone along with a few courses of Paludina Marble, whilst Ragstone was still used for rubble masonry. Beer Stone and Totternhoe Stone were used for some interior features. By the Tudor period, the main building material was brick.

Caen Stone comes from Normandy and was brought to London for the White Tower by the Normans for whom it was the local and familiar building material. It is a fine grained limestone, composed of almost pure calcite. Apart from the odd burrow, there are few fossils and other sedimentary structures. It is of Middle Jurassic (Bathonian) age.

Quarr Stone comes from Binstead near Ryde on the Isle of Wight. It was an important English building stone from the Roman to the early Medieval period, although mainly used locally on the Isle of Wight and at places like Winchester Cathedral and Boxgrove Priory. The quarries at Quarr are in the Late Eocene Bembridge Limestone Formation, underlying the Bembridge Marls. Described as a 'shell-brash' by Lott (2011) it is a cross-bedded, cemented coquina. The stone was completely worked out by the 14th Century and there is none left in outcrop today.

Kentish Ragstone and **Reigate Stone** are both derived from the Cretaceous Greensand Formation. Although both contain the diagnostic green clay mineral glauconite, they are very different stones. Kentish Ragstone is a sandstone, composed of quartz and glauconite. It is a hard stone but only occurs in thin beds and is therefore only suitable for rubble masonry. It is quarried along its outcrop in Kent. Reigate Stone come from the North Downs of Surrey and is composed of siliceous sponge spicules and glauconite. Reigate Stone was used as ashlar and also for delicate carving such as window tracery, however it has not stood up well to London's air pollution and much Reigate Stone used in the Medieval period is in a very poor state today.

Paludina Marble comes from the Early Cretaceous Weald Clay Formation and is superficially very similar to Purbeck Marble, being packed full of fossil gastropods *Viviparus elongates* which are typically bigger than the similar species found in the Purbeck Marbles. It was never found in great abundance and was extracted from several small pits throughout the Weald.

Beer Stone and **Totternhoe Stone** are both varieties of Chalk. Beer is from Dorset, whilst Totternhoe Stone is from Bedfordshire. They are both varieties of 'clunch', hard beds in the Chalk that are suitable for interior and occasionally exterior building stone. Like the rest of the Chalk Group they were deposited in the Late Cretaceous tropical seas.

Portland Stone has been seen (and will be seen) at several locations on this walk and is described therein. It should come as no surprise that 17th Century and later masons used Portland Stone for running repairs at the Tower.



The Tower of London: The White Tower and St John's Chapel.

Turn down towards the river and right into Lower Thames Street, you will find yourself in front of the Three Quays Hotel.

Three Quays Hotel

Jura Marble, as seen at Plantation Place is once again used here to clad the exterior of the Three Quays Hotel. Once again, good and photogenic examples of fossil sponges, belemnites and other cephalopods are seen here. This stone has become immensely popular in recent years and can be frequently seen cladding buildings like this and used as paving in shopping malls and many more establishments. Not only is it attractive, its is durable and available in large quantities. The main quarry owners and suppliers are the firm Naturstein Steigler based in the village of Solnhofen in the Altmühl Valley. The Solnhofen Formation overlies the Treuchtlingen Formation which is the source of the Jura Marbles, and it is well-known for incredible preservation of vertebrate fossils including *Archaeopteryx*, the organism transitional between reptiles and birds, effectively a chicken with sharp teeth.

Return back the way you came and carry straight on to Tower Hill. Cross over and enter Trinity Square Gardens.

Merchant Navy Memorial, Trinity Square Gardens

The large and impressive war memorial commemorates the seamen of the Merchant Navy who died at sea in both the First and second World Wars. It is a large complex, belonging to the Commonwealth War graves Commission and like the vast majority of their memorials, small and large, it is built from **Portland Stone**. The WWI section was designed by Edwin Lutyens with sculpture by William Reid Dick and the WWII section by Edward Maufe with sculpture by Charles Wheeler. 35,749 seamen are commemorated here. Portland Stone Whitbed is the main building stone used, with the more fossil-free Basebed variety used for some of the sculpture.



The Merchant Navy Memorial

This memorial marks the end of the walk. The nearest tube station is just across the park at Tower Hill.

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Locations of the buildings described above and brief details of the stones used can also be found in the London Pavement Geology archive: <http://londonpavementgeology.co.uk>