

Portland's Quarries and its Stone

Fig 1. *The City of London. A monument to the Portland stone industry and its artisans.*



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Introduction.

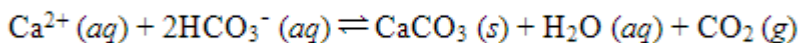
I have written this document as a handout for students visiting Portland in Dorset, who wish to gain a basic understanding of the island's geology and the modern extractive industry that operates here. I have not aimed to give a full and comprehensive account of Portland's geology or of the dimension stone quarrying and mining techniques used, but instead I have attempted to provide an accessible introduction to these subjects for the interested reader. I have used traditional quarrymen's terms where appropriate. These would have been familiar to a great many of my ancestors who earned a hard living hewing stone in Portland's quarries and I will be happy if using them here helps to keep these colourful words alive.

Geology.

Towards the end of the Jurassic Period, around 145 Ma (million years ago), because of continental drift, the land that makes up much of what is Southern England was located far south of its present global position, at about 38° north of the Equator. What is now Portland was positioned at a palaeolatitude similar to that of modern Florida or Israel, where the "Mediterranean" type climate was likely characterized by warm wet winters and hot dry summers.

Portland Stone formed in a specific type of marine environment, known as a carbonate ramp, on the floor of a shallow, warm, sub-tropical sea, not too far from land, as evidenced by carbonaceous driftwood trace fossils, which are not uncommon. As seawater was warmed by

the Sun, its capacity to hold dissolved gas was reduced; as a consequence, dissolved carbon dioxide CO₂ was released into the atmosphere (as a gas) disrupting the chemical mass balance in the water. In response, discrete calcium cations (Ca²⁺) and bicarbonate anions (HCO₃⁻) within the supersaturated seawater bonded together, forming calcium carbonate (CaCO₃) as a solid precipitate, according to the formula:



Minute particles of sand or organic detritus, such as shell fragments, lying on or in suspension close to the sea floor, acted as nuclei which gradually became coated with this fine-grained (micritic) calcareous precipitate. Over time more calcium carbonate accumulated (by accretion) around the nuclei in concentric layers, forming small calcareous spheres (< ~1mm diameter). Countless billions of these spherical sediments, called “ooids” or “ooliths”, ultimately became buried and partially cemented together (lithified) by more calcium carbonate, resulting in the oolitic limestone we now call Portland Stone. Fortunately, the degree of cementation in Portland Stone is sufficient to allow it to resist the detrimental effects of the weather, but it is not so well cemented that it can't be readily worked (cut and carved) by masons. This is one of the reasons why Portland Stone is so favoured as a monumental and architectural stone. Using the Folk classification scheme, geologists categorize Portland Stone as mainly porous oosparite.

Portland Stone is one of the youngest Jurassic rocks, laid down just before the end of the period. Contemporary (aragonitic) oolitic limestone, that might be considered a modern analogue for Portland Stone is forming today in warm, lime-rich waters, such as those found in the coastal margin of the Persian Gulf and in the Atlantic, on the Bahamas' Banks.

During the Alpine Orogeny (when the Alps were pushed up as Africa tectonically “crashed” into Southern Europe), minor related tectonic “ripples” affected much of the south of England. These forces compressed the already folded rocks of South Dorset, resulting in an east-west trending fold structure called the “Weymouth Anticline”. Portland, connected to the mainland by Chesil Beach (forming a tombolo) is what remains of the Weymouth Anticline's southern limb, where bedding dips at about 1.5° to the south east (fig. 4.). The Portland Beds which once

would have been folded over what is now Weymouth have long since been denuded and only the older middle Jurassic, (generally softer) rocks, originally from the core of the anticline remain, now exposed at the surface. Were it not for the protective barrier of Chesil Beach, Weymouth and its hinterland would probably have long been eroded away and the whole area would now lie beneath sea level. There is a narrow, linear exposure of Portland Stone, (striking roughly east-west) on the high ridge to the north of Weymouth; it crops out (dipping steeply north) on the northern limb of the Weymouth anticline forming part of the escarpment known locally as the Ridgeway. Portland Stone from the Ridgeway tends to be more fractured or jointed (compared to that quarried on Portland) because of the more intense folding that occurred there. Despite geological problems Portland Stone was once quarried from the Ridgeway, particularly at Portesham. The monument to Vice Admiral Sir Thomas Masterman Hardy (1769-1839), erected in 1844 at Blackdown, Portesham, SY 613875, was originally constructed using stone quarried from Portesham Quarry SY610860 although subsequent restoration has been carried out using Portland Stone from Portland.

Fig. 2 *Titanites*. (40cm dia). This specimen came from the Whitbed in Fancy Beach Quarry, Portland.



Before the quarrying of Portland Stone can proceed, the unwanted material which overlies it, (the overburden) must be removed. Most of the top of Portland is covered with Purbeck Group

limestones (the Lulworth Formation) of quite variable thickness, ranging from about 1m to 15m or more, across the Island (fig. 4.). Where the overburden is deepest; the top 4-5m (Top Rubble) is usually fairly unconsolidated, comprising thin beds of limestone, clay and marl. Stromatolites are common amongst the thin limestone or Slatt Beds which occur at these upper horizons. The largest of these Slatt Beds (the Thick Slatt) is typically 0.5m thick and has been commercially marketed as “Portland Blue“. The Thick Slatt often exhibits some very fine sedimentary structures, including halite (salt) pseudomorphs, bioturbation, ripple marks, rain prints and desiccation cracks, which all point to a seashore type environment, with high rates of sea water evaporation. Similar hyper-saline conditions exist today in the Middle Eastern sabkhas.

Simplified Geological Map of Portland

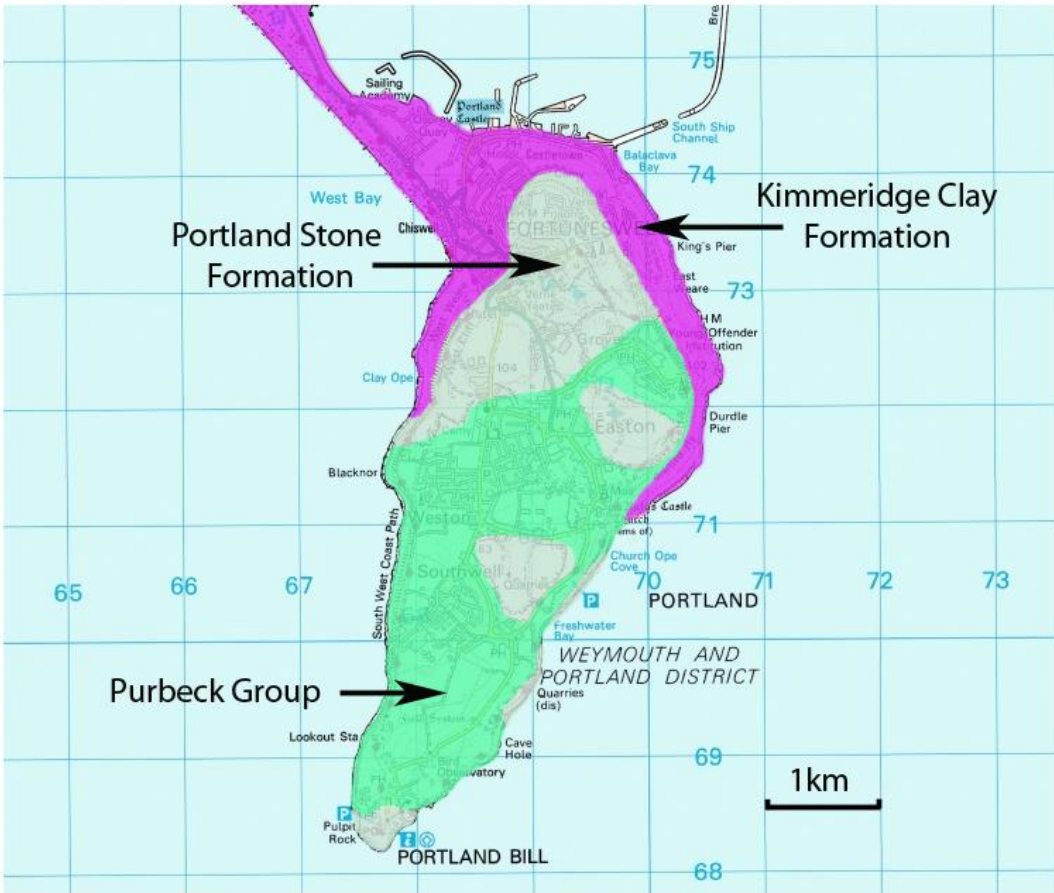


Fig 3

Some slabs of Thick Slatt quarried from the south of the Island have been found to contain trydactyl (three-toed) dinosaur footprints. These beds also contain small fossils including gastropods, bivalves, ostracods and very rarely, the occasional disarticulated vertebrate bone. The Thick Slatt's "blue heart" occurs as a result of staining by naturally occurring iron compounds. A distinctive white or gray margin is often visible at the edges of slabs of Thick Slatt, this is caused by vadose water (ground water migrating under the influence of gravity) moving through joints in the bed that has weathered the blue staining from the margins of individual joint-bounded blocks.

The lower 5-6m of overburden (the Bottom Rubble) consists of more massive beds of deformed evaporitic limestone (Aish and Soft Burr) with thin basal beds of ancient soil or palaeosol. The "chalky" Aish was traditionally used by Portland's housewives to whiten hearths and doorsteps. The noun "Aish" is probably a corruption of "ash", a colour term. It is just possible that "Aish" might have a linguistic connection to the noun "ashlar" (squared blocks of building stone) but given the soft and friable nature of Aish, this seems unlikely. Load structures are sometimes found at these horizons, where buried salts (gypsum and halite) that were subjected to high and possibly uneven gravitational loads, were mobilized upwards, forming small "diapiric plumes" which disrupt the overlying beds. The "Soft Burr" found here was traditionally used on Portland to build chimneys and fire places as it has the interesting property of resisting the detrimental effects of heat. It is in the Great Dirt Bed that many well preserved silicified tree trunks are found, some still in life position. The three palaeosols or "dirt beds" at the base of the Lulworth Formation represent ancient soils into which "proto-cypress" conifer trees (*Protocupressinoxylon purbeckensis*) and cycads once spread their roots, which are still abundantly evident as carbonaceous and limonitic trace fossils. Interestingly, fragments of fossilized charcoal (fusain) are sometimes found in the dirt beds, indicating that the plants that once grew here were affected by occasional forest fires, presumably started by lightning strikes.

Cap Beds, comprising the Hard Cap and the underlying Skull Cap, separated by the Lower Dirt Bed, is the collective name given to the basal units of Lulworth Formation and the bottom beds of overburden (fig. 6.). The Hard Cap often contains trace fossils of trees and the frequently encountered horizontal "chaff holes" are what remain of now largely decayed tree branches preserved in something close to life position. Careful examination of the holes does

occasionally reveal some traces of petrified wood. The ancient forest floor in which these trees once grew (represented by the Lower Dirt Bed) must have been flooded quickly. Much of the calcium carbonate in the Cap Beds is stromatolitic (algal) in origin, produced by the action of cyanobacteria (blue-green algae), living in backshore lagoons, on and around the newly submerged trees. Ostracod fossils are common within the Hard Cap. The sequence of limestones and palaeosols within the Lulworth Formation tell a story of significant environmental changes, with cyclic flooding and re-emergence of the land surface.

Cap Beds are typically 2-3m deep and generally very hard. The noun “Cap” is widely used in mining to describe the rock immediately above a coal or ore seam. On Portland, Cap Beds are those that immediately overlie the economically valuable Freestone Beds of the Freestone Member. Because Cap is generally very well cemented with a typically stromatolitic / thrombolitic texture, it has very limited potential as a masonry stone. Cap has however been successfully used as armour stone on sea-defence projects; it may also be crushed to produce a good quality aggregate for concrete or road building. The lower overburden beds including the Cap Beds are usually loosened by blasting with high explosives before they can be removed with mechanical excavators and dump trucks. In situations where the use of explosives is restricted by environmental factors, Cap can be removed using modern quarrying techniques but this is a relatively expensive and slow process.

At the top of the Portland Stone Formation’s Freestone Member is the Roach (1m). The Roach lies immediately beneath the Lulworth Formation’s Basal Dirt Bed. The junction between the Roach and the Basal Dirt Bed represents a massive environmental (and hence facies) change; from a marine limestone to a terrestrial palaeosol.

A “freestone” is defined as a stone that can be easily cut and worked in any direction, irrespective of bedding etcetera. Although not technically a freestone in the truest sense of the word, Roach has traditionally been considered as the topmost and youngest “freestone” bed on Portland. Roach is an oolitic limestone full of casts and moulds from gastropods and bivalves such as *Aptyxiella portlandica* or “Portland screw” and *Laevitrigonia gibbosa* or “osse’s ‘ead” [horse’s head]. The aragonitic shells of these molluscs are believed to have dissolved away (leaving behind mouldic voids) soon after deposition, by vadose water, following early uplift of

the Formation. Roach is a shelly littoral or beach deposit. The noun “Roach” is possibly derived from the old French “roke” or “roche” in English usage since the middle of the 13th Century, meaning a mass of rock, a cliff or boulder. Roach has been used extensively in the Portland Breakwater and the Cobb at Lyme Regis, it was also widely used by Victorian military engineers to construct numerous fortifications because of its ability to non-destructively absorb the impact of cannon balls! Roach that is used “Face bedded” (cut parallel to its bedding) makes a superb decorative stone. Roach is often available in very large block sizes.

Below the Roach is the Whitbed (up to 2.5m). The noun “Whitbed” is almost certainly a corruption of “white bed”. Whitbed is a fine grained, mainly oolitic limestone typically containing a proportion of comminuted shell fragments, ranging between ~5 mm and ~50mm in diameter. Whitbed can yield an excellent freestone suitable for all external work. Less shelly or cleaner” Whitbed (often occurring in the lower half of Whitbed faces) can be suitable for carving with intricate details.

Simplified Stratigraphic Section Through Portland

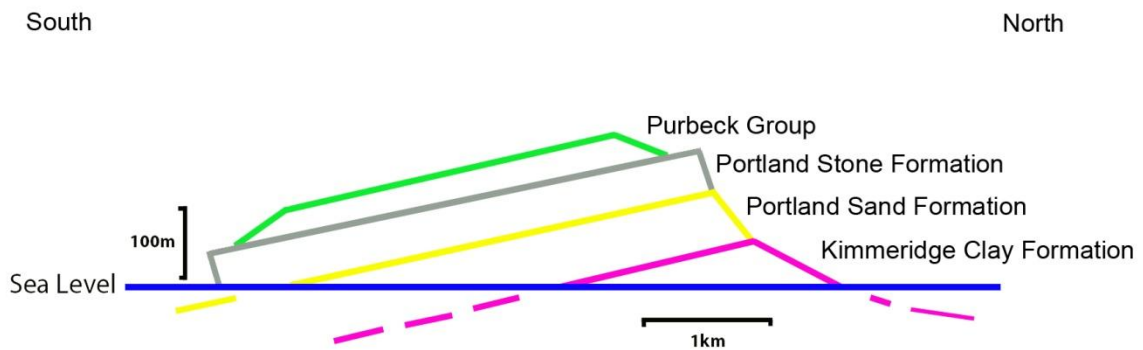


Fig. 4. *A simplified section through the Isle of Portland, situated on the southern limb of the Weymouth Anticline, showing an (exaggerated) ~1.5° dip to SE.*

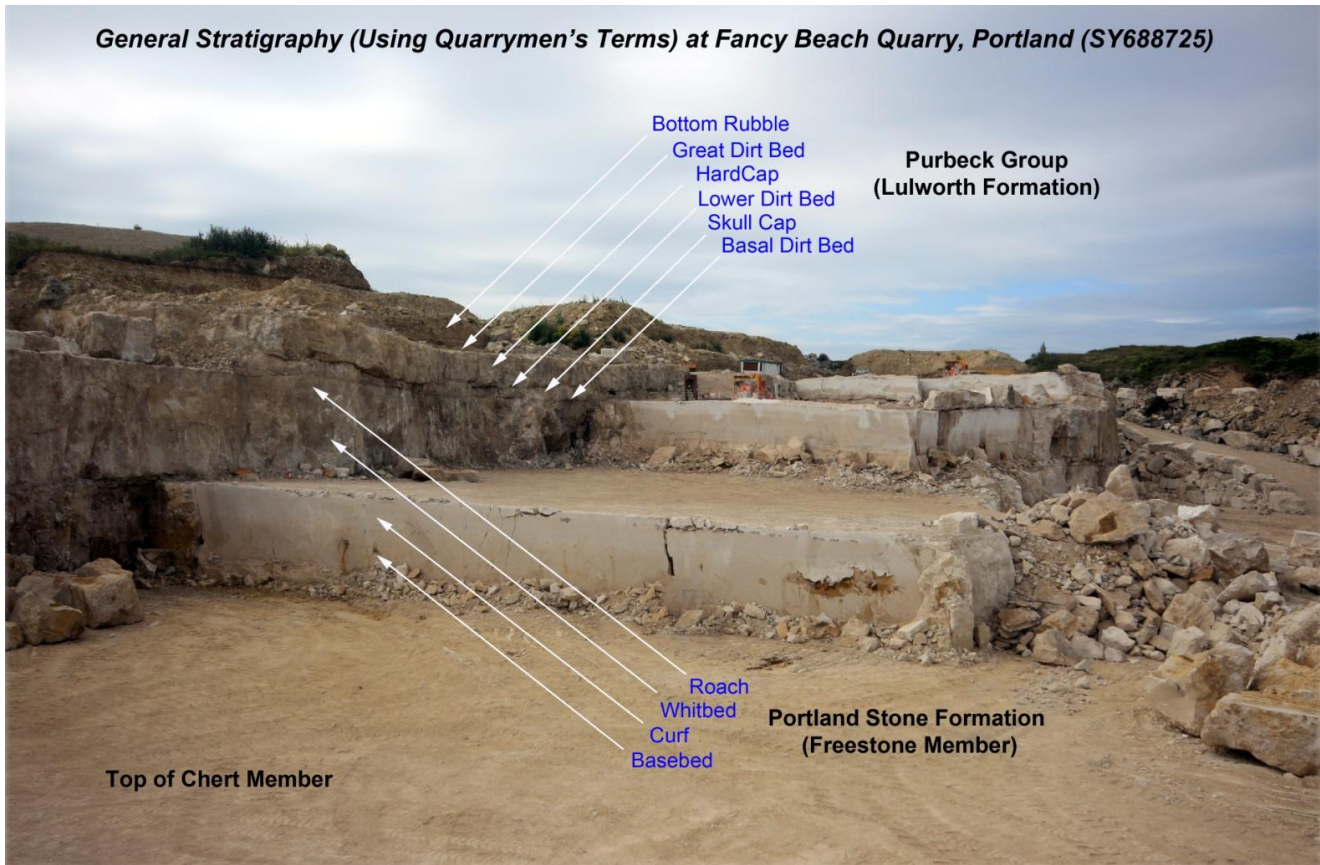


Fig. 5.

**Simplified Stratigraphic Section of the
Purbeck Group &
Portland Stone Formation at
Jordans Mine (SY687720)**

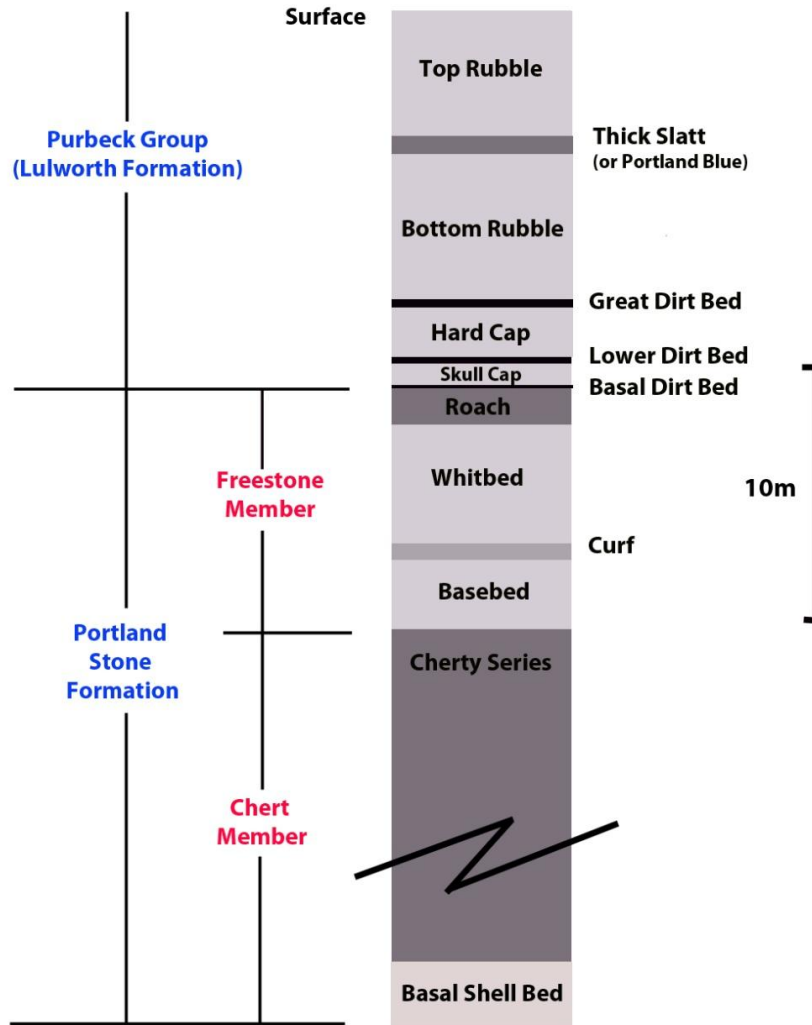


Fig. 6.

Shelly Whitbed, while not usually suitable for detailed carving, is an excellent stone for architectural use in ashlar and weathering courses. Whitbed in general is highly durable and

tests upon the stone predict a probable weathering or retreat rate of 1-2 mm per 100 years. Fossils from the Whitbed include the large Ammonite *Titanites* (fig. 2.), oysters and other bivalves (*Protocardia*, *Camptonectes*), echinoids and occasionally, vertebrate bones. Well cemented Patch Reefs often occur within the Whitbed, these are comprised mainly of densely packed colonial bivalves such as *Ostrea*, and *Plicatula* along with bryozoans and the red calcareous algae *Solenopora*. Despite the high density of fossils in the Whitbed and Roach, these tend to be restricted to a small number of species. This low faunal diversity has been attributed to locally elevated marine salinity levels at the time of deposition. Good examples of large scale cross-bedding can occasionally be found within the Whitbed, where foresets have become chertified, making them particularly well defined.

Beneath the Whitbed is the Curf (1m). Sometimes called the “Little Roach”, Curf comprises a series of sandy Chert Beds interspersed with micritic and shelly limestones. Curf from certain areas may weather rapidly (particularly when used externally in exposed locations) and it is not therefore, always suitable for use as masonry stone. The word “Curf” or “kerf” is an old verb used in some areas to describe the undercutting of a coal seam. It is also a name used in Dorset and Hampshire to describe the notch made with an axe or saw when felling a tree. This suggests that in the past, Whitbed was quarried by making an undercut in the Curf.

At the bottom of the freestone beds is the oolitic / micritic Basebed (up to 2m). Basebed is often considered the finest quality Portland Stone available. Typically Basebed has a very homogenous texture with a negligible shell content making it eminently suitable for carving fine detail in deep relief. Basebed can be cut and carved in any direction and as such is often a true free stone. It is not quite as durable in exposed locations as Whitbed but makes an unbeatable monumental and carving stone used on very many prestigious building projects. Probable rate of weathering or retreat is 3-4 mm per 100 years. Identifiable fossils are relatively rare in the Basebed, occasional ammonites and the odd carbonaceous driftwood trace fossil can sometimes be found.

The average density of all the Freestone Beds is around 2.4 tonnes/m³. Typically they all consist of >95% calcium carbonate (CaCO₃) along with small proportions of silica (SiO₂), iron (as Fe₂O₃), magnesium oxide (MgO) and alumina.

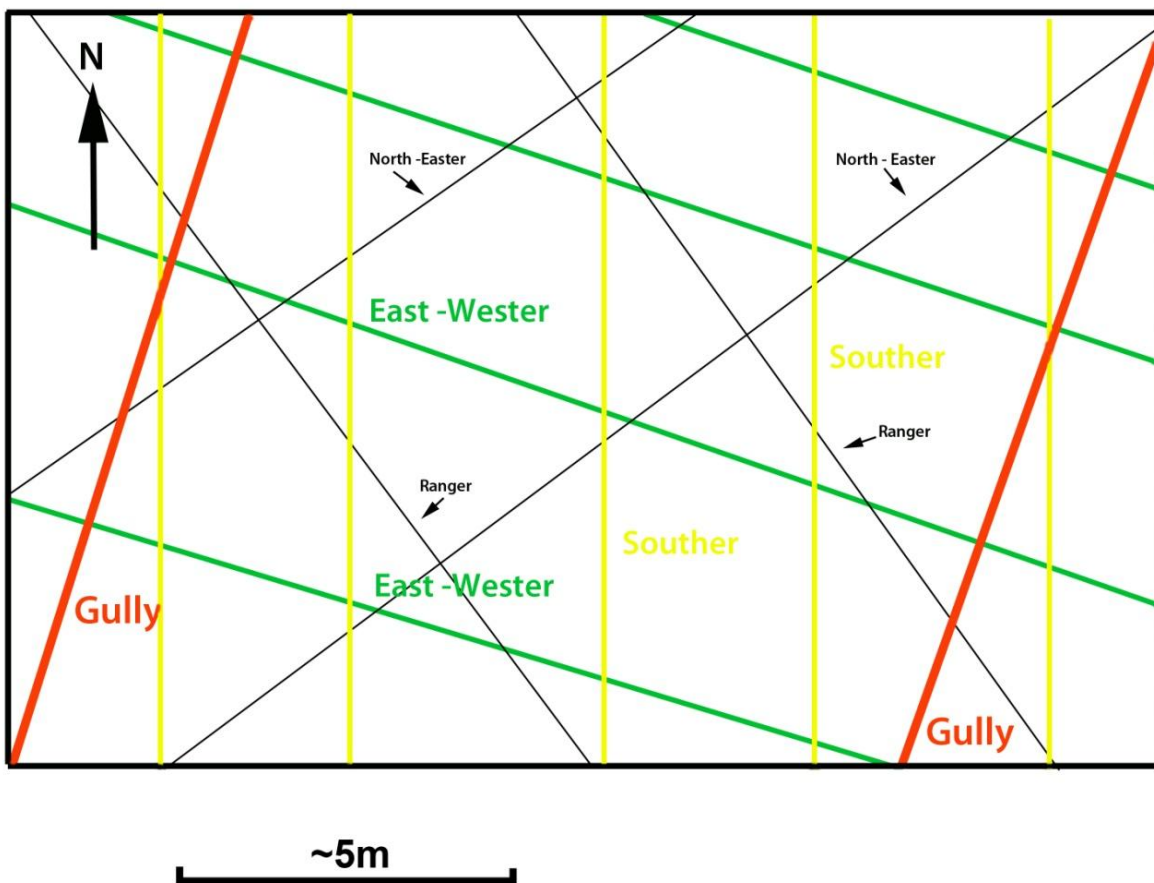
Hard black cherts commonly occur in bands at the junctions between the Roach and Cap, the Whitbed and Basebed and also at the base of the Basebed (the top of the Chert Member). Chert is composed of silica (SiO₂) which is believed to have been biological in origin (biogenic), probably coming from the skeletal remains of diatom-like organisms and siliceous sponge needles or spicules. It is believed that chert formed diagenetically, by a complex chemical process that took place in buried voids, after the Portland Stone beds were laid down. Cherts were collected (possibly from exposures on the coastal cliffs) and heavily exploited for tool manufacture by people living in prehistoric times. Interestingly, some archaeologists believe that knapped chert tools originating from Portland were widely traded across the whole of southern England.

Below the Freestone Member is the Cherty Series of the Chert Member (30m). The Cherty Series comprises numerous thin interspersed micritic limestone and nodular chert beds. Although geologically classified as part of the Portland Stone Formation, the Chert Member is of no use to a quarryman trying to extract dimensional stone. The Chert Member has however been quarried and crushed to produce a low-grade aggregate. There is a superb exposure of the Cherty Series (including “ladder cherts” that formed in what are possibly *Thalassinoides* burrows) in Admiralty Quarry SY695731. The Portland Stone Formation which was exclusively deposited in a marine environment exhibits a broadly progradational trend. This results in a general upward decrease in the density of chert and an increase in the density of included fossil shell, with the Chert Member at its base and the Roach at the top. The Portland Stone Formation is overlain by the partially terrestrial Lulworth Formation of the Purbeck Group, providing evidence of further progradation. The Basal Shell Bed which lies at the bottom of the Cherty Member is a grey argillaceous limestone packed with fossil bivalves and serpulids. The Basal Shell Bed is well exposed at the base of some fairly unstable cliffs at Freshwater Bay SY691701.

The Chert Member overlies the Portland Clay and the glauconitic / dolomitic Portland Sand (35m), which is well exposed at the base of West Cliff at Blacknor SY677714. Under the Portland Sand lies the fossiliferous Kimmeridge Clay Formation, with kerogen-rich horizons that were once burnt in lieu of household coal by Portlanders. The Kimmeridge Clay Formation has a total recorded thickness of over 500m in South Dorset. Only a small exposure of Upper

Kimmeridge Clay crops out at the northern end of Portland, the majority of lies at or below sea level. The Kimmeridge Clay Formation is the North Sea oil's source rock and is therefore of huge economic importance to the United Kingdom.

Fig. 7. Idealized diagram illustrating the sub-vertical joint sets found within the Freestone Member on Portland. North-Easters, Rangers, Souther and East-Westers (Quarrymen's terms) comprise two sets of generally closed, compressional conjugate joints. Occasionally tight joints dipping at $\sim 45^\circ$ that are aligned and associated with East-Westers are encountered. Called "Slyvers" by quarrymen, these joints can be highly disruptive to the quarrying process. Gullies (or master joints) are generally well dilated, typically $\sim 0.5\text{m}$, extensional joints.



After a diagram by SSB Hounsell, Mine and Quarry Engineering, June 1952.

Quarrying.

Fig. 8. *Traditional Portland quarryman’s hand tools used to extract and “square” blocks of stone (left to right); Sledgehammer, twibel, kivel and axe.*



The quarrying of Portland Stone is greatly influenced by the extensive jointing found within the Freestone Member (fig. 7.). Closely parallel extensional master joints (or “Gullies”) that are associated with the tectonics that folded the Weymouth Anticline and Shambles Syncline occur at regular spacings of around 25m. Gullies strike approximately NNE and are typically quite open (~0.5m). The area between the gullies is further divided by two discrete sets of older, tighter conjugate joints. “Southers” strike roughly N and “East-Westerns” strike ENE. Working in sympathy with the jointing yields roughly cuboidal blocks of stone that can be extracted with a minimum of cutting by quarrymen. The second, generally less persistent set of conjugate joints called “Rangers” (striking approximately SSE) and “North Easterns” (striking approximately NE) also occasionally occur within the Freestone Member on Portland.

Fig. 9. *Plugs & Feathers, a now largely out-dated method used to cut a quarry blocks by exerting a tensile stress into stone, eventually inducing a linear fracture.*



After the overburden has been stripped and the Portland Freestone Beds have been exposed, quarrymen can start to establish the local jointing pattern in the area of the quarry which is to be worked. Traditionally, small diameter holes (35 mm) were drilled horizontally under each rock to be removed; the holes were usually drilled either in or parallel to a bedding plane or “rising”. Once drilled, the holes were charged with a kilogram or two of black powder (gunpowder), chosen because of its relatively low velocity of detonation. When fired, black powder does not truly detonate but rapidly deflagrates, producing a large volume of gas which results in a “heave” used to dislodge the rock from its natural bed, hopefully undamaged. This operation exploits the natural weakness presented by the presence of horizontal bedding planes and vertical joints.

Fig. 10. *Modern quarry bench saws making vertical cuts downwards into the Whitbed and Basebed at Fancy Beach Quarry.*



In 1999, Italian stone cutting equipment, originally designed for use in Tuscany's marble quarries, was imported by Albion Stone and applied to Portland Stone. This new technology is now used to quarry all dimension stone produced by the company, thus completely eliminating the need for any blasting. Full account of the local jointing pattern is made when deciding the position and orientation of cuts. The elimination of blasting has significantly improved the quarries' environmental performance and removed the potential for any possible damage to the stone being quarried, through shock. Quarry faces are dry cut using bench saws fitted with 3m long, poly-crystalline diamond tipped, chain-saw type blades with low peripheral speeds of between 0.9 and 1.7m/s (fig. 10.). Once cut, the stone is gently displaced hydraulically using "Hydro-bags" (fig. 11.). These are thin, flat, steel bags or envelopes. When a number of Hydro-bags are placed deep into a bench saw cut and simultaneously inflated with water under moderate pressure (~20 bar), they are capable of producing the large forces (~2000kN or ~200

tonnes of force per bag), at right angles to the cut, necessary to loosen and displace the stone to the point where it can be easily removed using large wheeled loaders.

Fig. 11. *1m² high tensile steel Hydro-bags, only a few millimeters thick when empty (left), can be inserted into cuts to displace stone through several hundred millimeters (right) by producing forces equivalent to many hundreds of tonnes when slowly inflated with pressurized water. When using Hydro-bags, it is usual to inflate several (evenly spaced along a cut) simultaneously.*



Once removed from the quarry face, very large rocks must be cut to produce smaller, more easily handled “squared” stones ready for transport and use by masons. From the 1950’s up

until the late 1990's, most stone within Portland's quarries was cut using plugs and feathers (fig. 9.). A series of short, small diameter (typically 30mm) holes are "stitch drilled" in a line where a cut is to be made. One plug and two feathers (aligned with the direction of the cut) are inserted into each hole. Each chisel shaped plug is hit in turn using a sledgehammer, driving it between the feathers, until the stone yields to the extreme tensile stresses produced. Prior to the introduction of plugs and feathers to the Island in the early 1950's, large stones were cut by inserting iron "Wedges" and thin plates called "Scales" into a "V" shaped groove picked into the surface of the stone to be cut using a twibel (fig. 8.). Several wedges were inserted, each positioned between two or more scales and hit in turn with a sledgehammer to produce a large tensile stress. Before the introduction of explosives to Portland, stone was removed from the ground using similar techniques in conjunction with joints and bedding planes. Most stone is many times weaker in tension than in compression and both "plugs and feathers" and "wedges and scales" utilize this fact. It is also worth noting that, when employing these cutting methods, stone tends to split much more easily parallel to bedding planes (called "graining") than perpendicular to them (called "cutting").

Splitting stone using pneumatic drills is arduous work so wire-saws and tractor-mounted, Fantini chain-saws have been introduced into Albion Stones' quarries, replacing most of the plug and feather cutting (figs. 12 & 13.). Additional benefits of sawing are an increase in the quantity of stone produced, squarer blocks and improved quality control, as it is much easier to assess the quality of a block if it has sawn faces.

Fig. 12. A wire saw that uses a continuous ~12.5m loop of diamond impregnated wire, moving at 25m/s to cut stone. Water is used to cool the wire and flush fines from the cut.



Fig. 13. A Fantini, poly-crystalline diamond tipped chain-saw mounted onto a JCB tractor, squaring blocks in Bowers Quarry.



Mining.

Fig. 14. *The Portals at Jordans Mine, opened by Albion Stone during 2008.*



In October 2002 Albion Stone successfully initiated Portland's first ever underground mining operation in Bowers Quarry SY683717. This was a precursor to Jordans Mine, SY688721, started in 2008 and other mining operations, planned for environmentally sensitive areas elsewhere on Portland. It was possible to translate many of the skills learnt using modern stone cutting equipment in open quarries, to an underground mining situation. The mines use a 75% maximum aerial extraction ratio with roadways and pillars set out on an approximate 6m x 6m grid (fig. 16.). Systematic roof support is by means of 2.4m long, fully resin encapsulated rock-bolts installed vertically into the Skull Cap and Hard Cap. At working faces, stone is dry cut using poly-crystalline diamond tipped chain-saws (fig. 15.). Roadway alignment is closely controlled by the strikes of local conjugate joint sets. Stone is displaced from mine faces using hydro-bags and removed using a forklift. Mining allows the extraction of stone from beneath sensitive or otherwise inaccessible areas with a minimum of environmental disturbance at the surface, thus helping to ensure a harmonious future for the stone industry on Portland.

Fig. 15. *TwoFantini GU50 mining machines cutting Roach and Whitbed in Jordans Mine.*



Fig. 16. *Jordans Mine is designed with a 75% maximum aerial extraction ratio, with roadways and pillars set out on an approximate 6m x 6m grid.*

History.

Portland's Freestone has been used as a construction material since Roman times. The many well crafted Roman sarcophagi (stone coffins) with matching lids, hewn from single large blocks of Portland Stone that have been unearthed locally over the years, testify to the skill of their makers. It is interesting to speculate where the many large blocks of stone needed to make the sarcophagi were obtained and how they were transported. It is possible that stones came from coastal exposures, where they may have been dislodged by the action of the sea. Nevertheless the skills necessary to select suitable blocks, retrieve them, shape and hollow them are considerable and hint at an industry of some maturity. Were the sarcophagi “made to order” following someone's death? Considering the amount of work and more critically, length of time involved, this would seem unlikely because of the practical need to carry out a burial promptly after death. Is it possible then, that during Roman times, there was a stone industry on Portland producing “off the shelf” sarcophagi?

The earliest known building to be constructed using Portland Stone is Rufus Castle at Church Ope Cove, Portland SY697711. The original structure was probably built in around 1080, rebuilt in around 1259 and rebuilt yet again in about 1450 which is the likely date of the walls standing today.

The first known Portland Stone quarries were situated on the north eastern coast of the Island, close to Rufus Castle, where major joint controlled landslips (failure of the underlying Kimmeridge Clay led to toppling failure of the Portland Stone Formation between master joints) made the stone more easily accessible to quarrymen. The close proximity of the sea, allowed the quarried stone blocks to be easily transported over relatively large distances by barge.

Portland Stone was used to build the Palace of Westminster in 1347, the Tower of London in 1349 and the first stone London Bridge in 1350. Exeter Cathedral and Christchurch Priory, also constructed during the 14th Century are built of Portland Stone.

Inigo Jones (1573-1652) used Portland stone to build the Banqueting Hall in Whitehall in 1620. Sir Christopher Wren (fig. 17.) used nearly one million cubic feet to rebuild St. Paul's Cathedral

and many other minor churches after the Great Fire of London in 1666 (fig. 18.). All of the stone used by Wren was transported by sailing barge from Portland to the centre of London via the Thames. Wren's widespread use of Portland Stone firmly established it as London's "local stone" and as one of the best loved British building stones.

Fig. 17. *Sir Christopher Wren (1632-1723), appropriately carved in Portland Stone (Independent Basebed).*



Other famous London buildings constructed of Portland Stone include The Royal Naval Hospital, Greenwich 1712, The British Museum 1753, Somerset House 1792, General Post Office 1829, The Bank of England, Mansion House 1758 and the National Gallery 1838.

At the beginning of the Nineteenth Century the output of Portland Stone is believed to have typically been 25,000 tons per annum. One estimate suggests that there were 800 men and boys, 180 horses and 50 ships involved in Portland's stone trade at that time.

In the years following the Industrial Revolution, the acid rain, resulting from the heavy combustion of coal in cities had the effect of continuously (slightly) dissolving the surface of Portland Stone ashlar on buildings. This had the fortuitous benefit of keeping exposed and rain-washed surfaces white in contrast to other (non-calcareous) stones which quickly discoloured to black in the smoky atmospheres. This sacrificial self-cleaning property probably helped to enhance the popularity of Portland Stone at this time.

Following the First World War (1914-1918), Sir Edwin Lutyens (1869-1944), used Portland Stone (quarried from the south of Wakeham SY695712) to construct the Cenotaph in London's Whitehall. Erected in 1920, the Cenotaph commemorates the millions of people killed in this and subsequent conflicts, additionally most of the headstones used to mark the graves of British and Commonwealth war dead are also of Portland Stone.

After the Second World War (1939-1945) the devastated centres of many towns and cities, such as Plymouth, Bristol, Coventry and London that had been subjected to intensive bombing during the conflict, were reconstructed using vast facades of Portland Stone.

During the 1960's and 70's there was a change in popular architectural style with many buildings being constructed using only synthetic materials such as concrete and glass. The knock-on effect of this caused Portland's stone industry to contract to the point where only a handful of men were employed quarrying Portland Stone.

Recent years have seen a fundamental increase in environmental awareness amongst clients, architects and most other stakeholders within the building industry. There has also been a marked resurgence in popularity of more classical building styles. These changes have led to an increased use of traditional and more natural building resources which often have low carbon footprints compared to synthetic building materials. The stone industry on Portland has benefited from these changes with a much increased demand for Portland Stone, which as well

as having sound environmental credentials, imparts to the buildings constructed with it a timeless elegance and style.

Fig. 18. *Old and New; London's St Paul's Cathedral viewed from the new Paternoster Square Development, both constructed of Portland Stone.*



Acknowledgements.

When writing this document I made very grateful use of the following sources:

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