

Feature



Digging deep for Portland Stone

The Island of Portland has literally given its heart to London, and the heart of London comes mainly from Portland. Many of London's most recognizable buildings and monuments are constructed either wholly or partially from the white Upper Jurassic oolite quarried from Portland. St Paul's Cathedral, the British Museum, The Bank of England and more recently the New London Stock Exchange in Paternoster Square and the Bomber Command Memorial and the tube station in Green Park, are all built using Portland Stone. London is not the island's only beneficiary, Portland stone has also been widely used throughout the rest of Great Britain as well as having been exported for use in many other countries.

Situated close to the centre of the Jurassic Coast of southern England, Portland is a tied island, connected to South Dorset by the sweeping tombolo of Chesil Beach. The late Jurassic and early Cretaceous rocks that crop out on Portland all dip gently to the south-east. The island is a remnant part of the Weymouth Anticline's southern limb, giving the Island its distinctive wedge shaped profile when viewed from the east or west. Intensive opencast quarrying throughout the last 300 years has left its mark on Portland, with many disused quarries now littering the island's upper surface. Many of Portland's former quarries have naturally regenerated to become important and protected ecological sites because of the unusual flora and fauna the calcareous rocks and soils attract.

Portland freestones

At the top of the Portland Stone Formation's Freestone Member (Fig. 1) is the 'Roach' (1 m). The Roach lies immediately beneath the Lulworth Formation's Basal Dirt Bed which marks a huge environmental (and hence facies) change—from a marine limestone to a terrestrial palaeosol.

Although not technically a freestone in the truest sense of the word (i.e. one that can be freely worked in any direction), Roach has traditionally been considered as the topmost and youngest 'freestone' bed on Portland. The name 'Roach' is possibly derived from the old French *roke* or *roche* in English usage since the middle of the thirteenth century, meaning a mass of rock, a cliff or boulder. Roach is an oolitic

limestone full of distinctive casts and moulds from gastropods and bivalves such as *Aptyxiella portlandica* and *Laevitrigonia gibbosa*.

Below the Roach is the 'Whitbed' (up to 2.5 m-thick), its name almost certainly a corruption

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

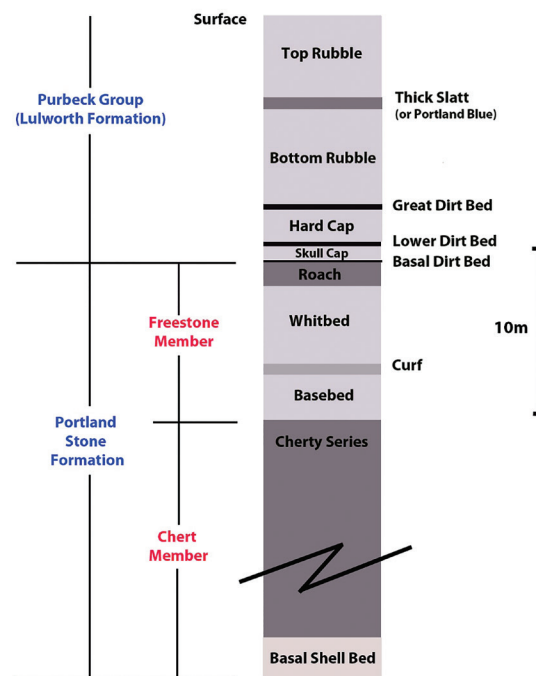


Fig. 1. Simplified stratigraphic section of the Portland Stone Formation (and overlying Purbeck Group) at Jordans Mine. Note that the Cherty Series is not shown to scale.

Fig. 2. The roof within Jordans Mine is coincident with the upper surface of the Lulworth Formation's Basal Dirt Bed. As a consequence the mine's roadways all dip at a couple of degrees (following the strata) to the south-east.



Fig. 3. Fantini GU mining machines are used to make 1.8 m deep (vertical and horizontal) cuts into faces to be extracted. This results in a number of cantilevered blocks, with sawn edges, attached only on their rear faces.



Fig. 4. Blocks are removed using a custom built Volvo loading shovel equipped with specially adapted quick release forks and a bucket.



Fig. 5. The mine is laid out on a notional 6.5x6.5 m grid forming a classic room and pillar configuration. Where pillars are bisected by dilated joints, they are often left oversized.

of 'white bed'. Whitbed is a fine grained, mainly oolitic limestone typically containing a proportion of comminuted shell fragments, ranging between ~ 5 mm and ~ 50 mm 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. 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 on the stone predict a probable weathering or retreat rate of 1–2 mm per 100 years.

Beneath the Whitbed is the 'Curf' (1 m-thick). 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 2 m-thick). The Basebed is often considered to be 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 freestone. It is not quite as durable in exposed locations as Whitbed but makes an unbeatable monumental and carving stone for use on very many prestigious building projects. Its 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 Portland freestone beds is around 2.4 tonnes/m³. Typically they all consist of >95 percent calcium carbonate (CaCO₃) along with small proportions of silica (SiO₂), iron (as Fe₂O₃), magnesium oxide (MgO) and alumina.

Below the Freestone Member is the Cherty Series of the Chert Member (30 m). 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 dimension stone.

Quarries and mines

With an area of approximately 10 square kilometres and with a population of around 12000 people, pressure on Portland's land use is intense. Fewer local people are dependent upon the stone industry for



Fig. 6. After the blocks of dimensional Portland Stone have been removed, some trimming of the roof to remove the thin Transition Bed and Basal Dirt Bed (which overlie the Roach) together with the removal of any irregularities in the newly exposed face is undertaken, using a backhoe-mounted hydraulic breaker. The mine roadway has advanced up to an extensional joint and excess rock is being removed to create a new flat working face.

Fig. 7. The mine's roof is systematically supported using rockbolts, installed in a regular pattern which is extended up to working faces as the mine advances. All cutting operations are therefore undertaken beneath a fully supported roof-beam.



Fig. 8. Whitbed and Roach pillars have rib support put into them with the aim of preserving the pillar's cross-sectional area.



Fig. 9. Access to the Basebed is by means of two easily navigable 10° ramps which were cut into the floor of the initial Whitbed and Roach workings.



employment than once was the case and obtaining 'green-field' Planning Permissions for new quarries on the island has become increasingly difficult in recent years. It was under these circumstances that Albion Stone decided to attempt mining on Portland in order to obtain new stone.

As a first step, in 2002 a trial mine was developed in Bowers Quarry (SY682717) with the aim of validating an initial mine design and developing efficient working methods. This initial experimental work ultimately led to a planning application for a new mine, to be cut into a remnant working face of (the long abandoned) Jordans Quarry (SY688721) sited in the centre of the island. Jordans Mine was to be developed beneath a local cricket pitch, in a seven-acre site surrounded by numerous sensitive environmental receptors.

Since it was started in 2008, Jordans Mine has been granted two planning extensions (effectively doubling its curtilage—its potential area of operation) and it is currently about halfway through its operational life.

Mine operations

Roadways were initially cut only in the upper part of the Portland Stone Formation's Freestone Member (the Whitbed and Roach) with the mine's roof being coincident with the upper surface of the Lulworth Formation's Basal Dirt Bed (the bottom surface of the Basal Purbeck's thrombotytic Skull Cap). Using a natural bedding surface as a mine roof means that the roadways all follow Portland's structural dip (Fig. 2).

Working faces are cut using computer-controlled Fantini GU mining machines, fitted with diamond tipped 'chain-saw' type blades (Fig. 3). Blocks of Portland Stone are displaced from cut mine faces using steel 'hydro-bags' that forcefully expand when inflated with water. Hydro-bags can produce sufficient pressure to shear the newly cut (and hence cantilevered) blocks on their rear faces. The displaced blocks are removed using a custom built Volvo L150H loading shovel fitted with specially adapted forks (Fig. 4).

The 'room and pillar' mine is laid out on an approximate 6.5 × 6.5 m grid. Mine design is locally quite flexible because it is often necessary to take account of the positions and strikes of well-dilated extensional joints when deciding where to cut mine

Fig. 10. Two ramps were cut in parallel to provide workers with more than one means of emergency egress. The ramps were incrementally extended until they reached the bottom of the Basebed (coincident with the top of the Portland Stone Formation's Chert Member).



Fig. 11. Work to bench-mine the Basebed then began, following the footprint of the Whitbed and Roach workings, leaving all of the pillars *in situ* but increasing their height to around 9 m.



Fig. 12. An uneconomic horizon of (often cross-bedded) chert nodules and limestone at the base of the Whitbed is routinely removed using a hydraulic breaker. The GU mining machines are able to cut this chert but because of its relative hardness, diamond usage often increases to unacceptable levels.



roadways. The presence of such dilated joints (known locally as 'gullies') often results in oversized but jointed pillars (Fig. 5). Despite its locally dynamic design, the roadway and pillar configuration within Jordans Mine always complies with a designed maximum aerial extraction ratio of 75 percent.

After the usable blocks of dimension stone have been extracted from working faces, the newly exposed faces (behind) are prepared for re-cutting, using a backhoe mounted hydraulic breaker to remove any protruding or loose material (Fig. 6). The Skull Cap/Hard Cap roof above the newly advanced roadway is then drilled and systematically supported using rockbolts installed into the holes using a bespoke bolting rig (Fig. 7).

The mine's roof beam and pillars are closely monitored for instability and signs of distress. To-date no significant problems with either the roof or pillars have been encountered. Horizontal, 2.4-m rib bolts are installed into pillars at the Whitbed and Roach horizon with the aim of preventing joint-controlled delamination and a consequential reduction in pillar cross-sectional area (Fig. 8).

Following the extraction of Whitbed and Roach across a significant proportion of the mine's curtilage, two access ramps were cut downwards into the mine's floor with the aim of creating vertical faces in the lower part of the Portland Freestone Member (the Basebed) (Fig. 9). Two ramps were emplaced to provide more than one means of egress during an emergency (Fig. 10).

Basebed is 'bench-mined' from the vertical faces that were created by cutting ramps into the original mine floor. The Basebed workings follow in the footprint of the initial Whitbed and Roach roadways, whilst keeping the pre-existing pillars *in-situ*. Lowering the mine's floor horizon increases the pillar heights from 4 m to 9 m (Fig. 11).

The basal Whitbed contains a great deal of chert which has no economic value and can be costly (in terms of diamond usage) if cut using the Fantini GU machines. This material is therefore broken out using backhoe mounted hydraulic breakers (Fig. 12) and is removed using the modified Volvo loading shovel, fitted with a bucket (Fig. 13).

After the Basebed has been extracted, the lower 5 m sections of the newly created 'full-height' pillars also have systematic rib-support applied to them. This helps to maintain structural competence in the bottom half of each pillar (Fig. 14).

The mine is force-ventilated. Fresh air is pumped from an externally located, electrically-driven fan via

Fig. 13. The broken cherts of the Basal Whitbed are cleared from the working area using the same Volvo machine as is used for block extraction, now fitted with a bucket.



Fig. 14. Following removal of the Basebed, the resultant full height pillars are also given rib-support at this horizon with the aim of preventing joint controlled pillar failure.

Fig. 15. The mine is force-ventilated via an 800 mm diameter pipe with smaller diameter capillary tubes feeding blind headings.



Fig. 16. Jordans Mine has been in operation since late 2008 and since then it has yielded many thousands of tonnes of high quality Portland Stone with virtually no environmental impact on the local population.



an 800 mm diameter arterial pipe, running to the mine's deepest extent. Smaller diameter capillary tubes diverge from the main tube to deliver fresh air to blind headings (Fig. 15). Besides trace amounts of radon, there are no concentrations of naturally occurring explosive or poisonous gasses within Jordans Mine. The principal purpose of the ventilation system is to flush diesel vehicle exhaust fumes from the workings but it also serves to prevent any harmful build-up of radon underground.

Conclusion

Since its beginnings in 2008, Jordans Mine has yielded many thousands of tons of valuable Portland Stone from an area in which would have been impossible to open-quarry because of the environmental impact (Fig. 16). Mining on Portland offers the island's stone industry the potential to recover dimension stone from areas where quarrying would be impossible. Mining will hopefully give Portland's stone industry a secure future and provide building stone to London for many decades to come.

Suggestions for further reading

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