Chapter 2
The landscape of Combe Down

Topography

The landscape of Combe Down is based entirely on Jurassic rocks, including the area northwards to Bath and south to Tuckingmill (Fig. 2.1), which are easily but differentially eroded and have resulted in the dramatic topography of the valley of the River Avon, with steep slopes (between 1:5 and 1:10 are common) on either side of the river rising to limestone plateaux to the north (Lansdown) and south. Combe Down occupies part of the down on the south. The slopes are modified, by headward erosion by springs, into combes. Between Bath and Combe Down the steep valley of Lyncombe is directly opposite the city centre (Bath Abbey), with springs emerging just below Prior Park House. Widcombe is to the west, and was followed by the Roman Fosse Way through what is now the built-up area known as Odd Down. Horsecombe is over the hill to the south of Combe Down and descends to the east from the west boundary of Combe Down near the Cross Keys Inn, to Tuckingmill. Strong springs emerge on the north side of Horsecombe near the west end below Shepherds Walk. A further branch combe is developed out of the lower part of Horsecombe, the top of which has a very strong series of springs known as Whittaker Springs (near and just above the de Montalt Mill). Further springs emerge just above Tuckingmill and these and the Whittaker Springs are used for water supply. In the east, Brassknocker Hill forms the modern day boundary where the gradient is somewhat more gentle.

Both the Avon Gorge and Horsecombe are over-deepened, that is, the deepening has been faster, due to the vulnerability of the rock, than the adjustment of the slope angles to a stable condition, so both slopes are unstable and have fairly widespread evidence of landslip and what is known as cambering of the superposed limestone strata (below). The limestone beds, known as the Combe Down Oolite with the Twinhoe Beds above, form an almost level plateau running, from west to east, through Odd Down, Combe Down, Claverton and Bathampton Downs, for some 5 km, with a width of around 1 km. It forms an elevated tract rising to about 200 m OD, about 150 m above the River Avon. This is the tract which has the freestone quarries. The river partially encircles the upland tract which was important when the adjacent canal was built, in giving several points of access from Combe Down. Meanders in the river have provided a site for the historic core of Bath.

On all but the west side, the limestone edge forms an escarpment with either cliffs or very steep slopes down to the softer beds beneath. Combe Down has only a north and south 'rim', marked on the south side by Shepherds Walk from the Cross Keys Inn to the village, and, eastwards, under the cliff, Summer Lane, formerly Combe Lane angling down the hillside to Combe, known today as Monkton Combe. It is aided in this route by crossing the rim where a fault has disrupted the strata. On the north side of the down the rim has a walk above the steep slope of the 'Hanginglands'. This was formerly known as Popes Walk, though this name where it passes through a modern housing estate, has now been adopted for part of the Bath – Combe Down – Tuckingmill footpath, known also as the Long Drung, which crosses over the whole of the hill, using Horsecombe and the west side of Lyncombe.

The down land was, in former times, mostly sheep pasture and is naturally dry underfoot. What was formerly a track called the Claverton Road, which is now the line of the Bradford and North Roads crosses from east to west over it, bounding the top of Prior Park. On the north – the Bath side – roads use the combes to access the downland. However the beds immediately below the rim, mostly clays, locate the emergence of springs, and in winter especially the clays can prove difficult to traverse, so that routes over them, until improved in modern times, proved difficult, and were treacherously soft underfoot on steep slopes. The problem is probably reflected in the name 'Summer Lane' on the southern slopes. Other roads reflect either the former needs of quarries or result from subdivision for housing.

Most of the houses in the modern village of Combe Down, with the exception of some on Summer Lane, and two or three in the upper part of Horsecombe, have chosen to be on the higher, drier ground. Prior Park, just outside the parish of Combe Down but very close by, was built on the limestone close to the clay margin, the springs being used for water gardens and a lake.

Geology

The following account is based mainly on the six-inch geological maps, and commentaries by Forster *et al*. (1985) and Macdonald *et al*. (2000). Other sources, whether historical or from detailed observation within the quarries are cited as appropriate. These include observations by William Smith, the 'Father of Stratigraphy', whose early studies took

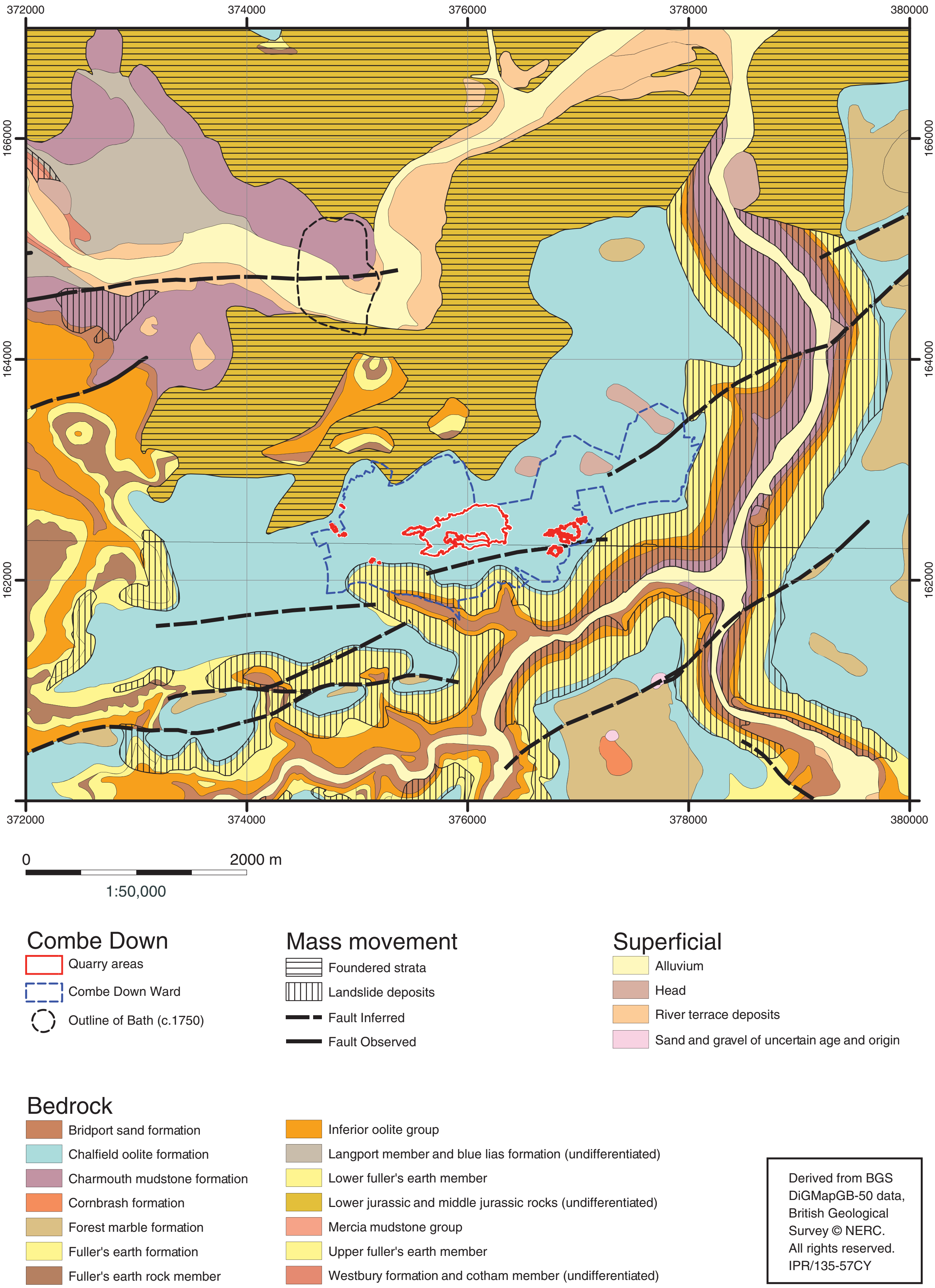

Fig. 2.1 The geology of Combe Down and the surrounding area, showing the parish boundary and selected place-names

Derived from BGS DiGMapGB-50 data, British Geological Survey © NERC. All rights reserved. IPR/135-57CY place in this and adjacent areas, and who lived at Tuckingmill.

All the outcropping rocks (solid geology) in the immediate area of Combe Down, as noted above, belong to the Jurassic period. Figure 2.2 schematically shows the local stratigraphic sequence. Bath and the River Avon rest on Liassic clay and limestone rocks (Blue Lias), which underlie but are not exposed in the Combe Down area. Liassic limestone was quarried west of Bath and its clays were probably used for brickmaking. An area known as Brick-kiln Fields lies to the north of Widcombe village (Chapman 1996, 5). Overlying the Lias are the Midford Sands. These are silty sands, sometimes with hard bands of calcareous concretions that thin laterally southwards to nothing around Wellow. These were probably the source of sand in a sandpit in Monkton Combe (perhaps at Tuckingmill) and the sands also outcrop on the lower slopes of Widcombe where they were worked as foundry moulding sands (1:10000 Geological Survey). Within Combe Down, they outcrop in the floor of Horsecombe Vale. A depth of up to 24.5 m has been recorded, but this substantial thickness may have been the result of a slip. The Inferior Oolite above the Midford Sands is made up of fossiliferous limestones, including the Trigonia Grit, the Upper Coral Bed and an oolitic limestone, in all about 11-12 m thick. These were worked locally for a monumental limestone, the Yeovil Marble and, from 'everywhere' at its base a friable 'calcareous sand' was 'used by cooks to sand their kitchens' (Townshend 1813, 105). The outcrop is marked by copious issues of springs and is found in Horsecombe and just below the railway cutting near Tuckingmill.

The Fullers Earth Clays (now termed the Bathonian Formation) are the next higher in the sequence. The once commercially important true Fullers Earth is a montmorillonite clay (60-70% of the rock) which occurs in only a thin stratum, up to 3 m of the *c* 54 m total thickness of the formation. The montmorillonite clay was derived from volcanic dust from a relatively close source which settled in a marine environment and was reworked by tidal currents and concentrated into thin, discontinuous, layers. The bulk of the sequence, however, is made up of the more common illitic clays and mudstones, together with thin bands of limestone. A thicker limestone band, the Fullers Rock, separates the Lower and Upper Fullers Earths, and the commercial bed lies from 3 to 10 m below the top of the Upper Fullers Earth. The commercial interest in the deposit led to a borehole (Horsecombe No. 18) being sunk in 1971 at the former quarry west of Combe Road, finding the top of the sequence some 7.62 m below surface. Borehole No. 9, at Shepherds Walk at Horsecombe Head, passed through 11.4 m of limestone before intersecting the clay (6 inch Geol. Survey; Penn *et al.* 1979).

The original use for Fullers Earth was for degreasing woollen cloth during the fulling process, a property which depended on its power to absorb oils on to its crystal surfaces. Fullers Earth, at least in recent centuries, was not worked in or under Combe Down, although mines operated early last century on the South Stoke side of Horsecombe Vale, within the study area, with other sites near Odd Down. A small boom in Fullers Earth production emerged about 1880 with demand from the nascent north American oil industry (Parfitt 2001,

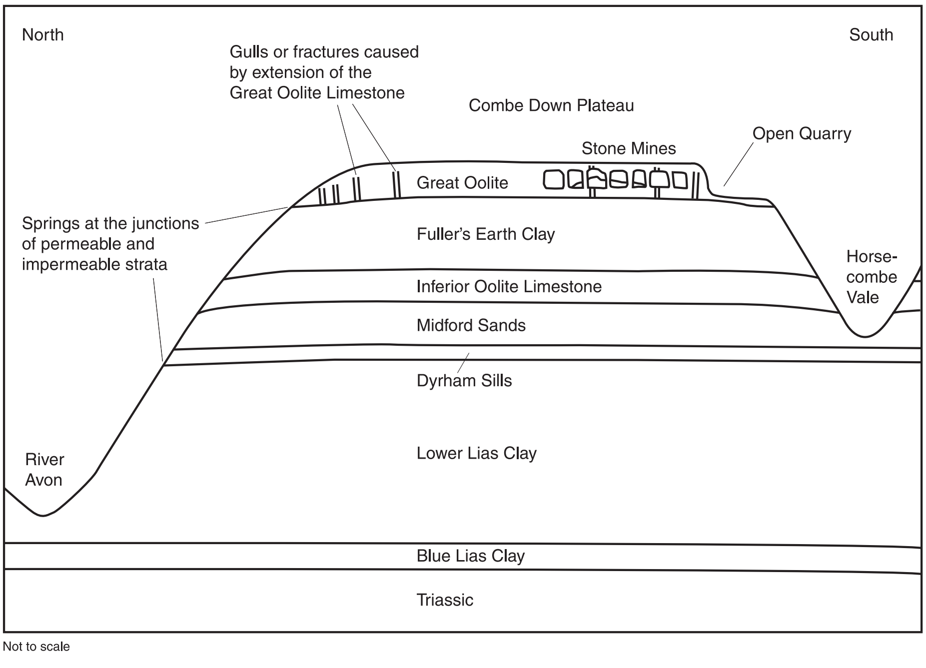

Fig. 2.2 The strata under Combe Down (after Hawkins 1994)

136. See also a recent published account by Macmillan 2009), and small works developed to process it, including at South Stoke and Tuckingmill. A gravity mineral tramway at South Stoke took the raw material, from several sources, down to the boundary stream with Combe Down where it was agitated with water, probably by a paddle wheel which survives in the stream bed, and the resultant slurry was piped about a kilometre to the Tuckingmill clay works. A section of this clay pipeline survives buried within Combe Down at the southern boundary below Beechwood. A Fullers Earth Union set up in 1890 to combine the various businesses was later taken over by Laporte, an industrial minerals company, who ran the Tuckingmill site until about 1970.

The clay-dominated sequence has been of immense importance locally in another way. Wells were sunk through the overlying oolitic limestone to reach it and use was made of springs issuing at the margin. The most notable of these was and is the Whitaker Spring next to the de Montalt Mill. There the water is delivered underground by a fault, which was tapped by tunnels bringing it to a central point. This, and water from springs at the same outcrop at the top of Horsecombe Vale, merge at Tuckingmill and provide much of the water pumped from there into local supplies. In former times these also provided power for the de Montalt Mill, Tuckingmill and, with additional water from the Wellow Brook, Monkton Combe. It was also used for growing of irrigated crops such as water-cress. Water in Widcombe's Prior Park also issues at this horizon and feeds the ornamental features and pond lower down.

Less positively, the clay, particularly in the Upper Fullers Earth, forms a weak substratum to the overlying rock and squeezes out, sometimes forming an almost level terrace just below the limestone rim on the otherwise steep valley slopes and, commonly, hummocky ground with the arcuate features of a typical landslip. It is also an extremely difficult material over which to build stable roads and tracks and created considerable problems for all those who descended from the plateau.

The Combe Down Oolite

The limestone plateau on which Combe Down is sited is formed from the lowest limestones in the Great Oolite sequence, the Combe Down Oolite and the overlying, and less useful, Twinhoe Beds. The Oolite incorporates the freestone which has been quarried over a large extent of the present territory and, especially, adjacent Odd Down. The oolite was deposited as a lime sand (medium grain-size, most grains between 0.1 and 1.0 mm in diameter) on a shallow, current-agitated sea-floor that deepened towards the south, during the Bathonian stage in the Middle Jurassic period of geological time, *c* 166 million years ago.

The Oolite as a whole is composed of generally fine ooliths of limestone calcretions around minute shell fragments created in shallow seas, but also has shelly and thin marly (limey-clay) horizons within it. More technically, the oolite can be described as an oolitic calcarenite or oobiosparite.

Not all the sequence can properly be described as freestone, which only occurs (reliably) in the upper few metres of the sequence, ie the part that is quarried. According to Palmer (2009) based on drill-core samples, the top is marked by a hardened, iron-stained layer that is perforated by contemporaneous mollusc and worm borings. This, termed a hard-ground, is due to a thin layer of cement coating adjacent grains, and opaque fine-grained sediment filling the remainder of the intergranular porosity. Below the worked freestone the beds are increasingly impure and clayey limestones become more common and are unsuitable for building or carving.

In samples taken by Palmer from stone artefacts found in the quarries, the ooliths dominated and were ovoid to spherical, depending on the shapes of their nuclei. The original sediment was well washed and winnowed so no fine grained material occupies the pore spaces and in this preferred material, the ooliths are formed round fragments too small to identify. The grains are un-compacted, just touching at contact points. They are cemented with a clear calcite cement which seems to grow out of the grain edges. Though the rock is still porous, and the individual grains are mechanically weak, it is this cement which provides the overall strength.

The porous nature of the ooliths makes them soft and crumbly on freshly-exposed surfaces, covering it with a chalky dust. This soon washes off to leave a surface on which the former positions of the ooliths are marked only by their impressions in the enclosing cement.

Slightly larger shelly fragments are also found which form a subsidiary grain type in its own right. These are from echinoderms, oysters (and maybe scallops), and rare brachiopods and bryozoans. Shelly fragments replaced by aragonite also found were probably derived from molluscs (mostly gastropods and bivalves), and maybe corals. During the burial process the original aragonite material formed a micrite envelope around the grains. This was less useful material and any horizons of coral debris or burrows seem to have been deliberately avoided of rejected by the quarry workers.

One sample examined was exceptional. It was strongly compacted and the already cemented grains forced into one another, becoming fractured and finally re-cemented. This is a condition where the rock has been subjected to tectonic movement nearby.

Palmer also notes that the material quarried from the same horizon in the Corsham area of Wiltshire, used widely in the 19th century under the name of Box Ground Stone (and other names), seems to have more, and larger, recognisable shell fragments. This apparent difference deserves a closer study, but it does suggest one reason why Box and Corsham found it difficult to directly compete with Combe Down stone and instead used freestone from higher in the Great Oolite sequence.

Unfortunately the term 'freestone', referring to stone easily workable in all directions, has often been applied to the whole sequence, up to 18 m thick. In fact, the quarryman (at least in honest moments) referred only to the very fine-grained oolite as freestone. Few historic descriptions appear to suggest more than about 7 m of true freestone was worked. Other horizons were also quarried – harder material made hard-wearing courses and floors, or roadstone, and the stronger shelly limestones were used for structures such as bridges and also to create decorative features.

The detailed geology affecting quarrying and use of the Combe Down beds

At the marginal areas of the Oolite, the combes dominate all but the plateau area and result from headward sapping at the springs with erosion by fast-running flows of water down the already steep gradients due to the deep dissection, overdeepening to the base level of the River Avon. The removal of the underlying clay by extrusion or other erosion causes the limestone margin to progressively collapse, resulting in slopes (some of periglacial, soliflucted origin) to be littered with limestone boulders and sometimes large masses (head deposits) which can obscure the underlying solid geology.

The combination of weak (Bathonian Formation) clays lubricated and weakened by water draining through the permeable limestone, and a thick overlying Combe Down limestone with a strong joint pattern, has led to very extensive and continuing land-slips, and to cambering or 'draping' of the limestone (referred to as 'foundered strata') at the marginal areas. With respect to landslip, the Lyncombe and Widcombe slopes are perhaps more mature and less unstable with a slightly lower slope gradient than Horsecombe Vale, which has minor active land-slippage in many places that has largely deterred house-building there.

These processes have had an important influence on the surface and underground quarries, since the strongly jointed limestone opens at the joints to form gulls – open or soil and debris-filled fissures up to a metre and more wide. Such fissures can be seen, for example, at the north-east face of Springfield Quarry at Entry Hill. Open joints and gulls allowed the quarryman to remove blocks of the stone with little effort, simply using a bar to pry them out, rather than having to cut back in the stone using pick and jad or stone saws. Such openness of joints, however, had the penalty of the roof to the workings being unstable. It produced a particular form of underground quarry landscape which is rare if not unknown elsewhere in England.

Hawkins (1994) investigated the rocks of the plateau area in some detail (Fig. 2.3), to which it is possible to add observations made during the archaeological survey. There is a regional dip of 2-5° towards the east, although local flexures, such as

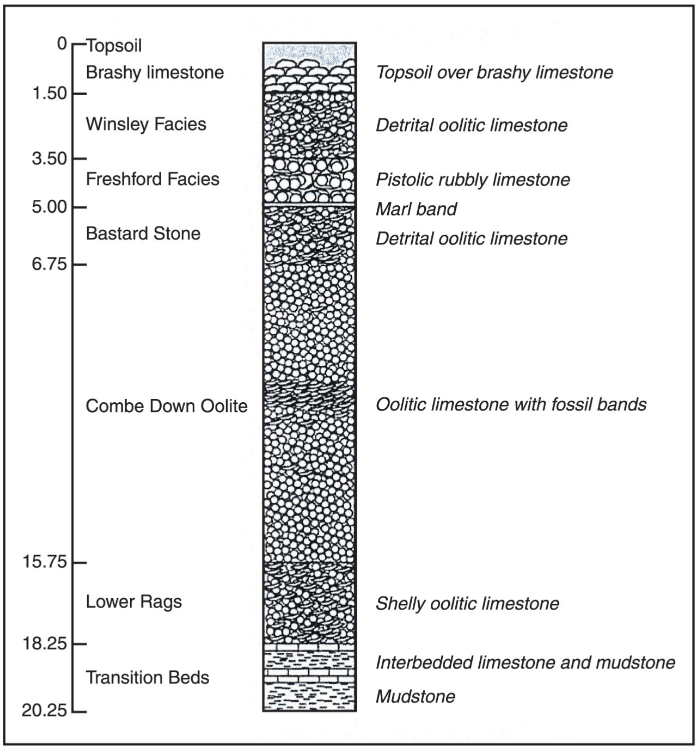

Fig. 2.3 The beds under Combe Down (after Hawkins 1994)

those running north-south through the Hadley Arms area, and variations in bed thickness can locally offset this.

The Combe Down Oolite is at its thickest around Combe Down, merging laterally into the Frome Clay. It is at a lower horizon than the Great Oolite 'Bath Stone' freestone horizons exploited near Corsham in Wiltshire. However a small exposure of this higher horizon occurs at Combe Down next to Summer Lane at Beechwood Road (Vinegar Down Quarry) due to graben-faulting (faults between which the strata have been let down). In the east part of Combe Down at Lodge Style, where current freestone working at Hancock's Upper Lawn Quarry allows easy observation, the Combe Down Oolite is overlain with up to two metres of the Twinhoe Beds, a detrital limestone (eroded from an earlier rock and redeposited) with shells and 'ironshot' grains, overlying up to two metres of a rubbly, shelly, friable limestone with a sandy-silty clay component. Neither of these two horizons is very competent. They sit unconformably on the eroded surface of the Combe Down beds, which has mollusc boreholes and is encrusted with oyster shells. The lower of these two horizons, up to two metres thick, is exposed at Springfield Quarry, forming a weak top to the cliff. Near Combe Down village itself both these horizons are largely absent, partly due to erosion, and partly, perhaps, because the horizons are discontinuous. Instead the Combe Down Oolite is found immediately below a metre or so of a regolith composed of broken rock fragments and soily material. In total, over the mined area these horizons result in up to seven metres of overburden which is usually very weak. If the top of the Oolite yields, there is a strong tendency for progressive upwards collapse to surface, leaving a subsidence or crown-hole. Particularly notable examples of progressive upwards collapse were found during the Stabilisation Scheme under the right-angle corner on Westmoreland Road, and of crown holing in the car park of Barclays Bank at the junction of Combe Road with North Road. Others, probably relating to surface collapses or subsidence were found under North Road, though of course these have now been stabilised.

At its base the Combe Down Oolite lies on an erosion unconformity over the Fullers Earth. The bottom two metres or so is a clayey, variable shelly limestone-clay, transitional sequence. Above this are two to three metres of thin-bedded, shelly, crystalline limestone, called the ragg or ragstone by the quarrymen, the Lower Ragstone today.

The worked horizons underground are up to some 9 m thick (the largest cavity height observed was 8.4 m. but this was a little above the true floor), but a metre or so less was probably more usual in the higher workings and about 5-6 m worked was probably closer to the average. It is clear that the lowest workings are still well above the ragstone, either being considered unsuitable due to greater hardness, or to caution about the stability if the underground workings were worked to greater heights. They have possibly discontinuous shelly horizons and, in the middle or top part of the sequence, a coralline bed. The beds are very variable and cavities, marl, shells, re-crystallization in vugs (with scalenohedral dogtooth calcite crystals known as 'cockles') were found fairly commonly. A known stratum with cockles lies under the north-east corner of Byfield (see below), but this seems to occur over a very restricted area. These and other features such as clay content either rendered the stone useless as a freestone, or led to much increased waste.

At the top of the worked sequence were the 'picking beds', apparently softer, of poor weathering quality, which were extracted to allow access

Fig. 2.4 The 'Bastard Bed' seen in the background behind H Pillar, East Byfield

for working the beds beneath. Above this there is up to 2 m of a shelly, pisolitic (coarser grained) more thinly-bedded and harder limestone unusable as freestone, called a 'bastard stone' by the quarrymen, which was left as a roof where it occurred under the regolith. Hawkins used this term specifically for the hard roof or ceiling stone, but Pollard (1994, 28) warns it was a generic term used regionally by the quarrymen for any such horizon within the worked beds.

According to Hawkins, the 'Bastard Bed' has a different fracture-pattern to the beds below and, in section can appear remarkably like a coursed rubble wall, as at near the margin of James Riddle's quarry (518) at H pillar in Byfield Quarry (Fig.2.4). Fallen blocks of Bastard Stone 'ring' when drilled, in contrast to the softer freestone beds. The Bastard Bed was not as distinctive, if present at all, in the eastern parts of the workings as in the centre and west of the underground quarries, and may have phased out laterally.

The freestone beds which were actually worked – below the Bastard bed and picking beds, were generally 5 to 8 m thick overall but possibly less in some eastern parts of the mines. Only rarely in the investigations was the full sequence revealed because of huge quantities of waste stone, occupying perhaps 50% of the original excavated space. Due to health and safety access requirements it was not possible during the archaeological investigation to make any meaningful geological close-up examination of a full-height pillar, so we were reliant on historical observations and a more recent measurement by David Pollard. The earliest description of a section through the Combe Down beds seems to have been by Richard Pocock in 1750 (Hemmings 1983, 46). This records that:

Under a foot of earth was

4 feet limestone, full of small shells

2 feet "strigery" stone mixed with spar

pitching stone (used for paving) with spar and pea-sized

4 feet ragstone, similar but with more spar [used for] *paving*

5 feet picking bed, similar but less spar, softer than rag, poor weathering

they at present work about 12 feet below the picking bed, in all about 30 feet. They say there is good stone 30 feet deeper than they work.

This suggests a total of 48 feet (12.8 m) of freestone, which is still substantially more than seems to have been worked.

Geologist William Smith (1767-1839) briefly became a quarry operator at Jackdaw and Kingham Quarry, just south east of the modern village but his venture ironically was 'finished utterly by the unexpected deficiency of the stone on whose good quality the whole enterprise depended' (Phillips 1844, 78). The likely cause was a fault running through or close to his workings, presumably leading to fractured stone. Debts from this and other causes led eventually to his imprisonment. This is, however, no reason to doubt the acuity of his observations at Combe Down (Pollard 1994, 27-28):

Letter from Bath, 21st April 1911

This stone on the north side of the Down [roughly north of North Road today] *has but a few inches of rag lying over it but on the south side* [ie the mined area] *thick and strong beds of it which form a good firm ceiling. The beds of stone are thin on the north side* [of] *the Down* [and] *become much thicker on the south side.*

The stone from the quarries on the north side cuts good ashlar but cannot be procured in large blocks but blocks of large dimensions may [be] *got on the other side – one 4 feet thick $4^1/_2$* [ft] *wide & 17 feet long was procured.* [306 cubic feet]

The stone is very thick on the north side [of] *the hill. The two top beds worked will stand any weather. The bottom beds are the hardest and on that account the men were paid 6d more per score for getting and working the ashlar. The quarrymen have names for the different beds – one which is very hard and bad to work 6 or 8 feet from the top is called the Iron Bed.*

In a section from the north side of the down Smith noted:

A hard bed, a part would do for the road
Rubble Stone
about a foot of hard stone with Screws, very sharp
Loose rubble
Rag with Oyster shells (and holes on the top)
[presumably unconformity]
Picking stone
2 Beds which will stand any weather
Iron Stone
Part quarried out for Freestone
Hard beds at bottom

and, in a letter of 1st November 1812 from Tuckingmill

The direction of the joints (many of which are faults which elevate or depress the stratum a little) is so prevalent that the principal part of the long joints seem to take this course. The gullys seem to have more of an east and west direction. These intersections & also with other joints more in a north and south direction makes the blocks and pillars of stone in a rhomboidal shape and sometimes triangular.

Smith also commented on a 'cockly bed' below the picking stone, which Pollard (1994, 28) interprets as three beds, the lower two of which were rich in cockles left *in situ* in a small area in north-west Byfield, with freestone removed above and below. This is the one instance found in the mines of an upper- and lower-level working system. The cockles would render the stone useless for fine building purposes, blunting the saws. A few cockles were found nearby in full-height working, but otherwise were not noted elsewhere. Stabilisation Scheme boreholes made to investigate the cavities between the upper and lower cavities showed the three beds varied laterally over some 20 m with a total thickness from about 1.5 m down to about a metre.

Large blocks were certainly restricted in availability and that mentioned by Smith was very large. The largest blocks in the early 19th century were found in John Pierce's quarry east of Combe Road with others in the quarries on the west side of the road. The survey noted particularly large beds, somewhat over 2 m below the roof, in West Firs and East Byfield just south of North Road. Two very large blocks (about 12 x 3 x 3 feet in contemporary measurements) form the gate posts to Allen's Home Farm (now Priory Close), opposite the lower gates to Prior Park (Fig. 2.5). These have well-developed current or cross-bedding exposed by weathering. Pollard relates this feature to the beds under the picking and cockly beds which were particularly used in exposed situations for plinths and string courses. It was, perhaps, this hard-to-get bed which earned the workmen sixpence a score (20 cubic feet was a nominal ton) more pay. Hawkins (1994, 222) refers to cross-bedding at Springfield Quarry (a worked-out open quarry near the Combe Down boundary with Odd Down) but specifically notes the phenomenon was not found in the mines. The archaeological survey also failed to note any underground example of cross-bedding and it seems likely it is only easily noticeable in weathered sections.

Fig. 2.5 One of the two Priory Close gateposts, nominally 3.7 m (above ground) x 0.9 m sq. The pair are the largest extant blocks of Combe Down freestone

A sequence recorded in 1894 by George Harris (Pollard 1994, 26) in an open quarry north of North Road, (probably at that date almost opposite the Hadley Arms) of 14.94 m (49 feet) had 4.27 m of 'building stone best in quarry', ie freestone (1994, 27-8), but they also used the overlying beds for various purposes and were unlucky to have this cockly bed or bastard stone.

12 feet	*Tile like rubble*	(3.66 m)
4 feet	*White stone, road metal*	(1.22 m)
5 feet	*Ragstone, pavements*	(1.52 m)
6 feet	*"Picking" bed, ashlar*	(1.83 m)
8 feet	*3 beds bastard stone with cockles*	(2.44 m)
14 feet	*Building stone, best in quarry*	(4.27 m)
Total 49 feet		(14.94 m)

None of the sections described show the full sequence in detail, and health and safety considerations prevented direct examination close up during the Stabilisation Scheme. However, laser scanning permitted the thickness of some 5 or 6 m of the beds exhibited on pillars to be recorded in the Grand Canyon (Fig. 2.6). There is no data on the beds here actually worked below this, which, so far as could be seen elsewhere were usually not worked at all.

The above sections and descriptions make clear that the beds of stone were very variable due to lateral variation during deposition, erosion and re-deposition caused by sea floor currents and tidal movements. The thickest worked beds and sequences were probably in Central and West Firs and Byfield or the open quarries west of Combe Road, which was perhaps why they were worked first on a large scale. In the north-east the beds were generally thinner and the very thickest beds probably absent. The usefulness of the stone varied and a degree of pragmatism was required by the quarrymen in deciding which beds to work for what purposes. Certain of the Twinhoe Beds in surface quarries could be used for specific purposes, especially for rubble wall building, which were entirely neglected in the underground mined quarries. The occurrence of thicker beds in the south of the area, noted by Smith, may be the reason why early 18th-century quarrying started at the far, southern rim rather than the north rim closer to Bath, although Allen's plans for the creation of his grand Prior Park House may also have influenced this.

Fig. 2.6 The Grand Canyon inclined barrow-way and pillars with sedimentary beds, derived from a laser scan image

The decision of Allen and others to work underground may also have been an economic decision if the Twinhoe Beds were not then easily marketable. In later years Allen opened a quarry 'open to the day', the refuse of which 'was of such use' that 'part was burnt into lime, part was used for building into common walls, some cut into slabs for paving and the rest was converted into steps and other things as was proper to be made from the harder stone' (Wood 1765, 425). This clearly made surface quarrying a more favourable option. Underground working, however, continued until the mid 20th century, perhaps because it did not disturb the surface and conflict with other land-use requirements. Thinner beds were not necessarily a major disadvantage, since they were more easily worked and handled, and there was a large demand in buildings for blocks of modest thickness and the major demand by far was for good-weathering rubble or 'walling stone' though this was rarely mentioned. However, for the finest grand work, thicker beds were advantageous, and their relative lack must have been a major disadvantage to Combe Down when Wiltshire Bath Stone (Great Oolite freestone) became easily available in the mid 19th century due to railway development, which occurs and can be worked in large blocks.

Historically the Combe Down freestone as a building stone has been frequently described in a complimentary way. By freestone, it is meant that it can be carved without fractures generating in any particular direction. When freshly dug, 'it is soft, moist, yellowish, and almost crumbly, and it seems very little more than congealed sand and that not well concreted together' (Owen 1754, in Woodward 1876, 129). Opponents of the stone described it as like 'Cheshire cheese, liable to breed maggots that would soon devour it'. Wood, however, at the occasion of the competition for the Greenwich Hospital contract in 1730, provided a sample which the opponents' architect actually mistook for Portland Stone (Wood 1765, 426-7). It is easily wrought or sawn and on exposure it hardens and becomes whitish, probably due to migration of lime-containing-moisture to the outer faces where re-crystallisation would take place, 'becoming an excellent stone', but careful selection and honest dealing were required for the best stone. According to an article in *The Builder* (12 April and 28 May 1894), following a description of microscopic examination, the better class of stone had granules which were semi-crystalline and as lasting as the (calcitic cement) matrix with fewer open cleavage planes and with the constituent particles interlocking with each other. This is a briefer but fundamentally similar description to that put forward by Palmer, above.

The quality marketed was certainly mixed. Woodward (1876, 128) wrote that Lodge Hill Stone had been used in the Henry VII Chapel at Windsor (he may have meant St Georges Chapel in which Henry VIII was buried) but 'It has not proved very durable', but he also suggested the Combe Down stone was the best for weathering, though there was a finer quality for interior work at Farley Down, and Boxhill, Wiltshire's Great Oolite freestone had a superior fineness. It is probably the more crystalline character and lower porosity of the better Combe

Fig. 2.7 Sailed pillars – the result of a fault running through north Firs

Down stone which allowed it to be used immediately, rather than, as with the Corsham, Wiltshire stone, needing a period of weathering or seasoning after extraction to let it dry out. Nonetheless it probably also benefited from such seasoning, if only because it exposed flaws before the stone was actually used. Stone from nearby Hampton Down had significant failures in the locks of the Kennet and Avon Canal around 1810, exfoliating after frost, but the use of a porous stone in conditions of frequent soaking and drying is probably an unsuitable one. Less scrupulous, market-orientated entrepreneurs were apt to adapt any of the local stone to the term freestone, or, as one said, 'we would call it Portland if that was what the customer required' (ibid).

Both joints and faults have a major impact on the stone. The major fault affecting Combe Down is a normal fault, running north of Beechwood Road, letting down the rock to the south, displacing, for example, Vinegar Down Quarry from Kingham and Jackdaw on the north side, by 20m or more (Macdonald *et al*. 2000, 3). It is possible there are several small faults, as intimated by Smith, with individual small movements leading to minor fault scarps. It is difficult to explain different quarry horizons otherwise.

Another fault runs through Horsecombe Vale and down-faults to the north, this and the Beechwood faults producing a graben, or lowered block between them. These faults in conjunction with flexures in the bedding seem to be responsible for the substantial flows of water at Whitaker's Spring and possibly those in the upper part of Horsecombe Vale. What may be a small fault runs roughly east-west just north of the Firs Shaft,

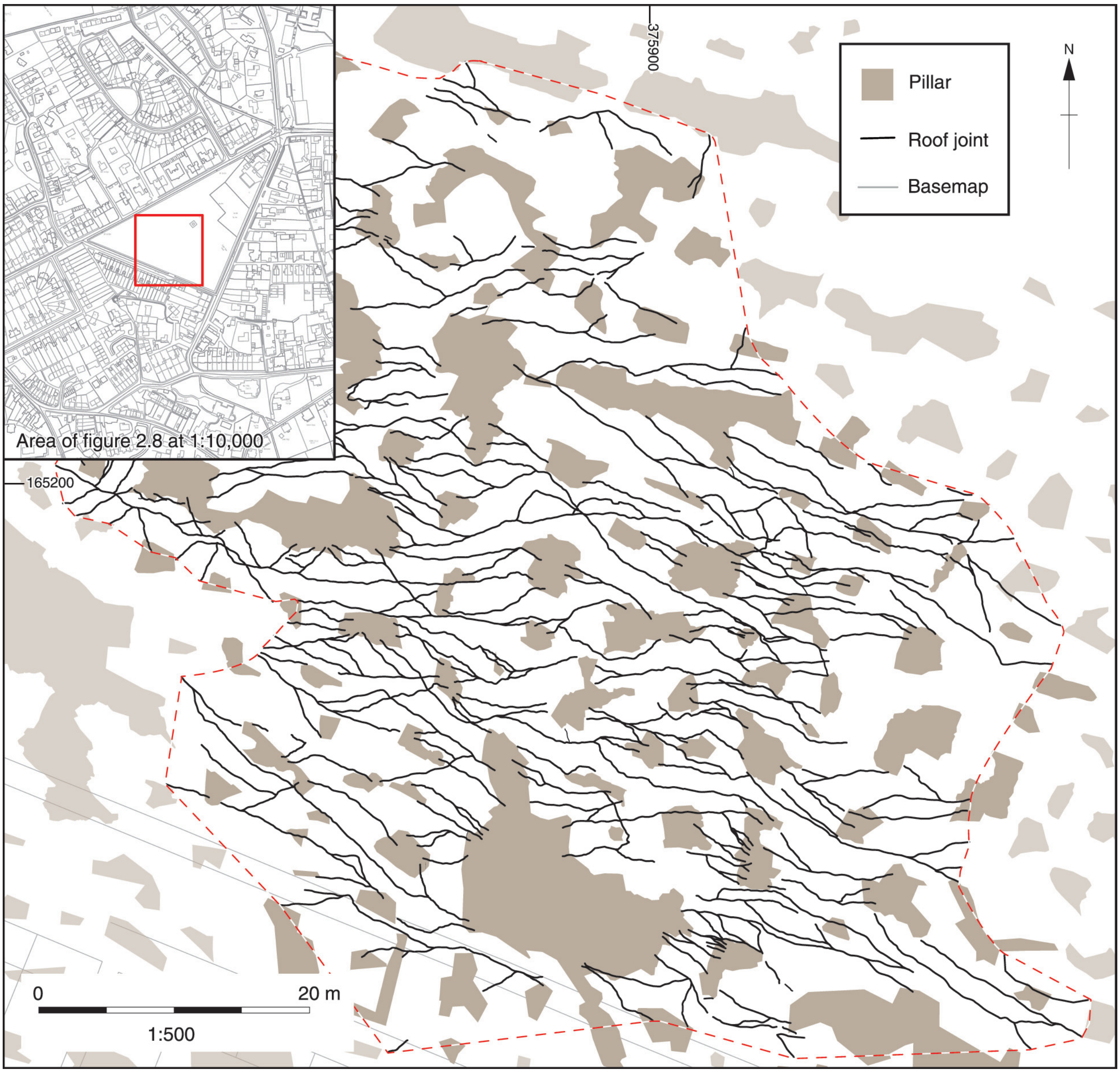

Fig. 2.8 Plan of roof showing joint system and pillar spacing in the Allen and Allen Estate workings in Central Firs

producing a zone of narrowly-spaced fractures with a strong inclination to the south, resulting in what we termed 'sailed pillars'. These are narrow with an elongated elliptical horizontal section (Fig.2.7). This may reflect the westward projection of a fault shown on the 1:10000 geological map which Hawkins (1994, 23) suggested may cut the northern boundary of Firs Quarry.

There is a strong system of fairly close joints or fractures through Combe Down roughly trending 70º and 140º with an average spacing of 0.8 m. According to Hawkins, the strongest and most continuous joints tend to follow the 070º direction, which is also roughly parallel to the general trend of faults and the southern outcrop. However this did not always appear to be so, and in Central Firs for instance the predominant joints appear to be on the 140º trend (Figure 2.8). The joints were often slightly open, but many joints in both pillars and roof opened as a result of post-working tensional stresses, so are anthropogenic rather than natural. The effect is two-fold, first that it assists removal of blocks by quarrymen, especially where the beds were also affected by foundering over the Fullers Earth at the margins, and second that it also limits the size of blocks available both by the fractures themselves and also, since they are trapezohedral rather than rectangular, by the need for considerable scalping to produce regular blocks. Faulting also, as well as displacing beds, also increases the degree of fracturing nearby and, as Smith found, could be disastrous for the business of quarrying.

This had implications for the placing of pillars, which tend to have their long direction aligned with the strongest set of joints. In some cases lines of pillars were left either using a single strong joint alongside a run of pillars, or systematically sidestepped joints from pillar to pillar. The former was seen in James Riddle's quarry (518) in Byfield where pillars had an alignment along a joint open some 75 mm wide. This was clearly a dubious practice but was not apparently punished by collapse. West of Firs Shaft and in Byfield, sidestepping of pillars to avoid exposing the same side of successive pillars to the same joints appears to have been used. However, many arrangements of pillars seem to have little logic in position or joint relationships. The general close spacing and openness of the joints which led to easier working is shown on pillar surfaces which are mainly natural discontinuities rather than split or broken faces. Hawkins suggests only 5% of pillar surfaces showed evidence of working (1994, 45).

The available stone at Combe Down of almost any type and quality was much more efficiently utilised during the 19th and 20th centuries. Some quarries only worked walling stone, perhaps scavenging from older workings, and it is possible that some of the 'honeycombed' and weathered stone found in many gardens in the area was deliberately worked for sale for this purpose. The architect Wood used some 800 tons of shelly-ragstone for the foundations of Allen's Prior Park House. This he referred to as usually left as the roof-stone (Hemmings 1983, 41). In Bath's Newbridge over the Avon, rebuilt after 1774 and enlarged *c* 1830, the voussoirs of the arch are shelly limestone, probably better able to stand the compressive forces than the softer, more friable freestone. Although it may have only accounted for relatively small quantities, stone was also burnt for lime, Ralph Allen adding this to his business probably around 1740, and there were still limekilns at Priory Farm and north of Brassknocker Hill in the late 19th century (1884 1:2500 OS.). Local mortars were made of crushed stone-dust and lime, the former perhaps made by the masons and builders from waste stone from the banker masons.