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297

British Geological Survey

The stratigraphy and building stone potential of the Portland Beds between Tisbury and Chilmark in the Vale of Wardour

The stratigraphy and building stone potential of the Portland Beds between Tisbury and Chilmark in the Vale of Wardour

A geological assessment for the
Commissioners of Salisbury Cathedral

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British Geological Survey
Technical Report WA/95/15C
1995

Contents

1. Introduction 1

2. Geology 3
  Portland Beds 3
    Wardour Formation 3
    Portland Stone 5
      Tisbury Member 5
      Wockley Member 6
      Chilmark Member 6

3. Petrography of outcrop samples collected from the Portland Beds in the Vale of Wardour - *Phase 2* 20

4. Conclusions and recommendations 25

5. References 27

6. Glossary 28

Appendix 1. Field samples and photomicrograph from the Tisbury-Chilmark area 29

Appendix 2. List of landowners/tenants of quarries in the Tisbury-Chilmark area

Map (in pocket at end)

1:10 000 scale geological sheet of part of sheets ST92NE and ST93SE

Figure

1. Geological sketch map of the western Vale of Wardour showing the position of localities mentioned in the text 2

Table 1. Stratigraphical nomenclature of the Portland Beds of the Vale of Wardour 4

1. Introduction

The purpose of this report is to describe the stratigraphy and lithology of the Portland Beds at the western end of the Vale of Wardour between Tisbury and the Chilmark Ravine (Figure 1), with particular reference to their potential use as a building stone in the repair of Salisbury Cathedral. The report follows a similar one describing the Portland Beds in the area north-west and south-west of Tisbury (Bristow and Lott, 1994).

The area was geologically surveyed by the senior author in October and November 1994 at the request of the Dean & Chapter of Salisbury Cathedral. The new 1:10 000-scale map is included in the folder at the end of this report. During the earlier survey, the stratigraphy of the Portland Beds was refined, and the various subdivisions traced across country. These subdivisions, with some minor modifications, have also been mapped in the area between Tisbury and Chicksgrove, and along the Chilmark Ravine (1:10 000-scale map; Figure 1; Table 1). Representative samples of the limestone were collected from brash and quarry exposures for thin sectioning. These are described by Dr G K Lott in Appendix 1, and compared with samples from the Cathedral already reported on (Bristow and Lott, 1994). In the following account, numbers prefixed by VR refer to thin sections described in Appendix 1.

Materials presented with this report include:
1. 1:10 000 scale geological map of parts of sheet ST92NE (Chicksgrove) and ST93SE (Chilmark).

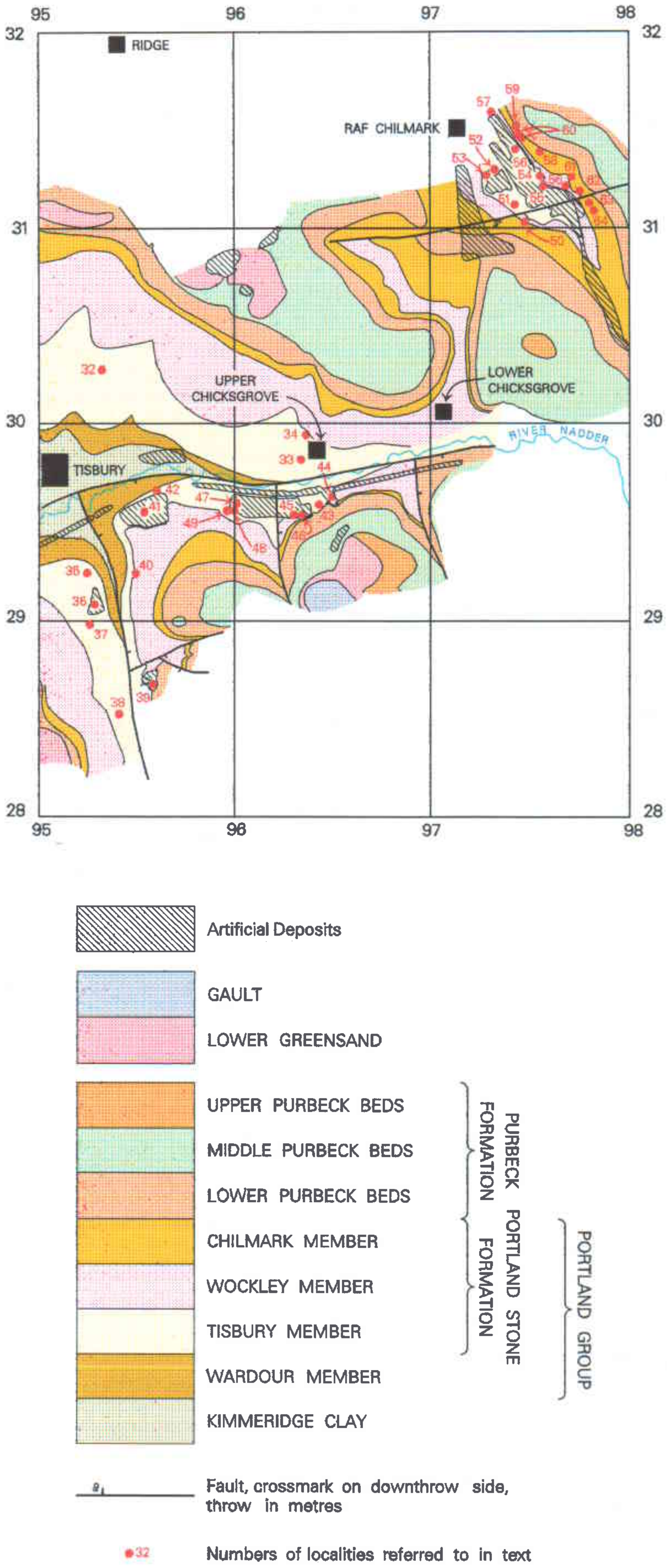

Figure 1. Geological sketch-map of the Chicksgrove – Chilmark area

2. Geology

Portland Beds

The main outcrop of the Portland Beds is on either side of the River Nadder in the west of the district, from the eastern outskirts of Tisbury to Lower Chicksgrove. A more restricted, but important, outcrop occurs along the Chilmark Ravine in the north-east. A third outcrop in the upper part of the sequence (Wockley and Chilmark members), previously unrecognised, occurs in the area [around 970 307] north of Lower Chicksgrove.

Traditionally, the Portland Beds are divided into a lower arenaceous unit, the Lower Portland Beds, overlain by a dominantly limestone sequence, the Upper Portland Beds (Woodward, 1895). The latter has been divided into four principal lithological units, based largely on their building-stone potential, which has been further subdivided into a number of beds based on quarrymen's terminology (Table 1). Unfortunately, it is not always possible to equate the terminology of one author with that of another. Similarly, unanotated published sections cannot be classified with certainty using the older nomenclature. Wimbledon (1976) formalised the nomenclature, dividing the Portland Beds into two formations, a lower Portland Sand Formation, comprising three members, and an upper Portland Stone Formation consisting of two (one only locally developed) members. The member and formational grouping is biostratigraphical rather than lithostratigraphical. In both this present and the earlier account, to preserve continuity where possible, Wimbledon's (1976) local names are used, but slightly modified, and have been given different ranking (Table 1).

Wardour Formation

The Wardour Formation corresponds to the Lower Portland Beds of Hudleston (1881), Woodward (1895), Reid (1903) etc. and to the Wardour Member of Wimbledon (1976).

The Wardour Formation has a limited outcrop low down in the Nadder Valley in the west of the district. Where there is a more extensive outcrop in the Tisbury area to the west, the base of the formation is taken at the base of a fine-grained, glauconitic sandstone. Springs issue from the base of the sand and enable the boundary to be traced with ease in the field. The bulk of the formation, 24m thick in the Tisbury Borehole [9359 2907], consists of siltstones and fine-grained, bioturbated, friable, sparsely shelly sandstones. As the Wardour Formation is unlikely to provide a significant source of building stone, it is not considered further in this account.

<table>
<tr><th>Blake (1881)</th><th colspan="3">Woodward (1895)</th><th colspan="2">Wimbledon (1976)</th><th colspan="2">Bristow (this account)</th></tr>
<tr><td>* Building Stone Series</td><td rowspan="5">UPPER PORTLAND BEDS</td><td colspan="2">Upper Building Stones</td><td rowspan="3">PORTLAND STONE FORMATION</td><td>(Members)
Chilmark</td><td rowspan="5">PORTLAND STONE FORMATION</td><td>Not present in the Tisbury area</td></tr>
<tr><td>Chalk of Chicksgrove</td><td colspan="2">Chalky Series</td><td rowspan="2">Wockley</td><td>Wockley</td></tr>
<tr><td>Upper beds of Swindon</td><td colspan="2">Ragstone</td><td rowspan="3">Tisbury
Sand</td></tr>
<tr><td rowspan="2">* Tisbury Freestone</td><td rowspan="2">Lower Building Stones</td><td>Trough Bed</td><td rowspan="3">PORTLAND SAND FORMATION</td><td>Tisbury</td></tr>
<tr><td>$ Glauconitic & sandy limestones</td><td>Chicksgrove</td></tr>
<tr><td>Lower Sands</td><td colspan="3">Lower Portland Beds</td><td>Wardour</td><td colspan="2">Wardour Formation</td></tr>
</table>

* = Main building stones

$ = Divisible in descending sequence into Green Bed, Slant Bed, Pinney Bed, Cleaving or Hard Bed, Fretting Bed and Under Beds

Table 1. Stratigraphical nomenclature of the Portland Beds of the Vale of Wardour

Portland Stone

The Portland Stone Formation consists dominantly of siltstones, fine-grained sandstones and micrites in the lower part (in part, the Chicksgrove Member of Wimbledon (1976)), passing up into a unit of fine-grained siliclastic and bioclastic sandy, glauconitic, peloidal, biosparites (the Tisbury Member of Wimbledon (1976)), overlain by micritic limestones with little or no siliclastic sand and glauconite (the Wockley Member of Wimbledon (1976)), and capped by cross-bedded oolitic sands (the Chilmark Member of Wimbledon (1976). Chert occurs sparingly in the Tisbury and Chilmark members, but is locally common in the Wockley Member. In the field, it has not been possible to map separately the Chicksgrove and Tisbury members. Accordingly, the use of the term Tisbury Member in this account has been extended downwards to include the lower unit. Similarly, in the field it has not been possible to separate the Ragstone, which forms the basal unit of Wimbledon's (1976) Wockley Member, from the Tisbury Member. Accordingly, the Tisbury Member has been extended upwards to include the Ragstone (see below; Table 1). Within the present area, the above three broad lithological divisions (the Tisbury, Wockley and Chilmark members) are the only mapping units recognised. Farther west, in the Tisbury area, a sandy unit has been mapped in the lower part of the Tisbury Member.

Tisbury Member

The member as herein defined broadly corresponds to the Lower Building Stones of Woodward (1895), but also includes the overlying Ragstone (Table 1).

The Tisbury Member crops out on either side of the River Nadder from Upper Chicksgrove westwards, and along the Chilmark ravine. It has been extensively quarried in both areas, but in the former area, it has only been locally worked on the north side of the River Nadder.

The base of the Tisbury Member is taken at the abrupt change from fine-grained, clayey sand of the Wardour Member to calcareous sandstones, sandy limestones and micrites. The basal beds of the Tisbury Member in the Chicksgrove Quarry, the Chicksgrove Member of Wimbledon (1976), are described as 2 to 4 m of well-bedded, pinkish grey, bioturbated, shelly micrites. Although formerly quarried at Chicksgrove, they do not appear to have been widely used as building stones. As no stone matching this description has been found in the Cathedral, this lower unit is not considered further as a potential source of stone.

The median part of the member consists of about 12 m of porous, fine-grained sandstones and siliclastic and bioclastic, peloidal, glauconitic limestones. The glauconite content varies from 0 to 6 per cent, the bioclastic sand up to 20 per cent, but averaging about 9 per cent and the siliclastic sand from 14 to 38 per cent, but averaging about 24 per cent (Appendix 1). There is a general gradual upward increase in bioclastic sand and a decrease in siliclastic sand and the beds pass into glauconitic, bioclastic biosparites. The Tisbury Freestone of Blake (1880), the principal source of building stone in the district corresponds to the median part of the Tisbury Member.

Wimbledon (1976) drew the base of his Wockley Member at the base of the 'Ragstone' (Table 1), a unit readily recognisable in quarry sections, but in the absence of exposure, not easily identifiable from brash. At Chicksgrove, the basal bed of the Ragstone consists of 0.5 to 0.85 m of a very hard micrite with common large bivalves, and is succeeded by up to 2.5 m of micritised peloidal limestone with common bivalves and scattered large ammonites. Wimbledon (1976) described the basal bed of the Ragstone as a yellow-based, bioclast sand with much quartz, glauconite, plant remains and large reptilian bones. This sand lens died out rapidly eastwards and passed into a thin clay with serpulid debris. The base of this unit rests on a highly irregular erosion surface cut into the Tisbury Member. Upwards, the sand lens passes into a hard, white-cream, lime mud with abundant minute gastropods. Neither unit was visible in the quarry in November 1994. In the field, the shelly, peloidal limestones (VR44, 46 and 49) which form the bulk of the Ragstone have been mapped with the Tisbury Member. The Ragstone has been extensively quarried, but it is generally too shelly to have been worked on a large scale as a freestone. It may have been used locally as a building stone, but it is unlikely to have been used in the construction of the Cathedral.

Wockley Member

The Ragstone is succeeded by 4 to 8 m of chalky micrite with common large bivalves (the Chalky Series of the old terminology). The Wockley Member varies laterally quite markedly. In the west of the district, on both sides of the River Nadder, much of the Wockley Member consists of hard and/or porcellanous micrite, commonly with moulds of small gastropods. Of the samples examined from the Cathedral, this unit does not appear to have been used in its construction and it is not considered in detail. Blake (1880, p.201) noted that the beds were burnt for lime.

Chilmark Member

One of the principal occurrences of the Chilmark Member, the Upper Building Stones of the older literature, is at its type locality, the Chilmark Ravine, to which it was thought to be restricted. However, the recent mapping shows that it can be followed westwards from north of Lower Chicksgrove along the south side of Lady Down and into the Tisbury area (Bristow and Lott, 1994), where it is now newly recognised. South of the River Nadder, it can be recognised as a very thin unit (c.0.3 m thick) in Chicksgrove Quarry. To the west, the outcrop broadens, presumably as the unit thickens, only to thin, or perhaps disappear, in the Wockley Quarry. There, it might be represented by the 0.6 m bed of 'compact limestones' classified as the basal bed of the Lower Purbeck by Woodward (1895, p.268) and by the 0.69 m thick bed of hard, flaggy limestone with black flints at the top of the Portland Beds as recorded by Andrews and Jukes-Browne (1894, p.49). It also appears to be present over a limited area on the opposite side of the valley [around 952 284].

Woodward (1895, p.268) described the Chilmark Member in the Upper Quarry [9755 3137], Chilmark, as 0.9 m of buff, oolitic stone, forming the roof bed of the mine, with a marly bed at the base, on 3.6 m of buff, compact, oolite, and in places rather sandy limestones; the lowest bed containing chert. Wimbledon (1976) notes that the gastropod *Aptyxiella portlandica*, the Portland Screw, is common in this unit. He also observed that the junction with the Purbeck Beds is not clear cut, with interbedded [presumed non-marine] stromatolitic tufas and [marine] oolitic sands forming a transitional zone between the two. In the field, the unit is typified by a brash of flaggy oolite.

Towlson (1991, p.37) notes that the stone weathers to a darkish grey and is considered more durable than the Lower Building Stone, but that it does not appear to have been used for detailed work. Hudleston (1883) stated that the Upper Building Stones had been used for restoration of the West Front of the Cathedral. Donovan (1992) observed that there are scattered blocks of oolite on the Cathedral exterior (but not the central tower) which he thought were from the Upper Building Stones. We have not been supplied with any stone from the Cathedral which we regard as from the latter unit. Only one sample, VR35, was collected from the Chilmark Member during the present survey, although samples (VR32-34) from beds up to 2.5 m higher that have traditionally classified as Lower Purbeck Beds, were taken.

Details

Tisbury Member

Oakley - New Barn area

North of the River Nadder, the Tisbury Member has an outcrop width of between 200 and 400 m. There are few exposures, but there is common brash of glauconitic, oolitic and bioclastic sandstone on the surface of the fields. The beds were worked at one locality [9532 3029] (Figure 1, locality 32[1]), but the shallow pit is ploughed over.

At Quarry Farm (Figure 1, locality 33), Upper Chicksgrove, an old quarry [9633 2982] exposes 4.3 m of glauconitic, bioclastic sandstone. This is presumably the pit referred to by Reid (1903) as 'north side of the River Nadder by Chicksgrove Mill', but he is in error in stating that Purbeck Beds occur at this locality. The present section is as follows:

	Thickness m
Sandstone, bioclastic, glauconitic	0.15
Sandstone, massive, cross-bedded, glauconitic, bioclastic; flaggy top (VR22)	0.60
Sandstone, laminated, bioclastic, glauconitic, with thin (up to 2 cm)chert nodules	0.10
Sandstone, bioclastic, glauconitic, planar-bedded	0.20
Sandstone, massive, glauconitic, bioclastic (VR23)	0.30
Massive, very hard, glauconitic, bioclastic sandstone (VR24)	0.35
Sandstone, massive, glauconitic, bioclastic	0.37
Sandstone, laminated passing into nodular chert	0.14
Sandstone, massive, friable, glauconitic, bioclastic sandstone (VR25 taken from the top)	1.00
Sandstone, massive, glauconitic, bioclastic	1.10

Although the face is broken by prominent, in part open, joints trending 30° and 120°, there is no evidence of valleyward cambering. If necessary, this pit could be extended westwards as an open quarry without incurring a serious overburden problem. On the north side of the main road, a hard limestone ('Spangle' - part of the Ragstone) crops out in the floor [9635 2994] of a track (Figure 1, locality 34). Some 500 m eastwards, the dip of the Tisbury Member takes the outcrop below Alluvium level.

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[1]The sequential numbering of localities follows on from the Stage 1 report (Bristow, C R and Lott, G K. 1994. *The stratigraphy and building stone potential of the Portland Beds in the western part of the Vale of Wardour. A geological assessment for the Commissioners of Salisbury Cathedral.* British Geological Survey

There is an east-west trending fault running along the Nadder valley which down throws the Portland and Purbeck about 10 m to the south. The outcrop south of the Nadder valley is further compartmentalised by small north-south trending faults which successively downthrow strata some 5 to 10 m to the east.

West of the unnamed northward-flowing stream which joins the River Nadder at Tisbury Mill, between 15 and 20 m of glauconitic sandstones of the Tisbury Member crop out. There are exposures [9524 2929 to 9527 2918] of glauconitic, bioclastic sandstones in the track (Figure 1, locality 35) leading up to the old quarry [9528 2908] at Dumplings Down (Figure 1, locality 36). According to Donovan (1992), the site was worked in medieval times. Miles (1920) reported that 'Tradition says that much of the stone used for the Spire of Salisbury Cathedral was obtained from these [Tisbury] quarries, chiefly from the hill known as Dumpling's Down'. The quarries must have been opened in the Tisbury Freestone, but there is now no exposure. The floor of the pit is covered in large grassy mounds of presumed spoil. Another overgrown pit [9526 2898] lies just to the south (Figure 1, locality 37). If necessary, the faces in these pits could be re-exposed and a sampling programme undertaken. The pits could be extended laterally as open pits both northwards and southwards, as well as westwards into the hillside. Because of its situation on the valley side, the rocks in the large pit may have been affected by cambering; any cambering effect should diminish westwards; there would, however, be an increasing overburden as the rocks are worked westwards into the hillside.

There is a small, overgrown pit [9540 2852] some 600 m farther south, but there is no recorded detail (Figure 1, locality 38). Oolitic sparry limestone occurs as brash close by. It is probable that this pit largely exposed Ragstone, possibly with the Tisbury Member exposed at the bottom. This pit can be discounted as possible future source of stone since there would be a considerable overburden of Ragstone to be removed before the Tisbury Member could be extracted.

On the opposite side of the valley is the old Oakley or Wockley Quarry [9555 2870], now the gardens of a private house (Figure 1, locality 39). There, there is an overburden of some 7 m of Purbeck Beds and up to 4.5 m of the Wockley Member, on 7.6 m of 'Freestone' (Andrews and Jukes-Browne, 1894; Fitton, 1836; Reid, 1903). The Ragstone at the base of the Wockley Member is absent (Reid, 1903). This quarry is more or less at the southern limit of the outcrop of the Tisbury Member. Because of its situation and present ownership, there is no point considering this pit further as a potential source of stone for the Cathedral.

Some 500 m north, another old quarry [9550 2924] (Figure 1, locality 40) exposes about 3 m of the Wockley Member, on 1 m of Ragstone, on about 6 m of glauconitic sandstone with thin chert beds of the Tisbury Member. Reid (Ms, BGS recorded 9 m of 'Lower Building Stones'. Samples

(VR56 and 57) of glauconitic, bioclastic, fine- to coarse-grained (VR56) and very fine-grained (VR57) sandstones were collected respectively 1.7 and 4 m below the top of the Tisbury Member (see Appendix 1). Despite its position at the top of a steep valley side, the succession appears to be unaffected by cambering. This pit could repay further investigation, but to avoid an increasing overburden, any extension would have to be to the north or south and a relatively narow outcrop worked.

East and north of North Barn is an old pit [956 295] (Figure 1, locality 41) over 200 m long from which the Tisbury Member, with the Wockley Member as overburden, was worked. Most of the face and spoil heaps are overgrown. Donovan (1992) recorded that the quarry was disused by c.1838. A small section [9544 2951] on the west side of the quarry exposes about 2.5 m of bioclastic, glauconitic, very fine-grained sandstone. Samples (VR58 and 59) were collected respectively 1 and 2.1 m below the top of the section (Appendix 1). Although a large area has been worked, it would be possible to extend the quarry southwards (with an increasing overburden) and eastwards.

A cutting [?9556 2964] on the railway 'west of Chicksgrove Mill, and north of Wockley' formerly exposed the lower part of the Tisbury Member and its junction with the Wardour Formation (Reid, 1903) (Figure 1, locality 42):

	Thickness m
Tisbury Member	
Greenish sandy bed	0.30
Hard, grey sandy limestone, weathering white, with *'Trigonia'* and *'Ammonites'*	0.38
Greenish and grey beds of more or less calcareous sandstone or sandy limestone	0.76
Shelly limestone with *'Serpulae'*	0.76
Sandy and shelly limestone with *'Serpulae'*	0.76
Sandy marl with *'Ostrea, Serpula*, spine of *Echinus'*	0.10
Grey shelly limestones	1.22
Wardour Formation	
Brown and greenish brown sand with clay seams and bands of indurated sand; scattered casts of shells, thin beds of stone near top	4.6-6.1

Chicksgrove

East of the cutting is the 500 m long Chicksgrove pit [960 296] (Figure 1, localities 43—49), worked in two parts separated by a north-south fault-guided valley. The original quarries [9640 2957 and 9648 2960] (Figure 1, locality 43 and 44) were in the east; it was probably the latter, now backfilled, that was seen by Miss Ethelred Benett in 1818 (Sowerby, 1818) and by Fitton (1836). At locality 43, the open quarry was extended eastwards in underground workings (Reid, 1903). These workings were re-exposed in c.1993 during quarrying operations by R. Collins, but have since been backfilled. The A and B beds (see below), currently worked in the main quarry to the west, were dug, with others, in the underground workings. The eastern part of the main quarry is now worked out and backfilled, but there are still some exposures on the southern face. One section [9630 2953] (Figure 1, locality 45) showed:

	Thickness m
Ragstone	
Limestone, massive, fine-grained peloidal - VR46	1.30
Micrite, shelly, hard - VR47	0.50
Marl, green	0.03-0.10
Tisbury Member	
Sandstone, very fine-grained, bioclastic; towards top becomes shell fragmental - VR48	1.20
Sandstone, bioclastic, hard -BED A	0.90
Sandstone, bioclastic, glauconitic, hard - BED B	1.20

Above the Ragstone there is about 4 m of chalky micrite with common *Camptonectes lamellosus* and *Protocardia*. From a nearby section [9634 2953] (Figure 1, locality 46), beds A and B were sampled (VR51 and 52 respectively). Additionally, blocks of beds A and B already extracted from close by and about to removed by the quarrymen for sale, were sampled (VR53 and 54 respectively) (Appendix 1).

Quarrying in the former Quarry Copse [960 296] (Figure 1, locality 47), recommenced in 1968 and ceased in 1980; working resumed in 1994, but within the existing quarry boundary, there is only a limited area of exploitable beds which can be worked.

A c.17 m section in the basal part of the Wockley Member, the Tisbury and Chicksgrove members and the upper part of the Wardour Member was measured by Wimbledon (1976, fig.1). Insole (1970) recorded an 11 m section in the Tisbury Member in this part of the quarry. A section [9599 2955] in this western quarry (Figure 1, locality 48) exposes:

	Thickness m
Sandstone, glauconitic, cross-bedded, flaggy weathering	1.2
Sandstone, massive, glauconitic, bioclastic with thin (up to 10 cm) chert lenses - BED A	1.1
Sandstone, glauconitic, massive, bioclastic with stringers of large bivalves - BED B	1.2
Sandstone, glauconitic, cross-bedded, fine-grained with a shelly top (mostly	

bivalves, but one ammonite) VR40	0.9

The top of the section must lie very close to the base of the Ragstone. In addition to the sample from the basal bed, samples were collected 2, 4 and 5 m below this bed (VR41-43 respectively)(Appendix 1). A nearby section [9596 2955] extended the sequence upwards (Figure 1, locality 49):

	Thickness m
Ragstone	
Limestone, peloidal, irregularly splitting - VR44	0.70
Micrite, porcellanous, hard, shelly - VR 45	0.85
Marl, greenish grey	0.1-0.2
Tisbury Member	
Sandstone, bioclastic, glauconitic	0.60

Chilmark

Some 2 km north-east of Chicksgrove is an inlier of Portland Beds in the south-eastwards trending valley known colloquially as the 'Chilmark Ravine'. It has long been a source of building stone, under the general term Chilmark Stone, and traditionally was the source of the stone used in Salisbury Cathedral. It is the nearest source of Portland Stone to the Cathedral. Numerous quarries have been opened over the centuries (Donovan, 1992) to exploit the Tisbury, Wockley and Chilmark members of the Portland Stone Formation and the basal beds of the Purbeck Limestone (Figure 1, localities 50-64) and there is an extensive geological literature from the time of Barry et al. (1839) onwards to the privately printed work of Towlson (1991). Most of the valley sides have been worked as open quarries and several sections remain. In addition, several adits in the back faces of the quarries lead to underground workings (see accompanying 1:10 000-scale geological map), but most are now disused.

The most extensive of these underground workings, the Chilmark Main Quarry, is on the west side of the ravine [975 310] (Figure 1, locality 50) and was worked over an area of some 4 hectares (10 acres). One of the earliest descriptions of the workings was by G F Harris in 1893 (Ms, BGS) who gave the following section: roof [Trough Bed]; Green Bed, 0 to 1.16 m; Soft Pinney, 0.91 m, on Hard Pinney (hardest in the middle), 1.22 m. The Green Bed was said to be not liked by architects. The Hard Pinney was regarded as the best bed, but was much harder to work and, because of its hardness, not liked by the workmen. Access to the underground workings at that time was by vertical shafts and the stone was brought out by gantry. This was still the method of entry in 1911 (Ord and Reader, 1912) when the Chilmark area was visited by the Geologists' Association. A composite section from exposures on both side of the ravine is given in Ord and Reader (1912) as follows:

	Thickness m
Lower Purbeck Beds	
Flaggy limestones, dirt beds and peculiar oolitic beds	2.4-4.8
Portland Limestone	
Chilmark Member (Upper Building Stones)	
Buff,sandy and oolitic limestone, compact limestone, and occasional chert seams in lower part	3-4.8
Wockley Member	1.2-7.3
Soft, white, chalky limestone with chert	
Tisbury Member	
Ragstone	
Brown, gritty and shelly limestone	1.2-1.8
Pale shelly and oolitic limestone	0.6-1.2
Lower Building Stones	
Trough Bed	0.5-1.2
Green Bed	0.6-1.5
Pinney Beds (Slant Bed, O.3 m thick at top)	2.4-3.6
Cleaving or Hard Bed	0.3
Fretting Bed	1.0
Under Beds	0.9

As in Harris' time, the Pinney Beds were the principal stone worked, with the unit being divided, as already noted, into an Upper or Soft Pinney, and a Lower or Hard Pinney. It was noted that the Green Bed differs from the Pinney by its coarser grain size, more complete fossils and a greater amount of glauconite. The Trough Bed is coarser grained than the Green and the Pinney, much more shelly, but less glauconitic, and because of its cement, much harder. It forms the roof of the mine (NB, Hudleston (1883) refers to the Ragstone forming the roof bed, but this perhaps only applies to some of the underground workings on the Teffont Evias side of the valley). Contours on the floor of the mine (?base Pinney) show a regular southward dip of 2°. By 1932, an adit had been sunk and stone was brought out on trolleys hauled by winch (Clayton, 1932). An illustrated account of the working methods is given by Clayton (1932) (note, however, that the second, third and fourth photographs are of the Teffont side of the valley (Locality 54)(E. Towlson, personal communication)). Clayton noted that there is no need to protect the stone from frost, and that the stones are worked more easily in a 'green' state; 'as the quarry sap dries out it tends to harden the surface'. The quarry was visited by Mr F H Edmunds of the British Geological Survey and one sample each taken from the 'Bottom', 'Middle' and 'Top' Pinney and the Green Bed. Thin sections of these samples are described by Lott *in* Bristow and Lott (1994). Tests on these samples for porosity, water absorption and weight loss were carried by the Building Research Station (Donovan, 1992). These tests showed that the porosity varied from 25 to 35 per cent.

Stone extraction ceased in 1937 when the site was taken over by the Air Ministry (later Ministry of Defence) and used for bomb storage. With the imminent closure of the site, the bomb store was cleared with the last explosive devices taken out in November 1994. Clearly, this mine was one of the major sources of stone in the area, with vast quantities extracted (minimum estimate of 119 000 tons of the Pinney Beds removed (Towlson, 1991)). However, it is now most unlikely that underground working would recommence since the roof has not been maintained for some time and is known to be unstable in places. Secondly, there is a high radon gas concentration and thirdly, and probably the most important reason, the workings are now nationally extremely important bat roosting sites.

To the north-west of the Chilmark Main quarry is as an overgrown working known as Levi Bowles [Wagon Quarry of the RAF] quarry [9740 3114] (Figure 1, locality 51). This is presumably the pit referred to by Crowley (1987, p.123) as beginning in about 1875 and continuing until about 1920. Most of the quarry is now overgrown, but two adits lead to underground workings. Harris (Ms, BGS 1893) referred to 'open works' in which the Trough Bed was the principal stratum dug. Because of roosting bats, entry was not allowed to the underground workings. The workings are not as extensive (0.5 hectare; 1.2 acres) as the Chilmark Main. The adit mouth is presumably capped by the Trough Bed; the Pinney Bed seems to have been the main stratum worked. Contours on the floor of the mine (?base Pinney) show a regular southward dip of about 2° towards the Chilmark Main. However, it is clear that there is an east-north-easterly trending fault with a southerly downthrow of about 9 m which forms the boundary between the two underground workings.

The northernmost quarry [973 312] on the Chilmark side of the valley is known as the Chilmark Open Quarry (Radiac Quarry of the RAF)(Figure 1, locality 52 and 53). This may be the quarry recorded by H T de la Beche and William Smith in 1838 (Barry et al., 1839) which was worked at that time by Mr G Lane (Towlson (1991) records a Mr G Lane working on the Chilmark side of the valley in 1852). The present quarry outline is essentially the same as it was during the original geological survey in 1890, and so large-scale quarrying must have ceased before that date. There is, however, a relatively fresh face [9731 3130] on the north-east side of the quarry (locality 52) which may have been more recently worked. There, some 5 m of massive, glauconitic, bioclastic, fine-grained sandstone, bedded in units 0.3 to 0.7 m thick, is exposed; there are some thin (2 cm chert lenses). Samples VR 39 and 38 (Appendix 1) were collected respectively 0.95 and 2.15 m from the base of the exposed section. On the west face [9727 3127] (locality 53), the following section was seen:

	Thickness m
Ragstone	
Sandstone, bioclastic, massive	1.00
Sandstone, bioclastic, soft	0.25
Sandstone, bioclastic, glauconitic	1.00
Biosparite, sandy, glauconitic, shelly, hard (VR36)	0.40
Sandstone, shelly, bioclastic, hard	0.60
Lower Building Stones	
Sandstone, bioclastic, friable	0.30
Sandstone, bioclastic, glauconitic, massive (VR37 from base)	1.00

The lower part of Wimbledon's (1976) section was measured in this pit.

Thin sections of the samples from this pit fall within the range of stone used in the Cathedral and the section ought to be examined in more detail in company with a mason. If suitable stone is identified, then this quarry has great potential since it could be extended northwards, with minimum overburden problem, into ground currently owned by the Ministry of Defence. There would be no problem with bats, and access would be directly off a public highway.

The Teffont Evias side of the valley has also been extensively quarried. There, both the Lower and Upper Building Stones were worked. The main quarry [9755 3125] (Figure 1, locality 54) has been referred to variously as the Lower Quarry (Teffont), Harris' Chilmark No.2 (Quarry No.75), Teffont Evias (Chilmark) Quarry (Ord and Reader, 1912, p.155), Chilmark (Teffont) Quarry (Reid, 1903, p.10; Woodward, 1895, p.204) (not to be confused with the Teffont (Chilmark) Quarry (Reid, 1903, p.9; Woodward, 1895, p.204)), and Teffont Quarry 1991 (mine). The floor of the old open quarry is now built over and there is no exposure in the quarry sides. The quarry must have exposed the upper part of the Tisbury Member and the lower part of the Wockley Member. There is little published detail for this site (see Wockley Member). Open working seems to have ceased by 1893 when Harris (Ms, BGS) visited the site, as he refers only to the underground workings, but he 'had no time to go underground'. Harris, however, does include a section measured in the 'Lower quarries' by T P Lilly in 1876:

	Thickness m
Rag	0.76
"	0.61
Trough Bed	1.07
" "	0.91
Green Bed	0.76
" "	0.76
" "	0.30
Pinney Bed	0.61
" "	0.61
" "	0.61
Fretting Bed	0.76
" "	0.46

Ord and Reader (1912, p.524) refers to a section in the Ragstone 'over the underground workings at Teffont Evias' of a bed, 0.76 m thick, composed chiefly of shells of *Cyrena (Cytherea) rugosa* and known as the Chilmark Cyrena-Marble. It is not known whether this distinctive stone has been used as a building stone.

The entrance adit [9758 3122] to the underground workings (Figure 1, locality 55) is situated on the south-east side of the quarry; originally, access was by a shaft situated close to the present adit. Working underground ceased in 1937 when the site was taken over by the Air Ministry. In 1983, working, by Rare Stone, resumed and continues to the present day. The workings extend about 100 m north-eastwards as far as the current boundary fence. A plan of the mine is given by Towlson (1991). From this plan, it appears that there may have been an entrance from the main face of the quarry, and this is supported by a manuscript note on the main quarry face by C Reid on the six-inch-to-the-mile geological fieldslip (1900) saying 'Lower Building Stones mined'. Between 3.6 and 4.5 m of Pinney Beds are currently worked; the roof is formed by the Trough Bed. Three samples (VR29-31) were collected from 0.85 and 2.25 m above the base of the Upper Pinney, and from the Lower Pinney (1.35 m below a prominent chert bed) (Appendix 1).

Close to the existing mine is an old quarry [976 312] (Figure 1, locality 56) exposing about 7.4 m of the Wockley Member (q.v.). A note by C Reid in 1900 on the six-inch-to-the-mile geological fieldslip shows the position of a shaft [9766 3123] in the bottom of the pit, and a note saying 'Lower Building Stones mined'. The extent of these workings is unknown; the position of the adit is now covered by spoil and talus.

For some 400 m north-westwards from the Lower Quarry, the Tisbury Member has been extensively quarried. Within the RAF compound, there is no exposure and much of the waste in front of the quarries has been graded and landscaped. Outside the compound, in Quarry Copse (Figure 1, locality 56), the back face [9746 3139 to 9733 3156] is readily identifiable and there are small exposures [e.g 9739 3150] in massive, glauconitic, bioclastic sandstone. If suitable stone is identified, it would be possible to reopen this quarry, but there would be an increasing overburden problem. Alternatively, adits could be driven from the old face north-eastwards into the hillside.

Just outside Quarry Copse, close to an area known as Pickett Furlong, is an old pit [973 316] which has been largely infilled (Figure 1, locality 57). Jukes-Browne recorded 6 m of sand beds and chert of the Lower Building Stone in 1890. About 5 m of bioclastic, glauconitic, sandy sparite is still visible in the back wall. The 'Chalky Beds' may occur at the inaccessible top of the pit.

Wockley Member

In the Lower Quarry (Figure 1, locality 54), Ord and Reader (1912, p.155) refers to a bed of white stone within the Chalky Beds that was quarried for hearthstone. It is not known whether this bed was ever used as a building stone.

Chilmark Member

The only published section in this member is that from the Upper Quarry [9755 3137], Chilmark (also known as the Teffont Quarry No. 74 (Harris, Ms BGS, 1893) and Teffont (Chilmark) Quarry (Reid, 1903, p.9; Woodward, 1895, p.204)) (Figure 1, locality 58) (Andrews and Jukes-Browne, 1894; Blake, 1880; Ord and Reader, 1912, plate B; Reid, 1903; Wimbledon, 1976; Woodward, 1895). There is some doubt as to whether Harris' Quarry No.74 has been correctly identified with the upper quarry since his sketch map (without scale) shows his No.74 low down in the valley and close to his Chilmark No.2 Quarry (locality 55). Towlson (1991, p.62 [unnumbered])) suggests that it might have been the Lower Quarry (Locality 54). Harris' section is also ambiguous:

	Thickness m
Rubble and odd stuff	'several feet'
"Brown" bed	0.71
"Best White" bed - Best bed in this quarry	0.61
"Roach"	0.15
"Bottom" white bed	1.52

The White Beds referred to in the above section could be the White Bed recorded by Reid (1903, p.9) just beneath the 'Chalky Series' (= The Lower White of Lilly - see below), but, more likely, it is the White Beds in the Upper Building Stones as recorded by Lilly in 1876 (Harris, Ms, BGS):

	Thickness m
Lower Purbeck Beds	
Rag	1.37
Dirt Bed	0.15
Chilmark Member	
Brown - upper	0.91
White - upper	0.76
Chert	0.15
White - upper, in three equal beds	1.82
White - upper	1.68
(the above beds were worked in the upper quarries)	
Wockley Member	
Rubble, soft broken stuff	5.79
White - lower	1.07
Tibury Member (details already given - Locality 54)	

In 1893, Harris (MS, BGS) noted that it was still an open working, 'but they are just beginning to go underground'.

The section recorded by Woodward (1895) at this locality is given in the general section. Little detail is added by subsequent authors. A photograph of the pit is figured by Ord and Reader (1912) - the base of the Purbeck Beds is traditionally drawn at the base of a 'dirt bed' beneath the bed forming the roof of the adits. However, the roof bed (VR34) (Appendix 1) does not differ significantly from the beds below:

	Thickness m
Lower Purbeck Beds	
Micrite, hard	0.25
?As above	0.10
Micrite, peloidal, shelly, planar bedded (VR32)	0.6-0.7
Micrite, peloidal, porous, locally flaggy or massive; pronounced bedding surface at base (VR33)	0.15-0.40
Oolite, micritic, massive (VR34)(roof to adit)	1.00
Chilmark Member	
Oolite, fine-grained	0.40
Oolite, fine-grained (VR35)	1.00

There are several small exposures [9741 3151, 9743 3146, 9748 3140, 9770 3125, 9779 3112] and adits [9743 3146, 9744 3145, 9770 3125, 9773 3119, 9779 3112, 9781 3108] along the upper part of the eastern side of the Chilmark valley (Figure 1, localities 59-64). Unfortunately, access to the quarries and adits inside the RAF compound was not possible at this time of the year because of roosting bats; exposures outside the compound are degraded and access to the adits is now through very small apertures. It is most likely that other adits exist, but the entrances are hidden by slump material and/or rock falls. Brash at all localities consists of fine-grained oolite.

3. Petrography of outcrop samples collected from the Portland Beds in the Vale of Wardour — *Phase 2*

Sampling

Thirty-one samples were collected and thin sections made from outcrop and quarry sites within the Vale of Wardour as part of the continuing search and assessment of potential new Chilmark Stone sources for the Salisbury Cathedral restoration programme.

The samples again comprise yellowish grey (5Y 7/2 — Munsell colour chart), shelly (a.k.a. bioclastic) limestones, shelly sandstones and variably shelly micrites (or muddy limestones). Samples VR32, 33 (Purbeck Beds), 45 (Ragstone), 48, 50 (uppermost Tisbury Member), 55 and 60 (Wockley Member) are micrites or very fine-grained lime mudstones, with variable proportions of shell debris and little or no siliciclastic (quartz sand) content. These samples are described in Appendix 1, but are not considered further, as from the available evidence, such lithologies do not appear to have been used for the masonry in the cathedral.

Samples VR34 (Purbeck Beds) and 35 (Upper Building Stones) are oolitic limestones with only minor siliclastic components, and samples VR44, 46, 47 and 49 (Ragstone) are micritized peloidal limestones.

The remaining samples (VR 29a—31, 36, 37—43, 53, 54, 56—58) (Tisbury Member) span the sandy, bioclastic limestone to bioclastic sandstone range and show petrological similarities to the samples described in our first report (Bristow and Lott, 1994). They make up the lithological group that most closely matches those lithologies used for the cathedral masonry (based on the samples provided) and are most likely to provide suitable building stone. They are discussed further below.

Thin Section

In analysing the thin sections of these sedimentary rocks, a number of characteristic features can be established. As for the first-phase report, the most important of these include, framework mineralogy, grain-size, cementation and (conversely) porosity/permeability of the sample. Each or all of these characteristics can, as discussed in the first report, have important effects on the durability of the Chilmark Stone for building purposes.

Mineralogy

The present suite of samples do not differ in their basic mineralogy and textures from those examined in the first phase of the study. They again range from sandy limestones to calcareous sandstones, dependent on the proportion of detrital siliclastic (dominantly detrital quartz) to carbonate grains, and cement present.

The framework-grain components are dominated by silica (as detrital quartz, feldspar and rock fragments) and carbonate grains (as broken and abraded shell fragments and micritic, internally structureless, rounded, peloidal grains).

The siliciclastic grains are dominated by monocrystalline quartz, with subordinate proportions of feldspar grains and, more rarely, polycrystalline rock fragments. The quartz grains are both mechanically and chemically very stable during burial diagenesis. However, the feldspar grains and. rare rock fragments are much less resistant, particularly to chemical attack and mechanical strain. Consequently, it is not uncommon to see that corrosion and mechanical fracturing of some feldspar and polycrystalline grains has occurred during burial diagenesis. As the proportions of these components is generally very low, this does not, however, adversely affect the durability of the stone.

Unlike the siliciclastic grains, the carbonate framework grains are inherently less stable during burial diagenesis. Shell fragments and other bioclastic material can undergo substantial mineralogical alteration from the time of their deposition to their subsequent exposure to weathering at the surface. This instability is apparent from the present mineralogy of the bioclastic debris. Calcium carbonate (or calcite), which forms the wall structure of most of these organisms, can occur in a number of subtly different mineralogical forms, some of which are very unstable. After the death and burial of the organism, they revert to more stable mineralogies, often with a consequent obliteration of the original shell structure.

The shell fragments in the thin sections can be divided into those which have retained their original structure, those which have been replaced by spar-calcite and now show none of their original wall structure, and those which, due to the activities of algal and fungal organisms at seabed, have been bored and altered to structureless, micritized (very finely crystalline) calcite grains. Many of the rounded, so-called fine peloidal, grains described in the sections are probably abraded shell fragments in which the seabed micritization process has entirely destroyed the wall structure. Despite the initial chemical instability of these shelly fragments and the variety of chemical changes that can and have taken place, the main product of the changes is to produce a much more stable mineralogical framework component and is, therefore, unlikely to affect the durability of the stone.

A few of the samples examined have a completely different carbonate framework-grain composition. In these limestone, the main framework components are oolitic grains. These inorganic carbonate grains are well-rounded, concentrically laminated grains of medium grain-size (0.25—0.05 mm). Individual ooliths are often heavily micritized and may show only vague remnants of their original concentric internal structure. In these oolitic limestones, there is only a minor siliciclastic component. Most commonly, the siliciclastic grains present acted as nuclei around which the carbonate layers accreted as the grains were rolled around the seabed.

Other framework grains present include glauconite, a green to yellow-brown, (when partially altered) iron silicate. There is evidence of alteration of the glauconite grains in some of the samples examined, usually characterized by a colour change from green to yellow or brown, but again, because of its low proportions (>5%) this is not thought likely to have a detrimental affect on the durability of the stone.

Grain-size variations

As with the samples examined in the first phase of the project, there is only a narrow range of grain-size variations in the siliciclastic (sandy) framework material. All the siliciclastic grains dominantly lie in the very fine to fine sand-grade range (0.0625—0.25 mm), with only occasional coarse siliciclastic grain fractions (up to 1 mm). The grain-size range is consistent with the variations seen in the Cathedral masonry samples, though in those samples, there was a bias towards the very fine-grained siliclastic lithologies.

As might be expected, the carbonate framework grains show a much greater range in grain-size and shape. They may comprise rounded and abraded fragments which show a similar grain size to the associated siliciclastic grains or they may comprise almost intact shell valves. Coarse bioclastic fragments are not uncommon in some samples, ranging from relatively small (< 1 mm) thin-walled bivalves to large (> 5 mm) shell or serpulid (worm-tube) fragments. When the carbonate framework material is finer than fine sand-grade, its original internal structure is usually lost, having undergone either micritization or been completely replaced by spar-calcite.

Cementation

The comments made in our earlier report concerning the mineralogy, texture and importance of the presence of intergranular cements and their influence on the durability of the Chilmark Stone as a building stone are equally applicable to this second suite of samples.

Calcite is present as coarsely crystalline spar cement in most of the samples. It occurs in varying proportions ranging from a pervasive phase, blocking all pore space, to small-scale patchy overgrowth developments on single bioclastic grains.

Mineralogically, the spar cements again range from non-ferroan to ferroan forms of calcite. This subtle change in mineralogical composition, identifiable by using chemical staining during the thin-section preparation, does not seem in itself to affect the durability of the stone as a building material.

The calcite cements are diagenetic developments precipitated initially around carbonate framework grains. They commence early in the sediment history as crystalline precipitates seeded onto any bioclastic material present and may continue to grow during burial, in some instance coalescing to occupy all the porosity. In other samples, their development has been arrested and they form only narrow isolated fringes or patches around bioclasts.

As noted in our earlier report, the presence of these calcite cements, binding together the varied framework constituents, is the single most important influence on the durability of the Chilmark Stone.

Other cements present include cryptocrystalline silica and pyrite, but their proportions are extremely low and they are not, therefore, likely to have a significant influence on stone durability in the samples examined.

Porosity/permeability

As described in the first report, the porosity/permeability characteristics of the Chilmark Stone are varied. The stone may range from highly porous, friable lithologies to very hard, cemented, non-porous varieties. Porous, moderately cemented sandy lithologies appear to be the most common variety of stone used in the cathedral masonry, with harder, better cemented lithologies used selectively in exposed masonry or in areas of heavy wear and tear.

Conclusions

The thin-section analysis has confirmed that the two most common building stone lithologies identified in the masonry samples from the cathedral are:

1) very fine-grained, carbonate cemented, glaucontic, bioclastic sandstones.

2) glauconitic, bioclastic limestone with a fine-grained, siliciclastic sand component.

In both these lithologies, the proportions of bioclastic material and calcite cement vary, as does the grain-size and proportion of siliciclastic material present. In the masonry samples supplied, the very fine-grained sandstones are particularly common.

The thin-section analysis of all the field samples so far collected by BGS (see Appendices in both this and the earlier report), from a wide range of quarry and outcrop sites and in the Tisbury borehole suggests that comparable lithologies are commonly present.

Samples **VR15—19, 23, 26 & 29** (all Tisbury Borehole samples), **VR31, 42, 43, 57, 58 & 59** are similar in thin section to the **very fine-grained** sandstone lithology, described as lithology 1 above, and samples **VR1—10, 30, 37, 38, 39, 40, 42, 43 & 54** are similar to the **fine-grained**, sandy, bioclastic limestone described above as lithology 2.

From the thin-section studies, it is apparent that the best lithological matches for the building stone in the Cathedral masonry are all from the Tisbury Member (formerly the Lower Building Stones) of the Portland Stone Formation.

4. Conclusions and recommendations

The Tisbury Member crops out in a fairly narrow band on either side of the River Nadder in the west of the district, and as an inlier along the Chilmark Ravine. As found in the area covered by the Stage 1 report, within this tract, the *overall* lithological aspect is constant, but the member varies vertically in detail (such as degree of cementation and lamination, glauconite and silica sand content, amount of shell debris etc) within the sequence, with the upper beds generally providing the better stone. The lithology of any one bed also varies laterally. Thin sections of several samples from the Tisbury Member from this area are similar in overall composition to that used in the construction of Salisbury Cathedral. Clearly, the Tisbury Member in this area has potential as a possible source of stone for use in rebuilding the Cathedral. Recommendations for further work in the area are included below.

On the south side of the River Nadder, much of the outcrop has already been quarried. Whilst some stone could still be worked in this area, most surface workings would involve an increasing overburden. Exceptions, however, occur in the vicinity of localities 35-37, and between 42 and 49. In the former area, it would be possible to clean up the face of Locality 36 with a JCB to assess its building-stone potential. The latter area is possibly the area for which Mr R Collins has a planning application in which to expand his existing quarrying operation. If so, there is no reason to think that stone from the new area would differ significantly from the present quarry. If planning permission to extend the quarry (in whatever direction) is denied, then it becomes increasingly urgent to find an alternative source of stone.

North of the river, there is a wider outcrop of the Tisbury Member. Locality 33 ought to be investigated in company with a mason to assess its building-stone potential, with a view to extending the quarry westwards.

The area between localities 32 and 33 offers the possibility of a green-field site, but should only be considered if all other options fail.

Quarries and mines in the Chilmark Ravine have clearly supplied vast quantities of building stone from the Portland Beds over the years. Much of the outcrop is now worked out; the scope for underground working is not clear, as the full extent of the existing underground workings is not known. The present mine already extends, we believe, up to its north-eastern boundary. Underground workings are known to exist on the north-west and south-east sides, but their exact position relative to the mine is unknown.

Localities 52 and 53 (Radiac quarry of the RAF) appear to offer the best potential for new workings. If the stone in this quarry should prove suitable as a building stone, then reopening this quarry and extending it northwards should be seriously considered. There is no bat problem with this quarry or the field to the north (formerly with housing, but subsequently demolished) which forms part of the RAF compound, there is easy access from a public highway and it is close to the existing workings so translocation of equipment and staff should not be a problem. From this quarry we collected only four samples - three from the Tisbury Member (VR37-39) and one from the overlying Ragstone (not considered further). The three Tisbury Member samples were similar, being fine-grained, porous, moderately well-sorted, bioclastic sandstones which superficially resemble stones from the Cathedral. There is, however, one significant, but not necessarily important, difference in that the siliciclastic grains of stones from the Cathedral are, with few exceptions, finer grained, within the range very fine- (0.06 to 0.12 mm) to fine-grained (0.12 to 0.25 mm) sand grade. We suggest an early visit to this quarry by a mason (with ladder) and the stone sampled more closely with a view to assessing its commercial exploitation.

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6. Glossary

Arenaceous Said of a sediment consisting wholly or in part of sand-sized fragments, or having the appearance of a sand

Bioclastic Said of a sedimentary rock consisting of fragmental or broken remains of organisms, such as a limestone composed of shell fragments

Biosparite A limestone consisting of a variable proportion of shell debris and clear calcite (spar)

Bioturbated Sediments churned and stirred by organisms

Brash Loose, broken rock, commonly incorporated in the soil

Cambering A superficial structure caused by gravitational sliding towards lower areas

Clast Fragment of rock

Gastropods Mollusc generally characterised by a spiral calcareous shell - e.g. a snail

Glauconitic Said of a mineral aggregate that contains glauconite (a dull green, amorphous iron silicate)

Interfluve The upland area or ridge between two adjacent valleys

Oobiosparite An oolitic biosparite (q.v.)

Oolite A sedimentary rock, usually a limestone, made up chiefly of ooliths(small, round or ovate, accretionary bodies resembling the roe of a fish)

Peloidal Round or ovate bodies superficially resembling ooliths, but with no internal structure

Roach Beds of limestone full of hollow moulds and casts of fossils

Siliciclastic Pertaining to clastic, non-carbonate rocks, usually exclusively silicon bearing, either as quartz or silicates

Sparry Resembling spar (a loose term applied to any transparent or translucent, pale coloured, non-metallic, usually readily cleavable, crystalline mineral)

Appendix 1. Field samples and photomicrographs from the Tisbury—Chilmark area

Petrography of outcrop samples collected from the Portland Beds in the Vale of Wardour - *Phase 2*

Sampling

Thirty-one samples were collected and thin sections made from outcrop and quarry sites within the Vale of Wardour as part of the continuing search and assessment of potential new Chilmark Stone sources for the Salisbury Cathedral restoration programme.

The samples again comprise yellowish grey (5Y 7/2 - Munsell colour chart) shelly (a.k.a. bioclastic) limestones, shelly sandstones and variably shelly micrites (or muddy limestones). Samples VR32, 33, 45, 48, 50, 55 & 60 are micrites or very fine grained lime mudstones, with variable proportions of shell debris and little or no siliciclastic (quartz sand) content. These samples are described in the accompanying Appendix but are not considered further as from the available evidence such lithologies do not appear to have been used for the masonry in the cathedral.

Samples VR 34 and 35 are oolitic limestones with only minor siliciclastic components and samples VR44, 46, 47 & 49 are micritized peloidal limestones

The remaining samples (VR 29a-31, 36, 37-43, 53, 54, 56-58) span the sandy, bioclastic limestone to bioclastic sandstone range and show petrological similarities to the samples described in our first report (Bristow & Lott 1994). They make up the lithological group that most closely matches those lithologies used for the cathedral masonry (based on the samples provided) and are most likely to provide suitable building stone. They are discussed further below.

Thin section

In analysing the thin sections of these sedimentary rocks a number of characteristic features can be eastablished. As for the first phase report the most important of these include, framework mineralogy, grain-size, cementation and (conversely) porosity/permeability of the sample. Each or all of these characteristics can, as discussed in the first report, have important effects on the durability of the Chilmark Stone for building purposes.

Mineralogy

The present suite of samples do not differ in their basic mineralogy and textures from those examined in the first phase of the study. They again range from sandy limestones to calcareous sandstones, dependent on the proportion of detrital siliciclastic (dominantly detrital quartz) to carbonate grains and cement present.

The framework grain components are dominated by silica (as detrital quartz, feldspar and rock fragments) and carbonate grains (as broken and abraded shell fragments and micritic, internally structureless, rounded, peloidal grains).

The siliciclastic grains are dominated by monocrystalline quartz, with subordinate proportions of feldspar grains and more rarely polycrystalline rock fragments. The quartz grains are both mechanically and chemically very stable during burial diagenesis. However, the feldspar grains and rare rock fragments are much less resistant, particularly to chemical attack and mechanical strain. Consequently it is not uncommon to see that corrosion and mechanical fracturing of some feldspar and polycrystalline grains has occurred during burial diagenesis. As the proportions of these components is generally very low this does not, however, adversely affect the durability of the stone.

Unlike the siliclastic grains, the carbonate framework grains are inherently less stable during burial diagenesis. Shell fragments and other bioclastic material can undergo substantial mineralogical alteration from the time of their deposition to their subsequent exposure to weathering at the surface.

This instability is apparent from the the present mineralogy of the bioclastic debris. Calcium carbonate (or calcite), which forms the wall structure of most of these organisms, can occur in a number of subtly different mineralogical forms some of which are very unstable. After the death and burial of the organism they revert to more stable mineralogies often with a consequent obliteration of the original shell structure.

The shell fragments in the thin sections can be divided into those which have retained their original structure, those which have been replaced by spar-calcite and now show none of their original wall structure and those which due to the activities of algal and fungal organisms at seabed have been bored and altered to structureless micritized (very finely crystalline) calcite grains. Many of the rounded so-called fine peloidal grains described in the sections are probably abraded shell fragments in which the seabed micritization process has entirely destroyed the wall structure. Despite the initial chemical instability of these shelly fragments and the variety of chemical changes that can and have take place, the main product of the changes is to produce a much more stable mineralogical framework component and is, therefore, unlikely to affect the durability of the stone.

A few of the samples examined have a completely different carbonate framework grain composition. In these limestones the main framework components are oolitic grains. These inorganic carbonate grains are well rounded, concentrically laminated grains which are of medium grain-size (0.25-0.50mm). The individual ooliths are often heavily micritized and may show only vague remnants of their original concentric internal structure. In these oolitic limestones there is only a minor siliciclastic component. Most commonly the siliclastic grains present acted as nuclei around which the carbonate layers accreted as the grains were rolled around the seabed.

Other framework grains present include glauconite, a green to yellow-brown (when partially altered) iron silicate. There is evidence of alteration of the glauconite grains in some of the samples examined, usually characterized by a colour change from green to yellow or brown, but again because of its low proportions(>5%) this is not thought likely to have a detrimental affect the durability of the stone.

Grain-size variations

As with the samples examined in the first phase of the project there is only a narrow range of grain-size variations in the siliciclastic (sandy) framework material. All the siliciclastic grains dominantly lie in the very fine to fine sand-grade range (0.0625-0.25mm) with only occasional coarse siliciclastic grain fractions (up to 1mm). The grain-size range is consistent with the variations seen in the cathedral masonry samples though in those samples there was a bias towards the very fine grained siliclastic lithologies.

As might be expected, the carbonate framework grains show a much greater range in grain-size and shape. They may comprise rounded and abraded fragments which show a similar grains size to the associated siliciclastic grains or they may comprise almost intact shell valves. Coarse bioclastic fragments are not uncommon in some samples, ranging from relatively small (<1mm) thin-walled bivalves to large (>5mm) shell or serpulid (worm-tube) fragments. When the carbonate framework material is finer than fine sand-grade its original internal structure is usually lost having undergone either micritization or having been completely replaced by spar-calcite.

Cementation

The comments made in our earlier report concerning the mineralogy, texture and importance of the presence of intergranular cements and their influence on the durability of the Chilmark Stone as a building stone are equally applicable to this second suite of samples.

Calcite is present as coarsely crystalline spar cement in most of the samples. It occurs in varying proportions ranging from a pervasive phase, blocking all pore space, to small-scale patchy overgrowth developments on single bioclastic grains.

Mineralogically the spar cements again range from non-ferroan to ferroan forms of calcite. This subtle change in mineralogical composition, identifiable by using chemical staining during the thin section preparation, does not seem in itself to affect the durability of the stone as a building material.

The calcite cements are diagenetic developments precipitated initially around carbonate framework grains. They commence early in the sediments history as crystalline precipitates seeded onto any bioclastic material present and may continue to grow during burial, in some instances coalescing to occupy all the porosity. In other samples their development has been arrested and they form only narrow isolated fringes or patches around bioclasts.

As noted in out earlier report the presence of these calcite cements, binding together the varied framework constituents, is the single most important influence on the durability of the Chilmark Stone.

Other cements present include cryptocrystalline silica and pyrite but their proportions are extremely low and they are not, therefore, likely to have a significant influence on stone durability in the samples examined.

Porosity/permeability

As described in the in the first report the porosity/permeability characteristics of the Chilmark Stone very varied. The stone may range from highly porous, friable lithologies to very hard, cemented, non-porous varieties. Porous, moderately cemented sandy lithologies appear to be the most common variety of stone used in the cathedral masonry, with harder, better cemented lithologies used selectively in exposed masonry or in areas of heavy wear and tear.

Conclusions

The thin section analysis has confirmed the two most common building stone lithologies identified in the masonry samples from the cathedral are:-

1) very fine grained, carbonate cemented, glauconitic, bioclastic sandstones

2) glauconitic, bioclastic limestone with a fine grained, siliciclastic sand component.

In both these lithologies the proportions of bioclastic material and calcite cement vary, as does the grain-size and proportion of siliciclastic material present. In the masonry samples supplied the very fine grained sandstones are particularly common.

The thin section analysis of all the field samples so far collected by BGS (see Appendices), from a wide range of quarry and outcrop sites and in the Tisbury borehole suggests that comparable lithologies are commonly present.

Samples **VR15-19, 23, 26, & 29** (all Tisbury Borehole samples) **VR31, 42, 43, 57, 58 & 59** are similar in thin section to the **very fine** sandstone lithology, described as lithology 1 above, and samples **VR1-10, 30, 37, 38, 39, 40, 42, 43 & 54** are similar to the **fine** sandy bioclastic limestone described above as lithology 2.

From the thin section studies it is apparent that the best lithological matches for the building stone in the cathedral masonry are all from the Tisbury Member (formerly the Lower Building Stones) of the Portland Stone Formation.

Section 1

Field Samples descriptions and photomicrographs

VR29a	G.R. ST9757 3126
VR30	G.R. ST9757 3126
VR31	G.R. ST9757 3126
VR32	G.R. ST9755 3137
VR33	G.R. ST9755 3137
VR34	G.R. ST9755 3137
VR35	G.R. ST9755 3137
VR36	G.R. ST9727 3127
VR37	G.R. ST9727 3127
VR38	G.R. ST9731 3130
VR39	G.R. ST9731 3130
VR40	G.R. ST9559 2955
VR41	G.R. ST9559 2955
VR42	G.R. ST9559 2955
VR43	G.R. ST9559 2955
VR44	G.R. ST9596 2955
VR45	G.R. ST9596 2955
VR46	G.R. ST9630 2953
VR47	G.R. ST9630 2953
VR48	G.R. ST9630 2953
VR49	G.R. ST9693 2953
VR50	G.R. ST9693 2953
VR51	G.R. ST9693 2953
VR52	G.R. ST9693 2953
VR53	G.R. ST9693 2953
VR54	G.R. ST9693 2953
VR55	G.R. ST9639 2954
VR56	G.R. ST9550 2924
VR57	G.R. ST9550 2924
VR58	G.R. ST9544 2951
VR59	G.R. ST9544 2951
VR60	G.R. ST9768 3124

Glossary

Framework grains - grains form the bulk of the rock fabric and may be composed of:-

1) bioclastic debris

a) carbonate material- broken and abraded e.g. mollusc shells, crinoid and foraminifera

b) siliceous sponge spicules

2) non-bioclastic carbonate e.g. ooliths

3) non-carbonate detrital material e.g. quartz and feldspar (i.e. siliciclastic grains)

4) non-detrital, non-carbonate material e.g. glauconite, pyrite

Cement - this is the inter-granular material binding together the framework grains and may include:-

1) coarsely crystalline or sparry carbonate either as non-ferroan or ferroan (iron-rich) calcite

2) finely crystalline or microcrystalline carbonate (micrite)

3) finely crystalline silica (chert)

Porosity/permeability

Most sedimentary rocks have spaces or voids between the framework grains - **primary porosity** - which, following deposition, either remain open or are subsequently closed by a combination of compaction and cementation. These voids or pore spaces may occur between the grains - **inter**-granular types or, may occur within the grain structure - **intra**-granular types e.g. the open chambers in a gastropod shell.

After burial and compaction, over time, the sediment is also subjected to frequent changes in temperature and pressure and may be flushed by groundwaters of varying chemical composition. These pore-fluids may be non-corrosive and precipitate cements in the pore spaces - destroying porosity or, they may be strongly corrosive removing any early cements and framework grains during their passage and generally improving porosity. These changes are known as **diagenetic** changes and may result, in the latter case, in the development of **secondary porosity** by removing or partially dissolving grains or cements from within the rock.

The **permeability** of a rock is a measure of the connectivity of the pore spaces. If the pore spaces present are interconnected by narrow, open channels (or pore throats) then the rock is likely to have good permeability i.e. will transmit fluids easily. If the pore spaces throats are blocked by cements than the rock will have low permeability.

Section 1 Field samples and photomicrographs

VR29a (Chilmark Ravine - Rarestone Quarry: 2.25m above base of Upper Pinney)
Tisbury Member
ST9757 3126

Carbonate cemented, sandy, bioclastic limestone

Framework grains

Dominated by abraded bioclastic debris, peloids and moderately well sorted, fine-grained siliciclastic grains in a porous, spar-carbonate cement. Some bioclasts are non-ferroan, retaining their original wall structure, others are partially replaced by ferroan spar. Glauconite is abundant.

Cement

Most bioclastic grains have a narrow, non-ferroan, fringing overgrowths which may coalesce to form more extensive sparry patches. Ferroan calcite sparry patches are also common.

Siliciclastics

Dominated by monocrystalline quartz, with subordinate feldspar.

Porosity

Patchy, poorly interconnected remnant porosity.

VR30 (Chilmark Ravine - Rarestone Quarry: 0.85m above base of Upper Pinney)
Tisbury Member
ST9757 3126

Porous, laminated, bioclastic, fine sandstone

Framework grains

Dominated by moderately well sorted, fine-grained siliciclastic grains and abraded bioclastic debris, porous and weakly cemented, with a sparse micritic matrix. The bioclasts are either non-ferroan retaining their original wall structure or partially replaced by ferroan spar. Glauconite is abundant and pyrite aggregates also occur

Cement

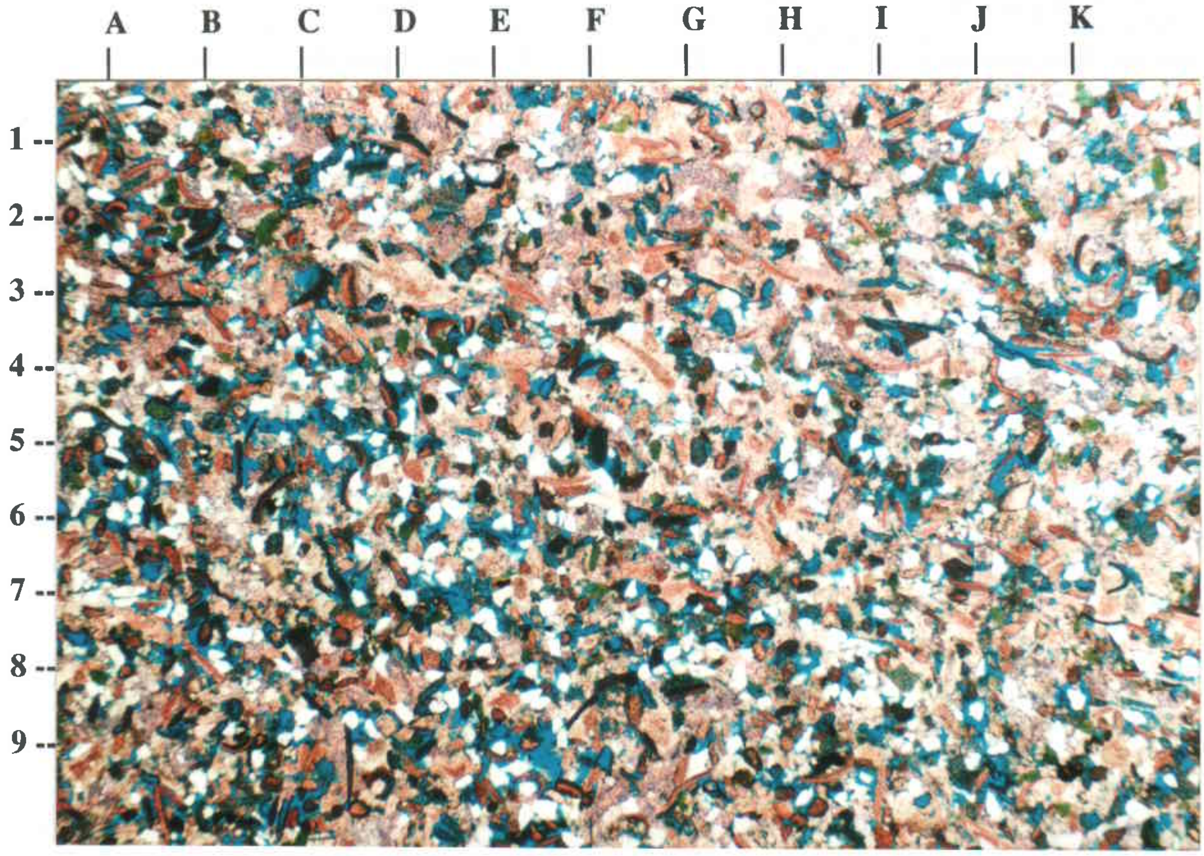
Many bioclastic grains have a narrow, fringing, non-ferroan cement which only rarely coalesce to form small sparry patches. Ferroan calcite sparry patches occur rarely.

Siliciclastics

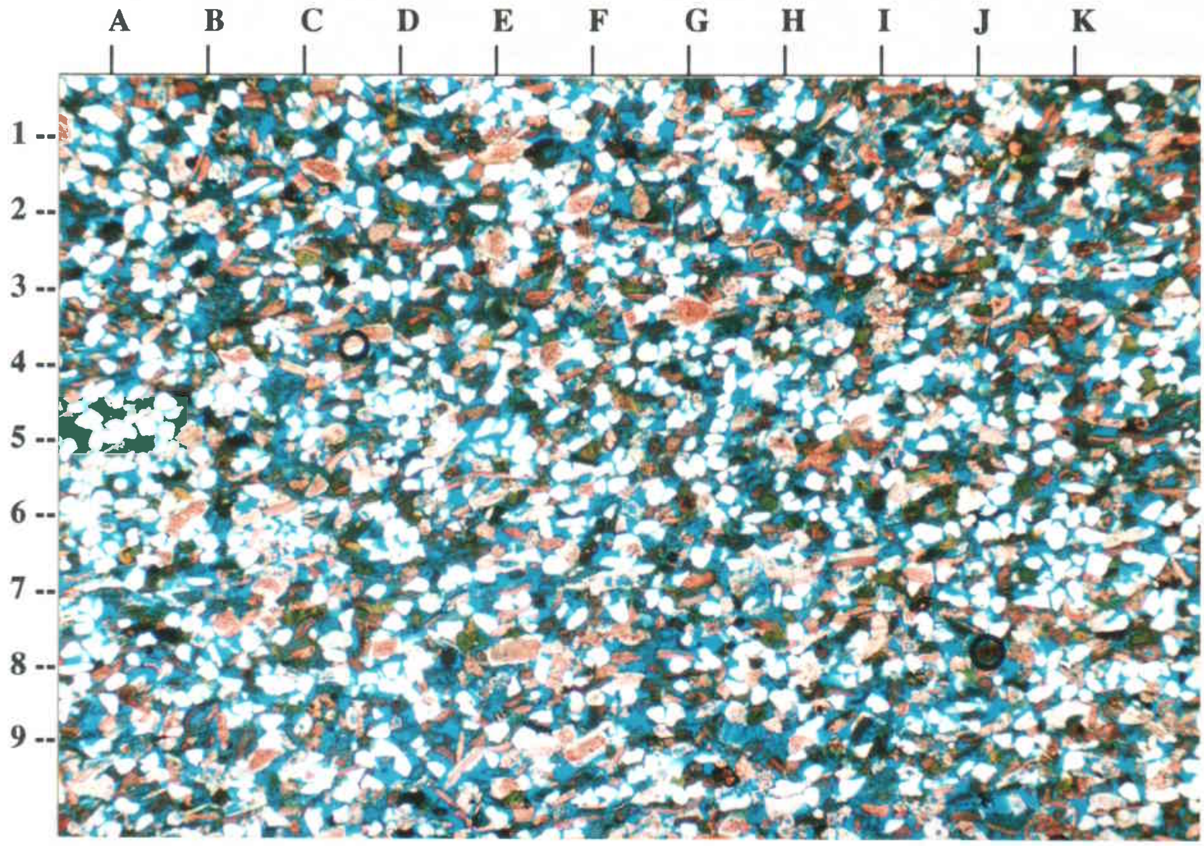
Dominated by monocrystalline quartz, with subordinate feldspar.

Porosity

Good primary interconnected porosity disrupted by micritic patches. Secondary porosity is common after dissolution of original bioclast leaving remnant sparry overgrowth



VR 29 Plate 1 (x2.5)



VR 30 Plate 2 (x2.5)

VR31 (Chilmark Ravine - Rarestone Quarry: 1.35m below chert of Lower Pinney)
Tisbury Member
ST9757 3126

Porous, bioclastic, very fine sandstone

Framework grains

Dominated by moderately well sorted, very fine-grained siliciclastic grains and abraded bioclastic debris, porous and weakly cemented, with a sparse micritic matrix. The bioclasts are non-ferroan retaining their original wall structure or are replaced by non-ferroan spar. Glauconite is moderately common and pyrite aggregates also occur.

Cement

Some bioclastic grains have extensive non-ferroan cement overgrowths.

Siliciclastics

Dominated by monocrystalline quartz with subordinate feldspar.

Porosity

Good primary interconnected porosity disrupted by micritic patches. Secondary porosity is commonly developed after leaching of carbonate grains.

VR32 (Upper 'Teffont Evias' Quarry)
Purbeck Beds: Section 66
ST9755 3137

Peloidal micrite

Framework grains

Dominated by moderately well sorted, very fine peloidal grains and thin-walled bivalve debris, porous and weakly cemented by microspar. The bioclasts are sparse, non-ferroan and retain their original wall structure. Glauconite is absent.

Cement

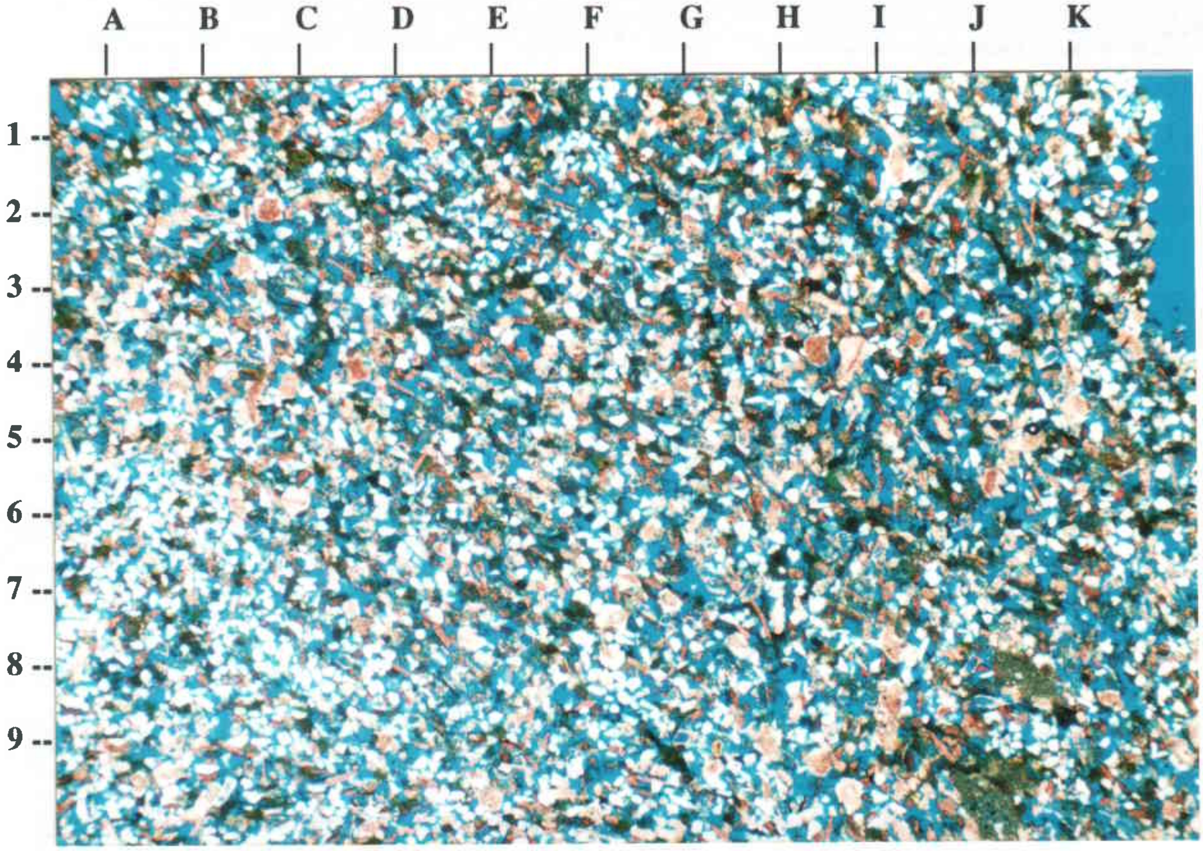
Many peloidal aggregates have a fringing, microsparry, non-ferroan cement which may coalesce to form sparry patches.

Siliciclastics

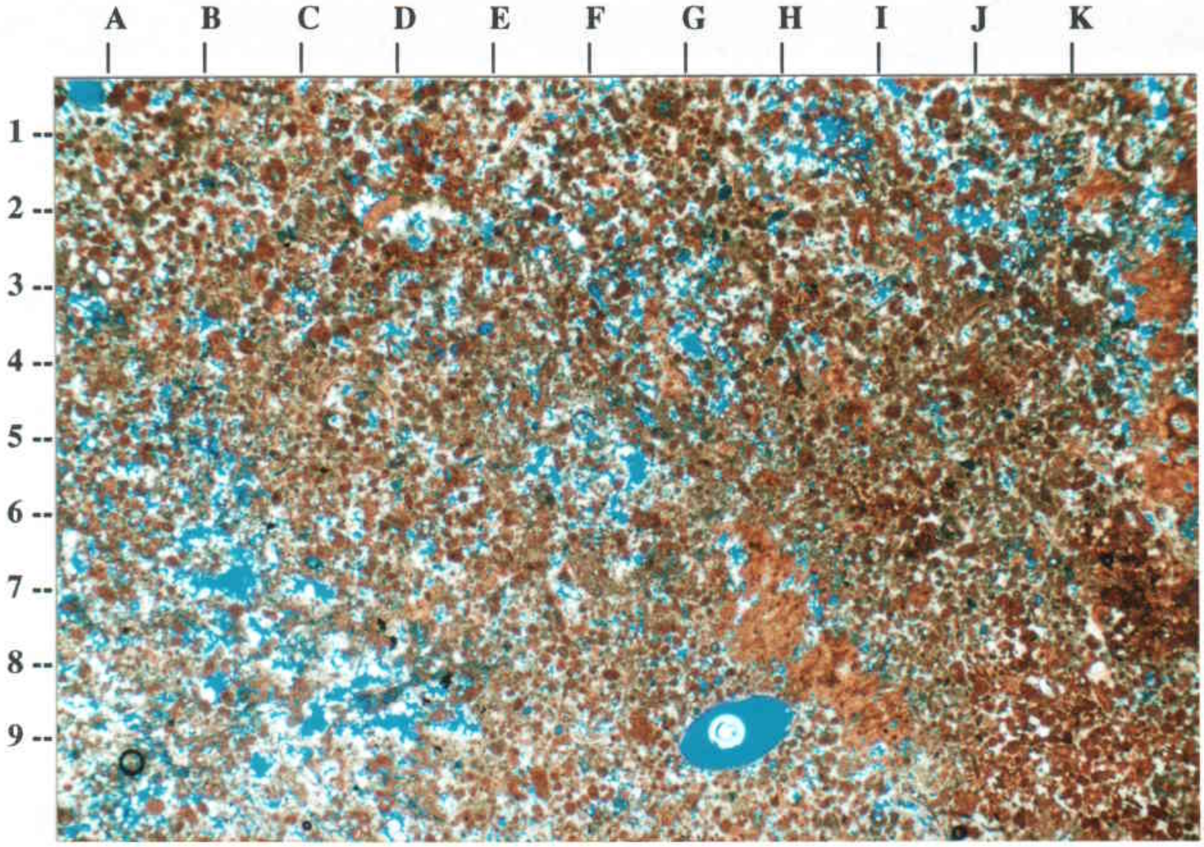
None.

Porosity

Poorly interconnected.



VR 31 Plate 3 (x2.5)



VR 32 Plate 4 (x2.5)

VR33 (Upper 'Teffont Evias' Quarry)
Purbeck Beds: Section 66
ST9755 3137

Highly porous, peloidal micrite

Matrix

Coalescing, non-ferroan, micritized peloidal patches, with abundant thin-walled, bivalve debris. Highly porous, very weak framework.

Cement

None.

Siliciclastics

None.

Porosity

Very good open porosity.

VR34 (Upper 'Teffont Evias' Quarry)
Purbeck Beds: Section 66
ST9755 3137

Porous, micritized, oolite

Framework grains

Coalescing, non-ferroan, poorly sorted, micritized , fine to coarse sand-grade oolitic, peloidal and coated (including grapestone) grains in a porous very weak framework. Moderately extensive coalescing patches of ooliths in a micritic cement occasionally occur. Oolith nuclei range from abraded bioclastic debris to siliciclastic grains.

Cement

A narrow fringing microspar cement coats many framework grains. Occasional cherty infills are present.

Siliciclastics

Monocrystalline quartz occasionally grains form the nuclei of coated grains.

Porosity

Good open porosity.

VR35 (Upper 'Teffont Evias' Quarry)
Chilmark Member, Upper Building Stones: Section 66
ST9755 3137

Porous, micritized, oolite

Framework grains

Coalescing, non-ferroan, poorly sorted, micritized , fine to coarse sand-grade oolitic, peloidal and coated (grapestone) grains in a porous very weak framework. Oolith nuclei range from abraded bioclastic debris to siliciclastic grains.

Cement

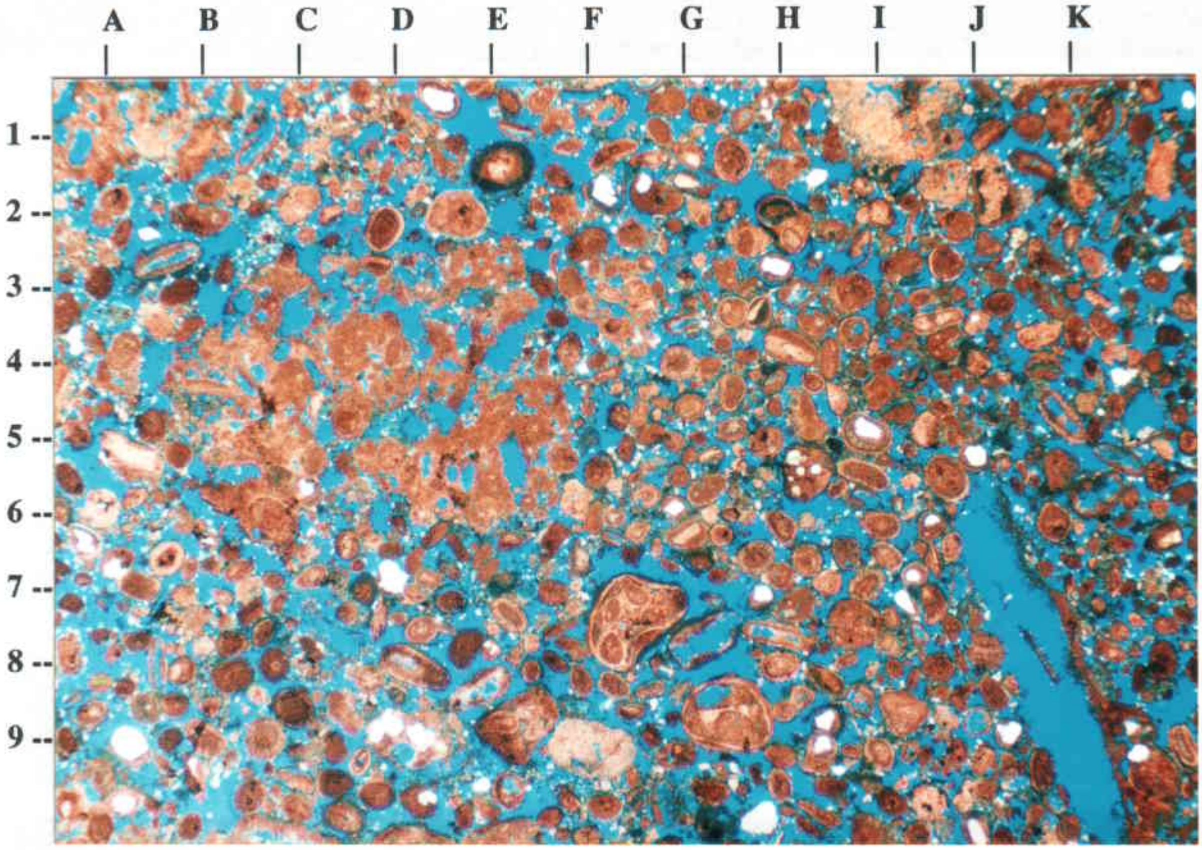
Narrow, fringing, microspar cements coat many framework grains.

Siliciclastics

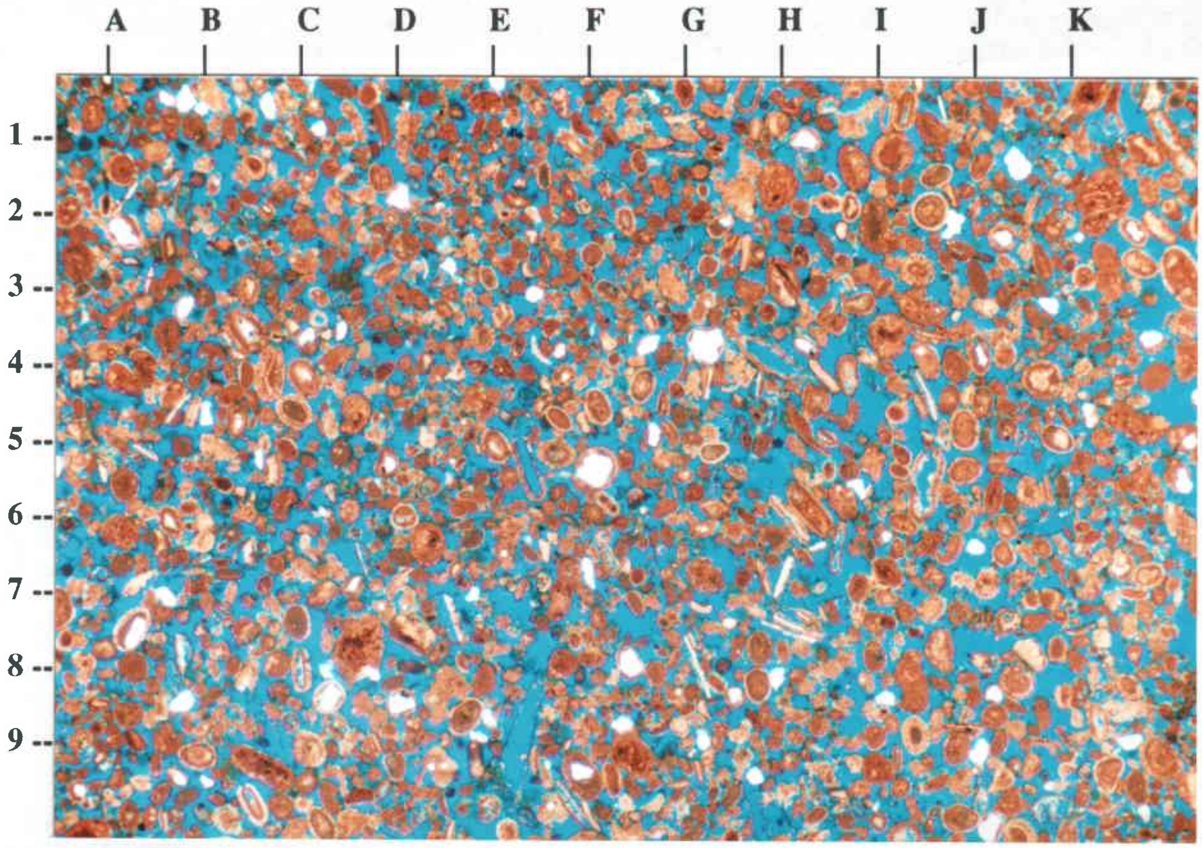
Occasional monocrystalline quartz grains occasionally form the nuclei of coated grains.

Porosity

Good open porosity.



VR 34 Plate 5(x2.5)



VR 35 Plate 6 (x2.5) Plane polars

VR36 (Radiac Quarry, West Face; Chilmark)
Tisbury Member, Ragstone: Section 68
ST9727 3127

Sandy, glauconitic biosparite

Framework grains

Dominated by moderately well sorted, fine-grained, siliciclastic grains, poorly sorted coarse bioclastic grains and finer abraded bioclastic/peloidal grains, in a spar-carbonate cement. Many of the coarser bioclasic fragments have been replaced by coarsely sparry ferroan calcite. Rounded glauconite grains are moderately abundant.

Cement

Pervasive sparry non-ferroan to slightly ferroan calcite cement. Chalcedonitic (cryptocrystalline-silica) replacement of carbonate fragments has rarely occurred.

Siliciclastics

Abundant fine sand-grade monocrystalline quartz with subordinate feldspar grains.

Porosity

Poor. Tightly cemented with minor secondary porosity after bioclastic grain dissolution.

VR37 (Radiac Quarry, West Face; Chilmark)
Tisbury Member, 1.15m below base of Ragstone: Section 68
ST9727 3127

Porous, bioclastic, fine sandstone

Framework grains

Dominated by moderately sorted fine-grained siliciclastic, abraded bioclastic and peloidal grains in a porous, micritic matrix. The bioclasts retain their original internal wall structure or are replaced by non-ferroan spar. Glauconite is moderately abundant.

Cement

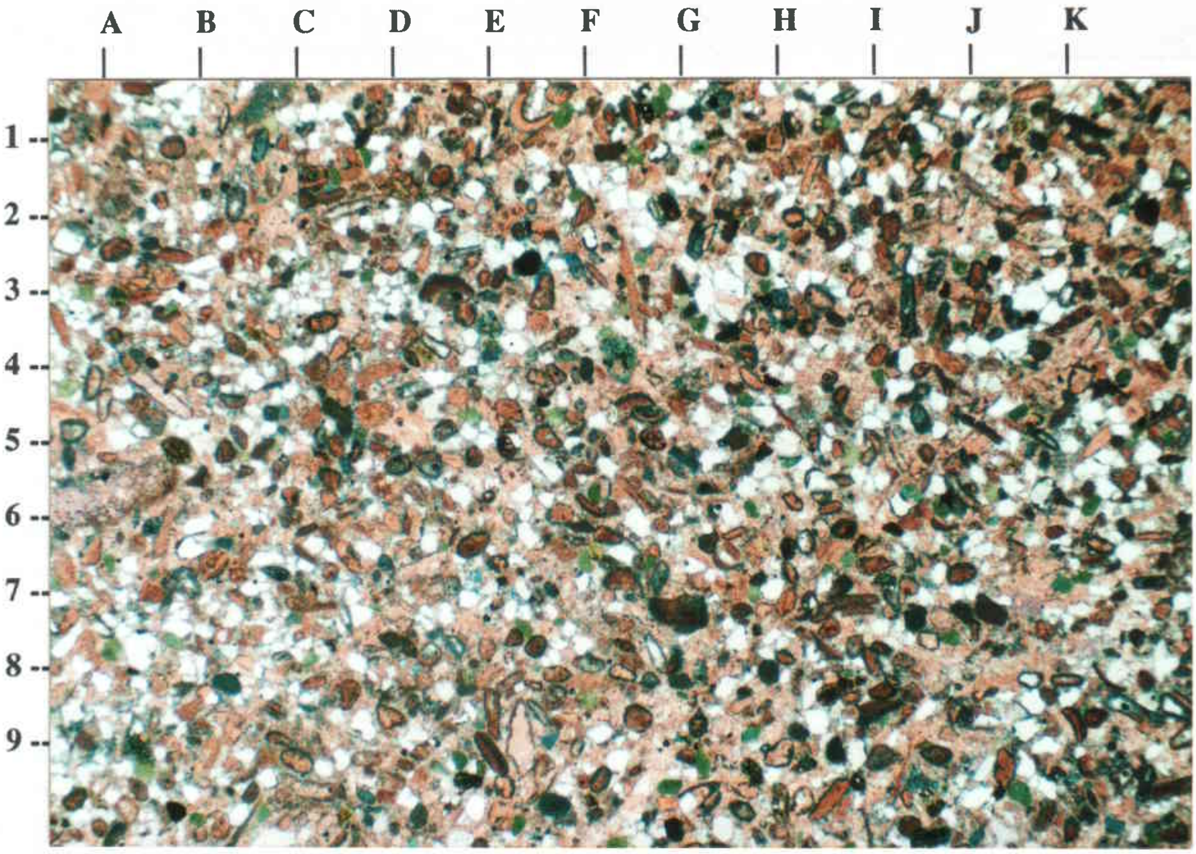
Many of the bioclastic grains have narrow, fringing, needle-shaped, spar-calcite overgrowths. More extensive patches of ferroan carbonate spar also occur, as a consequence of coalescing spar replaced bioclasts. Rare chalcedonitic cement patches occur as pore fills in some bioclasts.

Siliciclastics

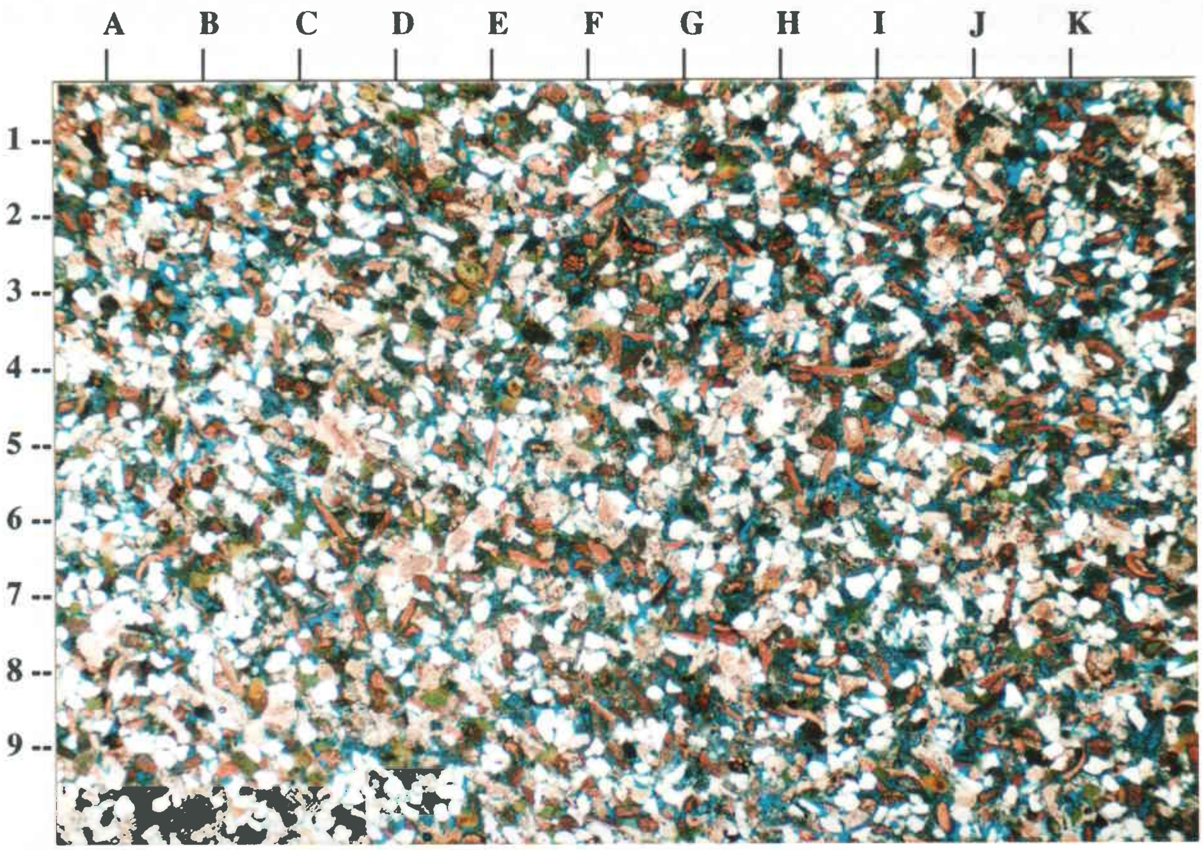
Abundant fine sand-grade monocrystalline quartz, with subordinate feldspar grains.

Porosity

Moderate to good, with pore systems partially disrupted by micritic matrix.



VR 36 Plate 7 (x2.5) Planre polars



VR 37 Plate 8 (x2.5) Plane polars

VR38 (Radiac Quarry, East Face; Chilmark)
Tisbury Member, 2.15m above base of section: Section 69
ST9731 3130

Porous, laminated, bioclastic fine sandstone

Framework grains

Dominated by moderately sorted, fine-grained, siliciclastic, abraded bioclastic and peloidal grains in a porous, micritic matrix. The bioclasts either retain their original internal wall structure or are spar-replaced. Glauconite is moderately abundant.

Cement

Most of the bioclastic grains have narrow, fringing, needle-shaped spar-calcite overgrowths. More extensive patches of non-ferroan carbonate spar also occur, as a consequence of coalescing overgrowths on spar-replaced bioclasts.

Siliciclastics

Abundant fine sand-grade, monocrystalline quartz, with subordinate feldspar grains.

Porosity

Moderate porosity, with pore systems partially disrupted by micritic matrix.

VR39 (Radiac Quarry, East Face; Chilmark)
Tisbury Member, 0.65m above base of section: Section 69
ST9731 3130

Porous, , bioclastic, fine sandstone

Framework grains

Dominated by moderately sorted, fine-grained siliciclastic, abraded bioclastic and peloidal grains in a porous, micritic, matrix. The bioclasts either retain their original internal wall structure or are spar-replaced. Glauconite is moderately abundant.

Cement

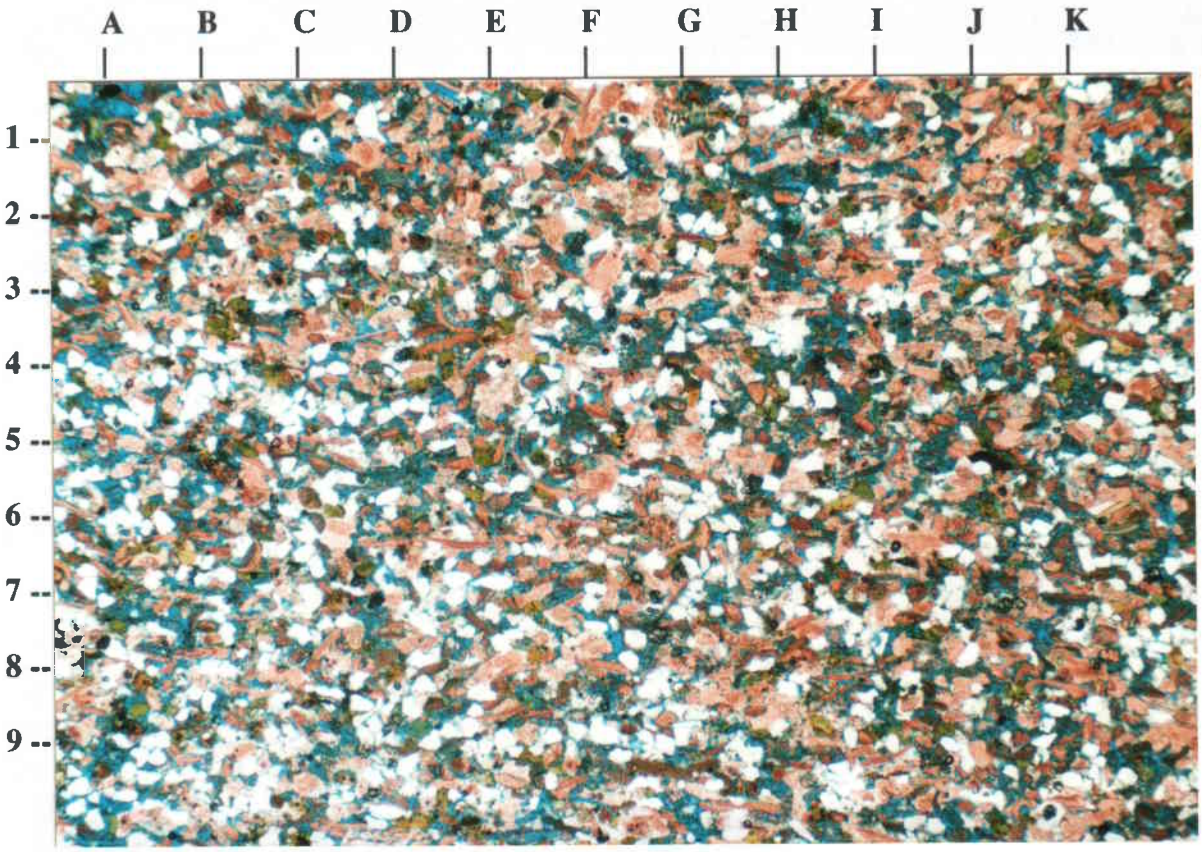
Many of the bioclastic grains have narrow, fringing, needle-shaped, non-ferroan spar-calcite overgrowths. More extensive patches of non-ferroan carbonate spar also occur, as a consequence of the coalescence of spar-replaced bioclasts and their overgrowths. Non-ferroan spar cement patches occur only rarely.

Siliciclastics

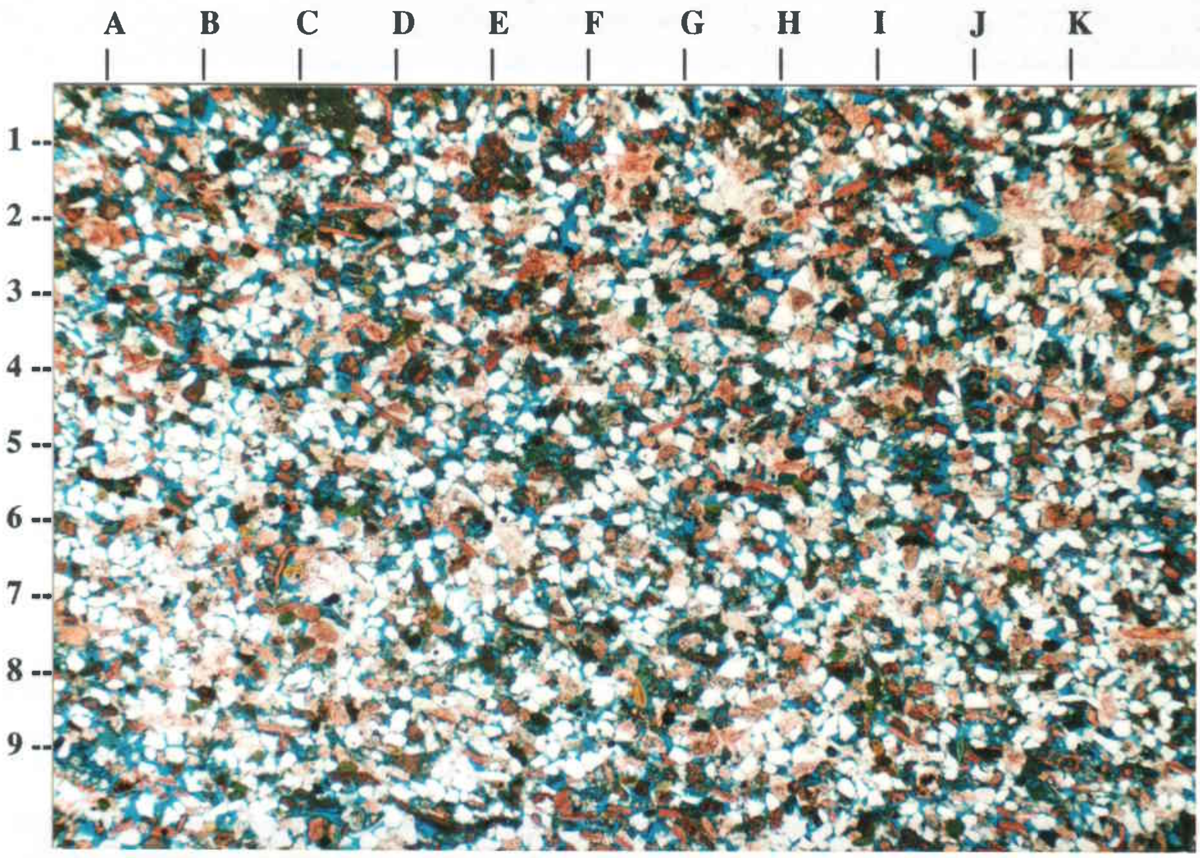
Abundant fine sand-grade monocrystalline quartz, with subordinate feldspar grains.

Porosity

Moderate porosity, with pore systems partially disrupted by micritic matrix.



VR 38 Plate 9 (x2.5) Plane polars.



VR 39 Plate 10 (x2.5) Plane polars

VR40 (Chicksgrove Quarry)
Tisbury Member, below bed B: Section 70
ST9559 2955

Porous, bioclastic, fine sandstone

Framework grains

Dominated by moderately well sorted, fine-grained, siliciclastic, abraded bioclastic and peloidal grains in a porous, sparsely micritic matrix. Some bioclasts retain their original internal wall structure others are spar-replaced. Glauconite is moderately abundant.

Cement

Many of the bioclastic grains have a very narrow fringing needle-shaped non-ferroan spar-calcite overgrowths.

Siliciclastics

Abundant fine sand-grade monocrystalline quartz with subordinate feldspar grains.

Porosity

Good porosity, with pore systems partially disrupted by micritic matrix. Secondary porosity is common after the dissolution of bioclastic grains.

VR41 (Chicksgrove Quarry)
Tisbury Member, 2m below bed B: Section 70
ST9559 2955

Porous, sandy, bioclastic limestone

Framework grains

Dominated by moderately sorted, abraded bioclastic, peloidal and very fine sand-grade siliciclastic grains in a porous, partially cemented framework. The bioclasts either retain their original internal wall structure or are spar-replaced. Glauconite is abundant often showing alteration.

Cement

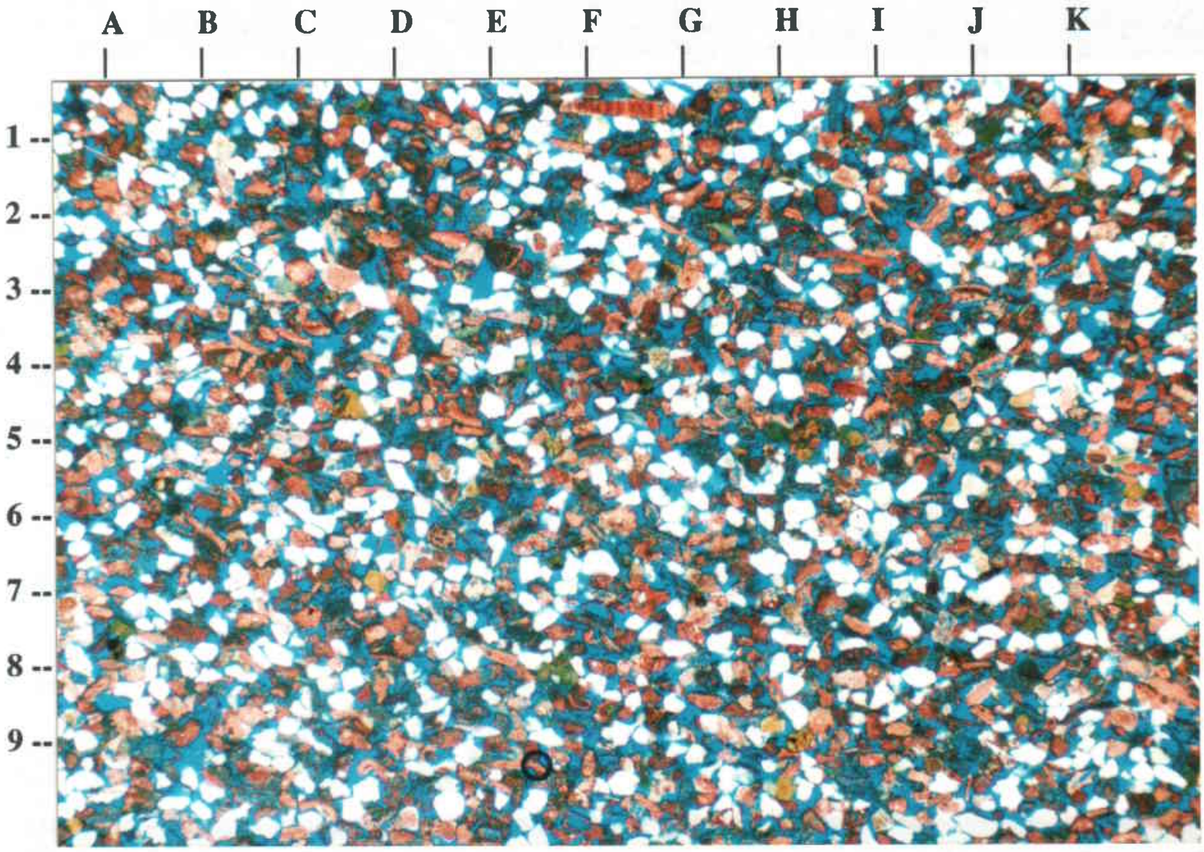
Many of the bioclastic grains have narrow, fringing, needle-shaped, non-ferroan spar-calcite overgrowths. More extensive patches of non-ferroan carbonate spar also commonly occur, as a consequence of the coalescence of spar-replaced bioclasts and their overgrowths. Non-ferroan spar cement patches occur only rarely.

Siliciclastics

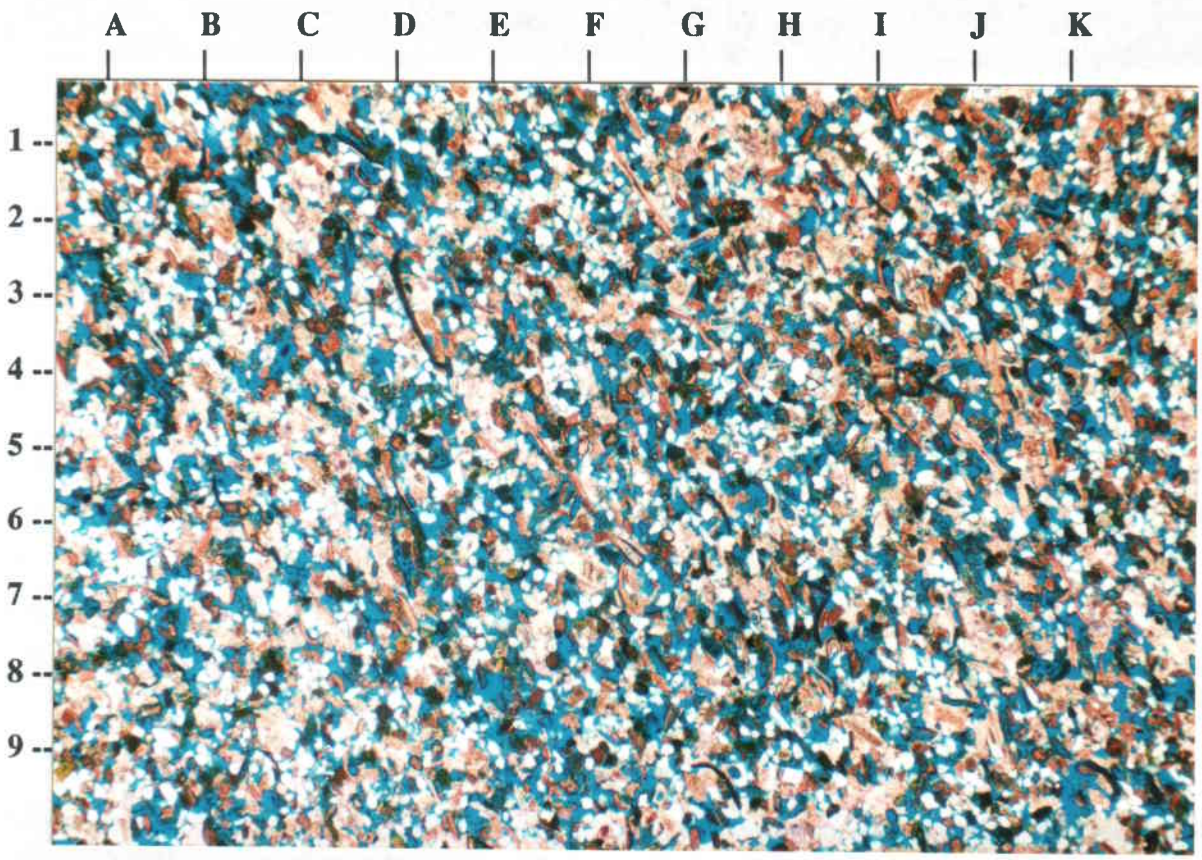
Abundant very fine sand/coarse silt-grade monocrystalline quartz, with subordinate feldspar grains.

Porosity

Moderate porosity, disrupted by patchy spar cementation and sparse micritic matrix



VR 40 Plate 11 (x2.5) Plane polars



VR 41 Plate 12 (x2.5) Plane polars

VR42 (Chicksgrove Quarry)
Tisbury Member, 4m below bed B: Section 70
ST9559 2955

Porous, bioclastic, very fine sandstone

Framework grains

Dominated by well sorted, very fine-grained siliciclastic grains largely in point contact. Abraded fine bioclastic debris and peloidal grains are common. A concentration of much coarser spar-replaced bioclastic grains also occurs. The bioclasts either retain their original internal wall structure or, more commonly, are spar-replaced. Glauconite is moderately abundant.

Cement

Extensive microspar cement. The bioclastic grains commonly have narrow fringing needle-shaped, non-ferroan spar-calcite overgrowths. More extensive patches of mixed non-ferroan and ferroan carbonate spar also occur, as a consequence of the coalescence of these spar-replaced bioclasts and their overgrowths.

Siliciclastics

Abundant very fine sand-grade, monocrystalline quartz with subordinate feldspar grains.

Porosity

Poorly interconnected porosity.

VR43 (Chicksgrove Quarry)
Tisbury Member, 5m below bed B: Section 70
ST9559 2955

Porous, (?bioclastic) very fine sandstone

Framework grains

Dominated by well sorted, very fine-grained siliciclastic grains largely in point contact. Very fine ferroan spar-debris (?bioclastic) is common. A sparse micritic matrix also occurs. Larger non-ferroan bioclastic grains occur rarely. Glauconite is moderately abundant.

Cement

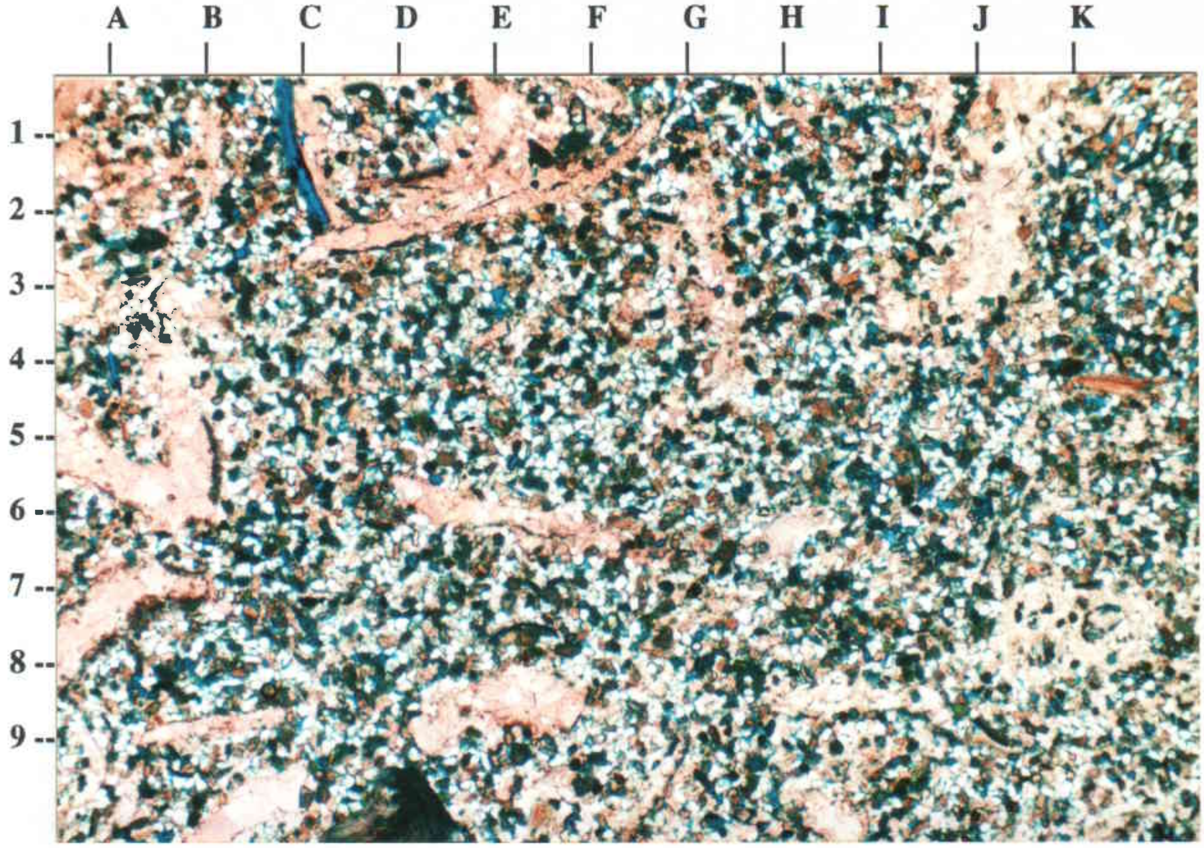
Minor ferroan microspar cement patches.

Siliciclastics

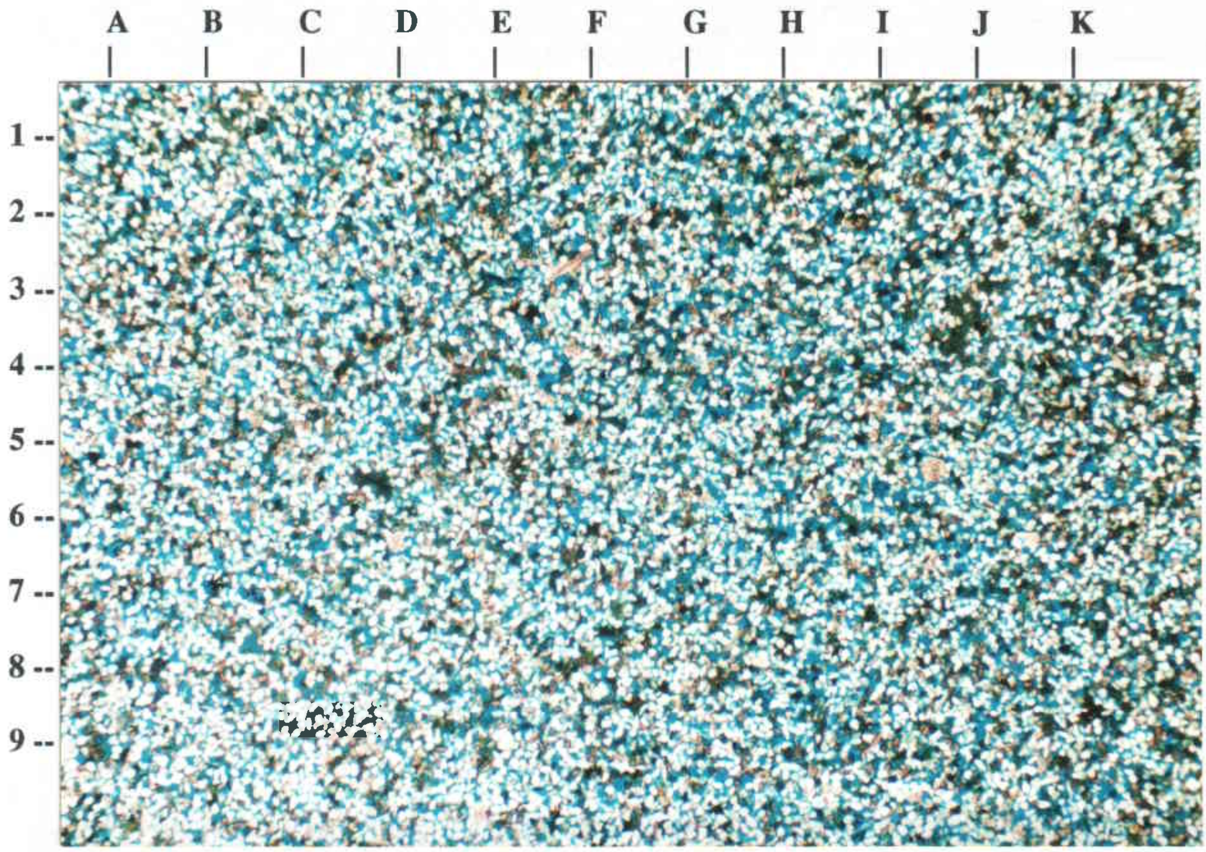
Very fine sand-grade, monocrystalline quartz, with subordinate feldspar grains.

Porosity

Good, but poorly interconnected porosity.



VR 42 Plate 13 (x2.5) Plane polars



VR 43 Plate 14 (x2.5) Plane polars

VR44 (Chicksgrove Quarry)
Wockley Member, bed above Ragstone: Section 71
ST9596 2955

Peloidal limestone

Framework grains

Dominated by poorly sorted, medium to coarse grained, micritized peloidal grains, partially cemented by mixed ferroan and non-ferroan spar patches. Some of the peloidal grains show remnants of bioclastic or siliciclastic nuclei suggesting that they were originally coated grains. Sparse medium to coarse grained siliciclastic grains. Glauconite is moderately abundant.

Cement

Moderately extensive, ferroan and non-ferroan spar patches

Siliciclastics

Sparse medium to coarse sand-grade, monocrystalline quartz grains acting as nuclei to some peloidal grains (ooliths?).

Porosity

Good, but poorly interconnected porosity.

VR45 (Chicksgrove Quarry)
Tisbury Member, Ragstone: Section 71
ST9596 2955

Biomicrite (muddy limestone with bioclastic debris)

Matrix

Coarse, spar-replaced bioclastic debris float in a non-ferroan, muddy, finely bioclastic, micritic matrix. Glauconite occurs only rarely

Cement

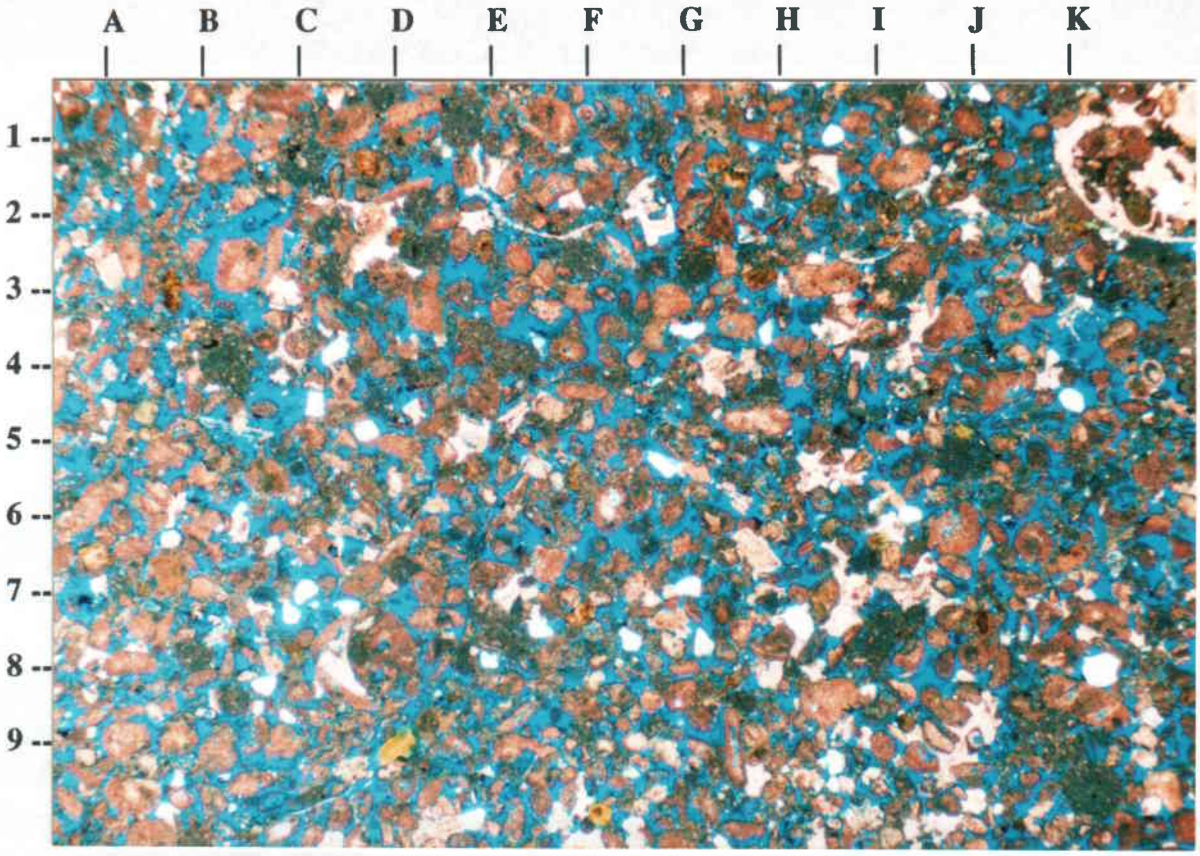
Micrite

Siliciclastics

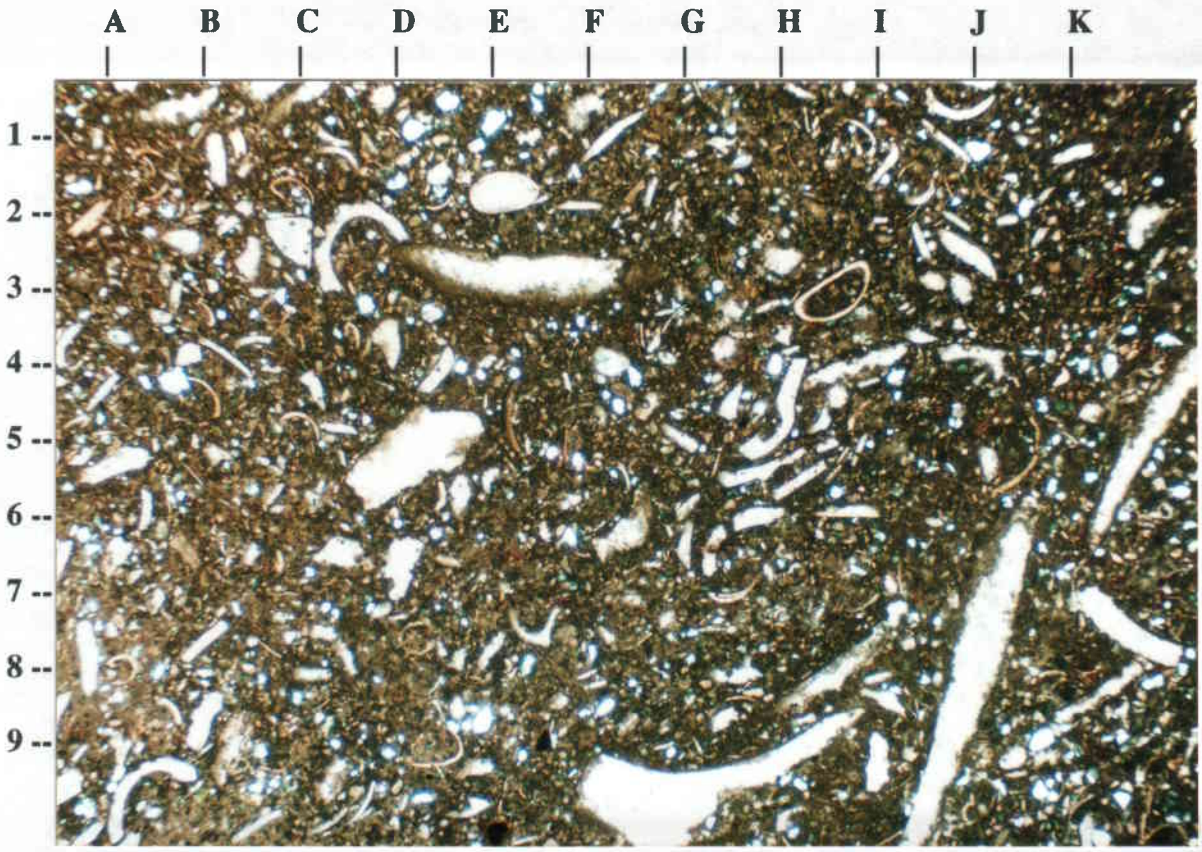
Sparse, coarse silt to fine sand grade, monocrystalline quartz grains.

Porosity

None



VR 44 Plate 15 (x2.5) Plane polars



VR 45 Plate 16 (x2.5) Plane polars

VR46 (Chicksgrove Quarry)
Wockley Member, bed above Ragstone: Section 72
ST9630 2953

Peloidal, bioclastic limestone

Framework grains

Dominated by poorly sorted, medium to coarse grained, micritized peloidal and bioclastic grains, patchily cemented by non-ferroan spar, in a micritic matrix. A large, multichambered ?serpulid fragment with the chambers occluded by non-ferroan spar carbonate is present, together with scattered coarse bivalve fragments. Some of the peloidal grains show remnants of bioclasts or siliciclastic grains as their nuclei, suggesting that they were originally coated grains. Sparse medium to coarse siliciclastic grains also occur and glauconite is rarely present.

Cement

Occasional non-ferroan spar patches.

Siliciclastics

Sparse medium to coarse sand-grade, monocrystalline quartz grains often acting as nuclei to some peloidal grains (ooliths?).

Porosity

Extensive, fine intra-granular porosity, poorly interconnected.

VR47 (Chicksgrove Quarry)
Tisbury Member, Ragstone: Section 72
ST9630 2953

Peloidal, bioclastic limestone

Framework grains

Dominated by poorly sorted, fine, micritized bioclast, peloidal grains, fine to very coarse spar replaced bioclastic grains, partially cemented by ferroan and non-ferroan microspar patches. Sparse medium to coarse siliciclastic grains. Glauconite is moderately common.

Cement

Extensive, non-ferroan spar patches.

Siliciclastics

Sparse, very fine to medium sand-grade, monocrystalline quartz grains acting as nuclei to some peloidal grains (ooliths?).

Porosity

Poorly interconnected patches.

VR50 (Chicksgrove Quarry)
Tisbury Member, Ragstone: Section 73
ST9693 2953

Sandy, bioclastic, micritic limestone

Matrix

Muddy, finely bioclastic, micritic limestone, with abundant coarser grained thin-walled bivalve fragments (largely replaced by non-ferroan spar) and occasional peloidal grains. Very fine to medium grained siliciclastic grains are moderately abundant altered glauconite grains are present.

Cement

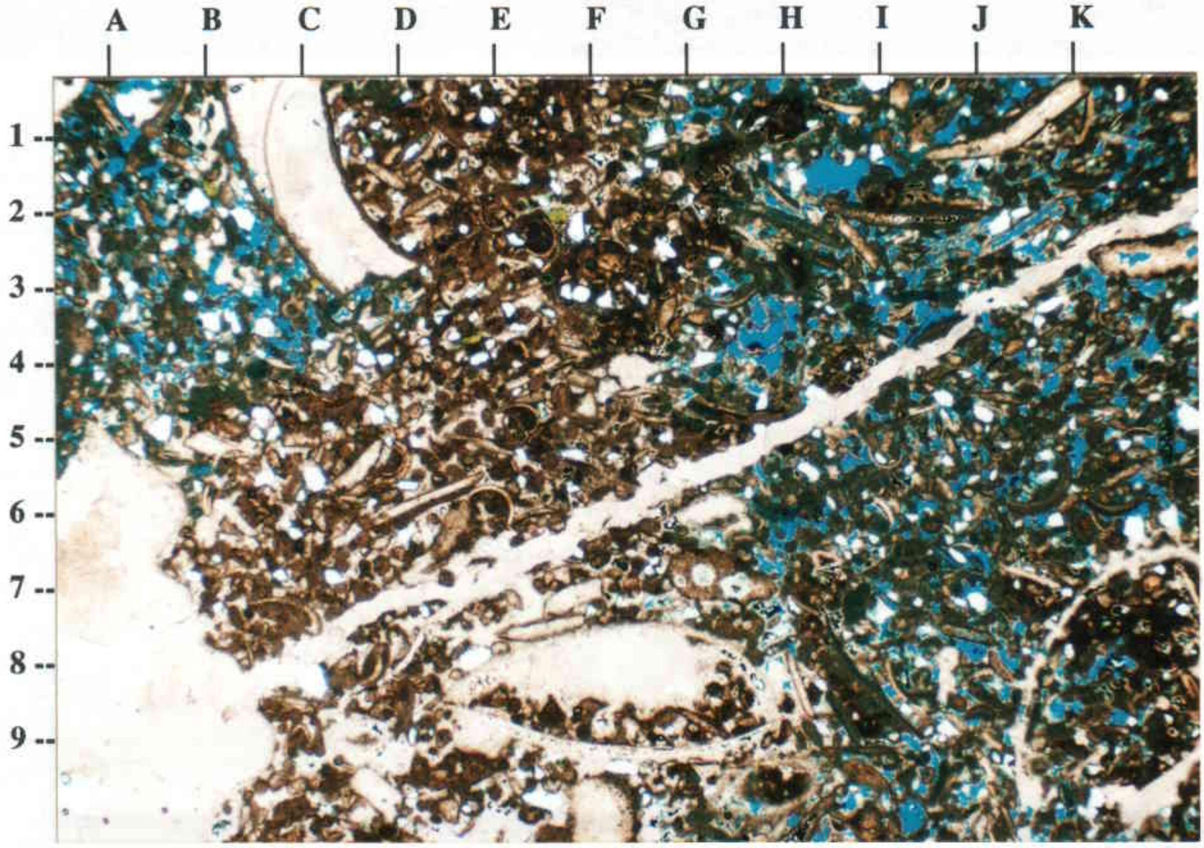
Micrite with occasional non-ferroan spar patches.

Siliciclastics

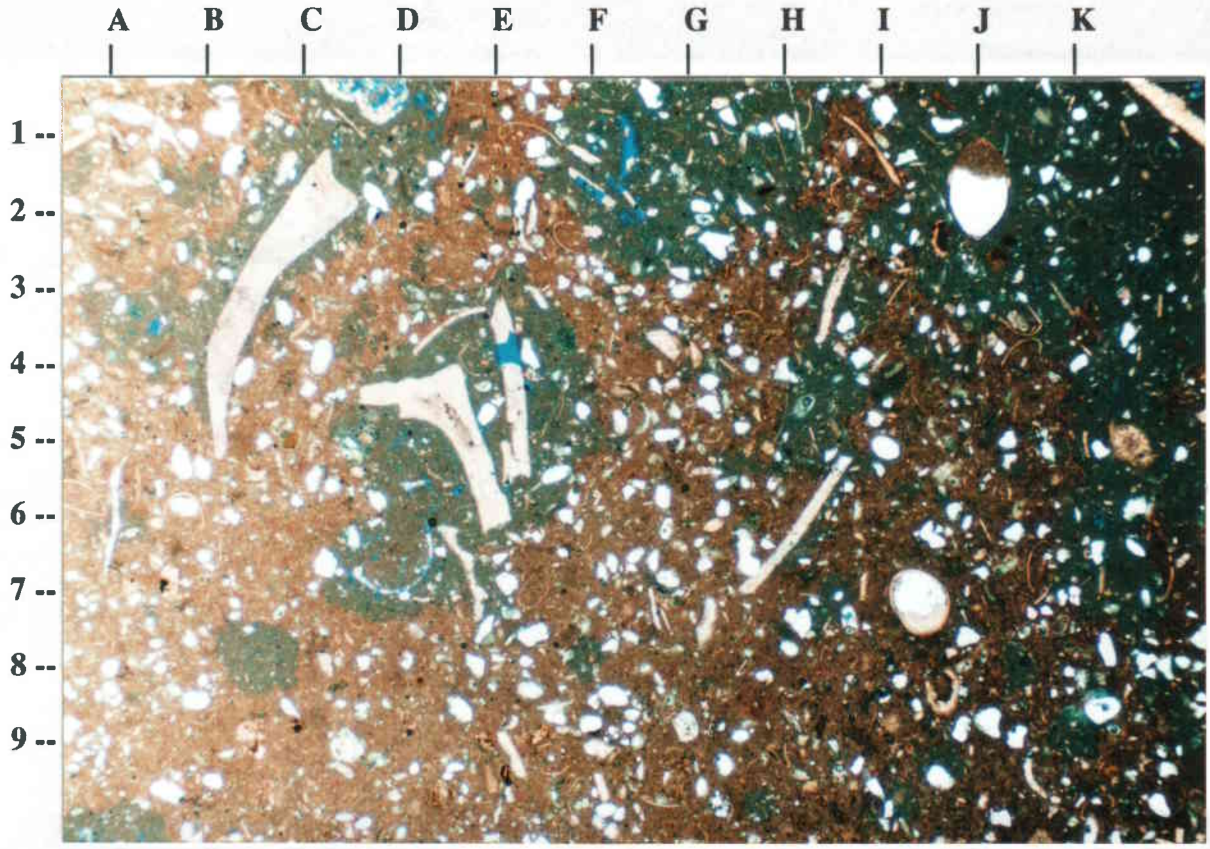
Very fine to medium sand-grade, monocrystalline quartz and leached feldspar grains.

Porosity

Poor, largely secondary porosity, after leaching out of bioclastic grains.



VR 47 Plate 17 (x2.5) Plane polars



VR 50 Plate 18 (x2.5) Plane polars

VR48 (Chicksgrove Quarry)
Tisbury Member, bed below Ragstone: Section 72
ST9630 2953

Sandy, bioclastic, micritic limestone

Matrix

Muddy micritic limestone, with abundant thin-walled bivalve fragments and occasional peloidal grains. Very fine to medium grained siliciclastic grains are moderately abundant.

Cement

Micrite

Siliciclastics

Very fine to medium sand-grade monocrystalline quartz grains.

Porosity

Moderate, largely secondary porosity, after leaching out of bioclastic grains.

VR49 (Chicksgrove Quarry)
Wockley Member, bed above Ragstone: Section 73
ST9693 2953

Peloidal, bioclastic limestone

Framework grains

Dominated by poorly sorted, medium to coarse grained, micritized peloidal and bioclastic grains, patchily cemented by non-ferroan spar, in a micritic matrix. Sparse very fine to fine siliciclastic grains also occur and glauconite is only rarely present and is usually partially replaced by spar.

Cement

Occasional non-ferroan spar patches.

Siliciclastics

Sparse very fine to fine sand-grade, monocrystalline quartz grains.

Porosity

Extensive, intra-granular microporosity porosity, poorly interconnected.

VR51 (Chicksgrove Quarry)
Tisbury Member, bed below Ragstone: - A: Section 73
ST9693 2953

Sandy, glauconitic, biosparite

Framework grains

Dominated by moderately well sorted, fine-grained, siliciclastic grains, abraded bioclastic and micritized peloidal grains, in a spar-carbonate cement. Some of the peloidal grains show a vaguely oolitic structure. Rounded glauconite grains are moderately abundant as are other much more irregular grains squeezed and fragmented by the crystallization of the spar cement.

Cement

Pervasive, sparry, non-ferroan to slightly ferroan calcite cement.

Siliciclastics

Dominated by abundant fine sand-grade, monocrystalline quartz with subordinate feldspar and polycrystalline grains. Occasionally cryptocrystalline silica partially replaces the walls of some bioclasts.

Porosity

Tightly cemented, with very minor secondary porosity, after bioclastic grain dissolution.

VR52 (Chicksgrove Quarry)
Tisbury Member, bed below Ragstone:- B: Section 73
ST9693 2953

Biosparite

Framework grains

Dominated by moderately well sorted, fine to medium grained, non-ferroan bivalve fragments, other bioclasts and occasional micritic peloidal grains in a spar-carbonate cement. Very fine to occasional coarse siliciclastic grains are present. Glauconite grains occur only sparsely.

Cement

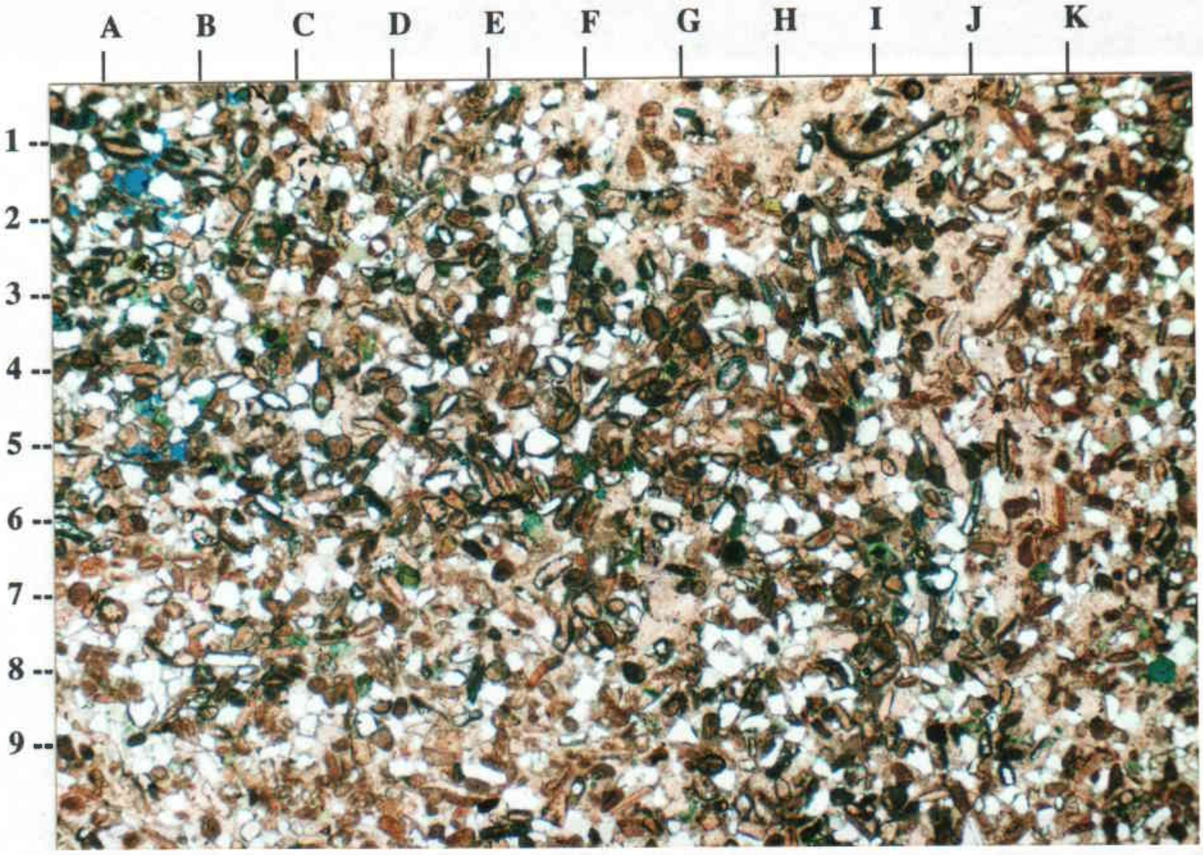
Pervasive sparry ferroan to non-ferroan calcite cement. Replacement of some bioclastic carbonate grains by cryptocrystalline silica has occurred in a single thin layer.

Siliciclastics

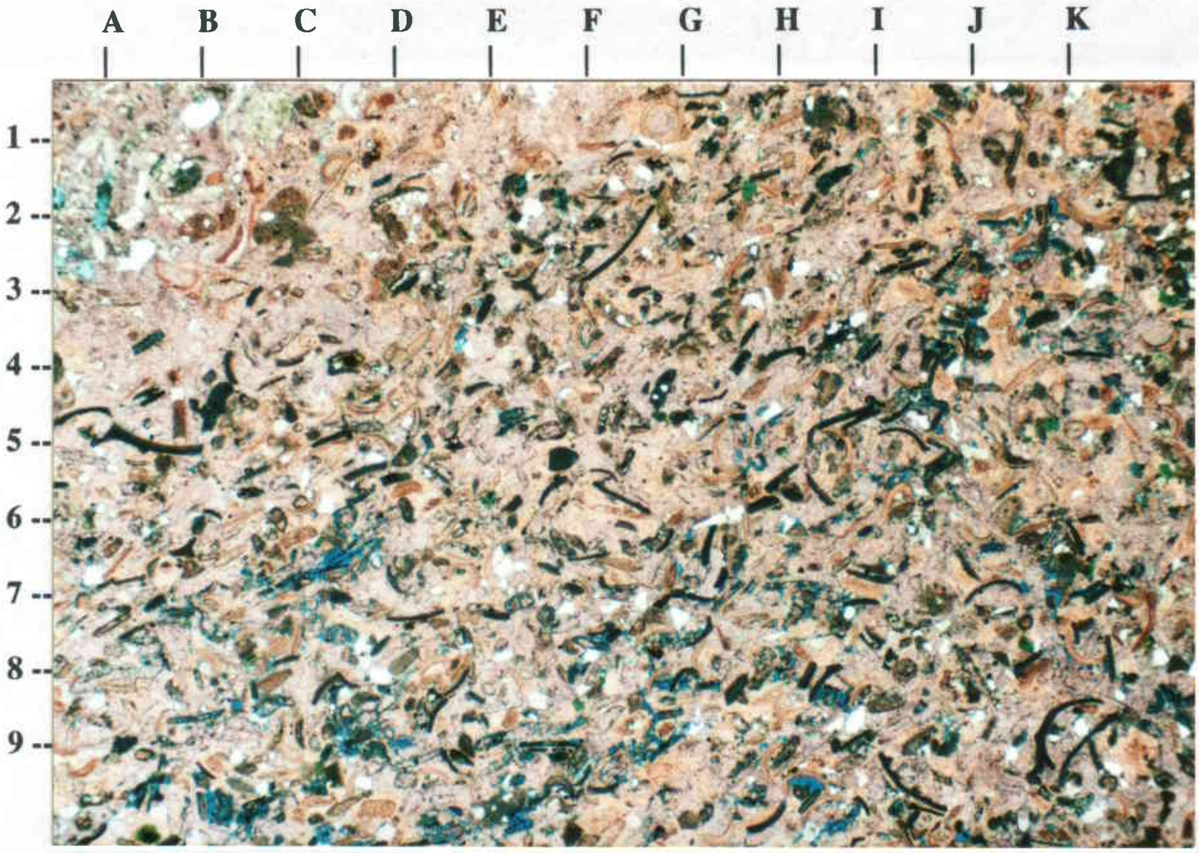
Abundant fine sand-grade, monocrystalline quartz, with subordinate feldspar grains.

Porosity

Poor. Tightly cemented with minor secondary porosity after bioclastic grain dissolution.



VR 51 Plate 19 (x2.5) plane polars



VR 52 Plate 20 (x2.5) Plane polars.

VR53 (Chicksgrove Quarry)
Tisbury Member: Bed A: Section 73
ST9693 2953

Porous, bioclastic, fine sandstone

Framework grains

Dominated by moderately sorted, fine-grained siliciclastic, abraded bioclastic and peloidal grains in a porous, micritic matrix. Some bioclasts may retain their original internal wall structure others are replaced by non-ferroan spar. Glauconite is abundant. Pyritized aggregates also commonly occur.

Cement

Poorly cemented. Some of the bioclastic grains have very narrow, fringing, needle-shaped, non-ferroan spar-calcite overgrowths.

Siliciclastics

Abundant fine sand-grade monocrystalline quartz, with subordinate feldspar grains.

Porosity

Moderate porosity, with pore systems partially disrupted by micritic matrix.

VR54 (Chicksgrove Quarry)
Tisbury Member: Bed B: Section 73
ST9693 2953

Laminated, sandy, bioclastic, limestone

Framework grains

Dominated by moderately sorted abraded bioclastic, peloidal and very fine to fine-grained siliciclastic grains, variably cemented or porous matrix. The bioclasts either retain their original internal wall structure or are replaced by non-ferroan spar. Glauconite is moderately abundant.

Cement

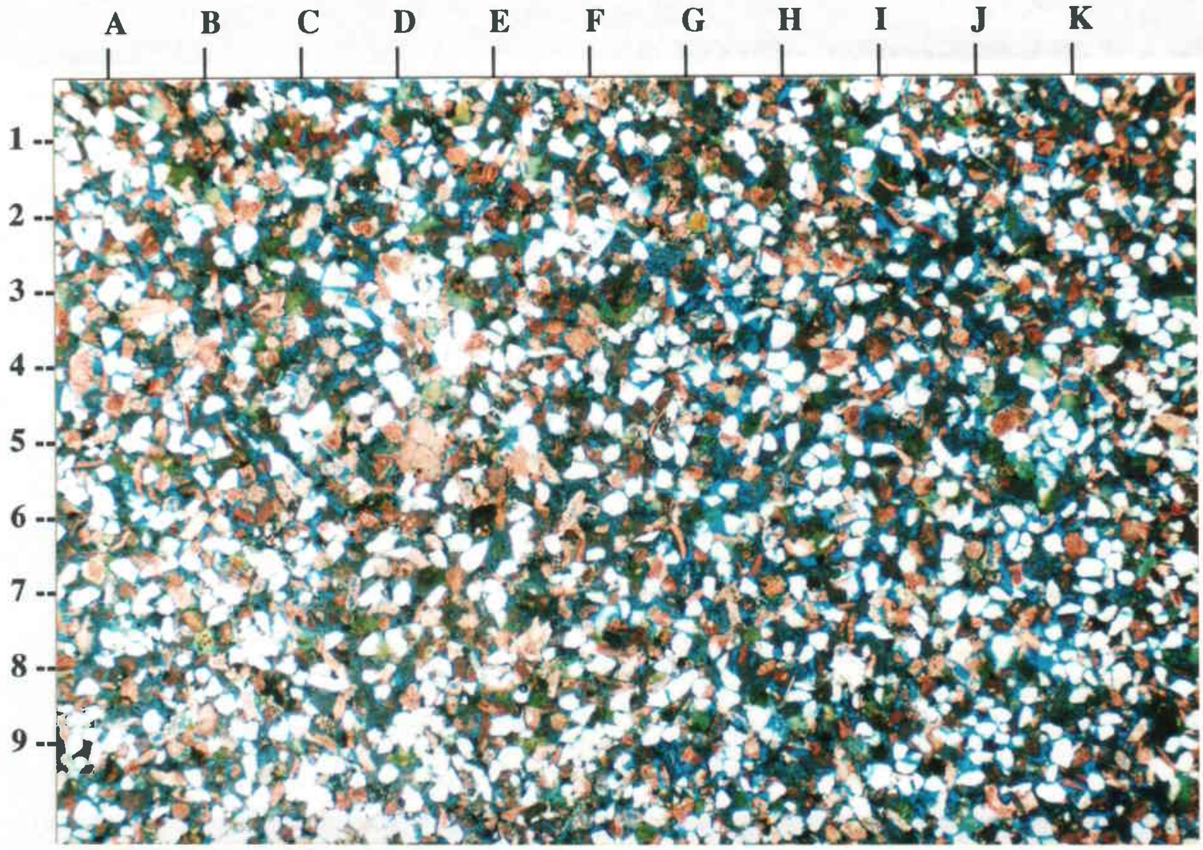
Many of the bioclastic grains have narrow fringing needle-shaped spar-calcite overgrowths which commonly coalesce to form more extensive sparry patches.

Siliciclastics

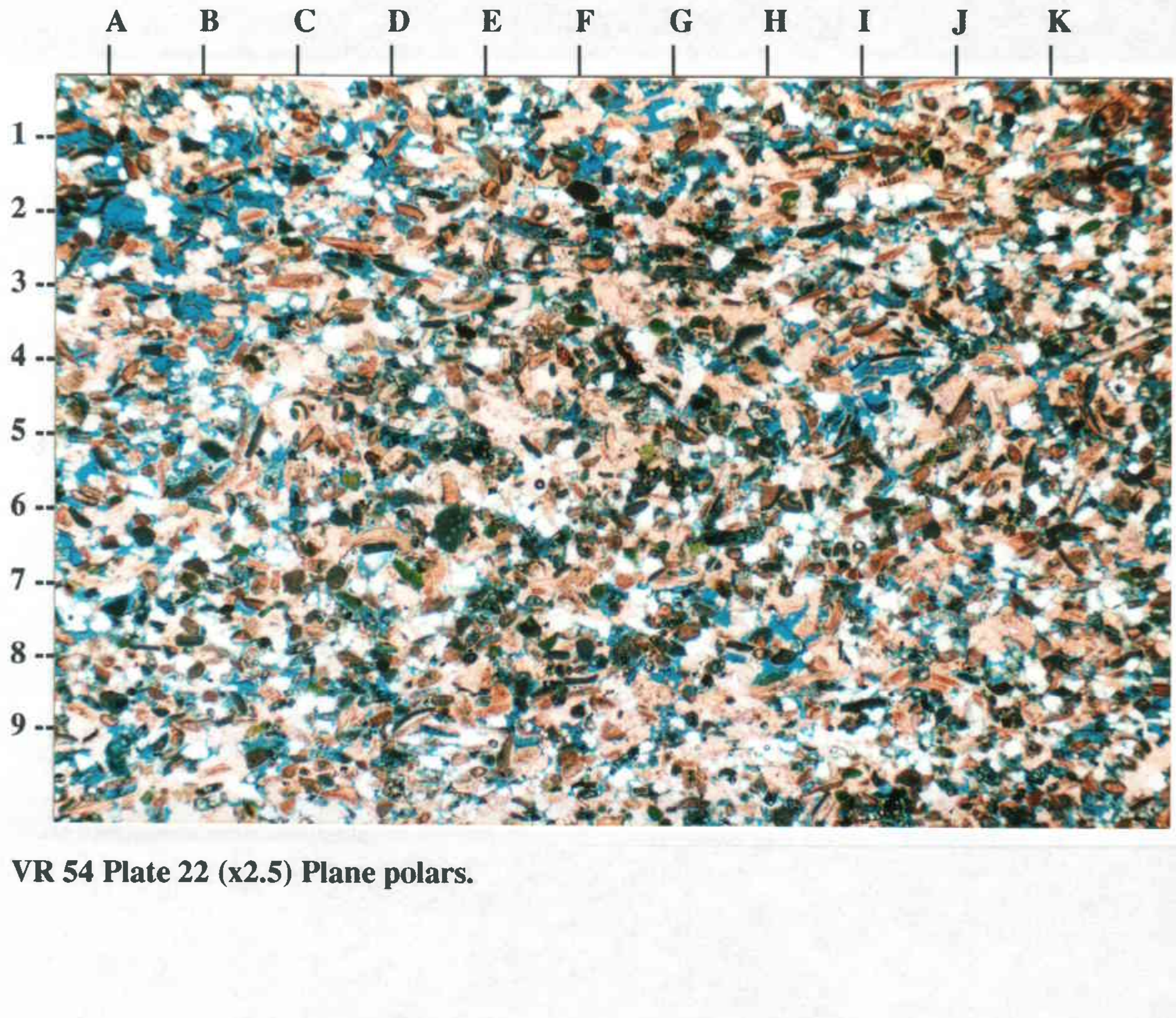
Abundant very fine to fine sand-grade monocrystalline quartz with subordinate feldspar grains.

Porosity

Moderate to good, varying within different laminae with pore systems partially disrupted by spar cement.



VR 53 Plate 21 (x2.5) plane polars



VR 54 Plate 22 (x2.5) Plane polars.

VR 55 (Chicksgrove Quarry)
Wockley Member, bed above Ragstone: Section 74
ST9639 2954

Porous, laminated micrite

Finely crystalline carbonate mud with a distinctive laminated structure with porous patches which may be of algal origin.

Siliciclastics

None

Porosity

Good

VR 56 (New Barn pit - south - Tisbury)
Tisbury Member: Section 75
ST9550 2924

Laminated, bioclastic, fine to coarse sandstone

Framework grains

Dominated by poorly sorted, fine to coarse grained siliciclastic, abraded bioclastic and peloidal grains, variably cemented or as porous laminae. The bioclasts either retain their original internal wall structure or are replaced by non-ferroan spar. Glauconite is moderately abundant.

Cement

Many of the bioclastic grains have narrow fringing needle-shaped spar-calcite overgrowths which commonly coalesce to form more extensive sparry patches.

Siliciclastics

Abundant very fine to occasionally coarse sand-grade, monocrystalline quartz, with subordinate feldspar grains.

Porosity

Moderate to good, varying within different laminae, with pore systems partially disrupted by spar cement.

VR 57 (New Barn Pit - south - Tisbury)
Tisbury Member: Section 75
ST9550 2924

Bioclastic, very fine sandstone

Framework grains

Dominated by well sorted, very fine-grained siliciclastic, abraded bioclastic and peloidal grains, variably cemented or porous framework. Some bioclasts retain their original internal wall structure others are replaced by non-ferroan spar. Some micritic matrix is present. Glauconite is moderately abundant and is commonly partially altered.

Cement

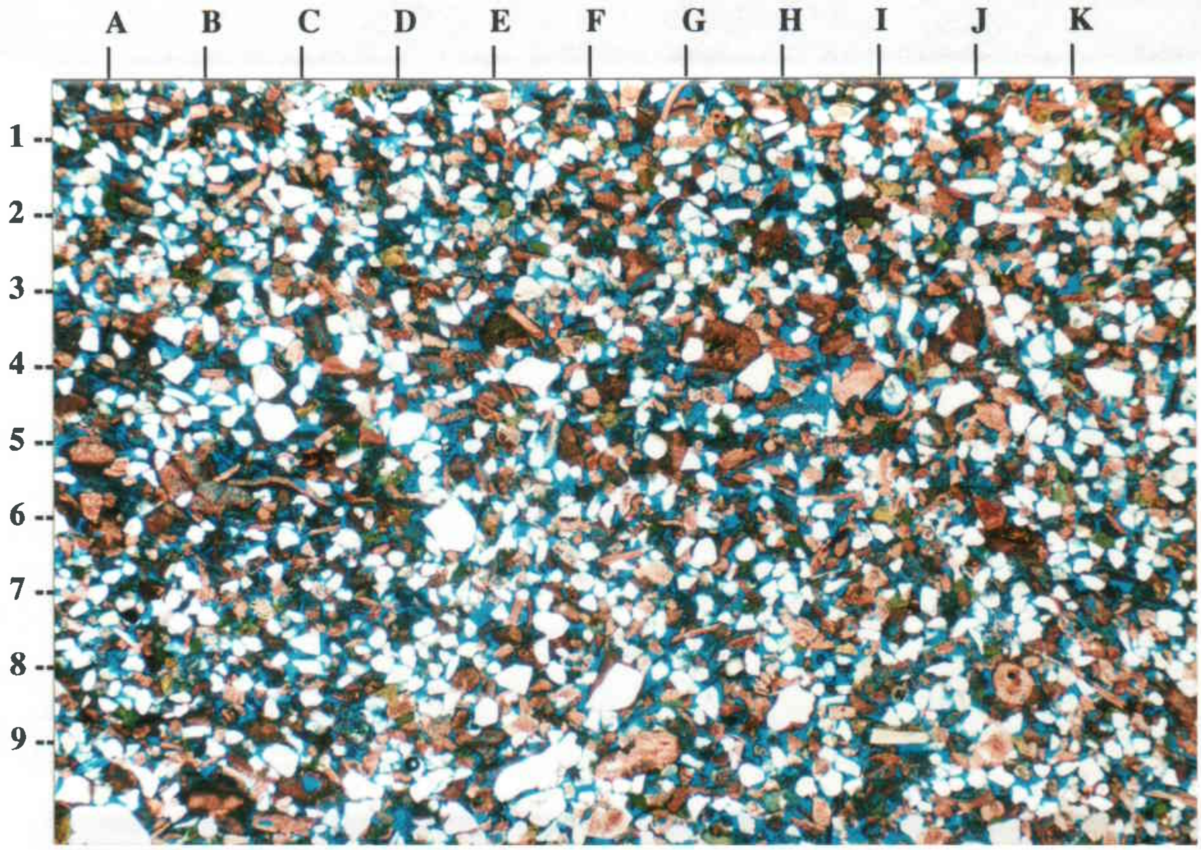
Many of the bioclastic grains have narrow fringing needle-shaped spar-calcite overgrowths.which commonly expand to form sparry patches.

Siliciclastics

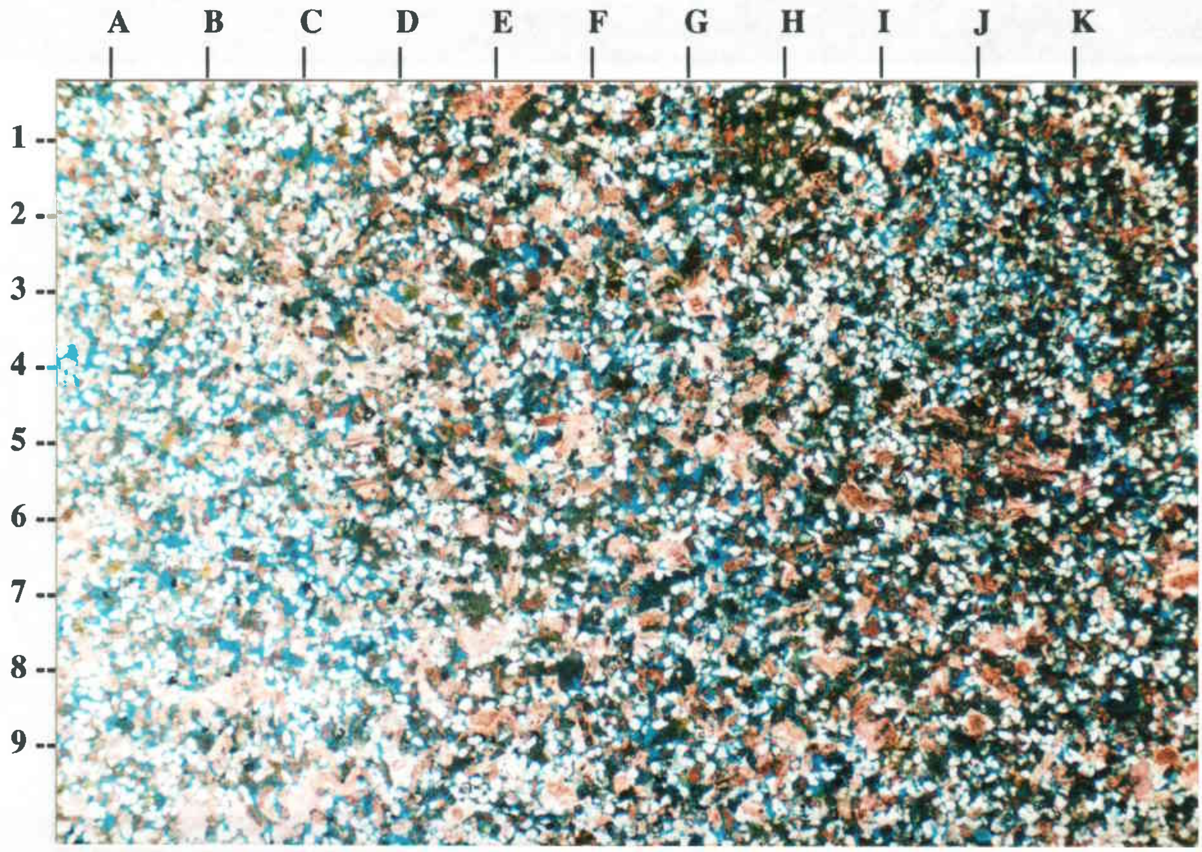
Abundant very fine sand-grade monocrystalline quartz, with subordinate feldspar grains.

Porosity

Moderate to good, however, the pore systems are disrupted by spar cement and patches of micritic matrix.



VR 56 Plate 23 (x2.5) Plane polars.



VR 57 Plate 24 (x2.5) Plane polars

VR58 (New Barn pit - north - Tisbury)
Tisbury Member: Section 76
ST9544 2951

Bioclastic, very fine sandstone

Framework grains

Dominated by well sorted, very fine, occasionally fine-grained siliciclastic, abraded bioclastic and peloidal grains cemented or porous matrix. The bioclasts either retain their original internal wall structure or are replaced by non-ferroan and ferroan spar. Some micritic matrix is present. Glauconite is moderately abundant.

Cement

Many of the bioclastic grains have narrow fringing needle-shaped spar-calcite overgrowths which have commonly expanded to form an extensive, mixed non-ferroan and ferroan spar cement.

Siliciclastics

Abundant very fine sand-grade, monocrystalline quartz, with subordinate feldspar grains.

Porosity

Moderate to good, however, the pore systems are disrupted by the extensive spar cement and patches of micritic matrix.

VR59 (New Barn pit - north - Tisbury)
Tisbury Member: Section 76
ST9544 2951

Bioclastic very fine sandstone

Framework grains

Dominated by well sorted, very fine-grained siliciclastic, abraded bioclastic and peloidal grains, in a variably cemented or porous matrix. Some bioclasts retain their original internal wall structure others are replaced by non-ferroan spar. Some micritic matrix is present. Glauconite is moderately abundant.

Cement

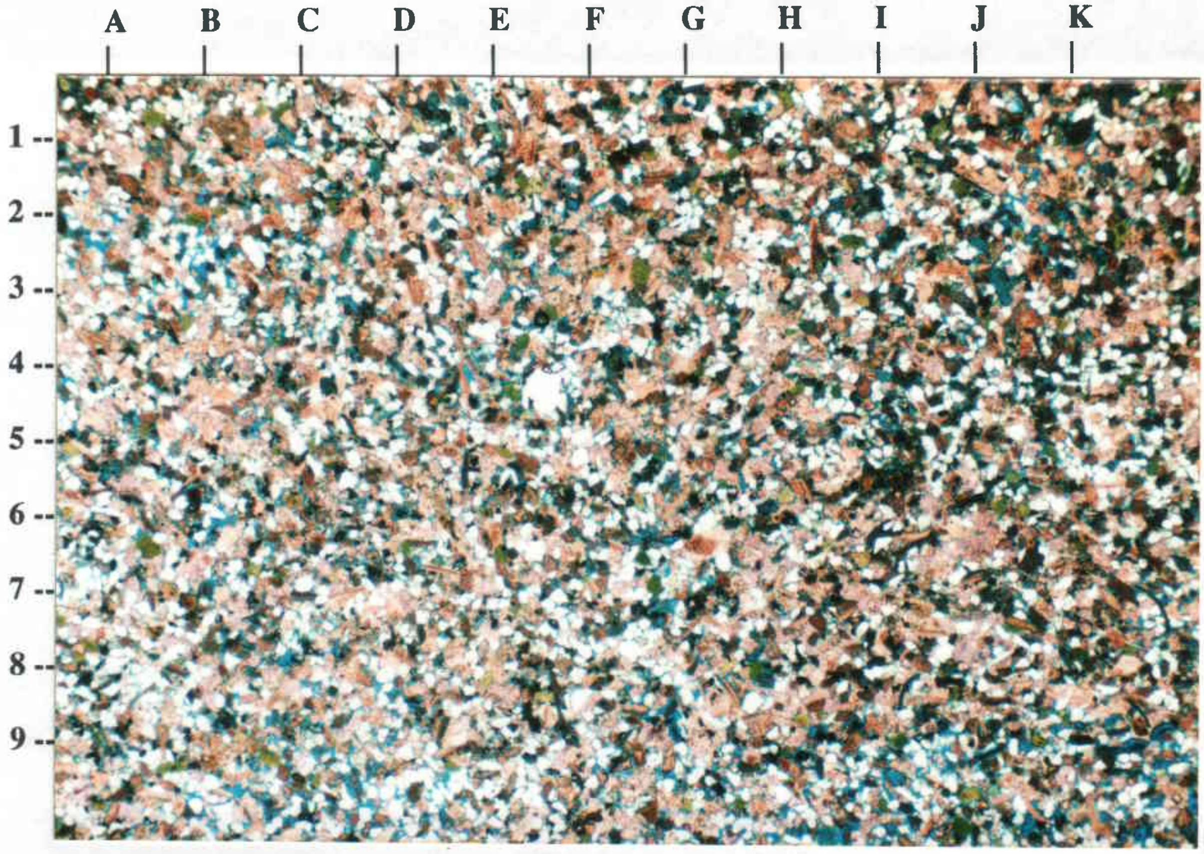
Many of the bioclastic grains have narrow, fringing, needle-shaped, spar-calcite overgrowths which may expand to form more extensive sparry patches.

Siliciclastics

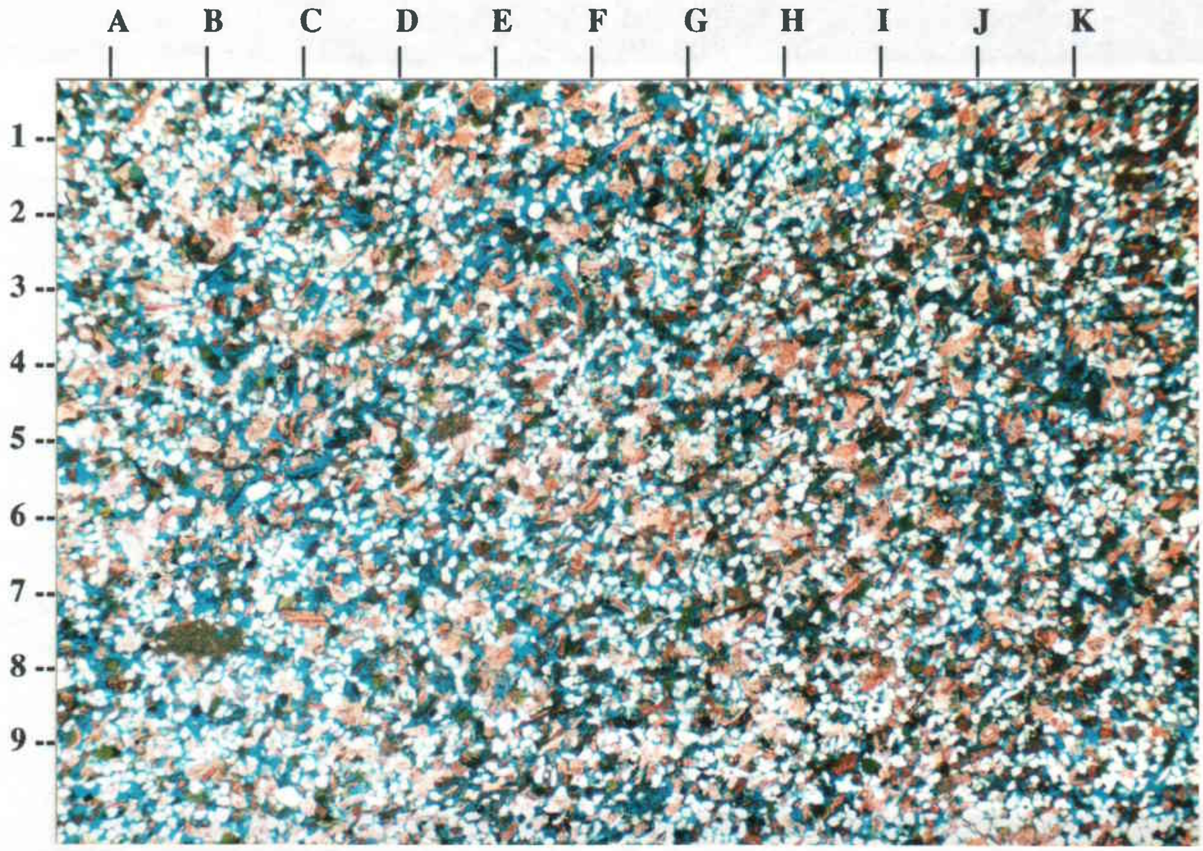
Abundant very fine sand-grade, monocrystalline quartz, with subordinate feldspar grains.

Porosity

Moderate to good, however, the pore system disrupted by spar cement and dispersed micritic matrix.



VR 58 Plate 25 (x2.5) Plane polars.



VR 59 Plate 26 (x2.5) Plane polars.

VR60 (Lower 'Teffont Evias' Quarry, Chilmark)
Wockly Member: Section 76
ST9768 3124

Biomicrite

Matrix

Well sorted, very fine-grained, abraded, spar-replaced ?bioclastic and peloidal grains in a micritic matrix. Most of the very coarse, bioclasts retain their original wall structure but some contain cryptocrystalline silica patches. Small calcispheres are common.

Cement

Micrite.

Siliciclastics

None

Porosity

Extensive microporosity and coarser secondary porosity after grain dissolution, but the latter is poorly interconnected

Location	Bioclasts	Quart/feld	Ooliths	Micrite	Peloid	Nfe spar	Fe spar	Glauconite	Pyrite	Porosity
VR29	11	18	0	3	15	21	9	3	0	20
VR30	20	23	0	7	4	19	0	5	0	22
VR31	10	28	0	8	4	23	0	1	1	25
VR32	0	0	0	0	72	16	0	0	0	12
VR33	nc									
VR34	0	2	32	27	21	2	0	0	0	16
VR35	1	3	25	6	37	2	0	0	0	26
VR36	12	26	0	2	13	35	0	5	0	7
VR37	15	24	0	4	6	19	1	5	2	24
VR38	20	14	0	7	6	26	0	3	1	23
VR39	15	17	0	4	5	29	2	6	0	22
VR40	12	26	0	4	15	11	0	3	0	29
VR41	10	25	0	0	5	27	2	3	0	25
VR42	2	21	0	2	5	21	19	3	0	27
VR43	3	38	0	3	1	0	20	0	0	35
VR44	0	3	2	0	72	9	1	1	1	11
VR45	23	2	0	40	25	9	0	1	0	0
VR46	7	5	0	33	15	19	0	2	0	19
VR47	10	6	1	8	39	29	2	0	0	4
VR48	4	16	0	58	6	3	0	0	0	13
Location	Bioclasts	Quart/feld	Ooliths	Micrite	Peloid	Nfe spar	Fe spar	Glauconite	Pyrite	Porosity
VR49	4	5	0	39	19	18	0	4	0	11
VR50	7	4	0	80	0	4	0	0	1	4
VR51	3	16	2	2	20	48	3	2	0	4
VR52	15	6	0	1	5	13	47	2	0	10
VR53	15	34	0	10	5	14	0	3	4	15
VR54	8	15	0	1	17	43	1	0	0	15
VR55	nc									
VR56	6	30	0	9	10	19	2	5	0	19
VR57	8	36	0	14	4	14	5	1	1	17
VR58	5	25	0	3	7	17	24	4	0	15
VR59	4	24	0	2	7	19	1	3	0	40
VR60	13	0	0	76	0	6	0	0	0	5
Location	Bioclasts	Quart/feld	Ooliths	Micrite	Peloid	Nfe spar	Fe spar	Glauconite	Pyrite	Porosity

Locality	Grid ref	Owner/Tenant	Telephone No
32	9532 3029	R M E Carter & Son, Place Farm, Tisbury (part of Fonthill Bishop Estate)	0747 870140
33	9633 2982	Rev. M A Shallcross, Walmead Farm, Tisbury	0747 870208
34	9635 2994	"	"
35	9524 2929 to 9527 2918	Mr G Fry, Totterdale Farm, Tisbury	0747 870292
36	9528 2908	"	"
37	9526 2898	"	"
38	9540 2852	"	"
39	9555 2870	?	
40	9550 2924	Mr G Barnes, Beckington	
41	956 295	"	
42	?9556 2964	British Rail	
43	9640 2957	?	
44	9648 2960	Rev. M A Shallcross, Walmead Farm, Tisbury	0747 870208
45–46	9630 2953 to 9596 2955	Mr R A Collins, Chicksgrove Quarry, Upper Chicksgrove, Tisbury	0747 871144
50–56	RAF Chilmark	MOD Wing Commander H G L Wooldridge	0722 716471
57	973 316	?	
58	9755 3137	MOD Wing Commander H G L Wooldridge	0722 716471
59–60	9741 3151 9743 3146	?Home Farm, Teffont Evias	
61–63	RAF Chilmark	MOD Wing Commander H G L Wooldridge	0722 716471
64	9781 3108	?Home Farm, Teffont Evias	

Appendix 2. List of landowners/tenants of quarries in the Tisbury—Chilmark area

BRITISH GEOLOGICAL SURVEY
(ENGLAND AND WALES)

1:10 000 Series

Part of SHEETS ST92NE (Swallowcliffe) and ST93SE (Chilmark)

SOLID AND DRIFT EDITION

Included in 1:50 000 Geological Sheet 298 (Salisbury)

Surveyed on the 1:10 560 scale by A.J. Jukes–Browne in 1890; resurveyed by C. Reid in 1900.
Surveyed on the 1:10 000 scale by C.R. Bristow in 1994.
I.R. Basham, Regional Geologist.
Published 1994.
Peter J. Cook, D.Sc., Director, British Geological Survey.

INDEX AND EXPLANATION

ARTIFICIAL DEPOSITS

Worked Ground

Made Ground

Worked Ground and Made Ground

DRIFT

QUATERNARY

Head

Alluvium — Organic, silty clay with a gravelly base

The Quaternary Deposits are not listed above in order of superposition

--------------- Geological boundary, Quaternary and Artificial Deopsits

FOR SOLID SEE GENERALIZED VERTICAL SECTION

Inclined strata, dip in degrees

Generalized dip of inclined strata

Fault, crossmark on downthrow side, throw in metres

Geological boundary, Solid

Swallow hole

Water well or borehole

Only selected boreholes are shown.
Numbers are those of the BGS record system in which they are preceded by ST92NE or ST93SE.

Pit shaft, abandoned

Adit or mine mouth, with orientation showing direction of entry

Adit or mine mouth abandoned; with orientation showing direction entry

Adit or mine mouth abandoned; orientation unknown

Broken lines denote inferred boundaries

Depths and thicknesses are given in metres

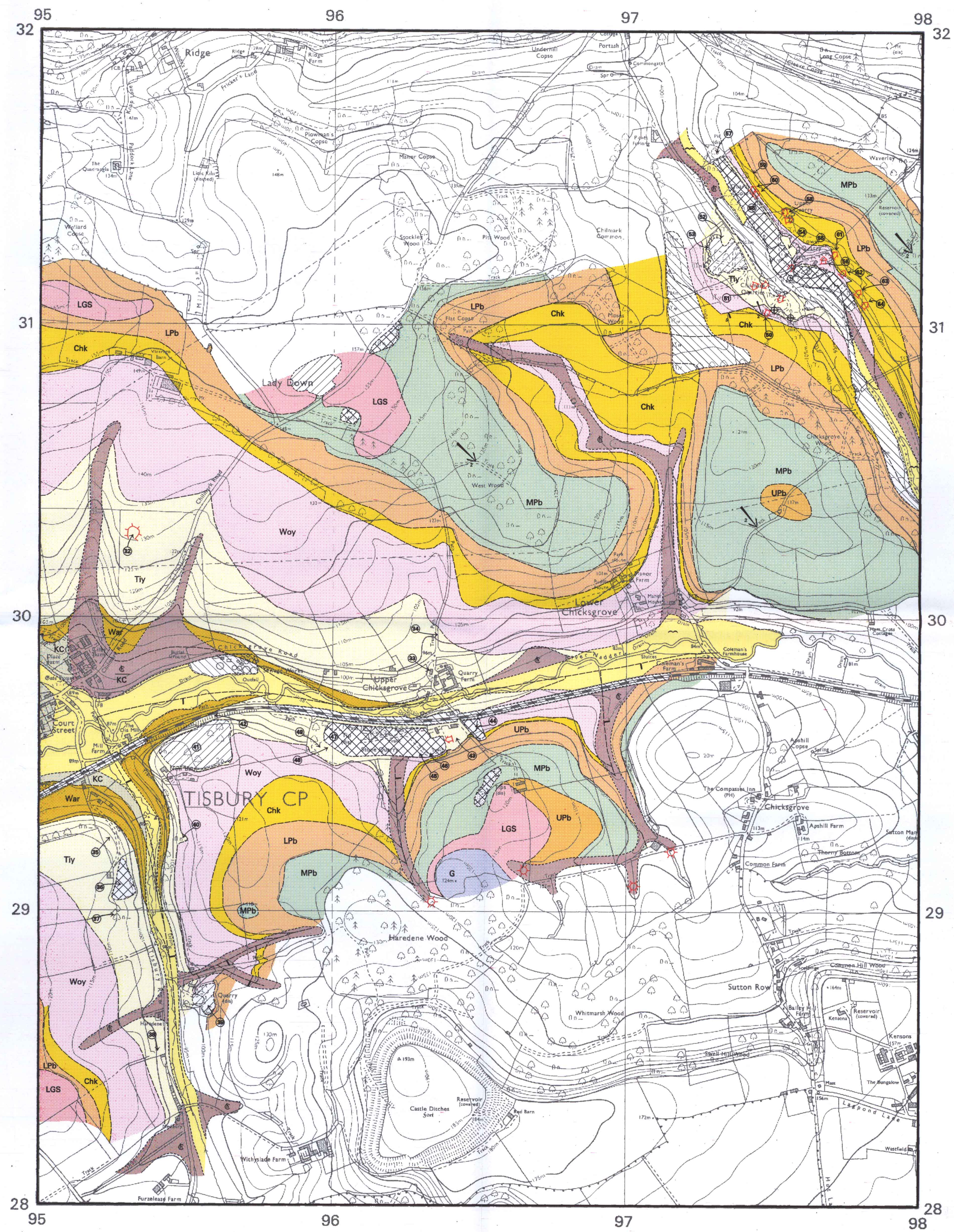
Abbreviations:
cm.....centimetre
m.......metre

(32) Numbers of localities referred to in text

This map gives an interpretation available at the time of survey.
Additional information is available in BGS files in the Exeter Office.

ORDNANCE SURVEY OF GREAT BRITAIN

The 1:10 000 topographical base was derived from large–scale surveys dated 1982–83.
The representation on this map of a road, track or path is no evidence of the existence of a right of way.
Heights are in metres. Contours are surveyed at 5 metres vertical interval.
Made by the Ordnance Survey, Southampton.



Digitally produced by M.A. Bradley, BGS, Keyworth.

GENERALIZED VERTICAL SECTION
Scale 1:1000 (1cm to 10m)