Appendix 6

Geology of Freestones in southern England and northern France

South-Central England

Lower Jurassic Freestones

Ham Hill stone (Figure A6.1)

Age: Upper Lias (Toarcian) (178-174 million years; Cope *et. al.,* 1980a)
Location: Hamdon Hill, Somerset GR (ST 478 173) (Explorer 129, BGS Map 312)

Ham Hill stone was chosen as the representative freestone of the Lower Jurassic for a number of reasons. First, the rock has a striking yellow-brown mottled appearance (Leary, 1989) which when coupled with its limited geographical extent permitted easy and rapid geological characterisation. Second, the freestone had been identified in hand specimen as the construction material for eight Roman sarcophagi at Dorchester (Farwell & Molleson, 1993), ashlar from London. (Bradley & Butler 2008[1]) and earlier architectural stonework from Colchester, (Hull, 1955). Finally the 120 metre high Hamdon Hill (Fowler & Branigan, 1976) had evidence for early Roman military occupation and was close to both the Fosse Way (1 km) and Ilchester (6 km).

The rock is thickest (27 metres) in the southern part of Hamdon Hill at Deep Quarry (GR ST 481 164) with cross bedded units of upper "Yellow Beds" lying above poorer quality "Grey Beds". The limestone is dominated by banded bioclastic debris deposited as a shell bank in a tidal channel (Davies, 1969). An overall porosity of 17.5% (Leary, 1989) for the Yellow Bed and regularly spaced jointing allow the freestone to be easily worked and extracted. Representative quarry samples from (GR ST 478 172) and (GR ST 481 161) were supplemented by sub-samples obtained from the Watson (Accessions 345) and BRE Schaffer Collection (E322).

Middle Jurassic Freestones (Inferior Oolite)

Freestones from the Inferior Oolite Formation (Aalenian to Bajocian) straddle most of the Middle Jurassic outcrop. Regional variability, however, necessitated its subdivision into two distinct regions (Cotswolds and Lincolnshire) each characterised by a thick succession of sediment (Figures A6.11 and A6.12).

Cotswolds

Leckhampton stone, Painswick stone, Guiting stone (Figure A6.2)

Age : Aalenian (174-171 million years: Cope *et. al.*, 1980a)
Locations: Leckhampton Hill, Devils Chimney Quarry (GR SO 949 183)
Painswick Hill (GR SO 867 121) (Explorer 179 BGS Map 234)
Guiting Quarries (GR SP 867 121) (Explorer 45 BGS Map 217)

These rocks form a prominent scarp feature that extends along the North Cotswolds between Stroud and Chipping Camden for a distance of 45 km. This part of the outcrop though was not traversed by the Fosse Way which only ran parallel with it, 15 km to the south-east. Ermin Street, however, cut through this exposure at Birdlip (GR SO 925 195).

[1] K.Hayward pers. obs.

A decision to sample from this outcrop was, in part, determined by the thickness of high quality freestone found here (25 metres at Leckhampton) (Barron *et. al.*, 1997). These totals were not exceeded anywhere else along the Middle Jurassic outcrop.

A second reason was the proximity of the Leckhampton outcrop and Painswick outlier (10 km) to the early Roman legionary bases at Kingsholm and Gloucester. Previous assumptions had linked the outcrop at Painswick to first century legionary defences at Gloucester (Bryant, 1983; Hurst *et. al.,* 1986). Evidence for Roman quarrying activity at Painswick Hill Fort, however, was lacking (Parry, 2002). Only petrological characterisation could confirm this.

The lithological character of the Lower Freestone remains constant along the length of this escarpment. Nailsworth, Painswick, Leckhampton and Campden stones could all be identified in hand specimen as a fine white oolitic grainstone, without appreciable bioclastic content. This homogeneity, coupled with the rocks relatively high porosity (20.9% BRE sample E983 Painswick), provided properties conducive to fine carving (Watson, 1912).

Samples of Lower Freestone were obtained at outcrop (Ager *et. al.,* 1973; Mudge, 1978; Baker, 1981; Barron *et. al.*, 1997) from disused quarry sections at Painswick Hill (GR SO 868 116) and Leckhampton Hill (GR SO 946 176). Supplementing these were museum samples of Painswick and Leckhampton stone from the Watson Collection (Accessions 350; 355)**.**

Guiting stone, which had been attributed to the Flavian columns at Fishbourne (Cunliffe, 1971) and the Forum-Basilica at Silchester (Wooders, 2000) needed to be sampled too (Watson Collection Accession 353). The Yellow Guiting stone was identifiable in thin-section and hand specimen by a predominance of skeletal material and the iron mineral goethite (Leary, 1989).

Dundry and Doulting stone

Age: Bajocian (171-165 million years; Cope *et. al.*, 1980a)
Location: Dundry Hill (GR ST 552 666) (Explorer 155; BGS Map 264)
Doulting (GR ST 645 435) (Explorer 142; BGS Maps 280, 296)

Dundry and Doulting stones are confined to small outcrops 20 and 30 miles (32-48 km) south of the main Cotswolds exposure (see Figure 2.8). Their inclusion into this study was based upon outcrop proximity to early Roman activity. Doulting stone outcrops close to the Fosse Way near the Roman roadside settlement of Shepton Mallet (Leach, 2003). Whilst, possible Roman quarries (Stanier, 2000) from the Dundry Hill outlier (Kellaway & Welch, 1993) warranted further investigation.

Both lithologies have a characteristic open shelly texture, dominated by echinoids with Doulting stone containing extraclasts derived from older Carboniferous material (Leary, 1989). All samples were obtained from the Watson Collection (Accessions 347; 348; 348a).

Lincolnshire

Age: Bajocian (171-165 million years; Cope et al. 1980a)

The Lincolnshire Limestone Formation forms a large and geologically complex outcrop extending between Kettering and the Humber Estuary as a narrow ridge (Sylvester-Bradley & Ford, 1968). The main freestone belt between Corby and Lincoln is over 50 miles (90 km) long traversed in part by Ermine Street. In section, the formation consists of a wedge-shaped deposit that can be up to 40 metres thick (Berridge *et. al.,* 1999).

Defining the geological source for monumental architecture carved from Lincolnshire Limestone has been difficult to prove (Blagg, 1990). Individual freestone units change rapidly in character (Ashton, 1980) or may be cut-out through intra-Jurassic erosion (Berridge *et. al.,* 1999). Only recent stratigraphic revision of the formation (Ashton, 1980; Berridge *et. al.,* 1999) has begun to locate the position and range of these freestones (Figure A6.12). In order to overcome some of these difficulties a decision was made to sample the major freestone units region by region (Lincoln, Ancaster, Stamford, and Corby) irrespective of their stratigraphic position.

Lincoln District

"Base Bed" (Greetwell Member) (Figure A6.3)
Lincoln Silver Bed (Leadenham Member)

Location: Greetwell Hollow Quarry (TF 003721) (Explorer 272; BGS Map 114)

Middle Jurassic freestone at Lincoln is represented by the narrow (0.9 metre) but distinctive Lincoln Silver Bed (Ashton, 1980). The decision to sample this layer together with the poorer quality "Base Bed" from Greetwell Hollow Quarry (TF 003721) was influenced by the quantity of first century stonework present at Roman Lincoln. The suggestion that the stonework may have come from Greetwell rather than Ancaster (Whitwell, 1971; Jones, 2002), however, requires petrological confirmation.

At Greetwell, the Silver Bed occurs as a distinctive light grey wackestone containing Nerineid gastropods throughout. An example from outcrop was supplemented by a sample (Accession 374a) from the Watson Collection. The underlying "Basal Bed" (Greetwell Member) (Ashton, 1980) consists of a two metre thick unit of ferruginous oolitic grainstone.

Ancaster District

Ancaster freestones (Clipsham Member) (Figure A6.4*)*
Clipsham stone (Clipsham Member)

Locations :Blockstone Quarry (SK 992410) (Explorer 247; BGS map 127)
: Medwells Quarry (SK 988160) (Explorer 248; BGS map 143)

The Lincolnshire Limestone Formation at Ancaster is represented by a thick sequence (7.5 metres) of freestone (Ancaster freestone, Ancaster hard-white, Ancaster weatherbed) from Blockstone Quarry (SK 992410) (Berridge *et. al.,* 1999). The decision to sample the Ancaster freestone was in part based upon its identification from a Roman milestone at Lincoln (Sedgley, 1975) and at London (Hassall & Tomlin, 1982; Hayward forthcoming.). The locality of the modern quarries close to Ermine Street and the early fort site at Ancaster (Whitwell, 1971) reinforces its choice for this study (Figure A6.4)..

The Ancaster freestone is a light brown, fine oolitic grainstone with an overall porosity of 19.2% (Leary, 1989) that permits easy carving. In contrast, the shellier weatherbed and finer grained hard white with overall porosities of 9.9% and 14.1% (Leary, 1989) are less suited to ornamental carving. Samples were obtained from Blockstone Quarry and added to from the Sedgwick (Accessions 370-371) and Tolley (E11663) collections.

Lincolnshire Limestone at Clipsham (30 km further south) was also sampled (Tolley Collection E6945). This fine shelly grainstone may have also been used as a Roman construction material (Whitwell, 1971).

Stamford District (Figure A6.5) (Explorer 234; BGS Map 157)

Ketton freestones (Sleaford Member) (Figure A6.5)
Barnack stone (Clipsham Member) *(*Figure A6.5*)*

Locations : Ketton Grange Top Quarry (SK 982 067) & Quarry Farm (TF 011 083)
Hills & Holes Geological SSSI (TF 076 053)

Ketton stone has been selected for this study for a number of reasons. First, it was easy to identify in hand specimen as the rock had a characteristic open oolitic texture (overall porosity 23.5%), bound together by tiny quantities of cement (see plate 2) (Leary, 1989). Second, is its limited geographical distribution, immediately to the north (TF 011083) and west (SK 982067) of Stamford as a series of small outcrops. Third, some of these outcrops are associated with early

Roman settlement. Ermine Street cuts through the outcrop at Great Casterton (TF 001090), where a first century Roman fort (Todd, 1968) was constructed.

Examples of Ketton freestone were obtained from outcrop (SK 982067; SK 978055) as well as the Watson (368) and Tolley (Econ 1998) Collections. Some harder, less frequent, lithotypes (Ketton rag and Stamford marble) associated with the Ketton stone were also examined and sampled at Casterton (TF 011 083) (Sharp, 1870; Judd, 1875; Ireson, 1986). These distinctive freestones have a much lower overall porosity of 7.7-11.6% (sample E217 BRE) but carve and polish easily.

The decision to sample Barnack stone was based upon its petrological identification at Roman London reused in the Riverside Wall (Dimes, 1980; Hayward forthcoming) and in Roman milestones throughout eastern England (Sedgley, 1975). The outcrop (TF 076 053) also lies close to Ermine Street (0.8 km) (Stanier, 2000). Samples of this shelly oolitic grainstone were obtained from the Hills & Holes SSSI (TF 076 053).

Corby District

Weldon stone (Clipsham Member)

Locations: Corby Landfill Site, Weldon (SP 920875) (Explorer 224; BGS Map 171)

The southernmost limit of the Lincolnshire Limestone Formation is represented by a condensed sequence of sediments (12 metres) (Sutherland, 2003) with a two metre horizon of Weldon stone (Taylor *et. al.*, 1963). It therefore lies closer to *Verulamium* (97 km) and *Londonium* (145 km) than the other Lincolnshire Limestones. The decision to sample this material was also based upon its petrological identification in the Roman riverside wall (Dimes, 1980; Hayward forthcoming).

The unit shares a characteristic open oolitic texture (27.4% porosity) (Leary, 1989) with Ketton stone. Weldon stone differed in that it had bands of oyster debris. These characteristics were identified in columns from *Verulamium* (pers. obs.) previously identified as Ketton stone (Williams, 1971a). Samples were obtained and examined in outcrop (SP 920875) and from the Watson (Accession 361) Collection.

Middle Jurassic freestones (Great Oolite)

Age: Bathonian (164-156 million years; Cope *et. al.,* 1980a)

The main freestone units of the succeeding Great Oolite Formation (Bathonian) concentrate along a 70 km stretch between Bath and Burford (Wyatt, 1996) forming part of the Cotswold escarpment**.** South of Bath, the Bathonian oolites are replaced by the mudstone dominated Fullers Earth Formation (Green, 1992). Northward from Oxfordshire and into Northamptonshire, freestones are poorly represented (Blisworth Limestone), the sediments becoming clays and shales.

Mention needs to be made of some of the softer limestone units from the succeeding White Limestone and Forest Marble Formation that are also suitable for fine carving.

Bathonian freestones are found along the southern and eastern fringes of the Cotswold escarpment relative to their Bajocian counterparts. The south-easterly dip of this escarpment means that successive sediments lie progressively to the south and east of it. This part of the escarpment therefore lies closer to the main centres of population in southeast *Britannia*. Roman sites were also located on this outcrop with towns (e.g. Bath and Cirencester) connected by a large section of the Fosse Way.

A complex regional stratigraphy (Wyatt, 1996; Wyatt & Cave, 2002) necessitates a region by region (South and Central-North Cotswolds) analysis of the principal freestone types (Figure A6.13).

South Cotswolds District (Figure A6.6)

Combe Down oolite, Box groundstone (Combe Down Oolite Member)
Monks Park oolite, Box corngrit. (Bath Oolite Member)

Locations : Tynings Quarry, Box (ST 836693). Bathampton Down (ST 777652)
Monks Park Quarry (ST 878683) (Explorer 155; 156, BGS Map 265)

The "Bath-stone" outcrop covers an area of approximately 16 km by 16-23 km (Green & Donovan, 1969) around Bath truncated into a series of sinuous outcrops and outliers by the River Avon. Recent lithostratigraphic subdivision (Wyatt & Cave, 2002) has placed it within the Upper Bathonian (Chalfield Oolite Formation).

It has been included into this study for a number of reasons. First the term had been widely used to describe the geological source for many early examples of Roman monumental masonry at important centres south-east England (Williams, 1971a; Boon, 1974; Phillips, 1975; Cunliffe & Davenport, 1985). Second, the Fosse Way cuts through the outcrop near Combe Down, where evidence for procuratorial Roman quarrying activity may be provided (RIB 179).

Describing all "Bath-stone" however as an easily worked cream coloured freestone over generalises its variable lithological character. Within the 30 metre thick Chalfield Oolite Formation at Bath (Wyatt & Cave, 2002) two major freestone units may be identified. The lower Combe Down Oolite Member forms a coarse grained shelly oolitic grainstone with a higher porosity of 25-27% (Leary, 1989). The upper Bath Oolite Member however is a finer grained oolitic grainstone with a lower porosity of 19-25%. Although this subdivision does not account for further localised variability within the formation, it was sufficient enough for a regional study of British freestone.

Representative samples from the Combe Down Oolite Member were obtained from outcrop at Box (ST 836693) and the Watson (Accession 383) and Tolley Collections (Econ 7036). Examples of the Bath Oolite Member were also obtained from Box (ST 836693) and Monks Park (ST 878683) together with material from the Watson (Accession 384) and Tolley Collections (Econ 7987).

Central-North Cotswolds District (Figure A6.7)

Athelstan oolite (Athelstan Oolite Formation)
Minchinhampton stone (Minchinhampton Beds)
Taynton stone (Taynton Limestone Formation)

Locations : Veizeys Quarry, Tetbury (SO 881 943) Minchinhampton Common,
Minchinhampton (SO 857015) (Explorer 168, BGS Map 251)
Lees Quarry, Taynton (SP 236152) (Explorer 45; BGS Map 236)

The freestones from the Great Oolite Formation of the Middle-North Cotswolds District (Tetbury to Burford) differ lithologically from those further south. Revision of the Bathonian succession (Wyatt, 1996; Wyatt & Cave, 2002) also places these freestones (Athelstan oolite, Minchinhampton and Taynton stones) stratigraphically below the "Bath-stones" (see Figure A6.13).

These freestones had all been identified in hand specimen from Roman monumental masonry at Colchester (Taynton stone), Gloucester (Minchinhampton stone) and London (Cotswold Dale stone or Athelstan Oolite) (Hull, 1955; Hurst *et. al.,* 1986; Grasby & Tomlin, 2002).

Taynton stone (Middle Bathonian) has been described as a coarse grained oolitic and shell fragmental grainstone with extensive cross bedding (Sumbler *et. al.,* 2000). At Taynton, close to a tributary of the Thames, the River Windrush, the character of the freestone varies, prompting extensive sampling at outcrop (SP 236152), from the Tolley Collection (Econ 9855) and examination of the BRE thin-section collection.

Minchinhampton freestone is a slightly younger (Wyatt, 1996) and shellier grainstone with a limited geographic distribution, located 10 km south of Gloucester close to a tributary of the Severn, the River Frome. A sample from the Watson collection (Accession 352c) was obtained for further analysis.

Athelstan oolite (Upper Bathonian) (Wyatt, 1996) lies 20km to the north of Bath close to the Fosse Way. It is represented by 2m of massively bedded very fine grained oolitic packstone at Tetbury Railway Cuttings (SP 894932). Samples were obtained from here and Veizeys Quarry (SP 881943).

Upper Jurassic Freestones (Corallian)

Age: Oxfordian (149-143 million years; Cope *et. al.,* 1980a)

Headington freestone (Wheatley Limestone Member)

Location: Lye Hill Quarry SSSI (SP 592068) (Explorer Sheet 180; BGS Sheet 237)

Headington freestone from the upper Jurassic (Middle Oxfordian) of East Oxfordshire was selected for this study for a number of reasons. It represented the closest provincial resource of calcareous freestone to *Londinium* (60 km). This lay approximately 15 km to the south-east of the Middle Jurassic freestone belt and was only 6 km away from the River Thames. Second, the freestone consisted of a distinctive white shell fragmental grainstone (Horton *et. al.,* 1995) with a limited geographical range (7 km²) making it an ideal lithology with which to conduct a provenance study. Finally, evidence for early Roman activity was found close to the exposure. A road truncates the outcrop and connects the first century forts of Dorchester and Alchester (Henig, 2000).

Despite these advantages, Headington stone does not form a reliable freestone material and has so far no been identified from Roman stonework. It blisters easily (Arkell, 1947) after prolonged exposure and its friability relates to a high overall porosity (BRE E5236; 34.7%).

Examples of Headington freestone and Headington hard (Accession 386) could only be obtained from building stone collections as all the early workings had been infilled. The Wheatley freestone was obtained from outcrop at Lye Hill SSSI (SP 592068).

Upper Jurassic Freestones (Portland and Purbeck)

Age : Portlandian (138-135 million years; Cope *et. al.*, 1980a)

Pond freestone (Portland Freestone Member)
Portland whit bed (Portland Freestone Member)
Chilmark stone (Wockley Micritic Member*)*

Locations: St Aldheims Head Quarry (SY 965763) (Explorer 15, BGS Map 343)
Tout Quarry (SY 685726) (Explorer 15, BGS Map 341)
Tisbury Quarry (ST 976 313) (Explorer 118 BGS Map 313)

Upper Jurassic freestone outcrops from the Portlandian Stage are found at three localities in Wiltshire and Dorset. The outcrops from the Isle of Portland and Purbeck represent the only examples of Jurassic freestone exposed along the coastline of the British Isles to have been worked commercially. Another outcrop is found inland at the Vale of Wardour (Arkell, 1933). Examples of Portland freestone were selected for a number of reasons. First, the freestone consists of a fine grained and durable material that could be quarried into large blocks (Leary, 1989).

Second, the economic advantages bestowed on it by its maritime locality would have allowed these freestones to be easily distributed throughout southern *Britannia.* Other stone types along the Dorset coast were exploited and transported around the province including Kimmeridge shale (Woodward *et. al.*, 1987; Allen & Fulford, 2004) and

Purbeck marble (Dunning, 1949; Beavis, 1970; Woodward *et. al.,* 1987; Williams 2002; Allen et. al. 2006; Pearson 2006). Carved examples of Portland stone (Boon 1973; Farwell *et al.,* 1993) Roman Britain are however rare.
could easily be identified in hand specimen.

All of the freestones from the Isle of Portland (base, whit and roach Beds) when weathered become white (Leary, 1989). The ooids within the Base and Whit Bed are also much smaller than any other freestone from the Jurassic belt. The roach bed could also be recognised with its hollowed casts of *Trigonia.* The freestones from all three outcrops also had a hard but highly porous texture of up to 23.1% (Leary, 1989) that gave the material a distinctive ring when hammered.

Examples of Portland freestone from the finer base and whit Beds (Accessions 391; 388) and the Chilmark stone (Accession 393) from the Vale of Wardour were obtained from the Watson Collection. Pond Freestone from the Isle of Purbeck was sampled at outcrop (SY 965763).

Continental Freestone – Northern France

The need to sample from the large Mesozoic and Tertiary freestone outcrop of Northern France was based, in part, upon its relative proximity to south-east *Britannia*. This was particularly true for the coastal Boulonnais exposures which are much closer (40-48 km) to Kent than native outcrops from Lincolnshire and the Cotswolds (209 km).

How this large outcrop could be sampled was more problematic. The overall size of the entire Middle Jurassic outcrop for Northern France extended for 540 miles (870 km) around the Paris Basin in two main outcrops. In addition, exposures of Upper Cretaceous and Tertiary freestone, to the North of Paris, extend the outcrop size still further (see Figure 1.6).

Narrowing down the sampling to just five main freestone types, based upon their identification in the archaeological literature (Cunliffe, 1971; Bedon, 1984; Stribrny, 1987; Worssam & Tatton-Brown, 1990; Holmes & Harbottle, 2003), was seen as the most effective strategy (see Appendix A2; A3.2).[2]

Calcaires à Polypiers (Figure A6.8)

Age : Bajocian (171-165 million years; Allemmoz *et. al.,* 1989)

Location : Norroy-lès-Pont-à-Mousson, Département Meurthe-et-Moselle
Quarry Feuille XXXIII-14 3-4, R 6 1'/H 48 56'
(Serie Bleue 3314E; Carte Géologique 193)

Middle Bajocian outcrops of Calcaires à Polypiers (Arkell, 1956; Allemmoz *et. al.,* 1989) or Lothringer freestone (Stribrny, 1987) are within the former Roman province of *Gallia Belgica* of North-East France. These pale coral rich grainstones cap an escarpment along the west bank of the River Moselle south of Metz (Gignoux, 1955).

The decision to sample this particular freestone was based upon the fact that there was clear epigraphic evidence that the main outcrop at Norroy (Dworkowska, 1983) had been extracted by legionary detachments of the Roman army from the Rhineland frontier. Altars dedicated to Hercules Saxanus by *Legio XX1 Rapax* from Mainz, *Legio X Gemina* and *VIII Augusta* from Cologne (CIL X111 4623-4625) confirmed this. A provenance study of first century tombstones and architectural fragments at Mainz (Stribrny, 1987) confirmed that it was being used extensively during the first century.

It was possible to take representative samples of Calcaires à Polypiers from the uppermost four metres of an infilled working near Norroy-lès-Pont-à-Mousson and 5km further south on the Massif de Puvenelle (R 6 1' H 48 52').

[2] Other freestones sampled included Euville, Yonne and Savonnieres stone (Appendix A3.2).

Caen stone (Figure A6.9)

Age: Bathonian (164-156 million years; Cope *et. al.,* 1980a)
Location : Caen, Département Calvados Quarry – La Maladrerie R 0 24' H 49 11'
(Serie Bleue 1612OT; Carte Geologique 120)

Lower Bathonian outcrops of Calcaire de Caen (Arkell, 1956) locate 10km inland from the Normandy coast around the town of Caen and along the L'Orne valley. Thick units (10m) (Gignoux, 1955) of this formation consist of a fine cream coloured packstone without any definable skeletal material in hand specimen. Its high overall porosity of 24.7-27.1% (BRE sample E188) and homogeneous texture made it a common medieval construction material throughout England (Tatton-Brown, 1990; Gilchrist, 1998; Holmes & Harbottle, 2003).

The selection of Caen stone for this study was based upon its possible use as a construction material in early Roman monumental architecture from Fishbourne (Cunliffe, 1971) and Colchester (Drury, 1984).

Petrological analysis of a sample obtained from the Watson Collection (Accession 871) was used to confirm whether the freestone was Caen stone or not. Defining the precise source of an individual quarry (Holmes & Harbottle, 2003) was not an objective of this study.

Marquise oolite (Figure A6.10)

Age : Bathonian (164-156 million years; Cope *et. al.,* 1980a)
Location : Marquise, Département Pas-de-Calais
Quarry: la Queue de Gibet XXI-3 R 1 43' N 56 47'
(Serie Bleue 1612OTE; Carte Geologique 120)

The outcrop of Middle Bathonian freestone at Marquise consists of a localised (10 km) and isolated exposure just 7 km from the north-east coast of France. At Leulingham Bernes it outcrops as a seven metre thick unit of pale grey grainstone characterised by millet size (0.2-0.5 mm) ooids and pseudooids (Bonte *et. al.,* 1958; Delattre *et. al.,* 1973; Worssam & Tatton-Brown, 1990). Its proximity to the English coastline (40-48 km) enabled it to be used as a construction material at medieval Canterbury (Tatton-Brown, 1990).

The decision to sample this freestone was not just based upon its proximity to the coastline of south-east *Britannia*. The naval headquarters for the *Classis Britannicus* were located at nearby Boulogne *(Gesoriacum).* Significantly, three naval funerary inscriptions at Boulogne Museum that confirm this link (Belot, 1990) are constructed from Marquise Oolite. This material has also been identified in hand specimen from the early naval bases at Richborough and Dover (Bushe-Fox, 1926; Strong, 1968; Worssam & Tatton-Brown, 1990).

Geological examples from the oolitic and oncolitic varieties of this freestone were obtained from outcrop at la Queue de Gibet and from the Tolley collection (Econ 16023).

Calcaire Grossier

Age: Middle Eocene (Lutetian) (Curry *et. al.,* 1978)
Location : St Leu, Dèpartement Oise Montanier Quarry, GR R 2 25' N 49 12'
(Serie Bleue 2312ET; Carte Geologique 127)

Samples of Tertiary freestone from within the Paris Basin were taken in order to confirm whether Roman monumental architecture from Fishbourne and Richborough were constructed from this material (Worssam & Tatton-Brown, 1990).

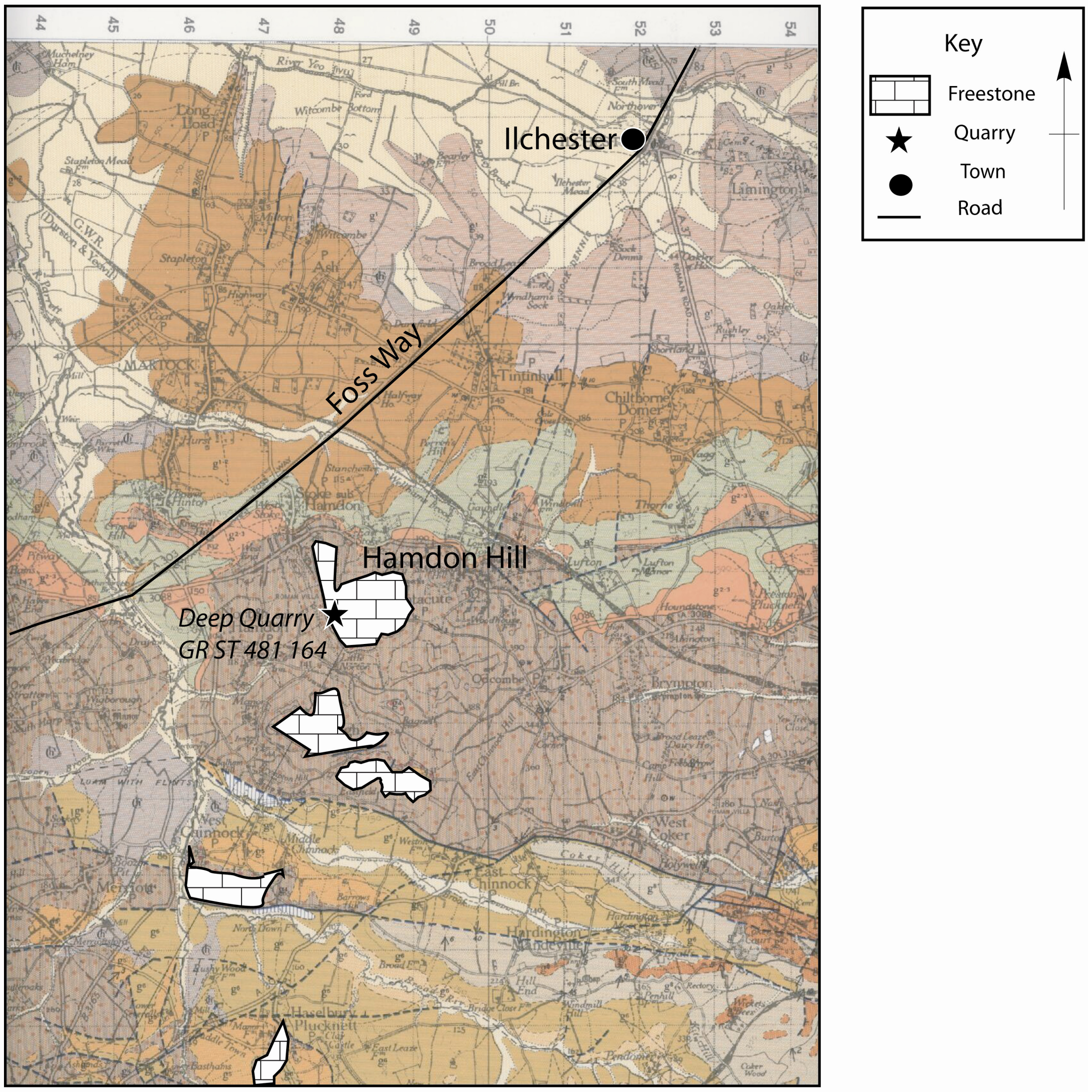
The middle Eocene (Lutetian) Calcaire Grossier formation (Curry *et. al.,* 1978) from St Maximin to the north-west of Paris was selected for further analysis. Here, the exposure attained its maximum thickness (40 metres) and lay alongside the navigable River Oise, a tributary of the Seine. It would have been possible to transport freestone from here directly to centres in south-east *Britannia* via the Seine Estuary and the English Channel

The main freestone unit Banc de St Leu (*Ditrupa* Limestone) forms a distinctive layer characterised by the cross-sections of calcareous worm tubes that can be identified in hand specimen (Worssam & Tatton-Brown, 1990). It has a very high overall porosity, up to 41.2%, (Honeyborne, 1982) that allows it to be easily carved but leaves the rock prone to weathering. A sample of Banc de St Leu from the Montanier Quarry (Econ 10882) was obtained from the Tolley Collection.

Dolomitic chalk

Age: Upper Cretaceous (Upper Turonian) (89-87 million years; Rawson, 1978)
Location: Rouen, Dèpartement Seine-Maritime.Caumont no.2 Quarry.
(Serie Bleue 1710ET; Carte Geologique 99)

Archived samples of hard dolomitic chalk (E10869 Tolley Collection) from the Lower Seine Valley (Rouen-Ètretat) were also analysed as its later use in southern England is confirmed in building material from the Tower of London.



0 5km

Figure A6.1 Geological Map of Yeovil District showing sample location of Ham Hill outcrop (Toarcian) Lower Jurassic

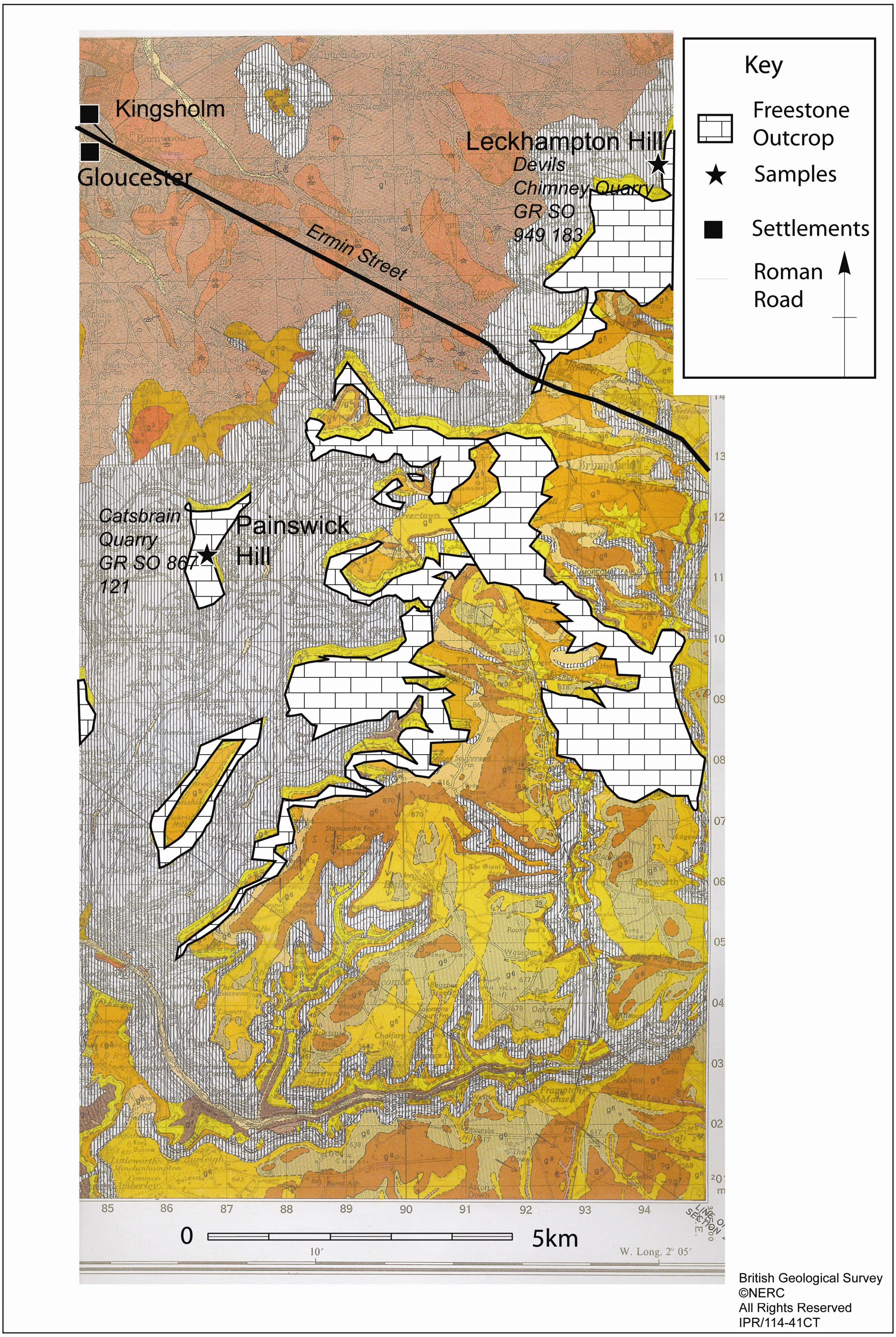


Figure A6.2 Geological Map of Gloucester showing sample locations for Leckhampton and Painswick stone (Bajocian) Middle Jurassic

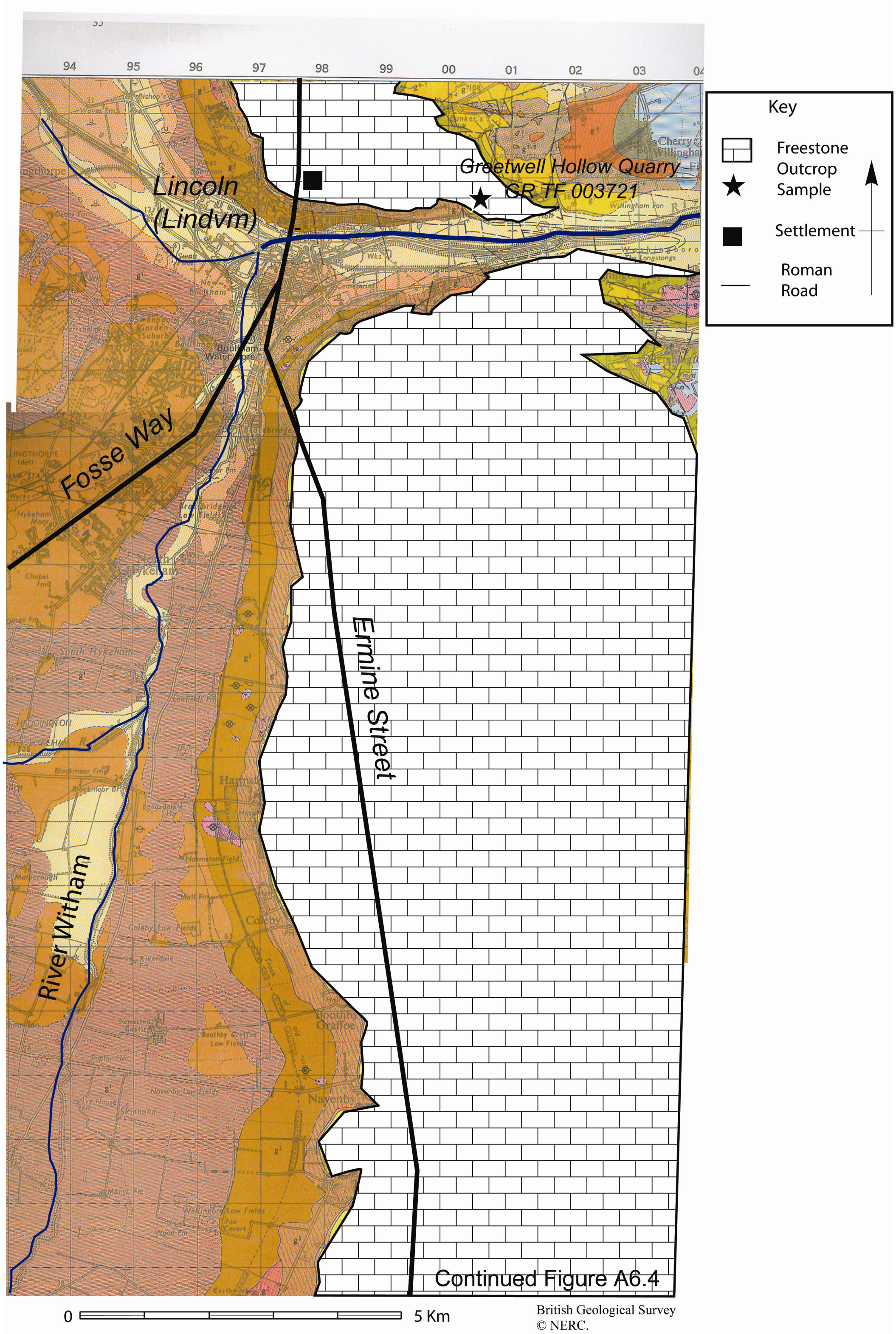


Figure A6.3 Geological Map of Lincoln showing sample location of Basal Beds and Lincoln Silver Bed- Lower LIncolnshire Limestone (Bajocian)

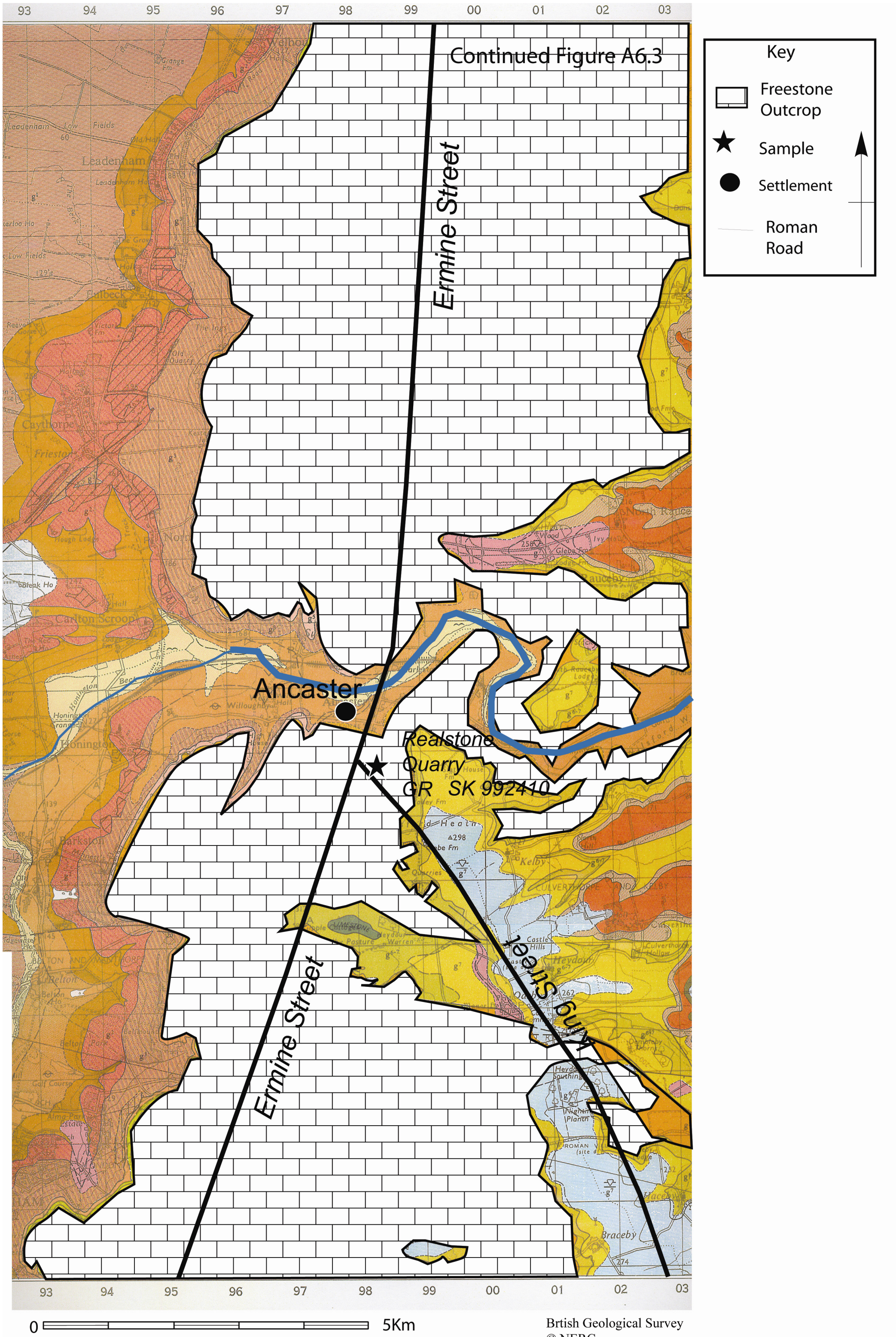


Figure A6.4 Geological Map of Grantham showing sample location for Ancaster Freestone Lincolnshire Limestone (Bajocian)

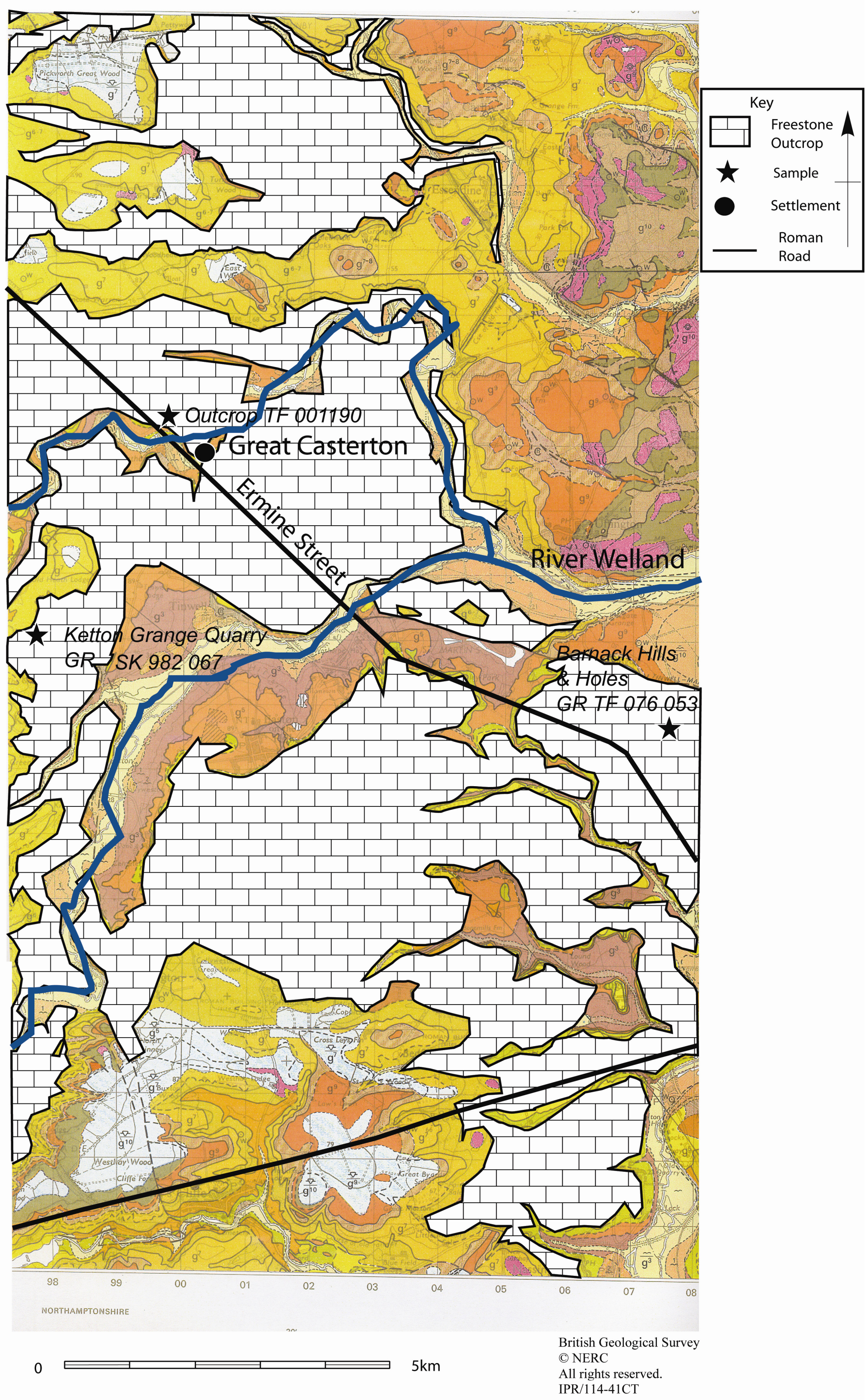


Figure A6.5 Geological Map of Stamford showing sample locations for Ketton stone, Stamford marble and Barnack stone (Lincolnshire Limestone) Bajocian

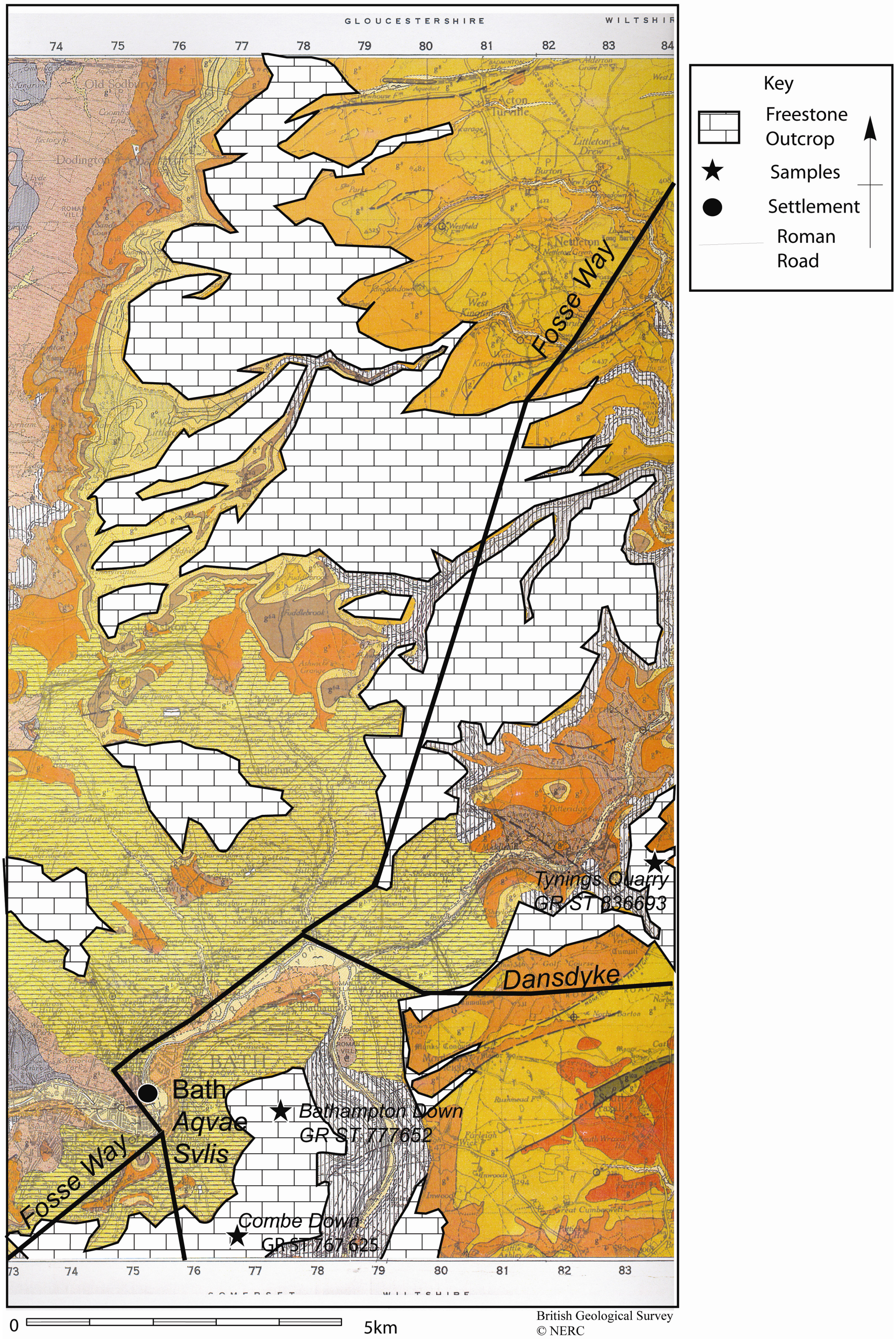


Figure A6.6 Geological Map of Bath showing the sample location of the Bath freestones (Bathonian) Middle Jurassic

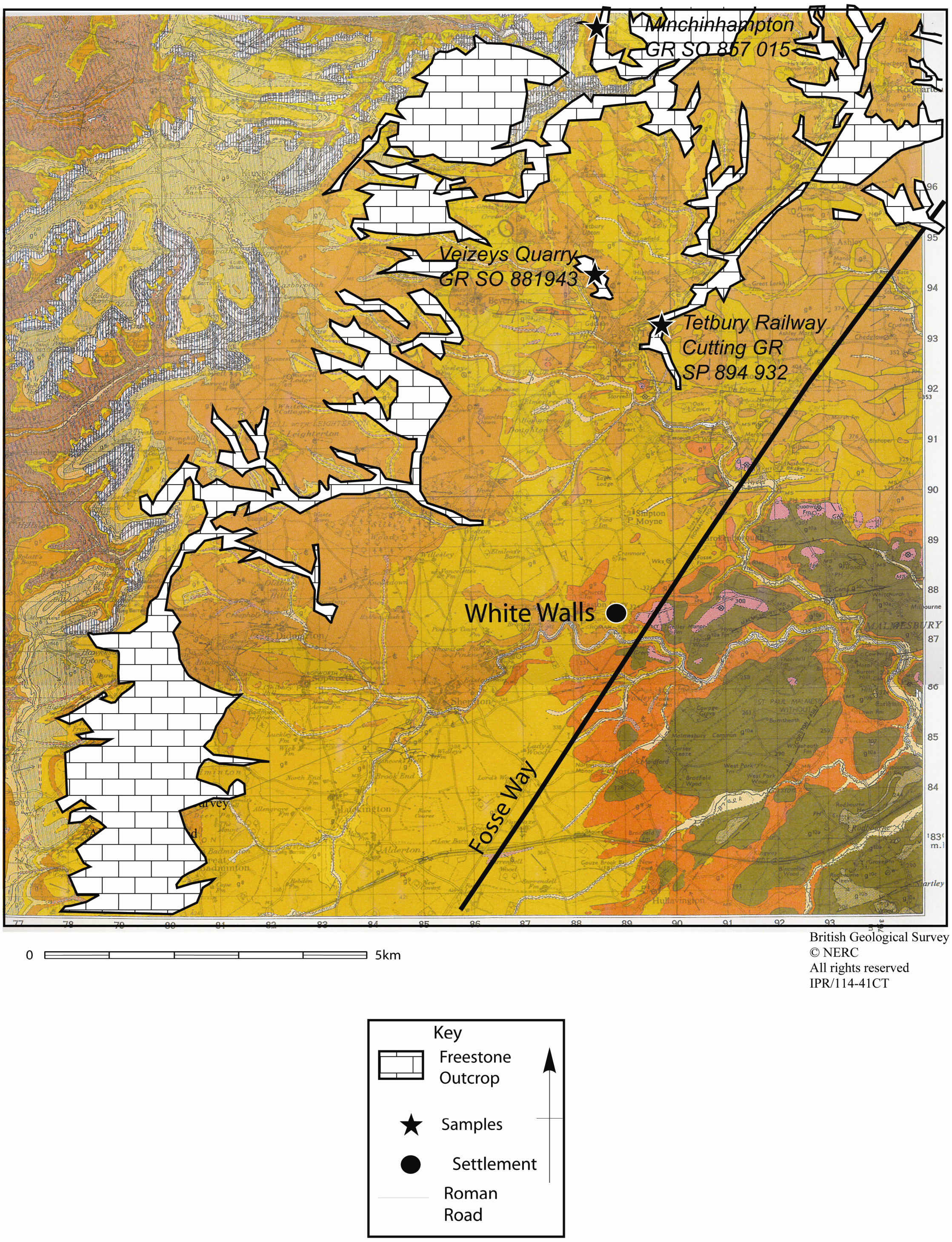
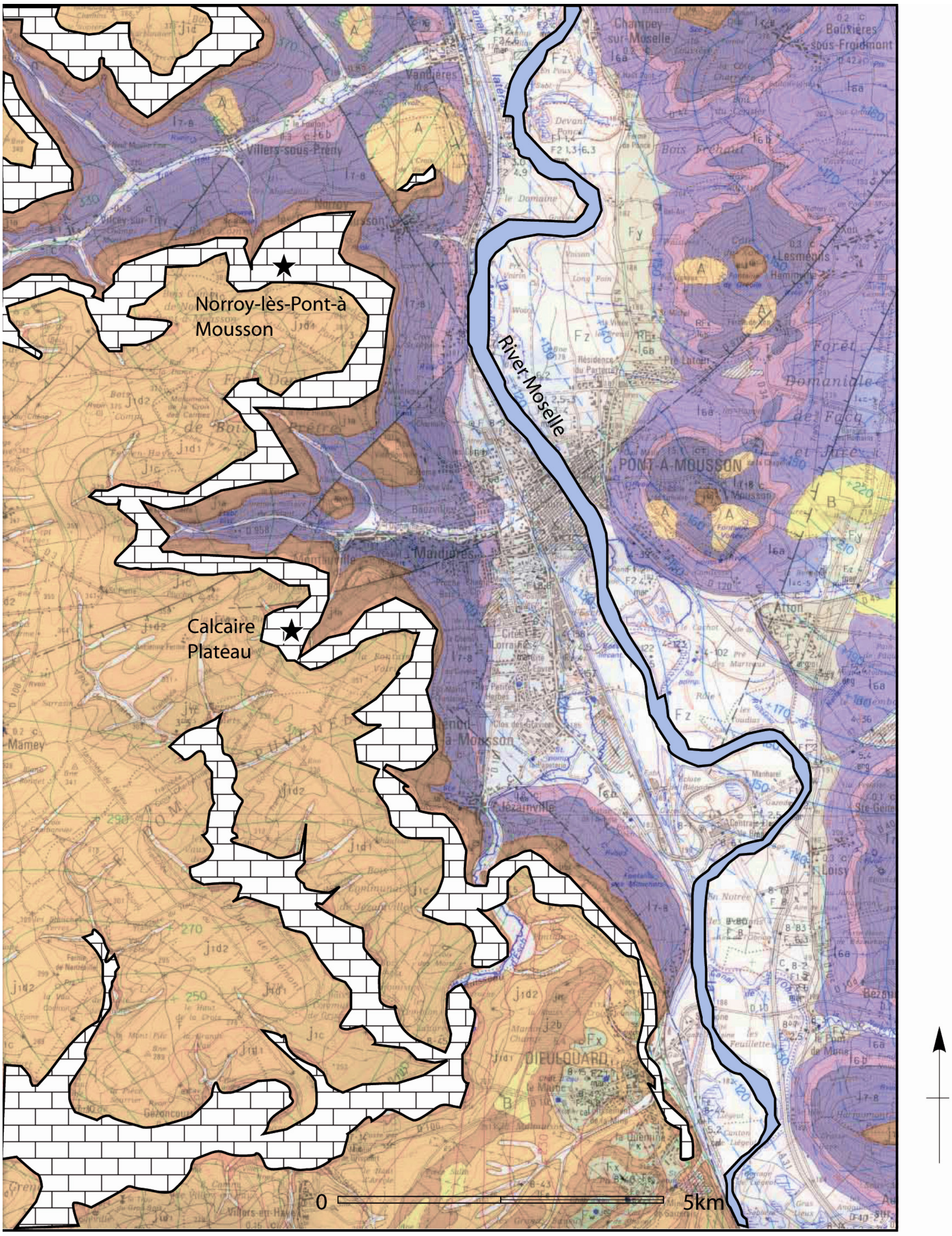
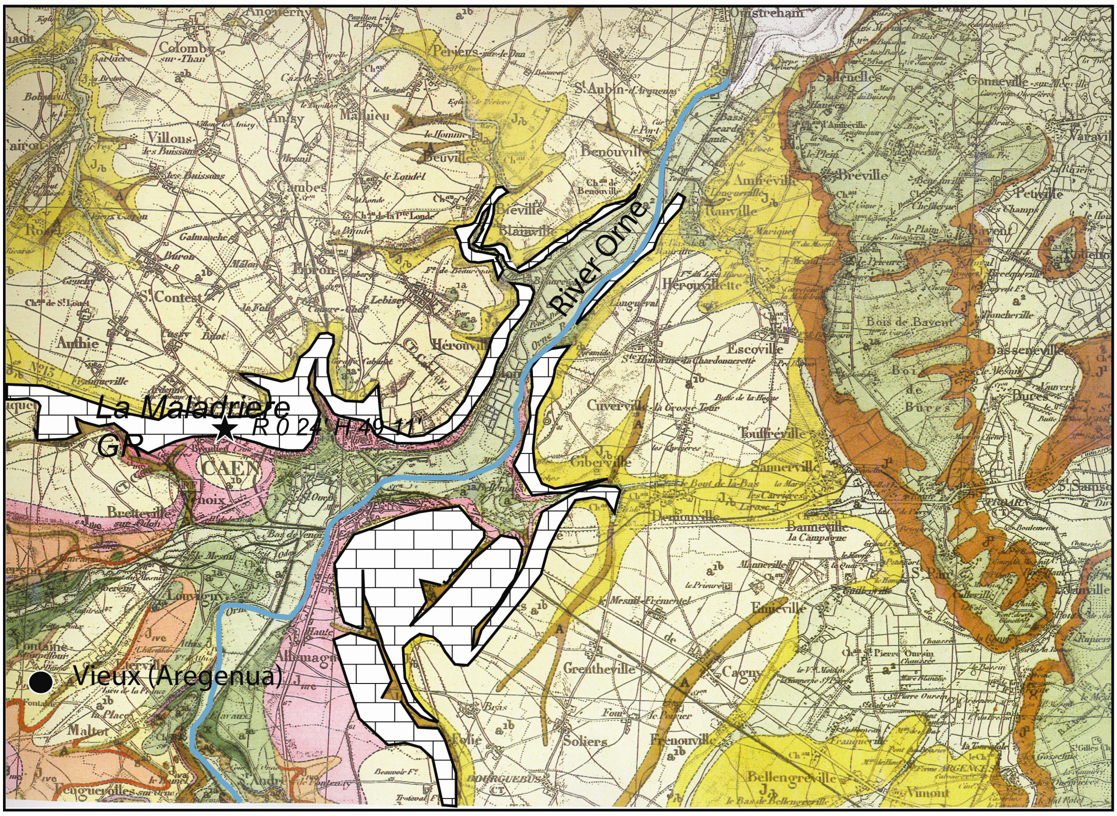


Figure A6.7 Geological Map of Tetbury District showing the sample locations for Athelstan Oolite and Minchinhampton stone (Bathonian) Middle Jurassic

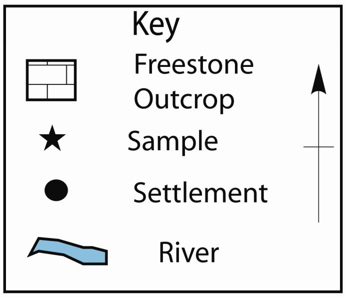


From Carte géologique de la France à 1/50 000, feuille nÐ 193, Pont-à-Mousson Ɛ BRGM - www.brgm.fr - Autor. R09/18Ed.

Figure A.6.8 Geological Map of Norroy-lès-Pont-à-Mousson showing sample location for Lothringer freestone (Calcaires à Polypiers) Bajocian



From Carte géologique de la France à 1/50 000, feuille n°120, Caen © BRGM - www.brgm.fr -Autor. R09/18Ed.



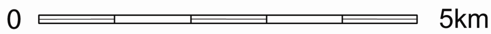
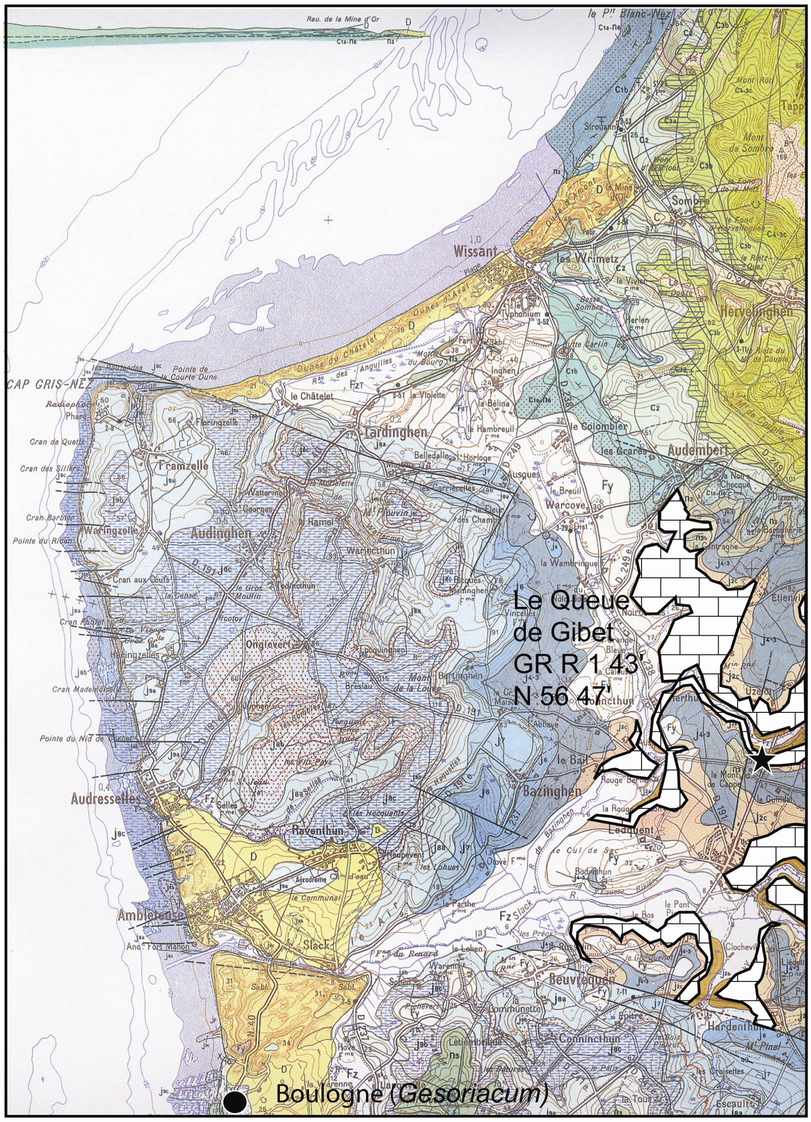
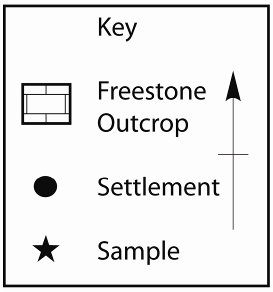


Figure A6.9 Geological Map of Caen showing sample location for Caen stone (Bathonian) Middle Jurassic



From Carte géologique de la France à 1/50 000, feuille n°5 Marquise



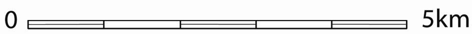


Figure A6.10 Geological Map showing sample location for Marquise oolite (Bathonian) Middle Jurassic

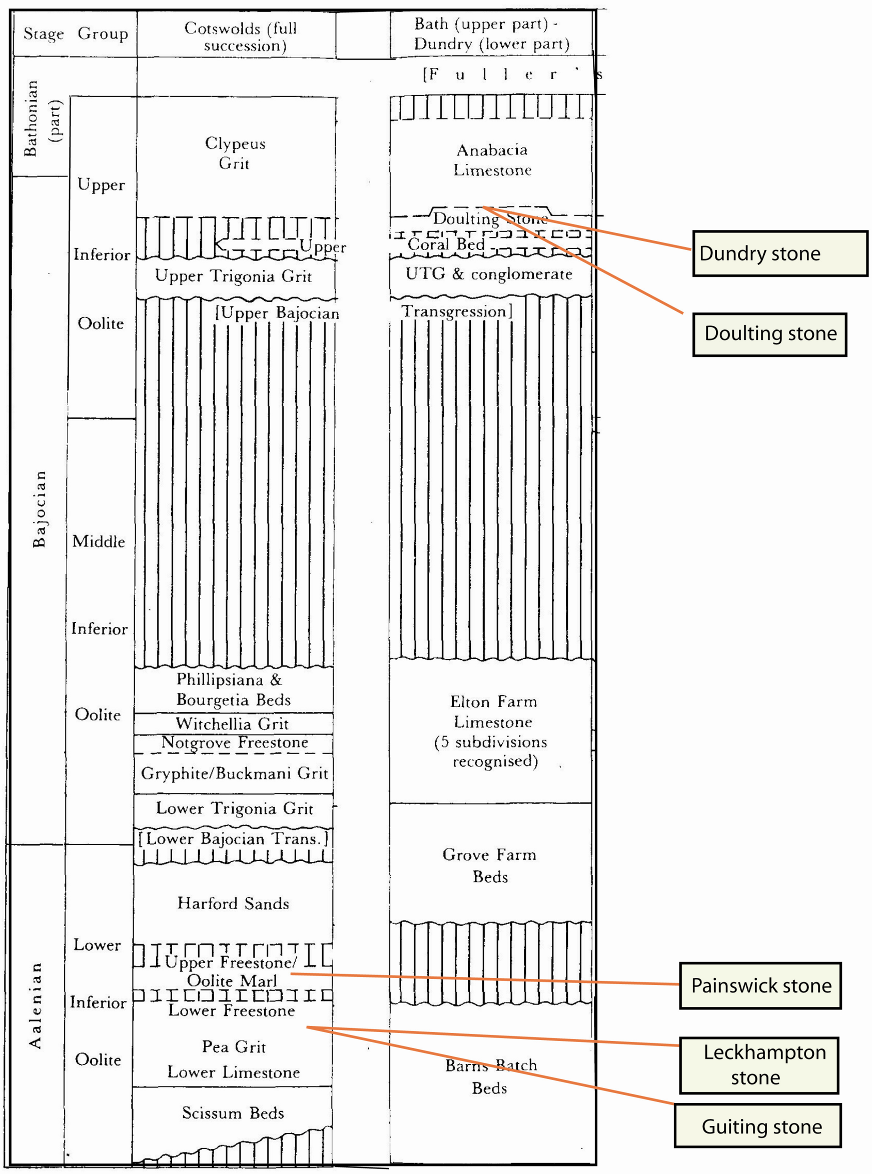


Figure A6.11 Stratigraphic Table for the Bajocian of the North Cotswolds - Boxed (from Green, 1992)

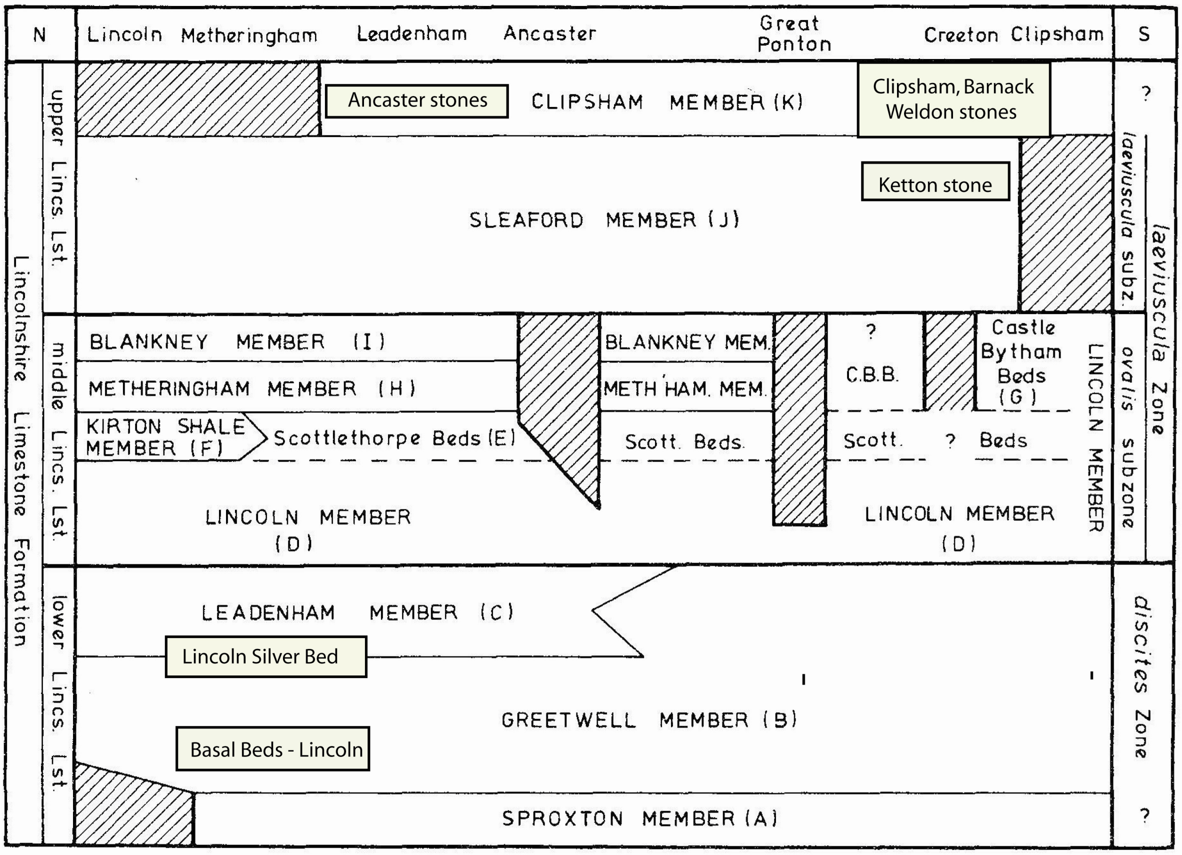


Figure A6.12 Stratigraphic Table for the Bajocian of Lincolnshire.
Freestone Units Boxed (after Ashton, 1980)

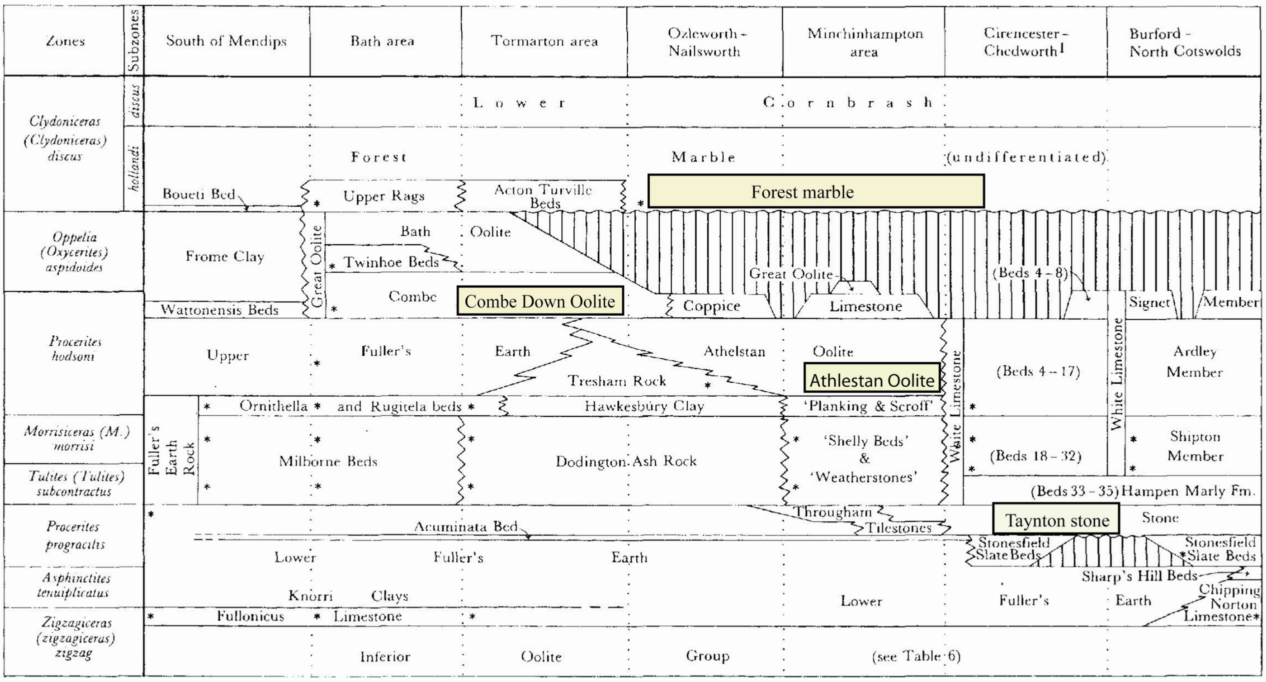


Figure A6.13 Stratigraphic Table for the Bathonian of the South Cotswolds
Freestone Units - Boxed (from Green, 1992)