Chapter 3 Quaternary environmental change in the Gordano Valley

3.1 Introduction

Current understanding of Pleistocene environmental change in the Bristol Channel/Severn Estuary region, summarised in Chapter 2, demonstrates that this is a region containing important evidence for past cold and temperate climates and changes in sea level, and this is reflected in the evolution of the Gordano Valley. Direct and indirect influences of a number of glacial episodes mean that Quaternary sediments of the Gordano Valley comprise a variety of unconsolidated drift that includes glacial, fluvial, littoral and estuarine beds and a mixed group of periglacial head deposits that grade into colluvium, mudflow and landslip (Green 1992). Hill *et al*. (2008) record the presence of a Lateglacial hydroseral succession on Weston Moor *c*. 15,000 Cal. BP. This was followed by deposition of estuarine alluvium and peat formation, the most extensive Quaternary deposits in the Gordano Valley, believed to have commenced around 9 ka in response to a post-glacial rise in sea level (Green 1992, Kellaway & Welch 1993, Hill 2006).

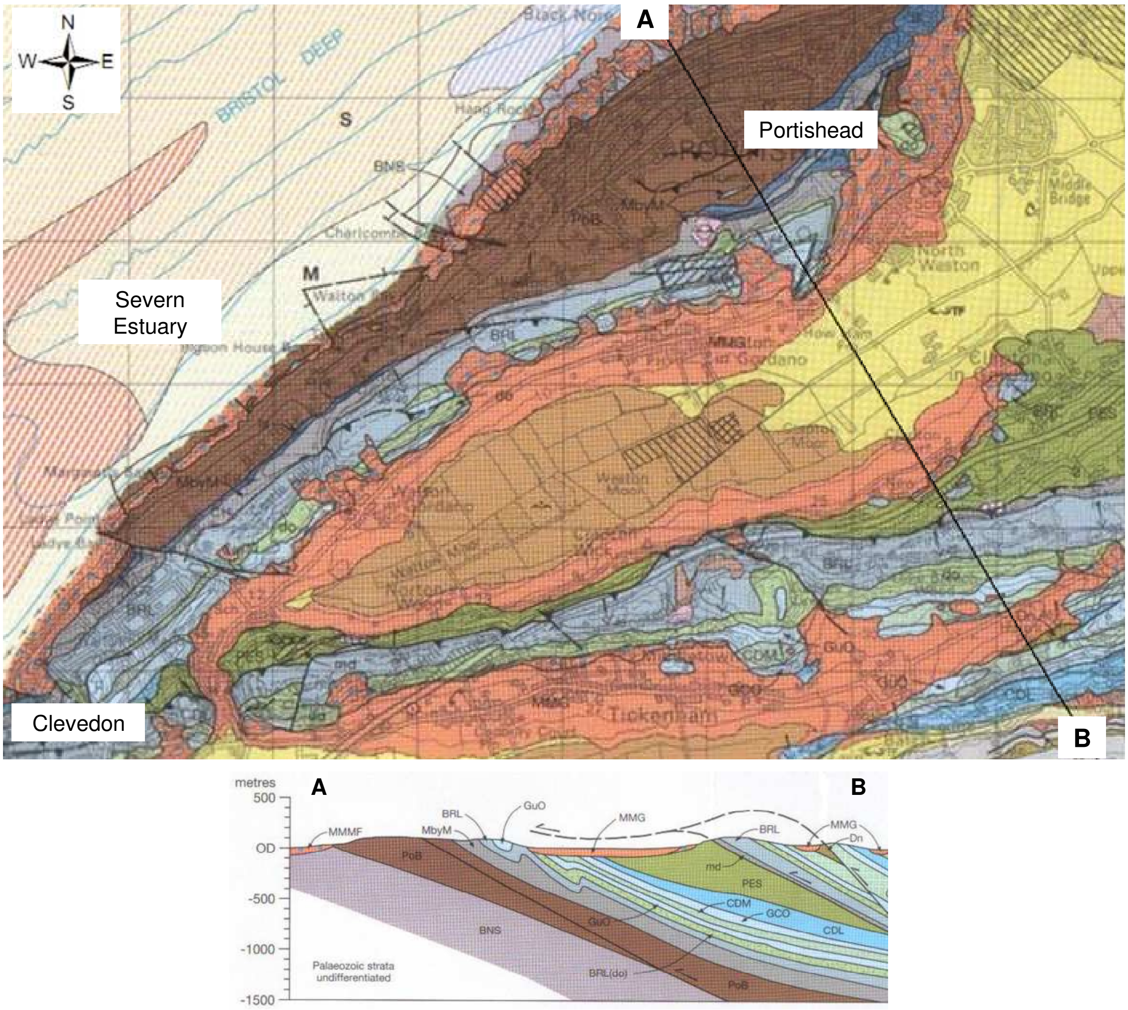
This chapter provides a summary of the available literature and places the Gordano Valley into a geographical context in relation to the Pleistocene evolution of north Somerset beyond that provided in Chapter 2. The Chapter begins by summarising the geological setting of the Gordano Valley. This is followed by a review of past research relating to the Quaternary evolution of the Gordano Valley.

3.2 The solid geology of the Gordano Valley

The geology of the Gordano Valley is shown in Figure 3.1. The solid geology comprises a mix of bedrock from the Devonian, Carboniferous and Permo-Triassic periods, with ages ranging from *c*. 410 to 210 Ma. Clevedon-Portishead ridge, on the northern side of the valley, is composed of Carboniferous Limestone with a core of Devonian Old Red Sandstone (Green 1992, Barton *et al*. 2002). Subsequent erosion has resulted in the present day exposure of Old Red Sandstone (Ussher 1914). Tickenham ridge, to the south, is almost entirely Carboniferous Limestone (Jefferies *et al.* 1968, Mills 1984 and Campbell *et al.* 1998), although Old Red Sandstone lies at its core east of Clapton-in-Gordano

(Kellaway & Welch 1993) and sandstones and coal measures of the Pennant Sandstone Group extend along its north-facing slope (Jefferies *et al.* 1968, Kellaway & Welch 1993, Barton *et al*. 2002). Isolated outcrops of volcanic basaltic rocks occur within the Carboniferous Limestone (Green 1992, Kellaway & Welch 1993). The geology of the Bristol and Gloucester District and the Bristol District is described briefly in Barton *et al*. (2002) and in more detail by Green (1992) and Kellaway and Welch (1993).

The present shape of the Gordano Valley, which suggests drainage from west to east towards a confluence with the River Avon east of Portishead, is a result of intensive folding and erosion prior to the Permo-Triassic period, which is partly responsible for the creation of the Clevedon-Portishead ridge and the WSW-ENE trend in the Gordano Valley (Williams & Hancock 1977, Green 1992, Barton *et al*. 2002). This was followed by extensive erosion of the exposed Devonian and Carboniferous outcrops, resulting in the formation of areas of moderate relief, largely contributing to the present geomorphological shape of the valley (Green 1992). Permian Beds are largely absent (Lloyd Morgan 1887) but thick screes of angular and rounded Permo-Triassic breccias and conglomerates (Mercia Mudstone Marginal Facies, formerly known in Bristol and the Mendips as Dolomitic Conglomerate) have accumulated up against the steep slopes of Carboniferous Limestone of both ridges (Jefferies *et al.* 1968, Green 1992, Barton *et al*. 2002). During the Triassic period Mercia Mudstones were deposited unconformably on Devonian and Carboniferous bedrock. Subsequent erosion from the ridges left a covering of these mudstones only on the valley floor (Kellaway & Welch 1993). The next sediments recorded in the valley are those of the Quaternary period; no sediments of the Jurassic, Cretaceous or Tertiary Periods are recorded.



Key

Artificially Modified Ground
- Made Ground
- Worked Ground
- Infilled Ground

Drift: Quaternary deposits not necessarily shown in order of superposition
- Landslip
- Head
- Peat
- Tidal flat deposits
- Glaciofluvial deposits , undifferentiated

Seabed sediments
- Predominantly gravel (G)
- Predominantly mud (M)
- Predominantly sand (S)

Bedrock

Triassic
- Mercia Mudstone Group (MMG)
- Mercia Mudstone Marginal Facies (MMMF) ("Dolomitic Conglomerate")

Carboniferous Coal Measures
- Downend Formation (Dn)
- Pennant Sandstone Formation (PES)
- Lower Coal Measures Formation And Middle Coal Measures Formation (undifferentiated) (Md)

Carboniferous Limestone
- Clifton Down Limestone Formation (CDL)
- Goblin Combe Oolite Formation (GCO)
- Clifton Down Mudstone Formation (CDM)
- Gully Oolite Formation (GUO)
- Dolostone, Black Rock Limestone Subgroup (do)
- Black Rock Limestone Subgroup (BRL)
- Mudstone, Maesbury Mudstone Formation (MbyM)
- Limestone, Maesbury Mudstone Formation (ls)

Devonian
- Portishead Formation (POB)
- Black Nore Sandstone

Figure 3.1: Geology of the Gordano Valley. A – B marks the line of geological cross-section. Vertical and horizontal scale of section is 1:50, 000 (British Geological Survey 2004)

3.3 Research on Pleistocene palaeoenvironments in the Gordano Valley

Research on Pleistocene palaeoenvironments in the Gordano Valley has been largely confined to the valley margins where there is evidence for up to three glacial episodes (ApSimon & Donovan 1956, Gilbertson & Hawkins 1978a, Hunt 1998a), three sea-level high stands (Hunt 1998a) and widespread slope deposits associated with Devensian (MIS 5d-2) periglaciation (Campbell *et al.* 1998). Most of this research took place prior to the 1980s, since when research on the Pleistocene of the Gordano Valley has been limited to Late Devensian (MIS 2) palaeoenvironments of the valley floor (Gilbertson *et al*. 1990, Hill 2006, Hill *et al*. 2008). Figure 3.2 shows the location of Gordano Valley sites referred to in the text.

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Figure 3.2: Pleistocene sites in the Gordano Valley. Key: 1. Court Hill, erratics; 2. East Clevedon Gap, meltwater channel, head; 3. Holly Lane, head, coversands & shore platform; 4. Walton Valley, meltwater channel; 5. Portishead Down, till; 6. Nightingale Valley, meltwater channel; 7. Weston in Gordano, till & temperate deposits; 8. Wynhol, head; 9. Clapton Wick Nurseries, coversands; 10. Tickenham Col, erratics; 11. Court Hill Col, erratics & till; 12. Weston Drove

Gravels on Court Hill (grid reference ST 421719, Figure 3.3) with a high erratic content were first described by Trimmer (1853). He inferred they were of Pleistocene rather than Triassic age, because they overlie Dolomitic Conglomerate. Reynolds (1934) later interpreted the gravels as 'Plateau Gravels', commonly found in the Bristol region and deposited fluvially prior to the reversal of drainage of the Bristol Avon in the Early Pleistocene.

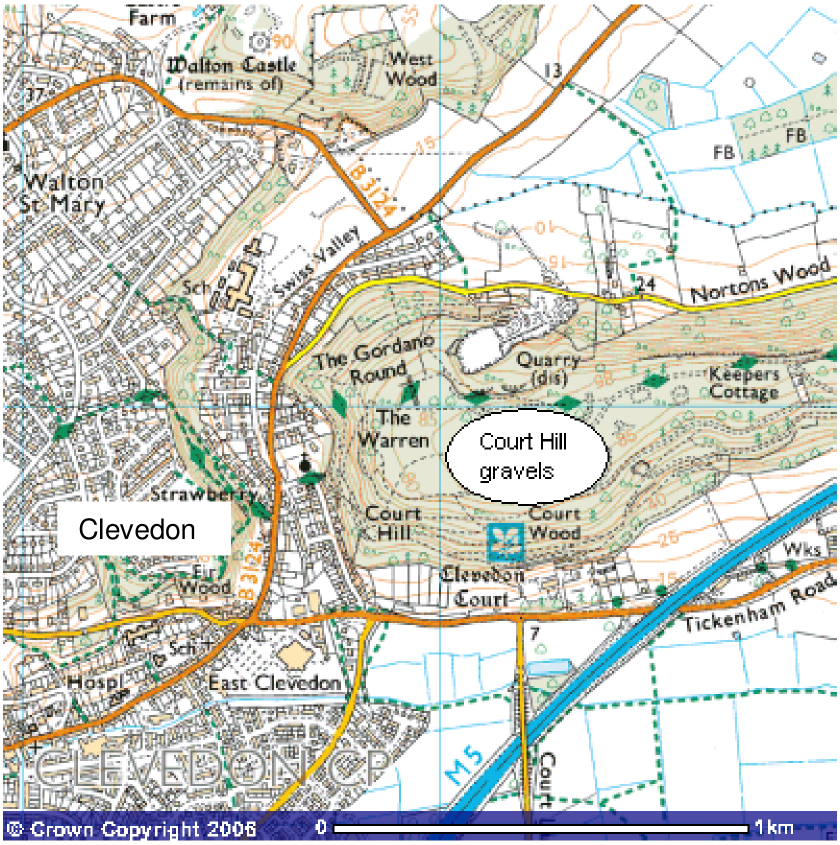

Figure 3.3: Location of Court Hill gravels (source: Trimmer 1853)

The existence of Triassic conglomerates, mapped as Mercia Mudstone Marginal Facies on the valley flanks and Mercia Mudstone Group on the valley floor of the Gordano Valley, (British Geological Survey 1:50 000 Bristol (Sheet 264) 2004) was disputed by Hawkins & Kellaway (1971) and Hawkins (1972) who argued that these are Pleistocene glacial deposits. A borehole located on Tickenham ridge revealed deposits containing fragments of Jurassic limestone, Cretaceous flint, chert, and Jurassic and Cretaceous microfauna, precluding the deposits from being Triassic Dolomitic Conglomerate (Hawkins 1972, Hawkins 1977, Gilbertson & Hawkins 1978a, Hunt 2006d). Because these deposits occur above the height of Triassic material, Gilbertson & Hawkins (1978a) concluded that they could not be interpreted as soliflucted Triassic deposits. A further borehole in East Clevedon Gap (grid reference ST 416717) also failed to confirm the presence of Triassic deposits, but instead *Pleistocene* head, sand and gravel were found to rest directly on Carboniferous Limestone (Hawkins 1972, 1977). Hawkins (1977) concluded that many of the deposits mapped as Dolomitic Conglomerate were actually Pleistocene head.

Evidence for glaciation was found at Court Hill Col (grid reference ST 437723, Figure 3.4) during excavations for the M5 motorway (Hawkins 1972). Part-filling a channel through Carboniferous Limestone are 24 m thick deposits consisting of well- to poorly-sorted sands, gravels and cobbles and unsorted, unbedded diamicts of local and non-local boulders in a matrix of red sandy silt. These were interpreted by Gilbertson & Hawkins (1978b) as tills and flow tills deposited by ice abutting the northwest side of Tickenham ridge (Hawkins & Kellaway 1971, Gilbertson & Hawkins 1978a, Hunt 1998a, Harrison & Keen 2005). To the south, the gravels are replaced by cross-bedded sands and stratified cobbles and boulders, interpreted by Gilbertson & Hawkins (1978a) as glaciofluvial outwash. Gilbertson & Hawkins (1978a) explain the channel as having been cut by meltwaters flowing into Gordano Valley from an ice sheet which advanced eastwards across the North Somerset Levels.

A barrier of calcreted gravel which fills the southern end of a U-shaped valley at Tickenham Col (grid reference ST 448727, Figure 3.5) has been interpreted by Hawkins (1972, 1990) as of glaciofluvial origin. These deposits pre-date Devensian (MIS 5d-2) periglacial activity (Gilbertson & Hawkins 1978a).

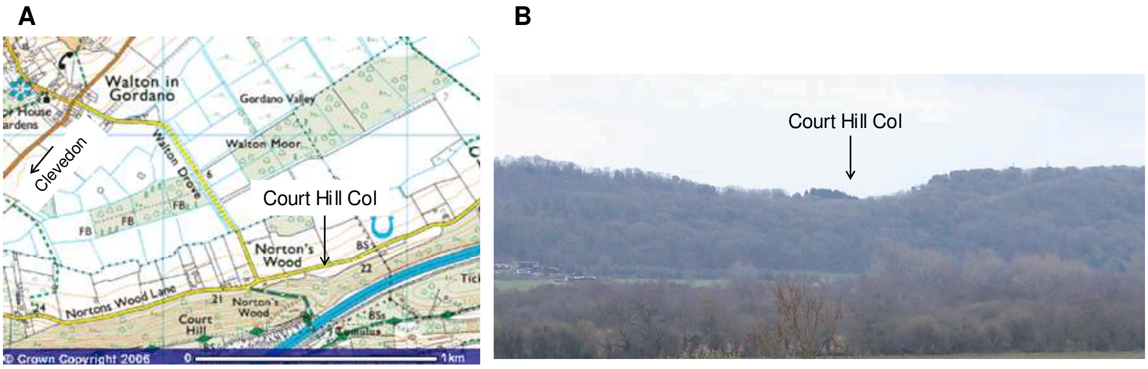

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Figure 3.4: Court Hill Col. A. Location of Court Hill Col. B. Photograph of Court Hill Col. C. Schematic cross-section through the Pleistocene deposits at Court Hill Col (After: Hunt 2006d Figure 27, p 113, adapted from Gilbertson & Hawkins 1978a)

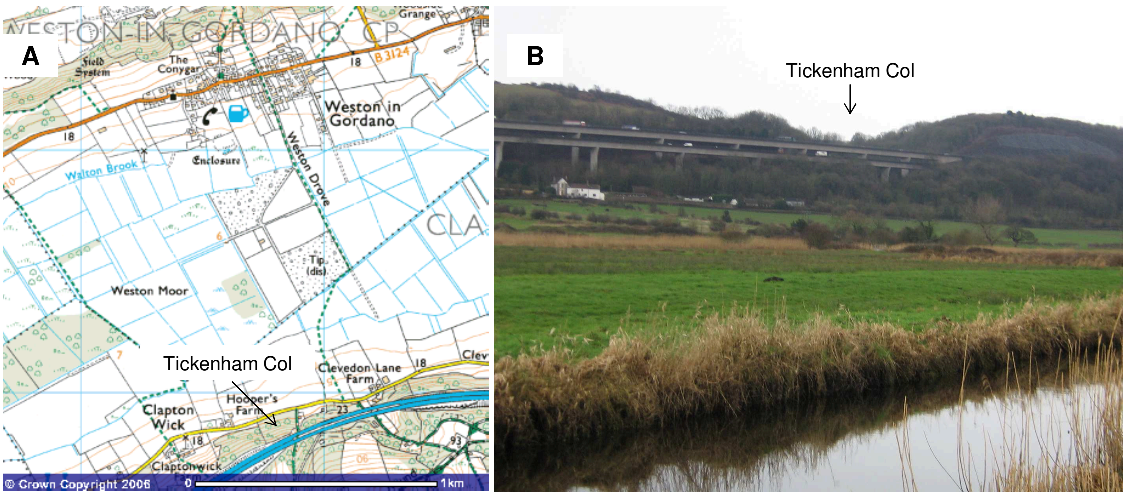

Figure 3.5: Tickenham Col. A. Location of Tickenham Col. B. Setting of Tickenham Col

Erratic-rich gravels and sands on Portishead Down (grid reference ST 445751, Figure 3.6), above the inferred meltwater channel of Nightingale Valley, have been interpreted as evidence for the inland advance of ice from the Bristol Channel which crossed the Clevedon-Portishead ridge (Hawkins & Kellaway 1971, Hawkins 1990, Kellaway & Welch 1993, Hunt 1998a, Campbell *et al.* 1999). Kellaway & Welch (1993) theorised that the gravels were possibly morainic; Hunt (1998a, 2006e) found the lithology, clast size, erratic content and stratigraphy of the gravels to be consistent with a glacial origin, possibly a flow till, since none of the erratic rocks outcrop on the Clevedon-Portishead ridge. The sands were interpreted as of probable glaciofluvial origin (Hunt 2006e).

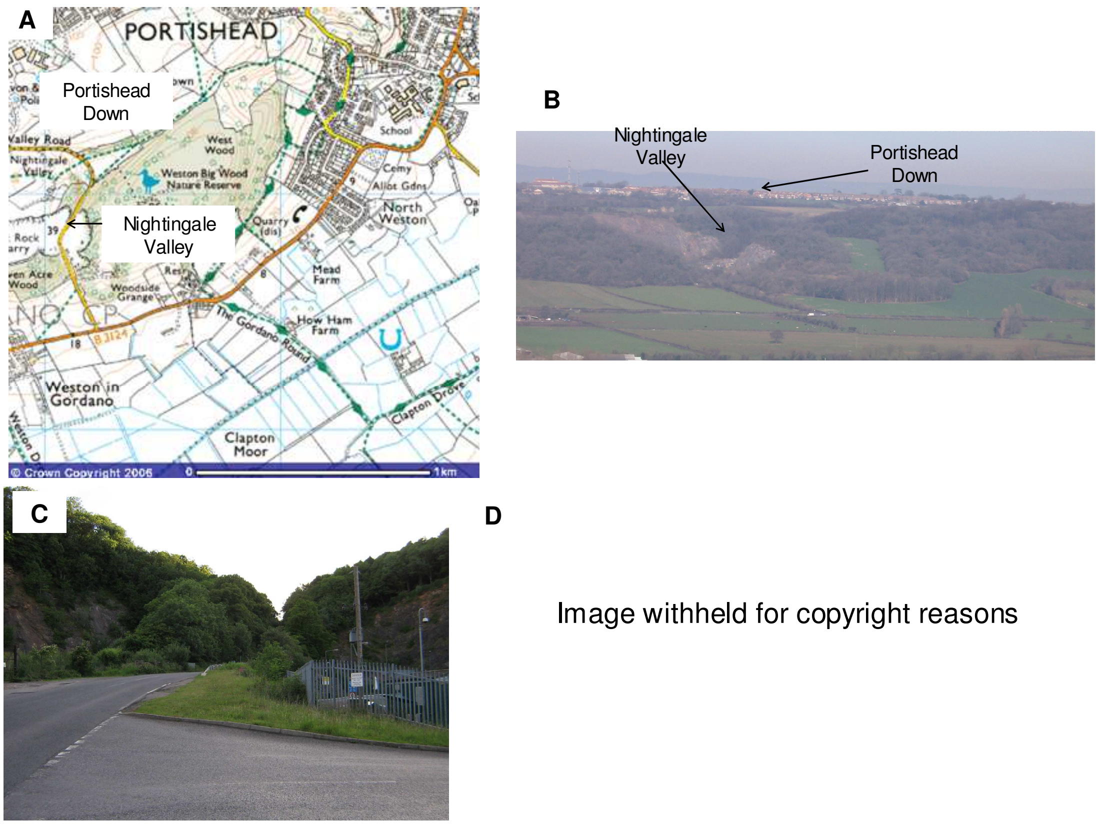

Figure 3.6: A. Location of Nightingale Valley and Portishead Down. B. Setting of Nightingale Valley and Portishead Down. C. Nightingale Valley. D. Cross-section showing the Quaternary sequence at Nightingale Valley (After: Hunt 2006e Figure 39, p 146)

Deposits within a sequence of marine sands, gravels and subtidal sands at Weston in Gordano (ApSimon & Donovan 1956) indicate that there may have been two glacial events in the Gordano Valley, separated by a marine incursion, or a single event, with the deposits moved by solifluction to their present position after a marine transgression (Hunt 2006f). ApSimon & Donovan (1956) considered these to be derived from local Triassic rocks.

However, Hunt (2006f) considered this unlikely, on the basis of contained erratic flints, and noting the apparent similarity to the tills of Portishead Down suggested these deposits were till, a derivation of till, or a weathered soliflucted deposit incorporating erratic clasts from the marine gravels underneath.

Walton Valley and East Clevedon Gap (grid references ST 424736 and ST 416721, Figure 3.7) have been interpreted as meltwater channels. Hawkins (1972) argued that Walton Valley, a valley with no catchment, is unable to produce a channel of the size and depth that exists, unless it is explained as a glacial meltwater channel, formed when ice was banked against the western side of the Clevedon-Portishead ridge (Hawkins 1972, 1977, Gilbertson 1974, Kellaway & Welch 1993). Hunt (1998a), however, contended that sub-aerial processes were responsible for its formation. East Clevedon Gap, which links the Gordano Valley with the North Somerset Levels, was also attributed by Gilbertson & Hawkins (1978a) to sub- or en-glacial meltwater erosion. It has a humped long-profile, diagnostic of a sub-glacial meltwater channel (Evans *et al.* 2005). Borehole evidence of 13 m of head, sands and calcreted gravels (Hawkins 1972, 1977, Gilbertson & Hawkins 1978a) led Hawkins (1972, 1977) to suggest Devensian (MIS 5d-2) slope processes were responsible, although this is probably influenced by the borehole's proximity to the valley sides.

Associated with the glaciation at Court Hill Col (MIS 12 or earlier), Gilbertson & Hawkins (1978a) proposed glaciolacustrine deposition for the lowermost sands on the north flank of Tickenham ridge, citing the 'hanging valley' of Court Hill Col, which becomes wider at its northern end, in support of this. Gilbertson & Hawkins (1978a) proposed two models for the formation of this lake.

(a) The Gordano Valley was ice free and normal drainage of the area through the East Clevedon Gap was obstructed by an ice-mass that stretched across the Severn Estuary. This would have produced a pro-glacial lake with a surface area of hundreds of km^2 (Gilbertson & Hawkins 1978a) which filled the whole Gordano Valley.

(b) Glacial impoundment of a small ice-marginal lake between an ice mass occupying the Gordano Valley and Tickenham ridge, the lake surface being measured in thousands of m^2.

Figure 3.7: A. Location and setting of East Clevedon Gap. B. Location and setting of Walton Valley

The preferred model of Gilbertson & Hawkins (1978a) was occupation of the Gordano Valley by ice which impounded a small ice-marginal lake (Gilbertson & Hawkins 1978a, Kellaway & Welch 1993). The altitude and dimensions of the proposed glaciolacustrine deposits would require a water level of ~ 75 m OD and indicate the presence of a small (50 m x 150 m) lake (Gilbertson & Hawkins 1978a).

At present evidence for glaciation on the valley floor is lacking. Glacial deposits are mainly found on the tops of the ridges surrounding the Gordano Valley, at about 85 m OD, although those at Weston in Gordano are at 8 m OD. (Campbell *et al.*1998). Clast alignment within the gravels at Nightingale Valley and Weston in Gordano is consistent with the advance of an ice sheet from the northwest which overtopped the Clevedon-Portishead ridge, advanced into the Gordano Valley and produced meltwater channels at Nightingale Valley and Walton Valley (Hawkins & Kellaway 1971, Hawkins 1990, Kellaway & Welch 1993, Hunt 1998a, Campbell *et al.*1998). However, clast alignment of the Court Hill and Tickenham Col deposits suggests an ice sheet entered the valley from the south (Gilbertson 1974, Gilbertson & Hawkins 1978a). In contrast to tills with an Irish Sea provenance, Trimmer (1853) reported the Court Hill gravels contain no shells, possibly excluding a marine derivation and calling these ice flow directions into question. The erratic content of the Nightingale Valley deposits also differs from that of Court Hill, and from glacial deposits elsewhere in northern Somerset (Hunt 2006e). This suggests either separate glacial events or different phases of the same event.

As Chapter 2 established, the ages of northern Somerset glacial episodes are unproven and controversial (Hunt 1998a, Harrison & Keen 2005). The Court Hill glaciation was originally assumed to be 'Wolstonian', in keeping with the then accepted age of the most southerly extent of ice (Gilbertson & Hawkins 1978a) and the Nightingale Valley deposits have been ascribed to a Wolstonian (MIS 6) glaciation (Kellaway & Welch 1993). Alternatively, Green (1992) suggested the glacial deposits of Court Hill and Tickenham were of Anglian (MIS 12) age. On the basis of their glacial interpretation it has been assumed the deposits at Court Hill and Nightingale Valley accumulated during the same glacial event, and they have correspondingly been correlated with, deposits nearby at Kenn (Campbell *et al.*1998, Campbell *et al.* 1999). If this correlation is accepted, then their age could be MIS 16, although Andrews *et al*. (1984) and Harrison & Keen (2005) inferred an age no older than MIS 10 for the Kenn glacial deposits (section 2.8.2). The basis for any of these correlations is uncertain as their age remains unknown (Hunt 1998a, 2006b, c and d, Bowen 1999b); no direct dating of the glacial deposits has so far been attempted. The fragmentary nature of Pleistocene deposits in this region means the deposits may represent a collection of events that took place at widely different times.

The complex sequence of deposits at Weston in Gordano (grid reference ST 456754, Figure 3.8) records a long history of Pleistocene sea-level change with evidence for three sea-level high stands following glaciation of the area (Hunt 1998a, Hunt 2006f). Slope deposits overlie fossiliferous marine and freshwater interglacial deposits that may represent a single, complex temperate stage containing two marine transgressions (Hunt 1998a). Alternatively they may represent separate periods with the intervening deposits removed by erosion (Hunt 2006c). The basal gravels contain a variety of erratics and therefore probably post-date a glaciation of the north Somerset coastlands (Hunt 1998a). ApSimon & Donovan (1956) suggested a possible source for the gravels could be those of Nightingale Valley; however, they also attributed them to marine or estuarine origins (ApSimon & Donovan 1956). The dates for the sea-level high stands are unknown;

Campbell *et al.* (1999) assigned the Weston in Gordano interglacial deposits to MIS 7-9. However, in a recent reappraisal of interglacial sea-level evidence for southwest England, Westaway (2010b) suggested the upper marine deposits may be Ipswichian (MIS 5e).

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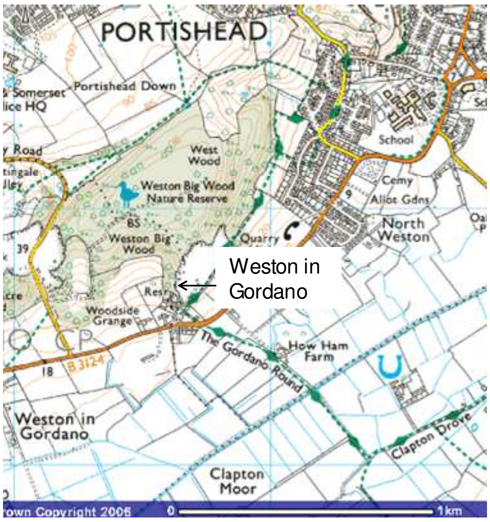

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Figure 3.8: A. Location of Weston in Gordano site. B. Cross-section of the Quaternary deposits at Weston in Gordano (After: Hunt 1998a Figure 10.8, p 353, adapted from ApSimon &Donovan 1956)

Other evidence for higher sea-levels in the Gordano Valley are found at Holly Lane (Figure 3.9), where a cliff, platform and notch were interpreted as of marine origin and tentatively ascribed to the Ipswichian (MIS 5e) stage (Gilbertson & Hawkins 1974, Hawkins 1977) or MIS 7 (Westaway 2010b) or pre-Quaternary (Gilbertson & Hawkins 1974).

Probably the most widespread Pleistocene deposits in the Gordano Valley are of periglacial origin. These are undated, but assumed to be Devensian (MIS 5d-2); glaciation is not thought to have penetrated into Somerset during this time, but the proximity of an ice sheet in Wales would have had a direct influence on the depositional environments of the Gordano Valley, resulting in a wide range of frost- and ice-generated landforms and deposits that formed a veneer over earlier deposits (Campbell *et al.* 1998). The main evidence for this is provided by a sequence of breccias comprising local, frost-shattered former glacial deposits and aeolian sands at Holly Lane (grid reference ST 419727, Figure 3.9), East Clevedon Gap (Figure 3.7), Clapton Wick Nurseries (grid reference ST 450729), Wynhol (grid reference ST 452729 Figure 3.10) and Weston in Gordano (Figure 3.8), some of which exhibit cryoturbation features.

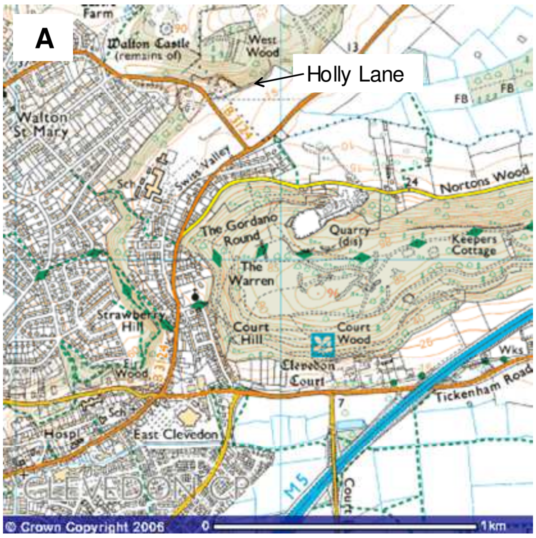

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Figure 3.9: A. Location of Holly Lane. B. Sketch map of location of Holly Lane sections (Hunt 1998a Figure 10.9, adapted from Gilbertson and Hawkins 1974). C. Cross-section of deposits at Holly Lane (After: Hunt 1998a Figure 10.9). D. Cross-section of deposits at Holly Lane (Gilbertson and Hawkins 1974, section B in Figure 3.9 B)

At Holly Lane up to 21 m of Pleistocene breccias, sands and silts are banked against an ancient cliff, filling a cave within the cliff. Breccia clasts were locally derived angular stone fragments, the result of intermittent frost-shattering (Greenly 1922, Gilbertson 1974, Gilbertson & Hawkins 1974). The sandy matrix of the breccias, and the sandy layers, were interpreted as aeolian deposits laid down during cold arid phases (Gilbertson & Hawkins 1974). Based on their mineralogy, a South Wales (Greenly 1922) or Dartmoor (Palmer 1931, 1934) provenance has been argued for the aeolian sands; a Dartmoor provenance is further supported by the sands being preferentially accumulated against south-facing slopes. Alternatively, Gilbertson (1974) speculated that the sands might be of local provenance, deflated from estuarine deposits exposed by falling sea levels (Gilbertson 1974).

Several beds in the Holly Lane sequence yielded mammalian fossils and terrestrial mollusc assemblages indicative of cold-climate conditions (Hunt 1998a). Vertebrate faunal remains recovered from the cave include the remains of the small-bodied form of horse (*Equus ferus*), an ecophenotype attributed to MIS 6 in Britain (Candy & Schreve 2007) which is absent from Ipswichian (MIS 5e) and Devensian (MIS 5d-2) deposits (Currant & Jacobi 2001, Murton *et al.* 2001) and indicate a cold environment, although Reynolds (1907) argued that the scattered nature of the remains indicated they were not *in situ*, but had been washed into the cave. Nonetheless, based on the faunal remains, a Middle Pleistocene age was proposed for the cave deposits (Reynolds 1907, Welch 1948). However, lack of palaeosols has been interpreted to indicate that the whole sequence represents a complex series of Devensian (MIS 5d-2) cold stage environmental changes and landscape evolution, reflecting cold/moist and cold/dry environments during a single, continuous cold stage (Greenly 1922, Palmer 1934, Reynolds 1934, Hawkins & Kellaway 1971, Gilbertson & Hawkins 1974, Hawkins 1977, Gilbertson & Hawkins 1983, Hunt 1998a). This interpretation is supported by mammalian and molluscan fossil evidence that suggests open, exposed periglacial conditions with damp ground locally present (Gilbertson 1974, Gilbertson & Hawkins 1974). However, an earlier examination of terrestrial molluscs from these deposits led Kennard & Woodward (1934) to infer the climate was similar, although damper, to that of the present day.

Deposits similar to those at Holly Lane were traced by Greenly (1922) across the whole width of the East Clevedon Gap and appear to be widespread at the Gordano Valley margins. Deposits at Clapton Wick Nurseries, Wynhol Valley (Figure 3.10), and Weston in Gordano have been attributed to a complex series of environmental changes with periods of cold-wet conditions interrupted by colder-drier conditions (Gilbertson & Hawkins 1983). All exhibit cryoturbation features (ApSimon & Donovan 1956, Gilbertson & Hawkins 1983) indicating a period of intense cold. The breccias in upper layers suggest a cold climate associated with periods of discontinuous permafrost and their loam matrix suggests continuous aeolian deposition of silt during breccia formation (Gilbertson & Hawkins 1983).

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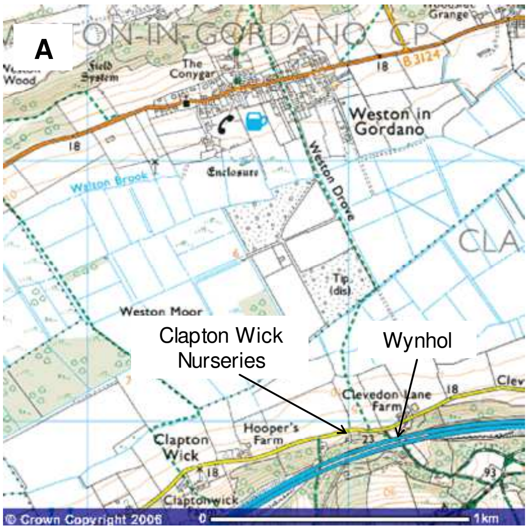

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Figure 3.10: A. Locations of Clapton Wick Nurseries and Wynhol. B. Section through Wynhol periglacial deposits (Gilbertson & Hawkins 1983 Figure 48). C. Section through Clapton Wick Nurseries Pleistocene deposits (Gilbertson & Hawkins 1983 Figure 47). D. Wynhol looking southeast. Note elevated section of M5 at top of photograph

Thinly bedded sand overlying breccias at Clapton Wick Nurseries is thought to indicate reworking by sheetwash and downslope movement, together with continuous aeolian deposition of fine silts and sands. The sandy sheetwash deposits underlie Holocene (MIS 1) peat deposits (Gilbertson & Hawkins 1983), and therefore predate them; a Devensian (MIS 5d-2) age is assumed. The extent of cryoturbated and periglacial slope deposits is unknown.

The situation is rendered more complex by the possibility of tectonic activity within the catchment. For many years the whole of the southwest of England, including Somerset, was thought to have been tectonically stable throughout the Quaternary (Heyworth & Kidson 1982, Haslett *et al*. 1998). However, Westaway (2010b) has recently suggested there may have been uplift in northern Somerset of *c*. 13-14 m since Ipswichian (MIS 5e) time and as much as *c*.130 m in the past 3 Ma. Alternatively, Watts *et al*. (2000) have suggested that the eastern part of the Bristol Channel/Severn Estuary, including the Gordano Valley, forms a broad, low-lying topographic depression that may have been a region of continuing erosion throughout the Quaternary such that the region was maintained more or less at sea-level despite being within a region of uplift. As evidence for this, Watts *et al*. (2005) cite the raised beach at Swallow Cliff and marine sands at Kenn Church (Bowen 1999a, Watts *et al*. 2005) as indicating that at sometime during MIS 7 – 5e the region was at or near sea-level. Either scenario has implications for Pleistocene palaeoenvironmental reconstructions of the Gordano Valley which are discussed later in the thesis.

Pleistocene environments in the Gordano Valley are summarised in Table 3.1; a conservative (Anglian, MIS12) inference for the age of glacial deposits, has been adopted. This follows current thinking (Harrison & Keen 2005) on the age of the north Somerset glaciation, although an earlier (MIS 14 or 16) age has previously been ascribed (Bowen 1991, Hunt 1998a). Unfortunately, very little evidence of Pleistocene environments in the Gordano Valley, other than the geomorphology of the valley interfluves, is still visible.

Table 3.1: Summary of Pleistocene environments in the Gordano Valley. Uncertainties of evidence or age are signified ?

Location	Evidence	Environment	Inferred age	Reference(s)
Court Hill	Erratic gravel	Glacial	Anglian (MIS12)	Trimmer (1853)
East Clevedon Gap	Meltwater channel	Glacial	Anglian (MIS12)	Gilbertson & Hawkins (1978a)
Walton Valley	Meltwater channel	Glacial	Anglian (MIS12)	Hawkins (1972)
Portishead Down	Till; glaciofluvial gravels	Glacial	Anglian (MIS12)	Hawkins & Kellaway (1971); Hawkins (1990); Kellaway & Welch (1993); Hunt (1998b); Campbell *et al*. (1999); Hunt (2006e)
Nightingale Valley	Meltwater channel	Glacial	Anglian (MIS12)	Hawkins & Kellaway (1971); Hunt (2006e)
Tickenham Col	Erratic gravel	Glacial	Anglian (MIS12)	Hawkins (1972, 1990); Gilbertson (1974); Gilbertson & Hawkins (1978a)
Court Hill Col	Till; erratic gravel	Glacial	Anglian (MIS12)	Hawkins (1972)
Weston Drove	? Moraine	Glacial	Anglian (MIS12)	Hawkins (1972)
Weston in Gordano	Marine molluscs	Marine (littoral)	? Post- Anglian (MIS12) or earlier	Apsimon & Donovan (1956); Hunt (2006f)
Weston in Gordano	? Till/head	Glacial /periglacial	? Anglian (MIS12)/ post-Anglian (MIS12)	Apsimon & Donovan (1956); Hunt (2006f)
Weston in Gordano	Marine molluscs	Marine	MIS 7 or earlier	Apsimon & Donovan (1956); Hunt (2006f)
Weston in Gordano	Freshwater molluscs	Temperate; terrestrial	MIS 7 or earlier	Apsimon & Donovan (1956); Hunt (2006f);Westaway (2010b)
Weston in Gordano	Marine sands	Marine (intertidal)	Ipswichian (MIS 5e) or earlier	Apsimon & Donovan (1956); Hunt (2006f); Westaway (2010b)

Table 3.1 (continued): Summary of Pleistocene environments in the Gordano Valley. Uncertainties of evidence or age are signified ?

Location	Evidence	Environment	Inferred age	Reference(s)
Holly Lane	Shore platform/wave cut notch	Marine (littoral)	? Ipswichian (MIS 5e) or MIS 7	Gilbertson & Hawkins (1974); Hawkins (1977); Westaway (2010b)
Weston Drove	? Beach/dune	Marine (littoral)	Ipswichian (MIS 5e)	Jefferies *et al*. (1968); Mills (1984)
East Clevedon Gap	Head	Periglacial	Devensian (MIS 5d-2)	Hawkins (1972, 1977)
Holly Lane	Head	Periglacial	Devensian (MIS 5d-2)	Greenly (1922); Gilbertson (1974); Gilbertson & Hawkins (1974)
Wynhol	Head	Periglacial	Devensian (MIS 5d-2)	Gilbertson & Hawkins (1983)
Clapton Wick Nurseries	Coversands	Periglacial	Devensian (MIS 5d-2)	Gilbertson & Hawkins (1983)
Weston in Gordano	Head	Periglacial	Devensian (MIS 5d-2)	Apsimon & Donovan (1956); Hunt (2006f)
Weston Drove	? Debris flow	Periglacial	Devensian (MIS 5d-2)	Hill (2006)

3.4 Holocene palaeoenvironmental research in the Gordano Valley

Whilst previous Pleistocene research has been confined to the valley margins, research on the valley floor has concentrated on Holocene (MIS 1) environments and this is the only period for which absolute dates are available. The research of Jefferies *et al.* (1968), Mills (1984) and Hill (2006) revealed Pleistocene sands and gravels which thicken in the area of Weston Drove, suggesting the presence of a cross-valley sediment ridge which divided the valley into two depositional basins and was subsequently influential in the development of contrasting Holocene (MIS 1) environments (Jefferies *et al*. 1968, Hill *et al*. 2008). However, the coring methods used by Jefferies *et al.* (1968) and Mills (1984) had limited penetration of these deposits. Bedrock was not reached on any of their cores, maximum core penetration into the sands being approximately 4 feet (1 m), so it is uncertain what sediments lie beneath the 'basal sands'.

Jefferies *et al*. (1968) collected cores for pollen analysis from two sites near Walton Drove, shown as D.B.1 and D.B.2 on Figure 3.11. The 'basal sands' of these cores were described as variable in composition, reddish-brown or orange or coarse grey sand with a small clay fraction (Jefferies *et al*. 1968). Jefferies *et al*. (1968) tentatively concluded the 'basal sand' was waterborne, probably deposited during the last interglacial, and inferred a pre-Devensian (pre-MIS 2) marine episode, probably during the Ipswichian (MIS 5e) sea-level high stand, for their deposition. Similarities were noted between the 'basal sand', the marine sand and gravel at Kenn and marine clayey sand described by ApSimon & Donovan (1956) at Weston in Gordano (Jefferies *et al*. 1968).

Mills (1984) reconstructed Holocene (MIS 1) environments of the Gordano Valley from single core extracted from Walton Moor. This core penetrated 11 cm of Pleistocene minerogenic deposits, and particle size analysis carried out on the 'basal sand' showed it to be fine and well-sorted, similar to beach, rather than dune, sands. The sands exhibited considerable post-depositional alteration, which Mills (1984) interpreted as an indication of reworking by Devensian (MIS 5d-2) periglacial processes. She suggested possible soliflucted marine Pleistocene deposits similar to those described at Weston in Gordano by ApSimon & Donovan (1956). Pollen analysis of the 'basal sand' indicated cold stage rather than interglacial deposition as suggested by Jefferies *et al*. (1968).

Image withheld for copyright reasons

Figure 3.11 Coring strategy of Jefferies *et al*. (1968, Figure 1, p 337) showing transects (T1-T7) and location of cores DB1 and DB2 where samples were taken for pollen analysis. Note the increased density of coring west of Weston Drove, circled in red, assumed to coincide with the presence of thicker deposits of sand and gravel

Gilbertson *et al.* (1990) carried out a radiocarbon assay of the Mills' (1984) core which provided a date for the commencement of peat accumulation of 11020 ± 190 ^{14}C BP. This implies the subjacent sands are Pleistocene, although their origins are unclear. Either intertidal/sea-bed or aeolian origins were inferred from the (unidentified) microfauna, almost identical to that in the sands at Holly Lane which Gilbertson & Hawkins (1983) interpreted as being wind blown, and consistent with their sub-Arctic pollen suite dominated by open-ground herb taxa (Gilbertson *et al*. 1990). Overlying minerogenic sediments were attributed, on the basis of palynological evidence, to cold climate accumulation at the Windermere Interstadial/Loch Lomond Stadial transition (Gilbertson *et al*. 1990).

Hill (2006) describes two distinct sedimentary successions wherein Lateglacial sediments are spatially divided into contrasting environments, terrestrial to the west of Weston Drove and marine to the east (Hill 2006, Hill *et al*. 2008). Although not dated directly, a Devensian (MIS 5d-2) age was assumed for cross-valley sediments that confined the waters of a small lake approximately the area of Weston Moor (Hill *et al*. 2008). The western basin contains a typical hydroseral succession in which biogenic sedimentation began towards the end of the LGM between 15060 and 13820 Cal. BP, making it the oldest such succession in southwest England (Hill *et al*. 2008). Although Hill (2006) used a more systematic coring strategy, a 125 m grid, than that of Jefferies *et al*. (1968), this resolution was too coarse to locate precisely the boundary between the terrestrial and marine successions.

Jefferies *et al.* (1968), Mills (1984) and Hill (2006) all report a yellow-grey mud overlain in places by blue-grey clay containing a molluscan fauna indicative of slow-moving clean water between the Pleistocene sands and the overlying Holocene (MIS 1) peat. The extent of these minerogenic muds and their contained molluscan fauna is unknown and it is uncertain that these sediments are valley-wide deposits.

Jefferies *et al.* (1968) used a coarse sampling strategy of essentially seven cross-valley transects and one down-valley transect (Figure 3.11). From this, Jefferies *et al.* (1968) produced a simple contour model of the topography of the Pleistocene sands (Figure 3.12). This model suggests two basins separated by a raised area which follows the approximately the line of Weston Drove. Hill (2006) provides a slightly more complex topographic model of the Pleistocene sands to that of Jefferies *et al*. (1968) in which a number of depositional basins are depicted (Figure 3.13).

Image withheld for copyright reasons

Figure 3.12: Contour model of the 'basal sands' in the Gordano Valley showing two basins (Jefferies *et al.* 1968 Figure 2, p 337). Contours are in feet

Image withheld for copyright reasons

Figure 3.13: A. Area sampled by Hill (2006) outlined in red. Hatching on map shows area represented in Surfer® reconstruction. B. Surfer® reconstruction of surface topography of the Pleistocene sands (Hill 2006). Contour heights are in metres OD. Figures along the axes indicate distance down or across the valley in metres. C. Three-dimensional Surfer® reconstruction of surface topography of the Pleistocene sands (Hill 2006)

In contrast to Jefferies *et al*. (1968), Hill (2006) described orange-brown pebbly sand and gravels that coarsen upwards, and the basal sands were described as a mix of coarse orange-brown sand and angular to sub-angular clasts (Hill 2006). This probably reflects the different locations and depth of penetration of their cores. A local provenance was suggested, with sand provided by Old Red Sandstone from Clevedon-Portishead ridge and Tickenham ridge contributing Carboniferous Limestone (Hill 2006, Hill *et al*. 2006).

Although palaeoenvironmental evidence is limited regarding their provenance and mode of emplacement, the abundance of poorly sorted coarse sands and gravels allowed Hill *et al*. (2008) to speculate that deposition resulted from Devensian (MIS 5d-2) hillslope processes, with similar processes responsible for a valley-wide deposition of a thin layer of basal sands and gravels (Hill *et al*. 2008). Hill (2006) found the sorting of the basal sands incompatible with a beach environment and aeolian activity was precluded by the presence of gravel (Hill 2006). The sands and gravels were explained by Hill *et al*. (2008) as hillslope material redeposited from pre-existing glacial deposits (Hunt 1998a, 2006e) on the northern side of the valley combined with active gully systems immediately to the south (Hill *et al*. 2008). An overlying unit with a loess affinity but with some input from Carboniferous Limestone on the valley sides was redeposited from the valley sides via surface runoff (Hill *et al*. 2008).

Alternative interpretations are possible: firstly, no evidence is presented which suggests a flow direction from the northern side of the valley; it could equally have come from unconsolidated glacial deposits on the southern side of the valley (Hawkins & Kellaway 1971, Gilbertson & Hawkins 1978a, Hunt 1998a, Harrison & Keen 2005). Additionally, as the sequence of deposits at Holly Lane shows (section 3.4), the presence of gravel does not *preclude* aeolian activity; it does, however, make it unlikely to be the *sole* mode of deposition. As for dismissal of a beach explanation, if Hawkins' (1972) finding that East Clevedon Gap (section 3.4) is filled with Devensian (MIS 5d-2) head is accepted (Hawkins 1972, Gilbertson & Hawkins 1978a) then the valley would have been open to direct marine influence during Ipswichian (MIS 5e) and earlier times, providing a route for tidal ingress into the Gordano Valley, the deposition of beach material and removal/redistribution of earlier sediments. As Chapter 2 has shown, raised beaches are common in the Bristol Channel/Severn Estuary region where they are frequently correlated with Ipswichian (MIS 5e) sea-levels. However, given the narrow channel through which tidal ingress would be made, any beach is likely to have been preferentially deposited where the channel widens into the valley at East Clevedon Gap.

Previous research, summarised above, has revealed the presence of Pleistocene sediments that have clearly been influential in the subsequent development of the Gordano Valley. However, the full aerial extent of the valley floor Pleistocene minerogenic sediment suite remains unknown, whilst resolution of the sub-surface topography has been insufficiently refined to determine its morphology, particularly with respect to the apparent thickening of deposits around Weston Drove, and the age, stratigraphy, provenance and depositional environment of the valley floor sediments remain unresolved. Little information has been added to the understanding of the Pleistocene of the Gordano Valley over the past thirty years, despite an improved understanding of the rapid nature of Pleistocene climate change and significant developments in analytical techniques. Information on the Pleistocene valley floor sediments has emerged only through research on the valley's Holocene sediments, resulting in gaps in the current understanding of the Pleistocene evolution of the Gordano Valley, summarised in Table 3.2, which this thesis addresses.

Table 3.2: Gaps in the current understanding of the Pleistocene development of the Gordano Valley

Aerial extent of valley floor minerogenic sediments	Poorly known
Surface morphology of valley floor minerogenic sediments	Known only at poor resolution
Geometries of valley floor minerogenic sediments	Unknown
Stratigraphy of valley floor minerogenic sediments	Unknown
Age of valley floor minerogenic sediments	Unknown
Depositional environments of valley floor minerogenic sediments	Unknown

The Gordano Valley effectively forms a sediment trap, making local derivation of sediments a distinct possibility and their preservation potential high. However, the exposures described in section 3.3 are no longer visible or accessible and the sediment provenance and depositional mode remains speculative; little is known of the valley floor Pleistocene sediments or palaeoenvironments in the interval between the Middle Pleistocene and the Late Devensian cold stage prior to the Devensian (MIS 2) Lateglacial period (Hill 2006, Hill *et al*. 2008). In order to further the current understanding of their aerial extent, surface morphology, geometries, provenance, age and depositional environments, this thesis uses a high resolution approach to interpret the surface morphology combined with an intensive approach to interpret the geomorphology, stratigraphy and sedimentology of the Pleistocene valley floor sediments of the Gordano Valley. This is achieved by the application of the analytical techniques outlined in the next chapter.