The Physical Geology of Beavers

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Abstract: Wild beavers (*Castor* sp.) are set to return to Britain. Beavers appear to have been present during the Chelford Interstadial at Chelford c100 ka BP, and the physical nature of the beaver-created environment, including dams, lodges and lakes, is compared with modern Canadian sites. The chronology of beaver presence in Britain includes both extinction and reintroduction. Both the importance and implications of beaver activity on the character of the geological record associated with the fluvial sedimentology of floodplain environments is reviewed. A case study is provided from the Kennet valley floodplain in southern England. A greater awareness of beaver geology is advocated for an improved understanding of prehistoric floodplain stratigraphy, and for possible future riparian environmental management.

The year 2009 is a landmark in the history of arguably the most charismatic of Britain's lost species – the beaver. Eleven animals, in four families, were transferred in May from southern Norway to Knapdale Forest, in south west Scotland (NGR NR 800900), an area with several freshwater lochs. Their release into the wild will be the culmination of a protracted campaign by ecologists for beaver reintroduction into the British fauna, and has been won against ill-informed opposition from landowners and fishing organisations. If this pilot scheme is successful, it will undoubtedly lead to similar reintroductions in parts of England and Wales.

This paper has had a very long gestation period, as the writer's first encounter with beaver geology came in the mid 1970s in Cheshire, England, when tentative taphonomic evidence indicative of beaver presence was discovered in periglacial alluvial sands (Chelford Sands Formation) beneath glacigenic sediments (Stockport Formation) correlated with the Last Glacial Maximum (Worsley, 1967). At that time, silica sand quarrying at the Oakwood Quarry near Chelford was exposing the Chelford Interstadial sequence in its type area, and sections showed for the first time that the organic-rich interstadial sediments formed the infill of an incised palaeochannel system draining towards the northwest. Burial compaction of the infill by later sediments, and probably also through loading from glacial ice, had reduced an original thickness of several metres to some 0.5 m of felted peat and organic mud. A recent summary of the Chelford area Quaternary geology is given in Worsley (2005).

Abundant detrital sub-fossil tree fragments and stumps formed part of the palaeo-channel infill and these retained their original dimensions (<1.9 m in diameter) in contrast to the smaller branch fragments which showed significant flattening. Only rarely were tree stumps seen *in situ*. During quarrying, the operator separated the large material from the sand and peat and placed these in dumps. Recurrent examination of these dumps over a decade revealed that some of the tree stump tops were conical in shape, rather than being fractured, as is usually the case with snapped tree falls. These conical terminations appeared reminiscent of those reported in the literature as being the product of beaver tree felling. To test this possibility, a large cone-like tree stump (Fig. 1) was placed in the path of two separate field groups of over 100 participants when they visited the quarry during the Birmingham INQUA congress in August 1977. Without prompting

Figure 1. *A sub-fossil tree stump extracted from a flood facies within the type Chelford Interstadial sequence in the West Oakwood Quarry in east Cheshire. It has a conical top similar to those produced by beaver felling, but had later been subject to rolling during fluvial transport. It was exhibited to the visiting INQUA Congress field party in August 1977.*

and without exception, all the North American visitors opined that this stump was a product of beaver felling activity. In addition to the conical stumps, parts of the sand facies within the channel contained high concentrations of chaotically dispersed fragmented woody material along with the fruits of pine and spruce, suggesting an origin as flood debris. The question arises as to whether the flooding was climatically induced or was related to the bursting of a beaver dam.

Shortly after this meeting, the writer commenced an academic year in Ottawa, Canada, which afforded the opportunity for field studies of beavers in Ontario and Québec under both summer and winter conditions. The outcome of this experience was increased confidence in the hypothesis of beaver presence during the Chelford Interstadial. At a 1978 meeting of the Quaternary Research Association in Cambridge, which had a Quaternary vertebrate theme, a paper and allied demonstration of contemporary beaver-cut wood material together with some comparative Chelford material was presented (Worsley, 1978). Later field observations of beaver have been made in various parts of the Americas from the Mackenzie Delta in Canada to Argentinean Tierra del Fuego.

Beaver species

Beavers are classified as rodents and are assigned to the genus Castor. This genus normally consists of an Old and a New World species, namely the Eurasian beaver *Castor fiber* Linnaeus 1758 and the very closely related Canadian beaver *Castor canadensis* Kuhl 1820. . A globally extinct Giant Beaver, named *Trogontherium cuvieri* Fischer 1809 in Europe did not survive after the Middle Pleistocene (Hoxnian interglacial) in Britain (Mayhew, 1978) although a similar species, *Castoroides*, survived in North America until the commencement of the present interglacial c10 ka BP.

***Figure 2**. A short beaver dam built with neatly arranged branches on its downstream face, across a small creek in the Eardley Plateau, Gatineux National Park, Québec, Canada.*

The beaver environment

In his book *Mammals of Canada*, Benfield (1974, p158) wrote 'Almost every Canadian is familiar with the work of the beaver. It is one of the few animals, aside from man, that can profoundly change its own habitat, and for this reason it has earned the title 'engineer of the world''. Over two centuries earlier in Sweden, Carl Linnaeus wrote of the beaver - 'in the art of building he is surpassed by no living creature except man. With his admirable cleverness he regulates the level of the water outside his house, he digs channels and builds roads for the transport of his necessities from the forest'. Prior to twentieth century reintroduction, the beaver became extinct in Sweden c1870. Alas, few Britons are similarly informed, simply because their native beaver has been extinct for several centuries, and consequently an appreciation of the environmental impact of beavers is not normally part of their experience. Beavers are

***Figure 3**. The dam shown in Figure 2 impounded a lake within a forest, where the beavers had constructed a lodge that can be seen rising above the lake surface. To the right of the lodge, the top of a submerged pile of cut tree branches is the winter food cache.*

***Figure 4**. The beaver lodge in Figure 3, seen some 10 months later, in August 1978. The lake is now drained, and the full lodge structure can be seen with its foundations on the former lake bed. It is likely that the lake drained during the previous winter as a result of human interference with the dam.*

exceedingly industrious and apart from wood cutting to supply material for dam and lodge building and food stores, are also engaged in digging and transporting sediment, hauling clasts, and excavating canals.

There are numerous excellent accounts of beaver biology (Wdowińscy & Wdowińscy, 1975; Novak, 1976; Pinder, 1980 a & b; Coles, 2006; Cole *et al,* 2008). Accordingly, the emphasis here will be on physical environmental aspects of beaver ecology as these are directly related to the geological record; there are five main factors relevant to beaver physical geology.

Dams and allied lakes or ponds

Undoubtedly the most dramatic activity of beavers is their instinctive ability to construct dams across streams to create artificial lakes. In plan, dams are normally convex in the downstream direction. Typical lengths are in the 10-100 m range and heights from 2-3 m are common (Fig. 2); but there are exceptions, and lengths of over 200 m are known. Any kind of available material is used in dam construction, although the core is normally a network of tree branches. On the dam's upstream side, sediment ranging from stone clasts to mud is used to create an impermeable seal. In the lakes upstream of the dams, the beavers concentrate their daily activity and in particular use the water to float-transport wood material that they have cut. In regions where lakes normally freeze in winter, lake water depth is crucial, although even in severe winter climates annual lake ice rarely exceeds 1 m in thickness. Beavers have an uncanny ability to control the minimum water depth necessary for winter survival. The degree of dam building is dependent upon local circumstances; the more southerly populations in France tend not to be so dependent on dams, as they inhabit rivers with larger discharges and burrow into the banks.

Field observations on the Canadian Shield indicate two basic types of beaver lake, each depending upon the nature of the local bedrock relief. In high relief situations, such as a linear steep-sided valley, the main dam is usually a relatively short, high structure, and is augmented by one or more additional dams downstream, seemingly built as security features should there be a problem with integrity of the main structure. The lake upstream of the dam is usually linear in shape and contains a single lodge. In contrast, low relief areas necessitate much longer dams that tend to be lower in overall height. However, the upstream lake inundates a much greater area and may contain several lodges that accommodate more than one family. Significant areas of swamp commonly characterise the more distant lake shores from the dam. In the Gatineux National Park, Québec, lodges within the peripheral marshes have access afforded by beaver-dug canals over 120 m long. The lakes also enable extended foraging around the perimeter, but for safety considerations this is normally restricted to a zone about 60 m inland from the lake shore, except where canals have been dug enabling an extension of this zone to at least 100 m from the main shore. On average a single family has a territory extending for some 3 km along the valley axis. Creation of a new lake results in the flooding of the formerly forested, freely draining area. Any pre-existing vegetation cover will soon be killed and dead trees will protrude above the lake level for several years until they are felled by storm events.

Lodges and burrows

The lodge is built within the beaver lake and consists of a mixture of old sticks and mud. Average dimensions of lodges are <10 m in diameter and <3.7 m in height, although it has to be remembered that the lower part of island lodges are submerged (Figs. 3 & 4). Lodges

***Figure 5**. An in situ birch stump recently felled by a beaver in Gatineux National Park, Québec.*

***Figure 6**. A half-felled cottonwood tree in the Dinosaur Provincial Park, Alberta, with a pile of shavings produced by the beaver gnawing. Scale provided by Tom Worsley (aged 4); he was not impressed since when he went to bed the tree was intact, and the beaver gnawing had taken place overnight while he slept in a tent beneath the same tree.*

are entered via underwater tunnels excavated through the debris pile, and have an interior chamber with a platform just above lake level. The outer surfaces are invariably plastered with mud and short sticks. The apex is left clear as it acts as an air vent to the living chamber below. A lodge serves as both an insulated home in winter, and also as a refuge from predators. Typically, Canadian beavers construct their lodges either within the flooded zone (island lodge) or on the bank of a lake or stream where the sediment is soft. The latter can be fortified by a land-based structure of aquatic lodge form. Adjacent to the lodge, the beaver builds a submerged winter food cache in the form of a pile of cut branches, which may be nearly as large as the lodge itself. There has been some inconsistency in the older literature as to the behaviour of European beavers, even to the extent of suggesting that they do not build dams or construct lodges at all. It appears that neither is true, although some European beavers have a greater tendency to adopt natural bank cavities or create artificial burrows as lodges.

Gnawed and felled wood and stripped bark

Beavers fell trees in order to acquire branches for building their dams, food stores and lodges. Trees with diameters of over 1 m are within their capabilities, and once felled the branches are dismembered. A felled tree is left with a conical stump top 0.1–0.4 m high (Fig. 5) and the corresponding main trunk displays a similar conical end. Partially felled trees are common, suggesting that the beaver was disturbed while gnawing (Fig. 6). The area around the stump is littered with the curled shavings resulting from the beaver's wood cutting. As a source of winter food, beavers often strip the bark from branches too large to remove from the site of growth to their lake (though they feed on aquatic and herbaceous plants in summer). They also cut low scrub such as willow and birch, and similarly remove the bark for nourishment. Wood chewed or gnawed by beavers bears characteristic markings, which are known in the geological record as far back as the Cromerian.

Lake drainage and site abandonment

After a number of years the food resources around a beaver lake become depleted, and ultimately a beaver family will move to a new area. The existing dam will then be no longer be under beaver maintenance, and progressively seepage will lead ultimately to lake drainage. Alternatively, a catastrophic event might terminally damage the dam with rapid emptying of the lake. Within what would have been woodland prior to lake creation, the old lake bed will convert to a clearing within the woodland or forest. If the beaver does not return to the site, swampy organic-rich meadows can develop where grazing can retard tree recolonisation.

Outburst flooding consequent to dam failure

Extreme weather events can cause excessive inflows into beaver lakes so that the dams can be overwhelmed. Rapid drawdown of the lake water can lead to catastrophic flooding downstream. Butler (1989) reported that clasts up 1 m in diameter can be transported and that one particular flood event caused four casualties and deposited a survivor 4 m up in a tree! At various times, both Canadas' transcontinental railway lines have been severed by flooding consequent on beaver dam failure.

Dating of Colonisation and extinction

The earliest known natural colonisation by *Castor fiber* in Britain is from the Cromerian Interglacial (c0.5 Ma). A mass of beaver gnawed branches (Fig. 7) was found in a coastal exposure of the Cromer Forest Bed near Bacton, and was thought to be part of a dam (McWilliams, 1967). However, *C. fiber* may have been present as early as the late Pliocene. After the Cromerian,

***Figure 7**. Beaver-gnawed small-diameter branches that could easily be taken for contemporary material; these were obtained from the Cromerian interglacial sediments of the north east Norfolk coast and hence are some 500,000 years old (now in Castle Museum, Norwich).*

beaver appears to have been present in Britain during each of the subsequent warm (interglacial) stages (Stuart, 1982). One of the classic Palaeolithic sites of late Middle Pleistocene age (MOI Stage 9) at Stoke Newington, London, may have yielded beaver-cut birch branches. Lack of sites makes it difficult to assess whether beaver was able to persist during the intervening cold stages. Similarly, it is unknown whether it survived the Devensian LGM c20 ka BP, when permafrost was widespread in southern England. The crucial factor here would have been summer temperature, as the average July 10ºC isotherm determines the position of the treeline, and beavers thrive on continuous permafrost in the Mackenzie Delta, northwest Canada (Gill, 1972). If beaver was banished during the LGM, then it must have re-colonised Britain from southern or eastern refugia before the marine transgression (following the LGM low stand of -120 m OD) drowned the land bridge that crossed the site of the present English Channel. The critical threshold height in this instance would have been some -37 m OD, and initial submergence of this corresponds to global sea level at c 9.5 ka BP. Beavers appear never to have colonised Ireland.

The first chronologically well constrained indications of beavers after the LGM occur at the two most important Mesolithic (early post-glacial) settlement sites of Thatcham in the Kennet Valley and Star Carr in the Vale of Pickering. These sites date from the onset of Holocene interglacial warmth at respectively c10 and c9.5 ka BP, and both include beaver in their extensive faunal lists. Coles (2006) lists 26 radiocarbon assays on beaver bones and these bracket the 9.3–1.2 ka BP time span. Within the last thousand years, human overkill, and possibly also loss of habitat, are likely to have been the main causes of extinction. Beavers were hunted for their skins, meat and their glandular secretion (castoreum) for medicinal purposes (it has similarities to aspirin). The demand for beaver meat was enhanced in the medieval period since the Catholic church anomalously classified beaver meat as fish and hence it could be eaten on Fridays! The precise date of the extinction is debateable, but an early medieval date for England and Wales is probable. However a recent assessment of the historical documentary evidence has concluded that survival as late as the 18th century on the River Wharfe in Yorkshire is possible (Coles, 2006). Even on the European mainland beaver came perilously close to extinction due to hunting at the start of the 20th century, and similarly in North America the beaver was almost wiped out by 1930. Fortunately, following near extinction, more enlightened attitudes to conservation have resulted in dramatic recoveries on both continents.

Pioneer reintroductions in Britain

European beaver is the captive species now normally found in British zoos. In 1729, William Burnet, then Governor of New England in Boston, presented a young live beaver to a Mrs Clayton, a bedchamber servant to Queen Caroline. Later she was promoted to be Mistress of the Robes and was appointed Viscountess Sunden. Burnet wrote, '…which I have not heard has yet been seen in England. As this is a famous animal for its industry and policy, and, I think, peculiar to America … it will require to be kept within stone walls, or iron bars, or be chained, because it will eat through anything of wood …'. (Thomson, 1847).

At three British country estate locations in the late 19th century, Canadian beaver colonies were established. The first was in Sotterley Park, Beccles, Suffolk in 1870 but this was soon abandoned as the beavers escaped confinement and their tree felling activity was judged unacceptable. The second attempt was from 1874 in a pine wood enclosure near Rothesay on the Isle of Bute, but by 1890 they had died out (Black, 1880; Harting, 1880; Hawks, 1883). It is possible that the Bute colony consisted of at least some European beaver (Gibson, 1980). A third colony was created in 1890 at Leonardslee Gardens, southeast of Horsham, in Sussex (Loder, 1898). Here beavers were introduced into an enclosure on the floor of an incised valley where a dam was built and a burrow lodge was created on the shore. In 1896 the enclosure was extended downstream and a further but larger dam ensued, partially submerging the former. These beavers had either died out or were moved to zoos by 1948. Waterfall Lake, which is the successor to the beaver lake, has an island with the dimensions of a degraded beaver lodge in shallow water close to its shore. A successful attempt to breed *Castor fiber* was at the Norfolk Wildlife Park in 1973. Escaped beaver are known in recent decades in Essex, Somerset, Surrey and northern Scotland.

***Figure 8**. Trails in sandy sediment produced by beavers walking from a creek to the attempted felling site shown in Figure 6, in Dinosaur Provincial Park, Alberta.*

Under Article 22 of the European Union Habitats Directives (EC/92/43), member states are obliged to consider reintroducing species to their territory which were once present, and also those which are endangered. As Kitchener & Conroy (1996, p156) have observed 'unfortunately many of our extinct mammals are big and most have sharp teeth and claws, as well as a bad public-relations image'. Despite this, the directive has given an impetus to reintroducing the European beaver into Britain, aided by the fact that it is quite small and vegetarian (big teeth not withstanding). Scottish Natural Heritage is taking a lead role.

Geological consequences of the beaver

Probably the first suggestion that beaver activity might have important repercussions for Quaternary geological sedimentary process was advanced by Ruedemann and Schoonmaker (1938). Rudolf Ruedemann was engaged in geological mapping in the area east of the New York state capital of Albany. In hilly terrain he encountered a series of gently sloping alluvial plains forming valley floors that typically were 7-15 km long by 0.5-3.0 km wide. These plains had been previously interpreted as former lacustrine features, but the gradient and underfit of the drainage systems indicated that another process was influencing their fluvial geomorphology. Accordingly Ruedemann proposed that a dynamic complex of beaver dams constructed over post-glacial time had induced widespread aggradation on the valley floors. An original longitudinal profile through a succession of infilled ponds would have given a stepped profile, but with time the individual beaver pond infills would have merged to produce a more regional planar feature. He asserted that the importance of this animal-induced sedimentation had hitherto been overlooked, and illustrated this by noting that in Fenneman (1938), a just-published regional geomorphology textbook, beaver geological activity was not mentioned. Alas the same can be said for one of the more erudite recent American textbooks of geomorphology, Bloom (1991). Yet Ruedemann and Schoonmaker were able to observe that the United States Government policy to encourage beaver reintroductions in the northwestern states in order to naturally control river bank erosion ('beavers as loyal government officials') had reduced erosion at a cost of a sixtieth of a human-created structure.

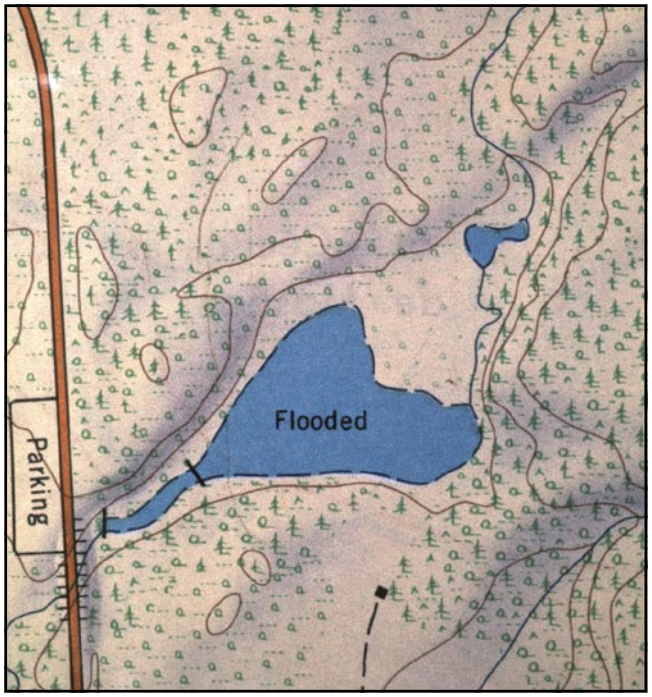

***Figure 9**. A beaver-dammed lake near Old Chelsea, Gatineux National Park, Québec. Of the two dams, one parallels the main road, while an upstream dam is seen in Figure 10.*

***Figure 10**. The beaver-created lake at Old Chelsea with the upstream of its two dams in the foreground.*

A development of the above idea came with a study of beaver meadows in the Rocky Mountains of Colorado (Ives, 1942). Extensive wet meadows were attributed to inheritance from former beaver lakes. Ives suggested that the infill sedimentation was characterised by a sedimentary architecture possessing a variant on the classic Gilbert-type delta with top, foreset and bottom set units. This mechanism was seen to be the dominant process of alluviation, rather than simply the infill of former glacial lakes. Ives was also aware that changing climate had previously enabled beavers to create meadows in areas that are currently beyond the limits of tree growth due to increased aridity; in these he claimed to be able to identify buried beaver dams.

Apparently unaware of the conclusions of Ruedemann and Ives, almost 30 years later, a Dutch geologist Martin Rutten observed that braided rivers were not restricted to periglacial environments but were also common in Mediterranean climates. But he observed that typically Alpine glaciated valley floors are much flatter than those due to braided river deposition alone. He also noted that braided rivers in Iceland and the Mediterranean were comparable in cross profile roughness. Thus he proposed that flat-bottomed Alpine-type valley floors could not be simply a product of braided river process nor a periglacial climate. An additional geomorphological agent was required - the beaver (Rutten, 1967). As European

***Figure 11**. A beaver lodge in swampy terrain at the inflow end of the beaver lake at Old Chelsea in Québec (map, Figure 9). Mud is plastered on the outside of the lodge, the food cache is adjacent, and beaver-excavated canals connect the lodge with the main lake.*

valley floors had long been settled and cultivated, the drainage networks were channelled artificially; hence he argued that an examination of natural river systems in areas such as displayed by the Bow and Columbia rivers in the Canadian Rockies might provide a better analogue for the former European alpine natural rivers. There, as expected, the floodplain marshes were heavily colonised by beavers. 'A beaver inhabited glacial valley is consequently characterised by horizontal, marshy bottoms, wherever its longitudinal gradient becomes so low that beavers are able to pond up the streams, separated by rapids of the braided river type where the gradient is stronger' (p357). Rutten augmented his analysis by comparing air photographs from Iceland and the Mediterranean (non-beaver areas) with the upper Columbia River in the Rocky Mountain trench where beavers are ubiquitous. In a postscript, he acknowledged that after submission of his paper he had been alerted to the pioneering paper by Ruedemann and Schoonmaker.

In assessing these conclusions, it is pertinent to recall that even today in North America beaver population levels are estimated to be only one tenth of those that prevailed before European human colonisation. Hence it is necessary to extrapolate by about an order of magnitude the contemporary scale of landscape modification due to beaver activity in order to gain a true appreciation of the role of beavers in geological processes in the modern valley floor sedimentary environment. It follows that there is a strong possibility that a similar conclusion could be applicable to Europe, at least in the early post-glacial prior to significant human modification of the landscape. It is salutary to consider this factor in the context of the Holocene floodplain sedimentary record.

Beaver lithostratigraphy in Britain

River Kennet case study, southern England

The notion that beavers *per se* might have influenced sedimentation in valley floodplains can be traced back at least to 1867. In that year, the Wiltshire Archaeological and Natural History Society convened a meeting in Hungerford, Berkshire. Two papers were presented and each independently suggested that the peats and calcareous marls (tufa) that occur extensively beneath the floodplain of the lower River Kennet might reflect wetland environments created by beavers' dam-building activity. The association of peat and beavers

***Figure 12**. The same lodge as shown in Figure 11, but 3 months later in the grip of winter. Unlike most of the year, winter affords the opportunity to walk up to the lodge – note the snow shoe prints in the left foreground.*

***Figure 13**. Ventilation hole in the summit of the lodge seen in Figure 12. Even at temperatures of -20ºC, the snow directly above the hole has melted, indicating that the body heat from the beaver family within the lodge below is sufficient to maintain a clear air passage, though hoar frost crystals have formed around the rim of the hole.*

was linked to the common occurrence of sub-fossil beaver bones within the peat along with material of other species and a range of Neolithic and Bronze Age artifacts. The discovery of these finds was due mainly to an extractive industry that required the hand digging of peat, which was in operation from before 1700 until about 1870. The peat was dried for fuel and also burned on site to yield ashes that were in demand as a fertilizer. A consequence of the extraction is that the floodplain landscape is heavily influenced by peat extraction, and at one locality the main Kennet river channel switches across its 'floodplain' on an embankment some 3 m above the adjacent fields.

A Rev John Adams of Stockcross (a parish northwest of Newbury) perceptively outlined the geology of the Kennet and stated 'may we not owe the peat of the Kennet valley in great measure to obstructions to the natural drainage caused by beaver's dams?' (Adams, 1869). In addition, Dr Silas Palmer (1878, p132) asserted 'The Beaver has been an effective agent in altering the conditions of river-valleys by his dams and weirs, and thus leading to the subsequent growth of peat, and often flooding and prostrating the forests in such valleys'. The next significant contribution was that of Harold Peake in his presidential address to the Newbury District Field Club in 1935. After reviewing all the previous literature pertaining to Kennet beavers, he claimed that their relict dams could still be identified in the floodplain landscape at Marsh Benham just west of Newbury and in the centre of Newbury town (Peake, 1935). Finally, Coles (2006) has suggested that unexplained 'trenches', revealed in earlier archaeological excavations at Thatcham and Newbury, might be relict beaver-dug canals. Surprisingly, when the area was mapped by the Geological Survey c1900, the origin of the peat was not addressed (White, 1907) and the same comment applies to the recent resurvey's explanation of the geological map (Aldiss *et al,* 2006).

A conundrum arising from the conclusions to John Wymer's Thatcham excavations relates to the concept that the low terrace bluff (on which most of the Mesolithic site was located) overlooked a lake; 'what is now a reed swamp is presumed to have been a stretch of clear water, probably a narrow lake' (Wymer, 1962 p336). It is suspected that comparisons with the roughly contemporaneous Star Carr led to the assumption that a lake must also have existed at Thatcham. Despite being a minor component, the presence of beaver in the fauna would have undoubtedly encouraged this thinking. Yet the allied geological study (Churchill, 1962) of the sequence in an open pit, dug through the modern reed swamp, revealed, below a surface peat, a bed of 'algal marl' consisting of sphaeroidal calcium carbonate concretions. In current terminology this is tufa, and Churchill made it clear that from his own observations that it forms in slow-flowing, shallow, hard, freshwater streams. Gravel was extracted from Thatcham Reedbeds below the Holocene floodplain and close to the excavation site in the 1970-80s, and this involved stripping surficial peats and tufa. Sections clearly indicated that the area had previously been dug for peat and that only a thin basal sequence remained, implying that the present day geomorphology reflects an abandoned mining landscape.

The presence of beavers, and parallels with Star Carr have led the archaeological community to favour a lake shore palaeo-environment. Cornwall (1969, p127) expressed the view that the presence of a thick calcareous marl 'certainly indicated a lake and a long phase of open water with a minimum of vegetation, for the material contained very little organic matter'. He enthusiastically asserted that there had been at least 2-3 m of 'deep water' forming a 'very extensive' lake. He attributed to F.E. Zeuner the suggestion that a beaver dam downstream towards Reading was responsible for the lake (perhaps he had read Peake, 1935!). Another

***Figure 14**. River Kennet floodplain stratigraphy, as exposed at the Thatcham Reedbeds in the mid 1970s, when the pre-Holocene gravels were being worked for aggregate after the cover of Holocene tufa and peat had been stripped away.*

Figure 15*. Section at the Thatcham Reedbeds showing a nearly vertical termination of the peat bed on the left. To the right, banked against the peat, is a complex of redeposited tufa and peat clasts that constitute an unlithified breccia. This section is interpreted as the limit to a former peat extraction site, with subsequent flooding and deposition in the old workings. This site lies within 250 m of the classical Mesolithic settlement site of John Wymer.*

worker supporting a beaver created lake at Thatcham is Evans (1975, p88), who considered that a lake was hard to explain solely on local topographic grounds. Yet despite this euphoria, the marl (or calcareous mud) is derived from tufa produced by an endothermic precipitation reaction in slow flowing water, a process especially active during warmer summer conditions; *i.e*., it signifies a river channel rather than a lake environment *per se*, (Collins *et al*. 2005). It appears that, in the Holocene, the Kennet floodplain was a dynamic network of channels, localised pools and swamps - a perfect beaver habitat. A complex of Holocene peats (= swamps) and tufas (= fluvial channels) accumulated across the floodplain and lapped onto the marginal terrace. Alas, any surviving dams remain elusive.

East Lincolnshire marsh

A possible example of an East Midlands site influenced by beavers occurs at Aby Grange on the east Lincolnshire marsh (NGR TF430798). This locality was investigated in one of the early papers that integrated palaeoecology and radiocarbon dating of late glacial deposits to establish the age of the last deglaciation of the east coast (Suggate & West, 1959). An irregularly shaped depression in till less than 1 km across was found to be capped by an extensive mottled silty clay. Auger holes and ditch sections showed that this clay overlies a late glacial sequence restricted to a small basin, the latter feature of possible kettle hole origin, being the focus of the study. However, the surface silty clay unit was 'interpreted as a rapidly accumulated deposit in a lake' and 'probably began … after a rapid rise in water level established a lake over the whole of the depression' (p265). Such a lake must have been controlled by the lowest point on the bounding perimeter at about 14 m OD. No further comment on the lake was made by the authors, as it was clearly postglacial in age and not relevant to their investigation. The mechanism for the flooding remains unresolved, but the field relations are such that it may be due to beaver dam activity.

Conclusion

It is clear that the effects of beavers on alluvial stratigraphy have been largely unappreciated. This is understandable in those areas that suffered beaver extinction some centuries ago. However, even in regions where beavers are common, the lessons that their presence ought to stimulate in the minds of physical geologists are often overlooked. The importance of beavers in influencing geological processes in floodplain environments is normally omitted in textbooks on fluvial geomorphology and sedimentology; this is to the detriment of a fuller and more realistic understanding of fluvial environmental change in the Holocene in particular.

The value of beaver dams in regulating stream flows, especially at times of high run-off, is rarely comprehended. In effect, the natural environment of those temperate regions currently lacking beaver because of overkill extinction are out of equilibrium with the longer term norm solely due to short-sighted human behaviour. An interesting question is whether the catastrophic impact of the flooding in parts of southern

Figure 16. *A beaver lake that has become a part of the landscape in the Canadian Yukon, with new shrub growth on the dam long abandoned by the beavers that built it.*

Figure 17. *Beaver at work in Alaska.*

England over July 19-20, 2007, would have been ameliorated if beavers still inhabited the floodplains. There is no doubt that beaver works check erosion and maintain the local water table, and on the longer timescale beaver meadows are a valuable resource for wildlife, grazing and cultivation.

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