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THE 'SUBMERGED FOREST' PALAEOSOLS OF CORNWALL

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INTRODUCTION

`Submerged Forests' have been remarked upon for centuries as one of the more interesting facets of the Cornish coastline and yet relatively little is known about them and the part they have to play in unravelling the vegetational history of the coast as well as helping to explain coastal development.

The available information, especially palaeobotanical, regarding Submerged Forests will be reviewed to elucidate what it can tell us about coastal processes. This will be supplemented by unpublished data from the 'Submerged Forest' at Pendower.

Quaternary palaeosols occur throughout Cornwall and offshore. The longest known is that of Reid's loam at Prah Sands (Reid, 1904) which lies within head strata and may be Devensian or earlier in age. Similarly an organic horizon within head at St. Loy has a radiocarbon date of 29,120+1690/-1400 years BP (Scourse, 1996). Other palaeosols are associated with archaeological structures, such as beneath Bronze Age barrows (Miles, 1975), are found overlying "tin ground" at the base of valley sections, or form distinct layers in valley or estuarine alluvium. Many of the valley sections were uncovered by tin-streaming operations, from the high moors to the sea, and were described in numerous nineteenth century papers including Henwood (1832) and Ussher (1879).

`Submerged Forests' refer to a group of palaeosols found beneath present-day offshore sediments and typically occur in the intertidal zone of most estuaries and bays (see Figure 1.). Their existence has been known for centuries and were first described in the mid-sixteenth century by John Leland (Toulmin Smith, 1964). On the infrequent occasions when they are exposed by storms and low spring tides 'Submerged Forests' excite local interest because of the conspicuous, often sizeable, remains of timber trees, both roots and tree trunks, which are generally well-preserved within the soil sediment. Similar tree remains have been reported farther out to sea, at a greater depth, at such places as Porthluny (Whitaker, 1792) or Maenporth (Enys, 1899) and these may be part of the same stratum. The most extensive deposits are known to occur within Mount's Bay (Borlase, 1758; Boase, 1827; Came, 1846).

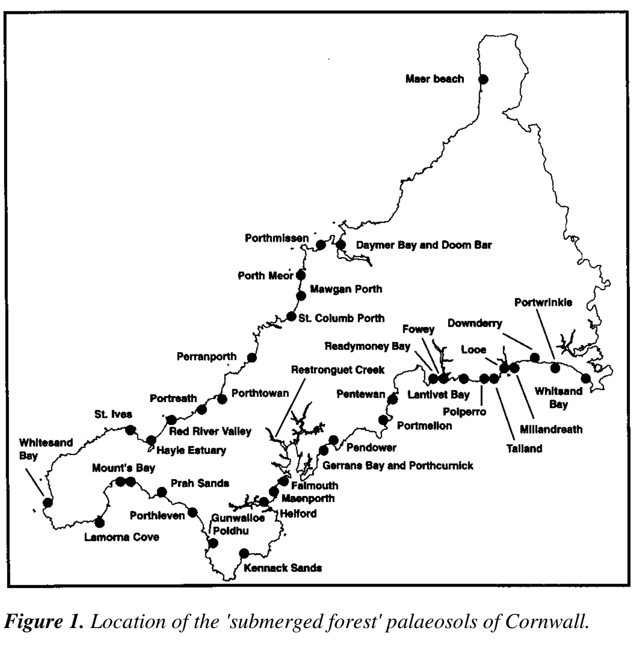

Figure 1. *Location of the 'submerged forest' palaeosols of Cornwall.*

`Submerged Forests' are developed on the Devensian land surface, such as the head deposits at Prah Sands (French, 1983), or on Holocene alluvium, such as in parts of Mount's Bay (Healy, 1995) or possibly beneath the Doom Bar in the Camel Estuary (Henwood, 1858). In a few cases these sub-fossil soils can be traced inland such as at Prah Sands and at Poldhu (shown by boreholes). A number represent, in part, a seaward extension of valley bottom marshes that still occur today such as at Marazion, Poldhu, Maenporth and Portmellon. In most cases the depth of organic sediments and the soil stratigraphy are not known. However, sizeable depths of 'peat' have sometimes been reported such as 7ft at Falmouth in 1871 (Robson, 1944) and *c.* 6ft at Portreath (Prof. A.C.Thomas, pers. comm.).

DATING

Dating 'Submerged Forests' has long proven problematical. Little archaeological evidence has come to light and it is imprecise. For example, a probable Iron Age pottery sherd was found in 1963 embedded in the clay of the Submerged Forest at Porthcurnick (Maxwell, 1965) and it was suggested this soil horizon was perhaps 2nd century B.C. At Prah Sands four tin ingots were found in 1974 reportedly from beneath the 'forest layer' of alder and oak (R.D.Penhallurick, 1986), indicating a post-Neolithic age.

The available ^{14}C dates for the 'Submerged Forests' also indicate that the intertidal sections are younger than 5000 BP but some may have begun forming much earlier as at Maenporth (Healy, 1995). The ^{14}C dated palaeosols include:

Maenporth	6110 +/- 85 (Q-2881)	-5.53 m O.D.
Mount's Bay	12070 +/- 80 (SRR 3022)	-32.0 m O.D. - Devensian late glacial.
Penzance (Gulval)	4278 +/- 50 (SRR 714)	
Penzance (Newlyn)	3656 +/- 150 (BM 29)	c. -1.6 m O.D.
Porthmellin	2345 +/- 100 (ST 3692)	-0.3 m O.D.
Ponsandane	680 +/- 50 (Q-2882)	+2.21 m O.D.
Ponsandane	1770 +/- 40 (James, 1990)	+2 m O.D.
Ponsandane	3050 +/- 65 (Q-2883)	+0.42 m O.D.
Prah Sands	1805 +/- 100 (ST 3694)	-2 m O.D.
Prah Sands	1290 +/- 70 (MAR 962) - wood from a layer under eroded dunes - probably above O.D.	
Prah Sands	1680 +/- 50 (Q-2372) - solid residue extract dated.	
Prah Sands	1570 +/- 50 (Q-2373) - humic alkali extract dated.	
St. Loy	29,120+1690/-1400 (Q-2414) - Devensian lacustrine sediment within head.	

The dates from Holocene, below O.D., palaeosols do not indicate when the soil was submerged, merely that the soil had not been inundated at the date given. Furthermore, the actual time of submergence could be substantially different for a number of reasons. For instance, the dated sample may not have been taken from the most recent stratum or that the sediments formed immediately prior to inundation are no longer part of the stratigraphy. Further dates from Marazion Marsh, however, suggest there was a period of rapid deposition of marine sediments after c. 4500 BP (Healy, 1996b).

STRATIGRAPHY

During the Devensian glaciation Cornwall was subject to periglacial conditions at a time when the sea level was c. 45m lower than present. The land surface was graded to this lower sea level and valley bottom gravels near the current coastline have been found at depths of more than -10m O.D. Soils developed on this land surface once the periglacial activity had ceased and they have been reported at Restronguet Creek and Pentewan at -13 m O.D. (Colenso, 1829) and in Mount's Bay at -32 m O.D (Taylor and Goode, 1987). Rapidly rising sea level would have overwhelmed these soils during the Devensian late-glacial or early Holocene period, and the rapidity of submergence is suggested by reports of oysters fastened to tree stumps (Colenso, 1829). Although trees had time to grow, as reported at Pentewan, these particular palaeosols are not normally thought of as the `Submerged Forest' because of their depth relative to O.D.

The 'Submerged Forest' beds are a much more recent phenomenon and are considered here to be separated stratigraphically and altitudinally close to O.D. This is best illustrated by studying the various sections taken around Mount's Bay. Within Mount's Bay the greatest expanse of 'Submerged Forest' is said to occur between Marazion Marsh and Newlyn with the largest continuous block found offshore between the railway station and Long Rock. Boreholes which most closely relate to this bed have been sunk on the land at Ponsandane, Longrock and Marazion Marsh (see Figure 2). Reid (1913) reported that the Mount's Bay 'Submerged Forest' was rooted in soil directly on solid rock. This is supported by the boreholes from Longrock and Ponsandane but not those from Marazion Marsh.

At Ponsandane (James, 1996) the peat which extends below O.D. is underlain by minerogenic sediments, chiefly gravel and clay which were considered to be alluvium. It is possible that the peat here represents a landward extension of the 'Submerged Forest' but no stratigraphic link between the two deposits has been demonstrated.

At Longrock a series of nine percussive boreholes sunk by the County Council in 1983 found a peat layer (0.5 - 1.5 m deep) at or just below O.D. with about a metre of sediment containing sub-angular or sub-rounded fragments between it and the well-weathered slate bedrock. Above the peat were layers of sands and rounded gravels which were between 4 m and 7 m in depth. The precise location of these boreholes is not known but the consistency of the peat band in these cores does confer a high probability that it is contemporaneous with the 'Submerged Forest' and suggests that the latter bed did extend farther inland prior to submergence. It also showed that a considerable amount of beach sediment was able to accumulate on top of the 'Submerged Forest' after submergence.

At Marazion Marsh (Healy, 1996b) a transect of boreholes parallel to the present beach demonstrated that the weathered bedrock formed two channels and the deeper parts were overlain by peat. This peat was succeeded by marine sediments (including sands and shells). In the deeper, eastern channel the marine transgression took place below -4 m O.D. and in the higher channel it occurred between -1.5 and -2.5 m O.D. A second peat band overlies the deeper channel at above 1 m O.D. and this is topped by further sand deposits. It is not known whether any of the peat bands in Marazion Marsh correspond with the 'Submerged Forest'. However, the depth of the peat deposit in the deeper channel would suggest that it could have been inundated at an earlier date.

Sections available from elsewhere in Mount's Bay, at Poldhu and Gunwalloe, further suggest that the sequence of events leading to the formation, submergence and preservation of the `Submerged Forest' palaeosol varied around the bay and there is no simple stratigraphy which explains the 'Submerged Forest' phenomenon.

At Poldhu borings made by the County Council in 1990 reached bedrock at around -8 m. This was immediately overlain by well-rounded gravel then by up to a metre of peat. The infill above was of dark blue sandy sediments, with several silty organic strata at intervals up the profile, culminating in an organic horizon about - 2 m (the 'Submerged Forest' layer). This was overlain by yellow sand - beach and dune sand. It is not known whether the blue sandy sediments are valley alluvium or marine in origin.

At Church Cove, Gunwalloe a 7.5 m deep core (French, 1996) did not reach bedrock. The basal sediments consisted of well-humified highly organic lake sediments and these were overlain by 6.5 m of minerogenic material with sand throughout. The pollen record indicates that open water remained until 70 cm from the surface. However, it is not possible to say whether marine sedimentation took place in this sequence or if brackish conditions were experienced. It is apparent that an important change in the sediment regime took place at -6.5 m and it is likely this was

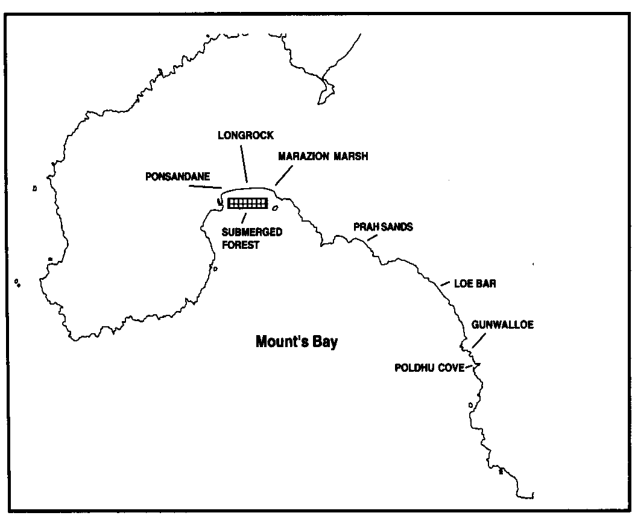

Figure 2. *Location of sites within Mount's Bay.*

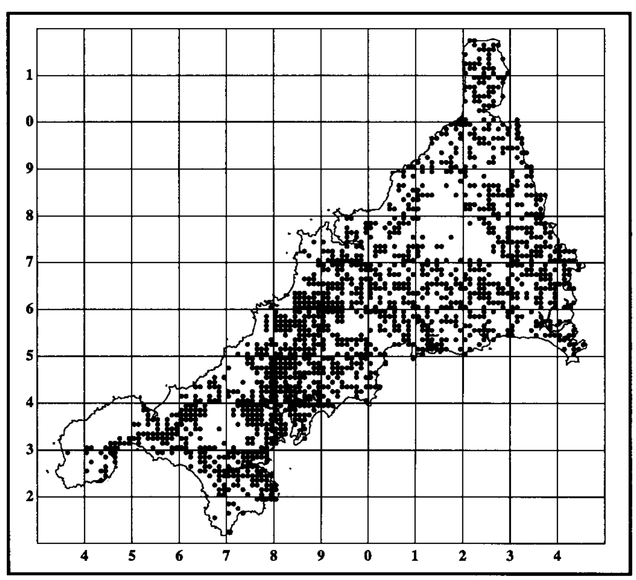

Figure *3. The present distribution of hazel (Corylus avellana) in Cornwall.*

triggered by changes in relative sea level and rising water table.

These sections point to a progressive submergence associated with the rising sea level. The deeper channels and valleys would have been subject to the influence of the rising sea level at an earlier date. The change from rounded gravels to peat at the base of the Poldhu section corresponds to a change from high energy levels associated with the gravels to a low energy environment of the peat. This may have been in response to the rise in relative sea level as was the change from organic to minerogenic sedimentation at Poldhu, Gunwalloe and Marazion Marsh. Where the rising sea level was kept at bay by sediment barrier structures (Healy, 1996a) the rising water table would have maintained poorly-drained freshwater environments on the landward side in which alluvium would have accumulated. At Marazion Marsh the sea breached the barrier structure and marine sedimentation began whereas at Poldhu and Gunwalloe alluvial deposition may have been maintained. These minerogenic sediments continued to accumulate against a backdrop of rising sea level and water table, although the rate of sea level rise was decreasing (Heyworth and Kidson, 1982), until a point was reached where organic deposits were able to form again as at Marazion Marsh and Poldhu where trees were able to grow. These were again overtopped by marine sediments at both sites.

At Longrock and the 'Submerged Forest' between Long Rock and Penzance the bedrock seems to form a shelf at higher elevation than the valley sections mentioned above. Here the organic deposits are on soil, alluvium or head and preserve an abundance of tree remains. The submergence event must have been dramatic for the trees to be preserved *in situ* and at Longrock this inundation reached farther inland than the present shoreline. Such a hypothesis is in accord with the breaching of barrier structures. After such a breach it also seems likely that the barrier reformed close to its present position between Eastern Green and Longrock.

The sand dunes fringing Mount's Bay can also be used as supporting evidence for sediment barriers which helped to determine the nature and timing of submergence. The dunes which overlie the Holocene palaeosol at Prah Sands are clearly younger than the underlying soil dated at 1290 +/- 70 BP and those within the valley at Poldhu are also relatively recent in origin. The extensive dunes at Mullion Golf Course, adjacent to Church Cove, Gunwalloe may also prove to be only a few thousand years old. Certainly, sand was not a significant part of the Gunwalloe Marsh stratigraphy below -6.5 m (French, 1996).

THE MACROFOSSIL RECORD

Large in situ tree stumps have been reported from many `Submerged Forests' and these and associated nuts and acorns are often in a good state of preservation, such that in 1792 the Revd. Whitaker reported that "a wheelwright about 100 years ago found one or two trees there [Pendower], and made three pairs of wheels out of them".

The macrofossils that have been identified do give an indication of the environment in which they grew and of the different habitats which comprise the Submerged Forests. Most of the available information is derived from nineteenth century descriptions. The vascular plants which have been recorded are shown in table 1.

It is likely that mistakes were made in the identification of some the macrofossils. Hazel nuts, acorns and pine cones are unmistakable whereas timber is much more difficult to identify. Hence, the records for yew and beech must be treated with caution until further evidence is provided.

The macrofossil record suggests that a number of different habitats were present. Bogbean, *Potamogeton* and white water-lily indicate that open water conditions existed at Portmellon and Maenporth, whereas *Equisetum fluviatile*, yellow iris, lesser spearwort, alder and willow

Alder	*Alnus glutinosa*	**Alder has been reported from Gyllyngvase (Claypole. 1870), Maenporth (Satchwell Roberts, 1896), Millandreath (Box, 1844), Mount's Bay (Boase, 1826 and Robson, 1944). Portmellon (Whitley, 1877 and Pascoe, 1970), Portreath (Pascoe, 1970), and in the Red River Valley at Gwithian (Stephens, 1899).**
Beech	*Fagus sylvatica*	**Beech occurred at Market Strand, Falmouth (Whitley, 1872). Millandreath Bay (Davey. 1909), Mount's Bay (Boase, 1826) and Polperro where large trunks "all in a recumbent position" were found (Couch, 1845).**
Birch	*Betide sp.*	**Birch was found at Market Strand, Falmouth (Whitley, 1872). Mount's Bay (Robson, 1944), Porthmissen Beach (Clarke. 1961) and Portmellon (Whitley, 1877).**
Hazel	*Corylus avellana*	**Thickets of hazel were identified in the sediments under the Doom Bar in the Camel Estuary (Henwood, 1858). Hazel has also been reported from Gyllyngvase (Claypole, 1870), Market Strand, Falmouth (Whitley, 1872), Maenporth Beach (Satchwell Roberts. 1896), Millandreath Bay (Pascoe. 1970), Mount's Bay (Borlase, 1758; Boase, 1828: Carne, 1846; Henwood, 1873 and Reid. 1913), Polperro (Couch, 1845). Porthcurnick (Maxwell, 1965). Porthmissen (Clarke, 1961) and Portmellon (Whitley, 1877 & Pascoe, 1870). Futhermore, extremely well preserved fresh-looking hazel nuts were exposed when deepening the lifeboat slipway within the harbour at St. Ives, c. 1995.**
Oak	*Quarcus sp.*	**Records of oak have come from the Doom Bar (Henwood, 1858), Gyllyngvase (Claypole, 1870), Maenporth (Satchwell Roberts, 1896 and Enys, 1889), Market Strand (Whitley, 1872), Millandreath (Box, 1844 and Pascoe. 1970), Mount's Bay (Kitchen. 1764; Boase, 1826; Came, 1845; Henwood, 1873; Enys, 1899; Reid, 1913 and Thurston, 1930), Pendower (Whitaker, 1792). Polperro (Couch, 1845), Porthcumick (Maxwell, 1985), Porthleven (Rogers, 1818 and Enys. 1899) and Portmellon (Whitley. 1877 and Pascoe. 1970).**
Pine	*Pinus sylvestris*	**Fir cones were found at Maenporth (De La Beche, 1839 and Satchwell Roberts, 1896) and pine was identified at Falmouth. (Robson. 1944), Mount's Bay (Boase. 1822) and Perth Meor (Lamb, 1909).**
Willow	*Salix sp.*	**Willow was observed at Maenporth (Rogers. 1832), Millandreath (Davey, 1909), Mount's Bay (Borlase, 1758; Boase, 1826: Ussher, 1879: Reid, 1913 and Robson. 1944) and Porthleven (Rogers. 1818; Rogers, 1832 and Enys. 1899).**
Yellow Iris	*Iris pseudacorus*	**Yellow Iris has been reported from Maenporth Beach (Rogers. 1832; Satchwell Rogers, 1896: Davey, 1909 and Pascoe, 1970), Market Strand (Whitley, 1872), Millandreath (Box, 1844) and Readymoney Bay (Peach, 1846).**
Misc.		**Ash (Fraxinus excelsior) at Millandreath (Box, 1844) and Mount's Bay (Boase. 1826); bogbean (Menyanthes trifoliate) seeds were found at Portmellon (Pascoe, 1970); bramble (Rubus sp.) seeds at Mount's Bay (Reid, 1913) and Portmellon (Pascoe, 1970); elm (Ulmus sp.) at Millandreath (Box, 1844 and Davey, 1909) and Mount's Bay (Boase. 1826); ferns were recorded at Market Strand (Whitley, 1872): holly (Ilex aquifolium) was tentatively identified at Millandreath (Box. 1844); lesser spearwort (Ranunculus flammula) at Mount's Bay (Reid, 1913): pondweed (Potamogeton sp.) seeds at Maenporth (Pascoe. 1970); Potentilla sp. at Mount's Bay (Reid, 1913); self heal (Prunella vulgaris) at Mount's Bay (Reid, 1913): water horsetail (Equisetum fluviatile) was present in the sediments at Poldhu (c. 1994): white water-lily (Nymphaea alba) was reported at Maenporth (Davey. 1909) and yew (Taxus baccata) at Gyllyngvase, Falmouth (Claypole. 1870) and Mount's Bay (Boase, 1826).**

Table 1. *Macrofossils recorded from 'Submerged Forest' palaeosols.*

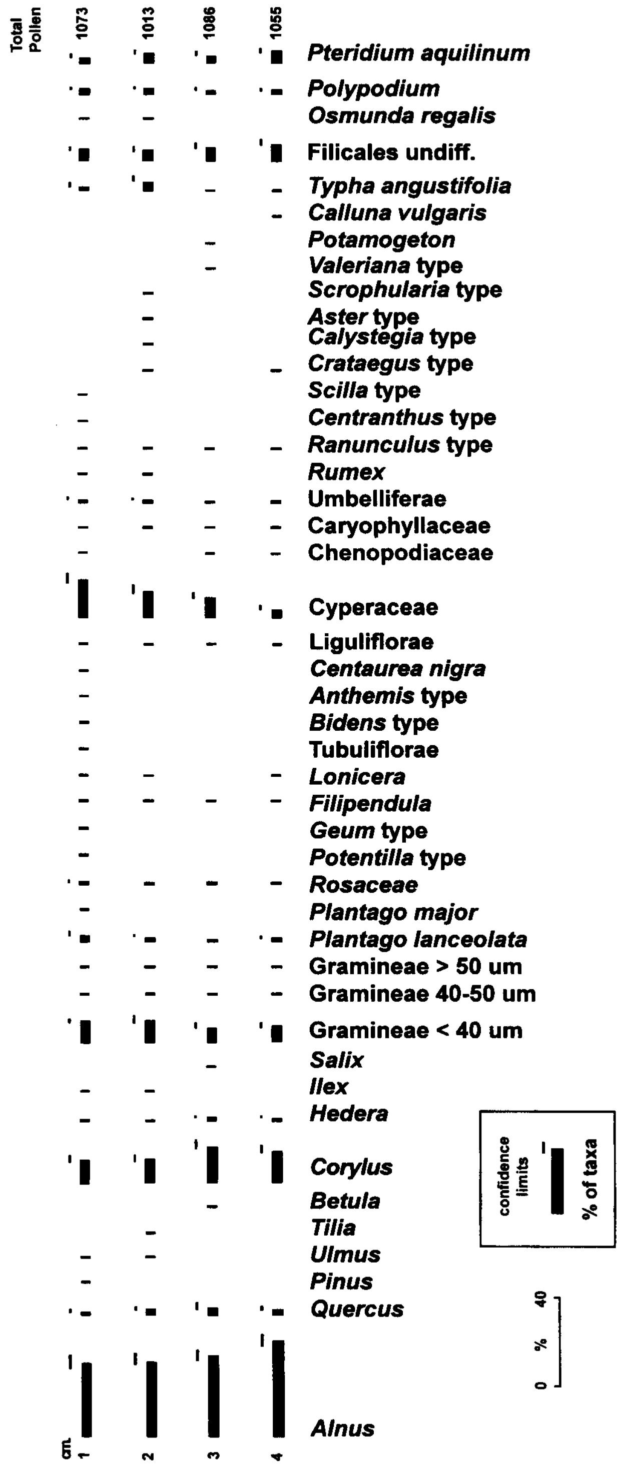

Figure 4. *Percentage pollen diagram from the 'Submerged Forest' palaeosol at Pendower [0.S. SW897381].*

point to marshy conditions and can being an important component of the 'Submerged Forest' communities. The remaining species are indicative of drier soils and are plants usually found at some distance (hundreds of metres) from the sea. Hazel in particular tends to grow away from the sea (see Figure 3) and prefers a dry substrate and sheltered conditions.

In a number of cases the species recorded in the 'Submerged Forest' are not found in the immediate vicinity today and indicate that the environmental conditions which once existed are no longer present. *Equisetum fluviatile*, for example, is not present in the Poldhu valley today.

THE POLLEN RECORD

Pollen analyses have been performed on a number of coastal sequences including St. Loy (Scourse, 1996), Marazion Marsh (Healy, 1995), Gunwalloe (French, 1996), Prah Sands (French, 1983), Chyandour or Ponsandane (James, 1992) and Pendower. The Holocene sequences point to the existence of a number of habitats in the vicinity of the 'Submerged Forests'. At Pendower (see Figure 4) the pollen rain is dominated by alder (*Alnus*) and hazel (*Corylus*) with significant levels of fern spores (Filicales, *Polypodium*, *Osmunda* and *Pteridium*). This indicates that the immediate vicinity was well wooded. However, the relative lack of oak (*Quercus*) and only a trace of pine (*Pinus*), elm (*Ulmus*), lime (*Tilia*) and birch (*Betula*) suggests that little woodland existed farther inland. Instead the varied herb and grass (Gramineae) content is consistent with an agricultural landscape. The area also had marshland present as indicated by such taxa as sedge (Cyperaceae), common valerian (*Valeriana*), reedmace (*Typha*) and meadowsweet (*Filipendula*) whereas pondweed (*Potamogeton*) demonstrates the presence of some open water. Proximal cliff-top communities are suggested by squill (*Scilla*) and ling (*Calluna*). The pollen evidence suggests that the `Submerged Forest' at Pendower was predominantly an alder carr with hazel being an important shrub in the locality. Grey willow (*Salix cinerea* ssp. *oleifolia*) is such a dominant feature of valley bottom marshes in Cornwall that one would expect it to form a significant proportion of the pollen rain. *Salix* is normally under-represented in pollen diagrams, although, its poor showing at Pendower does suggest it was only a minor component of the local vegetation.

The other Holocene pollen diagrams are all from around Mount's Bay and paint a similar picture of very localised coastal Alder-dominated wet woodland with little indication of extensive woodland inland, suggesting that much of Cornwall had already been cleared by Man. The diagram from Prah Sands demonstrates a steady decline in alder pollen showing a progressive and almost complete loss of alder-supporting habitat in the immediate vicinity. This decline is also shown in the basal sediments at Gunwalloe and at Ponsandane and although these events may not be synchronous they all point to the same process of loss of the 'Submerged Forest' community.

The pollen data do conflict with that of the macrofossils to a certain extent. Birch, beech and pine are found as macrofossils and yet their pollen count is so low as to suggest they were not present close to the pollen sampling sites. The occurrence of scots pine (*Pinus sylvestris*) at Maenporth is a real surprise as pine pollen is such a negligible component of the Cornish pollen rain of the last 5000 years. It is possible that the Maenporth sediments (Roberts, 1896) are older (early Holocene) and therefore more consistent with the presence of pine pollen.

THE DIATOM RECORD

Diatoms have been studied within the sediments of Loe Pool (Simola, 1981) and Marazion Marsh (Healy, 1995). Unlike pollen, diatoms are a sensitive indicator of salinity. The record from Loe Pool is much more recent than the 'Submerged Forests' but does indicate brackish conditions were prevalent until sometime after 1882 when the adit draining the Pool was reopened. At Marazion Marsh the earliest date for sedimentation occurs at -6.21 m O.D. and has an age of 5420 +/- 60 BP (Q-2779). The diatoms reveal the lower organic-rich sediments initially to have been laid down under freshwater conditions and that until they were transgressed by marine sediments sometime after 4400 BP the marsh was subject to rising water table and increasing salinity suggesting an increasing marine influence in response to rising sea level. The diatom record from the accumulation of marine sand and shells is dominated by marine-brackishwater diatoms but their influence declined as further organic-rich sediments formed near the surface. This latter horizon has been dated at 1210 +/- 40 (Q-2775) and 1610 +/- 40 (Q-2778).

CONCLUSION

The available evidence concerning inter-tidal 'Submerged Forests' suggest these palaeosols include a variety of habitats such as woodland, marshland and freshwater/brackish lagoons, and there is no simple stratigraphy which explains either their formation or the sequence of events leading to their submergence.

Coastal woodland was clearly an especially important component of the vegetation at numerous low-lying locations around the coast and it existed when much of the rest of Cornwall had already been cleared of forest by Man. For such a woodland to survive suggests that the area in which it grew was not worthy of clearing - an alder can with poorly drained marshy soils. There does not appear to be a close modern analogue of this `Submerged Forest' woodland community in Cornwall. It seems likely that this woodland developed when the sea was at a distance, as suggested by the hazel content, and for it to be maintained over any length of time, the area in which the trees grew, was not subject to frequent incursions by sea water. However, the diatom record from Marazion Marsh suggests that prior to final inundation, the influence of the sea became progressively more apparent. Furthermore, once submergence had taken place, the 'Submerged Forest' strata remained beneath sea water or marine sediments, thus ensuring the preservation of the soil and timber remains.

There is no reason to suppose that the inter-tidal 'Submerged Forest' beds were all submerged by the same event. It is more likely that local circumstances controlled the nature and timing of submergence and the resultant stratigraphic succession. Sediment barrier structures, which protected the low-lying areas from the sea, are considered to be especially important in determining the way in which the rising sea level was able to inundate the coastal lowlands. Indeed, they may have been instrumental in the formation of the 'Submerged Forest' community itself, by maintaining the poorly drained conditions which favoured the growth of alder can.

ACKNOWLEDGEMENTS

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