Paper Session 1

Late Quaternary Records of Rapid Coastal Change

in Southwest England

Late Quaternary Coastal Change in West Cornwall, UK

M.G. Healy, Department of Geography, MIC, University of Limerick, Republic of Ireland

Introduction

A wide variety of evidence for long term coastal change in Cornwall has been reported in the literature. Records of raised beaches, marine platforms and shoreline notches, coastal erosion, geographic coastal alteration and the submergence of organic-rich sedimentary horizons are reported in documentary sources (e.g. Borlase, 1758; de la Beche, 1839; Wunsch, 1895; Robson, 1944, 1950; Everard *et al.*, 1964; James, 1976; Wilson, 1975; Taylor & Beer, 1981; Goode & Taylor, 1988). The most commonly quoted evidence for changing sea-levels relates to rock platforms and raised beaches. Many examples of each type of feature are easily recognised on the coast of Cornwall.

More recent work by Healy (1993, 1995a) has examined records of relative sea-level change within embayed lag environments which lie to the rear of coastal barriers. The nature of these records appears considerably influenced by processes related to coastal morpho-dynamics. Back-barrier stratigraphies tend to consist of crudely intercalated organic-rich and sand-dominated horizons. Typical sediment sequences (e.g. Marazion Marsh, Maenporth Marsh, Hayle Lelant, Hayle Copperhouse) consist of a substantial basal organic-rich layer resting directly on bedrock which is overlain by a long marine sand deposit. The latter is succeeded by further organic-rich sedimentation before sand returns to predominate in the stratigraphy to the present marsh surface (Healy, This Volume). Microfossil evidence from these sequences indicates changing vegetation patterns and salinity levels adjacent to stratigraphic boundaries (Healy, 1995a). These changes are interpreted as reflecting alterations in barrier dynamics, coastal sedimentation and relative sea-level.

In addition to coastal process dynamics, the influence of anthropogenic activity has had a significant effect on the palaeogeography of the Cornish coast. Documentary evidence indicates a variety of land use practices linked to industry and agriculture which influenced coastal geomorphology. Chief amongst these was the impact of metalliferous mining (Dines, 1956; Healy, 1995b, 1996; Healy & Patel, This Volume; Pirrie, This Volume), which resulted in the transport of substantial volumes of terrigenous sediment to the coast via rivers and streams. Though efforts to effectively constrain associated rates and volumes of sedimentation in the coastal lowlands continue (e.g. Pirrie, This Volume), the precise contribution of anthropogenically generated sediments to the coast is not yet known.

Evidence for palaeoshorelines

Raised beaches resting on bedrock platforms or periglacial deposits are widely reported in Cornwall (Figure 1). The following examples demonstrate the nature, and confusion, of available reports. Arber (1960) describes surfaces "cut into Head deposits at 50ft and 100ft O.D." on the banks of the River Taw, near Barnstaple. Arkell (1943) describes a raised beach at Trebetherick Point "being 50ft O.D.". Raised beaches "at 50ft and at 100ft" have been reported by Round (1944) at Marazion, Mount's Bay. Hendricks (1923) has referred to similar features "at 150ft and 160ft at Helston and Porthleven respectively". According to Clarke (1963) Pleistocene and Holocene strandlines standing at "150ft, 120ft, 100ft, 88ft, 65ft, 50ft, 25ft and 15ft O.D" are identifiable along the Padstow Estuary area of the north Cornish coast.

What is clear from available records is that a series of 'stepped' palaeoshorelines can be identified along the Cornish coast. It would appear that their number is considerably exaggerated by their fragmentary spatial occurrence (James, This Volume). Problems of interpretation are increased by a degree of confusion which can be attributed to the lack of a common reference datum and the varied nomenclature used in early published accounts of these features. This view is supported by the work of Stride (1962) on submarine platform features in the south Irish Sea. McKenna (1990) finds similar exaggeration of numbers of such features on the coast of Northern Ireland.

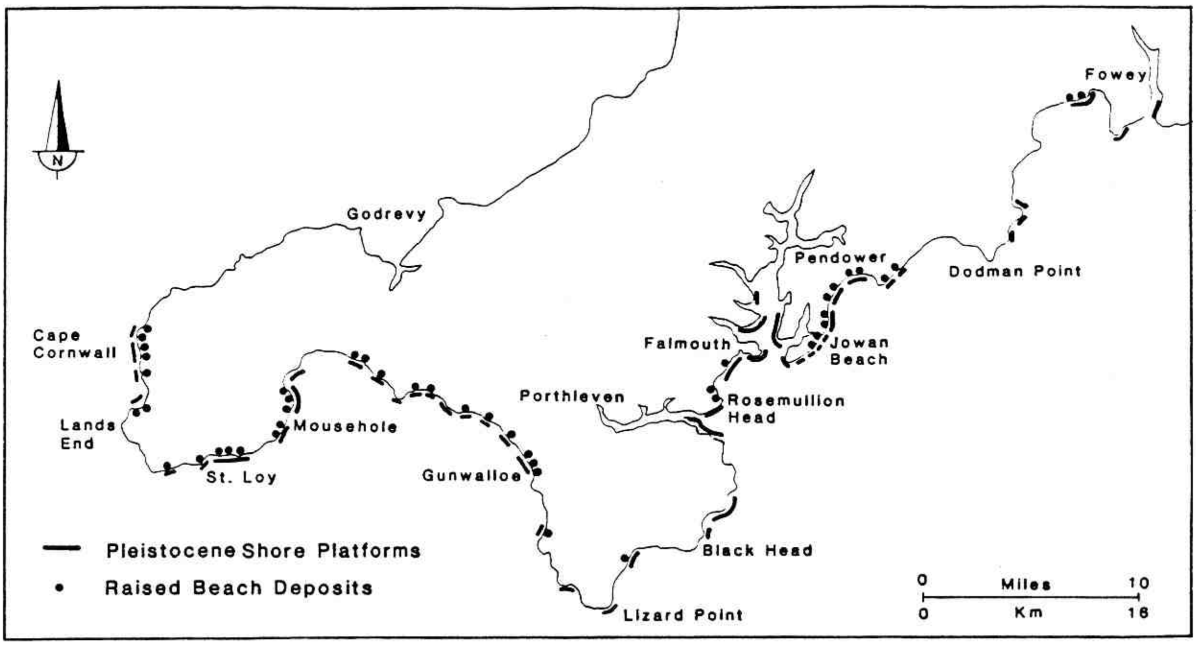

Figure 1. Documented shore platforms and raised beaches in west Cornwall

In addition to the problems of spatially associating individual palaeoshoreline fragments, dating raised beach deposits remains difficult (Mook & van de Plassche, 1986). Several authors have attempted to address this problem (Mitchell, 1960, 1972; Bowen, 1969; Stephens, 1970; Jardine, 1981). Radiometric dating using shells or shell fragments is precluded by the general absence of suitable material from both raised beach and 'head' , making radiocarbon dating impossible. Even in cases where shell material may be available there are serious difficulties in dating remains from what may be a mixed death assemblage (Andrews, 1987). The only remaining possibilities are amino acid racemization (Andrews *et al.*, 1979; Davies, 1984)), optical luminescence dating (James, 1995) and altitudinal correlation of raised platform fragments underlying the raised beach deposits (Mitchell *et al.*, 1973; Mitchell & Orme, 1967).

In the absence of effective dating and correlation techniques to date, as well as the lack of a mechanism which clearly links raised beach stratigraphies to water reference levels, the relationship between palaeoshoreline features and past sea levels remains poorly constrained.

Holocene coastal sediments

Evidence from biostratigraphic, palaeoecological and lithostratigraphic studies suggests that coastal evolution in Cornwall has been linked to the development and subsequent behaviour of morpho-sedimentary structures (Healy, 1995a). In the present day few of these structures remain active. However, remnant sand and gravel barriers at many sites (Figure 2) such as at Maenporth, Porthmellon, Hayle, Porthleven and Newquay, and within Mount's Bay at Loe Bar, Marazion, and Ponsandane, indicate that barrier structures may have been significant in controlling the evolution of the west Cornwall coast through to the present day. Documentary evidence makes clear that modern barrier remnants were once larger structures (Boase, 1822), which have been progressively destroyed under the influence of marine erosion and anthropogenic pressure.

The mechanisms by which morpho-sedimentary structures form and evolve has given rise to considerable debate in the literature. Under the influence of relative sea-level rise in a sediment-rich environment during the mid Holocene period, conditions for medium-coarse clastic barrier formation appear favourable. It is likely that crenellate coasts, typical of west Cornwall, particularly favoured the development of structures hinged to headlands. The evolution of spits, hinged on a single headland, into barriers which created embayments between pairs of headlands, appears likely under the influence of longshore sediment transport where sedimentary material was plentiful. The role of these structures in creating and preserving freshwater environments within embayments in the early to mid Holocene period

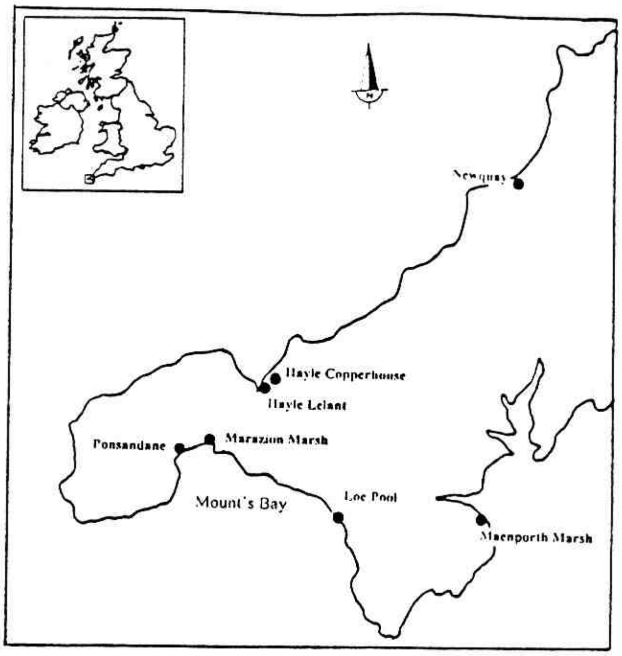

Figure 2. Site locations in west Cornwall

appears significant. Data from a number of sites examined by Healy (1993) in west Cornwall (Hayle Lelant, Hayle Copperhouse, Maenporth Marsh, Ponsandane, Marazion Marsh) suggest that such structures played an important part in determining the palaeogeography of the coast.

The earliest Holocene sediments recovered from coastal sites in west Cornwall (Figure 3) consist of organic-rich materials resting on weathered bedrock (see later paper by Healy, This Volume). Quaternary materials of younger age are absent from the depositional basins investigated, though periglacial sediments frequently occur on adjacent slopes. Basal organic-rich horizons originated in freshwater

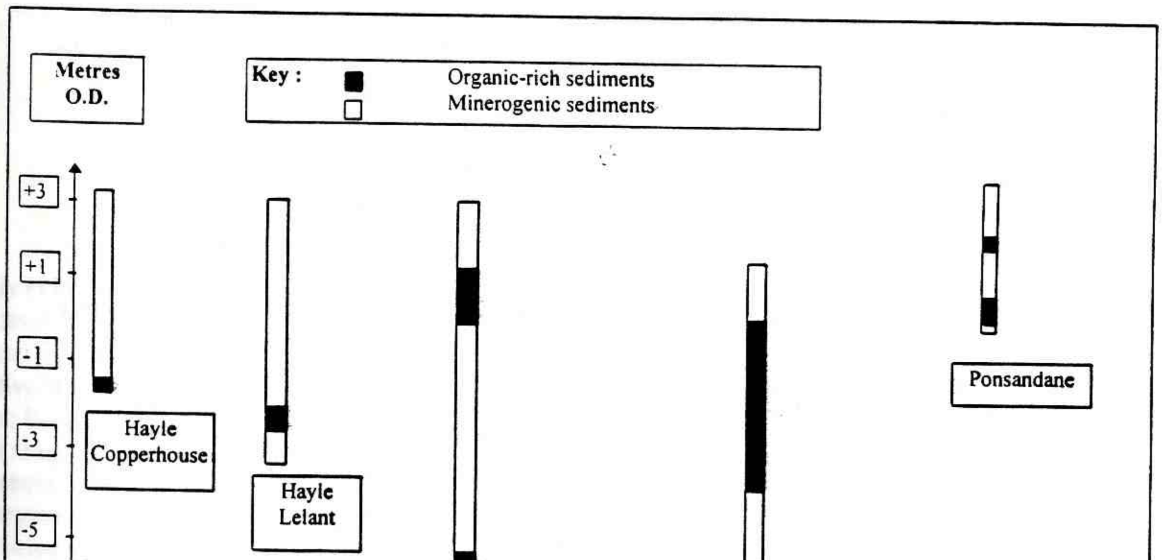

Figure 3. Altitudinal variation in the occurrence of organic-rich sediments in west Cornwall

environments. Evidence from studies of pollen and diatom assemblages from several sites supports this view (Healy, 1993, 1995a). While freshwater conditions prevailed trees dominated the vegetation. The main components of the arboreal vegetation correspond closely with those documented in reports of 'submerged forests' from the Cornish coast. *Alnus, Corylus* and *Betula* were common, along with *Quercus* and *Salix*. A variety of other tree and shrub pollen also occurs, though frequencies are generally low. It is unlikely that dry ground conditions prevailed other than on localised, elevated areas within marsh environments and along their margins. Herbaceous and aquatic plant pollen frequency indicates that groundwater levels were high. This facilitated the deposition of sediments rich in biological fossils, which formed the 'peats', commonly reported as outcrops on the foreshore as 'submerged forests'. It is likely that such freshwater conditions occurred within coastal embayments to the rear of protective coastal barriers (cf. Jennings & Orford, This Volume).

Microfossil evidence clearly shows that a transition from freshwater to brackishwater conditions occurs in the upper levels of basal organic-rich strata. Diatom assemblages change from oligohalobian to mesohalobian and eventually to polyhalobian dominated sequences towards the surface of the basal sediment layer. This pattern is evident at Marazion Marsh and Hayle Copperhouse. It appears that this transition is due to an increased marine influence linked to some degree of failure of protective sedimentary structures. Morpho-sedimentary stability may have been affected by changing relative sea-level and/or alteration in coastal process dynamics and sediment supply.

The surface of organic-rich basal deposits shares a sharp erosive contact with a substantial marine sand layer which forms several metres of stratigraphy at Marazion Marsh and Hayle Copperhouse, as well as other sites reported by Healy (1993). This sand deposit is rich in marine shell material. Adult and juvenile forms of *Cerastoderma edule, Littorina littorea, Macoma balthica* and *Hydrobia ulvae* were identified, along with large quantities of fragmented and comminuted shell material. Particle size analysis of sand samples from sequences recovered at Marazion Marsh and Hayle Copperhouse reveals a general fining upward trend. However, significant variation was observed within this trend, with well defined sub-suites of poorly sorted coarse sands occurring within the generally fining sequence (Healy 1995a). Results from Marazion Marsh and Hayle Copperhouse compare well, suggesting that controls on patterns of sand deposition may have been extra-local.

It appears that the initial period of sand deposition was relatively short. Stratigraphic and lithological evidence suggests that the first marine inundation of these sites was rapid. The deposition of long sediment sequences is considered concordant with the infilling of depositional basins. It is argued that the failure of protective morpho-sedimentary structures provided a mechanism by which rapid large-scale coastal inundation occurred. Radiocarbon dated organic-rich horizons from sites within Mount's Bay define a period of inundation as having taken place between *ca* 4,450 and 4,230 BP. A similar chronology of events is suggested by evidence from the Hayle Estuary sites. However, site-specific conditions may have had a significant influence on the timing of renewed organic-rich sedimentation where it occurred.

Stratigraphic, palaeoecological and documentary evidence indicates that the role of morpho-sedimentary controls on coastal evolution was not limited to a single period. Data from Maenporth Marsh, Hayle Lelant, Marazion Marsh and Ponsandane show that renewed organic-rich sedimentation occurred following the deposition of long marine sand sequences at these sites. There is no palaeoecological evidence to suggest that their development was linked to salt marsh growth. Rather, pollen and diatom data indicate that they were insulated from direct marine/peri-marine influences, with increasingly freshwater conditions predominating during their early development. Similarly to basal sequences, palaeoecological evidence for an increased marine influence becomes apparent prior to subsequent deposition of additional marine sand sequences. This pattern is particularly evident at Maenporth Marsh and Hayle Lelant. The evidence appears in keeping with the presence of temporary protective structures which controlled stratigraphic patterns at these sites. Present day observations, supported by historical documentary evidence, show that the remains of sedimentary structures perform similar functions at several coastal sites in a modern context (Marazion Marsh, Maenporth Marsh, Loe Pool).

Holocene relative sea - level change

Holocene relative sea-level movements in west Cornwall were dependant on both macro-scale coastal controls and site-specific parameters. The majority of the sites investigated by Healy (1993) are subject to high-energy impacts from wave, tide and wind behaviour. Evidence for the prevalence of high energy controls is demonstrated by the coarse nature of the lithostratigraphic record (e.g. Marazion Marsh, Hayle Lelant, Maenporth Marsh). Few of the sites retain sedimentary sequences consisting of intercalated silt/clay and organic-rich strata which typify estuarine sites or intertidal flats elsewhere in the U.K. Minerogenic sediments are mainly of a medium or coarse clastic nature. Many of the organic-rich strata are composed, in varying proportions, of minerogenic fines with organic remains (Figure 4). The occurrence of peat, *sensu* Troels-Smith (1955), is relatively rare.

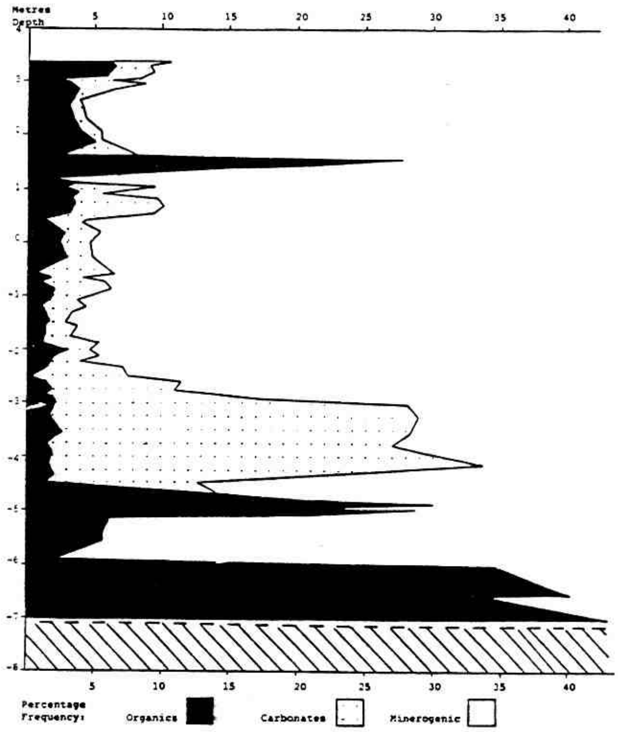

Figure 4. An example of the relative proportions of organics, carbonates and mineral sediments in a core from Marazion Marsh

Healy (1993, 1995a) uses ^{14}C-based time-altitude analysis to demonstrate the record of Holocene relative sea-level movements in west Cornwall (Figure 5), arguing that the pattern of recovery was dependent on coastal barrier dynamics. Within this scenario coastal barriers may have 'damped' the influence of rising relative sea - level, allowing organic-rich sediment to accumulate at, or even below, prevailing sea-level. Biogenic sedimentation may not necessarily be linked to tidal cycle controls, and variations in tidal range and amplitude may be only indirectly significant in this context. The main environmental influence in this situation would be controls on watertable levels in protected coastal lags and embayments. Subsequent destabilisation or breaching of protective barriers would have facilitated an increased marine influence to be brought to bear on back-barrier sedimentation. The culmination of this process was the inundation of embayed sites by marine sediments in the form of coarse, shell-rich sands and gravels. Subsequently, renewed organic-rich sedimentation occurred where barriers reformed further onshore, once again insulating embayed sites from direct marine influence.

Until recently, the regional pattern of recovery proposed by Heyworth & Kidson (1982) has represented a best approximation for west Cornwall in the absence of local relative sea-level studies. Their interpretation is based on five 'corrected' curves, from the Bristol Channel, the English Channel, Cardigan Bay, the Somerset Levels Trackways and north Wales (Figure 6, Curves A-E). They argue that, with the exception of north Wales, 'no real difference' exists among the curves when 'the inherent uncertainties' and the use

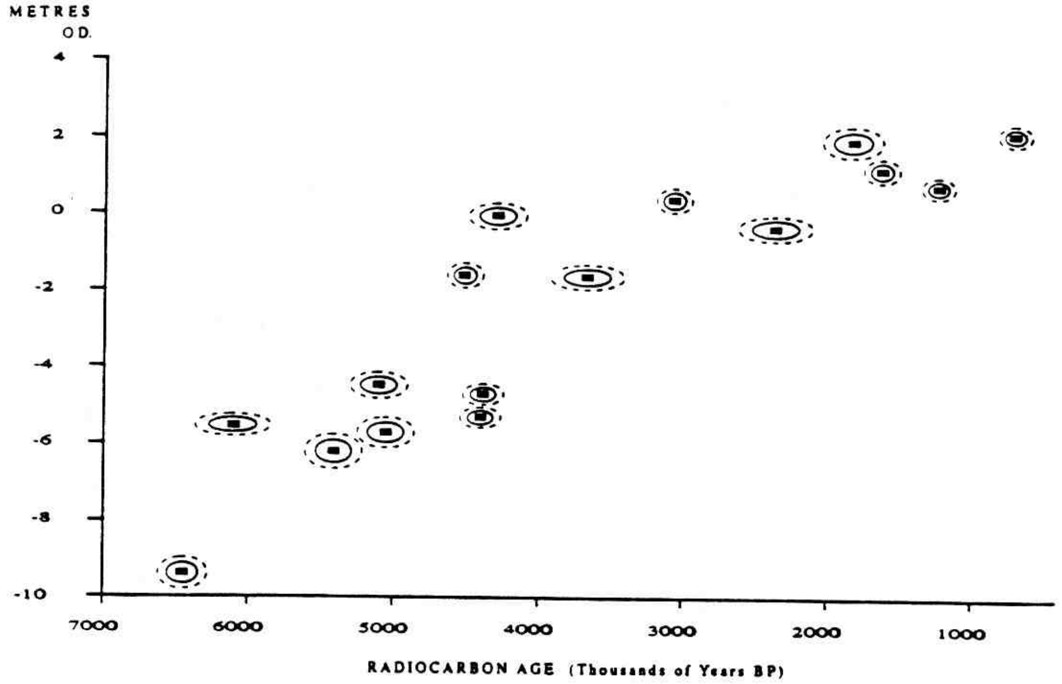

***Figure 5a.** The pattern of relative sea-level recovery in west Cornwall based on ^{14}C age determinations. Ellipses represent estimated time/altitude error range*

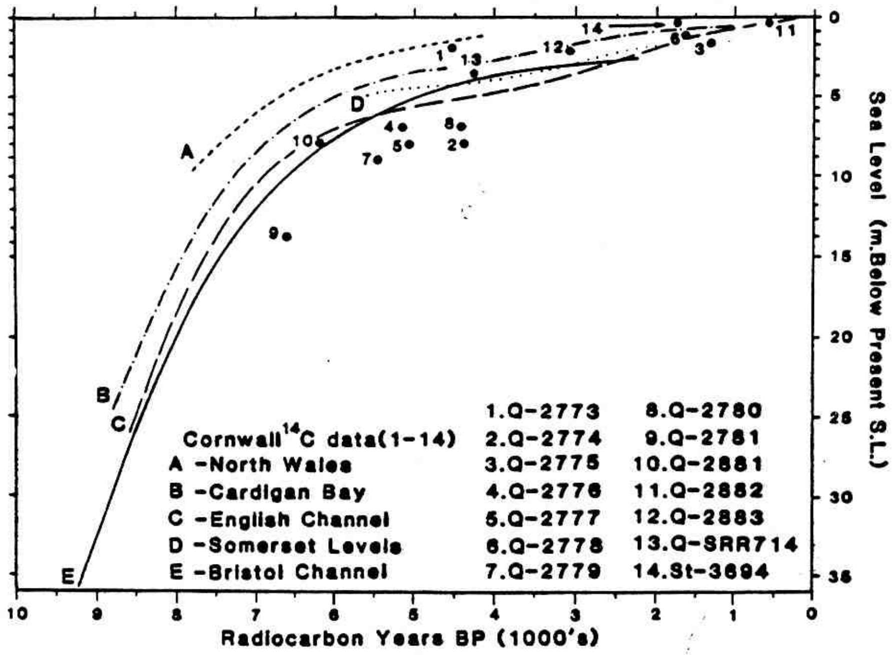

***Figure 5b.** ^{14}C age determinations from west Cornwall (adjusted to MHWST) plotted against Heyworth & Kidson's (1982) regional curves A-E*

'of present-day MHWST (mean high water spring tide) as the common reference datum' (Heyworth & Kidson, 1982, p 110) is taken into account. However, Healy (1995a) argues that the sea-level index points used by Heyworth & Kidson may mask considerable site-specific variability among the records used to produce regional relative sea-level curves.

It is evident that a broad correspondence in the overall pattern of relative sea-level behaviour exists between west Cornwall and the regional curves (Figure 5b). However, it is clear that organic-rich sediments accumulated at substantially different altitudes on the Cornish coast (Figure 3) before *ca* 4500 BP. The accumulation of these deposits at altitudes lower (notwithstanding post-deposition displacement) than those indicated by the regional relative sea-level curves proposed by Heyworth & Kidson (1982) suggest that other controls, in addition to relative sea-level / tidal cycle position, were important. The processes which governed relative sea-level recovery on the west Cornwall coast, as well as the larger set of controls which determine the nature of coastal evolution, may provide alternative perspectives on coastal behaviour in southwest England in the Holocene period.

Anthropogenic influences

There is substantial evidence that the activities of human populations along the coast of west Cornwall have had a significant impact on late Holocene coastal development. Documentary sources make clear that coastal sediments were used as a resource, being removed in large quantities for the purposes of agricultural manure and building materials. In the early nineteenth century it appears that these activities were already a source of coastal management concern in Mount's Bay coastal districts (Boase, 1822).

An additional human impact on the coast was the influence of mining activities. The exploitation of metalliferous ores in Cornwall dates back to the prehistoric period (Goode & Taylor, 1988). This activity generally reached its peak in the early nineteenth century (Dines, 1956), by which time the excavation of china clay was under way in some districts (St. Austell, Par, Pentewan, Carlyon Bay).

Sediments which display specific colour characteristics (red / brown / grey / green / black) with sub - laminar patterning have been identified at a number of coastal sites in Cornwall, including Marazion Marsh (Healy, 1995b, 1996), Loe Pool (O' Sullivan, This Volume, 1983; O' Sullivan *et al.*, 1982; Pickering, 1982; Healy, 1996; Coard *et al.*, 1983; Coard, 1987; Coard & O' Sullivan, In Press) , Hayle Copper House (Healy, 1995b, 1996), Fal Estuary (Pirrie *et al.*, This Volume) and the Red River catchment at Godrevy (Patel, 1996; Healy & Patel, This Volume) as well as other locations. Geochemical analyses of sediment samples retrieved at these sites reveal that certain stratigraphic horizons contain concentrations of heavy metals which lie well outside the expected or 'normal' range associated with precipitation from weathering processes. Documentary sources show that intense mining of metalliferous ores, particularly for tin and copper, occurred in headwater areas of river and stream catchments, as well as in alluvial gravels within depositional basins. It is concluded that mine waste sediments have contributed substantially to coastal sedimentation processes on the coast of west Cornwall in the nineteenth century and subsequently.

Historical documents which describe mining activities and production figures for individual mines (e.g. Dines, 1956) provide quite detailed information on which volumes of mine waste may be calculated. This information has a twofold potential in the field of coastal studies. Firstly, volumes and rates of mine waste reaching the coast at particular sites may be calculated, at least for some defined periods in the past. The impact of these materials through time on the coastal sediment budget, and ultimately on the palaeogeography of the coast, may be quantitatively assessed. Second, it is possible to identify well defined peaks in metal concentrations within mine waste sediment sequences. Using documentary evidence for peak periods of mine production and / or records of mine waste release from headwater areas, there is potential for accurate dating of sediment fluxes on the coast. With further refinement, this methodology may represent a new means for evaluating and interpreting the human influence on coastal evolution in the late Holocene period.

Conclusion

It has been possible to identify a number of sediment provinces which are the product of distinct spheres of activity in the evolution of the coast of west Cornwall. Three primary sedimentary provinces are recognised :

1. Sediments which accumulated in embayment lag environments; these are primarily organic-rich deposits which retain substantial palaeoenvironmental data in the form of biological micro- and macrofossils. They occur at various altitudes both as basal and interleaved horizons within coastal stratigraphies.

2. Sediments which are the product of marine inundation of the coast; these consist mainly of quartz-based sands which contain both well preserved and highly macerated carbonate materials in the form of marine shell remains. A variety of particle size suites and sorting, skewness and kurtosis characteristics occur within these sand sequences which generally exhibit a fining upward pattern.

3. Sediments which are the product of human activities within or adjacent to the coastal zone; these are primarily sub-laminated minerogenic fines with distinct coloration and geochemical signatures. They form identifiable stratigraphic suites.

It appears likely that morphodynamic processes produced protective barrier structures which influenced the relationship between organic sedimentation and the tidal cycle at the majority of embayed sites on the Cornish coast. Such processes may have had a profound influence on the expression of relative sea-level data in a time/altitude context. The precise impact of anthropogenic activities on recent coastal processes and sedimentation currently remains unknown.

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