SOURCES AND CHARACTER OF SAND SIZED MATERIAL ON THE BAR COASTS

Compiled by D. Robinson, map data by U. Dornbusch. Edited by C. Moses

1 Introduction: the distribution of beach sand

Sand sized material is a widespread component of the Channel Beaches. It is most abundant on the French side of the Channel where there are extensive stretches of predominantly sandy beach backed by sand-dunes, especially in the northern part of the BAR coast from the mouth of the River Authie, northwards to the border with Belgium (**Figure 2**). Of the 283 km of coastline from Cap Antifer to the Belgium boarder, 132 km are occupied by sand beaches (46.6%) and a further 18 km (6.4%) by discontinuous fringing and pocket beaches of sand beneath chalk cliffs (**Figure 1**). In contrast, on the English coast, shingle beaches are the norm, occupying 58% of the BAR coastline (99 km) with continuous stretches of sand beach restricted to a few localities and accounting for just 8.5% (16 km) of the coastline. In addition, along both the French and English coasts, extensive aprons of sand occupy almost the entire lower foreshore, except where well-developed rock-cut, inter-tidal shore platforms lie beneath cliffs. There is also a significant component of sand, averaging in excess of 25% by weight within the sub-surface layers of the shingle beaches. Along both coasts of the Channel, the prevalence of sand and sandy beaches generally increases northwards and eastwards along the BAR coasts.

Cliff/beach material	Cliff (km)	Beach (km)	Foreshore (km)
Chalk	114		101
Sandstone	23		9
Lowland	20		
Sand continuous	115*	132	173
Sand discontinuous		18	
Shingle continuous		55	
Shingle discontinuous		71	
No beach			

Figure 1: Cliff and beach materials along the French, BAR coast (283 km)
* dunes
Continuous = continuous unbroken band of either sand or shingle.
Discontinuous = discrete pockets of sediment e.g. fringing beaches under chalk cliffs

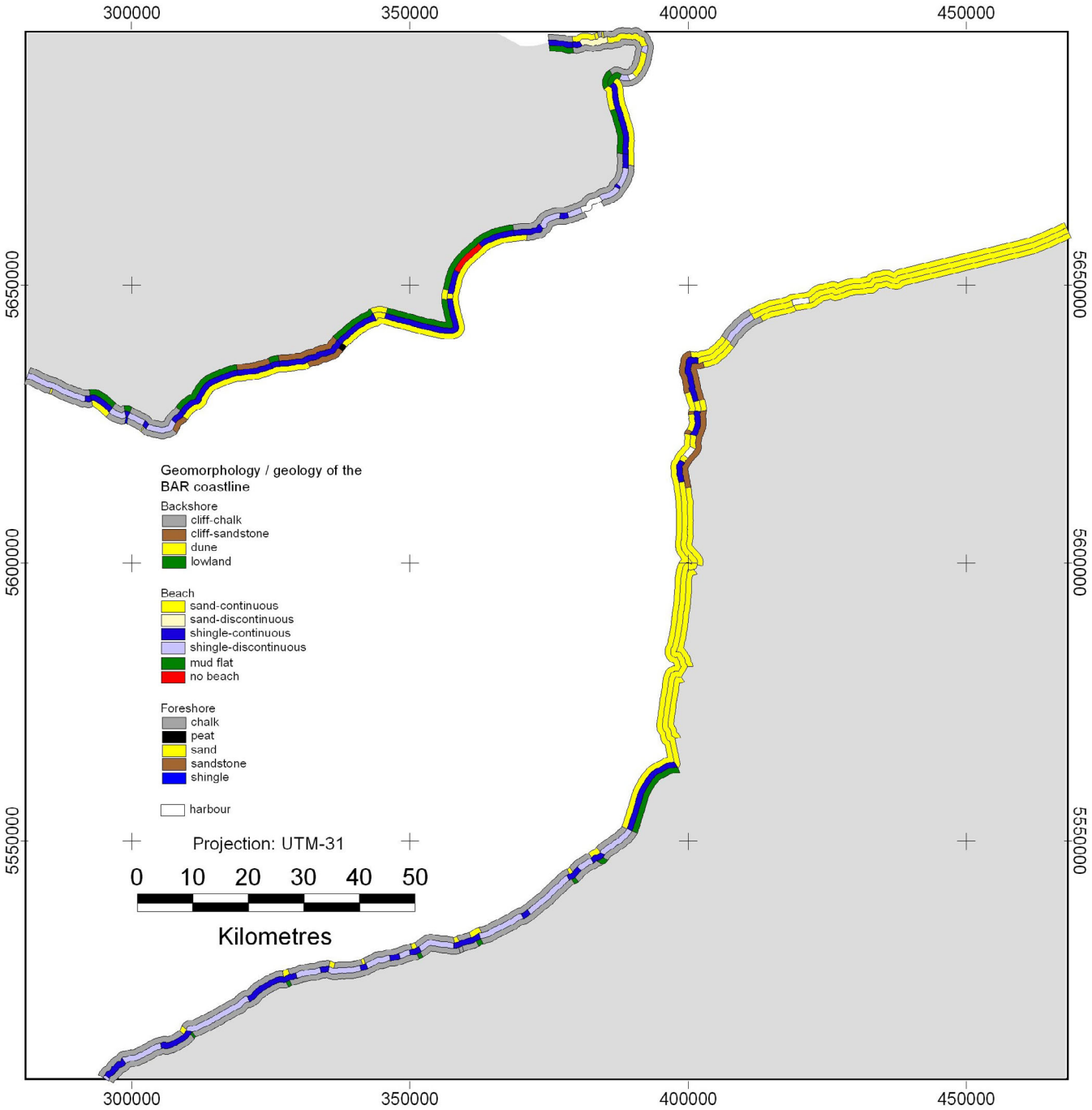

Figure 2: Geomorphology/geology of the BAR coast

In addition to the beach sand forming the present day beaches there are also significant accumulations of sand in fossil sand beaches beneath the major accumulations of shingle at The Crumbles and Dungeness on the English coast and the Cayeux Spit on the French coast (Greensmith and Gutmanis, 1990; Jennings and Smyth, 1990; Long and Hughes, 1995; Long et al., 1996).

Cliff/Beach material	Cliff (km)	Beach (km)	Foreshore (km)
Chalk	76		72
Sandstone	18		10
Lowland	84	3**	1***
Sand continuous	9*	16	99
Sand discontinuous		5	
Shingle continuous		109	1
Shingle discontinuous		42	
No beach		6	

Figure 3: Cliff and beach materials along the English, BAR coast (187 km)
* dunes: ** salt marsh: *** peat
Continuous = continuous unbroken band of either sand or shingle.
Discontinuous = discrete pockets of sediment eg fringing beaches under chalk cliffs.

2 Beach sand deposits

The beaches contain a considerable range of sand size, varying both with the position of the sand component on or in a beach and with the local source of sand. Sand within shingle beaches tends to be coarse grained, often angular to sub-angular, testifying to its relatively 'youthful' nature. On sand beaches the sand is finer, more 'mature' and rounded. In some localities the finer component is winnowed by winds to form dunes, landward of the beach. Sand aprons are predominantly fine grained and often mixed with silt and even clay sized material, especially where the beach overlies clays such as at Pevensey Bay in East Sussex, or where deposited in quiet water environments.

3 Sources of sand

3.1 On shore

A considerable range of rock strata that make up southeast England contain sand sized material and provide a variety of potential sources of supply of sand to the Channel beaches.

A proportion of sand is provided directly by marine erosion of sandy substrates exposed in cliffs (**Figure 1**, **Figure 2** and **Figure 3**). These are exposed for distances of 23 km along the French coast and 18 km along the English coast, comprising c.9% of the BAR coast. The most significant areas where they make a local contribution to beach sand are where undefended high cliffs of sandy Wealden Beds outcrop at the coast, notably between Hastings and Cliff End on the East Sussex coast, where high cliffs up are retreating at a relatively fast but as yet unquantified rate. Not only is the rate rate of retreat not known with any accuracy, but neither has the proportion of sand substrates exposed in the cliffs has not yet been estimated and therefore the contribution that the retreat of these cliffs makes to the sand content of the beaches remains unknown. However, erosion of the sandy Ashdown Beds exposed along this stretch of coast at Fairlight Head and Cliff End are thought to be a major supplier of sand to the extensive sandy beach and dunes at Camber which lies to the east.

The second source of sand sized material are the Tertiary beds that are exposed along parts

of the Channel coast. Although predominantly composed of clays, these strata also contain beds of sand. They outcrop along the coast immediately west of the study area where the coast is known to have suffered rapid erosion for much of the historic period (Robinson, 1999; Robinson and Williams, 1983), retreating by as much as 7 km along some stretches (Brandon, 1974; Castleden, 1996). Remnants also overlie stretches of the chalk exposed in the cliffs along both the French and English BAR coastlines from where they reach the beaches by both marine erosion and sub-aerial degradation of the cliffs.

A third source are the extensive deposits of Quaternary coversands, sand rich coombe deposits and sandy brickearth that overlie large stretches of the West Sussex coastal plain and the chalk downland. These deposits still cover large stretches of the coastal margins of the Channel coasts both along the BAR coastline, especially in the vicinity of Thanet and along the low lying coast of West Sussex. Deposited during the cold periods of the Quaternary, these deposits were formally much more extensive (Catt, 1977; 1978) but they have mostly been removed by fluvial erosion from much of the interior, particularly of south east England. A large proportion of this material now infills the lower valleys of the rivers that drain into the Channel (Burrin, 1981), but in the past, an unknown proportion possibly reached the sea to contribute fine sand and silt to the beach environments.

However, at the present day, although details of the sediment load of the rivers that drain into the Channel is limited and what little exists suggests that they carry very little sand-sized sediment to the coast (Anthony, 2002; Collins, 1981; Hamblin et al., 1992). This is despite the fact that the headwaters of many of the rivers are eroding sand rich, Wealden strata, especially in southeast England. Contemporary fluvial input is limited seemingly because the major rivers have drowned estuaries and all but the finest sediment is deposited before the rivers reach the sea. However, sandy sediment brought down by the eastern Rother to Rye is may contribute to the supply of sand that maintains the sandy beach and dunes at Camber on the Kent-Sussex border. On the French coast, estuaries such as the Somme and Authie are sand sinks rather than deliverers of sand sized material (Anthony and Dobroniak, 2000).

3.2 Off shore

Whilst sources and supply of sand from onshore sources seems limited, there are abundant sources of sand offshore (**Figure 4**). The floor of much of the Channel and southern North Sea is covered in mobile deposits of sand comprised of large tidal sand ridges, smaller sand ripples and sand waves(Hamblin, 1989; Hamblin et al., 1992; Larsonneur et al., 1982). Individual ridges exceed 20 km in length and are up to 6 km in width and up to 50 m in thickness, the sand waves between 1.5 and 4 m in height. These mobile sediments lie on an eroded surface dissected by palaeoriver channels that declines gently westwards (Curry, 1989). The sands are generally composed of predominantly well rounded quartz grains, with a little feldspar, mica and heavy minerals. The upper 5-10 m of sand are predominantly fine to medium grained and very well sorted At greater depth they are predominantly medium to coarse grained (Anthony, 2002). They are thought to be largely Pleistocene in age and polygenetic in origin. There are three main sources from which the sands are believed to derived; i) erosion of the floor of the sea bed and cliffs during repeated periods of marine transgression; ii) winnowing of sea-bed lag gravel deposits, and iii) fluvial inputs from erosion and transport from the surrounding land areas during periglacial conditions, especially by the Thames, Rhine and Seine rivers, all three of which debouche into the southern North Sea and eastern Channel.

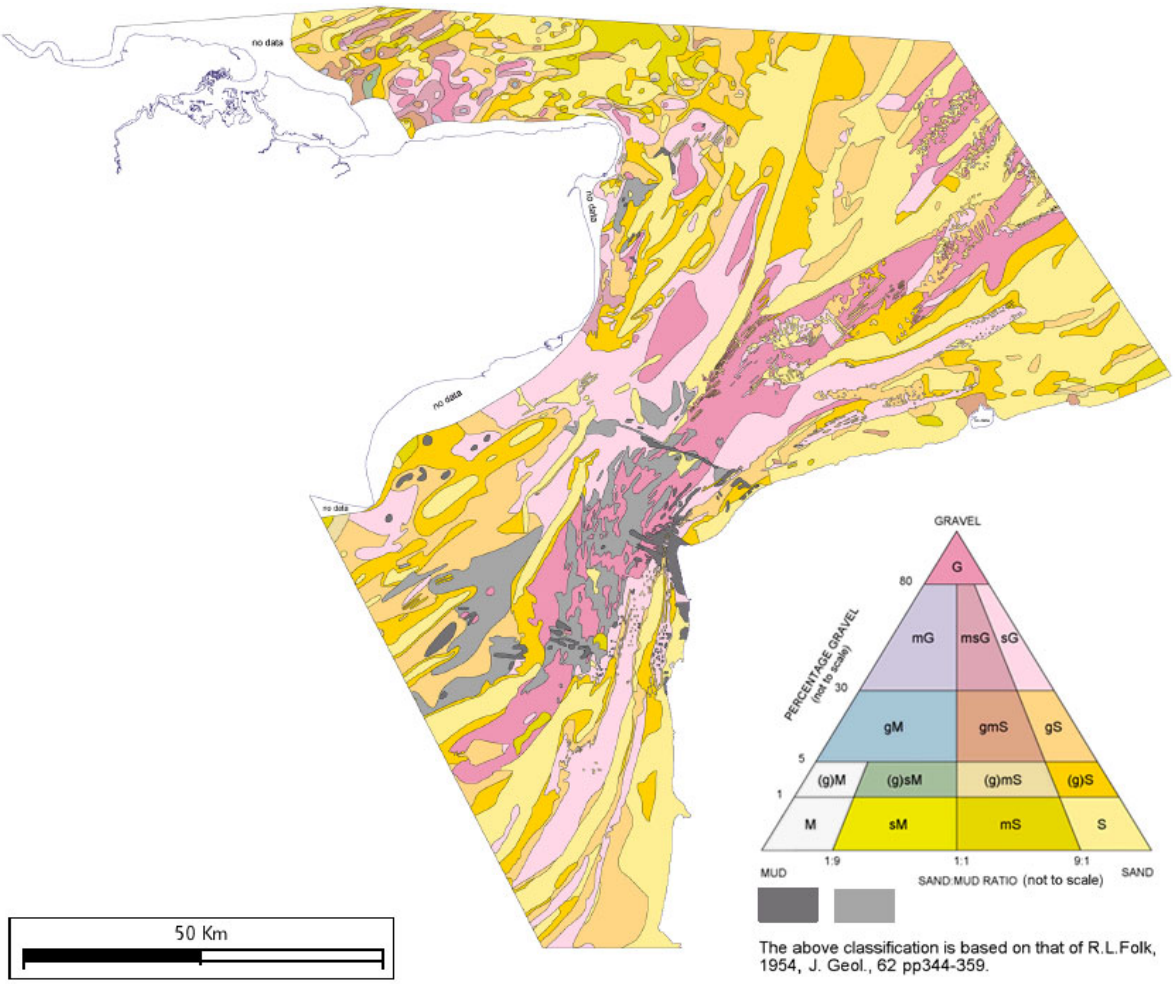

Figure 4: Seabed sediments in the Eastern Channel (modified from James, 2002)

The thickest sand ridges lie in the Eastern Channel, in the vicinity of the Straits of Dover and are formed by tidal currents. They are characterised by well to very well sorted medium grained sand, with a median grain size between 1 and 2 phi (0.2-0.5 mm) and a carbonate content usually less than 25%. Fine grained sand is limited to an area around Dungeness where it appears to be derived from the underlying lower Cretaceous bedrock (James, 2002). The thinner sand ripples are less well sorted and there are also extensive areas of poorly graded sands mixed with offshore gravel banks.

At the present day, net sand transport in the more westerly parts of the study area is from west to east, predominantly under the influence of flood tides (**Figure 5**). However, northeast of a line running across the Channel from approximately Hastings to the Baie de Somme, transport is influenced predominantly by the ebb tide and the net direction of movement is south westwards from the southern North Sea (Kenyon and Stride, 1970). The meeting of these two movement directions produces a convergence zone, that is the area of maximum sand accumulation.

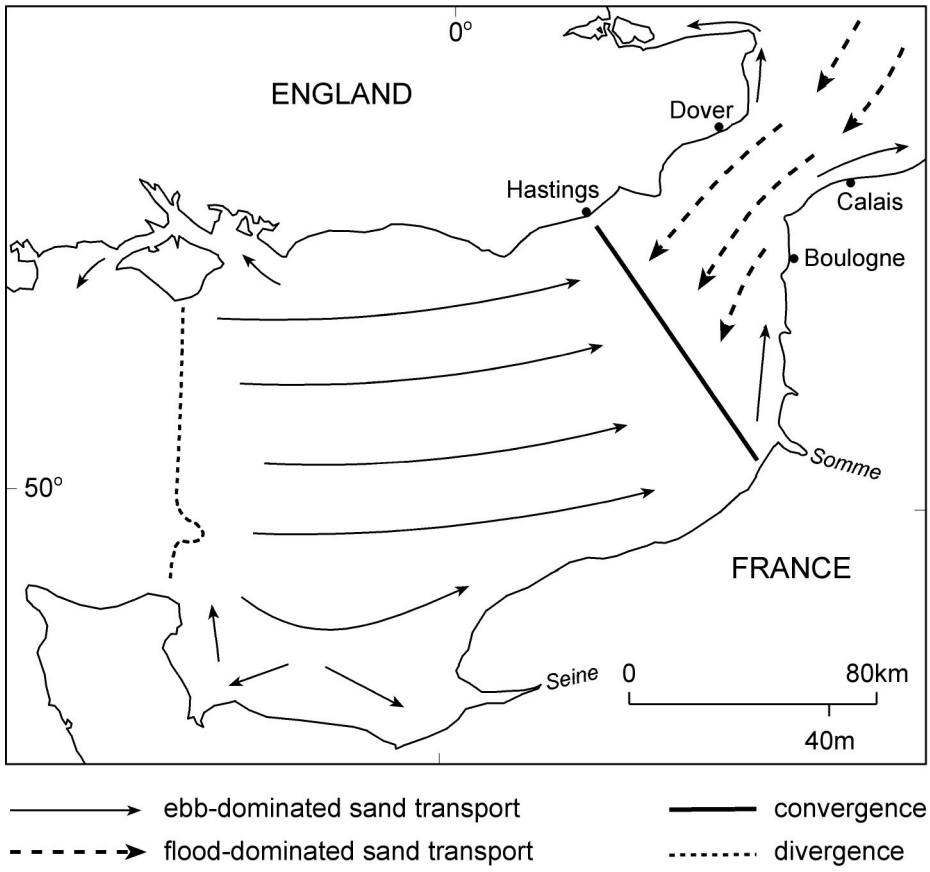

Figure 5: Major transport flows in the eastern Channel (modified after (Anthony, 2002).

In the near shore zone, local currents can move sand counter to these net movements. These are particularly prominent along the French coast where the flood tide dominated, easterly transport characteristic of the westerly parts of the study area continues all the way along the BAR coast to the Belgium Border (Anthony, 2002). This produces a predominant anti-clockwise circulation of sand, some of which feeds into the tidal zone, where it becomes bonded onto the beaches and helps to feed extensive dune systems.

Large accumulations of dune sand on the west and north west facing Channel coast of France are limited to a 50 km stretch between Boulogne in the north and the Somme estuary in the south (Anthony, 2002). They fill a gentle embayment and at their widest stretch 3km inland from the present day shoreline. Anthony and Dobroniak (2000) suggests that there have been two distinct two phases of bedload segregation that have created these deposits. An early Holocene phase of widespread infill of estuaries and coastal embayments by sandy and finer sediment followed by a later post-mid holocene phase of aeolian dune formation sourced from littoral and marine deposits. He links onshore sand accumulation and dune building in this locality to three specific conditions unique to this section of coast. First a coastal lithology and morphology comprised of relatively soft-rock cliffs with and without embayments. Second, preferential concentrations of sand in this eastern corner of the Channel, produced by tide- and wind-driven marine bedload segregation processes that have operated throughout the Holocene, linked to a shore-parallel, sand transport pathway carrying sand northwards in the near-shore zone, that continues to the present day. Third, a north-south aligned coastal orientation directly facing the dominant westerly winds that are capable of significant aeolian dune building from inter-tidal sandflats resulting from these sand accumulations.

On the English coast, a lesser eastward and northward coastal movement of sand is also suspected of operating (Grochowski et al., 1993a) but, at the present day at least, is less obvious and important than that off the French coast for little sand appears to come ashore. However, in the past considerable deposits of marine sand, almost certainly sourced from offshore (Anthony, 2002), accumulated beneath the extensive gravel accumulations of Dungeness (< 35 m) and the Crumbles (<25 m) (Greensmith and Gutmanis, 1990; Jennings and Smyth, 1987; 1990).

Localised eddy zones of tidal flow are believed to occur on either side of the projecting foreland of Dungeness and are predicted by numerical modelling (Grochowski et al., 1993b; Salomon and Breton, 1993). They develop in response the perturbation of the shore-parallel tidal flows and are potentially characterised by sediment accumulation on either side of the protrusion. This may explain the local sand-dominated beaches along the east-side of the foreland, especially around Greatstone-On-Sea and at Camber on the west. The dunes at Camber may be fed by onshore feeding of sand from a nearshore sand pool as a result of tidal eddying (Anthony, 2002),although further sources may be the erosion of the sand-rich cliffs at Fairlight Head and ebb tide delta formation at the mouth of the River Rother

Significant accumulation of sand on the English coast occurs also in the vicinity of Sandwich Bay and Pegwell Bay on the east Kent coast, where there is a further area of low dunes. As in France, this area is again aligned north-south and is dominated by a north flowing flood-tide (**Figure 5**). However, at the present day, unlike the sand accumulation zone in France, there is little evidence of any large scale, near-shore transport of sand that becomes bonded to the shore to feed the beach and dunes. Also, this area faces away from the dominant synoptic westerly winds, although it does receive significant winds from the east, especially during anti-cyclonic atmospheric conditions.

In recent decades beach recharging has added a further significant contribution of offshore, marine sand to the English BAR coast beaches. Although beach recharging has been primarily focussed on shingle beaches, the offshore shingle deposits used to recharge the beaches contain a significant quantity of sand, which is brought onshore and deposited on the beaches with the shingle. The proportion of sand in marine gravel used to recharge beaches is generally of the order of 25-30% by weight, sometimes higher. Subsequent wave action on the beaches quickly separates a proportion of this sand from the shingle, especially from the active (swash) zone. Because large scale recharging and beach monitoring surveys are relatively recent management practices, knowledge of how this sand component will be re-distributed and how it may influence the distribution and accumulation of sand on the BAR beaches remains largely unknown.

Beach recharging with offshore shingle has not yet become a widespread practice on the French coast so there is no significant contribution of marine sand from this activity on the French BAR coast.

4 Summary

Sand is unevenly distributed around the BAR coastlines of France and England. It is more abundant and widespread on the French coast than on the English. Sand may be derived from either on-shore sources by marine erosion or offshore sources brought ashore either by natural processes or by beach recharging. The major source is offshore marine deposits that became bonded to the shore during the Holocene marine transgression, a process that continues along some stretches of coast at the present day. The sand may occur as either a

significant component of predominantly shingle beaches; a major component of mixed sand/shingle beaches; as the dominant component of discontinuous fringing and pocket beaches beneath cliffs; as broad, wide continuous sandy beaches, or as dunes. In France, sand is the dominant beach material from the Somme estuary northwards but in England it is more localised with significant concentrations on either side of the Dungeness Foreland and on the east facing coast of Kent. A distinction can be made between coarse, youthful sand, found almost exclusively in shingle beaches, which is derived directly from the active breaking and rounding of fresh flints produced by present day retreat of chalk cliffs, and the more mature, mostly medium to fine grained sand derived predominantly from offshore sources.

The origins of the French sand and dune deposits have been the subject of considerable recent study, but there has been less work on the English sand beaches. Their origin and distribution is poorly understood and the impact of importing large quantities of sand during shingle recharging has not been studied.

5 References

Anthony, E.-. 2002. Long-term marine bedload segregation, and sandy versus gravelly Holocene shorelines in the eastern English Channel. *Marine Geology*, 187(3-4): 221-234.

Anthony, E.J. and Dobroniak, C., 2000. Erosion and recycling of estuary-mouth dunes in a rapidly sinfilling macrotidal estuary, Authie, Picardy, northern France. In: K. Pye and J.R.L. Allen (Editors), *Coastal and Estuarine Environments - Sedimentology, Geomorphology and geoarchaeology*. Geological Society London Special Publication 175. Geological Society, London, pp. 109-121.

Brandon, P.F., 1974. *The Sussex Landscape*, London.

Burrin, P.J., 1981. Loess in the Weald. *Proceedings of the Geologists Association*, 92(1981): 57-59.

Castleden, R., 1996. *Classic landforms of the Sussex coast*. The Geographical association, Sheffield, 56 pp.

Catt, J.A., 1977. Loess and coversands. In: F.W. Shotton (Editor), *British Quaternary Studies: Recent Advances.* OUP, Oxford, pp. 132-136.

Catt, J.A., 1978. *The contribution of loess to soils in lowland Britain.* CBA Research Report 21.

Collins, M.B., 1981. Sediment yield studies of headwater catchments in Sussex, S.E. England. *Earth Surface Processes and Landforms*, 6: 517-540.

Curry, D., 1989. The rock floor of the English Channel and its significance for interpretation of marine unconformaties. *Proceedings of the Geologists Association*, 100: 339-352.

Greensmith, J.T. and Gutmanis, J.C., 1990. Aspects of the late Holocene depositional history of the Dungeness area, Kent. *Proceedings of the Geologists' Association*, 101(3): 226-237.

Grochowski, N.T.L., Collins, M.B., Boxall, S.R., Salmon, J.B., M and Lafite, R., 1993a. Sediment transport pathways in the Eastern English Channel. *Oceanologica Acta*, 16(5-6): 531-537.

Grochowski, N.T.L., Collins, M.B., Boxall, S.R. and Solomon, J.C., 1993b. Sediment transport predictions for the English Channel using numerical models. *Journal of the Geological Society*, London, 150: 683-695.

Hamblin, R.J.O., 1989. *Dungeness-Boulogne, Sheet 50oN-00o, 1: 250 000 Sea Bed Sediments and Quaternary Geology.* British Geological Survey.

Hamblin, R.J.O. et al., 1992. *The geology of the English Channel*. HMSO, London.

James, J.W.C., 2002. *GEOSYNTH: A synthesis of the geology and sediments of the Dover strait and its hinterland.* Report CR/02/078, British Geological Survey.

Jennings, S. and Smyth, C., 1987. Coastal sedimentation in East Sussex during the Holocene. *Progress in Oceanography*, 18: 205-241.

Jennings, S. and Smyth, C., 1990. Holocene evolution of the gravel coastline of East Sussex. *Proc. Geol. Ass.*, 101(3): 306-308.

Kenyon, N.H. and Stride, A.H., 1970. The tide-swept continental shelf sediments between the Shetland Isles and France. *Sedimentology,* 14: 159-173.

Larsonneur, C., Bouysse, P. and Auffret, J., 1982. The superficial sediments of the English Channel and its western approaches. *Sedimentology*, 29: 851-864.

Long, A.J. and Hughes, P.D.M., 1995. Mid and Late - Holocene evolution of the Dungeness foreland, U.K. *Marine Geology*, 124: 253-271.

Long, A.J., Plater, A.J., Waller, M.P. and Innes, J.B., 1996. Holocene coastal sedimenatation

in the Eastern English Channel: New data from the Romney Marsh region, United Kingdom. *Marine Geology,* 136: 97-120.

Robinson, D.A., 1999. The coast and coastal changes. In: K. Leslie and B. Short (Editors), *An Historical Atlas of Sussex.* Phillimore, Chichester, pp. 8-9.

Robinson, D.A. and Williams, R.B.G., 1983. The Sussex coast past and present. In: G.E. Committee (Editor), *Sussex : Environment, Landscape and Society*, Sutton, Gloucester, pp. 50-66.

Salomon, J.C. and Breton, M., 1993. An atlas of long-term currents in the Channel. *Oceanology Acta*, 16: 439-448.