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DISCUSSION AND REPLY

Longshore Variation of Grain Size Distribution along the Coast of the Rhone Delta, Southern France: A Test of the "McLaren Model"—Reply

Gerhard Masselink*

Department of Physical Geography
University of Utrecht
P.O. Box 80115
3508 TC Utrecht
The Netherlands

INTRODUCTION

McLaren (1993) discusses the results of Masselink (1992) which examined the applicability of the McLaren model (McLaren, 1981; McLaren and Bowles, 1985) in determining net longshore sediment transport direction. Masselink studied 29 beachface samples from the Rhone delta and concluded that the McLaren model has limited application in assessing net longshore transport direction.

In the accompanying discussion, McLaren divided the samples into three regions, representing different transport environments (Figure 3 in the discussion). Using two, so far unpublished, improvements regarding the application of the McLaren model (R^2 statistic and the X-distribution; McLaren *et al.*, 1993, this issue), McLaren re-analyses the data and provides an alternative interpretation.

It is the aim of this note to discuss the re-interpretation of the Rhone delta data by McLaren in the discussion and to reply to his comments on Masselink (1992). It is stressed that the paper of Masselink (1992) and this reply are not a critique on the McLaren method in general, but regarding its application in determining net longshore sediment transport.

RE-INTERPRETATION OF McLAREN

East Beach

No significant trend could be established by McLaren for East Beach suggesting that cross-shore sediment transport dominates over a longshore transport regime. I agree with this interpretation.

Centre Beach

For Centre Beach, McLaren interprets a westward transport which is in agreement with the prevailing SSW wave direction and the ESE–WNW orientation of Centre Beach. McLaren also suggests on the basis of the X-distribution (Figure 4 in the discussion) that net accretion takes place along the transport path. Despite the net erosional trend for Centre Beach of 3–5 m per year (Elfrink and Masselink, 1989), McLaren suggests that the area may be accreting over the time interval represented by the samples. The samples were taken in May which generally coincides with the transition of the winter/erosion to the summer/accretion season. It is possible that the accretion season started earlier than normal resulting in an overall accretion of Centre Beach. However, this sort of beach cycle is induced by cross-shore processes not by longshore processes. Even if the accretion was accomplished by longshore processes, then the sediments would have been derived from East Beach which is not indicated by longshore trends in the grain size distribution.

West Beach

For the sheltered West Beach, McLaren concludes on the basis of the textural trends a high energy SW net sediment transport. The X-distribution further suggests that the beach is in dynamic equilibrium. McLaren further suggests

* Present address: Coastal Studies Unit, Department of Geography, University of Sydney, Sydney, N.S.W. 2006, Australia.

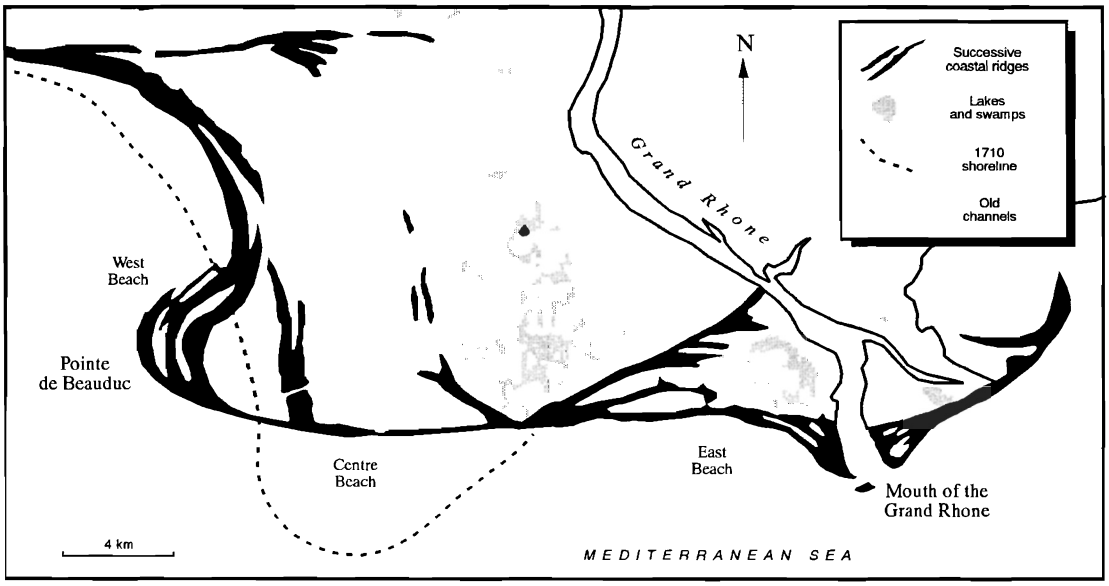

Figure 1. Geomorphology of the Rhone delta in 1960. Coastal ridges at Pointe de Beauduc clearly indicate that West Beach forms the coastline of a recurved spit complex, rather than a cuspate foreland. Also shown is the 1,710 shoreline (dashed line), showing that erosion of Centre Beach and accretion of West Beach is not a recent trend. From KRUIT (1955) and BIRD and SCHWARTZ (1985).

that the SW current on Centre Beach opposes the westward current on Centre Beach, thereby maintaining the foreland of Beauduc.

West Beach and the western part of Centre Beach, however, are not part of a cuspate foreland, but a recurved spit complex (Figure 1). The individual spits expand to the NE as recurved spits, which demonstrates that the sediment moves around Pointe de Beauduc. West Beach sediment is derived from erosion of Centre Beach and transported by the wave-driven, westward longshore current. The waves, whether from the SE or the W refract/diffract around Pointe de Beauduc and transport the sediment in a NE direction. Centre Beach is subject to 3–5 m erosion per year, whereas accretion at West Beach averages 9 m per year (ELFRINK and MASSELINK, 1989). McLaren's interpretation of a SW current on West Beach is in disagreement with the present morphology and it is also unclear which process would generate such a current.

The textural trend of West Beach may reflect progressive sediment mixing between two hydraulic populations, one consisting of relative coarse sand and the other of relatively fine sand (FLEMMING, 1988). The West Beach sediments are bi-modal due to the mixing in of a fine sediment fraction (2.25–2.75 phi) into the coarser sediment matrix. The bi-modality increases in NE direction as the proportion of fines increases (see Figure 5 in McLaren's discussion). However, as long as the finer sediment is less abundant than the coarser matrix sediment, the bi-modal population remains poorly sorted and more negatively skewed (FLEMMING, 1988).

There are three possible sources of the fine material. The West Beach dunes and also the dunes north of West Beach are being progressively eroded by the offshore wind (the "Mistral"). During a Mistral, large quantities of beach and dune sand are blown into the nearshore zone. Secondly, very strong Mistrals cause the salt water lakes behind the fragmented dunes (the "etangs") to inundate the beach depositing finer sediments in the nearshore, via natural and unnatural drains, or on the beach. A third source of fines may be the area offshore West Beach. The bay behind Pointe de Beauduc is shallow and characterised by fine sand/silty sediments (KRUIT, 1955). This material may be transported onshore by low energy waves and incorporated in the beachface sediment similar to the mechanism suggested by SONU (1972).

An alternative explanation for the fining and decrease in sorting of West Beach sediments in

the NE direction may be the decrease in wave energy level in that direction. The effect of wave energy level on beach sediment is well documented and a lower wave energy level generally results in finer and more poorly sorted sediment (CHAUDRI *et al.*, 1981; BRYANT, 1982; CHAUHAN *et al.*, 1988). The low wave energy does, however, not explain the bi-modal character of the West Beach sediments.

DISCUSSION

MASSELINK (1992) suggested that the McLaren model could not be applied to longshore sediment transport because of the violation of three assumptions. The author admits that the assumption of uni-directional flow and that the sediment in transport should be derived from a single source were incorrectly inferred from MCLAREN (1981) and MCLAREN and BOWLES (1985). However, the presence of another sediment source, as in the case of West Beach and in the example of FLEMMING (1988), may result in an unsuccessful application of the McLaren model. In nearshore environments, there are several potential sediment sources (*e.g.*, rivers, eroding beaches and dunes, shoreface) and the application of the model in the nearshore zone is at least limited. MASSELINK (1992) also mentioned that in the nearshore zone net sediment transport is not necessarily the primary factor in causing textural trends. According to McLaren, this is not an assumption but a conclusion which is self-evident by its successful application. The paper of MASSELINK (1992) was not a critique on the McLaren method in general, but regarding its application in determining net longshore sediment transport. Therefore, the examples quoted by McLaren in his discussion referring to its successful application and also the longshore transport examples quoted in MCLAREN (1981) and MCLAREN and BOWLES (1985) are examined.

PRAKASH and PRITVIRAJ (1988)

This study attempts to relate seasonal textural trends to seasonal longshore sediment transport patterns. Of the six cases that were investigated, only two textural trends were in agreement with the observed sediment transport direction at the 0.05 significance level. For the most significant case, the "balance" among the sample pairs was very poor in that two samples were responsible for 12 of the 15 favourable sample pairs.

NORDSTROM (1989)

Results of this study indicate that beach sediments flanking tidal inlets are coarser, more poorly sorted and more negatively skewed than the updrift beach samples, contradicting the McLaren model, rather than supporting it. NORDSTROM (1989) further concludes that grain size models "that are applicable at the regional scale may not be appropriate when applied at the local scale".

MCLAREN (1981)

One of the textural trends identified in MCLAREN (1981) (Case IIIa; finer, better sorted and more positively skewed) was later regarded incorrect by MCLAREN and BOWLES (1985). This effectively means that the example of Yakutat Foreland, Alaska (Example 1 in MCLAREN, 1981), no longer supports the McLaren model. After elimination of the finer, better sorted and more positively skewed trend, only two relevant sample pairs indicating opposing transport directions are left.

MCLAREN and BOWLES (1985)

Finally the example of Coburg Peninsula, Vancouver Island (example 3 in MCLAREN and BOWLES, 1985), is investigated. In this example, an eroding till provides sediments to the beach and a northward direction is shown by the sediment trends. The author does not question the presence of a northward drift; the morphological evidence is conclusive. However, the way in which this trend is "proven" lacks objectivity. MCLAREN and BOWLES (1985) include the finer, more poorly sorted and less positively skewed till sediment in the statistical analysis and due to the anomalous character of the till sediment this explains half (7) of the favourable data pairs. After exclusion of the till sediment and re-analysing the data, two transport trends are significant at the 0.05 significance level (although the number of samples is too small for a reliable Z-test). One of the trends (7 data pairs) shows a northward transport of sediment and the other trend (6 data pairs) indicates a southward sediment transport.

CONCLUSION

The paper by MASSELINK (1992) and this reply to MCLAREN's discussion are by no means a critique on the McLaren method in general, but rather on its application in determining the net

longshore transport direction in the nearshore. Some evidence is supportive of the model (Centre Beach trend); in other cases, however, the results of the model clearly contradict the actual transport direction (West Beach, NORDSTROM (1989)). In the majority of the cases, however, the model lacks the ability to confidently predict the actual transport direction (PRAKASH and PRITVIRAJ, 1988; MCLAREN, 1981; MCLAREN and BOWLES, 1985). What is required is an objective assessment of the usefulness of the McLaren model in determining net longshore sediment transport direction. The evidence so far suggests that its use is limited.

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