Geophysical Research Abstracts
Vol. 16, EGU2014-4029, 2014
EGU General Assembly 2014

The Influence of Physical & Biological Cohesion on Dune Development

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Existing predictions for dune bedforms are based on simplified physical parameters, with assumptions that sediment consists only of cohesionless sand. They do not include the complexities of mud: physical cohesion is imparted by cohesive clays and biological cohesion is created by the presence of organisms which, among other things, generate extra-cellular polymers (EPS). Using controlled experiments we show the profound influence on the size, development and equilibrium morphology of dune bedforms of both physical and biological cohesion.

Experiments were completed at the Total Environment Simulator facility at Hull University, UK in a 10 x 2 m channel. A flat sediment bed was laid to 0.15 m depth. A unidirectional flow of 0.25 m depth was passed over the sediment for 10 h. In Phase 1 eight different sand:clay mixes were examined, where clay content was 18.0 - 2.1%. In Phase 2, the same mixtures were used with additions of EPS. A velocity of 0.8 m s-1 was used throughout, corresponding to the dune regime for the selected sand. Bedform development was monitored via ultrasonic ranging transducers, sediment cores and water samples.

Phase 1 showed substantial differences in bedform type with clay content, with size inversely related to clay content, e.g. Run 1 (18.0% clay) generated 2D ripples; Run 7 (2.1% clay) generated 3D dunes. Transitional forms, included dunes with superimposed ripples, were present between these extremes. In Phase 2, EPS contents equivalent to only 1/30th of 1% by mass prevented the development of bedforms. Bedforms were generated in sediments with 1/20th and 1/10th of 1%, with an inverse relationship between bedform size and EPS content. Comparison of Phase 1 and Phase 2 runs with equal sand:mud ratios reveals that EPS acts to severely inhibit bedform development compared with the mud-only case.

We can conclude that (1) the ripple-dune transition can occur under constant flow conditions, i.e. clay content may dictate bedform type, that (2) EPS can severely constrain the development of bedforms, at masses two orders of magnitude smaller than mud, ultimately preventing their development in conditions that would yield dunes in non-cohesive sands and that (3) biological cohesion appears to be greater than physical cohesion at ratios found in natural estuaries.

We can conclude that, if the effects of physical and biological cohesion are not included when they are present, predictive models describing bedform growth, morphological equilibrium and migration will be inaccurate and in many cases misleading.