Geometry and internal structures of dunes in the bedload convergence regions in Beibu Gulf, northwest South China Sea

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ABSTRACT: Geometry and internal structures of sand dunes were surveyed with multibeam sonar and seismic profiler in the bedload convergence regions near several ridges in the Beibu Gulf, northwest South China Sea. The data reveal that the sand dunes are much steeper and higher than that in other areas. The heights of some dunes are even larger than a quarter of the depth. A good height-length correlation is built: $H=0.1192\ L^{0.901}(R^2=0.8766)$, which strikingly deviates from the Flemming's global mean relation. The seismic profiles illustrate the superposition, collision and mixing of the bidirectional inclining formations inside the sand dunes in the transitional areas. Bidirectional sediment supply in different periods encourage the vertical construction of the dunes. Erosions in the dune trough also enhance the height. Mutli-temporal evolution of the dunes and the affecting factors in the bedload convergence regions need to be further studied.

1. GENERAL INSTRUCTIONS

Through recent surveys, some relatively symmetrical dunes have been found in Beibu Gulf. In the two sides of these dunes, sand dunes usually have opposite asymmetry. No detail description on the geometry has been given. Their origins are still in the debate and ascribed to various triggers like reverse currents, surface waves in the limited literatures (Xia et al., 2001; Cao et al., 2006). Moreover, rare information is provided on internal structures of the dunes in Beibu Gulf.

We used a mutlibeam sonar and a seismic profiler (3.5KHz) to investigate the morphology and architecture of these dunes. The lengths and heights of sand dunes were measured and counted. Surface samples were obtained using a grab sampler and then processed and analyzed in the lab. The bathymetrical image was made using WGS 1984 UTM projection (49N zone). Bathymetrical data obtained in 2007, 2009, 2010, and 2014 were used to define the migrations of the dunes.

1.1. The bedload convergence regions

The study area is in the southeast of Beibu Gulf, which is a semi-enclosed gulf in the northwest South China Sea. Now there are several ridges devevloping in the study area which may largely affect the local hydrodynamics. Sand dunes are commonly found and have complex morphologies (Cao et al., 2006). The five regions (A,B,C1,C2, D) that we focused are mainly located in the head and the trough of the ridges, at depths of 8-45 m (Fig. 1). Sand dunes have opposite inclinations in the two sides (north and south, west and east) of these regions. Hydrodynamics data are not available here. However, bathymetric profile comparisons between different years are made and show that the dunes migrated oppositely. We inferred these regions as bedload convergence regions because the opposite dune migrations were coinsident with the asymmetries and could indicate face-to-face bedload transport in the same period (Fig. 2). The bathymetric profile (P5) in region R display that the dunes have the same asymmetry, and the profile comparison also show one-side dune migrations accordant with the asymmetry (Fig. 3). This could mean that region R is not a convergence region. Here region R is used to make a comparison with other regions when discussing dune morphology.

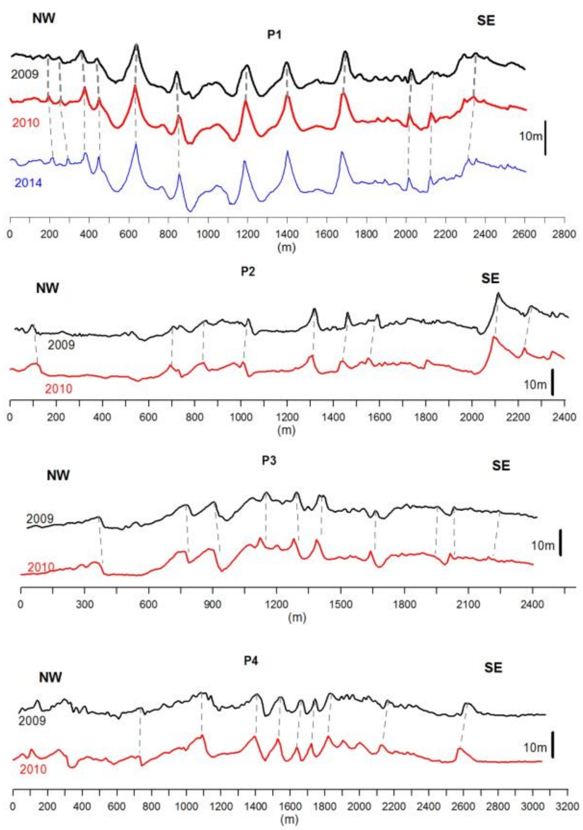

Figure 2. Bathymetric profile comparisons (P1-P4) show opposite migrations in the two sides of the focused regions. Seeing profile locations in Figure 1.

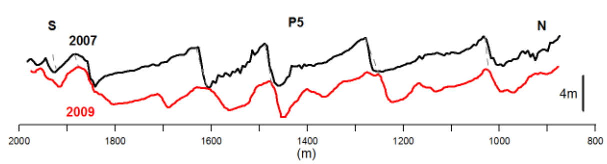

Figure 3. Bathymetric profile comparison (P5) in region R. The profile location can be seen in Figure 1.

1.2. Geometry of sand dunes

Sand dunes are developing in these convergence regions. These sand dunes have lengths of 20~180m and some heights up to 15 m (Figs. 4 and 5). The dunes are oppositely inclined in the two sides of "transitional lines" (Fig. 1). The heights and lengths of dunes near the transitional lines are counted and analyzed. The lengths and heights of sand dunes in all regions except region R have a good correlation: H=0.0676 $L^{1.0838}$(R^2=0.834). This relation largely deviates from the Flemming's global mean relation, which is close to the upper limit of Flemming’s relation (Fig. 4). Most dunes are very steep that have very large heights and relatively small lengths. However, the heights and lengths of dunes on the ridge (region R) fit very well to the global mean relation of Flemming and other previous regression lines (Fig. 4).

The heights of the dunes in the study area seem to be independent of the depths. According to Francken et al. (2004), heights of sand waves are smaller than a quarter of water depths in river environment. In sea water, the heights are even smaller at the same depth (Yalin, 1977; Van Landeghem et al., 2009). Here, most dunes in region A and region C have much larger heights than that in other areas, while the others in the focused areas seem to be normal in heights (Fig. 5).

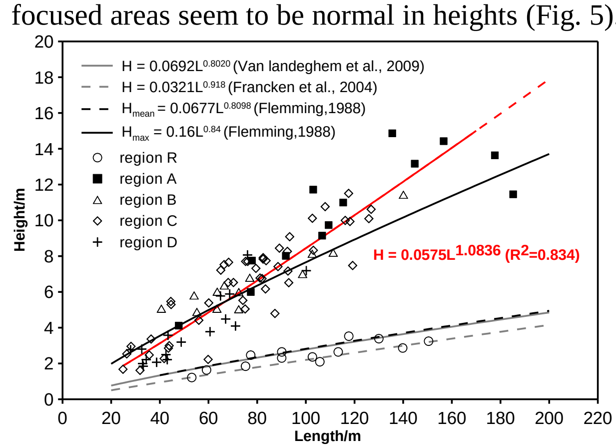

Figure 4. Height-Length relation of the dunes. (region C including C1 and C2)

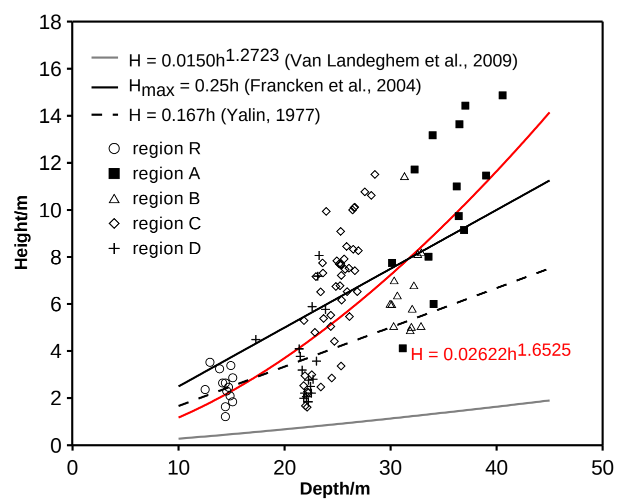

Figure 5. Height-Depth relation of the dunes

1.3. Internal structures of sand dunes

The profile of a typical sand dunes in region A show that the overlying beddings are oppositely asymmetrical, where the north-dipping layers overlie the south-dipping layers. Reflectors are truncated in the trough of the sand dunes (Fig. 6), reflecting the erosion in the trough.

Bi-directional layers also exist in the sand dunes in regions C1 and C2 (Figs. 7 and 8). Just like that in region A, the layers inside the sand dunes also change from south-dipping to north-dipping. The troughs are also partly eroded. Some reverse beddings just begin to but do not completely change the asymmetry of the dunes (Fig. 7).

Figure 9 illustrate that the opposite inclining beddings seem to collide inside the relatively symmetrical dune in region D, which may indicate the nearly same active bedload flux from the two sides.

Data show that the sediment near the transitional line becomes finer comparing with that in the north side and the south side in region D (Fig. 10). In contrast, sediment changes to be coarser from the outside to the inside of the region A (Fig. 11). This different trends may reveal that sediment are still moving together in region D while this process is largely decreased or even stopped in region A.

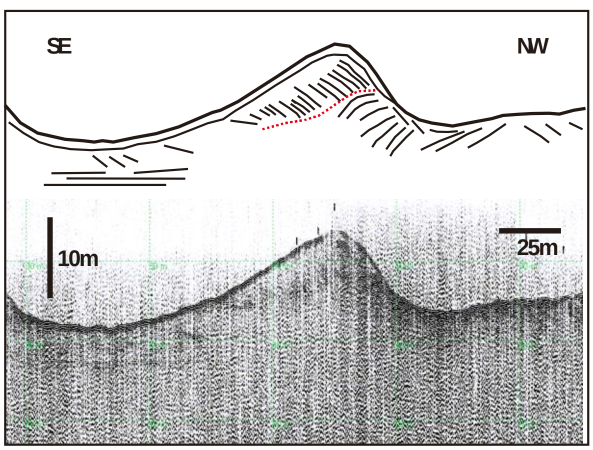

Figure 6. Detail interpretation of the internal structures of a large dune in region A. (Location seeing Figure 2)

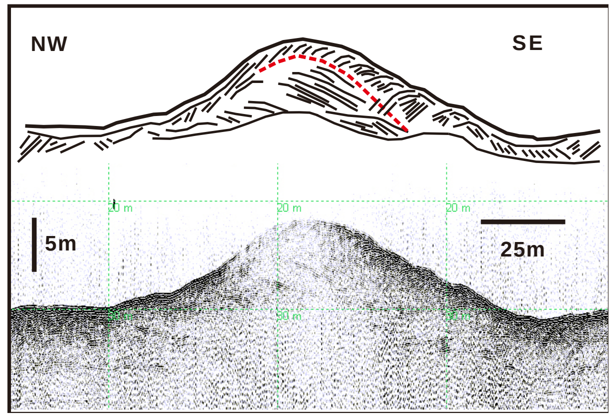

Figure 7. Detail interpretation of the internal structures of a typical dune in region C1.

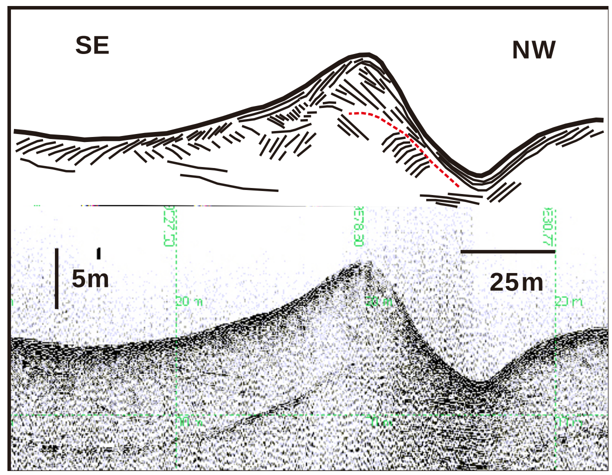

Figure 8. Detail interpretation of the internal structures of a typical dune in region C2.

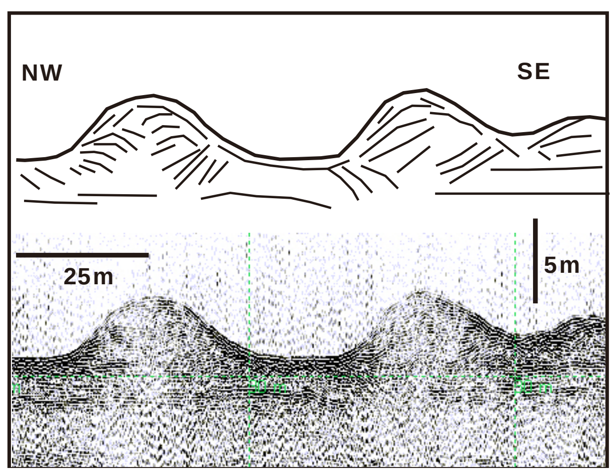

Figure 9. Detail interpretation of the internal structures of a typical dune in region D.

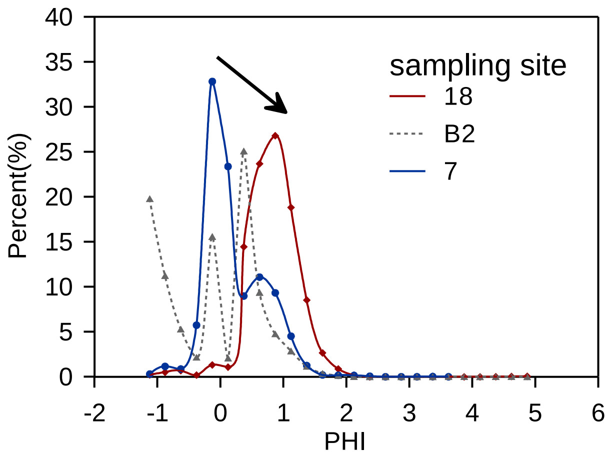

Figure 10. The characters of sediment in the two sides of region D.

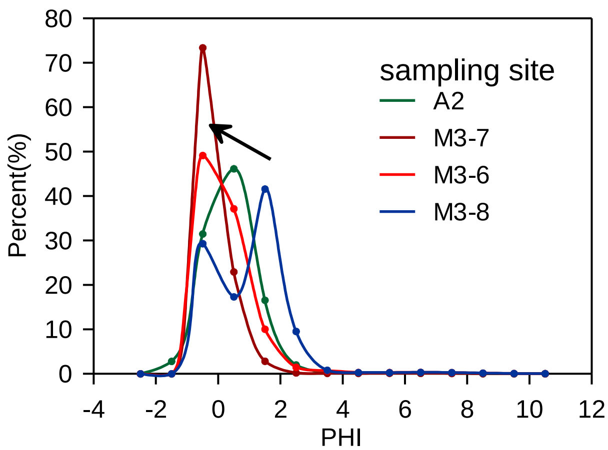

Figure 11. The characters of sediment around the region A.

2. CONCLUSIONS

The areas with opposite asymmetrical dunes in their two sides are suggested to be bedload convergent regions in Beibu Gulf. These dunes are also migrating oppositely under modern flows. The convergent regions other than dune individuals are focused in the present data.

In several bedload convergence regions in Beibu Gulf, steep sand dunes develop near the transitional lines (regions A-D) which display very different geometrical characters from that of dunes under one-side net sediment input (region R). The very large heights of dunes in region A, C1, and C2 can be attributed to the overlap of reverse formation and the erosions in the trough of the dunes. Sand dunes near the transitional line are mainly supplied by erosions as the supply from outside are blocked by the huge dune heights. Sediment from the north and south sides of region D are accumulating on the dunes near the transitional line. Superposed reversed beddings inside these dunes indicate the large changes of bedload transport or the hydrodynamics in the past. The evolution of the convergence regions and the inside sand dunes and the affecting factors should be further studied.

3. ACKNOWLEDGMENT

The authors are grateful to the crew on the R/V KEXUE Ш. This study is funding by National Natural Science Foundation of China (41406041).

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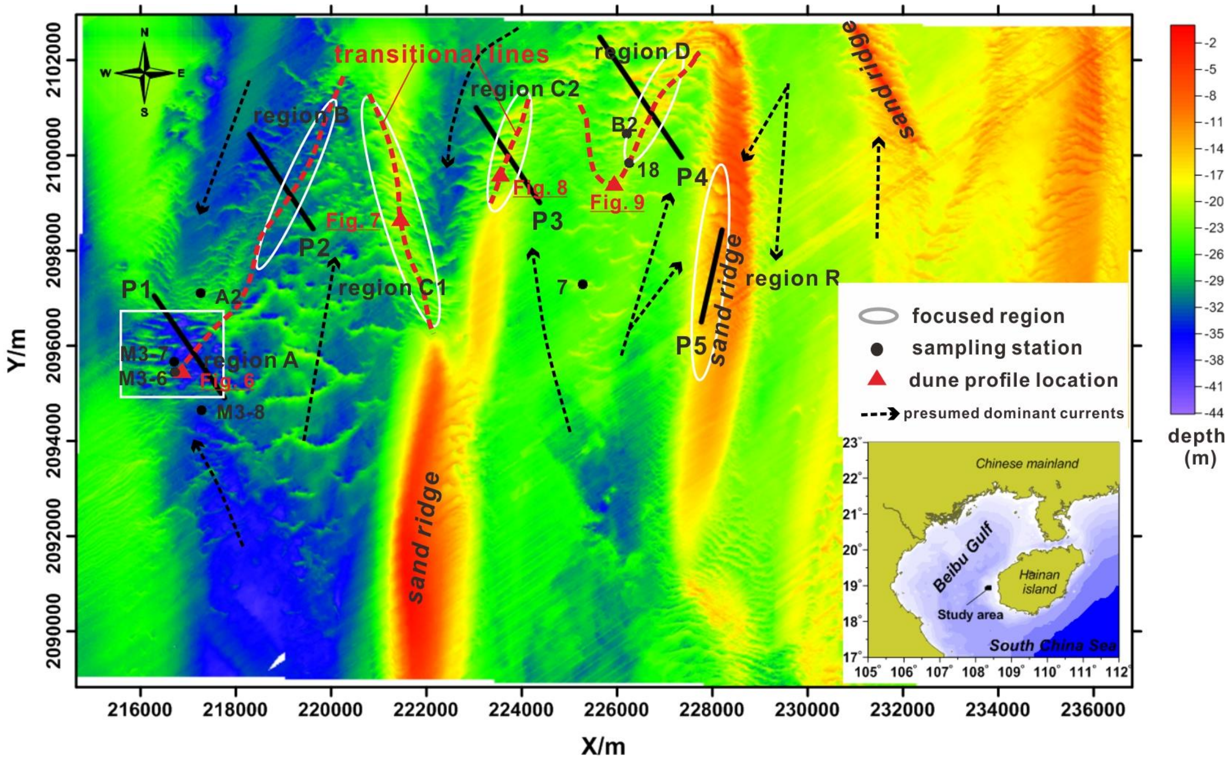

Figure1. The focused regions (white circle) in the study area and the details of seabed topography. The dominant current paths are induced by the asymmetries of dunes.