Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

SCG064-P01 Room:Convention Hall Time:May 24 10:30-13:00

Sediment transport pathways on the modern microtidal sand flat along the Kushida River Delta, Ise Bay, central Japan

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Sediment transport pathways on the modern microtidal sand flat along the Kushida River Delta were estimated by a new statistical model proposed herein (P-GSTA method), which is based on the grain-size distribution patterns, and the field observations.

The Kushida River flows into Ise Bay, and forms a bayhead delta. The tidal range of Ise Bay is about 2m during spring tide (microtidal). The sand flat is spread in front of the spit on the right bank of the river, and the width is about 0.4 km2. The sand flat is mainly composed of medium- to coarse-grained sand, and is characterized by sand bars and shallow braided channels. It is interpreted that sediment transport is dominated by fluvial and wave activities.

In the P-GSTA method, a linear function in which six parameters of grain-size distribution (mean, coefficient of variance, skewness, kurtosis, and mud and gravel logratios) are summated with different weighting factors was used to infer sediment transport direction. For automated determination of the weighting factor of each grain-size parameter, the principal component analysis (PCA) of grain-size parameters was conducted. PCA is a technique for explaining the correlation between explanatory variables and automatically organizing them into a few linear synthesis variables with different weights, and the weight of each parameter depends on its variance. It was revealed that the first principal component (PC1) account for the spatial variation of the grain-size distribution as a result of sediment transport. The factor loading of PC1 indicates that the grain-size distribution of sediments on the surface of the microtidal sand flat becomes finer, better sorted, less gravelly, and has a more negatively skewed downcurrent through the sediment-transport processes by fluvial and wave activities. Then, the eigenvector of PC1 was employed as weighting factors of grain-size parameters to calculate linear function of grain size parameters representing sediment transport. The outline of the sediment transport pathways reconstructed by this method is as follows: 1) sediments are mainly supplied from the river mouth, then, 2) they are drifted from northwest to southwest, and finally 3) dispersed northeastward.

Field observation was conducted at August 2008, October 2009, April 2010, October 2010 and January 2011. Sediment transport pathways are estimated based on arrangements of ripplecrest directions and other geomorphological features. Brief summaries of sediment transport patterns inferred by field observation are as described below. 1) At October 2010, it was observed that a large amount of sediment was supplied from the Kushida River into the sand flat by a fluvial flooding, and most of them had been dispersed by waves and tidal currents in April 2010. 2) The cuspate branches from the spit imply the eastward to southeastward local drift of the sediments around this area. 3) The crests of sand bars and ripplecrests on them are arranged roughly northwest-southwest throughout a year, and are almost perpendicular to the wave-incoming directions from northeast. Therefore, the direction of sediment dispersal probably is northeastward.

These two results indicate that P-GSTA method successfully worked on the studied area. More quantitative measurement of sediment transport patterns is required for the accurate evaluation of P-GSTA method in further studies.

Keywords: delta, sediment transport, tide, wave, grain-size distribution

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Grain-size analysis and identification of flood-related sedimentary features of crevasse-splay deposits

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This study addresses procedures for identifying flood-related sedimentary features in view of their future incorporation into community-based hazard mapping. The study area selected is large-scale crevasse-splay deposits of downstream area of the Kizu River located in southern part of Kyoto. It is likely that these flood-related subsurface features were formed by the levee breaching cases occurred in 1859 or 1876. The crevasse-splay deposits were investigated using non-destructive geophysical explorations, specifically in terms of resistivity prospecting, surface-wave seismic profiling and ground penetrating radar system. Considering the surrounding depositional environments and performance of geophysical explorations, the authors estimated that the sediment discharge associated with the levee breaching. The related hydraulic calculations led to an estimate for the flooding discharge involved.

Keywords: flood-related sedimentary features, crevasse-splay deposits, non-destructive subsurface explorations, grain-size analysis

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Alluvial cyclic steps produced with oscillatory discharge in a deltaic setting: Flume experiments

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Upper regime bedforms associated with spatially-periodic hydraulic jumps are called cyclic steps. Cyclic steps in natural alluvial rivers have intrinsically low preservation potential and are hardly recognizable in cross section. This is partly because a particular hydraulic condition allowing cyclic steps to develop hardly lasts in alluvial rivers for a significantly long period (e.g. 100 years). Any original deposit produced by cyclic steps would not escape significant modification or complete destruction under a new, different hydraulic condition that does not allow cyclic steps to develop. What if a pair of different hydraulic conditions (one suitable for cyclic steps; the other not allowing cyclic steps) is alternately provided to the river? And, what features are recorded in a stratigraphic section of the deposit? These questions have been examined using a series of flume experiments in which alluvial cyclic steps were produced on the topset surface of a Gilbert-type delta. During all runs, supply rate of sediment (0.1mm and 0.25mm quartz sand of a particular mixture ratio) was kept constant, whereas upstream water discharge was changed periodically/alternately between two particular magnitudes, between Qw1 and Qw2, or between Qw2 and Qw3 (Qw1: low discharge to prevent cyclic steps; Qw2 and Qw3: intermediate and high discharges to develop cyclic steps). The results of the experiments indicate: (1) with Qw2 and Qw3, characteristic forest bedding takes place synchronously with a hydraulic jump departing the river mouth, (2) periodical/alternate changes in discharge give rise to periodic changes in foreset bedding structure, (3) it takes a few minutes for bedform to become stable under new discharge, and (4) when water discharge is changed more frequently than this transient time, bedforms existing are all of transient state associated with no or obscure synchronism of foreset bedding with hydraulic jump, and thus (5) stratigraphic preservation of cyclic steps and related deposits depends in part on transient time of the bedform.

Keywords: cyclic steps, flume experiment, alluvial river, delta, discharge, stratigraphic sign

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Dissolution roughness of gypsum blocks: change in characteristics of roughness patterns with friction velocity and flow

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The dissolution roughness formed on some materials by flows such as stream flows and wind flows is considered to be controlled by the flow velocity, properties of bed sediments, and flow duration. Because it is difficult to perform studies on outcrops, most studies are carried out in laboratories (Allen, 1971; Blumberg and Curl, 1974; Curl, 1974). These studies have revealed the characteristics of roughness patterns affected by flow velocities and have visualized the flows that have acted on a bed surface. In this study, we performed erosion (dissolution) experiments by focusing on the friction velocity and flow duration. The substrate used in the experiments was made of plaster of Paris (gypsum) because of its low solubility and ease of casting. Fresh tap water was flown over the gypsum blocks.

The dissolution roughness induced on the surface of the gypsum blocks varied widely with the friction velocity and flow duration. Most of the dissolution roughnesses in the experiments are scallop-like patterns with various scales. The length of the scallops reduced as the friction velocity increased, whereas the widths of the patterns hardly changed. Although the patterns gradually spread uniformly on the entire surface of the bed when the flow duration increased, the size of the patterns showed no obvious change. The results suggest that the characteristics of roughness patterns strongly depend on the friction velocity whereas their distribution depends on the flow duration.

Keywords: dissolution roughness, friction velocity, flow of time

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Laboratory experiments about wavy topographies on non-movable beds generated by rotation of rigid bodies

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Wavy topographies can be seen ubiquitously, such as sand ripples on desert dunes and ”steps and pools” in mountainous rivers. In geology usually we consider wavy beds formed in natural environments due to fluid motions such as water or air flows. However, especially in civil engineering other kind of wavy topographies are known as ”washboard roads” that are formed on unpaved road due to passing of automobiles, i.e. caused by wheels. Obviously wheels are not fluids but solid. We can classify wavy topographies according to materials about the type of bed (movable or fixed) and a driving medium (fluids or solid). Hereafter we refer to ”fixed beds” as ”non-movable”, because beds should be eroded to become wavy and not strictly fixed, but do not allow re-deposition. Three types of the four in the above classification, wavy topographies of movable bed - fluids (e.g. sand ripples or dunes), non-movable bed - fluids (e.g. cyclic steps or ”steps and pools”) and movable bed - solid (washboard roads) were previously investigated through controlled laboratory experiments, but the conceivable fourth type, ones of non-movable bed - solid is not known well. To understand universal mechanism (if exists) of ubiquitously formed wavy topographies, we investigate the fourth combination of materials, i.e., non-movable bed - solid. In experiments, metal cylinders rolled many times due to the gravity on the 5 degrees slope consisted of hard but fragile sponge forms. We used three cylinders, one of aluminum and two of copper, one of which was heavier than but the same sized as the aluminum one and other was smaller than but the same weighted as the aluminum one. Results can be summarized as follows: (1) in the system of non-movable bed - solid, wavy topographies can be formed; (2) a heavier but the same sized cylinder produced larger amplitudes and wavelengths; (3) a cylinder of the larger diameter but the same weight generated similar wavelengths but smaller amplitudes. However we do not consider the difference in surface properties between different metals so far, and detailed investigation is the future work.

Keywords: Wavy topography, non-movable bed

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Flume experiments about formative processes of rhomboid rills

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It can be observed that several centimeters sized rhomboid microtopographies called rhomboid rills are formed by backwash on sandy beaches, which were reported from field researches. The formative processes of rhomboid rills, however, has not been well understand. This study aims at formative processes of rhomboid rills through laboratory experiments using sand (median diameter of 154 micrometer) taken from the site where actually rhomboid rills were generated on the beach. Each experimental was begun with flat sand slope with a give gradient (6-12 degree). Water was stored offshore at the depth of 2 cm. In each run, only one wave was generated with a flat wood board by hand and reached to the top of the slope.

Results are as follows (1) rhomboid rills were developed best at gradient 8 degree rather than those gentler and steeper. The gradient of beach slope at the sampling point where rhomboid rills were actually formed was also 8 degree. (2) According to high-speed movie, it is found that the transported sand particles that initially run in the direction of the maximum gradient were deposited on the midway and following stream branched into two directions avoiding the deposit. This is why rills were stretched in oblique directions to that of the maximum gradient of the slope.

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Bedform under complex oscillatory flow

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Some types of patterned three-dimensional ripples have been reported from modern and geological shallow-marine environments. Laboratory experiments have shown that ripples with polygonal crest line develop under circular oscillatory flow, which is induced by oblique-standing waves (e.g., Silvester, 1972; Jan and Lin, 1998), and it has been considered that patterned three-dimensional ripples may develop under horizontally two-dimensional complex oscillatory flow by interference waves. However, partially because of limitation of experimental equipments, relationship between patterned three-dimensional ripples and their formative conditions has not been well revealed. Based on these backgrounds, this study examined bedforms under two-dimensional oscillatory flow with complex trajectory through an analogue laboratory experiment. This study employed a newly developed two-directional oscillatory bed, which generates two-dimensional oscillation by combining two one-dimensional sinuous oscillations perpendicular to each other. The phase lag between two oscillations, and the period and amplitude of each oscillation are controlled by computer program. By using two-directional oscillatory bed, a circular tray filled with sediment was oscillated in still water within a circular tank in order to simulate relative motion between sand bed and oscillatory flow. The sediment tray is 100 cm in diameter and 2.5 cm in depth, and edge of the tray is taped off to hinder turbulence. The diameter and depth of water tank is 180 cm, and 60 cm, respectively. The experiment was conducted using fine sand with grain diameter of 0.2 mm. The oscillatory period was $<$ 3s, and amplitude was $<$ 7 cm. Three typical bedforms were observed in the experiment: (1) ripples with polygonal crest line (RPCL), (2) ladder-back ripples (LBP), and (3) two-dimensional ripples. The major and minor crests of LBR were perpendicular to oscillations. Patterned three-dimensional ripples formed when the mobility number of each oscillatory component exceeds 2, i.e., the threshold value for ripple formation from a bed with a perturbation. TPCL formed when the ratio, smaller period/larger one, of two oscillations ranged from 0.8 to 1.0. LBR occurred when the ratio of periods was less than 0.8. The size of bedforms was depended on the amplitude of oscillatory components. Ripple spacing between major and minor crests of LBR was 1/3 of corresponding oscillatory amplitude. The mean width of polygonal cells of RPCL under circular oscillation was 1/6 of amplitudes.

References
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Keywords: experiment, three-dimensional ripples, two-dimensional oscillation, two-directional oscillatory bed

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Inverse analysis of hydraulic conditions of turbidity currents

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A new method to estimate hydraulic conditions of turbidity currents from ancient turbidites is proposed here. This method of inverse analysis is based on downstream variation in thickness and granulometric characteristics of turbidites. It has been known that characteristics (grain size, internal sedimentary structure and bed thickness) in individual turbidites drastically change in vertical and downstream direction, and this spatial variation of turbidite characteristics can be regarded as an indicator of spatio-temporal change in hydraulic conditions of turbidity current such as velocity and sediment concentration. However, hydraulic conditions of turbidity currents have been rarely measured because these currents occur only in subaqueous environments so that it is quite difficult to observe directly.

In this study, firstly, the detailed variation of characteristics in individual turbidites is investigated in the Otadai Formation, the Pleistocene Kazusa Group distributed in the Boso Peninsula. As a result, grading and non-grading intervals in individual turbidites are clarified based on grain-size analysis. Non-grading intervals can be interpreted as deposits from quasi-steady turbidity currents.

Secondly, a numerical model of quasi-steady mixed grain size turbidity currents is established. We assumed that sediments in turbidity currents are composed of 5 classed sand and 1 classed silt mixtures. One-dimensional three-equation model and Exner equation were employed. Hiding effect in the basal active layer of sediments is considered in this model.

To confirm precision of model, inverse analysis of simulated turbidite is carried out. Boundary condition of simulated turbidite is U = 1 m/s, h = 360 m, T_{max} = 5000 s. The result of inverse analysis of simulated turbidite is U = 1 m/s, h = 340 m, T_{max} = 4500 s. As the result of inverse analysis of simulated turbidite, it was suggested that hydraulic condition of turbidity currents can be successfully reconstructed by inverse analysis method established in this study.

Finally, an inverse analysis of ancient turbidites in the Otadai Formation is carried out to estimate paleo-hydraulic condition of the turbidity current. The result of inverse analysis suggests that the turbidite in the Otadai Formation deposited from a quasi-steady turbidity current that was 0.9 m/s in flow velocity, 495 m in flow thickness, and 1995 s in flow duration time.

Although it is necessary to improve the forward modeling of turbidity currents containing mix-sized sediments and validation of the results of inverse analysis, numerical inverse analysis will become an important method for the turbidite sedimentology and reconstruction of paleoenvironment.

Keywords: turbidity current, turbidite, inverse analysis, paleo-hydraulic condition, grain-size distribution, the Otadai Formation

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Governing parameters on transgression and regression of shorelines

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What controls the transgression and regression of shorelines? This question has been an issue of arguments for long time in geological research field. The transgression is landward migration, and the regression means seaward migration of shorelines. When shoreline migration occurs in short time period (years to decades), it causes serious problems in human activities. On the other hand, the shoreline migration in long time period (100s to millions years) dominates stratigraphic patterns of geologic records. It is known that geometrical features of the sedimentary rocks are strongly influenced by transgressions and regressions. Therefore, studies on governing parameters can be useful for predictions of subsurface geometry of sedimentary rocks and inverse analysis of paleoenvironments from geological records.

Here, this study investigated shoreline migration mechanisms during relative sea-level rise by using geometrical and linear diffusion models of river-delta systems, revealing two governing dimensionless numbers for shoreline migrations. The first is a dimensionless rate of sediment supply. This parameter is obtained by rate of sediment supply subdivided by product of size of terrestrial depositional system and rate of relative sea-level rise. Conventional sequence stratigraphy considered that the shoreline migration is determined by ratio between rates of sediment supply and relative sea-level rise (A/S ratio). However, the result of this study indicates that the size-scale of the depositional system is also significant for shoreline migrations in addition to two parameters described above. The second dimensionless number is a ratio between size scales of terrestrial and marine depositional systems. This parameter describes the geometry of the entire depositional system, which tends to be ignored by discussions about the transgression-regression problems. However, the terrestrial and marine systems are actually combined, and their ratio in size scale plays a critical role for shoreline migrations.

To understand governing dimensionless numbers is significant also for comparison between experiments and natural systems. As future studies, it seems necessary to examine the mechanisms of shoreline migration by using more detailed models and field surveys.

Keywords: Sequence Stratigraphy, Transgression, Regression, Delta, Shoreline Migration