Japan Geoscience Union Meeting 2011
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SCG064-01 Room:202 Time:May 24 14:15-14:30

A review of sedimentary research on Mars

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A large volume of data is now available for sedimentary research on Mars. The data include topographic data from the Mars Orbiter Laser Altimeter (MOLA) and several kinds of satellite imageries. The spatial resolution of the images obtained from the High Resolution Imaging Science Experiment (HiRISE) reaches up to approximately 25 cm/pixel. This resolution is high enough to analyze large boulders (>25 cm) on the Martian surface, which might have been deposited through several processes such as meteorite impacts, slope failures, and hydrological activities. Sedimentary rocks, formed through various processes including aeolian, impact cratering, fluvial/lacustrine, have already been reported from many places on Mars, and such rocks are selected as possible landing sites for future rover missions by NASA and ESA. In this study, we will review the current understanding of sedimentary rocks on Mars, and will discuss how field geologists can contribute to the sedimentary research on Mars. In addition, we will briefly introduce how to use the available topographic and satellite datasets through the use of GIS software.

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SCG064-02 Room:202 Time:May 24 14:30-14:45

Seasonal changes in glacier velocity detected in West-Kunlun, Tibet: Glacier erosion and subsequent mountain building?

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West Kunlun mountains are the highest areas in the planet when averaged over ˜100 km scale. Although Tibetan plateau is often termed as ”a roof of the world” because of the very high average altitude, we should note that the West Kunlun-shan is peculiar in terms of both its location at the northern-most edge of the Tibet and an absence of significant thrust faults/earthquakes in the nearby region. Why are the West Kunlun mountains so high?

We recently discovered by chance that there exists a significant seasonal variability in the glacier surface motion in one of the numerous mountain glaciers at West Kunlun mountains. Based on this finding, we discuss a possibility of the glacial erosion effects on the tectonic evolution of the mountains at West Kunlun. Numerous mountain glaciers at West Kunlun mountains have higher elevations greater than ˜4000 m, and are regarded as ”polar (or sub-polar)” glaciers despite the mid-latitudes (˜35N), implying that no seasonal changes in glacier velocity have been expected so far.

While numerous theoretical studies have suggested an intimate link between climate and tectonic evolution of mountain ranges, compelling observational evidence of an impact of climate on mountain building has been lacking (Whipple, 2009). The effects of erosion on friction-dominated critical-tapered orogens have been examined extensively, but those impacts could be even more stronger in thicker and hotter orogens. However, such examples have been fewer. We will discuss that the West Kunlun mountains could be an example for the active tectonic response in such a region to the glacial erosion.

Keywords: glacial erosion, mountain building, Kunlun mountains

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Dynamic aspect on unconformity in the trench landward areas

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Trench landward slope area has been repeatedly changing from stable to unstable. Development of accretionary prisms has been explained by many researchers, but the theory is simply based on earth pressure theory. Among the bulldozer models, the critical stage is between the passive and active earth pressure conditions when the unstable zone remains to to sink for a depositional basin above unconformity. Eroded materials from the slope fill the depressed area, showing the change of stable to unstable of the slope. Thus to interpret this change by means of the study of unconformity makes the discussion very dynamic. Most of the examples from the submarine Nankai trough to onland Miocene-Pliocene Miura-Boso area are the best for such explanation, which include systematic and repeated change of development of trench slope. Jump of trench to oceanward is one of the causes but seamount (or ridge) subduction is an occasional principle as shown in the Tenryu Canyon by Kawamura (GSAB 2009; Springer in press). Another important example comes from the Cretaceous to Miocene forearc areas from Hokkaido to off Kashima of the Japan trench realm. Many unconformable stages in Paleogene to Miocene off Fukushima Prefecture and surrounding area are explained by much larger tectonic change, probably related to the Japan Sea side tectonism including opening and spreading of the Japan Sea during these stages.

Keywords: trench landward area, forearc basin, accretionary prism, unconformity, tectonics

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SCG064-04 Room:202 Time:May 24 15:00-15:15

Compositions and provenance of the sands in the southern Kumano Basin and the underlying accretionary prism, IODP Exp315

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Compositions of the submarine turbidite sands cored in the Integrated Ocean Drilling Program (IODP) Expedition 315 were examined in terms of bulk and heavy mineral modal proportions, mineral chemistries, and zircon U?Pb age spectrum to identify their provenance. Coring was conducted in the seaward flank of the Kumano forearc basin (Site C0002) and the seaward slope apron of the outer-arc high (Site C0001) at the Kumano-nada, Nankai Trough, Japan. Four lithostratigraphic units were recognised based upon core and log data in the Site C0002. The upper three units (Unit I-III from top to bottom) are the Kumano Basin sediments and the lowest Unit IV is the accretionary prism basement [1]. The Units I (0-136 mbsf) and II (136-830 mbsf) are composed mainly from alternation of non- to semi-consolidated sand and mud, and Unit III (830-922 mbsf) consists of mud. Unit IV (922-1053 m) consists of highly deformed sandstone and mudstone. Total 12 samples were collected from Units I, II and IV. At Site C0001, the upper 207 m (Unit I) is slope basin sediments composed mostly of non- to semi-consolidated mud with intercalation of volcanic ash layers. Sands are localised at the bottom of the unit where three samples were taken. The underlying Unit II (207-458 mbsf) is accretionary prism sediments composed of mudstone.

At Site C0002, sand compositions are quite different between Unit I and the deeper units. On the contrary, sands in Units II and IV are almost identical despite their different geologic settings. Heavy minerals in Units II and IV are dominated by high-pressure/temperature (high-*P/T*) type metamorphic component, which is most obviously demonstrated by the presence of sodic-amphiboles. Their compositions cover a wide range in term of Fe^{3+}/Al ratio and Na (M4) content from glaucophane to riebeckite, and to winchite. Garnet compositions are characterised by higher content of grossular component and wider variation of spessartine component than those of Unit I. Zircon U-Pb age spectrum has a cluster around 60-100 Ma. Based on the comparison with sand samples collected from several representative rivers in the Pacific side of the Central Japan, petrologic features of Units II and IV sands favour the Tenryu district as the most probable candidate for the source region. Heavy mineral compositions in Unit I have both igneous and metamorphic components (but no indication of high-*P/T* metamorphic rocks), and zircon U-Pb age spectrum has a major cluster around 10-20 Ma as well as subordinate cluster around 60-100 Ma. The igneous minerals and young zircons are considered to be derived from the 15 Ma Kumano acidic rocks distributed widely in the south-eastern Kii Peninsula. Hence, the petrological features of Unit I are interpreted as a mixture of two components from the Kumano and the Tenryu districts. Change in sand compositions between Units I and II indicates a drastic change of seafloor channel at around 1 Ma. Sediments of the Tenryu River origin in the deeper part of the Kumano Basin and the underlying accretionary prism suggest that the Tenryu Canyon was the main sediment conduit to the Kumano Basin before 1 Ma, which was blocked around 1 Ma due to change of seafloor topography and the Kumano River became a main contributor of the sediments to the Kumano Basin instead.

Samples of Site C0001 are all rich in ferro-magnesian minerals, particularly orthopyroxene, which is totally different from Site C0002. Their petrologic characters are closer to those of the toe region [2], which are probably derived from the Izu-Honshu collision zone.

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Keywords: sand provenance, forearc basin, Nankai Trough, sodic amphibole, garnet, zircon U-Pb chronology

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Study of the erosion based on paleontological approach

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It is difficult to study of erosion based on information obtained from the deposit.
Especially, it introduces the method of studying the erosive effect by using paleontological information.
Estimation of erosion for trace fossils:
Trace fossils shape based on the observation, the erosion can be determinded.
The dead shell assemblage of lag deposits:
Examining the lag deposits becomes an important clue that understands the process of piling up and the invasion. It is possible to examine whether to cause the invasion of which extent because the shell that moved along with the erosion is extracted based on the dead shell assemblage crowd analysis in the lag deposits, and those chronological values are examined.

Keywords: erosion, trace fossils, lag deposit

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Estimation of sand's source and transport system in the Taklimakan desert by quart's ESR intensity and crystallinity

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Taklimakan desert in the Tarim basin in Western china is the second largest sand desert, which is surrounded by Tinshan Mountains, Karakorum Mountains and Kunlun Mountains. Because of this specific location and climate, this desert is one of the most eolian dust source areas in the Northern Hemisphere now (Zheng et al.,2003). Thus, it is important to know eolian dust's generation and transport system in the Tarim basin in order to appreciate the impact of Northern Hemisphere in the past, present and future. So we characterize the sand and estimate sand's provenance and transport system by using quart's Electron Spin Resonance (ESR) signal intensity and Crystallinity.

Quart's ESR intensity indicates the amount of oxygen vacancies in quart's mineral (Toyoda and Ikeya, 1991), and shows a clear positive correlation with the age of the host rock (Toyoda and Hattori, 2000). Crystallinity of quartz reflects the condition of its formation such as temperature and speed of crystallization, so crystallinity of quartz varies from its original rock's type (Murata and Norman, 1976). These barometers reflect quartz's chemistry and they are independent of each other. Now, we collected river and desert sand samples across the Taklimakan desert, and measured ESR signal intensity and crystallinity after dividing samples to fine fraction ($<$0.016mm) and course fraction($>$0.064mm). Why we divide two fractions is to watch the difference of wind transport and river transport.

From measurement of river samples, we could detect quartz's origins like Tinshan Mountains, Karakorum Mountains and Kunlun Mountains and also realized that these data can be used for estimation of quartz's provenance. Moreover, fine fraction quartz near Kunlun mountains are mixed with them derived from Tinshan mountains by wind transport. In this presentation, we add the data of desert sand, and show the distribution from all sand's provenances in the whole Taklimakan Desert. We also consider sand transport system for two fractions by focusing on transport ability of wind and river.

Keywords: desert, deposition, erosion, material transfer, ESR, Crystallinity

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Comparison of Kolmogorov model and experimental data

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Kolmogorov (1951) proved that it is possible to calculate the distribution of layer thickness after infinite repetition of erosion and deposition, from PDF about occurrence of layer thickness for each event. Endo (2010) proved that it is possible to solve the inverse problem under some assumption. Both models for forward and inverse problems assume the continuity of PDF (probability density function) of the magnitude of deposition or erosion where erosion is defined as negative deposition. However it is not obvious that the assumption is always correct in any sedimentary processes or environments. Here we test the model using flume-experimental data conducted at SAFL in University of Minnesota that obtained topographic data during the experimental run and the sedimentary structure of the resultant deposit. By analyzing the topographic data it is found that the PDF of increments and decrements of the surface elevation can be regarded as continuous. After solving the inverse problem from the bed thickness distribution of the deposit, we can calculate the PDF of increments during arbitrary numbers of events. By comparison between calculation and the topographic data from the experiment, it is found that (1) the PDF of increments and decrements of the surface elevation within 8 hours well agrees with the model, but (2) the PDF for 16 hours does not agree with the model and instead the probability of occurrence of increment with the calculated average value (expectation) was quite larger than expected by the model. The result implies the dependence between an event and past ones (history-dependence) for a relatively longer term. To develop the model in the future, the history-dependence should be considered.

Keywords: Probabilistic model, Sedimentation model, Bed thickness distribution

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SCG064-08 Room:202 Time:May 24 16:00-16:15

Flume experiments on the change of transport mode on the bottomset in delta system: the response to flow discharge

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In delta system, the muddy sediment on the bottomset are interpreted as what was transported by (A) low density suspension load (Nishida et al., 2010) or (B) high concentrated flow such as hyperpycnal flows caused by a river of flood (Normark and Piper, 1991; Sasaki, 2010) and fluid mud (Nishida et al., 2010). To understand the formative mechanics of delta topographies, it is useful to conduct flume experiments dealing with each individual elements of processes. In this study, we performed experiments of micro-delta system to investigate the change of sediment transport mode on the bottomset and its dependence on the .increase rate of discharge.

The experimental flume was 1 m long, 15 cm deep and 2.5 cm wide, and was designed to assume a 2-D system between river ? still water area. Used sediment was silt (mean density 2.2 g/cm{3}, median diameter 37.8 micrometer, mode diameter 48.8 micrometer). We limited runs into the cases that the sediment transport modes on the topset were bedload sheet (Reesink and Bridge, 2007, 2010). In each run, the water depth on the topset changes according to flow discharge spontaneously. The observation area was set to be 50 cm downstream from the supply point of mixture of water and silt to take account of erosion of topset when the water discharge increases. The initial flow discharge was set 200 ml/min at which the sediment supplied from topset deposited only on foreset by turbidity currents.

In this study, both modes of sedimentation process corresponding to the above were observed from (A) low density suspension and (B) high concentrated flow. Sedimentation from low density suspension was previously reported in experimental runs at high constant flow discharge (600 ml/min) (Suzuki and Endo, 2010). Here we observed that similar processes occurred under waxing flows at low increase rate when the flow became high discharge. At this time, the shape of foreset became steep slope and 'angular contact (Jopling, 1965).' It was found that only at high increase rate of flow discharge, high concentrated flow occurred due to topset erosion and the sediment deposited onto the foreset and bottomset. At this time, the shape of foreset became gentle slope and 'tangential contact (Jopling, 1965).'

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Experiments on channel head bifurcation

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Channelization is an important aspect of geomorphological processes which attributes to the configuration of a landscape mainly in fluvial dominated areas. Besides, Channelization comprises of different phases: starting from the inception phase transforming to extension then finally to deletion. Therefore, profound understanding of these processes is fundamental to the study of the channel drainage networks evolution. Specifically, identifying the controlling factors and their threshold conditions for the onset of channel head bifurcation is very important in the field of landscape evolution study, particularly on channel networks. Hence, in this study we focused on the process of channel head bifurcation, which is the dissection of channel head into two or more channel branches.

We premeditated our experimental setup in a way that able to evaluate the validation of the theoretical finding that has been done by Mizushima, et al 2007, and to study the details of channel head bifurcation processes and their controlling factors. The theoretical study hypothesized that if the flow concentration is maximized at the top of the channel head, the channel migrates upstream without bifurcating. On contrary, if the flow depth at top edge of the channel head disperses, the channel head splits into two or more channels. They studied this problem using linear stability analysis and finally able to conclude that the channel head becomes unstable when the Froude critical depth divided by the bottom friction coefficient becomes sufficiently small compared with the width of the channel head.

Accordingly, we considered the findings of the theoretical study as our reference input for the experimental setup. A wide flat plain bed ending with a sudden fall at the downstream end was used to simulate a flat plain receiving shallow overland flow from a catchment. A small channel is introduced at the center of the downstream end, always made before the commencement of every experiment. we monitored the development of the channel as the experiment runs. When the experiment starts, the overland flow from upstream end flows as a very shallow water and heading towards downstream end, mainly to the channel head, because by keeping the flat plain horizontal we realized the flow on the flat plain as subcritical flow in the Froude sense so the upstream flow is influenced by the channel. The development of the channel was continuously monitored by recording successive photos from upstream top part of the flat plain, observation by our naked eye was made as well.

In this study we presented the relationships between the controlling factors such as flow depth and surface roughness with respect to the channel head width, for threshold conditions for the commencement of channel head bifurcation. In addition, we observed that channel head bifurcates when the channel head is enlarged in width into the level where the flow depth is sufficiently reduced to the level the flow is reorganized into two or more flow concentrations, and the bifurcation is realized when each small reorganized flows still persists eroding capacity to make the channel migrating upstream. Finally, we noticed that the experimental results are consistence with the basic considerations and results of the theoretical study.

Keywords: channelization, bifurcation, channel head, channel networks

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Geographycal evolution analysis using particle method based on shallow-water equation

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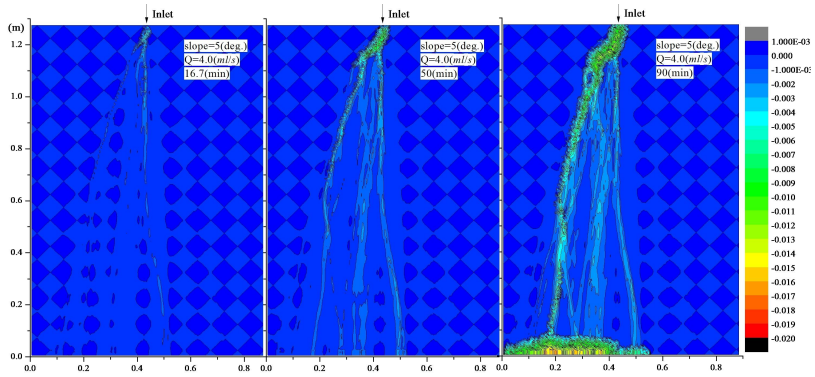
This study deals with a simple geographycal evolution analysis using a particle method based on the shallow-water equation. Since it is a Lagrangian particle method, mass conservation naturally holds. Particle interaction is simply modeled by a two-body potential that is derived from the water head difference. The bottom shear stress is estimated by the Manning equation. Bed load transportation is modeled by Meyer-Peter-Muller relation with a retardation time. Slope failure due to erosion is also considered in the simulation. The figure shows an example of the simulation. The material is a poorly-graded sand whose diameter is about 0.2(mm). The length, width and the angle of the slope is 1.3(m), 0.8(m) and 5 degrees, respectively. Small surface unevenness is introduced at the initial slope. Water discharge from the inlet at the upstream is set to 4.0(ml/s) in this example. The simulation result shows the frequent jump of the flow channel at the initial stage of the simulation (up to 14 minutes), while the channel is fixed at the later stage (after 50 minutes). The final erosion depth at 90 minutes is about 5 to 20 (mm), which is in good agreement with the experiment.



Keywords: Sediment dynamics, Particle method, Geographical evolution

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Three-Dimensional Dune Morphodynamics Using Dune Skeleton Model

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Sand dunes, which are the largest granular objects on the Earth, form the large scale of dune networks and the distinct patterns such as barchan, transverse, linear, star-shaped, dome-shaped, and parabolic dunes also formed. These patterns are determined by two dominant factors; the steadiness of wind direction and the amount of available sand in each dune field. For example, unidirectional steady wind generates barchans or transverse dunes. The former are crescentic shaped dunes, and are formed in dune fields with small amounts of available sand, whereas transverse dunes which extend perpendicular to the wind direction, are formed in dune fields with the larger amounts of available sand than the barchan-rich field. As a characteristic property, barchans move keeping their shape with two horns directing leeward at their lateral edges, additionally, their velocity is kept constant roughly inverse proportional to the height.

One of remarkable aspects of recent dune studies is that quantitative analysis of dune morphodynamics has largely progressed. In particular, rescaled water tank experiments and computer models have successfully reproduced qualitative properties of large scale of desert barchans[1][2]. However, the theoretical methodology explaining the mechanism for the complex morphodynamics of dunes beyond the numerical reproduction of their formation process is yet to be developed. We propose a *Dune skeleton model* consists of coupled ordinary differential equations each of which represents the dynamics of two-dimensional cross sections (hereafter, 2D-CSs). Using the model, we study the morphodynamics of dunes; i) the stability of the shape of transverse dunes, ii) the deformation form transverse dunes to barchan, iii) the condition for the formation of steady barchans and the scaling law with respect to their shape.

First, laterally arraying wind directional 2D-CSs of a 3D transverse dune or a barchan are set as an elements of the present *dune skeleton model*. Hence, we consider the migration process of each 2D-CS and the interaction between laterally neighboring them. The dune migration occurs by the sand flow along the surface is divided two types; (a) intra 2D-CS flow and (b) inter 2D-CS flow. This model simply describes the essential dynamics of 3D dunes as a system of coupled ordinary differential equations.

Dune skeleton model reproduced 3 typical shapes of dunes; straight transverse dune, wavy dune, and barchan, depending on the amount of available sand and wind strength. Also, the present model shows that the increase in the amount of available sand and the inter 2D-CS flow enhances the stability of the shape of transverse dune, whereas the decrease in the amount of available sand and the increase in the intra 2D-CS flow destabilizes its shape to enforce the deformation to a barchan. Additionally, the linear stability analysis of two 2D-CSs system obtained the stability condition of the straight and wavy transverse dune[3].

Moreover, we simulate the stability condition of barchan under 2 different types of sand influx condition from the upwind boundary; i) spatially uniform supply and ii) local supply. It was found that; i) under the uniform supply, steadily maintained barchans are formed within a narrow range of the amount of supply and their size is almost uniquely determined independent of the amount of supply. ii) under the local supply around the central axis of a barchan, steadily maintained barchan is formed and its size varies according to the amount of supply. Moreover, the scaling relations with respect to their shape and dynamics are found that correspond to the observation and the experimental fact.

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Keywords: sand dunes, barchan, transverse dune, mathematical model, numerical simulation, linear stability analysis

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Linear stability analysis of fluvial bars with aggradatio or degradation

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Riverbed degradation causes many engineering and environmental problems. For example, it destabilizes basements of river structures, and sometimes damages habitats of aquatic organisms because of severe local scours. In the Ishikari River in Asahikawa, the bedrock is exposed due to riverbed degradation. It is suspected that the bed degradation is caused by a decrease in sediment supply from the upstream region by flood control facilities such as dams, or an increase in bed shear stress due to the reduction of the width of low-water channels in river improvement works.

Though it is generally said that bed aggradation destabilizes the flat bed while bed degradation does the opposite, no studies have been done on the behavior of bars under non-equilibrium conditions to the authors' knowledge. Most of previous studies focus on bars only under equilibrium conditions. The existing linear stability analysis assumes that the river bed is in equilibrium, and that bed slope and flow in the base state are in normal flow conditions.

In this paper, linear stability analysis of bars under weakly non-equilibium conditions is performed by the use of the WKBJ method. Bed aggradation or degradation is assumed to be sufficiently slow compared with bed evolution due to bed instability, and its non-dimensional speed is used as a small parameter. We introduce two spatial variables with two different length scales: the length scale of aggradation or degradation, and that of bar wavelength. The former is assumed to be much larger than the latter. By solving the base state problem, it is found that one-dimensional base flow is a function of the slowly varying spatial variable. For instance, the flow velocity is accelerated in the streamwise direction, and riverbed has an upward-convex shape under degradation. In the perturbed problem, we expand all the variables with two small parameters: the non-dimensional aggradation/degradaion speed, and the amplitude of perturbations. Substituting the asymptotic expansions into the governing equations, and comparing each order of the two small parameters, we obtain base state equations and perturbed equations with the weakly non-equilibrium effects. Solving all the equations with appropriate boundary conditions, we obtain the growth rate of perturbations including the non-equilibrium effects, and instability diagrams for several values of non-dimensional aggradation or degradation speeds.

The analysis shows that, under degradation, the unstable region in the instability diagram is reduced, implying that there is a tendency of the flat bed being stable. In the unstable region, the dominant bar wavelength increases. Meanwhile, under aggradation, the unstable region in the instability diagram is expanded, which means that there is a tendency of the flat bed being unstable. In the unstable region, the dominant wavelength is reduced, implying that bars with short wavelengths are formed. In addition, alternate bars are more affected by bed aggradation/degradation than multiple bars are done.

Keywords: linear stability analysis, alternate bars, aggradation, degradation, sediment supply, WKBJ method

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THE FORMATION OF BOUNDARY WAVES IN CLOSED CONDUITS WITHOUT FREE WATER SURFACE

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Wavelike configurations are self-formed at the boundary between water and sediment under open channel flow, and are called dunes or antidunes depending on the flow regime. There have been a large number of studies on boundary waves in rivers. It has been found that the boundary waves are strongly related to the Froude number. The formation of dunes and antidunes is caused by a phase lag and lead, respectively, between the bed and water surface profiles; so that it is suspected that the presence of free water surfaces is important for the formation of dunes and antidunes.

Meanwhile, there are only few studies on the bed configurations in closed conduits without free water surfaces. Could any similar boundary waves be formed without free water surfaces? If so, what are the boundary waves like? These are questions that have not been completely solved yet. The stability of the boundary between water and sediment in closed conduits is not completely understood. In order to predict the flow resistance of closed conduits such as sediment bypass and ice-covered rivers, it is important to obtain detailed information on boundary waves formed in closed conduits.

Seki and Izumi [2008] proposed a linear stability analysis for the formation of small scale boundary waves in closed conduits and compare with their experimental results. According to analytical results, the Shields number and the Euler number are the dominant parameters that determine the formation of boundary waves in closed conduits. In addition, they reproduced the boundary waves without free water surface in small scale experimental conduits. However, there is room for improvement of the correspondence between analysis and experimental data.

One of purposes of this study is to improve a linear stability analysis for the formation of boundary waves in closed conduits. The previous analysis by Seki and Izumi assumed that the roughness on the sand layers is same as the roughness on upper walls of conduits. Therefore we introduce the rate of friction velocities as a new parameter, and express the difference of the roughness in the linear stability analysis. As a result, this improves the correspondence and proves the importance of the new parameter.

In addition, we proposed weakly nonlinear stability analysis in order to obtain more detailed information near the critical condition for the wave formations.

Keywords: dune, closed conduit, linear stability analysis, weakly nonlinear stability analysis

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Antidunes and cyclic steps: relating their features to a suspension index and a velocity coefficient

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There are very few comparative studies of the differences in hydraulic conditions and morphologic features of bed- and water-surface-waves associated with cyclic steps and antidunes. In this study, the features of both the bed and the water surface, as well as hydraulic conditions are examined over the spectrum from antidune to cyclic steps. Experiments were performed using a flume at the Osaka Institute of Technology. The resultant features of the bedforms are as follows. In the case of antidunes, bed waves and water surface waves are in phase except when they collapse. Antidunes show several kinds of behavior; migrating downstream, standing, or migrating upstream. Upstream-migrating antidunes are divided into three types such as with-breaking-waves, with-hydraulic-jumps and stable. Breaking antidunes appear alternatively with the plane bed state. Cyclic steps migrate upstream regularly associated with trains of hydraulic jumps, which divide each step. There is a significant change in water depth at the hydraulic jump, so that the phasing between the bed waves and water surface waves break at the each hydraulic jump. There is a kind of compromise between cyclic steps and antidunes, which we designate as intermediate steps. They move upstream and are associated with regular trains of hydraulic jumps. The jumps, however, occasionally collapse toward upstream. When this happens, bed waves move rapidly upstream; low-amplitude water surface waves and bed waves become in phase all over the bed shortly after the collapse. Then after some time, water surface waves become sufficiently prominent to yield regular hydraulic jumps. This cycle is then repeated.

The hydraulic conditions for these bedfoms were examined using three non-dimensional parameters, i.e. the Froude Number, the Suspension Index, and the Velocity Coefficient. The suspension index is the ratio of the shear velocity divided by the settling velocity of the sediment. The velocity coefficient is the ratio of mean flow velocity on the plane bed divided by the shear velocity on the plane bed. Data from previous experimental studies are examined together with the present data in studying the characteristic regimes of bedform formation.

In a diagram of Froude Number v.s. Suspension Index, antidunes, intermediate steps and cyclic steps can be divided along the axis of the Suspension Index. In the lowest range of the suspension index, downstream-migrating antidunes and upstream-migrating stable antidunes are found. The intermediate steps discussed above and antidunes with hydraulic jumps are located in the middle range. The highest range corresponds to cyclic steps and antidunes with breaking waves. As described above, the Suspension Index can serve as a scale to quantify the spectrum between antidunes and cyclic steps. The use of the parameter also helps verify that suspension plays an important role in the formation and maintenance of cyclic steps.

On the other hand, antidunes with breaking waves are located in the highest range of the velocity coefficient whereas cyclic steps located in the middle range. It is related to the stability of upstream-migrating antidunes, which is suggested by the weakly nonlinear stability analysis.

Keywords: Antidunes, Cyclic steps, Flume experiment, Stability analysis, Suspension index, Velocity coefficient

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SCG064-15 Room:202 Time:May 24 18:00-18:15

Transportational cyclic step formation in subaqueous environment

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Supercritical flow in the Richardson sense over a steep fragile bed may generate ephemeral short wave bed forms like antidunes, most commonly observed to migrate upstream. In some cases, however, antidunes give way to a much more stable cousin bounded by internal hydraulic jumps in the flow above them, which stabilize the flow morphodynamics while leaving depositional records unlike the antidunes. This long wave manifestation of the instability is christened as cyclic steps, by researchers and categorized under two main folds;erosional steps and transportational steps.

In subaqueous environments positive feed back between turbidity currents and the erodible bed gives rise to sediment waves and circumstantial evidences by numerical simulations and field observations have proven these sediment waves are non other than the cyclic steps. Studies related with the subaqueous cyclic step formation are not abundant and idealized models employing the mathematical elucidation of this formation phenomenon yet to be tested in this research arena. This is an endeavor to mathematically elaborate the formation of transportational cyclic step in subaqueous environment powered by the density driven turbidity current.

An idealized model has been developed preserving the essential physics of the system, employing one dimensional (1D) shallow water equations along with the dispersion equation of suspended sediment and Exner equation of sediment continuity. Assuming the interaction of sea water with the turbid underflow is considerably small in most of the region of our concern entrainment coefficient related terms are dropped in the continuity equation of the turbidity current. Being on the logic that the response of flow is sufficiently quick compared with the response of bed, quasi steady assumptions are employed during the solution phase for further simplification of the governing equations. Conservation of the suspended sediment through the hydraulic jump, zero bed evolution at the either ends of the selected step, specified threshold velocity for the incision of the bed erosion at the upstream end of the step and the Richardson critical conditions at the origin of the stream wise coordinate are employed as boundary conditions during the rigorous calculation procedure.

Considering a single step which migrates upstream preserving its shape, model is solved starting from the vicinity of the Richardson critical point where flow transits from sub critical to supercritical, to obtain the shape of the step along with the behavior of the characteristic parameters govern this formation process at the so called base state.

Keywords: cyclic steps, turbidity currents, subaqueous environment, 1D shallow water equations

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SCG064-16 Room:202 Time:May 24 18:15-18:30

Cyclic steps formed by bedrock incision

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Step-like morphology is formed on slopes composed of cohesive soil where erosion dominantly takes place (erosional cyclic steps), and slopes composed fine sediment where both erosion and deposition take place (transportational cyclic steps). The step-like morphology is called cyclic steps, and studied by many researchers by means of experiments, theory, and numerical simulation. The studies have elucidated the formation processes, the formative conditions, and the scales of cyclic steps in terms of several non-dimensional parameters. It has been known that similar step-like morphology is observed in bedrock rivers. Though it is suspected that these are a kind of erosional cyclic steps, the erosion processes of bedrocks are expected to be different from that of cohesive soil. In this study, the erosion processes of bedrocks are simply formulated, and the formation of cyclic steps due to bedrock incision is studied theoretically.

Keywords: cyclic step, bedrock, erosion, hydraulic jump

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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

Shota Yamashita[1*], Hajime Naruse[1], Takeshi Nakajo[2]

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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

Japan Geoscience Union Meeting 2011
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SCG064-P02 Room:Convention Hall Time:May 24 10:30-13:00

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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SCG064-P03 Room:Convention Hall Time:May 24 10:30-13:00

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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SCG064-P04 Room:Convention Hall Time:May 24 10:30-13:00

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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SCG064-P05 Room:Convention Hall Time:May 24 10:30-13:00

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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Jan C.-D., Lin M.-C., 1998, Journal of Waterway, Port, Coastal, and Ocean Engineering, 124, 295?302.

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