**Recent Geomorphology Articles**

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[Gravity tectonics of topographic ridges: Halokinesis and gravitational spreading in the western Ogaden, Ethiopia](http://www.sciencedirect.com/science/article/pii/S0169555X13001591)

1 July 2013
Daniel Mège | Laetitia Le Deit | Tewodros Rango | Tesfaye Korme

Abstract: The Cenozoic history of the western Ogaden region of Ethiopia, between the Ethiopian rift and the South Afar margin, is marked by uplift and incision of the Ogaden plateau down to the Gorrahei Formation, an upper Cretaceous evaporite formation. Debuttressing of this and the overlying sedimentary formations resulted in widespread and spectacular gravitational spreading landforms over a minimum surface area of 15,000km2, most of which remains unstudied. After clearing up some misconceptions about the surface geology of the study area, the Kebenawa Ridge in the Audo Range, observations are reported that point to a tectonic style controlled by halokinesis and subsequently, gravitational spreading. The role of diapirism and karstification in the observed halokinesis is discussed, as well as the influence of halokinesis on gravitational spreading. Spreading is in part akin to sackung, in that ridge deformation features include a crestal graben and basal ridge topography extrusion, and deformation was triggered by lateral ridge debuttressing. Ridge spreading also presents analogy with gravitational spreading of the Canyonlands grabens in the Needles District, Canyonlands National Park, Utah. The scale and the mechanisms are found to be basically similar, but two differences are noted. First, incision by the drainage network in response to plateau uplift in Ethiopia has debuttressed the topography along two parallel rivers, instead of a single river (the Colorado River) in Utah. Secondly, incision proceeded to the base of the evaporite layer in the Ogaden, whereas incision has not exceeded the top of the evaporite layer in Utah. These differences may have influenced the details of the spreading mechanisms in ways that remain to be investigated. Overall, in Ethiopia, association of halokinesis and a transitional mode of gravitational spreading at the interface between narrow ridge spreading (sackung) and plateau spreading (Canyonlands-type), illustrates a fascinating and unusual ridge evolution style.

[Glacial geomorphology of the Victoria Valley System, Ross Sea Region, Antarctica](http://www.sciencedirect.com/science/article/pii/S0169555X13001700)

1 July 2013
James G. Bockheim | Malcolm McLeod

Abstract: During the 2011–2012 austral summer, we had the opportunity to verify a surficial geology map prepared nearly 50years ago for the Victoria Valley system (VVS), the largest of the McMurdo Dry Valleys. We used high-resolution landsat images and a digital elevation model to identify landforms and prepare detailed maps of each of the five valleys in the VVS, including lateral and end moraines, rock glaciers, gelifluction sheets, gravel ripples, and hummocky and ice-cored drifts. Our mapping suggests that the Bull drift is less extensive than previously thought, attains a maximum elevation of ~750m in Balham and Barwick Valleys and the upper Bull Pass region, and does not occur in McKelvey Valley. We found Insel drift to 850m elevation in eastern McKelvey Valley and upper Bull Pass and were able to trace Insel drift down Bull Pass where it becomes Peleus drift in Wright Valley. The Victoria Lower Glacier likely responded to grounding of ice in the Ross Embayment and was out-of-phase with alpine glaciers elsewhere in the VVS. We amplified and quantified Calkin's relative chronology and provide here our multiple-parameter relative chronology for the McMurdo Dry Valleys that is based on surface-boulder weathering, soil weathering, salt stage, degree of development of the desert pavement, and form of patterned ground. Except for Victoria Lower Valley, we correlate Packard drift with Taylor II drift (ca., 120ka), Vida drift with Taylor III drift (ca., 300ka), Bull drift with Taylor IVb drift (2.7–3.5Ma, and Insel drift with Peleus drift (>3.7Ma, <5.4Ma). The lack of a strong correlation between soil salt stage and depth of visible salts with elevation leads us to question whether a high-level lake (ca., 200m deep) existed in the VVS during the early Holocene.

[Channel planform change and detachment of tributary: A study on the Haora and Katakhal Rivers, Tripura, India](http://www.sciencedirect.com/science/article/pii/S0169555X13001839)

1 July 2013
Shreya Bandyopadhyay | Sushmita Saha | Kapil Ghosh | Sunil Kumar De

Abstract: The main objective of the paper is to find the probable causes behind the shifting course of the Haora River, one of the major rivers of West Tripura and detachment of one of its major tributaries, the Katakhal River. From a recent satellite image, we observed that the River Haora has changed its course drastically near the confluence. Earlier, it used to take a sharp northward bend to meet with the River Titas immediately after crossing the Indo-Bangladesh border; but presently it is flowing westward to do so. Moreover, the Katakhal River, a right bank tributary of the River Haora, that used to flow through the northern side of the city of Agartala and meet with the River Haora at Bangladesh, is no longer a tributary of the Haora River. Now it is completely detached from the Haora River and meets with the River Titas separately.Spatiotemporal maps have been used to detect the changes. Field investigation, with the help of GPS, has been done in order to find the link between the Haora River and the Katakhal River within the Indian territory. Changing patterns of the Haora and Katakhal River confluences are also analysed, and earlier courses are identified. The shifting trends of both of these two rivers are found along the flanks of the interfluvial area because of microscale tectonic activity, i.e., upliftment of the interfluvial zone.

[Influence of ice sheet and glacial erosion on passive margins of Greenland](http://www.sciencedirect.com/science/article/pii/S0169555X13001888)

1 July 2013
S. Medvedev | A. Souche | E.H. Hartz

Abstract: The presence of Mesozoic and Cenozoic marine sediments at an altitude of 1.2km near Scoresby Sund (central east Greenland) and Nuussuaq Peninsula (central west Greenland), and even up to 2km in the Kangerdlugssuaq region (south-central east Greenland), illustrates significant uplifts of Greenland's margins. The magnitude of these uplifts somewhat contrasts with the absence of major tectonic activity along Greenland margins during the Cenozoic. In this study we test to which degree these vertical motions can be explained by glacial processes. We analyze the influence of the ice sheet loading in the central part of Greenland and the carving of the fjord systems on the evolution of the topography by numerically modeling these processes backward in time. In our experiments, we start with the modern topography and ice thickness and evaluate the pre-glacial topography calculating the flexural isostatic response to unloading the ice sheet. By restoring erosion backward in time and calculating the flexural isostatic effects, we estimate the influence of glacial carving (hereafter, the carving of the Earth surface by glacial-related erosion) and evaluate the pre-erosional topography of Greenland. Our analyses show that (1) the load of the ice sheet causes up to 850m subsidence of the bedrock topography of the central part of Greenland. (2) The peripheral bulging caused by this ice loading has a negligible effect on amplitude of the uplifted Greenland margins. (3) Glacial carving and corresponding development of the large fjord system has a significant influence on vertical motion of passive margins of central (east and west) Greenland and can explain up to 1.2km uplift. (4) The models show, however, that much of Greenland's topography is not caused by ice-related processes, and thus origin of these older mountain chains remains enigmatic. (5) Masses eroded from the regions of significant glacial erosion are larger than the recognized amount of sediments within adjacent off-shore basins, meaning that either the topography of those margins formed before breakup of Greenland or that sediments can be moved far away by the ocean. We also illustrate that our estimations are conservative because of low resolution of the DEMs used for calculations. Higher DEM resolution may increase effects of glacial carving by ~40%.

[An evaluation of Mesodon and other larger terrestrial gastropod shells for dating late Holocene and historic alluvium in the Midwestern USA](http://www.sciencedirect.com/science/article/pii/S0169555X13001906)

1 July 2013
Monica T. Rakovan | Jason A. Rech | Jeffrey S. Pigati | Jeffrey C. Nekola | Gregory C. Wiles

Abstract: Understanding the history of stream erosion and changes in channel morphology is important for managing and restoring unstable streams. One of the significant challenges in this type of research is establishing accurate dating of late Holocene and historic alluvium. Here we evaluate the potential of using 14C dating and amino acid racemization (AAR) to date large terrestrial gastropod shells that are often preserved within alluvial sediments. Many terrestrial gastropods incorporate old carbon from limestone or other carbonate rocks into their shells and therefore are unsuitable for radiocarbon dating. Recent studies, however, have shown that some taxa avoid this ‘limestone problem’ and can yield reliable 14C ages. In this study, we measured the 14C activity of specimens for the genera Mesodon, Ventridens, and Allogona collected live and from alluvial sequences dated independently by dendrochronology, 14C dating of wood, and/or 137Cs analyses. Mesodon zaletus contained old carbon in similar concentrations (up to ~30%) found in previous studies of other large taxa and should be avoided for 14C dating when possible. In contrast, shells of Ventridens ligera and Allogona profunda showed minimal limestone effects and therefore may be suitable for dating late Holocene alluvium. These results highlight the importance of taxonomic identification of gastropod taxa prior to their use for 14C dating and demonstrate that shell fragments that are not identifiable should be avoided. We also measured d/l ratios (n=17) of aspartic and glutamic acid from eight different taxa of terrestrial gastropods recovered from four late Holocene and historic stratigraphic sequences. Average d/l ratios of aspartic and glutamic acid from historic sediments <300years old are lower in shells from younger stratigraphic units, indicating that AAR can be used to differentiate between multiple historic stratigraphic units.

[Phytogenic mounds of four typical shoot architecture species at different slope gradients on the Loess Plateau of China](http://www.sciencedirect.com/science/article/pii/S0169555X13001955)

1 July 2013
Hua-Dong Du | Ju-Ying Jiao | Yan-Feng Jia | Ning Wang | Dong-Li Wang

Abstract: In semi-arid regions, the spatial pattern of vegetation usually appears as a mosaic of plants surrounded by bare soil. Phytogenic mounds often develop under these plants and create microenvironments that promote plant establishment. This study examined the effects of ground slope and plant shoot architecture on mound formation. Four species representing different shoot architectures (Artemisia gmelinii, with dense shoot architecture; Artemisia giraldii, with expanding shoot architecture; tussock-forming Bothriochloa ischaemum; and Sophora viciifolia, with a main-stem shoot architecture) and four classes of slope were selected. A two-dimensional ‘microprofilemeter’ was used to measure mound shape and height, and mound area was measured using the Image Pro-plus software with a planer mound picture. Phytogenic mound shapes changed from symmetrical mound type to asymmetrical terrace type as slope increased. With increasing slope mound height increased for all species; the mound area of S. viciifolia decreased; and that of A. giraldii increased. A. gmelinii and B. ischaemum had a relatively constant mound area irrespective of slope. Among the plant shoot architecture parameters, the basal diameter along the slope (Dba) significantly correlated with mound height, while the plant basal diameter perpendicular to the slope (Dbp) and the total cross-sectional area of the stem at the base (Sn) were related to mound area. The results indicate that phytogenic mounds on gentler slopes are formed due to the difference in rain splash erosion beneath the plant canopy and surrounding bare surfaces. On steeper slopes, mounds are formed due to water erosion on bare soil and the prevention of erosion and sediment accumulation under plants. Plant shoot architecture also influences mound formation. Species with expanding shoot architecture, such as A. giraldii that spread laterally to create high density stems and occupy a large area, can create relatively large mounds. Species with main-stem shoot architecture such as S. viciifolia, have a mound area that shrinks rapidly with increasing slope.

[A spatially lumped model to investigate downstream sediment flux propagation within a fluvial catchment](http://www.sciencedirect.com/science/article/pii/S0169555X13001979)

1 July 2013
Andrea Forzoni | Gerben de Jager | Joep E.A. Storms

Abstract: A spatially lumped process–response model, PaCMod, is presented, which calculates long time series (103–106years) of fluvial water discharge and sediment load at the river catchment outlet, based on climatic data, drainage basin characteristics and user-defined parameters. Key aspects of the model are (i) the lumped approach, allowing for fast simulations and preserving the same resolution from palaeoclimatic conditions and geomorphological reconstructions; (ii) the parameterization of sediment routing and storage within the catchment. PaCMod was successfully tested on observed data from three present-day fluvial systems: the Meuse, the Waipaoa, and the Po Rivers. Moreover, the simulated sediment flux for the Meuse and for the Waipaoa Rivers in the late Quaternary is in agreement with published field and modelling work. PaCMod experiments show how the downstream propagation of the original climatic signal is hampered by sediment routing and storage within the catchment.

[Geomorphological and seismological investigations in a part of western Kumaun Himalaya, Uttarakhand, India](http://www.sciencedirect.com/science/article/pii/S0169555X13002018)

1 July 2013
Vivekanand Pathak | Charu C. Pant | Gopal Singh Darmwal

Abstract: The Kumaun Himalaya in India is seismotectonically one of the most responsive sectors of the Himalayan arc. The region falls in the seismic gap and is frequently rocked by the earthquakes of low to medium magnitude. In the present investigation, the seismic data of the area were obtained by deploying a seismic network, and an attempt is made to interpret the seismological data of the local events and their relation with the geomorphology and thrusts/faults rejuvenation. The epicentral distribution of the earthquakes defines a relatively narrow zone of seismicity. A majority of earthquakes are confined to shallow depth with low stress drop and higher peak ground velocity (PGV). Further, the neotectonic investigations along the major river valleys indicate the neotectonic activity in the form of paired and unpaired terraces, shifting of river courses, fault scarps, development of palaeolakes, straightening of river channels, and deep cut V-shaped valleys. From the geomorphological and seismological data, the thrust and fault systems in the area are seismotectonically quite active even today. Some of the transverse faults — viz. Dwarahat-Chaukhutia fault, Takula-Basauli fault (Sim Gad valley), Tilora-Jyala fault (Kosi valley) — show spectacular tectonic landforms and seismicity. As a matter of fact, the NNW/NW–SSE/SE trending faults are active in the region.

[Changes in the channel-bed level of the eastern Carpathian rivers: Climatic vs. human control over the last 50years](http://www.sciencedirect.com/science/article/pii/S0169555X1300202X)

1 July 2013
Maria Rădoane | Florin Obreja | Ionuţ Cristea | Dumitru Mihailă

Abstract: This paper is focused on the changes over the past 50years in the channel beds of seven major rivers that are part of the Siret drainage basin located in eastern Romania. Each river has been subjected to various degrees of human intervention, assessed based on the morphological quality index (MQI): two rivers (Siret and Bistrita) have undergone complex human interventions on 40 and 60%, respectively, of their channel lengths, two rivers (Suceava and Moldova) are 30% artificial, and the remaining three rivers (Trotus, Putna, and Buzău) have a good or moderate MQI.The changes occurring in channel beds and data on water discharge (Qw) and sediment load (Qs) were assessed simultaneously for the last 50years. The bedload was indirectly evaluated as ranging between 5 and 15% of the total sediment load. It was determined that incision was prevalent among the processes acting on the channel-bed sections under investigation (representing 62% of the altered area and changing bed level by between −0.25 and −2.70m), with aggradation accounting for the remaining 38% (causing changes ranging from +0.15 to +1.25m). The magnitude of the processes (incision or aggradation) for sections with an MQI<0.3 was four times higher than for sections with a moderate or good MQI (>0.3).The pattern of change in the channel-bed processes between 1960 and 2010 for all river categories was as follows: a low rate of incision from 1960 to 1979, followed by a higher rate of incision from 1980 to 1989, and finally a tendency of recovery toward the river's initial state, characterised by a decrease in the incision rate or slight aggradation after 1990. The variable that exhibited the strongest response to climate conditions was water discharge (Qw), whereas the sediment load (Qs) was highly responsive to both climatic signals and anthropogenic factors. The sediment load has been instrumental in the adjustments of the channel beds by maintaining a balance between the two controlling factors, nature and man.

[Sediment tracing in the upper Hunter catchment using elemental and mineralogical compositions: Implications for catchment-scale suspended sediment (dis)connectivity and management](http://www.sciencedirect.com/science/article/pii/S0169555X1300216X)

1 July 2013
Kirstie Fryirs | Damian Gore

Abstract: River bed colmation layers clog the interstices of gravel-bed rivers, impeding the vertical exchange of water and nutrients that drives ecosystem function in the hyporheic zone. In catchments where fine-grained sediment supply has increased since human disturbance, understanding sediment provenance and the (dis)connectivity of supply allows practitioners to target sediment source problems and treat them within catchment management plans.Release of alluvial fine-grained sediment from channel bank erosion since European settlement has resulted in the formation of a colmation layer along the upper Hunter River at Muswellbrook, eastern Australia. X-ray fluorescence spectrometry (XRF) and X-ray diffractometry (XRD) are used to determine the elemental and mineralogical signatures of colmation layer and floodplain sediment sources across this 4480km2 catchment. This sediment tracing technique is used to construct a picture of how suspended sediment supply and (dis)connectivity operates in this catchment. In this system, the primary source areas are subcatchments in which sediments are stored largely in partly confined floodplain pockets, but from which sediment supply is unimpeded and directly connected to the receiving reach. Subcatchments in which alluvial sediment storage is significant — and which contain large, laterally unconfined valleys — are essentially ‘switched off’ or disconnected from the receiving reach. This is because large sediment sinks act to trap fine-grained sediment before it reaches the receiving reach, forming a buffer along the sediment conveyor belt. Given the age structure of floodplains in the receiving reach, this pattern of source area contributions and (dis)connectivity must have occurred throughout the Holocene.

[Impact of soil characteristics and land use on pipe erosion in a temperate humid climate: Field studies in Belgium](http://www.sciencedirect.com/science/article/pii/S0169555X13001062)

15 June 2013
E. Verachtert | M. Van Den Eeckhaut | J.F. Martínez-Murillo | E. Nadal-Romero | J. Poesen | S. Devoldere | N. Wijnants | J. Deckers

Abstract: This study investigates the role of soil characteristics and land use in the development of soil pipes in the loess belt of Belgium. First, we tested the hypothesis that discontinuities in the soil profile enhance lateral flow and piping by impeding vertical infiltration. We focus on discontinuities in soil characteristics that can vary with soil depth, including texture, saturated hydraulic conductivity, penetration resistance, and bulk density. These characteristics as well as soil biological activity were studied in detail on 12 representative soil profiles for different land use types. Twelve sites were selected in the Flemish Ardennes (Belgium): four pastures with collapsed pipes (CP), four pastures without CP, two sites under arable land without CP and two sites under forest without CP. Secondly, this study aimed at evaluating the interaction of groundwater table positions (through soil augerings) and CP in a larger area, with a focus on pastures. Pasture is the land use where almost all CP in the study area are observed. Therefore, the position of the groundwater table was compared for 15 pastures with CP and 14 pastures without CP, having comparable topographical characteristics in terms of slope gradient and contributing area. Finally, the effect of land use history on the occurrence of pipe collapse was evaluated for a database of 84 parcels with CP and 84 parcels without CP, currently under pasture. As to the first hypothesis, no clear discontinuities for abiotic soil characteristics in soil profiles were observed at the depth where pipes occur, but pastures with CP had significantly more earthworm channels and mole burrows at larger depths (>120cm: mean of >200 earthworm channels per m2) than pastures without CP, arable land or forest (>120cm depth, a few or no earthworm channels left). The land use history appeared to be similar for the pastures with and without CP. Combining all results from soil profiles and soil augering indicates that intense biological activity (especially by earthworms and moles), in combination with a sufficiently high groundwater table, favours the development of soil pipes in the study area.

[Palaeoglacial and palaeoclimatic conditions in the NW Pacific, as revealed by a morphometric analysis of cirques upon the Kamchatka Peninsula](http://www.sciencedirect.com/science/article/pii/S0169555X13001529)

15 June 2013
Iestyn D. Barr | Matteo Spagnolo

Abstract: The distribution of glacial cirques upon the Kamchatka peninsula, Far Eastern Russia, is systematically mapped from satellite images and digital elevation model data. A total of 3758 cirques are identified, 238 of which are occupied by active glaciers. The morphometry of the remaining 3520 cirques is analysed. These cirques are found to show a very strong N bias in their azimuth (orientation), likely resulting from aspect-related variations in insolation. The strength of this N bias is considered to indicate that former glaciation upon the peninsula was often ‘marginal’, and mainly of cirque-type, with peaks extending little above regional equilibrium-line altitudes. This is supported by the fact that S and SE-facing cirques are the highest in the dataset, suggesting that glacier-cover was rarely sufficient to allow S and SE-facing glaciers to develop at low altitudes. The strength of these azimuth-related variations in cirque altitude is thought to reflect comparatively cloud-free conditions during former periods of glaciation. It is suggested that these characteristics, of marginal glaciation and comparatively cloud-free conditions, reflect the region's former aridity, which was likely intensified at the global Last Glacial Maximum, and during earlier periods of ice advance, as a result of the development of negative pressure anomalies over the North Pacific (driven by the growth of the Laurentide Ice Sheet), combined with other factors, including an increase in the extent and duration of sea ice, a reduction in global sea levels, cooler sea surface temperatures, and the localised growth of mountain glaciers. There is published evidence to suggest extensive glaciation of the Kamchatka Peninsula at times during the Late Quaternary, yet the data presented here appear to suggest that such phases were comparatively short-lived, and that smaller cirque-type glaciers were generally more characteristic of the period.

[A scaling distribution for grain composition of debris flow](http://www.sciencedirect.com/science/article/pii/S0169555X13001566)

15 June 2013
Li Yong | Zhou Xiaojun | Su Pengcheng | Kong Yingde | Liu Jingjing

Abstract: Debris flow is composed of a wide range of grains. This study proposes a general form of grain size distribution, P (D)=CD−μexp (−D/Dc), which is satisfied well by various debris flows and by soils and sediments related to debris flows. The parameters μ and Dc are found to be related to debris-flow density in power laws. In particular, μ represents some characteristic porosity of soil in a natural condition and controls the variation of soils in developing debris flows; and Dc defines a characteristic size governing the sediment concentration. Field observations indicate that debris flows fall into a certain range of parameters (μ, Dc). Almost all debris flows have μ<0.10, and most debris flows of high density have μ<0.05. Moreover, experiments show that the exponent μ increases during soil failures under rainfall, providing an index varying in the course of debris flow initiation. Finally, grain size distribution is used to evaluate the properties of debris flows in different regions. The distribution provides a simple but quantitative method of predicting a potential flow through the source soils.

[Coastal geomorphic conditions and styles of storm surge washover deposits from Southern Thailand](http://www.sciencedirect.com/science/article/pii/S0169555X13001578)

15 June 2013
Sumet Phantuwongraj | Montri Choowong | Futoshi Nanayama | Ken-Ichiro Hisada | Punya Charusiri | Vichai Chutakositkanon | Santi Pailoplee | Akkaneewut Chabangbon

Abstract: The characteristics of tropical storm washover deposits laid down during the years 2007 to 2011 along the southern peninsular coast of the Gulf of Thailand (GOT) were described in relation to their different geomorphic conditions, including perched fan, washover terrace and sheetwash lineations preserved behind the beach zone within 100m of the shoreline. As a result, washover terrace and sheetwash lineations were found where the beach configuration was uniform and promoted an unconfined flow. Non-uniform beach configurations that promoted a confined flow resulted in a perched fan deposit. Washover sediments were differentiated into two types based on sedimentary characteristics, including (i) a thick-bedded sand of multiple reverse grading layers and (ii) a medium-bedded sand of multiple normal grading layers. In the case of thick-bedded washover deposits, the internal sedimentary structures were characterized by the presence of sub-horizontal bedding, reverse grading, lamination, foreset bedding and wavy bedding, whereas, horizontal bedding, normal grading, and dunes were the dominant structures in the medium-bedded washover sand. Rip-up clasts were rare and recognized only in the washover deposits in the bottom unit, which reflects the condition when a mud supply was available. All washover successions were found in the landward inclined-bedding with a basal sharp contact. A high elevated beach ridge associated with a large swale at the backshore proved suitable for a thick-bedded washover type, whereas a small beach ridge with uniformly flat backshore topography promoted a medium-bedded washover sediment.

[Correlating river terrace remnants using an Equotip hardness tester: An example from the Miño River, northwestern Iberian Peninsula](http://www.sciencedirect.com/science/article/pii/S0169555X1300158X)

15 June 2013
Augusto Pérez Alberti | Alberto Gomes | Alan Trenhaile | Maria Oliveira | Jesus Horacio

Abstract: This paper describes a new method to distinguish river terrace levels based on clast hardness and degree of weathering measured with an Equotip hardness tester. The technique was applied to a series of terraces on the Miño River in the northwestern Iberian Peninsula, where the lack of suitable material, high degree of weathering, and intense iron cementation precluded routine dating. Detailed mapping demonstrated that terrace sediments occupy a range of altitudes that make assignment to a specific terrace, and/or correlation between levels, difficult. Statistical analysis of the Equotip hardness data from quartzite clasts using k-means clustering allowed four probable terrace levels to be identified; a series of t-tests generally supported these groupings. A fifth, lowermost terrace level, was not included in the analysis because of limited exposure above a reservoir. Clast hardness and degree of terrace weathering were generally consistent with progressive river downcutting. The occurrence of faulted sediments, however, suggested that terrace elevations were modified locally by post-depositional tectonic movements, which may explain why probable younger terraces in some sectors of the Miño River are at higher elevations than older terraces in adjacent sectors. The Equotip tester helped to resolve stratigraphic uncertainties and to assign deposits to specific terrace levels and was found to be a useful tool to distinguish and correlate river terraces.

[The influence of surface slope on the shape of river basins: Comparison between nature and numerical landscape simulations](http://www.sciencedirect.com/science/article/pii/S0169555X13001724)

15 June 2013
Sébastien Castelltort | Philippe Yamato

Abstract: We investigate the influence of initial conditions of slope and surface roughness on the shape (length to width aspect ratio) of incipient drainage basins in numerical experiments of simple tilted surfaces using the CASCADE code of landscape evolution. Comparison with data on the shape of river basins in nature shows that simple rules of the steepest-descent routing of water are sufficient to account for a natural range of incipient drainage basin shape, independently of the erosion processes at work. To produce numerical basins that respect the main aspect ratio of natural drainage basins, one must use very low initial regional surface slopes of less than 1° at the scale of the entire drainage basins, and a local roughness slope of less than 3° at the scale of local surface irregularities. Numerical studies addressing real study cases may take advantage of the relation between local roughness and regional slope in order to produce catchment aspect ratios similar to the natural studied cases.

[Denudation rates of the Southern Espinhaço Range, Minas Gerais, Brazil, determined by in situ-produced cosmogenic beryllium-10](http://www.sciencedirect.com/science/article/pii/S0169555X13000585)

1 June 2013
Helen N. Barreto | César A.C. Varajão | Régis Braucher | Didier L. Bourlès | André A.R. Salgado | Angélica F.D.C. Varajão

Abstract: To investigate denudation rates in the southern part of the Espinhaço Range (central-eastern Brazil) and to understand how this important resistant and residual relief has evolved in the past 1.38My, cosmogenic 10Be concentrations produced in situ were measured in alluvial sediments from the three main regional basins, whose substratum is composed primarily of quartzites. The long-term denudation rates (up to 1.38My) estimated from these measurements were compared with those that affect the western (São Francisco River) and eastern (Doce and Jequitinhonha Rivers) basins, which face the West San Francisco craton and the Atlantic, respectively. Denudation rates were measured in 27 samples collected in catchments of different sizes (6–970km2) and were compared with geomorphic parameters. The mean denudation rates determined in the northern part are low and similar to those determined in the southern part, despite slightly different geomorphic parameter values (catchment relief and mean slope). For the southern catchments, the values are 4.91±1.01mMy−1 and 3.65±1.26mMy−1 for the Doce and São Francisco River basins, respectively; for the northern catchments, they are 4.40±1.06mMy−1 and 3.96±0.91mMy−1 for the Jequitinhonha and São Francisco River basins, respectively. These low values of denudation rates suggest no direct correlation if plotted against geomorphic parameters such as the catchment area, maximum elevation, catchment relief, average relief and mean slope gradients. These values show that the regional landscape evolves slowly and is strongly controlled by resistant lithology, with similar erosional rates in the three studied basins.

[Sea saltwater weakening of chalk and the impact on cliff instability](http://www.sciencedirect.com/science/article/pii/S0169555X13001098)

1 June 2013
J.A. Lawrence | R.N. Mortimore | K.J. Stone | J.P. Busby

Abstract: Chalk forms one of the major coastal cliff formations throughout Northwest Europe, with large population centres and critical infrastructure being exposed to and at risk from cliff collapses in this rock type. Traditionally, the two main factors leading to chalk cliff collapse have been considered to be: (i) waves attacking and eroding the base of the cliff and (ii) water weakening as the chalk becomes saturated. This work challenges the established view by identifying the role of salt from seawater in the degradation of porous rocks in coastal environments as a third and potentially the most important mechanism leading to chalk cliff collapse. Field and laboratory investigations have identified and quantified the role of sea saltwater weakening of chalk in coastal environments. A series of triaxial strength tests have identified that coastal chalks are up to 55% weaker than their inland equivalents. This weakening process is as a result of saltwater ingress into the chalk. SEM imaging has shown that seawater penetrates the porous chalk and the salt progressively concentrates, forming salt crystals which disrupt the pore structure and weakening the rock material which then leads to catastrophic cliff failure. Saltwater weakening of cliffs could be one of the main factors leading to large- and small-scale collapses observed along the chalk coast line, and is likely to be the primary reason for the increasing frequency of cliff failures along protected coastal sections as the sea salt progressively concentrates in the cliff reducing its mechanical strength. Rock strength is not usually considered to be temporally variable and is, therefore, rarely considered in relation to climate change. However, this is not true of soft rocks like chalk, which weaken and collapse in short time periods as they are exposed to external factors.

[Variation in canyon morphology on the Great Barrier Reef margin, north-eastern Australia: The influence of slope and barrier reefs](http://www.sciencedirect.com/science/article/pii/S0169555X1300113X)

1 June 2013
Ángel Puga-Bernabéu | Jody M. Webster | Robin J. Beaman | Vincent Guilbaud

Abstract: New high-resolution bathymetry, seismic reflection profiles, and existing sidescan data have revealed the presence of a series of submarine canyons in the slope off the Noggin Passage region, north-eastern Australia. The morphology of the Noggin Canyons contrasts with that of the canyons in the Ribbon Reef region, further north along the north-eastern Australia margin. The Noggin Canyons are mostly slope-confined, with canyon heads located at water depths between 200 and 400m. These narrow and straight canyons show a decrease in canyon relief with depth, and have incision values and canyon gradients lower than the Ribbon Reef Canyons. New findings on the Ribbon Reef Canyons reveal an increase of canyon relief with depth in the shelf-incised canyons, as well as complex relationships between geomorphic parameters, such as canyon gradient, incision, canyon width and canyon wall gradient. The main factors controlling the differences in canyon morphology are the shape of the continental slope and the presence of barrier reefs at the shelf-edge. Steep exponential and linear slope profiles, and the presence of an extensive shelf-edge barrier system in the Ribbon Reef region, are related to large shelf-incised canyons. In contrast, the slope-confined canyons of the Noggin region are linked to sigmoidal slopes, and more open outer-shelf conditions lacking barrier reefs. These conditions allow higher overall sediment supply to the upper slope, and the resulting formation of sigmoidal slope profiles. In the Ribbon Reef region, the physical barriers provided by the shelf-edge barrier reefs reduce the amount of shelf-to-basin sediment transport, thereby forming exponential slopes. Further, sediment gravity flow deposition through the canyons is more prominent in the Ribbon Reef region, as a direct consequence of the more frequent breaching of the shelf by the canyons, otherwise infrequent in the Noggin region. Our results highlight this particular relationship between canyon and slope morphology, and the importance of the variable shelf-edge morphology in controlling the shelf-to-basin sediment transport. This aspect is especially relevant for understanding the margin development in modern and ancient mixed carbonate-siliciclastic continental settings.

[Modelling the effects of tidal range and initial bathymetry on the morphological evolution of tidal embayments](http://www.sciencedirect.com/science/article/pii/S0169555X13001104)

1 June 2013
B. van Maanen | Giovanni Coco | K.R. Bryan

Abstract: Tidal embayments are characterized by a wide variety of landscape features, often including either complex tidal channel networks or extensive flood-tidal deltas. The origin of these features and the influence of hydrodynamic drivers and initial geological setting on their long-term characteristics are essentially unexplored. A model was applied to simulate the long-term morphological evolution of tidal embayments, with the purpose of providing insight into the environmental conditions that lead to the differences in tidal embayment morphology. Numerical simulations indicated that the interaction between hydrodynamics, sediment transport, and the evolving topography gives rise to the formation of channel networks. The tidal range and the depth of the initially unchannelized tidal basin controlled the way in which the morphology evolved and determined the timescale over which channels and intertidal areas developed. Channel network formation occurred more rapidly when the tidal range increased and/or when the initial basin depth decreased. Tidal basins with a large initial depth showed the development of a flood-tidal delta and for these deep basins channel incision could remain absent over long timescales. Both tidal range and initial bathymetry affected final basin hypsometry and channel network characteristics, including the channel density and the fraction of the basin occupied by the channels. All the simulated morphologies, with different combinations of the tidal range and depth of the basin, evolved towards a state of less morphodynamic activity for which the relative intertidal area was proportional to the ratio of tidal amplitude to basin depth.

[The relationship between bank erosion, local aggradation and sediment transport in a small Carpathian stream](http://www.sciencedirect.com/science/article/pii/S0169555X13001141)

1 June 2013
Ł. Bąk | A. Michalik | T. Tekielak

Abstract: River bank erosion is the main process in small mountainous basins, especially those where the main channel is built of poorly resistant sedimentary rock or alluvium, exemplified by the Słomka basin.The main goal of the study, based on the field survey work and the erosion pin method, was to define the relation between river bank erosion, accumulation, and sediment transport.The investigations were carried out in the Słomka stream basin (watercourse length of 25.2km, basin area of 69.9km2) on an ~1.0-km-long stream reach, strongly anthropogenically transformed, between watercourse kilometres 5.0 and 6.0. We found that with an increase in flow the retreat bank rate increased nonlinearly. An average migration rate of the undercut banks ranged from 0.10m for the flow rate of 11.5m3s−1 to 0.92m for the flow rate of 35.5m3s−1. The maximum observed rate exceeded 0.8m for the flow rate of 11.5m3s−1 and 9.0m for the flow rate of 24.8m3s−1. With respect to the channel vertical morphology over the whole measurement section, we found that bed gradeline was raised, on average, by ~0.04m. The trend is contrary to the results of field surveys performed earlier on the Carpathian watercourses. The phenomenon is related to the abundant supply of rock rubble into the stream channel.High flow stages in the Słomka stream, which caused the stream bed material to move, had a predominant impact on stream channel morphology. Processes such as destructive activity of rain drops, aeolian erosion (sandblasting), soil expansion, and shrinkage during the rainy and dry seasons were of minor significance.

[Influence of filling–drawdown cycles of the Vajont reservoir on Mt. Toc slope stability](http://www.sciencedirect.com/science/article/pii/S0169555X13001165)

1 June 2013
Paolo Paronuzzi | Elia Rigo | Alberto Bolla

Abstract: In the present work, the 1963 Vajont landslide has been back-analyzed in detail to examine the influence of reservoir operations (filling and drawdown) on Mt. Toc slope stability. The combined seepage–slope stability analyses carried out show that the main destabilizing factor that favored the 1963 Vajont landslide was the reservoir-induced water table that formed as a consequence of rapid seepage inflow within the submerged toe of the slope — decrease in the factor of safety (FOS) up to 12% compared to the initial slope stability condition, i.e., in the absence of the Vajont reservoir. Rainfall would only have been a decisive factor if the initial stability condition of the Mt. Toc slope had already been very close to failure (decrease in FOS caused by heavy or prolonged rainfall is about 3–4%, for the worst case scenario analyzed). The permeability of the shear zone material occurring at the base of the prehistoric Vajont rockslide has been evaluated at 5×10−4m/s, and back-calculated values of the friction angles Φ range from 17.5° to 27.5°. When considering mountain reservoirs, slope failures can occur during both filling and drawdown phases. In the Vajont case, owing to the highly permeable materials of the shear zone, slope stability decreased during filling and increased during drawdown. Another displacement-dependent phenomenon of a mechanical nature – progressive failure of the NE landslide constraint – has to be considered to understand the slope collapse that occurred during the last drawdown (26 September–9 October 1963). The results of the combined seepage–slope stability models indicate that permeability of bank-forming material and filling–drawdown rates of reservoirs can strongly influence slope stability. Slow lowering of the reservoir level is a necessary measure to reduce the occurrence of very dangerous transient negative peaks of FOS.

[A hydrologic and geomorphic model of estuary breaching and closure](http://www.sciencedirect.com/science/article/pii/S0169555X13001153)

1 June 2013
Andrew Rich | Edward A. Keller

Abstract: To better understand how the hydrology of bar-built estuaries affects breaching and closing patterns, a model is developed that incorporates an estuary hydrologic budget with a geomorphic model of the inlet system. Erosion of the inlet is caused by inlet flow, whereas the only morphologic effect of waves is the deposition of sand into the inlet. When calibrated, the model is able to reproduce the initial seasonal breaching, seasonal closure, intermittent closures and breaches, and the low-streamflow (closed state) estuary hydrology of the Carmel Lagoon, located in Central California. Model performance was tested against three separate years of water-level observations. When open during these years, the inlet was visually observed to drain directly across the beach berm, in accordance with model assumptions. The calibrated model predicts the observed 48-h estuary stage amplitude with root mean square errors of 0.45m, 0.39m and 0.42m for the three separate years. For the calibrated model, the probability that the estuary inlet is closed decreases exponentially with increasing inflow (streamflow plus wave overtopping), decreasing 10-fold in probability as mean daily inflow increases from 0.2 to 1.0m3/s. Seasonal patterns of inlet state reflect the seasonal pattern of streamflow, though wave overtopping may become the main hydrologic flux during low streamflow conditions, infrequently causing short-lived breaches. In a series of sensitivity analyses it is seen that the status of the inlet and storage of water are sensitive to factors that control the storage, transmission, and inflow of water. By varying individual components of the berm system and estuary storage, the amount of the time the estuary is open may increase by 57%, or decrease by 44%, compared to the amount of time the estuary is open during calibrated model conditions for the 18.2-year model period. The individual components tested are: berm height, width, length, and hydraulic conductivity; estuary hypsometry (storage to stage relationship); two factors that control wave-swash sedimentation of the inlet; and sea level rise. The elevation of the berm determines the volume of water that must enter the estuary in order to breach, and it modulates the wave-overtopping flux and frequency. By increasing estuary storage capacity, the estuary will breach less frequently (−27% change in time open for modeled excavation scenario) and store water up to 3months later into the summer. Altering beach aquifer hydraulic conductivity affects inlet state, and patterns of breaching and water storage. As a result of sea-level rise of 1.67m by 2100, and a beach berm that remains in its current location and accretes vertically, the amount of time the estuary remains open may decrease by 44%. Such a change is an end-member of likely scenarios given that the berm will translate landwards. Model results indicate that the amount of time the estuary is open is more sensitive to changes in wave run-up than the amount of sand deposited in the inlet per each overtopping wave.

[Quantifying spatial and temporal trends in beach–dune volumetric changes using spatial statistics](http://www.sciencedirect.com/science/article/pii/S0169555X13001359)

1 June 2013
Jordan B.R. Eamer | Ian J. Walker

Abstract: Spatial statistics are generally underutilized in coastal geomorphology, despite offering great potential for identifying and quantifying spatial–temporal trends in landscape morphodynamics. In particular, local Moran's Ii provides a statistical framework for detecting clusters of significant change in an attribute (e.g., surface erosion or deposition) and quantifying how this changes over space and time. This study analyzes and interprets spatial–temporal patterns in sediment volume changes in a beach-foredune–transgressive dune complex following removal of invasive marram grass (Ammophila spp.). Results are derived by detecting significant changes in post-removal repeat DEMs derived from topographic surveys and airborne LiDAR. The study site was separated into discrete, linked geomorphic units (beach, foredune, transgressive dune complex) to facilitate sub-landscape scale analysis of volumetric change and sediment budget responses. Difference surfaces derived from a pixel-subtraction algorithm between interval DEMs and the LiDAR baseline DEM were filtered using the local Moran's Ii method and two different spatial weights (1.5 and 5m) to detect statistically significant change. Moran's Ii results were compared with those derived from a more spatially uniform statistical method that uses a simpler student's t distribution threshold for change detection. Morphodynamic patterns and volumetric estimates were similar between the uniform geostatistical method and Moran's Ii at a spatial weight of 5m while the smaller spatial weight (1.5m) consistently indicated volumetric changes of less magnitude. The larger 5m spatial weight was most representative of broader site morphodynamics and spatial patterns while the smaller spatial weight provided volumetric changes consistent with field observations. All methods showed foredune deflation immediately following removal with increased sediment volumes into the spring via deposition at the crest and on lobes in the lee, despite erosion on the stoss slope and dune toe. Generally, the foredune became wider by landward extension and the seaward slope recovered from erosion to a similar height and form to that of pre-restoration despite remaining essentially free of vegetation.

[Frequency–magnitude distribution of debris flows compiled from global data, and comparison with post-fire debris flows in the western U.S.](http://www.sciencedirect.com/science/article/pii/S0169555X13001475)

1 June 2013
Karin L. Riley | Rebecca Bendick | Kevin D. Hyde | Emmanuel J. Gabet

Abstract: Forecasting debris flow hazard is challenging due to the episodic occurrence of debris flows in response to stochastic precipitation and, in some areas, wildfires. In order to facilitate hazard assessment, we have gathered available records of debris flow volumes into the first comprehensive global catalog of debris flows (n=988). We also present results of field collection of recent debris flows (n=77) in the northern Rocky Mountains, where debris flow frequency increases following wildfire. As a first step in parameterizing hazard models, we use frequency–magnitude distributions and empirical cumulative distribution functions (ECDFs) to compare volumes of post-fire debris flows to non-fire-related debris flows. The ECDF of post-fire debris flow volumes is significantly different (at 95% confidence) from that of non-fire-related debris flows, suggesting that the post-fire distribution is composed of a higher proportion of small events than that of non-fire-related debris flows. The slope of the frequency–magnitude distribution of post-fire debris flows is steeper than that of non-fire-related debris flows, corroborating evidence that small post-fire debris flows occur with a higher relative frequency than non-fire-related debris flows. Taken together, the statistical analyses suggest that post-fire debris flows come from a different population than non-fire-related debris flows, and their hazard must be modeled separately. We propose two possible non-exclusive explanations for the fact that the post-fire environment produces a higher proportion of small debris flows: 1) following fires, smaller storms or effective drainage areas can trigger debris flows due to increased runoff and/or decreases in root strength, resulting in smaller volumes and increased probability of failure, and 2) fire increases the probability and frequency of debris flows, causing their distribution to shift toward smaller events due to limitations in sediment supply.

[Detection of land surface memory by correlations between thickness of colluvial deposits and morphometric variables](http://www.sciencedirect.com/science/article/pii/S0169555X13001360)

1 June 2013
A.V. Mitusov | S. Dreibrodt | O.E. Mitusova | S.V. Khamnueva | H.-R. Bork

Abstract: Some morphometric variables store information about past land surfaces longer than others. This property of morphometric variables is recognised as land surface memory. Slope deposits, soils, and vegetation also have this memory. In this study, a memory effect was quantitatively detected by Spearman correlations between thickness of colluvium and morphometric variables of the modern land surface.During long-term sedimentation, the sign of horizontal curvature (kh) may be inverted from minus to plus, suggesting that locations with positive kh values are not accumulation zones. However, the thickness of colluvial deposits at such locations in our study area indicates sediment accumulation. The sign of minimal curvature (kmin) tends to be more stable and remains negative. This difference provides the stronger correlation of colluvial layer thickness with kmin than with kh. The strongest correlation was found for total thickness of the colluvial deposits of the Neolithic and Iron Age with kmin (−0.84); the correlation with kh was weaker (−0.71).

[Spatio-temporal changes in river bank mass failures in the Lockyer Valley, Queensland, Australia](http://www.sciencedirect.com/science/article/pii/S0169555X13001499)

1 June 2013
Chris Thompson | Jacky Croke | James Grove | Giri Khanal

Abstract: Wet-flow river bank failure processes are poorly understood relative to the more commonly studied processes of fluvial entrainment and gravity-induced mass failures. Using high resolution topographic data (LiDAR) and near coincident aerial photography, this study documents the downstream distribution of river bank mass failures which occurred as a result of a catastrophic flood in the Lockyer Valley in January 2011. In addition, this distribution is compared with wet flow mass failure features from previous large floods. The downstream analysis of these two temporal data sets indicated that they occur across a range of river lengths, catchment areas, bank heights and angles and do not appear to be scale-dependent or spatially restricted to certain downstream zones. The downstream trends of each bank failure distribution show limited spatial overlap with only 17% of wet flows common to both distributions. The modification of these features during the catastrophic flood of January 2011 also indicated that such features tend to form at some ‘optimum’ shape and show limited evidence of subsequent enlargement even when flow and energy conditions within the banks and channel were high. Elevation changes indicate that such features show evidence for infilling during subsequent floods. The preservation of these features in the landscape for a period of at least 150years suggests that the seepage processes dominant in their initial formation appear to have limited role in their continuing enlargement over time. No evidence of gully extension or headwall retreat is evident. It is estimated that at least 12 inundation events would be required to fill these failures based on the average net elevation change recorded for the 2011 event. Existing conceptual models of downstream bank erosion process zones may need to consider a wider array of mass failure processes to accommodate for wet flow failures.

[MSI (morphometric slope index) for analyzing activation and evolution of calanchi in Italy](http://www.sciencedirect.com/science/article/pii/S0169555X13001128)

1 June 2013
Marcello Buccolini | Laura Coco

Abstract: The “calanchi” (singular calanco) are a typical example of Italian badlands, widespread in areas with hills of clay-rich sediments and rocks. They appear as a very dense and rapidly evolving drainage system characterized by an alternating pattern of narrow furrows and sharp crests. The calanchi can be considered as small hydrographical basins, characterized by two possible drainage patterns, parallel and dendritic. The two patterns show both linear and areal erosion processes.In this study, calanchi with dendritic drainage patterns were analyzed in three different areas representative of the Italian Peninsular: Atri in the Abruzzi region, Mount Ascensione in the Marche region, and Orcia Valley in the Tuscany region. For each calanchi, the pre-erosion topographic surface was reconstructed and the value of MSI (morphometric slope index) was calculated for the surface. The volume of eroded material was estimated by comparing the pre-calanchi and present surfaces. We assumed that slope morphometry influences the type of erosion processes, and the efficacy of these processes with respect to the amount of eroded material is a function of their duration. We deduced that calanchi inception was contemporaneous, because the duration of the processes was common to all landforms, and probably due to a common climate input. Moreover, the relations among MSI, eroded volume and erosion processes indicate that, over a long period, areally distributed surface processes contribute more to total sediment yields than channel flows.

[Development of Pleistocene glaciomarginal lake in the foreland of the Sudetes (SW Poland)](http://www.sciencedirect.com/science/article/pii/S0169555X13000743)

15 May 2013
T. Salamon | D. Krzyszkowski | A. Kowalska

Abstract: Numerous glaciomarginal lakes existed during the Pleistocene in the Sudetes and their foreland (SW Poland) because of damming off by an ice sheet. In the mountain area they were formed in the valleys or intermountain basins during the phase of maximum ice extent. In the mountain foreland they were developed at the front of the more active ice margin in the period preceding the maximum ice sheet advance. The latter lakes were less confined by the topography and their contact with the ice sheet was often considerably larger. This caused their different development.The sedimentological development of a small lake of this type, located near Mokrzeszów, was studied. The lake was characterized by high variability in water level and high energy depositional processes. Because of its small size, the lake responded very quickly to all changes in external factors. The lake became filled mainly by a coarse-grained delta. This happened in several phases because the water level fluctuated considerably owing to oscillations in the ice sheet extent. During lowstands, the delta became incised. Locally, subaqueous fans were formed. The lake basin eventually became overridden by the ice sheet.

[Influence of particle shape on surface roughness: Dissimilar morphological structures formed by man-made and natural gravels](http://www.sciencedirect.com/science/article/pii/S0169555X13000767)

15 May 2013
Jie Qin | Deyu Zhong | Guangqian Wang | Sai Leung Ng

Abstract: Static armored gravel surfaces composed of man-made and natural gravels have been analyzed using precise digital elevation models. The scaling behavior and spatial arrangement of the gravel surfaces were evaluated and discussed with respect to the successive formation of stable armor layers. The key results relate to structure functions and imbrication analysis of these surfaces: (1) man-made gravel surfaces show a similar scaling behavior and spatial correlation pattern to natural gravel surfaces; (2) man-made gravel surfaces have larger Hurst exponents than natural gravel surfaces; and (3) man-made gravels are poorly imbricated in comparison with natural gravels. Our results suggest that different morphological structures between man-made and natural gravels were attributed to shape features of individual grains.

[Genesis of an esker-like ridge over the southern Fraser Plateau, British Columbia: Implications for paleo-ice sheet reconstruction based on geomorphic inversion](http://www.sciencedirect.com/science/article/pii/S0169555X13000779)

15 May 2013
Andrew J. Perkins | Tracy A. Brennand | Matthew J. Burke

Abstract: Robust interpretations of meltwater systems operating during ice sheet decay are integral to reconstructing deglacial patterns and style. Yet over reliance on meltwater landform morphology with limited attention to morpho-sedimentary relationships, and basin-scale geomorphic and stratigraphic context can lead to unreliable geomorphic inversion-based paleo-ice sheet reconstructions. This problem is illustrated by the evolution of Young Lake esker-like ridge (YLER) formed in the Young Lake basin (YLB) on BC's southern Fraser Plateau during decay of the last Cordilleran Ice Sheet (CIS). We integrate data from digital elevation models, aerial photographs, sedimentary outcrops, water wells and shallow geophysics (ground-penetrating radar, electrical resistivity tomography). Previous interpretations of YLER as both an esker and an ice-contact, poorly-sorted, stratified deposit emplaced by westerly flowing meltwater, imply an eastward retreating ice margin. Geophysical data from a flat-topped component of YLER reveal slipface and planar-bedded sand and gravel overlying lacustrine sediments, characteristic of a Hjulstrom delta. Eastward-dipping foresets in a Gilbert delta exist at the eastern terminus. Contextually our observations suggest, despite esker-like morphology, YLER was not deposited within a subglacial ice tunnel. Instead, it formed through deposition of subaerial outwash between and/or on dead ice in front of a regionally backwasting ice margin. The complex deglacial evolution of YLB, including a drainage reversal and formation of two glacial lakes, supports northwestward backwasting of the CIS and dead ice within YLB. We conclude that accurate geomorphic inversion of meltwater landforms for deglacial paleo-ice sheet reconstruction requires knowledge of landform-scale morpho-sedimentary relationships and basin-scale geomorphic and stratigraphic context.

[Relative importance of breakage and decay as processes depleting large wood from streams](http://www.sciencedirect.com/science/article/pii/S0169555X13000780)

15 May 2013
Eric C. Merten | Pedro G. Vaz | Jo A. Decker-Fritz | Jacques C. Finlay | Heinz G. Stefan

Abstract: Large wood pieces affect virtually every physical, chemical, and biological process in fluvial systems, including hydraulics, transport of materials, algal biomass accrual, nutrient uptake, and trophic interactions. The processes that deplete wood are thus of broad importance to stream ecosystems. We assessed the relative contributions for breakage-induced mobilization (where pieces are more prone to transport as a result of breakage into shorter parts) and gradual biochemical decay to wood depletion rates in a field study on 12 northern Minnesota, USA, streams. Wood pieces>0.05m in diameter for a portion>1m in length were individually tagged (n=651), measured, and remeasured a year later. Pieces showed significant reductions in density and branching complexity (i.e., branches and twigs) and 22% of pieces broke (i.e., lost 10% or more of length). Processes related to breakage and decay were examined using Bayesian structural equation modeling and multiple regression. Breakage was more likely for pieces that were thin in diameter, long, deeply submerged, braced, buried, and traveled long distances. Pieces lost more density if they were initially dense, traveled a long distance, were not deeply submerged, lacked bark, were thin in diameter, were steeply pitched, were long, and were not buried. Pieces lost more branching complexity if they were complex with little gap between them and the streambed. Actual mass losses related to breakage and decay were 7.3% and 1.9% (respectively), both less than the 36% observed for total fluvial export. In contrast to the associations of breakage and decay with structural properties of the wood pieces and their position, hydraulic and geomorphic variables (stream power, slope, velocity, width) had little effect.

[Climatically influenced denudation rates of the southern African plateau: Clues to solving a geomorphic paradox](http://www.sciencedirect.com/science/article/pii/S0169555X13000792)

15 May 2013
J.E. Decker | S. Niedermann | M.J. de Wit

Abstract: Southern Africa displays a high topography but paradoxically exhibits tectonic stability and low denudation rates. Here the present controls on denudation in southern Africa are investigated by comparing maximum denudation rates for Karoo dolerite surfaces in the region, determined from the abundances of cosmogenic noble gas nuclides (3He, 21Ne and 38Ar) in pyroxenes, with the predictions of a climate-dependent weathering rate model. In general, we find an excellent agreement in the value ranges of both datasets (<4m/Myr), and interpret this as evidence that present denudation in southern Africa is weathering-limited and climatically influenced due to an apparent absence of significant regional neotectonic uplift. The onset of this geodynamic coupling is unknown but may be of considerable antiquity, thus allowing for the prolonged tenure of southern Africa's inherited Cretaceous topography.

[DEM and GIS analysis of geomorphic indices for evaluating recent uplift of the northeastern margin of the Tibetan Plateau, China](http://www.sciencedirect.com/science/article/pii/S0169555X13000950)

15 May 2013
Mingxing Gao | Gerold Zeilinger | Xiwei Xu | Qingliang Wang | Ming Hao

Abstract: The northeastern margin of the Tibetan Plateau is a tectonically active region consisting of a series of faults with bounded intermountain basins and is located in the transition zone between the Tibetan Plateau and the Loess Plateau. Active deformation that may affect the topography in this region can be quantified using geomorphic indices. Therefore, we applied geomorphic indices such as the hypsometric integral and the stream length gradient index to infer neo-tectonics in the northeastern margin of the Tibetan Plateau. Different time-scaled geodetic leveling data and river incision rates were also integrated into the investigation. The results show that the hypsometric integrals are not significantly affected by lithology but spatially correspond to the hanging walls of thrust faults. The hypsometric integrals are also positively correlated with the leveling data. Although the stream length gradient index is influenced by lithology, its most pronounced anomalies of the stream length gradient are associated with the thrust faults. Consequently, the uplift in the northeast margin of the Tibetan Plateau appeared to be concentrated along the hanging walls of the thrust faults.

[Landslide model performance in a high resolution small-scale landscape](http://www.sciencedirect.com/science/article/pii/S0169555X13000998)

15 May 2013
V. De Sy | J.M. Schoorl | S.D. Keesstra | K.E. Jones | L. Claessens

Abstract: The frequency and severity of shallow landslides in New Zealand threatens life and property, both on- and off-site. The physically-based shallow landslide model LAPSUS-LS is tested for its performance in simulating shallow landslide locations induced by a high intensity rain event in a small-scale landscape. Furthermore, the effect of high resolution digital elevation models on the performance was tested. The performance of the model was optimised by calibrating different parameter values. A satisfactory result was achieved with a high resolution (1m) DEM. Landslides, however, were generally predicted lower on the slope than mapped erosion scars. This discrepancy could be due to i) inaccuracies in the DEM or in other model input data such as soil strength properties; ii) relevant processes for this environmental context that are not included in the model; or iii) the limited validity of the infinite length assumption in the infinite slope stability model embedded in the LAPSUS-LS. The trade-off between a correct prediction of landslides versus stable cells becomes increasingly worse with coarser resolutions; and model performance decreases mainly due to altering slope characteristics. The optimal parameter combinations differ per resolution. In this environmental context the 1m resolution topography resembles actual topography most closely and landslide locations are better distinguished from stable areas than for coarser resolutions. More gain in model performance could be achieved by adding landslide process complexities and parameter heterogeneity of the catchment.

[Subglacial bedforms reveal an exponential size–frequency distribution](http://www.sciencedirect.com/science/article/pii/S0169555X13001049)

15 May 2013
J.K. Hillier | M.J. Smith | C.D. Clark | C.R. Stokes | M. Spagnolo

Abstract: Subglacial bedforms preserved in deglaciated landscapes record characteristics of past ice–sediment flow regimes, providing insight into subglacial processes and ice sheet dynamics. Individual forms vary considerably, but they can often be grouped into coherent fields, typically called flow-sets, that reflect discrete episodes of ice flow. Within these, bedform size–frequency distributions (predominantly height, width and length) are currently described by several statistics (e.g., mean, median, and standard deviation) that, arguably, do not best capture the defining characteristics of these populations. This paper seeks to create a better description based upon semi-log plots, which reveal that the frequency distributions of bedform dimensions (drumlin, mega-scale glacial lineation, and ribbed moraine) plot as straight lines above the mode (ϕ). This indicates, by definition, an exponential distribution, for which a simple and easily calculated, yet statistically rigorous, description is designed. Three descriptive parameters are proposed: gradient (λ; the exponent, characterising bedforms likely least affected by non-glacial factors), area-normalised y-intercept (β0; quantifying spatial density), and the mode (ϕ). Below ϕ, small features are less prevalent due to i) measurement: data, sampling and mapping fidelity; ii) possible post-glacial degradation; or iii) genesis: not being created sub-glacially. This new description has the benefit of being insensitive to the impact of potentially unmapped or degraded smaller features and better captures properties relating to ice flow. Importantly, using λ, flow sets can now be more usefully compared with each other across all deglaciated regions and with the output of numerical ice sheet models. Applications may also exist for analogous fluvial and aeolian bedforms. Identifying the characteristic exponential and that it is typical of ‘emergent’ subglacial bedforms is a new and potentially powerful constraint on their genesis, perhaps indicating that ice–sediment interaction is fundamentally stochastic in nature.

[Delineation of lakes and reservoirs in large river basins: An example of the Yangtze River Basin, China](http://www.sciencedirect.com/science/article/pii/S0169555X13001050)

15 May 2013
Xiankun Yang | X.X. Lu

Abstract: One of the major impediments to water resources management in developing countries has been the fragmented nature of available data on the surface area, size and distribution of natural lakes and artificial reservoirs. In this study we used a parsimonious method based on remote sensing techniques to identify and extract water bodies in the Yangtze River Basin and classify them into three main categories: natural lakes, artificial reservoirs and rivers. This method combines data from the best available free sources, resulting in higher data quality. Using Landsat TM/ETM+ images, we delineated nearly 43,600 reservoirs and 42,700 lakes and estimated a total quantity of 0.7 million smaller (surface area <0.0036km2) reservoirs and 0.5 million smaller lakes. The combined surface area of the reservoirs was ca. 8600km2 with a total storage capacity of ca. 288km3, and the total surface area of natural lakes was ca. 16,200km2, with a total storage capacity of only 46km3. These results indicate that the 43,600 reservoirs are capable of storing a volume of water equaling nearly 30% of the annual mean runoff in the Yangtze basin, but there is considerable geographic variation in the potential surface water impacts. Capacity–area ratios, which are strong indicators of the general hydrologic effects of reservoirs, range from 22,600m3km−2 in the Jinshajiang tributary to 347,500m3km−2 in the Poyang Lake Region. The greatest river flow impacts may occur in the Hanjiang tributary, where the reservoir capacity is equivalent to up to 90% of the mean annual runoff. The results of this study show that the Yangtze River Basin, which was previously dominated by natural lakes, has become dominated by reservoirs as a result of reservoir construction and the shrinkage of natural lakes.

[Recurrence analysis of the mass movement activity at Stambach (Austria) based on radiocarbon dating](http://www.sciencedirect.com/science/article/pii/S0169555X13001074)

15 May 2013
Ingmar Unkel | Dominik Ehret | Joachim Rohn

Abstract: The Stambach mass movement (Austria) is a large and deep-seated mass movement in the Austrian Alps. It consists of a complex and compound mass movement system. The latest major reactivation of the Stambach mass movement was initiated in 1982 by rock fall activity that triggered an earth flow, which transformed into a mud flow. Six sediment cores were taken along the entire earth flow body showing a complex mixture of rock fall blocks and earth flow material. Whenever the earth flow was active, numerous wooden remains were buried within the flow mass. Thirteen of these remains sampled from the sediment cores were radiocarbon dated. The results indicate that the first activation of the Stambach mass movement occurred at least around 9750–9900cal BP, followed by at least three further events during the Holocene, around 6310–5650, 2320–1880, and 1600–1180cal BP. Accumulation of toppled rock towers in the head area of the earth flow, followed by a sudden collapse and saturated, undrained loading of the earth flow body, is the main trigger for activating the earth flow. These long lasting preparatory processes make it difficult to determine certain recurrence intervals. However, our data show that the Stambach mass movement was (and most probably still can be) reactivated after more than 3000years of dormancy.

[Generating an optimal DTM from airborne laser scanning data for landslide mapping in a tropical forest environment](http://www.sciencedirect.com/science/article/pii/S0169555X13001086)

15 May 2013
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Abstract: Landslide inventory maps are fundamental for assessing landslide susceptibility, hazard, and risk. In tropical mountainous environments, mapping landslides is difficult as rapid and dense vegetation growth obscures landslides soon after their occurrence. Airborne laser scanning (ALS) data have been used to construct the digital terrain model (DTM) under dense vegetation, but its reliability for landslide recognition in the tropics remains surprisingly unknown. This study evaluates the suitability of ALS for generating an optimal DTM for mapping landslides in the Cameron Highlands, Malaysia. For the bare-earth extraction, we used hierarchical robust filtering algorithm and a parameterization with three sequential filtering steps. After each filtering step, four interpolations techniques were applied, namely: (i) the linear prediction derived from the SCOP++ (SCP), (ii) the inverse distance weighting (IDW), (iii) the natural neighbor (NEN) and (iv) the topo-to-raster (T2R). We assessed the quality of 12 DTMs in two ways: (1) with respect to 448 field-measured terrain heights and (2) based on the interpretability of landslides. The lowest root-mean-square error (RMSE) was 0.89m across the landscape using three filtering steps and linear prediction as interpolation method. However, we found that a less stringent DTM filtering unveiled more diagnostic micro-morphological features, but also retained some of vegetation. Hence, a combination of filtering steps is required for optimal landslide interpretation, especially in forested mountainous areas. IDW was favored as the interpolation technique because it combined computational times more reasonably without adding artifacts to the DTM than T2R and NEN, which performed relatively well in the first and second filtering steps, respectively. The laser point density and the resulting ground point density after filtering are key parameters for producing a DTM applicable to landslide identification. The results showed that the ALS-derived DTMs allowed mapping and classifying landslides beneath equatorial mountainous forests, leading to a better understanding of hazardous geomorphic problems in tropical regions.

[Quantifying the scale of gravel-bed clusters with spatial statistics](http://www.sciencedirect.com/science/article/pii/S0169555X1300264X)

Available online 12 May 2013
Philip L’Amoreaux | Stanford Gibson

Abstract: Clustering of large surficial particles affect the critical shear stress, bedload transport rate, and ecological processes of gravel rivers. Particle clusters have been the subject of careful study and taxonomy but would benefit from new quantitative, reproducible, statistical analysis, particularly in the gravel size classes where clusters are difficult to reliably resolve by visual, gestalt methods. This study quantified a clustering length scale for a gravel and cobble bed. The size, orientation, and location of 7726 gravel and cobble particles were measured from 100 photographic samples of a symmetrical bar on the Navarro River, California. Nearest neighbor spatial statistics were used to analyze particle associations. Clustering was identified between gravel particles throughout the river bar. Clustering was also identified for large (> d84 of the sample) and medium (between the d50 and d84 of the sample) particles relative to the local gradation. The spatial scale of these large and medium particle clusters were 1.75d84 and 3.0d50, respectively.

[Origin of step-like and lobate seafloor features along the continental shelf off Rio de Janeiro State, Santos basin-Brazil](http://www.sciencedirect.com/science/article/pii/S0169555X13002638)

Available online 9 May 2013
A.T. Reis | R.M.C. Maia | C.G. Silva | M. Rabineau | J.V. Guerra | C. Gorini | A. Ayres | R. Arantes-Oliveira | M. Benabdellouahed | I. Simões | R. Tardin

Abstract: A combined analysis of seismic and morphological features identified in a set of high-resolution seismic reflection and bathymetric data, shows a systematic relationship between major modern seafloor morphological traces and the basinward migration of Late Pleistocene coastlines along the continental shelf of the Santos basin (Rio de Janeiro State, SE Brazil). Observed fairly continuous and sinuous mid-outer shelf escarpments are related to the sea-level variations and shelf exposure during the Last Glacial cycle. A bathymetric step at -110 m is an erosional remnant of offlapping detached forced-regressive wedges that spread over 50 km in the shelf-dip direction, probably developed during periods of falling sea level between MIS 3 and 2. A second major escarpment at -130 m was interpreted as the shoreline during the LGM, at the time of most extensive subaerial exposure of the continental shelf. However, a distal escarpment at -150 m is expressed as a straight contour feature along the two main shelf-edge embayments that characterize the shelf break. This escarpment is coupled with a basal seaward-inclined and highly eroded ramp, and was interpreted as the erosional action of bottom currents during the last transgression due to the displacement of the southward flowing Brazil Current towards the present-day outer shelf. Previously published articles have regarded the morphological features observed on the modern shelf as indicators of stillstands during the post-LGM transgression. We conclude that, on the contrary, most of these features are actually from earlier parts of the Late Pleistocene and were formed in a regressive scenario under oscillating and relative slow sea-level fall.

[Using airborne LiDAR and USGS DEM data for assessing rock glaciers and glaciers](http://www.sciencedirect.com/science/article/pii/S0169555X13002614)

Available online 9 May 2013
Jason R. Janke

Abstract: Varying topographic and geologic conditions affect the location of rock glaciers. Despite being found worldwide, rock glaciers are often confused with glacier counterparts or other periglacial landforms. Light Detection And Ranging (LiDAR) data, because of its accuracy and resolution, may help the assessment of topographic variables needed to form rock glaciers or help reveal unique characteristics to enhance regional, automatic mapping. The objectives of this paper are to compare the elevation, slope, aspect, hillshade, and curvature for 1 m LiDAR and 10 m US Geological Survey (USGS) Digital Elevation Models (DEMs) from the Andrews and Taylor glaciers with the Taylor rock glacier in Colorado. The utility of these data sources will be assessed for landform discrimination and to evaluate the uncertainty between the DEMs. According to the LiDAR data, the Taylor rock glacier exists at a lower elevation and has a gentler slope compared to the glaciers. Each landform has steep areas from which snow and debris are delivered. The Andrews glacier has the most northern aspect, which helps maintain it through snow accumulation and reduced insolation. Glaciers exhibit a concave mean curvature, whereas the Taylor rock glacier has a convex mean curvature. The fine resolution of the LiDAR data clearly identifies some distinct characteristics. On Taylor rock glacier, ridges, furrows, and a pronounced front slope were easily identifiable on the LiDAR DEM, whereas crevasses, the boundary between snow and debris covered surfaces, and a lateral moraine were detectable near the Andrews glacier. The accuracy assessment revealed that at a common 10 m resolution, the USGS DEM estimated a maximum elevation about 150 m greater compared to the LiDAR data in areas of rugged topography surrounding the landforms. A comparison of Root Mean Squared Errors (RMSE) between the LiDAR and USGS DEMs showed that Taylor rock glacier has the lowest RMSE for the elevation and the curvature variables. As a result, readily available USGS DEMs may better for analysis to characterize the topographic setting of landforms at the regional scale. At the fine scale, however, the micro-topography of rock glaciers is illuminated much more clearly on the LiDAR data, making it an ideal, yet costly source, for feature extraction.

[Continuous measurements of bedload transport rates in a small glacial river catchment in the summer season (Spitsbergen)](http://www.sciencedirect.com/science/article/pii/S0169555X13002626)

Available online 9 May 2013
Waldemar Kociuba | Grzegorz Janicki

Abstract: The study on bedload transport was conducted on the gravel-bed Scott River catchment with a glacial alimentation regime, located in the NW part of the Wedel Jarlsberg Land (Spitsbergen) with subpolar climatic conditions. In the melt season 2010, bedload transport rate was continuously monitored at 24-hour intervals by means of four River Bedload Trap devices aligned across the width of the channel. The maximum bedload transport rate varied strongly at portions of the cross section from 16 to 152 kg m−1d−1 in cross-profile I (c-p I) and 4 to 125 kg m−1d−1 in cross-profile II (c-p II). The maximum channel-mean bedload transport rate (qa) amounted to 54 kg m−1d−1 (c-p I) and 35 kg m−1d−1 (c-p II). Mean daily bedload discharge (Qb) was estimated at a level of 97 kg day-1 (c-p I) and 35 kg m−1d−1 (c-p II), and the total bedload yield was determined at approx. 4345 kg in the measurement period (2086 kg – c-p I; 2203 kg – c-p II from 13.07 to 10.08). The analysis of the relationship between channel-mean bedload transport rate and water velocity or shear stress revealed a significant value of the correlation coefficient (R2=0.6). Discharge and rate of bedload transport were dependent on the weather and number of days with flood discharge. Approx. 58% of the entire discharged bedload was transported during 3 violent ablation-precipitation floods. Bedload grain size distribution was right-skewed and showed moderate sorting.

[Beach morphodynamics and types of foredune erosion generated by storms along the Emilia-Romagna coastline, Italy](http://www.sciencedirect.com/science/article/pii/S0169555X1300250X)

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Clara Armaroli | Edoardo Grottoli | Mitchell D. Harley | Paolo Ciavola

Abstract: The objectives of this study are to examine the response of a dune and beach system on the Adriatic coastline in northern Italy to the arrival of storms, compare it with seasonal (months) and medium-term (3-year) morphodynamic change, and evaluate results predicted by the numerical model XBeach. The studied coastline stretches 4km from the Bevano River mouth to the north of the site to the township of Lido di Classe to the south, where the beach is protected by coastal structures. Fieldwork consisted of topographic profile surveys using RTK-DGPS technology (7 times over an approx. 3-year period). 103 samples of surface sediment were collected along 20 of the cross-shore profiles at 6 distinct cross-shore positions, selected on the basis of morphological beach characteristics. Data analyses of dune and beach slopes enabled the study area to be divided into 6 separate morphological zones using the spatial (longshore and cross-shore) variation of morphologies located on the backshore and intertidal beach observed in a preliminary survey of the area. Other criteria were a spatial consistency in beach slopes and/or presence/absence of intertidal morphologies identified in the aerial photographs and Lidar data. The swash zone slope did not show any significant variability for the entire area. A weak seasonal trend in the variability of the mean foredune slope was observed, with steeper slopes typically during winter and flatter slopes during summer. Analysis of grain size revealed that the beach sediment is well-sorted fine sand tending to medium, with a decreasing trend in size from the Bevano River mouth southwards towards Lido di Classe. According to the Masselink and Short (1993) classification, the natural part of the study site has an Intermediate Barred Beach (IBB) and following the Short (1999) classification, results in a modally LBT (Longshore Bar-Trough) or LTT (Low Tide Terrace) with a small section being TBR (Transverse Bar and Rip). Storms are considered the main factor controlling changes in the beach and dune slope. The most significant storm was recorded in March 2010 with a peak significant wave height of 3.91m. Contrary to the seasonal dune trend, several foredune slopes were observed to flatten following this event, which can be attributed to the action of dune slumping from the already weakened dune state. Modelling of foredune erosion, using a process-based model (XBeach), reproduced the erosion of the upper beach and dune toe reasonably well, but is currently limited by the acceptable slope value for dune stability, which does not account for biotic factors (e.g. plant roots). The comparison between the storm impact categories of Sallenger (2000) and the DSF (Dune Stability Factor) of Armaroli et al. (2012) shows a very good correspondence between the effects of the winter 2008–2009 storms and the vulnerability of the dune system predicted using both classifications.

[Beaver dams and channel sediment dynamics on Odell Creek, Centennial Valley, Montana, USA](http://www.sciencedirect.com/science/article/pii/S0169555X13002511)

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Rebekah Levine | Grant A. Meyer

Abstract: Beaver dams in streams are generally considered to increase bed elevation through in-channel sediment storage, thus, reintroductions of beaver are increasingly employed as a restoration tool to repair incised stream channels. Here we consider hydrologic and geomorphic characteristics of the study stream in relation to in-channel sediment storage promoted by beaver dams. We also document the persistence of sediment in the channel following breaching of dams. Nine reaches, containing 46 cross-sections, were investigated on Odell Creek at Red Rock Lakes National Wildlife Refuge, Centennial Valley, Montana. Odell Creek has a snowmelt-dominated hydrograph and peak flows between 2 - 10 m3s-1. Odell Creek flows down a fluvial fan with a decreasing gradient (0.018–0.004), but is confined between terraces along most of its length, and displays a mostly single-thread, variably sinuous channel. The study reaches represent the overall downstream decrease in gradient and sediment size, and include three stages of beaver damming: (1) active; (2) built and breached in the last decade; and (3) undammed. In-channel sediment characteristics and storage were investigated using pebble counts, fine-sediment depth measurements, sediment mapping and surveys of dam breaches. Upstream of dams, deposition of fine (≤ 2 mm) sediment is promoted by reduced water surface slope, shear stress and velocity, with volumes ranging from 48 – 182 m3. High flows, however, can readily transport suspended sediment over active dams. Variations in bed-sediment texture and channel morphology associated with active dams create substantial discontinuities in downstream trends and add to overall channel heterogeneity. Observations of abandoned dam sites and dam breaches revealed that most sediment stored above beaver dams is quickly evacuated following a breach. Nonetheless, dam remnants trap some sediment, promote meandering and facilitate floodplain development. Persistence of beaver dam sediment within the main channel on Odell Creek is limited by frequent breaching (<1 – 5 years), so in-channel sediment storage because of damming has not caused measurable channel aggradation over the study period. Enhanced overbank flow by dams, however, likely increases fine-grained floodplain sedimentation and riparian habitat. Contrasts between beaver-damming impacts on Odell Creek and other stream systems of different scales suggest a high sensitivity to hydrologic, geomorphic, and environmental controls, complicating predictions of the longer-term effects of beaver restoration.

[Sliding stones of Racetrack Playa, Death Valley, USA: The roles of rock thermal conductivity and fluctuating water levels](http://www.sciencedirect.com/science/article/pii/S0169555X13002481)

Available online 3 May 2013
Gunther Kletetschka | Roger LeB. Hooke | Andrew Ryan | George Fercana | Emerald McKinney | Kristopher P. Schwebler

Abstract: On occasion, Racetrack playa in Death Valley National Park becomes flooded and temperatures then drop appreciably below freezing. The thermal conductivity of rock is greater than that of water, so heat is conducted from a partially-submerged rock faster than from water. Consequently, a collar of thicker ice forms at the water surface, a layer of ice forms on more deeply-submerged parts of the rock, and playa sediment beneath the rock may even become frozen to it. While this occurs, only a surface layer of ice forms on water away from the rock. Once the ice becomes thick enough, perhaps only 5 – 10 mm, either the buoyancy of the ice or additions of water to the playa by rain, snow-melt, or groundwater seepage then reduce the normal force between the rock and the playa to the point where wind shear can move the ice sheet with its entrained rocks, making trails (Reid et al., 1995; Stanley, 1955). After the ice melts, rocks are left at the ends of the trails, sometimes atop a pedestal of silt. A renewed increase in water level on the playa before the ice melts may lift a rock completely free of the playa surface and whisk it away, leaving a rockless trail. Changes, during a movement event, in rock orientation or water depth may result in along-track changes in width. Rock speeds are likely tens to hundreds of millimeters per second.