modified, fractional–order diffusion equation which is derived from a more generalized form of the standard Maxwell equations.

H31B-0474 0830h POSTER

Demonstration and Validation of a Passive Flux Meter under Controlled Field Conditions

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Subsurface contaminant mass flows and fluxes are increasingly being viewed as critical information needed to address issues pertinent to aquifer and groundwater remediation. Theses issues include; source prioritization, risk prediction, compliance monitoring, remediation endpoint evaluation, and contaminant attenuation assessment. Field experiments were conducted to demonstrate and validate a passive flux meter (PFM), which is a down-hole monitoring technology that provides for simultaneous, direct, in situ, point measurements of cumulative or time-averaged contaminant mass flux and water flux. The experiments were conducted in a subsurface flume located at the Base Borden Test facility in Ontario, Canada. The sheet-pile enclosed flume was 15-m long and 2 m wide. Steady flow was established using four pumping wells located in the closed end of the flume. Flow rates and contaminant concentrations measured at the producing wells provided estimates of average groundwater and contaminant fluxes within the flume. Flux estimates were compared to direct measurements obtained from 6 flux meters and to calculated fluxes generated from multilevel samplers. Fuzzy analysis was used to characterize the uncertainty in MTBE mass flow and flux estimates generated from spatially integrating PFM measurements.

H31B-0475 0830h POSTER

Determination of specific storage of porous rocks from flow pump experiments: theoretical analysis and experimental evaluation

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Flow pump permeability experiments are one of the methods used to obtain both hydraulic conductivity and specific storage of rock samples. However, transient pore pressure changes during the experiments are affected by the storage capacity of the flow pump apparatus. In this study, we used two approaches to deal with this problem. One is a theoretical analysis using the concept of sensitivity and the other is a comparison of experimentally obtained specific storages from flow pump experiments and poroelastic measurements, to evaluate the effects of the storage capacity of the apparatus to calculate the specific storage of the samples. Both results show that it is necessary to reduce the ratio of the storage capacity of the flow pump apparatus to that of the sample as small as possible (less than 0.3 from theoretical analysis and less than 0.7 from experimental results) to accurately obtain the specific storage of the sample. Thus, to determine the best estimate of sample storage, we need to take into account the effect of the storage capacity of the apparatus. This allows proper design of the experimental apparatus for measuring the specific storage of rock.

H31C MCC: Level 1 Wednesday 0830h

Extreme Event Geomorphology I Posters *(joint with T, C, NG)*

Presiding: **K X Whipple,** Massachusetts Institute of Technology; **D R Montgomery,** University of Washington

H31C-0476 0830h POSTER

Hydraulic Response of a Mountain Stream to a Large Debris Flow Sediment Pulse

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Field and laboratory studies of landslide-induced sediment pulses have been used to develop numerical models of pulse dispersion and translation. Evolution of sediment pulses has been found to be dominated by dispersion when the grain-size distribution of the sediment wave is coarser than the ambient bed material and when the flood Froude number is high, whereas translation dominates the evolution of fine-grained sediment pulses in channels with low Froude numbers. A large debris flow, which delivered an estimated 750,000 m^3 of sediment and woody debris to Squire Creek in the North Cascades of Washington, provides a rare opportunity to examine the hydraulic response of a sediment pulse that includes clasts exceeding the flow competence of the receiving channel. The landslide initiated on a ridge approximately 670 m above Squire Creek during the morning of February 25, 2002 and filled a 400-m length of the valley floor to a depth of approximately 20 m. The pre-disturbance, step-pool channel had an estimated slope of 0.08 and drains an area of 25.7 km^2 at the study site. While the deposit has been incised to a depth of 5 to 10 m in the first 18 months following the event, considerable armoring of the bed surface appears to have stabilized a knickpoint at the toe of the deposit, a process hypothesized to reduce the dispersion rate of the sediment pulse. Because many of the clasts in the armor layer exceed the flood flow depth, rates of dispersion may be overestimated by the transport equations incorporated into numerical models. Relict boulders and steep reaches observed along Squire Creek and throughout similar mountain drainage basins in the Pacific Northwest suggest that channel-bed armoring and profile stabilization may be a more significant influence on the decay of large sediment pulses delivered by debris-flows than previously recognized. In particular, the persistence of such deposits has implications for large debris-flow dams as sediment capacitors in mountain channels that are confined by steep valley sideslopes prone to large infrequent landsliding. Monitoring of the Squire Creek profile over the next several years and comparison with ancient deposits identified elsewhere in the basin will investigate the mechanisms by which large landslide-induced sediment pulses disperse downstream and evolve into the boulder lag deposits that characterize many mountain streams.

H31C-0477 0830h POSTER

Effects of Alluvial and Debris Flow Fans on Channel Morphology in Idaho, Washington, and Oregon

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Formation of debris flow and alluvial fans at tributary confluences from episodic erosion associated with large storms and fires ("extreme events") are often viewed negatively over short time spans (years). However, when viewed over long periods of time (decades to centuries), fans that form at tributary junctions are often sources of morphological diversity in streams and rivers. To evaluate effects of tributary fans on the morphology of mainstem channels, we surveyed a total of 44 km of streams in the Sawtooth Mountains of Idaho (27 km), Olympic Mountains of Washington (10 km), and Central Coast Range of Oregon (7 km). Rejuvenated alluvial fans resulting from post-fire gully erosion in the Sawtooth Mountains created gradient nick points in 4th to 6th order mainstem channels (30 to 350 km^2 drainage area) that increased sediment storage upstream resulting in decreased channel gradients, widened flood plains, side channel construction, and the beginning of terrace formation. Downstream effects included increased channel gradients, often creating rapids. In 3rd and 4th order mainstem channels ($<$ 10 km^2 drainage area) in the Olympic Mountains, there was statistically significant association between low-order confluences containing debris flow deposits and gravel abundance, wide channels, and numbers of logs and large pools. Moreover, heterogeneity of mainstem channel morphology increased in proximity to low-order confluences prone to debris flows in the Olympic study sites. In 3rd and 4th order channels in the Oregon Coast Range, density of large wood and boulders in mainstem channels ($<$ 30 km^2 drainage area) increased with proximity to all debris flow fans at low-order confluences regardless of fan age, while channel gradients and sediment depth in mainstem channels increased with proximity to recent ($<$ 60 yrs old) debris fans. Consequently, alluvial and debris flow fans can be significant agents of heterogeneity in riverine habitats, similar to other sources of major gradient nick points on mainstem channels (e.g. bedrock, rock falls, canyon constrictions, channel bends, etc.). However, not all channels are prone to tributary fan effects. Steep and confined mountain channels with high stream power may quickly transport deposits from debris flow and alluvial fans, leaving no morphological effects. Overall, these field studies provide a possible physical basis for recent observations of increased habitat use near tributary junctions (e.g. salmon spawning density, aquatic invertebrate density) and underpin emerging stream network theory on the organization of disturbance in creating and maintaining a variety of habitat in aquatic and riparian ecosystems.

URL: http://leebenda.siskiyou.net

H31C-0478 0830h POSTER

Erosion and its Effects on Geophysical Granular Avalanches

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Many types of extreme geophysical flows such as debris avalanches and pyroclastic flows can be classified as granular avalanches. While sedimentation from these flows and their resulting deposits have been the subject of intense study for the past half-century, the effects of erosion have been difficult to ascertain. Despite the known relationship between slope angle and thickness of a stable layer of loose debris on a slope, h_{stop}, which requires erosion during flow events, the positive change in volume of geophysical granular flows during transport has not been systematically studied. We present the results of experiments on the propagation of erosive granular flows. We use the experimental results to test a model that simulates granular avalanches in which erosion and deposition cause significant changes in mass and momentum during flow. Granular flow experiments were conducted under a variety of initial conditions to gain a quantitative understanding of erosion and its effects on propagation. Sand flows were released on a masonite plane to which 36 grit sandpaper had been glued. The masonite plane measured 95 cm times 60 cm. The plane was tilted at angles of 29.4 – 36.5 degrees. Particles of sand grains sieved to 2 and 2.5 phi were used. The 2 phi particles were dyed blue to aid in visualization. The angles of repose for the 2 and 2.5 phi particles were measured in two types of slumping experiments yielding angles of 34 degrees for the 2 phi particles and 35 degrees for the 2.5 phi particles. The 2.5 phi particles were poured onto the plane before each experiment to provide an erodible surface. The thickness of the erodible layer was h_{stop}. 425 $\pm$ 0.9 g of 2 phi particles were then released on this surface from a 10.5-cm diameter cylindrical container. The propagation of the sand was measured by videotaping while a horizontal grid was projected onto the plane to measure flow thickness. Because of geometrical distortions and the difficulty in ascertaining the edge of the flow during periods when the material was thinly spread, the error in the measurements of the flows positions is estimated to range from 1 – 2.5 cm. The sand was allowed to flow off the end of the inclined plane into a bin. We separated the two fractions by sieving. Using this technique, we were almost always able to ensure that $<$ 1% of the

blue, 2 phi particles were lost due to experimental error. It was possible to determine an erosion gradient for the experiments by starting separarate runs at each angle at different positions on the inclined plane. In this way, particles were collected after flowing different distances down the plane. Using the erosion gradient and flow speed data, we estimated erosion rate. It was possible to quantitatively match data on amount of material eroded and flow speed with the numerical model. Because it was not possible to distinguish bed particles in the numerical model, the results were summarized by comparing the mass of particles transported off the end of the slope. The results show that as slope angle increased and distance of the starting mass from the end of the slope decreased, the total mass of particles transported off the slope increased in both data and model. The results suggest that the numerical model is able to reproduce erosion conditions reasonably well over a range of slope angle and slope length conditions. The numerical model could be used to understand the process and effects of erosion in extreme geophysical granular flows.

H31C-0479 0830h POSTER

Rock avalanches revisited: New insights into catastrophic event triggering through experimental physics

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Rock avalanches remain among the largest and most devastating of mass-wasting phenomena, and are responsible for the fragmentation and transport of significant rock volumes from mountains to basins. Many aspects of their physics remain poorly understood, including triggering, transport, long run-out, and deposition. Recent experiments in granular physics suggest that many phenomena and features simply reflect the non-linear nature of granular flows. These effects are captured using high-speed cameras (>3000 frames/second) and particle tracking to map out the velocity field during flow initiation, transport, and cessation. A series of experiments suggest that the peculiarities of granular physics explain many features within rock avalanches, including long run-out, inverse grading, preservation of inherited stratigraphy, shear band occurrence, morphology, and flow initiation. To date, long run out has not yet been reproduced despite many attempts and configurations. Examples from the Blackhawk landslide, Frank landslide, Sherman Glacier, and others are discussed and compared to results from laboratory experiments. This work supports several new conclusions. First, flow triggering may depend on the history and geometry of earlier shear. This is due to subtle anisotropies in the granular framework that affect the initial collapse of the bulk granular framework. Second, the plug-like rheology of sheared granular material is consistent with many observations of rock-avalanche features without special mechanisms (e.g., air lubrication, frictional melting, acoustic fluidization). Third, the morphology of the flow (e.g., longitudinal and lateral ridges) may reflect the flow dynamics over a range of conditions, and may be more generic than previously though. If correct, then these conclusions can be used to create better hazard maps and more accurate risk characterizations than currently deployed. Moreover, they suggest caution in the interpretation ancient physical phenomena, especially from geomorphological data alone, before the physics of granular flows are better understood and applied in context.

H31C-0480 0830h POSTER

An Objective Method for the Intercomparison of Terrain Stability Models

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A terrain stability map quantifies the propensity for landslide initiation at a point in space. There are a number of process based models used for terrain stability mapping. SHALSTAB and SINMAP are two such models that combine steady-state hydrology assumptions with the infinite slope stability model to quantify slope stability. Inputs are digital elevation data from which slope and drainage area are evaluated as well as hydrologic and soil parameters. SHALSTAB quantifies terrain instability in terms of the critical effective rainfall required to trigger pore pressure induced instability. SINMAP quantifies terrain stability in terms of the probability that the infinite slope stability model factor of safety is greater than one over uniform probability distributions quantifying the uncertainty in model parameters. These are two models with similar physical basis but they use different indices to quantify instability. Because of this the relative performance of these models, when compared to observed landslide locations, is difficult to assess. A new statistic based on the cumulative fraction of the stability index at locations of observed landslides, relative to the cumulative fraction of the stability index over the terrain has been developed. This statistic quantifies the discriminatory capability of a stability map in terms of the degree to which a terrain stability map is successful in "capturing" observed landslides in areas mapped as unstable while minimizing the extent of these areas. This statistic provides a way to compare models that use different stability indices and is a quantity that can be used for the calibration or optimization of model parameters using observed landslide initiation locations. This is useful when physical data necessary to estimate model parameters is limited. We show results where the performance of these models that use different indices are compared using data from the Chetwynd area in east central British Columbia where 696 landslide initiation locations were mapped. We found that in this particular region slope was the dominant variable that discriminated terrain instability. The optimally calibrated SHALSTAB and SINMAP models that also use drainage area as a predictor offered only marginal improvement over slope alone. The additional flexibility of the probability framework used by SINMAP gave it a slight advantage over SHALSTAB in discriminating unstable terrain in this data set.

URL: http://moose.cee.usu.edu/sinmap/sinmap.htm

H31C-0481 0830h POSTER

Catastrophic Flooding From an Orographic Thunderstorm in the Central Appalachians

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An orographic thunderstorm in Pendleton County, West Virginia, produced 125 - 150 mm of rainfall during a period of less than 30 minutes on 9 August 2003. The most severe fluvial impacts were concentrated in the 2.2 km^2 Saul's Run watershed. According to longtime residents, the August 2003 flood was the largest in Saul's Run since the June 1949 flood, which stimulated Hack and Goodlett's study of catastrophic flooding in the central Appalachians (approximately 20 km east of Saul's Creek). Hydrometeorological analyses of the storm are based on WSR-88D radar reflectivity observations and rain gage observations. Peak discharge estimates at three locations on Saul's Run are based on hydraulic computations, using surveyed high-water marks and channel cross-sections. Longitudinal profiles of the channel bottom and high-water surface were surveyed for a 2.4 km reach of Saul's Creek. The Saul's Run drainage basin contains a mixture of forest and pasture. The agricultural portions of the basin had a uniform vegetation cover. Anecdotal evidence indicates that Hortonian overland flow was prevalent over vegetated pastureland and that saturated soil columns did not develop. No first-hand observations were available for forested portions of the watershed. A large debris dam, consisting of trees, boulders and gravel deposits, formed in Saul's Run at a drainage area of approximately 1.0 km^2. Abrupt changes in the extent of incision and channel widening are seen along the 2.4 km reach. Large geomorphic impacts are present despite the short duration of the event, and in some places the channel is incised to bedrock. At a drainage area of 0.5 km^2 the stream was incised 2.0-2.5 meters to a depth of near 3 meters with a width of 2 meters at the bottom and approximately 6 meters at the top of the banks. Unlike the study site of Hack and Goodlett, this area did not sustain major slope failures or debris flows.

H31C-0482 0830h POSTER

High-Magnitude Short-Duration Floods in Small Urban Watersheds

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Urban watersheds are characterized by high percentages of impervious cover and efficient storm drain networks, with exaggerated hydrologic response to high-intensity, short-duration summer thunderstorms. In our study of small watersheds in the Baltimore, MD metropolitan area, the availability of high-resolution weather radar data (5-minute time interval, 1-km^2 grid) and high-resolution lidar data (approximately 1-m point spacing with 15-30 cm vertical accuracy) in watersheds with stream gages recording at 1-5 minute time intervals allows detailed reconstruction and modeling of extreme flood events that is not possible in most other environments. The end member in terms of flood magnitude and response time is the Moores Run watershed (drainage area 9.1 km^2). Moores Run drains an urban neighborhood that dates back to the early 20th century, and there is no surface drainage in the northern half of the watershed. Flood peaks generally occur within 20 minutes after the initial rise of the hydrograph; a small tributary of Moores Run with a drainage area of 0.5 km^2 typically reaches peak discharge within 1 to 5 minutes. The flood of record on the main stem occurred in June 2003, with discharge exceeding 150 m^3/s and possibly as high as 220 m^3/s. This event falls on the envelope curve for flood peaks in the mid-Atlantic region and corresponds to floods at comparable drainage area in other environments with recurrence intervals of 100-500 years. Flood-producing rainfall over the watershed lasted approximately 20 minutes, with rainfall intensities (125-150 mm/hr for 5-15 minutes) that are expected to recur with a frequency of 2 to 5 years. Flood peaks exceeding 100 m^3/s in response to similar storms have occurred four times in the past six years. Ongoing upgrades to the storm-drain network are expected to increase the efficiency of the system with the possibility of even larger and more frequent flood peaks. The channel of Moores Run (up to 3-4 m deep and 7-10 m wide) is grossly enlarged by comparison with streams of comparable drainage area in rural settings, and the bed is armored by cobbles and boulders. Moores Run appears stable and highly resistant to the shear stresses imposed by floods, presumably as a result of adjustments that have occurred over multiple decades of recurring high flows. Lidar data, supplemented by field-survey data, are being used to characterize longitudinal trends in channel and floodplain topography for use in hydrologic and hydraulic modeling. Models will allow us to simulate hydrologic response and shear-stress distribution along the channel for floods produced by 15-minute rainfall rates ranging from 25 to 250 mm/h.

H31C-0483 0830h POSTER

Geomorphic Change in Two Historical Flood Events on the Umatilla River, Oregon

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We mapped geomorphic change in an 80-km length of the active channel and floodplain of the Umatilla River for two flood events, 1965 and 1996/1997, both about 20 to 70-yr events. More artificial bank stabilization structures were in place during the 1996-7 cluster. We scanned and georectified pre- and post-flood aerial photos, achieving RMSE of 1.5 to 3m, and we digitized channel and floodplain features. Sinuosity generally decreased, and the scour zone and active bars increased in each flood. Secondary channels were created or reactivated. Changes were smaller during the 1996-7 flood cluster, due partly to increased bank protection. In both floods, geomorphic change was spatially variable and related to local influences (tributary junctions, human influences) as well as landscape-scale controls (downstream trends in alluvial deposit characteristics and incision). Both flood events increased areas of several types of features important for fish habitat and water quality, such as alcoves and riparian woody vegetation. Where human influences such as bank protection severely limit geomorphic change, floods can no

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longer renew habitat and ecological health may decline over time.

URL: http://geography.uoregon.edu/mcdowell/Umatilla/index.html

H31C-0484 0830h POSTER

The Role of Extreme Flooding in the Inception of the Lower Colorado River and the Excavation of the Grand Canyon-Stratigraphic Insights from the Southern Tip of Nevada

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The origin of the course of the lower Colorado River in Mohave Valley at the conjunction of Nevada, Arizona, and California, can be traced to a catastrophic flood in the late Miocene (approx. 5.6 Ma). The occurrence of this ancient and essentially instantaneous extreme event is solidly linked to the primary integration of the lower Colorado River system and the ultimate excavation of much of the Grand Canyon-which arguably constitutes one of the most extreme geomorphic events in the late Cenozoic history of the western US. Exceptionally clear, well-preserved, and previously undocumented stratigraphic and sedimentologic evidence near Laughlin, Nevada supports a model of river integration in Mohave Valley through catastrophic divide-breaching by a large lake in an adjacent valley upstream (Cottonwood Valley). This event was followed by the formation of a deep lake in both valleys. The maximum age of the lake is constrained to 5.6 Ma by a bed of volcanic ash near the base of the lacustrine section. This lake ultimately breached a bedrock divide at the southern end of Mohave Valley and it is likely that subsequent lakes formed and failed in a similar manner in Chemehuevi and Parker valleys downstream. Following this calamitous series of events, the newly integrated course of the lower Colorado River was subject to a tremendous aggradation event forced by deep incision in the Grand Canyon. In Mohave Valley, the aggradation event culminated in the Pliocene (approx. 3.6 Ma) as indicated by a key bed of volcanic ash very near the top of the section. This major aggradation event was followed by deep incision to the pre-integration valley bottom that may have persisted into the early Quaternary. The downstream-directed, cascading lake-failure model of river integration supported by stratigraphic and geochronologic data in Mohave Valley presents a serious challenge to previous models of Lower Colorado River integration that involve marine incursion, rapid uplift, and spectacularly effective headward erosion.

H31C-0485 0830h POSTER

Geomorphic Effects, Chronologies, and Archaeological Significance of El Nino Floods in Southern Peru

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The catastrophic effects of large floods have been well documented, on both contemporary and paleo-timecales, especially for the conterminous U.S. Less is known, however, about extreme events in hyper-arid sub-tropical climates where synoptic scale meteorological causes, such as El Nino-Southern Oscillation events, are the driving atmospheric mechanism. This research documents the geomorphic effects of extreme floods in the Moquegua River valley of southern Peru, in the core of the Atacama Desert. Using a combination of geomorphic mapping, hydrolologic modeling, aerial photography, ASTER satellite imagery, and GIS, we document the geomorphic signature of large contemporary floods within the mid-valley section (1500 masl) of the Rio Moquegua. Stratigraphic evidence and paleostage indicators of paleofloods, such as slackwater deposits and preserved high level flood gravels, are used to evidence late Holocene paleoflood magnitude-frequency relationships. On contemporary timescales, channel belt expansion by lateral erosion during large floods, such as the recent '97 and '98 floods, correspond to as much as 30-40 hectares of floodplain loss along the 20 km study reach. Sixty years of repeat aerial photography indicates that channel belt expansion and floodplain erosion commonly occurs along the Rio Moquegua. The frequent resetting of floodplain alluvium conditioned by these large floods is supported by radiocarbon dating of floodplain exposures. These dates indicate that most of the contemporary floodplain alluvium is younger that 560 14C yrs BP. The highest terrace remnants date to 3250 14C yrs BP and record a series of overbank flood gravels. Evidence for the regionally extensive Miraflores ENSO flood, ca. 1300 AD, exists in tributary and along mainstem sections. This flood has been documented along the coasts of Northern Chile to northern Peru, and has been evoked to explain significant social collapse. Our field evidence indicates that it catastrophically affected mid-elevation inland sections as well. A 400 yr sequence of interbedded mainstem slackwater sediments and tributary debris flows suggests that ENSO-spawned debris flows occur, on average, with a once in one hundred year return frequency although these post-colonial debris flow sediments indicate flows considerably less than the Miraflores flood. This research further demonstrates the impact and role of extreme events on pre-historical cultural response.

H31C-0486 0830h POSTER

Environmental change and human impact on mollusk assemblages in brackish Lake Nakaumi , Japan

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Biofacies of brackish environments are sensitive to environmental change because they are affected by the mixing characteristics of marine and fresh-water masses in addition to changes in climate. We examined the diversity of bivalves in a brackish lagoonal lake with complex topography in order to evaluate the effect of human modification of flow in the lake. Three sediment cores (X, N1 and N2) were collected from Lake Nakaumi, one of the largest brackish lakes in Japan, to analyze shell assemblages in three different settings. Core X was collected near an inflowing river from another brackish lake (Lake Shinji), N1 was collected from the central part of the lake, N2 was located off a delta created by the largest river that flows into the lake. Core samples contain a large number of fossil shells, and bivalve assemblages were analyzed at 5 cm intervals. In each sample, the numbers of shells are counted; bivalves having hinges were counted as one individual. Bivalve fossils assemblages were then analyzed by using Morisita diversity index (Morisita, 1987) that describes the diversity of the assemblage. High amplitude fluctuation in the index value was observed from the core X, implying frequent disturbance associated with Lake Shinji. The lower sections of both N1 and N2 are characterized by smaller variation in the index value, followed by high amplitude fluctuation in the upper portions. The amplitude is larger in the upper part of N2 than in N1. The distinct change in the index value between the lower and the upper part of N1 and N2 is most likely associated with artificial river course change. Only Theora fragilis, which has a high tolerance of environmental change, is found through the cored intervals, implying that this river diversion had a great impact on the lakeOs mollusk community. Benthic surveys have shown that the diversity of the mollusk fauna in Lake Nakaumi has dropped significantly in comparison to the fauna represented by core samples. Both core data and recent shell assemblage data indicate that other factors have affected mollusk diversity in addition to the river diversions of 1665 and 1840.

H31C-0487 0830h POSTER

The Origins of Magnetic Minerals and Their Changes in the Sediments from Lake Nakaumi and Lake Shinnji, Western Japan: Effects of Ancient Iron Manufacture

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Magnetic properties have been investigated on five sediment cores collected by a Mackereth type corer from Lake Nakaumi and Lake Shinnji, Sanninn district, Japan. Magnetic properties of river sediments taken from typical geological units exposed in the catchment areas of the lakes have been also investigated to study changes of the origin of the magnetic minerals in two lakes. The natural remanent magnetization of these sediments is stable enough to detect paleosecular variations of geomagnetic field. Although these cores have not yet been dated and the sedimentation rates of the cores were tentatively estimated by correlation of the secular variations with the archeomagnetic study for the past 2000 years in southwestern Japan, the AMS radiocarbon dates will be shown at the meeting. The rockmagnetic measurements showed that the magnetic-mineral contents are increased in the uppermost portion of most cores. Especially in two cores from Lake Shinnji, the increase is very rapid and on average they are about ten times as much as those in the lower portion of the cores. XRD analysis for the magnetic extract and stepwise thermal demagnetization of composite IRM for the sediments of two lakes shows that the magnetic mineral in the uppermost part is magnetite and the predominant magnetic mineral in the lower part of the cores is the solid solution between ilmenite and hematite. Granite containing a large amount of magnetite is distributed widely in the catchment areas and it is well known in these areas that after the beginning of the 17th century, weathered granite had been broken down on a large scale in order to extract the iron sand used for iron manufacture. The water of the Hii River has been flowing to the sea through Lake Shinnji and Lake Nakaumi. But, it had been flowing directly into the sea before the two floods in the 17th century. The possible cause of the enrichment of magnetite in the uppermost part of the cores is thought to be this industrial activity and/or the change in the Hii River's flow. The source of magnetic mineral of the solid solution between ilmenite and hematite, which has not observed as main magnetic mineral in the catchments area of the lakes, may be andesite at Mt Sannbe located in the west of this district.

H31C-0488 0830h POSTER

The effect of pore water pressure on debris flow dynamics

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Pore-water likely plays an important role to reduce shear force in debris flow. In experiments, we observed pore-water pressure during flow to clarify the relationship between the flow speed and pore water pressure which would be affected by flow depth and particle size distribution. Soil materials were prepared with mixing materials of sand, silt and clay. Pore-water pressure on the flume bed, flow depth, velocity and run out distance was observed, and the following results were quantitatively obtained in this series of experiments. 1. A positive relation was observed between strain rate and pore-water pressure ratio in the flow. The strain rate and pressure ratio were dimensionless parameters of the ratios of surface velocity to flow depth and pore-water pressure head to flow depth, respectively. This relationship indicated that shear resistance decreased as the pressure potential leading to acceleration of flow velocity increased. 2. A positive relation was also observed between flow depth and pore-water pressure ratio. This indicated that the pore pressure diffusion became increasingly obstructed as the flow depth increased. 3. The pore-water pressure ratio tended to increase with the uniformity coefficient of debris flow materials. The reason for this might have been that smaller particles suspended in the flow increased pore-water pressure, and the wider range of particle distribution effectively prevented pore-water pressure diffusion. 4. There was an apparently negative correlation between the equivalent coefficient of frictions and the pressure ratios. Equivalent friction is apparent friction during flow. The most likely reason for this is that shear resistance would decrease and run out distance increase as the pressure ratio increased. These results indicated that the effect of pore water fluctuations should be one of the most important factors affecting the shear resistance in debris flows. This work was supported by the National Science Foundation under Agreement Number Ear-0120914, and was partly supported by an overseas research fellowship from the Japan Society for the Promotion of Science (JSPS).

H31C-0489 0830h POSTER

Paleoenvironmental Change in a Brackish-water Lake during the past 3000 years as recorded in the Sediment of Lake Nakaumi, Southwest Japan.

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Major environmental change in a brackish-water lake can occur through natural or human influenced changes in landforms as well as through eustatic sea level change. The hydro-environment of Lake Nakaumi, southwest Japan, has been greatly affected by both man-made and natural landscape evolution. In this study, environmental change during the past 3000 years is discussed based on high-resolution sedimentologic and geochemical analysis of 3 cores collected from Lake Nakaumi. Lake Nakaumi is located near the Sea of Japan coast in the southwest Japan, and is a brackish-water lake of about 86 square kilometers. Presently Lake Nakaumi experiences seawater inflow from Nakaura Channel via Sakai Channel and low saline water and fresh water inflow from the Oohashi and Iinashi Rivers. This leads to complex two-layer water-mass structures in the lake. Three sediment cores (X, N1 and N2) were collected in order to examine the effect of the inflow of low saline water from Oohashi River, seawater from Nakaura Channel, and fresh water from Iinashi River, respectively. The cores are 3.5 - 4m in length, and consist of mud with shell fragments in most horizons. Sample were taken at 1cm interval and grain size, C, N, S elemental content, and carbon stable isotope ratios were measured. Mean grain size ranges from 6.5 to 8.0 phi, and averages 7.5 phi in most samples. Mean grain size in the N2 core coarsens above 70cm. In N1 core, total organic carbon (TOC) contents show a peak (ca.3.5%) at 380cm, and decreases in steps toward the top of the core. TOC content shows the lowest value (ca.1.5%) at 30-40cm. Above this horizon, TOC contents increase upward. A similar TOC pattern is seen in the other cores. Total Sulfur (TS) content follows change in TOC content. The TOC and TS maxima at 380cm (ca. 2700 yr. B.P.) in N1 core indicates the most reducing environment in the interval covered by the cores. This suggests that Lake Nakaumi was isolated by the evolution of a sand bar (Yumigahama Beach). After that, TOC contents decrease in response to the re-establishment of a marine water influx, and shallowing due to a significant increase in the sedimentation rate. Marine faunas were re-established at 2000B.P. in Lake Nakaumi. A temporary change in the mean grain size in N2 core sediments can be attributed to a diversion of the Iinashi River in 1665. Another excursion in mean grain size above 40cm may be due to another modification of the channel of the Iinashi River in 1840. The rapid increase in TOC above 30 - 40cm resulted from human modification of the lake, such as dredging in the Sakai Channel and the closure of the Honjo Area (16 km2) by embankments in a land reclamation project.

H31D MCC: Level 1 Wednesday 0830h

Hydrologic Flow Near the Earth's Surface III Posters

Presiding: **D A DiCarlo,** USDA Agricultural Research Service**; T S Steenhuis,** Cornell University

H31D-0490 0830h INVITED POSTER

Capillary rise in porous media: analytical and numerical solutions

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Capillary rise in porous media is frequently described using the Green-Ampt model (the Washburn equation). Recent accurate measurements of the advancing front clearly illustrate the failure of the GA model to describe the phenomenon in the long time. The observed under-prediction in the position of the front is due to the neglect of dynamic saturation gradients in the formulation of the Green-Ampt model. Here we consider the full governing macroscopic equation, retaining these gradients. An approximate solution is derived and gives new analytical formulae for the position of the advancing front, its speed of propagation and the cumulative uptake. A numerical solution is also developed based on the Kirchhoff integral transform. Comparison between the analytical and numerical solutions demonstrated that the former solution is very accurate despite its simple form. These solutions are found to describe properly the observed behaviour of the capillary rise in the long time. It is shown that the Washburn equation can be recovered as a special case of the new analytical solution.

H31D-0491 0830h POSTER

Short- and long-time behavior of aquifer drainage after sudden drawdown according to the linearized Laplace equation.

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Ten years ago, Jean-Yves Parlange put forward a very general analytical solution for the drainage of fully penetrated aquifers (*van de Giesen et al.*, WRR: 94WR01733). This solution was based on the Laplace equation and linearized boundary conditions. The BC linearization assumed that the transient water table had a depth comparable to the water table as $t \to \infty$. In more recent years, *Parlange et al.* (WRR: 2000WR000189) put forward a re-analysis of the drainage of a horizontal aquifer after sudden drawdown, using the Boussinesq approximation. For this solution it was assumed that the water depth in the bounding drains was zero for $t>0$. Following the general approach of *Brutsaert and Lopez* (WRR: 97WR03068), it was determined that for this geometry the aquifer behavior could be characterized by $dQ/dt \sim Q^3$ for small t and by $dQ/dt \sim Q^{3/2}$ for large t. It was remarked that $dQ/dt \sim Q$ for large t is often observed. In practice, it is also difficult to determine if $dQ/dt \sim Q^3$ for small t because this behavior can only be observed over a very short period. Here, we present a similar analysis of aquifer behavior based on the earlier Laplace solution for penetrated aquifers with sudden drawdown. It has been shown that also when the drain does not fully penetrate the aquifer, the solution still produces good results (*Szilagyi*, WRR:2002WR001564). The Laplace solution quickly shows that $dQ/dt \sim Q$ for $t \to \infty$ and $dQ/dt \sim Q^{\infty}$ for $t \to 0$. This analysis reconfirms previous findings concerning long-time behavior. More importantly, the analysis shows that the exponent B in $dQ/dt \sim Q^B$ does not have a fixed limited value for short times for the given geometry.

H31D-0492 0830h POSTER

Studies on Water Phase and its Movement in Unsaturated Porous Media

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Soil water moves not only in liquid phase but also in vapor phase even in constant temperature laboratory. The test column that consists of glass beads with diameter of 0.1mm controlled water pressure by lowering water level. We measured water pressure of the test column by using micro-tensiometer at three cross sections and in three directions during four months. The experimental results indicated as follows; 1) In the funicular stage, at every measured point water pressure obeyed hydrostatic pressure until threshold value -90cm. Hence the maximum possible height of this column was 90cm in drying process. 2) Since the value of tensiometer represent pressure of liquid phase water in porous media became independent and forms pendular ring. 3) Lowering water level further, the column became film stage in which contains pendular ring and adsorbed film. In some points water pressure observed constant value about -90cm. Others changed in wide range from -90cm to -630cm. 4) Though macroscopic trend of change of water pressure was not related to each other, microscopic trends synchronized. 5) Consequently driving force of water movement in vapor phase was not pressure but potential especially in film stage.

H31D-0493 0830h POSTER

Analytical modelling of chemical and electro-osmosis in clayey soils

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Groundwater flow and solute transport are generally well described by the linear Darcy and Fick equations. In clayey environments however, these equations may not suffice to describe evolution of salinity and hydraulic head. Because of the semipermeability of clay, various other driving forces come into play. For example, water flux can be induced by a concentration gradient (chemical osmosis) or by an electrical potential difference (electro-osmosis). Understanding the role of osmosis in groundwater systems may, for instance, facilitate assessment of contaminant leakage from waste disposal sites screened by clay liners.

In this study, various coupled processes in clay soils were investigated. Analytical methods were employed to model experiments from literature. For example, closed form solutions have been found for differential equations describing chemical osmosis across a clay sample. Also, an experiment on streaming potential was modelled: the buildup of potential, related to the pressure evolution, was reproduced in numerical simulations. The counterpart of streaming potential is electro-osmosis; the aforementioned modelling of chemical osmosis was extended with the influence of an electric potential gradient.

During a chemical osmosis experiment on clay, the sample will swell due to the uptake of water. This phenomenon was investigated using material coordinates and solutions were obtained for one-dimensional swelling and consecutive shrinking of clay.

URL: http://www.hydrology.citg.tudelft.nl/work/staff/sbader.html

H31D-0494 0830h POSTER

Pore-Scale Numerical Investigations of 2-Phase Displacement Including Buoyancy forces

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Understanding the behavior and geometry of multiphase immiscible displacement fronts is critical in the fields of environmental restoration, geologic hazardous waste storage, and petroleum engineering (*e.g.* air sparging, NAPL infiltration, and secondary recovery of petroleum by water flooding). Depending on the flow conditions, the presence of gradients, such as those caused by gravity forces, viscous forces or permeability gradients, can variously lead to either stabilized (*e.g.* piston-like) or to unstable (*e.g.* gravity or viscous fingering) displacement fronts. Previous studies have found that the resulting displacement fronts may have patterns with percolation, or fractal, characteristics which cannot be adequately described by continuum equations [Chaouche *et al.*, 1994; Glass & Yarrington, 1996; and, Zhang *et al.*, 2000]. Numerical pore-network models which incorporate the appropriate physics provide a framework in which to study these characteristics of flow in porous materials. We present results of numerical simulations on regular two- and three-dimensional lattices which are based on the method of invasion percolation in a gradient (IPG). The pore-network is populated with pore throats and bodies whose radii are drawn from a random statistical distribution. The network is initially water saturated and then invaded by a non-wetting fluid (drainage). Both capillary and buoyancy forces are included to define a filling potential for each pore. The invasion advances in quasi-static steps, by increasing the capillary pressure and invading accessible pores with the lowest filling potential at each step. The wetting phase can become trapped in pores that become isolated from the outlet face. We identify the regimes in which stable and unstable displacement occurs and we examine how the fractal geometry of the displacement front and the relative permeability of each phase varies with the Bond Number (the ratio of characteristic buoyancy and capillary forces). We also confirm the power-law scaling of the front width with the Bond Number as derived from percolation theory

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