in desultory fashion. Numerous studies, show that tsunami derived deposits share many characteristics, e.g. sand sheets, marine shells deposited in subaerial settings, boulder deposits, etc. Sediments fine inland and upland (a distribution pattern not unique to tsunami). Tsunami deposits could be restricted to a single event, or alternately the backwash could erode and mix materials from multiple events (e.g. material in wave cut notches). It is difficult to differentiate between tsunami and storm deposits. Modern cementation of coral and basalt clasts on rocky shores today resemble proposed paleo-tsunami deposits. Tsunami deposits reflect their local source. Although tsunami deposits should reflect the carrying power of the waves, they can only do so if material of the appropriate size and density is present to reflect that carrying power. Complicating the situation, uplift can expose conglomerates above sea level. Although subsidence is characteristic of many oceanic islands, it should not be assumed to dominate in all cases.Tsunami deposits are ephemeral (easily eroded by normal beach processes, mixed with soils, and remobilised by anthropogenic activity) and many of their most diagnostic features can disappear within years after an event.

OS21D-08 1205h

Numerical Modeling of Generation of Surface Water Waves by Motion of the Drowned Soil

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Recent scientific publications contain enough evidences that the key source mechanisms of formation of abnormal tsunami waves in near-shore areas of the World Ocean are the large-scale underwater landslides. The mathematical modeling of generation of waves of such nature is reduced to the description of dynamics of the motion of the drowned mass of a soil and to the solution of a hydrodynamic problem for the arising surface waves. The scales of temporal and (or) spatial characteristics of lithodynamic processes are different, therefore several approaches to simulation of the motion of a landslide were proposed. In a number of publications the landslide is treated as a non-deformable solid body. The attempts to consider a landslide as elastoplastic medium moving and interacting with the surrounding flow are made. For some underwater slides the simulation of a phenomenon is represented within the framework of a two-layer fluids of different density and viscosity. To construct the numerical model of a phenomenon it is necessary to match the mathematical models of the slide motion and surface water waves propagation. The aim of this work is to construct and to investigate the hydrodynamic component of such a complex model. It is supposed, that the phenomenon has the long-wave nature, and the simulation of surface waves in ideal incompressible fluid is conducted in a usual way - within the framework of a hierarchy of shallow water models of different order of hydrodynamic approximation (linear, non-linear and non-linear-dispersion equations). The numerical algorithms are based on finite-difference methods. For hyperbolic equations the Mac-Cormack type schemes with special adjustment of the right hand side is used. For non-linear-dispersion equations the schemes of the second order of approximation keeping a number of control parameters, permitting to allow for or to leave out the non-linear effects, and also selectively to apply a procedure of smoothing are constructed. A one dimensional numerical model of waves generated by a body moving over the bottom was constructed as a first step. The relation of parameters of a generated wave to the shape and size of a mooving body, and also from the law of is studied. We consider the cases of a horizontal and an inclined bottom. The problem was further investigated, when the landslide is modelled within the framework of elastoplastic medium. Our numerical experiments have proved that the specific features of the wave generation process can be robustly reproduced within the framework of approximated hydrodynamic models: the forerunners by the way of denivellation waves, rearrangement of wave process are described at the moment when the landslides slows down and other effects. The features of the processes, related to the non-linear and dispersive characteristics of the medium are determined. The work is executed under financial support of the Russian Foundation for Basic Researches, grant 03-05-64108, and also the Program of Integration Researches SB RAS, grant 2003-5.

OS22A MCC: Level 2 Tuesday 1330h

Identifying Submarine Landslide Time of Failure I Posters *(joint with T)*

Presiding: **D R Tappin,** British Geological Survey**; P Watts,** Applied Fluids Engineering, Inc.

OS22A-1146 1330h POSTER

The Matakaoa Margin Multiple Mudflows, North-East New Zealand

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The 45 km-long, 30 km-wide Matakaoa re-entrant near the collisional Australian-Pacific plate boundary off New Zealand, has incised the at least 1000 m-thick, seaward dipping sedimentary section of the East Cape margin. Swath bathymetry and seismic reflection data provide clear insights into the margin's evolution, and in particular the mechanisms associated with submarine debris avalanches and flows. The re-entrant morphology suggests active erosion at its head, as shown by pervasive gully formation, large slump blocks in the process of collapse, and an active, fan/channel system. Blocks up to 2.8 km across scatter the area north of the re-entrant, and indicate the large Matakaoa debris avalanche. North of the re-entrant, three major debris flows are identified within the first kilometres beneath seafloor. (1) The oldest flow is 60 km wide and extends 70 km north from a large basement anticline at the re-entrant mouth. At the base of the flow, coherent reflections indicate numerous imbricated thrusts and faults over a distance of at least 50 km. This may indicate viscous behaviour possibly due to dewatering during flow emplacement. (2) The second flow overlies the first over its entire 70 km-length. Its western flank is eroded into a conspicuous 200 m-high NNE-trending scarp, outlined by numerous kilometre-scale angular blocks detached from the main body of the debris flow. The scarp forms the eastern limit of the major channel that guides turbidity currents descending from the re-rentrant. (3) The youngest flow, the Matakaoa debris flow, fills the major channel, and extends 200 km north. It appears contemporaneous with the Matakaoa avalanche. First estimates give debris flow volumes ranging 500-1000 km3. The eastern re-entrant is filled by an estimated 15 km3 of material slumped from the margin either contemporaneous with or post-dating the Matakaoa debris flow. Rapid sediment accumulation, from high discharge rivers draining the rapidly uplifting East Cape region, may provide enough material to generate 20 km3 debris flows every 500-2000 yrs. Deposition of thick sediment piles about the faulted headward scarp of the re-entrant, coupled with the region's high seismicity, are prime factors controlling the multiple margin failures.

OS22A-1147 1330h POSTER

Investigation of gravitational mass transport processes using numerical simulations

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High-production regions, i.e. the NW African continental margin, are characterized by high sedimentation rates at upper slope. These materials are episodically transported down-slope in form of slides, debris flows, or turbidities. The main aim of our studies is to quantify the influence of different key parameters, i.e. material properties and geometrical settings, for deformation and kinematic behavior of gravitational mass transport processes. We use a numerical particle-based method - the Distinct Element Method (DEM) which has been proved to be an efficient tool to simulate geodynamical processes. This technique provides detailed information about mechanics and kinematics of downslope processes, their mass transfer patterns, as well as internal and morphological structures. Furthermore, it enables a wide range of material parameters and model configurations to be tested. We develop a 3D DEM model which consists of a plane shelf, continental slope, and abyssal plain. Sediment layer is built up by spherical, elastic frictional particles which settle down under gravity on upper slope. We change iteratively the basal friction of slope surface as well as internal friction of sediments. Further model configurations are fixed. A decrease of basal and internal friction of sediments causes always an increase of run out length of the flow while thickness of depositions and lateral extension decrease. In addition, surface structures of lower slope change remarkable. Thus, we identified basal friction as important key parameter for spatial dimension and morphology of mass flow events. Nevertheless, we have to investigate the influence of model configurations in the face of transferability of model results into a natural system. Therefore, we developed a high-resolution 2D DEM model where (a) all spheres settle down under gravity in a triangular shaped box on upper slope. Removing box boundaries releases a gravitational mass flow. In experiment (b) all particles are settled under gravity on top of a shelf surface and they are transported progressively by a bulldozer to the upper slope. In both experiments, we observe a similar relationship between friction distribution and mass flow behavior. However, experiment settings (b) produce more natural process behavior.

OS22A-1148 1330h POSTER

Landslide Deposits, Cookie Bites, and Crescentic Fracturing Along the Northern Puerto Rico-Virgin Islands Margin: Implications for Potential Tsunamigenesis

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The seismogenic North America-Caribbean oblique-slip plate boundary forms the 8-km-deep Puerto Rico trench north of the densely populated islands of Puerto Rico and Virgin Islands (combined population of just over 4 million people). The southern slope of the Puerto Rico trench adjacent to the Puerto Rico-Virgin Islands (PRVI) carbonate platform is characterized by frequent seismicity, rapid trenchward tilting, oversteepened slopes, and mass wasting. We present high-resolution bathymetry, HMR1 sidescan imagery, and single-channel seismic data to document extensive landslide deposits that we infer to have been the result of multiple slide events capable of producing prehistoric tsunamis along the coasts of Puerto Rico and the Virgin Islands. Landslide deposits can be traced upslope to two, 45-55 km-wide arcuate-shaped embayments or "cookie bites" carved out of the PRVI platform. Three-dimensional visualization of the debris field and the slope of the largest of the arcuate-shaped embayments centered at 66° 40' constrain volume removal to 1.1 km^3 of the PRVI carbonate platform and underlying volcanic and volcaniclastic basement. Sidescan sonar and single-channel seismic data reveal crescentic cracks in the seafloor of the PRVI platform 35-45 km in length located 35 km offshore the northwestern tip of Puerto Rico. These cracks, interpreted to represent the sites of future breakaway scarps and landslides, are similar in shape and length to the head wall scarps of the amphitheaters to the east. An $\sim$500 km^2 section of the PRVI platform (750 m thick) has begun to detach and slump trenchward along the larger of these cracks. Investigation of the existing arcuate-shaped embayments is essential because massive (tens to hundreds of km^3) and instantaneous slope failure has the potential to be tsunamigenic. Puerto Rico and the Virgin Islands were inundated by tsunamis in 1867 (mainly affecting St. Thomas and St. Croix, 7 m of runup, casualties in the hundreds) and 1918 (mainly affecting western and northwestern Puerto Rico; 6 m of runup, 120 casualties). Calculation of the potential volume, runout extent, and triggering mechanisms of past submarine landslides will better constrain the tsunamigenic potential of the newly discovered crescentic faults.

OS22A-1149 1330h POSTER

Dating Submarine Landslides: the July 17th 1998 Papua New Guinea Event

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Identification of a suitably located cohesive sedimentary slump offshore off the north coast of Papua New Guinea, mathematical modelling of which provided appropriate run-ups compared with onshore measurements, might have been expected to provide compelling evidence for the source of the registered tsunami in the context of an alternative hypothesis based on a shallow dipping thrust source. However, notwithstanding the evidence, alternative slump source mechanisms, as well as those attributed to a thrust fault, are still considered by some investigators as a likely alternative. In this context we present evidence on the dating of the slump by observational, acoustic and biological methods that supports the slump source of the tsunami. The observational data from Remote and Manned Submersibles shows that seabed features, such as fissures and fractured limestone, on the surface of the slump, to be more recently deformed than outside the slump area. Fluid expulsion from the seabed was only observed from the area of the slump mass. Additionally, the seabed chemosynthetic cold water faunas, such as mussels and tubeworms, as well as bacterial mats that are intimately associated with sulphide rich sediment, are much more common on the slump surface. Their presence is interpreted to indicate active expulsion of sulphide and methane rich pore fluids. T-phase data, from an unblocked hydrophone on Wake Island, in the context of the arrival time of the tsunami from eyewitness accounts and mathematical simulation, suggest that a slump source for the tsunami to be more likely than an earthquake.

OS22A-1150 1330h POSTER

Exploration of the Humboldt Slide using Anisotropy of Magnetic Susceptibility - Comparison with the Gaviota Slide

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The origin of the "so-called" Humboldt Slide has raised much controversy. Some researchers argue that it is a slide deposit, while others interpret the deposit as a depositional feature mantling an old slide scar formed by down-slope gravity flows. We adapted the standard paleomagnetic tool of Anisotropy of Magnetic Susceptibility *AMS* in order to detect minor post-depositional deformation *i.e.*, "*crypto − slumps*" in sedimentary successions and applied it to the Humboldt Slide controversy. Crypto-slumps are slumps that are not easily observed in outcrop or core samples. Undeformed sediments show a typical oblate fabric while even slightly deformed sediments develop a triaxial fabric. Based on examining cores from the center and top of the Humboldt Slide structure, we find no evidence for deformation. The cores from the top are in an area that is clearly free from drape and thus we can be sure that we are sampling the structure seen in chirp seismics. We recently sampled a known slide for comparison to the Humboldt Slide. We used 5 gravity cores from the USGS V1-81-SC cruise which sampled the Gaviota Slide. The Gaviota Slide in on the northern slope of the Santa Barbara Basin and is just to the west of the much larger Golita Slide. The AMS measurements from the Gaviota Slide show a clearly deformed fabric that we expect from a slide. From these analyses we found that the fabric is dominantly oblate for the Humboldt Slide while the Gaviota Slide is predominantly triaxial. Based on these results, we re-emphasize our conclusion that the Humboldt Slide is not a slide. We now know that the ridges and swales of the Humboldt Slide appear to have grown as sediment waves on an old slide scar and our chirp seismics show thickening on the upslope side of these structures and continuous reflectors across regions where others have mapped normal faults.

URL: http://schwehr.org/agufall2003

OS22A-1151 1330h POSTER

Submarine Landslides, Isostasy, and Drastic Reorganizations of Depositional Environments on the Shelf and the Slope

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We present analytical evidence that large-scale submarine landslides will result in isostatic readjustment of the crust and lithosphere. Some of the possible results of this readjustment include: (1) increased seismic activity, (2) relative sea-level fall and a consequent basinward shift in facies, (3) development of sequence boundaries due to subaerial exposure of a shallow continental shelf, (4) deflection of drainage patterns and sediment pathways on land, on the shelf, and on the slope, and (5) oversteepening of the headwall region due to domal uplift of the evacuated slide scar. We demonstrate that isostatic readjustment can be increased by almost a factor of two due to the feedback effect of overlying seawater. Many of these factors are also positive feedbacks toward future mass-failure events. Considering that gas hydrates may be destabilized by mass-failure, isostatic readjustment associated with submarine landsliding may be a strong positive feedback toward climate change. Isostatic readjustment of the crust and lithosphere takes the form of uplift in the area of the evacuated slide scarp, and subsidence in the area of the mass-transport deposit (MTD). Two-dimensional mathematical modeling indicates that for a slide scarp or MTD with dimensions of 100 km wide, 100 km long, and 100 m thick, the magnitude of the primary isostatic readjustment will vary from about 21-48m, depending on the effective elastic thickness (Te) of the lithosphere (a lower Te leads to a greater isostatic response). Additionally, changes in the depth of the overlying water column act as a feedback to both the uplift and/or the subsidence. The magnitude of this factor is nearly as great as the primary isostatic response, bringing the total isostatic adjustment to approximately 39-88 m. The wavelength of the isostatic response (area affected) also depends on the Te of the lithosphere. Calculations show this to vary from 28 km for lithosphere of very low Te (2 km) to greater than 250 km for lithosphere with high Te (>38 km). Therefore, the isostatic response of the lithosphere and crust to submarine landslides is of sufficient amplitude and wavelength to significantly alter large areas of continental shelves, and is almost certainly an important but previously unrecognized mechanism for drastic reorganizations of depositional environments.

OS22B MCC: Level 2 Tuesday 1330h

Progress in Tsunami Research and Mitigation III Posters *(joint with T)*

Presiding: **E N Bernard,** NOAA Pacific Marine Environmental Laboratory**; C Synolakis,** University of Southern California

OS22B-1152 1330h POSTER

Deep-sea tsunami deposits in the Miocene Nishizaki Formation of Boso Peninsula, Central Japan

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Many sets of deep-sea deposits considered to be formed by return flow of tsunami were found from the middle Miocene Nishizaki Formation of Boso Peninsula, Central Japan, which is located near the convergent plate boundary at present as well as in the past, and has been frequently attacked by tsunami. The characteristics of the tsunami deposits in the Nishizaki Formation are as follows. Each set consists of 10-20 beds with parallel laminations formed under upper plane regime composed of alternated pumiceous beds in white and black colors. The white bed comprises coarse sands and pebbles with thickness of 5-10 cm. In contrast, the black bed is made of silts with thickness less than 1 cm. Among the 10-20 beds, the grain size is coarsest in the middle part of the set in general. The uppermost bed of each set shows cross-lamination formed by lower plane regime, gradually changing into finer graded bed on top. Sometimes, the lower part of the parallel laminated bed is associated with an underlying debrite or turbidite bed. Each set of these parallel-laminated beds is lenticular in shape thinning to the east in consistent with the generally eastward paleocurrent of the cross-lamination at the top. Such sedimentary characteristics are different from any event deposits reported in deep-sea but similar to the deep-sea K/T boundary deposits in the Caribbean region. Statistically, tsunami waves occur totally 12-13 times. Among them the height of 5-6th wave is known to be strongest. Interval time of each return flow is known to be 30-40 minutes, enough to settle the finer clastics at each bed top. The parallel-laminated parts have common dish structure and never trace fossils, indicating rather rapid deposition for the whole parts of the set. Consequently, the sedimentary characteristics shown from the parallel-laminated beds of the Nishizaki Formation are attributed to the return flow of tsunami to the deep-sea. We considered that such deep-sea parallel-laminated deposits of pumiceous clastics occur just after a large earthquake which forms the debrite or turbidite at the lowermost part.

OS22B-1153 1330h POSTER

Tsunami Inundation Mapping for Alaska Communities of Homer, Seldovia, and Seward

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The Geophysical Institute of the University of Alaska Fairbanks and the Alaska Division of Geological and Geophysical Surveys continue to participate in the National Tsunami Hazard Mitigation Program by evaluating and mapping potential inundation of coastal communities in Alaska. The two Kachemak Bay communities of Homer and Seldovia were selected in coordination with the Alaska Division of Emergency Services. We considered two earthquake scenarios as potential sources of tsunami waves that can affect Homer and Seldovia. For both communities, we calculated the extent of maximum inundation for the two scenarios, depths of inundation on dry land, and the maximum velocity current distribution in the inundation zones. The work is under way for Seward, the next community on the list. One of the most significant sources of errors in tsunami inundation mapping is inaccuracy of topographic and bathymetric data used in the model. Many of the Alaskan communities of interest have topographic data of limited quality, and new data must be developed in order to produce accurate inundation maps. The Alaska Tsunami Modeling Team cooperated with the local USGS glaciology office to perform photogrammetry in the Seward area. Using ten air photos and the APEX software, along with several precisely located GPS points, we developed a new georeferenced and highly accurate DEM with a 5-meter grid spacing. A variety of techniques was used to remove the effects of buildings and trees to yield a bald earth model. Finally, we resampled the new DEM to match the finest resolution grid, and combined it with all other data, using the most recent and accurate data in each region. The new dataset has contours that deviate by more then 100 meters in some places from the contours in the previous dataset, showing significant improvement in accuracy for the purpose of tsunami modeling.

OS22B-1154 1330h POSTER

Volcanic Tsunami Generation in the Aleutian Arc of Alaska

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Many of the worlds active volcanoes are situated on or near coastlines, and during eruptions the transfer of mass from volcano to sea is a potential source mechanism for tsunamis. Flows of granular material off of volcanoes, such as pyroclastic flow, debris avalanche, and lahar, often deliver large volumes of unconsolidated debris to the ocean that have a large potential tsunami hazard. The deposits of both hot and cold volcanic grain flows produced by eruptions of Aleutian arc volcanoes are exposed at many locations along the coastlines of the Bering Sea, North Pacific Ocean, and Cook Inlet indicating that the flows entered the sea and in some cases may have initiated tsunamis. We evaluate the process of tsunami generation by granular subaerial volcanic flows using examples from Aniakchak volcano in southwestern Alaska, and Augustine