climate and riverine sediment supply only, with deeper and broader profiles associated with decreasing sediment supply, increasing wave height and/or increasing wave period.

URL: http://www.vims.edu/physical/projects/CHSD/projects/Euro

OS51A-04 0845h

On the Hydrological Routing of Water and Sediment into the Northern Adriatic

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The research focuses on long-term and short-term climate changes, and the perturbations from humans, which influence the Po and representative rivers along the Apennines. The modern Po is partly influenced by arge Alpine Lakes/reservoirs that condition the timing of source water release and the trapping of sediment. Runoff from the southern and western Alps flows more naturally to the Po valley. The 15 M inhabitants of the Po valley intersect this flow, and along with strong agricultural use and an extensive canal system, regulate the flow. Even the dispersal through the Po delta distributary system is regulated. As a result the flux of sediment into the coast is predicted to be 50% less that under pristine conditions. The Apennine Rivers are regulated to maintain stream flow during the dry season. The otherwise high inter annual variability is presently mitigated and flood discharges to the Adriatic are a rare occurrence. As a result sediment flux to the coastal zone has been reduced by at least 40%. This agrees with dated marine cores from the northern Adriatic that show a change in both sediment dispersal and sediment supply across the last 50 years. The Apennine Rivers that once went hyperpycnal every couple of years would seldom (once ever 100 years) go hyperpycnal in their dynamics. Intra annual variability is very high for the Po and Apennine rivers despite the regulation and this is brought on by the strong frontal dynamics that control precipitation in this part of southern European continent.

OS51A-05 0900h

Numerical modeling of hyperpycnal flow generated by the discharge of Apennine Rivers

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Under natural conditions, the Apennine Rivers are likely to develop hyperpycnal discharges; a few (i.e. 25 yr to 50 yr return interval floods) will last for greater than 24 hours, but many more events are likely to occur for shorter duration. Hyperpycnal flows may account for 20 to 40 % of the total sediment flux from these Apennine Rivers. These relatively small rivers transport on average between 0.4 and 1.3 MT/yr. A single hyperpycnal event, however, can transport between 0.3 and 4 MT in one day. Hyperpycnal flow generated at the mouth of dirty' rivers carrying large concentration of silt and clay can have major impact on the continental strata formation. Here, we considered five Apennine Rivers (Chienti, Potenza, Pescara, Toronto, & Metauro) for simulated hyperpycnal events and their impact on the sea floor morphology. We have used a 2-D depth-integrated finite volume model of density/turbidity current to study the spreading of hyperpycnal flow and the resulting deposition of sediment in the Adriatic. We used results from *Hytrotrend* model runs under pre and post dam scenario as input conditions in our simulation. It has been found that alongshore current can significantly impact the spreading and deposit pattern of a hyperpycnal flow. In addition, the effect of the variability of flood intensity on the deposit pattern is also studied.

OS51A-06 0915h

Emplacement and Modification of the Autumn 2000 Po River Flood Deposit

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During October - November 2000, flooding by the Po River (northern Italy) created a flood deposit on the adjacent prodelta (10 to 30-m water depth) of the Adriatic Sea. An event-response cruise in December 2000 and six additional cruises during the ensuing 30 months have yielded a rich data set pertaining to the initial distribution and properties of the flood bed and its subsequent physical and biological modification. In contrast to previously documented flood deposits (e.g., Eel River, northern California) the deposit was located immediately adjacent to the river's mouths, exhibited clear proximal-distal indicators and had sharp thickness gradients. In addition, wide variation in bed thickness (up to 40 cm) and a diversity of physical sedimentary structures suggest that multiple emplacement processes (e.g., gravity-driven transport, and suspension fall-out) may have operated during the creation of the flood deposit. The flood deposit is evolving in a variety of ways. First, a rich subsurface stratigraphy with unique marker beds has permitted quantitative estimates of erosion and deposition. On most portions of the margin, there is little evidence of net erosion, but much evidence of physical reworking. Bed consolidation is also being quantified using digital x-radiographs and compared to results from a micro-resistivity profiler. Lastly, bioturbation structures have increased in abundance and depth within the deposit, such that in some areas of the margin the flood deposit, despite being many centimeters thick, is almost completely obliterated.

OS51A-07 0930h

Measurements of Sediment Transport in the Western Adriatic Sea

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Instrumented bottom tripods were deployed at two depths (10 and 20 m) off the mouth of the Chienti River in the western Adriatic Sea from November 2002 to May 2003 as part of the EuroSTRATAFORM Po and Apennine Sediment Transport and Accumulation (PASTA) Experiment. Waves, currents, and proxies for suspended-sediment concentrations were measured with upward-looking acoustic Doppler current meters, downward looking pulse-coherent acoustic Doppler profilers, single-point acoustic Doppler velocimeters, and acoustic and optical backscatter sensors. Flow was dominated by the western Adriatic coastal current (WACC) during the experiment. Mean southward alongshore velocity 2 m below the surface was 0.10 m/s at the 10-m site and 0.23 m/s at the 20-m site, and flow was modulated by tides, winds, and fluctuating riverflow. The largest waves (3 m significant height) were generated by winds from the southeast during a Sirocco event in late November that generated one of the few episodes of sustained northward flow and sediment transport. Most of the time, however, sediment resuspension and transport was dominated by Bora events, when downwelling-favorable winds from the northeast generated waves that resuspended sediment and simultaneously enhanced southward flow in the WACC. Mean flow near the bottom was slightly offshore at the 20-m site (0.01 m/s at 3 m above the bottom), but there was no significant correlation between downwelling and wave-induced resuspension, and cross-shelf sediment fluxes were small. The combination of persistent southward flow with low rates of cross-shelf leakage makes the WACC an efficient conduit for sediment past the Chienti region. If these observations are representative of typical winter conditions along the entire western Adriatic, they may help explain the enigmatic development of Holocene shelf-edge clinoforms that have formed hundreds of kilometers south of the Po River, which provides most of the sediment to the Adriatic Sea. Future data analysis and modeling is planned to investigate the mechanism(s) that apparently limit(s) sediment leakage from the WACC.

OS51A-08 0945h

Sediment dispersal pathways on the Western Adriatic continental shelf

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A 100-year flood event of the Po River during October 2000 resulted in a thick, greater than 15cm, sediment deposit on the subaqueous delta in close proximity to the main Po distributaries. The processes that contribute to and redistribute the modern deposit were investigated by deploying an instrumented benthic tripod along the 12-m isobath, from January 2001 to May 2002, which collected time-series data of nearbed sediment transport parameters. An additional series of deployments occurred from October 2002 until May 2003, 3km south of the initial Po tripod, providing a third winter of time-series data. Spatial variations in processes were evaluated by examining water-column salinity, temperature, and sediment concentrations that were collected during nine seasonal cruises between December 2000 and May 2003. The dispersal of sediment away from the Po River mouth can be largely attributed to both surface plume and bottom boundary layer (BBL) processes. In environments with larger mean waves and currents, such as on the northern California and Amazon continental shelves, the BBL sediment load is almost always larger than the surface plume load over the depositional site. A majority of the Po sediment falls out of the water column in the form of flocs inshore of the 6-m isobath, but there is still sediment carried in the surface plume offshore of the 6-m isobath. During relatively calm conditions, sediment load in the Po River surface plume over the delta has been observed to be up to 5 times larger than that in the BBL along the 10- and 15-m isobaths. During storms, which occur about 10% of the time along the western Adriatic continental shelf, the BBL sediment load can exceed the surface plume load and the along-isobath currents can be enhanced, providing an opportunity for a considerable amount of resuspended sediment to be advected in the BBL. Bora wind resuspension events increase surface plume velocities and coastal currents, as well as adding to nearbed shear stress and BBL transport. The sediment transport dynamics are reflected in the distribution of flood sediment on the Po River delta, with most of the sediment being initially deposited in relatively close proximity to the river mouth from the surface plume and a small fraction of this being subsequently resuspended in the BBL during storm events and transported southwards.

OS51B MCC: Level 2 Friday 0830h

Beyond Hydrate Ridge: Studies of Natural Gas Hydrate From Around the Globe III Posters *(joint with A, B, PP, T, C, GC)*

Presiding: **G A Barth,** U.S. Geological Survey**; D W Scholl,** U.S. Geological Survey

OS51B-0840 0830h POSTER

Thermal Conductivity of THF Hydrate Between -25 °C and +4 °C

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We observe two temperature dependencies in the thermal conductivity of tetrahydrofuran (THF) hydrate at atmospheric pressure between -25 and +4° C. After accounting for 4± 2% H_2O in our sample, the thermal conductivity of THF hydrate between -25 and -4° C rises only 0.2%, from .507 to .508 W/mK. As temperature approaches +4° C, thermal conductivity rises nonlinearly to 1.822 W/mK, 350% of its value at -4° C. We attribute the rapid thermal conductivity rise to THF hydrate dissociation. Close to its stability temperature

of +4° C at atmospheric pressure, heat absorption for dissociation dominates heat conduction through the hydrate structure. As a result, heat is transferred to hydrate much more efficiently in this temperature range, increasing the measured thermal conductivity. THF hydrate has been used as a laboratory analog for estimating physical properties of natural methane hydrate, despite differences in the water molecule arrangement and cage occupant species. Because thermal conductivity appears to depend only weakly on these parameters, our THF hydrate results suggest thermal conductivity in methane hydrate should be nearly constant with temperature until the hydrate is within 8° C of its stability temperature. Based on a marine geothermal gradient of 25° C/km, this 8° C range corresponds to the lowest 320 m of the hydrate stability zone. At a local scale, increased heat transfer efficiency in this zone may facilitate heat input schemes for recovering methane as a resource. At regional and global scales, efficient heat transfer to gas hydrates has both geohazard and climate change implications. Along upper continental slopes (400–1000 m water depth) with normal geothermal gradients, the entire hydrate stability zone occupies only the upper 300 to 400 m of the sediment column. In the late Quaternary, these water depths were exposed to warmer bottom water, which could efficiently transfer heat to near surface hydrates. The resulting hydrate dissociation would destabilize the hydrate-bearing sediment, initiating submarine landslides and potentially releasing vast quantities of methane into the atmosphere. This rapid methane transfer, a potent greenhouse gas, from the marine subsurface to the atmosphere provides a rapid response mechanism for tying bottom water warming to observed rapid global warmings in the late Quaternary.

OS51B-0841 0830h POSTER

Experimental Study on Growth Kinetics of Gas Hydrates in Marine Sediments

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Large amounts of gas hydrates, clathrate compounds of water and gases formed under high pressure and low temperature, are found in marine sediments and permafrost. To extract methane gas from its reservoir in a practical method, it is necessary to obtain fundamental information on the mechanism underlying the formation and dissociation of gas hydrates and their properties, including kinetics and crystal growth. We have proposed an advanced method of gas hydrate production, by which methane gas is extracted from the reservoir by replacing methane with CO2 at the molecular level. This method would be feasible to achieve the sequestration of CO2 into the sediments. The main purposes of this research are to elucidate the mechanism underlying hydrate reformation and replacement and accumulate practical data for completing the original concept of the proposed method. We have carried out experiments on the dynamics on reformation and replacement of gas hydrates using an apparatus consisting of a high-pressure vessel and a Raman spectroscopy. It was shown that reformation of gas hydrates easily occurred in the quasi-solid structure when the dissociated solution is used. The rate of reformation of CO2 gas hydrate was observed by Raman spectroscopy. The results of the bulk scale experiment showed that replacement of CO2 gas hydrate could be achieved within a period of 12 hours in pure samples of CH4 gas hydrate that had been synthesized as solid crystal, if the pressure and temperature are precisely controlled in the pressure cell. The replacement of guest elements in CO2 and CH4 gas hydrates may be quite innovative from both aspects, the extraction of gas hydrates and sequestration of CO2, to maintain the global environment and stability of marine sediments.

OS51B-0842 0830h POSTER

Coexistance of two Different Methane Hydrate Phases at Moderate Pressure and Temperature Conditions

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For a better understanding of the formation and decomposition of natural gas hydrates, detailed data on their thermodynamical properties are an important prerequisite. Until now, it was generally accepted that small guest molecules such as methane and carbondioxid form structure I hydrates whereas large molecules such as propane form structure II hydrates. Expectedly, natural gas hydrates and synthesized methane hydrates grown under natural conditions, prefer structure I. The formation of structure II methane hydrates was only observed at very high pressures (100 MPa) by Chou et al. 1 In this contribution, results from Raman spectroscopic investigation on pure methane hydrates are presented. It will be shown, that a coexistence of structure I and structure II methane hydrates at pressures between 3.0 and 9.0 MPa and at temperatures between -15°C and +15°C is possible. However, structure II methane hydrate are present as a metastable phase in a kinetic inhibited equilibrium with the established structure I methane hydrate phase. A slight variation of the T-P-x-conditions initiates the transformation of the structure II methane hydrates into structure I hydrates. This (exothermic) process results in a re crystallization of the complete hydrate phase until a stable state is reached. It turned out, that the instability of the structure II methane hydrate phase is also the driving force for other processes, such as the exchange of CH4 with CO2: A change in the composition of the gaseous phase through the addition of CO2 induces an immediate replacement of methane with carbondioxid in the structure II hydrate. In contrast, the exchange of CH4 with CO2 in structure I hydrates is a very slow process. 1 Chou, I-M.; Sharma, A.; Burrus, R. C.; Shu, J.; Mao, H-k.; Hemley, R. J.; Goncharov, A. F.; Stern, L. A.; Kirby, S. H.; PNAS; vol. 97; no. 25;13484-13487 (2000)

OS51B-0843 0830h POSTER

Properties of Porous Media Flow in Sand Column with Gas Hydrates

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Gas hydrate is one of the potential resources of natural gas in the near future, because it exists in marine sediments or in permafrost regions worldwide. It is very important to understand the porous media flow in marine sediments with gas hydrate formation, especially in developing the extraction system for gas hydrates, and when considering the environmental impacts due to the development. We have designed and made the special type experimental apparatus, in which the properties of multiphase flow and transport could be measured by a method of high pressure and low temperature technology. Methane gas and water migrate in marine sediments during the dissociation of gas hydrates in the reservoir. An experiment on the measurement of water permeability was conducted using an experimental apparatus, composed of a high-pressure vessel filled with various kinds of sand grains. In this experiment we observed the flow rate in sand column, Darcy law's parameters, pressure and temperature as functions of hydrate saturation, porosity, and multiphase conditions. Relative water permeability, the ratio of water permeability compared with absolute permeability without ant hydrate formation, was measured and analyzed as a function of hydrate saturation in porous media. The change in properties of permeability was also measured in the process of formation and dissociation of gas hydrates. As a result, the properties for permeability and saturation can be evaluated as the practical parameters for the simulation of porous media flow in marine sediments. Further, the extraction system by heat stimulation method was considered for the practical mining method for gas hydrates.

OS51B-0844 0830h POSTER

Effects of THF hydrate concentration and cyclic hydrate formation on sediment bulk properties.

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In earlier experiments, using a near stoichiometric tetrahydrofuran (THF) mixture in sand, we found that this type II hydrate evolved as a second solid phase in a multiphase system. The results indicated the hydrate species formed in the pore bodies and only affected the bulk properties of the sediment. Shear properties changed only when the remaining pore fluid (water) freezes and welds the two solid phases (Kunerth 2001). The original experiments, and those presented, here were performed in an insulated one-dimensional (1-D) acoustic reflection cell that allowed for the simultaneous measurement of the temperature gradient and the reflected P and S waveforms as a function of time and temperature. The experiments presented here address questions of the effect of THF concentration, and resulting percent hydrate, on the bulk properties and the effect of cyclic loading (hydrate formation and dissasociation) on the sediment system. The concentration experiments were conducted by iteratively raising the concentration of THF in the sediment cell and running the system through a hydrate formation cycle. Corresponding THF concentration was then found through IR spectroscopy. Cyclic experiments were performed by iteratively forming and disassociating hydrates from a near stoichiometric THF mixture. Initial results from the concentration experiments show amplitude variation with concentration and results will be presented with respect to common mixing models. Cyclic results showed amplitude behavior that may be associated with structural or sediment packing changes.

OS51B-0845 0830h POSTER

Nucleation and Growth of Gas Hydrate in Natural Seawater

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Large-scale nucleation of gas hydrate takes place when hydrate-forming gas and seawater are brought together under suitable pressure-temperature conditions or where dissolved hydrate-forming gas in saturated or near-saturated seawater is chilled or brought to higher pressures. Profuse formation of hydrate shells on gas bubbles and nucleation of at least five different forms of gas hydrate have been achieved in fresh natural seawater. Growth of masses of solid gas hydrate takes place when hydrate-forming gas reactant dissolved in seawater is brought into the vicinity of the hydrate. The gas concentration of the enriched water in the vicinity of hydrate is higher than the hydrate equilibrium gas concentration. Hydrate growth under these conditions is accelerated due to the chemical potential difference between the enriched water and the hydrate crystals, which induces mass flux of dissolved hydrate forming gas into new hydrate crystals. As long as water enriched in the hydrate-forming gas is circulated into the vicinity of the hydrate, growth proceeds into the water space. Experimental approaches for growth of examples of solid masses of hydrate are presented. Results of these experiments provide an insight into the growth of gas hydrate under natural conditions where interstitial water in marine sediments is captured by burial from open seawater, and where solid gas hydrate forms on the seafloor. By using fresh natural seawater, which is a chemically and materially complex fluid, our experiments in pressurized, refrigerated reactors should closely track the growth history of solid hydrate in the natural environment. In our model for hydrate growth in sediments, nearly complete pore fill by diagenetic hydrate can best be accomplished by nucleation of hydrate at a point source within the pore water or at a particular point on sediment particulate, with growth outward into the water space that is refreshed with ground water having high concentrations of hydrate-forming gas. Best growth can be achieved by circulation of water through constricting pore space although dissolved gas will also migrate along diffusion gradients.

OS51B-0846 0830h POSTER

Gas Hydrate Nucleation Processes

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The onset of gas hydrate nucleation is greatly affected by the thermal history of the water that forms its lattice structure. Hydrate formation experiments were performed in a 72 liter pressure vessel by bubbling carbon dioxide through a 1 liter column at hydrate formation pressures (1.4 to 3.7 MPa) and temperatures (275.0 to 278.0 K) to quantify this effect. They show that when even a fraction (e. g. 20 %) of the water in which hydrate has formed was recently frozen and thawed, the overpressurization for nucleation was reduced by an average of 50 % versus experiments performed in distilled water. In those experiments where a lower overpressure is present when hydrate nucleated, they tended to form on the surface of bubbles, whereas when a higher amount of overpressure was necessary for hydrate to nucleate, they appeared to form abruptly on bubble surfaces as well as from the bulk liquid phase. In approximation of classical nucleation, hydrate formation could be described as occurring by the spontaneous joining together of arising components of the hydrate lattice. In water that was frozen, and kept at a low temperature (< 275 K), molecular simulation models predict the predominance of water molecules organized as penatmeters, a possible subunit of the hydrate lattice. Our results suggest that in nature, initiation of hydrate formation may be strongly influenced by temperature dependant pre-structuring of water molecules prior to their contact with gas.

OS51B-0847 0830h POSTER

Kinetics of convective crystal dissolution and melting, with applications to methane hydrate dissolution and dissociation in seawater

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Large quantities of methane hydrate are present in marine sediment. When methane hydrate is exposed or released to seawater, it dissolves in seawater or dissociates into methane gas and water. There was some confusion in the literature about the kinetics of these processes. It is critical to realize that dissolution and dissociation are two different processes. Dissolution is due to instability in the presence of seawater (similar to dissolution of NaCl in water) and is controlled by mass transfer. Dissociation is due to inherent instability (similar to melting of ice) with or without water (although presence of warm water may increase the dissociation rate). Dissociation of methane hydrate into gas and water is similar to ice melting and is controlled by heat transfer. Hence dissolution is relatively slow and dissociation is rapid. In this work, we extend previous theory on convective crystal dissolution and melting to greater Reynolds numbers. We carry out laboratory experiments on the dissolution and descent of NaCl, KCl, NaBr and KBr in water to verify the applicability of our theory. We then apply our models as well as previous ones to estimate methane hydrate dissolution and dissociation rates for several cases, including dissolution of exposed methane hydrate floor, dissolution and dissociation of hydrate as it rises through seawater. The results show: (i) Convective dissolution rate of exposed hydrate floor is of the order 0.07 m/yr; (ii) Convective dissolution rate of a rising hydrate crystal is 0.2 to 0.3 micrometer/s and a crystal of 5 mm radius is able to survive the rise through an 1800 m seawater column; and (iii) Convective dissociation rate is high and depends on the difference between the ambient water temperature and the equilibrium dissociation temperature of hydrate. Starting from a depth when hydrate just reaches dissociation instability, a hydrate sphere of 5 mm radius would survive only a 47 m water column. Because hydrate is unstable in the surface ocean and would undergo rapid dissociation, only very large hydrate chunks (greater than about 0.09 m radius) would be able to survive a 530-m surface water column.

OS51B-0848 0830h POSTER

A Pore-Network Study of Methane Clathrate Hydrate Dissociation

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Clathrate hydrates are very important compounds due to their capacity to store large volumes of gases. They are studied extensively as a possible source of energy, since an enormous reservoir of carbon is deposited in worldwide accumulations of hydrates, containing predominantly methane, both on-shore (under the permafrost), and off-shore (in marine sediments). They are also considered as a possible way to sequester carbon dioxide, as a means to remove it from the atmosphere and in order to reduce its effect in global warming. In this study, a 2-D pore-network simulation based on concepts from Invasion Percolation in a Gradient is introduced to study the isothermal dissociation of methane clathrate hydrate in porous media. We use reported experimental values of porosity and permeability that are found in oceanic sediments to reconstruct a porous medium with similar properties. This is done by varying appropriately the size range of throat radii and the ratio pore/throat radii. The reconstructed porous medium is either fully or partially saturated with hydrate. Two important issues are addressed. First, we examine the stability of the dissociation front of a porous medium fully saturated with hydrate and show that stable fronts (having a characteristic width) are obtained. The front width is similar to the case of Invasion Percolation in a Stabilizing Gradient. Scaling of the front width is obtained as a function of the mean position of the front with exponent 0.57. Second, we examine the patterns formed by the release of methane gas in a partially saturated porous medium after the hydrate dissociates, and investigate how the various patterns are affected by parameters such as the viscous pressure drop applied to the system, the in size range of throat radii, hydrate saturation, and pore size distribution. In order for the methane gas to be produced from the system, the critical gas saturation (the volume fraction of the gas phase at the onset of bulk gas flow) must be reached. For this to occur the produced gas clusters must: either (i) connect to each other forming a sample-spanning gas cluster through which the gas phase can be produced, or (ii) be mobilized by the presence of viscous or buoyancy forces and thus arrive at the producing end of the network (this is a limiting case where continuum models may break down because of the formation of gas bubbles). In order to obtain a better understanding of the production efficiency for the commercial development of hydrate deposits we address the significant question whether the resulting dissociating system (at lower hydrate saturation values) is below or above the critical gas saturation. We also examine scaling of the critical gas saturation as a function of various parameters of the system.

OS51B-0849 0830h POSTER

Phase Transition of Methane Gas Hydrate and Response of Marine Gas Hydrate Systems to Environmental Changes

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Gas hydrates, which contain mostly methane as the gas component in marine sediment, are stable under relatively high pressure and low temperature conditions such as those found along continental margins and permafrost regions. Its stability is mostly controlled by in-situ pressure, temperature and salinity of pore fluid. Environmentally introduced changes in pressure and temperature can affect the stability of gas hydrate in marine sediment. While certain changes may enhance the process of gas hydrate formation, we are much more interested in the resultant dissociation processes, which may contribute to sub-marine slope instability, seafloor sediment failure, formation of mud volcanoes and pock marks, potential vulnerability of engineering structures, and the risk to drilling and production. We have been developing models to quantify phase transition processes of marine gas hydrates and to investigate the response of marine gas hydrate systems to environmental changes. Methane gas hydrate system is considered as a three-component (water, methane, salt) four-phase (liquid, gas, hydrate, halite) system. Pressure, temperature and salinity of pore fluid constrain the stability of gas hydrate and affect phase transition processes via their effects on methane solubility and fluid density and enthalpy. Compared to the great quantity of studies on its stability in the literature, in-depth research on phase transition of gas hydrate is surprisingly much less. A method, which employs pressure, enthalpy, salinity and methane content as independent variables, is developed to calculate phase transition processes of the three-component four-phase system. Temperature, an intensive thermodynamic parameter, is found not sufficient in describing phase transition of gas hydrate. The extensive thermodynamic parameter enthalpy, on the other hand, is found to be sufficient both in calculation of the phase transition processes and in modeling marine gas hydrate systems. Processes considered in this study to introduce gas hydrate dissociation in marine sediment include sedimentation, sea level drop and increasing seafloor temperature. Calculations indicate that dissociation of gas hydrates may lead to a build-up of excess pore pressure in marine sediment. The most significant factor constraining the magnitude of over-pressure is sediment permeability. The rate of sedimentation and pressure or temperature change at seafloor affects the degree and rate of gas hydrate dissociation and, hence, also the degree of excess pore pressure. The relationship between gas hydrate dissociation and the stability/failure of marine sediment are to be further discussed.

OS51B-0850 0830h POSTER

An Inversion Algorithm for Gas Hydrate Quantification

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The presence of gas hydrate in oceanic sediments increases the velocity and attenuation of the composite medium. The effects of hydrate saturation on compressional and shear wave velocities and their attenuations are different. These effects depend on the sediment microstructure, composition, the level of hydrate saturation and also the mode of hydrate formation in the pore space (inclusions vs connected). Using these parameters, we predict the velocities and attenuations of the sediments without hydrate, and thereby quantify hydrate saturation as deviation from these predicted velocities and attenuation factors. The influence of different parameters used and the variation of the predicted velocities and attenuations with frequency are studies using field and laboratory based datasets. Based on these studies we have developed an inversion algorithm to predict the gas hydrate saturation from velocities (Vp and Vs) and attenuation factors (Qp-1 and Qs-1) using porosity and physical parameters of the minerals constituting the sediment. Uncertainties in the estimates of hydrate saturation were quantified by testing the method on different datasets with accurately known parameters and corresponding estimated uncertainties. The algorithm will give hydrate saturation along with uncertainty. Using velocities and attenuation factors, the present method can predict the hydrate saturation accurately. The uncertainty in hydrate saturation is estimated to be less than 5% in usual situations. The method is applied to velocity sections estimated from OBS and multi-channel seismic data from the Storegga slide area, offshore Norway and offshore Svalbard. The method is also tested on velocity and attenuation measurements at seismic frequencies using a resonant column apparatus.

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Preliminary Results of 3D Seismic Analysis of Methane Hydrate on the Blake Ridge

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Methane hydrates may play a significant role in past and perhaps future global warming events; nonetheless, mechanisms for hydrate dissociation and subsequent gas escape remain controversial . During the fall of 2000, we conducted a 3D seismic survey over a 290 km square area of the Blake Ridge to investigate the dynamics of methane hydrate and free-gas at passive ocean margins. A primary goal of this study is to identify possible migration pathways of methane gas and their relationship with the free-gas reservoir below the BSR. Initial results from amplitude analysis of the stacked 3D volume reveal significant amplitude variability at the BSR, suggesting highly uneven free-gas concentrations beneath the Blake Ridge. In particular, the lowest amplitudes exist beneath erosional features at the seafloor where normal faults extend continuously from below the BSR to the surface. The results suggest faults that outcrop at the seafloor act as primary conduits for gas-migration into the water-column. In addition, 3D mapping of regions where concentrated hydrate exists shows faults bounding most hydrate reservoirs, implying that faults act both as pathways and barriers for free-gas migration and hydrate formation.

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3D and 2.5D Prestack Depth Migration of Hydratech OBS Data

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The Hydratech project investigates the amount of gas hydrate in the pore space of sediments at continental margins. Four active seismic experiments were performed at the continental slope of western Svalbard and in the Storegga area using Ocean Bottom Hydrophones (OBH) and Seismometers (OBS). Three OBH/OBS arrays with 20 instruments were deployed with a spacing of 400 metres between OBS and one line profile with 600 metres instrument spacing. The OBS array data is used for a 3D prestack depth migration, which leads to an image of the subsurface and to a velocity model. The image of the sediments has a lateral extension of 2 x 2 km and it reaches 400 metres in depth bsf. The Bottom Simulating Reflector (BSR), which marks the base of the gas hydrate stability zone, can be identified in the northern Svalbard area at a depth of 200 metres bsf. Below the BSR there is a low velocity zone of 125 metre thickness, where the P wave velocity decreases from 1800 m/s to 1200 m/s. The image of the 2D line of the Storegga area shows a thin layer of 10 metre thickness, where the P wave velocity decreases to 1000 m/s. Both low velocity zones can be explained by the presence of free gas in the sediments.

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Seafloor methane discharge at the Guaymas Transform, Gulf of California: New insights from seismic reflection, thermal, and ROV data

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We combine seismic reflection profiling, thermal gradient data, and ROV observations to examine active venting associated with the methane hydrate system in the Guaymas Transform, Gulf of California. In comparison to the 13 degrees C/km regional average, thermal gradients at the vent site are locally elevated in both measured values (584 C/km) and values calculated from BSR depths (321 C/km). Corresponding with the locally elevated thermal gradient is an abrupt shallowing of the BSR beneath the vent, which suggests a strong link between advective heat flow, vent activity, and hydrate stability zone thickness. A well-developed chemosynthetic biological communities was found surrounding the vent, and similar communities elsewhere along the transform ridge indicate that methane has recently escaped to the seafloor in multiple locations. There is little evidence of other BSR anomalies at these locations indicating that the seeps that supplied methane to these areas were either "cold" or that the local advective heat transport in this system is highly transient and the base of hydrate stability is able to respond to the changes in temperature over time scales of years.

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Recently Discovered Near-Shore Gascharged Sediments and Pockmarks, Northern Iceland

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The approx. 150 km long and 50 km wide Tjornes Fracture Zone (TFZ), formed in response to the eastward jump of the spreading axis in N-Iceland that began in late Miocene time (7-9 Ma). The fracture zone is made up of three N-S trending extensional half graben, Eyjafjordur, Skjalfandi and Oxarfjordur, and bordered to the south by a WNW-trending transtensional fault, the Husavik-Flatey fault (HFF). A 0.5-4 km thick sedimentary sequence has accumulated within the TFZ graben. Near-shore marine sediments are exposed on the Tjornes peninsula, at the eastern margin of the Skjalfandi graben, where approx. 500 m thick Miocene-Pliocene sediments contain several lignite layers. Natural gas emitting from geothermal areas at the shore of Oxarfjordur contain high concentrations of evolved hydrocarbons. The gas probably originates from marine sediments and lignites similar to those observed on the Tjornes peninsula. In 2001, a sidescan sonar imaging and CHIRP subbottom profiling were conducted along the HFF, within Skjalfandi Bay. CHIRP data show amplitude anomalies and acoustic wipe-out zones, indicative of gas accumulation within the sediments. In addition, the sidescan data reveal a number of shallow, circular and elongated depressions up to 30 m in diameter along the northern edge of the HFF. Areas of large, elongated and circular depressions (pockmarks) within Skjalfandi Bay were mapped during a multibeam bathymetric survey in 2002. A second Chirp subbottom and sidescan-sonar survey was conducted this summer along with gravity coring and digital bottom photography in order to assess the origin of these pockmarks and define the distribution of the gas charged sediments. Where present, acoustic wipe-out zones associated with the gas obscured all underlying reflectors as shallow as 5 meters below the ocean floor, in areas as large as 2 square km. The gas charged sediments are more widespread than previously observed within the bay. In northern Skjalfandi the gas seems connected to rather large, elongated pockmarks, which appear active, but in the southernmost Skjalfandi no pockmarks seem associated with the gas. These pockmarks reach 400-500 meters in length and 100-200 m in width and are commonly 2-5 meters deep. The pockmarks in northeastern Skjalfandi bay are all elongated NE-SW, with deeper NE ends. The pockmarks in the northwestern part of the bay are elongated WNW-ESE, with deeper WNW ends. The northeastern pockmarks seem to follow N-S lineaments and are possibly linked to sediment covered N-S aligned marginal faults of the Skjalfandi graben whereas the northeastern pockmark field seems to be linked to two WNW-ESE trending transform faults with little or no vertical displacement. Sidescan data show the larger pockmarks to be made up of a cluster of smaller pocks, none which exceeds 25-30 meters in length. Pockmarks along the northern edge of the HFF seem to be of similar dimensions, on the EM300 maps, but are more rounded. Gas was also detected there, and possible seafloor gas-emissions photographed. Sediment samples are being analysed. The newly discovered pockmarks and gas charged sediments within the TFZ seem to be associated with deep transform and normal faulting. The unusually high geothermal gradient (50-170°C) locally, and findings of thermogenic gas nearby, suggest that the pockmarks are formed by active gas seeps associated with oil and/or gas forming processes.

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Methane Hydrate Recovered From A Mud Volcano in Santa Monica Basin, Offshore Southern California

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In July 2003, a short (2.1 m) piston core from the summit of a mud volcano recovered methane hydrate at a water depth of 813 m in Santa Monica Basin. The discovery core penetrated into in the hydrate as evidenced by chunks of ice and violent degassing of the core section between 162 and 212 cm depth. The core consists of shell hash and carbonate clasts (to 7-cm long) in silty mud. The methanogenic carbonates are of two types: massive, recrystallized nodular masses with an outer mm-thick sugary patina and a bivalve coquina with carbonate cement. Living clams including the genus *Vesicomya*, commonly found at cold-seep sites elsewhere, were recovered from the top of the core. Further sampling attempts using piston, gravity, and box corers, all of which were obtained within 15 m of the discovery core, recovered olive-brown silty mud with variable amounts of whole and fragmented bivalve shells and methanogenic carbonate fragments characteristic of cold-seep environments. Gases collected in cores adjacent to the discovery core contain elevated amounts of methane and trace amounts of heavier hydrocarbon gases, indicating some component from thermogenic sources. Hydrogen sulfide was also detected in these sediment samples. Vertical channels in one core may have served as fluid pathways. The existence of hydrate at such a shallow depth in the sediment was unexpected, however, the presence of *Vesicomya* and hydrogen sulfide indicate that the mud volcano is a site of active methane venting. The mud volcano, which is about 24 km west-southwest of Redondo Beach, is about 300 m in diameter at the base. No internal structure is resolved on either high resolution deep-tow boomer or single-channel air-gun profiles, most likely as a result of the gas content and sediment deformation. The diapiric structure has ascended through well-bedded sediment on the lower slope of the basin, producing as much as 30 m of bathymetric relief. It is located in an area where strike-slip motion along the San Pedro Basin fault zone to the south is replaced by convergent motion to the north. The source horizon for the gas in the hydrate is unknown but appears to be collecting in beds as shallow as 200 m below the regional seafloor based on the presence of a strong and irregular reflection interval.

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Natural Gas and Hydrate Accumulations in the Aleutian Basin of the Bering Sea

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The deep water Aleutian Basin of the Bering Sea is a major storehouse of trapped greenhouse gases. Preliminary volume estimates based on seismic reflection observations easily approach 1000 Tcf of natural gas within the basin. USGS seismic reflection data from the deep water (>3500 m) Bering Sea region include over 20,000 km of single channel profiles coincident with GLORIA sonar tracks acquired during the 1986-7 EEZscan program, plus several older multichannel lines also crossing the deep water Aleutian and Bowers Basins. These airgun-source data all provide images from seafloor to basement, over 3 km of penetration. The basin fill includes generally horizontal and uniform sedimentary reflection sequences, comprising predominantly mudstones and distal turbidites, upon oceanic crust of probable Cretaceous age. In seismic reflection images of these flat-lying sediments, methane chimneys overlain by hydrate caps stand out as distinctive velocity pseudostructures. These velocity-amplitude anomaly structures ("VAMPs") characteristically include a zone of velocity pull-up (attributed to high-seismic-velocity hydrate within the sediment) directly overlying a zone of velocity push-down (attributed to low-seismic-velocity gas in the pore spaces). A prominent hydrate bottom simulating reflection (BSR) is also present throughout the basin. Within the VAMPs, the BSR roughly separates the pull-up from the push-down. Hundreds of VAMPs have been imaged, and thousands must exist within the deep water basin. Individual examples vary widely in lateral extent, focused appearance, and amplitude effects. Some also present a seafloor manifestation of slight doming. Five example case studies are presented, focusing particularly on interval travel time anomalies and quantitative interpretation in terms of presence of hydrate and free gas. Individual large VAMPs (1-3 km across, ~30 ms pull-up, ~80 ms push-down) are estimated to contain gas volumes (including hydrate) similar to those of conventional economic gas fields (e.g. $>10^9$ m^3). It is intriguing to note that the VAMPs are predominantly located within the "donut hole" of international waters in mid-Bering Sea, beyond the present territorial limits of any nation. However, the majority of the basin could be claimed by the United States under Article 76 of the United Nations Convention on the Law of the Sea, were it ratified.

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Constraints on Subsurface gas and gas Hydrate Distribution in a Gulf of Mexico Mound

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The Gulf of Mexico is well known for seafloor methane hydrate accumulations associated with hydrocarbon seeps, but the distribution of free gas, gas in solution and gas hydrate below the mounds is poorly known. Numerical simulation of fluid flow and analyses of industry 3-D seismic data (reprocessed for higher resolution in the shallow sediments), and high resolution seismic data recently acquired by the USGS provide some constraints on the distribution of these phases via their significantly different effect on seismic returns. Below an 8 m high, 300 m diameter mound at 1300 m water depth in Atwater Valley lease block 14, lies a convex upward, bell-shaped, subsurface reflection. The reflection can be modeled quite closely as a reflection from the base of hydrate stability (top of gas here) perturbed from about 300 to 45 m below the seafloor by localized, upward fluid and heat flux. The flow modeling therefore predicts free gas much higher below the mound than away from the mound. This is confirmed in the USGS data by a push down of 24 percent on a reflection passing below the perturbation, suggesting a velocity below the mound of less than 1400 m/s, indicative of at least some free gas. A strong upward perturbation to the base of the hydrate stability zone significantly constrains the volume available for methane hydrate formation below the seafloor, potentially impacting volume estimates of methane hydrate below seafloor mounds.

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Temperature Time-Series from a Seafloor Gas Hydrate Deposit on the Gulf of Mexico Slope

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Gas hydrate deposits at the seafloor in the Gulf of Mexico are subjected to frequent ambient temperature changes as bottom water temperatures fluctuate. The effect of temperature changes on hydrate formation and dissociation will depend on thermal diffusion between bottom water, the sediments at the seafloor interface, and the interior mass of hydrate deposits. During a two year study, we recorded multiple temperature time-series in a gas hydrate mound at a depth of 550m. Temperatures were recorded using Antares autonomous thermistors and data loggers installed at each end of a 50 cm probe. Probes were implanted 7 cm deep into tight-fitting holes that we bored in the hydrate mass with a specially-designed drill and 50 cm deep into unconsolidated sediment next to the mound. This allowed synoptic measurement of the ambient water temperature (top) and the hydrate or sediment temperature (bottom). The integrity of probe insertion was verified by detailed photographic inspection after installation and upon recovery. We obtained temperature time-series of 327 and 404 days, as well as shorter intervals. The range of bottom water temperature was 3.2 C over the two years of observation. Mean temperatures for the water, hydrate, and sediment, respectively were 7.90 C (sd 0.437), 7.81 C (sd 0.344), and 7.81 C (sd 0.156). Spectra of the temperature records showed significant, high-frequency peaks for in-water data corresponding to K1, M2 and M3 lunar tides. Of these peaks, only the K1 (23.9 h) was evident for in-hydrate records and none of the tidal peaks were evident for in-sediment records. All three records showed significant low-frequency periodicity at about 288 h. In-hydrate temperatures lagged the in-water temperatures by 6 h with high correlation. In-sediment temperatures lagged in-water temperatures by 288 h with weak correlation. Careful examination of the temperature records does not show any separation of the hydrate and sediment temperatures from the bottom water cycles and trends. We therefore infer that geothermal heat flow was not perturbed by episodic gas or fluid venting. Analysis of the records can therefore provide the following estimates for the thermal diffusivity of hydrate and sediments. Hydrate: 2.57 cm^2 h^{-1} and Sediment 6.36 cm^2 h^{-1}. These values are significantly lower than published estimates of thermal diffusivity for gas hydrates created in the laboratory (9.32 cm^2 h^{-1}). Although the hydrate deposit is active biological substratum and is gradually increasing in size, on a yearly time scale it appears to be a relatively stable component of the seep environment and is relatively unaffected by changes in ambient water temperature.

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Long-term Measurement of Sediment Resuspension and Gas Hydrate Stability at a Gulf of Mexico Seep Site

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To study the temporal topographic and hydrologic changes in Gulf of Mexico cold seeps, we deployed a deep-sea time-lapse camera, several temperature probes and an ADCP mooring at the continental shelf seep community surrounding a gas hydrate outcropping. The digital camera recorded one still image every six hours for three months in 2001, every two hours for the month of June 2002 and every six hours for the month of July 2002. A pair of 300 kHz Workhorse acoustic Doppler current profilers (ADCPs) attached to a 540 meter-long mooring were anchored approximately 2 km from the site in 2002. Temperature probes were deployed at the site over the entire experimental period. The data recovered provide a comprehensive record of gas hydrate mound processes. We calculated biological activity by identifying fauna observed in the time-lapse record and recording the number of individuals and species seen in each image. 1,381 individual organisms representing over 20 species were observed. An average of 4.6 ($\pm$3.0) organisms were seen in each frame during the three-month deployment, while 3.6 ($\pm$4.2) were seen per frame in the one-month deployment. An extensive amount of sediment suspension and redistribution occurred during the deployment period. By digitally analyzing the luminosity of the water column above the mound and plotting the results over time the turbidity at the site could be quantified. A 24.1-hour diurnal pattern can be seen in the record, indicating a possible tidal or inertial component to deep-sea currents in this area. Contrary to expectations, there was no major change in shape or size of the gas hydrate outcrop being studied. This indicates a higher degree of stability than laboratory studies or prior in situ observations have shown. The stable topography of the gas hydrate mound combines with high organic output and sediment turnover to serve as a focus of benthic predatory activity. The frequency and recurrence of sediment resuspension indicate that change in the depth and local distribution of surface sediments is a robust feature of the benthos at this site. Because the sediment interface is a critical environment for hydrocarbon oxidation and chemosynthesis, short term variations and heterogeneity may be important attributes of these settings.

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Long-Term Fuid Flow Measurements From Widely Varied Oceanic Settings Elucidate Near-Surface Hydrologic Environments

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The quantification of aqueous flux rates from various ocean floor environments has been a goal of numerous scientific programs for more than a decade with increasing focus on gas hydrate regions. Six years ago we developed the Chemical and Aqueous Transport (CAT) meter to collect long-term temporal records of low to moderate aqueous flow rates in sedimented ocean floor environments and, more specifically, to quantify to mass flux associated with the formation of gas hydrates. Since that time thirty of these instruments have been built and over a hundred deployments accomplished in a variety of hydrate and non-hydrate settings. We present here an overview of the results of these deployments and compare and contrast the flow records from these varied hydrological environments. Specific environments include: Gas Hydrates (Hydrate Ridge and the Eel River area on the Cascadia convergent margin, and Bush Hill in northern Gulf of Mexico), Hydrothermal (Japan's Sagami Bay and the incoming plate offshore Costa Rica's Nicoya Peninsula, TicoFlux area), and the tectonically active convergent margin off Nicoya and Osa. One of the most important outcomes of this research is the realization that fluid flow across the seabed/ocean interface is often dominated by shallow subsurface and oceanographic processes which vary significantly over time. These processes can be as simple as the diurnal pressure gradients caused by the rise and fall of tides to highly complex processes associated with the formation and transport of subsurface free gas. These processes have been both a boon and a bane to our research. Tidal oscillations have tended to mask the net flow in many very low flux settings. The high degree of spatial and temporal variation in some environments have revealed the extreme difficulty of quantifying the more widespread mass flux associated with the underlying tectonic processes. Yet, the nature of these variations have allowed us to better constrain the fundamental processes involved, ultimately leading to a better understanding of the overall hydrologic system. Our greater understanding of the near-surface hydrological environment has also increased our understanding of shallow sediment biological and geochemical processes. The serendipitous collection of data from the OOST region of Nicoya containing synchronous hydrologic events suggests that CAT meters may also prove to be effective monitors of volumetric strain such as that associated with aseismic creep events.

OS51B-0861 0830h POSTER

Solid and Dissolved Barium Profiles in Gas Hydrate Systems at Blake Ridge (ODP 164) and Peru Margin (ODP 201): Implications for Long-Term Carbon-Cycling in the Deep Biosphere.

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While many investigations have focused on quantifying either the amount of gas hydrates in marine sediment sequences or the methane fluxes to and from these systems, relatively little is known about how gas hydrate reservoirs evolve over time. Our research focuses on barium in gas hydrate systems, which may serve as a proxy for the accumulation of organic matter throughout the history of a depositional location, while also providing an indication of certain post-depositional processes. The accumulation of Ba in marine sediment is intimately associated with the supply of organic matter so that the total Ba abundance should reflect the extent to which organic matter has been supplied to a gas hydrate system. Once in the sediment column, the partitioning of Ba is highly correlated to dissolved sulfate concentrations, such that present and past levels of anaerobic oxidation of methane (AOM) and sulfate reduction can be traced with Ba profiles. Prior investigations of Ba cycling in gas hydrate systems generally have been limited by low-resolution profiles of dissolved or solid Ba concentrations. Moreover, there have been no sites with data for both dissolved and solid Ba profiles as well as dissolved sulfate and methane profiles. We present high-resolution profiles of pore fluid and sedimentary Ba in sediments from Blake Ridge and the Peru Margin, locations where profiles of sulfate and methane have also been generated. At both locations, dissolved Ba is low in the shallow sulfate reduction zone. Immediately above the depth of present AOM, dissolved Ba concentrations rapidly rise. These intervals are also marked by a prominent peak in solid Ba, or Ba-front. At Peru Margin, Ba concentrations increase fairly steadily below the depth of AOM to 1200 μM at 250m depth, among the highest dissolved Ba concentrations ever reported for a marine borehole. At the Blake Ridge, however, Ba concentrations oscillate below the depth of AOM with a series of highs and lows, reaching a maximum of only 44 μM at 250 m depth, followed by a steady decrease to 10 μM at 750 mbsf. Although many pore water profiles are similar at the Blake Ridge and Peru Margin, the contrasting Ba profiles indicate some fundamental difference between the two locations. Below 250 m depth at the Blake Ridge, dissolved sulfate slowly rises and barium concentrations are at saturation with respect to barite. The decrease in barium concentrations along this interval may thus result from systematic seawater contamination during drilling, in which case the widely discussed profiles of other species in the Blake Ridge boreholes need to be corrected. Alternatively, unidentified processes in the deep biosphere (e.g., oxidation of sulfide-bearing minerals) release sulfate to pore waters, accounting for the depletion in dissolved barium concentrations. If this is the case, certain biotic processes at great depth are different at Blake Ridge and the Peru Margin.

OS51B-0862 0830h POSTER

Large-scale Submarine Landslide of the South Caspian Sea: Possible Evidence for Generation by Gas Hydrate Dissociation During Sea Level Lowstand

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Massive slope failure in the South Caspian basin, identified on industry multichannel seismic reflection data, shows a close spatial relationship with buried gas hydrates in the continental slope in the deepwater of Azerbaijan. Covering a region in excess of 200 sq. km, the Absheron Allochthon is characterized by a highly faulted and disrupted stratigraphic sequence 200-300 m in thickness, with extensive normal faulting updip and a clearly recognizable toe thrust along the downdip extent. Pleistocene strata below the allochthon appear unaffected by this shallow deformation, while seafloor expression of this deformation suggests one of two possibilities for the age of the Absheron Allochthon: (1) Late Pleistocene movement, followed by relatively minimal deposition in Recent time, or (2) Recent (and ongoing?) development of the allochthon. Basin bathymetry suggests the former model is plausible, since rising sea-level has apparently displaced deltaic depocenters laterally by hundreds of kilometers. Historic sea level changes in the Caspian basin have exceeded 3 m over the last century, and were significantly amplified in comparison with global sea level changes during Pleistocene time. Since the inland Caspian Sea has been affected by sea level fluctuations at much shorter time scales and much larger amplitudes than the world's oceans, climate-induced changes in Caspian Sea level may have been responsible for large scale slope failure and seabed deformation through massive dissociation of buried gas hydrates during the sea level falls at the end of Pleistocene. Due to the historic large-scale variations of sea level of the landlocked Caspian Sea, this region represents a natural laboratory to study the relationships among the gas hydrate dissociation and seafloor deformation, and can be used as a proxy for similar processes in the world's oceans.

OS51B-0863 0830h POSTER

Describing the Spatial Continuity of Gas Hydrate Deposits Using Indicator Variography

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Gas hydrates observed on the Gulf of Mexico and Nigerian continental margins provide a basis for characterizing the spatial continuity of gas hydrate environments as a function of distance and direction from neighboring sampled locations. A total of 1039 sites for the Gulf of Mexico margin and 484 sites for the Nigerian margin were compiled from published data sets. Each data set included sites where gas hydrates were observed or where drilling occurred without gas hydrate contact. The spatial distribution of the deposits within the study areas were characterized by preparing multiple experimental indicator variograms with values assigned as one for hydrate presence and zero for hydrate absence. The nugget, sill and correlation length of both isotropic and anisotropic variograms were adjusted to determine the best-fit models. An isotropic variogram with an active lag of 200 km and a uniform interval of 5 km produced the clearest structure for the Gulf of Mexico study area. The isotropic variogram was fit with an exponential model with a correlation length of 52 km, a sill value of 0.047, and a relative nugget effect of 45.8% The maximum direction of spatial continuity trends approximately 43° with the minimum axis at approximately 133°. Sampled sites are correlated at a distance of 85 km in the direction of maximum continuity and 55 km in the direction of minimum continuity. The sill value for an anisotropic spherical model was 0.047 with a relative nugget effect of 38.3%. An isotropic variogram with an active lag of 180 km and a uniform interval of 5 km produced the clearest structure for the Nigerian continental margin study area. The isotropic variogram was fit with a spherical model with a range of 161 km, a sill value of 0.043, and a relative nugget effect of 4.7%. No significant spatial anisotropy was evident in the Nigerian continental margin for the data set as a whole. The nugget effect observed in the variogram models of both study areas may in part be the consequence of the sampling procedures used to establish each data set. The maximum direction of spatial continuity derived from the Gulf of Mexico data set corresponds with the trend of gas hydrate locations collected along the edge of the Salt Deformation Province. Indicator variograms suggest a spatial relationship does exist between gas hydrate locations as a function of both distance and direction.

OS51C MCC: Level 2 Friday 0830h

Gas Hydrates in Accretionary Complexes I Posters *(joint with A, B, PP, T, C, GC)*

Presiding: **D L Valentine,** University of California**; N L Bangs,** Institute for Geophysics, University of Texas

OS51C-0864 0830h POSTER

Detailed Seismic Studies of Gas Hydrate Deposits Offshore Sabah and Costa Rica

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Methane hydrates are discussed to hold a high potential as geohazard and future energy resource. In this context, the German Federal Institute for Geosciences and Natural Resources (BGR) has recently carried out a number of marine seismic cruises on active and passive continental margins were gas hydrates occur. BGR's activities concentrate on reservoir investigations, structural studies, and comparative studies to understand the origin of the gas. Latest results from offshore Sabah and Costa Rica will be presented. Gas hydrate occurrence off Sabah appears to be linked to structural and tectonic units and to be focused mainly in the folded, thrusted, and uplifted structures. The bottom simulating reflectors (BSRs) occur mainly in the hanging walls of the individual thrust sheets which form anticline-like structures. Due to the tectonically controlled morphology of the seafloor the distribution of BSRs appear mainly as elongated bodies which run parallel to each other. The convergent continental margin of Costa Rica is an area with large occurrences of heterogeneously distributed gas hydrates. Southwest of Nicoya Peninsula, continuous BSRs are observed between the upper and lower continental margin. North of the so called fracture zone trace, in the area of ODP-Leg 170, no BSRs are observed, presumably related to the unusually low heat flow in this area, whereas southeast of Nicoya Peninsula BSRs are characterized by patchy occurrence with strong lateral variation in reflection amplitude, indicating focussed fluid migration along deep-reaching faults. In both survey areas BGR has acquired long-offset seismic data for high-resolution seismic studies and pre-stack amplitude variation with angle (AVA) analyses. The implementation of an effective medium theory accounting for the local properties of shallow marine sediment allowed to model synthetic AVA responses as a function of gas hydrate concentration and free gas saturation at the BSR. Results indicate the possibility to detect free gas, and to quantify free gas at low saturations after careful data processing. Areas with strong BSRs are thus characterized by bulk free gas saturations of not more than five percent. Furthermore, the results indicate that the contribution of gas hydrate to the observed angle-dependent reflection coefficient is negligible and can hardly be resolved and quantified from AVA.

URL: http://www.bgr.de

OS51C-0865 0830h POSTER

A High Resolution Deep Towed Seismic Survey Across Mound Culebra, Costa Rica

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In July 2003 RV SONNE conducted the SUBDUCTION II cruise SO173-1 offshore Costa Rica and Nicaragua. During this cruise the GEOMAR deep towed multichannel seismic streamer was used along several profiles studying mound structures at the continental margin of Middle America. Besides a survey area offshore Nicaragua (Breitzke et al.) sites of mound structures off Costa Rica were revisited. During earlier multichannel and wide angle seismic profiling with RV METEOR and RV SONNE a prominent mound structure of 150 m height was found and named Mound Culebra. During cruise SO173-1 multichannel deep towed seismic data as well as sidescan sonar data were recorded along 15 profiles, partly crossing one another. The major target Mound Culebra has been covered by 8 profiles which are offset by approximate 600 m. Additional lines with 1000 m offset cover the surrounding area where additional seafloor highs (additional mound structures) were identified from swath bathymetry. A BSR reflection is visible on all reflection seismic profiles with variable intensity. Within single fold seismic sections the BSR display becomes very weak underneath Mound Culebra, however final data processing has to proof if it can be traced continuously underneath the mound. ENE of Mound Culebra another seafloor high could be identified as a mound structure within seismic records. Again BSR patterns are clearly visible to both sides. An overview of the data and first results will be presented.

URL: http://www.geomar.de/projekte/sfb_574/index.html

OS51C-0866 0830h POSTER

A High-Resolution Deep-Towed Seismic Survey in the Mound Region Along the Continental Slope off Nicaragua

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In July 2003 RV SONNE conducted the SUBDUCTION II cruise SO173-1 offshore Costa Rica and Nicaragua. During this cruise the GEOMAR deep-towed multichannel seismic streamer was used along several profiles to study mound structures and fluid escape features at the continental margin of Middle America. Besides revisiting locations off Costa Rica a new survey area was investigated offshore Nicaragua. According to earlier recorded multibeam bathymetry several mound structures of unknown size were expected within this area. A set of 13 parallel profiles covered an area of approximately 700 km^2 in water depths between 1000 m and 2300 m. Both bathymetry and seismic lines showed that the continental margin off Nicaragua is dominated by deeply incised canyons and numerous mound structures as well as slides at the lower slope. The two most prominent mounds "Nica-1" and "Nica-2" are located at the uppermost continental slope. The larger one rises about 300 m above the surrounding sea floor. Well stratified sedimentary layers of about 250 - 300 m thickness in the deep towed seismic sections are based by a band of strong reflections throughout the entire area. They seem to form the recent base for the deeply incised canyons, which at some locations have stopped some meters above and at other locations have cut into this high reflectivity band, but none of them cut through this reflection band. Underneath occurs a less reflective zone in which a BSR is visible in most parts of the survey area. This BSR varies in strength along the profile lines and appears to be discontinuous in parts. Preliminary single-fold seismogram sections additionally indicate local interruptions of the BSR underneath mound structures. Further data will proof if the BSR can be followed underneath the mounds. An overview of the data and first results will be presented.

URL: http://www.geomar.de

OS51C-0867 0830h POSTER

Seismic Observations of a Possible Carbonate Mound on the Continental Slope off Vancouver Island

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