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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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A large carbonate or mud mound was identified about 5 km west of ODP Site 889 on the Vancouver Island continental slope. At its base, the mound is 1 km wide perpendicular to the margin and 2 km long parallel to the margin. In dives with the remotely-operated submersible ROPOS in May 2001, we observed widespread carbonate pavement was observed which made it impossible to collect sediment push cores. Piston coring also failed to penetrate the pavement or collect sediment samples. ROPOS also observed several biological communities of tubeworms and clams, indicating that venting of methane was likely active. To interpret the structure of this carbonate mound, a high resolution single channel seismic survey was carried out in summer 2001. The source was a 40 cu.in. sleeve airgun, fired by distance at an interval of 12.5 m. The grid consisted of 80 lines, each 3 km in length and separated by 25 m. The seismic lines, recording coherent reflectivity down to about 400 m beneath the seafloor, provide excellent images of this carbonate/mud mound and of the BSR beneath it. The single channel data form a pseudo-3D single channel seismic grid with 25 m e 25 m square bins, and so we can use 3D migration techniques to image the complex structures. The mound is bounded on its landward and seaward sides by faults that dip toward Vancouver Island. The faults appear to connect to a particularly strong section of BSR, which may trap locally large concentrations of gas. The faults intersect the surface on either side of the mound, and may provide pathways for methane and other fluids from the gas reservoir to vents at the surface.

OS51C-0868 0830h POSTER

Biostratigraphic age of the Sediments From Southern Hydrate Ridge, ODP LEG 204

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ODP Leg 204 drilled 9 sites on the southern Hydrate Ridge, and 4 of them penetrated the top of the accretionary complex of the Cascadia subduction zone. Diatoms and calcareous nannofossils from sediments recovered were studied to assign ages for these sediments. 13 late Pliocene to Pleistocene microfossil events, 5 diatom and 8 calcareous nannofossil events, were recognized. We determined precise ages of the sediments using these bioevents. Highly-deformed sediments of the accretionary complex recovered at Site 1244, 1251 and 1252 were assigned to late Pliocene to earliest Pleistocene (ca. 2.5-1.6 Ma). Fine-grained hemipelagic sediments with turbidite layers which uncomformably overlies Accretionary complex were assigned to early Pleistocene to Holocene (ca 1.6 Ma to present). The unconformity between deformed accretionary complex and slope basin sediments found at the eastern flank of Hydrate Ridge and the eastern slope basin (Site 1244, 1251 and 1252) was assigned to early Pleistocene (ca. 1.0-1.5 Ma). At the western flank of Hydrate Ridge thick sediment (more than 350 m) deposited at the same time. This difference in sedimentation pattern must have resulted from topographic change and movement of depocenter at around 1 Ma. Sedimentation rates at Leg 204 sites ranges from 2 cm/k.y. to 163 cm/k.y. and varies by sites and periods. In the eastern slope basin (at Site 1251 and Site 1252), the sedimentation rate has increased significantly at about 300 ka or younger.

OS51C-0869 0830h POSTER

Rock Magnetic Signature of Gas Hydrates in Sediments from Southern Hydrate Ridge (Cascadia Margin)

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Hydrate Ridge is a structural high located in the Cascadia accretionary wedge offshore Oregon, where gas hydrates were detected on the seafloor and an ubiquitous BSR suggested widespread distribution of hydrates. During ODP Leg 204 (July-September 2002), nine sites (1244 to 1252) were drilled along and across southern Hydrate Ridge. We took more than 600 samples (systematically 2/core) plus higher resolution (1/section) when crossing specific structural layers such as the BSR, and Horizons A, B, and B', defined on the 3D MCS. Sedimentological, mineralogical, geochemical and rock magnetic analyses are being carried out. We have completed measurements of magnetic susceptibility (k), Anhysteretic Remanent Magnetization (ARM), and Isothermic Remanent Magnetization (IRM) at 0.1, 0.4 and 0.9 T. Our data indicates two distinctive magnetic behaviours: 1) Low remanence intensities with low IRM/ARM and remanence to susceptibility ratios, and 2) Very high (and variable) remanence intensities with distinctively high IRM/ARM and remanence to susceptibility ratios. The first type mostly characterizes the first few meters of sediments and other intervals deeper in the cores, whereas the second one appears in discrete zones (e.g. around the BSR and other hydrate-rich intervals). We suspect that the first behaviour is dominated by magnetite and that the second one is linked to diagenetic formation of magnetic iron sulfides (mainly greigite), which frequently appear as cm-scale nodules. We will compare these results with sedimentological (grainsize), bulk/clay mineralogy and geochemical (major/trace-element and TOC) data from the same core intervals. This will allow us to examine the possible link between formation of gas hydrates and diagenetic growth of magnetic iron sulfides, which may have implications on the detection of gas hydrates and identification of fossil BSRs.

OS51C-0870 0830h POSTER

Stratigraphic and Structural Evolution of South Hydrate Ridge

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Hydrate Ridge is a structural high in the Cascadia accretionary wedge. A widespread seismic BSR suggests widespread occurrence of gas hydrate, but limited evidence for seafloor venting indicates inhomogeneous distribution of gas hydrate. We present a reconstruction of the geologic history of the southern part of Hydrate Ridge based on a high-resolution 3D seismic survey constrained by lithologic data from ODP Leg 204. The objective of this study is to better understand stratigraphic and structural features that affect the distribution of fluids in the subsurface and the migration pathways to cycle these fluids through the gas hydrate stability zone by mapping the strata and structures and reconstructing their former configuration. We conclude that southern Hydrate Ridge is composed of a landward-verging thrust fold, initiated 1.2 mybp near the deformation front, which is juxtaposed against a dome-shaped core of older, fractured accretionary material. Several distinct and overlapping tectonic basins have formed as a result of interactions between these structures. These have been uplifted, folded, faulted and eroded in response to episodic uplift of the dome, resulting in the complicated structure imaged by the 3D seismic survey.

OS51C-0871 0830h POSTER

Lithostatic Gas Pressures and Venting at Southern Hydrate Ridge

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Seismic reflection data suggest that vents at the summit of southern Hydrate Ridge are fed by a stratigraphic horizon, 'Horizon A,' which is imaged as a strong reflection with negative amplitude. Multiple penetrations during Leg 204 of Horizon A revealed that it is composed of multiple volcanic glass-rich turbidite layers. The amplitude of this reflection increases abruptly above 1050 m below sea level (mbsl). It decreases where it crosses from the free gas zone (FGZ) to the gas hydrate stability zone (GHSZ) beneath the western flank of Hydrate Ridge. We interpret the amplitude increase within the FGZ to represent the change from water-saturated to gas-saturated sediments and the decrease in the GHSZ to indicate formation of gas hydrate. The in situ density and seismic velocity in the the FGZ obtained by logging during Leg 204 are very low, confirming high gas saturation. We propose that gas is trapped within Horizon A by stratigraphically adjacent, less permeable sediments. Horizon A flattens within the FGZ at a depth of 940 mbsl beneath the southern summit. Assuming that pore pressure at 1050 mbsf is hydrostatic, we determine that the gas pressure a the crest of this 110-120 m high gas column is 10.5 MPa, similar to the lithostatic stress. We interpret this to be a critically pressured system in which lithostatically pressured gas is dilating fractures that allow migration of methane gas through the GHSZ. This is a ongoing process as long as the supply of methane in horizon A is maintained. Chemical aspects of gas hydrate formation associated with this model are discussed in a companion paper (Torres et al.). This model also implies that gas venting can be suddenly initiated if the overburden thins through slope instability.

OS51C-0872 0830h POSTER

Two Dimensional Multi-phase Flow Modeling of Hydrate Systems in Accretionary Complexes

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Multi-phase flow in hydrate systems is modeled in anticlinal structures within accretionary prisms such as Hydrate Ridge, offshore Oregon. Methane generation is assumed to be temperature-dependent and follow from the Arrhenius reaction theory. Methane migrates as a separate gas phase, driven by buoyancy and hydrodynamic flow. Hydrate formation kinetics are coupled with mass and heat transfer to simulate hydrate formation. Sediment permeability is assumed to decrease with hydrate formation within the hydrate stability field. Ultimately, methane in the free gas phase is trapped beneath the crest of the ridge until its pressure converges on the least principle stress, whereupon it migrates vertically by fracture permeability. In this manner, methane that is generated over a large area at Hydrate Ridge is focused toward the crest of the ridge and ultimately expelled at the crest. Given sufficient time, constant water flux (sourced by prism dewatering) and methane generation, a steady state system is developed where gas is focused toward the crest and expelled at the crest at a constant rate. In this steady state system, a constant volume of gas is trapped that is controlled by the total overburden stress and the capillary properties of the sediments in the free gas zone. Free gas is continually vented through the hydrate stability zone. Perturbation of this system, by erosional unloading or warming, will result in rapid export of methane to the sea floor.

OS51C-0873 0830h POSTER

Consolidation Characteristics of Hydrate Saturated Sediments from ODP Site 1244, Hydrate Ridge, Cascadia Continental Margin

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A geotechnical investigation to measure consolidation and strength properties was performed on piston core sediment samples from ODP Site 1244, Hydrate Ridge, Cascadia Continental Margin. Eight whole core sections taken between 5.7 meters below sea floor (mbsf) to 136 mbsf were used for consolidation testing.

The deepest sample was from the free gas zone beneath the gas hydrate zone. Constant Rate of Strain Consolidation (CRSC) tests were conducted on both intact and remolded samples. The CRSC results are used to evaluate the preconsolidation pressure, hydraulic conductivity, and compressibility parameters of the soil (e.g. compression ratio, recompression ratio). The preconsolidation pressure is usually determined by the Casagrande method or the strain energy method. The Casagrande method is a graphical method of determining the preconsolidation pressure that relies heavily on good quality samples to produce accurate results. The strain energy method is also a graphical method, but uses a plot of the work per unit volume vs. effective stress and has been found to be less subjective. Both techniques give comparable results and rely on the existence of a sharp transition between the elastic and plastic loading domain. The observed compression curves are rounded and do not have a clear transition between the overconsolidated and normally consolidated state. Furthermore, the strains at this transition stress are high compared to typical on-shore clay samples. Unload-reload cycles were performed during testing in order to compare the initial loading to subsequent unload-reloading. The resulting comparisons show that the initial loading slope is much softer than the unload-reload slopes. All of these characteristics indicate that the samples are of poor quality. As a result, the estimation of the preconsolidation pressure is obscured and contains a significant amount of uncertainty. Application of the strain energy method yield high preconsolidation pressures that indicate the soil is normally to slightly overconsolidated (1<OCR<2). Because of the uncertainty in these OCR values, an alternative method was used to estimate the pre-consolidation stress based on the in-situ void ratio and the extrapolation of the virgin consolidation curve. This method predicts that samples shallower than 33 mbsf are near normally consolidated (OCR 1.2) whereas deeper sediments are underconsolidated (OCR<1). The in-situ hydraulic conductivity was found by extrapolating the log-hydraulic conductivity vs. void ratio curves back to the in-situ void ratios. The in-situ hydraulic conductivity is found to vary between 9x10-6 to 8x10-7 cm/s with no trend with depth. The compression ratio (Cc) ranges from 0.473 to 0.704 with an average of 0.600. Cc is fairly constant up to a depth of 79 mbsf, after which, Cc decreases. The recompression ratio (Cr) ranges from 0.015 to 0.027 with an average of 0.021. Cr is constant throughout the depth.

OS51C-0874 0830h POSTER

Stress Orientations and Constraints on the Magnitudes of In Situ Strength of Hydrate Bearing Sediments - Evidence from Borehole Breakouts at ODP Leg 204 Sites, Hydrate Ridge

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Borehole breakouts are observed in the boreholes drilled in gas hydrate-rich marine sediments near Hydrate Ridge off the coast of Oregon. These stress-induced features are expressed as elongations in the cross sectional shape of the borehole, caused by compressive failure of the formation under differential horizontal stresses that exceed the formation's in situ strength. Breakouts were detected using resistivity-at-the-bit tool (RAB) in images of the borehole wall. Breakouts occur at ODP Sites 1244 and 1245, located close to the summit on the west and east flank of the ridge, respectively; and at ODP Site 1251 to the east of the ridge. No breakouts were observed at sites west of Hydrate Ridge. Breakouts indicate that the direction of the maximum horizontal stress, SHmax, at Site 1244 is NE-SW (ridge sub-parallel) and NNW-SSE at Site 1245 (also ridge sub-parallel). These directions correspond to the strike of mapped subsurface normal faults within 2 km of the holes and are aligned with the strike of Hydrate Ridge. The SHmax direction at Site 1251, located further away from the ridge, is ESE-WNW and coincides with the direction of the strike of the regional Alvin Canyon Fault and is roughly perpendicular to the front of the subduction backstop to the east (Siletz Terrain). In the vicinity of the ridge summit (Sites 1244 and 1245), the presence of breakouts in the RAB images and laboratory tests on core samples provide constraints on SHmax and Shmin (minimum horizontal stress) at the depths where breakouts occur. Assuming that the SHmax/Shmin ratio remains constant in shallow seafloor sediments above the breakouts, a lower limit of in situ formation strength can be estimated at these shallower depths; this interval contains gas hydrate. Understanding the in situ strength of the host formation and the impact of hydrate dissociation within the gas hydrate stability zone is critical to establishing the stability of the slope and possible triggering of landslides in some submarine settings.

OS51C-0875 0830h POSTER

Azimuthal Variability in Gas Hydrate Concentration using LWD Resistivity and Density Images

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We estimate the concentration of gas hydrate in several boreholes drilled in the vicinity of Hydrate Ridge during ODP Leg 204. Logging-while-drilling (LWD) tools were used, which measure formation resistivity and density at azimuthal positions around each borehole as a function of depth. We utilize the density data to compute porosity and the resistivity data to compute water (Sw) and hydrate (1-Sw) saturation at each azimuthal position in these holes. The results allows for delineation of the shape, geometrical distribution, and azimuthal orientation of the porous sediment structures that are saturated with gas hydrate as a function of depth. This 360-degree approach contrasts with conventional methods that use wireline logs or core data and produce a single saturation value at each measurement depth. In addition, LWD data are acquired only minutes after the formation is drilled, limiting the extent of hydrate dissociation on the measured in situ properties. From these results on Hydrate Ridge, the clay-bearing sediments within the gas hydrate stability zone (GHSZ) appear to contain patchy zones with high concentrations of hydrate that are locally distributed around the borehole. Patchy zones occur throughout the GHSZ and at all of the Sites (1244-1251), where LWD data were acquired. LWD neutron and density data indicate that there is no significant free gas occurrence within the GHSZ, confirming that the images represent gas hydrate features, not free gas, in these sediments. Within the limitations of the method, which include uncertainties in the Archie parameters, the accuracy of porosity measurements, and the effects of ship heave, among others, our estimates of azimuthal hydrate concentration compare closely, when averaged around the borehole, to estimates from other conventional log and core measurements. However, the computation of this information from LWD images adds significantly to our understanding of the spatial distribution of hydrate in these formations.

OS51C-0876 0830h POSTER

Downhole Log Assessment of Gas Hydrate and Free-Gas Concentrations on Hydrate Ridge

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The downhole-logging program on ODP Leg 204 was designed to assess the occurrence and concentration of gas hydrates on Hydrate Ridge. Logging while drilling (LWD) tools were deployed at eight (Site 1244-1150) of the nine sites drilled on southern Hydrate Ridge. LWD tools measure in-situ formation properties with instruments located in the drill collars immediately above the drill bit. The LWD tools used during Leg 204 included the resistivity-at-the-bit (RAB-GVR) tool, the magnetic resonance while drilling (MRWD) tool, and the azimuthal density-neutron (VDN) tool. The downhole log inferred distribution of gas hydrate beneath Hydrate Ridge and the adjacent slope basin is heterogeneous, with downhole RAB images showing gas hydrate occupying fractures and occurring as a disseminated pore-filling material within flat lying stratigraphic units with thicknesses varying from several centimeters to as much as 10 m. It has been shown that it is possible to obtain gas-hydrate saturations (percent of pore space occupied by gas hydrate) by using the Archie relation to analyze the electrical resistivity of gas-hydrate-bearing sediments. In this study, the Archie relation was used with resistivity data from the GVR tool and porosity data from the VDN density tool to calculate water saturations at all eight LWD log sites on Hydrate Ridge. The Archie relation yielded water saturations ranging from low values near the crest of the ridge, of about 10% in Hole 1249A, to a more common value of about 90% along the flanks of the ridge. It is generally accepted that with the zone of gas hydrate stability, gas hydrate saturations (Sh) are the mathematical complement of Archie derived water saturations (Sw), with Sh=1-Sw. Thus, the Archie derived gas hydrate saturations at the crest of the ridge exceed 90

OS51C-0877 0830h POSTER

Gas Hydrate Distribution From Acoustic Waveform and Electrical Image Logs in Accretionary Complexes, ODP Legs 201 and 204

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During the summer of 2002, ODP Leg 204 drilled 9 sites on Hydrate Ridge, offshore Oregon, to investigate a particularly rich marine gas hydrate deposit. Earlier that year, Leg 201 had drilled one site (1230) in the Peru trench to study the relationship between gas hydrate formation and subseafloor microbial activity. All of these sites were drilled in active continental margin sediments with variable lithology and degrees of deformation. One clear observation can be drawn when comparing these sites - the distribution of gas hydrate is highly heterogeneous, with significant lateral differences between adjacent holes and vertical differences within individual holes. At some of the sites (i.e. Site 1230 in the Peru Trench and Sites 1247 and 1252 on Hydrate Ridge), only a few gas hydrate samples were recovered. However, downhole measurements such as wireline logs and core-scanning infrared camera images indicate a more widespread hydrate distribution. We use sonic waveform logs and downhole electrical images to discriminate the fine scale variability and the 3D distribution of gas hydrate at these sites. In Hole 1230A and in most Leg 204 sites, cm-scale electrical images (FMS) and monopole and dipole sonic waveforms at various frequencies were recorded simultaneously, allowing accurate correlations between individual measurements. Sonic and electrical logs are sensitive to the presence of hydrate because they record the induration and insulation generated by the solid ice-like compound replacing the pore fluids in marine sediments. The presence of gas hydrate increases electrical resistivity and sonic velocity, and decreases sonic waveform amplitudes. Elastic-wave modeling shows that this effect is dependant on hydrate concentration and on the nature and frequency of the sonic source. Together with FMS images, the analysis of acoustic logs allows for precise identification of gas hydrate occurrences that were not recovered in cores. In addition, the combination of the high-resolution azimuthal images with the sonic data provides insight into how the presence of gas hydrate in the pore space may be affecting the sonic waveform amplitudes.

OS51C-0878 0830h POSTER

Combined Studies of ODP log Data and Seismic Reflection Data at Southern Hydrate Ridge

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In August 2002 Ocean Drilling Program (ODP) Leg 204 (Hydrate Ridge) provided essential borehole data to complement recent seismic studies at Hydrate Ridge to correlate amplitude analysis investigations and to constrain previous results. Seismic data was acquired during cruise SO-150 in September 2000 on the German RV SONNE, aiming at qualitative and quantitative estimates of free gas and gas hydrates within the sediments across Hydrate Ridge. Hydrate Ridge is part of the accretionary complex and is characterized by the presence of extensive gas hydrates, causing a prominent Bottom Simulating Reflector (BSR) in marine seismic records. Several seismic in- and crosslines were shot across the ridge to map the spatial distribution of the BSR. Wide angle reflection data of narrowly spaced Ocean Bottom Seismometers (OBS) allow frequency dependent amplitude variations with offset (AVO) investigations. Seismic reflection data, recorded simultaneously with a single channel surface and deep tow streamer completed the data set. The usage of different sources during acquisition provided additional information of the frequency response of the BSR signature. This data set was used to study the complex seismic behaviour of such gas hydrate environments in detail. The borehole data, collected during ODP Leg 204, now improve recent seismic investigations and support previous results. Within the COLIBRI project log information (Vp, Vs and density) was used for forward modeling to combine seismic investigations with new borehole data. The P wave velocity model of a traveltime inversion and AVO analysis of the seismic OBS sections suggest rather low quantities of gas hydrate or at least the lack of massive hydrate zones. Shear wave phases, identified in the seismic OBS sections, refer to slow S wave velocities in the upper sediment layers above the BSR, which support a model with small amounts of hydrate or patchy hydrate zones within the upper sediments.

OS51C-0879 0830h POSTER

Seismic Study of Natural Gas Hydrates at Northern Hydrate Ridge, Cascadia Accretionary Complex

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The abundance of gas hydrates at Hydrate Ridge, located landward of the deformation front of the Cascadia accretionary complex, makes it an ideal research target for studying the dynamics of hydrate formation and dissociation processes. Thus, a detailed seismic investigation of Hydrate Ridge was carried out within the HYDGAS project aboard the R/V Sonne in September 2000. The major aim was the quantification of the amount of solid gas hydrate and free methane using multi-frequency sources and streamer (deep tow and surface SCS) and ocean bottom (OBH/OBS) receivers. Core and log data collected during ODP legs 146 (Westbrook et al., 1994) and 204 (Trehu, Bohrmann et al., pers. comm.), MCS data from survey OR89 (MacKay et al., 1995; Trehu et al., 1999) and side-scan sonar data (SO165-1, 2002) were available for an integrated data analysis. Here, we present results from the northern ridge, the summit of which reaches ∼590 m water depth. A total of 34 densely spaced GI-Gun profiles (line spacing 400 - 1500m) were acquired with a single channel surface streamer. Analysis of the BSR depth distribution shows two major regions of an anomalous shallow BSR, interpreted as a result of upward fluid migration and associated high heat flow. These areas are located westward of ODP drill site 892 and near the topographic summit. Site 892 penetrated a eastward-dipping thrust fault at a depth of ∼100 mbsf along which deep-seated fluids rise feeding a carbonate chemoherm structure located 350m further west (Linke et al., 1994, Davis et al., 1995). The mapped reflection amplitudes of the BSR show disrupted or disturbed BSR signatures interpreted as zones of upward migrating fluids. Comparison of the BSR depth and amplitude anomalies with side-scan sonar data shows good correlation of chemoherm structures and active venting fields. An AVO analysis of the wide angle OBH/OBS data using P and PS converted waves was done to determine the elastic properties of the sediments beneath the instrument locations. A strong PS conversion at the seafloor might be enabled by an increase in the shear modulus due to outcropping gas hydrate or carbonate crusts. The concentrations of gas hydrate and free gas derived from the OBS data are used to calibrate the P wave amplitude data and allow an estimate of the regional hydrate/gas distribution.

OS51C-0880 0830h POSTER

Distribution and Seismic Characteristics of Gas Hydrate Offshore Southwestern Taiwan

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This study compiled and analyzed all the available seismic reflection data in the area offshore southwestern Taiwan for the identification and characterization of BSR (bottom simulating reflection). A BSR map has been generated that shows the distribution of gas hydrate in the studied area. This map indicates that gas hydrates are widely presented beneath the sea floor over an area of 20,000 km2, from the passive margin of the South China Sea continental slope and the near shore accretionary Kaoping Slope, to the toe of the accretionary wedge adjacent to the Manila Trench in 3500 m water depth. Seismic characteristics typically associated with the presence of gas hydrate, such as blanking zones above BSR, high amplitude reflections beneath BSR, negative polarity and amplitude increases with offset for BSR reflections, etc., have all been observed. Velocity structures derived from pre-stack depth migration and from analyzing the wide-angle reflection and fraction data collected by the ocean bottom seismometers show that the hydrate-bearing sediments generally have velocity ranges from 1750 to 2000 m/s, with most values around 1900 m/s. Low velocity zones observed beneath the gas hydrate bearing sediments clearly indicate the presence of free gas below. This study has found that gas hydrates are concentrated the most in the accretionary wedge north of 21o45'N offshore southwestern Taiwan, especially under anticlinal ridges and adjacent to thrust faults. This clearly demonstrates the structural control of gas hydrate distribution within the accretionary wedge environment.

OS51C-0881 0830h POSTER

Characteristics of Gas Hydrate and Free Gas Offshore Southwestern Taiwan: A Combined Seismic Reflection/Refraction Analysis

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Offshore southwestern Taiwan, BSRs have widely been observed in water depths ranging from 600 to 3000 m. The highest concentration of BSR is located in the northwestern portion of the Manila accretionary prism where rapid deposited terrigenous sediments may have relatively high amounts of organic carbon, thereby providing a source for the methane. Special efforts have been made to derive the best velocity information from the seismic reflection and OBS refraction data. A series of pre-stack depth migrations in a streamlined Deregowski loop was implemented in a layer stripping approach: During each iteration, residual move-out in the image gathers are analyzed and the migration velocity field is update from the resulting Depth/Depth error. In order to account for the 2D complexity of the surveyed area, about 15 iterations were necessary. Manual picking was indispensable during the early iterations in order to stabilize the inversion processing by integrating the interpreter's knowledge. A spatially continuous residual velocity analysis automatic picking has proven efficient for refinement of the velocity model in the later stage. These acoustic velocities are then tested in a ray-tracing scheme on the vertical and hydrophone components of the OBSs. A damped least-square to the linearized inverse problem, using the partial derivatives of the travel times with respect to the model parameters and the travel time residuals better constrains the acoustic velocities in the vicinity of the OBS. Poisson Ratio values we estimated at the vicinity of the 3 OBS stations analyzed in this study will be presented. The modeling of the complex seismic waves recorded by the 4 component stations allows us to propose estimates of the elastic properties of sediments bearing gas hydrate and free gas and derive hydrate saturation values offshore southwestern Taiwan.

OS51C-0882 0830h POSTER

High Resolution, Deep-Tow Seismic Survey to Investigate Methane Hydrate-Bearing Sediments, Nankai Trough, Offshore Japan.

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A 2D deep-towed seismic survey was carried out over part of the Nankai Trough, Offshore Japan, in 1996. The area is known to have a major accumulation of methane hydrate; conventional seismic surveys have mapped thousands of sq. km. of BSR events, and the presence of methane hydrate was confirmed by a MITI research well in 2000. The objective of the deep-towed survey was to obtain high resolution stack and velocity profiles of the methane hydrate-bearing sediments down to the BSR, which occurs at around 300 msec below the sea bottom in this area. The data was acquired using the "Deep-Towed Acoustics/Geophysics System (DTAGS), developed by the Naval Research Laboratory, USA. Both the source and the hydrophone cable are towed close to the seabed, allowing a "close look" at the shallow sediments. The source is a vibrator-type Helmholtz transducer with a 0.25 sec sweep from 250-650 Hz. The hydrophone cable has 48 channels and a maximum offset of 620m. This paper focuses on the data processing, carried out in 1998 and 2002. The main challenge in the processing was to handle the floating acquisition datum with source and receiver depths being maintained at typically 200-300 m above a varying seabed. The measured depths had to be corrected by residual statics derived from picks of the sea bottom reflection event. A total of around 200 km of data was processed, with water depths of 700-1400 m. The results showed that it is possible to obtain high resolution profiles and velocity data, and that it is also possible to fail to achieve such data. Success largely depends upon control of the depths during acquisition; they should be kept smoothly varying and measured as accurately as possible. The deep-tow system has the advantage over conventional data in water depths of around 1000 m or deeper, for zones close (within 100's m) to the seabed. The advantage of the system becomes greater with increasing water depth.

OS51C-0883 0830h POSTER

Application of AVO Analysis for Gas Detection to Seismic Data Acquired in Nankai Trough Area, offshore Japan

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The drilling in Nankai Trough, offshore Japan in 1999, confirmed the occurrence of methane hydrate (hereafter called MH). It gave Japan so big impact for the future energy source. Since 2001, Japan's national research project, named MH21, has been conducted by METI for technology development of geology, geophysics for MH exploration. When the drilling, we never obtained any direct evidence of gas occurrence below MH-bearing zone except circumstantial evidence such as very low P-wave velocities. This result gave us hope that there is so much gas that we could recover as an energy source. In our research, for the purpose of confirming the gas occurrence below MH-bearing zone, we applied Amplitude Versus Offset (AVO) analysis to the seismic data acquired in Nankai Trough area in connection with the well data. The procedure of AVO analysis includes AVO attribute analysis, cross-plot analysis and primitive offset-amplitude analysis. After integration and detailed analysis of the results from each analysis, we concluded that there are so few gas occurrences below MH-bearing zone, which never become energy resources. On the contrary, a little gas localization in obliquely stratified sediment above BSR is found in spite of the MH stability zone. To understand this result, we need more study by using other new geological information.

OS51C-0884 0830h POSTER

Methane Hydrate Detection Using Dense Velocity Analysis

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As one of approach to evaluating the total amount of methane hydrate, a method utilizing the results of velocity analysis on reflection seismic exploration data is studied. Well log sonic data reveals that the velocity of the methane hydrate bearing zone is greater than that of surrounding sediments. Thus, the velocity information can be used for detection of the methane hydrate zone.
In order to delineate detailed velocity variations, a dense velocity analysis is performed using an automatic velocity picking tool. Because the target depth of this analysis is fairly shallow (less than 400m below sea bottom), a simple algorithm can be used for the picking.
Dense velocity analysis is applied to 2D marine seismic data acquired over the Nankai Trough, Offshore Japan. Comparison between automatic and manual picking results showed a similar trend at the shallower zone above BSR. The processing time, however, is considerably different; it takes several days for manual picking against a few minutes for automatic picking.
In the automatic picking process, the velocity trend is also estimated. The difference between actual velocity and velocity trend provides another viewpoint for the delineation of velocity anomaly zone.
On going work includes an analysis of 3D marine seismic data in the Nankai Trough. Provisional results will be shown in this meeting.

OS51C-0885 0830h POSTER

A trial of the delineation of gas hydrate-bearing sediments using multi seismic attributes analysis offshore Tokai Japan

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MITI Research well Nankai Trough was drilled at the offshore Tokai Japan in 1999/2000 and the occurrence of gas hydrate was confirmed by borehole measurments or core. It gave us so big impact to the view of Japanese future energy resources and other scientific interests. METI, Ministry of Economy, Trade and Industry of JAPAN, started "The Research for Methane Hydrate Resources in Japan" from fall of 2001. Bottom Simulating Reflectors (BSRs) were widely found on the marine seismic data acquired offshore Japan, especially in the shelf-slope near the Nankai Trough. If we will explore and exploit the gas hydrate, we have to get the information of hydrate-bearing sediments, such as their saturation, porosity or thickness. BSRs indicate the existance of gas hydrates accurately, they, however, do not estimate reservoir parameters. In order to estimate the amount of gas hydrates accurately, we have to get the more detailed reservoir parameters. We computed the multi-seismic attributes and after that, we tried to delineate hydrate-bearing sediments. Firstly, we get some seismic attibutes sections which show such as the P-reflectivity(P), Gradient(G), Products(P*G), Poisson's ratio change sections from pre-stack(AVO) analysis and the P-wave interval velocity section and P-wave impedance sction.

OS51D MCC: 3000 Friday 1020h

Sedimentation on European Margins II *(joint with C)*

Presiding: **J P Syvitski,** Institute of Arctic and Alpine Research**; C A Nittrouer,** University of Washington**; P Weaver,** Southampton Oceanography Centre**; F Trincardi,** CNR-Istituto di Geologia Marina

OS51D-01 1020h

Sediment Accumulation Along the Italian Adriatic Coast

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Sediment supply to the Adriatic Sea is dominated by the Po and Apennine Rivers in the northern and southern regions, respectively. Recent investigations have revealed that processes impacting sedimentation in this area are active on a variety of time-scales, ranging from events (e.g., floods) to seasonal and decadal variations. In the northern region, flooding of the Po River is common, and a 100-year flood event occurred in October 2000. Using ^{7}Be (half-life 53.3 days) as a tracer of flood sediment, the deposit was found to be up to 15-cm thick. However, the depth of ^{234}Th (half-life 24.1 days) exceeds ^{7}Be in cores of the flood deposit, indicating that thicknesses derived from ^{7}Be are minimum estimates and that the first sediment deposited during the flood event likely originated from the river channel. The location of the flood deposit immediately adjacent to the distributary channels at the river mouth can be predicted considering the relatively low-energy physical oceanographic conditions during the time of emplacement. Near the Po River Delta, sediment from flood events contributes significantly to longer-term (100-year) sediment accumulation. The signature of flood layers is observed in radiochemical (low ^{210}Pb activities; half-life 22.3 years) and textural (fine grain size) profiles, which lead to accumulation rates >2 cm/y. Southward, the character of sediment accumulation transitions to steady state, reflecting the decreased impact of event sedimentation, and accumulation rates decrease to levels near and below 1 cm/y in the southern portion of the Po River dispersal system. Sedimentation near the Apennine Rivers is even more strongly impacted by anthropogenic activities (dam construction), which increased after the second World War. These activities have resulted in a reduction of sediment accumulation in the area, evidenced by changes in ^{210}Pb profiles. Across-shelf accumulation rates reach a maximum on the foreset of a shelf clinoform and are $\sim$ 1 cm/y.

OS51D-02 1035h INVITED

Sediment transport processes across crenulated clinoforms on the western Adriatic prograding mud wedge

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Sea-floor crenulations of complex and uncertain origin characterize large portions of the late Holocene prograding mud wedge in several sectors of the Apennine shelf. Sediment failure has been postulated as the most plausible mechanism for their formation, although their maintenance through time seems to be related to different sediment accumulation rates in the flat and steep flanks. In order to establish relationships between active sediment dynamics, cross-shelf transport and sediment accumulation in these crenulated fields, as part of the EuroSTRATAFORM program, and in combination with the Po and Apennine Sediment Transport and Accumulation (PASTA) study, a tripod and a mooring were deployed off the Pescara River during autumn and winter 2002-2003, in a region characterized by a crenulated clinoform. The tripod was placed at 20 m water depth, close to the clinoform roll-over point, and the mooring was located at 50 m depth, in the foreset region. Several sediment-resuspension events were recorded at the tripod site, mainly related to Bora and Sirocco storms, during which current and wave shear stresses reached similar values. Sediment transport around the roll-over point was predominantly towards the SE, following direction of the coastal current and the bathymetry, but showing a significant offshore component that was intensified during storm events. Currents at the mooring site were also directed to the SE. In mid-waters they were clearly aligned with the local bathymetry, whereas near the bottom they had an important and continuous offshore component. This predominant offshore current behavior near the bottom seems to be associated with an intense bottom Ekman transport, which will enhance the suspended sediment transport from the topset down the foreset region and contribute to the development of the clinoform feature. In addition, activity of near-inertial waves was also recorded by the moored current meters and temperature sensors. During periods characterized by a strong near-inertial signal (17 h), increases of the water turbidity clearly coincided with the offshore direction of the cross-shelf velocity component and with strong temperature fluctuations through the water column. During these events, velocities in the cross-shelf and along-shelf components were similar, which suggest that near-inertial internal waves also contribute to the offshore transport of suspended sediment across the crenulated clinoforms. Further analysis about the role of near-inertial internal waves in the sediment dynamics of the study area will provide insights for understanding if this mechanism could have created and/or maintained the crenulated clinoforms that that extends along the Apennine shelf.

OS51D-03 1050h INVITED

Organic Carbon and its Isotopic Composition in Surficial Sediments From the Western Adriatic Continental Shelf

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Continental shelves play an important role in the global carbon cycle because they represent the largest modern repository of particulate organic carbon. However, recent studies indicate that the role of shelves as sinks for C_{org} is still poorly known in details, suggesting that more understanding of sedimentary processes affecting the distribution and preservation of organic matter on the continental shelves is required. The western Adriatic continental shelf receives inputs of allochthonous, terrestrial organic carbon via rivers and autochthonous, marine organic carbon from coastal biological productivity. In the northern region, the Po river dominates the supply of organic carbon. The central coast is characterized by a series of small, distributed fluvial sources draining the Apennine mountains. In this region, modern sedimentation occurs on a clayey-silt shelf clinoform oriented parallel to the coastline. The organic carbon content of surface sediments collected during 2 cruises (April 2002 and October 2002) follows the same pattern of fine sediment dispersal. The highest values (from 0.60 to 1.71 wt%) were recorded close to the Po river delta, while in the central Adriatic the contents range from 0.11 to 0.91 wt%, with slightly higher values toward the bottomset region and negligible along-shelf variability. Riverine contributions measured on sediment collected along the axis of some rivers (Po, Uso, Marecchia and Aso), are characterized by intermediate C_{org} contents (from 0.56 to 0.82 wt%), and very negative $\delta^{13}C_{org}$ values ranging from -25.39 to -26.47$^{o}/_{oo}$. The $\delta^{13}C_{org}$ distribution of surface sediments near the Po delta shows a clear increasing trend with distance from the river mouth, as a consequence of the decrease in the contribution of terrestrial organic carbon and the increase of marine carbon. The signature of terrestrial C_{org} is almost lost at about 9 km offshore the Po river's mouths. The sedimentary $\delta^{13}C_{org}$ values in the central Adriatic Sea suggest an overall dominance of the organic matter of terrestrial origin and a stronger influence of terrigenous organics close to the mouths of

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