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Water height data provided by seafloor tide gauges is a combination of sea-level variations and ground motion. Both of these signals are of scientific interest, but they must be separated in order to be useful. Estimating ground motion is specially important in very tectonically active areas such as the Pacific Ocean rim. One promising method to separate the two contributions is to use satellite altimetry data which gives absolute water height, but these data must be calibrated using ground truth measurements. Once different components of the signal are separated, bottom pressure gauges can be used to detect vertical movements of the seafloor such as co-seismic or slow inter-seismic motions.
The Vanuatu archipelago is part of the Pacific ring of fire, where plates are rapidly converging. In the area, movements are very rapid and the seismic activity is intense, which gives a good opportunity to study deformation and seismic cycle. To get an integrate picture of vertical deformation over one plate and between the two plates, one needs to be able to monitor vertical movements on both underwater and emerged areas. We conducted an experiment in the Vanuatu archipelago, South-West Pacific, to compare measurements from bottom pressure gauges located beneath altimetry satellite tracks with sea surface altitude measurements from GPS. Two bottom pressure gauges are immerged since Nov. 1999 on Sabine bank (15.90°S, 166.14°E) and Wusi Bank (15.34°S, 166.55°E), West of Santo island, Vanuatu. In order to perform absolute calibrations of JASON and ENVISAT altimeters that overfly the Wusi and Sabine banks, respectively, we performed GPS measurements of instantaneous sea surface altitude. The GPS antennae were fixed on top of the 30m long R/V Alis. An inertial unit also recorded the high frequency vessel motions. The height of the antennae over the sea surface was measured using a laser distancemeter in calibration sessions during particularly calm sea states. We present results of GPS computations in kinematic mode, together with the corrections for pitch and roll from the inertial unit. We compare the results with the sea level variations recorded by the tide gauges.

### OS42A-0833 1330h POSTER

## Multibeam Sonar Image Classification

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High-frequency multibeam sonar has become an increasingly common geophysical tool used in shallow water environments. It is used to rapidly acquire depth and co-registered backscatter intensity data, effectively providing a snapshot view of the seabed. These high-resolution data contain detailed information about the morphology and texture of the modern layer of the stratigraphic record that can be used to understand the dynamics of the sedimentary environment if patterns in the acoustic imagery can be related to the physical environment. Using data collected with an EM 3000 (300 kHz) multibeam sonar system at the Shallow-Water High Frequency Acoustics Experiment site (SAX99) off western Florida, we have developed image classification techniques that can be used to aid acoustic image interpretation. This particular dataset is ideally suited for developing classification algorithms because multibeam tracks were closely spaced and lines were run in several orientations. In addition, the site had relatively uniform water depth and sediment type with the exception of a muddy trough that transects the survey area. Within the sandy sediments are seabed ripples with wavelengths of approximately 70 cm. The image classification techniques focus primarily on multibeam acoustic backscatter data and can be used to distinguish broad transitions in sediment type (mud v. sand). In addition, we are able to detect variations in ripple properties throughout the sandy region of the survey area. We also apply these methods to EM 3000 data collected in other environments, including the Hudson River, in order to verify their validity. By utilizing other datasets, we are able to better understand the acoustic image classification as it relates to the physical environment.

### OS42A-0834 1330h POSTER

## Determination of shallow water depth by using optical satellite images

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The remote sensing method processing with multi-temporal images collected by optical/near infrared sensor of the SPOT satellites can be a more effective approach to retrieve shallow water depth in compare to the traditional sounding ones. This method based on Lambert-Beer law, which presumes that attenuation of sunlight in water is an exponential function of water depth, is known for depth retrieval from optical data. We compare two satellite images gathered in different dates and calibrate each one by the correspondent tidal records. With the reference of the water-level difference in these two dates, we can derive the attenuation coefficient of sunlight in the water by image pair. This method also assumes that the attenuation coefficient is spatially homogeneous. We apply this method to the Peng-Hu archipelago, which comprises 64 basaltic volcanic isles lay on the southeastern Eurasia continental plate V geographical location between the Mainland China and Taiwan. Around and within these isles, the water depth is very shallow and the bathymetry information is quite lack. Our results provide water depth information for the shallow water area, which can contribute further information for ship traffic.

# OS42B MCC: 3000 Thursday 1340h

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

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

### OS42B-01 1340h INVITED

## Global Occurrences of Marine Gas Hydrate Beyond Active and Passive Continental Margins

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Natural gas hydrate occurs worldwide in oceanic sediment mainly in slopes and rises of active and passive continental margins. The Blake Outer Ridge, a passive margin in the Atlantic Ocean, and Hydrate Ridge, an active margin in the Pacific Ocean, are two regions of gas-hydrate occurrence that are particularly well studied. But gas hydrate occurs in other geologic settings where conditions of temperature, pressure, and amount and composition of gas and water are appropriate. For example, gas hydrate has been recovered from inland seas and lakes (Black Sea, Caspian Sea, and Lake Baikal). Gas hydrate has been inferred, based mainly on geophysical evidence, to be present in sediment of the Central Argentine Basin, the Bering Sea, and the Barents Sea. Submarine mud volcanoes such as Haakon Mosby in the Norwegian Sea and Kula in the Mediterranean Sea have yielded samples of gas hydrate, and near-surface sediment of the Gulf of Mexico contains gas hydrate associated with submarine gas vents. In fact, submarine gas hydrate was first observed by Russian scientists about thirty years ago when near-surface sediment recovered from the Black Sea was found to contain micro-crystalline aggregates of gas hydrate resembling hoarfrost. Most marine gas hydrate contains micorbially-generated methane; however, thermogenic methane has been observed in gas hydrate from the Gulf of Mexico and the Caspian Sea. Although most marine gas hydrate is found in sediment of active and passive margins, various occurrences beyond these margins demonstrate how globally extensive natural gas-hydrate phenomena actually are.

### OS42B-02 1355h INVITED

## Laboratory and Seafloor Experiments with Hydrocarbon Clathrate Hydrates: A Review with Potential Applications to Hydrates in Nature

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The in-situ chemical composition, structure, and textural positions of clathrate hydrates within sediments, and their effects on the properties of their host sediments are important features that are rarely, if ever, determined directly. All hydrocarbon clathrate hydrates retrieved from their natural environments for study in the lab at atmospheric pressure have been to some degree altered and/or partially decomposed during transit and handling. Thus interpretation of their structures, textures and properties is not always straightforward. Laboratory and seafloor experiments on synthetic hydrocarbon hydrates and aggregates with sediment are useful for aiding the interpretation of retrieved materials. Here we describe such exploratory efforts at the USGS, MBARI and LLNL: (1) Rock-physics theory and measurements of the physical properties of multi-phase granular materials in general indicate that the textural position (conformation) of hydrates in the pore space of sediment dictate the quantitative effects of hydrates on sediment properties. Our ice-to-hydrate synthesis method permits us to make synthetic sediment/hydrate aggregates with known conformation as well as measure accurately their bulk properties and test the rock-physics theories. Such tests currently seem infeasible using natural samples. (2) Such synthetic samples with known hydrate characteristics and properties can be subjected to known P-T-time pathways that simulate the retrieval pathways of natural samples. The effects of the retrieval process can be evaluated by comparing the starting hydrate characteristics and properties with those of the simulated "retrieved" material. Optical-cell experiments can be potentially useful in evaluating the textural effects of retrieval by direct observation. (3) The governing physical chemistry of our ice-to-hydrate synthesis method is probably different from that in natural environments. We have found, however, that exposure of lab-made samples to the seafloor and their subsequent retrieval within the P-T stability of methane hydrate alters their grain textures as determined by cryogenic SEM. Such samples resemble natural samples taken from the shallow seafloor of the Gulf of Mexico, suggesting that similar processes that lead to rapid textural equilibration are occurring in both settings. (4) Samples of hydrates at vents sampled by ROV's may be quickly decomposed to gas near the seafloor and retrieved for later gas analysis. Such analyses are not as prone to gas partitioning during transit and hence may be more representative of the in-situ hydrate gas compositions.

### OS42B-03 1410h INVITED

## Coordinated Studies of High-Resolution Marine Methane Hydrates

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High resolution Studies of marine methane hydrates based on Long-Base-Line (LBL) acoustic navigation allow investigators to collocate direct samples (e.g., cores, heatflow, water-samples, etc.) with remote measurements such as conventional and deep-tow seismic data. Examples are presented based on work done on the Cascadia margin off Vancouver Island using the Naval Research Laboratory's DTAGS (Deep-Towed Acoustics/Geophysics system), coring, water samples and direct observations with an ROV. These data were acquired at the "Bullseye" vent using an acoustic bottom transponder constellation to position DTAGS' source and receivers with an accuracy of 1 to 2 meters. (The constellation was also used to co-locate piston cores with the seismic data with the same accuracy.) This site is of particular interest as it brings together, in a relatively small area, processes of hydrate dissociation, generation, fluid flow, and evidence of chemosynthetic communities. These data are used to constrain numerical simulations of perturbation of the gas hydrate stability zone, fluid flow through the sediments and the impact of these processes the dynamics of gas hydrates.

## OS42B-04 1425h INVITED

### Beyond BSR's: Direct Hydrate Detection and the Dynamic Free Gas System

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Two decades of increasing effort in studying methane hydrates, much of it devoted to mapping and analysis of the bottom simulated reflection (BSR), has produced a new appreciation for the possible significance of methane hydrates to slope stability, resource evaluation, and the global carbon cycle. A number of outstanding challenges remain, including remote quantification of hydrate and gas amounts, identification of the locales and mechanisms of gas release into the oceans and atmosphere, and improved understanding of the effects of hydrate and gas on the mechanical strength of marine sediments. In this contribution I will present recent results demonstrating (1) direct detection of methane hydrate, (2) the dynamic nature of the free gas zone, and (3) the possibility that the thickness of the free gas zone is mechanically regulated by the strength of the overlying sediments. Data will be presented from the Blake Ridge, Gulf of California, and Storegga Slide hydrate provinces.

## OS42B-05 1440h

### S-Wave Velocities and Anisotropy in Methane Hydrate- and Gas- Bearing Sediments Offshore Svalbard - the HYDRATECH Project

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As part of the HYDRATECH project, an EC Framework-5 research project devoted to the development of techniques for the quantification of methane hydrate in European continental margins, seismic experiments were conducted at two sites in the continental margin off western Svalbard. At each site, an array of 20 four-component OBS at 400-m spacing was deployed at the centre of a grid of seismic lines shot with 200-m line spacing and a 20-m shot spacing. The seismic source comprised two 0.65-litre sleeve guns, and single-channel reflection profiles were recorded along each shot line. The bottom-simulating reflector [BSR] lies about 200 m below the seabed. The BSR, with opposite polarity to the seabed reflector, cuts obliquely across the reflectors related to bedding, which show increased relative amplitude and lower frequency content beneath the BSR. Some of these reflectors show a change in polarity where they cross the BSR, and in places the hydrate/gas transition is only evident from the change in amplitude of the bedding reflectors. Seismic velocity was obtained in 2D and 3D by ray-tracing and tomographic inversion of travel times. In a zone about 50-m thick above the BSR, P-wave velocity is increased above that expected for a typical increase of velocity with depth from compaction. It decreases sharply beneath the BSR, and returns to more normal values, with increasing depth, over the next 150 m. Clear S-waves were generated by P-to-S conversion on reflection. Poisson's ratio decreases rapidly in a 50-m thick zone beneath the BSR, in response to a reduction in the bulk modulus caused by the presence of free gas, whereas the shear modulus increases consistently with depth. At this location, the presence of hydrate seems not to have increased the shear modulus of sediment significantly. Travel-time anomalies and S-wave splitting indicate anisotropy that is probably caused by vertical cracks in the gas-bearing sediments beneath the BSR. These cracks may provide the principal route for the upward migration of methane.

URL: http://www.hydratech.bham.ac.uk

## OS42B-06 1455h

### Use of Seismic Attributes in Identifying and Interpreting Onshore Gas-Hydrate Occurrences, North Slope, Alaska

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Gas hydrates occur in shallow subsurface environments where both water and natural gasses are present within low-temperature and moderate-pressure regimes. Although much hydrate research focuses on gas hydrates in marine environments, significant accumulations of gas hydrate occur onshore in arctic regions, such as the North Slope of Alaska, within and below permafrost. The shallow subsurface geology of the North Slope is structurally dominated by the Barrow Arch and is riddled with a myriad of high-angle normal faults generally trending north-south and east-west. In addition to the complex shallow structure, the hydrate-bearing units are also stratigraphically complicated; the depositional environment is predominantly a fluvial, northward-prograding deltaic system. The complexity of the local geology and generally lower quality of onshore seismic data, coupled with a lack of consistent amplitude anomalies associated with these gas-hydrate occurrences, make interpretation of gas-hydrate-bearing zones more difficult than is typical in marine environments. In order to gain a better understanding of the gas-hydrate distribution as well as a clearer picture of the local geology, seismic attributes have been used in conjunction with traditional seismic interpretation and well-correlation techniques. Several of the attributes can yield information about the physical properties of the hydrate-bearing units. For example, hydrate layers, which have relatively high acoustic velocities and low densities, may have anomalous frequency responses. Local polarity reversals and amplitude and frequency anomalies along hydrate-bearing layers indicate the presence of free gas down-dip from the hydrates below the local hydrate-stability field. Delineation of high-angle faults and possible channel deposits are aided by the use of edge-detection volumes and additional post-stack processing. Such analyses show that shallow faults cause significant compartmentalization of the hydrate-bearing zones. The use of these and other attributes yields a more accurate structural model as well as a clearer picture of hydrate distribution.

## OS42B-07 1510h

### The Extent of $CH_4$ Emission and Oxidation in Thermogenic and Biogenic Gas Hydrate Environments

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The role of methane hydrate in the global methane budget is poorly understood, because relatively little is known about the transport of gaseous and dissolved methane through the seafloor into the ocean, from the water column into the atmosphere, and the extent of water-column methanotrophy that occurs en route. We characterize the transport and consumption of methane in three distinct gas hydrate environments, spanning the spectrum of thermogenic and biogenic methane occurrences: Bush Hill in the Gulf of Mexico, Eel River off the coast of Northern California, and the Noth and South Hydrate Ridges on the Cascadia Oregon margin. At all the sites studied a significant enrichment in $\delta^{13}CH_4$ with distance along isopycnals away from the methane source is observed, indicative of extensive aerobic bacterial methane oxidation in the water column. The effects of this process are principally pronounced in the mostly biogenic methane setting, with $\delta^{13}C$-$CH_4$ measured as high as -12 permil (PDB) between North and South Hydrate Ridge. The $\delta^{13}C$-$CH_4$ values ranged from -12 to -67 permil at Hydrate Ridge, -34 to -52 permil at Eel River, and -41 to -49 permil at Bush Hill. The large variation in methane carbon isotope ranges between the sites suggest that major differences exist in both the rates of aerobic methane oxidation and system openness at the studied locations. A mean kinetic isotope fractionation factor is being determined using a closed-system Rayleigh distillation model. An approximate regional methane flux from the ocean into the atmosphere is being estimated for the Gulf of Mexico, by extrapolation of the flux value from the Bush Hill methane plume over 390 plume locations having persistent oil slicks on the ocean surface, mapped by time series satellite data.

## OS42B-08 1525h

### Exploring Ideas About Why Methane Generation and Hydrate Formation Occur So Abundantly in the Bering Sea Basin

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INTRODUCTION: Beneath the virtually flat surface of the abyssal floor (3700-4100 m) of the Bering Sea Basin, geophysical data record a regionally persistent BSR at a depth of 450 m. Above vertical chimneys of ascending gas ( 0.5 km in dia, 1-2 km in height) the horizontal attitude of the BSR is deflected (domed) upward at what are called VAMP (Velocity-Amplitude) structures. VAMPs are thought to record the massive deposition of interstitial hydrate that forms a velocity pull-up lens in a sequence of flat-lying turbidite and diatom beds. The areally extensive ( 450,000 km2) BSR and abundance (thousands) of gas chimneys and associated VAMPs testify to high, basin-wide flux of methane. Why should this be so? Taking a basin analysis approach, the following combination of depositional, diagenetic, and oceanographic factors are hypothesized to be involved. SEDIMENT COLUMN: The basin floor is underlain by a 3-12-km thick sequence of mostly Eocene and younger mudstone and turbidite deposits, the Miocene, Pliocene, and Quaternary part of which is, or was, richly diatomaceous. During the past 2-3 Myr a 1-km-thick, water- (porosity = 50-60%) and diatom-rich turbidite section accumulated rapidly over the latest Miocene basin floor. Below the turbidite sequence silica diagenesis has formed porcelaneous shale via the downsection conversion of the opal-A of diatom tests to opal-CT and, at great depths, chalcedonic quartz or chert. HEATFLOW: The average flux of heat across the basin floor is 55-60 mW/m2 (n= 31, range 42-90), which is higher than could be produced by its basement of Cretaceous oceanic crust. The near-sea floor thermal gradient is 50-60 deg C/km. PRODUCTIVITY: The Bering Sea Basin is one of Earth's most productive fishing grounds, a circumstance linked to the regional upwelling here of part of the nutrient-rich global conveyor belt of circulating thermohaline water. Drilling and dredging document that high surface water productivity, in particular for diatoms, has been maintained over the basin since at least the early Miocene. WORKING HYPOTHESIS: We suggest that the rapid deposition of a basin-wide blanket of glacial age turbidite deposits warmed underlying organic- and diatom-rich hemipelagic beds of early Pliocene and older age. Warming accelerated conversion of diatomaceous units to porcelaneous shale, a process that is accompanied by rock volume contraction, fracturing, and the release of heat and water. Subsurface heating stimulated the production of thermogenic methane that ascended toward the seafloor along fracture pathways in the shale. Methane entering the turbidite and diatomaceous section locally nourished the growth of massive hydrate deposits to form an abundance of VAMP structures, each releasing heat of crystallization. This flux of methane to the basin floor is thus linked to the late Cenozoic warming of middle Tertiary beds that enhanced the production of thermocatalytic gases and facilitated their upward advection through fractured siliceous shale to form wide-spread deposits of methane hydrate in porous late Cenozoic beds.

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