OS42C MCC: 3000 Thursday 1600h

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

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

OS42C-01 1600h INVITED

How and Why the Global Estimates of Hydrate-Bound Gas in Marine Sediments Decreased Over the Last Thirty Years, and What This Means for Resources and Global Change Evaluations

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It is often assumed that oceanic gas hydrates contain huge volume of natural gases, mainly methane. The most widely cited estimate of global hydrate-bound gas is 21×10^{15} m^3 of methane at STP (or $\sim$10,000 Gt of methane carbon), which is proposed as a "consensus value" from several independent estimations. This large gas hydrate reservoir is further suggested as an important component of the global carbon cycle and as a future energy source. I present a revised and updated set of relatively well-justified global estimates and analyze how and why they changed over time. It appears that the global estimates of hydrate-bound gas decreased by at least an order of magnitude from 1970s - early 1980s (estimates on the order of 10^{17}-10^{18} m^3) to late 1980s - early 1990s (10^{16} m^3) to late 1990s - present (10^{14}-10^{15} m^3). The decrease of estimates is a result of growing knowledge of the distribution and concentration of gas hydrates in marine sediments and ongoing effort to better constrain the volume of hydrate-bearing sediments and their gas yield. These parameters appear to be relatively well constrained at present through DSDP/ODP drilling and direct measurements of gas concentration in sediments. The global estimate of hydrate-bound gas that best reflects the current knowledge of submarine gas hydrate is in the range (1-5)$\times10^{15}$ m^3 ($\sim$500-2,500 Gt of methane carbon). A significantly smaller global gas hydrate inventory implies that the role of gas hydrate in the global carbon cycle may be not as significant as speculated before. Gas hydrate still may be considered as a future energy resource, not because the global volume of hydrate-bound gas is large, but because some gas hydrate accumulations may contain resources significant and concentrated enough to be profitably recovered in future.

OS42C-02 1615h

The Clathrate Gun is firing blanks: Are there alternative scenarios?

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Kennett et al. (2003) have proposed the release of clathrates as the primary cause of the rapid increases in atmospheric methane seen during deglaciation and the warm Dansgaard-Oeschger (D-O) events. To balance the global carbon isotope budget and make a deglacial biospheric carbon transfer of $\sim$1000 GtC compatible with the marine carbon isotope data, we deduce a release of $\sim$120 GtC gas hydrate methane (Maslin and Thomas, 2003). Compilation of the occurrence of continental slope failures over the last 45 ka supports the suggestion that there was large release of gas hydrates during the Allerod-Bolling and Pre-Boreal periods. But 120 GtC represents less than 30 percent of the enhanced atmospheric methane release between 18 and 8 ka observed in ice cores, leaving 70 percent unaccounted for. We outline a new model for driving atmospheric methane changes due to flooding and decomposition of organic rich continental shelf sediments by rising sea level, which may explain the very rapid rise in methane during both the Allerød-Bølling and Pre-Boreal periods. The underlying increase between glacial and interglacial methane however we maintain is due to the expansion of tropical wetlands. Compilation of the occurrence of continental slope failures suggest that during the last glacial period they occur during Heinrich events. This does not support the Clathrate Gun Hypothesis, which requires gas hydrates release synchronous with the warm D-O events. We therefore conclude that a continental shelf flooding hypothesis is a more plausible explanation, as rapid rises in sea level associated with the warm D-O cycles provides a direct and synchronous causal mechanism.

OS42C-03 1630h

Compositional changes in natural marine bubble plumes: Observations from Shane Seep, Coal Oil Point hydrocarbon seep field, CA

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Detailed measurements of bubble composition, dissolved gas concentrations, and plume dynamics were conducted during a 9-month period at Shane Seep, a very large (surface gas flux = 1900 m^3 day^{-1}), shallow (22 m water depth) marine hydrocarbon seep in the Santa Barbara Channel, California. The field study illustrates the important chemical and physical processes that occur in the modified environment of large bubble plumes. Despite the very short travel time of bubbles from the seafloor to the surface (about 40 s), a significant amount of gas exchange between the bubbles and plume water occurs, creating distinctly different seafloor and surface gas compositions. Methane, carbon dioxide, and heavier hydrocarbons were lost from rising seep bubbles, while nitrogen and oxygen were gained. Enough methane was lost from the bubbles to increase the dissolved methane concentration within the plume by more than four orders of magnitude above atmospheric equilibrium values. However, there was insufficient time (rise distance) to bring the plume water into equilibrium with the bubbles (methane concentrations <10% saturation). Leifer et al. (2000) reported that surface methane concentrations were slightly supersaturated within the bubble plumes of deeper (70 m water depth), large (surface gas flux > 600 m^3 day^{-1}) Coal Oil Point seeps. This observation demonstrates that given enough time, large bubble plumes can saturate the plume water with methane and, thus, the loss of this gas from the bubbles will cease. Once saturated, the methane remains in the seep bubbles and is transported through the water column directly to the atmosphere. The depth of methane saturation in the Coal Oil Point seep field is relatively shallow, between 20 m and 70 m, suggesting that large bubble plumes will transfer methane to the atmosphere regardless of depth.

OS42C-04 1645h

Evidence of subsurface gas hydrate in the northern Gulf of Mexico

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The northern Gulf of Mexico is characterized by an extremely heterogeneous near-surface geology that makes geophysical identification of subsurface gas hydrate challenging and ambiguous. Bottom Simulating Reflections (BSRs) are rarely reported. A recent multidisciplinary suite of geophysical and geological observations at two sites provides examples of possible subsurface hydrate occurrence in 1350 m water depth at two different geologic settings. At the first site, near Keathley Canyon block 195, a distinct BSR over a region of 15 km2 occurs at the transition between a salt-withdrawal basin and its flanking salt-cored structural high. Analyses of 3D and high-resolution 2D multichannel seismic data show that the distribution and strength of the BSR may correlate to alternating fine and coarser-grained layers and to the geometry of faults, which presumably influence migration of warm, gas-rich fluids. Thermal gradients are variable and geochemistry indicates that hydrate may exist at depth. The second site, near Atwater Valley block 14, lies within the Mississippi Canyon and contains several sea-floor mounds. Seismic analysis of mound "F," which may be a vent, has a BSR that is significantly shallower beneath the center of the mound than it is beneath the flanks of the mound. The mound is underlain by free gas that causes 40 ms of velocity pull-down on a sub-horizontal reflection. An integrated, multidisciplinary approach that constrains the geometry, geochemistry, and rate of fluid flux is essential for understanding the dynamics of gas hydrate systems in these different environments.

OS42C-05 1700h

Expulsion of Barium and Methane at Mud Volcanoes in the Gulf of Mexico

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Submarine mud volcanoes and cold-seeps along continental margins transfer methane from gas-charged marine sediments to the water column. Such methane venting is dynamic and may provide an important and variable supply of carbon to the ocean and atmosphere through time. Barite mounds and chimneys have been found around some modern mud volcanoes and seeps, and similar structures can be identified in the geological record (e.g., bedded barite deposits). These observations suggest that expelled methane-rich fluids are greatly enriched in dissolved barium. However, there are very few analyses of barium concentrations in these systems. Here, we examine the dissolved barium of pore fluids from a series of shallow piston cores across two submarine mud volcanoes in the Gulf of Mexico. Dissolved barium concentrations at 1.5 m below the seafloor at the Garden Bank volcano range from 18200 μM at the center of the feature to 0.56 μM on its flanks approximately 1 km away. Similarly, dissolved barium concentrations at the Mississippi Canyon volcano range from 15600 μM to 0.50 μM. Thus, the concentrations in the cores of the mud volcanoes are nominally 5 orders of magnitude greater than in mean ocean water ($\sim$0.1 μM). Anaerobic oxidation of upward flowing methane consumes sulfate, which leads to the dissolution of barite and release of barium to pore fluids. Because this mechanism alone cannot explain the extreme concentrations in the mud volcanoes, a deep source of barium may exist in the Gulf of Mexico strata. Our current work is focused on quantifying the fluxes and sedimentary fate of expelled barium at these locations. However, even if a large fraction of the barium precipitates adjacent to the sites of methane venting, fluid expulsion at mud volcanoes must significantly impact the barium cycle in the Gulf of Mexico. Conceivably, submarine mud volcanoes and cold-seeps along continental margins are a major source of barium to the deep ocean, a concept that has profound implications with respect to certain paleoceanographic reconstructions.

OS42C-06 1715h

Hydrocarbon Seepage and Gas Hydrate Deposits in the Southern Gulf of Mexico - Results From R/V Sonne Cruise 174.

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During October and November 2003, the German ship R/V Sonne visited the Campeche Escarpment in the southern Gulf of Mexico. The primary objectives of the cruise were the following: 1) extend our knowledge of gas hydrates buried just below the seafloor in the deep ocean; 2) determine whether natural hydrocarbon seeps in the southern Gulf of Mexico support chemosynthetic fauna, and 3) pinpoint sites for future exploration with deep-diving submersibles. Recent findings indicate that marine deposits of gas hydrate represent an important contribution to the global carbon cycle. Methane released from the gas hydrate reservoir may interact with other components of the Earth system influencing climate and is a potential source of energy. Although most gas hydrate is buried under hundreds of meters of marine sediment, the Gulf of Mexico is one place where it exists at or near the seafloor, where it can be sampled and studied. Gas hydrate is one component of the natural hydrocarbon system of the Gulf of Mexico; other components - known primarily from the northern Gulf - include oil seeps that produce natural oil "spills" visible from space and lush communities of chemosynthetic tubeworms and mussels. Natural oil seeps also occur in the southern Gulf of Mexico on the Campeche Escarpment and were expected to harbor chemosynthetic fauna and possibly gas hydrates. Recently, satellite remote sensing has been successfully used to pinpoint active seeps based on the unusual synthetic aperture radar signature generated by oil slicks on the sea surface in the northern Gulf of Mexico. Using a combination of satellite image analyses, acoustic profiling techniques, detailed bathymetric mapping, and interpretation of seafloor reflectivity data, we were able to identify and study such areas of active seafloor seepage of hydrocarbons in the previously unexplored southern Gulf of Mexico.

URL: http://www.gashydrate.de/projekte/omega/otega2/

OS42C-07 1730h

Mud volcanoes and gas Hydrates in the Black Sea - new Data From Dvurechenskii mud Volcano

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METEOR cruise M52/1 revealed the presence of gas hydrates in sediments of mud volcanoes in the Sorokin Trough of the Black Sea. Methane Hydrates were sampled from Dvurechenskii MV, Odessa MV, Yalta MV, and an unnamed mud volcano. Dvurechenskii mud volcano (DMV), a flat topped "mud pie"-type structure, seems to be presently active. Pore water in the sediments of DMV is enriched in several constituents such as ammonium and chloride. These elements can only have come from deeper sediments. High sediment temperatures of up to 16.5°C in close contact to the ambient bottom water of 9°C also suggest a strong activity. Steep gradients in temperature indicate a high fluid and/or mud flux in DMV which is independently deduced by the shape of pore water profiles. Active fluid expulsion sites are also evidenced by TV-sled observation, and a potential methane flux from the sediment to the bottom water was traced by measurements.

OS42C-08 1745h

ULTRADEEP LARGE SCALE POCKMARKS OFF CONGO - EXAMPLES FOR MASSIVE OCCURRENCE OF GAS HYDRATE, FLUID AND GAS SEEPAGE

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Deep sea pockmarks belong to the large scale features on the sea floor, where major fluxes of fluids and gases can be observed. They are also among the rare places, where gas hydrates are found near the sea floor in the reach of sampling. The southwest African continental margin off Gabon and Congo has revealed numerous such structures during recent surveys using high resolution seismic and acoustic systems , and 3 pockmark structures had been subsequently selected to be studied within the framework of the German geotechnologien gas hydrate initiative. Main objectives were the occurrence, evolution and properties of gas hydrate, fluid and gas seepage and its physical appearance within the hemipelagic sediment cover. Deep Tow Side Scan Sonar and sea floor video observations confirmed the widespread distribution of shallow carbonate precipitates and gas hydrates, contributing to high backscatter as well as very high reflection amplitudes in sediment echosounder data. Only parts of these a few to 30 meters deep sea floor depressions are affected by fluid escape on sub-circular areas of a few hundred meters diameter. Numerous samples of gas hydrates had been recovered from the vicinity of all 3 surveyed pockmarks, indicating a close relationship between fluid pathways, chemosynthetic communities as clam fields or tube worms, gas hydrate growth and carbonate precipitation. 3D seismic data collected at high to very high resolution, using seismic sources up to 1 kHz source frequency, reveal a complex nature of the fluid upflow zone and their relationship to deeper shallow gas pockets. It is assumed that they allow the spatial reconstruction of gas hydrate occurrence, gas distribution and the sediment volume, contributing to the overall fluid flow, as well as the quantification of gas hydrates stored in the vicinity of the pockmarks in the upper 200 meters of the sediment column.

OS51A MCC: 3000 Friday 0800h

Sedimentation on European Margins I

(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

OS51A-01 0800h INVITED

Ravinement Surfaces And Deglacial Sediments On The Rhone Margin (France)

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The significance of key surfaces and parasequences on the Rhone margin is investigated by comparing high-, very high-, and ultra-high resolution seismic data to long Calypso cores. Each surface and deposit correspond to typical seismic facies, distinct lithologies and different faunal associations. Radiocarbon datings allow us to tie these surfaces and deposits to the deglacial history of the area. However, it is necessary to consider the Rhone subaqueous delta in three dimensions, in order to decipher the impact of global (sea-level), regional (climate, sediment flux), and local (hydrodynamics, avulsion) processes. The last deglacial sea-level rise is well recorded through surprisingly similar clinoform parasequences, that consist of sand and gravels progressively passing seaward to clayey silts. When these systems have a sufficient lateral extent, they can be utilized as a "dipstick" for sea-levels in the Western Mediterranean Sea. Cemented sands, that formed along the phreatic zone, are also observed at different depths and provide an independent way to constrain paleo-water depths.

OS51A-02 0815h

Continental-Margin Response to Sea Level: Theory and Experiment

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We present the results of theoretical and experimental studies on the stratigraphic response to high-amplitude eustatic sea-level cycles. Our theoretical work focused on the development of three-dimensional, integrated-morphodynamic models of shelf-clinoform response to eustatic cycling and the corresponding development of stratigraphic sequences. In our models, which treat the shoreline as a dynamic moving boundary, characteristic floods and coastal storms, of specified magnitude and intermittency, drive long-term evolution of the coupled fluvial and shallow-marine sediment surfaces. Clinoform behavior and overall margin morphology are sensitive to the relative efficacy of fluvial and shallow-marine sediment dynamics. The interplay of eustasy with large, frequent coastal storms generates compound clinoforms with broad, strongly interfering shelf environments and relatively small, highly three-dimensional fluvial systems. Such storm-dominated clinoforms develop significant phase shifts between the shoreline and the shelf edge (clinoform rollover) that affect the timing of sediment delivery to the deep marine and overall growth of the margin. Phase shifting decreases with increasing flood frequency and magnitude and, by extension, the transition to fluvio-deltaic sedimentation. In the experimental study, which we performed in a subsiding-floor basin at St. Anthony Falls Laboratory, we analyzed the stratigraphic response to both isolated and superimposed eustatic sea level cycles in a passive-margin setting. The interplay of subsidence and high-amplitude sea level cycling generated a complex stratigraphic architecture consisting of a series of stacked shelf-slope clinoforms. We measured the shoreline response, the partitioning of sediment between fluvial and marine environments, and the timing and nature of sequence-boundary formation.

OS

OS51A-03 0830h

Gravity-Driven Sediment Transport on the Continental Shelf: Implications for Equilibrium Profiles Near River Mouths

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An analytical model is developed for equilibrium bathymetric profiles off river mouths associated with the shoreward, convex upward portion of subaqueous deltas and clinoforms. The model builds on recent field results demonstrating that gravity-driven flux of suspended mud is important on shelves provided that wave-induced suspension of sediment supports the requisite turbid hyperpycnal layer. Because the maximum sediment load is determined by the critical Richardson number, the results are independent of the properties of the suspended mud or the bed. The model assumes the equilibrium state to represent a balance between the supply of sediment by a river at the coast and the down-slope bypassing of sediment to deep water within wave-supported turbid near-bed layers. Progressive seaward increases in bed slope across the convex shelf profile allow the attenuation of wave agitation with depth to be compensated for by a down-slope increase in the contribution of gravity. The model is consistent with shelf profiles off the mouths of the Po (Italy), Rhone (France), Eel (California), Ganges-Brahmaputra (Bangladesh), and Waiapu (New Zealand) Rivers. The equilibrium profile is predicted to be a function of wave