July 5, 2005

IODP EXPEDITION 308: GULF OF MEXICO HYDROGEOLOGY
SITE U1322 SUMMARY

Hole U1322A Latitude: 28°, 5.9628' N, Longitude: 89°, 1.5120' W
Hole U1322B Latitude: 28°, 5.9642' N, Longitude: 89°, 1.4995' W
Hole U1322C Latitude: 28°, 5.9640' N, Longitude: 89°, 1.5228' W
Hole U1322D Latitude: 28°, 5.9753' N, Longitude: 89°, 1.4995' W
Water depth: 1319.5 m

Site U1322 is the easternmost site drilled in the Ursa basin by Expedition 308. Of the three sites in the Ursa Basin, Site U1322 has the thinnest sediment cover above the permeable Blue Unit. The principal objectives of drilling Site U1322 were to document rock physical properties at the location of minimal overburden in the Ursa Basin, measure in-situ formation temperature and pressure, document geochemical composition of the pore water, and establish a preliminary age model leading to an estimate of sediment accumulation rates at this location. The ultimate goal of drilling the Ursa Basin is to explore fluid flow and fluid pressures in an overpressured basin.

Site U1322 was the first dedicated measuring while drilling (MWD) and logging while drilling (LDW) hole in the overpressured Ursa Basin. For the first time in the history of IODP (and ODP/DSDP) a hole was logged before being cored. This established MWD/LWD as a viable tool to monitor real time pressure in a drill hole. Drilling at Hole U1322A advanced at an average rate of penetration (ROP) of 30 m/hr to a depth of 200 mbsf and, to prevent any communication with the highly permeable Blue Unit, continued with a reduced ROP of 20 m/hr to the target depth of 238 mbsf. The LWD/MWD operation at Hole U1322A reached the initial target depth of 238 mbsf without encountering any major sand units. Overall, hole quality remained good for almost the entire borehole. Hole U1322A is characterized by relatively monotonous logging data mostly indicating clay, mud and occasionally silt. Resistivity and gamma ray measurements show the highest variability and can be correlated to several units defined by visual observation of the cores (see below) and to seismic reflectors S10 and S30. In particular, logging data supports the subdivision of the lithostratigraphic column encountered in Hole U1322B into two lithostratigraphic units (Unit I and II), and the further division of Lithostratigraphic Unit I into subunits. The constructed synthetic seismogram for Hole 1322A demonstrates that the correlation between logging data and high-resolution seismic matches only the uppermost 100 mbsf. Nevertheless, the overall quality of the time-depth model allows an approximate correlation of seismic reflections with observations in core and log data. The GVR electrical images obtained at this hole reflect the occurrence of undisturbed, but also contorted and faulted sediments. The most striking features are parallel E-W orientated contours of analog resistivity that may represent breakouts indicating the direction of the minimal horizontal stress exposed by the drilling process.

Based on visual description of the cores in Hole U1322B, the 234.5 m sediment succession was divided into two lithostratigraphic units (Unit I and Unit II). The total depth of this succession ties closely to seismic reflection S60-1322 and the boundary between Lithostratigraphic Units I and II (125.8 mbsf) occurs just above the prominent Seismic Reflector S30. Lithostratigraphic Unit I is dominated by clay, locally interbedded with silt and further subdivided into four subunits (Ia-Id) based on the occurrence of intervals of deformed sediment. Lithostratigraphic Unit II is characterized by alternating intervals of meter-scale deformed and coherently-laminated clay and mud. The deformed intervals are composed of brownish and greenish gray mud yielding intervals of dipping beds, small-scale faults, recumbent folds, and mud clasts. Nine deformed intervals with thicknesses varying from 2 to 5 m were recognized based on the occurrence of undeformed mud layers at their base.

Lithostratigraphic Unit I at Site 1322 can be correlated to Lithostratigraphic Unit I at Site U1324, because of the continuous seismic reflections and similar lithostratigraphic patterns. Core and seismic data indicate that two major processes controlled sedimentary accumulation at Site U1322: turbidity currents and mass transport deposits. Overspills of mud and clay built the levee deposit corresponding to Lithostratigraphic Unit I. The Southwest Pass Canyon channel, west of Site U1324 is thought to be the source for the levee sediments. Seismically, the deformed intervals correlate with acoustically transparent to chaotic seismic packages. The presence of such deformed beds in the core and their acoustic response strongly suggest that these intervals represent mass transport deposits. Particularly, Lithostratigraphic Unit II represents the stacking of at least 9 mass transport events. Coherent layers in between the mass transport events can be interpreted as either periods of quiescence, or as preserved slipped blocks that were not fully deformed.

Preliminary biostratigraphic data from nannofossils and planktonic foraminifers indicate that the sediment sequence recovered at Site U1322 was essentially deposited over the last 60 kyr, more specifically during Marine Oxygen Isotope Stages (MIS) 1 to 4. These results support the stratigraphic correlation between Sites U1322 and U1324 based on pre-cruise seismic data. Sedimentation rates of about 1 to 2 m/kyr were estimated for the intervals above 30 mbsf and between 125-185 mbsf (Lithostratigraphic Subunit Ia and upper part of Unit II in Hole U1324B). Between 30 and 125 mbsf and below 185 mbsf, sedimentation rates increased to 12 m/kyr, or possibly higher in the intervals of mass flow deposits. Distinctive cyclic patterns were observed in the distribution of nannoplankton and foraminifers, indicating periodic influx of sediments from the Mississippi River associated with turbidity currents in the Ursa Basin. Persistent low-oxygenated “stress” environments due to rapid sediment loading encouraged the proliferation of infaunal benthic foraminifers. A deltaic benthic foraminifer assemblage from the interval between 185 and 234 mbsf is similar to those existing today along the shelf edge of the Mississippi delta, suggesting a period of strong gravity flow due to levee overspills or slope failures about 60 ka ago.

Variations in physical properties correlate well with lithostratigraphic units and seismic reflectors at Site U1322. The porosity profile shows a relatively rapid decrease from the seafloor to 30 mbsf and then a more gentle decrease down to the bottom of the borehole. Shifts from the main trend are observed at slumped intervals. These shifts have a maximum magnitude of 5% with slumps generally showing lower porosities than non-slumped intervals. These porosity changes are mirrored by the bulk density profile.The undrained shear strength shows a more linear increase with depth. A shift of 50 kPa at 125 mbsf is observed at the base of Lithostratigraphic Subunit Id, a 30 m thick slump deposit. Smaller shifts are also observed at the base of each slump deposit. Slumps typically have higher undrained shear strengths than non-slumped deposits. From the main trends in porosity, undrained shear strength and the relation of the later to the hydrostatic vertical effective stress it is possible to make some inferences regarding the sediment consolidation state. First, the change in porosity and undrained shear strength at 125 mbsf indicates that Lithostratigraphic Unit II is probably underconsolidated. Secondly, slumps tend to be more consolidated which might result from recompaction of the originally loose sediments due to dewatering during the transport process. Third, porosity and undrained shear strength at the top of the slumps does not vary significantly with respect to the in-situ sediments above. This might imply that dewatering and consolidation preferentially takes place at the base of the slump where shearing is more important. Units Id and Ib correspond to the same slump intervals at Sites U1322 and U1324, and the general trend in porosity and undrained shear strength is similar at both sites. However, the porosity and undrained shear strength profiles at Site U1324 shows more subdued variations (or no variation at all) between slumped and non-slumped units than those at Site U1322. A hypothesis to explain such differences relates the amount of deformation of the mass flow to its consolidation state. At Site U1324, upslope on the Mississippi Canyon levee, the velocity of the mass flow might have been lower than that at Site 1322, in the center of the basin. Thus the amount of shearing and deformation might have been lower at the latter site, and the higher shearing at Site U1322 would translate into a higher degree of consolidation.

Chemical composition of the interstitial waters at Site U1322 shows large variations in the top 100 mbsf, in particular around the boundary between seismic reflectors S-10 and S-20. Alkalinity, pH, concentrations of Ca, Sr, Li and B ions, and ammonium show concave depth profiles with maxima centered at the depth around reflector S-10. Above reflector S-10, salinity and sulfate concentrations are constantly high, and they show a rapid decrease between reflectors S-10 and S-20, associated with the decrease of several other elements such as Ca, Mg, B, Li, and Sr. Hence, the large pore-water chemical variations at shallow depths and their intimate relationship with the seismic reflectors S-10 and S-20 may suggest that these reflector surfaces were geologically favorable channels for lateral fluid flow in the Ursa Basin. At Site U1322, the Sulfate-Methane Interface (SMI) is very deep at 74 mbsf, which corresponds to a rapid increase in methane concentrations. Above the SMI, only minor amounts of methane (several ppmv) were detected. The highest concentration of methane (51,001 ppmv to 29,536 ppmv) was observed between 75 mbsf and 129 mbsf. Only trace amounts of ethane (<3.4 ppmv) and ethylene (<2.6 ppmv) were detected in a few headspace samples. No higher hydrocarbons were detected at Site U1322. The high C1/C2 ratios suggest a biogenic origin of the methane, which could come from *in-situ* microbial activities or hydrogeologically driven migration. Considering the low abundance of sub-surface microbes, *in-situ* methanogenesis should also be low. Hence the anomalously high concentrations in the middle part of Lithostratigraphic Unit I are inferred to be associated with from fluid flow beneath the above-mentioned strata.

A maximum cell density of 4.0×10^5 cells / ml was observed at 2.9 mbsf in Hole U1322B. Microbial abundance decreased with depth below the cell enumeration confidence limit of 1.0×10^4 cells / ml at 74.5 mbsf. The extremely low cellular biomass at Site U1322 is consistent with microbial abundance levels at site U1324. An important observation is that microbial biomass at the Ursa Basin is an order of magnitude lower than cell densities observed at Sites U1319 and U1320 in the Brazos-Trinity Basin. This phenomenon is as yet unexplained.

In Hole U1322C there were one high quality DVTP-P deployment at 236 mbsf and one high quality T2P deployment at 150 mbsf. These provided us with a reasonable record of in-situ temperature and pressure for Site U1322. Most of the other deployments recorded sub-hydrostatic pressures immediately after the drill string was raised. We interpret that when the drill string was raised, some extensional force was felt by the probe even though the colletted delivery system is designed to not place tension on the tool. Based on these results (or lack thereof), we decided to spend the remaining 36 hours of operation time drilling an additional geotechnical hole at this site. This decision was also motivated by the fact that our revised authorized depth of penetration at Site U1323 (174 mbsf) meant that the interval of major scientific interest could not be penetrated. The purpose of the new Hole U1322D was to deploy the pressure and temperature probes and spot core after each deployment. The cores obtained were to be sampled for geotechnical analysis and then processed through the onboard laboratories.

All of the objectives set for Site U1322 are considered fulfilled. The principal result is that we acquired a good dataset of formation pressures and temperatures for this site that can now be compared to Site U1322. T2P probe and DVTP-P measurements at Sites U1322 and U1324 provided critical data for understanding overpressure and associated flow in the Ursa basin. Dissipation curves at Site U1322 (seven measurements) and Site U1324 (nine measurements) document overpressure at 50 mbsf and continuing to the bottom of each site. The temperature gradient at Site U1324 is 18.6^{o}C/km (17 measurements from 50-608 mbsf); however at Site U1322 the gradient is 26.4^{o}C/km (13 measurements from 42-238 mbsf). This elevated temperature gradient could be due to lateral transport of warm fluids towards Site 1322 from Site 1324 within the Blue Unit. Further analyses of the flow field and the geochemical signature of the fluids will hopefully provide insights on the source of the fluids.