AAPG HEDBERG CONFERENCE
"Gas Hydrates: Energy Resource Potential and Associated Geologic Hazards"
September 12-16, 2004, Vancouver, BC, Canada

CAN FRACTURES IN SOFT SEDIMENTS HOST SIGNIFICANT QUANTITIES OF GAS HYDRATES?

T. McGee and C. Lutken
Center for Marine Resources and Environmental Technology
University of Mississippi

There has been much discussion recently concerning what type of geologic feature in the Gulf of Mexico would most likely contain significant accumulations of gas hydrate. The interest arises from an expectation that someday commercial quantities of natural gas will be produced from hydrates. Although it is not difficult to image, seismically, the various geologic structures within the hydrate stability zone, there is little consensus as to which structures should be considered serious candidates for exploratory drilling. Some investigators are of the opinion that commercial hydrates will be produced first from sandy sediments because porosity and permeability are greater there than in silts and clays. Others say that most hydrates will be found in fractures within fine-grained sediments. The latter scenario seems to be more in agreement with laboratory results.

Hydrates have been created in the laboratory by adding natural gas, sea water and naturally occurring microbial surfactants to artificial sediments under appropriate conditions of pressure and temperature (Rogers, 2004). The artificial sediments consisted of layers of clay and sand. Two types of clay were tested, smectite and kaolinite. It was found that the presence of biosurfactants greatly enhanced hydrate formation and that the hydrates formed preferentially on smectite rather than either kaolinite or sand. Smectite is known to be a common component of soft sediments in the Gulf. Thus, given a sufficient supply of natural gas, all that remains to complete the scenario is a mechanism of producing a dense population of fractures that are open enough to allow gas and water to circulate, come into contact and form hydrates. This presentation postulates that the mechanism is polygonal faulting and provides supporting evidence.

Cartwright et al. (2003) defines a polygonal fault system as "an array of layer-bound extensional faults within a mainly fine-grained stratigraphic interval that exhibit a diverse range of fault strikes which partially or fully intersect to form a polygonal pattern in map view" and argues that the extensional characteristic is produced by syneresis, "a spontaneous contraction (shrinkage) without evaporation". Syneresis is a process that acts only on gels. Therefore, invoking syneresis as a mechanism implies that polygonal faulting occurs only in sediments that are deposited as gels. Such sediments must consist of clay-sized particles. The strikes of individual faults are oriented in an almost random fashion with fault intersections becoming very complex as the system develops. Development is accompanied by mobilization of pore fluids, mainly through open faults acting as conduits. Assuming that a sufficient quantity of gas is available, a smectite-rich, polygonally deformed layer located in the hydrate stability zone could be very conducive to the formation of massive, fracture-filling hydrates.

The hydrate stability zone in the northern Gulf of Mexico is located along the outer continental shelf and down the continental slope. Throughout much of that region, fine-grained material comprises the upper 50-to-100 meters of sea-floor sediment. This material forms a layer that appears nearly transparent on conventional high-resolution seismic profiles such as the G.I.gun profile in fig.1. In contrast, very-high-resolution profiles show the layer to be crowded with nearly vertical features that have been dubbed “brooms”. Closer inspection (fig.2) shows the brooms to be confined between the sea floor and a nearly featureless unit that has been dubbed the “wavy bed”. The wavy bed is present over a large area and is thought to be a mobile unit of low shear resistance. Still closer inspection (fig.3) shows the brooms to be interference patterns associated with local changes in dip and small offsets which may be evidence of polygonal faulting.

The profiles shown in figures 1 thru 3 were recorded in Mississippi Canyon Area, Block 798. Hydrates have been sampled in the block (Neurauter and Bryant, 1989). Measured temperature and depth values indicate that much of the block’s sea floor lies within the hydrate stability zone (Trevor Lewis, pers.com.). Heat-flow measurements have been made (TDI-Brooks, 2001) and piston cores collected. Oddly, the highest heat-flow value was measured at the base of the mud diapir from whose top the hydrate sample reported by Neurauter and Bryant (1989) had been collected. Lewis (pers.com.) suspects that a stream of warm brine flows, perhaps episodically, from the base of the diapir and that cool sea water flows into the sea floor at other locations. Further data will be collected in the area including simultaneous swath bathymetry, side-scan sonar and chirp sonar from an autonomous underwater vehicle. These will provide a plan view of the sea floor which may serve to verify the presence of polygonal faulting.

Acknowledgments

The G.I.gun profile was recorded by the U.S.G.S. Menlo Park office. The deep-tow boomer profile was recorded by Geoforce Consultants Ltd. personnel using U.S.G.S. equipment. The chirp-sonar profile was recorded by TDI-Brooks International, Inc. Funding for the project was provided by the Department of Interior's Minerals Management Services and from the Department of Energy's National Energy Technology Laboratory. The figures were prepared by Paul Mitchell.

References

Cartwright, J., James, D., and Bolton, A., 2003: The genesis of polygonal fault systems: a review. *Subsurface Sediment Mobilization*, Van Rensbergen, Hillis, Maltman and Morley (eds), Geological Society of London Special Publication 216, pp 223-243.

Neurauter, T.W., and Bryant, W.R., 1989: Gas hydrates and their association with mud diapir / mud volcanos on the Louisiana continental slope. *Proc.21st Offshore Tech. Conf.*, Paper No. 5944, 1, 599-607.

Rogers, R., 2004: Lab Analysis of Gas Hydrate Formation in GOM, *Report to the annual meeting of the Gulf of Mexico Gas Hydrates Research Consortium in Oxford, MS.*

TDI-Brooks, 2001: The 2000 University of Mississippi Mississippi Canyon Heat Flow Program, *TDI-Brooks International, Inc. Technical Report # 01-697, February, 2001.*

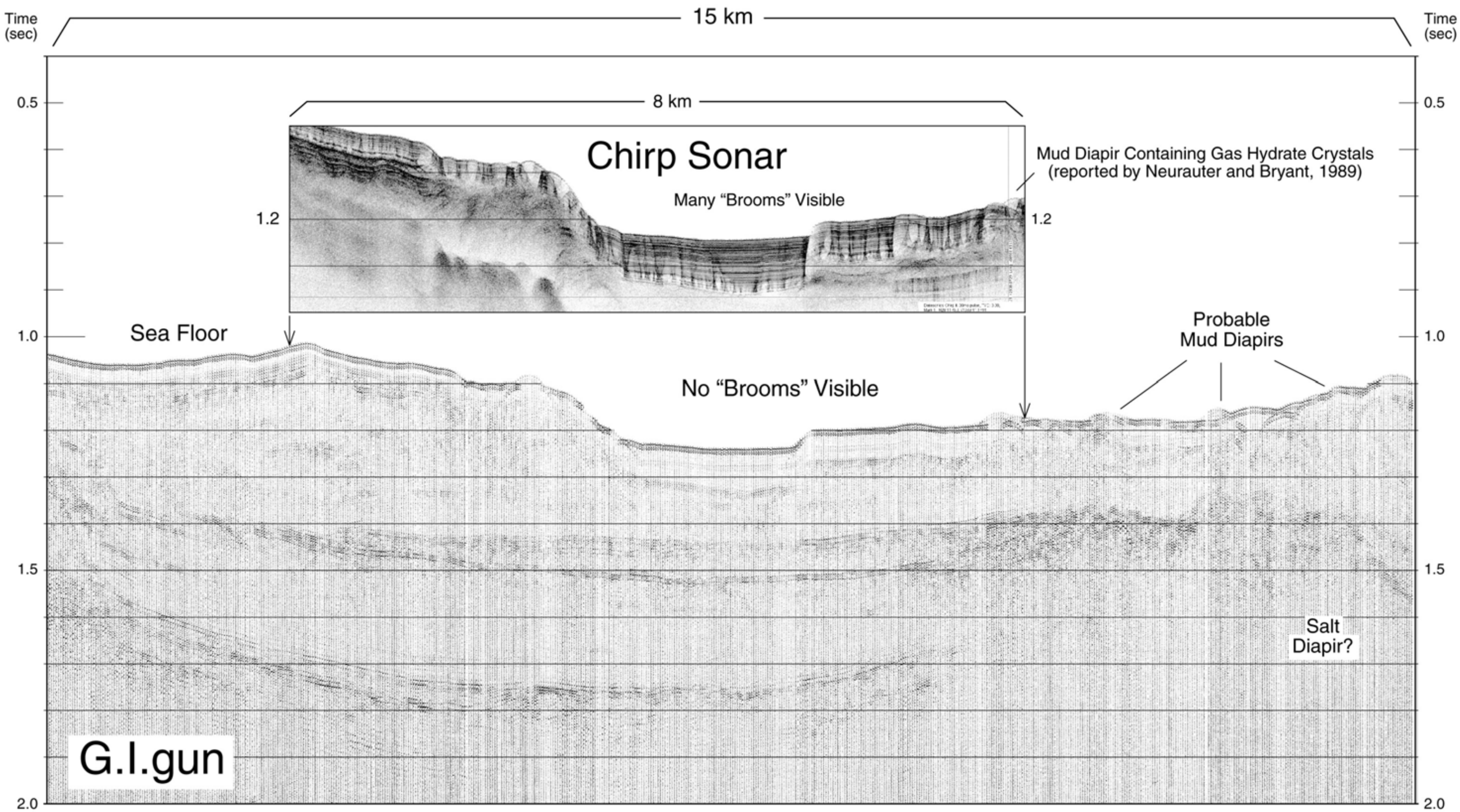

Figure 1 Comparison of conventional high-resolution seismic data and very-high-resolution seismic data.

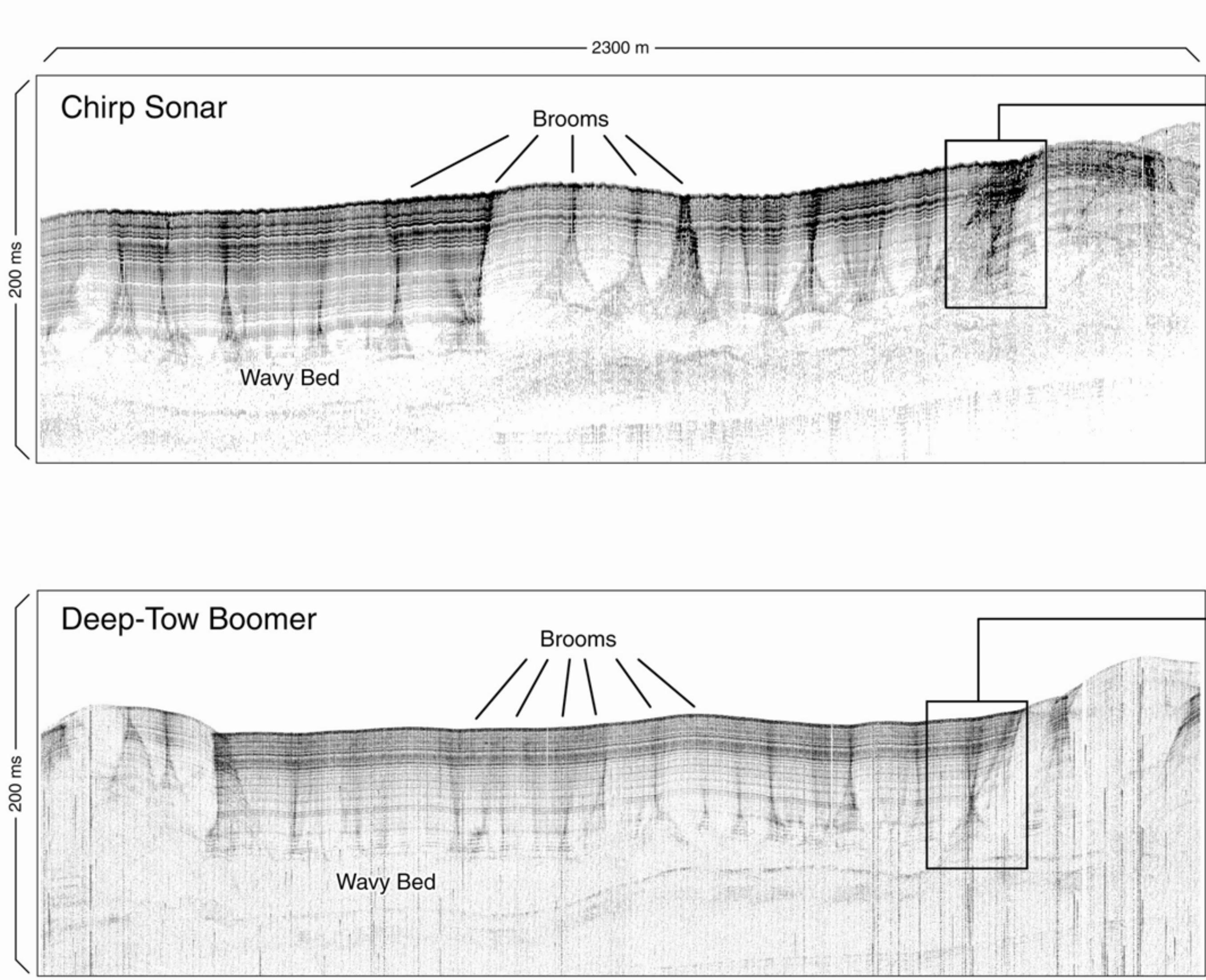

Figure 2 Approximately coincident Chirp Sonar and Deep-Tow Boomer profiles

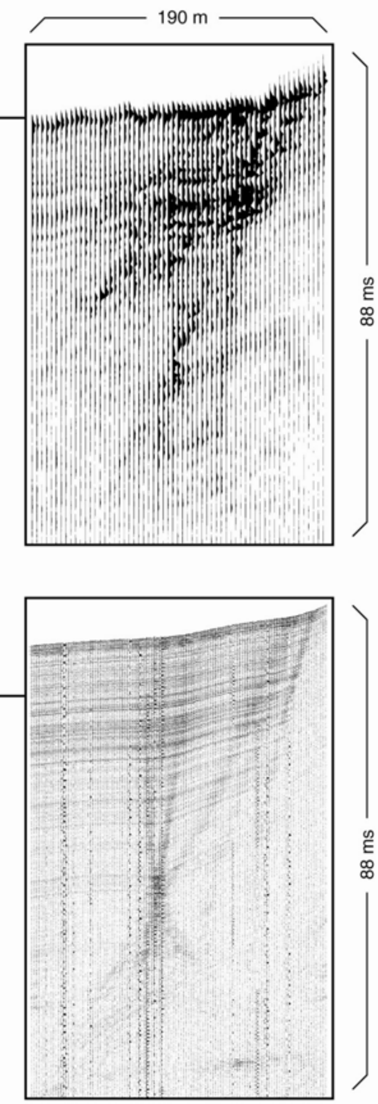

Figure 3 Enlargements of boxes in figure 2 at left.