GC Seismic Attributes of Gas Hydrate Systems*

By

Diana Sava and Bob Hardage[1]

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[1]Bureau of Economic Geology, The University of Texas at Austin (bob.hardage@beg.utexas.edu)

General Statement

The need to understand deepwater gas hydrate systems is increasing, as several quarters of the geosciences world want answers about:

1) The use of hydrate as an energy resource.
2) The role of hydrate in seafloor stability.
3) Hydrate linkage to shallow-water flow.
4) The nature of hydrate system architecture.

Gas hydrate (Figure 1) is a solid material in which water molecules link together to form a cage, or clathrate, which encloses a single gas molecule. Several of these clathrates then link together to form a basic "unit volume" of crystalline hydrate. Depending on the type of gas molecules that are trapped in these cages, the number of clathrates that are linked to form these unit volumes may be 8 (Structure I), 24 (Structure II) or 6 (Structure H).

Because this ice-like material affects V_P and V_S seismic propagation velocities in deepwater sediment, it appears that accurate measurements of V_P and V_S made across deepwater, near-seafloor strata may allow hydrate concentrations within these strata to be estimated. However, a major problem that confronts geophysicists who attempt to use seismic attributes to infer hydrate concentration in deepwater systems is that no one knows with confidence how these small unit-building blocks of hydrate are distributed within their host sediment.

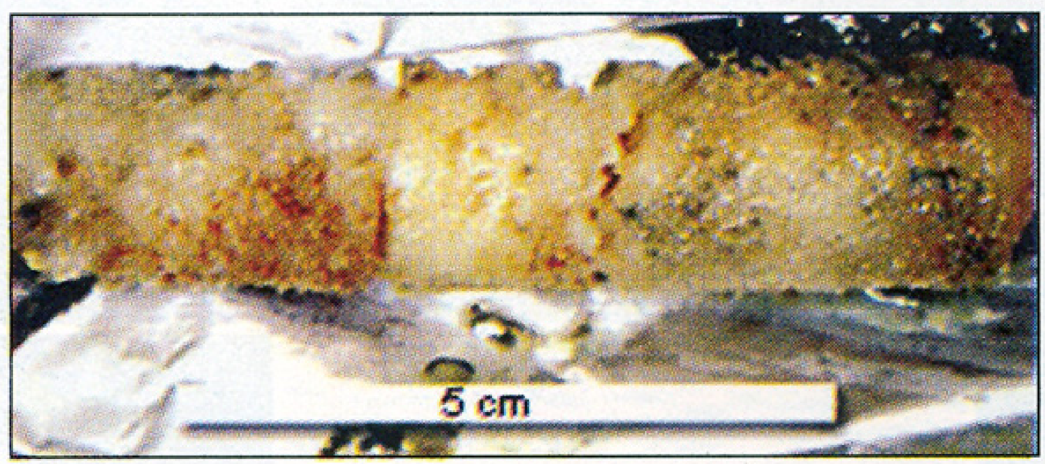

Figure 1. Core recovered from the Johnson Sealink cruise in the Gulf of Mexico in July, 2001. Photo courtesy Ian McDonald, Texas A&M.

Four Hydrate-Sediment Morphologies

Four possible hydrate-sediment morphologies are illustrated in Figure 2:

1) Model A assumes that the unit volumes of linked clathrates make physical contact with the sediment grains, become a part of the matrix, and bear part of the sediment load.
2) Model B assumes that the unit hydrate volumes float freely in the pore spaces and do not bear any sediment load.
3) In Model C, many unit volumes link together to form thin layers of pure hydrate, and the hydrate system is a series of these pure-hydrate layers alternating with layers of hydrate-free sediment.
4) Model D is similar to "C," except the layers of pure hydrate are replaced with layers of uniformly dispersed, load-bearing hydrate, the concept described by "A."

In some areas, hydrate no doubt exists in vertical fractures and dikes, but for brevity, vertically oriented hydrate distributions are not included in this suite of models.

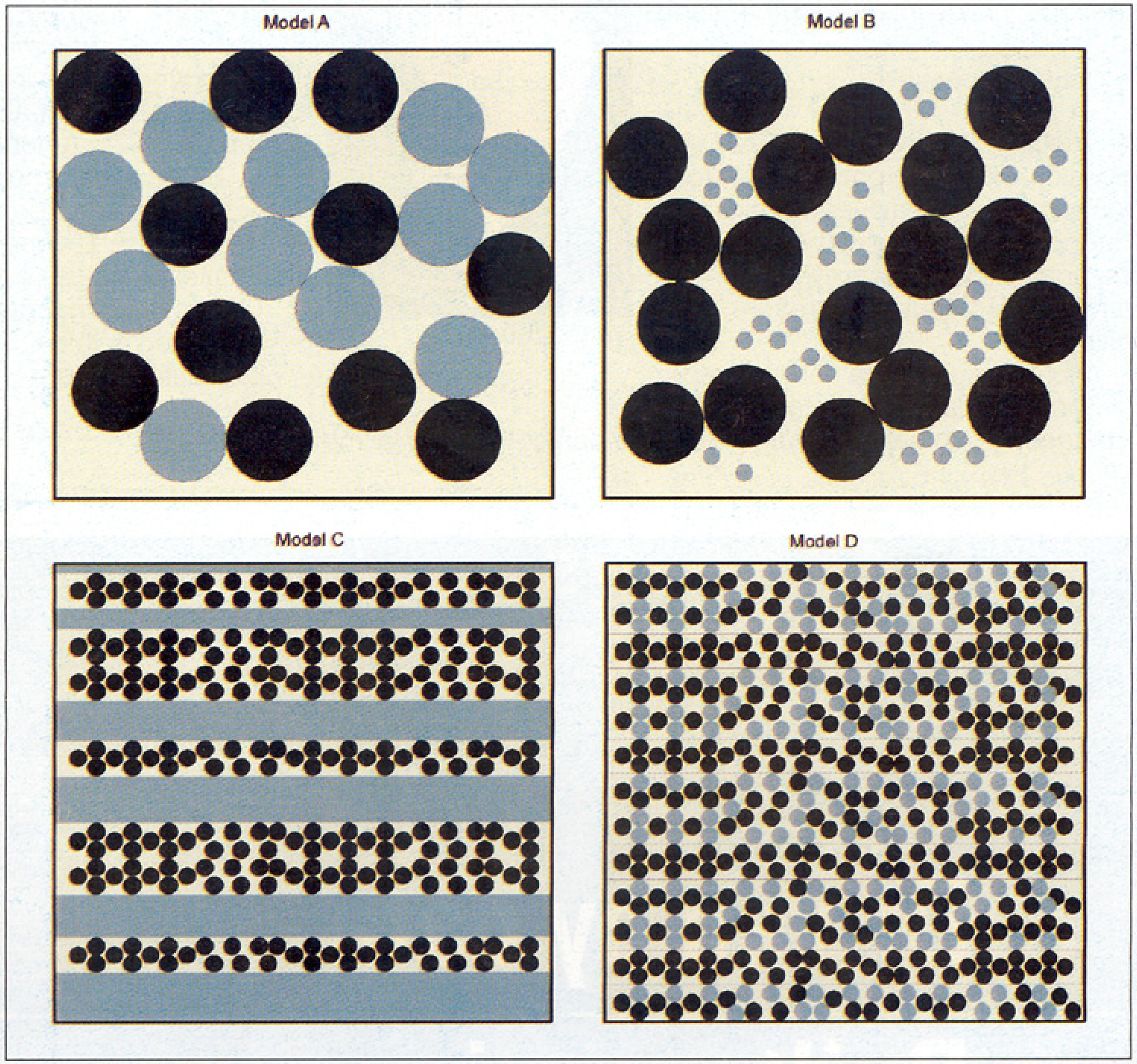

Figure 2. Four possible models of gas hydrate systems: (A) load-bearing hydrate; (B) pore-filling hydrate; (C) thin layers of pure hydrate intercalated with layers of hydrate-free sediment; (D) thin layers of load-bearing hydrate intercalated with thin layers of hydrate-free sediment. Hydrate is represented in blue, with sediment in black.

Problems in Determining Concentration

The dilemma confronting hydrate investigators is that for any given hydrate concentration, seismic propagation velocity changes significantly for each of these possible hydrate distributions (Model A, B, C, and D). For example, P-wave velocity V_P for each of these four hydrate models is illustrated in Figure 3 as a function of hydrate concentration, and S-wave velocity V_S behavior is shown in Figure 4.

For a fixed concentration of hydrate (say a volumetric fraction of 30 percent), V_P can range from 3300 m/s (Model D, fast mode) to 2000 m/s (Model C, slow mode), and V_S can vary from 1600 m/s (Model D, fast mode) to 200 m/s (Model B). As a result, seismic-based and well log-measured values of V_P and V_S cannot be used to predict deepwater hydrate concentration unless you know how the hydrate is distributed inside its host sediment.

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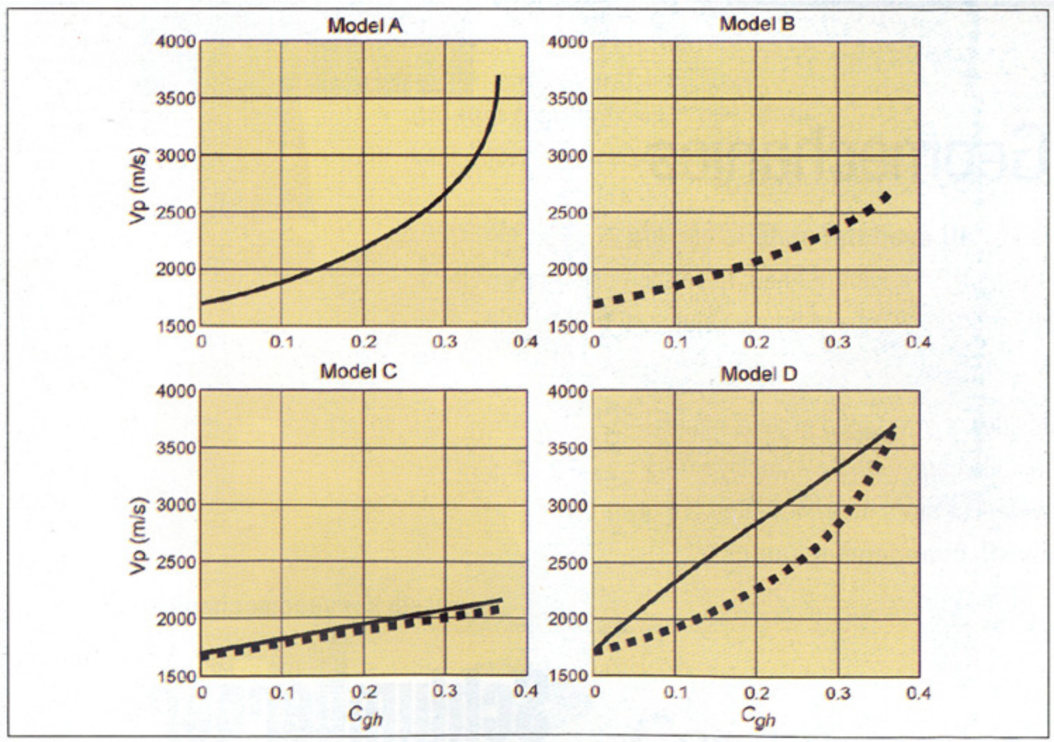

Figure 3. P-wave velocity V_P shown as a function of the volumetric fraction of hydrate (Cgh) in deepwater sediment for each of the four hydrate-sediment models illustrated in Figure 2. Layer Models C and D allow both a slow mode (dashed curve) and a fast mode (solid curve) to propagate. Sediment porosity is assumed to be 0.37, and the effective pressure is set at 0.01MPa

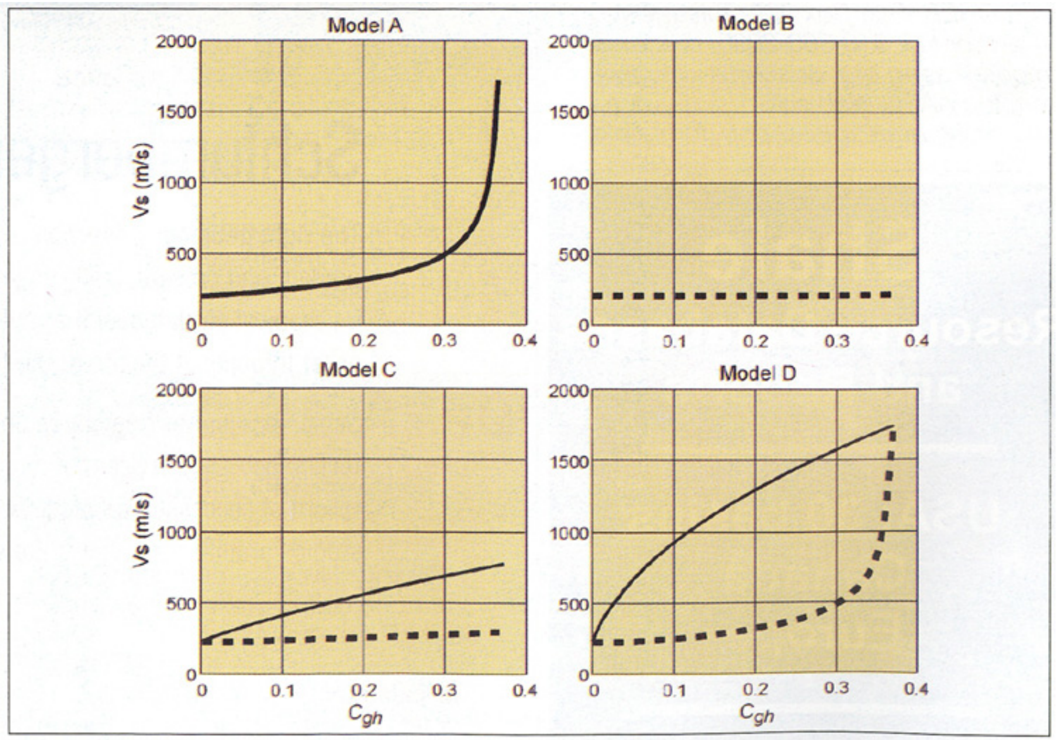

Figure4. S-wave velocity V_S shown as a function of the volumetric fraction of hydrate (Cgh) in deepwater sediment for each of the four hydrate-sediment models illustrated in Figure 2. Layer Models C and D allow both a slow mode (dashed curve) and a fast mode (solid curve) to propagate. Sediment porosity is defined to be 0.37, and effective pressure is assumed to be 0.01 MPa.

Laboratory Analyses of Cores

This lack of understanding about hydrate-sediment morphologies in deepwater strata exists because there is such a paucity of laboratory analyses of cores that traverse deepwater hydrate systems. For seismic and well log analyses of deepwater hydrates to accelerate at a faster pace, deepwater cores:

1) Must be obtained.
2) Must be maintained in their in situ temperature and pressure environment.
3) Must be subjected to laboratory studies while maintaining these in situ conditions.

These laboratory tests must be designed so that the spatial distribution of hydrate throughout each test sample is accurately defined for specific hydrate systems. Only then can researchers decide whether Model A, B, C, and/or D, or some other hydrate morphology model, describes the rock physics concepts that have to be used to relate V_P, V_S and other seismic attributes to hydrate concentration in each type of hydrate environment that needs to be evaluated in deepwater basins.