Gas hydrate—a source of shallow water flow?

BOB A. HARDAGE and RANDY REMINGTON, Bureau of Economic Geology, University of Texas at Austin, USA
HARRY H. ROBERTS, Louisiana State University, Baton Rouge, USA

Shallow water flow is a serious drilling hazard encountered across several areas of the Gulf of Mexico (GoM). Numerous incidents have occurred in which intense shallow water flows have disrupted drilling, added millions of dollars to the cost of a well, or caused a well to be abandoned. In one survey of 74 offshore wells, Alberty and colleagues found only 34% of the wells did not encounter problems related to shallow water flow. In separate writings, Holm and Alberty stated that steps taken to prevent or remediate shallow water flow add at least $2 million to the cost of a well.

One interesting aspect of shallow water flow is that a high production rate of water tends to start long after the drill bit has passed the interval where flow originates, implying that a time-delay factor is involved in the genesis of the water production. In one instance, shallow water flow did not initiate beneath a multiwell seafloor template until several strings of 36-in and 30-in casing had been set to depths of several hundred feet below mud line in a batch-drilling approach. Resulting seafloor erosion then caused major damage to the template and its wells. Furlow reported that 10 of 21 well slots were lost in this incident because of severe casing buckling. In short, shallow water flow is a major factor in drilling safety, marine environmental impact, and drilling costs across the GoM, with a time-delay factor usually involved that as one drilling supervisor said “never allows you to be sure the problem is solved.”

Defining “shallow.” The term shallow used to describe these destructive water flows is somewhat misleading but seems to be fixed terminology. The phenomenon originates in strata that are in water depths of 500 m or more in the GoM, but the water-flow interval is relatively close to the seafloor. Thus the adjective shallow in shallow water flow describes the depth where the water flow occurs below the seafloor, not the depth of water at the drill site (Figure 1). A common definition of shallow water flow found in engineering papers is “water flowing on the outside of structural casing to the ocean floor,” which is the flow path shown in this figure.

The freshwater conundrum. Since becoming involved in gas-hydrate research, we have had the opportunity to discuss shallow water flow with people who have had to deal with the problem. During these conversations, we have frequently asked the question, “What is the salinity of the water produced by shallow water flow; is it freshwater?” A common answer has been “It’s freshwater.” The only other reply has been “I don’t know.” We should exercise caution and not conclude that all shallow water flow involves freshwater, but judging from this modest survey, freshwater is produced in numerous shallow water flows.

The observation that shallow water flow can produce freshwater leads to a puzzling question: “How does freshwater come to be near the seafloor in deepwater areas of the Gulf of Mexico?” Sediment deposited in an offshore basin would ordinarily have connate water with a salt content equal to or greater than the salinity of seawater. To explain this puzzle, some investigators have proposed that rapid and massive fluvial deposition can entrap and transport freshwater into some offshore environments, which may be true in some unique situations. A second group

Gas hydrate and freshwater. The smallest repeating unit volumes of hydrate structures I, II, and H are shown in Figure 1 of another Special Section paper, “Gas hydrate in the Gulf of Mexico: What and where is the seismic target?” The unit volume of structure I has eight cavities (eight possible gas molecules) and 46 water molecules; structure II’s unit volume has 24 cavities (24 possible gas molecules) and 136 water molecules; and the unit volume of structure H has six cavities (six possible gas molecules) and 34 water molecules. Comparing the number of cavities and the number of H2O molecules defined in the diagrams, one can see that, on average, there are 57 molecules of H2O per cavity in each hydrate structure. In other words, there are more than five molecules of H2O for each possible molecule of gas. Gas hydrate thus has a great deal of freshwater trapped in its crystalline structure. If this hydrate crystalline structure dissociates, freed H2O molecules can become a significant source of freshwater.
The dissociation process. For hydrate to dissociate, its crystalline structure must be exposed to an altered environment having increased temperature, or reduced confining pressure, or both. One explanation for a dissociation process that could initiate shallow water flow in deepwater Gulf of Mexico wells is an increase in temperature within a hydrate interval penetrated by a well bore. During drilling, warm circulating drill mud can, over time, raise formation temperature within a hydrate zone and initiate dissociation. During production, warm fluids produced from deep reservoirs can also raise the temperature of a hydrate-bearing interval as fluids flow to the surface. In some instances, the time required for either process to raise the formation temperature to the point of hydrate dissociation may be rather long, explaining why shallow water flow often does not initiate until the drill bit has progressed far beyond the shallow subsea floor depth where flow originates, or until additional wells have been drilled and several warm, closely spaced well bores have sufficient time to affect shallow formation temperatures.

Conclusion. Shallow water flow is not confined to the GoM where we do our hydrate research. Shallow water flow has been reported in wells drilled offshore West Africa, west of Shetland, Borneo, southeast Asia waters, the Norwegian Sea, the North Sea, and the southern Caspian Sea. In the Gulf of Mexico, the Deep Star Drilling and Completions Committee has identified shallow water flow as “one of the most imposing problems encountered in deepwater drilling” (see Snyder). This same conclusion probably applies to the other deepwater areas just named.

Some descriptions of the destructive force of shallow water flow are spectacular. One ROV video showed a plume of sand and debris jetting 60 ft above the seafloor, a true “over the derrick” blowout (see Furlow). Alberty and colleagues described a seafloor fissure extending 300 ft from the well head with a vertical displacement of 7 ft between opposing walls of the trench. Furlow reported an incident where seafloor erosion produced gulllylike features large enough for a ROV to enter and traverse the length of the chasm and another where a cementing job had to fill an open hole that had enlarged to an average diameter of 50 in.

Almost all papers in engineering journals and conferences ascribe the source of shallow water flow to overpressured sands. This conclusion is based on hard engineering data amassed over many problem wells. However, these papers do not mention the salinity of the produced water, and therein lies the issue. Is the water produced by shallow water flow fresh (as numerous colleagues have told us), or does its salt content equal or exceed the salinity of seawater? If the water is salty, connate water in shallow over pressured sand is a logical model for the genesis of the shallow water flow. If the water is fresh, then hydrate somehow has to be involved.

The concept discussed here, that there is a genetic link between deepwater gas hydrate and some shallow water flow, is a hypothesis, not a proven fact. The connection seems logical and adds importance and urgency to gas-hydrate research. The possibility introduces a new work area for geoscientists and causes deepwater geophysical imaging and facies-detection technologies to become invaluable to engineers who have to avoid shallow-water-flow complications as they plan and execute drilling and production programs.

Much of the information related to shallow water flow is anecdotal. Some of this unpublished information needs to be made available to gas-hydrate researchers so that the idea proposed here can be investigated on a case-by-case basis. If a shallow water flow incident involves confidential data that cannot be shared with one of the numerous gas-hydrate research efforts now under way in several countries, the operator of the shallow water flow well needs to do an internal postmortem analysis to determine whether there is a plausible link between the shallow water flow and dissociated gas hydrate. A common thread in any of these investigations would be to determine the salinity of the produced water so that a link between shallow water flow and deepwater hydrate can be discounted or supported.

A point worthy of emphasis is that any effort to dissociate methane and other gases from gas hydrate for commercial purposes will involve large volumes of produced water. Managing this produced water will be an important factor in deciding the economic feasibility of methane hydrate production. In some instances, the production of this much water may turn out to be positive because the water is pristine freshwater. In some areas of the world, a prolific supply of freshwater can be valuable.


Corresponding author: bob.hardage@beg.utexas.edu