Gas hydrates in coarse-grained reservoirs interpreted from velocity pull up: Mississippi Fan, Gulf of Mexico

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Madof (2018) invokes the presence of high-velocity natural gas hydrates to describes a velocity pull up (VPU) associated with a near-seafloor turbidite channel complex on the Mississippi Fan. If the channel complex is indeed a high-saturation hydrate reservoir, it is by far the largest hydrate reservoir in the world. Consequently, seismic VPUs may become a powerful tool in remote detection of hydrate systems. The VPU below the turbidite complex is larger than surrounding sediments. Madof (2018) suggests that ‘dense water-filled sands encased in uncompact ed (porous) muds’ may be a possible cause of the VPU but then dismisses this possibility suggesting that the observed VPU is larger than any sediment-related velocity variation. We argue, however, that the variation in sediment velocity for water-saturated sands within the channel and water-saturated marine muds outside the channel complex probably explains part, and may potentially explain all of the VPU.

Clay-rich marine muds settle at very high porosities of 60–90% at the seafloor, but undergo significant compaction (reducing 20–30% porosity units) within the first several hundred meters of sediment (Komínz et al., 2011). In contrast, sand sediments deposit at the seafloor at much lower porosities (28%–42%) and undergo very minor compaction and porosity reduction in the same interval (Beard and Weyl, 1973; Komínz et al., 2011). This difference in depositional porosity and compaction rates causes a significant difference in the physical properties in the near seafloor environment, where sands have significantly higher density and higher velocity in the first several hundred meters (Fig. 1). On average, in fact, sand sediments have a higher velocity than marine muds for the first kilometer from the seafloor, though the velocity contrast reduces with depth in the sediment column (Cook and Sawyer, 2015). These travel-time variations between coarser-grained sediment in the turbidite complex and surrounding marine muds can accumulate and could result in a VPU.

In Figure 1, we show the mean velocity trends for marine mud and sand. The marine mud trend was compiled from over 16000 logging-while drilling measurements of velocity with depth (Cook and Sawyer, 2015) and the marine sand data was collected under in situ pressures in a lab by Zimmer (2004). In this case, the marine mud trend from Cook and Sawyer (2015) is the same as the marine mud trend measured in hole at Deep Sea Drilling Project (DSDP) Site 621 (Bouma et al., 1986), which is above the turbidite channel complex P3 described in Madof (2018, Fig. 2C). Figure 1 also shows the marine mud velocity trend from DSDP Site 620, which was measured outside of the turbidite complex, and has a lower measured velocity because the muds are overpressured (Bouma et al., 1986).

We use the velocity trends in sand and mud to determine two-way-time and the potential VPU (Fig. 1). We find that by 600 mbsf, both mud trends have accumulated enough travel time difference to be close to, or exceed the highest VPU observed by Madof (2018). Of course, the turbidite complex does not extend from seafloor to 600 mbsf, and instead occurs over intervals ranging from ~50–300 m, based on thickness TWT from Madof (2018). This suggests, however, that VPUs up to ~50 ms may be easily explained by sediment velocity contrast. Larger VPU would require that sediments outside the channel are overpressured, like Site 620, or that the water-saturated sands and gravels within the turbidite complex have above average velocity.

Additionally, Madof describes the VPU below three thalwegs, P1-P3, where P3 is the shallowest channel and P1 is the deepest. P3 also has the largest and most significant VPUs, where P2 and P3 have lower or no VPUs below the thalweg. (Madof, 2018, Fig. 2D). This is consistent with the velocity difference between sand and mud sediments reducing over depth (Cook and Sawyer, 2015).

In summary, we argue that natural velocity differences in water-saturated coarse-grained and marine mud sediments near the seafloor may cause all or part of the observed VPU along the turbidite complexes on the Mississippi Fan. We acknowledge, however, that it is impossible to know if hydrate occurrence or if normal to extreme natural sediment velocity variation is causing part or all of the VPU without drilling, logging and coring the turbidite complex. Given that the VPU below the Mississippi Fan turbidite complex could indicate the largest hydrate reservoir in the world, we think testing this anomaly through drilling is the most reasonable strategy.

REFERENCES CITED