

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

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I thank Cook and Portnov (2018) for their Comment to Madof (2018). In that paper, I introduced a new velocity pull-up (VPU) method designed to identify and quantify gas hydrates in coarse-grained reservoirs on seismic-reflection data, and applied the technique to the central Gulf of Mexico. The analysis led to the recognition of marked traveltime deficits located below the youngest channelized systems of the Quaternary Mississippi Fan (i.e., the P1–P3 reservoirs). Using a new equation that relates VPU to the P-wave velocity of gas hydrate-bearing sediments, I interpreted high-amplitude reflections to be evidence for high-saturation (>60%) gas hydrates. While I suggested that “dense water-filled sands encased in uncompacted (porous) muds are a possible cause of traveltime deficits” this mechanism was regarded as unlikely, primarily because VPU magnitudes were larger than those expected from variations in sediment velocity alone. Although Cook and Portnov test my hypothesis and conclude that “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”, I stand by my initial claim that asserts that observed VPUs in the central Gulf of Mexico are more likely to be caused by gas hydrate-bearing sediments.

Here, I outline three main issues that call into question the methodology and conclusions raised by Cook and Portnov: topics relate to sediment velocity, predicted VPUs, and overpressure-driven diffusion.

(1) Sediment Velocity

Cook and Portnov use velocity contrasts in marine muds and sands to create a global solution for lithologically driven VPU with depth. Although they use more than 16,000 logging-while-drilling values for marine muds (from Cook and Sawyer, 2015), they draw on sand-velocity measurements from a laboratory-based study (from Zimmer, 2004). While the former is a robust and ground-truthed data set, the latter is experimental and biased toward artificially increased sand-velocity values. This is apparent in the mean sand trend of Cook and Portnov, which predicts an average velocity of ~1910 m/s in the first 200 m below the sea floor. Yet, when compared to sand and gravel measurements directly above the P3 reservoir, this value is >10% higher than the measured ~1680 m/s (see Deep Sea Drilling Project [DSDP] Leg 96 Sites 621–622). More importantly, if the analysis of Cook and Portnov is a global solution for lithologically driven traveltime deficits, then they have failed to explain the paucity of VPUs observed under the world’s channelized shallow sandy turbidites, particularly those related to submarine fans. Because their solution is neither confirmed by local observations nor global seismic data, the general applicability of the Cook and Portnov method remains questionable.

(2) Predicted VPUs

Comparing the observed VPUs from Madof (2018) to those calculated by Cook and Portnov provides a basis for testing hypotheses related to lithologic contrasts versus those associated with gas hydrate presence. To address this issue, two transects are used in the Mississippi Fan for the P3 reservoir: one in a proximal location, and the other in a distal setting. As seen in figure 2B of Madof (2018), inboard high-velocity slope valley deposits transition outboard to high-velocity channel-levee complexes;

the former is associated with an observed VPU of ~85 ms, whereas the latter displays ~65 ms of VPU (see figure 2D of Madof, 2018). This offshore decrease in local VPU maxima is opposite to predictions made by Cook and Portnov: namely, ~25 ms of VPU in the inboard setting and ~85 ms VPU in the outboard location (calculated from their figure 1). Because the predicted VPU trend of Cook and Portnov is unable to account for the observations from the P3 reservoir, the fundamental assumptions underlying their technique remain in contention.

(3) Overpressure-Driven Diffusion

Along with lithologic contrasts, Cook and Portnov invoke overpressured (low-velocity) muds lateral to the P3 reservoir, rather than the presence of (high-velocity) gas hydrate-bearing sediments, to enhance velocity contrasts. However, the very existence of overpressure has been proposed as a mechanism responsible for driving short-range methane migration into coarse-grained gas hydrate reservoirs in deep-marine settings (see Nole et al., 2016, 2017). It was this short-range diffusion (and/or subseismic faults) that was identified as a plausible gas-migration mechanism in the P3 reservoir (see Madof, 2018).

In summary, Cook and Portnov invoke lithologic contrasts between marine muds and sands to explain marked VPUs under the coarse-grained P1–P3 reservoirs in the central Gulf of Mexico. However, their analysis does not explain the observed sand velocity in sediments overlying the P3 reservoir, the lack of VPUs observed under the world’s channelized shallow sandy turbidites, and the mismatch between predicted and observed VPUs. Although Cook and Portnov identify low-velocity overpressured muds directly surrounding high-velocity sands of the P3 reservoir, they do not recognize overpressure as a driving mechanism responsible for the short-range diffusion of methane into gas hydrate reservoirs. While I continue to defend the work of Madof (2018), I thank Cook and Portnov for their analysis, and agree that direct sampling of the P3 reservoir is the only way to explicitly confirm the presence (or absence) of gas hydrate-bearing sediments in the Quaternary Mississippi Fan.

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