The message is the medium

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It amazes me that the micron-scale topology of rocks has a profound influence on acoustic properties at the seismic scale. Most rock physics studies, however, focus on the 'physics' and are hindered by inaccurate depictions of the 'rock'.

New models where the 'rock' gains the same elegance as the 'physics' of existing models would be vastly more satisfying scientifically, while having the intriguing potential to serve as a more accurate basis for subsurface predictions. To build a better medium for the physics, we need to incorporate knowledge from the field of petrology.

Existing rock physics models do not rigorously account for *compaction* — the reduction in bulk rock volume — despite the critical role it plays in reducing porosity in virtually all sandstone reservoirs (Lundegard 1991). In clay-poor sandstones, depositional intergranular volumes (IGVs), or 'critical porosities' in rock physics speak, generally range from 35 to 45 volume percent. Deeply buried sandstone reservoirs, on the other hand, typically have IGVs on the order of 25 percent in rocks rich in rigid grains (Paxton et al. 2002) or down to 10 percent or less in rocks with abundant lithic fragments (Pittman and Larese 1991).

The primary driving forces for compaction in sandstones are elastic deformation, plastic deformation, grain fracturing, and dissolution at grain contacts. Simulations made with our 3D grain-scale petrology model, which considers each of these compaction processes while also using realistic grain shapes derived from micro CT scans of natural sands, indicate that plastic deformation and contact dissolution generally have the largest impact on contact properties. Elastic deformation, in contrast, is much less important despite having received the most attention in existing rock physics models. Our petrology models show that although the average 'coordination number' — the number of contacts a grain has — increases somewhat during compaction, the areas of individual contacts increase greatly. Contact areas and stresses also are influenced by grain shapes and physical properties as well as the grain size distribution and vary considerably from one grain to the next.

The other critical process that should be accounted for when depicting the 'rock' is *cementation*. Cements, even in small volumes, can greatly increase acoustic velocities.

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Quartz cement has rightly received the most attention in existing rock physics models. However, there are problems with the way it has been depicted in previous work leading to three misconceptions:

1. **It forms on all grains.** From petrology we know that quartz cement in sandstones generally forms as overgrowths where the cement represents continued growth on a pre-existing quartz crystal substrate. Non-quartz grains — a significant fraction of most reservoirs — therefore do not develop quartz overgrowths.
2. **It grows uniformly on grains or more rapidly at grain contacts or adjacent to large pore bodies.** There is considerable anisotropy in overgrowth thickness that reflects crystallographic orientations and nucleation surface types. Grain contacts and pore bodies affect cement distribution only by acting as passive barriers or reservoirs for crystal growth.
3. **It grows in uncompacted grain packs (IGV > 35%).** The thermal exposure required for quartz cement to reach measurable volumes usually is achieved only after reaching burial depths sufficient to greatly reduce IGV from compaction.

The good news is that petrology models have been developed that accurately depict quartz cement at the grain scale (e.g., Lander et al. 2008; Wendler et al. 2015).

References

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