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# Controls on Acoustic Anisotropy Observed in Unconsolidated Sands using Laboratory Measurements and Digital Rock Technology

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## Abstract

We combine quantitative analysis of 2D images from thin sections, lab measurements of acoustic properties, and 3D micro CT analysis to characterize acoustic anisotropy in unconsolidated sands from fold-thrust belts, from sub-salt settings, and for sands in normal compaction settings. In the latter, vertical effective stress is the principal stress throughout the sand's burial history. In contrast in thrust belts, the principal stress is non-vertical for some portion of the burial history. Similarly, in sub-salt settings horizontal stress gradients arise due to rapid changes in salt thickness.

We measure the polar and azimuthal acoustic properties under isostatic stress conditions. Azimuthal anisotropy in thrust belt sands averaged 15% in both crest and flank structural positions. Polar anisotropies are substantially lower than azimuthal values. In sub-salt settings the degree of azimuthal anisotropy ranged from 5-10, whereas polar anisotropies are less than 1%. In extensional basin settings, measured azimuthal anisotropy ranged from 0-3%, and polar anisotropy is larger than the azimuthal value.

The measured plugs were impregnated with epoxy, and marked with the position of the maximum and minimum azimuthal velocities. Analyses of grain contact length and orientation were performed on three mutually perpendicular thin sections. Pore body aspect ratio and orientation were also analyzed. The level of anisotropy measured in the core plugs was directly tied to textural changes observed in thin section.

Finally, we make the same measurements using 3D micro computed tomography (CT). Using image processing techniques we obtain digital pore-grain representations of the samples, and document the orientation distributions of grain long axes and grain contact surfaces. This information is used to perform finite element modeling (FEM) directly on the 3D rock volume, and to calculate elastic constants. The result is a forward model for directional variation of the acoustic velocities which was directly compared to the lab measurements.

While FEM methods were able to predict the degree of acoustic anisotropy the method always over estimates the strength of the material because cemented contacts were assumed. We estimate contact moduli by bringing the laboratory measurements and model predictions of velocity into agreement. The presence of preferentially oriented grain fractures contribute to the anisotropy, although the dominant