Can we use Conventional Seismics in Unconventional Resource Plays?

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SUMMARY

Unconventional resource plays are currently driven by advances in drilling and completion technology, rather than in exploration technology. In order to increase the efficiency of operations in these fields, it is necessary to actually explore for the best places, the "sweet spots", to drill and frac. This will require unconventional geophysics, to match these unconventional rock formations. In particular, the exploration techniques of acquisition, processing, and interpretation will recognize the fact that these formations are *anisotropic*, both seismically and electromagnetically.
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Key words: unconventional resources, shale, anisotropy, electromagnetics

INTRODUCTION

"Unconventional resource plays" are now understood to offer the potential of substantial increases in the stock of hydrocarbon resources worldwide, available for economically viable future production. These unconventional plays include shale gas, shale oil, tight gas sands, coalbed methane, heavy oil, etc., all previously considered largely non-prospective by conventional techniques of exploration and production. The recent re-classification of these resources (as economically viable) has been driven by advances in drilling and completion technology, rather than in exploration technology. The purpose of this talk is to discuss the role that advanced geophysical exploration might serve, to improve the economics of these plays.

UNCONVENTIONAL ISSUES

The major *new* interest is in shale resources, so I concentrate on those here, although most of the discussion is more broadly applicable. In the typical shale resource province, the variability in production (among wells drilled with apparently similar prospects) is high; perhaps 80% of the production comes from 20% of the wells (or frac stages). We find lots of gas, but not a lot of profit, since the expenses are high (because of the inefficiency). Hence, it is clear that more selective drilling (or fracking) would improve the economics substantially; this makes an *a priori* case for exploring for these optimal "sweet-spots", instead of drilling on a grid. The question is: *how* should we do this, and is *conventional* geophysics the answer?

Conventional seismic exploration has become very good at imaging subsurface structures, even when they are very complicated. But, this *imaging* issue is rarely important in shale plays; the structures are generally simple. Instead, the central issues usually involve subsurface *physical characterization*, in terms of fluid content, fluid pressure, fracture intensity and orientation, brittleness, etc. Solving these problems requires that the seismic technology be augmented by ideas from seismic *rock physics*.

The problem is that, with few exceptions, our ideas of seismic rock physics contain, at their core, the basic assumption of *isotropy*, whereas almost all of these unconventional plays involve rocks that are *anisotropic*. Shales are almost always anisotropic, with a vertical symmetry axis where they are unfractured. Where they are fractured, the symmetry is lower; hence the seismic data and its interpretation are more complicated. The anisotropy is usually weak, but can have strong effects on the data, in some contexts. For an introduction to the issues, see Thomsen (2002, 2013).

This mismatch between theory and reality is the root cause for the low reported *skill* in exploring for the sweet-spots of optimal production. What is required is substantial advancement in the theory and practice of *anisotropic* seismic rock physics.

EXAMPLES

As an example, we all know the theory of the seismic effect of fluid replacement, due to Biot and Gassmann. However, this is for isotropic rocks. What is the corresponding theory for anisotropic rocks? There are some unexpected subtleties, which require discussion (Thomsen, 2013).

As another example, there is a well-known empirical correlation between the (elastic) Young's modulus and the (anelastic) brittleness (or "frack-ability"). Of course, we do not measure Young's modulus in seismic (or sonic) experiments, but we can calculate it from the P- and S-velocities, and the density. However, this is for isotropic rocks. What is the corresponding argument for anisotropic rocks? It turns out that the vertical Young's modulus cannot be calculated from the vertical P- and S- velocities, and the density. There are some unexpected subtleties, which require discussion (Thomsen, 2013).

As another example: *electromagnetic* methods of exploration are now well-proven, especially in deepwater marine contexts. Could this technology be applied to shales, on land? If so, the data must be acquired, processed, and interpreted assuming that the rocks are anisotropic.

CONCLUSIONS

The conclusion is that, in order to explore for the best places to drill and frac in unconventional resource plays, correspondingly unconventional exploration technology will be required. This new technology will have, at its core, the assumption that the rocks are anisotropic, with or without the presence of natural or induced fractures. It is fair to say that we do not yet know how to do this, but we may predict that, in just a few years, our understanding will be much more advanced. We can expect a corresponding improvement in the economics of production in these plays.

REFERENCES

Thomsen, L., 2002. Understanding Seismic Anisotropy in Exploration and Exploitation, the SEG/EAGE Distinguished Instructor Short Course #5 Lecture Notes, 240 pp, Soc. Expl. Geoph., Tulsa. 2nd Edition 2013.

Thomsen, L., 2013. Weak Elastic Compliance Anisotropy, accepted for publication, **Geoph.**