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A Microseismic Primer

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Summary

Microseismic can enrich our understanding of reservoirs, the efficacy of applied completion designs, and ultimately well performance, informing future operations and strategy. Despite its competitive advantage, it remains poorly understood. If you've ever wondered about microseismic or if you need a refresher, this talk is for you.

Microseismic basics

Microseismic events are simply seismic waves that are generated when rock breaks or slides. Waves from this rock movement are detected on sensors (typically geophones) that might be placed on or near surface or within a wellbore. Because we vaguely know how fast these waves travel through rock, we can use this information to estimate where the rock broke from the times of the wave arrivals at the geophones.

As useful as microseismic is on its own, it doesn't tell us everything. Although we can make educated guesses, it doesn't tell you if the microseismic event was related to fluid or stress or whether that crack saw any proppant. Often the accuracy is insufficient to resolve information beyond the stage level. It can, however, show you overlap between stages and wells, highlight faults and pervasive rock fabrics, and track progressive fracture growth. With the right array geometry, we can even figure out how the rock broke, which can be useful to tie back to the local geology and reservoir mechanics. Processing varies vendor to vendor and so the design and processing flow should be selected with care.

Though microseismic is useful on its own, results are maximized when it can be integrated and validated with seismic and wellbore performance attributes like completions information and early production.

Array selection

Surface and downhole are the two categories of array that can be selected, each with their advantages and drawbacks. Surface data works well in good signal-to-noise areas and the distribution of sensors lends itself to more detailed solution with every stage being monitored relatively equally. In some environments it can be the more expensive option because it requires access to stations over a large lateral area. XY resolution is typically excellent with higher errors in Z (but not terrible, if well-calibrated).

Figure 1 shows site evaluation work done using seismic during the design of a surface array. PSTM gathers from a quaternary channel and a site representing the more regional geology demonstrate the differences in expected signal-to-noise under a single survey. Sensors were preferentially placed in better signal areas, avoiding channels, where possible.

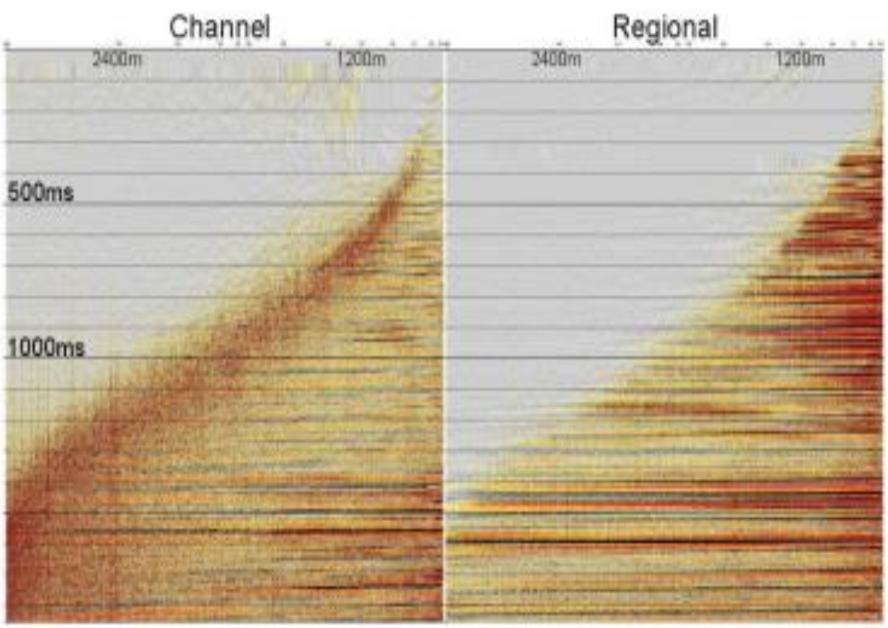

Figure 1: From Taylor & Snelling, 2012: Seismic data was used to assess expected subsurface signal quality. Sensors were preferentially placed in good signal areas and quaternary channels were avoided.

Downhole data can be a cost-effective option for a simple program to get sensors closer to the source of the fracturing. Because monitoring often occurs from a single wellbore, the results vary with distance from the sensors and interpretations are limited in this respect. XYZ resolution depends strongly on the orientation of the array and the distance from the array. Arrays should be selected based on well geometry, geographic location, expected formation response (signal-to-noise), and project goals (height growth, evaluation of completion tests, etc.) rather than on a cost-alone basis.

Interpreting data

The best solution is an integrated solution, leveraging a team's knowledge of the subsurface and then layering on completions approaches and variations. By far the most comprehensive way to digest variation in the microseismic is to compare results to 3D seismic data. In this way any changes in reservoir or structure can be identified before looking at completions. The rock is, after all, the material that contains the fracture.

The example below from Norton et al (2010) shows seismic-derived minimum Poisson's ratio and ant-tracking attributes and faulting that bound microseismicity activity and causes apparent fracture asymmetry, even away from the monitoring array. Warm colours indicate low calculated Poisson's ratio. In this case, rock attributes derived from amplitude variation with offset (AVO) inversion, combined with other success indicators like production, can guide future well placement.

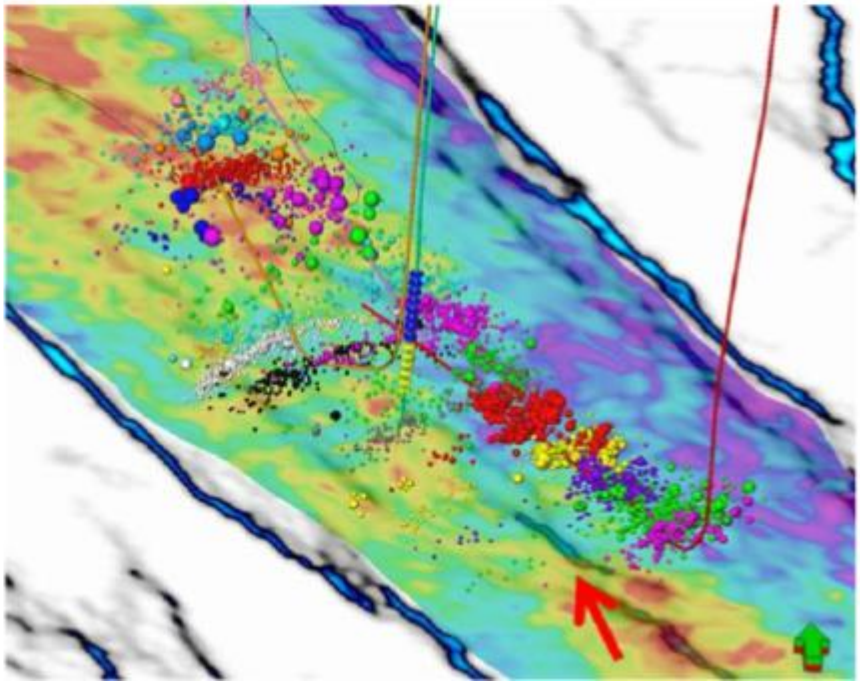

Figure 2: Example by Norton et al (2010) where microseismic attributes and event distribution vary based on geomechanical parameters generated from 3D seismic volumes.

When things don't go as planned

When results deviate from expectations the likely cause is either unexpected geology – such as dominant rock fabric, strong contrasts in rock properties, or abrupt changes in stress conditions; or engineering problems (failed completion, poor cement, failed packer, screenout etc.).

Often, characteristic differences highlighted by microseismic can be explained post-acquisition by integrating seismic interpretations. The out of zone growth mapped by Hart (2015) in Figure 3 can be explained by complex faulting in the section above. Another example by Eyre (2019), involving induced seismicity, is shown in Figure 4 where geologic structure (fault strands and a reef edge interpreted on seismic) guides and bounds events. Often microseismic can highlight subtle features that may impact hydraulic fracture behavior and overall program success.

Engineering problems are another cause of microseismic anomalies. These can manifest as anomalously high event counts for a given stage, an odd distribution of events along a wellbore, or a notable lack of data where data is expected. Integration of completions data and reports should alert you to any problems that were encountered during the program.

Processing artifacts are also possible. Any oddities in the data that cannot be validated can be discussed with the processing company and remedied, if appropriate.

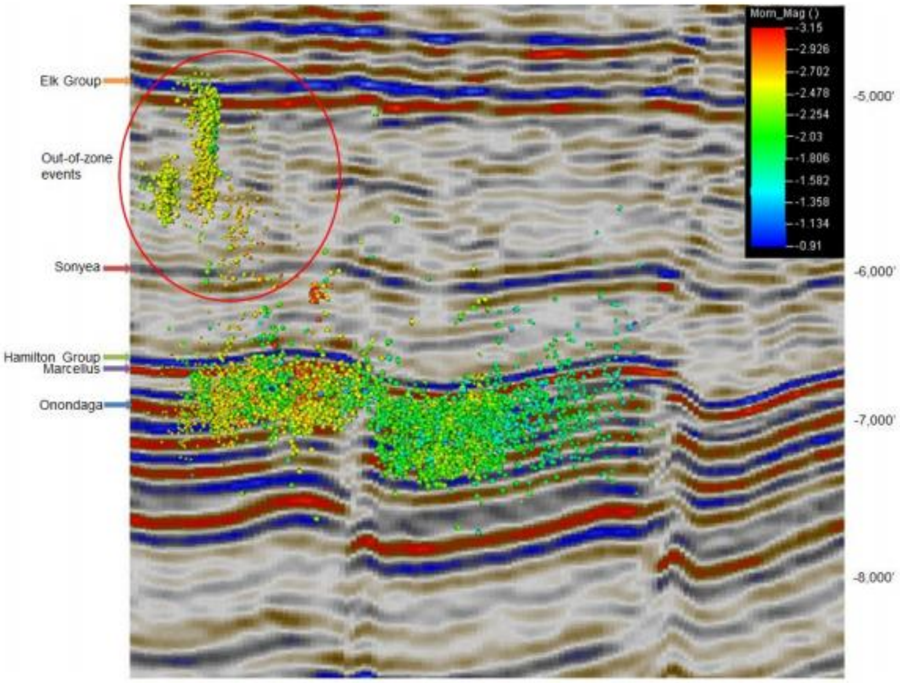

Figure 3: Out of zone growth from Hart (2015) interpreted using seismic attributes.

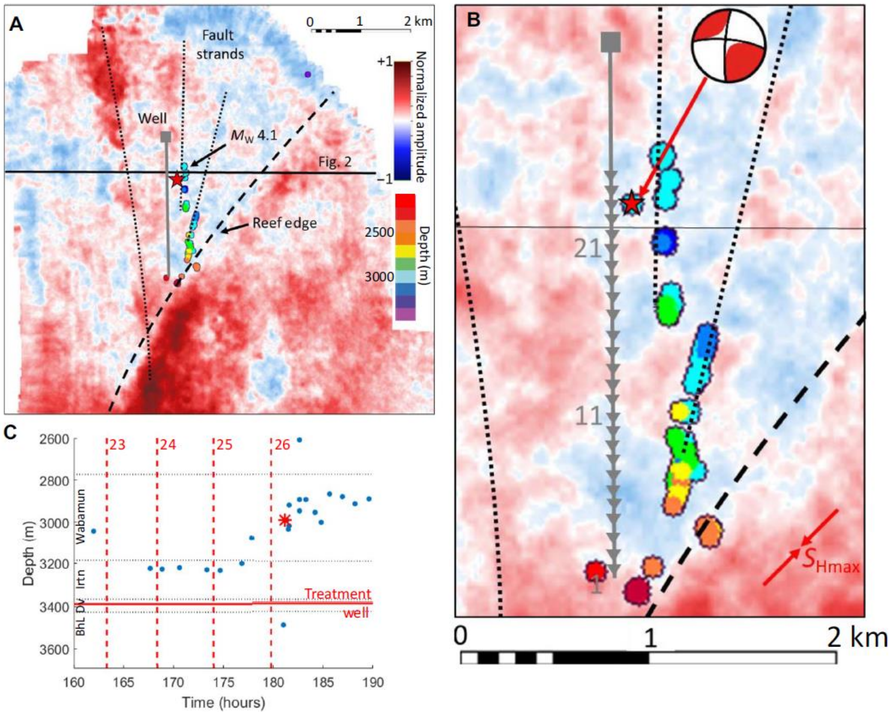

Figure 4: Induced seismicity in the Duvernay occurred in proximity to a reef edge along imaged fault strands (Eyre, 2019).

How to explain results to management

Learnings from microseismic should be related in terms of cost savings, program efficiencies, or future value to decision makers. Examples of applied findings include

- changes in lateral and vertical well spacing to reduce parent-child interactions;
- changes in stage spacing to reduce repeat stimulations and cost when stages are too close or increase stimulated fracture area when stages are too far apart;
- deciding on future completions parameters like fluid type or number of clusters when different approaches are tested;
- recommending geohazard avoidance or focus on more geomechanically favourable reservoir using seismic to extrapolate results within reason.

Conclusion

A successful project should answer key questions about completions and reservoir performance. Microseismic should be treated with care from early stages in project planning to ensure that the maximum value of information can be extracted from the results. By integrating other data types like seismic data, microseismic results can be validated and context can be added to the interpretation.

Acknowledgements

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References

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