Borehole seismic, challenges and solutions

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Summary

For decades, borehole seismic had been commonly used in the context of Oil & Gas exploration. Except for a few specific projects, rather research related, it was mainly considered as a calibration tool designed to establish a link between the surface seismic and the geological formations described by the logging and core data.
With the development of reservoir imaging and characterization projects, the trend is now to requalify borehole seismic as a complementary and necessary tool to be fully integrated in the technology tool box used to better understand the reservoir structure and behavior and address various production challenges, in both domains of conventional and unconventional resources.
Borehole seismic is now clearly evolving through high end technologies, such as advanced "VSP" techniques and the newly developed micro-seismic monitoring technique.
Both technologies are complementary and require ever higher time and space resolution, larger aperture, broader frequency range and higher sensitivity along with longer exposure to harsh borehole conditions.

Introduction

Today's major challenges for downhole seismic acquisition include complex 3D and time lapse imaging surveys around deeper wells and semi-permanent or permanent reservoir monitoring in production and injection areas.
Current major constraints include dramatic reduction in acquisition time for cost effective operation in increasingly complex and harsh environments.

Discussion

While VSP is an "active" seismic method delivering static images, micro-seismic is a "passive" seismic method delivering dynamic images and information.
VSP is mainly a calibration and imaging tool, however micro-seismic could be considered not only as an imaging tool but also as an acoustic tracer of the formations disturbances related to geo-mechanics and fluids flows.
Borehole acquisition systems, should offer real-time telemetry and multi-well capabilities, and be designed to address the needs of both large VSP and monitoring surveys and to allow simultaneous high resolution borehole and surface seismic acquisition.
Such surveys include challenging requirements ranging from cost efficiency, time saving, reliability, large simultaneous channels count, high quality signals and broad frequency range.

Furthermore, borehole acquisition systems should offer the advantage of key features such as continuous acquisition without gap, full synchronization for multi-well configurations, and comprehensive testing capabilities during deployment and throughout long term acquisition.

Examples

Following are some illustrations of large VSP and monitoring surveys

Figure 1: Data quality : vector fidelity (hodograms).

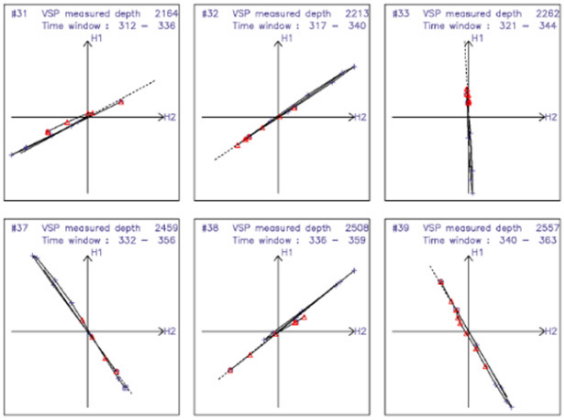


Figure 2: Data quality : enhanced sensitivity

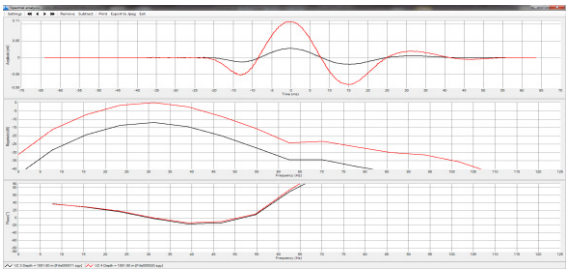


Figure 3: Micro-seismic image (multi-stage hydraulic fracturing monitoring)

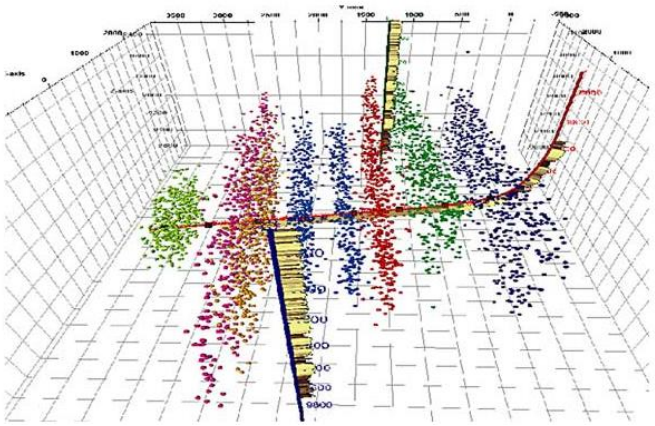
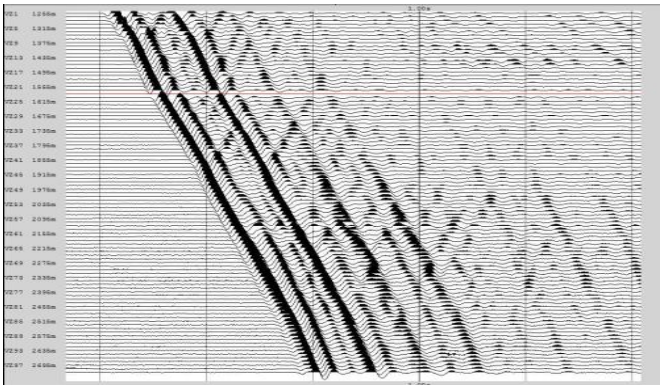


Figure 4: High count channels acquisition

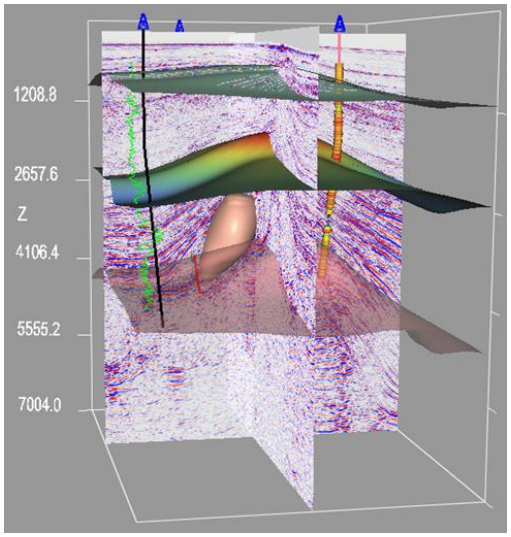


Conclusion

To address the current challenges of complex surveys the borehole seismic technology has seen tremendous developments during the last decade on the hardware side. However further progress remains yet to be achieved on the data processing side to meet the requirements of 3DVSP, time-lapse surveys, and micro-seismic monitoring in order to deliver more efficient and convincing imaging.

The achievement of such progress might, in return, generate new requirements for further acquisition techniques and associated hardware developments.
Optical and MEMS technologies as well as reliable and cost effective permanent arrays would most probably have a growing influence in the future.

Figure 5: Large 3DVSP survey results



Courtesy of VSFusion

Figure 6: Simultaneous borehole and surface high resolution 3D seismic acquisition (Field images from Middle East)

Courtesy of Baker Hughes and CGG