Uni-axial or Tri-axial Seismic Systems?

We are regularly asked by potential clients whether they should invest in a tri-axial system as opposed to a uni-axial system for Downhole Seismic Testing (DST) investigations such as the Seismic Cone Penetration Testing (SCPT). In this technical note we want to address this query by summarizing the advantages of a tri-axial system over a uni-axial system:

1. *Full waveform analysis:*
   Tri-axial systems allow the recorded seismic source waves to be rotated onto the full waveform wave axis, while in case of a uni-axial system the source wave can only be viewed on one axis.

2. *Application of Polarization and Hodogram Analysis:*
   Tri-axial systems allow polarization analysis to be applied on the recorded traces, which increases the signal-to-noise ratio when correlated responses are rotated onto a single full waveform axis. This also simplifies vertical seismic profile displays and the estimation of trend lines for initial interval velocity estimation.

3. *P-wave and S-wave Interval Velocity Estimation:*
   As is shown in Figure 1, the source P, S and SH wave are orthogonal to one another, and therefore require an orthogonal recording system when processing both P-wave and S-wave seismic time series data. A tri-axial system provides this.

4. *Absorption and/or Attenuation Analysis:*
   Absorption and/or attenuation analysis requires processing of the full waveform, which can only be done with a tri-axial system.

5. *SCPT Rod Rotation is not a Problem:*
   With a tri-axial system the rotation of the probe as it is advanced is of no concern. As the probe rotates with depth, the sensitive axis of the seismic sensor in a uni-axial system is no longer aligned with the dominant particle motion of the SH source wave, which reduces the amplitude of the signals being recorded.

6. *Incident Angle Estimations:*
   With a tri-axial system the seismic source incident angles can be estimated. These angles provide insight into the validity of the straight ray assumption and into the tilt of the probe.

These advantages are obviously offset by the increased cost of a tri-axial system. Moreover many DST investigations can be performed very successfully with a uni-axial system. Therefore there is no definitive answer to the question at the beginning of this note. However, a tri-axial system definitely provides the user with more options, which will allow for successful analysis of more complex data sets or data sets of a lesser quality.

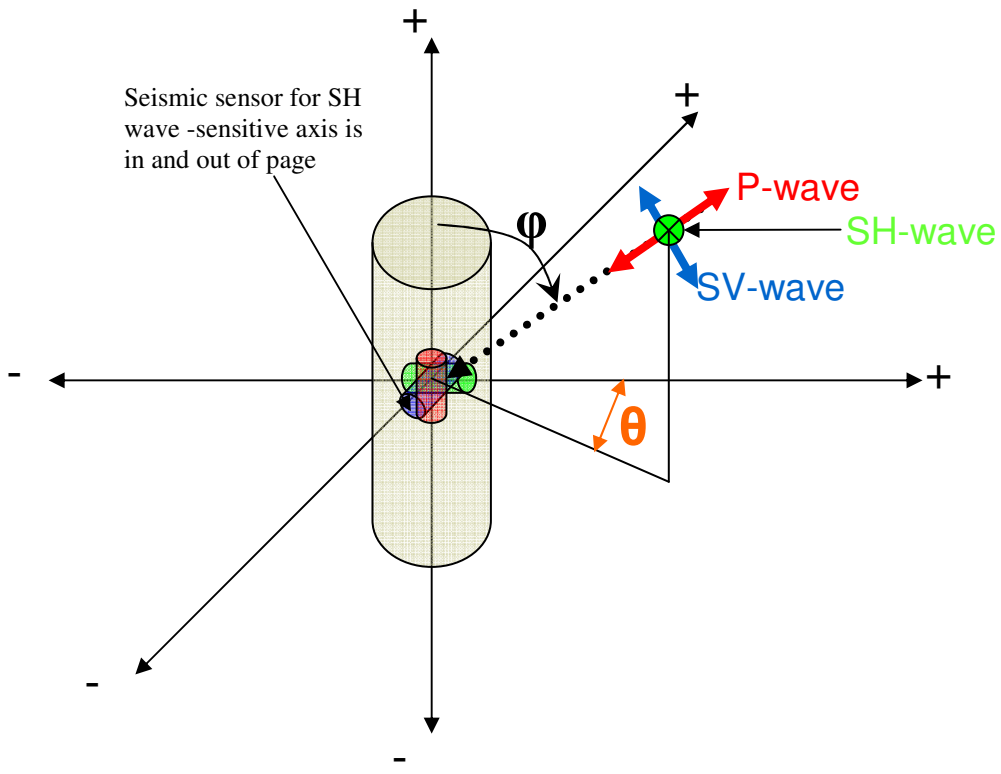

Figure 1. Source P, SV, and SH body waves impacting upon a triaxial sensor package.

Erick Baziw
Gerald Verbeek

BCE's mission is to provide our clients around the world with state-of-the-art seismic data acquisition and analysis systems, which allow for better and faster diagnostics of the sub-surface. Please visit our website (www.bcengineers.com) or contact our offices for additional information:

e-mail: info@bcengineers.com

phone: Canada: (604) 733 4995 – USA: (903) 216 5372