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Prony Decomposition for Sealing and Leaking fault analysis

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Summary

In this work, we demonstrate for the first time how Prony (Prony, 1795) frequency decomposed data can be used for direct analysis of Sealing and Leaking faults.

Prony Decomposition is a unique decomposition similar to the Fourier transform, into a series of damped complex exponentials. Apart from amplitude, phase and frequency, it also computes damping coefficients. Seismic amplitudes attenuate more in reservoirs and high porosity rocks, especially at high frequencies (Knopoff L., 1964). Thus, an analysis of the data decomposed into different frequencies by the Prony technique, allows to identify zones with higher attenuation potentially caused by the presence of fluids (*Mitrofanov G., 2013)*: reservoirs, migration paths and sharp ends of areas where fluid is no longer present. Therefore, it provides an opportunity to analyse sealing and leaking faults.

The suggested technique application example. Barents Sea, near Hanssen Reservoir.

During the first stage of analysis, we decompose the seismic section to Q-factor component, Figure 1. The retrieved Q-factor allows to see the areas with the most attenuated amplitudes. Such zones with high attenuation are likely caused by the presence of large volumes of fluid accumulations e.g. reservoirs. On the seismic section we can observe bright amplitudes and clear flat spot. On the Figure 1, the biggest amplitude damping zones are highlighted by black arrows. Detailed fault studies require additional techniques (e.g. instantaneous attributes, frequency decompositions, relative inversions and etc.) applied to a seismic section and theirs analysis.

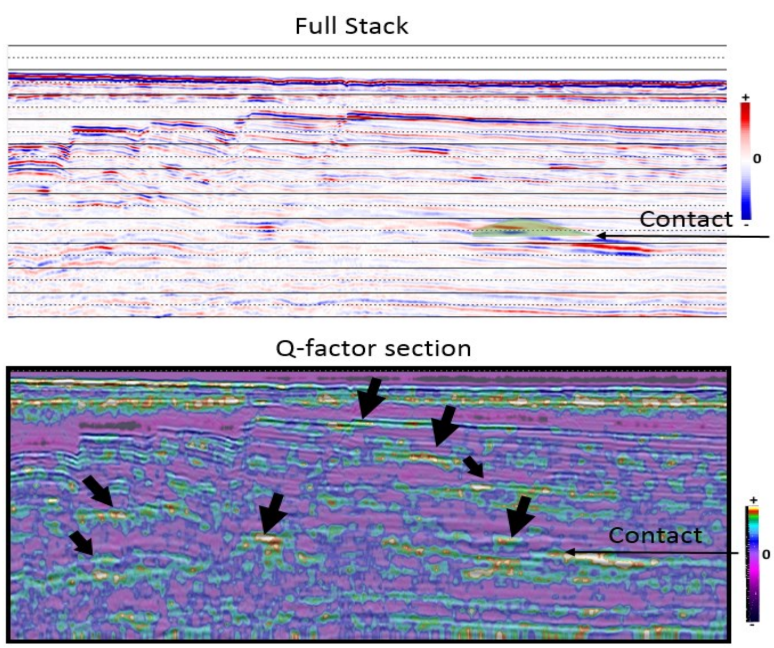

Figure 1 *Seismic section and its expressed Q-component by Prony method.*

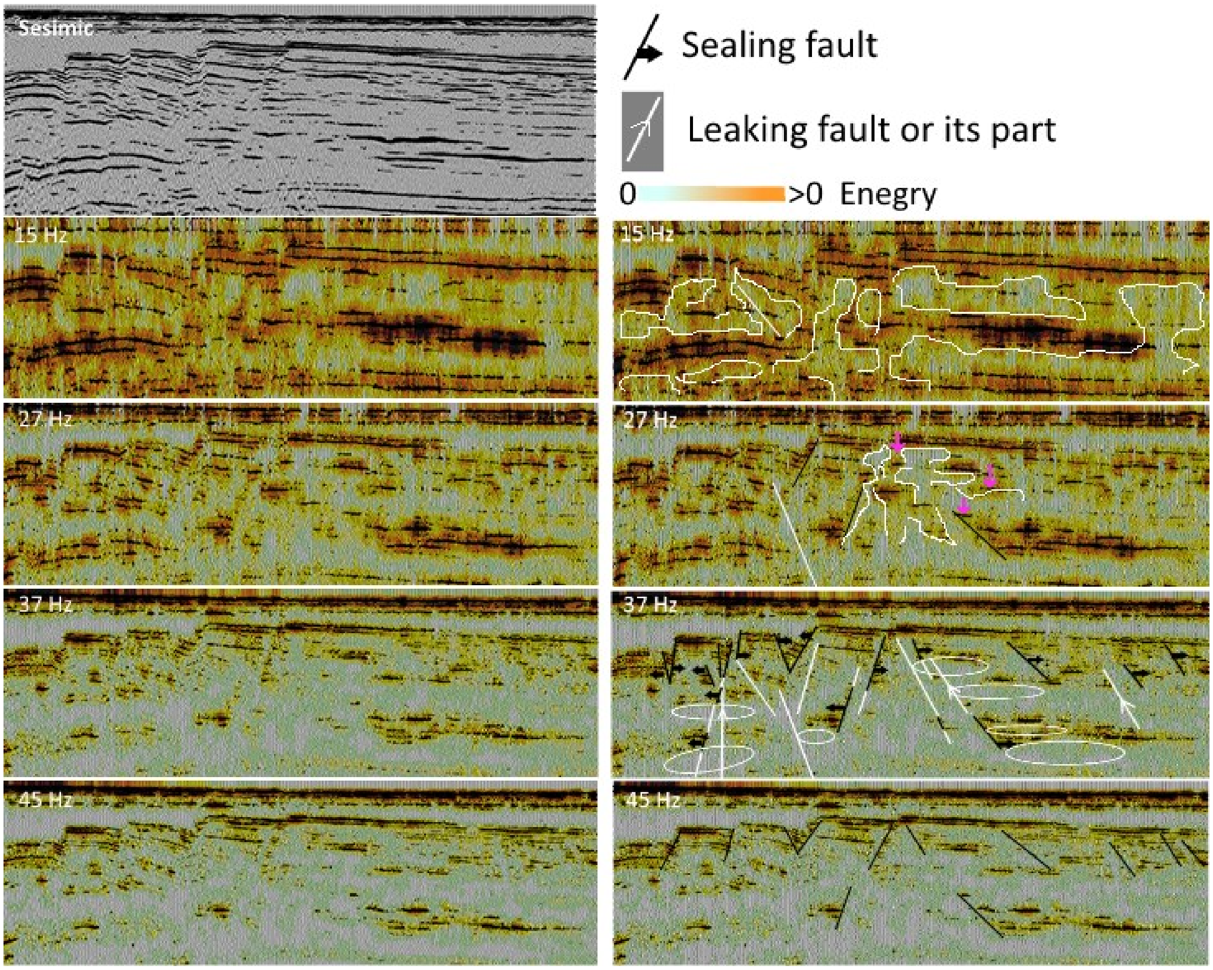

***Figure 2** Seismic section and its frequency' components, expressed by using Prony decomposition method – left, and its suggested interpretation - right.*

During the second stage, we derive seismic sections for different frequencies components. The most dominant frequencies were chosen to decompose the data. For the given seismic section, we used 15Hz, 27Hz, 37Hz, and 45Hz. The visualised section has a bandwidth of 6Hz. Figure 2 illustrates the seismic section and its frequencies' components with overlaid energy (left part). The same frequency decomposed sections with interpretation, are shown on the Figure 2, right part. On the 15Hz decomposed section, we see larger zones where particular frequencies are attenuated. We mark them by white outlines. At 27Hz and 37Hz, these zones are split by higher frequency events (pink arrows). That can be sealing tops (e.g. shales) and bases of the structures. Hard rocks will be more "pronounced" at the high frequencies as well, because seismic wave attenuate less in hard rocks at high frequencies. At 27Hz, we can track amplitudes that cross geological structures down the section, and kind of lines with no information (empty data) that are also crossing the geological structures. We can interpret it with straight lines as faults (black and white lines, Figure 2). At 37Hz, we can see that at some geological structures, seismic reflectors are suddenly breaking and the break is happening along the already marked faults. For these cases we color the interpreted fault in black and add black arrow to highlight what we called "holding side of the structure" – *Sealing Faults*. The other faults, we mark in white. They are *Leaking Faults* that cross the reflectors which are having damped seismic amplitudes and these reflectors disappear fully at high frequencies, Figure 2, 37Hz. At 45Hz, we mark only sealing faults to highlight the reflectors' breaks: the geological structures that suddenly disappear (loss of amplitudes) along and on the sides of the fault.

Figure 3 illustrates the 37Hz component of the seismic section with marked sealing and leaking faults, and amplitude damped areas (yellow outlines). The fluid migration is very likely happening within the marked outlines. The interpreted faults as *Leaking (white)* are inside of the yellow outlines, confirming the interpretation analysis.

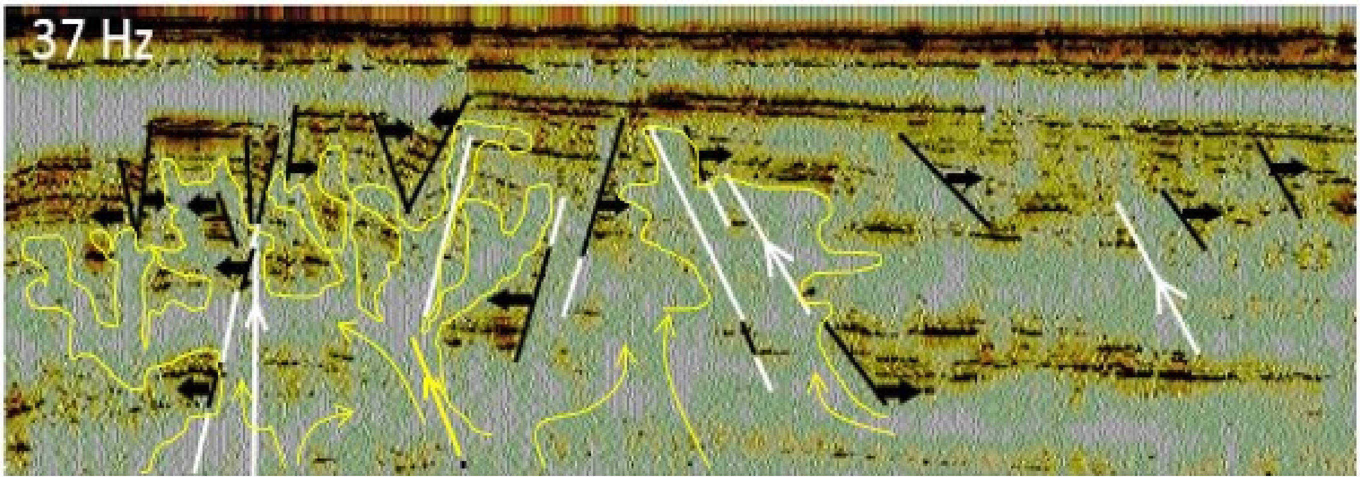

Figure 3 *Decomposed to 37Hz seismic section with marked of Sealing and Leaking faults, and amplitude dumped areas (yellow outline).*

Conclusions

We suggest a new approach of Sealing and Leaking fault analysis bases on seismic attenuated amplitudes studies. To visualise the attenuated amplitudes we use the Prony Decomposition method. It allows to decompose seismic signals with taking into account damping factor to different frequencies and to express damping factor Q itself. We base our analysis on the fact that seismic wave attenuates more in reservoirs and rocks with high porosity, especially at high frequencies. Therefore, if all frequencies are presented and no attenuation, it gives us understanding about absence of fluid in a rocks (or rocks with very low porosity). When amplitudes are damped, it allows to track possible fluid migration paths, leaking faults and reservoirs. In addition, sudden amplitudes break from clear to damped and supported by fault, within the same geological structure, may improve our understanding of sealing fault properties.

The technique still requires statistical verification. At the present stage, we show that it is a new promising approach for sealing and leaking fault analysis.

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References

Prony, G.R.B. [1795] Essai experimental et analitique. Paris. J. l'Ecole Polytech, 1, 24-76.
Knopoff, L. [1964] Q. Reviews of Geophysics, 2(4), 625-660.
Mitrofanov, G. and Priimenko, V. [2013] Prony filtration of seismic data: mathematical and physical modelling. Revista Brasileira de Geofísica 31, 151-168.