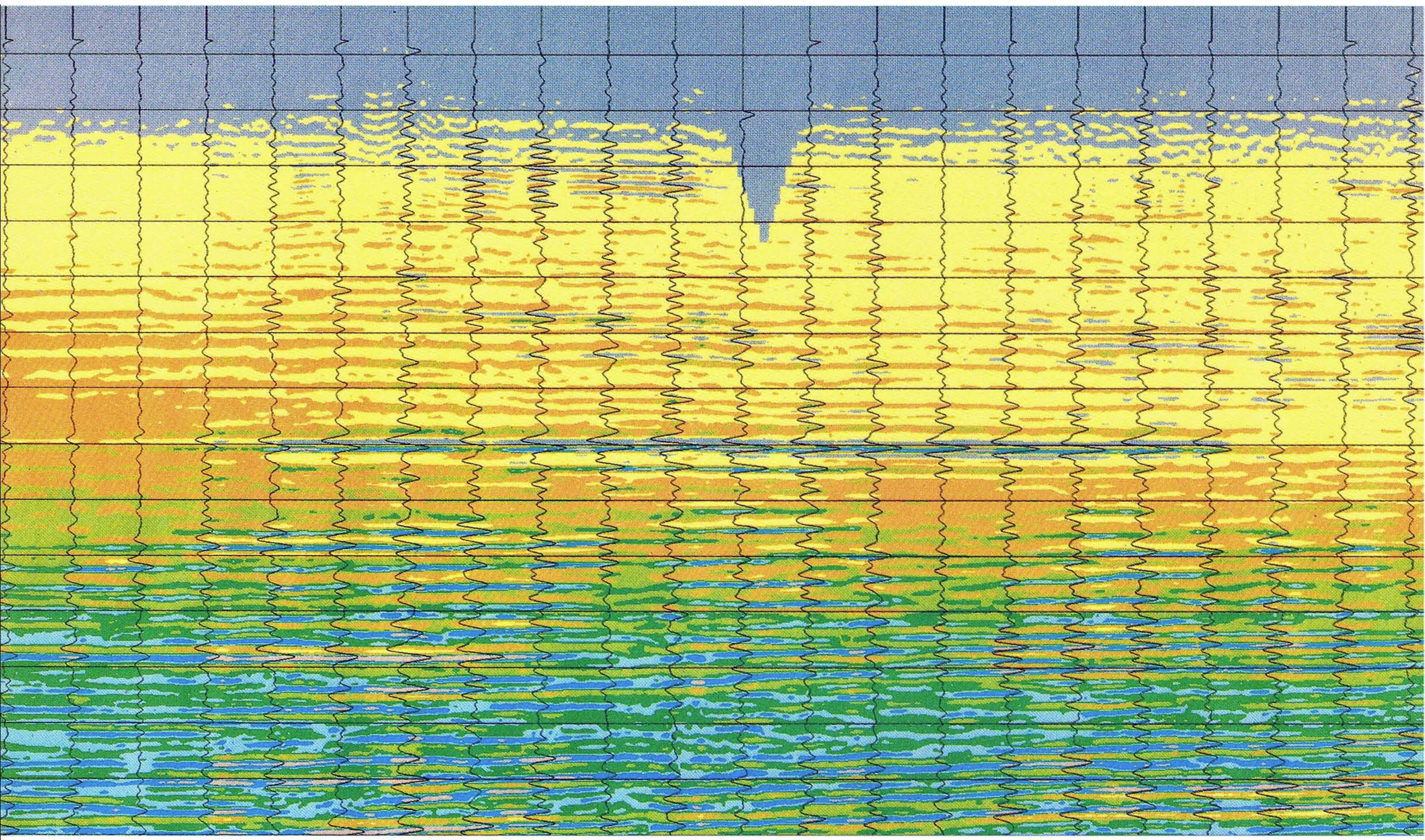
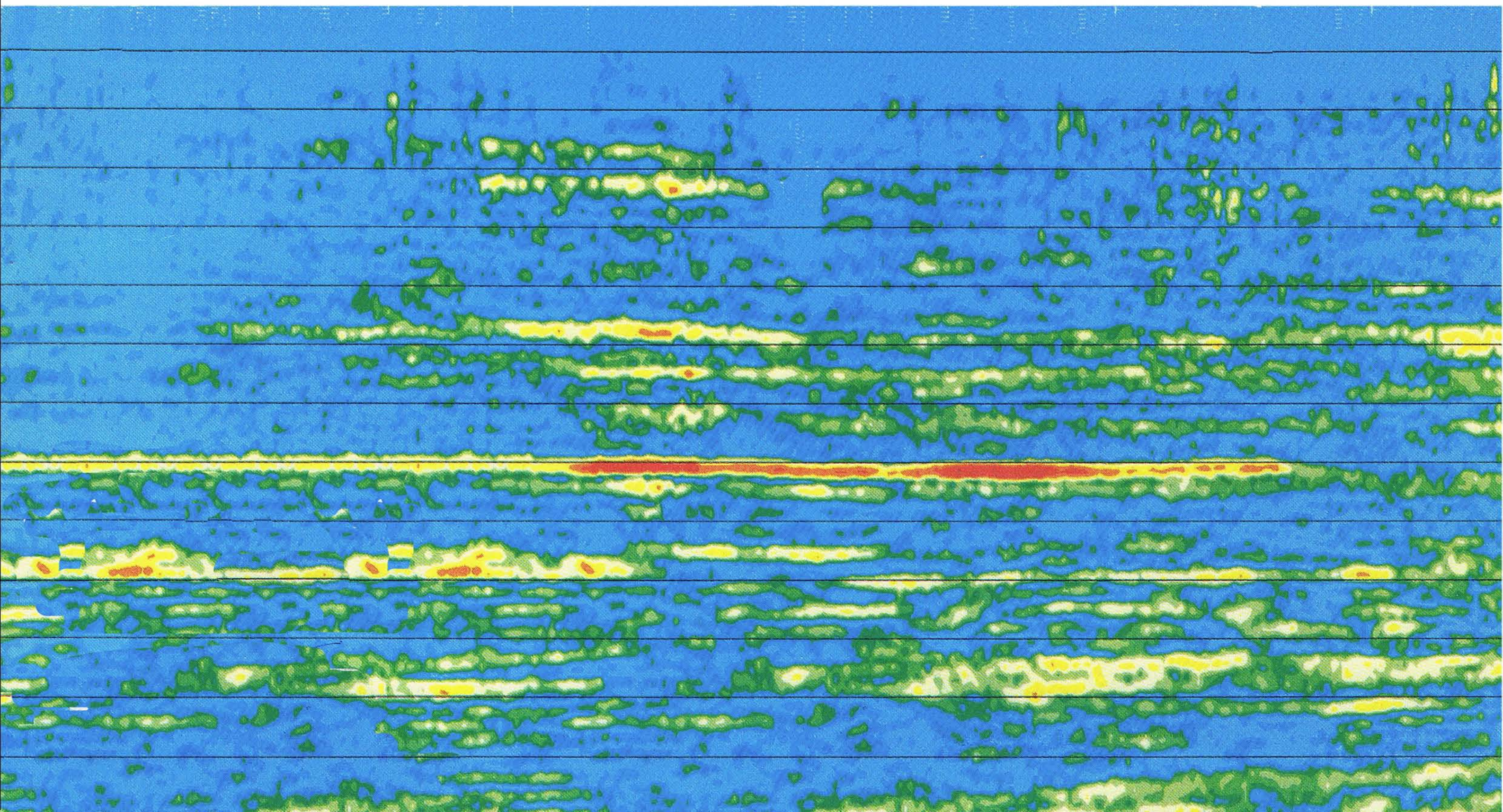
PRAKLA-SEISMOS INFORMATION No. 53

Seismic Stratigraphy





Seismic Stratigraphy

Seismic reflection traces obviously contain two forms of information: traveltimes and amplitudes. Permanent efforts are still made in hydrocarbon exploration to extract as much as possible from this information to estimate the stratigraphical and lithological character of subsurface layering. Particularly during the past fifteen years several new and efficient analytical techniques have been developed creating the now familiar topics

seismic stratigraphy
seismic lithology.

The aim of **seismic stratigraphy** is to define depositional sequences from high resolution reflection seismic data for subsequent facies interpretation.

In **seismic lithology**, the analysis of the variations of reflection amplitudes is used to extract various reservoir parameters such as thickness changes, fluid content, porosity and density.

Another source of additional seismic information is provided by considering the **shear wave seismic response** [2], [4], [5]. S-wave velocity and reflectivity used in connection with P-wave velocity and reflectivity can give valuable information about the petro-physical properties of the subsurface. The converted wave velocity can also be used as a lithological indicator as its dependency on Poisson's ratio describes in turn the particular rock type.

The classical P-wave seismic reflection data is the primary basis for the geologist's interpretation work. To enhance the reliability of his results other subsurface measurements such as **well logs**, **well velocity surveys**, and **vertical seismic profiles** [3] using P- and S-waves should be considered whenever they are available.

There are, in general, two procedures used to combine log data and seismic data:

forward problem – matching well log data to the seismic data (synthetic seismograms).

inverse problem – matching seismic data to the well log data (pseudo logs).

Seismic inversion techniques imply a correct **wavelet processing** of the data in the pre- and poststack stage. Many forms of signature deconvolution were created in this way. The inverse filter computed from the wavelet corrects the basic wavelet to zero phase and levels the spectrum. A filter operator which carries out the required process is usually called a shaping filter. In PRAKLA-SEISMOS's software this is realized by a two-sided recursive (TSR) filter type [1].

This brochure deals with the inversion method for deriving **acoustic impedance logs** and the extraction of invaluable attributes from the **complex trace analysis** method (M. T. Taner). Colour coded displays are in common use in the geophysical industry to reveal the importance of the information contained.

For further information on related subjects please refer to

[1] PRAKLA-SEISMOS Information No. 28 TSR-Phase / Amplitude Compensation Techniques
[2] PRAKLA-SEISMOS Information No. 33 Shear Wave Downhole Surveys
[3] PRAKLA-SEISMOS Information No. 42 Well Seismics – Survey and Processing
[4] PRAKLA-SEISMOS Information No. 52 Shear Wave Surveys and Equipment
[5] Shear Wave Seismics

Front Cover: Pseudo Acoustic Impedance Section
Reflection Strength of the same Section

Pseudo Acoustic Impedance Logs

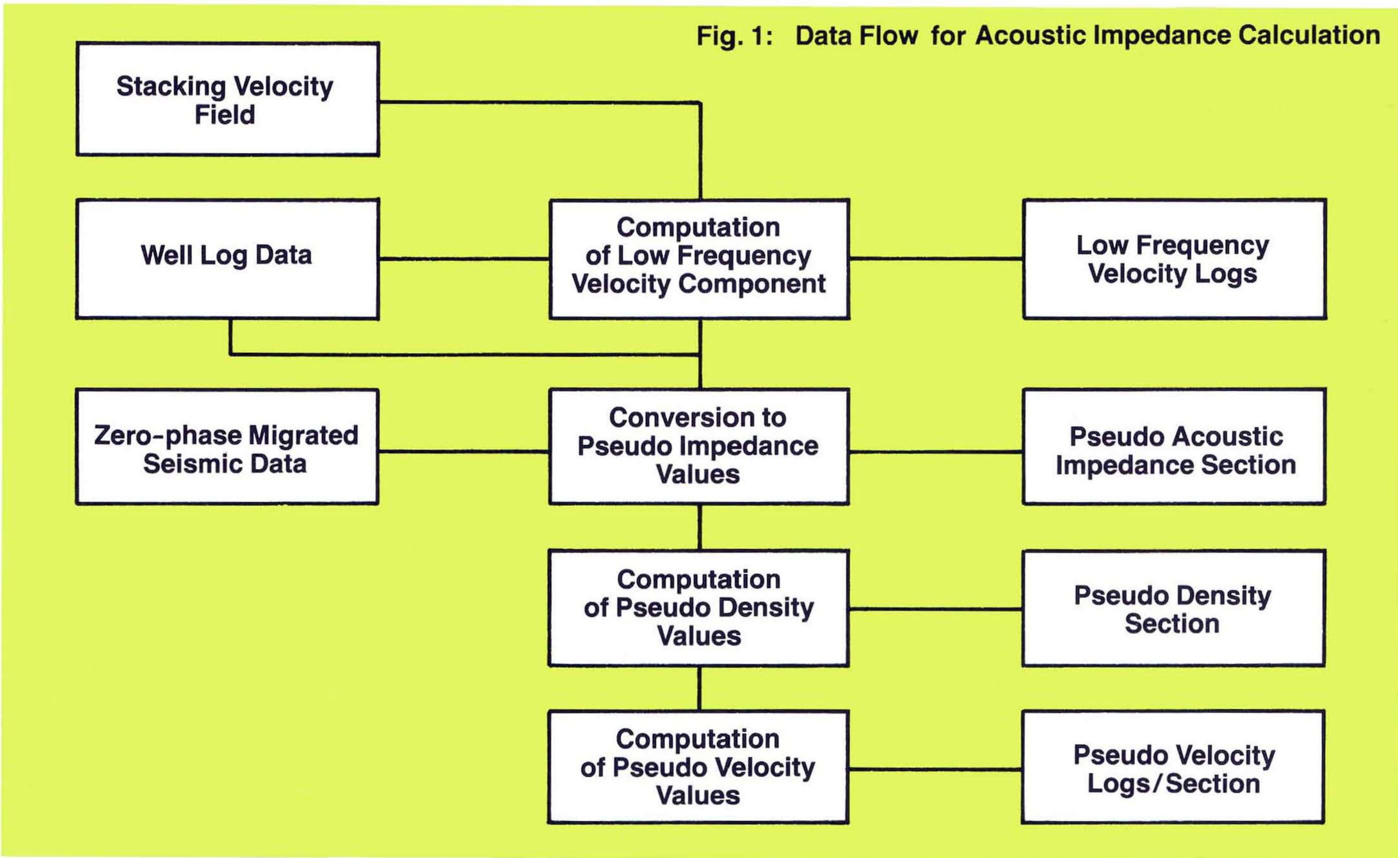
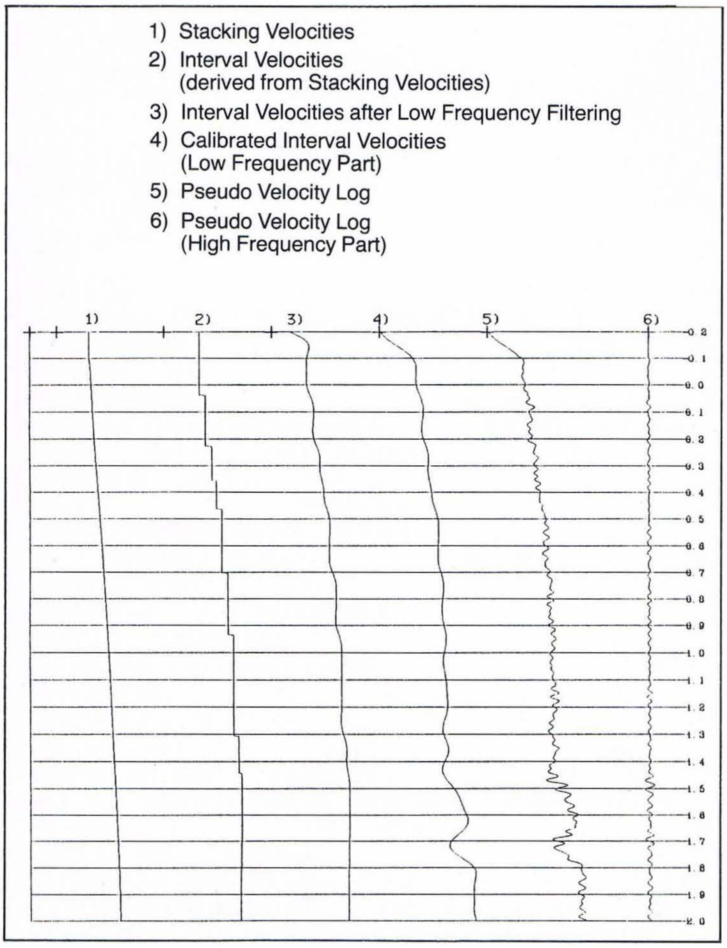


Fig. 1: Data Flow for Acoustic Impedance Calculation

Fig. 2: Principle of Pseudo Velocity Log Derivation from Stacking Velocities



The calculation of pseudo acoustic impedance logs requires a proper preparation of the seismic data:

- lateral amplitude variations should be maintained by **Real Amplitude Processing.**
- phase errors should be eliminated and the data be transformed to zero-phase by **Wavelet Processing.**

Generally it should be realized that the band width of the seismic signal has to match the geological objective to allow a reliable interpretation.

The calculation may start from a zero-phase migrated section of optimum signal to noise ratio and without multiples (fig. 3). The limited band width implies the consideration of the stacking velocities covering the low frequency range. As illustrated in the flow chart (fig. 1) and the log display (fig. 2) the stacking velocities are carefully prepared considering dip correction and matching the reflection events of the seismic data. The resulting low frequency part (fig. 4) and high frequency part for every CDP are then combined to provide the corresponding pseudo velocity logs presented in fig. 5 in wiggle mode or the colour coded pseudo velocity section in fig. 8.

Density values can be calculated with the help of an empirical formula (L. W. Gardner) for each sample of the CDP traces (fig. 7). The velocity-density products provide the pseudo acoustic impedance presentation shown in fig. 6.The ability to quickly relate the log lithology to the seismic section is a great aid to interpretation.

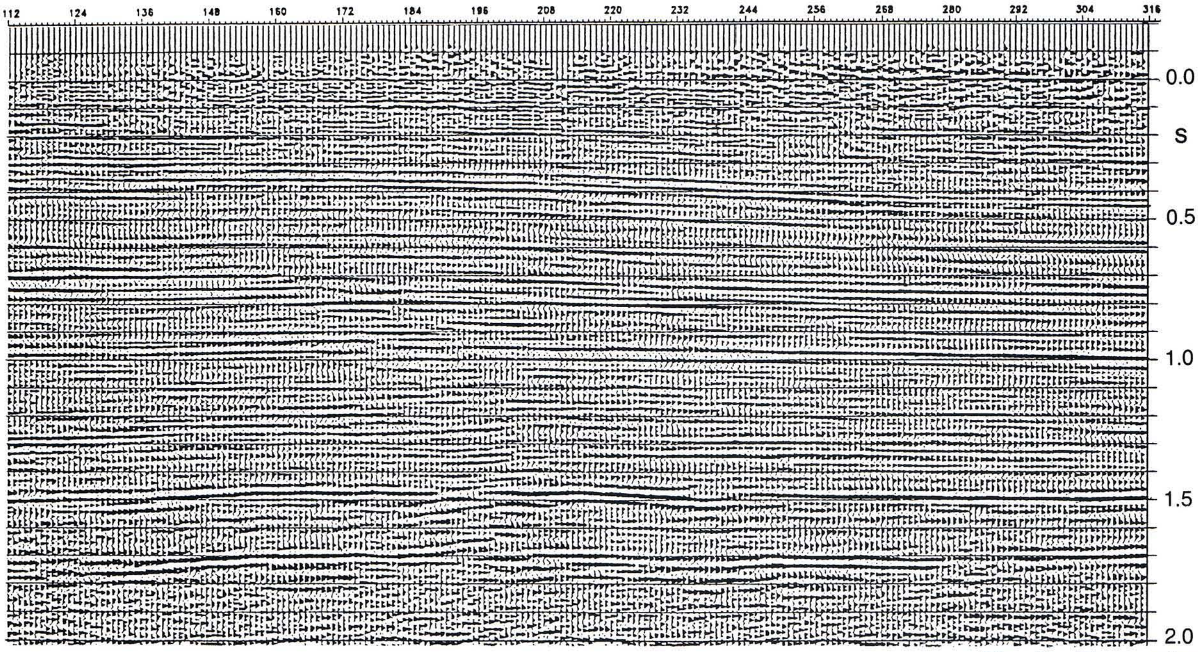


Fig. 3: Zero-phase Migrated Section

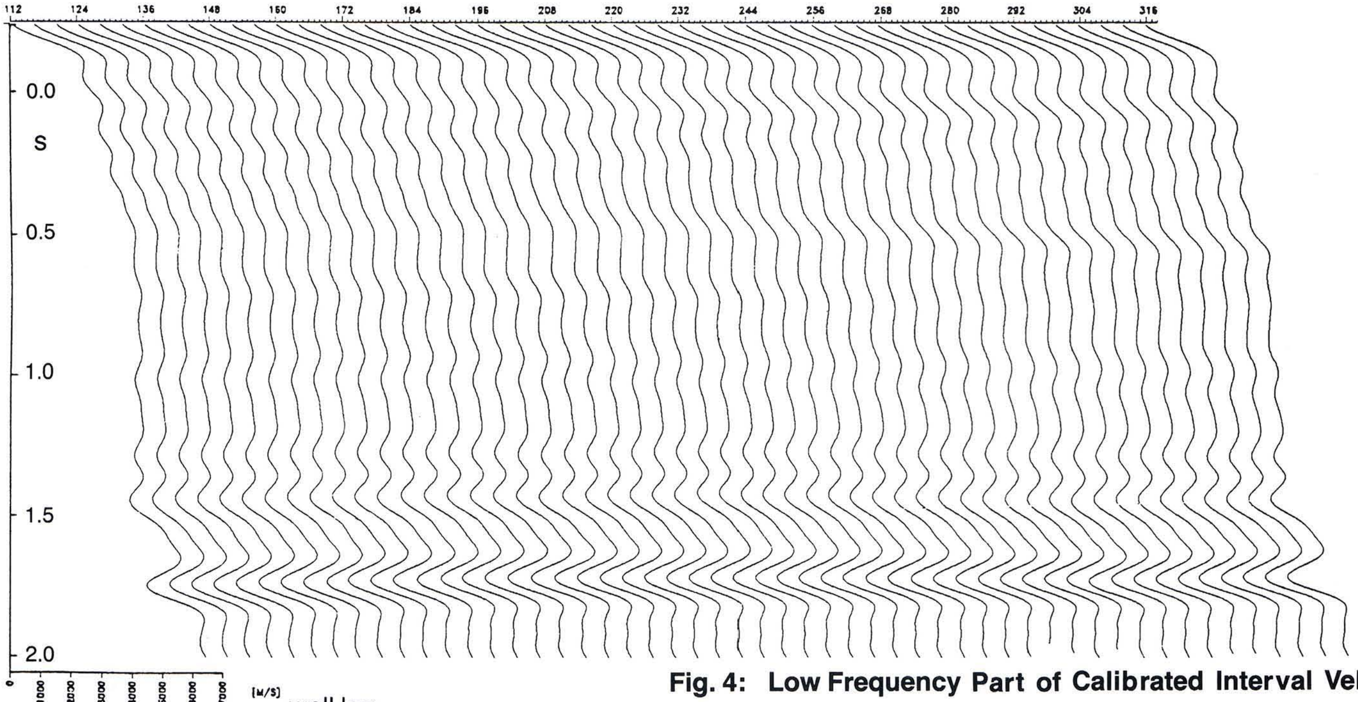


Fig. 4: Low Frequency Part of Calibrated Interval Velocities

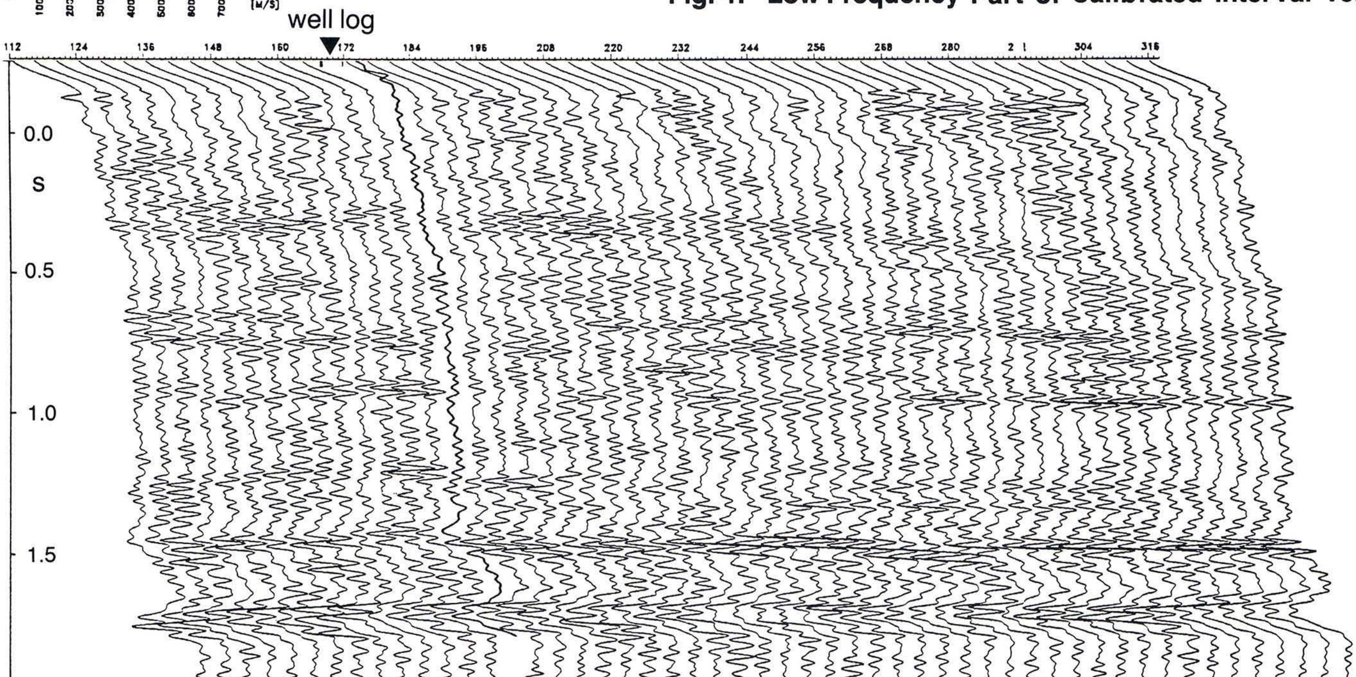


Fig. 5: Pseudo Velocity Logs

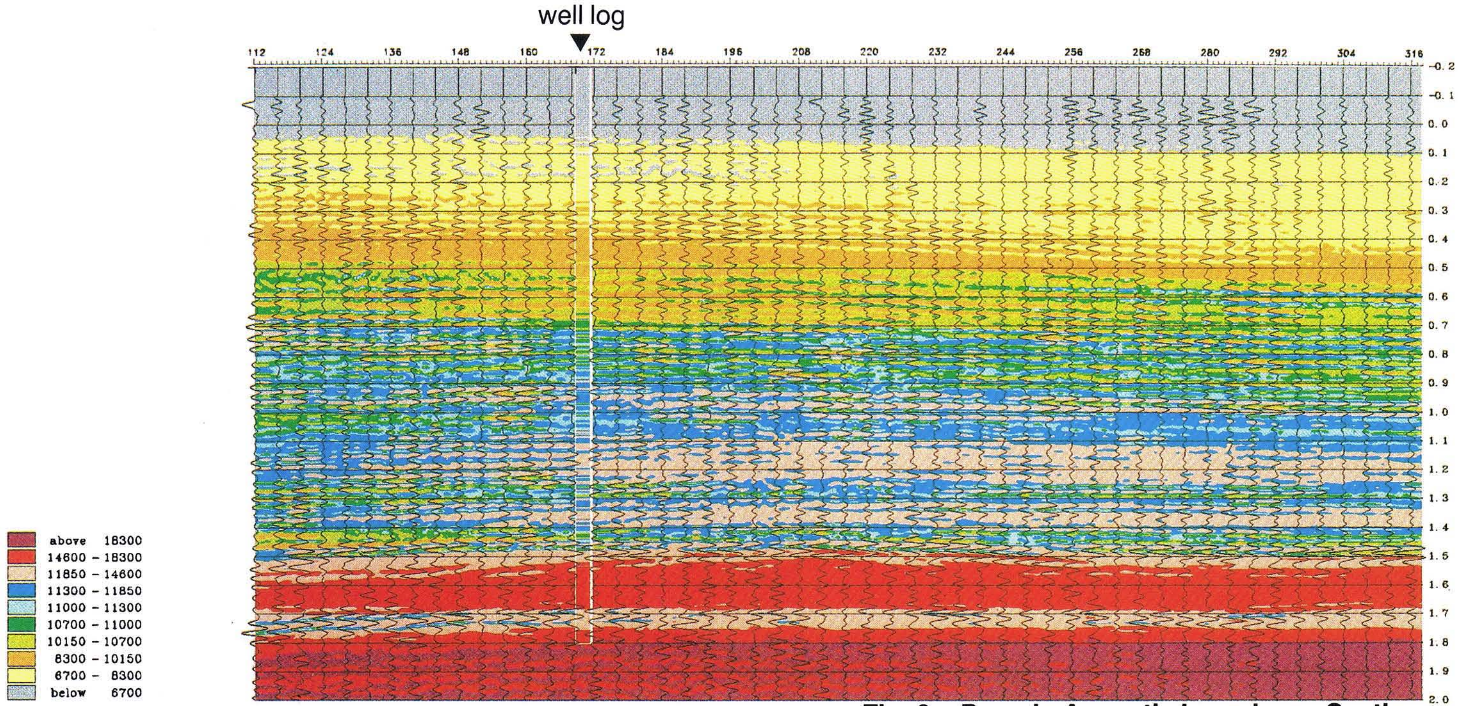


Fig. 6: Pseudo Acoustic Impedance Section

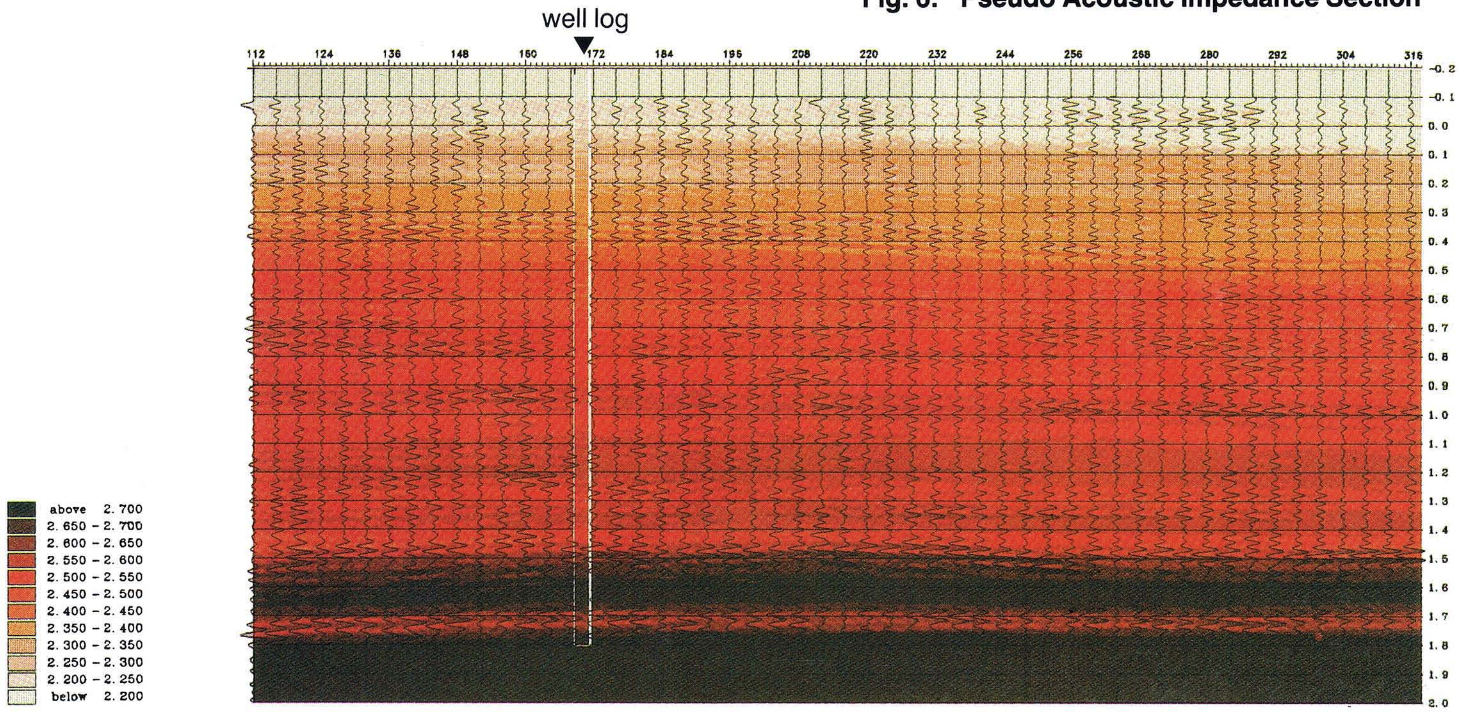


Fig. 7: Pseudo Density Section

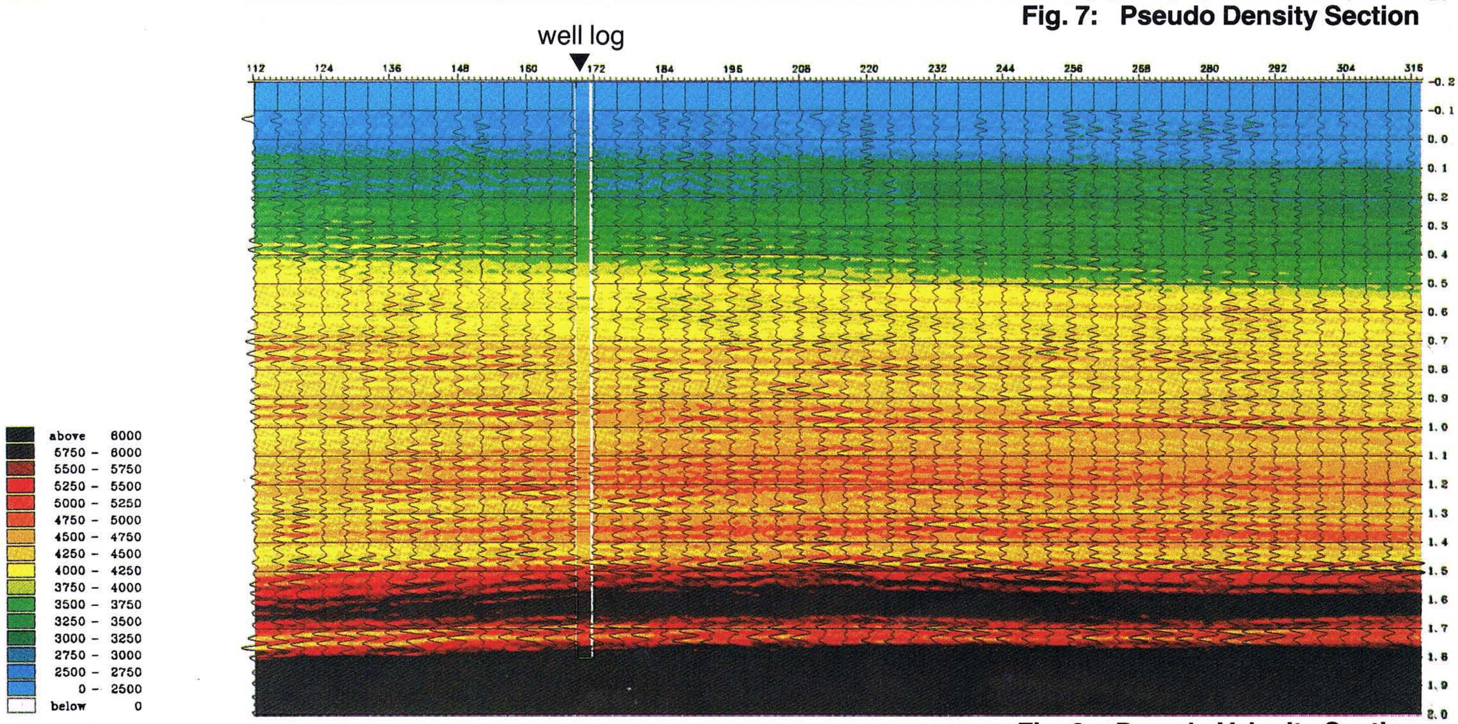


Fig. 8: Pseudo Velocity Section

Blow-ups: an Aid to Detailed Interpretation

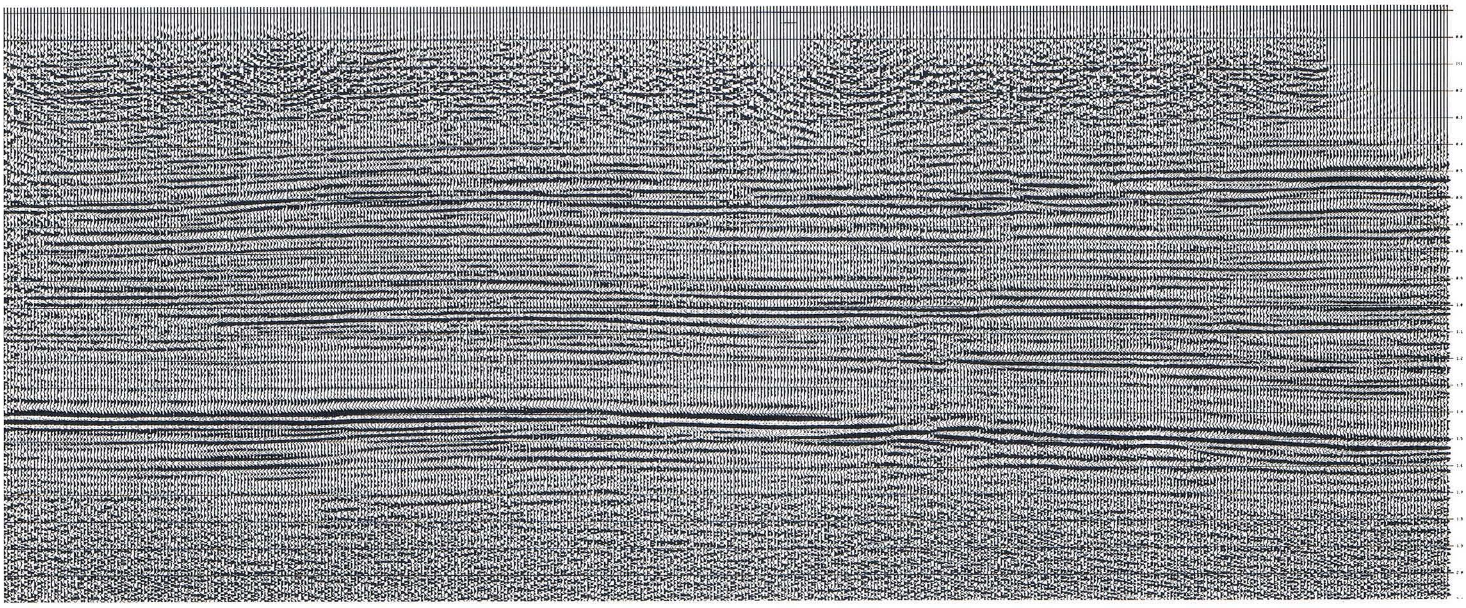
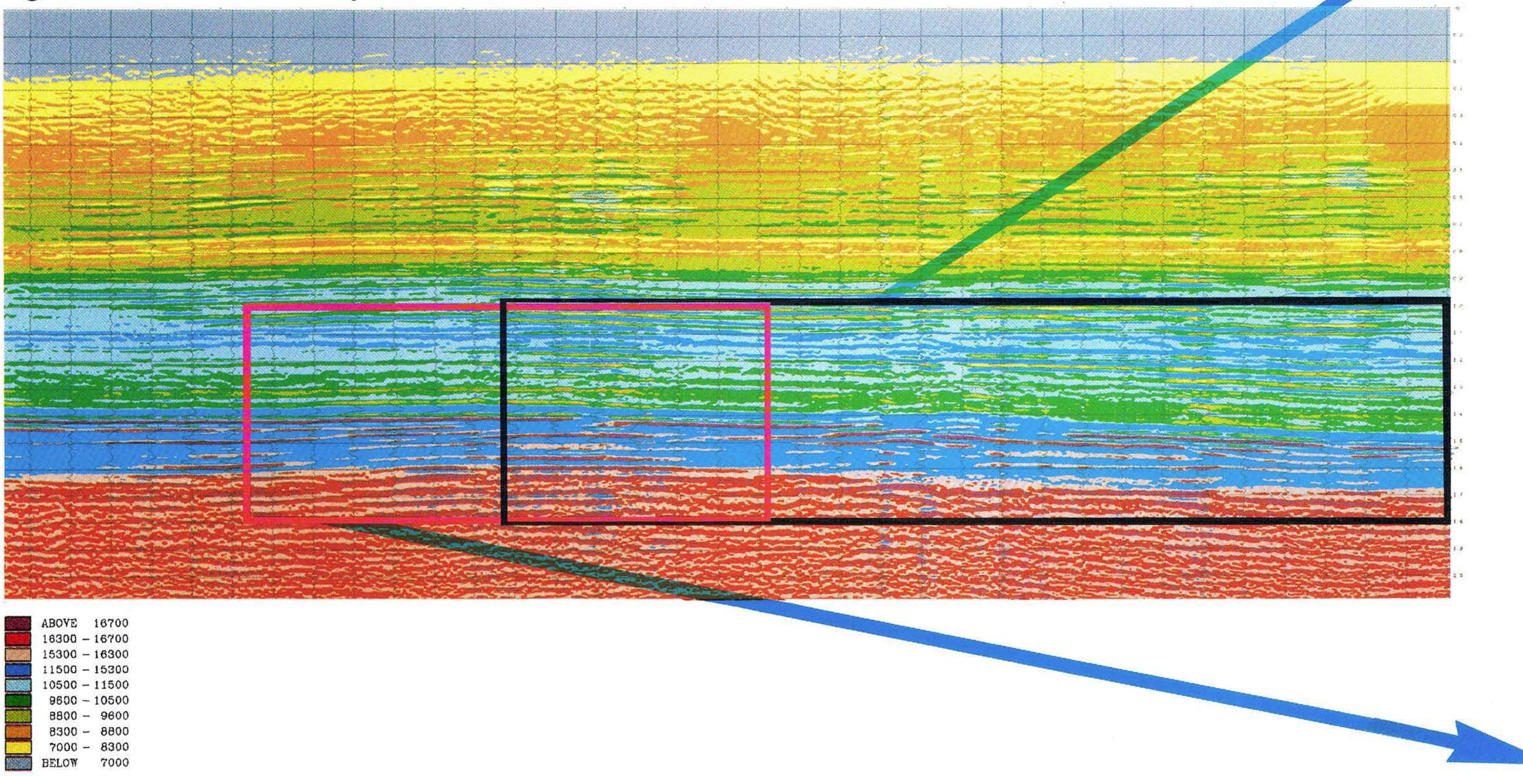


Fig. 9: **Zero-phase Migrated Section**

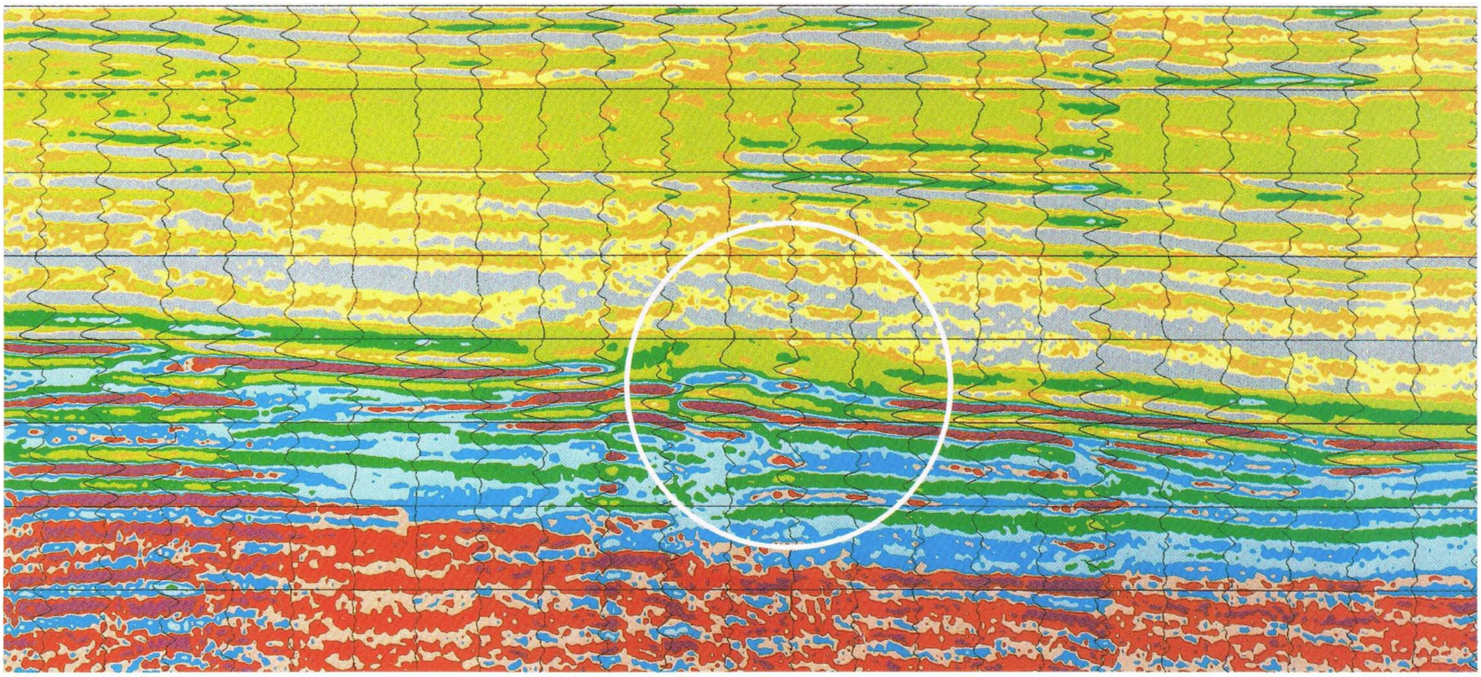
Fig. 10: Pseudo Acoustic Impedance Section



For detailed studies the acoustic impedance section can be interpreted in certain time zones of interest (fig. 10).

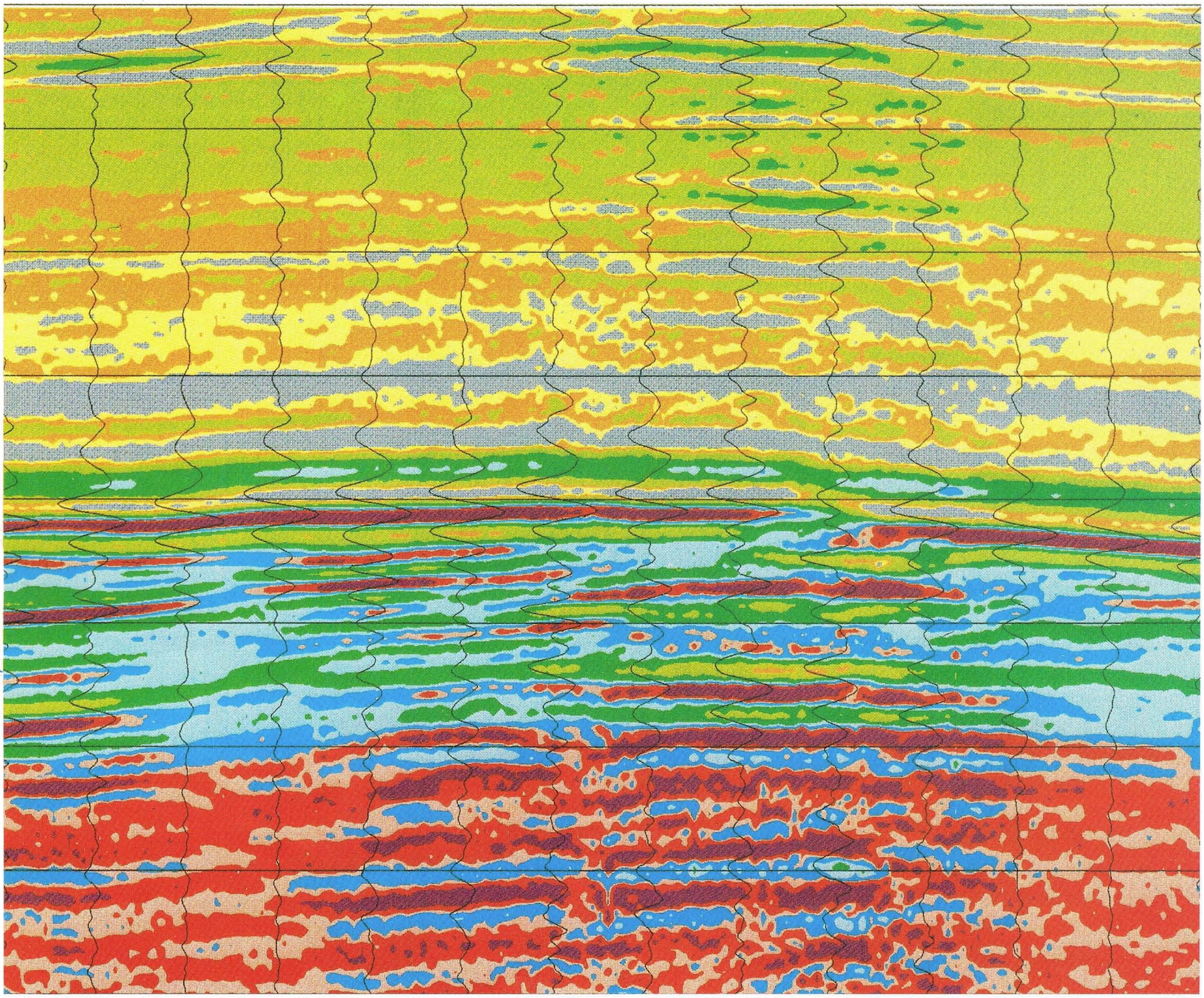
These time frames can be zoomed and colour coded individually as illustrated in figs. 11 and 12. The same number of colour codes as was used for the total section is now applied to a smaller range of impedance values. This allows a more precise identification of facies changes in the blown-up section.

Figure 11, e.g., clearly shows the decrease of acoustic impedance in a Cretaceous layer indicating oil accumulation, which has been proved by drilling. This cannot be identified in the total section (fig. 10).



▲
Fig. 11:
Selected Blow-ups for Detailed Acoustic Impedance Interpretation
Fig. 12:
▼

ABOVE 16900
16300 – 16900
15900 – 16300
15100 – 15900
14200 – 15100
12600 – 14200
11000 – 12600
10500 – 11000
10100 – 10500
BELOW 10100



Complex Trace Analysis

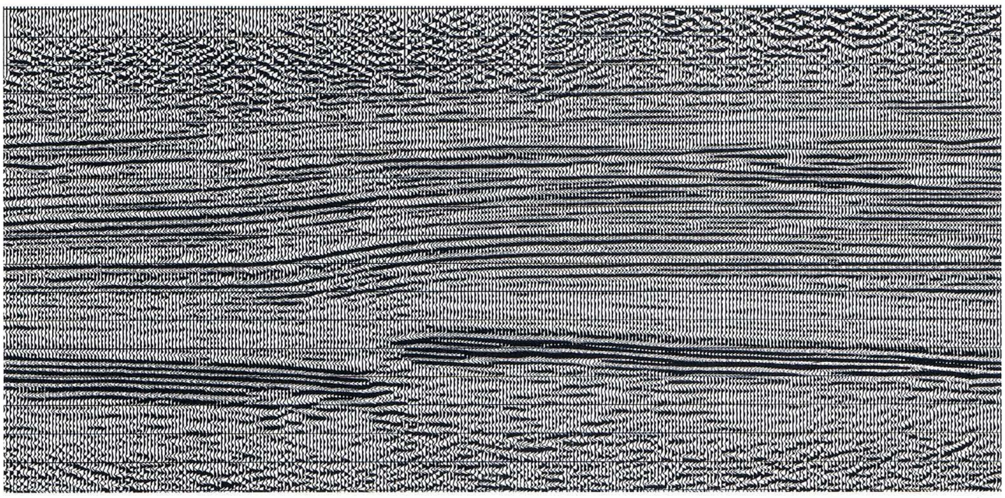


Fig. 13: Zero-phase Migrated Section

Seismic lithology is concerned with local interpretation of seismic data. This involves the availability of a series of local parameters derived from the seismic wavelet. The recorded seismic wave can be thought of as the real part of an analytic signal. Hilbert transform techniques enable the generation of the so-called **complex trace** from the observed real trace. Both portions are then available for further analysis.

A special transformation separates the amplitude, phase and frequency information for each sample of the seismic wavelet, which are then displayed as sections. The interpretational significance of **instantaneous phase, instantaneous frequency, reflection strength** and **apparent polarity** can be demonstrated simply by comparison of these attributes for the same seismic section (fig. 13, 15 to 18).

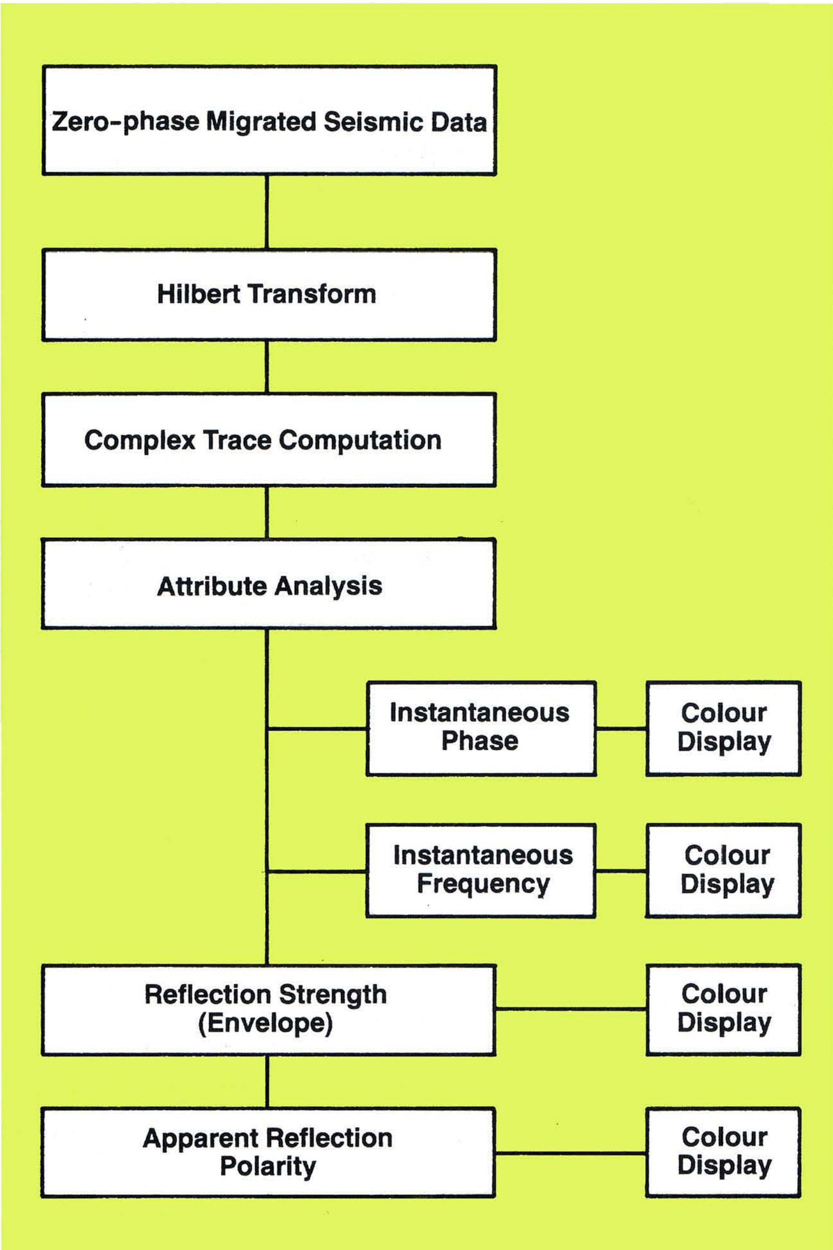


Fig. 14: Data Flow for Complex Trace Analysis

Fig. 15: Instantaneous Phase

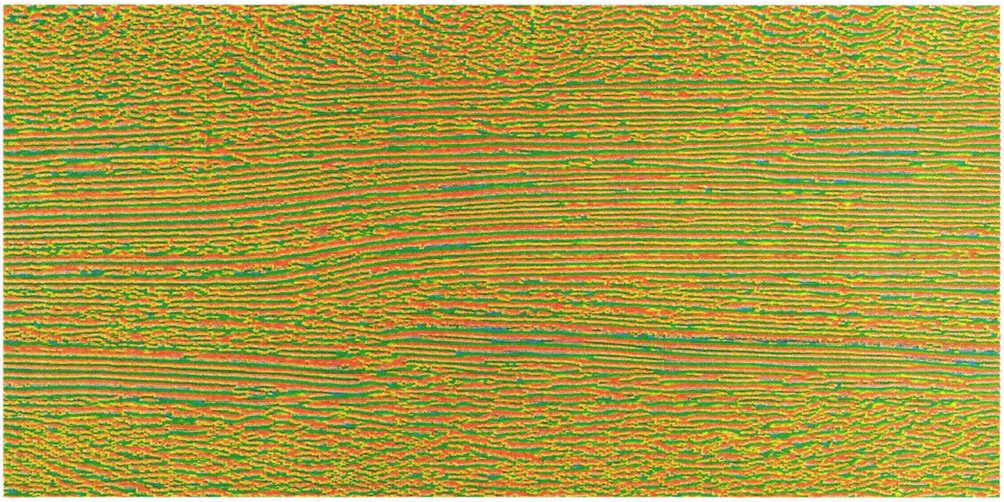


Fig. 16: Instantaneous Frequency

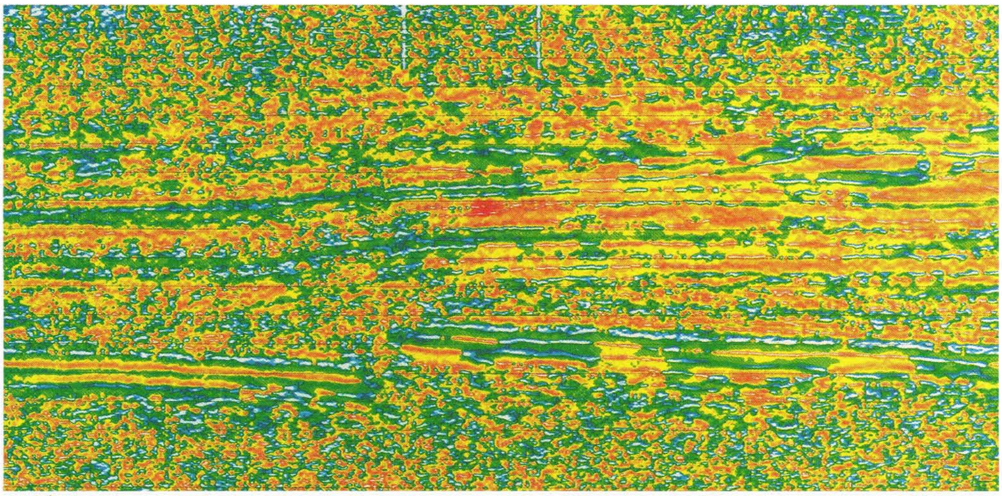


Fig. 17: Reflection Strength

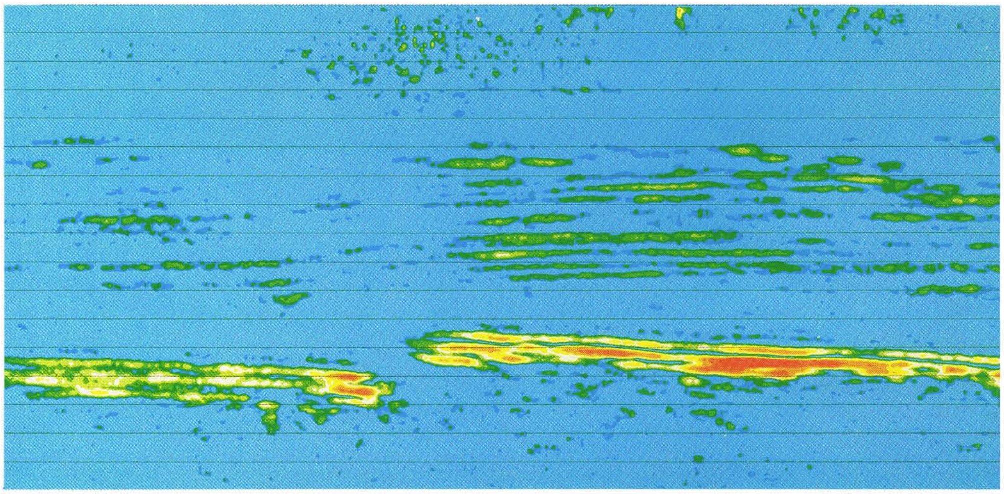
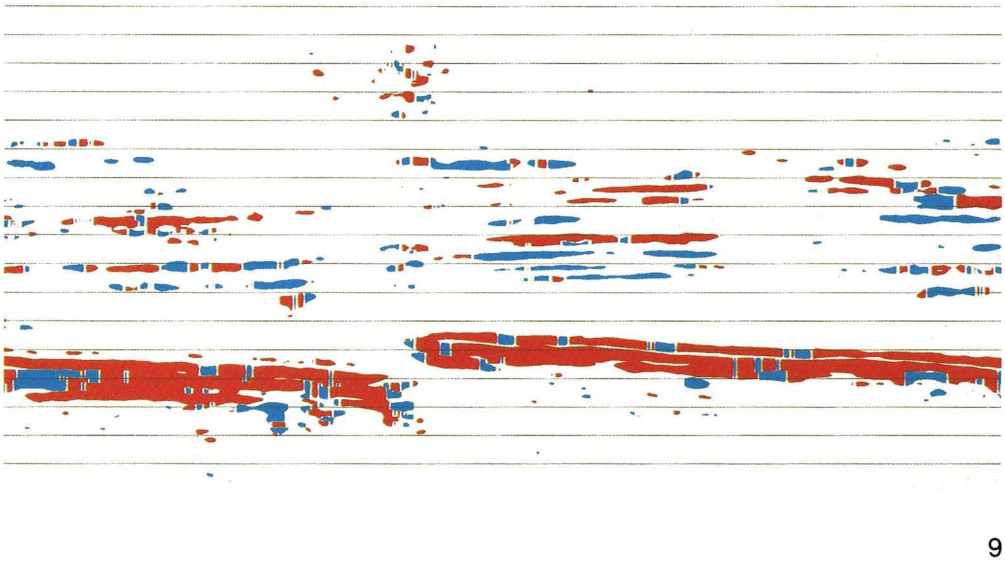


Fig. 18: Apparent Reflection Polarity



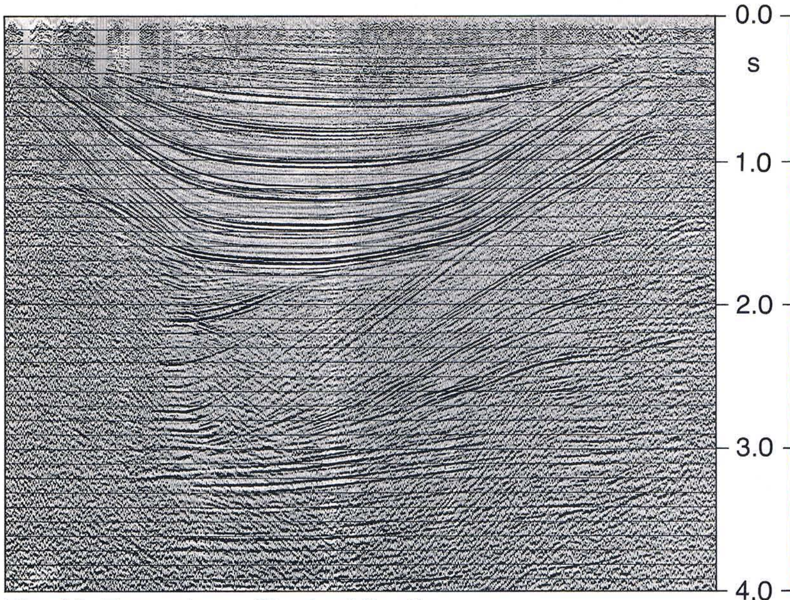


Fig. 19: Zero-phase Stacked Section

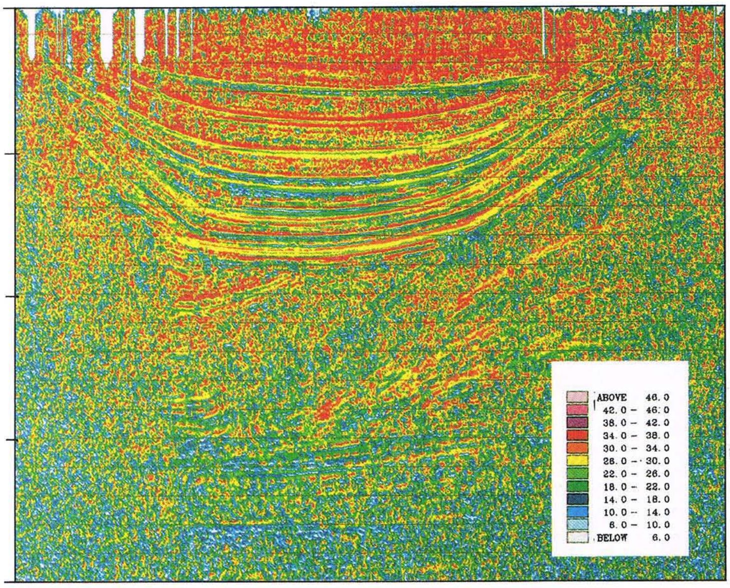


Fig. 20: Instantaneous Frequency

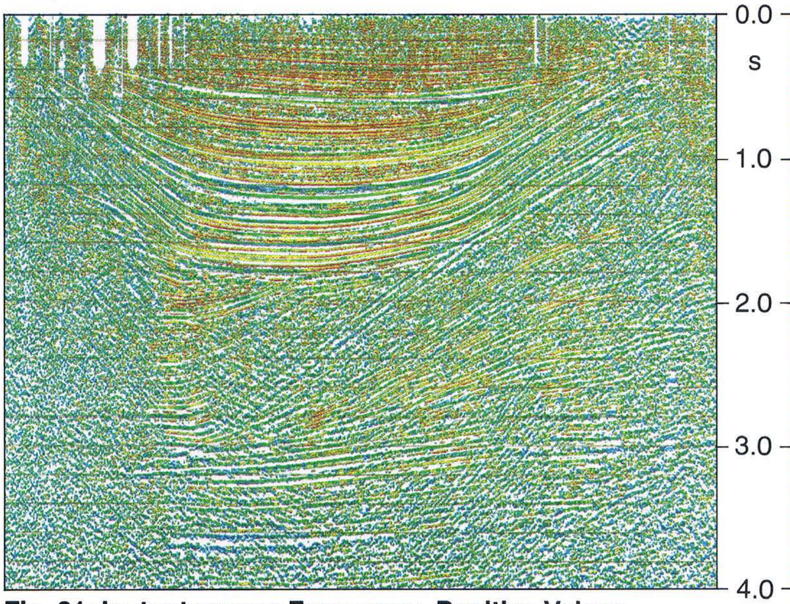


Fig. 21: Instantaneous Frequency, Positive Values

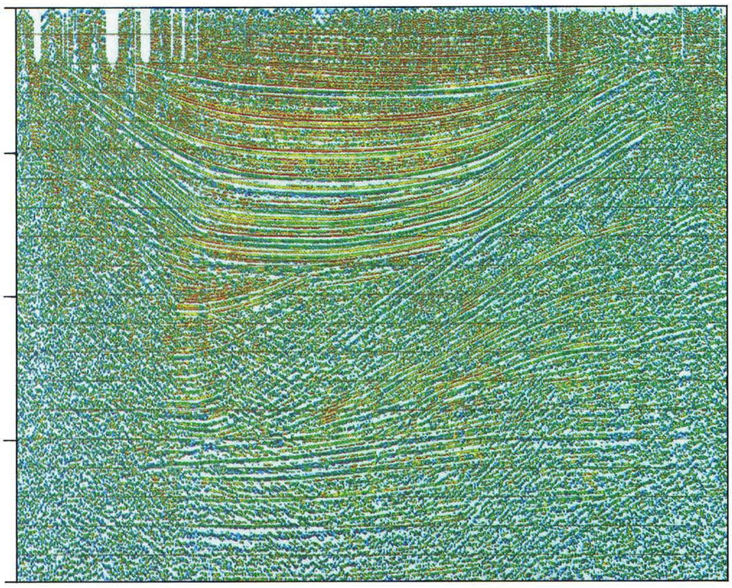


Fig. 22: Instantaneous Frequency, Negative Values

Instantaneous frequency displays are advantageous in that they often clearly illustrate rapid changes in individual reflections from closely spaced interfaces. The continuity known from the seismic section (fig. 19), however, gets lost for the dominant reflector interpretation.

In this case it is useful to mask the instantaneous frequency data (fig. 20), which leads to positive and negative values as displayed in figures 21 and 22. Here the line-up of events has clearly been maintained.

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