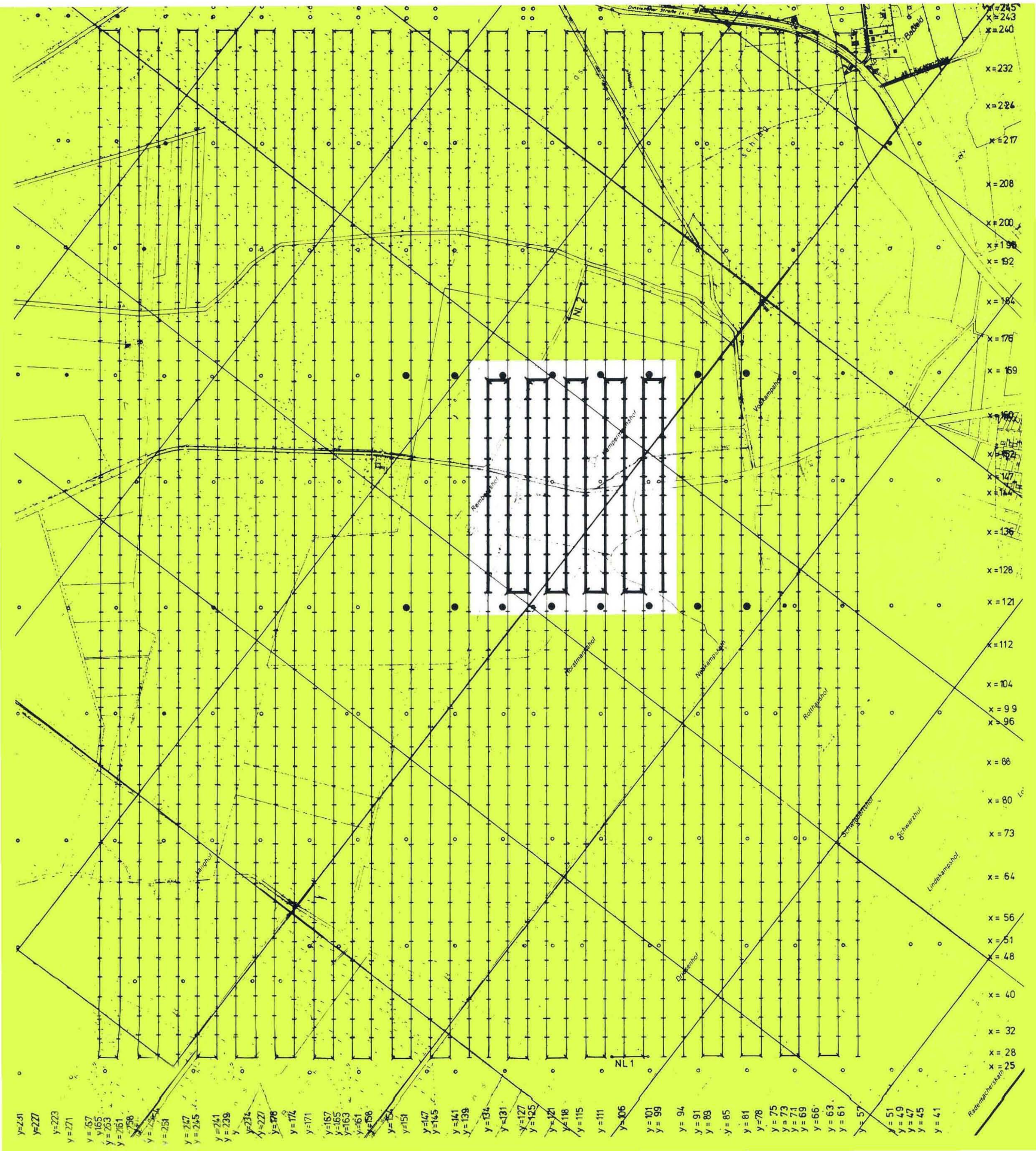
PRAKLA-SEISMOS INFORMATION No.19

3-D Seismics



General Remarks on 3-D Seismics

Since 1975 PRAKLA-SEISMOS has provided their clients with the new seismic technology generally known as 3-D seismics. In an earlier publication PRAKLA-SEISMOS Information No. 3 this technique was introduced as "Areal Reflection Seismics". The term "3-D Seismics" has since entered the international scene. This title has now been adopted in order to avoid possible misunderstandings.

Seismic information based on conventional line surverys – or 2-D techniques – remain inadequate and unsatisfactory in many cases, in particular when complex structures have to be revealed.
3-D techniques lead, in principle, to two types of result:

1. Plane sections in arbitrary spatial direction after application of 3-D migration. Superior signal-to-noise ratio and strength of multiple attenuation are the most significant properties of 3-D migrated sections.

2. Large series of stacked parallel echelon-profiles in any desired orientation imply a high degree of realibility to interpretation.

A broad spectrum of 3-D field techniques has been developed and successfully carried out in practice, 3-D data processing techniques advancing parallel to these developments. The four examples for 3-D seismics in this brochure show how 3-D technology can be adapted to different prospective targets and survey conditions. Onshore and offshore objectives so vastly different as

- deep targets
- shallow layers with high-resolution
- steep dips and and complex faulting

can be surveyed using different energy sources such as

- explosives
- vibrators
- hydraulic hammers
- airguns.

Environmental and access problems are overcome by highly flexible survey concepts.
Economic application of 3-D technology is best provided by multichannel recording instruments (up to 240 channels) and by emitterintensive means such as vibrators and "lanced" shallow shotholes.
The 3-D technology has been applied for practically all kinds of prospecting: coal, salt, hydrocarbons, thermal springs, and for the solution of engineering problems.

This unique process unravels complex three-dimensional structures by plane vertical sections. The tremendous quantity of data involved provides a considerably enhanced signal/noise ratio – a welcome secondary effect.

The upper picture is a stacked section from a low coverage 3-D survey for coal-mine exploration. The parameters of this specific survey were adapted to preserve the maximum of the high-frequency information by employing a narrow CDP grid with 12.5 m spacing (arrangement see figure 4, page 5). The seemingly poor data was converted into a highquality section by the powerful 3-D migration process as shown in the lower picture.

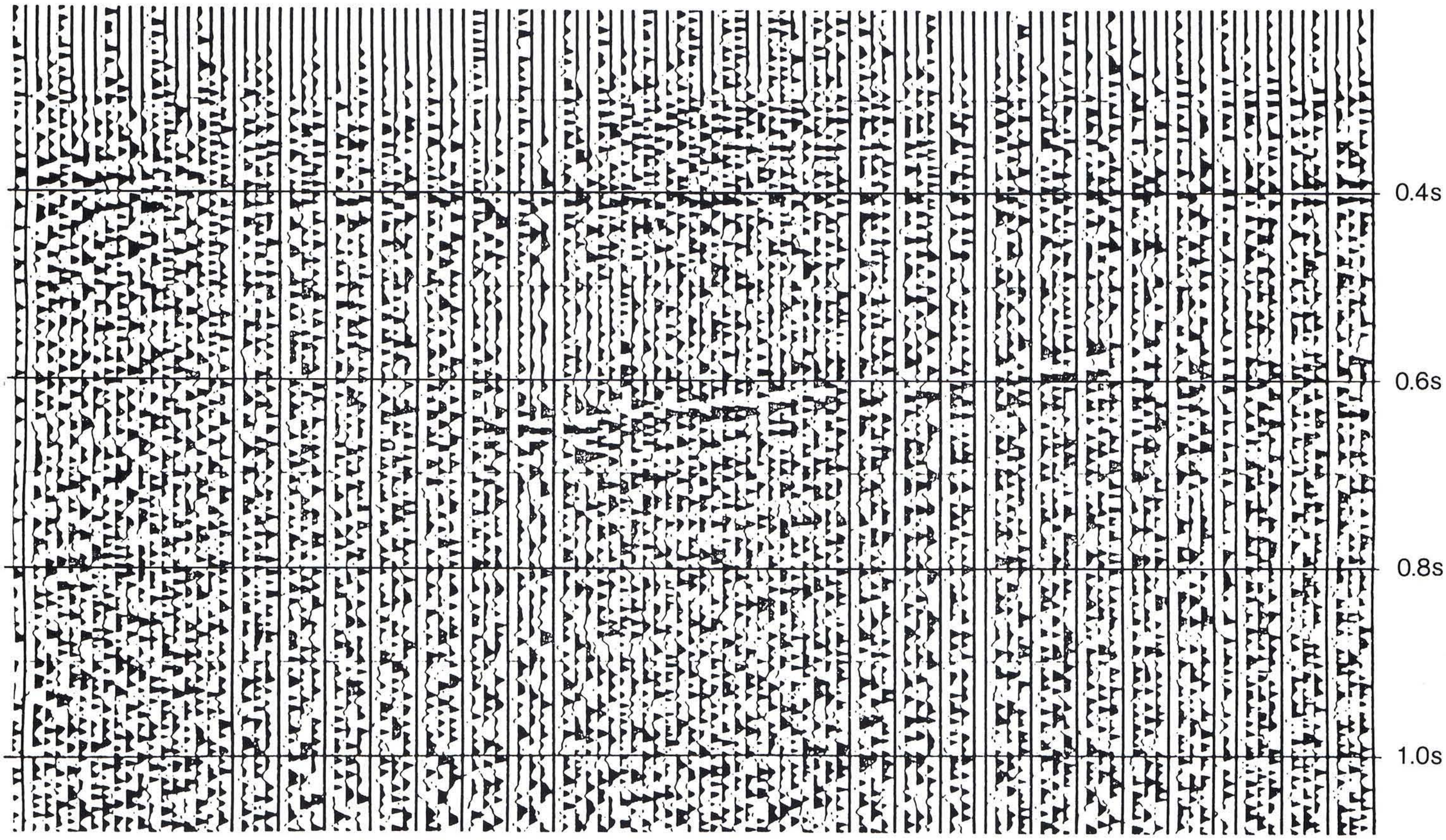


Fig. 1: Stacked section from 3-D survey (Coverage from zero- to threefold)

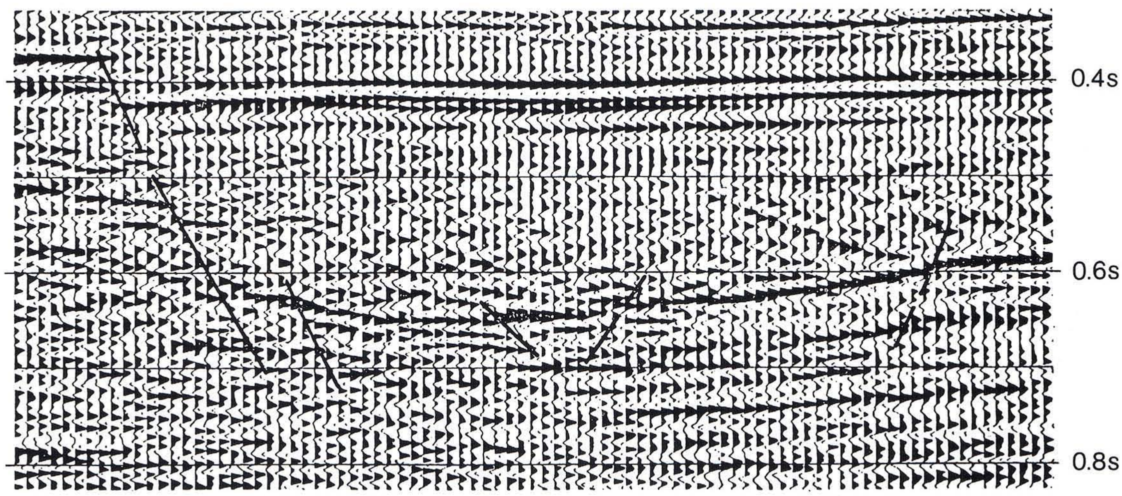


Fig. 2: Same section after 3-D (Kirchhoff) migration showing clear fault evidence

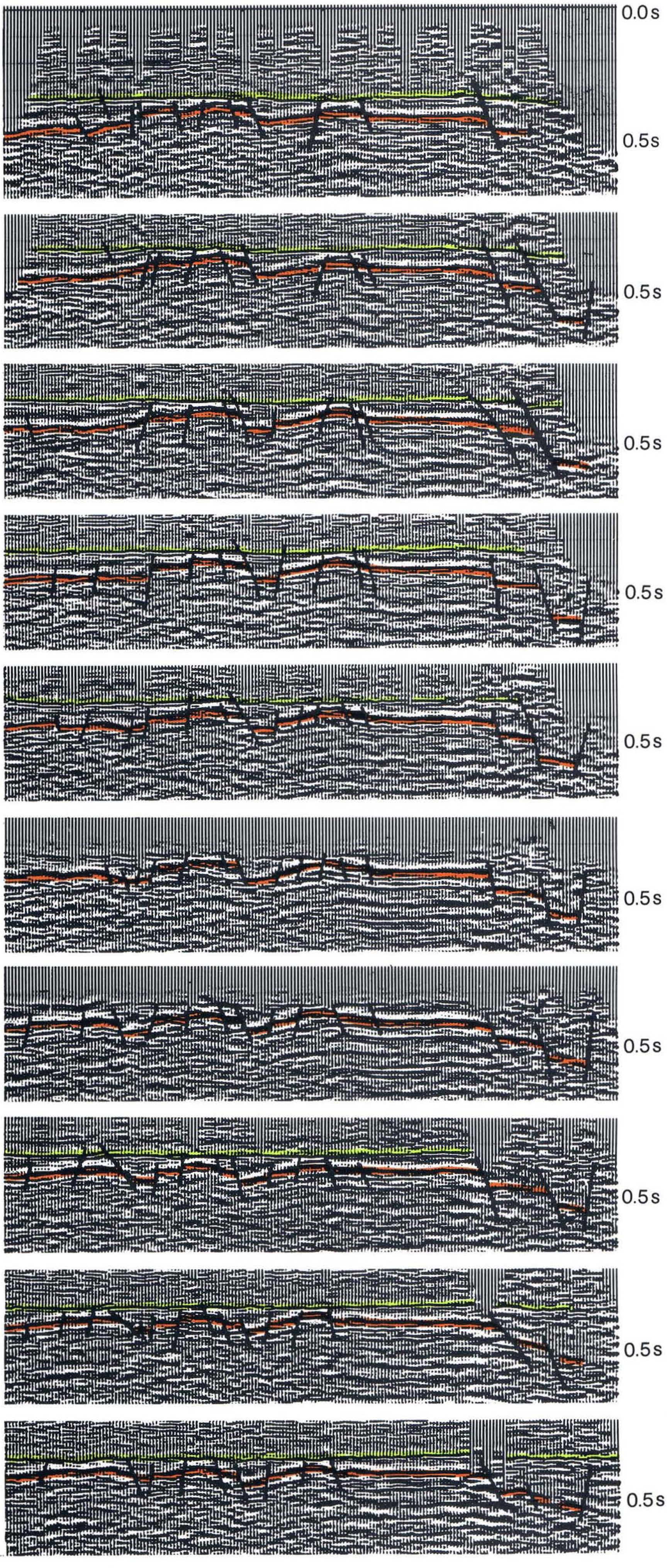


Fig. 3

The series shown is a sequence taken from 88 sections of a 3-D survey for coal-mine prospecting covering an area of 4 x 4 km. Faults can easily be traced by the interpreter. Coverage of the survey was 6-fold, CDP gridding 50 m.

Fig. 4: Building-Block System for areas without access problems. The area to be surveyed is regularly covered by receiver and emitter stations. The system shown here is based on 50 m geophone-station spacing and 125 m shotpoint spacing along distinct shot rows. The mean coverage achieved is 2-fold, the grid spacing 12.5 m (for results see figures 1 and 2 on page 3).

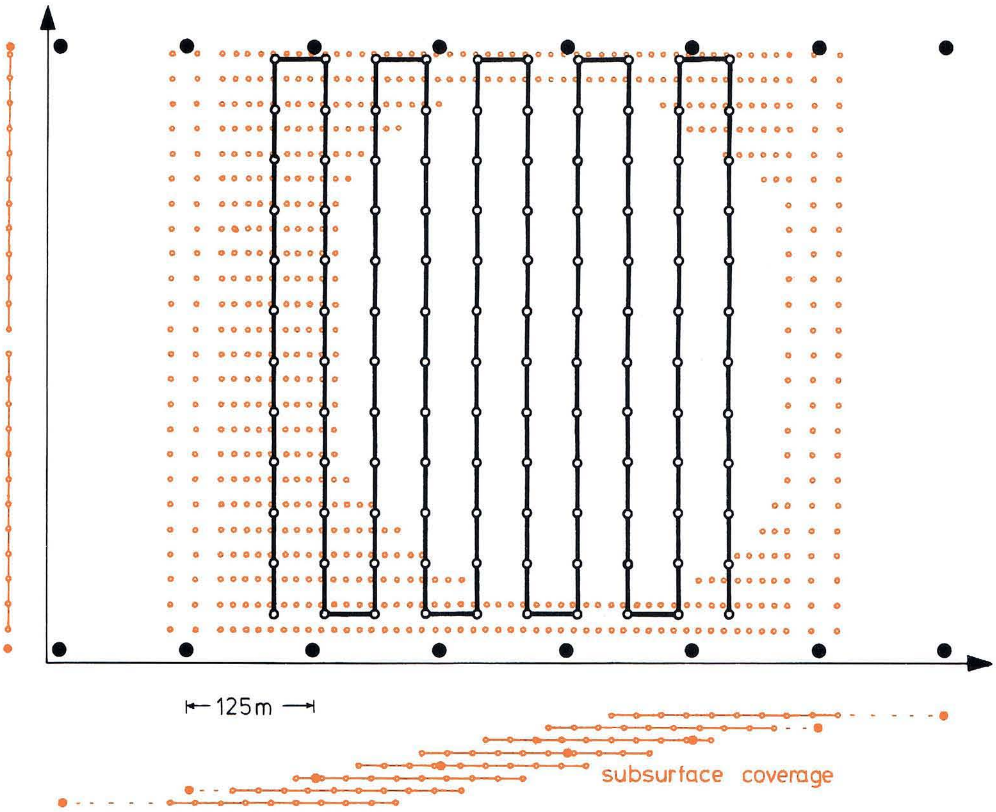
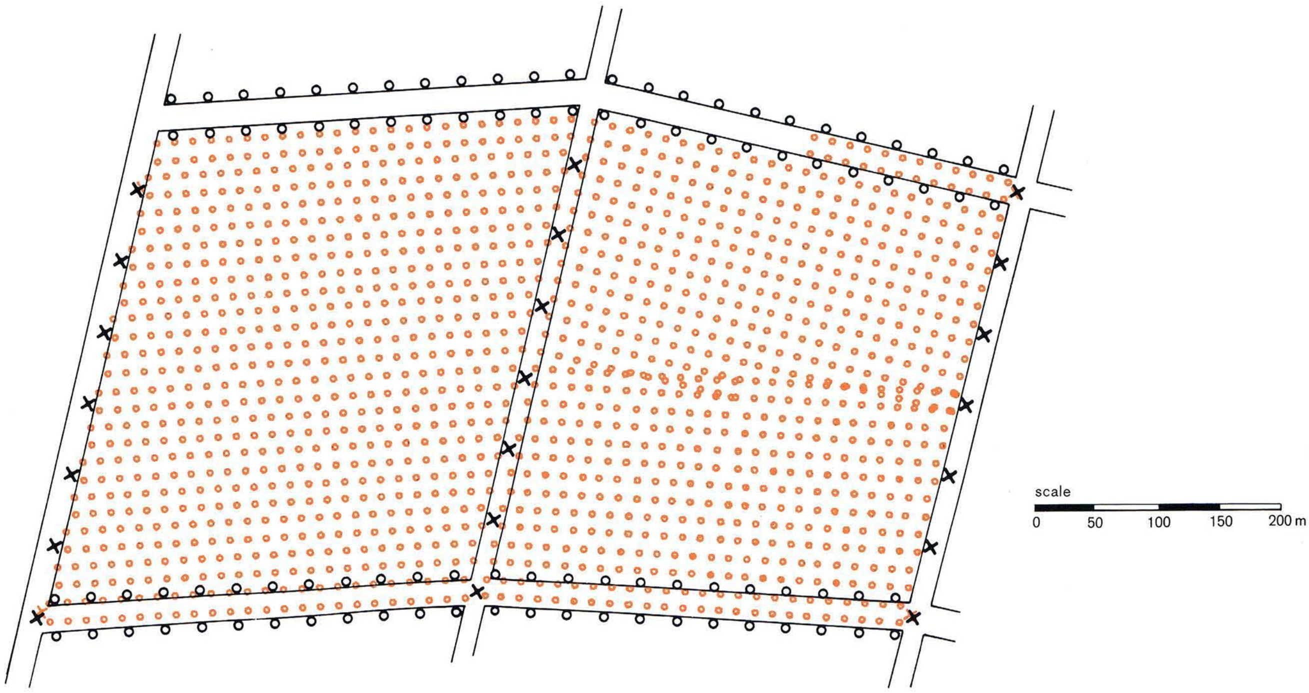


Fig. 5: Frame-Work System, applicable where acess to the survey area is restricted to roads and paths. Receiver and emitter stations are separately arranged on lines which are more or less perpendicular to each other. Coverage in the scheme shown is singlefold. A specific application of this concept is demonstrated in figure 19 (page 11).



The survey arrangement corresponds to the scheme in figure 4 (page 5) and on the cover sheet. The data quality was primarily superior to that shown in figure 1 (page 3). 3-D Finite Difference migration (in the past simply called Wave Equation migration) was applied to all of the 2-fold stacked data points. On this page three stacked sections are shown and the corresponding 3-D (finite difference) migrated vertical sections (figure 7 and figure 8).

The upper right figure 6 shows the lay-out of the geophone pattern applied (3-arm windmill, 18 geophones) and response curves showing the omnidirectional reject power of about – 12 dB.

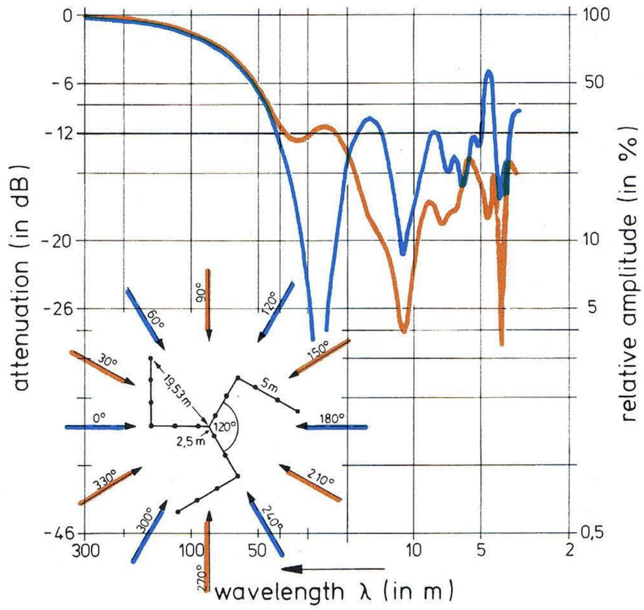


Fig. 6: Layout of the Geophone Pattern

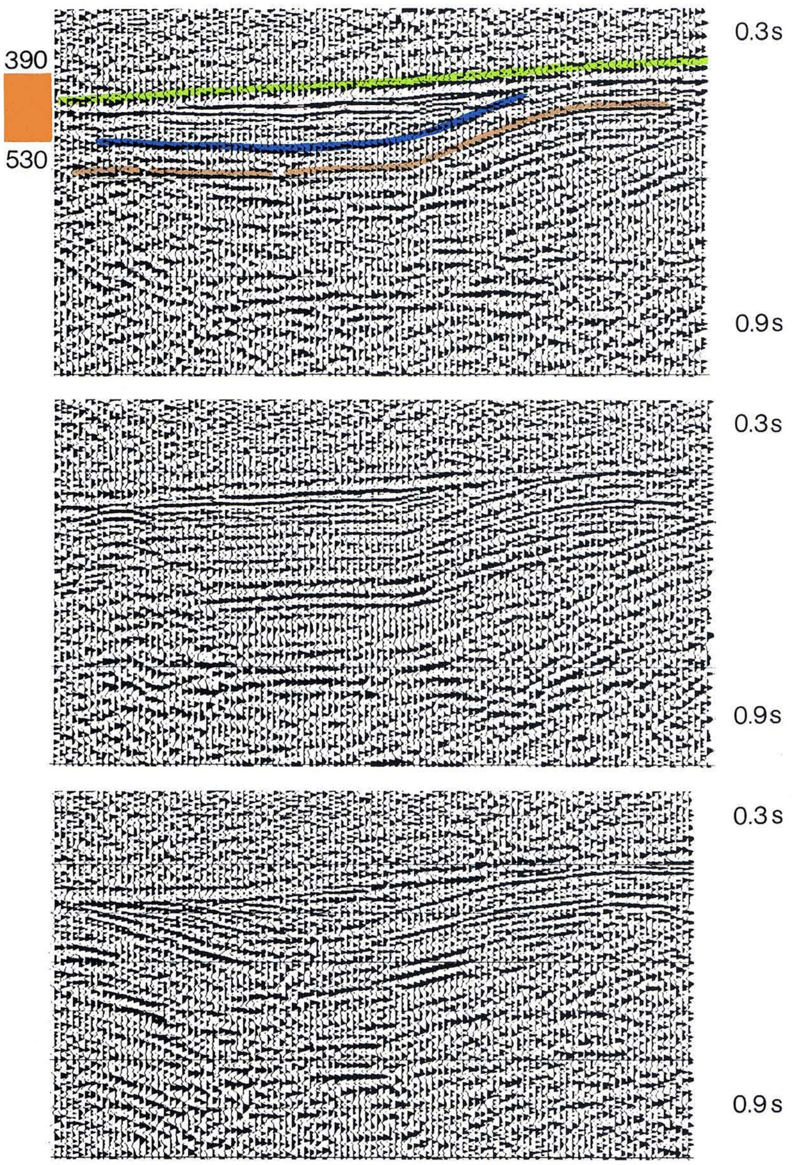


Fig. 7: Stacked Sections

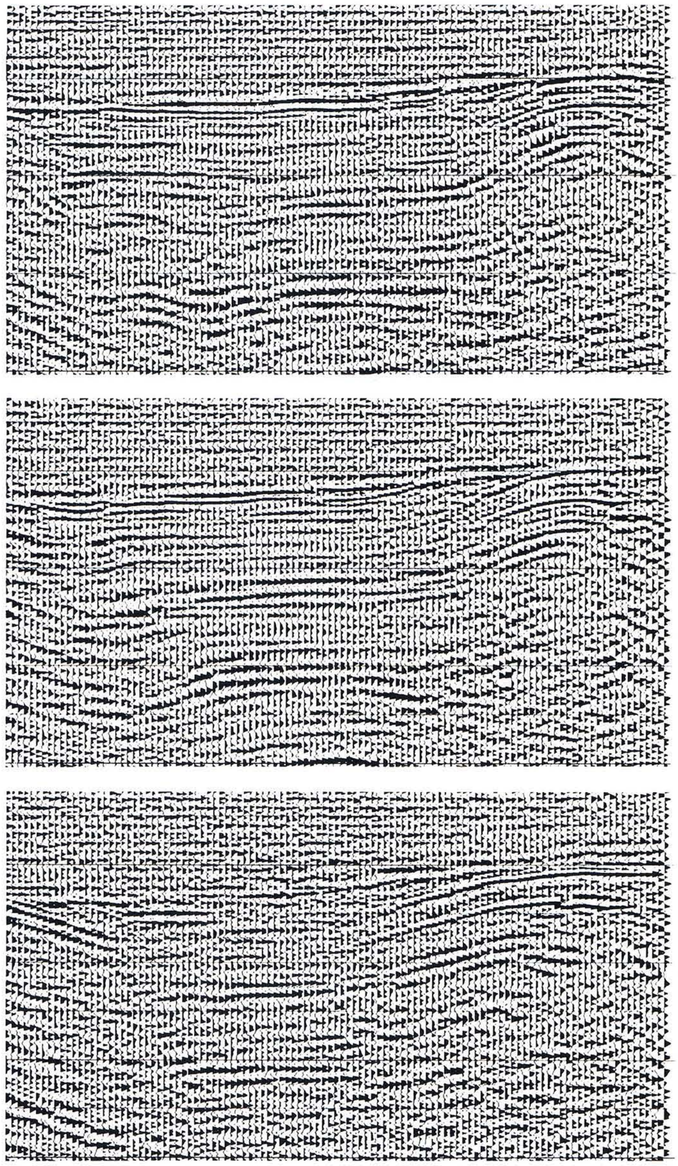


Fig. 8: Migrated Sections

The displays below are a selection of a few horizontal "time-slices" at 20 ms intervals taken from a larger series.
These useful aids to accurate fault interpretation are a by-product of the 3-D Finite Difference migration technique.

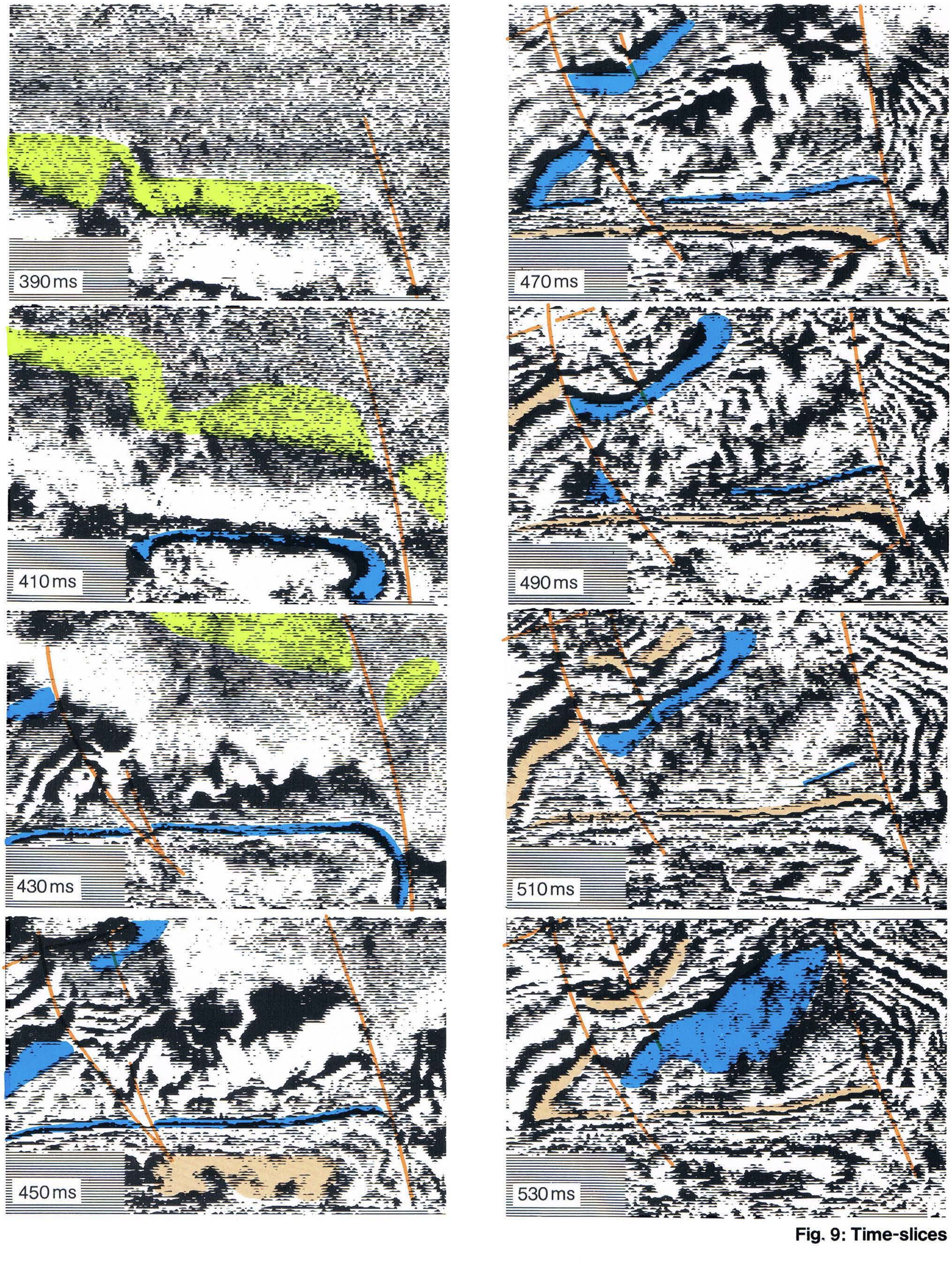


Fig. 9: Time-slices

Example 2: High-Resolution Prospecting

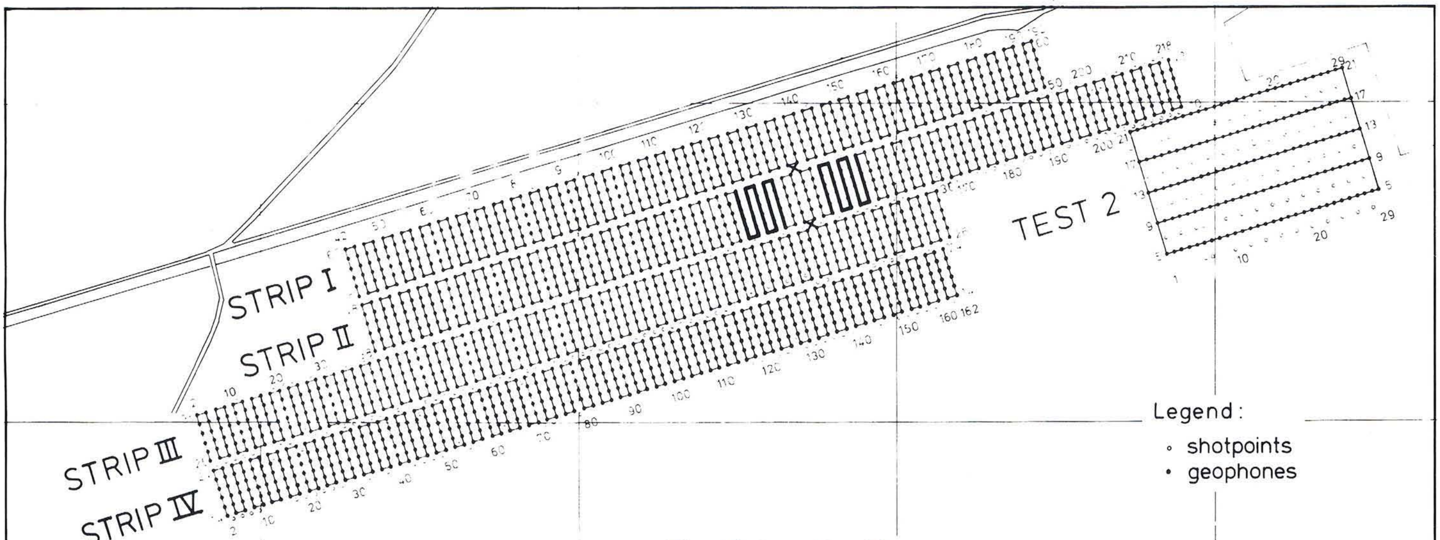


Fig. 10: Location Map

On these pages stages of a high-resolution survey are shown, the target being in the time range of 0.2 to 0.3 s. **The problem to be solved: detection of small faults with throws of only a few metres.** Particular survey parameters were: 5-fold coverage, 1 ms sampling rate using a 60-channel telemetry instrument, bunched 20 Hz geophones, 100 g single-hole charges in 2 m holes sunk with lances. Maximum shot-receiver distance was 255 m, the regular CDP grid spacing was 15 m. The survey area was subdivided into parallel strips of 180 m width. The deconvolved version of a field-record trace shows the resolving power to be expected from this type of survey.

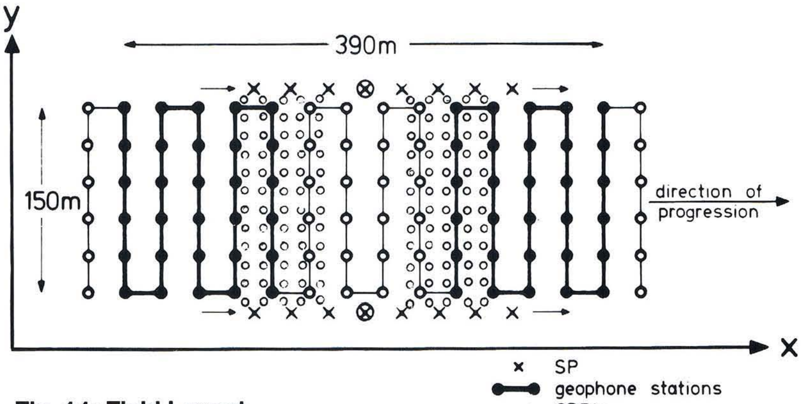


Fig. 11: Field Layout

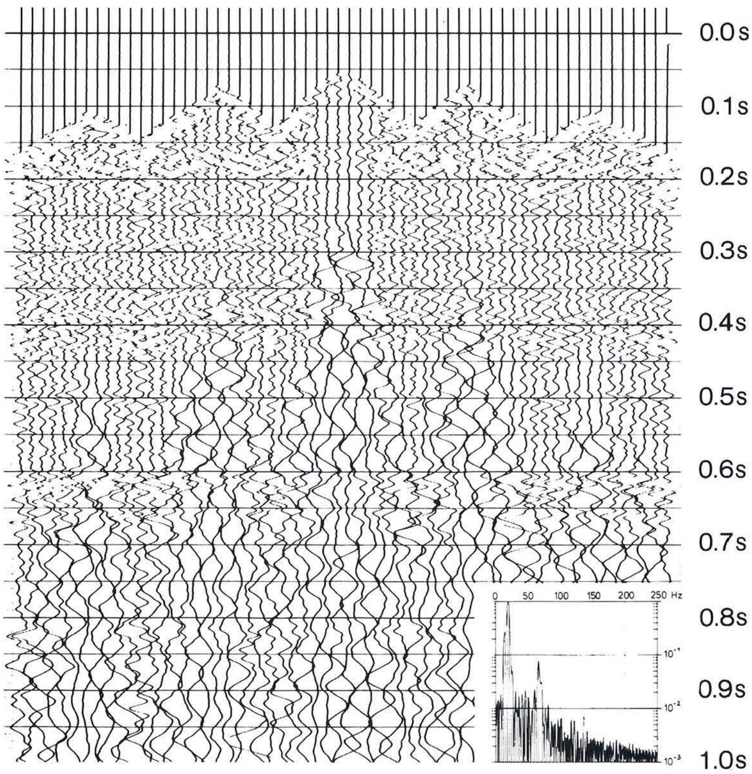


Fig. 12: Field Record

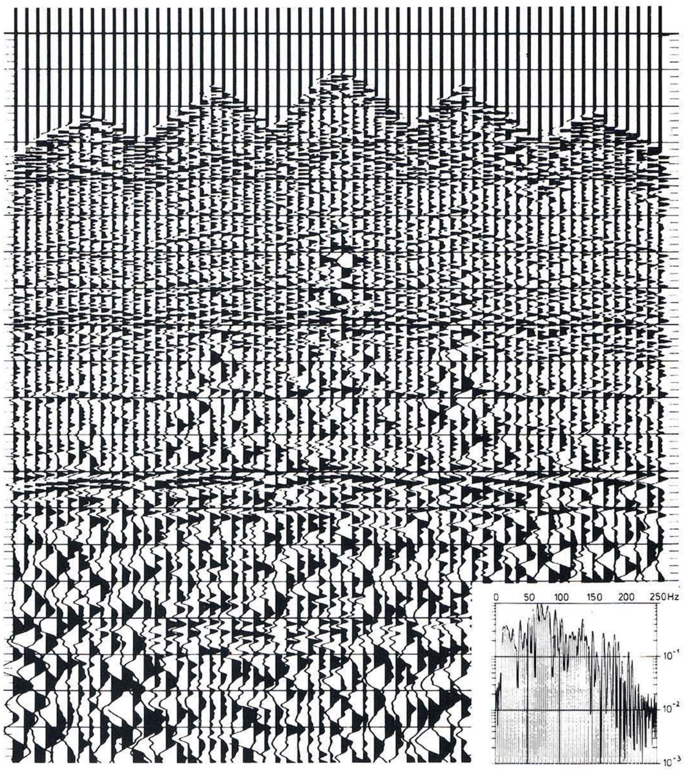


Fig. 13: Field Record with Deconvolution

The portion of a stacked section (figure 14) which includes 3-D residual statics does not show obvious faulting in the shallow range. Intensive faulting is obvious, however, in the time range below 0.8 s (Carboniferous layers), made evident and interpretable in the 3-D (Kirchhoff) migrated section (figure 15).

Post-Carboniferous dragging can be traced back in the overburden layers until about 0.4 s, as becomes evident from the 5x exaggerated version of the whole section (figure 16). The high-frequency content of this signals in the upper range (down to 0.4 s) is from 150 to 200 Hz.

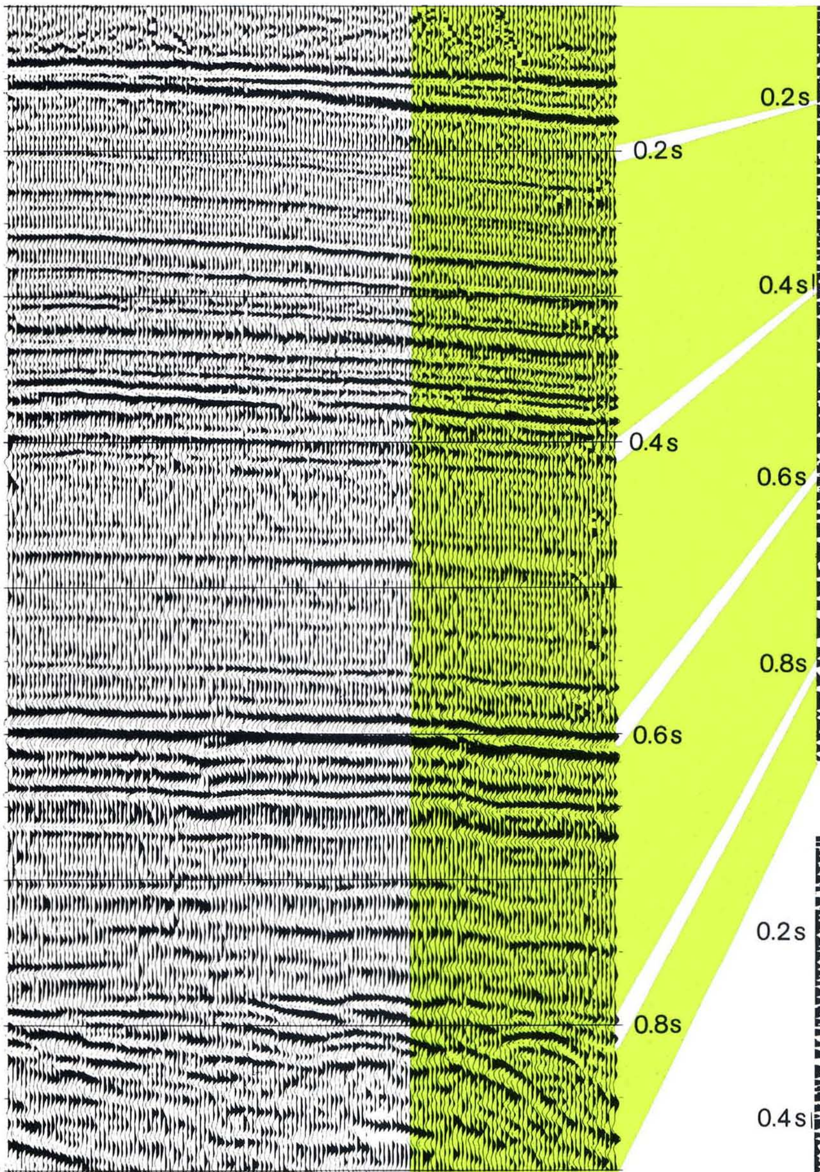


Fig. 16: Exaggerated Stacked Section

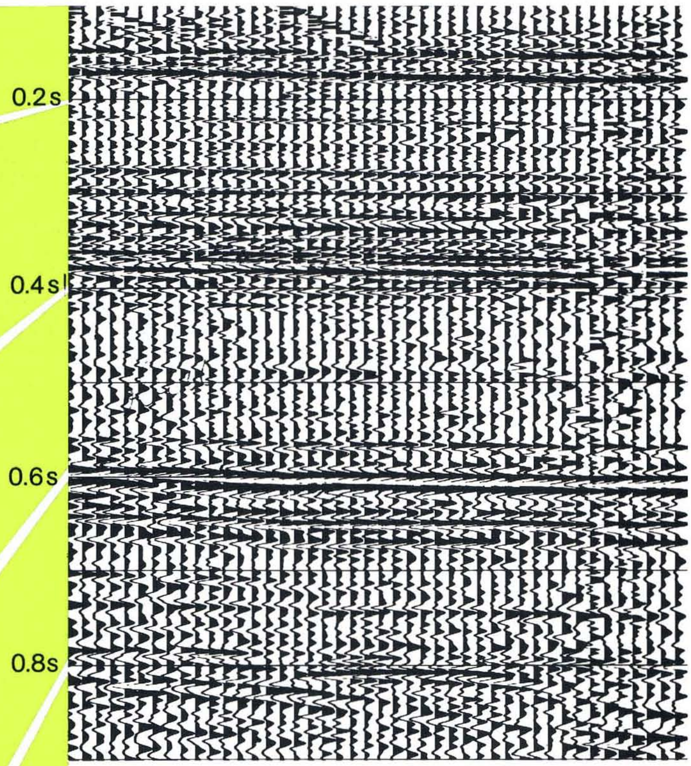


Fig. 14: Stacked Section

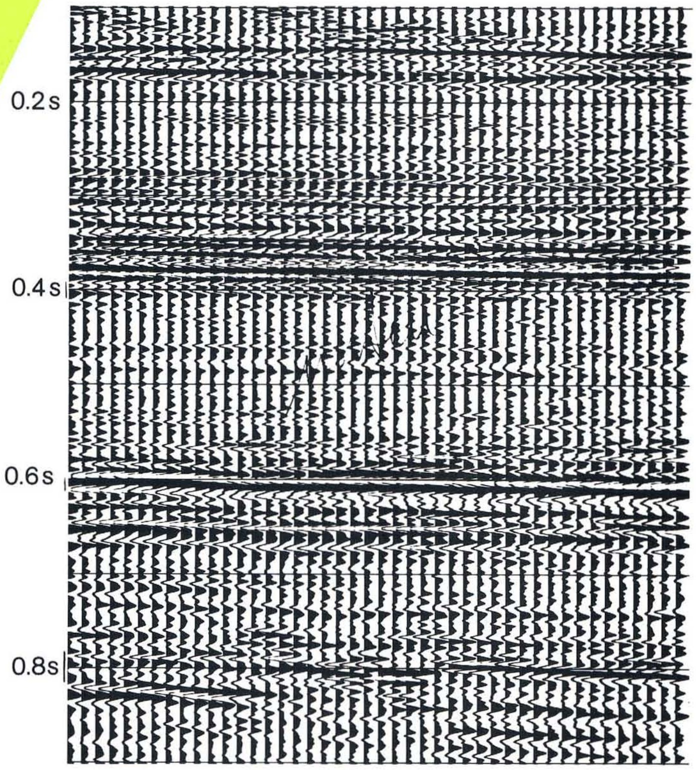


Fig. 15: Migrated Section

Example 3: Prospecting in Mountainous Areas

The concept of the "Ladder-System" used here belongs to the Frame-Work category. It is well suited to the application of VIBROSEIS*: vibrators move anlong accessible roads and paths with moderate indines which correspond to the uprights of a ladder. Receivers are planted along more or less straight "rungs" in the rougher off-road terrain.

An area of 17 km^2 was surveyed with 4-fold coverage within two weeks. Target depth was in the order of 4000 m (~1.7 s). Receiver-group spacing was 80 m, vibrator-station spacing 100 m.

* Trade mark of Continental Oil Company

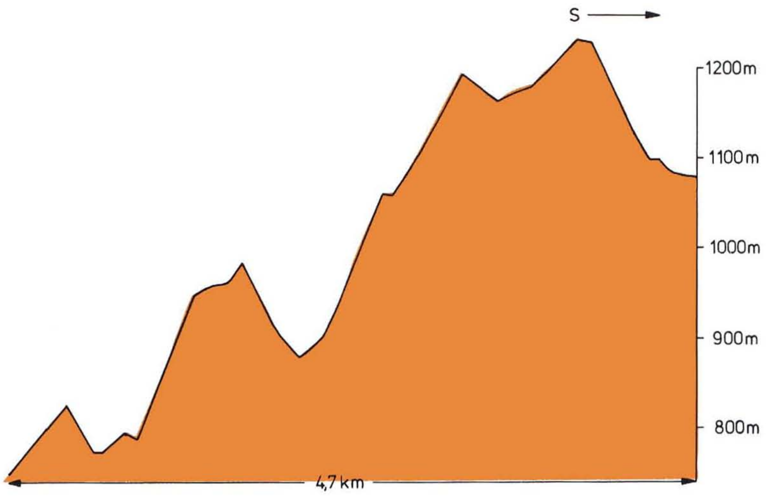


Fig. 17: Relief of geophone line L4

Fig. 18: Scattergram showing the scatter of the subsurface data points, geophone lines L1 to L8, and the vibrator stations.

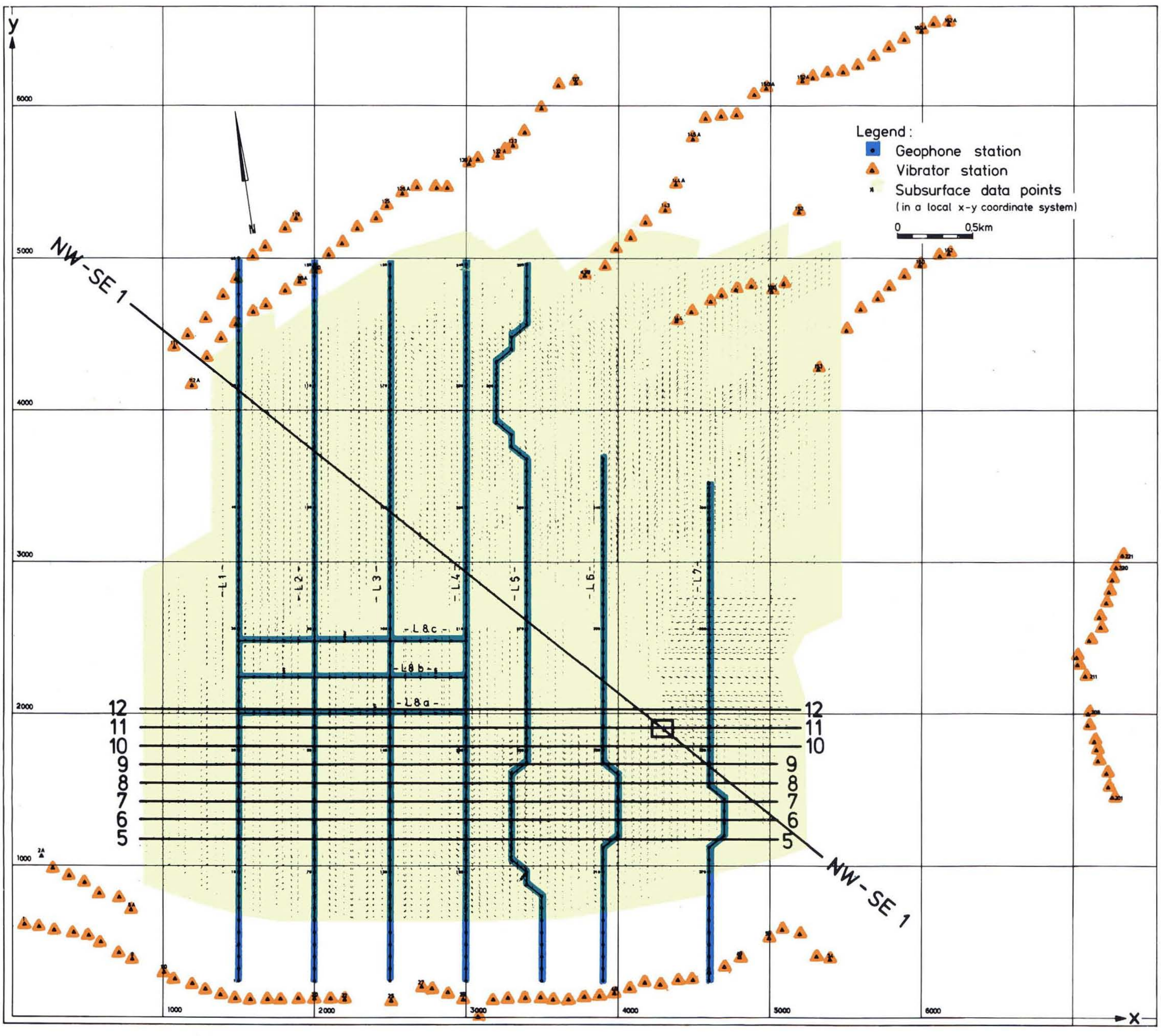
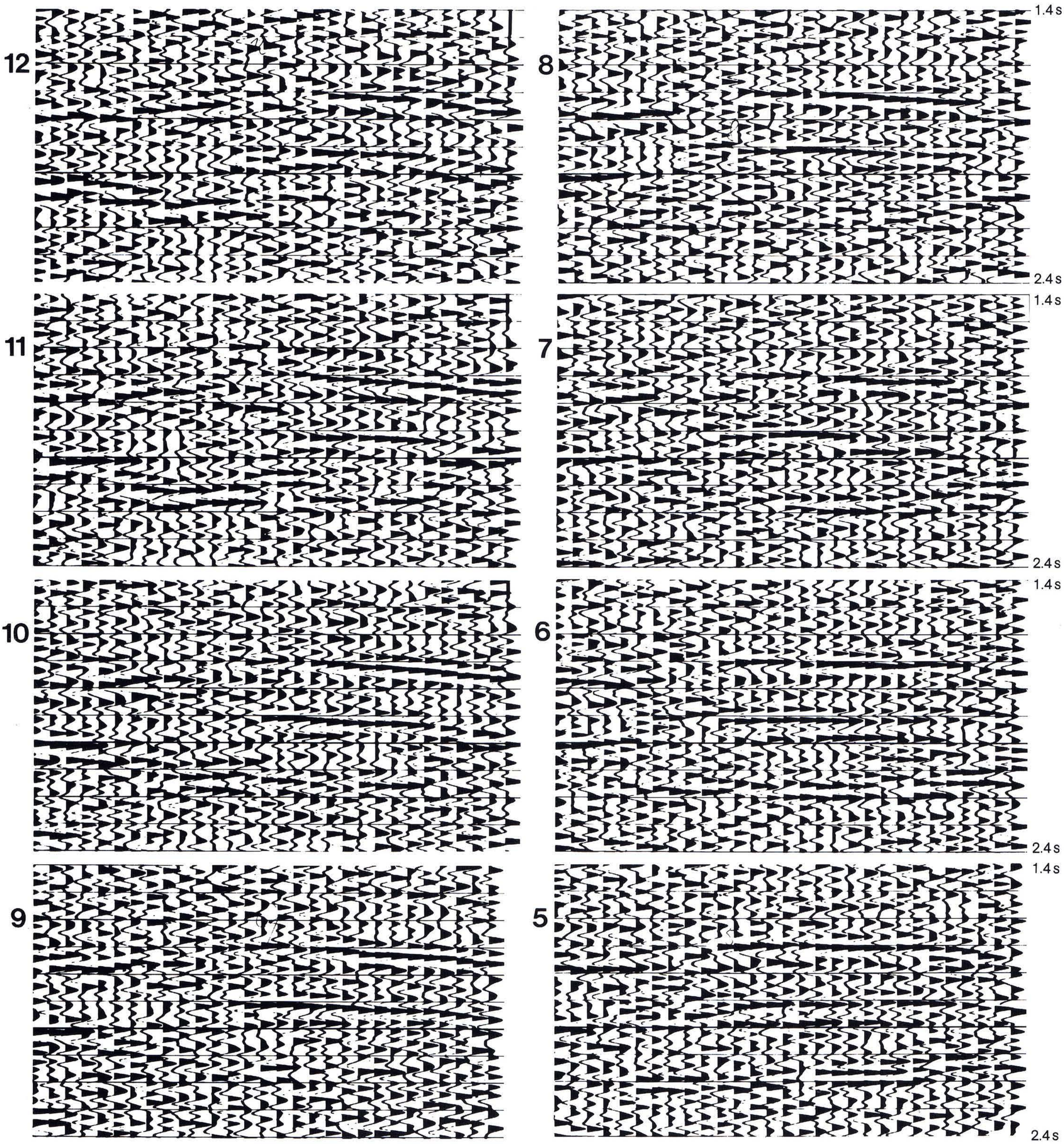


Fig.19: The eight stacked-section portions running E-W (1.4 to 2.4 s) show two distinct horizons with clear fault evidence. Each stacked trace of these sections is a composition of about 36 data points which establish a large "quasi-CDP family", and cover a subsurface area of 120 m x 150 m (see rectangle in the Scattergram).



Example 4: Rhine Survey

Special 3-D survey system as a reply to an unusally challenge (figure 20).

A 6-km section of the meandering River Rhine was covered by an areal survey within one week. The mean degree of coverage was 8-fold. Comprehensive knowledge of the subsurface structure was thus obtained in a former "white zone" in seismic mapping.

The field technique applied: Airgun pops fired at 25 m intervals from a ferry along traverses across the river were recorded by two 48-channel recording instruments, one on each river bank. Four parallel geophone lines in 200 m intervals and with 12 stations each on both river banks were recorded from each SP-traverse, the traverse interval being 100 m. The total number of lines produced was 113, each being 1 km in length, the area convered thus being 5.75 km^2.

Stacking was done in the direction of the geophone lines. The sections shown are the result of re-arrangement parallel to the river (see red lines in the map) and of subsequent 3-D (Kirchhoff) migration (figure 21).

Fig. 20: Location Map with re-arranged sections (red)

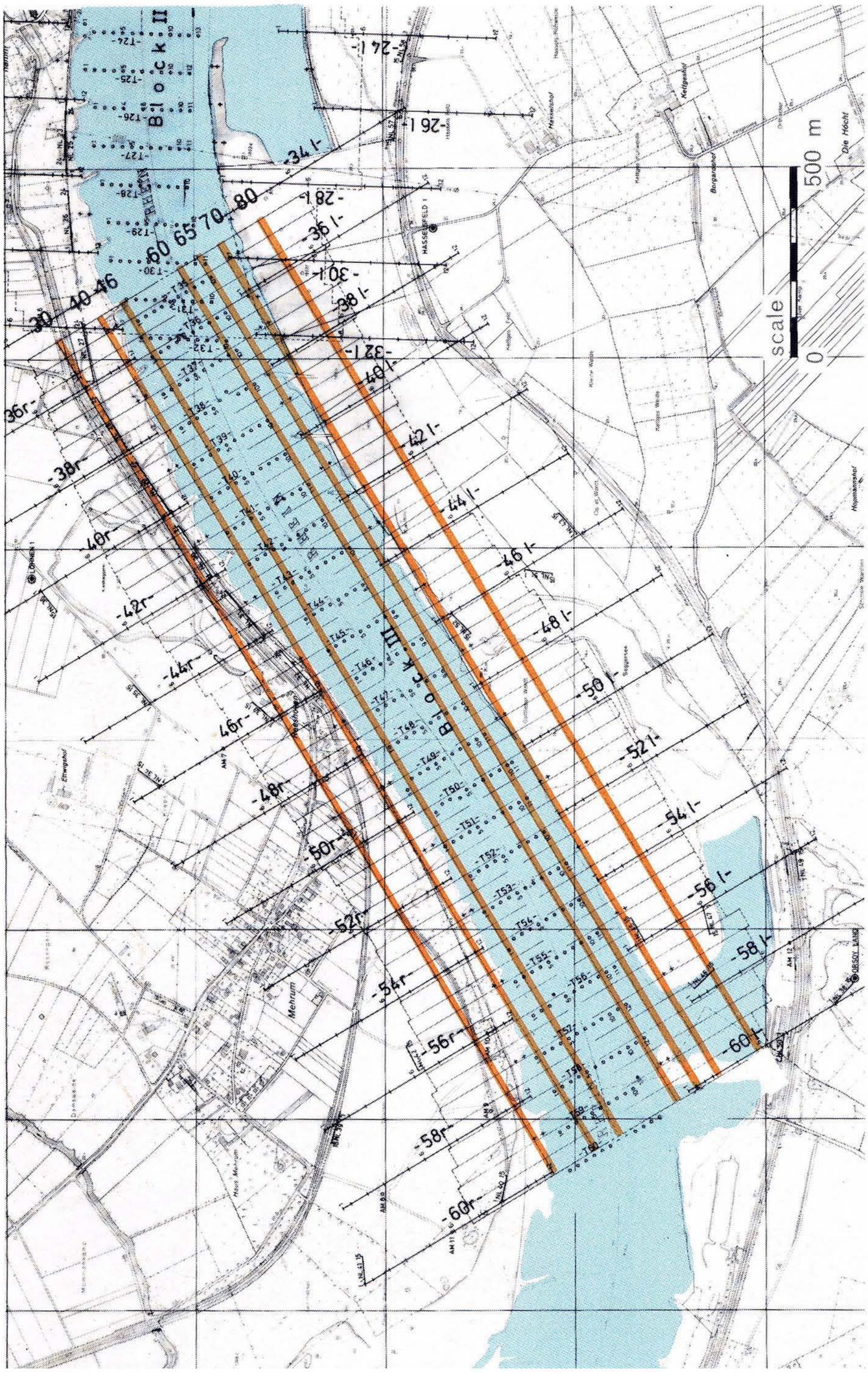
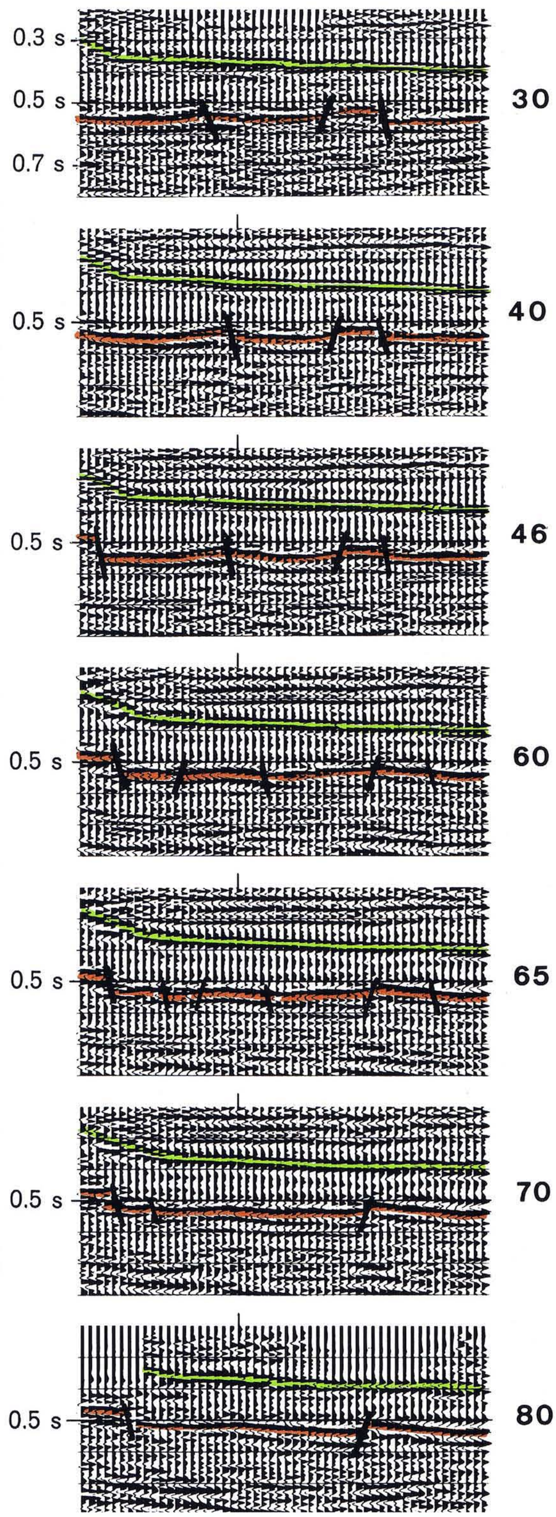


Fig. 21: Migrated Sections



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