PRAKLA-SEISMOS
Report

3
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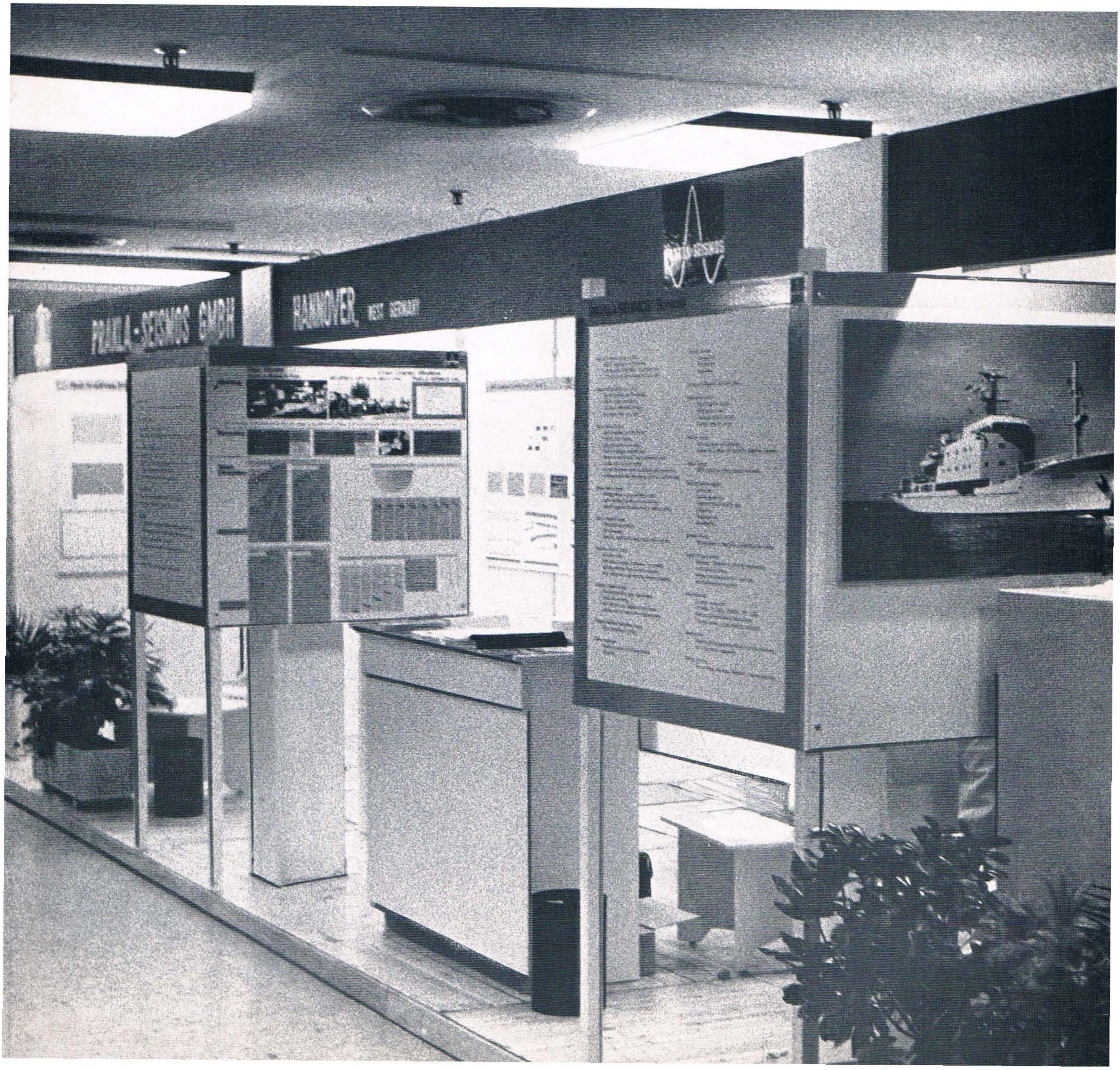
PRAKLA-SEISMOS



THE PRESENT ISSUE 3/74

of our PRAKLA-SEISMOS Report is different from all others before insofar as it contains only one text and only one pictorial report.

At the beginning of 1974, Prof. Dr. Th. Krey read a paper "Modern Aspects in Exploration Seismics" at the "Free University, Berlin (Freie Universität in Berlin) which gave a general view of the modern developments in applied seismics.

Our company had booths at the exhibitions during the EAEG-meeting '74 in Madrid and the SEG-meeting '74 in Dallas with numerous tables displaying our services. Most of theese tables are represented on the following pages the majority of them serving as reference to the themes of Th. Krey's text. Thus, the paper and the pictorial report complement each other in an excellent manner.

H. J. Körner was responsible for the organization of the two exhibition booths. He will report on the EAEG-meeting in our next issue 4/74.

The Editor

Title page: Our Exhibition-booth at the EAEG Meeting '74 in Madrid

Back page: One display-board from our Exhibition-booth in Madrid

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Modern Aspects in Exploration Seismics

If we look back over the time since the introduction of digital seismics, that is the last 8 to 10 years approximately, we note that at the beginning not very many fundamental changes took place. The time domain filter already existed, e. g. the magnetic-delay-line of Seismac. We already had multiple coverage with the required static and dynamic corrections. We had deconvolution in its simplest form, that is the so-called Backus-filter. Of course, with digital seismics all these survey and processing procedures experienced an immediate and significant increase in processing speed and a greater precision. A considerable step ahead, made possible by digital seismics, was the automatic determination of the important parameters in data processing by the digital computer itself. I am thinking mainly of the determination of the deconvolution operator according to Levinson's algorithm by Enders Robinson a. o., of the optimum filter, of the determination of static and dynamic corrections or additional corrections based on correlation – or coherence computations. I mentioned all these things nearly 4 years ago in my paper "Betrachtungen zum Stand der angewandten Seismik" (Observations on the stage of development in applied seismics), which I read in Hannover at a common geophysical colloquium of the Universities of Niedersachsen. Since then quite significant progress has occured or has been initiated, some of which I would like to discuss presently. It was caused by the continued development of the computer with considerably increased storage capacities and computational speed.

To be able to assess the advance in applied seismics within the last 4 to 5 years and to foresee the probable future trend, I would first like to recall the basic object of applied seismics. To my feeling it can be described as

Vibrating

Field Vibrator

PRAKLA-SEISMOS VVB

Cross Country Vibrators

GEOSPACE VSH-10 on Mertz Crab

PRAKLA-SEISMOS VVC

All vibrators with: Automatic digital phase compensator / Reduced environmental disturbance by sound attenuation of 7 db

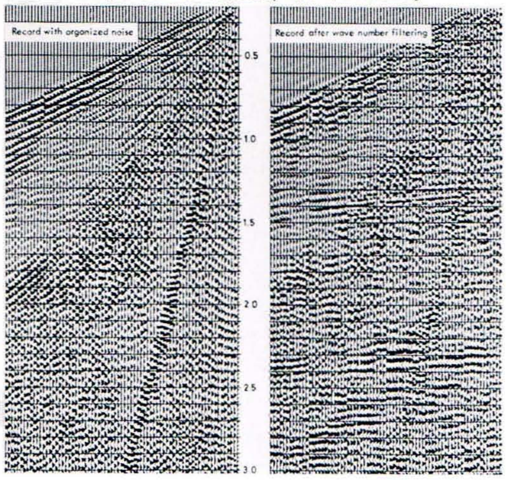
Recording

Data Gathering	Vertical Stacking	Sweep Generation
DFS II Texas Instruments 24 Channels Sampling Rate 2 or 4 ms	ADD-IT - Fixed Point - Mandrel Industries Manual Rejection of noisy records	a) Library Tape b) Sweep Generator Correlation MW-11 (Real Time Geophysics) - 8 bit for sweep - - 8 bit for trace -
DFS IV Texas Instruments 48 Channels Sampling Rate 4 ms 24 Channels Sampling Rate 2 ms	ADD-IT -Inst. Float. Point- Mandrel Industries Automatic Noise Reduction Inverted Stacking	Sweep Generator (Digital Appl. Comp.) (Mandrel Industries) (Pelton) Correlation Model 24 (Quantum Electronics) - 8 bit for sweep - - 8 bit for trace -

Data Gathering + Vertical Stacking + Sweep Generation + Correlation
Extended CFSI
(computerized field system)
Texas Instruments
24 or 48 Channels
Diversity Stack
Fully Correlated Output
to be introduced in autumn 1974

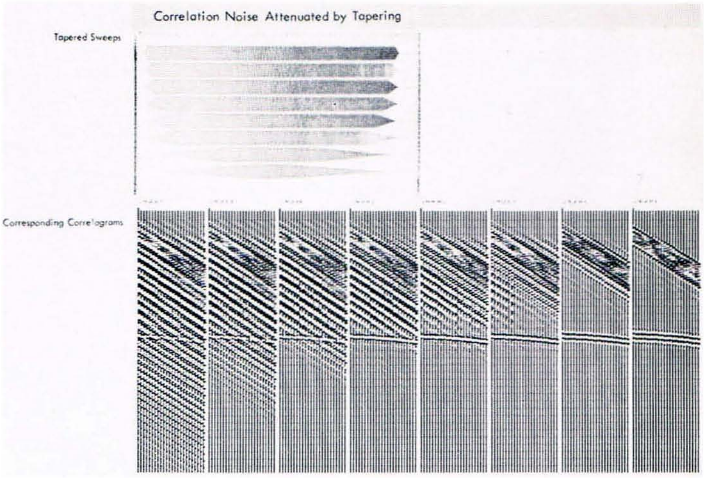
Noise Elimination

Organized Noise Attenuated by Wave Number Filtering

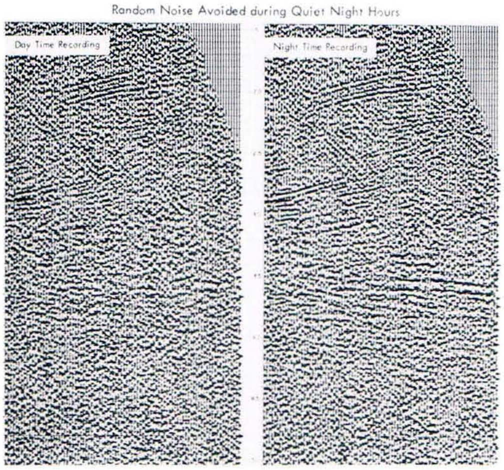


Accurate pattern techniques guarantee optimum wave number filtering

Correlation Noise Attenuated by Tapering

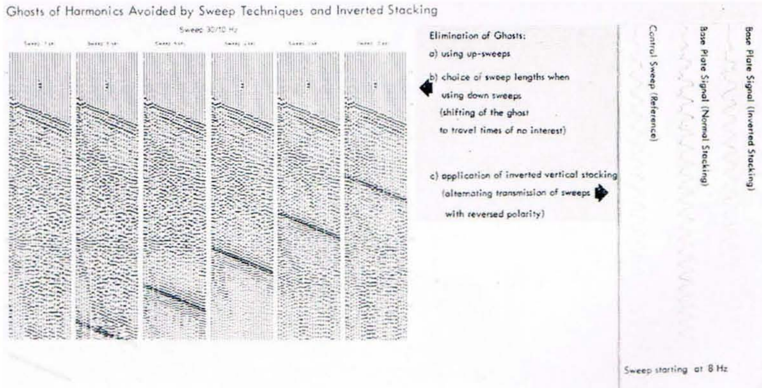


Random Noise Avoided during Quiet Night Hours



Routine in our VIBROSEIS-crews:
- Spread layout during day-time
- Recording during night-hours

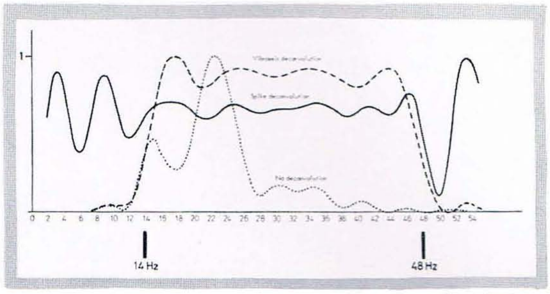
Ghosts of Harmonics Avoided by Sweep Techniques and Inverted Stacking



follows: From a multitude of time functions — here I mean the seismogram traces recorded at the earth's surface — we wish to draw conclusions upon certain properties in the subsurface, those are essentially density and elasticity. That means, we want to determine 1, 2, 3 or more functions in a 3-dimensional space, i. e. in the earth's subsurface. But how many dimensions of observation we have really against these? Firstly we have the time dimension of the seismogram. We have further the possibility to vary independently on the 2-dimensional earth's surface the shotpoint or, expressed more generally, the source of the seismic energy, and the observation point, that is the geophon location. Expressed in another way, if we could effect any arbitrary number of observations, we might be able to obtain a 5-dimensional scope of observations: 2 dimensions for the shot location, 2 dimensions for the geophone location and one time dimension. This should result in a redundancy for the determination of density, both the elastic constants and also anysotropy. We should like to keep this statement in mind for later.

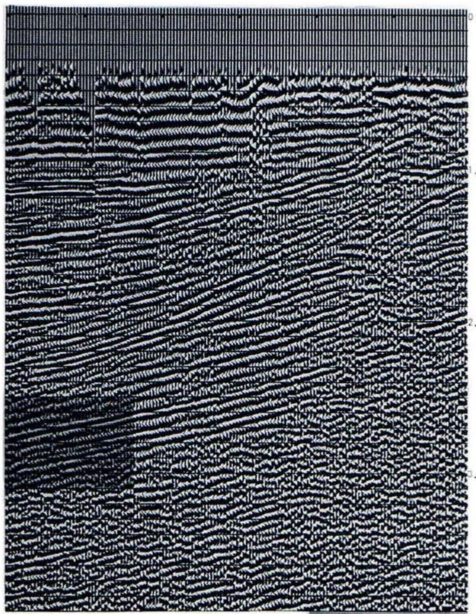
At first we want to restrict ourselves to considering the 2-dimensional case which corresponds more or less to the classical reflection and refraction seismic surveys that have been carried out along certain lines of the earth's surface. With regard to the field surveys, to begin with, a certain perfection has been achieved as to the recording

The New Time-Variant Vibroseis Deconvolution
to be applied after Correlation

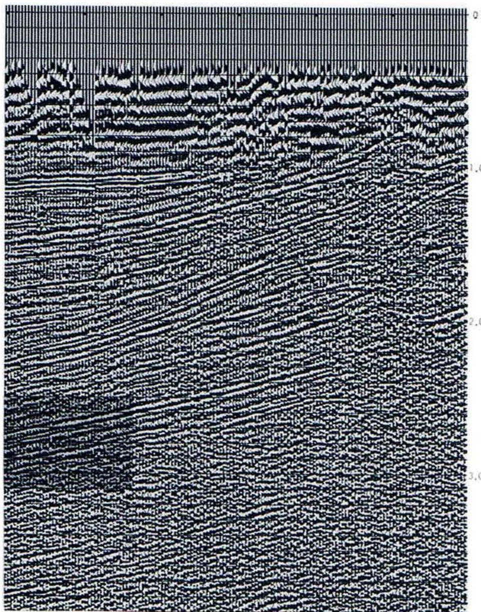


Power Spectra

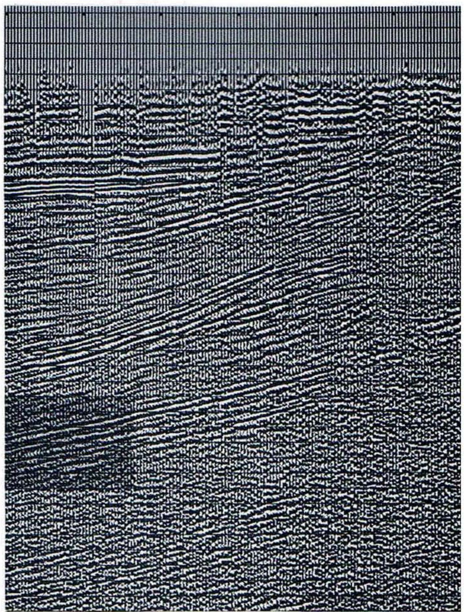
Comparison with Conventional Deconvolution



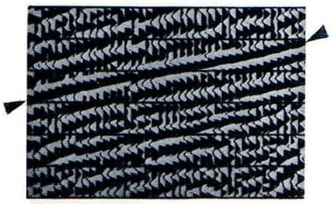
Non-Deconvolved Stack



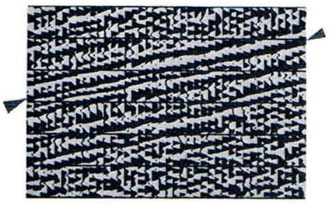
Stack with additional TV-Spike Deconvolution
(applicable to minimum-delay signals only)



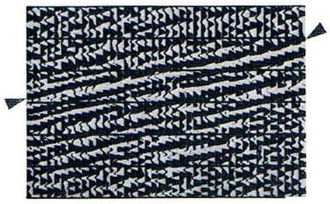
Stack with additional TV-Vibroseis Deconvolution
(applicable to symmetrical signals)



Symmetrical Signals



Emphasis of Pre-Phases



Emphasis of Main-Peaks

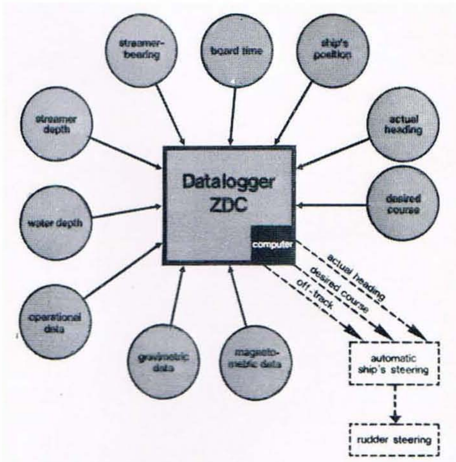
equipment resulting in the Instantaneous-Floating-Point-Amplifier, which as implied by its name, records with a floating point. This recording equipment is fed by so-called digital-grade geophones, that is by geophones whose characteristics have been tailored for the digital recording instruments; here some development is still in progress. The natural frequencies of the geophones are as low nowadays as 8 or 10 Hz to record the low-frequency portion of the seismogram as perfectly as feasible. We will have something to say on the importance of these lower frequencies later on.

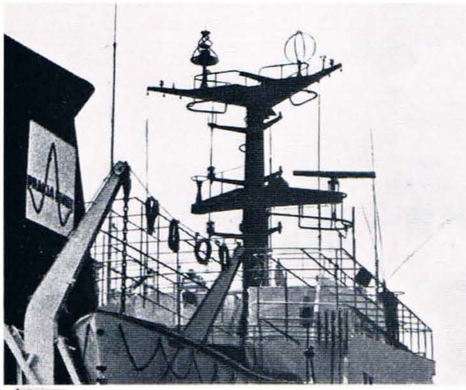
On land, dynamite still remains the modern energy source and it will probably stay this way at those places where it is easy to place the dynamite below the so-called seismic weathered layer, that is down to the ground water level or down into more or less consolidated layers. However, at all those places where this is difficult or where in built-up areas explosives cannot be used, the Vibroseis method is increasingly being used (tables on pages 4 and 5) while at sea air pulsers are predominantly being employed.

To attenuate ambient noise, ground roll, and other undesired waves, a multiplicity of geophones per amplifier have been used for many years. Considerably greater attention has lately been paid to these geophone patterns than in the past and I think this trend will continue in the future. The wave number filter which results from the

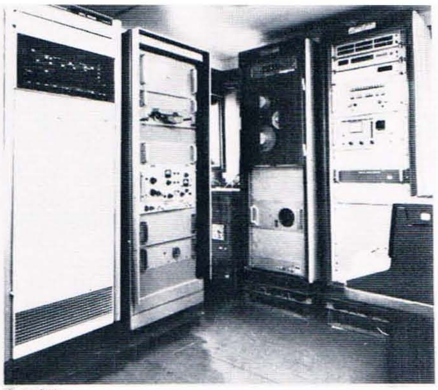
Combined Recording of

Reflection Seismics
Refraction Seismics (Sonobuoy)
Gravimetry
Magnetometry
Bathymetry
Navigation Data (various systems)

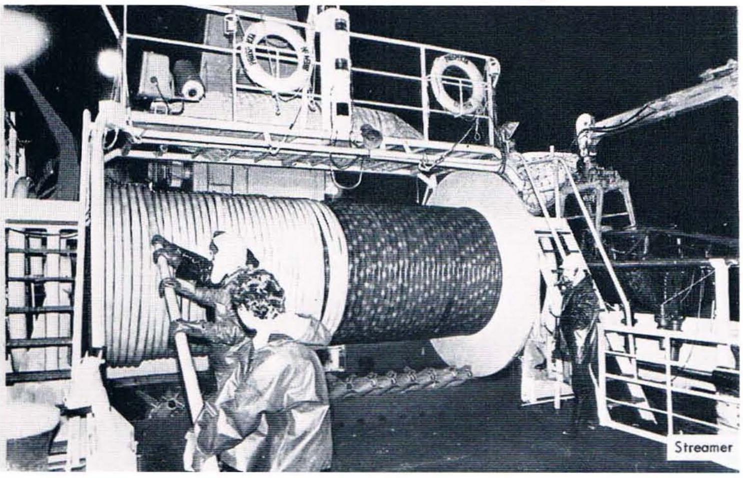




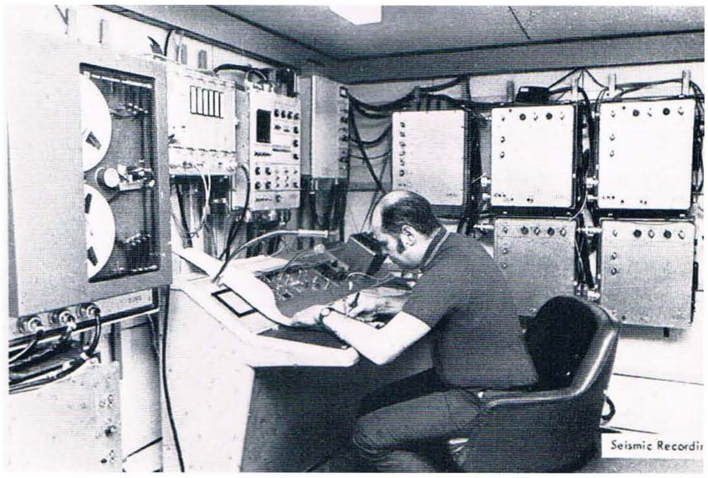
Antennae



Data Logger



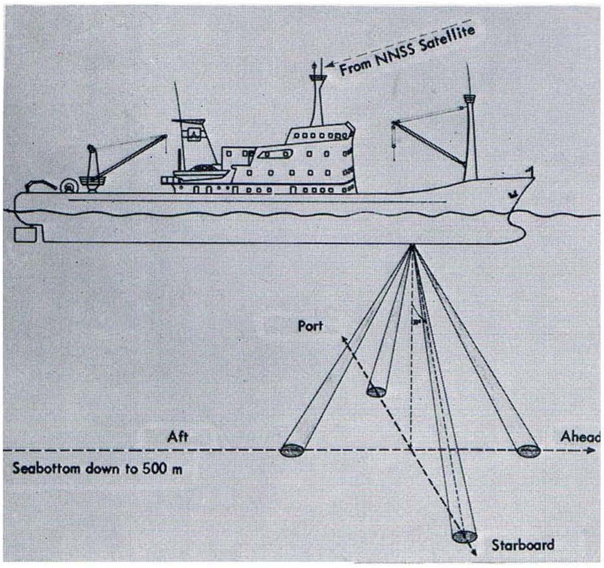
Streamer



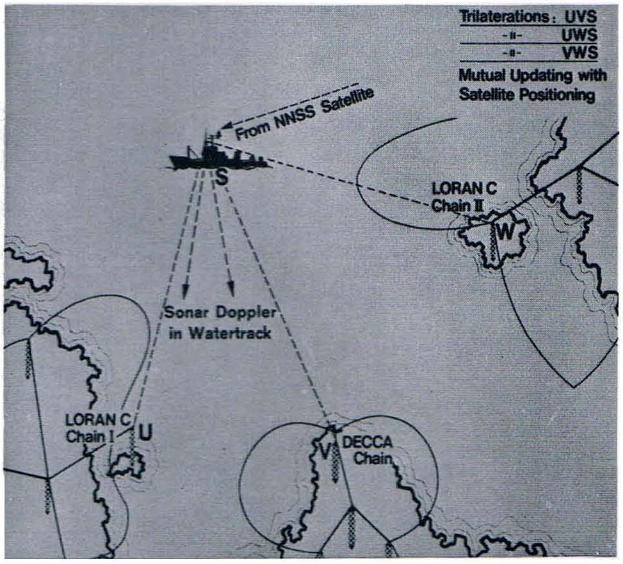
Seismic Recordi

geophone pattern has to be as effective as possible without impairing progress in the field. The same applies to the source of the seismic energy, i. e. the simultaneous shooting from multiple holes and, still more important, the configuration of the vibration points in the Vibroseis system. How the resulting wave-number filter curves may look like nowadays can be seen from figure 1.

Why do we apply such care on the attenuation of noise? The reason is, we need records which are to a high degree free from noise and which contain essentially only the reflections from the subsurface, if the desired physical parameters as e. g. elasticity are to be computed from the seismogram traces. We have already seen in figure 1 that the noise waves can be attenuated down to −40 dB and better. In contrast, the dynamic range of the recording equipment it some 80 to 100 dB. It is therefore desirable that the noise is attenuated to a still higher degree than by the utilization of multiple geophones and multiple energy sources only. This can be achieved essentially by multiple coverage, that is by stacking seismogram traces with common reflection points. This method is known as common-reflection-point-stacking. We should like to recall that in this method the seismogram traces have to be reduced to zero distance between shot and geophone point before the traces are stacked. This time correction is generally denoted as dynamic as it is time-dependent.



For Shelf Areas: INDAS Navigation System integrating
Doppler Sonar
Gyrocompass
Satellite receiver using NNSS Satellites



For Deep Sea: INDAS Navigation System integrating
Doppler Sonar
Gyrocompass
Satellite receiver using NNSS Satellites
ANA receiver using any radio stations available

INDAS (Integrated Navigation and Data Acquisition System) permits self-contained worldwide 24 hour operations.

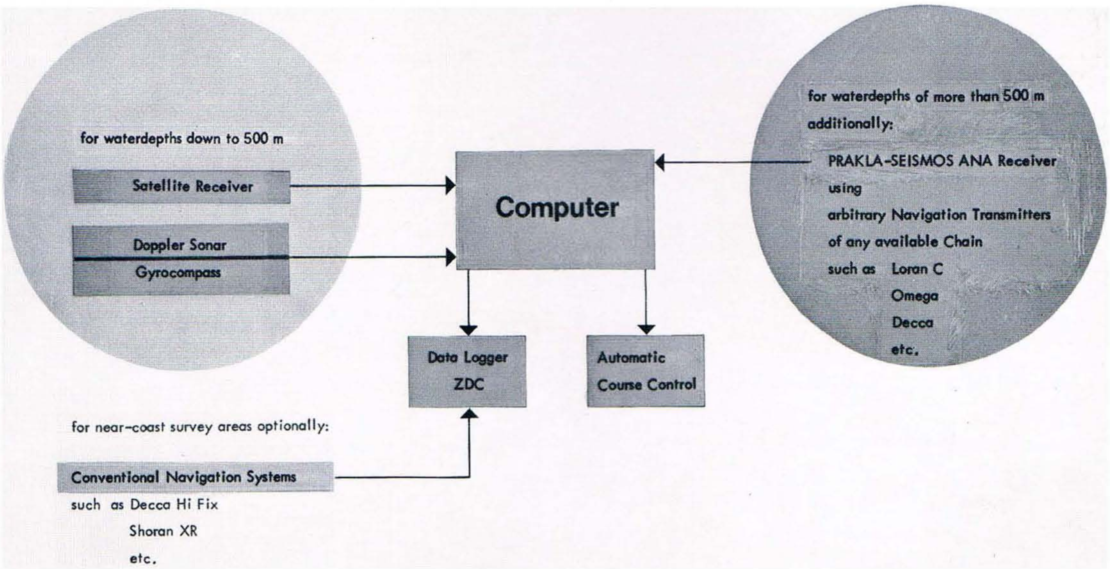
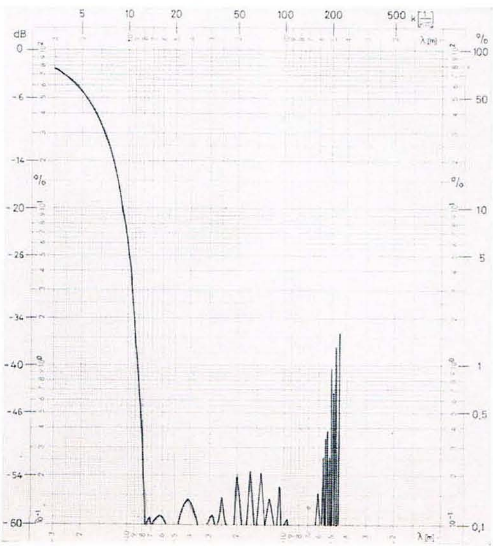


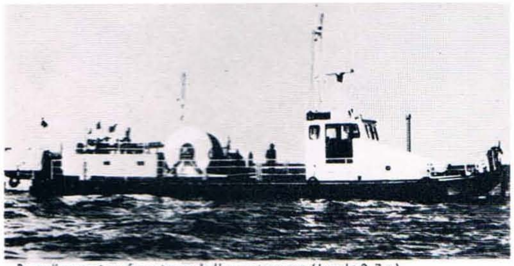
Fig. 1



Today the trend is towards a very large multiplicity in Common-Reflection-Point-Stacking in order to bring out the desired reflections. Previously, 6-fold stacking was considered to be normal on land. Today 12-fold stacking is commonly applied and very often it is extended to 24-fold stacking. In a recent survey, just completed, we applied even 48-fold stacking. At sea, 24-fold stacking is the rule, and very often 48-fold stacking is applied. A further −10 to −20 dB attenuation of noise can quite readily be achieved with such high degrees of stacking.

The Common-Refection-Point-Stacking is, however, not only suitable for the attenuation of ambient noise or of ground roll but it also attacks multiple reflections. This is

Shallow Water Surveys

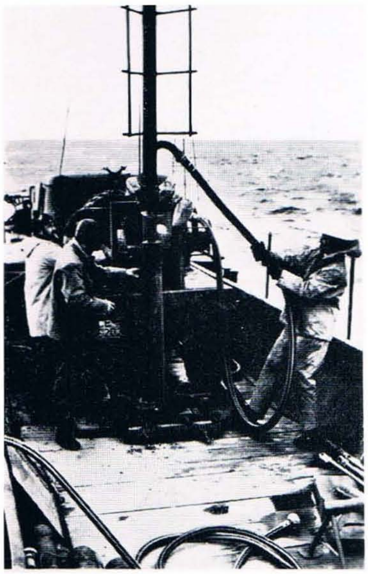


Recording-pontoon for extreme shallow water areas (draught 0.7 m) fully equipped with seismic recording instruments, streamer, radar, Decca positioning systems, echo sounder etc.

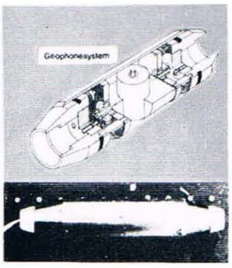
by special shallow water crews
for extensive surveys in coastal waters

by flexible land crews
for extensions of land and/or offshore surveys

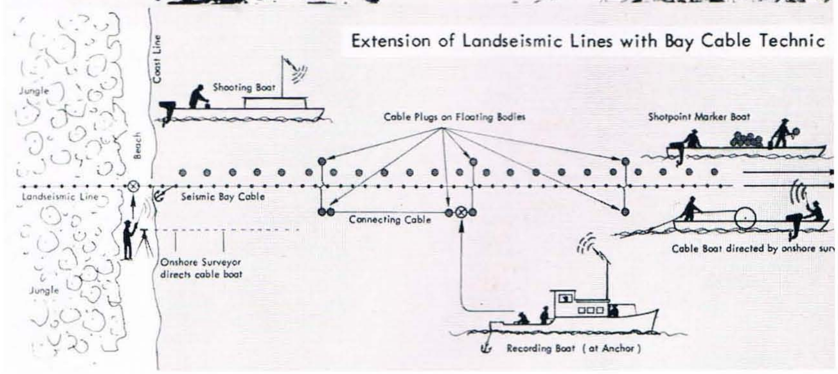
Recording with Catam



Drilling Pontoon



PRAKLA-SEISMOS Geophone HGL
(independent of watercoverage; selforientating)
to be used with bay cable.



Drilling at low tide under extreme working conditions.
Shot will be fired later at high tide.

Working with Hovercraft (here in sand dunes)
for ideal connections between land and offshore s

based on the fact that for multiple reflections the so-called dynamic corrections are commonly larger than those for primary reflections which arrive at the same time.

In many cases however, multiple coverage is not adequate to sufficiently attenuate the multiple reflections. Here the cause could be that the differences in dynamic corrections are too small because the velocity differences in the subsurface are only small, or because the upper horizons are curved concavely upward which significantly reduces the move-out times of the multiple reflections. For all such cases we at PRAKLA-SEISMOS developed an additional data processing procedure, called the Long-Leg-Multiple-Attack method. The process consists in a kind of feedback. As to its fundamental idea and effectivity, see PRAKLA-SEISMOS Report 2/74.

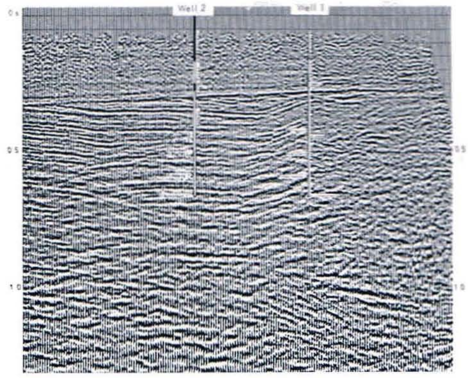
Multiple coverage can also not be sufficient to attenuate the multiple reflections for another reason, i. e. when the reflection coefficients which are inherent in the multiple reflections, are particularly large. This is valid, for example, for multiple reflections that have originated from the sea-floor, especially if we deal with a rather deep sea. In very shallow shelf areas the normal deconvolution process generally suffices to attenuate the sea floor multiples, but it does not in deeper marine basins. Here, too, adequate processes are being developed which will be important in future oil exploration outside the

Surveying with Explosions, Weight Drops or Vibrations for even Shallow Seismic Problems

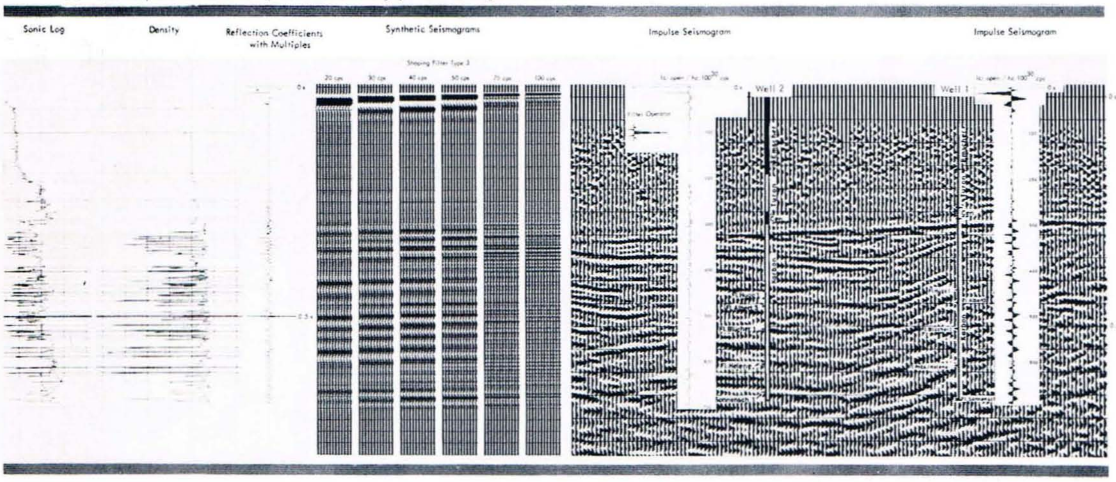
For Coal Mining

Reflection Seismic Surveys from Surface.
Distinctive features are:
- 3 Component Recording,
- High Resolution Technique (sampling rate 1 ms)
- Three Dimensional Recording,
- Vertical and Horizontal Stacking Techniques.

6 fold Stack

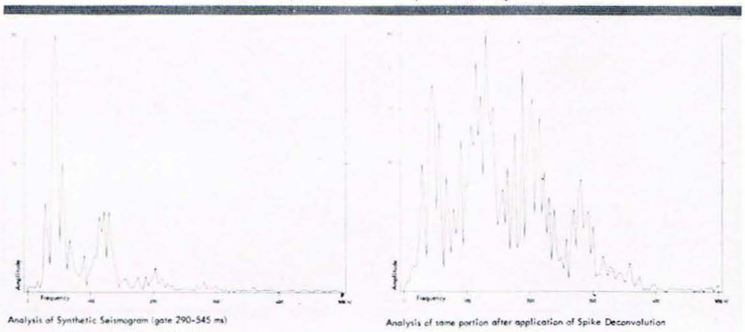


Detailed Interpretation for certain part of sections using synthetic seismograms and others



Processing and Interpretation
- Real Amplitude Processing
- Frequency Analysis
- Correlation Techniques
- Velocity Determinations
- 2D- and 3D-Migration
- Modelling based on Sonic- and Density Logs
  - Profile Sections
  - leading to Synthetic Seismograms
  - Synthetic Profiles

Study of Frequencies of real and synthetic seismograms



Analysis of Synthetic Seismogram (gate 290–545 ms) with Shaping Filter (Type 3, 40 cps)

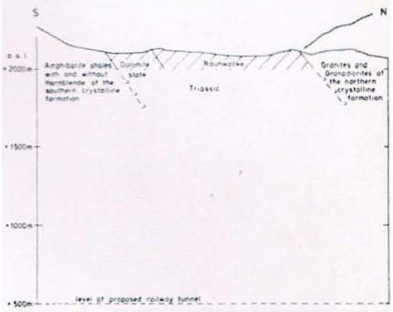
Analysis of same portion after application of Spike Deconvolution

For Tunneling

Combined Reflection and Refraction Seismics from Surface and Underground

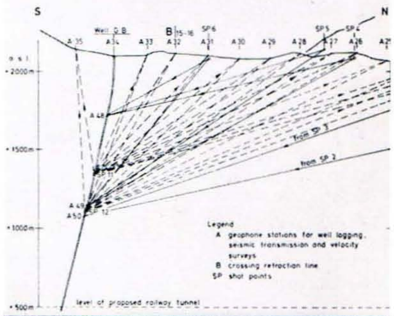
Aim of the Exploration

Definition of a triassic body containing many small caverns, fractures, breccies etc. which are expected to cause water from surface and underground to be encountered in the proposed tunnel.



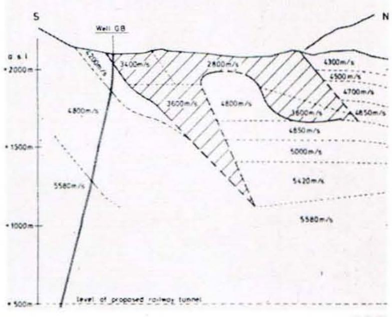
Execution of the Exploration Survey

Combined refraction and seismic transmission surveys, well logging and velocity surveys.



Result of the Exploration

The deliniation of the boundaries was interpreted by employing GARDENER curves using the wave front method and utilizing the HERGLOTZ-WIECHERT method for the determination of a possible maximum increase of velocities in the northern crystalline formation. Assuming a 3 % lesser maximum increase of velocities the triassic body is not expected to reach the level of the proposed tunnel.

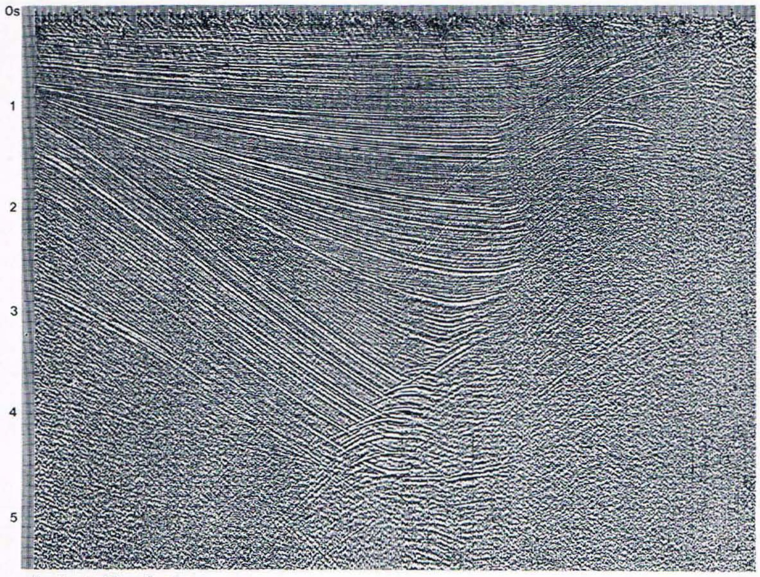


proper shelf areas, and it is to be noted that oil and gas exploration increasingly moves to always greater depths of the sea floor. In the northern North Sea, to the east of the Shetland and Orkney Islands we already have producing oil fields in water depths of 130 and 140 m.

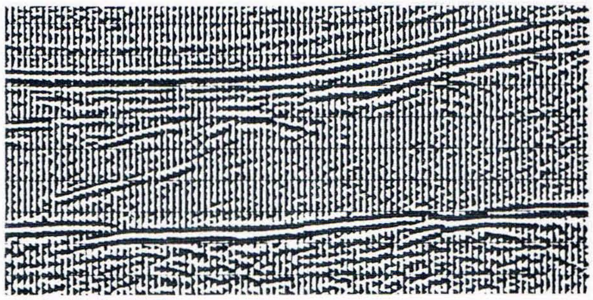
We shall now take it for granted that we were able to produce seismograms which are to a high degree free of noise and also of multiple reflections due to the recording parameters applied in the field or at sea and by the first steps of data processing as e. g. Common-Reflection-Point-Stacking, by deconvolution and by long-leg-multiple-attack. What else can be done with the records? There is primarily the question, where now lie the inhomogeneities in the subsurface which appear in the seismograms. Previously one used to interpret the seismograms or seismogram sections, by marking certain reflection horizons and presenting them at their true position in the subsurface, not only at the right depths, but also with their respective lateral offsets. Expressed in another way, reflections were picked and migrated. For some years already this migration has been carried out directly, proceeding from the stacked seismograms (compare PRAKLA-SEISMOS Reports 1/72, 2/72, 3/72, 4/72, 1/74 and table on page 10).

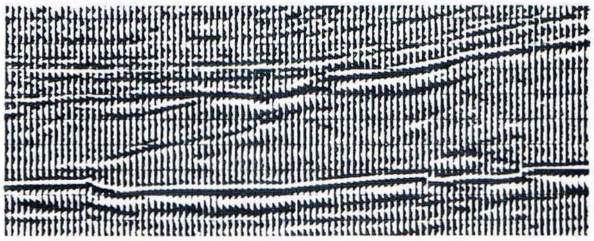
The method of this seismogram migration is based according to Bortfeld simply on a reversal of Huygen's

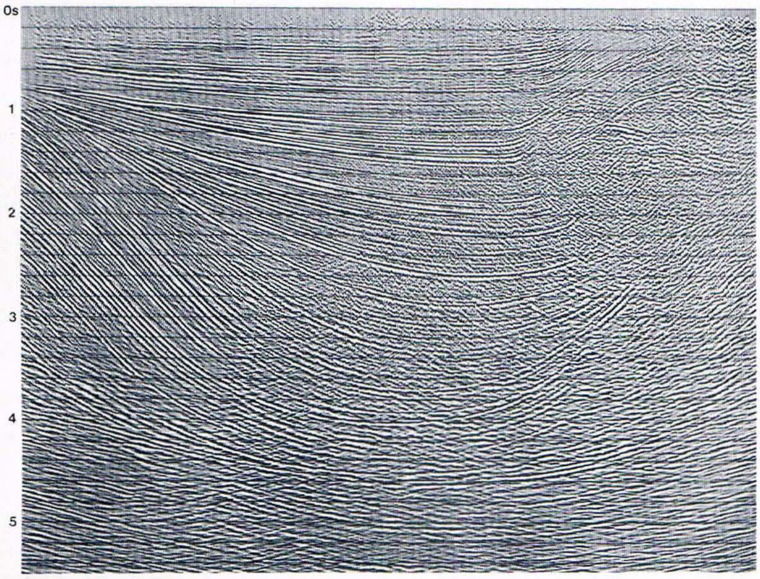
Migration



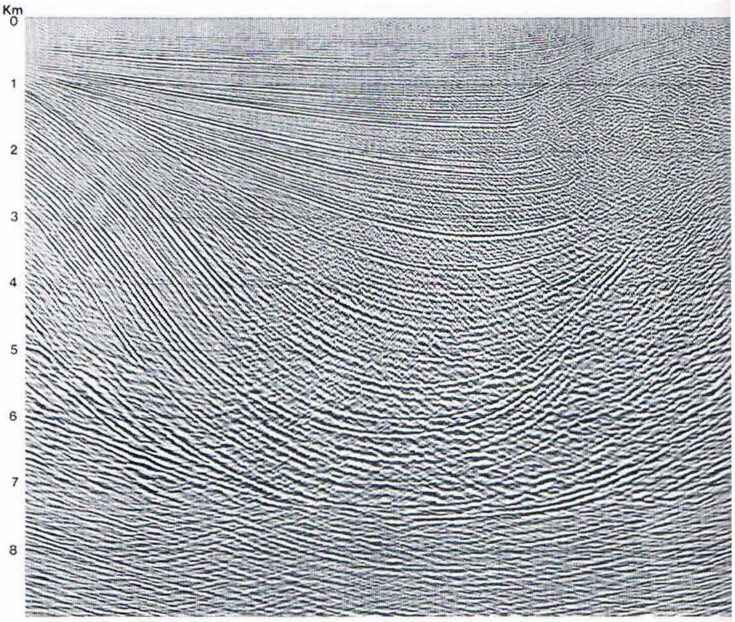
Unmigrated Time Section


Unmigrated Time Section


Migrated Time Section



Migrated Time Section



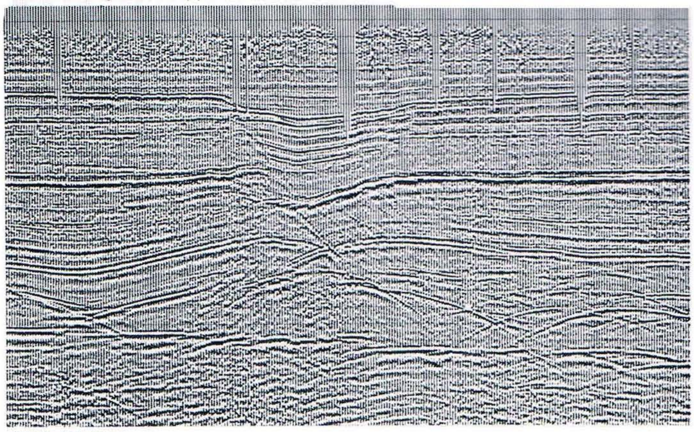
Migrated Depth Section

principle. For this, one divides the area of the depth section into small rectangles. A somewhat similar division already exists in the time domain in the digitally stacked seismogram section, where the values of the trace are entered in time intervals of 2 or 4 ms. Now for each rectangle of the depth section we check which value, that is which sample of a certain seismogram trace could originate in this rectangle as a reflected or rather as a diffracted ray on account of its travel time. This procedure is performed on all traces which are recorded within a certain reach of the little rectangle. 100 traces are commonly considered. All these selected values are now simply added.

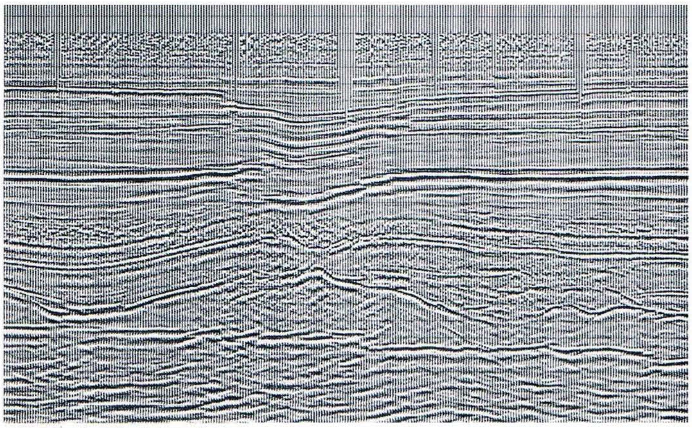
You have probably already noticed that to carry out this process we need to know the velocities in the subsurface. In the simplest case of a constant velocity the samples to be selected in the unmigrated seismogram section lie on a certain hyperbola. Generally, however, these hyperbolae are modified according to the true velocities in the subsurface. They may grow rather complex if dipping or even curved velocity interfaces exist in the overburden. But even here we attempt to surmount the difficulties as can be seen by papers read by Sattlegger, Dohr, and Stiller.

After knowing that a reversal of Huygen's principle by the digital computer can successfully be carried out

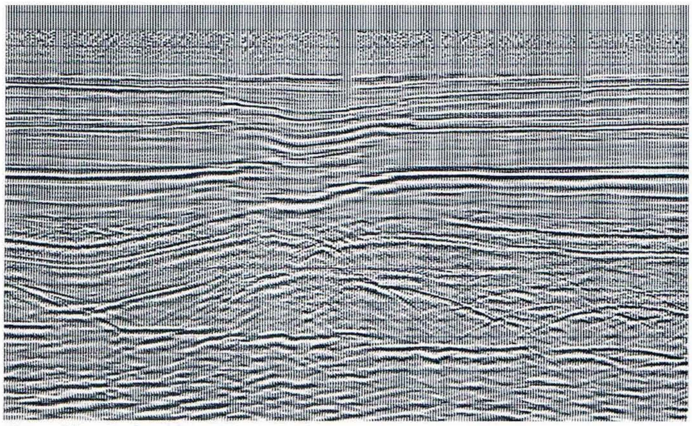
Inverse Migration Applied to Real Sections



Stacked Section

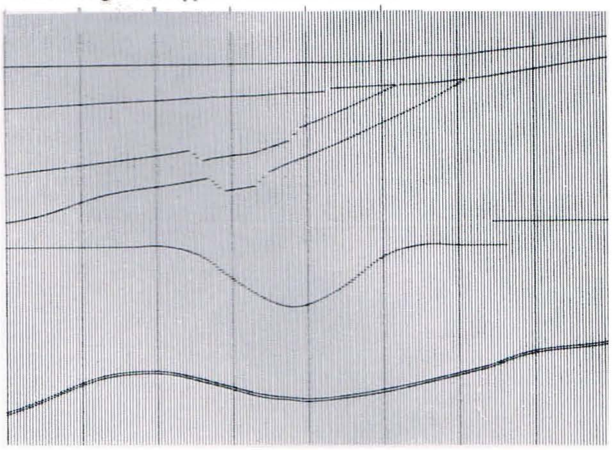


Migration from Stacked Section

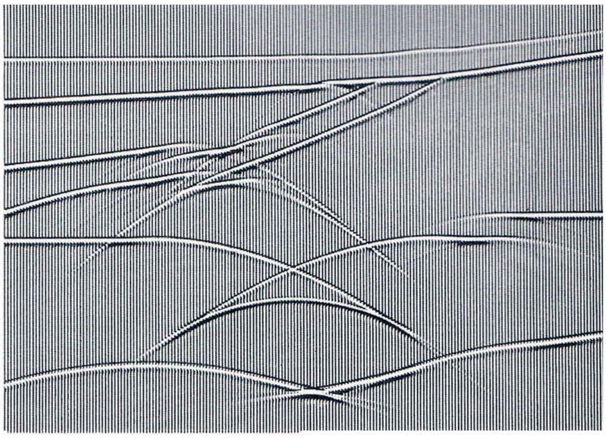


Inverse Migration from Migrated Section

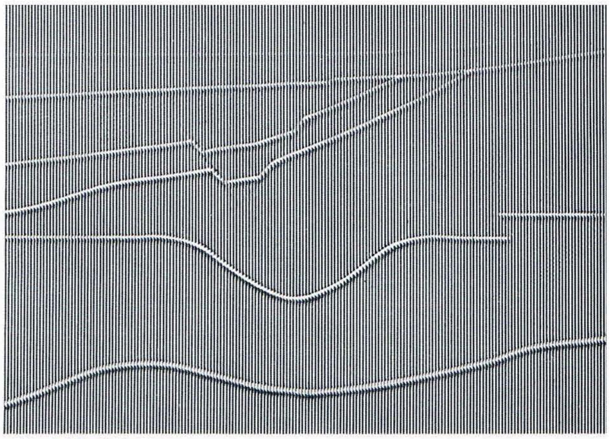
Inverse Migration Applied to Model Sections



Assumed Depth Section (Model)



Time Section gained by Inverse Migration



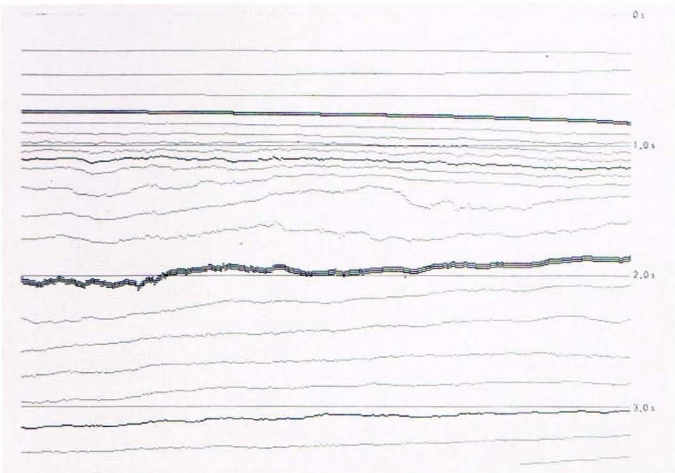
Migrated Depth Section

resulting in a localization of the inhomogenous interfaces in the subsurface from the stacked seismogram sections, the idea was suggested to simulate the corresponding primary process, i. e. the computational determination of the stacked seismogram section if the reflecting interfaces in the subsurface are known. In the PRAKLA-SEISMOS Report 2/72 the result of such a model examination and the subsequent migration is shown which leads, quite satisfactorily, back to the original model (table on this page).

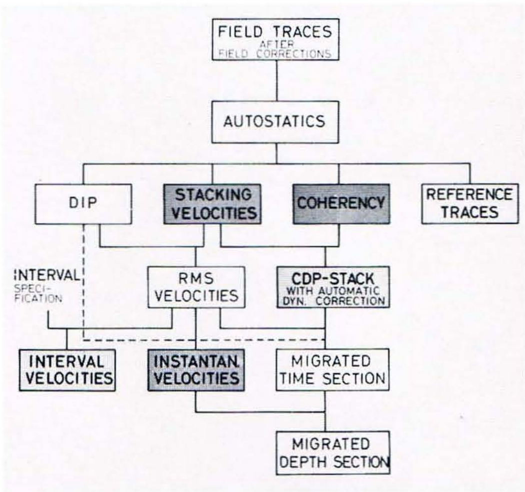
The 2-dimensional migration which I had in mind in my considerations so far assumes that the recorded line runs normal to the strike of all the geologic horizons concerned. This assumption is however, very often not true, not even approximately. Nowadays therefore, the endeavour is to carry out a 3-dimensional, that is a spatial migration. The importance of this development can readily be seen in the table on page 15.

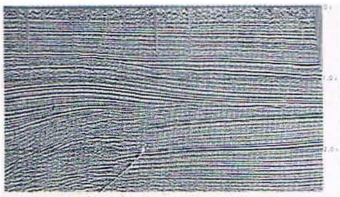
This extension into the third dimension affords no new fundamental idea. While with two dimensions we proceed from a sequence of stacked seismogram traces which are obtained at fixed intervals on a straight line along the earth's surface, one now proceeds from a 2-dimensional manifold of stacked seismogram traces which may belong to the points of a square grid extending over the earth's surface. Further, the hyperbolalike curves, along which we

Continuos Velocity Analysis

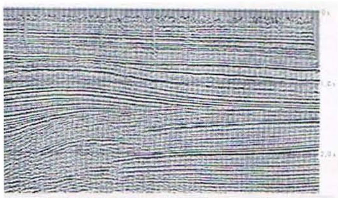


Stacking Velocities

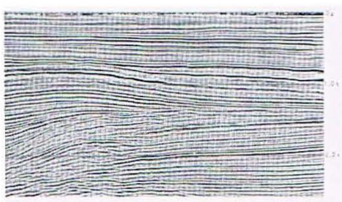




Conventional Stack
(not necessarily inferior to ASP-Stack)

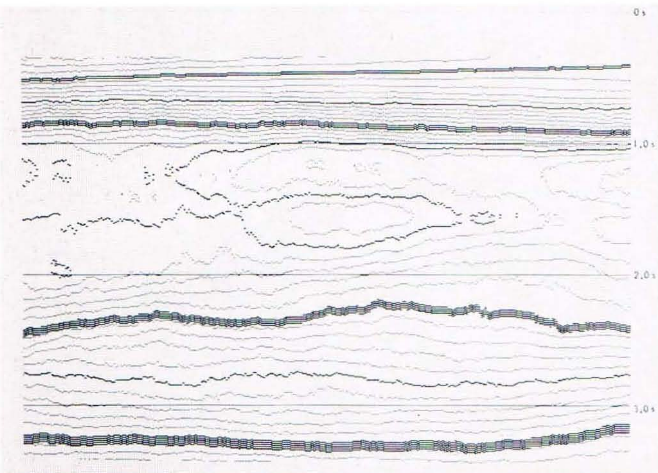


ASP-Stack (Field Statics / ASP-Autodynamics)

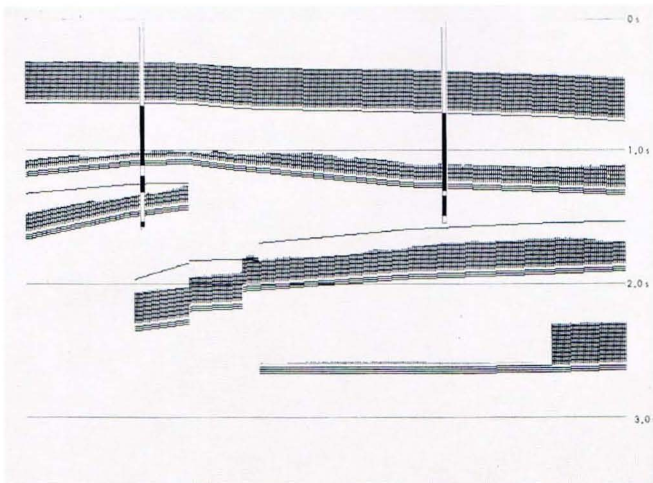


Reference Traces

Coherency



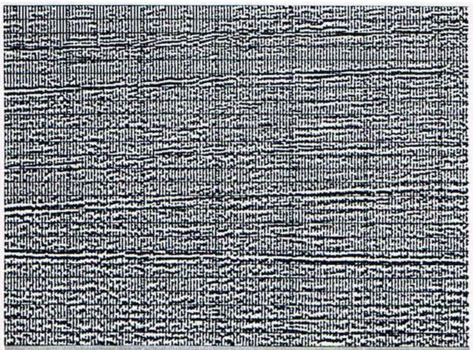
Instantaneous Velocities



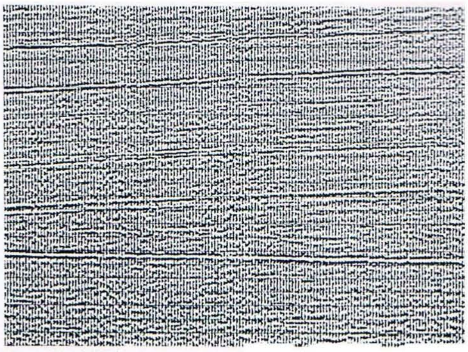
Interval Velocities

add in the case of two dimensions are now replaced by hyperboloid-like surfaces. Spatial migration naturally requires a change in field techniques. Here various suggestions exist. For example, one can lay out the geophones along a straight line and the shotpoints along a zigzag line which covers the geophone line in a wide strip (fig. 2). One can lay out several parallel geophone lines and have the shotpoints or vibration points in the Vibroseis method on one of these lines etc., etc. PRAKLA-SEISMOS uses a most general three dimensional seismic field and data processing system which is part of the so-called extended ASP program. This program which was developed by Bortfeld and his team will be explained later on. According to Bortfeld's design the shotpoints lie at arbitrary lateral distances from the geophone line. A certain width of the whole shot hole strip should however, not be exceeded and a statistical equal-spacing should be aimed at if possible. By this principle one has in built-up areas considerably more possibilities to lay out shotpoints than if one is tied to a fixed scheme. This kind of strip recording and the processing with the extended ASP-program provide as additional values, continuous information on the cross-dip i. e. the reflection time difference per unit length in the direction perpendicular to the line. The expected seismic traces at the above-mentioned grid points can then be computed whereby the necessary data

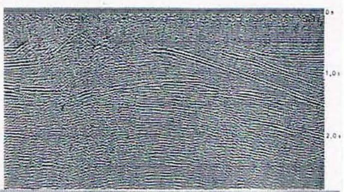
Improved Stacking



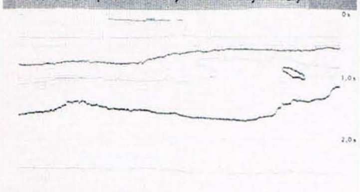
ASP-Coherency-Stack (Field Statics / ASP-Autodynamics)



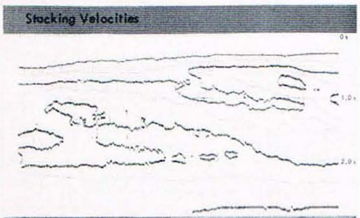
Conventional Stack
(Field Statics + GENT-Autostatics
Dynamics similar to ASP-Autodynamics)



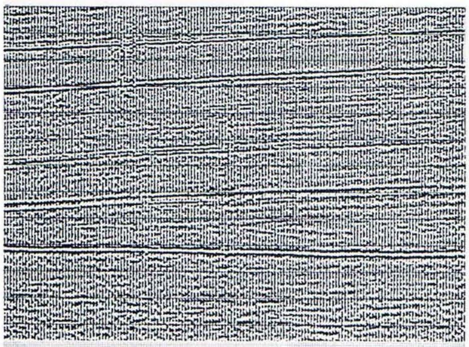
ASP-Stack (Field Statics / ASP-Autodynamics)



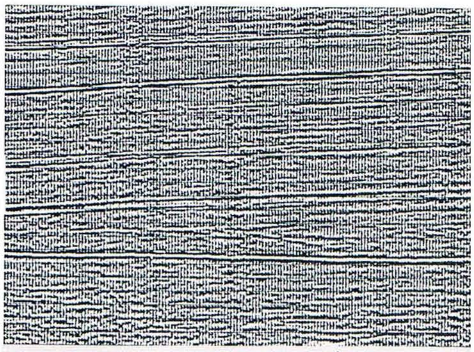
Stacking Velocities



Instantaneous Velocities

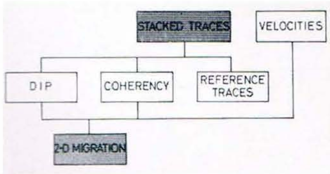


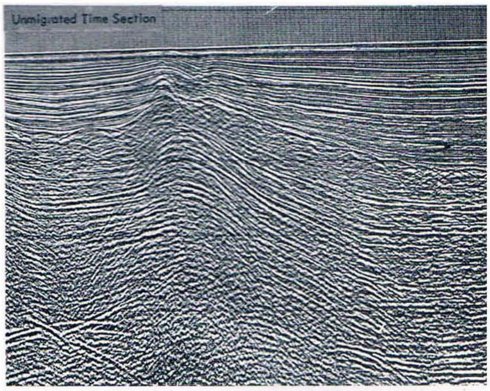
ASP-Coherency-Stack incl. ASP-Autostatics



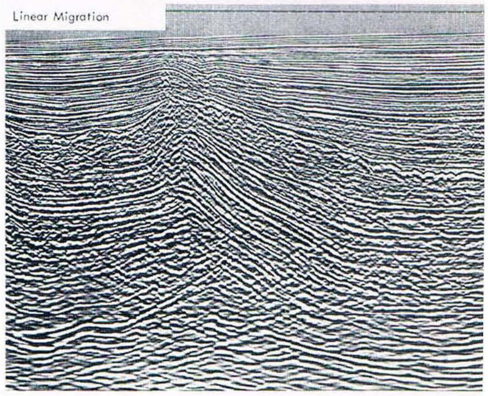
Dip-dependent Weighting of ASP-Coherency-Stack incl. ASP-Autostatics

Two-Dimensional Migration

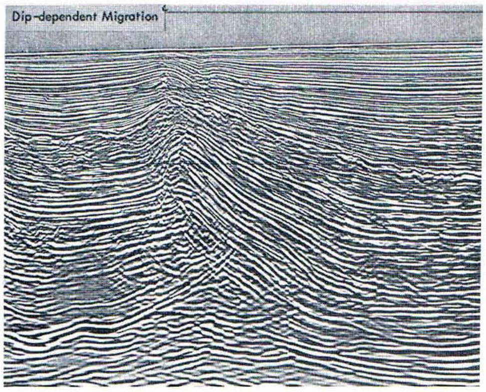




Unmigrated Time Section



Linear Migration



Dip-dependent Migration

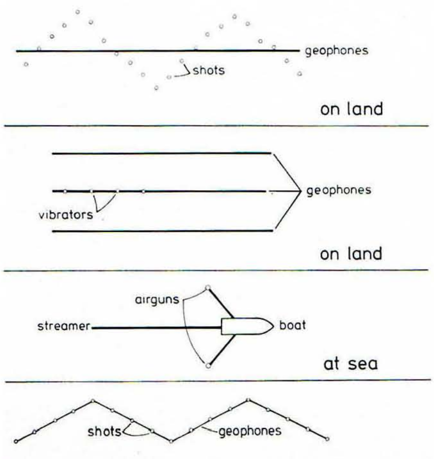
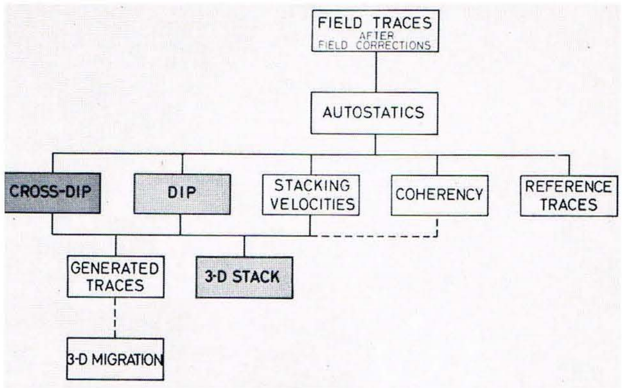


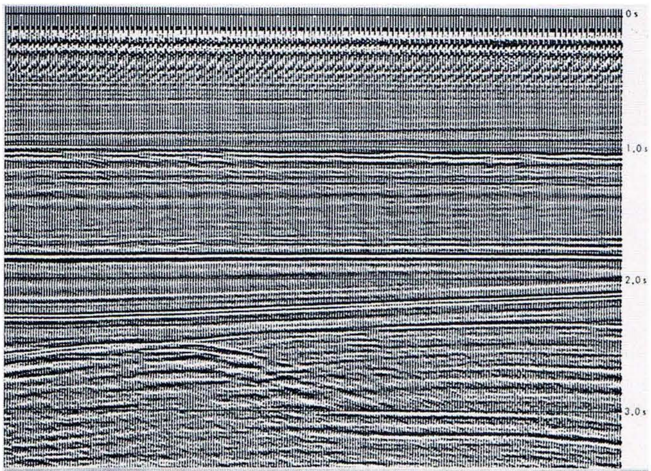
Fig. 2

are obtained to start 3-dimensional migration after several such strip recordings have been carried out.

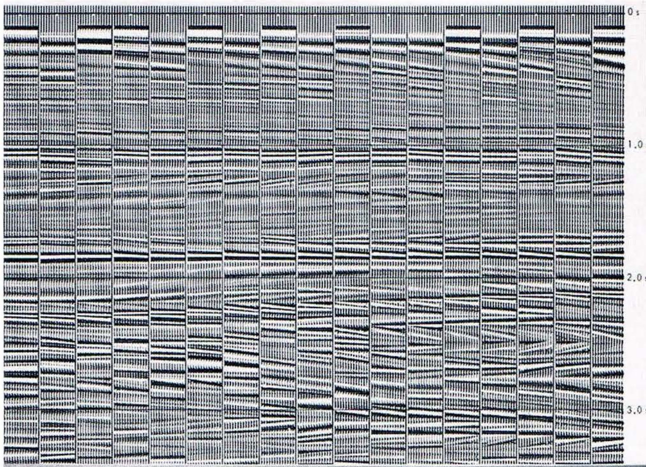
Worth mentioning is that at sea, PRAKLA-SEISMOS determines the cross dip information by placing the airguns, which today commonly serve as energy source, below outriggers at lateral offsets of 40 to 50 m from port and starboard sides of the vessel (fig. 2). In jungle areas we want to retain the shotpoints on the geophone line in order to avoid the labourious cutting of cross tracks off-line for the placing of shotpoints. Instead, the geophone line, which is also the shotpoint line, will be a zigzag line with angles from 20° to a maximum of 30° to the direction of the line proper. The corners of the zigzag should have

Continuos Determination of Cross-Dip

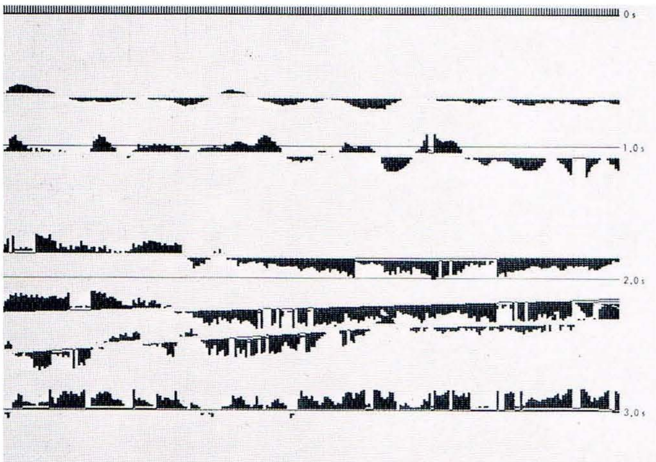




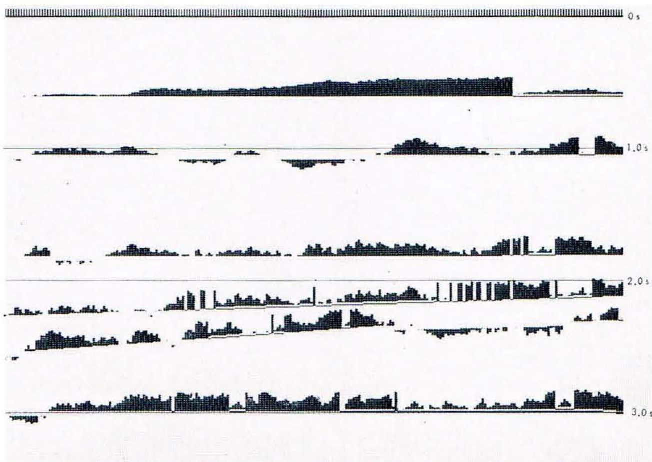
3D-ASP-Stack



Generated Cross Lines



In-Line-Dip



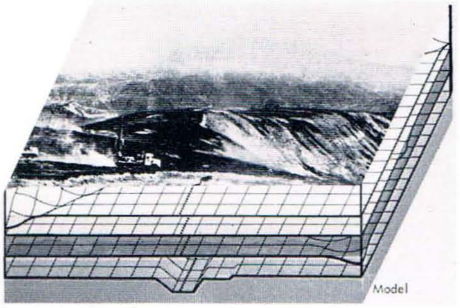
Cross-Dip

a spacing equal to approximately one half the maximum shot-geophone distance. In this manner too, continuous information can be obtained about the cross dip without causing noticeably greater field work.

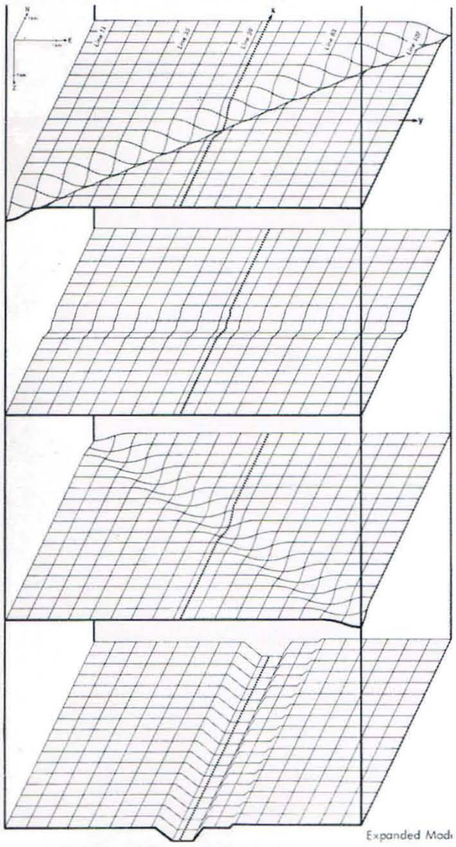
My discussions so far have concentrated on how to obtain seismograms which are free of interfering noise to a high degree and which contain, if possible, only primary reflections and in which the shotpoint and the recording point coincide. Further we showed how to obtain a true image of the structure features in the subsurface by 2- and 3-dimensional migration.

I mentioned that the required knowledge of velocities in the subsurface can be obtained from the reflections themselves. In this respect, the most ingenuous method in my opinion is the ASP-program developed by Bortfeld about which I should now like to make some comments (tables on page 12, 13, 14, compare PRAKLA-SEISMOS Reports 2/73 and 2/74).

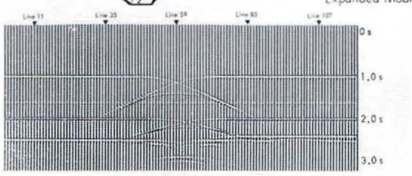
Let us assume that all unstacked seismogram traces are clearly arranged, first according to progressive centre points between shot- and recording-location, and then within all traces with one common such centre point, according to progressive distances between shot- and recording locations. The optimum dynamic correction and with this, the optimum stacking velocity may be known up to the Nth such trace; further more the dip in the time



Model



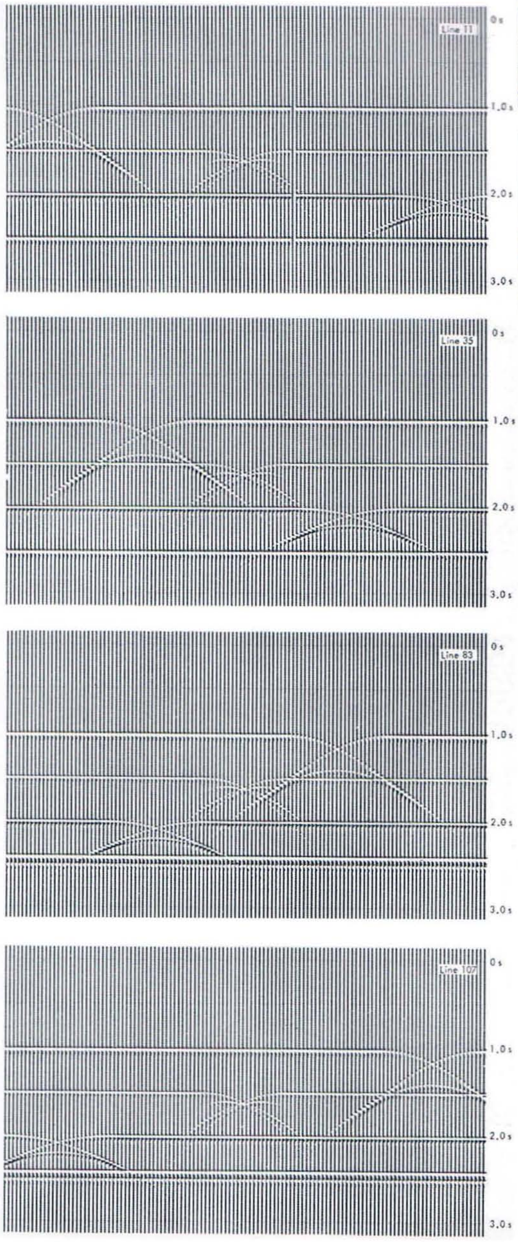
Expanded Model



Time section crossing the model along depth section Y

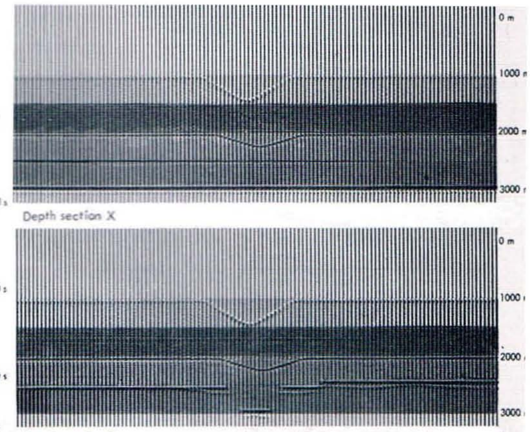
Time Sections of Model

(120 parallel sections - Lines No. 1-120 - served as input to 3D-Migration Program)



3D-Migrated Depth Sections along Arbitrary Lines

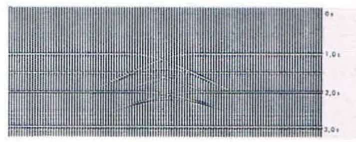
(resulting sections are available in all directions within the model)



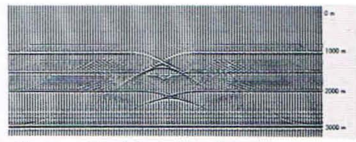
Depth section X

Depth section Y

Compare:

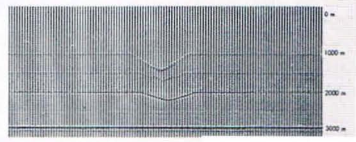


Time Section Line 59



2D-Migrated Depth Section Line 59

(result not satisfactory because strike of structural features not perpendicular to the line)



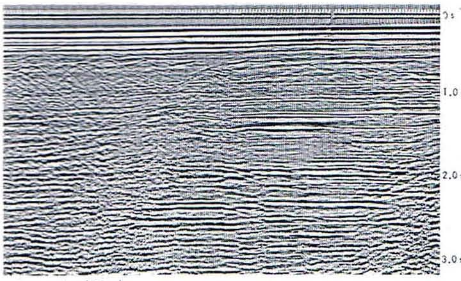
3D-Migrated Depth Section X

(situated on Line 59)

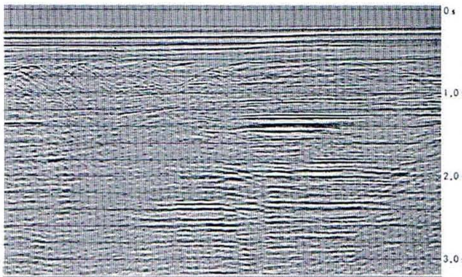
domain and the most probable stacked trace which we call the reference trace. Also the coherence is assumed to be known, that is the measure of similarity of neighbouring traces. From the above magnitudes belonging to the Nth trace we now predict the reference trace for the (N+1)th trace. By crosscorrelating the predicted (N+1)th reference trace with the actually observed (N+1)th trace, we then determine how the abovementioned magnitudes (including the reference trace) have to be changed in order to get the most likely coincidence with observation.

Starting with certain probable initial values, ASP thus continuously determines the change of the above magnitudes, the most interesting of which is the stacking velocity, that is, the velocity which results in the most satisfactory stacking. Practical calculations have proved that with erroneous initial values ASP finds out the correct values already after approx. 10 to 15 subsurface points. The effectiveness of the ASP-program is due to the fact that seismic waves are always continuous even with discontinuities in the geologic structure of the subsurface, as for example faults. In this respect I only need to remind you of diffraction phenomena.

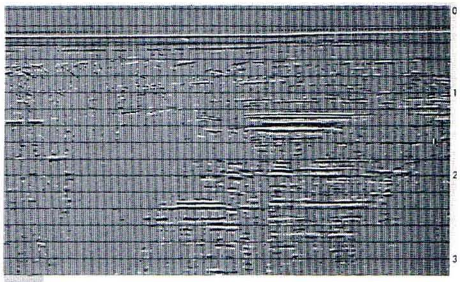
The table on page 12 shows the performance of the ASP-program. From the stacking velocities represented in the upper left part, we can calculate the "instantaneous velocities" as shown in the lower left part. We deal here with



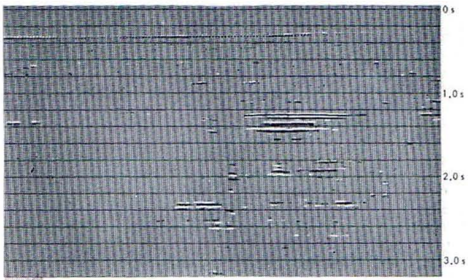
Conventional Stack



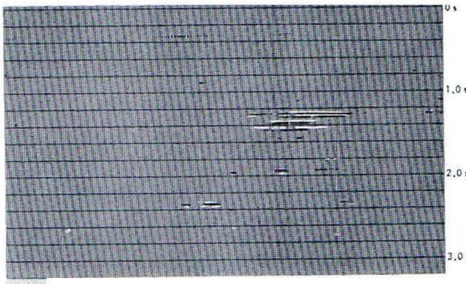
Stack after Real Amplitude Processing
compensated for spherical divergence, transmission losses, and absorption



(1)



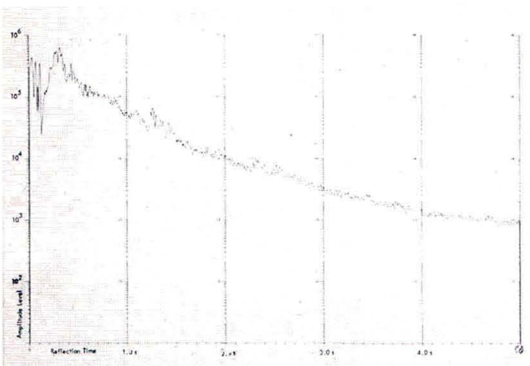
(2)

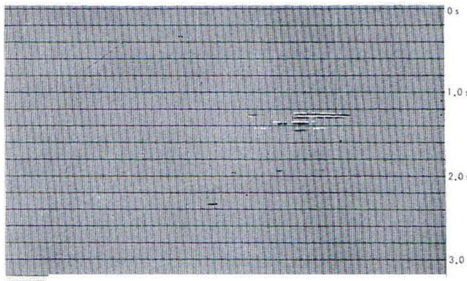


(3)

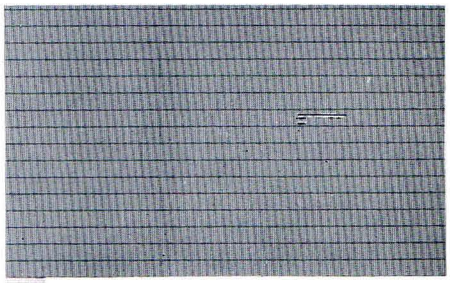
Amplitude Scanning after Compensation

(1) Amplitudes below level 1 suppressed
(2) Amplitudes below level 2 suppressed
(3) Amplitudes below level 3 suppressed
(4) Amplitudes below level 4 suppressed
(5) Amplitudes below level 5 suppressed





(4)



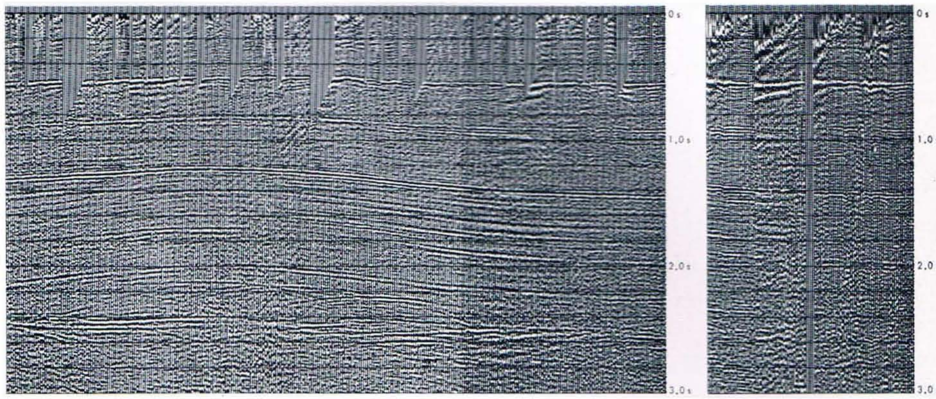
(5)

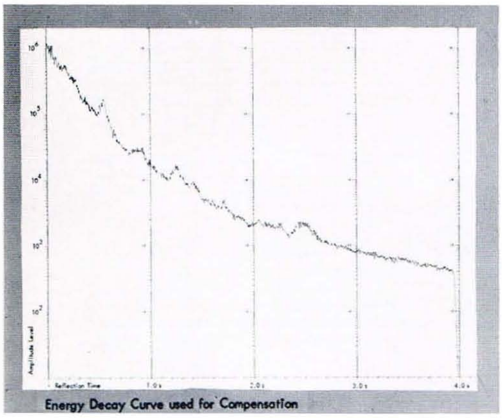
the mean value of the velocity over a certain vertical interval which corresponds, for example, to a reflection travel time difference of 200 ms. The velocities obtained require certain corrections when dealing with dipping and curved velocity interfaces. We call the velocities so obtained "geometric velocities" as they result from the geometry of the seismic field work.

I should now like to come back once again to seismogram migration. I told you that this method starts from the stacked CRP-traces. But this is in no way required; one can work as well directly with the dynamically uncorrected single traces. Now, of course 6 to 24 times as many values have to be added for each little subsurface rectangle, but one avoids the imperfections as connected with CRP-stacking. Even in this "rigorous migration from the start" as I might call it here, we have of course, the possibility to determine the "geometric velocities" and especially the "instantaneous velocities" because the correct velocities result in the most satisfactory migration picture. In future, there will certainly be further development in this direction in spite of the required increased computing effort.

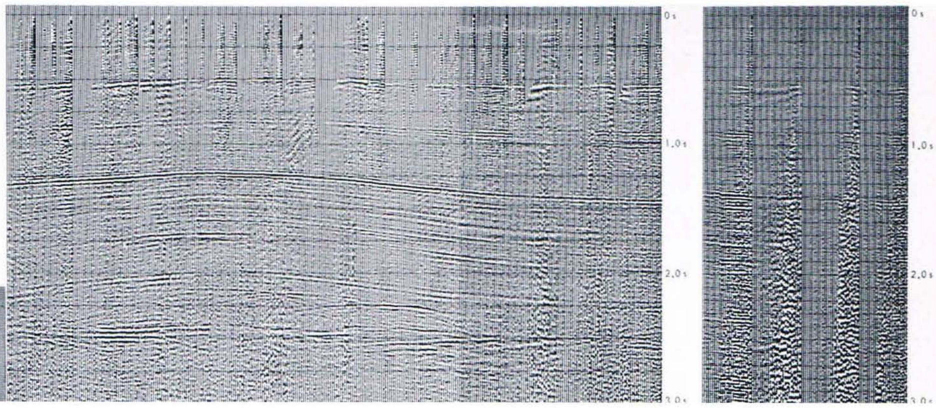
The ASP-program and similar processes, with or without curvature and dip corrections, will always supply us only with mean velocities over certain larger intervals. The smaller this interval the less the accuracy becomes. If we

Conventional Stack (+ Single Coverage)

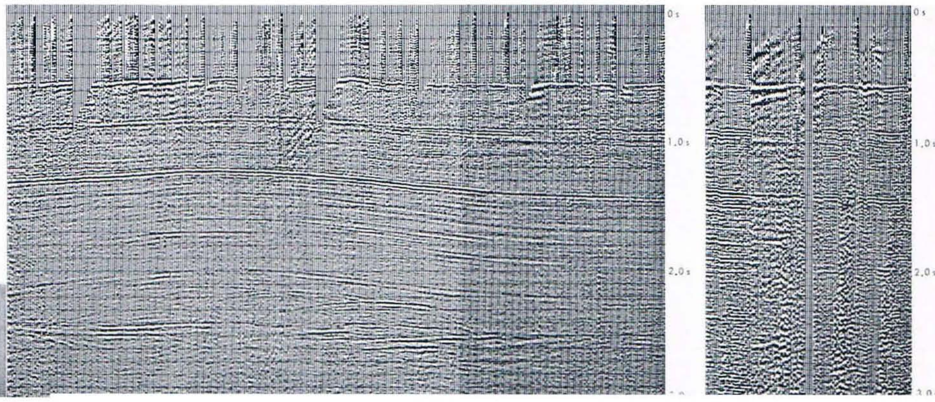




Energy Decay Curve used for Compensation



Stack according to Real Amplitude Processing using WAMP-Process (Compensation of spherical divergence, transmission losses, and absorption according to slightly changing curve)



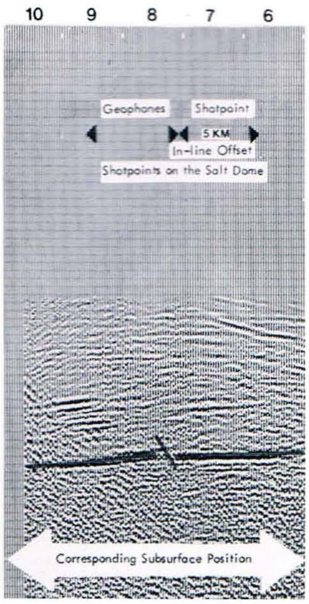
Stack according to Real Amplitude Processing using WAMP-WABS-Process (Compensation of spherical divergence and of differences in shot-energy, geophone coupling, and instrumental influences)

require detailed velocity information we have to look for other methods. The solution which is offered here is the interpretation of amplitudes. As is well known, with zero offset reflections the amplitude of the reflections in the pulse seismogram is only dependant on the relative change of the magnitude $\varrho \times v$, that is density $\times$ velocity. If we assume the less variable density to be known then by suitable integration we can determine the velocity as a function of depth, or expressed in another way, we can then compute an acoustic log from the seismogram. For this we need however, a pulse seismogram which only contains the primary reflections. Here we presently consider only the case of horizontal layering. Unfortunately our seismogram has been considerably altered by filter processes in the subsurface and in the recording instrument. Moreover, the reflections still suffer interference from the remainder of undesired signals and noise, especially multiple reflections, although our endeavour has been to suppress this interference as far as possible by adequate recording and data processing techniques. It is now obvious why I stressed the importance of a high signal-to-noise-ratio at the start of my discussion.

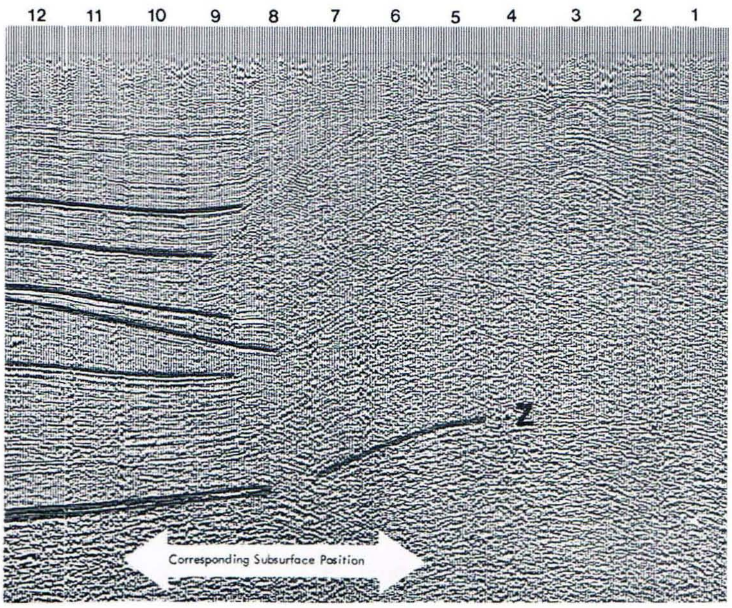
Particularly burdensome for the calculation of the Acoustic Log from a seismogram section are the missing low frequencies between about 0 and 8 Hz. Here, a combination of the instantaneous velocities, the geometric

Saltdome Undershooting

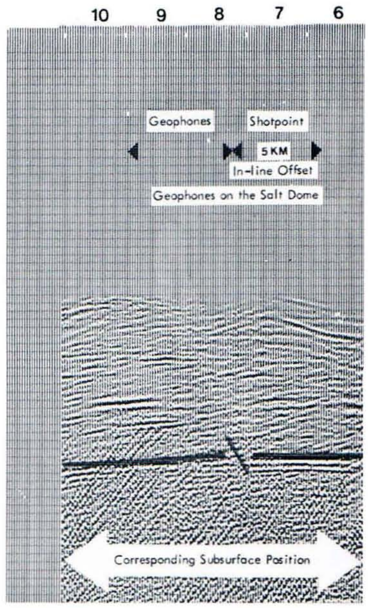
Section AII of Undershooting
(6-fold CDP)



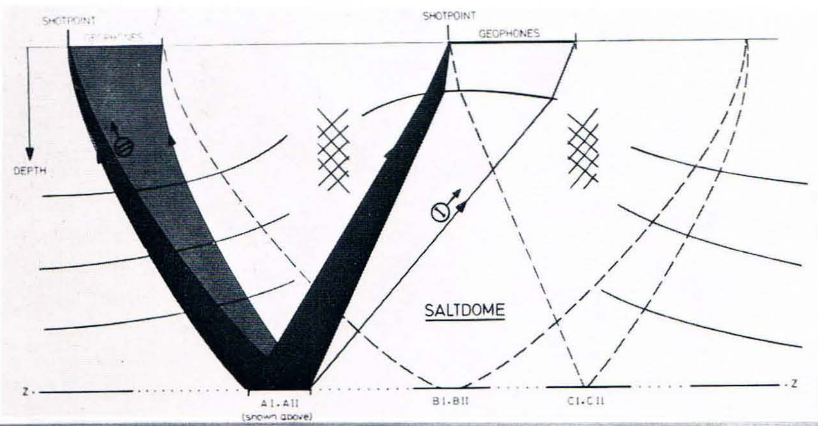
NORMAL SECTION (NO OFFSET)

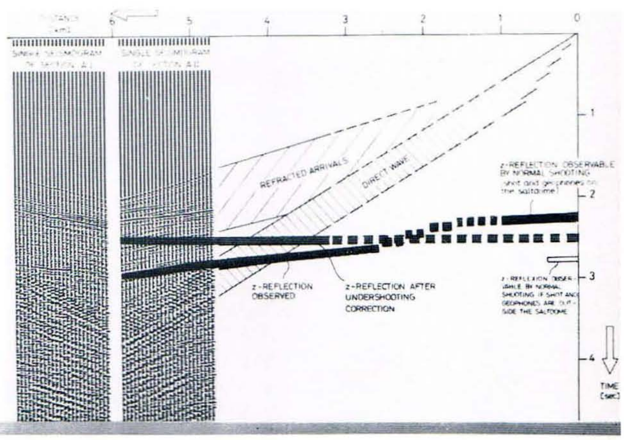


Section AI of Undershooting
(6-fold CDP)

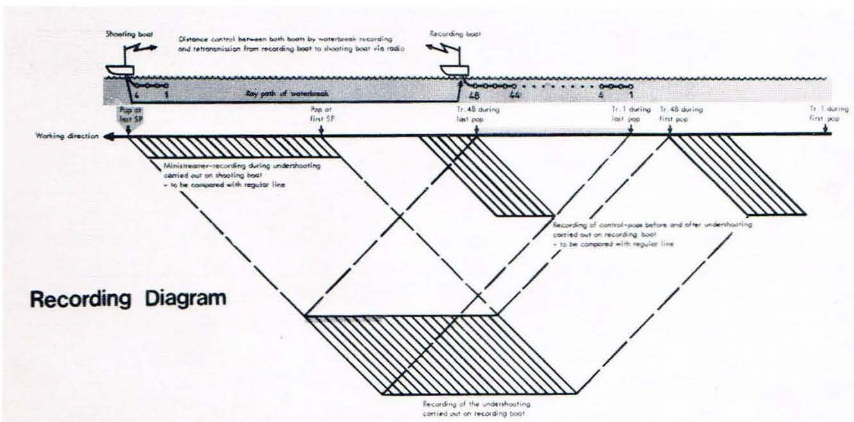


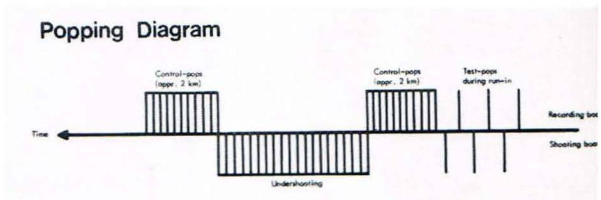
SCHEME OF COMPLETE UNDERSHOOTING

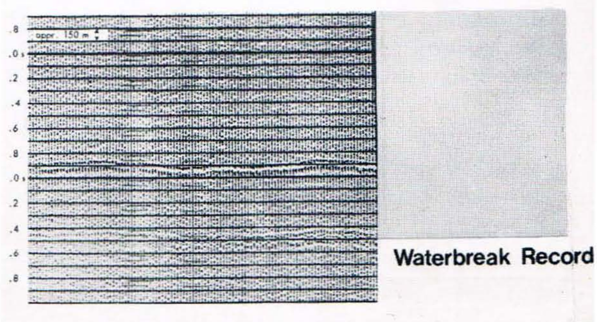




MARINE UNDERSHOOTING







Distance Control Recording on Shooting boat

Waterbreaks are recorded at the shooting boat (received via radio from the recording boat)

Result shows actual distance variation of ± 35 m

The interpretation of seismic results is not only the picking of reflections and their mapping,

our experienced seismologists take into account the

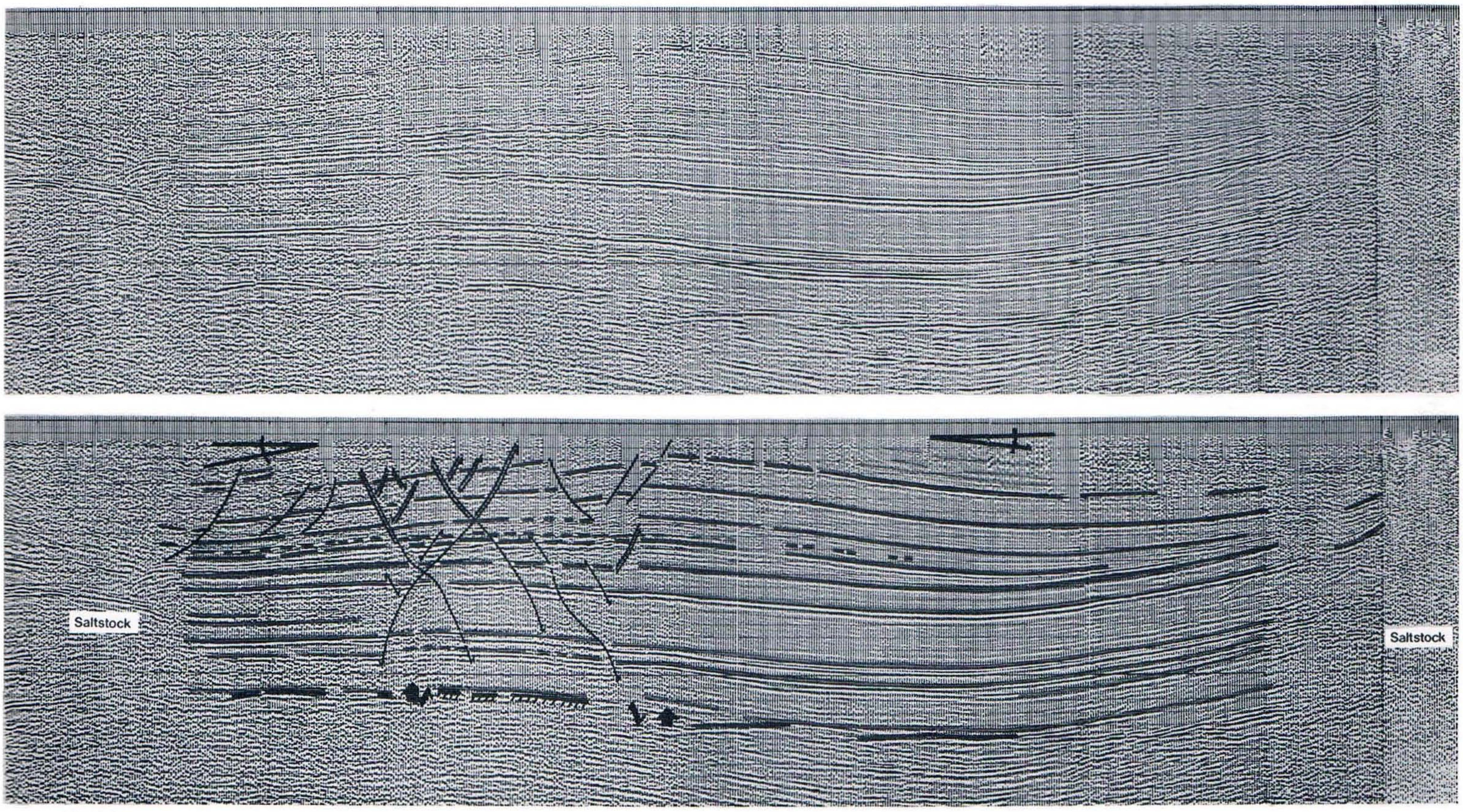
PALEOGEOGRAPHIC AND TECTONIC DEVELOPMENT

by scrutinizing the cross-sections with regard to variations of:

Thicknesses of Layers • Character of Reflections • Interval Velocities • Throws of Faults • etc.

hereby utilizing distortional elements such as diffractions and reflected refractions for fault localization, amplitude and frequency studies for detection of lithologic changes etc.

Example for Variations of Layer Thicknesses and Fault Throws



Appendix

Salt base, faulted, with horst, salt almost completely migrated.

The condition for the reconstruction of the tectonic development in the overburden of the salt is the initial horizontal bedding of all layers.

Layers overlying the salt. Bedding almost uninfluenced by local salt movements and affected only by regional alterations in thickness; with transgression.

Layers of primary rim sink. Reduction of thickness towards salt pillows (s.p.) being simultaneously formed.

Younger parallel layering. Regionally sinking without salt movement.

Secondary rim sink. In the positions of the former salt pillows the salt breaks through overlying layers forming salt stocks (s.s.). The outer limbs of the primary rim sink break down. Increase of thickness towards the salt stocks.

In contrast to the fault-free subsidence of the right limb of the primary rim sink, where there is no underlying horst, faulting occurs over the horst in the left limb.

Fault system in upper layers, in which much tension is obvious,

Gentle arching of overlying layers presumably due to pressure from salt, which is trapped beside the horst.

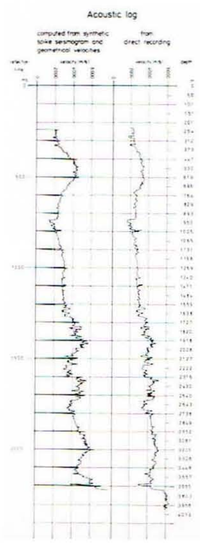
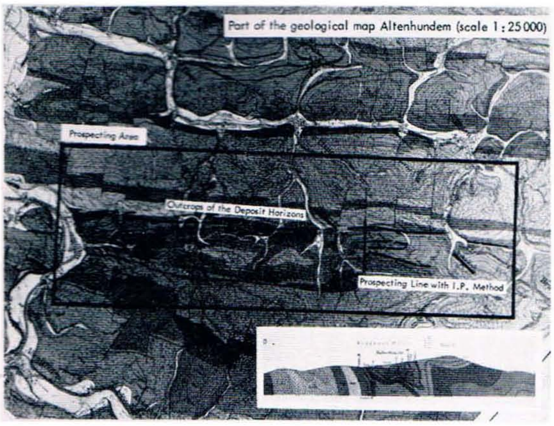


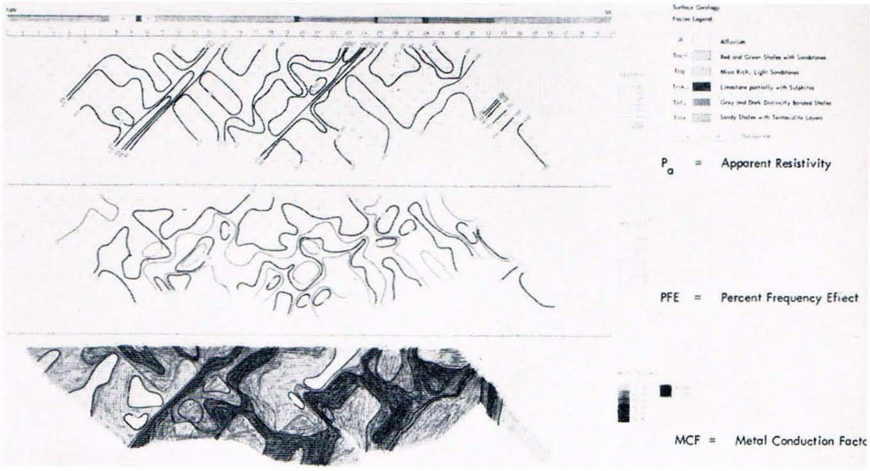
Fig. 3

velocities, derived from ASP or similar programs with the above-mentioned integration of seismogram traces offers the possibility to surmount these difficulties. First steps in this direction have already been carried out by PRAKLA-SEISMOS (fig. 3).

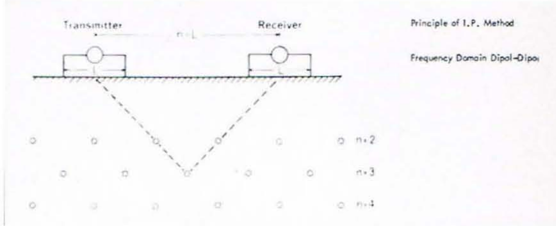
The strong absorption of high frequencies in the subsurface is of course another serious obstacle in the endeavour to determine the Acoustic Log from the seismograms, especially because it prevents us from cancelling by deconvolution the many high-frequency reverberations which are generated by the fine structure in the geologic bedding and which may have a greater effect, according to Anstey, on the seismogram than the real sequence of

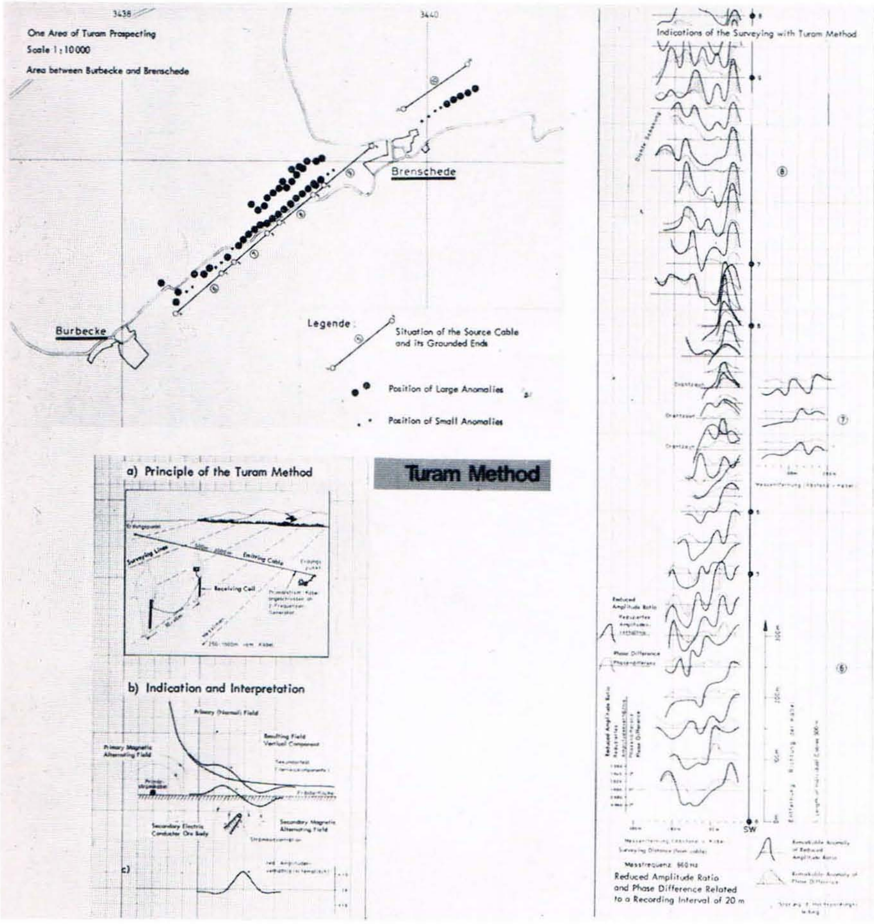
Geoelectrics



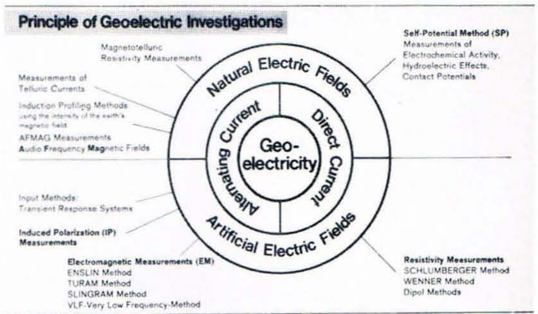


I.P. Method





Turam Method



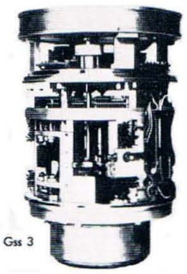
Geoelectrical Surveys	
Resistivity Depth Survey Method	Mapping of Structures and Underground Occurrence e.g. Limestone, Marl, Sand, Gravels, Eruptives, Basalt, Tuffs, etc. Hydrological Problems
Self-Potential Survey Method Electromagnetic Survey Methods a) Turam b) Enslin	Detecting and Surveying of Massive Ores
Induced Polarization Survey Method	Detecting of Disseminated Ores, Clay, Saltwater

reflecting interfaces. Thus, a satisfying way to the "pseudo acoustic log" derived from seismic field records has not yet been found out.

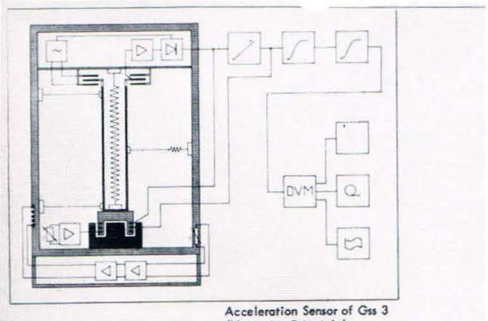
More useful information can be derived nowadays by studying lateral amplitude variations as compared to vertical ones. Here I especially mean the change of reflection amplitudes with the kind of pore filling of a certain geological bed. The seismic compressional wave velocity in not too consolidated sediments can significantly depend on whether the pore spaces are filled with gas or fluid. Considerable amplitude differences in the reflections can thus be caused which make gas fields and the gas water edge line directly recognizable. In areas of rapid sedimentation, the interesting beds very often remain rather unconsolidated to appreciable depths.

On account of these facts Diekmann and Wierczeyko have been able to draw important conclusions from observations that had already been made in 1966 above subterranean gas storage facilities of the Ruhrgas Co. In 1973, Schmoll elaborated this subject and presented the result at the EAEG-meeting in Brighton. In this case the velocities in sand were about 1200 m/s when filled with gas and about 1800 m/s when filled with water (see PRAKLA-SEISMOS Report 3/72).

In the past few years similar observations have been made on offshore sections (page 16). Here one talks about



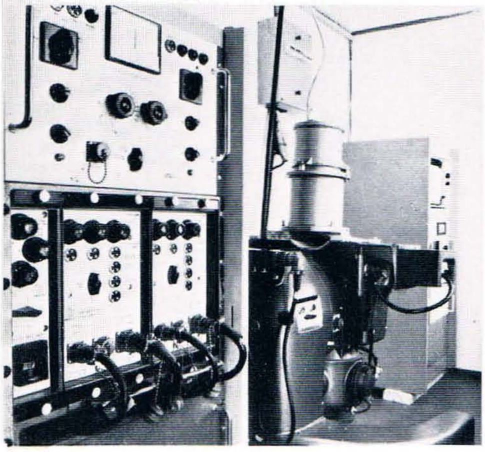
Inside of Seagravimeter Gss 3



Acceleration Sensor of Gss 3 (Measuring Principle)

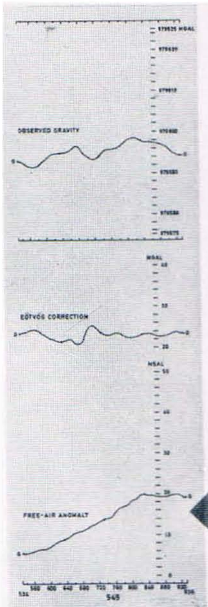
Sensitivity of Askania Seagravimeter Gss 3: 0,1 mgal

Accuracy of Resulting Anomalies better than 1 mgal

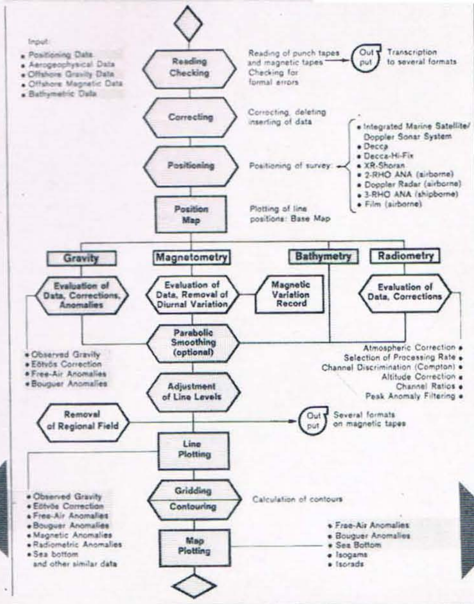


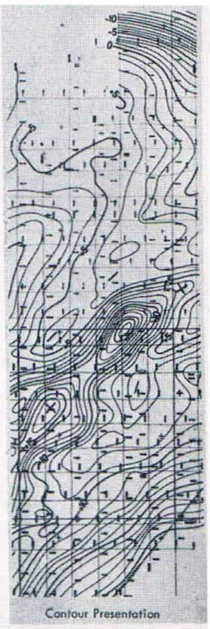
Background	Electronics cabinet with analog recorder, AD-converter, digital voltmeter, electronic panel and power supply
Middle	Gyrotable with Seagravimeter Gss 3
Foreground	Gyro amplifier and Servo amplifier for the gyrotable

Processing Flow Chart for Offshore Gravimetry



Line Presentation





Contour Presentation

2- and 3-Dimensional Gravity Interpretation Programs available

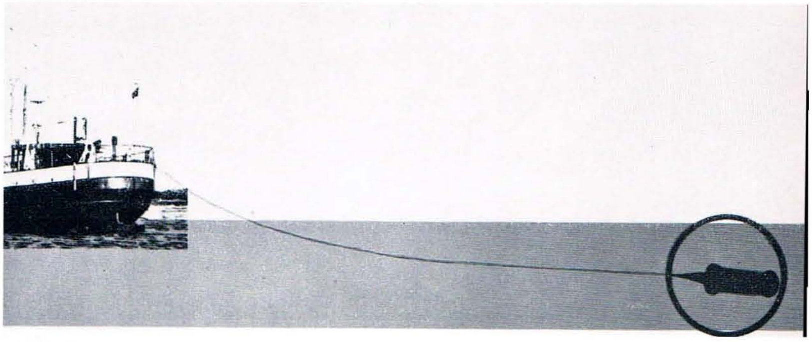
"hot spots" and "bright spots". In many cases, including the example shown, these "bright spots" have in the meantime been confirmed to be caused by gas-filled layers. These, commonly quite shallow gas fields, are not necessarily of commercial interest, but they are in many cases indicative of oil in greater depths.

Due to these reasons it is not surprising that we not only try to produce well interpretable seismogram sections with the aid of suitable amplitude gain control and normalization procedures but also to retain the real amplitude relations in a quantitatively easily reproducible manner. Colour scales are often used to represent the differences in amplitudes. Another possibility of representation is shown in the table on page 16.

I have already mentioned that the aim is to obtain indications of the magnitude $\varrho \times v$ (density×velocity) from the amplitudes of the seismogram traces. If we want to determine the two magnitudes ϱ and v independently of each other, and there are no borehole density logs, we may shoot with very small shot-geophone distances and additionally with very large ones. With very large reflection angles, at the latest in the range of the critical angle, the dependence of the reflection coefficient on $\varrho \times v$ passes into one of v alone.

There are other reasons too, to use a large shot-geophone spacing. There is first the more effective attenuation of

Magnetometry



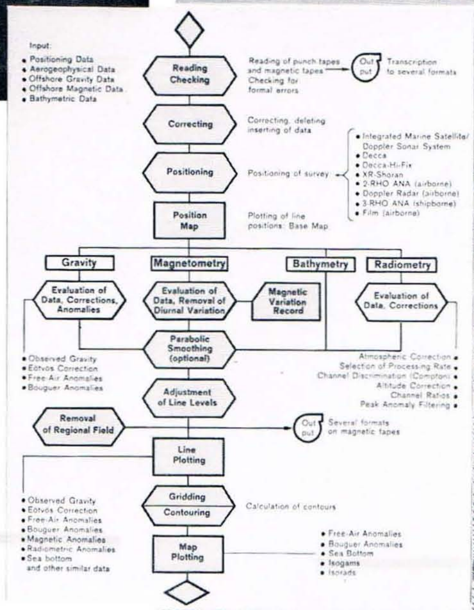
Instruments available:

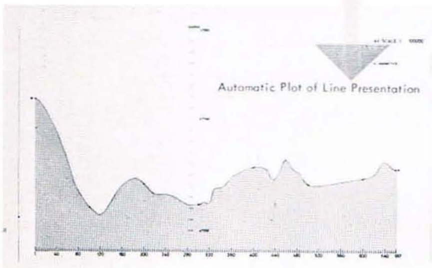
Proton Precession Magnetometer Geometrics G 803 (± 1 gamma)

High Sensitive Proton Precession Magnetometer Geometrics G 804 (± 0.1 gamma)

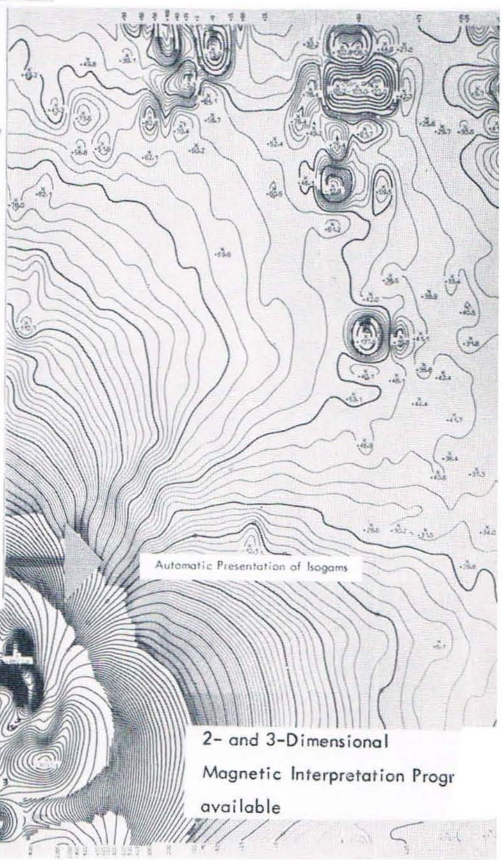
Measuring Sequence 2/3 sec

Processing Flow Chart for Airborne and Shipborne Magnetometry





Automatic Plot of Line Presentation

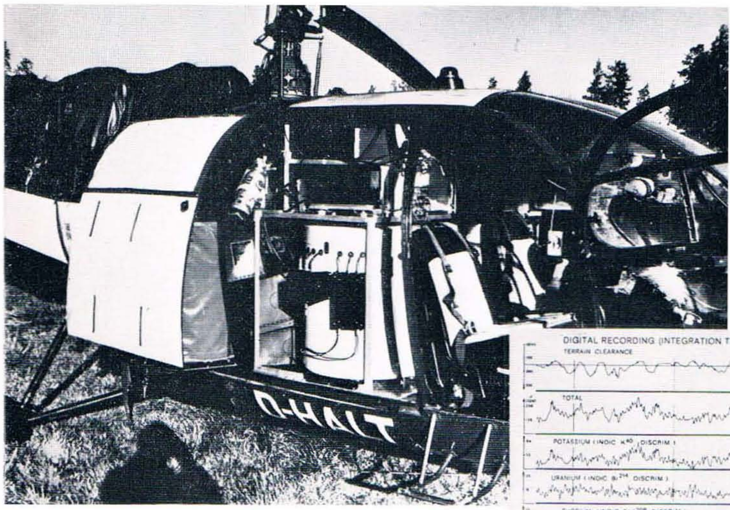


Automatic Presentation of Isogams

2- and 3-Dimensional Magnetic Interpretation Progr available

multiple reflections by CRP stacking and, what is closely connected to this the increase in accuracy in the computation of the geometric velocities as well as possible information on anisotropy. Furthermore, a large shot-geophone spacing offers the possibility to undershoot complicated bodies which are sometimes encountered above rather interesting geological horizons. I am thinking here particularly of the undershooting of saltdomes (see table on page 18).

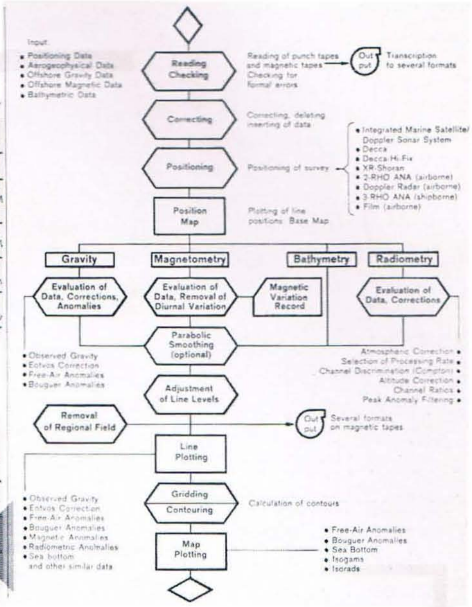
I may summarize that we are presently in a period of an especially intensive development in applied reflection seismics. Geophysicists have realized the great potential that is contained in the two dimensions of the vector from the shotpoint to the geophone location at the earth's surface as well as in the real amplitude relations. With the first two dimensions it has now become possible to recognize more clearly and localize more precisely the discontinuities in the subsurface and also to determine the "instantaneous velocities". The conventional CRP-stacking will in future probably widely be replaced by the immediate migration of single-shot seismograms. The real amplitude in the seismogram is increasingly being evaluated in the endeavour to get direct indications on natural gas and under favourable conditions on oil as well. Work is also in progress to obtain details on the velocity as a function of depths (pseudo acoustic log).

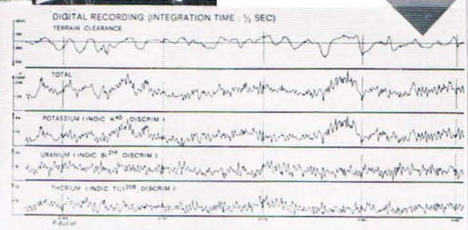


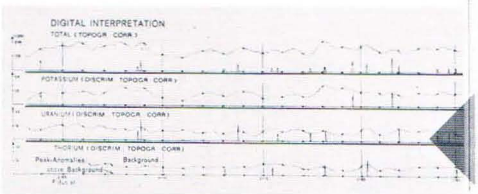
Airborne Digital Radiation-Spectrometer System II enables a four channel digital recording of

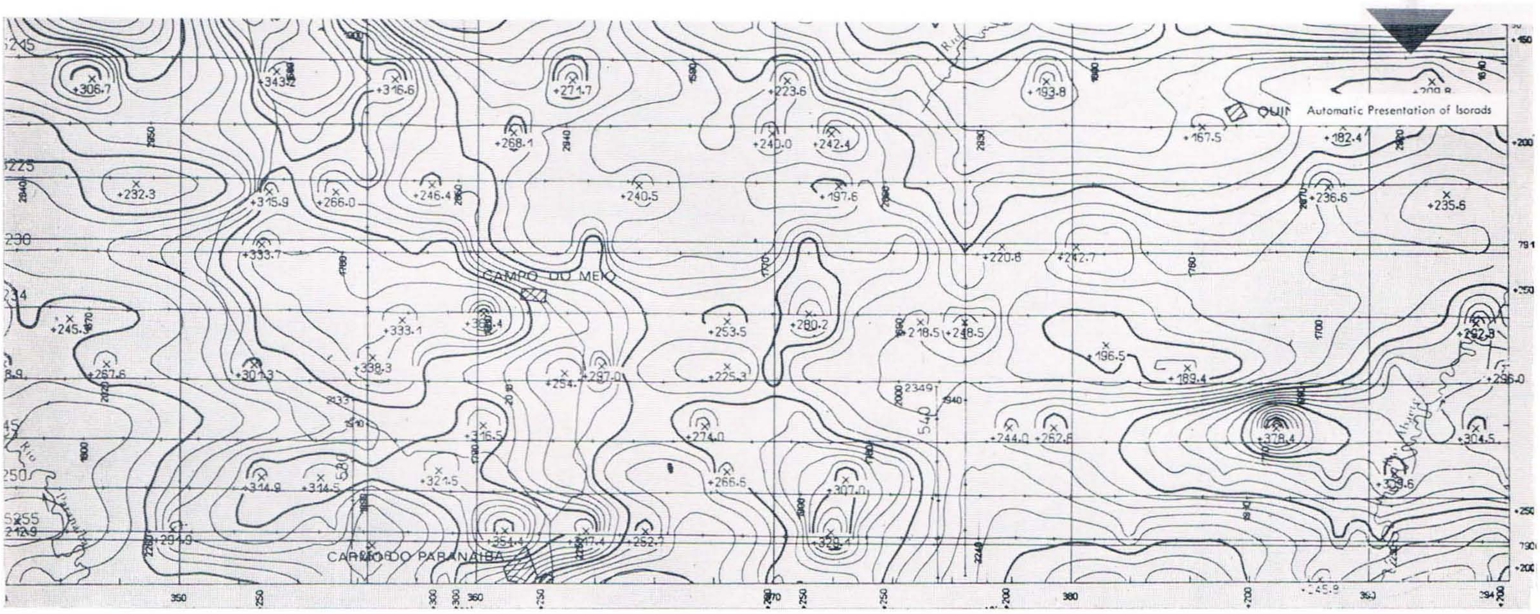
Total
Potassium (K)
Uranium (U)
Thorium (Th)

Processing Flow Chart for Airborne Radiometry









I have not discussed refraction seismics, nor surveys with guided waves which are utilized for example in mines (see PRAKLA-SEISMOS Report 1/71). Here, not too much has happened in the last few years, although many processes have been transferred from normal reflection seismics to these special methods as for example, prediction error filtering and migration refraction (compare Report 1/73) and CRP-stacking to coal seam seismics but this is outside the scope of the present report.

Before finishing, I should like to give you an impression of the wealth of structural information which is inferred from a modern seismic section as may be seen from the table on page 19.

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PRAKLA-SEISMOS Reports:
Nr. 1/71, 1/72, 2/72, 3/72, 4/72, 1/73, 2/73, 1/74, 2/74.

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Digital recording up to 96 channels
with dynamite in shot holes, or explosive cord,
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With gravimeters on gyro-stabilized platform,
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execution together with seismic and/or magnetic surveys.

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With proton magnetometers,
digital recording,
execution together with seismic and/or gravity surveys.

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geophones.

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over sea with two-range ANA navigation systems.

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airpulser.

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Acquisition of data such as position, time, heading,
cable depth, water depth, feathering angle, magneto-
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punched tape and/or printout.

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frequency standard. ANA aircraft navigation and
positioning system for survey over sea.

Digital Plotter
KPU plotter with raster and seismic mode for display
of seismic sections in all standard modes. Combination
of seismic sections with presentation of static and
dynamic corrections as well as velocities etc. on one
photographic film or paper sheet.
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cartography, photogrammetry etc.

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