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DIGITAL INFORMATION RECOVERY FROM PAPER SEISMIC SECTIONS FOR WORK STATION LOADING

İş İstasyonlarına Veri Aktarımı İçin Sismik Kesitlerden Sayısal Bilgi Kazanımı

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ABSTRACT

Until recently, paper seismic sections were the primary \vorking medium for most seismic interpreters. With the advent of economical seismic work stations, manipulation of seismic traces in digital form for detailed analysis and display has become an integral part of the interpretation process.

Although recent seismic lines are usually available on tape and can be loaded straight on to a vvorkstation, plenty of useful older data remain in paper form, out of reach of quantitative techniques. Fortunately, improved optical scanner technology has provided an impetus for the development of efficient routines for vectorizing seismic traces on paper sections to convert them back into digital traces on tape.

Case histories from many different parts of the world can be used to show the effectiveness of Standard post stack processing techniques applied to scanned and vectorized seismic data, prior to workstation loading.

This paper also revievvs the vectorizing techniques and their implementation upon problem data sets; poor quality prints, deteriorating films, sets with interpretation marks, and small scale originals such as photographs, microfilm.

ÖZET

Kağıt basılı sismik kesitler, sismik yorumcuların çoğu için yakın zamana kadar başlıca çalışma ortamıydı. Ucuz sismik iş istasyonlarının gelişmesi ile ayrıntılı çözümlemeler için sismik izlerin sayısal olarak işlenmesi ve görselleştirilmesi veri-işlemin ayrılmaz parçası olmuştur.

Yeni ölçülen sismik hatlar genellikle manyetik ortamda kaydedilmesine ve doğrudan iş istasyonlarına aktarılmasına rağmen, birçok kullanılabilir eski veri, nicel yöntemlerin uygulanamayacağı kağıt kesitler üzerindedir. Mamafih, optik tarayıcı teknolojisi, kağıt kesitleri sayısal izlere çeviren etkin yazılımların geliştirilmesi için gerekli etkiyi sağlamıştır.

Dünyanın birçok bölgesinden örnekler ile, iş istasyonlarına veri aktarımından önce tarayıcı ile elde edilmiş ve vektörleştirilmiş sismik verilere uygulanan yığma sonrası veri-işlem yöntemlerinin etkinliği gösterilebilinir.

Bu makale aynı zamanda, vektörleştirme yöntemlerini ve kötü nitelikli baskı, bozulmuş filmler, yorumlama işaretleri kapsayan veriler, fotoğraf ve film gibi küçük ölçekli basımlar gibi sorunlu veri kümelerindeki uygulamaları gözden geçirmektedir.

INTRODUCTION

Explorationists may disagree on many things but one subject brings about almost unanimous agreement; the key to a successful oil exploration effort is good seismic control. This means adequate coverage in the correct location. It also means maximizing the field effort, i.e. sufficient input energy, noise control and elimination, a suitable level of information redundancy, and no compromise of the time and spatial sampling.

Once acquired the data must be processed. A rigorous testing program must be investigated to set the processing parameters and overall sequence. This is followed by

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even more rigorous quality control at ali the majör processing steps, such as static control, velocity analysis, and first break mute selection ete.

Ali of this effort can be spoilt at the last step by inadequate or poor quality displays and/or presentation. Final section plotting is crucial, and the choice of poor parameters at this stage can greatly hinder the quality and accuracy of the interpretation and eventually the proposed well location.

The final processed data should also be arehived, so that reprocessing using new or enhanced techniques can be easily effected at a latter date. Special displays can also be produced on demand and last but by no means least, the data can be loaded onto a vvorkstation for ease of interpretation. This is the ideal situation, unfortunately we ali have to work in the real world.

THE "REAL WORLD" PROBLEM

When work starts in a new area or restarts in an old area negleeted for a length of time, the explorationist can be confronted with several problems, not least of which is the variation that exists within the seismic data base. The interpretation has to proceed on a data set with various incompatibilities: a) sections at different horizontal and/or vertical scales, b) sections are at different stages of processing, e.g. migrated or un-migrated, different filters, ete, c) mixed source wavelets e.g. dynamite versus vibroseis, airgun versus vaporehoc, d) processed to unique and different datum planes.

The first step is to re-process and re-display from the arehived stack tapes if available. This can produce a sufficiently uniform data set for a first pass interpretation.

In many cirumstances for political, economic, geographical or even historical reasons, the arehived stack tape is not always available. This will severely restrict any attempt at simple reprocessing and/or workstation loading.

If the time and budgets allow, reprocessing can be undertaken from the field tapes. This is expensive and time consuming, büt if properly quality controlled, it vvill usually yield optimum results. Even if the field tapes can be found, they may not be usable. This is often the case with older and poorly stored tapes. Any reprocessing also requires the simultaneous use of supporting data on paper of floppy disk, vvhich are often stored separately. This frequently leads to the data being not lost, but mislaid. Either way it is not available for immediate use. Even if eventually found it may not be readable and thus unusable. Seemingly we, the explorationists, are trapped, and it gets worse before it gets better.

And added complication can be the often poor quality of seismic copy available in our databases, e.g. a) badly produced original films, b) unstable or deteriorating media, c) inferior printing, d) badly stored or handled films, e) sections with interpretation and/or drafting, f) small scale originals. With the development of scanning, vectorizing and reconstruction technology, these problems can largely be overeome.

REAL WORLD SOLUTION

It is now possibie to produce digital output from various types of paper copy: a) full scale blackline prints/films, b) reduced size originals, c) text book and teehnieal paper examples, d) teehnieal report enelosures, e) mierofiche/microfilm, f) pre-rastered files, g) weird and wonder-

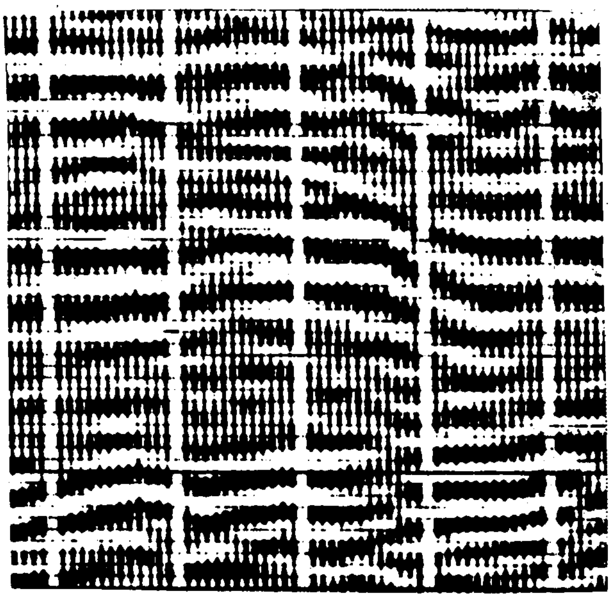

Fig. 1. North Africa example-original double sided VA before scanning.

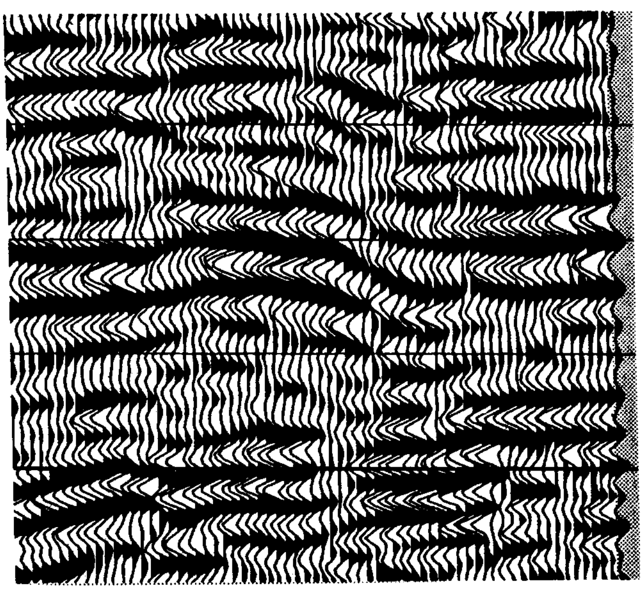

Fig. 2. North Africa example-after scanning.

ful display formats; variable density, wiggle, trace only dual polarity, double sided variable area, ete., h) poor quality paper/film copy. The sections can be scanned, the vectorized or reconstructed into industry Standard SEG-Y format suitable for further applications processing and display.

Figüre 1 shows a part of an old seismic section from North Africa displayed in a double sided variable area format. After scanning and vectorization, the results achieved can be seen as Fig. 2. The improvement in visibility and interpretability is elear.

The quality of improvement seen in the previous example is typical of what can be achieved from ali of the Standard display formats as well as the non-standard ones.

METHOD AND RESULTS

The original section is scanned and output to a raster file (a digital image but not in as seismic trace format). At this stage it is necessary to select appropriate parameters for the scanning resolution and the image contrast threshold. After scanning the image must be corrected for skew in case of misalignment in the scanner.

The scanning process uses a charge coupled device array camera to record the input printed image as an electronic image, storing the output as a raster file for further work. The raster file is a matrix of binary (black/vvhite, on/off) value assignments for each point of the image. These points are known as pixels. The input, in our case a seismic section, is represented by an organized arrangement of pixels, somevvhat akin to the way a newspaper photograph is composied. Vectorization is the process of automatic digitization from the raster image of the original analogue display. Once in a digital format the section can be reprocessed and/or re-displayed with preferred parameters, and arehived.

In the vectorizing program a portion of the raster file is displayed on a workstation sereen in black and white (see Figüre 3). Using the chosen algorithm the computer generates a coloured trace overlay of the digitized output. If the fit is not up to Standard, parameters are adjusted until an adequate agreement is observed between the output trace and the raster file image beneath.

A number of different algorithms have been developed, one for each type of display mode likely to be encountered on the input sections; Variable AreaAViggle Trace (VAAVT), Variable Area only (VA), Wiggle Trace only (WT), and Variable Density (VAD). Statistically analysed pixel distribution curves, and pixel pattern recognition techniques form the basis of the vectorising process for each of the algorithms.

Common to ali algorithms is the initial space and time scale calibration, set up from previewing the scanned image. This is only a starting point and a finer calibration is made during the vectorizing process. A visual eheck is made that the calculated time scale corresponds to the timing lines of the original section. The timing parameters can then be adjusted until a suitable mateh is made.

The precise trace location is established by counting the number of black pixels around the initial calibration position. A maximum count will oecur when the location is centred on the aetual trace.

For accurate vectorizing the zero erossing, or baseline, must be established at ali times for every trace. This is achieved by counting the number of black pixels contained in each vertical raster line, in a progression aeross a trace location. Över a given time gate the count will vary spatially and a maximum rate of change will oecur betvveen the raster lines either side of the baseline position, see Fig. 4.

Each trace has its location and baseline established prior to the start of vectorizing, and each trace is vectorised separately. Vectorization starts at the top of each trace, and progresses in a downward direetion. A trace amplitude, i.e. distance from the associated baseline position is calculated for each horizontal raster line.

In the case of the VAAVT algorithm, both the variable area peak and vviggle trace are tracked. The location of the vviggle trace will appear as a spike on the pixel distrubition curve (See Fig. 5, 'Winggle Tarce Analysis'). The maximum number of pixels counted vvill correspond to the location of the vviggle trace on the image. The other parts of the distribution curve, vvith a less than maximum count, are from the inter-trace gap. The analysis continues vvith the next raster line dovvn.

For the VA only algorithm, and for peaks of the VA/WT, the pixel distribution curve has a different shape. From the baseline out to the edge of the peak the pixel count vvill be high, hovvever at the edge and beyond, the count vvill diminish quite rapidly (see Fig. 5, 'Peak Analysis'). The observed distribution curve vvill resemble a high plateau, followed by a shoulder zone and a valley of minimal values. The location of the shoulder point is vvhere the edge of the peak oecurs.

Parameters can be set such that the geometric relationship betvveen the seleeted vectorized points remain vvithin certain threshold boundaries, e.g. steepness of interpolated slope. Where peaks overlap adjacent peaks, such that the edge cannot be found vvithin the set thresholds (i.e. trace excursion values or slope steepness) vectorized points or trace values remain undefined. Analysis continues in a dovvnvvard direetion until the next legitimate value is found. The gap in the peak profile can be filled by the use of a cubic polynomial interpolation funetion using the slopes on either side of the gap. The same technique çan be used to reconstruct the missing vviggle trace for VA only displays. In this vvay a full wave form trace is reconstructed.

Figüre 6 shows a good quality input section displayed vvith VA only but at a very high trace bias, approximately 30 %. This has the effect of reducing the standout of the smaller amplitude peaks.

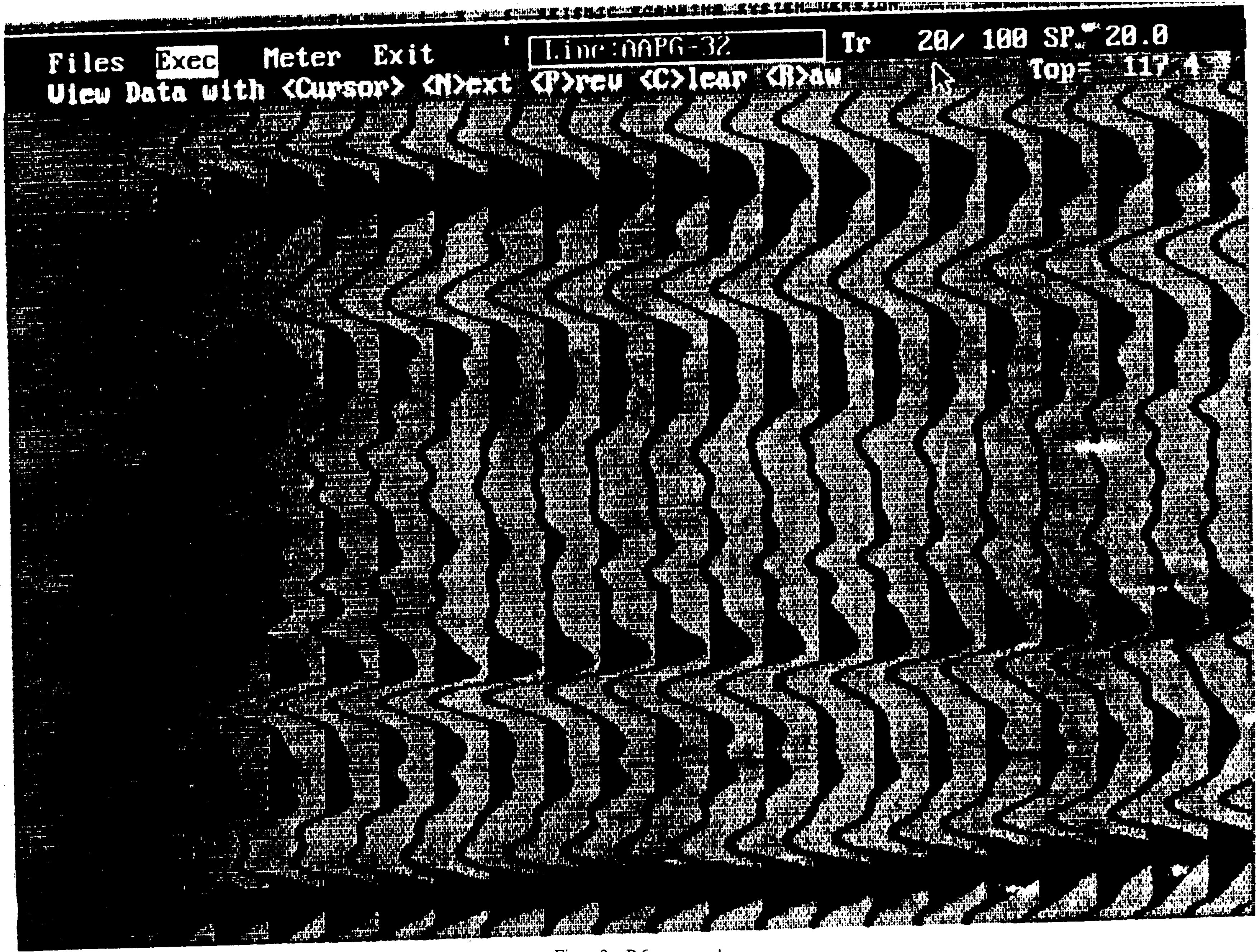

Fig. 3. P.C. screen dump.

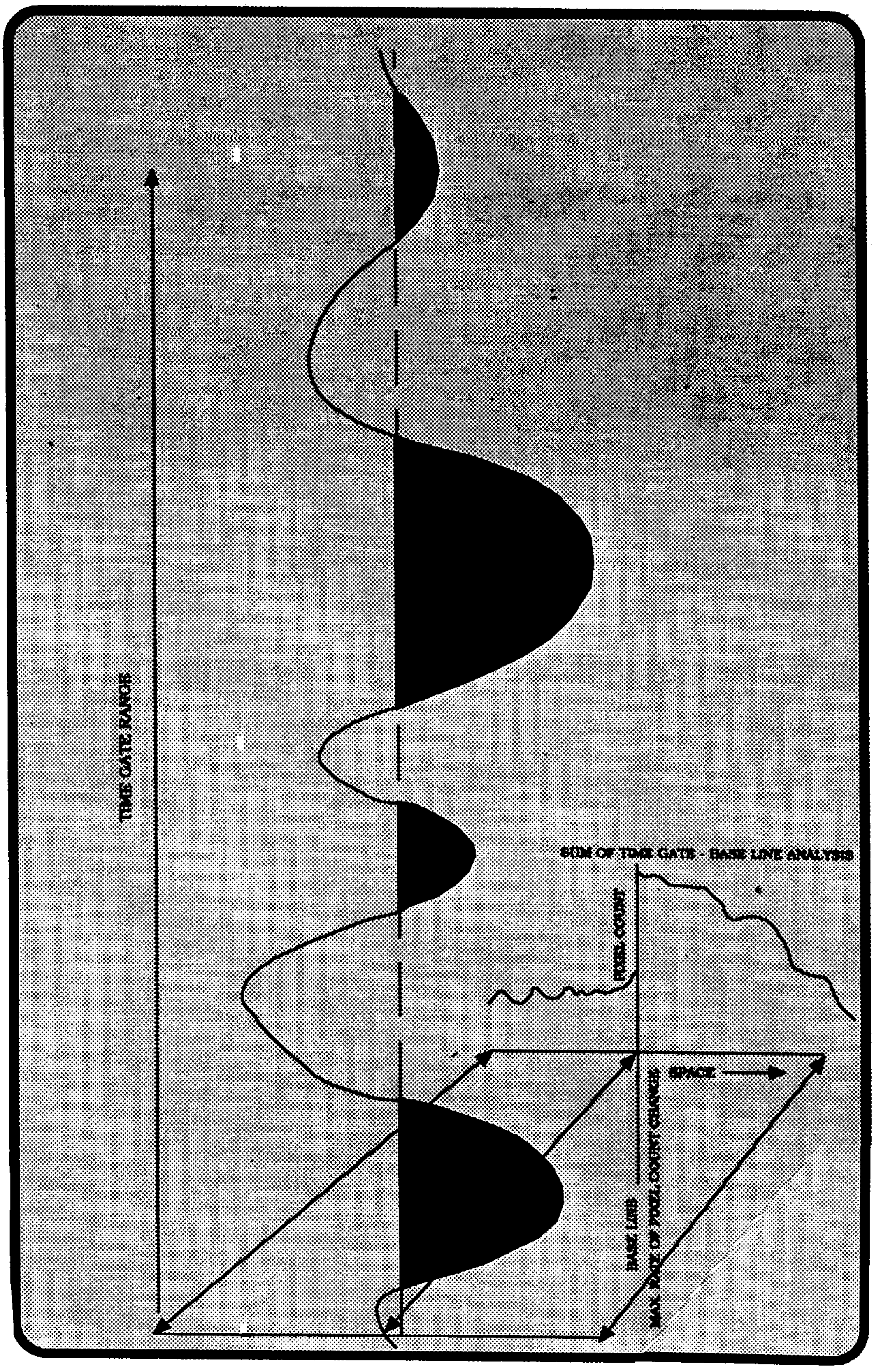

Fig. 4. Trace analysis-baseline.

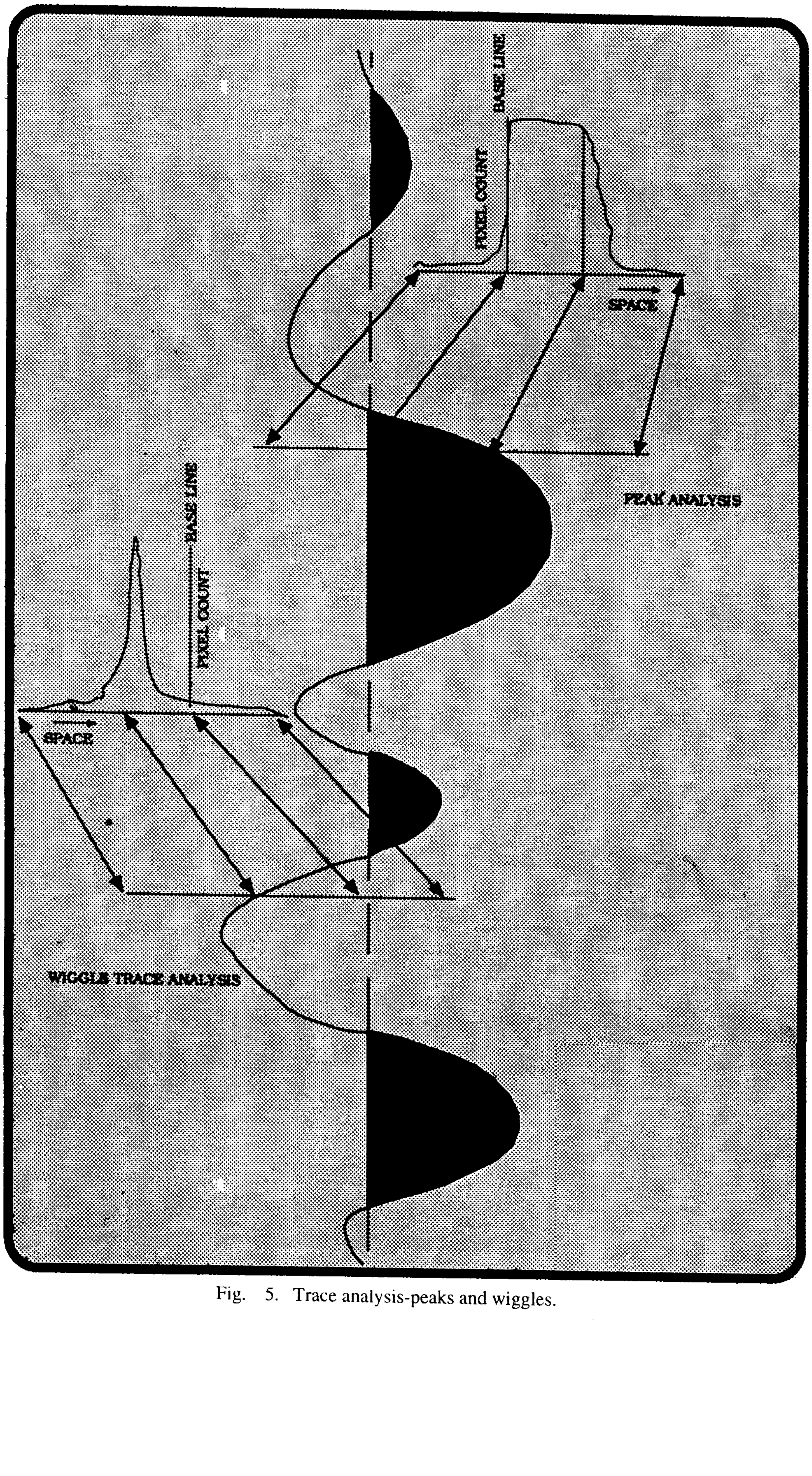

Fig. 5. Trace analysis-peaks and wiggles.

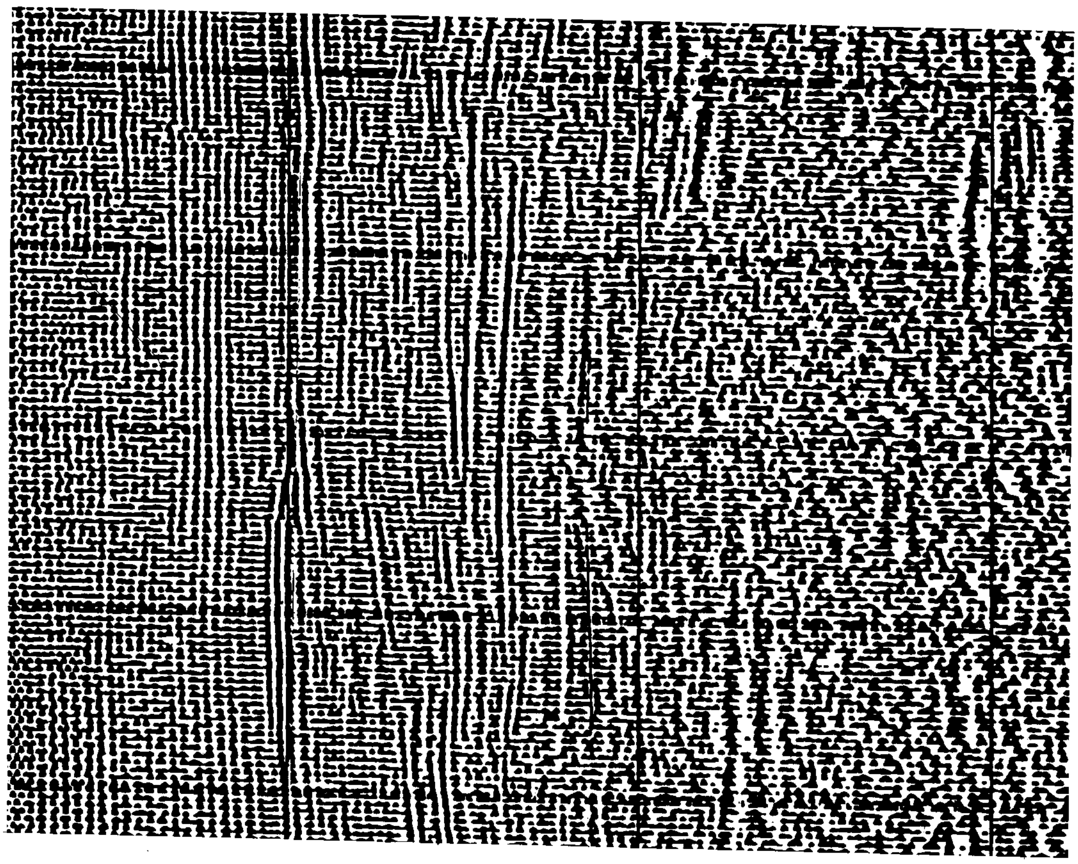

Fig. 6. Offshore Nigeria-original section.

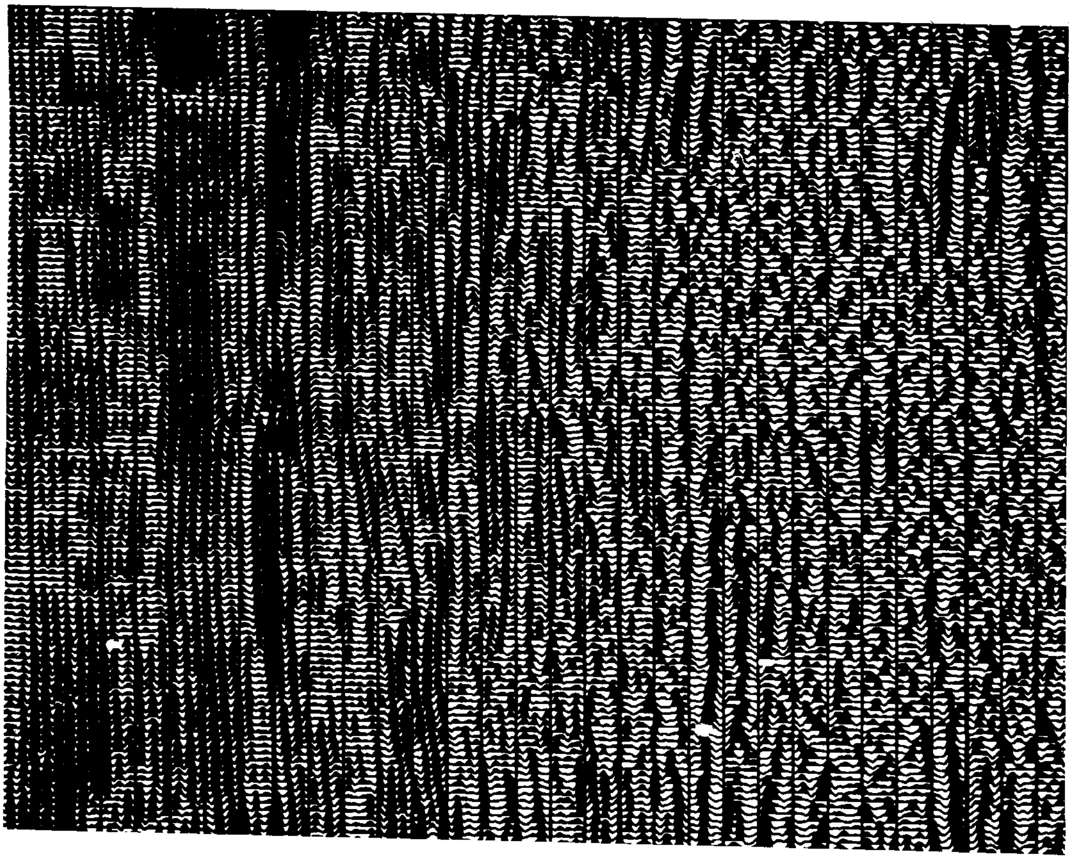

Fig. 7. Offshore Nigeria-scanned section.

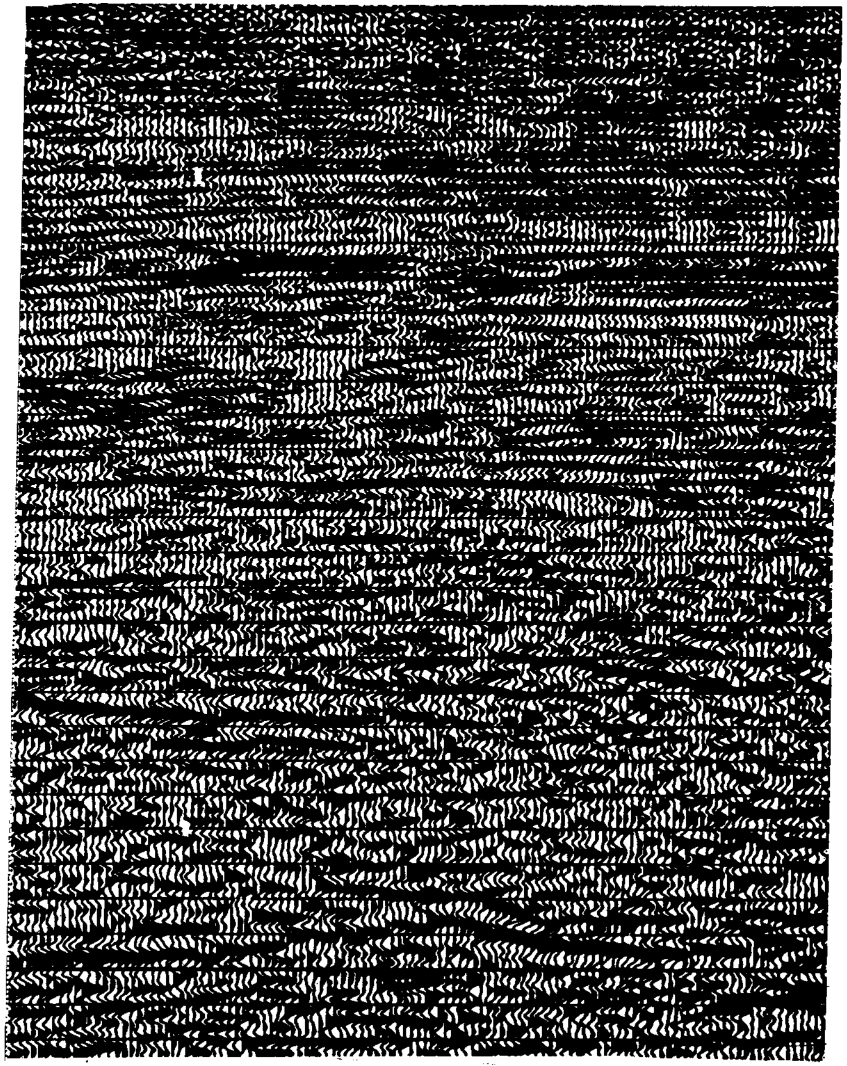

Fig. 8. Offshore Nigeria-migrated sections.

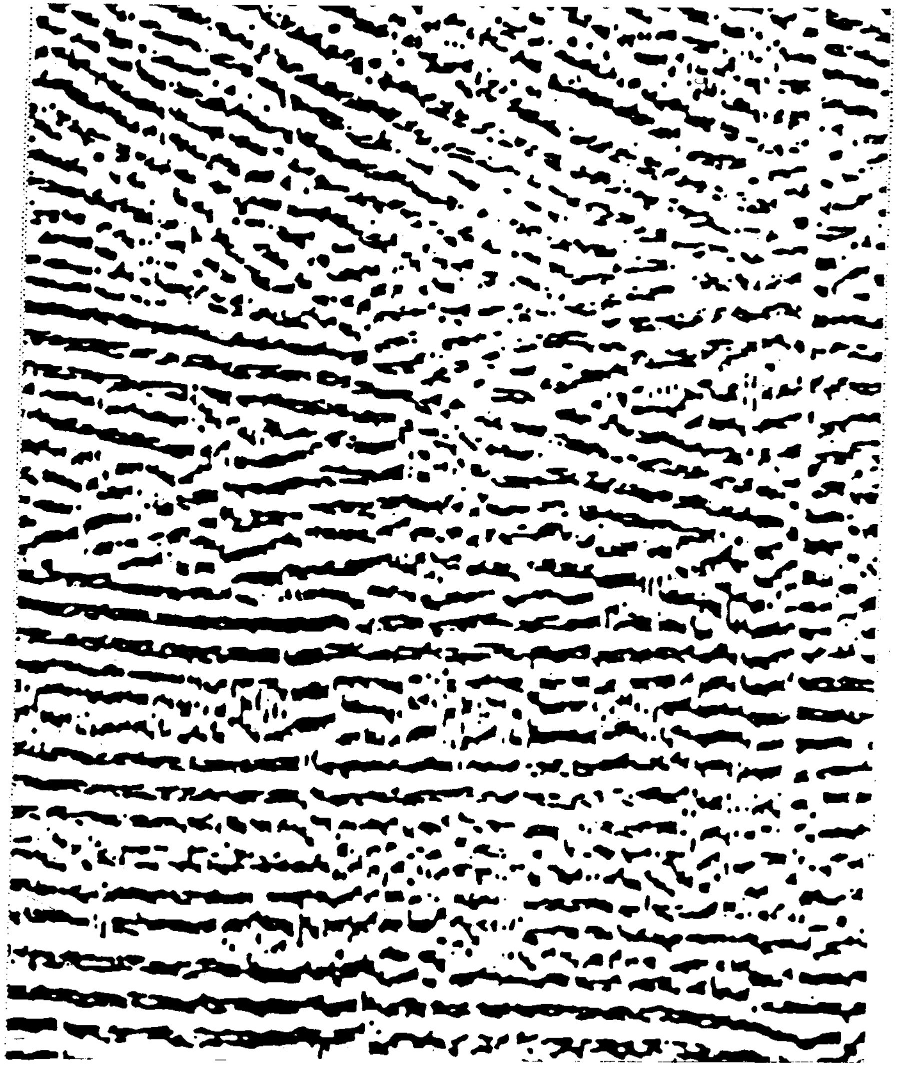

Fig. 9. CİS-original.

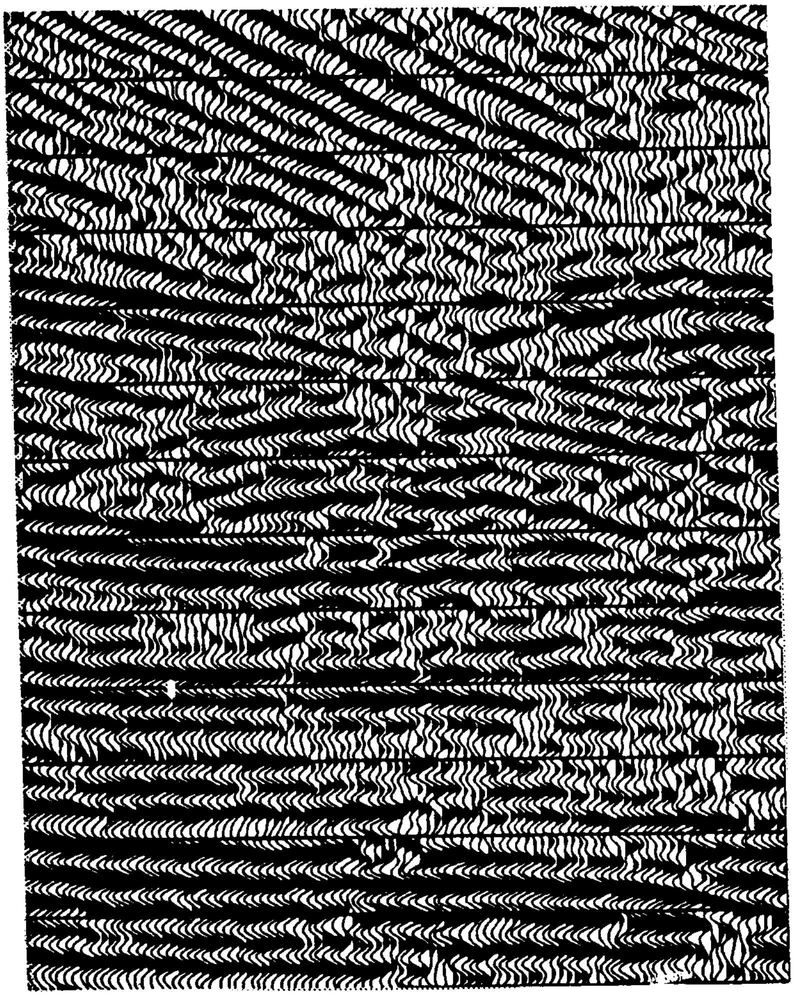

Fig. 10. CIS-reconstruction.

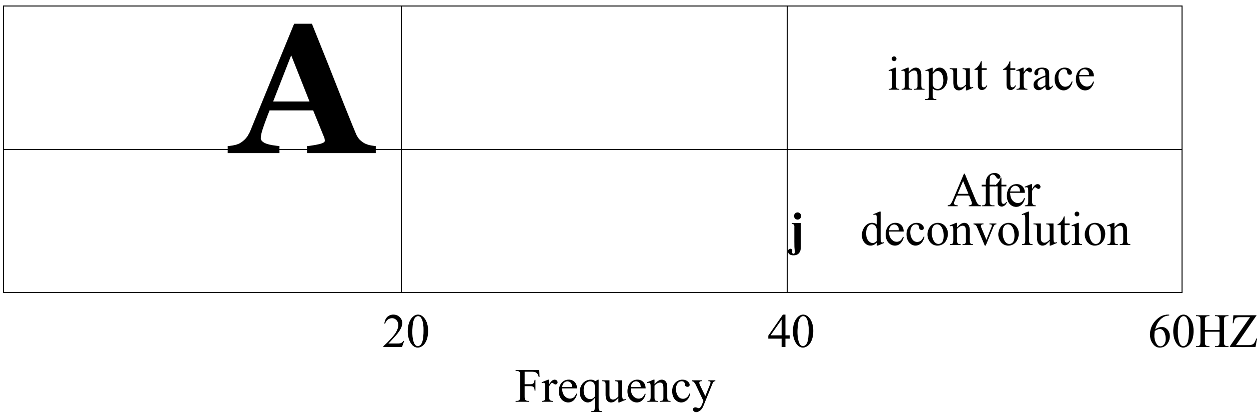

Fig. 11. Red Sea-power spectra.

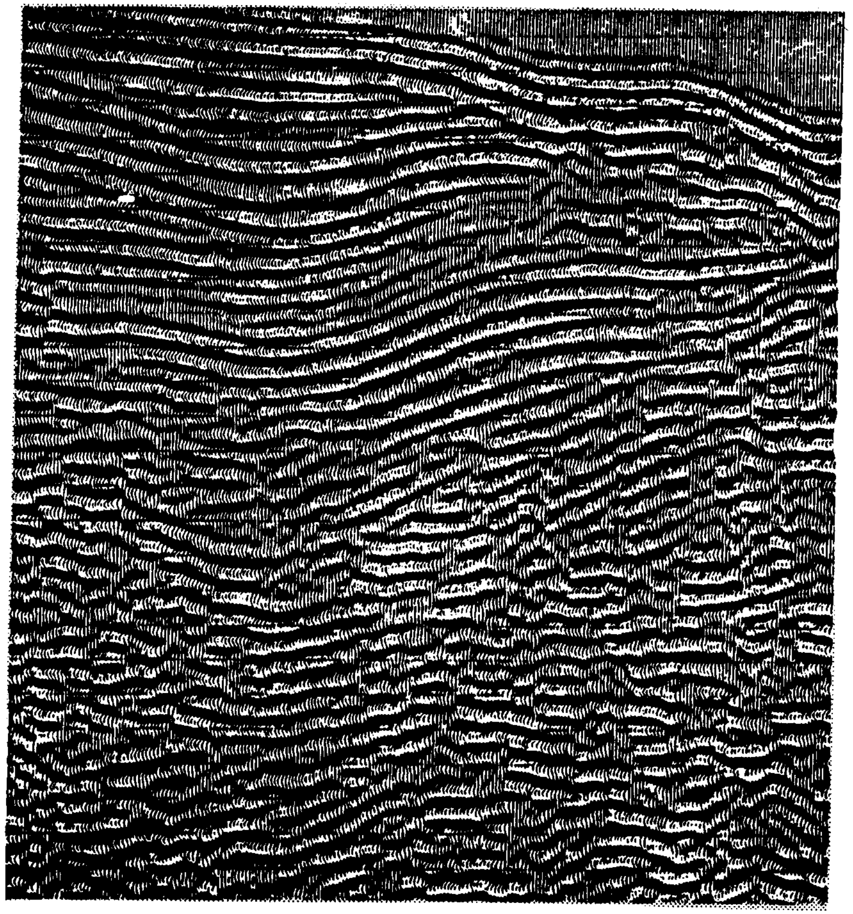

Fig. 12. Red Sea-original 12-24 Hz.

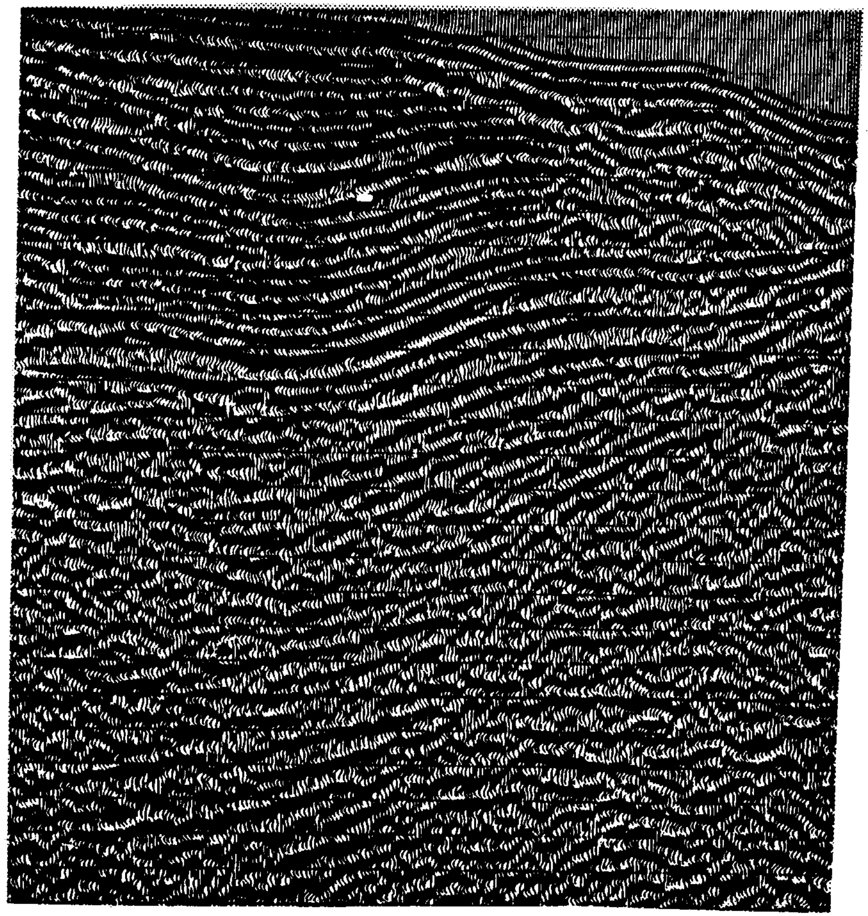

Fig. 13. Red Sea-after deconvolution and filter.

put section has been scanned and vectorized vvith vviggle trace reconstruction. The bias level has been reduced to a more normal 1990's value of 10 %, and the improved display is shovvn in Fig. 7. The improvement seen betvveen Figures 6 and 7 is due entirely to better display parameters. Note the increased resolution in the upper half of the diagram and the enhanced event standout in the lovver half.

Figüre 8 shovvs a further refinement due to post stack processing. Deconvolution has been applied, followed by the application of a Kirchoff migration algorithm. The resolution and the fault definition has improved considerably in the upper part of the diagram. A series of faults can be seen in the lovver part of the diagram, vvhile the deepest event now clearly turns över.

The technique for VAD displays relies on an accurate count of the density of black pixels över given unit areas bounded by the trace limits. A trace amplitude is assigned to each area according to the grey or density scale. Thus the blackest area of the whole raster file assumes a maximum positive amplitude (peak), and the whitest area a maximum negative amplitude (trough). Ali other areas of the section are assigned an intermediate amplitude level according to their black pixel density.

There is also a hybrid algorithm, Variable Area Integration (VAI) that combines essential features of both the VA only and VAD methods. this is particularly suitable for use on poor quality or damaged films and prints.

Figüre 9 shovvs some data from the CIS. Note how the peaks deflect to the left and not the right. Many of the peaks have faded out due to poor quality copying or printing. The reconstructed version is shovvn as Figüre 10 and contains a high level of appropriate repair, greatly improving the usability.

The VAAVT is the most rigorous method, but it can only be used vvhere the vviggle trace of the original print is clearly visible. The VAI method is more robust and it can be used on even the poorest quality sections.

The VAI algorithm is also useful in removing unvvanted marks that can appear on the film sections due to: a) film degradation; scratches, folds, tears, creases, dirt during reproduction, chemical instability of film because of production problems of inadequate storage facilities, b) interpretation marks and colours, and/or drafting annotation. More persistent marks may need to be removed from the raster file, prior to rectorizing, by using a pixel editing facility.

In addition to the post stack processing already shovvn, a full range of options are available: a) vvavelet procesing/analysis, b) deconvolution, c) spectral vvhitening, d) vveighted trace mix, e) recursive dip filtering, f) space variant muting and editing, g) ırace scaling/ balancing, h) filtering, i) structural static application, j) phase rotation/match filtering, k) Kirchoff migration.

Figures 6 to 8 shovv the povver of reprocessing after scanning. As a further example, Figüre 11 shovvs the povver spectra from a Red Sea section before and after deconvolution. The bandvvidth of the scanned original is severely restricted to a 12-14 Hz freguency range (Figüre 12).

The deconvolution operatör has recovered some of the energy associated vvith the slopes of the filter but also introduced a lot of noise. This vvas filtered back and the comparison of Figures 12 and 13 clearly shovvs the benefits of the vvhiter, albeit stili limited, spectrum. The resolution of the upper section is superior and the deeper section shovvs a number of continuous events dipping in the opposite direetion to the vvater bottom and its expected multiples.

Another problem associated vvith poorer quality films/prints is that of spatially varying intensity of both seismic and annotation images. One technique is to scan the seismic lines a number of times at differing threshold levels. Each scan is vectorized and displayed to test if the optimum threshold has been established. If no re-scanning is required the portions are merged to form a complete section.

A second method is to use dynamic threshold adjustment, such that each part of a highly varying image can be optimised prior to vectorization. This can be achieved in one pass using grey scale or photo mode scanning. The output is a binary (black or vvhite) image vvhich can be used conveniently in the vectorizing algorithms.

This majör development also allovvs ali arehived films to be scanned and stored on a CD-ROM optical disk in a compact binary format vvithout being vectorized. Both seismic trace and full header/sidelabel annotation can be handled. Ali these data can be easily revievved from CD on, an inexpensive PC. Hard copy can also be made available from an online thermal plotter.

It is then feasible to run dovvn voluminous and expensive film vaults by substituting this eleetronic method of storage.

CONCLUSIONS

Seismic paper sections (analog) can be converted accurate ly and cost effectively into a trace image in SEG-Y format. During the vectorization, data reconstruction can be effected to repair damaged and marked films. Manual editing is available if required.

The trace image data can be subsequently reprocessed using a full range of post stack techniques including but not limited to migration, phase rotation and structural static adjustment. Any number of displays at preferred scales can be reproduced and new drafting can be included on them.

The SEG-Y tape can be arehived for future processing or display uses or loaded onto a vvork station for a detailed interpretation.

The techniques discussed above can successfully and economically convert an inventory of difficult and underutilised seismic sections into a highly usable and very valuable exploration resource.