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COMPARISON:SEMBLANCE SPECTRA AND VELOCITY FUNCTION TECHNIQUES OF VELOCITY ANALYSIS

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مقارنة طريقتي الأطياف والدوال لتحليل السرعة السيزمية

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أعطى تحليل السرعة السيزمية بإستخدام طريقة الأطياف (Semblance spectra) تنائج أفضل من التي تم الحصول عليها باستخدام دوال السرعة (Velocity functions) ولقد تميزت بالحصول على قيم أعلى لسرعات التكدس (Stacking velocities). تبين من خلال تقييم ومقارنة سرعات التكدس المتحصل عليها باستخدام دوال السرعة مع السرعات المتوسطة (Average velocities) المقاسة من سرود الآبار الواقعة على الخطوط السيزمية أن السرعات المتوسطة أعلى من جميع سرعات التكدس بينما تتباين نسبياً بمقارنتها مع السرعات المتحصل عليها بطريقة الأطياف.

لقد أدى إستخدام طريقة الأطياف إلى تحسن واضح في نوعية المقاطع السيزمية والذي مكن من التعرف بصورة أوضح على بعض الظواهر الجيولوجية مثل. الصدوع.

ABSTRACT

The velocity analysis by using the spectra has shown better results than the velocity function technique, besides that the former is characterized by higher stacking velocity values. The stacking velocities obtained from the two techniques were evaluated in relation to the average velocities from wells located on the seismic lines. The comparison shows that all the velocity function values are much lower than the average velocities. The stacking velocities by using velocity spectra vary slightly between lower and higher values than the average velocities.

The raw final stack using velocity spectra show better improvement than the final stack using velocity functions; for example in the recognition of faults.

INTRODUCTION

The basic scheme in velocity analysis has been described by authors such as Taner and Koehler (1969), Neidell and Taner (1971), Al-Chalabi (1979), Robinson (1983), Robinson and Durrani (1986) and Mayne (1962). There are various velocity analysis techniques which are applied by the industry as source of stacking velocity required for dynamic correction, stacking and migration of the seismic traces. Velocity spectra and velocity functions are the most common of these techniques.

The seismic data used in this study were recorded for the Zuetina Oil Company during 1988 from Block 102, Sirt Basin, Libya (Fig. 1). The data were processed by Halliburton Geophysical Service (HGS) using the velocity function technique. The velocity spectra technique, and CMP stack were conducted on the same seismic data. The aim was to derive meaningful stacking and to investigate their accuracy for stacking of seismic sections in comparison with the stacking velocities already picked by HGS. This comparison is to bring out errors in stacking velocity obtained from the velocity function technique.

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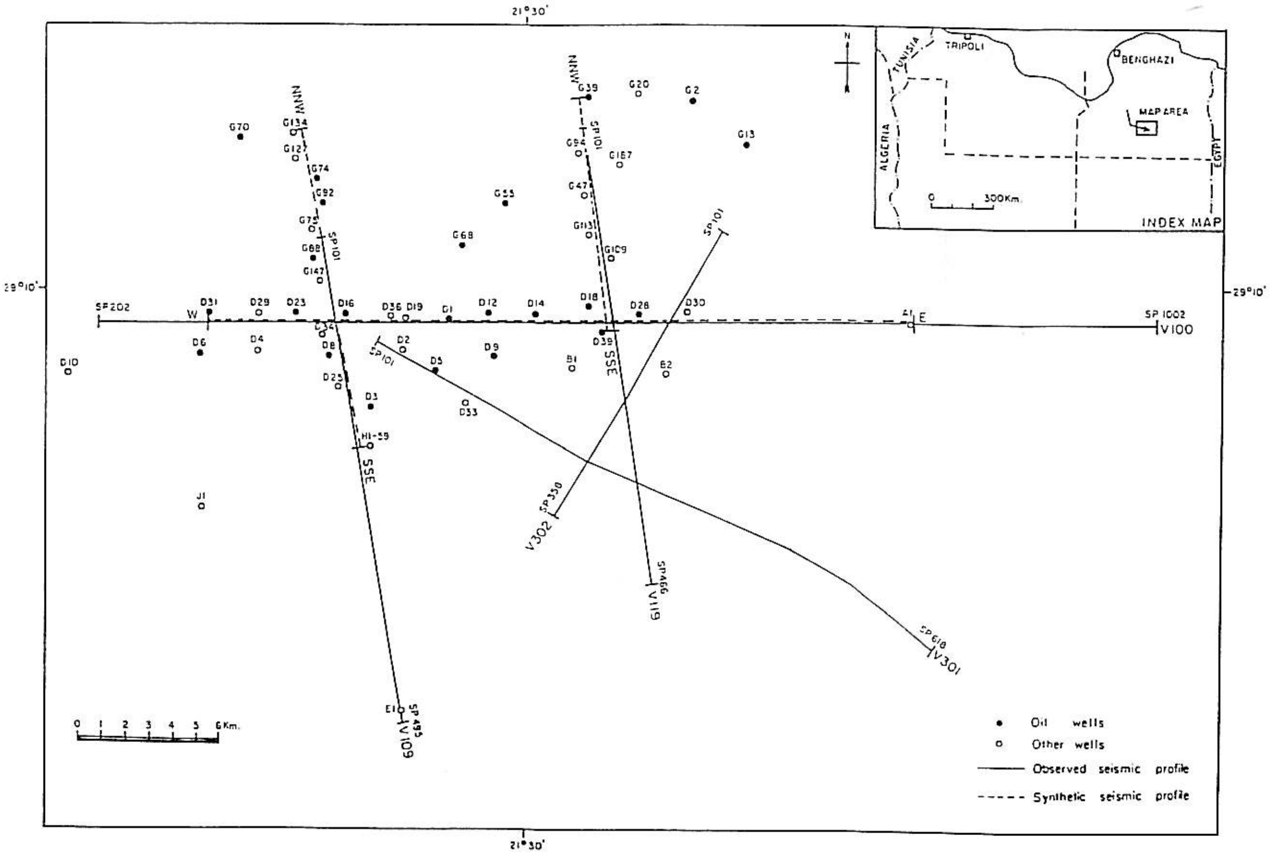

FIG. 1. Location map showing the seismic lines.

VELOCITY ANALYSIS METHODS

1. Velocity Functions and Trial Stacks Method

The Halliburton company's approach consists of selecting a portion of stacked data (23 stacked traces) which have been NMO corrected using 11 velocity values. These values range from the lowest to highest expected velocity (1.600–5.000 km/s). A single trial velocity is used for stacking all events from the beginning to the end of the record. Reflections had their highest amplitude on the stack panels when corrected with the optimum stacking velocity. The display of optimum velocities against the time where each optimum velocity results with highest amplitude, is known as velocity function. Hatton *et al.* (1986) have mentioned the weaknesses of the method which are mainly its lack of resolution in velocity due to the often coarse increment selected for reasons of economy and poor visual dynamic range. Besides, the velocity function technique is heavily dependent on the human's judgement of alignment of the seismic events. Therefore, different processors may not pick the same stacking velocities.

2. Velocity Spectrum Technique

Taner and Koehler (1969) have described a technique which was designed to permit interpretation of stacking velocity Vs as a function of the zero-offset travel time To. The technique involves plotting a measure of trace coherence computed along moveout curves which are defined by discretely sampled values of Vs and To. Their approach consists mainly on the trial of different values of stacking velocity at particular values of normal incidence time to calculate hyperbolic moveout within a short time gate. When the best value of Vs is found the data are corrected with time shifts based on this velocity and stacked together. The velocity spectra are plots of a coherence measure, called semblance, of reflections that exist at times To, having stacking velocities Vs.

a. Semblance

Semblance is a measure of the goodness of the stacked trace within a time gate. It is also defined by Sheriff (1978) as the ratio of energy resulting from a stacking velocity assumption compared to the amount of energy available to be stacked. Semblance has been described by Al-Chalabi (1979), Robinson (1983), Said (1990) and Hatton *et al.* (1986). Neidell and Taner (1971) have defined it as follows;

$$S_t = \frac{\Sigma_i a_i^2}{\Sigma_i \Sigma_j b_{i,j}^2}$$

where a_i is the ith amplitude of the stacked trace and $b_{i,j}$ is the ith amplitude of the jth trace of the component CMP set. The semblance S_t has a possible range from 0 to 1 ($0 < St < 1$) with perfect comparison corresponding to 1, which depends on whether the traces contain only the signals or contain noise in addition to the signal. This affects the line-up of the reflection events which leads to a decrease in the amplitude of the correct Vs peak power (see Taner and Koehler, 1969; Neidell and Taner, 1971 for details). Different Vs values are calculated at the same To and a plot of semblance versus Vs will show a peak where the correct value of Vs has been used and all the traces have been brought into alignment.

This procedure is repeated for a collection of zero offset times, generally at equally spaced time increments all the way down the CMP gather. The result is called the velocity spectrum at the common midpoint. A curve or contour of power will develop showing the stacked semblance maxima wherever there is appreciable reflection energy and will give spot determinations of Vs and To between which linear interpolation may be made for intermediate travel time.

Not only does the semblance tend to be large when a coherent event is present but the magnitude of the semblance is also sensitive to the amplitude of the event. Strong events exhibit large semblances and weak events exhibit moderate values of semblance whereas incoherent data have very low semblances (Robinson, 1983). Semblance and other coherence measures are used to determine the value of parameters that will optimize a stack. The most important application of semblance is in the computation of a velocity spectrum from which stacking velocity is determined as a function of stacking time (Said, 1990). The velocity that produces the maximum semblance represents the best fitting hyperbola and thus produces the best stack at stacking time. As a result this optimum velocity is called the stacking velocity.

b. Velocity spectra display

Velocity spectra display is one of the most common forms of displaying the result of velocity analysis as described by Al-Chalabi (1979), and Taner and Koehler (1969). Figures 2 and 3 show examples of spectra displays with the coherency buildups. In these displays the coherency value as a function of time and velocity is represented in plots with time varying along the vertical axis and velocity varying along the horizontal axis. The velocity analysis is presented as contours of semblance. The contour in effect brings the values of stacking velocity as a function of arrival time which would result in bringing out events on a stacked section.

The displays are frequently accompanied by numerical tables of the measured coherency values for verifying root mean square velocity (Vrms) estimated from the display and curves for semblance and amplitude (Fig. 3). The velocity analysis program gives a listing of velocity as a function of time at the particular location where the analysis is made.

c. Interpretation of spectra displays

Velocity spectra are used to pick stacking velocities and are considered to be a very convenient method for good quality high volumes of data (Hatton *et al.*, 1986). The interpretation of velocity spectra plots basically involves the identification of coherency build-ups which are caused by primary reflections, and the isolation of those due to multiples and other spurious coherent events. The determination of the velocity function needed for optimum stacking, relies heavily on the build-ups of coherency at each point in the spectrum. Thus it requires high precision in selecting the best coherency which represents the primary reflection events especially in poor quality displays.

The observation of lateral variation in stacking velocities at any particular time interval is essential because a sudden change in velocity between the location of velocity analysis might lead to a change in reflector continuity or strength which could be interpreted as a geological change. Establishing close reference to the seismic section and the CMP record display, when available, is important in identifying the presence and strength of primary reflections at appropriate travel times, and also allows the presence of non-primary events to be checked (Al-Chalabi, 1979).

Well data at the same CMP locations could provide a valuable check for the spectra display through the identification of the main lithological interfaces which are expected to generate the primary reflections. Recognition of non-primary coherency build-ups on the velocity display can be a valuable guide for the processing and interpretation of the seismic section.

The interpretation, especially of good quality data, simply consists of connecting contoured highs that clearly indicate a realistic velocity-time function

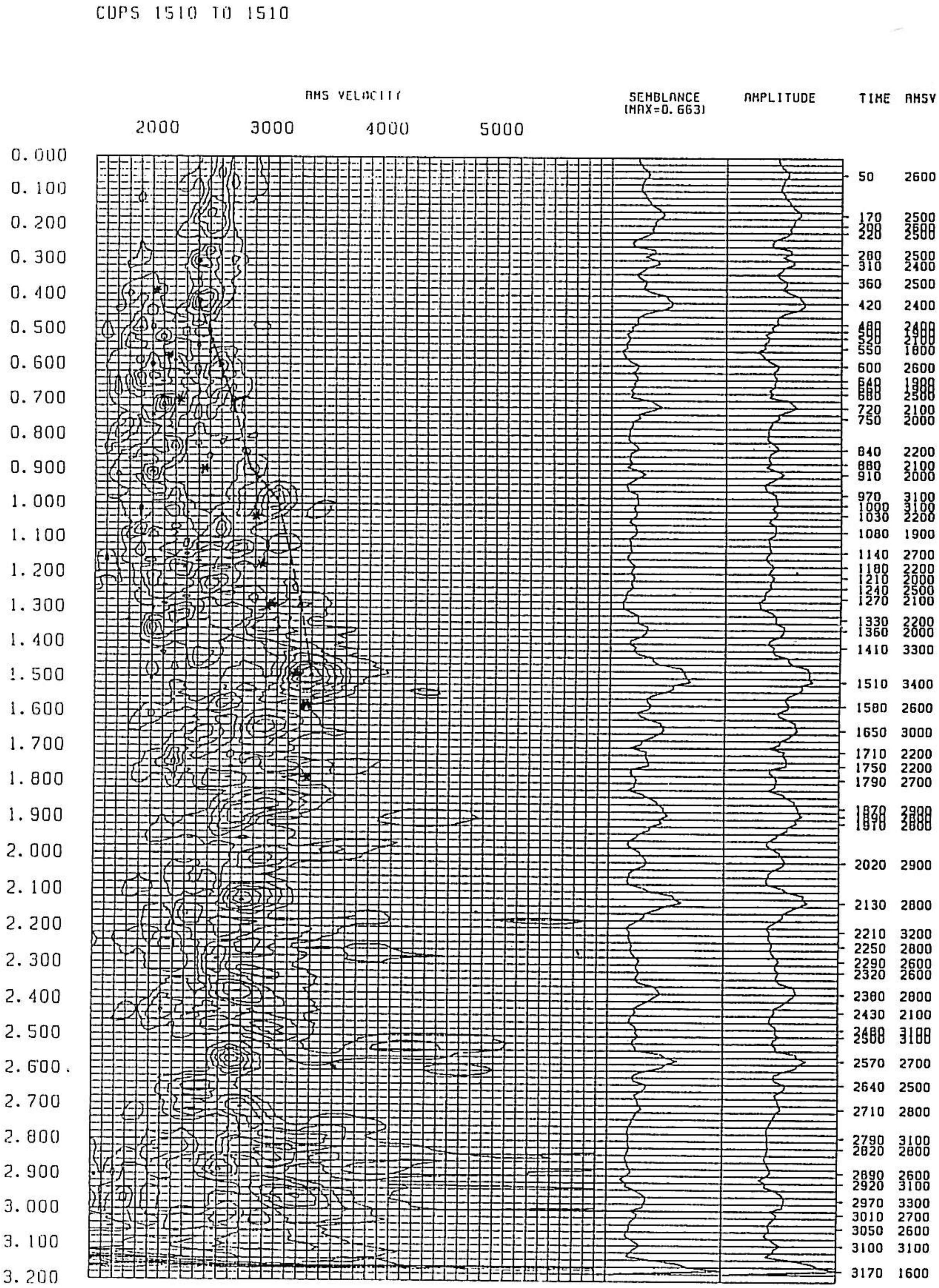

FIG. 2. Display of velocity spectra, CDP 1510, seismic line V100 showing the picking of stacking velocities.
------------ = Picked velocity.
* * * * * = HGS picked velocity.

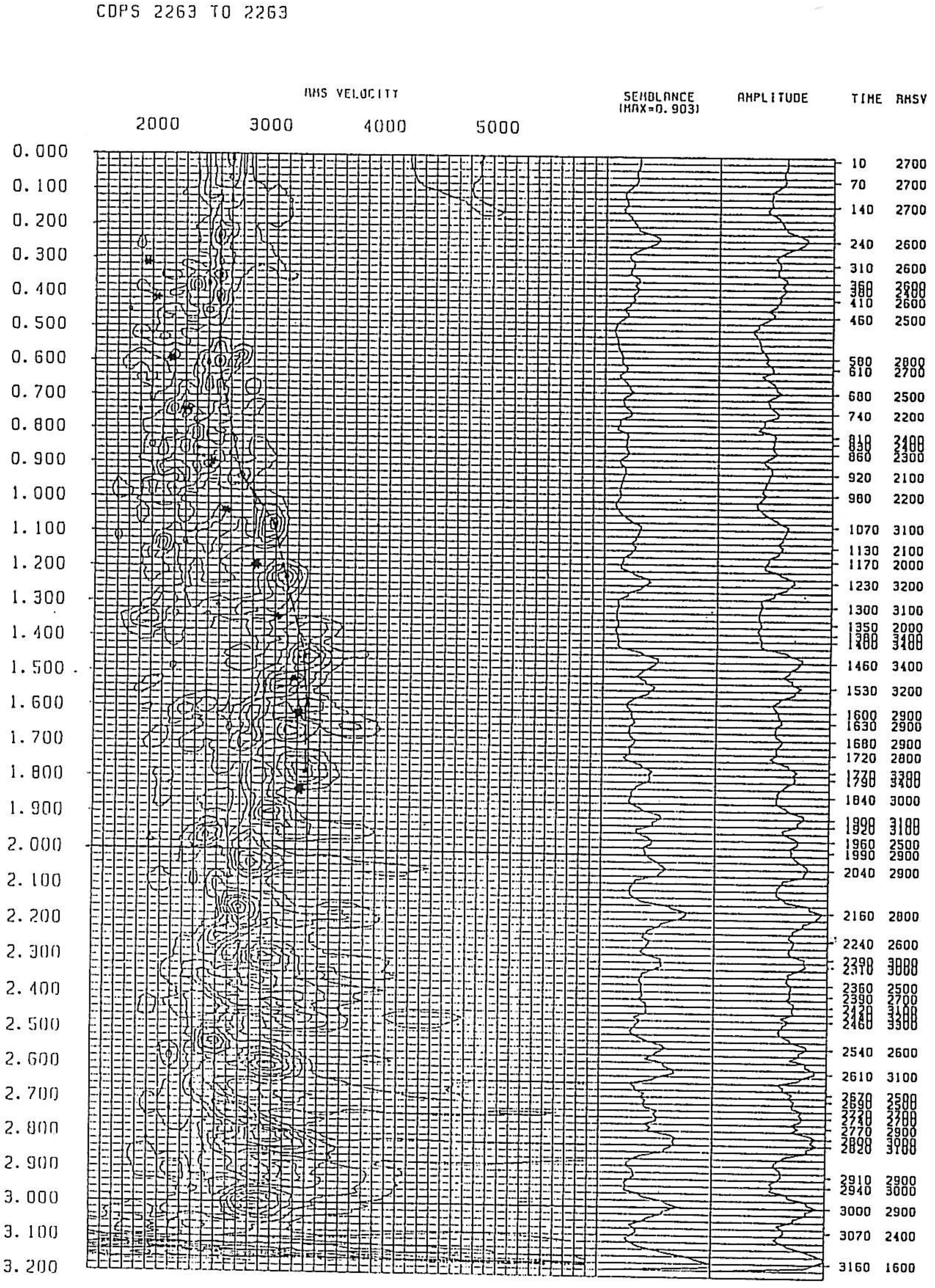

FIG. 3. Display of velocity spectra, CDP 2263, seismic line V100 showing the picking of stacking velocities.
———————— = Picked velocity.
* * * * * = HGS picked velocity.

(Fig. 3). Plots of semblance indicate the location in time of the most coherent events. In case of poor quality data reliable events should be picked first and the gaps should then be filled by comparison with adjacent analyses. Multiples are usually clearly identified in a velocity spectrum display, tending to align nearly vertically beneath the generating primary events.

VELOCITY ANALYSIS OF SEISMIC LINES V100 AND V109

The final display of the data showed that the primary reflection events are affected by the presence of multiples which obscure recognition of main reflectors such as the basement interface. Therefore, the main purpose of conducting velocity analysis was to improve the quality of the primary reflectors of the main reservoir rocks. This can be achieved by recognizing and subsequently attenuating the multiples and other effects. The step was decided after running post-stack deconvolution and the establishment of improved quality data such as the bringing out of a distinctive basement reflector and the reduction of the effect of multiples. The result indicated that the multiples could be partly the result of improperly picked stacking velocities used for the CMP stack.

1. Procedures

The velocity analyses were carried out as follows:

1. Seismic lines V100 and V109 (Fig. 1) were selected for carrying out the velocity analysis. The data were requested in the form of CMP gathers with static correction and pre-stack deconvolution applied. The V100 line consists of 1597 CMP gathers and the analyses were selected at every 50 CMP gathers. The V109 line consists of 768 CMP gathers and the analyses were selected at every 60 CMP gathers.

2. A number of CMP gathers were displayed at different parts of the seismic line in order to check their quality and arrangement. Figure 4 shows an example of such display.

3. The velocity spectrum at each velocity analysis location was derived from 10 CMPs, 5 at each side of the selected CMP in order to reduce the semblance peaks created by noise. Displays of velocity spectra were obtained at the selected CMP locations.

4. The velocity spectra displays were used for picking stacking velocities needed for stacking the seismic sections (Figs 2 and 3). Comparison between these displays was conducted to check the trend of coherency build-ups of the picked velocities.

5. The stacking velocities obtained were used for producing brute stack sections (Fig. 5). The velocities are applied to CMP stacks to check if any improvement could be achieved regarding the primary reflection events, and attenuation of multiples and any other events interfering with the primary reflectors.

6. Comparison is carried out between the new stacking velocities and those picked by the company (Figs 2 and 3) and also between the produced sections and the contractor's final sections (Fig. 5a–b) to check against any error resulting from procedure, interpretation, or computation of the stacking velocities which are suggested by the presence of multiples in the contractor's final sections.

7. Average velocities measured from well data of well A1 are used for evaluating both the new and the contractor's picked stacking velocities as shown in Fig. 6.

2. Data Interpretation

a. Velocity spectra

Velocity displays were interpreted by picking the readily recognizable primary coherency build-ups. The picking out was at the high velocity edge of data which represents mainly the primary reflections. The stacking velocity functions were obtained by connecting those build-ups. Figure 2 shows a typical velocity spectra display computed from 0.100 sec to 3.200 sec for velocities varying from 2.500 km/s to 3.500 km/s at 0.100 km/s intervals. Coherency representing the primary events are characterized by displacement in the direction of increasing time. It has a maximum time limit down to about 1.50 sec. Stacking velocities are obtained by connecting the interpreted primary energy arrivals. The spectra also show that multiple energy started around 0.400 sec to 3.200 sec. These multiples are of lower velocities than the primary events and align nearly vertically especially around 1.650 to 3.200 sec. The coherency buildup of the basement reflector was confirmed by comparison with the available well data of well D1–102 (754.5 ms OWT) which has defined the time limit of the primary events at around 1.500 sec. Figures 2 and 3 show that the contours become increasingly stretched along the velocity axis, with increasing travel time. This stretching represents a deterioration in the sensitivity of the coherency measure with increasing time and causes a loss in resolution. It results from the fact that with increasing time, large stacking velocity changes correspond to increasingly smaller NMO changes and low frequencies become increasingly predominant.

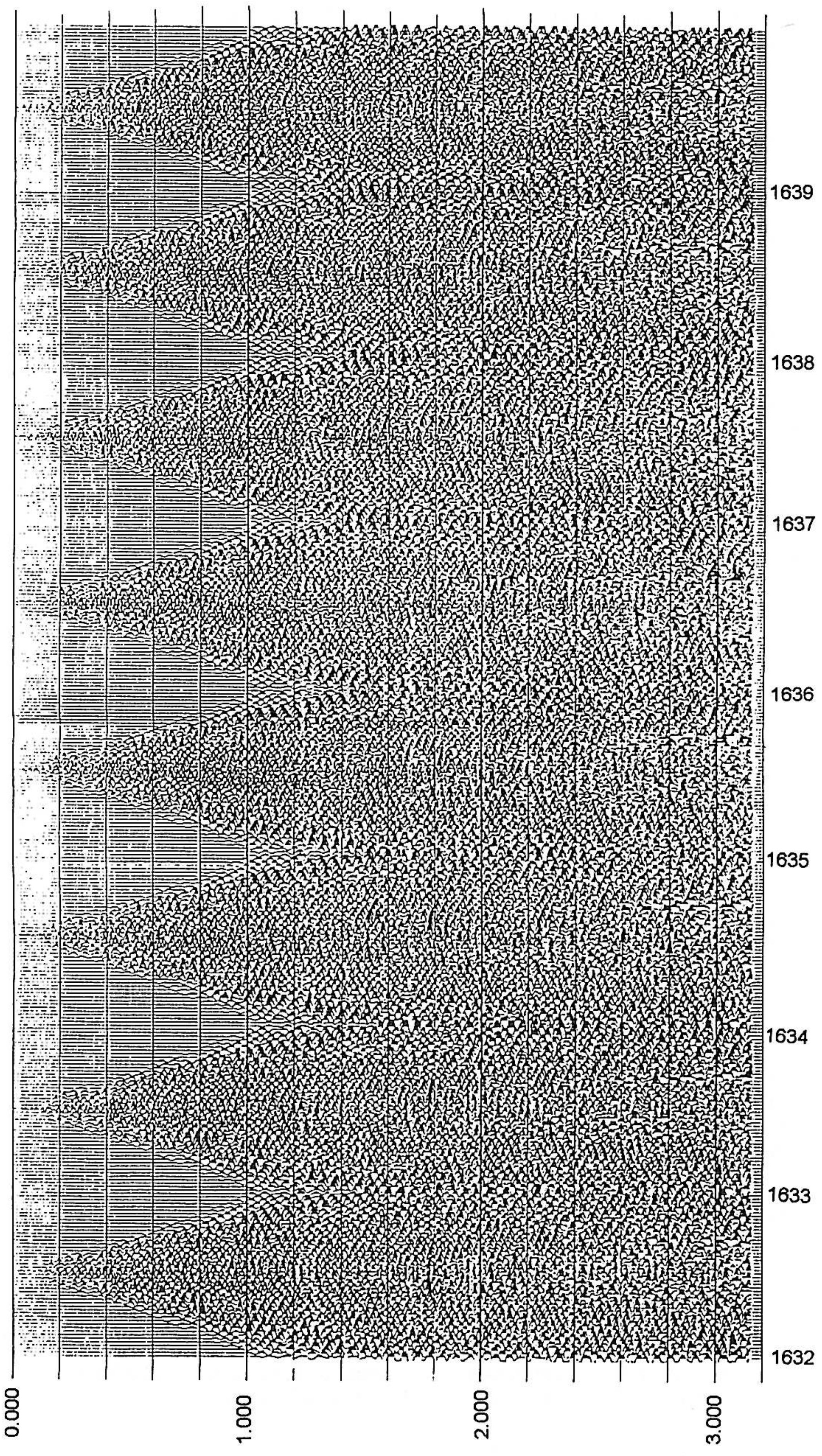

FIG. 4. Display of CDP gathers from seismic line V100, to check their quality and arrangements along the line. The display is showing good quality data.

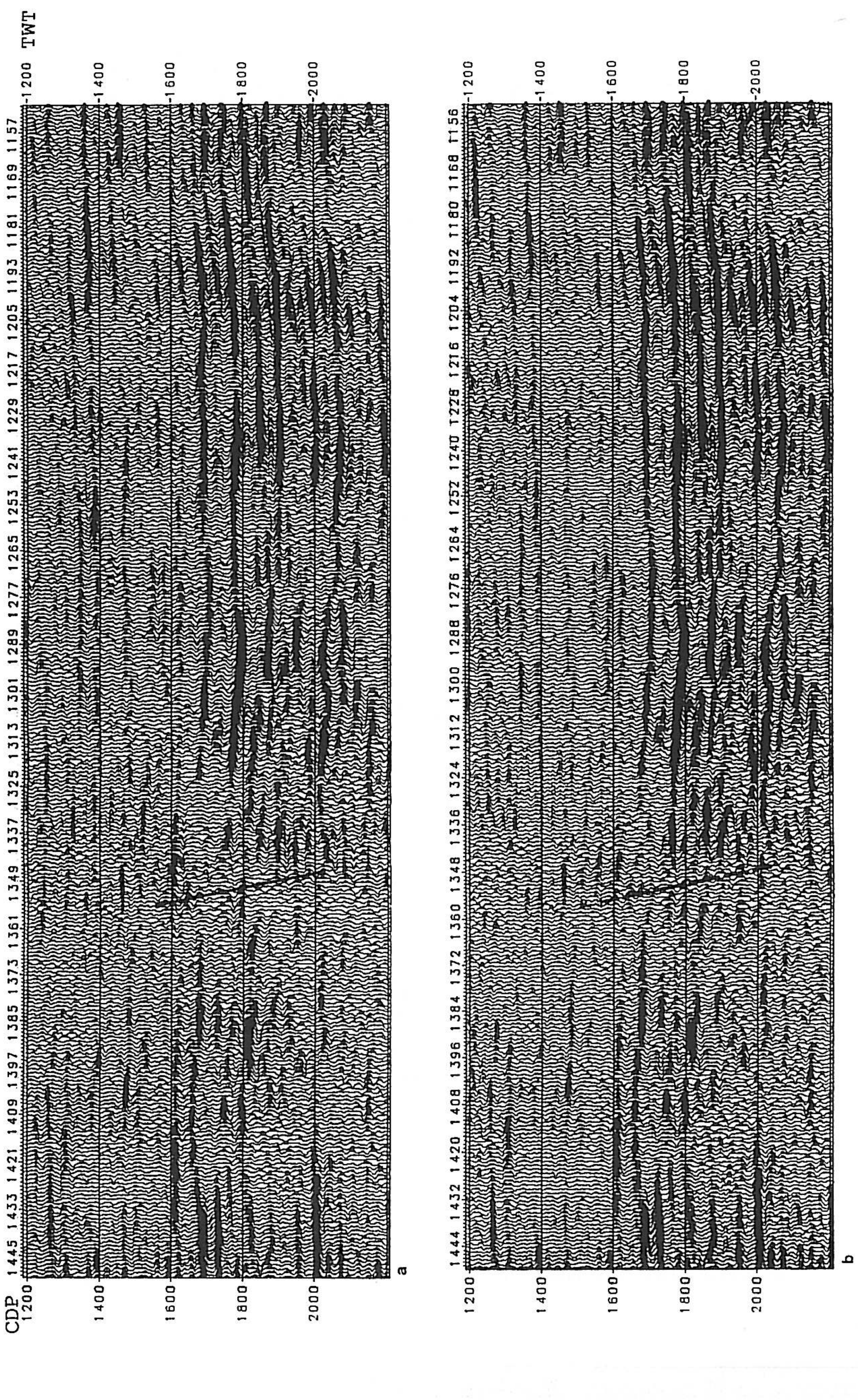

FIG. 5. Part of seismic section V109. (a) final section stacked by using the contractor's picked velocity. (b) Raw final section stacked by using newly picked stacking velocity.

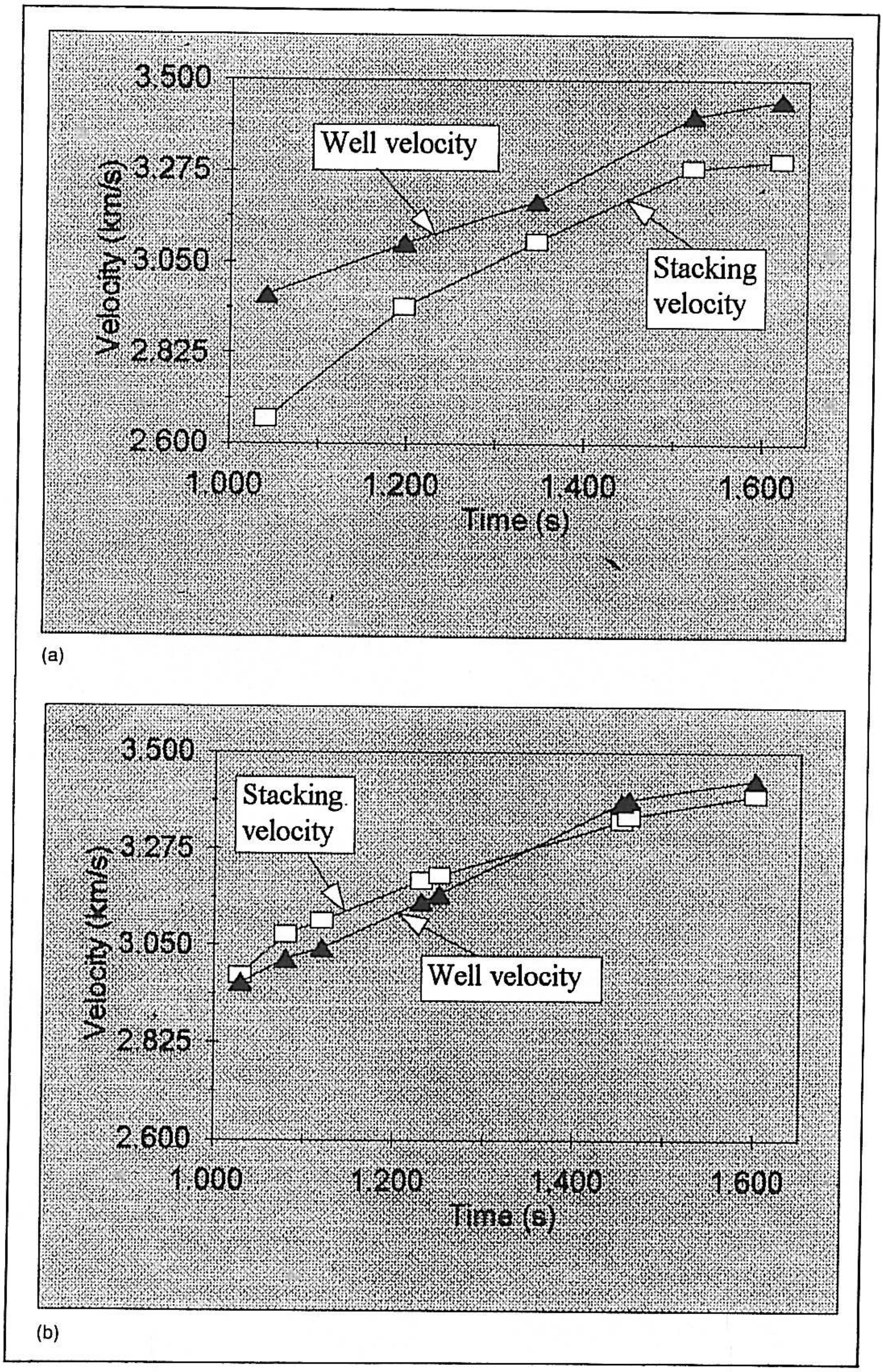

FIG. 6. Comparison between the average velocities measured from well A1 and stacking velocities. (a) Contractor's picked stacking velocity; (b) Repicked stacking velocities. □ = Stacking velocity, ▲ = Well velocity.

The contractor's picked stacking velocities are plotted on the velocity spectra (Figs. 2 and 3) to show the differences between the picked velocities which are expected to represent the primary reflection events.

b. Comparison with the contractor's final sections

An example of the noticeable improvement in the raw final stack section is shown in Fig. 5 which represents a part (between CMPs 1151–1449) of seismic section V109. Fig. 5b shows that the multiples generally became weak or attenuated all over the section and in particular at the lower part between TWT 1800 and 2000 ms. There is also evidence of weakening of multiples at the interval between CMPs 1372 and 1410, and TWT 1600 and 1800 ms. This could be partly a result of improperly picked stacking velocities.

Another example of the improvement (Fig. 5b) is the sharpness and better continuation of the reflection event between CMPs 1358 and 1449 and TWT 1450 and 1480 ms, and also between CMPs 1180 and 1332, and TWT around 1470 ms. There is a clear fault in this part of the section between CMPs 1353 and 1347, and TWT 1400 and 1800 ms, which is much better defined in the raw final stack section.

c. Comparison with well data

It has been mentioned (Dix, 1955; Taner and Koehler, 1969) that the root mean square velocity (Vrms) is generally about 2% higher than the average velocity unless affected by other factors such as dipping and is generally 1% lower than stacking velocity.

The contractor's stacking velocities and the newly picked stacking velocities are compared with the average velocities computed from well data of well A1–102 as shown in Fig. 6. At A1 well location a plot of average and interval velocities against depth is used to measure the average velocities at the selected picked time positions. Comparison between stacking velocities and average velocities measured from velocity logs is carried out. As shown in Fig. 6a the contractor's picked Vrms are lower than the average velocities computed from data of well A1. The velocities are different by an average of 0.169 km/s. Figure 6b shows that the newly picked Vrms for the five TWT between 1030–1250 ms are higher than the average velocity from A1 well by 0.046 km/s. For the three TWT between 1452–1600 ms, the Vrms are lower by 0.040 km/s.

MUTING

The mute is generally considered to be a necessary part of the processing sequence, and it is usually applied before velocity analysis. It is carried out to cut off refraction and noise caused by geometric and other effects on the far traces. Muting has been described by Dobrin and Savit (1988) as eliminating or suppressing a portion of the recorded data, and can be divided into three main types: first break muting, NMO stretch muting, and inner trace muting.

Yilmaz (1987) has mentioned that as a result of NMO correction, traces are stretched in a time-varying manner causing their frequency contents to shift towards the low end of the spectrum. Frequency distortion increases at shallow times and large offsets. Therefore, muting before stacking is required to prevent degradation especially of the shallow events. Mute produces lower fold data near the surface part of the section and it can be a few hundred milliseconds before the data is full fold. Normally this would be critical in the interpretation of shallow reflections where the fold is low.

Mute was performed by picking one of the CMP gathers at the start of the seismic section as shown in Fig. 7. The available velocities (Vrms) at the CMP location were then used for NMO correction. Display of the CMP after the correction was applied, was then used to mark the part of the CMP to exclude the shallow reflections at large offsets at the upper part of the CMP until about 200 ms TWT. The plot was then used to obtain the offset and time according to the picked points along the line which defines the mute. The last point should be the maximum offset in order to obtain smooth mute.

STACKING

Stacking is one of the important applications of seismic data processing in improving data quality. The CMP stacking method is used because of the redundancy in the multiple coverage method applied in seismic prospecting (Mayne, 1962). Stacking relies heavily on the velocity derived from velocity analyses. The NMO correction puts all the corrected traces into alignment and produces one output trace for each CMP gather. This composite trace is called the stacked trace for that midpoint and collection of all the traces forms the stacked section. The primary reflections stack constructively while multiples tend to stack destructively because the reflection times of multiple reflections generally increase faster with increasing shot-receiver distance than do those of primary reflections with the same vertical time. The newly picked stacking velocities produced from the velocity analyses of the CMPs along the seismic lines were used for obtaining brute stack displays (Fig. 5b). The sections are used for comparison with the contractor's final seismic sections (Fig. 5a) in order to find out if the previous velocity analysis was unsatisfactory.

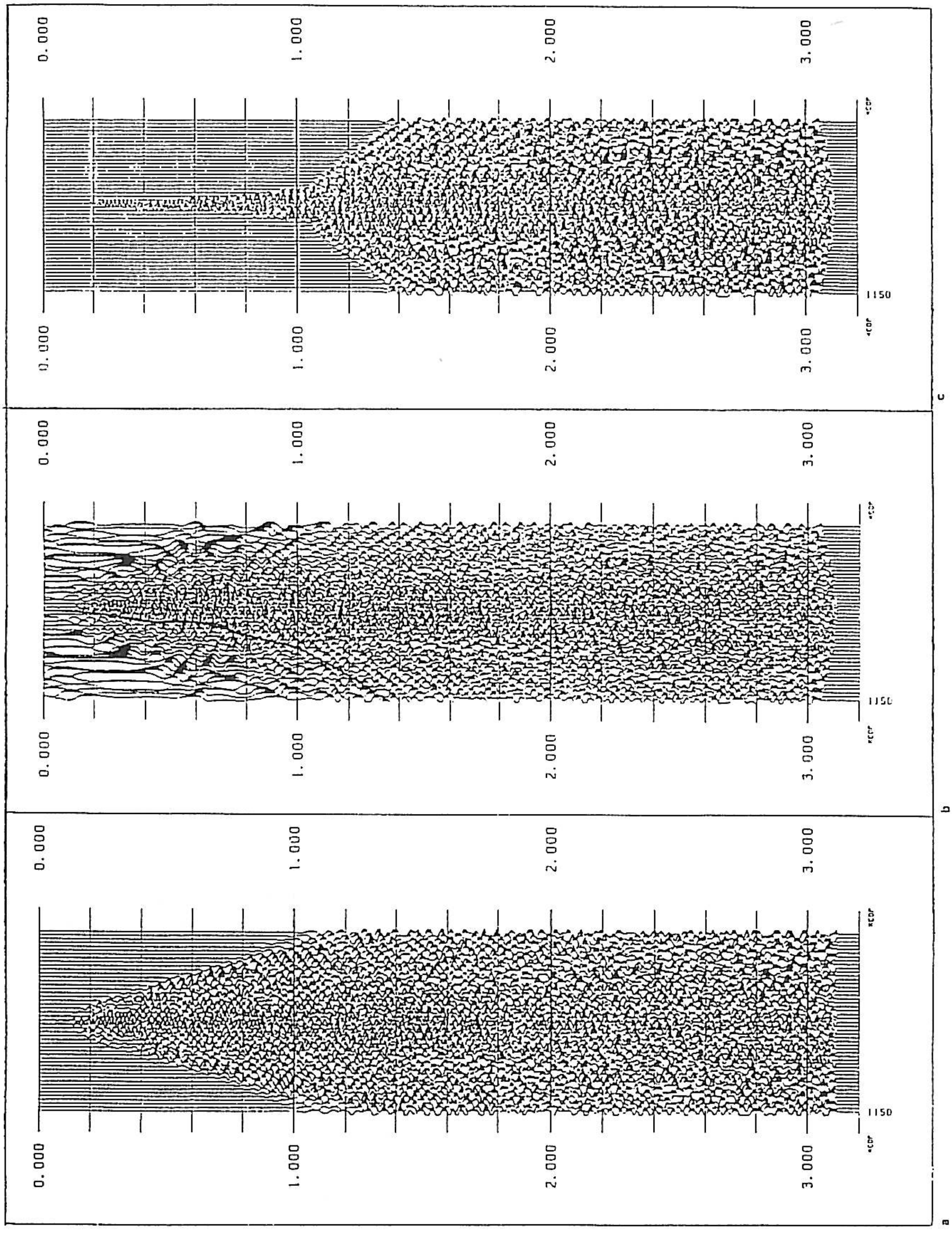

FIG. 7. CDP gather 1150, seismic line V100. (a) Before NMO; (b) NMO applied and the excluded part is marked; (c) After NMO and mute is applied.

DISCUSSION

The displays of velocity analysis of the selected CMPs show the picking of velocity when strong coherency build-ups exist. Such coherency, which represents the stacking velocities of the primary reflection events is more convincing than the velocity picked by using the velocity functions technique (Figs 2 and 3). Comparison of the velocity spectra have shown similarity in the trends of coherency build-ups at the selected locations along the seismic sections.

Comparison between the contractor's and the newly picked stacking velocity (Figs 2 and 3) shows that the newly picked coherency build-ups which represent the stacking velocities are characterized by higher values and are more convincing than the contractor's velocities.

The raw final stack sections were compared with the contractor's final sections (Fig. 5). They showed better improvement regarding the sharpness of the primary reflection events and the attenuation of the multiples which already existed in the final section. The variations between the raw stack and final sections could be taken as an indications of the effect of stacking velocity on reflection events. Indications for presence of a fault are shown in both sections. The fault in the raw final stack section can be recognized and sharply defined more easily than in the contractor's final section where scattered events obscure the main features of the fault.

Figure 6 indicate that the differences between the contractor's stacking velocities and the average velocities from well data are much greater than those between the newly picked velocity values and the same well data.

The attempted comparison suggests that the newly picked stacking velocities are much more representative than those picked by the contractor.

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