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Improved Static Corrections over Sand Dunes for Seismic Line NC151-V532, Western Libya

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تحسين التصحيحات الإستاتيكية الناجمة عن الكثبان الرملية للخط السيزمي NC151-V532، غرب ليبيا

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هذه الورقة تهتم بدراسة المشاكل الاستيايكية الناجمة عن الكثبان الرملية في الكشف السيزمي بطريقة الانعكاس وذلك بمنطقة عقد الامتياز NC-151 الواقع غرب ليبيا، ففي هذا الامتياز توجد كثبان رملية تمتد إلى عدة كيلومترات ويصل ارتفاعها إلى 100 متر في بعض الأحيان مسببة بذلك صعوبات لوجستية وفنية في عمليات الاستكشاف السيزمي بطريقة الانعكاس، ويرجع ذلك إلى التباين في ارتفاعها وانحدارها الشديد وكذلك إلى انخفاض سرعة الموجات السيزمية فيها والتي تسبب تأخيرا في انتقال الموجات السيزمية (سواء كانت الهابطة منها أو الصاعدة)، حيث يكون من الصعب حساب هذا التأخير الزمني لانتقال هذه الموجات في مثل هذه الكثبان الرملية.

ففي هذه الدراسة تمت مقارنة النتائج المتحصل عليها من استخدام طريقتين لحساب القيم الزمنية المستخدمة في التصحيحات الإستاتيكية، حيث اختير خط من الخطوط السيزمية المارة عبر هذه الكثبان الرملية، وتمت معالجة هذا الخط بمنظومة المعالجة السيزمية ذات البعدين (ProxMAX) . ومن خلال النتائج المتحصل عليها وجد أن طريقة الانكسار المسماة زائد- ناقص والمستخدمة في حساب القيم الزمنية للتصحيحات الإستاتيكية على أساس تصنيف زمن الوقت الزائد لكل مصدر أو لاقط وربطها بالقيم المتحصل عليها تعطي نتائج أفضل من الطريقة الروتينية المستخدمة سابقا والتي تعتمد على إيجاد نموذج تقريبي لسمك الطبقات السطحية وسرعة الموجات السيزمية النافذة خلالها. والسبب أن طريقة الانكسار المستخدمة هذه لا تتطلب إيجاد نموذج تقريبي كما هو سائد في معظم الطرق.

ولحساب القيم الاستاتيكية المتبقية، اختيرت طريقة الـ Maximum power autostatics من عدة طرق موجودة بمنظومة المعالجة السيزمية وذلك لأفضلية النتائج المتحصل عليها وخاصة إذا ما استخدمت هذه الطريقة مع تحليل السرعات مرتين على التوالي بالإضافة إلى ذلك تم استخدام التصحيح المتبقي والمسمى بـ Trim statics وذلك لتحسين نتائج المقاطع السيزمية النهائية.

Abstract: *Concession NC151 is located in the northwestern part of the Murzuq Basin (Libya), which is covered by linear sand dunes that reach heights of ~100 m above the gravel plain. The sand dunes cause large increases in the travel times of reflected events in seismic data. In recent years, the conventional method used to calculate field static corrections has been to interpolate the near-surface velocity structure between upholes. Results are often unsatisfactory on lines that cross the dunes because the reflection events contain false structures that correlate with sand dune topography. These structural artifacts are caused by residual static errors which are too large for automatic statics programs to correct during processing.*

An alternative method of calculating field statics is to pick the first breaks on the Vibroseis field records, calculate the delay times at each station, and use the delay times directly as the field statics after applying a linear adjustment to match them to the upholes. This simple version of the refraction method does not require near-

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surface velocity-depth models to be produced, and gives much better results than the conventional field static method. Since this method does not require any near-surface velocity-depth model because it works in time, it can be used in areas with variable LVL or HVL (e.g., sand dunes or permafrost).

The maximum power autostatics method was chosen from several residual statics methods that are available in the ProMAX package. Two iterations of maximum power autostatics and velocity analysis followed by non-surface-consistent trim statics improved the final stacked section.

INTRODUCTION

Robinson and Al-Husseini (1982) addressed the static problem due to sand dunes and described one approach to its solution. Their data were from Rub' Al-Khali, Saudi Arabia, where the dunes are about 1 km wide with a vertical relief of 60-90 m. They have generated a crossplot of traveltime against the elevation of the dune surface, above the sabkha or dune base, using data obtained from many dunes in the area. The crossplot cannot fully resolve either the long or short-wavelength statics in the dunes, but it can be used as an approximation in the computation of datum static corrections.

An important technique for estimating field static corrections is to analyse the first breaks on the seismic field records. In Vibroseis surveys, the first breaks are head-wave arrivals that have been refracted along a higher velocity layer beneath the surface layers. Several refraction methods have been used to estimate the thickness and velocities of the near surface layers. All of these methods are based on the same basic principles for analysis of refracted head waves. Marsden (1993) reviewed the refraction statics methods, starting with the slope/intercept method and ending with time-term technique. He concluded that most methods produce almost identical statics solutions; the differences between them lie in their speed of application.

The presence of extensive sand dunes in NC151 (Fig. 1) causes logistic and technical difficulties for seismic reflection prospecting, due to the steep angle of repose of the sand dune faces and the low seismic

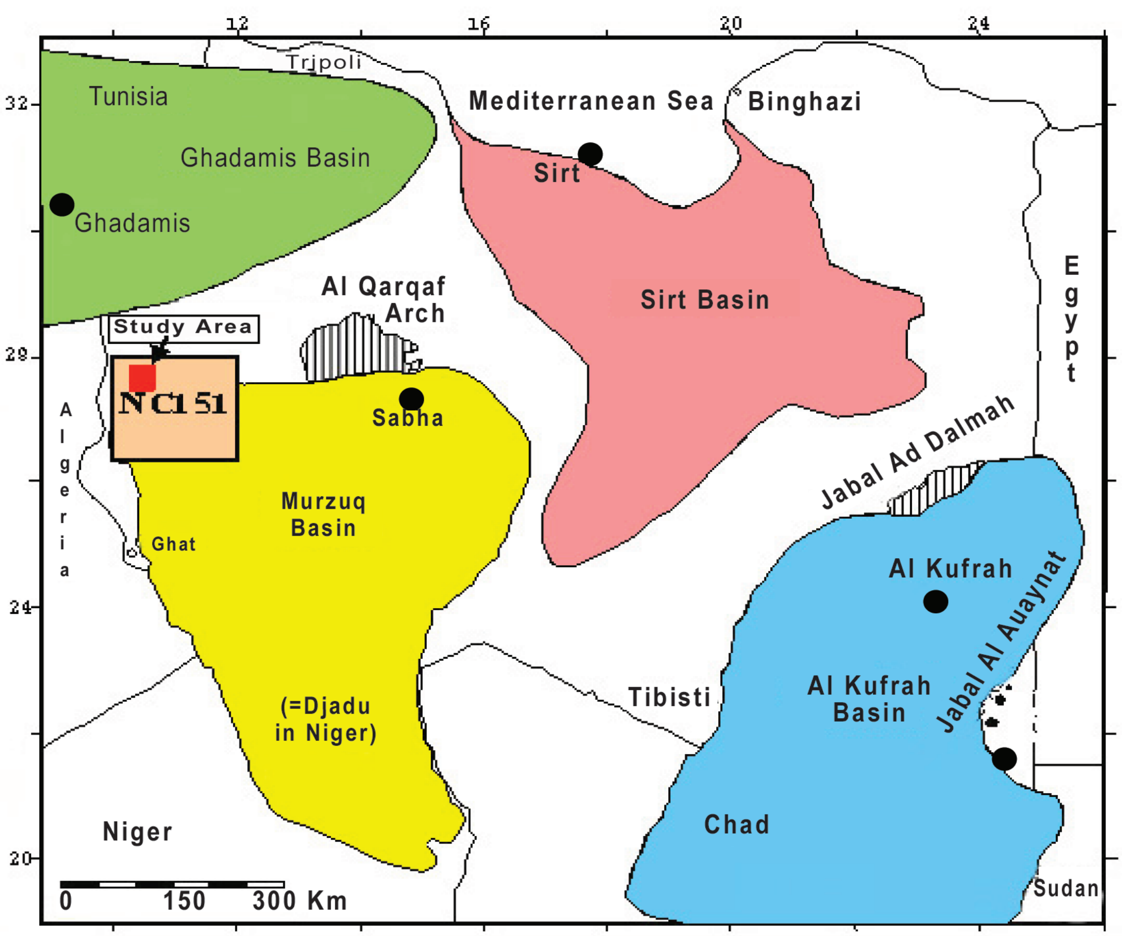


Fig. 1. Generalized location map of sedimentary basins showing study area in Concession NC151.

velocity within them, which causes significant time delays to the reflected waves. These static time shifts in areas of sand dunes are difficult to determine and the conventional method for calculating static corrections does not provide satisfactory results

In this paper, one form of the reciprocal method that may be used for static corrections in seismic reflection surveys is described. It is then applied to seismic line NC151-V532. The estimated receiver and source statics are adjusted to match the uphole data.

FIELD STATICS ESTIMATION

Uphole Surveys

Four upholes were drilled at selected locations along seismic line NC 151-V532 to provide direct measurements of the velocities and thicknesses of the weathering and sub-weathering layers (Fig. 2). Each uphole has been interpreted as a four-layer case with the thicknesses of the top three layers determined and the interval velocities of all four layers determined. Datum static corrections (weathering and elevation corrections) calculated for the four upholes which are located on seismic line NC151-V532 are shown in Table 1.

Conventional Method

For seismic line NC 151-V532, the first two upholes are located on the first two sand dunes (Fig. 3), the other two upholes are located out of the sand dunes (beyond the third sand dune and at the end of the line).The uphole information alone cannot solve the static problems. Additional information is provided by the intersection points with the seismic lines located between the sand dunes. Control points are chosen at pegs to each side of the line intersections close to the flank of each sand dune. At the control points, the thicknesses of layers 1 and 2 and the velocities of the weathering layers are assumed to be the same as at the adjacent line intersection (Table 2). The thickness of layer 3 at each control point is

Table 1. Computation of datum static corrections (weathering and elevation corrections) at the upholes along seismic line NC151-V532.

Variables	Uphole 1161	Uphole 1356	Uphole 1531	Uphole 1641
E_A (Surface elevation)	517.9 m	536.7 m	501.6 m	509.2 m
E_d (Datum elevation)	500.0 m	500.0 m	500.0 m	500.0 m
Z_1 (Thickness of layer1)	16.0 m	10.0 m	16.0 m	4.0 m
Z_2 (Thickness of layer2)	20.0 m	38.0 m	16.0 m	12.0 m
Z_3 (Thickness of layer3)	8.0 m	21.0 m	16.0 m	24.0 m
$E_A - (Z_1 + Z_2 + Z_3) - E_d$	-26.1 m	-32.2 m	-46.4 m	-30.8 m
V_{w1} (Weathering velocity of layer1)	546.0 m/s	459.0m/s	588.0 m/s	435.0 m/s
V_{w2} (Weathering velocity of layer2)	745.0 m/s	786.0m/s	914.0 m/s	749.0 m/s
V_{w3} (Weathering velocity of layer3)	1818.0 m/s	1093.0m/s	1839.0m/s	963.0 m/s
V_r (Replacement velocity)	2609.0 m/s	2500.0m/s	2381.0 m/s	2218.0 m/s
Weathering correction				
Z_1/V_{w1}	29.3 ms	21.7 ms	27.2 ms	9.1 ms
Z_2/V_{w2}	26.8 ms	48.2 ms	17.5 ms	16.0 ms
Z_3/V_{w3}	4.4 ms	19.2 ms	8.7 ms	24.9 ms
Elevation correction = $[E_A - (Z_1 + Z_2 + Z_3) - E_d]/ V_r$	-10.0 ms	-12.9 ms	-19.5 ms	-13.9 ms
Datum correction = - (Weathering correction + Elevation correction)	-50.5 ms	-76.2 ms	-33.9 ms	-36.1 ms

Table 2. Information obtained at upholes (Uh), control points (CP), and intersection points (I\V593, I\V595, I\V597) with other seismic lines.

Type of Points	Station No	Elevation (m)	Thick (m) Layer1	Thick (m) Layer2	Thick (m) Layer3	V_{W1} (m/s)	V_{W2} (m/s)	V_{W3} (m/s)	V_{W4} (m/s)
CP\SOL	1051	504.20	4.00	20.30	6.00	571	832	1591	2932
CP	1056	487.90	4.00	4.00	6.00	571	832	1591	2932
I\V593	1105	496.70	4.00	4.00	6.00	571	832	1591	2932
CP	1146	484.80	4.00	4.00	7.50	571	832	1591	2932
Uh	1161	517.90	16.00	20.00	8.00	546	745	1818	2609
CP	1238	481.70	6.00	2.30	2.90	625	1002	2162	2717
I\V595	1281	471.20	6.00	2.30	0.10	625	1002	2162	2717
CP	1304	468.40	6.00	2.30	6.50	625	1002	2162	2717
Uh	1356	536.70	10.00	38.00	21.00	459	786	1093	2500
CP	1397	481.20	4.00	4.00	15.50	354	952	1818	2703
I\V597	1408	475.40	4.00	4.00	14.00	354	952	1818	2703
Uh	1531	501.60	16.00	16.00	16.00	588	914	1839	2381
Uh\EOL	1641	509.2	4.00	12.00	24.00	435	749	963	2218

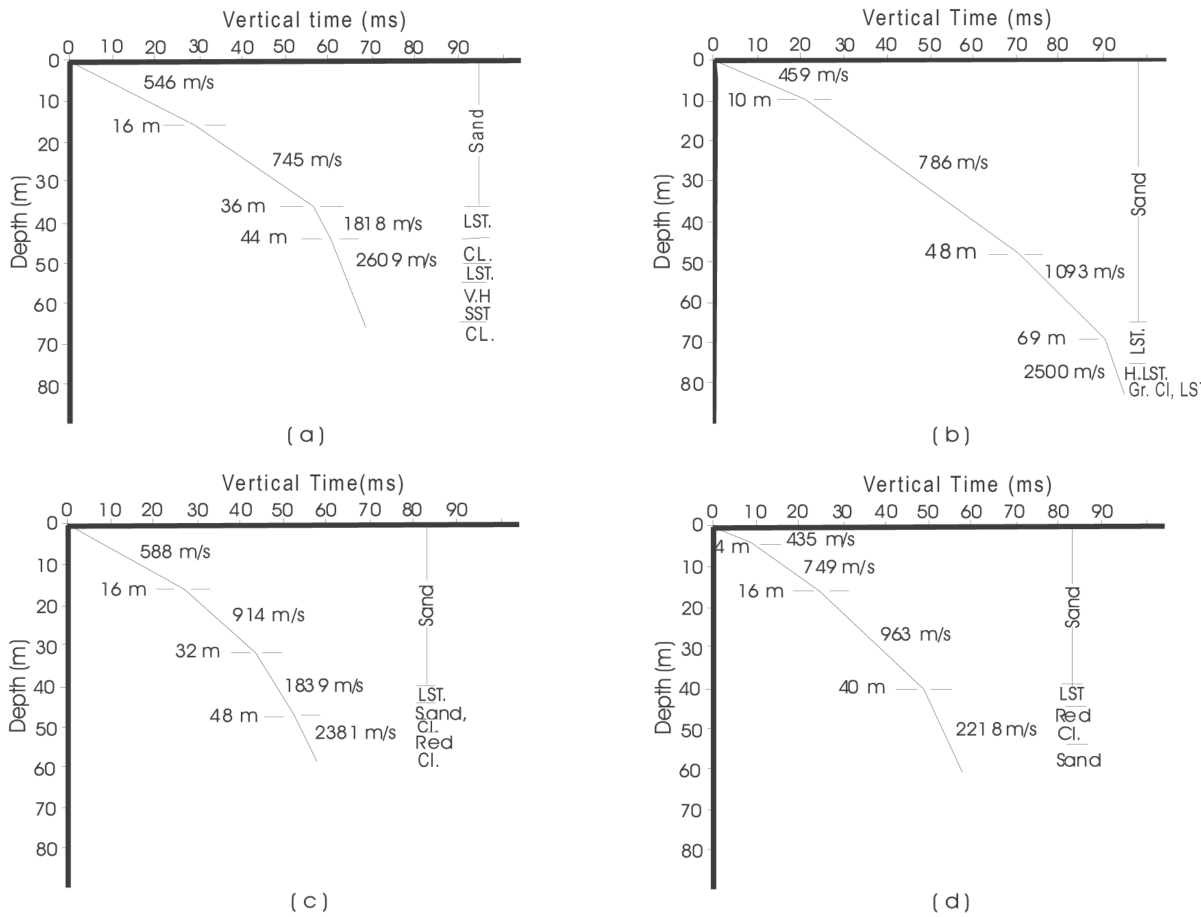


Fig. 2. Interpretation of four upholes survey data depicting four geologic layers. (a) Uphole (VP/SP 1161). (b) Uphole (VP/SP 1356). (c) Uphole (VP/SP 1531). (d) Uphole (VP/SP 1641).

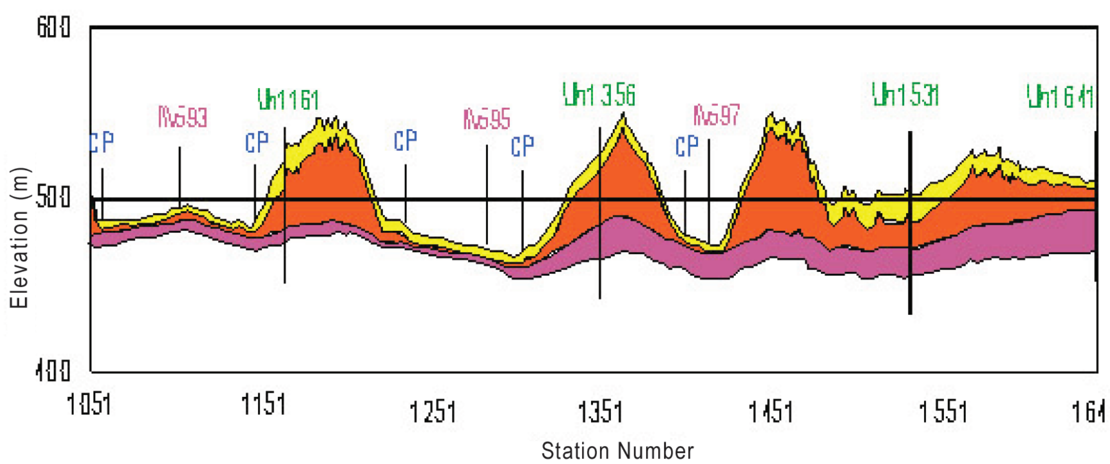


Fig. 3. Layer thickness model (layer 2 forced by factor 0.8).

obtained by linear interpolation between the line intersection and the uphole. Between the upholes and the adjacent control points or line intersections, the thicknesses of all three layers are interpolated using a more complicated scheme described by Ushah (2004). The results are shown in Figure 3.

Several variations on this method were generated by changing the thickness factor that was used in the conventional method (Fig. 3). The results of the field statics for sources and receivers obtained by these variations on the conventional method are shown in Figure 4.

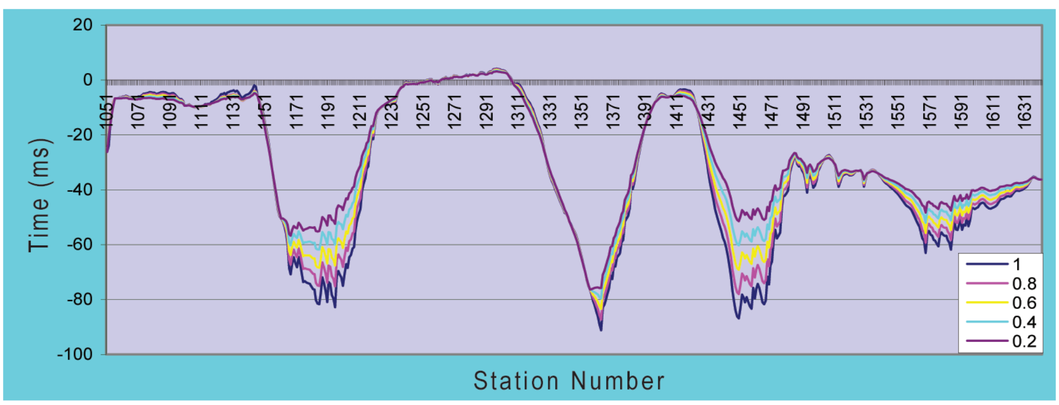
Refraction Method

The plus-minus method developed by Hagedoorn

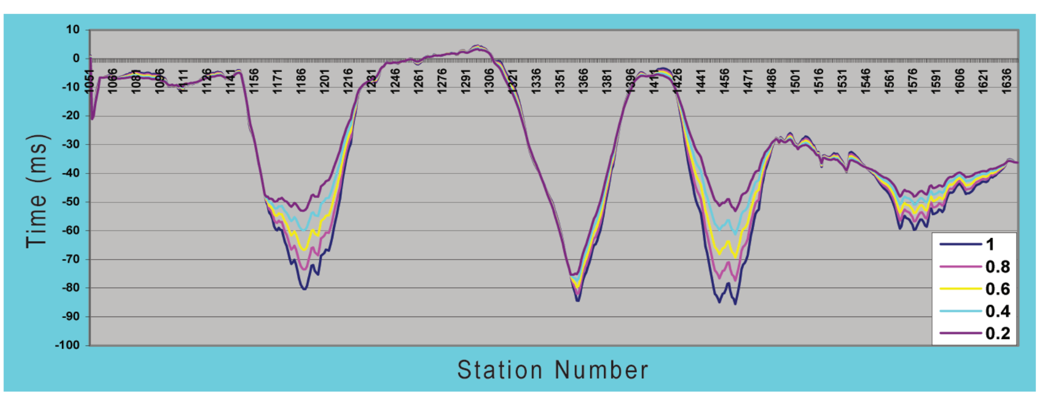
(1959) has been one of the most popular methods of refraction interpretation (Fig. 5). He developed the plus-minus method to estimate bedrock velocity and depth below each geophone station on a reversed seismic refraction profile. Since the reflection data used in this study were acquired using Vibroseis (the first breaks can not be seen directly), the troughs have to be picked manually, and in some cases interpolation is needed to estimate their positions (Fig. 6). Over the sand dunes, the group interval varies between 12 and 20 m instead of 25 m between the sand dunes, and the shortest source-receiver offset varies between 200 m and 257 m instead of 87.5 m. Therefore, the velocities in the near-surface layers are not measured, so the plus times were integrated with the uphole data, and the results are shown in Figure 7. A comparison between conventional and refraction field statics with elevation for a portion of seismic line NC151-V532 was made and is shown in Figure 8.

Examples of Stacked Sections

Seismic line NC151-V532 consisted of 589 split-spread shot gathers, with 25 m source and receiver



(a)



(b)

Fig. 4. Field statics models for line NC151-V532 generated by changing the thicknesses of layer 1 and layer 3 linearly while layer 2 is forced by factors 1.0, 0.8, 0.6, 0.4, and 0.2; (a) Receiver field statics models, (b) Source field statics models.

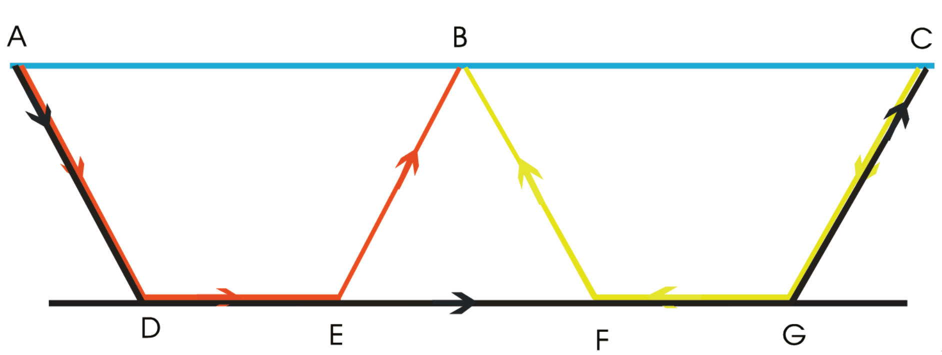


Fig. 5. Raypaths for a reversed refraction profile to illustrate the plus-minus method.

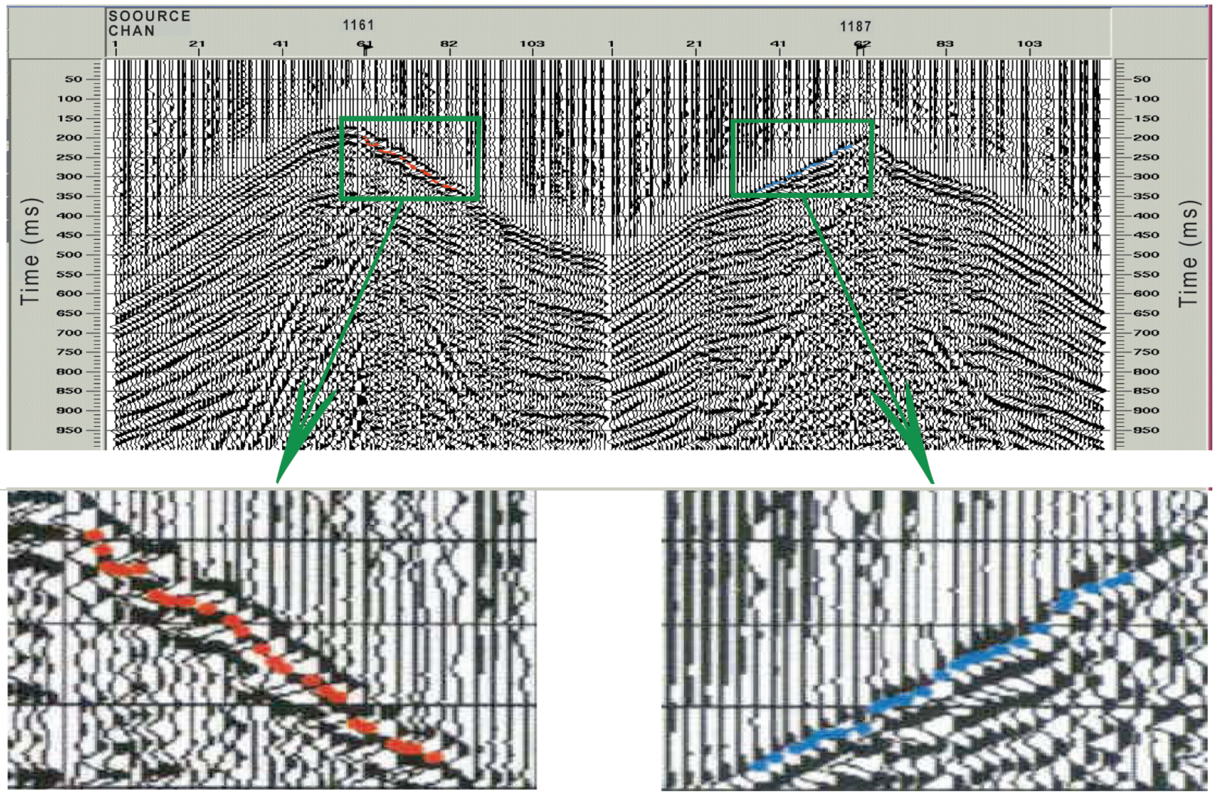


Fig. 6. Common-shot gathers (SP1161 and SP1187) of Vibroseis data from seismic line NC151-V532 after applying a gain ramp ($T^{1.5}$) and automatic gain control (AGC). The red and blue circles represent the picked troughs, corresponding to the centre of the Klauder wavelet, for the first arrivals on the forward and reverse shots, respectively.

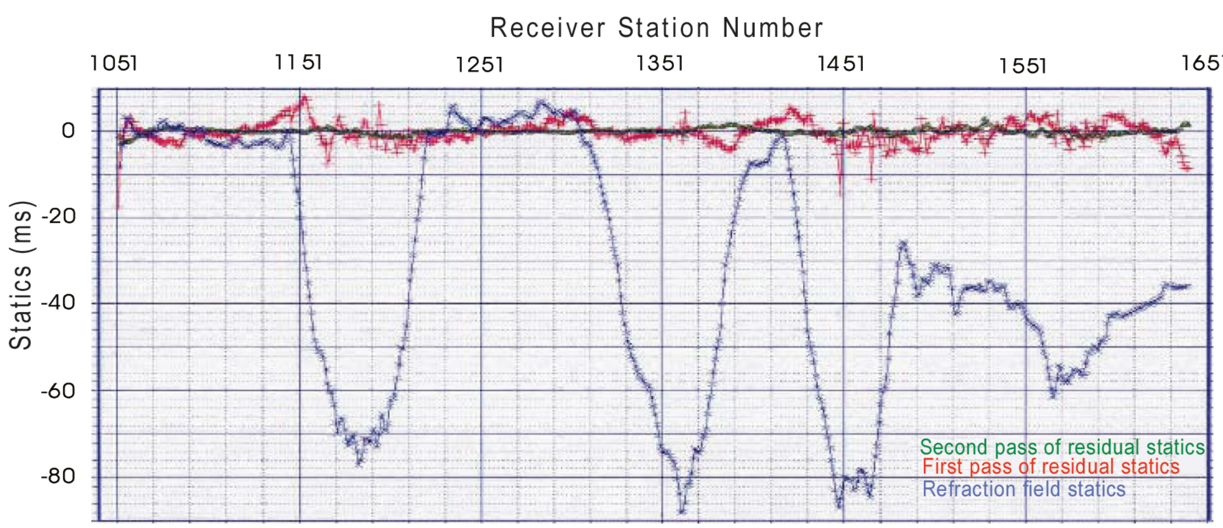


Fig. 7. Receiver field statics (blue) computed as half the plus times ($T^+/2$) after adjustment to the upholes, first and second passes of residual statics (red and green) for the same receivers.

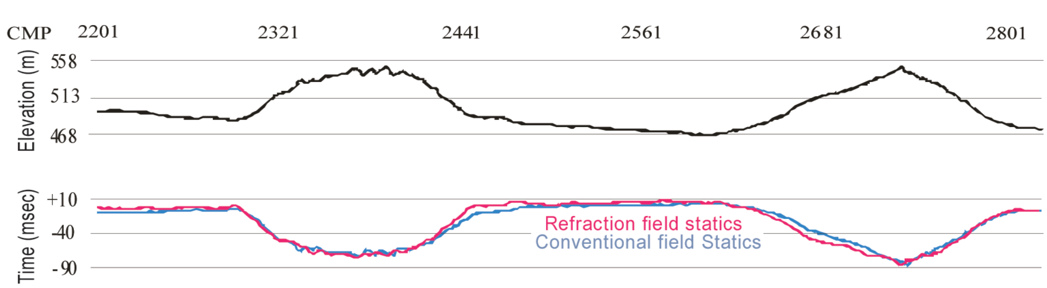


Fig. 8. Common mid point (CMP) elevations on seismic line NC151-V532 (top); refraction and conventional field statics for the same CMPs (bottom).

spacing (along most of the line). Each shot gather consisted of 120 traces with 25 m receiver spacing (but where the line crossed the sand dunes the spacing was less). It has been processed in Durham using the 2-D ProMAX package (Landmark, 1997). The conventional processing steps that were used in processing include geometry set up, filtering and data editing, deconvolution, field statics, CMP sorting, normal movout correction, residual statics and velocity analysis.

Figure 9 shows a portion of the brute stack section for seismic line NC151-V532. In Figure 9, conventional field statics were applied, while in Figure 10a refraction field statics (plus minus method) were applied. The brute stack section with refraction field statics shows better results for removing the long wavelength statics. Figure 10b shows the final stacked section with refraction field statics, automatic mute (stretch mute is 30%), velocity analysis, residual (maximum power) statics (applied twice) and trim statics (with maximum time shift ± 8 ms).

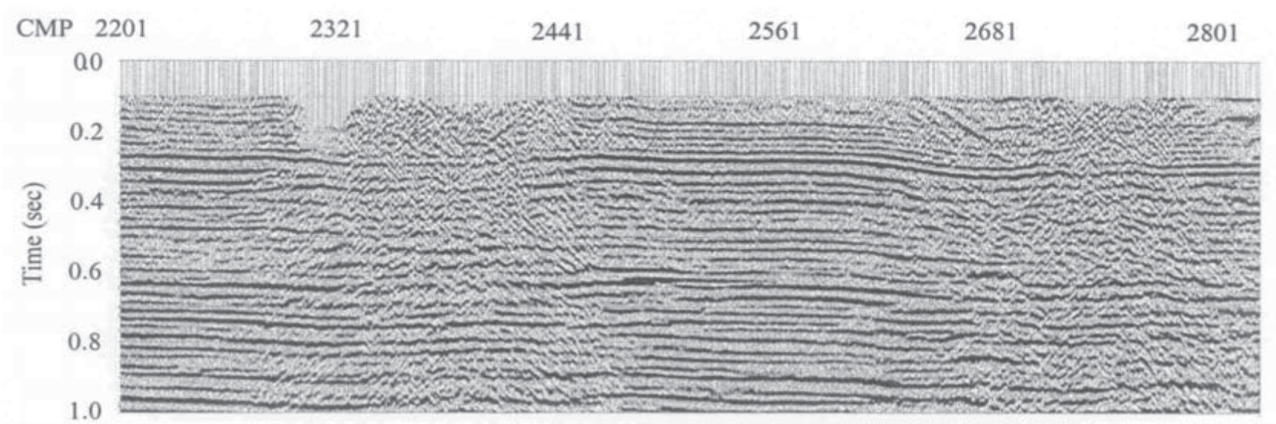


Fig. 9. A portion of the brute stack section of seismic line NC151-V532 after the application of conventional field statics.

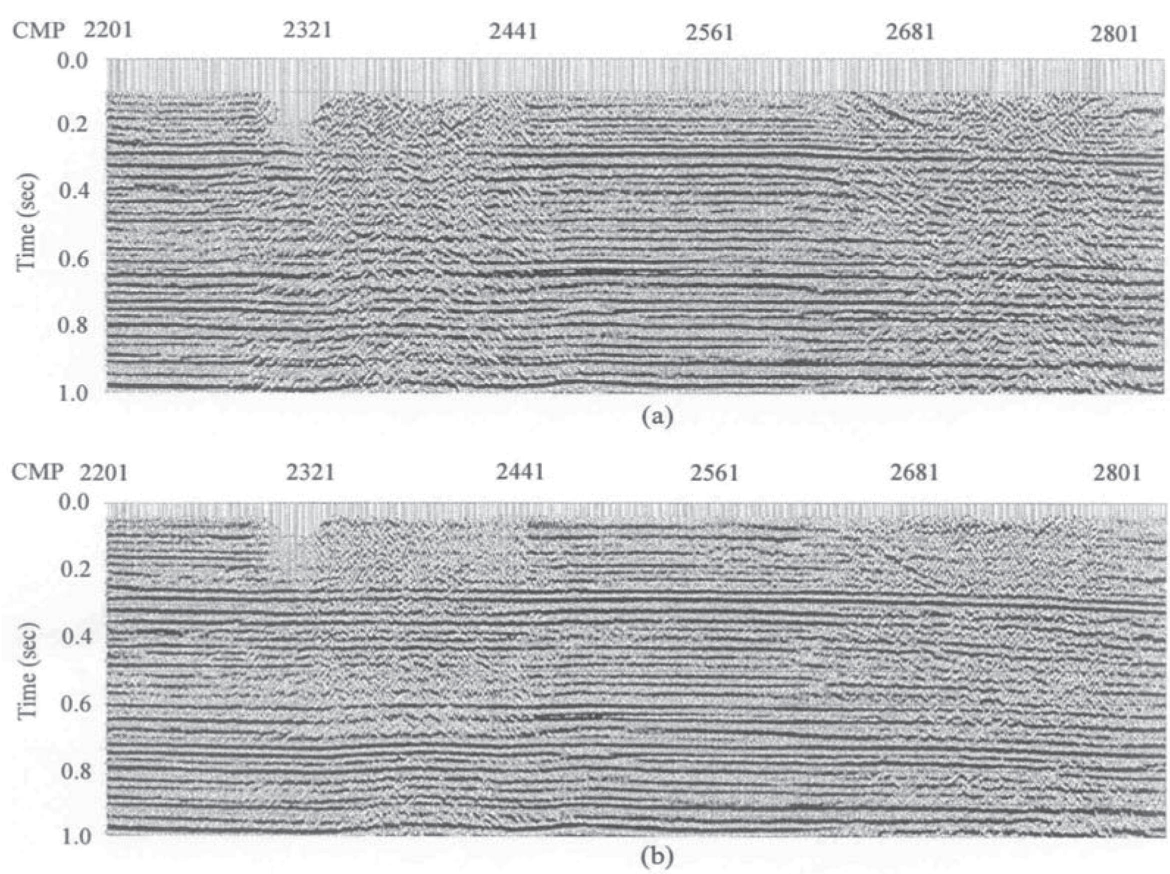


Fig. 10. (a) A portion of the brute stack section of seismic line NC151-V532 after the Application of refraction field statics (plus-minus method) using the upholes as control points, (b) The same stacked section but with refraction field statics, automatic stretch mute 30%, velocity analysis and maximum powerautostatics applied twice, and trim statics.

CONCLUSIONS

The work presented in this paper has dealt with static corrections in sand dune areas in Concession NC151, Murzuq Basin. In this area, one seismic line crossing sand dunes, NC151-V532, was processed using the ProMAX software and two methods of long wavelength statics (refraction and conventional) were applied. It was found that the approximation of each source or receiver field static by $T^+/2$ (where T^+ is the plus time found by the refraction field statics method), with linear interpolation between upholes gives better results than the conventional method of calculating field statics.

For residual statics, the method of maximum power autostatics was found to work well in these data. Improved results were obtained by applying residual statics and velocity analyses twice, followed by trim statics

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REFERENCES

Hagedoorn, J.G., 1959. The plus-minus method of interpreting seismic refraction sections. *Geophysical Prospecting*, **7,** 158-182.

Landmark 1997. *ProMAX Reference Manual*, Volumes 1 and 2.

Marsden, D., 1993. Static corrections-a review: Part II. *The Leading Edge,* **12**, 115-120.

Robinson, D.K. and Al-Husseini, M.I., 1982. Technique for reflection prospecting in the Rub'Al-Khali. *Geophysics*, **47**, 1135-1152.

Ushah, A.M.A., 2004. *Static Problems due to Sand Dunes in NC151, Western Libya*. Ph.D thesis, University of Durham.