THE UNIVERSITY OF MANITOBA

DEVELOPMENT OF THE PROCESSING CAPABILITY FOR CRUSTAL EXPLORATION ON THE CANADIAN SHIELD BY THE NEAR VERTICAL REFLECTION TECHNIQUE

by

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ABSTRACT

The development of the near vertical reflection seismic technique to the stage where it can be used to map shallow and deep crustal structure has been a goal of the Department of Earth Sciences at the University of Manitoba since 1969. This thesis develops and describes techniques by which this goal can be achieved.

The primary method of improving the quality of data obtained in the field this year was very simple--larger unit charges, and more of them, were used. Thus, the effective charge weights used approximately equaled the theoretical minimum charge size necessary to observe deep crustal reflections. This approach was based on the theoretical estimates produced by Baer (1972).

The use of linear arrays has proven to be successful in attenuating surface waves. However, because of the more difficult terrain in the area of this study, these arrays were not employed. Other methods of overcoming the problems of surface waves were used.

As a further step in the development of the data processing capability of the geophysics group at the University of Manitoba, the existing computer programs were critically assessed and significantly modified in the light of the data obtained in the summer of 1973. Weighted stacking was introduced to do a better job of summing multiple shots; and by proper use of frequency filtering techniques, good quality records were obtained. Velocity filtering routines were further developed so as to improve the S:N ratio of different events, thus aiding in their identification.

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The success of this study in obtaining observable reflections indicates that the development of the near vertical reflection technique is now at the stage where it can be used to study the geologic structure of the earth's crust. This thesis does not mark the end of the development processes, but rather the successful start. Continuous effort will be necessary if the maximum amount of information is to be extracted from the data collected.

The 1973 field season was the first in which the Precambrian Centre attempted to obtain near vertical reflection seismic data on or near the Aulneau Dome. The data collected this year was not sufficient to make a complete interpretation, but was used to evaluate and to improve this method for the next four field seasons. The data collected in this five year period (1973-1977) will be used along with other geologic and geophysical information available for this area to answer more questions about the structure and nature of the earth's crust.

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CHAPTER 1

EVALUATION OF FIELD PROCEDURES

1.1 Introduction:

The Department of Earth Sciences, University of Manitoba has been actively engaged in the study of crustal structure in Manitoba and northwestern Ontario for over a decade. The results have been published in several papers: Hall and Brisbin (1961, 1965), Hall (1964, 1969, 1972), Hajnal (1969, 1970, 1971), Hall and Hajnal (1969, 1973), and Gurbuz (1969, 1970). The primary research method has been refraction seismology including interpretation of wide angle reflections.

The need for the development of a near vertical reflection capability was voiced by Hall and Hajnal (1969) and Wilson (1971). Reasons to believe that the near vertical reflection technique could answer more questions about the structure and nature of the earth's crust have been well documented. Summaries of deep crustal reflections were given by Steinhart and Meyer (1961), Beloussov et al. (1962) and the German Research Group for Explosion Seismology (1964). Other recent results are provided by Robertson (1963), Dix (1965), Khalevin et al. (1966), Kanasewich and Cumming (1965) and Clowes et al. (1968). In response to this need, Hajnal (1970), Homeniuk (1972) and Baer (1972) worked on the development of this method, advancing it to a certain degree.

1.2 Present Project:

The present thesis forms part of a project designed to develop a near vertical reflection technique capable of mapping shallow and deep crustal structure. It must be stressed that the work done this year is developmental in nature and not designed just for mapping a specific structure. However, if this technique is successful, the work done this year will form the starting point for continued exploration of the Aulneau Dome.

The work necessary to achieve this goal can easily be broken up into two distinct areas: 1) Field work, and 2) Lab work. Based on the theoretical and practical experience of the three previous attempts, improvements in both areas are possible and necessary if the end results are to be successful.

1.3 Field Work:

1.3.1 When and where:

The field work was carried out in May 1973 on or near the northeast portion of the Aulneau Dome. Figures 1.1 and 1.2 indicate the area of the survey, and show the locations of the shot point and recording sites occupied this year. Table 1.1 gives the relevant information regarding the exact locations, distances from the shot point, and other related information.

1.3.2 Instrumentation:

The recording equipment was the same unit described by Hall and Hajnal (1969), and Hajnal (1970) with minor modifications to the timing circuits. The time code generator was removed and a filter amplifier called a tone amplifier was added. The tone amplifier was used

to amplify and to filter a 475 hertz tone that was received over the radio from the shot point. This tone was then recorded on tape in place of the time code.

The shot point equipment was identical to that described by Hajnal (1970) with the addition of a tone generator called a tone box.

The geophones used were the Hall-Sears, Model H.S.-10-1 seismometers. Eight vertical and four horizontal phones were used.

1.3.3 Shot point procedures:

The shot point was located in an abandoned mine shaft. The shaft had an aperture of approximately 12 by 15 feet, a depth of 100 feet, and contained 25 feet of water when shooting began, dropping to about 8 feet for the last shot.

The explosive agent used was a stable compound designed for underwater detonation called Hydromex. It was purchased in 50-pound cardboard cases containing two plastic bags of Hydromex. Thus, explosive charges of 25, 50 or 75 pounds could easily be used with 25 pounds being the most common.

The procedures used at the shot point stressed safety and efficiency. At a predetermined time, the shaft was loaded with explosives and radio contact was established with the recording crew. At the agreed time, 30 seconds of tone was transmitted over the radio, with the detonation of the charge terminating the tone transmission. Radio contact was again established and the entire cycle was repeated. Multiple shots were fired into each recording location (see Table 1.1 for exact number) with a time interval between shots of fifteen minutes being typical during normal operating conditions.

The exact instant of detonation was also recorded at the shot point if radio communication was poor, by a method documented by Hajnal (1970, page 28).

1.3.4 <u>Recording site procedures:</u>

The spread used consisted of 12 seismometers spaced 220 feet (67.1 meters) apart. Channel 1 was always closest to the shot point. The 1st and 11th seismometers measured the in-line component of horizontal motion. The 2nd and 12th seismometers measured the perpendicular component of horizontal motion, while all other seismometers measured vertical motion. The recording equipment was located in a -boat at the center of the spread.

The recording attenuations and frequency settings were recorded in the field book for all shots. However, in general it can be stated that the attenuations were set only high enough to prevent saturation of the system, and the frequency settings were always set at 48 hertz. This allows the maximum amount of information to be recorded.

Once the tone began on the radio, the recording process was started and continued for one minute after the tone cut-off. Regular checks were made of noise conditions and the quality of records obtained, but problems with development of records necessitated doing all playbacks over in the lab.

1.4 Evaluation of Field Procedures:

This year's was the first attempt to take the VLF-2 and taperecording system away from any roads. The recording equipment was placed in a boat, and all recording locations were chosen along the lake shore. This method extends the amount of freedom available to pick recording sites, but there still exist serious limitations on where the recording spread can be placed. If the cables used allowed end-on recording (all geophones in one direction from the recording equipment) many more locations around the lake shore could be used. However, with such limited mobility, this VLF-2 system is not practical for exploration on the interior of the dome. The new system presently under development by the Physics Department in collaboration with the Precambrian Centre will go a long way towards solving the mobility of recording locations.

The location of the shot point is still the least mobile aspect of this exploration method. Air shots are considered too dangerous in the present study area, if adequate charge sizes are used. Lake shots are generally prohibited by government regulations, and drilling of large enough holes to accommodate adequate charges is too expensive. Mine shafts that contain adequate amounts of water now appear to be the most feasible shot points, but these do not exist in sufficient number in the particular areas of interest to be ideal either. This problem must be solved or circumvented for a study to be feasible.

After solving the problems of where to locate the shot and recording sites, the success of the project depends principally on

putting enough energy into the ground in order to get observable reflections. The theory of effective charge weight and the statistical benefits of stacking multiple shots together was documented by Baer (1972). The equation for calculating effective charge weights is

$$W = \sqrt{\frac{t}{r}} \sum_{i=1}^{t} (\chi_i)^{\frac{2}{3}}$$
(1.1)

where W is the effective single charge necessary to achieve the same S:N ratio that could also be achieved by stacking t traces together from r records that were generated by individual charges of \mathcal{M}_{i} . (See Table 1.1 for effective charge weights for each recording location). In this survey, we have used the largest individual charge weights for near vertical reflection data, used to date by the University of Manitoba, and also increased the number of individual records being stacked. These facts alone give this year's efforts the greatest possibility of success.

As with any seismic survey, the exact determination of shot time relative to the recorded events is critical. The tone break system presently employed by the University of Manitoba is sound in principle, but has certain practical limitations. When radio reception deteriorated, so did the tone break quality. Laboratory examination of the filter response of the tone amplifier showed it to be a relatively poor filter (see Figure 1.3). If the filter were to be improved, the quality of tone break would be improved significantly. The use of better radios would improve this system. The possibility of getting radio antennas higher by the use of balloons should be

considered especially since the field work for the present is not near power lines. On the other hand, if the antenna should come in contact with a power line, this would endanger the observers.

Even after considerable effort is put into improving the tone break quality, the need for a back-up system still exists. The equipment described by Hajnal (1970) should be replaced by a magnetic recording of WWV, shot instant and shot generated wave form.

The use of linear arrays as discussed by Homeniuk (1972) was considered, but not employed this year. Linear arrays of adequate length are not available commercially. However, by proper spacing of geophones, the velocity filtering technique could be used to give similar results.

It should be pointed out that the present survey would not, even if successful in yielding recognizable reflections, by itself provide adequate sub-surface data. The major reasons are the wide separation of recording locations and the lack of a reverse profile. However, additional work planned for the next four years should solve this problem.

1.5 Lab Work:

The lab work commenced in July 1973 and continued until the end of the year. The theoretical and practical results obtained in the lab form the basis for the remaining portion of this thesis.

1.6 Sample Calculation of Equivalent Charge Weights:

We had (equation 1.1):

$$W^{2_{3}} = \sqrt{\frac{t}{r}} \sum_{i=1}^{r} (\gamma_{i})^{2_{3}}$$

We use location 65-9 for the sample calculation. After running the data through the program WTSTACK, r = 18, $A_i = 25$ pounds for all shots and t = 1 because no trace mixing has been done.

$$W^{2/3} = \sqrt{1 \times 18} (25)^{2/3}$$

After VSTACK, where t = 8 because we now mixed eight traces together:

$$\sqrt{\frac{2}{3}} = \sqrt{\frac{8}{18}} (25)^{\frac{2}{3}}$$

W = 1039.25 pounds.

(See Table 1.1 for all equivalent weights).



Figure 1.1 Map of Manitoba and northwestern Ontario





Figure 1.3 Frequency response of tone amplifier

Table	1.1	Table	of	data	regarding	shot	point	and	recording	locations
							•			

Shot Point**	Latitude	Longitude
9	49 ⁰ 30.93'	94 ⁰ 26.78'
Recording Location		
65	49 ⁰ 29.73'	94 ⁰ 26.88'
66	49 ⁰ 28.82'	94° 25.17'
67	49 ⁰ 27.28'	94 ⁰ 18.53'
68	49 ⁰ 23.63'	94 ⁰ 13.92'
69	49 ⁰ 18.30'	94 ⁰ 1.10'

Recording	Distance from	No. of Records	Equivalent	Charge Wt.
Location	Shot Point 9	Stacked	After WTSTACK	After VSTACK
65	2.20 km.	18	218.5 lb.	1039.25 lb.
66	3.81 km.	14	181.0 lb.	861.0 lb.
67	12.04 km.	16	200.0 1Ъ.	951.25 lb.
68	20.50 km.	12	161.25 lb.	767.0 lb.
69	30.93 km.	N.P.*	-	-

*Not processed.

**Shot and recording site numbers follow those of Hall and Hajnal (1973).

CHAPTER 2

STATISTICALLY OPTIMAL STACKING OF SEISMIC DATA

2.1 Introduction

The process of stacking seismic traces together in order to improve the S:N (signal to noise) ratio has been used with varying success for years. Mayne (1962, 1967) and Galbraith and Wiggins (1968) reported success in common depth point stacking techniques applied in the petroleum industry. Whitcomb (1969), Hajnal (1970, 1971), Capon (1972), Baer (1972), Homeniuk (1972), Kanasewich et al. (1973) all used a stacking procedure as a velocity filter in order to improve the S:N ratio of events with specific moveout velocities. Baer (1972) and Homeniuk (1972) also vertically stacked multiple shots with common shot and geophone coordinates.

The theoretical results of stacking γ traces together is a $\sqrt{\mathcal{M}}$ improvement in the S:N amplitude ratio as documented by Baer (1972). In most cases, the first attempts at stacking traces were based on at least two general assumptions about the input data: 1) the signal amplitudes on all traces being stacked were approximately equal, and 2) the signal to noise amplitude ratios were approximately constant on all traces. Individual traces were assumed to have these characteristics or were normalized in such a way as to impose a relatively consistent amplitude to all input traces (Hajnal, 1970; Baer, 1972).

However, upon closer examination of input data, it is found that these two assumptions are in general, not perfectly valid. Indeed, cases exist in our present data where these assumptions are grossly invalid. Capon et al. (1967), Christoffersson and Jansson (1967) and Robinson (1970) all worked on ways of computing weighting factors to apply to various traces that violate these two assumptions, in order to optimize the output S:N ratio of a stacking procedure.

Since the data recorded in May 1973 by the Department of Earth Sciences, University of Manitoba, was found not to conform to the above-mentioned assumptions, a stacking program (WTSTACK) incorporating weighting factors calculated according to the theory put forward by Robinson (1970) was written. This method allows the stacking of traces with variable signal amplitudes and variable S:N ratio-features which are present in this data. This theory also allows us to calculate the theoretical S:N ratio of the stacked record. (See Appendix A.)

It is interesting to note that when this theory is applied to the sum of n traces that do conform to the above mentioned assumptions, the results are consistent with those predicted by Baer (1972).

2.2 Theoretical Optimum Weighting Factors:

The first step must be the development of a mathematical model of a seismic trace and some criteria on which to evaluate the effectiveness of the stacking procedure.

The model seismic trace presented has a signal and a noise component. The signals are assumed to be identical, with the exception

of scale, on all traces that are to be stacked together. The noise on any given trace has zero mean value and is assumed to be statistically independent of the noise on any other trace. The signal and noise components are also statistically independent of each other on all traces. The signal to noise ratio is reasonably constant for each individual trace (at least over the time extent of the windows used). The last requirement put on the seismic trace is that the noise level is constant with respect to time on any individual trace.

The mathematical expression for the j th sample of the ith trace is

$$t_{ij} = \alpha_i (s_j + n_{ij})$$
(2.1)

where α_i is signal amplitude factor of i th trace.

- S_j is signal component for the jth sample which is identical on all traces.
- \mathcal{N}_{ij} is noise component which is in general different for each individual trace and sample.

Also define \mathcal{J} as the number of samples in a seismic trace, and \mathbb{I} as the number of records to be stacked.

The signal energy (S), noise energy (N_{i}) and total energy (T_{i}) of the *i*th trace are defined as: $S \equiv \sum_{j=1}^{J} S_{j}^{2}$; (2.2)

$$N_{i} \equiv \sum_{j=1}^{J} n_{ij}^{2} ; \qquad (2.3)$$

$$T_{i} \equiv \sum_{j=1}^{J} t_{ij}^{2}. \qquad (2.4)$$

A unique signal to noise power ratio can be defined as:

$$\delta_i = \frac{S}{N_i} . \tag{2.5}$$

The objective is to determine weighting factors ($\omega_{\tilde{l}}$) to be applied to the \dot{L} th trace such that the signal to noise energy ratio of the output trace will be a maximum.

In the case of a twofold stack, the weighting factors are determined as follows:

$$t_{j}^{(2)} = t_{jj} + w_{z} t_{2j}^{\prime} . \qquad (2.6)$$

Arbitrarily we have set $W_j = 1$ and $a_j = 1$. Substituting equation 2.1 in 2.6 and collecting signal terms gives

$$t_{j}^{(2)} = (1 + a_{2}w_{2})s_{j} + n_{ij} + a_{2}w_{2}n_{2j}$$

= $s_{j}^{(2)} + n_{j}^{(2)}$. (2.7)

The signal energy of the stacked trace is

$$S^{(2)} = (|+\omega_{2}\alpha_{2}|)^{2} \sum_{j=1}^{J} S_{j}^{2}$$

= (|+\omega_{2}\alpha_{2}|)^{2} S. (2.8)

The noise energy of the stacked trace is

$$N^{(2)} = \sum_{j=1}^{J} \left(n_{1j} + a_2 \omega_2 n_{2j} \right)^2$$

$$= J \left(n_1 + \omega_2 a_2 n_2 \right)^2$$
(2.9)
(2.10)

where the bar indicates mean value for \mathcal{J} samples. However, because \mathcal{N}_{i} and \mathcal{N}_{z} are statistically independent and have zero mean value, we obtain for the noise energy of the stacked trace

$$N^{(2)} = N_1 + (\omega_2 a_2)^2 N_2.$$
(2.11)

(See Lee, 1960, equation 5.82.)

By substituting equation 2.8 and 2.11 into equation 2.5, we find the signal to noise energy or power ratio as

$$\gamma^{(2)} = \frac{(1 + \omega_2 a_2)^2 S}{N_1 + (\omega_2 a_2)^2 N_2} . \qquad (2.12)$$

By setting $\frac{\Delta \chi^{(2)}}{\partial \omega_2} = 0$ and solving for ω_2 , we find that a) $\omega_2 = -\frac{1}{a_2}$ (2.13)

or

b)
$$W_2 = \frac{N_1}{a_2 N_2}$$
 (2.14)

Clearly solution a) minimizes the signal to noise power ratio and solution b) maximizes the power ratio.

Thus the twofold optimum stack becomes

$$\left\{t_{j}^{(2)}\right\}_{opt} = t_{ij} + \frac{N_{i}}{a_{2}N_{2}}t_{2j}$$
 (2.15)

The output can be normalized to any value by multiplying $\begin{cases} t_j^{(2)} \\ opt \end{cases}$ by some constant. At this time it is convenient to choose S/N_1 as such a constant. As a result

$$\left\{t_{j}^{(2)}\right\}_{opt} = \frac{S}{N_{i}} t_{ij} + \frac{S}{a_{2}N_{2}} t_{2j}$$

$$= \frac{Y_{i}}{a_{1}} t_{ij} + \frac{Y_{2}}{a_{2}} t_{2j} . \qquad (2.16)$$

Recall that $\alpha_1 = 1$.

Stated in words: the optimum stack is effected by first equalizing the scale factors on each trace, then weighting the resulting traces with their respective signal to noise energy ratios, and finally, stacking the traces together.

If we substitute equation 2.14 into equation 2.12 we find that

$$\chi^{(2)} = \chi_1 + \chi_2$$
 (2.17)

Thus the optimum signal to noise power ratio of the stacked trace is equal to the sum of the individual signal to noise power ratios.

By an iterative method using $\{t_j^{(2)}\}_{opt}$ in the place of t_j we can extend this procedure to the sum of I traces.

$$\left\{t_{j}^{(I)}\right\}_{opt} = \frac{1}{C} \sum_{i=1}^{I} \left(\frac{\aleph_{i}}{\alpha_{i}}\right) t_{ij} \qquad (2.18)$$

where C is a normalizing factor. Also we find that

$$\left\{ \chi^{(I)} \right\}_{opt} = \sum_{i=1}^{I} \chi_{i} . \qquad (2.19)$$

Thus if we can, by some method, measure $\mathcal{V}_{\mathcal{L}}$ and $\mathcal{A}_{\mathcal{L}}$ for all

our input traces, we can determine

$$w_i = \frac{y_i}{a_i} \tag{2.20}$$

and we can also estimate the expected signal to noise power ratio of the stacked trace.

2.3 Practical Calculation of Weighting Factors:

In order to calculate the weighting factors for each trace, we first must calculate the power of the seismic trace in two windows. The first window is selected before the first-break energy. In this we will measure the noise energy level (T_i') of the *i*th trace. Under our assumption that the noise level is constant with respect to time over the entire trace, the noise level measured in the first window is representative of the noise level over the entire trace. The total energy in the first window (just noise) is then

$$T_{i}' = \sum_{j=1}^{J} t_{ij}^{2} = \sum_{j=1}^{J} (a_{i} n_{ij})^{2} = a_{i}^{2} N_{i}. \quad (2.21)$$

The second window is centered over a strong arrival. The signal to noise power ratio in this window will represent χ_i for this trace. Clearly changing the position of the second window will change χ_i . However, it is the relative magnitude of each χ_i which is of importance in designing weighting factors and not the actual magnitudes. The total energy in the second window (T_i) on the L th trace is

 $T_{i} = \sum_{j=1}^{J} \left\{ a_{i} \left(S_{j} + n_{ij} \right) \right\}^{2}$ $= a_i^2 J \overline{(s_j + n_{ij})^2}$

(2.22)

By the same argument that was used to derive equation 2.11, we claim that

 $T_{i} = \alpha_{i}^{2} (S + N_{i}). \qquad (2.23)$

Up to this point, both windows have been J samples long. In practice, WTSTACK divides both T_i' and T_i by the number of samples in the first and second windows respectively. As a result, the windows are not restricted to being of equal length.

We now have enough information to calculate the signal to noise power ratio of this trace.

$$\mathcal{V}_{i} = \frac{S}{N_{i}} = \frac{T_{i} - T_{i}'}{T_{i}'}.$$
(2.24)

By looking at the signal energies of the different traces relative to trace 1 we can calculate the scaling factor α_i as

$$a_{i} = \left\{ \frac{T_{i} - T_{i}'}{T_{i} - T_{i}'} \right\}^{\prime / L}.$$
(2.25)

The quantities T_{l}' and T_{l} are measured directly from the input data for all traces. We could proceed to substitute equations 2.24 and 2.25 into 2.20 and directly calculate the appropriate weighting factors. Or we can look at the overall expression for ω_{l} and simplify it slightly.

$$\omega_{i} = \frac{\chi_{i}}{a_{i}} = \frac{T_{i} - T_{i}'}{T_{i}'} \cdot \left\{ \frac{T_{i} - T_{i}'}{T_{i} - T_{i}'} \right\}^{2}.$$
 (2.26)

We can multiply these weights by any constant we desire in

order to normalize the output trace. The constant we use is

$$k/\sqrt{T_{i}-T_{i}}''$$
 where k is determined in such a way that
 $\sum_{i=1}^{I} \omega_{i} = 10$, (2.27)

This is done to ensure that the maximum amplitude of the output record is always less than 20470. Thus the final form of the weighting factors used by the subroutine WEIGHT is

$$W_{i} = \frac{k\sqrt{T_{i}-T_{i}}'}{T_{i}'} \qquad (2.28)$$

(see Appendix A.)

2.4 Evaluation of Weighted Stacking:

The evaluation of weighted stacking will be approached in two ways. Method 1 will be a direct comparison of the output of STACKER and WTSTACK. Method 2 will be based on statistical measurements performed on the input and output data.

The data recorded at location 67-9 is considered typical. This is the center location of the five recording locations for the 1973 field season and is at the intermediate distance of 12.04 km. from the shot point. The number of records going into the stack (16) was only one more than the average of fifteen. The performance of STACKER and WTSTACK on all the different locations is adequately represented by 67-9. Method 1:

The relevant data appear in Figures 2.1 and 2.2. Each plot consists of 2.15 sec. of data. Figure 2.1 is the result of sixteen input records stacked by STACKER. Figure 2.2 shows the identical input records stacked by WTSTACK. Neither record has had any further processing except that each trace is normalized by PLOTMOD so that the first-break amplitude is $\frac{1}{2}$ inch. Thus the relative amplitudes of the data, trace to trace and also record to record, give a comparative indication of the output signal to noise amplitude ratios.

For all traces, it becomes obvious from looking at this comparison that WTSTACK has done a much better job than STACKER.

Method 2:

Although WTSTACK did a superior job to STACKER, some measure of how well WTSTACK approaches its theoretical potential is also desirable.

In order to do this evaluation, we may use the subroutine WEIGHT to measure the signal to noise amplitude ratios of the data. Figure 2.3 is a plot of the S:N amplitude ratios of all the individual traces recorded at location 67-9. Also plotted is the average S:N amplitude ratio. By using equation 2.10 we calculate the expected S:N amplitude ratio that WTSTACK would produce. This is also plotted in Figure 2.3 along with the actual S:N amplitude ratios of WTSTACK and STACKER. By using the expected S:N amplitude ratio as the optimum output, we can calculate the percentage efficiency of WTSTACK and STACKER. This is plotted in Figure 2.4.

By studying these two graphs and the two plots, a number of interesting points appear:

1) By comparing Figures 2.1 and 2.2 with Figure 2.3 we can see that the statistical method for measuring S:N amplitude ratio does give a consistent picture of data quality, i.e.: the best trace from Figure 2.2 is also the best in Figure 2.3. This adds some degree of confidence to the method of measuring \aleph_{i} .

2) The very large variation in S:N amplitude ratios of the input data stands out. This is in fact the main justification for using a weighted stack.

3) Some of the individual traces have a very high S:N amplitude ratio. In general, these traces have an extremely low background noise level measured before the first breaks. This low noise level is not usually representative of the noise over the entire record. For this reason, these traces are not consistent with the model seismic trace as specified in Section 2.2. Improvements in measuring S:N ratios would help here.

4) Figure 2.3 clearly shows the benefits of WTSTACK over STACKER. This is firm evidence that we are moving in the right direction, but it also indicates that some overall improvement in the theoretical or practical aspects are needed to bring estimated and actual S:N amplitude ratios closer together.

5) Figure 2.4 indicates the relative efficiencies of WTSTACK at 55±17% and STACKER at 24±17%. These levels of efficiency are typical of all locations.

6) The short-fall in actual WTSTACK output S:N ratio must be attri-

buted to the degree to which our model seismic trace does not fit our data or to errors in estimating \mathcal{J}_{i} and α_{i} from our data. The 5% of the individual traces that have individual S:N ratios higher than the output trace indicate that the theory does in fact, not apply exactly. However, the S:N ratio on STACKER output was below the S:N ratio on 32% of the input traces.

2.5 Conclusions:

WTSTACK represents a considerable step forward over previously used methods in the processing of multiple shot data.

New and, hopefully, better ways should be found of evaluating \mathcal{V}_i and \mathcal{A}_i from the input data.

Other theoretical methods of optimizing the stacking procedure should be looked into in the future.

2.6 General Comment:

The algorithm used by WTSTACK attempts to maximize the S:N power ratio. Inherent in this method is a definition of signal energy. Signal energy is considered to be all shot-generated energy measured at the recording location and includes such arrivals as Rayleigh waves. It will be left to other means than stacking multiple shots to enhance reflections with respect to surface waves or other types of shot-generated noise.

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Figure 2.1 67-9 after STACKER (2.15 sec.)

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CHAPTER 3

EVALUATION OF PROCESSING ABILITY, PAST AND PRESENT

3.1 Introduction:

A considerable amount of time, energy, and money was spent this year on seismic data processing. The solutions of problems that arose and some initial concepts on how data should be processed formed the basis of a processing philosophy. The more important aspects of this philosophy and the evolutionary history of the programs developed this year constitute an important segment in the development of the near vertical reflection technique as an exploration and research tool on the Canadian Shield.

3.2 Processing Philosophy:

The processing philosophy developed for the handling of seismic data can best be described by stating it in six propositions, as follows:

Exact shot time must be present on BINBIN's (see Section 3.3.1)
 output tape. This information is absolutely essential in poor
 quality data in order to allow stacking to be used.

2) All programs after BINBIN should maintain absolute timing information on the output tapes, i.e. the first sample of the output should represent zero time. Exact timing information can then be plotted on output displays simply by counting samples.

3) Careful manipulation: of the integer data values is essential if a significant amount of information is not to be lost.

4) Each program should print out as much information about the data as possible.

5) Processing efficiency should be reviewed regularly.

6) Critical studies should be made on the quality of data out of each processing step. Program deficiencies, poor parameter selection and input errors will not necessarily stop execution and eliminate the output from the various programs. When the output was not up to expected standards, it was often due to some unsolved problems.

These propositions are to be upheld at all stages and in all programs used in the processing sequence if possible. They outline technical requirements that have to be built into every program as well as outlining methods that should be used in processing data.

3.3 Program Evolution:

The programs used this year fall into five main categories: 1) Utility programs, 2) Stacking programs, 3) Filtering programs, 4) Gain adjustment programs, and 5) Velocity filtering programs. Significant programing changes were made in all these areas.

3.3.1 Utility programs:

The principal program in this area was BINBIN, as documented by Hajnal (1970). Its main function was to perform a data conversion from a 7 to a 9 track tape. The program was written in COBAL and is very difficult to modify, because of a general lack of familiarity with this language at the present time. Serious attempts were made, although unsuccessful, to modify BINBIN so that 13 channels could be processed. (The tone channel was processed in channel 12, making it necessary to omit one seismic trace.) BINBIN's strongest point is its efficiency, and because of this consideration, no attempts were made to completely replace it.

However, as of December 15, 1973, BINBIN ceases to be of use, because of changes in the computer facilities at the University of Manitoba. The exact form of its replacement is not yet certain.

Another utility program, READER, was written to perform the printout operations in place of BINBIN. It is efficient and allows much greater freedom in choosing exactly what blocks should be printed.

PLOTMOD is another utility program used extensively. This program will produce a calcomp plot of a seismic record from a 9 track tape. This program now counts output samples and plots timing marks in place of channel 12.

3.3.2 Stacking programs:

The evolution of the programs that perform the stacking operation has to be considered the greatest single area of improvement. The program that existed, COSPS (or VERTS) as documented by Baer (1972), was modified in several minor ways to make the output consistent with proposition 2. Some changes in read formats made it slightly more efficient. The program STACKER was written as a more efficient substitute. It performed exactly the same operations as COSPS with the exception of normalizing the output traces. The signal to noise amplitude ratios of input and output data were measured by a routine that later evolved to become WEIGHT.

The wide variation in signal to noise amplitude ratios, and the

poor performance of STACKER provided the incentive for evaluating the benefits of weighted stacking. The result was WTSTACK which was not only a theoretical improvement, but was more efficient time-wise and did a much better job of handling the integer data.

A more complete write-up of the theory of weighted stacking and a critical evaluation of WTSTACK is found in Chapter 2. The actual production data is in Chapter 4, while the program listing and additional comments can be found in Appendix A.

3.3.3 Filtering programs:

The program that existed was CONVOLV as documented by Hajnal (1970). Attempts were made to make this program conform to the concept of absolute time, but this proved infeasible. The program was modified to include in its output the timing error it introduced. Allowances for this error could be made in PLOTMOD so that the output record would have proper timing information plotted in place of channel 12. CONVOLV's efficiency was questionable and certain round-off errors in the algorithm indicated improvements could be made in the overall processing system if CONVOLV was replaced.

FILTER was written to do the frequency filtering process, and was used to produce all data displays where filtering had taken place.

3.3.4 Gain adjustment programs:

The problem of large amplitude surface waves (Rayleigh waves) has not been dealt with yet. Geophone arrays were not used in the field and the result is evident in Figure 4.9. PLOTMOD normalized each trace such that the maximum amplitude is $\frac{1}{2}$ inch. The result

is that reflections, that are arriving after Rayleigh waves have passed, are plotted at a scale so small that they cannot be seen. Some method of balancing the relative amplitudes of the trace with time and yet still maintain wave forms is considered necessary. McClure (1973) used a method of normalizing data over different windows on a single trace to balance the amplitudes of different events. This was tried in the present study with limited success and other methods were considered.

The method finally adopted is similar to that used in the petroleum industry in the past. The resulting program written to achieve this gain adjustment was AGC. The theory and algorithm used are explained in Appendix B. The data processed through this program is displayed in Figures 4.13 and 4.14.

3.3.5 Velocity filtering programs:

STACK was the previously existing velocity filtering program written by Hajnal (1970). It was working, but modifications desired in the output posed more of a problem than writing a new program (VSTACK).

VSTACK incorporates all the advantages and efficiency that the processing experience to date has taught us. The output of VSTACK is a series of traces (up to 8) each with a different Δ t shift applied to data before stacking. The traces are all normalized to a constant value and plotted versus the time of the event on trace 6 of input data.

The data processed by this program are displayed in Chapter 4.

3.4 Evaluation of Processing Capability:

It can be seen that the present processing capability of the University of Manitoba is the result of a continuous evolutionary process in which programs are used, critically assessed, modified and/or replaced. This process has been going on for five years now, and must continue if the maximum amount of information is to be extracted from the data.

The introduction of weighted stacking, improvements in frequency filtering techniques, the automatic gain control (AGC) program, and the new display after velocity filtering, have added much to the processing capability of the University of Manitoba. However, it is premature to claim that the better processing is the principal reason for the significant improvement in data quality obtained this year. The larger effective charges used this year have also helped.

In order to evaluate better the overall improvements in the processing ability, it is recommended that the data collected by Baer (1972) and Homeniuk (1972) be processed according to the revised models.

CHAPTER 4

FINAL PROCESSING MIX

4.1 Introduction:

The final processing mix is outlined in Figure 4.1. This procedure for processing near vertical reflection data yields what appears to be acceptable records. These steps and the final data displays will be explained in this chapter.

4.2 Analog to Digital Conversion:

The conversion process was carried out exactly as described by Gurbuz (1969) and Hajnal (1970) with one modification. The tone channel was digitized on channel 12 in place of the seismic trace. This was done because of limitations in BINBIN and because of the importance of having exact shot time information.

4.3 BINBIN, READER:

All digitized tapes were processed through BINBIN with the 12th channel being the tone break. READER was used to print out the appropriate blocks from each record. The block and sample where the tone cut off is picked at this stage, and is used to program WTSTACK. Record quality was checked at this stage by first plotting a selected number of records output from BINBIN, then by filtering and plotting these records, thus giving a direct comparison to the analog playback records. These records should be identical.

4.4 WTSTACK:

All the records were then processed through WTSTACK thus reducing 60 individual records to 4 stacked records. Record 68-9 is plotted in Figure 4.2 and is representative in both character and quality to the other three locations. The top trace represents the first geophone and the bottom seismic trace represents the 11th geophone. The 12th trace now represents time and is graduated in tenths of seconds with the second marks being larger.

4.5 FILTER:

4.5.1 Tests:

In order to decide on the optimum bandpass filter to use on the stacked records, filter tests were performed on all stacked records. The operators used for these tests, 179 points in length, allowed a 10-hertz wide bandpass of frequencies centered on 5, 15, 25, and 35 hertz. Figure 4.3 indicates the amplitude responses of these operators with the 20-30 bandpass being identical in shape to the 10-20 and 30-40 filter operators. The filter slices for 67-9 are displayed in Figures 4.4 to 4.7.

Filter slices of frequencies up to 100 hertz were evaluated for location 65-9 and although large amounts of energy are present in the high frequencies, these frequencies do not improve the S:N amplitude ratio of any "events" when included in the final filtered record.

4.5.2 Final filtered records:

The final filter chosen for locations 65-9 and 66-9 was a 5-25

bandpass while locations 67-9 and 68-9 were filtered with a 2-25 bandpass. Figure 4.8 indicates the amplitude response of these two filters. Because of the wider bandpass used here than in the filter tests, the operator length was shortened to 99 points. The filtered records are displayed in Figures 4.9 to 4.12.

These records have a higher equivalent charge weight (see Table 1.1) than the individual records and the improvement in data quality is evident.

4.6 AGC:

Only records 65-9 and 66-9 were processed through AGC. An operator length of 1 second was used in both cases and the results are plotted in Figure 4.13 and Figure 4.14. It is important to note the variable noise level before the first breaks on record 66-9 (Figure 4.14) and to realize this can also happen later in the record. For this reason, the decision was made to process both the AGC records and the non-AGC records for location 65-9 and 66-9 through VSTACK.

4.7 VSTACK:

The output displays from VSTACK (Figures 4.15 to 4.19) are different from the other plots. Each output trace now represents the sum of eight vertical seismometer traces. A different time shift has been applied for each output trace in order to enhance events with specific apparent horizontal velocities. These velocities can be determined by this equation:

 $V = (d \cos \theta) / \{ \delta + (I-1) \}$

(4.1)

where \bigvee is apparent horizontal velocity, \checkmark is the geophone separation, \eth is the acute angle between the recording spread and the line of sight to the shot point, \checkmark is the sampling interval and \underline{I} is the trace number counting from the top of VSTACK display. The relative amplitudes of events, trace to trace, are retained in this display. The time of the event on VSTACK output will agree with the time of the same event on trace 6 of the input record. By looking at the input record at this time, and considering the specific velocity filtered, it is easy to line up the exact portions of each event that have been summed together. Figures 4.15 to 4.19 contain the VSTACK output for all 4 locations.

4.8 Summary:

The programs in this processing mix give the University of Manitoba the processing capability to extract detailed information from near vertical reflection data. Each and every program is essential and performs a function critical to the ultimate success of the processing.

The data presented in this chapter is now part of the data file of the Department of Earth Sciences, University of Manitoba. This data will be used along with more data that will be collected in the future to gain additional information about the structure and nature of the earth's crust. The resulting interpretations will

be published at a later date.

4.9 Additional Processing Possibilities:

The only additional processing planned at present is to modify VSTACK to perform an Nth root velocity stack as explained by Kanasewich et al. (1973). This should aid in the selection of possible events.

All the output data of previous processing steps has been retained on 9 track magnetic tape so that additional processing may be done at any time in the future. This will depend on new or better programs being developed to extract more information from the data.



Figure 4.1 Flow chart of data processing



Figure 4.2 68-9 after WTSTACK (15 sec.)







Figure 4.7 67-9 after FILTER (30-40)



Figure 4.8 Amplitude response of final filters

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Figure 4.14 66-9 after AGC

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Figure 4.13 65-9 after AGC

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Figure 4.16 66-9 VSTACK after FILTER

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Figure 4.17 66-9 VSTACK after AGC

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CHAPTER 5

CONCLUSIONS

The data presented in Chapter 4 exemplifies the stage to which the development of the near vertical reflection method has progressed. The appearance of events that could represent possible reflections from deep in the earth's crust suggests that this method is approaching a stage where it can be considered a viable exploration and research tool on the Precambrian Shield.

Modifications of the field equipment as suggested in Chapter 1 will make the system more usable. By closer spacing of the recording sites, the correlations of events on the output records will be much easier, thus allowing different reflecting horizons to be mapped.

Further processing of this data, as well as other data collected by a similar method, will be necessary to establish the minimum unit charges and minimum effective charge weights that can be used successfully. This study indicates that 25-pound unit charges and effective charge weights of just over 760 pounds will give what appear to be good results. However, it is recommended that larger unit charges and larger effective charge weights be used in order to improve the output data quality.

Weighted stacking has proven to be a more effective method of putting multiple shot records together than conventional stacking techniques. However, additional effort should be spent looking

into theoretical and practical improvements in methods to calculate the weighting factors.

The processing capability of the University of Manitoba now must rate as very acceptable. It is probably not as efficient as possible, but it does the job required of it. These programs should not be used without careful study and modifications should be made if ways can be found to make them more efficient or to make them do a better job on the data.

APPENDIX A

Program WTSTACK:

This program was written by O.G. Stephenson and G.H. Friesen. It performs a weighted vertical stack designed to optimize the output signal to noise power ratio.

The program requires only a limited number of input parameters. These parameters and the appropriate input formats are listed in the program. The subroutine WEIGHT was designed to calculate the optimum weighting factors. (See Chapter 2.)

The four parameters that require some judgements based on actual input data are W1, W1L, W2 and W2L. These parameters specify the two windows used in calculating the weighting factors. The first window should be located entirely before, but ending close to the first break energy. A gap of 0.2 sec. is required between windows. The second window should be centered over some strong signal energy, usually the strongest energy on the record. The lengths of the two windows can vary. The program normalizes the energy measured in each window by dividing by the number of samples in the window. It is recommended that the windows be between one and two sec. in length in order to achieve the best results.

The subroutine WEIGHT will automatically kill any trace on which the energy in the second window is less than the energy in the first window. For this reason, caution is recommended when stacking data of extremely poor quality. Modifications might be in

order if this is found to be a serious problem.

On a technical side, this program requires 350 K of core, 15,000 I/O counts, and 14 minutes CPU time to stack 16 records and output 25 sec. of data on an IBM 360/65. There is, at present, a limitation of approximately 30 sec. of data that can be output. However, by enlarging the appropriate arrays, disk storage and core requirements, longer records can be processed.

A list of the program, including comment cards, follows.

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C THIS PROGRAM DOPS A VERTICAL STACK OF SEISMIC RECORDINGS WITH THE C SAME SHOT AND RECORDING PCINT LOCATIONS. AN ENTIRE RECORD IS READ C IN AT ONE TIME WHICH IMPOSES A LIMIT OF 30 SECONDS TO THE LENGTH C OF DATA TO BE STACKED. C INPUT TO THE PROGRAM IS FROM A 9-TRACK TAPE ON UNIT 8. CATA ON C THIS TAPE MUST BE IN BLOCKED FORM (LRECL-BLKSIZE-1864) MITH THE C FIRST FOUR BYTES REPRESENTING RECORD NUMBER AND BLOCK NUMBER IS. C THE SAME AS INF OUTPUT FROM 'SINDIN' WITH THE DIGITIZER CN LOM C DENSITY, AND WITH 12 CHANNELS OF INFORMATION. FT THE HIGH DENSITY OR A DIFFERENT NUMBER OF CHANNELS IS USED THE PROGRAM WILL C RESULRE GREAT DEAL CF WODIFICATION BUDGEX MUMBER AND THE C THIS FACTOR IS A FUNCTION OF THE ENERGY IN THE 'NDIGE' AND THE C THIS FACTOR IS A FUNCTION OF THE ENERGY IN THE 'NDIGE' AND THE C THIS FACTOR IS A FUNCTION OF THE ENERGY IN THE 'NDIGE' AND THE C THIS FACTOR IS A FUNCTION OF THE ENERGY IN THE 'NDIGE' HAND THE C THIS FACTOR IS A FUNCTION OF THE ENERGY IN THE 'NDIGE' HAND THE C MUST BE SOCIFIED AS TO THEIR START TIME AND LENGTH IN SECONDS IN C THE INDUT PARAMETERS. THE NOISE MINDOWS SHOULD COVER THAT PORTION C DE THE TRACE REFORE FIBST BREAKS. THE SIGNAL C WINDOG SIDULD COVER TANY PERTION OF THE TRACE WHICH CONTAINS SOME C INPUT PARAMETERS C INPUT PARAMETERS C ON THE IST CARD IN 14 , 4 FE3 C ON THE IST CARD IN 14 , 4 FE3 C ON THE IST CARD IN 14 , 4 FE3 C ON THE IST CARD IN 14 , 4 FE3 C MARMETERS READ IN CONCERNS AF AS FOLLOWS, C ON THE LOWE CARD FOR SOLVEN TO STACK C ON THE LOWE CARD FOR EACH RECORD TO STACK C M THE CARD IN 14 , 4 FE3 C MODE C (WILL CARD IN 14 , 4 FE3 C MARMETERS READ IN CONCERNAL WINDOW C MILL CARD IN 14 , 4 FE3 C MODE C (WILL AND IN 14 , 4 FE3 C MARMETERS PECHAD FOR SACK RECORD TO STACK C MINDE C (WILL CARD IN 14 , 4 FE3 C MINDE C (WILL CARD FOR EACH RECORD CESE FORMAT 20). C HILLENGTH DF NISSE MINDOW C MILL CARD INDE CARD FOR EACH RECORD IS THE STACKING PROCESS. C ISCINAL CARD INDE CARD FOR EACH RECORD IS THE STACKING PROCESS. C ISCINAL CA		С	
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C VALUE AND A WEIGHTING FACTOR FOR EACH TRACE, AND WHICH TRACES, IF C ANY, ARE KILLED. C		С	OUTPUT ON THE LINE PRINTER FOR FACE RECORD IS THE AVERAGE
C ANY, ARE KILLED. C		С	VALUE AND A WEIGHTING FACTOR FOR FACH TRACE, AND WHICH TRACES IF
<u> </u>	·	С	ANY, ARE KILLED.
	4777477474	C	

(Manager	· · · · · · · · · · · · · · · · · · ·		n tan bisan manang kanang kanang kanang kanang kanang sa kanang kanang kanang kanang kanang kanang kanang kanan	ا المالية مقاولة المركزة المحيرة ويترجع محادث المتعاد معادينة متعاد متعاد محرج مريدة و <u>المعاورة م</u>	مى ئۇرىكى ئۇرۇش سىرىي بىرىي بىرىي بىرىي بىرىي بىرىيى بىرىيى بىرىي بىرىي بىرىي بىرىي بىرىيى بىرىيى بىرىيى بىرى	57
IV G	LEVEL	21	MAIN	DATE	= 73345	14/25/3
	C C	THE STACKED SAME FORMAT (B	FECORD IS CUPUT LOCK SIZE, LOGIC	ON 9-TRACK T AL RECORD LEN	APE (UNIT GTH, ETC.)	9) IN THE AS THE
	C C	INPUT TAPE, TO	BE COMPATABLE W	ITH EXISTING	PLOT PROGR	RAMS.
	с с	A DISK (UNI	T 13) IS USED DU	RING EXECUTIO	N OF THE F	ROGRAM TO
	C C	STORE DATA TEM ED BY THE FIRS	PORARILY. THE S T PARAMETER INSI	IZE OF STORAG DE THE BRACKE	E REQUIRED	DIS DETERMIN- DEFINE FILE*
	с <u>с</u>	STATEMENT IMME NUMBER MUST BE	ADIATELY FOLLOWI EQUAL TO OR LAR	NG THE FORMAL GER THAN THE	SPECIFICA NUMBER OF	BLOCKS IN
	C C	THE OUTPUT REC	ORD. (.GT. (SST / 0.171))	ning and a second s
	С	INTEGER*2 DATA	(12,10650)	, PROFNO, N	BLKST, TEMP	0(12,70),
		1A, B, ICR, IDUM1, INTEGER NULL(1	IDUM2, ITB, IR(20) 2,25)	,IB(20),IS(20)	· · · · · · · · · · · · · · · · · · ·
	20	REAL NORM(25,1 FORMAT(314;2X;	2) 12I1)			
	30 31	FORMAT(250A2,2 FORMAT('-','RE	50A2,25CA2,52A2) CORD',16,' IS S	TACKED BEGINN	ING AT BLO	CK , I4, , SAM
	32	1PLE',14/) FORMAT('-',14,	RECORDS ARE ST	ACKED FOR A L	ENGTH OF",	F8.3, SECON
	33	1DS, AND ARE OU FORMAT('1')	TPUT AS RECORD N	UMBER , 15)		
	108 130	FORMAT(' ','TR FORMAT(' ','TR	ACE',I3,' IS KIL ACE',I3,' AVE	LED') RAGE =',F6.1,	• WEIGH	TING FACTOR =
		1',F7.3) DEFINE FILE 13	(16C,1688,L,INT)		
	С	WRITE(6,33)				•
	с с	READS ANE CALC	ULATES PARAMETER	S •		
		INT=1 ND=1		~~~~~~		
		DI=.002449 READ (5,11)	PROFNO , SST			
	10	FORMAT (14 , READ (5,10) N	4F8.3) RST,W1,W1L,W2,W2	L		
	11 C	FORMAT (14 ,	F8.3)	~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~	YE COMPANY & VANDALIN AND AND AND AND AND AND AND AND AND AN	
	C C	NBLKST=NUMBER	OF BLCCKS OF DAT	A TO STACK		
		NBLKST=(SST/DI DO 40 IU=1,NRS)/70 T			- -
	40	READ(5,20) IR(CALL WEIGHT (N	IU),IB(IU),IS(IU RST,W1,W1L,W2,W2),(NULL(I,IU) L,IR,IB,IS,NU	,I=1,12) LL,NORM)	
	с	WRITE (6,32) N	RST,SST,PROFNO			
	С С	PERFORMS THIS	LOOP CNCE FOR EV	ERY RECORD IN	THE STACK	
	с	DO 500 IRA=1,N	RST			
	C C	SEARCHES FOR T Memory. (The	HE APPRCPRIATE R SAMPLES FOLLOWIN	ECORD AND BLC G THE 'IS' SA	CK AND REA	AUS IT INTO
	C C	BLOCK ARE TRAN BLOCKS ARE THE	SFERRED TO THE F N READ INTO THE	RCNT OF THE A REMAINDER OF	RRAY AND	NBLKST
	C					শিক্ষা

Residen-

IV G LI	EVEL 21	MAIN	DATE = 73345	14/25/35
	READ(8,30)	A,B		·······
5((IKA) .AND .B.EV.(IE(IR)	A)-1)) GU TU 60	
61	O READ(8.30)	TOUM1. TOUN2. / / CATA/T		
	WRITE(6.31) IDUM1.IDUM2.IS(IRA)	57,1-1,127,5-1,101	
7(0 IRD=70-IS(TRA)		
n an	DO 80 IRE=	1,IRD	and a second	
	IRJ=IS(IRA)+IRE		n far an far star an an
	DO 80 IRF=	1,12		
8(DATA(IRF, I	RE)=DATA(IRF, IRJ)		[10] Bryanachi Chenara, and A. Katalani. A strategic
	NSX=IRD+70	τ , τ , τ , τ		a desta a supra
		-1 NDLKCT		
		TDUM1 IDUM2 ((PATA/)	1) T-1 10) 1-TDD NOVA	
		IDUMI, IDUMZ, (ILATALI	$J_{j} = I_{j} I_{j} J_{j} = I_{N} S_{j} S_{j}$	
10	0 NSX=NSX+70			a de la construcción de la constru La construcción de la construcción d
C			*****	
C	II=TOTAL N	UMBER OF SAMPLES PER T	RACE	and a second of the second of
C				
	<u> </u>	RA)+70*NBLKST		ne en la transferie de la construcción de la const
С			· ·	
<u> </u>	PERFORMS T	HIS LOCP FOR EACH TRAC		
C .				
<u>، ا</u>	<u>90 170 1P=</u>	1,12		
C C	7EDOES TOA	CES TO BE VILLED		•
<u> </u>	ZEROLS INA	JES TO BE NILLED		· · · · · · · · · · · · · · · · · · ·
	IF(NULL(IP	(IRA)) 105,105,110		
10	5 DO 107 IQ=	L,II		ŢŦŎŎŎŎŎŎŎŎŎŎŎŎŎŎŎŎŎŎŎŎŎŎŎŎŎŎŎŎŎŎŎŎŎŎŎŎ
10	7 DATA(IP,IQ) = 0		
	WRITE(6,10	3) IP		
·····	<u>GO TO 170</u>			
C A				
<u> </u>	<u>LALCULATES</u>	THE AVERAGE UP THE TR	ACE	· · · · ·
L 11				
<u>* 1</u>	$\frac{0}{0}$ $\frac{30}{120}$ 10^{-1}	. 1 T		
12	0. SUMIT=SUMI	+DATA(IP.IQ)		
	AVRG=SUMIT,	'II		
<u>C</u>				
С	SUBTRACTS	HE AVERAGE AND MULTIP	LIES BY THE WEIGHTING	FACTOR
<u> </u>				
	STA=NCRM(IF	(A, IP)		
1./.	$\frac{00 140 IG}{0}$, II		
14	UDITERA 120	$= \{UA \mid A \mid P_{\gamma} \mid Q\} - A V R G\} \times S$	IA	
17		I IP AVRG STA		****
	IE(TRA.EO.1) GO TO 240	\mathbf{b}	
С				
Ċ	READS DATA	FROM DISK AND ADDS RE	CORD BEING PROCESSED T	O PREVIOUS-
C	LY STACKED	RECORDS.		
<u>)</u>	****			
200	D DD 230 IBC=	1,NBLKST	· · · · · · · · · · · · · · · · · · ·	₩₩₩₩ ₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩
······	READ(13' IN	T) A, B, ((TEMP(I, J)	, I=1,12), J=1,70)	
	DO 230 IP=1	,12		
	IX=180*70-6	70		·····
		-DATAITO TVN TENDITO		

SANGER S

.

IV G	LEVEL	21	MAIN	DATE = 73345	14/25/35
	230	IX=IX+1			
	240 2	IFTIRA.EG.NR	SI) GU IO 600		
	2	WRITES THE D	ATA ON DISK		
	ب 	INT=1			** • 2
		DO 260 IBC=1 IX=IBC*70-69	, NBLKST		
		NSY=IX+69			
2	2 <u>60</u> 500	WRITE(13' IN INT=1	T) IDUM1,ICUM2	((DATA(I,IZ),I=1,12),IZ=	IX,NSY)
				· · · · · · · · · · · · · · · · · · ·	
C C		OUTPUTS STAC	KED RECORD		e fan en
6	00	IX=1	Na may na kita da mana ka mana		
		$\frac{NSY=70}{ITB=0}$	***************************************		
		DO 650 ITA=1	• NBLKST		
		WRITE(9,30)	PRCFNC, ITE, ((DATA)	I, IZ), I=1, 12), IZ=IX, NSY)	a the second sec
4	50	I X = I X + 70			••••••••••••••••••••••••••••••••••••••
	20	STOP			Ŧ₩\$₽₩₩₩\$₽₩ ₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩
		END			
				· · · · · · · · · · · · · · · · · · ·	
	**************************************	***************************************			*****
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The second s					
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Part in an and a state of a state back					
		·			.

IV G	LEVEL	. 21	WEIGHT	DATE =	73345	60 14/25/35
		SUBROUTINE WE	IGHT (NOREC, SEC1, DS	EC1,SEC2,DSE	C2, IR, MB, N	ST, NULL, WT)
n an Allanda An Allanda An Allanda An Allanda An Allanda	<u> </u>					
	<u>č</u>	SUBROUTINE WE	IGHT WRITEN BY G.H.	FRIESEN , OC	T. / 73	
ing san ta Marina Marina	C	DESTONED C		THEON DUDI TO		
	C	VOL. 35 ,	# 3 , JUNE 1970	INSUN PUBLISI	HED IN GEU	PHYSICE
	<u> </u>	A CTATICTI				And an and a second
	СС	• STATISTI	CAL UPTIMAL STACKIN	G OF SEISMIC	DATA 1	
	C	INTEGEDA2 IT(
		INTEGER NULL(12,25)	URECI, MELNURI	EC), NSI (NU	<u> </u>
		DIMENSION POW	ER(25,12) , SN(25,1	2) , SS(25,1	12)	
		DIMENSION SWI	(12)			
		REAL SUM (25)	, STDN(25), STDS(25),STON(25)		
		DI = 0.002449			· · ·	
		PDI = DI = 70 DSEC = DSEC 1	•			
		IB4 = SEC1 / I	HDI			
	88) (), 1997 - 1997 (), 1997 - 1997 - 1997 ()	H4 = SEC1 - IB	4 * +DI	nennanna viennanna vigana girana anna kuna kasa anna anna anna anna anna anna an		
		$\frac{11}{185} = \frac{14}{522} / 1$	HDI			
	· .	H5 = SEC2 - I	B5 * HDI			
		$\frac{M5}{SREC} = 0.0$				
******		DO 100 KA=1, N	OREC			•
		IB1 = MB(KA)	+ IB4 • M4			·
·		IF (MM.LT.70) GO TO 207			
		$\underline{IB1} = \underline{IB1} + \underline{1}$				· · · ·
	207	CCNTINUE			• Ala	e este
		IF (MM.GT. O) GO TO 208	***************************************	************	***************************************
	· · · · · · · · · · · · · · · · · · ·	IF (MM.EQ. 0) GC TO 208			· · · ·
		MM = 70 + MM				
nga kang t	208	CENTINUE				
		$\frac{NSI}{IB2} = MB(KA) + \frac{1}{1}$	+ 1R5			
		MM = NST(KA) +	- M5		· ·	
	209	IF (MM.LT. 70)) GO TO 210			·
12 S		$\frac{102 - 102 + 1}{MN = MM - 70}$			······	
- 	210	CONTINUE				
		NS2 = MM IB = IB1			•	
		IO = IR(KA)				
		IST = NS1	· · · · · · · · · · · · · · · · · · ·	•		
		D0 15 IX=1.700	0			
	• •	REAC(8,10) IRR	R,IBR		······································	<u>መም ስማት መሆን ላይ የውስ መስለር የወረገ ሃሳት መስለ የውስ የእና የውስ ላይ መስለት ላይ መስለት ላይ የመስለት እንዲሆን እንዲሆን እንዲሆን እን</u>
	10	FURMAT(2A2,250	ND. IBR. FO. (TP.)) C	2) 0 TO 12		
partes Second		<u>GO TO 15</u>				 .
	12	DO 99 I = 1,	12			· .
**************************************	<u> </u>	SUM(1) = 0.0				

n fina falial also den n	an tanin tahun saya dagan			an makin dan makin dalam da	61
ÍV G	LEVEI	21	WEIGHT	DATE = 73345	14/25/3
		BACKSPACE	8		
		H6 = DSEC	- NB * HDI		
		M6 = H6 /	DI		
		N = NB * 7	0 + M6		₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩
		IF (M6 .E	Q. O) NB = NB - 1		• • · · ·
		IK2 = IK2	+ M6 $-$ ND $-$ ND $+$		an a
		$\frac{1F}{NR} = NR + 1$	$\frac{31 \cdot 10}{1} = \frac{10}{10} + \frac{1}{10}$		Argonieu Agricologija Na statelja provinska se statelja postala se statelja postala se statelja postala se statelja postala se statelja
		IEND = 70			n - Senara Sanara 19 - Maria Maria Manaratrian Maria Maria Maria Maria Maria
		DO 30 IJ =	1,NB		
		READ(8,10,	END=15, ERR=15) IR	R, IBR, ((IT(I,J), I=1, 12),.	J=1,70)
		DO 101 I =	1,12		
	101	$\frac{100 \text{ IOI } \text{J}}{\text{SUM(I)}} = \frac{100 \text{ IOI } \text{J}}{\text{SUM(I)}}$	1SI, IEND	T / T / A	
	101	$\frac{30MTT}{1ST} = 1$	$JMAII + II(I,J) \neq I$	I (I , J)	an a
		IF (IJ .E(C. (NB - 1)) IEN	D = M6	
	30	CONTINUE			a an
	· · ·	IF (IB.EQ.	IB2) GO TO 119		
	120	DO 120 I =	1,11	·	
	120	SIDN(1) = S	SUM(I) / N		e alexenter
		$\frac{1KZ}{IR} = \frac{1R2}{IR2}$			
		F1 = SEC1			
	· · · ·	F2 = SEC1 +	· DSEC1		
		DSEC = DSEC	2		
		IST = NS2			
		<u>GC TC 15</u>			
	119	DU 122 I =			
	122	$\frac{5105(17 - 3)}{5705(17 - 3)}$			
		F4 = SFC2 +	DSEC2		e• :
		DSEC = DSEC	1		
-	*****	<u>GO TO 129</u>			
1	15	CONTINUE			
	129	$\frac{\text{ASIGN}=0.0}{\text{NDITE}}$	2.2.1		
	222	WRILE (6,3	33) /// 18 1		
•		WRITE (6.1	14) IRR		
	114	FORMAT (//,1X, RECORD NO.	= $(.14, 20X, 314)$	and a state of the
		WRITE (6,30	0) F1,F2,F3,F4		
	300	FORMAT (/,	1X, POWER WINDOWS	ARE FROM ', F8.3, 2X, ' TO	7 7
-]	F8.3,2X	, AND FRCM, F8.3,2X	<pre>X, *TO *, F8.3,2X, _</pre>	
]	L · SECC	NDS CN THES RECORD	<u> </u>	
9 S		KK=0	1 1 1		·
54-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1		$S(KA_{1}) =$	$\frac{1}{1} \frac{1}{1} \frac{1}$		#/###\$^C#**C*#*###########################
1.		STON(I) = S	S(KA,I) / STEN(I)		× .
		IF (STON(I).GT.0) GD TD 239		
		SS(KA,I) =	0.0		ан алан айтай алан айтай алан айтай алан айтай айта Айтай айтай айта
		STON(I) = 0	.0		
		POWER(KA,I)	= 0.0		
		NULL(I,KA) =		•	
	204	FORMAT 1/ 1	A I NECATIVE VALUE		
		GO TE 123	NY NEGATIVE VALUE	IN PRAUE ' 14]	
	239	CONTINUE		······	
		POWER(KA.T)	= STON(T)	• • • •	

NS6540

VGLE	VEL	21	WEIGHT	DATE = 73345	5 14/25/3
		STON(I) = SQRT	(STON(I))		
	.23	ASTCN = ASTCN	+ STON(I)		
4	244	WI(KA,I) = STON(I		
	r	ASIUN = ASIUN	/ (11 – КК)		
		00 125 1 = 1,1			
*****		$\frac{SIDN(I)}{SIDS(I)} = \frac{SURI}{SIDS(I)}$			
1	25	2ID2(I) = 2KI			
<u>eristi i</u> Stati	.29	$\frac{SNINA1II}{MDITE 16 11E I}$			
1 1	15	ENRMAT 1/.1V	TRACE STO NOISE S	TO STONAL STONAL	· NOTSE PATIOIN
i ng dina di san d Ng Sang pan	±	D0 135 T = 1.1	1	15 STONAL STONAL	· NOISE RATIO
		WRITE (6.116)	I.STDN(I), STDS(I),	STON(T)	
enten 1927 - 1	35	CONTINUE	195104(1790105(179)		in a standard and a s A standard a standard and a standard
1	16	FORMAT (1X.14.	3X. F9. 2. 2X. F9. 2. 7X. 1	=7.2	a second and provide the second s
sectores.		SREC = SREC +	Δ		en e
		WRITE(6.117)	ΔΥΓΩ		and the second
1	17	FORMAT (50X ,	AVERAGE SIGNAL TO M	NOISE RATIO = ".	F7.2)
10	0	CONTINUE			
		SREC = SREC / I	NOREC		e Maria e
		WRITE (6,9)	SREC		[1] The second s Second second secon second second sec
9		FORMAT (/ , 50	OX , I AVERAGE AVERA	AGE = * , F 7.2	
		WRITE (6,900)		
9	00	FORMAT (/,1X,	I4)		
		REWIND 8			
	_	DO 192 I = $1, N$	DREC		
1	92	WT(I, 12) = 0.0	0	-	
		WRITE (6, 2)			• · · · · · · • • • · · ·
	****	FURMAL (///,1)	X, NULL ARRAY PASS	ED TU MAIN PROGR	<u>AM)</u>
n n	00	WELLE 1 0,003) { { NULL{J,1},J=1,	12 $3,1=1$, NUREU	· • • • • • • • • • • • • • • • • • • •
7	70	WDITE (6, 1)	10.21		
· · · · 1		EORMAT (///.1)	X. I STONAL TO NOTSE	AMPLITUDE RATIO	a she an
		WRITE(6.998)	(WT(1,1),1=1,12)	I = 1.NORE(1)	
		DO = 0 + 1 = 1 + 11	1		a and a second sec
	*****	SWT(J) = 0.0			
		$DO 5 I = 1 \cdot N($	DREC		and the second
5		SWT(J) = SWT(J)	+ WT(I,J)		
6		SWT(J) = SWT(J)	/ NOREC		
		WRITE (6,8)		· · ·	
		FORMAT (1X, '	TRACE AVERAGES !)		
		WRITE (6,998)	(SWT(J), J=1,11))	*******
· · · · ·		DO 301 I = 1,1	1		
		SUN = 0.0			
		DO 303 KA = 1, N	NOREC		· · · · · · ·
. 3	03	SUN = SUN + POV	VER(KA,I)		
3	01	SWT(I) = SQRT (SUN)		· .
		WRITE (6,302)			
3	02	FORMAT(1X, 'EXPE	CTED SIGNAL TO NOIS	E AMPLITUDE RATI	O OF WISTACK)
		WRIIE (6,998)	(SWT(I), I = 1, 1)	1)	••••
		WRITE (6, 3)			
3		HUKMAH (///,1X	(, ' SIANDARD DEVIAT	ILN UF THE NUISE	
······································		WK11E (6,50)((SN(1, J), J=1, 11), I=1	, NUKEL)	*****
6	55	FUKMAL (10X,12	21Z J		e a constante de la constante d
		$\frac{1}{10} \frac{40}{10} J = 1 \frac{1}{11}$			
.*		LI -000 DO 20 I = 1 NOP	2 EC		18 (1997)
		SN(1.1) = 1 / 9			

. Noroda

IV G L	EVEL	21	WEIGHT	DATE	= 73345	14/25/3
1 <u>44</u> 1969	20	E1 = E1 + WT(I,J)				
		F1 = 10.0 / E1 D0 31 I = 1 , NOR	REC			
	<u>31</u> 40	$\frac{WT (I,J) = WT(I)}{CONTINUE}$,J) * E1	**************************************		
	4	WRITE (6, 4)	I WEIGHT ARRAY	DASSED TO	MAIN PROCRAM #	
	50	WRITE (6,50) ((WT	(I,J),J=1,11),I=	=1,NOREC)		
		RETURN				
		END				
			، بر این			
			******	*****		
					<u>en en e</u>	
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	•		1999 1999 1999 1999 1999 1999 1999 199			
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1997 - 1997 -				·		. •
APPENDIX B

Program AGC:

This program was written by O.G. Stephenson, and is based on an algorithm supplied by G.H. Friesen. The program is designed to apply a time variable amplification to seismic data on a trace by trace basis.

This program should only be used to solve a specific problem that occurs on near vertical reflection seismic records with shot to geophone distances of less than 5 km. Record 65-9 in Figure 4.9 best typifies the problem of very large amplitudes over a short time period and large time segments with amplitudes so low that possible events cannot be picked. This program will balance the amplitudes over the entire trace leading to a better portrayal of wave forms, thus aiding interpretation. This program will also create a variable noise level on each trace. Relative amplitudes of events are maintained only to a partial degree over short segments of the trace, approximately ½ the length of the operator used.

The input parameters and the appropriate formats are listed in the program. The critical parameter is the operator length. The larger the shot-geophone distance, the longer the operator should be for best results: Operators of one second or more in length are recommended.

The program designs a triangular shaped operator, OP(j),

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symmetric about the center point j = 0 where it has a maximum value of 1 and dropping to zero at $j = \pm t$. This operator is used to calculate an envelope for each trace. The *i*th sample of the envelope [ENV(*i*)] is

$$ENV(i) = \sum_{j=-t}^{+t} OP(j) \cdot X(i+j)$$

where $\chi(i)$ are the input data. The maximum value of the envelope (ENVMAX) is found and used to calculate the output data $[\gamma(i)]$ in the following way:

$$Y(i) = X(i) \cdot \frac{ENVMAX}{ENV(i)}$$

It is clear that the amplification will always be greater than or equal to one.

On a technical side, this program requires 150 K of core, approximately 36000 I/O counts and 20 minutes CPU time on the IBM 360/65 to process 15 sec. of data on 11 traces with an operator length of 1 sec. Longer operators will substantially increase the CPU time required.

A list of the program follows.

V G LEVEL 21

MAIN

DATE = 73345

<u> </u>	
č	
C	PRCGRAM 'AGC' WRITTEN BY C. G. STEPHENSON FROM AN ALGORITHM BY
C	G. H. FRIESEN
Ç	
<u> </u>	DDOCCAN DESCRIPTION-
r r	THIS PROGRAM DESCRIPTION THE VARIANT AMPLIFICATION TO SEISMIC
C C	DATA ON A TRACE BY TRACE BASIS. IT DOES THIS BY CALCULATING
Č	A TRACE ENVELOPE, AND NORMALIZING THIS ENLELOPE TO 1 AND THEN
C C	DIVIDING THE TRACE VALUE BY THE NORMALIZED ENVELOPE TO GIVE THE
<u> </u>	OUTPUT DATA VALUE.
Ç	가 있는 것 같은 것 같
<u> </u>	PRCCRAM USES-
č	THE PROGRAM IS USEFUL IN EVENING OUT THE AMPLITUDES OF THE
C	TRACE WITH TIME. RECEMENDED USE IS FOR RECORDS RECORDED LESS
<u> </u>	THAN 5.0 KILCMETERS FRCM THE SHOT.
C	
<u> </u>	TNDUT DADAMETERS-
Č	FIRST CARD (SEE FORMAT 5)
Č	NOREC = THE NUMBER OF FECORDS TO PROCESS
Ē	SECS = THE LENGTH OF OPERATOR USED TO CALCULATE THE ENVELOPE
C	AND THE CODMAN TO THE CUDDONTINE SCEADCHES
<u> </u>	SECOND CARD ISEE FURMATIO IN SUBRUCIINE SEARCH ?
6	IR = THE PLOCK IN 'IR' CONTAINING ZERO TIME (OR THE TIME AT
<u> </u>	WHICH PROCESSING IS TO BEGIN)
č	IS = THE SAMPLE IN THE 'IB' BLOCK AT WHICH PROCESSING IS TO
C	BEGIN
<u> </u>	SECSDA = THE NUMBER LE SECUNUS OF DATA TO BE PROCESSED
C C	PRUFNU = THE UUTPUT ACCORD NONDER TRACTICARTY
<u> </u>	
	INTEGER*2 TRACE(11000), DATA(12,700), A, B, JAK, IS
	INTEGER*2 PRCFNO
	DINENSION OPERAT(700), ENVEL(11000)
	$\frac{1}{100} = \frac{1}{100} = \frac{1}$
	DI = -0.02449
	READ (5,5) NOREC . SECS
5	FORMAT (14, F8.3)
<u> </u>	THE COEDITOR LENCTH (IN CANDIES)
C C	LENGTH = THE LPERATUR LENGTH (IN SAMPLES)
	IENGTH=SECS/CI-2
	IF((LENGTH/2)*2.EQ.LENGTH) LENGTH=LENGTH+1
	WRITE(6,1) SECS, LENGTH
1	FORMAT(*1*, //**, "OPERATOR LENGTH = ", F4.2," SECUNDS (*, 12, * SAM)
1993년 3월 1993년 1월 1993년 199	1PLES)')
	I EN-LENGURLZ
С	
C .	THIS PORTION OF THE PROGRAM CALCULATES AND PRINTS DUT THE SYMETRIC
С	TRIANGULAR-SHAPED OPERATOR
C	

IV G LEVEL	21		MAIN		DATE	= 7334	-5	18/15/0
	OPERAT	(M) = FLCAT	[(M)/LEN1				<u>\</u>	······································
110	OPERAT	(2*LEN+2-	-M)=OPERAT(M))				·
	OPERAT	(LEN1) = 1		LENCTUN		an An Arthur		
21	EUBWAT	(1-1-20)	$\frac{2 \text{ERAL}(1) \text{I} = 1}{100000000000000000000000000000000000$	LENGIHJ	1101.1	10F10.3	11	
L 7	WRITE	6,2)		LULS ANL		10:10:30		
2	FORMAT	('-')					éser a d	a da la composition de
-c	y Hardel							
C	THIS LO	DOP IS PE	RFORMED FOR	EVERY REC	ORD TO	BE PRO	CESSED	
<u> </u>								
		$LII = I_{y}NL$	JKEC					
<u> </u>	LALL SI	EARCH (13	S S ELSLA PKLF	NUT	eneria esti secono sug Santa estat		andara da seria da Antica da secial	n an an Anna an Anna an Anna an Anna
С С	TT = Tt		R OF DATA POI	NTS TO PR	DCESS			
Č			<u>, u vsia i v</u>		<u>wyc</u>			
	II=SECS	SCA/DI+.	5		, al alta Sal			
	NBLKS=	II/70C+1					CARLES -	
<u> </u>	an an de Mariana.				<u> (a. 689. c.)</u>			
· C .	THIS PO	DRIION RE	EADS THE CALL	A FRUM IAP	E IN H	KAUE PA	KALLEL	FURMAL ,
<u> </u>	SUKIS	INIU LAP	AT THE ET	ST TRACE	TS RET	ATNED T	N THE	TRACE
č	ARRAY A	AND TS PE	ACESSED FIRS	T. ALL T	HE CAT	A IS 'PR	OCESSED	TRACE BY
C	TRACE.							and the second
<u> </u>								
	CO 100	M=1,NBLH	(S	en e				e de la companya de l
	I X = 1				5 S.			
사람은 가슴이 가는 것으로 같은 것은 것을 가는 것이다. 같은 가슴 것을 가는 것이다.		L=1, 10			n an			la de la companya de La companya de la comp
	$\frac{1}{2} = 1 \times + 0$	301 A.B.	((DATA(T. 1))	T = 1, 12	=14.17	}		
10 -	TX=TX+7	70		1 1 1 1 2 , 30	1///1/			
	NM=7CC*	*(M-1)						
	DO 50 M	Y=1,700	erten de la composition de la compositi Reference de la composition de la composit					
50	TRACE(M	M + NY) = DI	ATA(1, NY)		ى ئەس ۋەرىپى ئۇنىڭلۇرلىيەرمۇرىيا ب			
	DO 60	<u><=2,11</u>						
60		F(K-1)+M) IDATAIK	1.1-1.700			and the second	
100	CONTINI		I LUAIAINOS	193-19100				
	IF(IS.	EQ.0) GO	TO 106		가 있는 것이 가 가 있다. 			
	DO 105	LI=1,II						
105	TRACE (1	I)=TRACE	(LI+IS)	and a straight of the second sec				
106	KTRACE=	=1					an a	
115	EMAX=0	• •				and and a start of the start and the start of the	·	
an a								
an an Anna an Anna An Anna Anna An Anna Anna	NFI = IFN	<u></u>						······
C								
C C	THIS PC	ORTION PE	RFORMS THE C	ONVOLUTIO	N ON TI	HEFIRS	T HALF-	OPERATOR
<u> </u>	LENGTH	OF DATA,	IE FALE TH	E OPERATO	R IS U	SED TO	DETERMI	NE THE
C.	ENVELOP	PE VALUE	FOR THE FIRS	T DATA PO	INT.	THE SEC	OND ENV	ELOPE
	VALUE J	INTEL TO	ODEDATOR TO	MOVED CO	MDIETE	K PLUS	THE DA	NIS ANU
Č	SU UN C		. UPERAIUN 13	- MUVED CU	HELCICI		THE LA	1 14 10
	CC 150	L=1.1FN	······································	**************************************				
	SUM=0.		na an a	·	1			
	CC 120	M=1,LEN2					an a	
	CK=TRAC	<u>E (M)</u>			ander Augustander T		and the second	
	IF(CK.L	T.O.) CK	=-CK				, . •	e y a service de
⇒ 120	SUM=SUM	(+UPERAT	NFT+W1+CK					

.

IV G LEVEL	21	MAIN	DATE = 73345	18/15/0
	NEL=NEL-1			
	ENVEL(L) = SUM	0 150 160		
140	IFISUM-EMAXI 10 EMAX=SIIM	0,170,140		
140	$\frac{1}{1} EN2 = 1 EN2 + 1$			ang menangan kang di
	III=II-LEN			
C,			NTO THE OATA THIS DODIE	N OF THE
<u> </u>	CNCE THE OPERAT	OR IS ENTIRELY I	CN UNTIL THE LAST HALF-	
Č	I FNGTH OF DATA	IS ENCOUNTERED.		
Č Č				
	DO 250 IB=LEN1,	III		
	MS=IE-LEN1			
	$\frac{SUM=0}{100}$			
an a	CK = TRACE (MS + IS)			
	IF(CK.LT.O.) CK	<		
200	SUM=SUM+OPERAT(JS)*CK		
	IF (SUM-EMAX) 25	50,250,240		
240	EMAX=SUM	n an		
250				
	LEN=LENGTH/2			
	LEN2=LEN2-1			
Ç			LIAL C-ODEDATOD LENCTH O	E DATA IN
<u> </u>	THE SAME MANNER	NVLLVES IFE LAS	ISTNG LESS AND LESS OF T	HE OPERATOR
с С	INTI. FOR THE	LAST ENVELOPE VA	LUE, ONLY THE FRONT HAL	F OF THE
C C	OPERATOR IS USE			
	DO 350 L=1,LEN			
	CO 320 M=1, LEN2	2		
이 있는 것 가지 것 같은 것 같이. 1997년 - 1997년 - 1997년 - 1997년 1997년 - 1997년 - 1	CK=TRACE (TI-NEL	+M)		
	IF(CK.LT.O.) CK	<pre><=-CK</pre>		
320	SUM=SUM+OPERAT	(M) 7(K		
340	EMAX=SUM CARE	0+0,00,0+0		
330	NEL=NEL-1	an an Anna an Anna an Anna Anna Anna An		
	ENVEL(III+L)=SU	N State of the second se	방에 10, 등을 것은 12, 것을 가장을 수 있다. 10, 10, 10, 10, 10, 10, 10, 10, 10, 10,	
350 C	LEN 2=LEN 2-1			
C C	THE MAXIMUM ENV PORTIONS (AS "E	VELCPE VALUE DETE EMAX*) IS USED TO	RMINED IN ONE OF THE AB	OVE THREE TO A
C C	MAXIMUM VALUE C	F 1 IN THE FOLLO	WING PORTION OF THE PRO	GRAM.
	EMAX=1./EMAX			
400	ENVEL(I)=ENVEL(IA=700	(I)*EMAX		
C				
eeste die C	THE TRACE VALUE	S ARE MULTIPLIE) BY IFF NURMALIZED ENVE	LUFE AND ARE
Ç	THE NEVT TRACE	TO BE DECORCED	TS READ FROM DISK AND C	ONTROL IS
	TRANSFERRED PAC	CK IN STATEMENT	15	
č	IN-HUI LINNED CAU			
	DG 500 I=1,NBLK	<s< td=""><td></td><td>na an an Anna a Anna an Anna an</td></s<>		na an an Anna a Anna an Anna an
New Arrent Contractor	$TW = 700 \times (T - 1) + 1$			

	21	MAIN	DATE =	= 73345	18/15
	INT=15*(KTRACE	-1)+I			
12월 2일 12일 원리는 12일 - 12일 문화 20일 - 12일 - 12일 문화 20일 - 12일	IF(I.EQ.NBLKS)	IA=II-(NBLKS-1)*7	00	·	
	DO 550 IG=1,IA				San Kathar
	IY = IW + IQ - I				an Maria ang Kabupatèn sa
	LK=IKALE(IY)				
		(Comparing the second statement of the second state			
	TETENVELITVI E	(L^{1})			
	TDACS (IV) -1 K/E				
	CO TO 550				
540	$\frac{1}{10} \frac{1}{10} \frac{1}{10} = 0$	an the second			
550	CONTINUE	경제 전값의 중요한 전통 관계적으	1999년 1998년 1999년 1999년 - 1999년 1 1999년 1999년 19 1999년 1999년 199		
	TWW=TW+699				
500	WRITE(13' INT) (TRACE (TH). TH=	TW. TWW)		
	IF (KTRACE, FO, 1	1) $60 TC_{700}$	<u> </u>		e gereit de la company. La companye de la com
	KTRACE=KTRACE+		and the second		
	INT=15*(KTRACE	-1)+1	the second second	the start for a start	
	DO 600 M=1.NBL	KS			영상 등 감독적
	IW = 700 * (M - 1) + 1	an an an far altha an an an an an an	The state of the state of the		
	Ihh=Ih+699	[11] [1] Yokowe (2007)		가지 않는 것을 가지는 것을 가지 않는다. 같은 것은 것은 것은 것은 것을 가지 않는다. 같은 것은 것은 것은 것은 것은 것을 같이 같은 것을 같이 같은 것을 같이 같은 것을 알 수 있는다. 같은 것을 같은 것을 알 수 있는 것을 같은 것을 알	- 2011년 1월 28일 1월 28일 - 1923년 1월 21일 1월 2 - 1923년 1월 21일 1월 21
600	READ(13'INT)(TRACE(IY),IY=IW,	IWW)	na series de la companya de la comp Na companya de la comp	
	IF(15.EQ.0) GC	TC 615			
	CO 610 LI=1.II		******		t ^a natan sa sa
610	TRACE (LI)=TRAC	E(LI+IS)	an Tan		
615	GO TO 115				
700	JAK = 1		n an	a terretaria de la competencia de la c Competencia de la competencia de la comp	
C				· · ·	
C	CNCE THE LAST	TRACE HAS BEEN PRO	CESSED IT IS	RETAINED.	THE OTHER
C	TRACES ARE REA	D FROM THE DISK, BI	OCK BY BLOC	K, AND THE	CATA IS
C	OUTPUT ONTO MA	CNETIC TAPE IN TRA	CE PARALLEL	FORMAT.	
C	and the second second			Alter and a second	
	DO 7C5 M=1.NBL	KS			
	IX=1 (10.000 (10.000 (10.000)))				
	DG 704 MM=1,70	0			
	MMM = 70C * (M-1) +	MM	이 이상 사람은 영화		
704	CATA(11, MM) = T	RACE (MMM)	en en en ser		
	DO 710 I=1,1C				
	INT=(T-1)*15+M	그는 것 같은 것 같은 것 같은 것 같은 것 같은 것 같이 많이 있다.			방법 이 물건 옷 문
(
	REAC(13' INT) (DATA(I,J),J=1,	700)		
710	REAC(13' INT DO 7C5 IH=1,10) (DATA(I,J),J=1,	700)		
	REAC(13' INT DO 7C5 IH=1.10 IZ=IX+69) (DATA(I,J),J=1,	700)		
710	REAC(13' INT DD 7C5 IH=1,10 IZ=IX+69 WRITE(9,30) FR) (DATA(I,J),J=1, CFNC,JAK,((CATA(K,I	/00) .),K=1,12),L	=IX,IZ)	
710	REAC(13' INT DD 7C5 IH=1,10 IZ=IX+69 WRITE(9,30) PR IX=IX+70) (DATA(I,J),J=1, CFNC,JAK,((CATA(K,I	/00) .),K=1,12),L	=IX,IZ)	
710	REAC(13' INT DD 7C5 IH=1,10 IZ=IX+69 WRITE(9,30) FR IX=IX+70 JAK=JAK+1) (DATA(I,J),J=1, CFNC,JAK,((CATA(K,I	700) .),K=1,12),L	=1X,1Z)	
710	REAC(13' INT DD 7C5 IH=1.10 IZ=IX+69 WRITE(9,30) PR IX=IX+70 JAK=JAK+1 STCP) (DATA(I,J),J=1, CFNC,JAK,((CATA(K,I	700) _),K=1,12),L	=IX,IZ)	
710	REAC(13' INT DD 7C5 IH=1.10 IZ=IX+69 WRITE(9,30) FR IX=IX+70 JAK=JAK+1 STCP ENC) (DATA(I,J),J=1, CFNC,JAK,((EATA(K,1	700) .),K=1,12),L	=IX,IZ)	
	REAC(13' INT DD 7C5 IH=1.10 IZ=IX+69 WRITE(9,30) PR IX=IX+70 JAK=JAK+1 STCP ENC) (DATA(I,J),J=1, CFNC,JAK,((CATA(K,I	700) _),K=1,12),L	=IX,IZ)	
710	REAC(13' INT DD 7C5 IH=1,10 IZ=IX+69 WRITE(9,30) FR IX=IX+70 JAK=JAK+1 STCP ENC) (DATA(I,J),J=1, CFNC,JAK,((CATA(K,I	700) .),K=1,12),L	=IX,IZ)	
710	REAC(13' INT DO 7C5 IH=1.10 IZ=IX+69 WRITE(9.30) FR IX=IX+70 JAK=JAK+1 STCP ENC) (DATA(I,J),J=1, CFNC,JAK,((CATA(K,	/00) .),K=1,12),1	=IX,IZ)	
710	REAC(13' INT DD 7C5 IH=1.10 IZ=IX+69 WRITE(9,30) FR IX=IX+70 JAK=JAK+1 STCP ENC) (DATA(I,J),J=1, CFNC,JAK,((CATA(K,	700) _),K=1,12),L	=IX,IZ)	
710 705	REAC(13' INT DD 7C5 IH=1.10 IZ=IX+69 WRITE(9.30) FR IX=IX+70 JAK=JAK+1 STCP FNC) (DATA(I,J),J=1, CFNC,JAK,((EATA(K,I	700) _).K=1,12),1	=IX,IZ)	
710	REAC(13' INT DD 7C5 IH=1.10 IZ=IX+69 WRITE(9.30) FR IX=IX+70 JAK=JAK+1 STCP ENC) (DATA(I,J),J=1, CFNC,JAK,((CATA(K,	700) .),K=1,12),1	=IX,IZ)	
710 705	REAC(13' INT DO 7C5 IH=1.10 IZ=IX+69 WRITE(9.30) FR IX=IX+70 JAK=JAK+1 STCP ENC) (DATA(I,J),J=1, CFNC,JAK,((CATA(K,I	700) .),K=1,12),L	= I X, I Z)	
710	REAC(13' INT DD 7C5 IH=1.10 IZ=IX+69 WRITE(9.30) FR IX=IX+70 JAK=JAK+1 STCP ENC) (DATA(I,J),J=1, CFNC,JAK,((CATA(K,	700) .),K=1,12),1	=IX,IZ)	

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N IV G	LEVEL	21 SEARCH	DATE = 73345	70 18/15/
		SUBROUTINE SEARCH (IS, SECSDA, PROF	NO)	
	СС С	THIS SUBROUTINE READS IN INFORMAT AND POSITIONS THE INPUT TAPE FOR	ION REGARDING THE INPU THE MAIN PROGRAM.	T RECORD
<u></u>	C	INTEGER*2 PRCFNO INTEGER*2 A.B.IR.IB.IS		
	10	READ(5,10) IR, IB, IS, SECSCA , PROF FORMAT(314, F8.3, I4)	NO	
	30 、	READ(8,30) A,B FORMAT(2A2)		
salatung ng pislaman nisusan	100	IF(A.EQ.IR.AND.B.EQ.IB) GC TO 15 CONTINUE		۰
	15	ISS=IS WRITE(6,20) A,SECSCA,E,IS, PROFNO		
	20	FORMAT(* *, *RECORD *, I3, * IS PROC 1ECONDS, BEGINNING AT BLOCK *, I3, * RETURN	, SAMPLE',I3,'OUTPUT A	S*,14)
		END		
	······			
				· · · · · · · · · · · · · · · · · · ·
		\		
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		·	-	
<u>.</u>				
Redection Redection Red Red Red				
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