SPREAD DESIGN FOR MAXIMUM MULTIPLE ATTENUATION

By

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ABSTRACT

Recently Common Depth Point Stacking has become the general rule for seismic evaluation. Stack shooting is carried out to enhance the primary event as well as to attenuate the multiple. Actual multiple attenuation can only take place providing the multiple event is stacked out of phase. Such out of phase stacking can only take place providing there is an increase of velocity with depth.

Most effective attenuation is achieved by using a long gapped spread, whereas short split spreads yield virtually no multiple cancellation.

A series of tables and instructions are attached whereby a spread with near perfect attenuation of a 1st order multiple can be instantly designed for any area. Comparison stacked sections are enclosed indicating presence of multiple structure; also a re-shoot of the same line with the multiple attenuated.

INTRODUCTION

New developments in seismic methods and technology have made it possible to evaluate areas in which a valid evaluation would have been out of the question a few years ago.

Even with such technological developments the geophysicists, in order to derive dependable data, must still stress quality control rather than depend entirely upon high powered processing to improve his data.

Derivation of such quality control involves proper selection of at least the following:

(a) Geophone array, including number of geophones, spacing between geophones, proper group length, geophone type and frequency, etc.

(b) Shot hole pattern, hole spacing, hole depth, charge type and charge size.

(c) Type of instruments, instrument settings, recording tape.

It is only after every attempt to improve field data has been met that the consideration of data improvement by utilization of maximum recording range and high powered processing is worthy of note.

A further consideration is that a valid interpretation assumes working with valid data, thus again demanding the utmost from the field recording as well as from the processing standpoint.

SEISMIC STACK CONSIDERATIONS

Presently, one of the most common forms of data improvement is the dependence upon stack. Stacking must be classified according to:

(a) Stacking for the sake of primary energy reinforcement.

(b) Stacking for the sake of multiple energy attenuation.

In the first instance, stacking serves several purposes:

(i) Duplication and verification of dips over structure.

(ii) Reinforcement of poor quality data or events.

(iii) Cancellation of random noise thus, an improvement in signal to noise ratio.

When stack is shot for these purposes, the multiplicity of stack as well as spread length are chosen largely from an observational standpoint, the main consideration being that when several records from the same subsurface point are stacked, data will be improved by reinforcement.

When records are stacked to attenuate multiples, additional stacking considerations are vital. Attenuation of the multiple event is accomplished by the stacking of the multiple event out of phase. Such out of phase stacking is dependent on excess move-out (Δ NMO) of the multiple event after primary move-out has been removed.

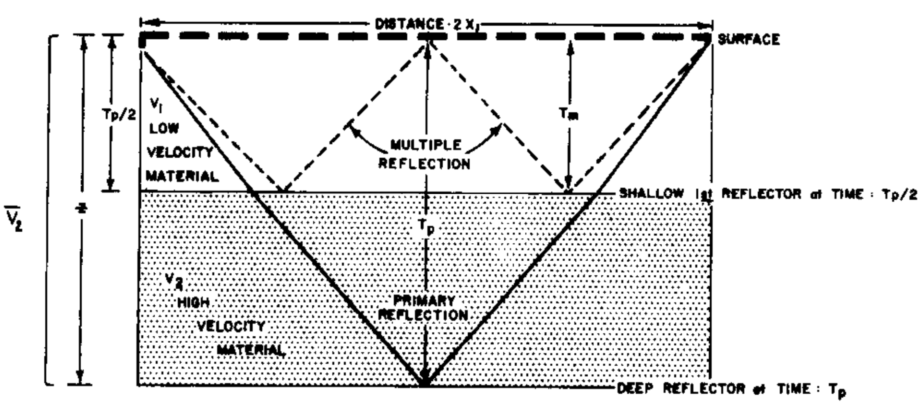

Illustration of Primary and Multiple Reflections

Δ NMO = NMO Multiple — NMO Primary

$\approx 2(X_1^2/2V_1^2 Tmav)$ — $((2X_1)^2/2\bar{V}_2^2 2(Tmav))$*

*Yields close approximation — may be refined at any point or compensated by use of slightly higher period.

$\approx X_1^2/Tm\ (1/V_1^2 - 1/\overline{V}_2^2)$

$$\Delta\,NMO \approx X_1^2/Tp\ (\overline{V}_2^2 - V_1^2/2\overline{V}_2^2\,V_1^2) = \frac{\text{NMO Factor}}{Tp}$$

X_1 = Distance shot to geophone for multiple.

$2X_1$ = Distance shot to geophone for primary = X.

V_1; $\overline{V}_2$ = Average velocities surface to multiple and primary reflectors respectively.

Tm, Tp = Two Way time at 0 distance of multiple and primary respectively where Tp = 2Tm.

$2Z = Tp\overline{V}_2$

$Tpav = Tp + \Delta Tp$

ΔTp = ½ NMO across spread.

$Tmav = Tm + \Delta Tm$ as above.

$\Delta Tm \sim 2\,\Delta\,Tp$

Table 1 has been supplied to yield NMO factors for various ratios of $V_1/\overline{V}_2$ and distance (X) of $(3160)^2\ X^2 = 10^7$.

Table 2 has been supplied to yield proportionate values of Δ NMO as a function of distance.

Generally, minimum multiple attenuation results when the normal move-out of the multiple event is nominal — thus for all short spreads.

Maximum multiple attenuation results when the multiple event is sufficiently out of phase to attenuate itself. For a 200% stack this demands an out of phase relationship of 180°, i.e., 360/2. For a 400% stack an out of phase relationship of 360/4 = 90°, etc.

Any such attenuation is dependent on a constant frequency as well as a constant amplitude. Seismic frequencies and amplitudes are generally not constant, for this reason it is generally advisable to consider stack multiplicity of 400% or greater. A stack designed to yield out of phase relationships of 90° will yield good attenuation; if signals are out of phase 60°, i.e., 1/6 of a cycle as in 600% stack or 120° as in 300% stack, providing total phase shift is 270° for 400% stack, and approximately 300° for 600% stack. But it is undesirable to have signals out of phase less than 60° or more than 150°, as a signal out of phase in excess of 150° approaches 200% stack.

THE 400% STACK

The 4 phases of an ideal 400% stack may be drawn as vectors at 90° angles, thus forming a square. See Figure 1 (a). The following phase relationship then exists:

	Phase Shift
Phase 1	
	90°
Phase 2	
	90°
Phase 3	
	90°
Phase 4	
Total Phase Shift	270°

A stack of this type would yield attenuation of approximately 85% - summation based on typical seismic wavelet. See Figure 1 (b).

If angles between the various phases are 0° as in short split spreads, attenuation is 0%. It is thus evident that if the angle between adjacent pulses is plotted and observed, approximate attenuation is evident at a glance. See Figures 1 (c) to 1 (f) inclusive.

Observing the phase relationship for a perfect 400% stack, it is evident that to obtain a stack of this nature the following conditions should be strived for:

(a) Each phase shift equal and 90°.

(b) Total phase shift Δ NMO = 270°.

Since Δ NMO is a function of distance squared, it is also a function of station or flag position with respect to the shot point, squared.

Flag	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
$(\text{Flag})^2$	1	4	9	16	25	36	49	64	81	100	121	144	169	196	225

Our desired spread requires that ΔNMO, which is a function of flag position, remain a constant from station to station. When ratio of $(\text{Flag})^2$ is calculated for adjacent stations, the following is the result:

$(\text{Flag})^2$	1		4		9		16		25		36		49		64
% Ratio		400		225		178		156		144		136		131	

Results of $(\text{Flag})^2$ versus % ratio of Flag 1 to Flag 2, etc. have been plotted. See Figure 2. Observation of the plot indicates ratio of normal move-out change is not near constant for the first 6 stations, however, is relatively constant beyond the 7th station. It becomes obvious that should we desire a near constant Δ NMO between adjacent stack points, the first 6 flags must be ignored, thus the spread must be offset at least to flag position No. 7.

ΔNMO thus becomes a function of $(\text{Flag } 7)^2$ to $(\text{Flag } 30)^2$.

For a 400% stack the first stack set then comprises Flags 7, 13, 19, and 25. It has been established that ideal Δ NMO between Flag 7 and Flag 25 is 270°. Column 2 is normalized by multiplying by .47 to yield the desired Δ NMO in column 3.

Col. 1 Flag	Col. 2 $(\text{Flag})^2$	Col. 3 = Col. 2x.47	Stack Set #1	Stack Set #2	Stack Set #3	Stack Set #4	Stack Set #5	Stack Set #6
7	49	23°	23°					
8	64	30°		30°				
9	81	38°			38°			
10	100	47°	Δ(57°)			47°		
11	121	57°		Δ(62°)			57°	
12	144	68°			Δ(68°)			68°
13	169	80°	80°			Δ(73°)		
14	196	92°		92°			Δ(79°)	
15	225	106°			106°			Δ(84°)
16	256	120°	Δ(90°)			120°		
17	289	136°		Δ(96°)			136°	
18	324	152°			Δ(102°)			152°
19	361	170°	170°			Δ(108°)		
20	400	188°		188°			Δ(113°)	
21	441	208°			208°			Δ(119°)
22	484	228°	Δ(124°)			228°		
23	529	249°		Δ(130°)			249°	
24	576	271°			Δ(135°)			271°
25	625	294°	294°			Δ(141°)		
26	676	318°		318°			Δ(147°)	
27	729	343°			343°			Δ(152°)
28	784	369°				369°		
29	841	396°					396°	
30	900	423°						423°
		Σ Δ NMO	271°	288°	300°	322°	339°	355°
Approximate Attenuation:			80%	80%	80%	80%	80%	80%

Adjacent Phase Shifts Indicated by: Δ( )

For Vector Diagram See Figure 1(d).

A spread design which conforms to the above conditions should then yield an 80% multiple attenuation on all stack sets. Total spread length is such that station 30 is at 423° ΔNMO, thus total desired phase shift of multiple for such a spread at station 30 is at $423°/360° \approx 1.2$ cycles ΔNMO at trace 30.

In planning such a spread:

Step 1: Determine period (P) of multiple, e.g. = .036 sec.

Step 2: ΣΔNMO at station 30 = 1.2P, e.g. = 1.2(.036) = .043 sec.

Step 3: Calculate multiple source time Tm, e.g. = .500 sec. Primary time Tp at zone of interference. 2Tm = 1.000 sec.

Step 4: Calculate $\overline{V}_1$ = average velocity at time Tm, e.g. = 7,400'/s.

Step 5: Calculate $\overline{V}_2$ = average velocity at time Tp, e.g. = 10,600'/s.

Step 6: Calculate ratio $\overline{V}_1/\overline{V}_2$ = 7,400/10,600 = .7.

Step 7: Consult Δ NMO Factor Chart Table 1, to determine factor for .7 and 10,600 = .045.

Step 8: Divide result by Tp = .045/1.000 = .045.
ΔNMO @ 3160' = .045.

Step 9: Using proportionate NMO chart, ΔNMO .045 distance 3160, find distance at which ΔNMO = 1.2P for P = .036; this value = .043 at distance of approximately 3100 feet.

Total spread length = 3100 feet.

Station 24 at Flag 30, at approximately 3100 feet, consider 3300, allows for anisotropy and curved ray path — Station 1 at Flag 7.

Flag to Flag distance = 3300/30 = 110 feet.

NMO's for any distance along the spread can be checked employing proportionate NMO chart, will be found to conform to spread as designed. See Page 7.

Should this same flag spacing be used to lay out a single end spread, phase shift would be as follows: See Figure 1 (e).

	Stack Set 1			Stack Set 3			Stack Set 6		
Station	1	0°		3	4°		6	17°	
			Δ(23°)			Δ(34°)			Δ(51°)
	7	23°		9	38°		12	68°	
			Δ(57°)			Δ(68°)			Δ(84°)
	13	80°		15	106°		18	152°	
			Δ(90°)			Δ(102°)			Δ(119°)
	19	170°		21	208°		24	271°	
% Attenuation:			55%			60%			70%

Average Attenuation: 60%

Laid out as a split: See Figure 1 (f).

	Stack Set -3			Stack Set -1			Stack Set +1			Stack Set +3		
Station	-3	4°		-1	0°		+1	0°		+6	17°	
			Δ(0°)			Δ(12°)			Δ(12°)			Δ(0°)
	+3	4°		+5	12°		-5	12°		-6	17°	
			Δ(34°)			Δ(11°)			Δ(11°)			Δ(51°)
	-9	38°		-7	23°		+7	23°		+12	68°	
			Δ(0°)			Δ(34°)			Δ(34°)			Δ(0°)
	+9	38°		+11	57°		-11	57°		-12	68°	
% Attenuation:		10%			10%			10%				

Observation of the split indicates that if it were lengthened, a fair 200% stack would result.

It follows that if split spreads are employed for multiple attenuation, 800% stack minimum should be used with total spread length approximately 3P.

Obviously an asymmetrical spread would have an attenuation level greater than the split, less than the single end spread, and far less than the offset spread. Furthermore, a slightly longer single end would have greater attenuation than the described one, up to 65% but no greater.

Spread lengths considerably in excess of 1.2P would generally tend to cancel primary energy as the wave path would approach a horizontal path and would arrive out of phase at the last geophone in the group as compared to the first.

Examination of graph Fig. 2, indicates slightly better attenuation would result if offset distance is increased to flag 13 rather than 7. Total spread length is then 36 flags, group to group distance is then shortened as entire spread layout is 2/3 of the distance between shot point and final group. From a practical standpoint so little is gained that this procedure should only be considered when extremely long spreads are used, i.e., 1 mile or greater.

SUMMARY

For multiple problem areas, a near perfect spread for multiple attenuation can very readily be designed by combining tables 1 and 2 together with the 4(P) formula as supplied to yield table 3. Table 3 yields spread length as a function of velocity ratio and geologic section depth. Period of multiple has been assumed constant at .030 seconds.

Use of Table 3

(a) Left hand column denotes velocity ratio $\overline{V}_1/\overline{V}_2$

(b) Upper column denotes two-way time of primary Tp

(c) The intersection of left and upper column yields spread ratio as function of subsurface depth of primary reflection.

(e.g.) As per Page 8 $V_1 = 7{,}400'/s$ $\overline{V}_2 = 10{,}600'/s$
$\overline{V}_1/\overline{V}_2 = .7$ Tp = 1.000 seconds
Table 3: Spread ratio = .53
Subsurface primary depth = $\overline{V}_2$ x Tp/2 = 10,600 x 0.5 = 5,300 feet
4(P) spread length = section depth, multiplied by spread ratio = .53 x 5,300 = 2,800 foot spread length

A near perfect theoretical attentuation of the multiple results if total spread length yields a residual normal move-out of 1.2 times period of the multiple and if first group of geophones is offset at least to the 7th flag position. Theoretical multiple attentuation of such a spread is approximately 80%, as compared to 60% attentuation for a single end spread using the same flag spacing, and 10% attentuation for a split with same flag spacing.

A split spread with approximately equivalent attenuation could be designed but would require 1200% stack whereas the asymmetrical would require 800% stack. A single end spread with slightly improved attenuation could also be designed but would require omitting 1 stack set, thus, would have to be shot as 600% stack and stacked as 500%.

Numerous other methods of calculating and refining the spread technique can be employed.

APPLICATION OF SHOOTING TECHNIQUES OTHER THAN THE (4P) SPREAD

In areas where multiples are no problem, it is more practical to shoot split spreads, where spread length on either side of the hole may be 1.2P, thus 12 stations cover the same distance as was previously spread over 30 stations. A spread of this length will yield good primary reinforcement, is not too long to yield problems for ΔNMO correction nor for primary attenuation, and is also long enough for multiple recognition, should multiples prove to be present. If field equipment on hand does not allow for the laying out of a split of this length, an asymmetrical spread may be considered with one side of length 1.2P, thus an adaptation of equipment to the desired spread length.

CONCLUSIONS

Multiple attenuation by stack shooting cannot result unless at least the following conditions hold:

1. There is a definite increase of velocity with depth.
2. Spread is sufficiently long to create a minimum of 1 cycle of residual normal move-out: maximum attenuation results from an offset single end spread.
3. Data is stacked with minimum error in move-out and static calculations.

In a case where an ideal stack program was shot, an error in move-out calculation of .015 sec. across a spread with a multiple period of .030 sec. will attenuate the primary and multiple to an equal extent. If error exceeds .015 sec., greater attenuation of the primary than of the multiple may result.

REFERENCES

1. GRAEBNER, R. J., "Seismic Data Enhancement — A Case History:" Geophysics February 1960, Vol. XXV, No. 1, Pages 285-311.
2. MAYNE, W. HARRY, "Common Reflection Point Horizontal Stacking Technique:" Supplement to Geophysics, 1962, Vol. 27, Pages 927-938.

3. MARR, JOHN D., and ZAGST, EDWARD F., "Exploration Horizons from New Seismic Concepts of C.D.P. and Digital Processing:" Geophysics, Vol. XXXII, No. 2, Pages 207-224.
4. DOBRIN, M. B., "Geophysical Prospecting," McGraw Hill, 1960.

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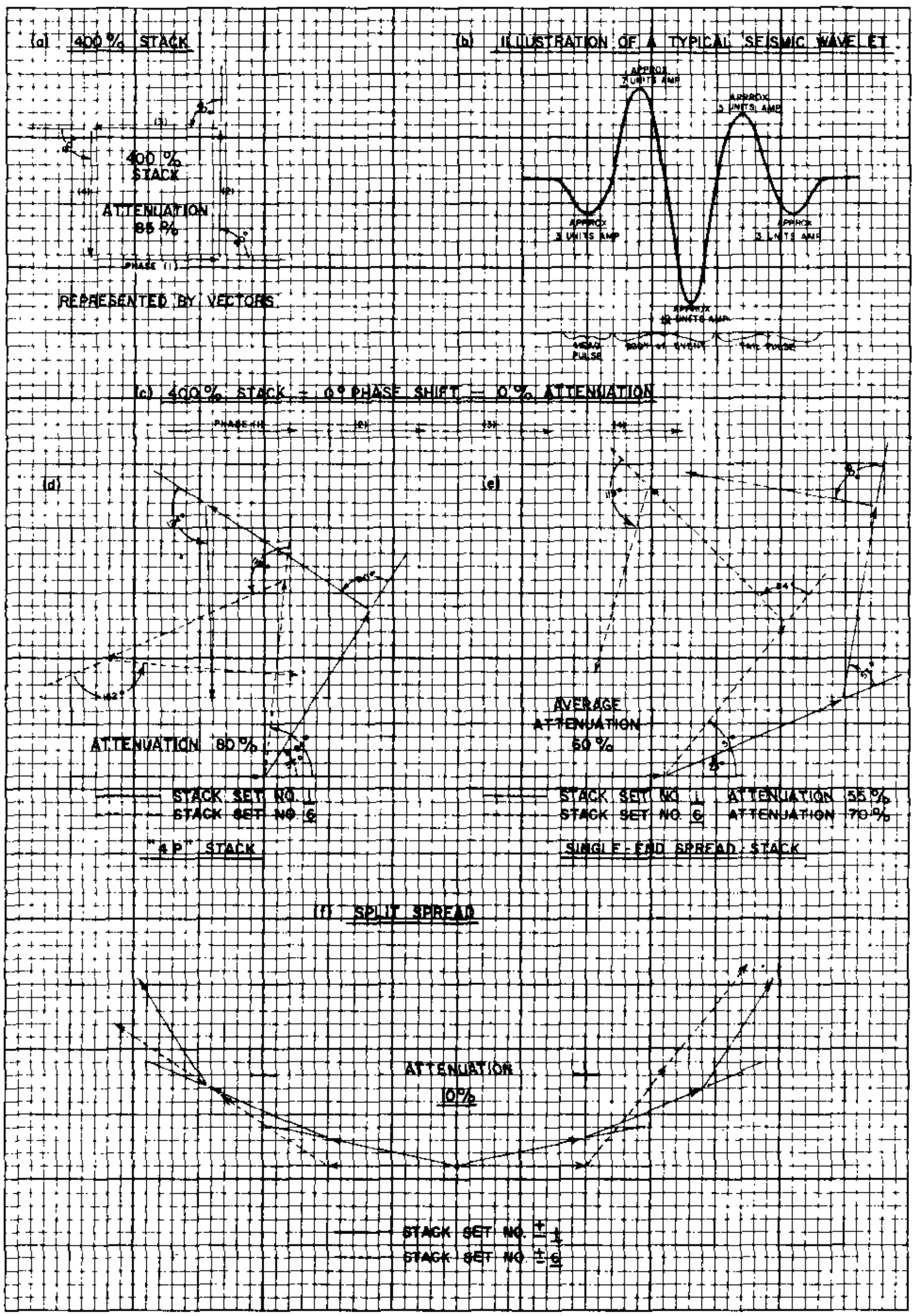

(a) 400 % STACK
400 %
STACK
ATTENUATION
85 %
REPRESENTED BY VECTORS
(b) ILLUSTRATION OF A TYPICAL SEISMIC WAVELET
(c) 400 % STACK = 0° PHASE SHIFT = 0 % ATTENUATION
(d)
ATTENUATION 80 %
STACK SET NO. 1
STACK SET NO. 6
"4 P" STACK
(e)
AVERAGE
ATTENUATION
60 %
STACK SET NO. 1 ATTENUATION 55 %
STACK SET NO. 6 ATTENUATION 70 %
SINGLE-END SPREAD STACK
(f) SPLIT SPREAD
ATTENUATION
10%
STACK SET NO. ± 1
STACK SET NO. ± 6

FIG. 1.

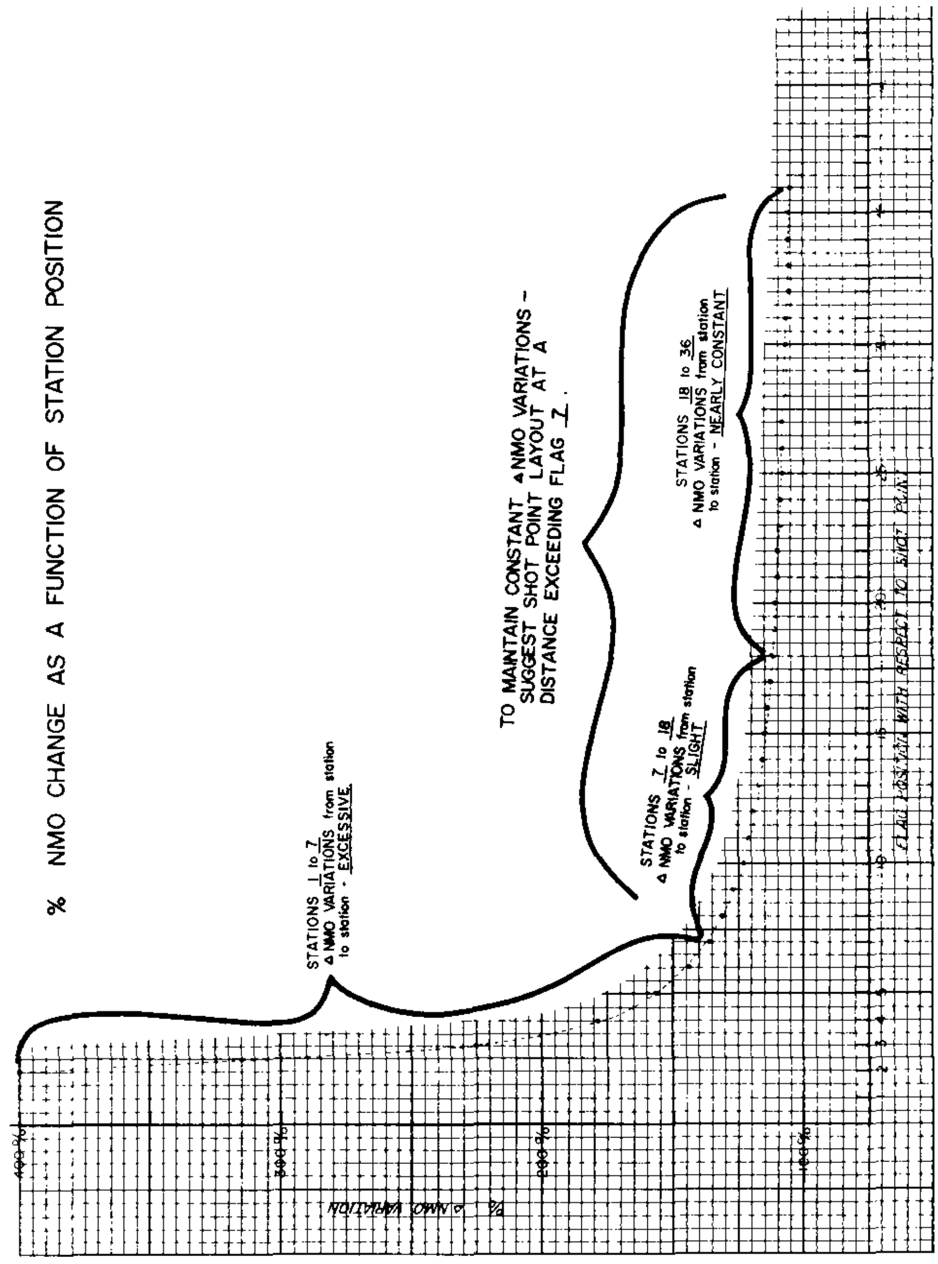

% NMO CHANGE AS A FUNCTION OF STATION POSITION
STATIONS 1 to 7 Δ NMO VARIATIONS from station to station - EXCESSIVE
TO MAINTAIN CONSTANT Δ NMO VARIATIONS - SUGGEST SHOT POINT LAYOUT AT A DISTANCE EXCEEDING FLAG 7.
STATIONS 7 to 18 Δ NMO VARIATIONS from station to station - SLIGHT
STATIONS 18 to 36 Δ NMO VARIATIONS from station to station - NEARLY CONSTANT
400 %
300 %
200 %
100 %
% Δ NMO VARIATION
JANUARY 1968

FIG. 2.

Δ N.M.O. FACTOR $(\bar{V}_2^2 - v_1^2 / 2\bar{V}_2^2 v_1^2)$ FOR RATIOS OF $v_1/\bar{V}_2$

$\bar{V}_2$ in thousands of feet per second

v_2	8.6	8.8	9.0	9.2	9.4	9.6	9.8	10.0	10.2	10.4	10.6	10.8
.44	.281	.271	.257	.248	.237	.227	.217	.209	.200	.193	.185	.179
.46	.250	.241	.229	.221	.211	.202	.195	.187	.179	.172	.165	.160
.48	.226	.218	.206	.199	.190	.182	.174	.167	.161	.155	.149	.144
.50	.203	.195	.185	.179	.170	.163	.156	.150	.144	.139	.133	.129
.52	.182	.175	.167	.161	.153	.147	.141	.135	.130	.125	.124	.116
.54	.164	.158	.150	.145	.138	.132	.127	.121	.117	.112	.108	.104
.56	.148	.142	.135	.1305	.124	.119	.114	.109	.105	.101	.0975	.094
.58	.133	.128	.121	.117	.112	.107	.103	.0985	.095	.092	.088	.084
.60	.121	.116	.110	.106	.102	.097	.093	.0895	.086	.083	.080	.077
.62	.108	.104	.099	.0955	.091	.087	.0835	.080	.077	.074	.071	.069
.64	.097	.0935	.089	.087	.082	.078	.075	.072	.069	.067	.064	.062
.66	.088	.0845	.080	.077	.074	.071	.068	.065	.063	.060	.058	.056
.68	.083	.080	.076	.073	.070	.067	.064	.0615	.059	.057	.055	.053
.70	.069	.066	.063	.061	.058	.0555	.053	.051	.049	.047	.045	.044
.72	.063	.0605	.057	.055	.053	.0505	.048	.0465	.045	.043	.041	.039
.74	.0555	.053	.0505	.049	.047	.045	.043	.041	.039	.038	.036	.035
.76	.049	.047	.045	.043	.0415	.040	.038	.0365	.035	.034	.032	.031
.78	.044	.042	.040	.039	.037	.035	.034	.0325	.031	.030	.029	.028
.80	.038	.036	.035	.033	.032	.030	.029	.028	.027	.026	.025	.024
.82	.032	.031	.030	.029	.027	.026	.025	.024	.023	.022	.021	.021
.84	.028	.027	.026	.025	.024	.023	.022	.021	.020	.019	.019	.018
.86	.024	.023	.022	.021	.020	.019	.018	.0175	.017	.016	.0155	.015
.88	.019	.0185	.018	.017	.016	.0155	.015	.014	.014	.013	.013	.0125
.90	.016	.0155	.0145	.014	.013	.013	.012	.012	.011	.011	.010	.010
.92	.013	.012	.0115	.011	.011	.010	.010	.009	.009	.009	.008	.008
.94	.009	.008	.008	.008	.007	.007	.007	.0065	.006	.006	.006	.006
.96	.008	.0075	.007	.007	.0065	.006	.006	.006	.0055	.005	.005	.005

v_2	11.0	11.2	11.4	11.6	11.8	12.0	12.2	12.4	12.6	12.8	13.0	13.2	13.4	13.6	13.8
.44	.172	.166	.160	.155	.150	.145	.141	.136	.132	.127	.123	.120	.116	.113	.1095
.46	.154	.148	.143	.138	.134	.128	.1255	.121	.118	.114	.110	.107	.104	.1005	.098
.48	.138	.133	.129	.125	.121	.116	.113	.109	.106	.102	.099	.096	.093	.091	.088
.50	.124	.119	.115	.111	.108	.104	.1015	.098	.095	.092	.089	.086	.084	.081	.079
.52	.111	.107	.108	.1005	.097	.094	.091	.088	.0855	.0825	.080	.078	.075	.073	.071
.54	.101	.0965	.0935	.090	.0875	.0845	.082	.0795	.077	.074	.072	.070	.068	.066	.064
.56	.0905	.087	.084	.0815	.078	.076	.074	.0715	.069	.067	.065	.063	.061	.059	.058
.58	.0815	.078	.076	.073	.071	.068	.067	.064	.062	.060	.058	.057	.055	.053	.052
.60	.074	.071	.069	.0665	.0645	.062	.0605	.0585	.057	.055	.053	.0515	.050	.0485	.047
.62	.066	.063	.0615	.0595	.058	.055	.054	.052	.051	.049	.047	.046	.0445	.043	.042
.64	.0595	.057	.0555	.0535	.052	.050	.049	.047	.046	.044	.043	.041	.040	.039	.038
.66	.054	.052	.050	.050	.047	.045	.044	.0425	.041	.040	.0385	.037	.036	.035	.034
.68	.051	.049	.047	.046	.044	.043	.042	.040	.039	.038	.036	.035	.034	.033	.032
.70	.042	.041	.039	.038	.037	.035	.0345	.033	.032	.031	.030	.029	.028	.028	.027
.72	.038	.037	.036	.035	.033	.032	.031	.030	.029	.028	.0275	.027	.026	.025	.0245
.74	.034	.033	.0315	.0305	.0295	.0285	.028	.027	.026	.025	.024	.024	.023	.022	.022
.76	.030	.029	.028	.027	.026	.0250	.025	.024	.023	.022	.022	.021	.020	.020	.019
.78	.027	.026	.025	.024	.023	.023	.022	.021	.021	.020	.019	.019	.018	.018	.017
.80	.023	.022	.0215	.021	.020	.019	.019	.018	.018	.017	.017	.016	.016	.015	.015
.82	.020	.019	.0185	.018	.017	.017	.016	.016	.015	.015	.014	.014	.013	.013	.013
.84	.017	.017	.016	.016	.015	.015	.014	.014	.013	.013	.012	.012	.012	.011	.011
.86	.0145	.014	.0135	.013	.013	.012	.012	.011	.011	.011	.010	.010	.010	.009	.009
.88	.012	.012	.011	.011	.0105	.010	.010	.009	.009	.009	.008	.008	.008	.008	.0075
.90	.010	.009	.009	.009	.008	.008	.008	.008	.007	.007	.007	.007	.007	.006	.006
.92	.008	.007	.007	.007	.007	.006	.006	.006	.006	.006	.006	.005	.005	.005	.005
.94	.005	.005	.005	.005	.005	.004	.004	.004	.004	.004	.004	.004	.004	.004	.003
.96	.005	.005	.004	.004	.004	.004	.004	.004	.004	.004	.003	.003	.003	.003	.003

TABLE 1.

PROPORTIONATE ΔN.M.O. VALUES AS A FUNCTION OF DISTANCE

Distance in Feet

200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3150	3200	3400	3600	3800	4000	4200	4400	4600	4800	5000	5200	5400
000	000	000	000	001	001	002	002	003	003	004	005	005	006	007	008	008	009	010	012	013	014	016	017	018	020	022	023
[illegible]	000	000	001	001	001	002	0025	003	004	005	006	007	008	009	010	010	012	013	014	016	018	019	021	023	025	027	029
[illegible]	000	000	001	001	002	002	003	004	005	006	007	008	009	010	012	012	014	015	017	019	021	023	025	027	030	032	035
000	000	000	001	001	002	003	0035	004	006	007	008	009	011	013	014	014	016	018	020	022	025	027	030	032	035	038	041
000	000	000	001	002	002	003	0035	004	006	007	008	009	012	014	016	016	018	021	023	026	028	031	034	036	040	043	047
000	000	000	001	002	003	003	0045	006	007	009	010	0125	014	016	018	018	021	023	026	029	032	035	038	041	045	049	053
000	000	000	001	002	003	004	005	006	008	010	011	013	016	018	020	020	023	026	029	032	035	039	042	045	050	054	058
000	000	000	001	002	003	004	0055	007	009	011	013	015	017	020	022	022	025	028	032	035	039	043	047	050	055	059	064
000	000	000	001	002	003	005	006	008	010	012	014	016	019	022	024	025	028	031	035	038	043	047	051	054	060	065	070
000	000	000	001	003	004	005	0065	008	010	012	015	017	020	023	026	027	030	034	037	042	046	050	055	059	065	070	076
000	000	001	002	003	004	005	007	009	011	013	016	019	022	025	028	028	032	036	040	045	050	054	059	063	070	076	081
000	000	001	002	003	004	006	0075	010	012	014	017	020	023	027	030	031	035	039	043	048	053	058	063	067	075	081	087
000	000	001	002	003	004	006	008	011	013	015	018	021	025	029	032	033	037	041	046	051	057	062	068	072	080	086	093
000	000	001	002	003	005	006	0085	011	014	016	019	023	026	031	034	035	039	044	049	054	060	066	072	077	085	092	099
000	000	001	002	004	005	007	009	012	014	017	020	024	028	032	036	037	041	046	052	058	064	070	076	081	090	097	105
000	000	001	002	004	005	007	0095	012	015	018	022	025	030	034	038	039	044	049	055	061	067	074	080	086	095	103	111
000	000	001	003	004	006	008	010	013	016	019	023	027	031	036	040	041	046	052	058	064	071	078	084	090	100	108	116
000	001	002	003	004	006	008	010	013	017	020	024	028	033	038	042	043	048	054	061	067	074	081	089	095	105	113	122
000	001	002	003	004	006	008	011	014	018	021	025	029	034	040	044	045	051	057	063	070	078	085	093	099	110	119	128
000	001	002	003	005	006	009	0115	015	018	022	026	031	036	041	046	047	053	059	066	074	081	089	097	103	115	124	134
000	001	002	003	005	007	009	012	015	019	023	027	032	038	043	048	049	055	062	069	077	085	093	101	108	120	127	140
000	001	002	003	005	007	010	013	016	020	024	029	034	039	045	050	051	058	065	072	080	088	097	105	112	125	135	145
000	001	002	003	005	007	010	0135	017	021	025	030	035	041	047	052	053	060	067	075	083	092	101	110	117	130	140	151
000	001	002	003	005	008	010	014	017	022	026	031	036	042	049	054	055	062	070	078	086	095	105	114	121	135	146	157
000	001	002	004	006	008	011	014	018	022	027	032	038	044	050	056	057	064	072	081	090	099	109	118	126	140	151	163
000	001	002	004	006	008	011	0145	019	023	028	033	039	045	052	058	059	067	075	083	093	103	112	122	130	145	157	169
000	001	002	004	006	008	011	015	019	024	029	034	040	047	054	060	061	069	077	086	096	106	116	127	135	150	162	175
000	001	002	004	006	009	012	0155	020	025	030	035	0415	048	056	062	063	071	080	089	099	110	120	131	140	155	167	180
000	001	002	004	006	009	012	016	020	026	031	036	043	050	058	064	065	074	083	092	102	113	124	135	144	160	173	186
000	001	002	004	007	009	013	0165	021	026	032	038	044	0515	059	066	067	076	085	095	106	117	128	139	148	165	178	192
000	001	002	004	007	010	013	017	022	027	033	039	046	053	061	068	070	078	088	098	109	120	132	143	153	170	183	197
000	001	003	004	007	010	013	0175	022	028	034	040	047	055	063	070	071	080	090	101	112	124	136	148	157	175	189	204
000	001	003	005	007	010	014	018	023	029	035	041	048	056	065	072												
000	001	003	005	007	010	014	0185	024	030	0355	042	050	058	067	074												
000	001	003	005	008	011	014	019	024	030	036	043	051	059	068	076												
000	001	003	005	008	011	015	0195	025	031	037	044	052	061	070	078												
000	001	[illegible]	005	008	011	015	020	026	032	038	046	054	062	072	080												
000	001	[illegible]	005	008	0115	016	0205	026	033	039	047	055	064	074	082												
000	001	003	005	008	012	016	021	027	034	040	048	056	0655	076	084												
000	001	003	006	009	012	016	0215	0275	034	041	049	058	067	077	086												
000	001	003	006	009	012	017	022	028	035	042	050	059	069	079	088												
000	001	003	006	009	013	017	0225	029	036	043	051	060	070	081	090												
000	001	003	006	009	013	0175	023	029	037	044	052	062	072	083	092												
000	001	003	006	009	013	018	0235	030	038	045	054	063	073	085	094												
000	[illegible]	003	006	010	013	018	024	031	038	046	055	064	075	086	096												
[illegible]	[illegible]	004	006	010	014	019	0245	031	039	047	056	066	0765	088	098												
000	[illegible]	004	006	010	014	019	025	032	040	048	057	067	078	090	100												
001	[illegible]	004	007	010	014	019	025	033	041	049	058	068	080	092	102												
001	[illegible]	004	007	010	015	020	026	033	042	050	059	070	081	094	104												
001	[illegible]	004	007	011	015	020	027	034	042	051	060	071	083	095	106												
001	[illegible]	004	007	011	015	021	027	035	043	052	062	072	084	097	108												

ΔN.M.O. in Milliseconds

TABLE 2.

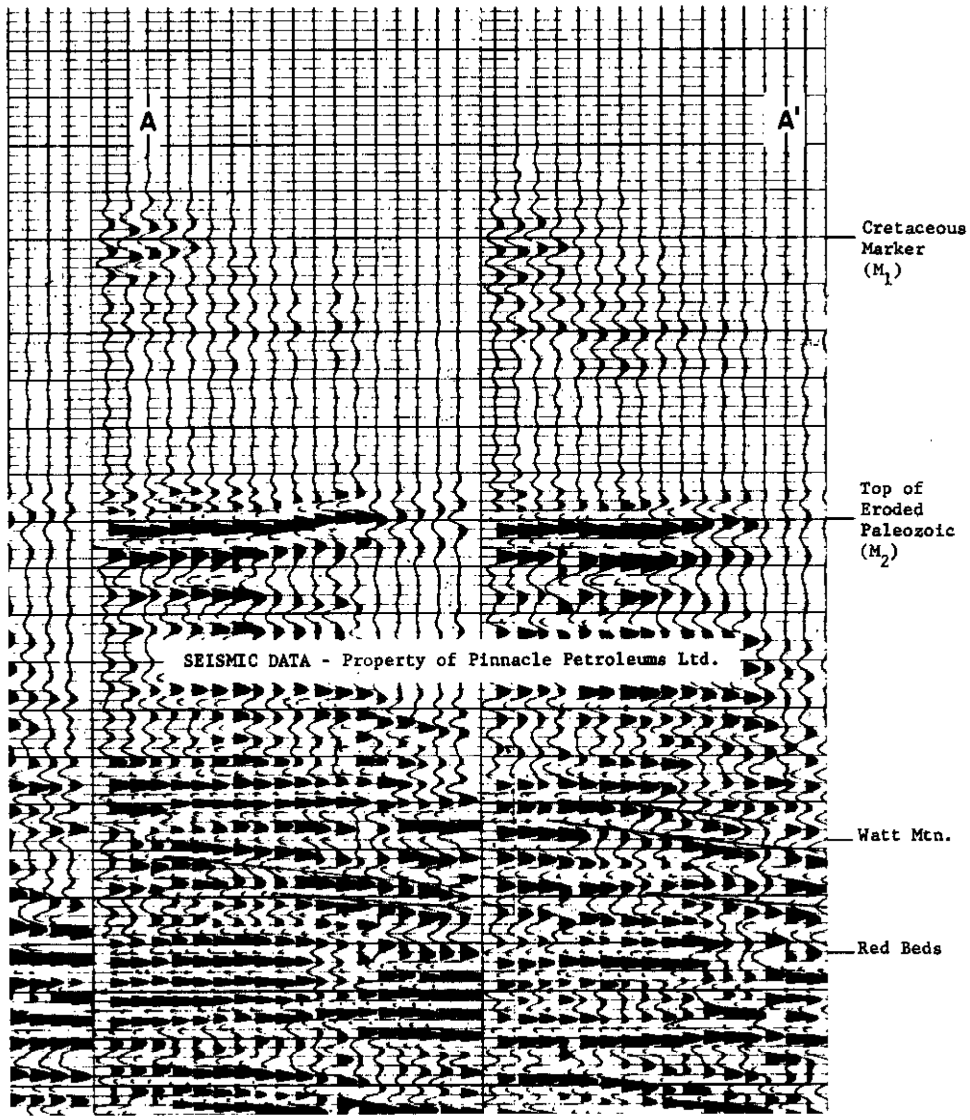
For P = .030 to yield △NMO 1.2P
Two way time of primary Tp

$V_1/\bar{V}_2$	.60	.70	.80	.90	1.00	1.10	1.20	1.30	1.40	1.50	1.60	1.70	1.80	1.90	2.00
.50	.40	.37	.35	.33	.31	.30	.28	.27	.26	.25	.25	.24	.23	.22	.21
.52	.42	.39	.37	.35	.33	.32	.30	.29	.28	.27	.26	.25	.25	.24	.23
.54	.44	.42	.39	.36	.35	.33	.32	.30	.29	.28	.28	.27	.26	.25	.24
.56	.47	.43	.41	.39	.36	.35	.33	.32	.30	.30	.29	.28	.27	.26	.25
.58	.50	.46	.43	.41	.38	.37	.34	.33	.32	.31	.30	.30	.29	.28	.27
.60	.52	.48	.45	.42	.40	.38	.37	.35	.34	.33	.32	.31	.30	.29	.28
.62	.55	.50	.47	.44	.43	.41	.39	.37	.36	.35	.34	.33	.32	.31	.30
.64	.58	.53	.50	.47	.45	.42	.40	.39	.38	.36	.35	.34	.33	.32	.31
.66	.61	.57	.53	.50	.47	.45	.42	.41	.40	.38	.37	.36	.35	.34	.33
.68	.63	.58	.54	.52	.49	.47	.44	.43	.41	.40	.39	.38	.36	.35	.34
.70	.69	.64	.59	.56	.53	.50	.48	.47	.45	.44	.42	.41	.40	.38	.37
72	.72	.67	.62	.59	.56	.53	.50	.49	.47	.46	.44	.43	.42	.41	.40
.74	.76	.70	.67	.64	.59	.57	.54	.52	.50	.48	.47	.46	.44	.43	.42
.76	.80	.75	.70	.67	.63	.60	.57	.55	.53	.51	.50	.49	.47	.45	.44
.78	.86	.79	.74	.70	.66	.64	.60	.58	.56	.54	.52	.51	.50	.48	.46
.80	.93	.87	.82	.75	.72	.68	.65	.63	.61	.58	.57	.56	.54	.52	.49
.82	1.00	.93	.88	.81	.77	.74	.70	.68	.66	.64	.62	.59	.58	.56	.55
.84	1.00	.99	.93	.88	.83	.79	.76	.73	.69	.68	.67	.65	.63	.60	.58
.86	1.20	1.10	1.01	.96	.92	.87	.81	.79	.78	.73	.72	.71	.68	.65	.64
.88	1.30	1.20	1.12	1.07	1.02	.96	.92	.89	.86	.82	.79	.77	.75	.74	.71
.90	1.40	1.38	1.26	1.12	1.10	1.07	1.03	.96	.93	.90	.89	.85	.82	.80	.79
.92	1.70	1.49	1.36	1.28	1.23	1.17	1.10	1.03	1.01	.99	.95	.94	.92	.90	.87
.94	2.00	1.84	1.68	1.58	1.52	1.43	1.42	1.36	1.26	1.24	1.22	1.15	1.09	1.08	1.07

TABLE 3.—Spread Length as Ratio of Section Depth.

V_1 = Average velocity from surface to multiple source.

$\bar{V}_2$ = Average velocity from surface at time Tp



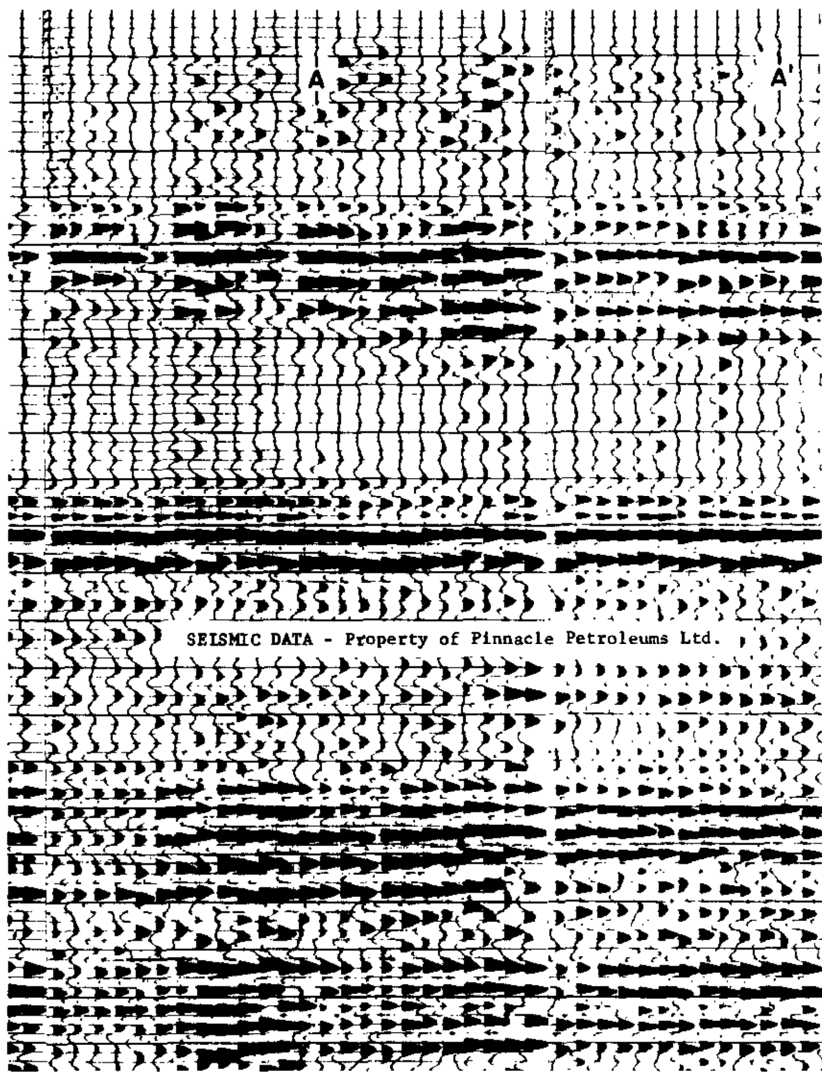
100% long trace display indicating severe multiple interference problem in a Northern Alberta area.

Coefficient Reflection Rc; $M_1 = .09$ $M_2 = .345$

Rc of Multiple = $M_1(M_2)Rcs = .031$

$$Rcs = \rho_2 V_2 - \rho_1 V_1 / \rho_2 V_2 + \rho_1 V_1 = 1 \qquad \rho_2 \sim 2, \ \rho_1 \sim 0$$

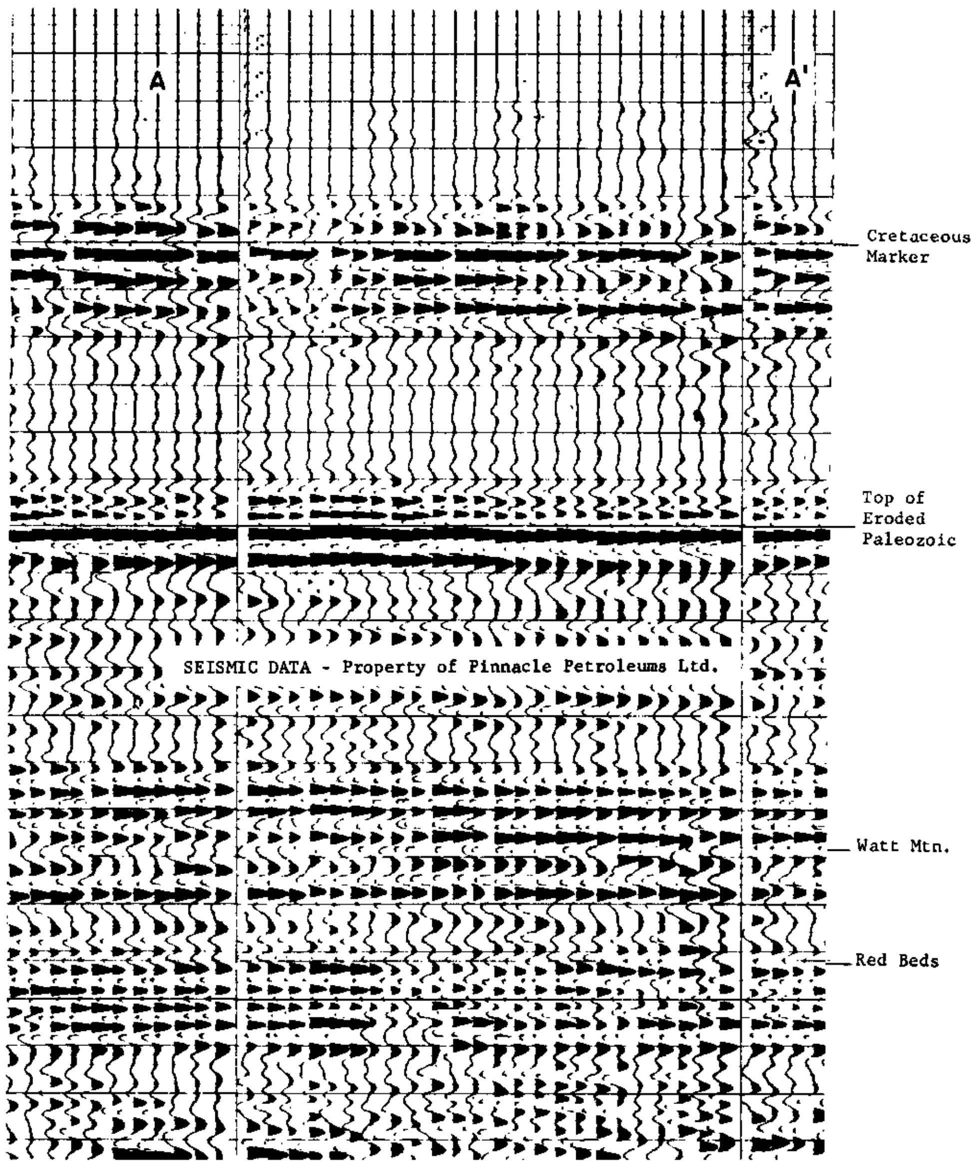
Rcs = Reflection Coefficient at Surface.



400% single end, stacked 300%, theoretical multiple attenuation approximately 60%. Note presence of apparent structure at Watt Mtn. level.

Spread Type = 0 - 150' - 3600'.

NOTE CHARACTER CHANGE KEG RIVER LEVEL.



4(P) stack, re-shot to confirm if structure is primary or multiple. Note structure evidence practically removed.

Spread Type = 0 - 770' - 3300'.