Geophysics Open-File Report 3
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A CRUSTAL and P-WAVE VELOCITY STUDY of PORTIONS of S.W. NEW MEXICO and S.E. ARIZONA USING OPEN PIT MINING EXPLOSIONS

by

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Submitted in partial
fulfillment
of
the requirements
of
Geophysics 590
and the
Masters Degree Program
at
New Mexico Institute
of
Mining & Technology

May 1973

ABSTRACT

Seismic energy from large daily explosions at the Santa Rita and Tyrone, New Mexico and Morenci, Arizona open pit copper mining operations was recorded at 10 stations within a 30 km. radius of Socorro, New Mexico. The data was used to construct a composite travel time curve for first arrivals. Application of standard refraction interpretation techniques resulted in a uniform crustal thickness of 34.2 km. in the region of the pits. P-wave velocities across the recording station array were 6.2 km./sec. for the direct and 8.1 km./sec. for the head wave.

INTRODUCTION

A crustal study of a limited portion of Southwestern New Mexico and Southeastern Arizona was conducted using the explosions from three open pit mines as energy sources and a total of ten recording stations in the vicinity of Socorro, New Mexico..Figure 1 shows the distribution of recording stations with respect to the pits, designated SR, TYR, and MCR.

Although the data was recorded over a region only about 60 km. in length, the distance travelled by the waves on a direct line from pit to recording station ranged from 150.6 km. to 260.7 km. Because of the large source to detector seperations it was felt that application of plane wave ray theory was justified.

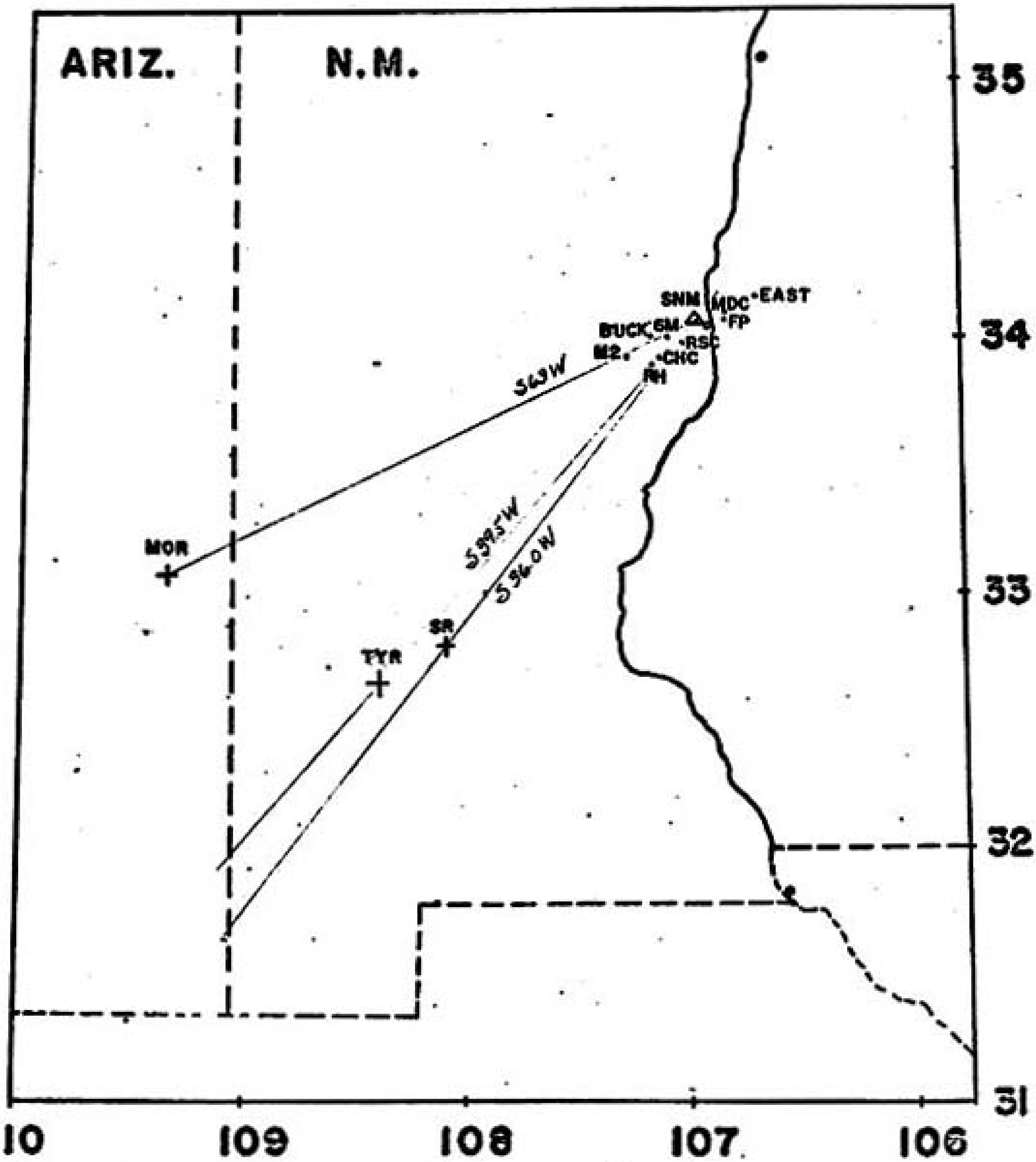


Figure 1. Map showing distribution of open pit mines and recording stations. Scale 1 cm. = 25 km.

DATA RECORDING TECHNIQUE

The basic recording technique employed a portable micro-earthquake seismograph, which was moved from one field station to another, and a fixed recording unit at the New Mexico Tech Seismological Station in Socorro. The base station, designated SNM, was used to determine the origin times of the events recorded on the portable unit, designated PS-1. The travel time to the field station for each event was calculated by subtracting the origin time from the arrival time at the field station.

A measurement of the travel time from SR, TYR, and MOR to SNM was made for a single explosion at each mine with the PS-1 located a few kilometers from the shot(see Figure 2). The difference between the SNM and PS-1 arrival times was taken as the " apparent travel time " from pit to base. The " apparent shot location " corresponding to this travel time was the position of the wavefront advancing towards SNM at the time it was recorded by the PS-1. Referring to Figure 2b, one can see that if the PS-1 is located between the shot point and the base station, the " apparent shot location ", or apparent origin(A.O. in Figure 2), corresponds to the PS-1 location. However, in the cases of Santa Rita and Morenci, Figures 2a and 2c, A.O. does not correspond to the PS-1 position because in the interval of time "t_r" required for the wavefront to reach the PS-1, the portion of the spherical wavefront directed towards SNM had moved to the A.O. positions indicated.

In order to use the PS-1 location at each pit as the apparent origin, a correction was applied to the SR-SNM and MOR-SNM travel times. This correction, "t_r", was equal to the time required to travel the distance between the shot point and the PS-1 at a velocity of 4.5 km./sec. The apparent origin correction was +0.25 seconds for the Santa Rita PS-1 location and +1.15 seconds for the Morenci PS-1 location.

Each time the appropriate corrected apparent travel time is subtracted from the arrival time at the base for SR, TYR, and MOR events, the apparent origin of the shot will correspond to the PS-1 location at the appropriate mine, regardless of the true position of the shot generating the event of interest. This is necessary because blasting takes place over an extensive area within each pit, and it was desirable to have a commom reference point for all blasts from each pit. Figure 3 illustrates the foregoing fact. If S_a and S_b are the positions of two shots, not used to measure the apparent travel time(t_{rb}),

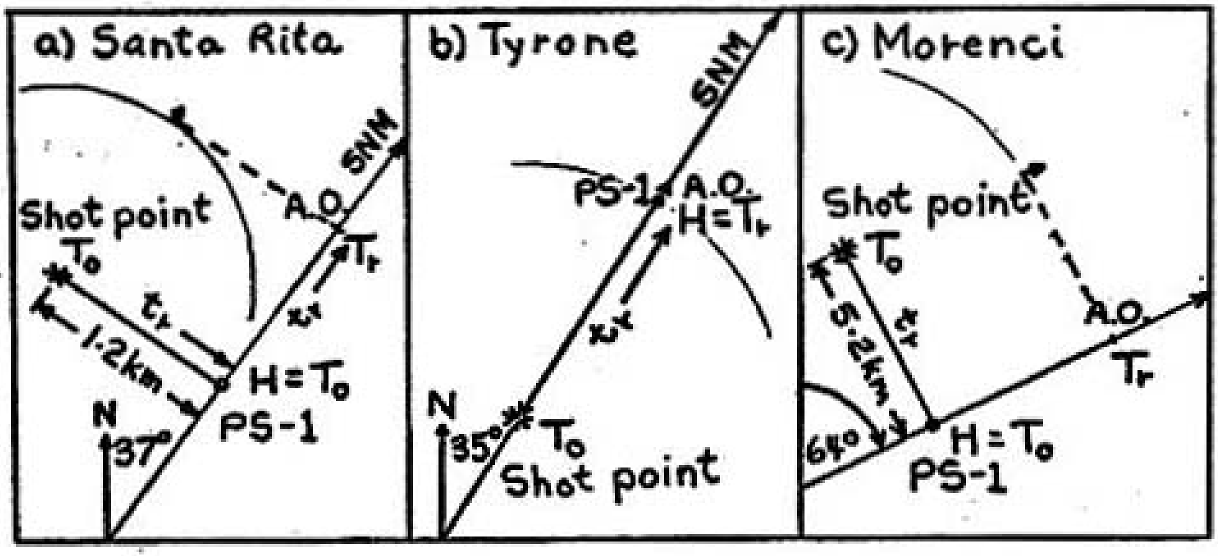


Figure 2. Location of portable recorder, PS-1, with respect to shot point, apparent origin, A.O., and base station, SNM, when travel time from pit to SNM was measured. a) Santa Rita, b) Tyrone, c) Morenci.

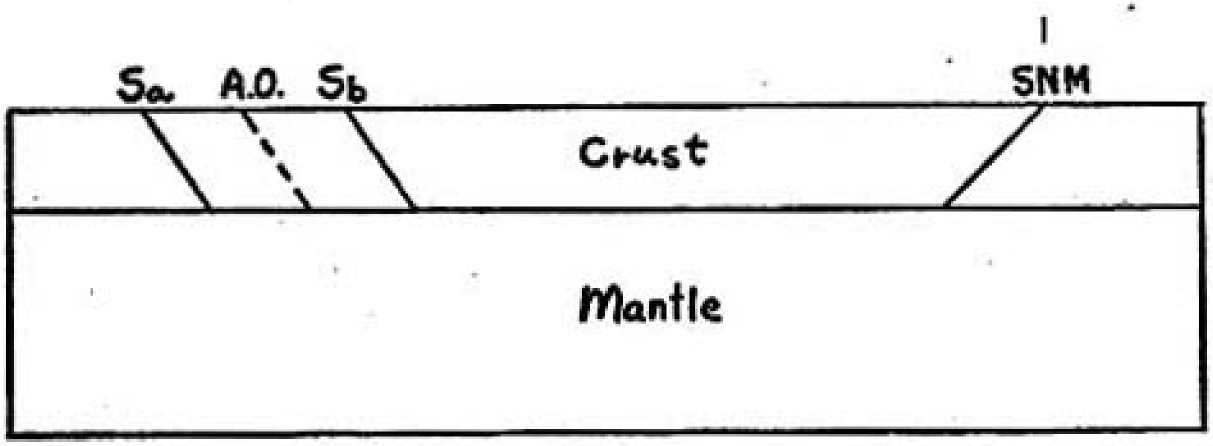


Figure 3. Apparent origin will be the same for all shots in one pit.

and T_a and T_b are the respective arrival times at the base station, then the calculated apparent origin time of each shot, T_{AOa} and T_{AOb}, will be:

$$T_{AOa} = T_a - t_{rb}$$

$$T_{AOb} = T_b - t_{rb} \quad .$$

Now, for purposes of comparison, let $T_a = T_b$; in other words, let the arrival time at the SNM be the same for S_a and S_b. Then the apparent origin times of each event must be equal even though the shots occurred at two different locations. This shows that the apparent origin time for a particular event is independent of the position of the shot. This is reasonable when the dimensions of the pits are much smaller than the total length of the wave path, as is the case in this study.

Table I lists the names and locations of all recording stations and the distance of each station from the apparent origin at Santa Rita, Tyrone, and Morenci.

Table I. Recording Sites and Distances to Apparent Origin at Mines.

Recording Stations- Code Designation		Location: Latitude	Location: Longitude	Elevation (Meters)	Distance to Apparent Origin at Mine (Kilometers): Santa Rita	Tyrone	Morenci
Ryan Hill Canyon-	RH	33°54'11.1"	107°7'13.1"	2373	150.6	181.9	225.9
Chavez Canyon-	CHC	33°56'10.2"	107°5'55.8"	2279	154.7	186.0	229.2
M-2 Ranch-	M2R	34°4'30.2"	107°14'23.3"	2260	160.9	190.5	224.6
Buckeye Mine-	BUCK	34°1'7.0"	107°8'5.4"	2209	160.5	191.0	230.2
Six Mile Canyon-	6MC	34°0'18.4"	107°3'23.7"	1982	163.2	194.4	236.0
Rattlesnake Can.-	RSC	33°59'14.9"	106°59'47.6"	1780	164.9	196.5	240.2
*New Mexico Tech-	SNM	34°4'12.6"	106°56'36.7"	1600	175.2	206.6	248.5
Chupadera Mines-	MDC	34°6'33.5"	106°48'22.4"	1616	186.4	218.2	261.8
Flourite Pits-	FP	34°5'3.1"	106°48'20.8"	1629	184.3	216.2	260.7
East-	EAST	34°9'33.5"	106°39'37.5"	2272	199.3	231.5	276.4
		Apparent	Origin				
Santa Rita-	SR	32°47'48.1"	108°3'30.1"	2100	-	34.0	123.0
Tyrone-	TYR	32°38'42.0"	108°22'22.5"	1925	34.0	-	101.3
Morenci-	MOR	33°3'47.5"	109°20'4.8"	1350	123.0	101.3	-

* Base recording station, New Mexico Tech Seismological Station.

INSTRUMENTATION

The portable seismograph used in the project was a Kinemetrics PS-1 unit with smoked paper recording. A time resolution of 10 mm./sec. was achieved by using the fastest recording speed available. Since the approximate time of the explosions was known, the 3½ hour record length was sufficient to insure that no events were missed due to the necessity of changing recording drums. Filtering was used to enhance the response of the system in the 5-15 c.p.s. range. The PS-1 has a maximum overall amplification of 500,000. Attenuation of 12-30 db. was applied depending on noise conditions. For the most part, the quality of the records obtained was excellent.

The recording unit at the base station, SNM, is located in a tunnel in Socorro Mtn. It has a normal operating magnification of 10 million in the frequency band of interest. The timing resolution on these records was 4 mm./sec.

Short(1 sec.) period seismometers were used with both recording systems. Both seismographs were synchronized with W.W.V. standard time code.

Note: Direction of first motions is:
↑ Up ↓ Down
See Tera explosions 14 Nov 1972
9 Nov 1972
24 Oct. 1972
leads to seismometer reversed sometime from April 1973 to Oct. 1973.

FIRST MOTION ANALYSIS

On both seismographs, compressional arrivals were recorded with "up" first motions. Although the source mechanism for all explosions was compressional, downward first motions were recorded, on the whole, as frequently as upward on both units. Examination of the base station records yields the following first motion data for each pit:

SR	2 up	5 down
TYR	2 up	8 down
MOR	7 up	1 down .

This does not jibe with data given on sheet in back of this report.

The predominance of downward first motions for the SR and TYR events indicates that a phase reversal has taken place along the wave path from the Santa Rita- Tyrone region to Socorro. Referring again to Figure 1, one can see that the travel paths are significantly different for events with normal(up) and reversed(down) first motions.

A compressional to dilatational reversal might be caused by a low viscosity material. The Basin and Range Province in which Santa Rita and Tyrone are located is an area of high heat flow, while the Colorado Plateau is currently believed to have normal to low heat flow. Since increased temperatures can decrease viscocity, a possible explanation of the reversed first motions for SR and TYR events is that they travel in an area of high heat flow.

TIMING FIRST ARRIVALS

In those cases where the first motions on the SKM and PS-1 seismograms did not agree, for the same event, the PS-1 record was retimed so that the sense of motion agreed with that of the base station record. By so doing, one can be fairly certain he is picking the same arrival on both seismograms; albeit, not the true first motion.

With a magnifying lens it is not difficult to measure distances on the seismograms accurate to 0.25 mm. On the PS-1 record, this distance corresponds to 0.025 secs., or 25 millisecs. On the base station record, 0.25 mm. equals 62.5 millisecs. Assuming the error in picking the arrivals is zero, the maximum error in measuring the travel time from pit to field station would be 175 millisecs., including the error in determining the origin time of the event. However, the base station unit has a temperature dependent drift in its chronometer. Although this drift can be roughly corrected for, it does introduce additional error. A liberal estimate of the timing error, assuming that picking error is negligible, would be 250 millisecs., or 0.25 secs. For travel times of the order of 25-40 seconds, this amounts to an error of less than 1%.

Check of M. Dee's distances by R. Ward June 16, 1976

STATION	LAT	LONG	ELEV	SANTA RITA		TYRONE		MORENCI	DEE
SR	32.797	108.058	2059	0.0		33.52		122.77	
TYR	32.645	108.373	1921	33.52		0.0		131.17	
MOR	33.063	109.335	1349	122.77		131.17		0.0	
RH	33.933	107.120	2372	150.77	150.6	182.05		225.03	225.9*
CHC	33.936	107.099	2278	154.92		185.13	186.0	221.94	229.2
M2R	34.075	107.240	2259	161.19	160.9	193.70	192.5	224.37	
BUCK	34.019	107.135	2208	160.67	160.5	191.23	191.0	229.92	230.2
GRC	34.005	107.057	1981	163.43	163.2	194.52	194.4	235.72	236.0
RSC	33.937	106.997	1779	165.09	164.9	196.59	196.5	239.69	240.2
SAM	34.070	106.944	1599	175.39	175.2	206.75	206.6	245.26	248.5
MDC	34.109	106.806	1615	186.56	186.4	218.37	218.3	261.54	
FP	34.084	106.806	1628	184.42		216.34		260.37	260.7
EAST	34.159	106.660	2271	199.44	199.3	231.34	231.5	276.04	

Table II. Travel Times from Apparent Origin at Mine to Recording Station with Corrections.

Recording Station	Event	Distance (Km.)	Travel Time (Seconds)	Net Elev. above SMM	Elev.Corr. (Secs.)	Corr.Time (Secs.)	Origin Corr.	Corr. Time (Secs.)
RH	SR	150.6	25.27	1273	-0.19	25.08	+0.25	25.33
BUCK	SR	160.5	26.94	1109	-0.16	26.78	+0.25	27.03
M2R	SR	160.9	26.34	1160	-0.17	26.17	+0.25	26.42
6MO	SR	163.2	27.41	882	-0.13	27.28	+0.25	27.53
RSC	SR	164.9	27.52	680	-0.10	27.42	+0.25	27.67
SNM	SR	175.2	28.96	500	-0.07	28.89	+0.25	29.14
CHC	TYR	186.0	30.26	1004	-0.15	30.11	-	30.11
MDC	SR	186.4	30.06	516	-0.07	29.99	+0.25	30.24
M2R	TYR	190.5	31.10	985	-0.14	30.96	-	30.96
BUCK	TYR	191.0	30.86	934	-0.14	30.72	-	30.72
6MO	TYR	194.4	31.22	707	-0.10	31.12	-	31.12
RSC	TYR	196.5	31.60 31.35 31.51	505	-0.07	31.53 31.28 31.44	-	31.53 31.28 31.44
BAST	SR	199.3	31.64	1172	-0.17	31.47	+0.25	31.72
SNM	TYR	206.6	32.79	325	-0.05	32.74	-	32.74
FP	TYR	216.2	33.81	354	-0.05	33.76	-	33.76
MDC	TYR	218.2	34.19	341	-0.05	34.14	-	34.14

Table II continued.

Recording Station	Event	Distance (Km.)	Travel Time (Seconds)	Net Elev. (Meters)	Elev.Corr. (Seconds)	Corr.Time (Secs.)	Origin Cor.(Secs)	Cor.Time (Secs.)
RH	MOR	225.9	33.94	523	-0.08	33.86	+1.15	35.01
CHC	MOR	229.2	34.54	429	-0.06	34.48	+1.15	35.63
BUCK	MOR	230.2	34.35	359	-0.05	34.30	+1.15	35.45
EAST	TYR	231.5	35.36	997	-0.15	35.21	-	35.21
6MO	MOR	236.0	35.14 35.18	132	-0.02	35.12 35.16	+1.15	36.27 36.31
RSC	MOR	240.2	35.67 35.75	-70	+0.01	35.68 35.76	+1.15	36.83 36.91
SMM	MOR	248.5	36.74	-250	+0.04	36.78	+1.15	37.93
FP	MOR	260.7	38.18	-220	+0.03	38.21	+1.15	39.36

PRESENTATION OF DATA

In Table II are listed the uncorrected and corrected travel times for 28 explosions that were recorded at 9 field stations and the base station. The data is listed in order of increasing station-to-apparent origin distance.

The elevation of the base station, SNM, was chosen as datum level for making corrections for both field station and apparent origin elevations. Elevation above SNM was taken as positive. The net elevation is the sum of the elevation differences of both the field station and apparent origin with respect to the datum. All elevations are given in meters.

The net elevation correction, "t_{ec}", was calculated using the delay time method:

$$t_{ec} = Z_{net}\cos(i_c)/V_o$$

$$i_c = \sin^{-1}(V_o/V_c)$$

where Z_{net} is the net elevation(positive or negative) with respect to the datum and i_c is the critical angle of incidence at the V_o-V_c interface. The near surface velocity V_o was measured in the vicinity of Socorro from a series of large surface explosions detonated by the Navy and found to be 4.5 km./sec. This value also agrees with sonic well log data as a representative value for most post-Precambrian units. The crustal P-wave velocity V_c determined from this study was 6.2 km./sec. From the expression for the delay time correction, it can be seen that the correction is rather insensitive to changes in V_c. At any rate, the correction is small in comparison to the overall travel time as was the timing error previously mentioned.

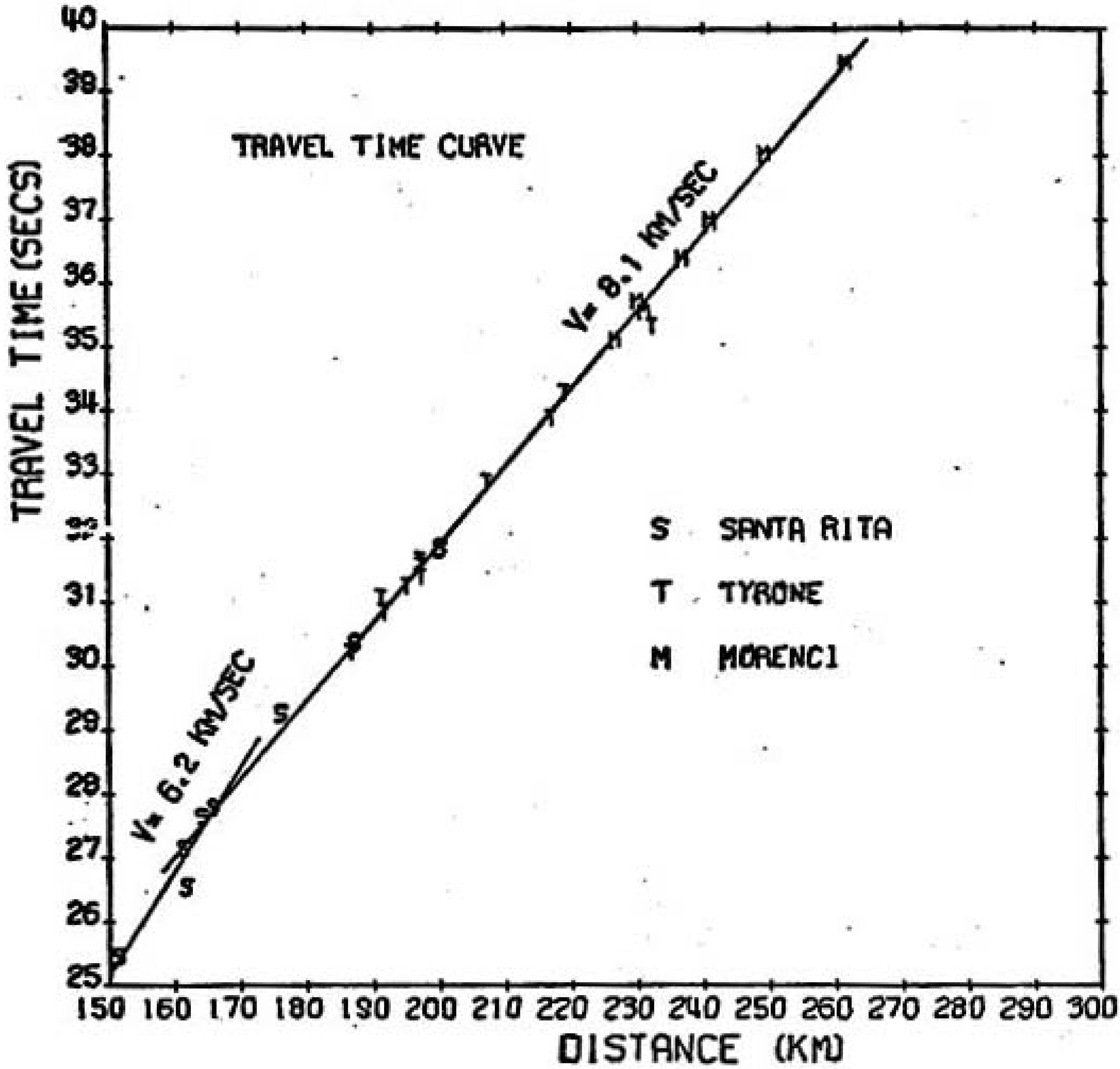
It was necessary to correct the Santa Rita and Morenci apparent origin locations to the PS-1 position at the mine, as was discussed previously.

The travel time data from Table II is displayed graphically in Figure 4. It should be noted that this travel time curve represents first arrivals on only a portion of the total wave path. The origin of the coordinate axis is 150 km. and 25 secs.

The velocities of 6.2 km./sec. for P_g arrivals and 8.1 km./sec. for P_n were obtained by making a first degree least squares polynomial fit to the travel times. If the early S event at about 161 km. is ignored in the velocity determination, the direct wave velocity is lowered to about 6.0 km./sec. A listing of the Fortran IV program used to make the polynomial fit is provided in the Appendix.

Geographic coordinates of recording stations were obtained from 7½' and 15' topographic maps. The plane triangulation method, described by Richter, was used to calculate distances between points. Distances are believed to be accurate to ¼ km. A listing of the distance program is also given in the Appendix.

Figure 4. Travel time curve for first arrivals.



INTERPRETATION

It is important to mention that the travel time curve indicates uniform crustal thickness between the Morenci mine in SE Arizona and the Santa Rita and Tyrone mines in SW New Mexico. This is true because head waves from the Mohorovicic discontinuity from all three pits fall on the same line. It was estimated that an increase in crustal thickness of 10 km. between Morenci and the New Mexico mines would be indicated by an early offset of MOR travel times with respect to SR and TYR, at the same station-apparent origin seperation, of approximately 1 second.

Using the zero intercept times determined by the straight line fit to the travel time data and standard interpretation techniques, the following crustal model was determined for the region interior to the pits.

Datum
2.3 km. 4.5 km/sec

6.2 km/sec

35.8 km. Moho

8.1 km/sec

Figure 5. Crustal model based on intercept times of 0.7 secs. for 6.2 km/sec layer and 7.5 secs. for mantle. Numbers indicate depth below SNM.

DISCUSSION

The interpretation presented in Figure 5 is based on the simplifying assumptions that each layer is horizontal, continuous, and homogeneous. With respect to sea level, the depth to the Mohorovicic discontinuity under the above mentioned assumptions would be 34.2 km. Since nearly all of the 4.5 km/sec layer lies above sea level, this interpretation is essentially a two layer model.

It is believed that this type of seismic profile using a combination of several sources and a distribution of recording stations near the critical distance can provide usefull data on seismic wave velocities and crustal thickness. It is an inexpensive method of doing crustal studies on a regional basis. provided there are large open pit mines or other large energy sources in the region.

The method can be used to detect changes in crustal thickness between sources and beneath the recording station array by studying the time residuals of head waves with respect to the travel time curve.

APPENDIX

Computer Programs

a) Distance calculation using Richter's method

b) Least squares polynomial fit using Gauss-Jordan Elimination method

```
C     THIS PROGRAM COMPUTES DISTANCE BETWEEN TWO POINTS GIVEN THEIR LATITUDE
C     AND LONGITUDE. THE METHOD EMPLOYED IS THAT DESCRIBED BY RICHTER
C     FOR ACHIEVING ACCURACY OF A TENTH OF A KILOMETER FOR DISTANCES LESS THAN
C     500 KILOMETERS.  VALUES OF COEFFICIENTS USED IN THE CALCULATION ARE
C     INTERPOLATED BETWEEN VALUES GIVEN BY RICHTER FOR AVERAGE LATITUDES OF
C     THIRTY-TWO(32)DEGREES TO THIRTY-SIX(36)DEGREES.
C
C
C     REPEAT       PROGRAM ONLY WORKS IF THE AVERAGE LATITUDE OF THE TWO
C                  GIVEN POINTS IS BETWEEN 32DEG  AND36DEG.
  100 FORMAT(6F8.2,1X,3A4)
    1 FORMAT(5X,'COEFFICIENTS NOT DEFINED FOR AVERAGE LATITUDE')
    3 FORMAT(1X,////,1X,'STATION          LATITUDE              LONGITUDE
     5          STATION          LATITUDE              LONGITUDE
     6    DISTANCE')
    2 FORMAT(1X,3A4,F4.1,2X,F4.1,2X,F5.2,3X,F5.1,2X,F4.1,2X,F5.2,3X,3A4,
     6F4.1,2X,F4.1,2X,F5.2,3X,F5.1,2X,F4.1,2X,F5.2,3X,F8.4)
      DIMENSION C(5,2)
      DIMENSION NAME(6)
      C(1,1)=1.848073
      C(1,2)=1.857132
      C(2,1)=1.848372
      C(2,2)=1.857231
      C(3,1)=1.84867
      C(3,2)=1.857331
      C(4,1)=1.848980
      C(4,2)=1.857435
      C(5,1)=1.849290
      C(5,2)=1.857588
      PRINT 3
 9999 READ 100,AALT,BLT,CLT,ALN,BLN,CLN,(NAME(I),I=1,3)
      READ 100,DLT,ELT,FLT,DLN,ELN,FLN,(NAME(I),I=4,6)
      IF(AALT)5,9,9
    9 ABCLT=AALT*60.0 +BLT +CLT/60.0
      ABCLN=ALN*60.0 +BLN +CLN/60.0
      DEFLT=DLT*60.0 +ELT +FLT/60.0
      DEFLN=DLN*60.0 +ELN +FLN/60.0
      ALT=(ABCLT+DEFLT)/2.0
      IF(ALT.GE.1920.0)GOTO32
      GOTO20
   32 N=1
      IF(ALT.GE.1980.0)GOTO33
      GOTO10
   33 N=2
      IF(ALT.GE.2040.0)GOTO34
      GOTO10
   34 N=3
      IF(ALT.GE.2100.0)GOTO35
      GOTO10
   35 N=4
      IF(ALT.GE.2160.0)GOTO20
   20 PRINT 1
      GOTO9999
   10 B1=C(N,1)
      B2=C(N+1,1)
      AI1=C(N,2)
      AI2=C(N+1,2)
      X=ALT-(31+N)*60.0
      B=B1+(B2-B1)*X/60.0
      AI=AI1+(AI2-AI1)*X/60.0
      ALT=ALT/60.0
      AVLAT=ALT*3.14159/180.0
      A=AI*COS(AVLAT)
      DELLAT=ABCLT-DEFLT
      DELLNG=ABCLN-DEFLN
      IF(DELLAT.GE.0.0)GOTO45
      DELLAT=-DELLAT
   45 IF(DELLNG.GE.0.0)GOTO46
      DELLNG=-DELLNG
   46 DIST=((A*DELLNG)**2.0 +(B*DELLAT)**2.0)**0.5
      PRINT 2,(NAME(I),I=1,3),AALT,BLT,CLT,ALN,BLN,CLN,(NAME(I),I=4,6),D
     6LT,ELT,FLT,DLN,ELN,FLN,DIST
      GOTO9999
    5 STOP
```

b.

FORTRAN IV   MODEL 44 PS   VERSION 3, LEVEL 3   DATE 73135   8:45:25

```
      DIMENSION X(30),Y(30)
      DIMENSION XFIT(30),TFIT(30)
      DIMENSION A(6,6),B(6),D(6),P(10)
      DIMENSION NSYMBL(30)
      INTEGER D
      CALL FACTOR(0.4)
      CALL PLOT(4.,2.,-3)
      DO 50 K=1,15
      CALL PLOT(1.,0.,-2)
      CALL PLOT(0.,0.1,2)
      CALL PLOT(0.,-0.1,2)
      CALL PLOT(0.,0.,3)
   50 CONTINUE
      DO 51 K=1,15
      CALL PLOT(0.,1.,-2)
      CALL PLOT(0.1,0.,2)
      CALL PLOT(-0.1,0.,2)
      CALL PLOT(0.,0.,3)
   51 CONTINUE
      DO 52 K=1,15
      CALL PLOT(-1.,0.,-2)
      CALL PLOT(0.,0.1,2)
      CALL PLOT(0.,-0.1,2)
      CALL PLOT(0.,0.,3)
   52 CONTINUE
      DO 53 K=1,15
      CALL PLOT(0.,-1.,-2)
      CALL PLOT(0.1,0.,2)
      CALL PLOT(-0.1,0.,2)
      CALL PLOT(0.,0.,3)
   53 CONTINUE
      CALL PLOT(0.,0.,-3)
      DO 54 I=1,16
      C=I-1
      XAXIS=150. + 10.*C
      CALL NUMBER(C-0.5,-0.5,0.3,XAXIS,0.,-1)
   54 CONTINUE
      CALL PLOT(0.,0.,3)
      DO 55 J=1,16
      T=J-1
      TAXIS=25.+T
      CALL NUMBER(-0.6,T,0.3,TAXIS,0.,-1)
   55 CONTINUE
      CALL PLOT(0.,0.,3)
      CALL SYMBOL(6.5,-1.2,0.4,' DISTANCE (KM) ',0.,15)
      CALL SYMBOL(-1.,7.,0.4,' TRAVEL TIME(SECS) ',90.,19)
      CALL SYMBOL(2.,13.,0.3,'TRAVEL TIME CURVE ',0.,18)
      CALL SYMBOL(8.,7.,0.3,' S   SANTA RITA ',0.,16)
      CALL SYMBOL(8.,6.,0.3,' T   TYRONE ',0.,12)
      CALL SYMBOL(8.,5.,0.3,' M   MORENCI ',0.,13)
      CALL SYMBOL(.5,2.,0.3,' V= 6.2 KM/SEC ',61.,15)
      CALL SYMBOL(7.,10.,0.3,' V= 8.1 KM/SEC ',51.,15)
      CALL PLOT(0.,0.,3)
    9 READ 11,NRUN
   11 FORMAT(I2)
      DO 21 D=1,NRUN
      READ 11,NPTS
      DO 19 I=1,NPTS
```

b. cont.

```
FORTRAN IV     MODEL 44   PS        VERSION 3,  LEVEL 3    DATE  73135      9:45:25

          READ 12,X(I),Y(I),NSYMBL(I)
       19 PRINT 13,X(I),Y(I)
       12 FORMAT(2F10.0,4X,I2)
       13 FORMAT('0',5X,2(F10.4,5X))
          M=1
     1009 MX2=M*2
     1010 DO 1014 I=1,MX2
     1011 P(I)=0.0
     1013 DO 1014 K=1,NPTS
     1014 P(I)=P(I) + X(K)**I
     1015 MP1 =M+1
     1016 DO 1023 I=1,MP1
     1017 DO 1023 J=1,MP1
     1018 KK=I+J-2
     1019 IF(KK)1022,1022,1020
     1020 A(I,J)=P(KK)
     1021 GOTO 1023
     1022 A(1,1)=NPTS
     1023 CONTINUE
     1024 B(1)=0.0
     1026 DO 1027 K=1,NPTS
     1027 B(1)=B(1) + Y(K)
     1028 DO 1032 I=2,MP1
     1029 B(I)=0.0
     1031 DO 1032 K=1,NPTS
     1032 B(I)=B(I) + Y(K)*(X(K)**(I-1))
C          VALUES OF  A & B MATRICES HAVE NOW BEEN CALCULATED AND STOR
     1034 DO 1054 K=1,M
     1035 KP1=K+1
     1036 L=K
     1037 DO 1040 I=KP1,MP1
     1038 IF(ABS(A(I,K))-ABS(A(L,K)))1040,1040,1039
     1039 L=I
     1040 CONTINUE
     1041 IF(L-K)1049,1049,1042
     1042 DO 1045 J=K,MP1
     1043 S=A(K,J)
     1044 A(K,J)=A(L,J)
     1045 A(L,J)=S
     1046 S=B(K)
     1047 B(K)=B(L)
     1048 B(L)=S
     1049 DO 1054 I=KP1,MP1
     1050 DFACT=A(I,K)/A(K,K)
     1051 A(I,K)=0.0
     1052 DO 1053 J=KP1,MP1
     1053 A(I,J)=A(I,J)-DFACT*A(K,J)
     1054 B(I)=B(I)-DFACT*B(K)
     1055 D(MP1)=B(MP1)/A(MP1,MP1)
     1056 I=M
     1057 IP1=I+1
     1058 SUM=0.0
     1059 DO 1060 J=IP1,MP1
     1060 SUM=SUM+A(I,J)*D(J)
     1061 D(I)=(B(I)-SUM)/A(I,I)
     1062 I=I-1
     1063 IF(I)1064,1064,1057
     1064 DO 1065 I=1,MP1
```

b. cont.

FORTRAN IV   MODEL 44 PS   VERSION 3, LEVEL 3   DATE 73135   8:45:25

```
 1065 PRINT 1066,I,D(I)
 1066 FORMAT(//,I5,F15.10)
   33 DO 4398 I=1,NPTS
      XP=X(I)/10.-15.
      YP=Y(I)-25.
      NSYM=NSYMBL(I)
      CALL SYMBOL(XP,YP,0.25,NSYM,0.0,-1)
 4398 CONTINUE
      CALL PLOT(0.0,0.0,999)
      IF(0.EQ.NRUN)GOTO 801
      PT1=D(1)+D(2)*150.-25.
      PT2=D(1)+D(2)*170.-25.
      CALL PLOT(0.,PT1,3)
      CALL PLOT(2.,PT2,2)
      CALL PLOT(0.,0.,3)
      GOTO 21
  801 CONTINUE
      PT3=D(1)+D(2)*160.-25.
      PT4=D(1)+D(2)*265.-25.
      CALL PLOT(1.,PT3,3)
      CALL PLOT(11.5,PT4,2)
      CALL PLOT(0.0,0.0,999)
   21 CONTINUE
      CALL PLOT(0.0,0.0,999)
  724 READ(5,12,END=687)DX,DY,NSYM
      DX=DX/10.-15.
      DY=DY-25.
      CALL SYMBOL(DX,DY,0.25,NSYM,0.0,-1)
      GOTO 724
  687 CALL PLOT(20.0,0.0,-3)
      STOP
      END
```

SCALAR MAP

SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL
K	000174	I	000178	C	00017C	XAXIS
T	000188	TAXIS	00018C	NRUN	000190	D
M	00019C	MX2	0001A0	MP1	0001A4	KK
L	0001B0	S	0001B4	DFACT	0001B8	IP1
XP	0001C4	YP	0001C8	NSYM	0001CC	PT1
PT3	0001D8	PT4	0001DC	DX	0001E0	DY

ARRAY MAP

SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL
X	000158	Y	000260	XFIT	0002D8	TFIT
B	000458	D	000470	P	000488	NSYMBL

SUBPROGRAMS CALLED

SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL
FACTOR	000528	PLOT	00052C	NUMBER	000530	SYMBOL
FRXPI#	00053C					

LABEL MAP

LABEL	LOCATION	LABEL	LOCATION	LABEL	LOCATION	LABEL
50	0008CE	51	000914	52	00095A	53
55	000A78	9	000AEE	11	000810	19