A STUDY ON POISSON'S RATIO & V_p/V_s RATIO IN THE RIO GRANDE RIFT

by

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ABSTRACT

The arrival times of longitudinal waves (P) and transverse waves (S) of strong microearthquakes were used to study the values of Poisson's ratio and V_p/V_s ratio in the Rio Grande Rift between Albuquerque and Socorro, New Mexico. The Poisson's ratio and the V_p/V_s ratio were found to be 0.217 and 1.664, respectively. These two comparatively low values are probably the normal values for the Rio Grande Rift.

ACKNOWLEDGMENTS

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INTRODUCTION

The Rio Grande Rift is a structure that consists of en echelon structural depressions having raised margins extending from northern Mexico to central Colorado. It is up to 150 km wide at the southern end (Fig. 1), and has up to 2.5 km of topographic relief, and up to 10.5 km of structural relief (Toppozada, 1974).

A study of the ratio of P wave velocity to S wave velocity and Poisson's ratio was conducted in the Rio Grande Rift area between Albuquerque and Socorro (Fig. 1). Seismic records of ALQ (Albuquerque) and SNM (Socorro) stations for the time period January 1, 1969 through June 30, 1973, were used for this study.

ALQ station is 106.44 km NNE of SNM station. Both stations are located in the Rio Grande Rift (Fig. 1). Thirty-two well recorded microearthquakes were selected from thousands of seismograms. All of these earthquakes had epicenters within 45 km radius from SNM station.

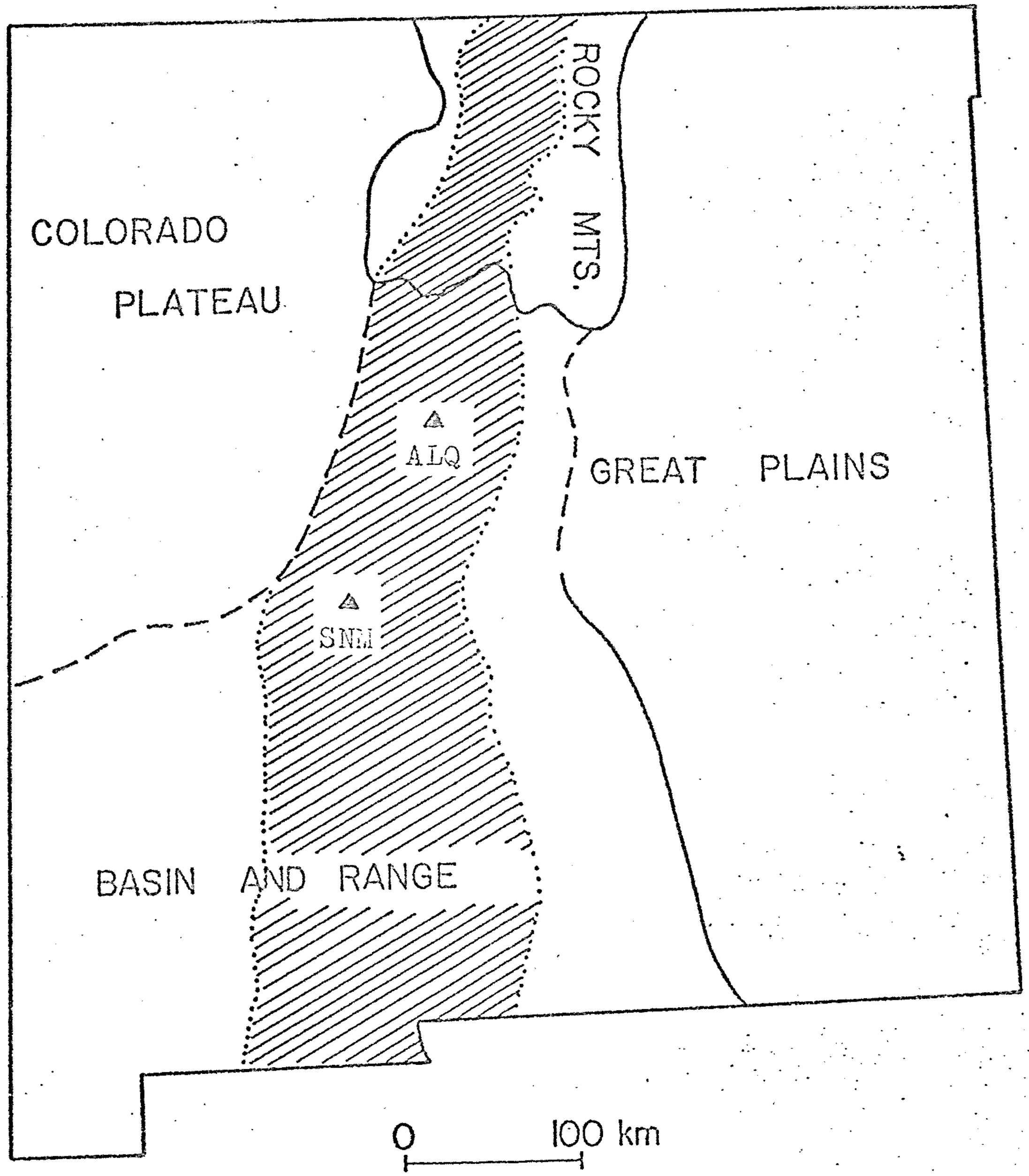

Fig. 1. Physiographic provinces in New Mexico. The Rio Grande Rift is shaded (after Toppozada, 1974).

SOURCES OF DATA

All data used in this study came from the seismographs of ALQ and SNM stations, which having the following characteristics (Sanford et al., 1973):

Station	System	Type of Recording	Components Recorded Z	NS	EW	Normal Magnification at 10 Hz
SNM	NMT	Pen and ink helical, at 4 mm/sec	x			1.3×10^6
SNM	LRSM	Film (Benioff) and magnetic tape	x	x	x	6.0×10^4
ALQ	WWSSN	Photographic paper helical, at 1 mm/sec	x	x	x	2.0×10^4

METHOD, CALCULATION, AND RESULTS

Hundreds of comparatively strong microearthquakes were selected from SNM records. The date and time of each of these events were then used to check the ALQ records. Only 32 events that had clearly defined P and S phases at both stations were selected for the study.

P arrival times and (S-P) time intervals of each microearthquake were read from the SNM and ALQ records. The average value of Poisson's ratio (v) of the rocks between ALQ and SNM stations was determined from the equation of origin time in the following way:

Let P_{ALQ} = P arrival time at ALQ station

P_{SNM} = P arrival time at SNM station

$(S-P)_{ALQ}$ = (S-P) time interval at ALQ station

$(S-P)_{SNM}$ = (S-P) time interval at SNM station

Origin time = Origin time of the quake

X = a function of Poisson's ratio.

X(S-P) = transit time

$$\text{Origin time} = P_{ALQ} - X(S-P)_{ALQ}. \qquad (1)$$

$$\text{Origin time} = P_{SNM} - X(S-P)_{SNM}. \qquad (2)$$

Each microearthquake must have only one origin time, therefore,

$$P_{ALQ} - X(S-P)_{ALQ} = P_{SNM} - X(S-P)_{SNM} ,$$

which yields

$$X = \frac{P_{ALQ} - P_{SNM}}{(S-P)_{ALQ} - (S-P)_{SNM}} .$$

Thus, by picking the P and S arrival times on the ALQ and SNM records, the X value can be obtained from each microearthquake event.

Let V_p = P wave velocity
V_s = S wave velocity
E = Young's modulus
p = density of the rock
v = Poisson's ratio
D = hypocentral distance
O = origin time

$$\text{The transit time of P wave} = P - O = \frac{D}{V_p} . \tag{3}$$

$$\text{The transit time of S wave} = S - O = \frac{D}{V_s} . \tag{4}$$

The wave velocities in terms of the elastic constants and density are

$$V_p = \sqrt{\frac{E(1-v)}{p(1-2v)(1+v)}} , \tag{5}$$

and

$$V_s = \sqrt{\frac{E}{2p(1+v)}} \; . \qquad (6)$$

Dividing equation (6) by equation (5) gives

$$V_s = V_p \Big/ \sqrt{\frac{2(1-v)}{(1-2v)}} \; . \qquad (7)$$

Substituting this expression for V_s into equation (2) gives

$$S - O = \frac{D}{V_p} \sqrt{\frac{2(1-v)}{(1-2v)}} \; . \qquad (8)$$

Subtracting equation (3) from (8) yields

$$S - P = (P-O)\left(\sqrt{\frac{2(1-v)}{(1-2v)}} - 1\right) . \qquad (9)$$

Comparing equations (9) and (1), we get

$$X = 1 \Big/ \left(\sqrt{\frac{2(1-v)}{(1-2v)}} - 1\right) ,$$

or

$$v = \frac{\frac{1}{2} - \frac{X^2}{2} + X}{1 + 2X} \; .$$

From equation (7) we get

$$V_p / V_s = \sqrt{\frac{2(1-v)}{(1-2v)}} .$$

The 32 microearthquakes used in this study yield the following results (details available in the Table 1.):

$$\text{Poisson's ratio } v = 0.2169 \pm 0.0121$$

$$V_p/V_s \text{ ratio} = 1.664 \pm 0.022$$

Standard deviations

The P wave velocity in the Rio Grande Rift is 5.8 km per second (Toppozada, 1974). Therefore, the S wave velocity in this region should be 3.49 km per second.

ERRORS

The P phase can be easily picked (Fig. 2), but the onset of the S phase can be rather difficult to identify because of interference with preceding P phases. All types of available records and components of each event were used to define the S phase. A gross misidentification of the S phase can be easily identified because it yields a physically unreasonable value for the Poisson's ratio.

If the clocks on the recording systems are accurate, the only error involved is reading error. Time measurements on the records were to the nearest 0.1 mm or less, which leads to the following reading errors:

ALQ records	P	$\leq$ 0.1	second
	S-P	$\leq$ 0.05	second
SNM records	P	$\leq$ 0.05	second
	S-P	$\leq$ 0.05	second

which yields a possible error ≤ 0.0233 for the V_p/V_s ratio.

The formula

$$X = \frac{P_{ALQ} - P_{SNM}}{(S-P)_{ALQ} - (S-P)_{SNM}}$$

used in the calculation will not work if the microearthquake is located at a point such that P_{ALQ} equals P_{SNM}.

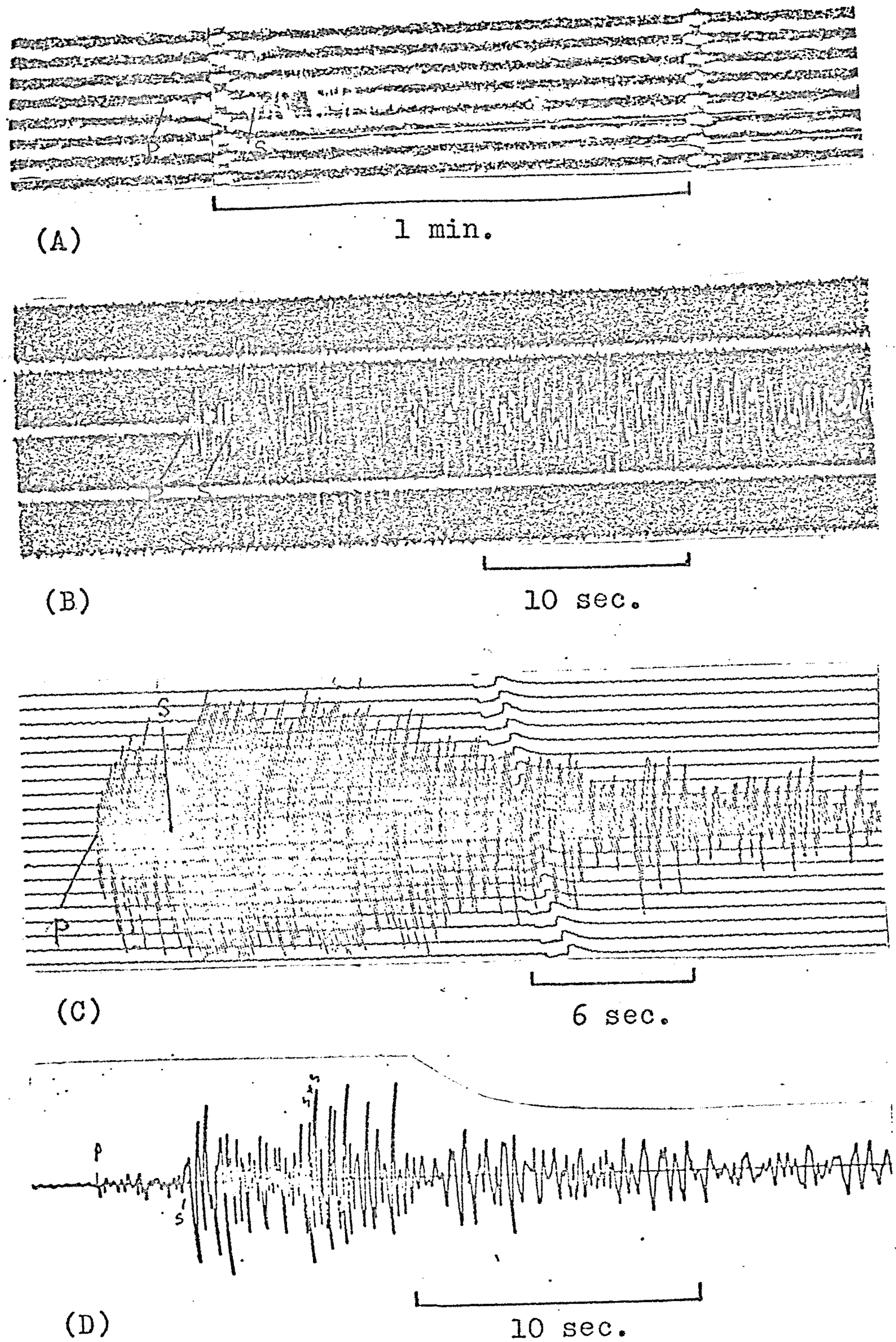

Fig. 2. Samples of seismic records:
(A) ALQ's WWSSN photographic paper record ;
(B) SNM's LRSM film;
(C) SNM's NMT pen and ink helical record;
(D) SNM's LRSM magnetic tape.

Fortunately, the smallest value of $P_{ALQ} - P_{SNM}$ of the earthquakes used in this study is 3.63 seconds, which is quite far from the neighbourhood of zero. The above formula can, therefore, be used confidently.

DISCUSSION

The comparatively low values of Poisson's ratio and V_p/V_s ratio may be interpreted as the following points of view:

1) The January 1, 1969 to June 30, 1973 time interval lies within a precursory period of a major earthquake during which V_p/V_s is depressed (Semenov, 1969; Rikitake, 1968; Whitcomb et al., 1973; Scholz et al., 1973). The values of V_p/V_s as a function of time are shown in Figure 3. The times of local earthquakes of magnitudes 3 or greater in the same period are also shown in the same figure. The figure indicates a depressed V_p/V_s ratio for greater than 4.5 year. This indicates the coming major earthquake must have a magnitude 6.5 or larger. According to Scholz et al. (1973) and Whitcomb et al. (1973). A quake of this magnitude is possible inasmuch as 1906 earthquakes near Socorro had magnitudes of 6 or greater (Sanford, 1965; Reid, 1911; Richter, 1958). However, the depressed value of V_p/V_s is only about 5 % lower than the normal value,

if the normal value of V_p/V_s is 1.732 (Richter, 1958), or 1.75 - 1.77 (Aggarwal et al., 1973; Whitcomb et al., 1973; Scholz et al., 1973). It is far from reported values which are 10 - 20 % lower than the normal value. However, the smaller depressed value of V_p/V_s could be explained by the fact that not all of the region covered in undergoing dilatancy.

Another argument is that period of depressed V_p/V_s values prior to an earthquake have only been observed for earthquakes generated by thrust faulting (McEvilly and Johnson, 1973). The earthquakes in the Rio Grande Rift are generated by graben type normal faults. Therefore one might expect they should have other types of characteristics.

In Figure 3, the earthquakes of magnitudes 3.0 - 3.8 are not preceeded by any identifiable reduction in V_p/V_s values. However, the data points may be too scattered in this study to identify such periods prior to small earthquakes.

2) The comparatively low values of Poisson's ratio and V_p/V_s ratio might be the normal values for the rocks between ALQ and SNM stations. For this point of view, the values of Poisson's ratio of the earth's

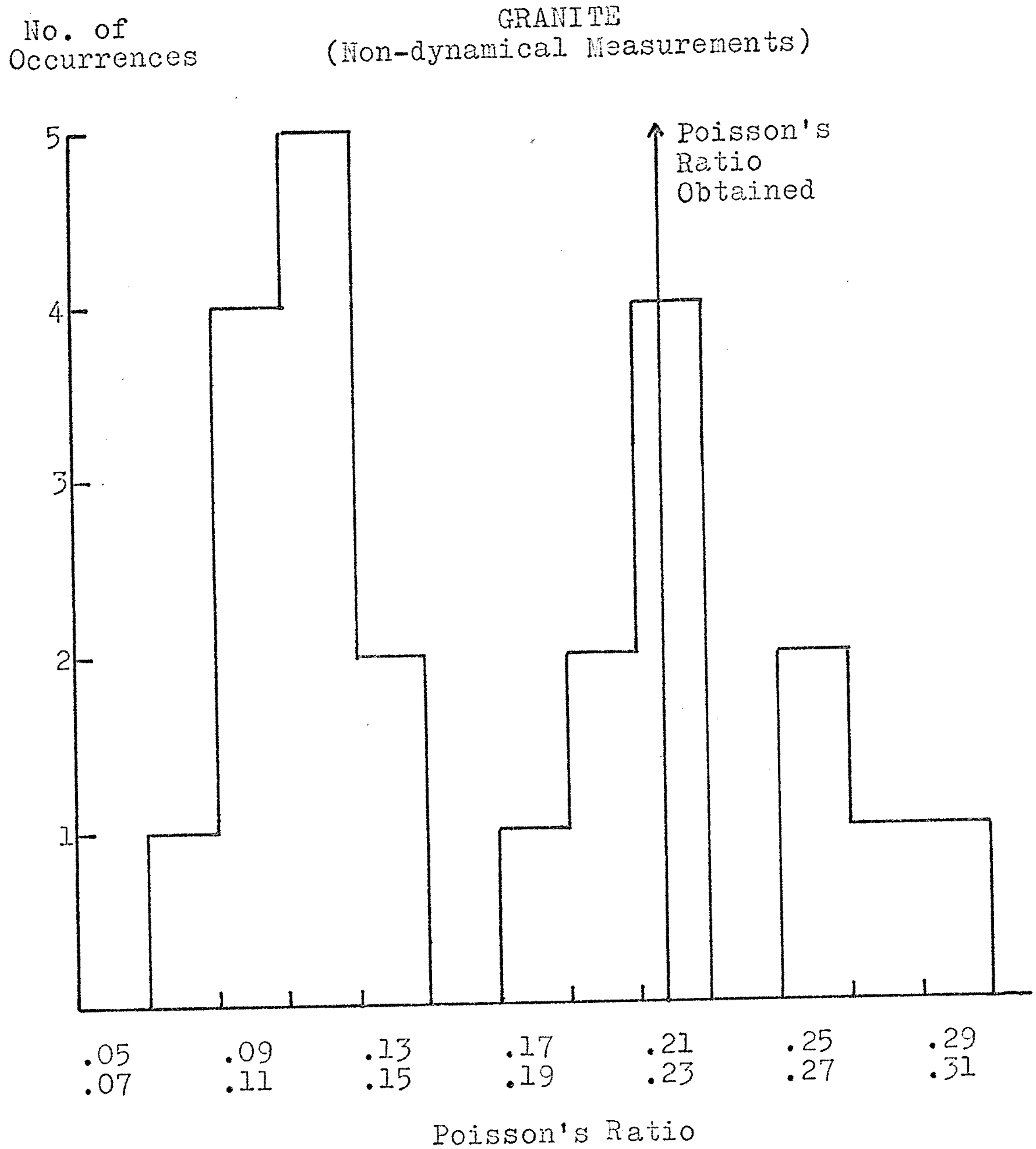

Fig. 4. Histogram of Poisson's ratio of granite (based on the Handbook of Physical Constants, GSA Memoir 97).

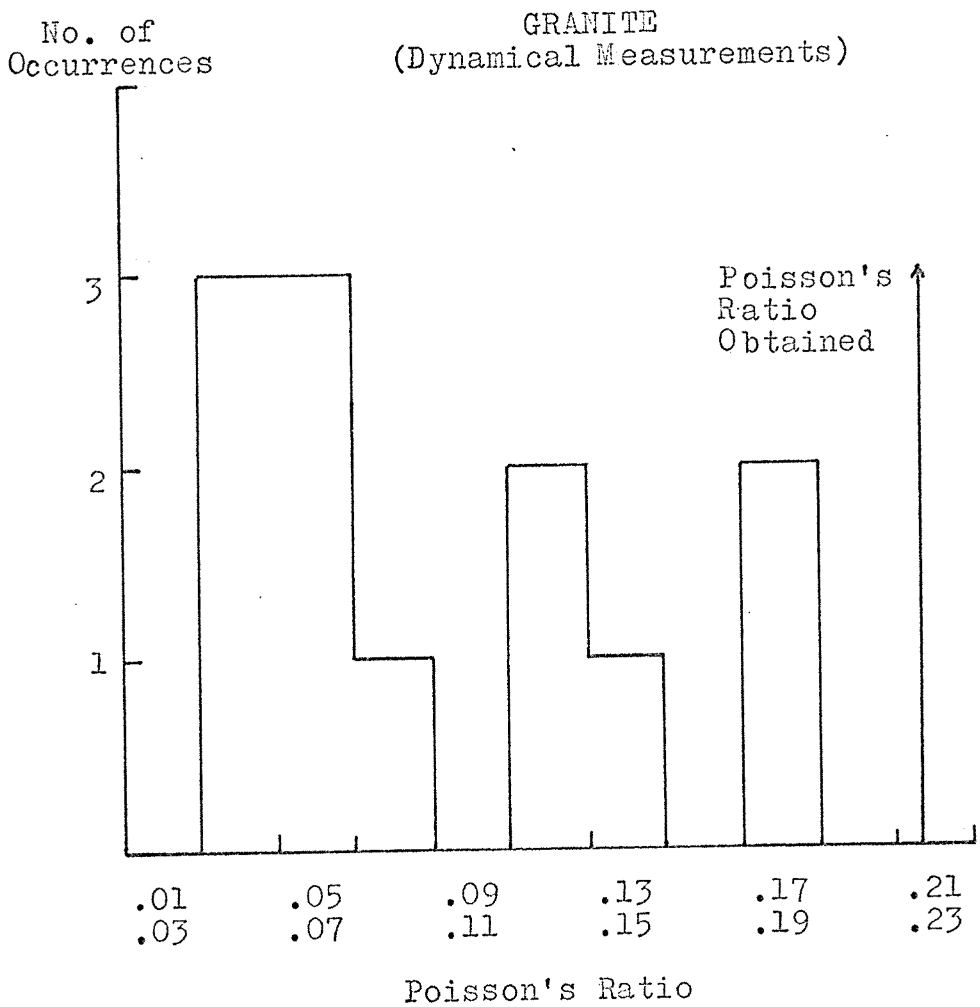

Fig. 5. Histogram of Poisson's ratio of granite (based on the Handbook of Physical Constants, GSA Memoir 97).

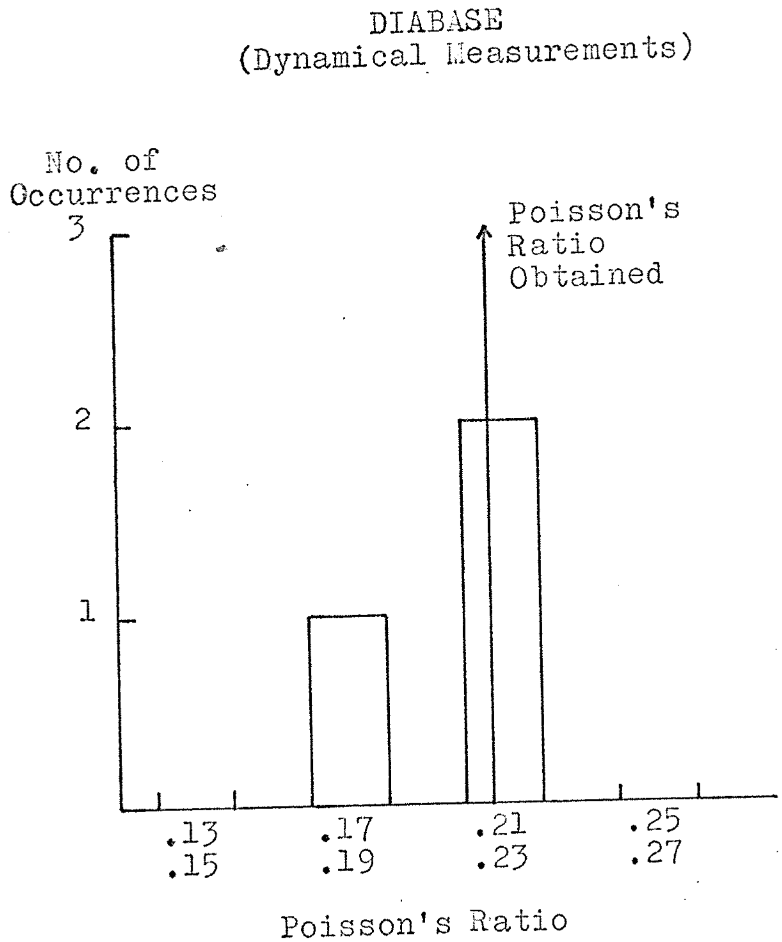

Fig. 6. Histogram of Poisson's ratio of diabase (based on the Handbook of Physical Constants, GSA Memoir 97).

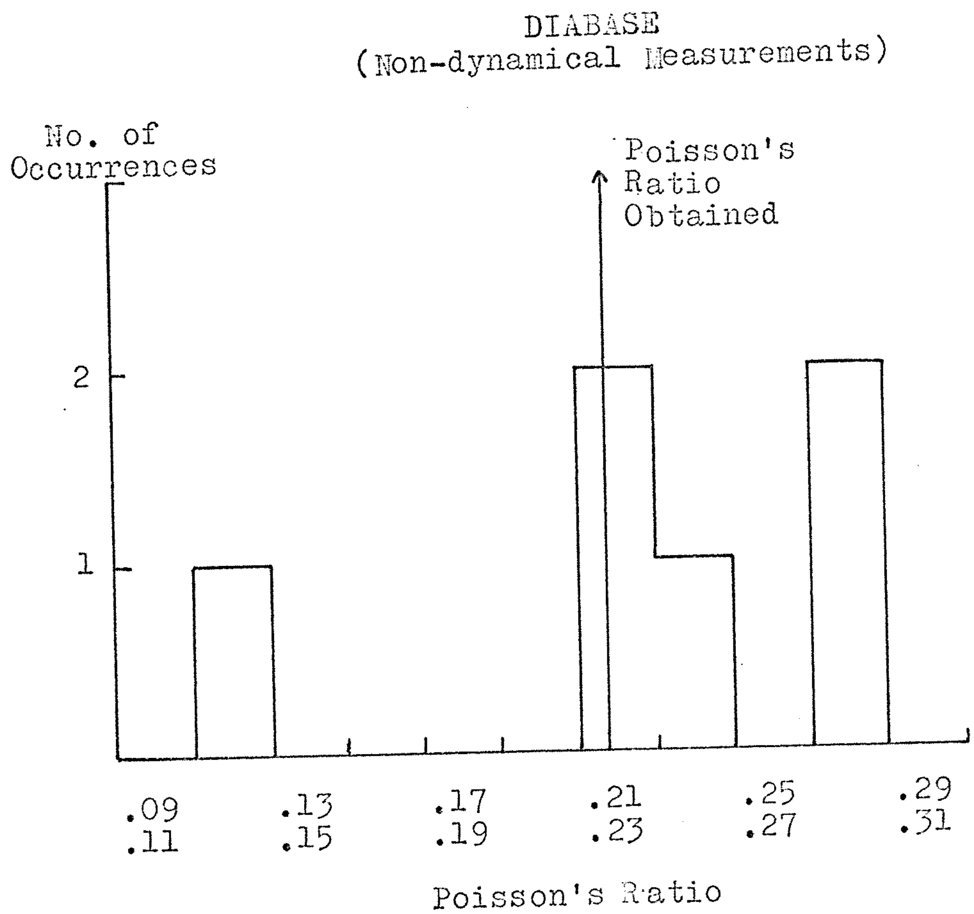

Fig. 7. Histogram of Poisson's ratio of diabase (based on the Handbook of Physical Constants, GSA Memoir 97).

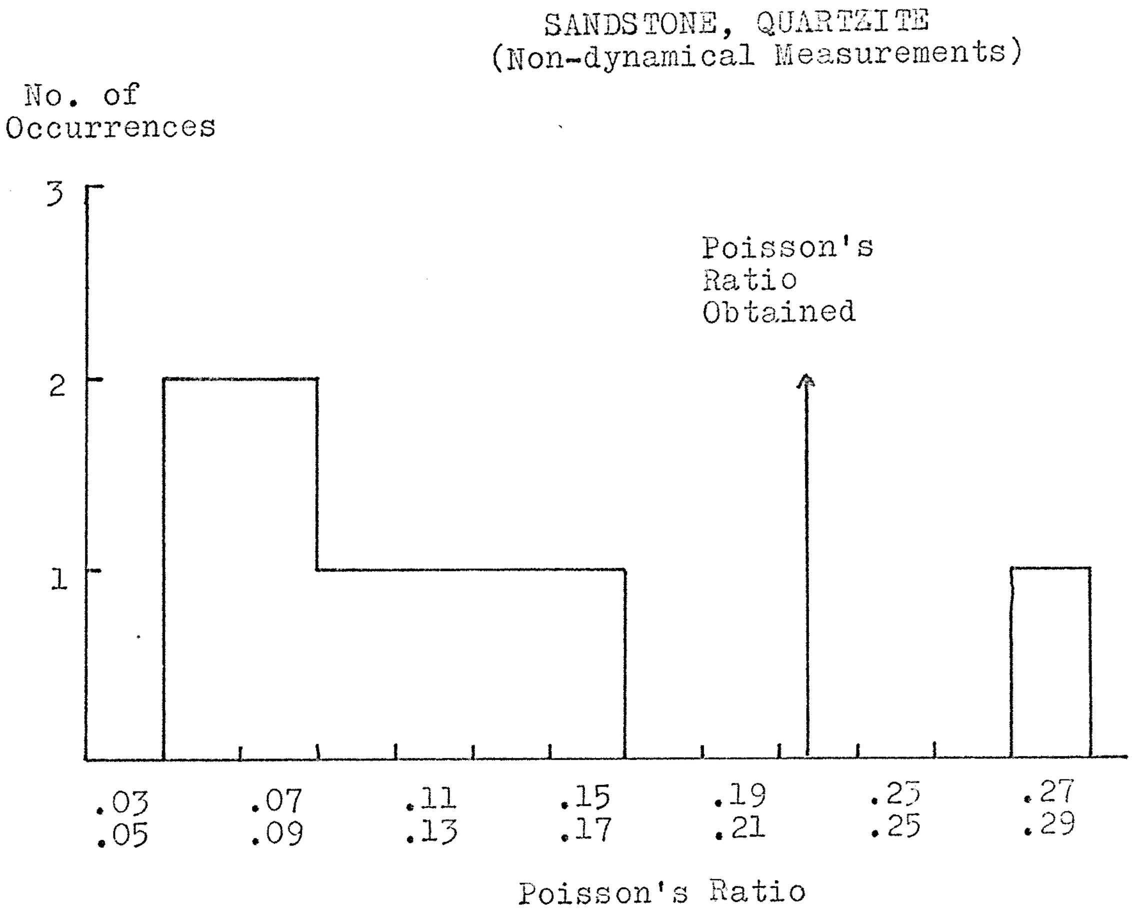

Fig. 8. Histogram of Poisson's ratio of sandstone and quartzite. (based on the Handbook of Physical Constants, GSA Memoir 97).

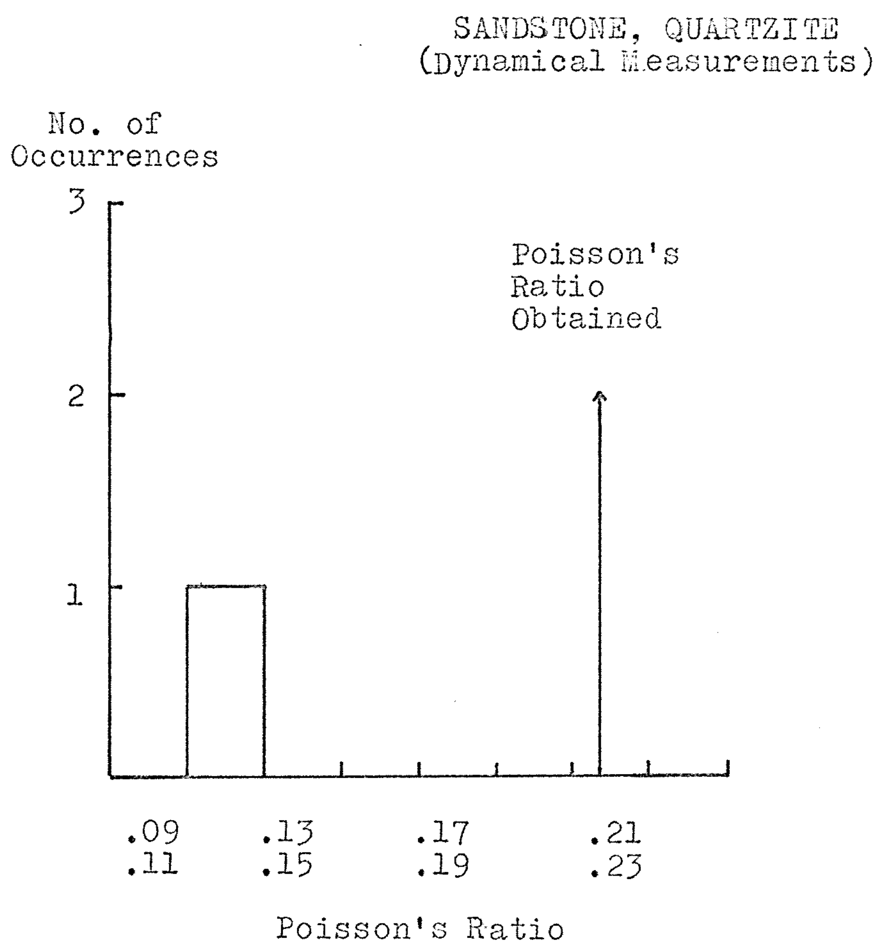

Fig. 9. Histogram of Poisson's ratio of sandstone and quartzite (based on the Handbook of Physical Constants, GSA Memoir 97).

crustal rocks (Handbook of Physical Constants, GSA Memoir 97) were examined. Histograms of number of occurrences and Poisson's ratio values of some types of crustal rocks were constructed (Fig. 4 - 9). Diabase and granite fit most closely to the value of Poisson's ratio found for the crustal rock between Albuquerque and Socorro. According to Foster and Stipp (1961) much of the crustal rock between Albuquerque and Socorro could be granite. Thus the comparatively low values of Poisson's ratio and V_p/V_s ratio obtained could be the expected normal values for the Rio Grande Rift.

3) The comparatively low values of the Poisson's ratio and V_p/V_s ratio might be the typical values for a rift type structure. The results obtained in the Rio Grande Rift need to be compared with those found in a similar way for other rift zones.

CONCLUSION

The upper crust in the Rio Grande Rift between Albuquerque and Socorro has an average S wave velocity of 3.49 km/sec, an average P wave velocity of 5.8 km/sec, a Poisson's ratio of 0.217, and a V_p/V_s ratio of 1.664.

The comparatively low values of Poisson's ratio and the V_p/V_s ratio are believed, at this time, to be the normal values for Precambrian rocks comprising the upper crust between Albuquerque and Socorro.

Appendix 1. Computer Program

```
//NEU JOB SAKDEJAYONT
// EXEC FORTRAN(CLG)

      C          PALQ=PA=P ARRIVAL TIME AT A
      C          SALQ=SA=S ARRIVAL TIME AT A
      C          PSNM=PS=P ARRIVAL TIME AT S
      C          SSNM=SS=S ARRIVAL TIME AT S
      C
      C   DATA CARD:
      C          COL 1-2   HOUR OF PALQ IN I2
      C          COL 3-4   MINUTE OF PALQ IN
      C          COL 5-9   SECOND OF PALQ IN
      C          COL 10-11  HOUR OF SALQ IN
      C          COL 12-13  MINUTE OF SALQ I
      C          COL 14-18  SECOND OF SALQ I
      C          COL 19-20  HOUR OF PSNM IN
      C          COL 21-22  MINUTE OF PSNM I
      C          COL 23-27  SECOND OF PSNM I
      C          COL 28-29  HOUR OF SSNM IN
      C          COL 30-31  MINUTE OF SSNM I
      C          COL 32-36  SECOND OF SSNM I
      C          COL 40-41  MONTH IN I2
      C          COL 42-43  DATE IN I2
      C          COL 44-45  YEAR IN I2
0001         WRITE(6,200)
0002     200 FORMAT('1',21X,'PALQ',11X,'SALQ',11
            $8X,'NEU',9X,'DATE',5X,'VP/VS')
0003         SUMX=0
0004         SUMV=0
0005         SRAT=0
0006         N=0
0007       1 READ(5,100)IPAH,IPAM,PAS,ISAH,ISAM,
            $,IM,ID,IY
0008     100 FORMAT(4(I2,I2,F5.2),3X,3(I2))
0009         IF(IPAH.EQ.50) GO TO 2
0010         AIPAH=IPAH
0011         AIPAM=IPAM
0012         AISAH=ISAH
0013         AISAM=ISAM
0014         AIPSH=IPSH
0015         AIPSM=IPSM
0016         AISSH=ISSH
0017         AISSM=ISSM
0018         PA=AIPAH*3600.0+AIPAM*60.0+PAS
0019         SA=AISAH*3600.0+AISAM*60.0+SAS
0020         PS=AIPSH*3600.0+AIPSM*60.0+PSS
0021         SS=AISSH*3600.0+AISSM*60.0+SSS
0022         X=(PA-PS)/(SA-PA-SS+PS)
0023         V=(0.5-X**2/2.0+X)/(1.0+2.0*X)
0024         VRAT=SQRT(2.*(1.-V)/(1.-2.*V))
0025         N=N+1
0026         SUMX=SUMX+X
0027         SUMV=SUMV+V
0028         SRAT=SRAT+VRAT
0029         WRITE(6,201)IPAH,IPAM,PAS,ISAH,ISAM,
            $IPSH,IPSM,PSS,ISSH,ISSM,SSS,X,V,IM,
0030     201 FORMAT(/,18X,4(I2,':',I2,':',F5.2,4)
            $I2,4X,F6.4)
```

```
      GO TO 1
    2 AN=N
      XAV=SUMX/AN
      VAV=SUMV/AN
      RATAV=SRAT/AN
      WRITE(6,202)XAV,VAV,RATAV
  202 FORMAT(/,30X,'THE AVERATE VALUE OF X IS',2X,F6.4,/
     $,30X,'THE AVERATE VALUE OF NEU IS',2X,F6.4,/
     $,30X,'THE AVERATE VALUE OF VP/VS IS',2X,F6.4)
      STOP
      END
```

```
TOTAL MEMORY REQUIREMENTS 000718 BYTES

COMPILER HIGHEST SEVERITY CODE WAS  0

LOADER HIGHEST SEVERITY WAS  0  --  EXECUTION
```

Table 1. Microearthquakes used in this study.

Table 1. (continue)

```
      STOP        0
   /&
```

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