On the Measurement of V_p/V_s Ratio in the Area around Lake Biwa

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Abstract

It has been reported that the vertical movement of the crust at the west coast of Lake Biwa changed its mode recently.[1]

The large active fault, Hanaore is very near the region. Encouraged by these facts, many researchers have carried out gravity measurements, measuring of vertical and horizontal movements of the crust, observation of micro-earthquakes in and around the region, and other geophysical studies. The authors are among them and they calculated V_p/V_s ratio using the data at the net stations of Hokuriku Micro-earthquake Observatory, Abuyama Seismological Observatory and at some temporal stations. The averaged value of V_p/V_s has been determined to be 1.673. Smaller values than this are of the stations near the coast.

Special stations were set for about a month along the Hanaore fault to catch the seismic waves from the Wakayama region, and two earthquakes occurred during the time. The V_p/V_s ratio of the two earthquakes were in the interval 1.70 to 1.75 for almost all the stations.

1. Introduction

V_p/V_s ratio indicates the nature of the media in which the seismic waves run through, and the low value of it in the crust may be a sign of earthquake occurrence. Many investigators have studied on the value in various regions, especially on its time variance. And many of their studies are listed by Ohtake and Katsumata[2] as reference papers. Some of the works state that the ratio seemed to decrease before an earthquake event, and some of the others state otherwise.

Here the authors calculate the V_p/V_s values at the region around Lake Biwa, which will be an elementary factor to discuss whether a large earthquake will occur near the region in the future or not.

2. V_p/V_s calculated by the formula $1+(T_{sp}/T_p)$

Seismicity maps and some characteristic features of them have been already reported and discussed.[3]

Fig. 1 represents the distribution of epicenters, which were relocated for the use of V_p/V_s calculation. More than four p times were used to determine a hypocenter location and the origin time by means of the least square method. 885 was the number of earthquakes thus located whose depths were less than 50 km and the mean residual remained smaller than or equal to 0.2 sec. from Aug. 1975 to Jul. 1976. Fig. 2a shows the p wave velocity structure of the crust on which the travel

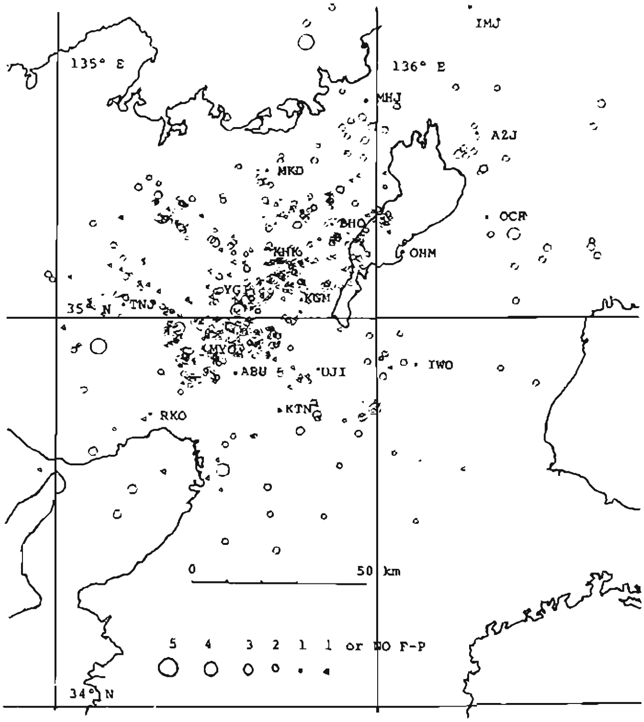


Fig. 1. Distribution of 885 eipcenters relocated for the present paper. These are selected from the data obtained at 17 stations in the figure, from August 1975 to July 1976 by the conditions that the depth is less than 50 km and the mean residual of p times is less than or equal to 0. 2 sec. Radii of the circles indicate magnitudes of the earthquakes as the examples at the bottom of the map.

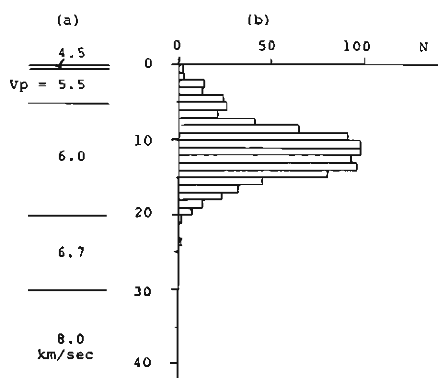
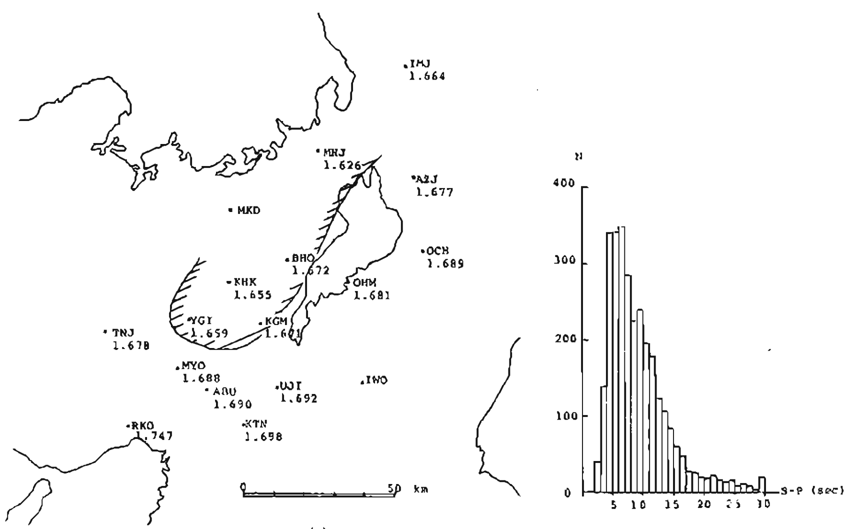


Fig. 2. (a) Structure of p wave velocity assumed to calculate travel times.
(b) Frequency distribution of focal depths of the same earthquakes plotted in Fig. 1.

Table 1. Mean value of V_p/V_s ratio at each station. In the second column are the numbers of available data.

STATION	NUMBER	V_p/V_s RATIO
MHJ	14	1.626 ± 0.085
KHK	368	1.655 ± 0.051
YGI	481	1.659 ± 0.044
IMJ	3	1.664 ± 0.018
KGM	423	1.671 ± 0.045
BHO	269	1.672 ± 0.061
AZJ	27	1.677 ± 0.081
TNJ	402	1.678 ± 0.058
OHM	203	1.681 ± 0.055
MYO	231	1.688 ± 0.060
OCH	21	1.689 ± 0.045
ABU	262	1.690 ± 0.058
UJI	164	1.692 ± 0.067
KTN	94	1.698 ± 0.071
RKO	31	1.747 ± 0.071
TOTAL	2993	1.673 ± 0.081



(a) (b)

Fig. 3. (a) Mean value of V_p/V_s ratio at each station. Region of lower V_p/V_s than the mean value (1.673) is hatched.
(b) Frequency distribution of S-Ptimes.

times were calculated. Fig. 2b is the frequency distribution of focal depths. V_p/V_s value was calculated by the formula $1+(T_{sp}/T_p)$, where T_{sp} and T_p are the S-P and the P-O times respectively. P and S-P times of c, d ranks, that is, reading errors greater than 0.2 sec, were omitted from the data, and thus the number of available sets of data came down to 2993. Fig. 3a shows the mean value of V_p/V_s over all data at each station. The values are also listed on Table 1. with their standard deviations. The deviations seem to be very large, but the number of data is also large, so the confidence intervals with 95% significance are far narrower for most stations. The mean of total data, 1.673, is rather small compared with that of Hashizume's result.[4] In fig. 3a., the region of lower V_p/V_s than the mean value is hatched. Frequency distributions of S-P times (Fig. 3b) and focal depths (Fig. 2b) show that the values above mentioned are largely depended on data of near and shallow earthquakes, so they may reflect the character of shallower part of the crust.

3. P time residuals

Mean values of p time residuals of the 885 earthquakes were obtained for the stations. (Fig. 4 and Table 2) The numbers in Fig. 4 and Table 2 are O-C values, so the positive value indicates that the first motion of p waves was detected at the station later than the calculated time, which was based on the assumed p structure as in Fig. 2a. In Fig. 4 the positive areas of p residuals are hatched. Thick lines indicate the regions where the existance of a lower velocity layer (V_p=5.55 km/sec)

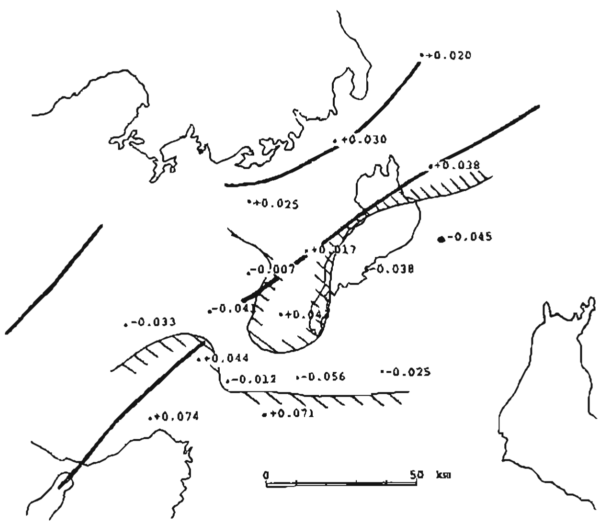


Fig. 4. Mean values of p time residuals. Hatched areas are those of the positive numbers which denote that the actual p wave velocity is lower than the calculated value. These areas show fairly good coincidence with the thick line region, where a low velocity layer was concluded to exist at the top of the crust by the Miboro Explosion.[5]

Table 2. Mean value of p time residuals at each station. Numbers of used data are in the second column.

STATION	NUMBER	P-TIME RESIDUAL
UJI	524	−0.056±0.088
OCH	74	−0.045±0.116
YGI	866	−0.041±0.057
OHM	437	−0.038±0.083
TNJ	790	−0.033±0.071
IWO	150	−0.025±0.117
ABU	553	−0.012±0.092
KHK	732	−0.007±0.058
BHO	553	0.017±0.080
IMJ	7	0.020±0.073
MKD	257	0.025±0.105
MHJ	92	0.030±0.087
AZJ	132	0.038±0.119
KGM	780	0.043±0.067
MYO	539	0.044±0.088
KTN	275	0.071±0.104
RKO	133	0.074±0.102
TOTAL	6894	−0.002±0.089

whose thickness is about 5 to 10 km at the top of the crust, just above the layer with V_p of 6 km/sec, was concluded by the Miboro Explosion.[5] These two regions show fairly good coincidence, and referring to Fig. 3a, it is concluded that the low velocity of p wave is one of the causes for low V_p/V_s ratio of the stations west of the lake. On the contrary, at MYO, KTN, and RKO stations, instead of low p wave velocity, V_p/V_s ratios are somewhat high.

4. Special observation of V_p/V_s

Five more stations were set during October 1975 along the Hanaore fault to catch seismic waves from Wakayama region, where earthquakes of magnitude larger

Table 3. Locations of the five special stations to catch earthquakes from Wakayama. These stations are on or very close to the Hanaore fault.

STATION	LATITUDE	LONGITUDE	MEMO	
SZH	35°06′15.60″ N	135°47′56.40″ E	Drums	1 Hz
KCH	35°08′07.00″ N	135°49′46.90″ E	FM rec.	1 Hz
TAI	35°11′38.00″ N	135°51′45.70″ E	DR rec.	4.5 Hz
MUR	35°18′36.60″ N	135°53′39.20″ E	DR rec	4.5 Hz
MKG	35°23′21.50″ N	135°55′19.50″ E	DR rec.	4.5 Hz

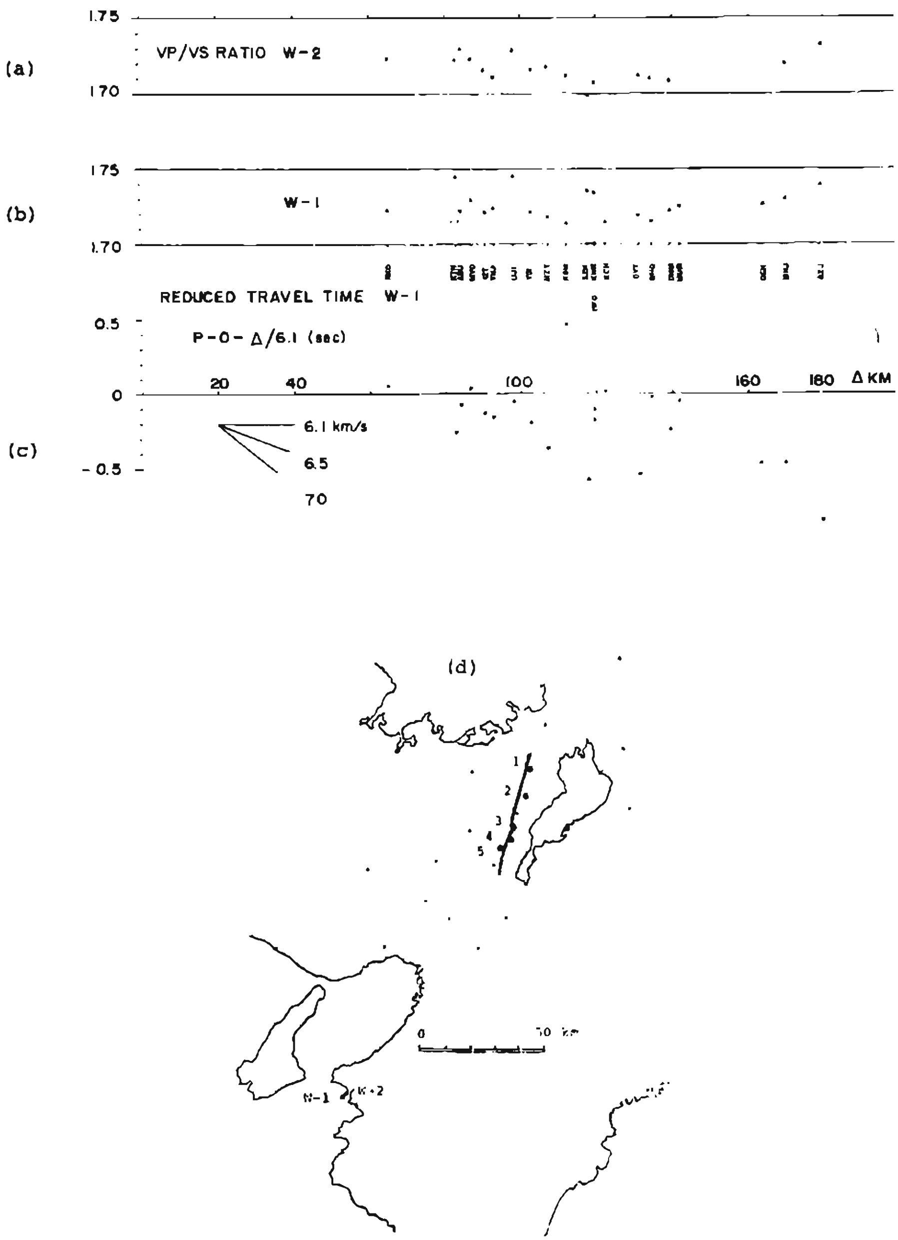


Fig. 5. (a) V_p/V_s ratio of W-2.
(b) V_p/V_s ratio of W-1.
(c) Reduced travel time of W-1. Apparent velocity at the stations farther than 123 km seems to be about 7 km/sec.
(d) Locations of the five special stations. 1; MKG, 2; MUR, 3; TAI, 4; KCH, and 5; SZH. Small solid points are other routine stations. W-1 and W-2 are the epicenters. Solid line at the west coast of Lake Biwa is the Hanaore fault.

than 3 were expected often to occur. The locations of these stations are listed on Table 3. (Fig. 5d.) At three of these stations, MKG, MUR, and TAI, direct recording (DR) portable cassette recorders were used. Three or two components of pickups with natural frequency of 4.5 Hz and a crystal clock at each station were to ensure time accuracy of 0.02 sec for p and s first motions. At KCH station, an FM data recorder, pausing at normal times, was triggered to run when a large amplitude seismic wave came into the vertical component of the pickup. An analogue memory set worked all the time so as not to miss the first arrival. Three drum recorders were in use at SZH station. The natural frequency of six pickups at KCH and SZH stations were all 1 Hz.

On October 12, an earthquake (W-1), magnitude of which was 3.7, occurred in the region of Wakayama, which was followed by another earthquake (W-2, M=3.0) after one hour. Unfortunately the crystal timer at MKG had run down on the day and high amplitude of noise at TAI station covered the first arriving signal. P and s times obtained at the other three stations were served for analysis together with those at stations of routine observation. Calculation method is the same as was used in paragraph 2, but as the origin times, the values determined by Wakayama Micro-earthquake Observatory were adopted.[6] Fig. 5b shows the V_p/V_s values of W-1 earthquake and Fig. 5a W-2. Reduced travel time of W-1 is plotted for reference as Fig. 5c. Almost all the V_p/V_s values of both W-1 and W-2 fell between 1.70 and 1.75.

5. Discussion

The averaged V_p/V_s ratio calculated in paragraph 2 is about 1.673, and in paragraph 4 all values are larger than this by a few percents. One of the reasons to explain this disagreement is the difference of the methods of calculation in the two paragraphs, in other words, the difference of the determination methods of origin times. In fact, when we calculate V_p/V_s values by drawing a 'Wadati-diagram', which does not need the origin times, the averaged value of V_p/V_s's of the same earthquakes as are dealt with in the second paragraph is 1.69, a little greater than 1.673, while those of W-1 and W-2 calculated in this way still remain 1.73 and 1.72 respectively. Another possible reason is the difference of S-P times in the two cases. In paragraph 4, S-P times range from 7.68 sec to 21.10 sec, while in paragraph 2, most frequent S-P time is 6 or 7 sec as is shown in Fig. 3b. This suggests to us that the V_p/V_s value of W-1 and W-2 may largely reflect the nature of the deeper part of the crust or even the nature around the Moho discontinuity. Further more, the assumed structure of p wave velocity for them (Fig. 2a) is somewhat different from the actual one. If they are not so different from each other, the authors must have overlooked the first motion on the records at the stations whose epicentral distances of W-1 are farther than 123 km, at which distance Pn waves come as the first motion, and so the aparent velocity should be 8 km/sec, while as can be seen from Fig. 5c, it is measured as about 7 km/sec. But overlooking the wave does not increase the V_p/V_s ratio, if the S phase is read in the right way.

6. Conclusions

V_p/V_s ratio is derived in two ways. For the first one it is 1.673 as the averaged value, and the second, it is larger than 1.70. This difference is partly explained by the difference of the wave paths in two cases. Lower values in the first method are of the stations at the west coast of Lake Biwa. This may result from the low velocity of p waves revealed in paragraph 3. These facts alone, however, are not enough to predict a large earthquake occurrence in the region in near future, for the V_p/V_s values obtained by the 'Wadati-diagram' method in paragraph 5 were not anomalously low.

It is desired to measure the seismic wave velocities again, when other evidences of earthquake precursors are found out in and around the region.

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