It was found that, we actually expect the large amount of time difference when there is the velocity anisotropy of surface layer and when there is a fault right beneath the source. In the former case, we may get rid of the misleading by precise velocity distribution measurement of surface layer near the source region. However, in actual case, it is not easy to do so mainly due to the economical reason. In the case of middle size exploration such as the Yumenoshima expedition, geophone intervals are sparse unavoidably near the source, since the main objective is to clarify the P wave velocity structure to obtain approximately the depth down to the Pre−Tertiary base rock. When there is a hidden fault, the refraction method is not apposite to clarify the structure. The reflection method should be employed in such a case.

Finally, we applied the derivings to the Yumenoshima data. And found that, the discrepancy of intercept time obtained from the North and West spreads is true and not due to the observation error. We claim that such phenomena will not be a rare case especially in Japan where the geology is extremely complex.

Reference

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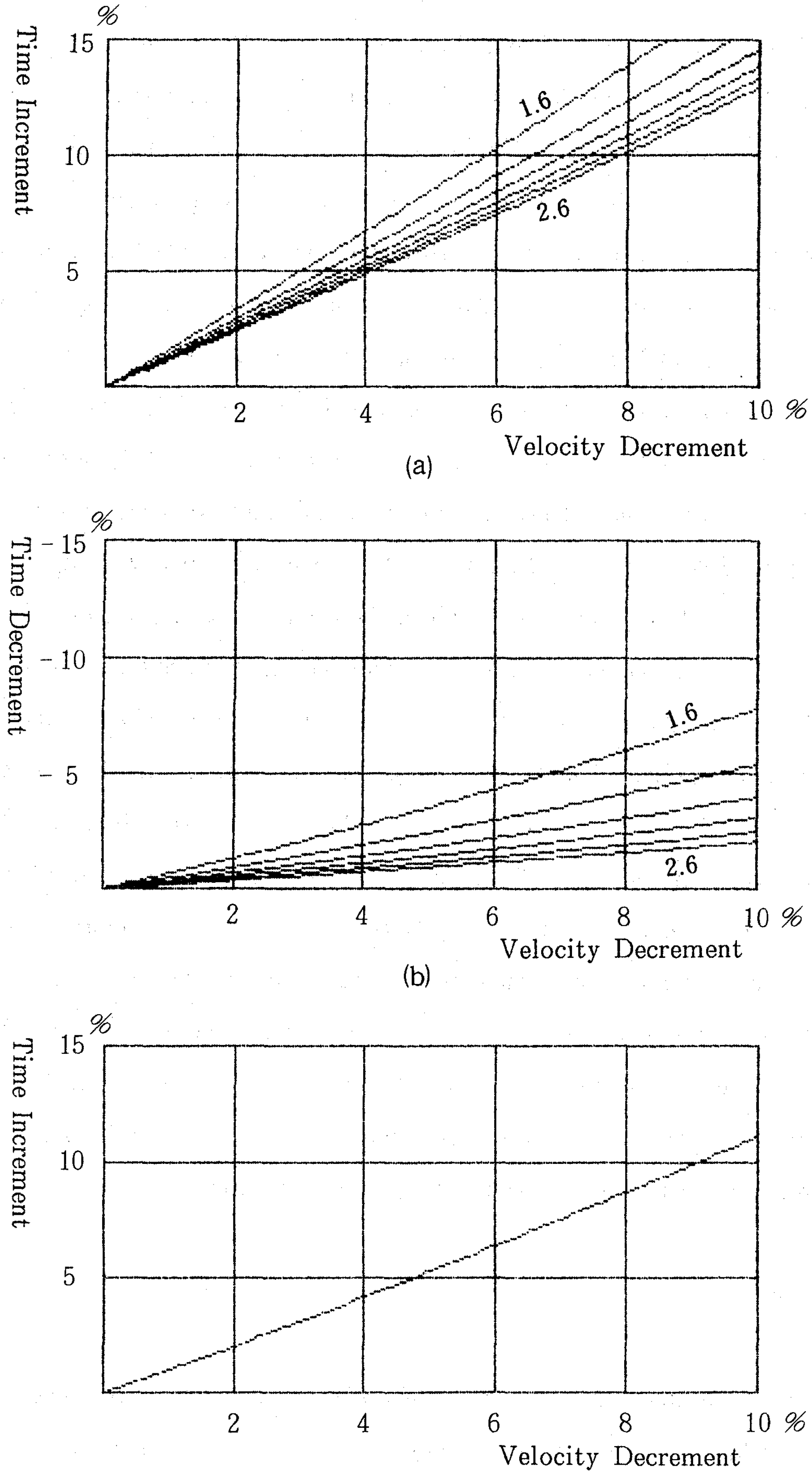
subsurface layer overlaid upon the model. It is very hard to discriminate whether there is an abrupt change of underground structure under the shot point or not from a glance, so we are inclined not to pay much attention about the near source observation, since we believe erroneously that there is a uniform underground structure. Analytical errors may be reduced if we carry out the near source observation carefully in the cases a) and d). Errors for b) may also be reduced through the accurate observation of refracted waves surveyed in different directions. c) may be the most risky case which lead us to the erroneous conclusion. For example, one sometimes insert a ghost layer into the structure so that we obtain the same intercept times deduced from observations carried out in different directions. From the Yumenoshima explosion data (Shima, 1990), P wave velocity of the base rock obtained from the North spread from Yumenoshima was found to be 5.6 km/s. The intercept time at Yumenoshima was 2.06 s. While from the West spread from Yumenoshima, P wave velocity and the intercept time were found to be 5.3 km/s and 2.0 s, respectively. This situation is the same with that of the model shown in Fig. 1b although the underground structure at Yumenoshima consists of three layers. We simplified two surface layers to be one layer having mean P wave velocity of 2.3 km/s. Substituting these values into Eq (3), we found that the decrement of the intercept time will be 2.5 % or 0.05 s. This estimation agrees well with the observation. Thus, we claim that the disagreement of intercept times obtained from the different spreads from the source is not an observational error, and such phenomena may be observed often in Japan where geological structures are extremely complex.

5. Conclusion

We occasionally found the discrepancy of intercept times derived from the observations carried out in different directions from the source. It is easy to prove that the discrepancy is false when the underground structure is consisted of homogeneous inclined layers. Thus, one sometimes consider that the discrepancy is due to an observation error. However, if there is an abrupt change of structure beneath the source, we may expect properly the intercept time difference. In this short note, we have examined the extent of time difference numerically taking the realistic underground structure models shown in Fig. 1 as examples.



(c)

Fig. 2. Increment of intercept time in % (a, c).
Decrement of intercept time in % (b).

thus computed when the velocity ratio between surface and base layers shown in Fig. 1 a and lb varies from 1.6 to 2.6. From Fig. 2 b we see that the intercept time of the underground structure shown in the left side of the figure decreases, and the decrement becomes smaller when the velocity ratio becomes higher. When the velocity ratio of the standard model is 2 and the velocity decrement of the base layer is 6 %, the time difference is found to be around 2 %. However, when velocity ratio becomes 1.6, the time difference well exceeds 4 %. On the contrary, in the case of Fig. 2 a, the intercept time of the model becomes larger than that of the standard model. When the velocity ratio is 2, and the decrement of velocity is 4 and 6 %, the difference becomes 5.5 and 8.4 %, respectively. And if the velocity ratio is 1.6, and the decrement of velocity is as above, the increment becomes 6.8 and 10.3 %, respectively. Thus, the model a) produces a larger effect than the model b). However, if the velocities of the surface layers of both sides are known beforehand through the observation, one will not introduce an erroneous conclusion. This suggest that the near source observation is indispensable in analyzing the data. Fig. 1 c is a case where there is a hidden fault under the source point. This situation may be most probable one among other cases. The intercept time difference in this case depends only on the ratio of the thicknesses of the surface layer as is clear from Eq. (4). Finally, we will consider the case of Fig. 1 d in which velocities of both surface and base layers were decreased. For simplicity, we consider the case when the velocity ratios between surface and base layers of both variable and standard models are constant. That is, the critical angles for both models are constant since $V_1^- / V_2^- = V_1^- / V_2$. In this special case, 4, 6 % velocity changes will result the time differences of 4.2, 6.4 %, respectively. This example also suggests the necessity of precise near source observation.

4. Discussions

We have examined the underground models which give us the different intercept times. It may not be seldom to select the source point in such a situation, since geological structures in Japan are extremely complex. In this short note, we examined the realistic underground models which can be found everywhere in Japan. We often misunderstand the case shown in Fig.1 a as a uniform parallel layers structure when there is a thin

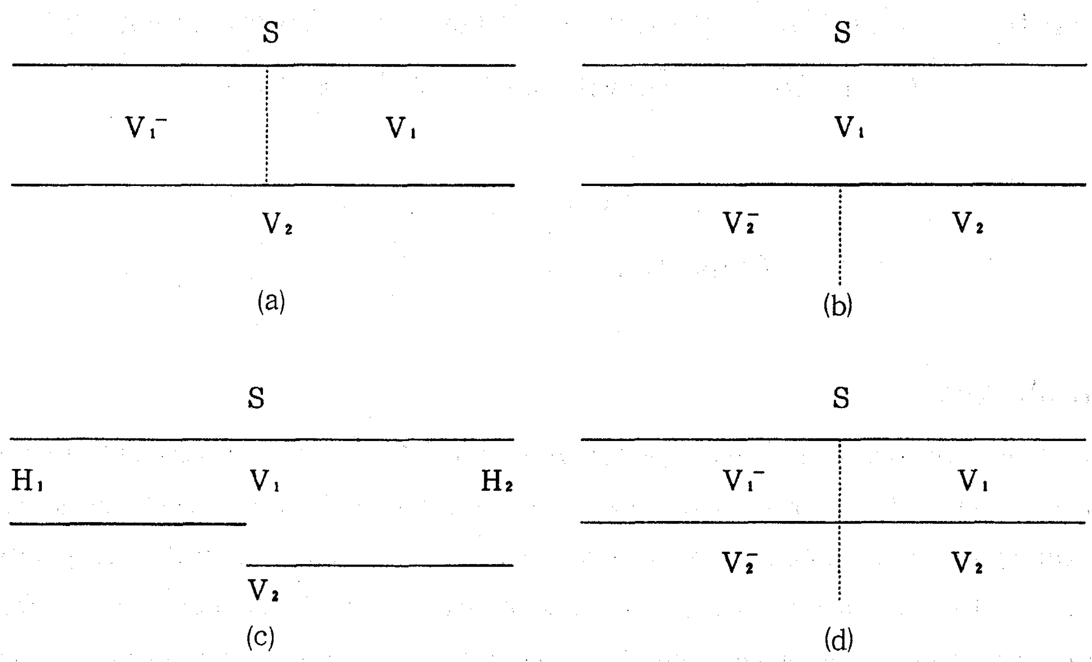


Fig. 1 Underground structure models

And $V_n^- < V_n$.

The intercept time T_o of travel time for two layered structure is

$$T_o = 2H\cos(i)/V_1, \qquad (1)$$

where, i is the critical angle, and $i = \sin^{-1}(V_1/V_2)$. Therefore, the ratios between the intercept times of both sides shown in the Fig. 1 can be given as follows if we consider the right side of the model is unity.

a) $(\cos(i^-)/V_1^-)/(\cos(i)/V_1)$, (2)

b) $\cos(i^-)/\cos(i)$, (3)

c) H_1/H_2, (4)

d) $(\cos(i')/V_1^-)/(\cos(i)/V_1)$, (5)

where $i^- = \sin^{-1}(V_1^-/V_2)$, $i' = \sin^{-1}(V_1^-/V_2^-)$.

3. Numerical Estimation of Intercept Time Difference

For the convenience' sake, we will normalize the intercept time difference assigning that the right side of each model is standard. Fig. 2 shows the intercept time differences

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Note on the Discrepancy of Intercept Times Obtained from the Different Survey Directions

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1. Introduction

The seismic refraction method is a useful tool to clarify the underground stucture at the given region. In general, observations of seismic signals are carried out along the long linear spread with appropriate geophone intervals. Usually, several shot points are placed along the observation spread. So, the observations will be made both directions from the shot points. Intercept times can be determined thus independently from the data sets obtained from the observations of both directions. During the travel time analysis of such data, we occasionally find the discrepancy of intercept times deduced from two different data sets. When we fail to observe the seimic wave velocity of the surface layer because of the sparse geophone intervals, this type of discrepancy is found frequently. We may easily prove that the discrepancy is false even if the underground structure is consisted of homogeneous inclined layers. So, one sometimes consider that the discrepancy is due to the observation error. However, when there exists an anisotropy of the underground structure, intercept times may not be the same. Therefore, we must be very careful to analyze the data so that we do not derive the erroneous conclusion. As far as the author knows, no one treated this matter quantitatively. In the following, we will discuss numerically the realistic underground structure models which will give us the different intercept times at the source.

2. Underground Structure Models

As shown in Fig. 1, if there exists a fault or an abrupt change of seismic wave velocities under the source, we expect the discrepancy of intercept times obtained from the observations carried out in different directions. They are the cases : a) the seismic wave velocities of both sides of surface layers are different, b) there is an anisotropy in base rock, c) there is a hidden fault under the source, d) the geology is different in both sides of the source. In the Figure, S, V_n, H_n, $(n=1, 2)$ denote source, velocity and depth respectively.