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32. *On the Crustal Structure Derived from Observations of the Second Hokoda Explosion.*

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1. On velocities of P waves in the P_1 and the P_2 layer

From the first Hokoda explosion[1] the P velocity near the surface was obtained as 1.79 km/sec. From the second Hokoda explosion we obtained 1.71 km/sec and from both data it was obtained as 1.74 km/sec, as was shown in the preceding paper.[2]

As to the second layer, as shown in Fig. 1, travel times at Ôya, Mito A, Mito B, Sano, Tomoegawa (for the first explosion) and Tamari (for the first explosion) are arranged very well on a straight line show-

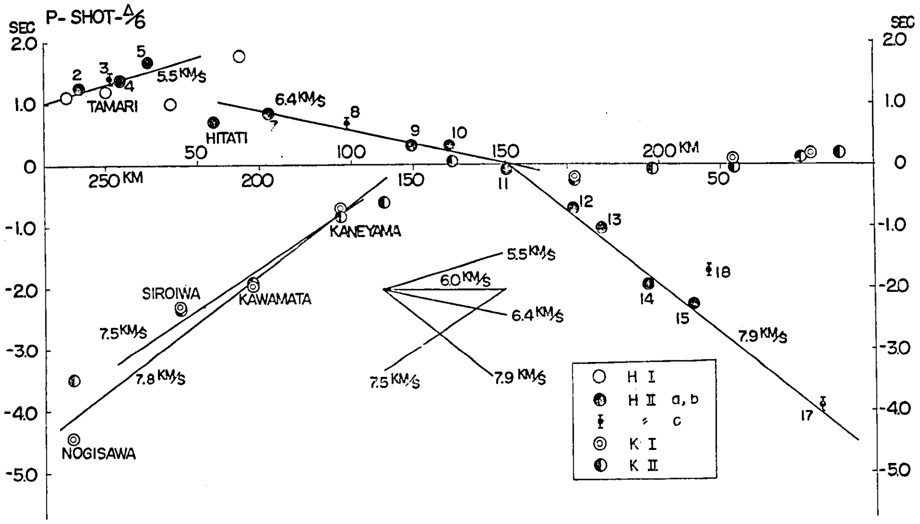

Fig. 1. Travel time curves of the waves from the second Hokoda Explosion. HI, HII, KI and KII mean observed travel times of the first, second Hokoda Explosion, the first and second Kamaisi Explosion respectively.

1) The Research Group for Explosion Seismology, *Bull. Earthq. Res. Inst.*, **36** (1958) 529-548.

2) The Research Group for Explosion Seismology, *Bull. Earthq. Res. Inst.*, **37** (1959).

ing velocity of 5.5 km/sec with intercept time of 1.02 sec. If we use exclusively the values for the second explosion, i.e., values at 4 stations between Ôya and Sano, and deduce a straight line by the method of least squares, putting weights 4, 3, 2 and 1 corresponding to its classes of accuracy a, b, c and d given in the former paper,[3] then we get

$$t = 1.01 + \Delta/5.40 ,$$

where t in sec and Δ in km.

We have two sets of velocity V_2 and intercept time τ_2 for the second layer and three sets of them for the first layer. For some combinations of them the depth of the P_1 layer, z_1, is calculated as shown in Table 1.

Table 1. Thickness of the P_1 layer

V_2 km/sec	τ_2 sec	V_1 km/sec	τ_1 sec	z_1 km
5.5	1.02	1.74	0.035	0.92
		1.74	0.035	0.895
5.4	1.01	1.79	0.053	0.906
		1.71	0.028	0.885

As apparent from the table, for any combination, z_1 can be rounded to 0.9 km. Therefore, we adopt the P velocity in the first layer,

Table 2.

Station	$O-C$	Correction for height	$(O-C)_H$*
1. Hokoda			
2. Ôya	0.06 sec	negligible	0.06 sec
3. Mito A	0.05	〃	0.05
4. Mito B	−0.03	〃	−0.03
5. Sano	0.15	〃	0.15
6. Hitati	−0.03	−0.05 sec	−0.08
7. Daigo	0.05	−0.01	0.04
8. Tanakura	0.16	−0.02	0.14
9. Tamagawa	0.01	−0.02	−0.01
10. Tamura	0.12	−0.04	0.08

* $(O-C)_H$ means $(O-C)$ in which correction for height is taken into account.

3) The Research Group for Explosion Seismology, *loc. cit.*, 2).

1.74 km/sec, the thickness of the layer, 0.92 km, the P velocity in the second layer, 5.5 km/sec, and the intercept time, 1.02 sec.

$O-C$ values at stations between Ôya and Sano calculated from these assumptions are tabulated in Table 2, together with other values.

The value at Sano, 0.15 sec, is rather large, however, it may be explained from a reasonable supposition that the thickness of the P_1 layer is larger at Sano than at other stations.

2. Probable models of the crustal structure

As apparent from Fig. 1, travel times between Hitati and Tamura or Hitati and Siroiwa belong to a line with velocity, nearly 6 km/sec, however, owing to the abnormally small value at Hitati, according to various ways of its interpretation, some different values of velocity can be taken. Namely, various models as follows can be at least assumed, without paying any attention to the crustal structure in neighbouring areas.

(1) A model, in which 6.4–6.5 km/sec is adopted as the apparent velocity, i.e., the travel time at Hitati is excluded as a singularity. Then, five points between Daigo and Siroiwa are arranged fairly well on a straight line with velocity of 6.4 6.5 km/sec. Using the method of least squares we can fit following equations for points respectively from Daigo to Tamura, and from Daigo to Siroiwa, namely,

$$t_3 = 1.61 + \Delta/6.39 \text{ and } t_3 = 1.74 + \Delta/6.44 \ .$$

In this model, we adopt P_2 layer with 5.5 km/sec and take 6.4–6.5km/sec for an apparent velocity due to the inclination of the boundary surface. We call it model 1 (Fig. 2).

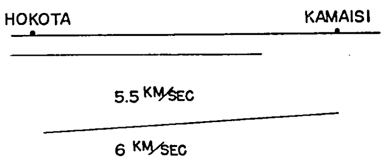

Fig 2. Model 1.

(2) A model, in which 6.2 km/sec is taken as the apparent velocity. A line passing through five points from Hitati to Tamura (including Hitati) with velocity 6.2 km/sec is taken and its position relative to the line 5.5 km/sec is explained by putting a fault under the ground.

In this case two further subdivisions are possible.

(a) A layer with velocity 5.5 km/sec exists really: model 2a.

(b) The velocity 5.5 km/sec is only an apparent one and explained by inclination of the boundary surface: model 2b.

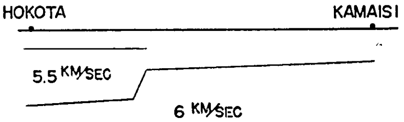

Fig. 3(a). Model 2a.

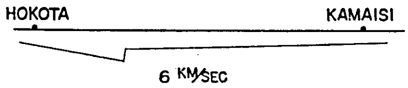

Fig. 3(b). Model 2b.

(3) A model in which an apparent velocity of 6.3 km/sec is assumed (model 3).

The large travel time at Sano is excluded as a singularity owing to a supposed large thickness of a surface layer[4], and a line passing through seven points from Ôya to Tamura (excluding Sano) with velocity of 6.3 km/sec is adopted. As a consequence a line with velocity of 5.5 km/sec is discarded. This model is somewhat akin to model 2b, however, an underground fault is not necessary. (Fig. 4).

(4) A model in which the velocity of 5.8 km/sec in the second layer is adopted. (model 4).

In models 1, 2 and 3, different assumptions of apparent velocities near 6 km/sec were due to differences in the way of grouping the observed travel times. In this model we adopt 5.8 km/sec in the P_2 layer which was already obtained for North-east Japan[5] and try to explain the apparent velocity of 5.5 km/sec by the inclination of the layer boundary (Fig. 5).

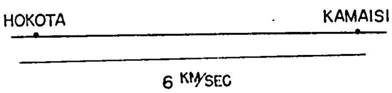

Fig. 4. Model 3.

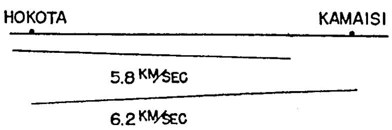

Fig. 5. Model 4.

In investigating these four models we take the crustal structure of North-east Japan and of Kwantô District into consideration and select such a model well reconcilable with them.

3. Form of the lower boundary of the P_2 layer and the velocity in the P_3 layer

First, model 1 is investigated. The true velocity in the P_3 layer 6.1 km/sec, which was obtained in the northern part of Kwantô District,[6]

4) "A surface layer" in this paper stands for an unidentified surface layer with a low velocity, for example, a weathered layer in common use.

5) The Research Group for Explosion Seismology, *Pub. Bureau Central Séism. Intern. Série A. Trav. Sc.*, **19** (1954), 229-242; T. MATUZAWA, *Bull. Earthq. Res. Inst.*, **37** (1959).

6) T. USAMI *et al.*, *Bull. Earthq. Res. Inst.*, **36** (1957), 349-357.

is tentatively adopted, because the area concerned is a direct continuation to it.

As for the allowance of the residue $O-C$, we take it ± 0.1 sec, as in the case of North-east Japan.[7]

Now, in order to produce an apparent velocity of 6.4–6.5 km/sec instead of the true velocity of 6.1 km/sec, the layer boundary must be shallower in the north with a dip of 5°14′–6°32′. Its depth at the shot point is calculated as 5.3 km, using $\Delta = 30$ km of the intersection point of lines for 5.5 km/sec and for 6.4-6.5 km/sec. If we assume a uniform inclination, the P_3 layer should be exposed to the earth surface at $\Delta = 46.3$-57.9 km. Even if we use the depth of 6 km of the P_3 layer obtained in the northern part of Kwantô District, the said distance should be 52.4–65.5 km. On the other hand, the line belonging to the apparent velocity of 6.4–6.5 km/sec is extended to 73–132 km (from Daigo to Tamura) or 73–150 km (from Daigo to Siroiwa). This is contradictory to the alleged short distance of the exposure.

In order to avoid this contradiction, taking a mode of stratification similar to model 2a, we assume a model as shown in Fig. 6.

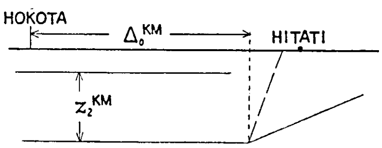

Fig. 6.

Namely, until a certain distance Δ_0 km, the layer boundary is horizontal and then may be shallower toward the north. If we take 30–50 km as the break distance of the travel time lines (between Sano and Hitati), then the depth of the lower boundary of the P_2 layer turns out as 3.4–5.7 km. Thus we adopt tentatively the value of 6 km for the northern Kwantô District. Taking Δ_0 as a parameter, $(O-C)$ values for stations between Hitati and Siroiwa are calculated as shown in Table 3.

As is apparent from the table the absolute values of $O-C$ are too large in general. The absolute values of $O-C$ are still larger than 0.1 sec even if the bottom surface of P_2 layer is assumed to be inclined without changing its depth under the shot point. The next step to make the absolute values of $O-C$ smaller is to take the bottom shallower. This procedure does not induce any contradictions against the value of depth of bottom surface of P_2 layer obtained before for the Kwantô

7) The Research Group for Explosion Seismology, *loc. cit.*, 4). T. MATUZAWA, *loc. cit.*, 5).

8) T. USAMI *et al.*, *loc. cit.*, 6).

Table 3.

Station	Δ km	T_0 sec	$O-C$ sec	
			Δ_0=20 km	Δ_0=30 km
Hitati	55.16	9.88	−0.25	−0.29
Daigo	73.03	13.01	−0.02	−0.03
Tanakura	98.94	17.16	−0.07	−0.09
Tamagawa	119.47	20.22	−0.37	−0.40
Tamura	131.79	22.27	−0.31	−0.37
Siroiwa	150.33	25.00	−0.71	−0.70

District, because the seismic ray concerned did not pass through this part of the bottom under the shot point. Taking the value of the depth of the P_2 layer and Δ_0 as parameters, the $O-C$ value at Hitati is calculated as shown in Table 4.

Table 4. $O-C$ in sec at Hitati

z_2 km \ Δ_0 km	20	30	35	40
3.8	—	−0.04	−0.05	−0.08
4.0	−0.04	−0.06	−0.08	−0.11
4.5	−0.09	—	—	—

As the travel time of the first wave at Sano should be associated with waves through the P_2 layer, z_2 value must be at least 4 km.

Thus tentatively adopting $z_2=4$ km and $\Delta_0=30$ km, the $O-C$ values at Tamagawa and Tamura are again −0.21 sec and −0.17 sec respectively, even if the waves pass through the P_3 layer only. These very small values suggest that the adopted velocity 6.1 km/sec in the P_3 layer be too small.

As an another piece of evidence, taking velocity V_3 of the P_3 layer as a parameter, for a few combinations of the apparent velocity V_3' and the true velocity of P_2 layer V_2, and assuming that the P_3 layer be exposed to the earth surface at a distance $\Delta=150$ km (near Siroiwa), the depth d of the bottom surface of the P_2 layer under Hokoda is calculated as shown in Table 5.

As apparent from the table, d values for $V_3 \leq 6.1$ km/sec are too large.

Table 5. Depth d km of the bottom surface of the P_2 layer under Hokoda

V_3'km/sec	6.3			6.4				6.3			6.4			
V_2 〃	5.4			5.4				5.5			5.5			
V_3 〃	6.0	6.1	6.2	6.0	6.1	6.2	6.3	6.0	6.1	6.2	6.0	6.1	6.2	6.3
d km	11.4	7.2	3.4	17.5	12.7	8.3	4.4	14.8	9.6	4.4	19.3	14.0	8.7	4.8

Thus, assuming 6.2 km/sec as the true velocity in the P_3 layer, similar examinations are repeated.

At first, the depth z_2 of the P_2 layer corresponding to the break distance of 35-50 km (between Sano and Hitati) turns out 4.3-6.2 km. $O-C$ values of Hitati for some combinations of Δ_0 and z_2 are calculated as shown in Table 6.

Table 6. $O-C$ at Hitati (in 0.01 sec)

z_2 km \ Δ_0 km	30	35	40	45
4.3	4	1	−3	−8
4.5	—	—	−5	—
4.9	−5	—	—	—

As the correction for the height of Hitati is −0.05 sec, $O-C$ for Hitati is −0.08 sec for $z_2=4.3$ km and $\Delta_0=40$ km. This value is also compatible with the interpretation that the first motion at Sano is due to waves through the P_2 layer.

The first waves at Tamagawa and Tamura are supposed to be propagated exclusively in the P_3 layer after refraction into this layer. The dip of the line connecting Tamagawa and the point at $\Delta_0=40$ km on the bottom plane is 3°46′ and that for Tamura is 3°15′. On the other hand, the dip of the bottom plane giving the apparent velocity of 6.4 km/sec must be 3°18′.

$O-C$ values at Daigo, Tamura and Tamagawa for both values of inclinations are given in Table 7.

Table 7. Inclination and $O-C$ in sec

Inclination \ Station	Daigo	Tanakura	Tamagawa	Tamura
3°46′	0.05	0.19	0.05	0.12
3°15′	0.05	0.16	0.01	0.12

As apparent from the table, differences between the two cases are trivial. We adopt the latter value 3°15′ of the dip.

5. On P_n

As stated in § 1, the main object of the present investigation has been to increase the knowledge of the P_n layer, together with the data obtained in North-east Japan. Among all observation points, stations at which the first motion is expected to be due to waves passing through the P_n layer are those beyond Siroiwa, and as apparent from Fig. 1 they are arranged fairly well on a straight line with apparent velocity of 7.9 km/sec.

Comparing it with the value obtained in North-east Japan, we take for granted that this value corresponds to the P_n layer. In calculating the travel time for P_n waves, it is necessary to know the crustal structure above the P_n layer, however, the structure near Siroiwa and Kawamata is still obscure. Therefore, we must assume a probable one there. On the other hand we obtained in North-east Japan that the boundary between the layer of 5.75-5.85 km/sec and that of 6.1-6.2 km/sec has a dip of 6-11° nearly westward and a strike of 200-210° from the north over the east and its depth under the Kamaisi shot point is 0.5-2.0 km, while as apparent in Fig. 1 of the former paper[9] the observation points beyond Siroiwa are spread nearly along a line parallel to the strike direction. The distance of this line from the strike line passing through the Kamaisi shot point is about 30 km. The depth to the boundary, z_2', under this line (Fig. 7) is calculated for some combinations of inclination θ and depth under Kamaisi shot point h as shown in Table 8.

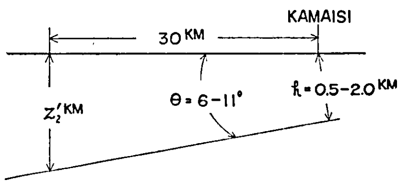

Fig. 7.

As apparent from the table, the thickness of the layer 5.8 km/sec under this line is confined between 4-8 km.

In the next place, the approximate depth of the Mohorovičić discontinuity is calculated as 25 km from the distance, 145 km, of the intersection point of lines

Table 8. z_2' km

θ \ h	0.5 km	2.0 km
6°	3.7	5.2
11°	6.3	7.9

9) *loc. cit.*, 2).

with 6.2 km/sec and with 7.9 km/sec. The relation between the inclination θ of the Mohorovičić discontinuity and the true velocity V_4 in the P_n layer, which should give the apparent velocity of 7.9 km/sec is shown in Table 9.

Table 9. V_4 and θ which give 7.9 km/sec (The negative sign of θ means the dip toward the north.)

V_4 km/sec	7.5	7.6	7.7	7.8	7.9	8.0	8.1	8.2
θ	4°04′	2°58′	1°56′	57′	0°	-54′	-1°45′	-2°35′

6. Case of the horizontal Mohorovičić surface

For the assumption of the horizontal Mohorovičić discontinuity, i.e., $\theta=0°$ and $V_4=7.9$ km/sec, $O-C$ values corresponding to several values of z'_2 are calculated as shown in Table 10.

Table 10. $O-C$ (in sec) for various z'_2 (in km) ($V_4=7.9$ km/sec, and $d_3=27.5$ km)

Station \ z'_2	0	2	4	5	6	8
Siroiwa	-0.09	-0.12	-0.15	-0.17	-0.18	-0.22
Kawamata	0.11	0.08	-0.05	0.03	0.02	0.00
Isida	0.17	0.14	0.11	0.09	0.08	0.05
Kaneyama	-0.14	-0.18	-0.21	-0.23	-0.23	-0.27
Watari	0.13	0.10	0.07	0.05	0.04	0.01
Miyatoko	0.13	0.10	0.07	0.05	0.04	0.01

We find from the table that travel times at Siroiwa and Kaneyama are too early compared with other stations, and moreover, the variation of $O-C$ value of each station in the range of $z'_2=4$-8 km is trivial. These very large absolute values of $O-C$ for Siroiwa and Kaneyama are not explained by the assumption that the thickness of the 5.8 km/sec layer would be smaller than those under other stations, because, even if we take $z'_2=0$ km, $O-C$ values for Siroiwa and Kaneyama are calculated as -0.09 sec and -0.14 sec respectively. As for the effect of a surface layer, we know from the investigation of North-east Japan that at almost all stations in the area, which is adjacent to the area here concerned, the 5.8 km/sec layer is nearly exposed to the surface.

There are a few possible ways of explanation. First, we resort to an explanation that the Mohorovičić discontinuity under these stations might be shallow in such a way that the $O-C$ values at other stations would not be affected. The result is shown in Fig. 8. As for Siroiwa station, the inclination of 5° of the Mohorovičić surface begins at a refracting point of the wave arriving at Tamura, 52.44 km to Siroiwa and continues to a point 26.08 km to Siroiwa, which is a point where waves arriving at Siroiwa refracted into the upper layer with a critical angle. Further north the upheaval ceases to exist and turns back to the original level. As for Kaneyama, similarly, the inclination of 5° begins at a point 49.10 km south to Kaneyama and ends at a point 26.42 km south to Kaneyama and turns back quickly to the original level. In this way $O-C$ values at Siroiwa and Kaneyama become respectively -0.02 and -0.05 sec.

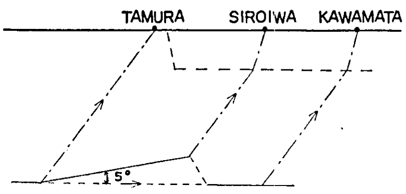

Fig. 8.

As this procedure introduces two local independent assumptions, it is somewhat arbitrary.

The second alternative is as follows. The small $O-C$ values (absolute values are large) at Siroiwa and Kaneyama are supposed to be due to the lack of a surface layer, while positive $O-C$ values at other stations are assumed to be due to a thick surface layer. From this standpoint, as shown in Table 11, $z'_2=5$ km and $d_3=26.5$ km are adequate.

The third alternative is that at Siroiwa and Kaneyama the 5.8 km/sec layer is lacking and other stations are covered by a thick surface layer. In this case $d_3=27$–27.5 km is adequate.

7. Case of the inclined Mohorovičić surface

In the case of the inclined Mohorovičić surface also, for the explanation of travel times at Siroiwa and Kaneyame we can take three standpoints similar to the case of the horizontal Mohorovičić surface.

If we assume $V_4=7.7$ km/sec obtained in the northern part of Kwantô District, from the first standpoint it is found adequate that its depth under Hokoda shot point d_3 is equal to 29 km and its inclination is 1°56′, becoming shallower in the north. (Refer to Table 9 and Table 11). As for the explanation of the small travel times of Siroiwa and

Kaneyama, upheaval of the Mohorovičić surface, i.e., increase of its dip under each station is taken. Namely, for Siroiwa dip of 6°56′ (i.e., 1°56′+5°) begins at a point 51 km south from Siroiwa and ends at a point 22.9 km south to Siroiwa and in the further north it takes sharply its original trend with inclination of 1°56′. For Kaneyama corresponding points are at 55 km and 20.8 km south from there, the dips being the same. (Fig. 9) $O-C$ values are given in Table 11.

From the second standpoint, in which large values of $O-C$ at other stations are attributed to a thick surface layer, the adequate value of d_3 is 27.5 km, and $O-C$ values for this case are given in Table 11.

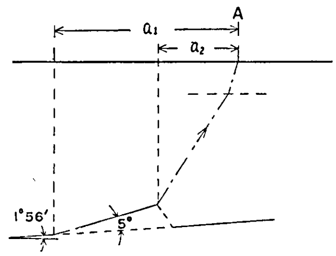

Fig. 9.

The third standpoint is omitted, because it is easily inferred from these results.

From investigations stated above, we see that observed data are equally well explained for both values of V_4, 7.7 km/sec and 7.9 km/sec and thus the unique determination of V_4 is not possible. In order to put a limit to the variable range of V_4, we added in Table 11 $O-C$ values corresponding to V_4=7.5 km/sec and 8.2 km/sec, which have been both limits hitherto appearing in publications. As far as the data here concerned, no contradictions occur.

8. Reference to the data of Kamaisi explosions

As the second Hokoda explosion forms a reverse profile to the Kamaisi shots,[10] their data must be taken into account. In Fig. 1 travel times for two Kamaisi shots are plotted. Among P_n travel times, accurate ones are those of Kaneyama for the first and second Kamaisi shot and those of Kawamata and Siroiwa for the second Kamaisi shot. At farther stations sometimes amplitudes were too small and sometimes natural earthquakes disturbed the record. These four travel times of three stations are fairly well arranged on a straight line with an apparent velocity of 7.5 km/sec. If we add the travel time at Nogisawa for the first shot (that for the second shot was disturbed by a natural earthquake), a straight line with velocity of 7.8 km/sec is obtained.

Combination of the apparent velocity of 7.9 km/sec for the Hokoda

10) The Research Group for Explosion Seismology, *Bull. Earthq. Res. Inst.*, **32** (1954), 79; **33** (1955), 699.

shot and 7.5 km/sec for the Kamaisi shot gives 7.7 km/sec as the true value and an inclination of 1°56′, and another combination of 7.9 km/sec and 7.8 km/sec gives 7.8 km/sec as the true velocity and an inclination of 29′. In both cases the dip is from the north to the south.

We are inclined to adopt $V_4=7.7$ km/sec and $\theta=1°56'$, because the data at Nogisawa were somewhat dubious.

As for the alternative models explained in § 6 and § 7, we are inclined to adopt the second alternative, i.e., relatively small $O-C$ values at Siroiwa and Kaneyama are attributed to thick surface layers at other stations. This alternative is more consistent with our guiding principle of adopting simple a model as possible. Thus we adopt the depth of the Mohorovičić discontinuity at Hokoda $d_3=27.5$ km.

9. Final Model

Summarizing examinations stated above we obtain a crustal model as shown in Fig. 10 as a final one.

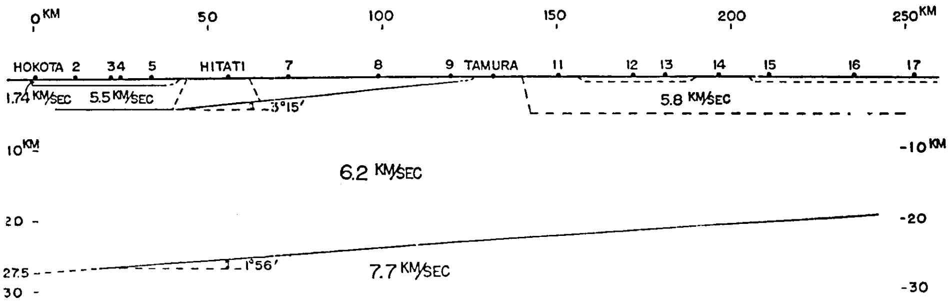

Fig. 10. Final model

The P_1 layer has a velocity of P waves of 1.74 km/sec and is 0.92 km thick. It is somewhat thicker near Sano and ceases to exist beyond Hitati. The P_2 layer has a velocity of 5.5 km/sec and is 4.3 km thick under the Kwantô area and tapers northward with inclination of 3°15′ of the bottom surface from a point $\Delta=40$ km from Hokoda and the P_3 layer is nearly exposed to the earth surface near Tamura. Station Hitati, being a point with much deviation from the profile, is an exceptional point, and the P_3 layer is supposed to be almost exposed to the surface as shown by conical dotted lines in the figure.

Beyond Siroiwa the P'_2 layer has a velocity of 5.8 km/sec and a thickness of 4–8 km. Excluding Siroiwa and Kaneyama, it is supposed that the surface is covered by a certain thin surface layer.

The P_3 layer has a velocity of 6.2 km/sec, and the depth of its lower surface, i.e., the Mohorovičić surface, is 27.5 km under Hokoda and tapers northward with an inclination of 1°56′.

The velocity of the P_n wave is 7.7 km/sec. $O-C$ values for this model are shown as far as Tamura in Table 2. As for P_n waves, they are given in Table 11 for some combinations of V_4 and d_3.

Table 11.

Station	Correction for height	$V_4=7.7$, $z_2'=5$, $\theta=1°56'$		$V_4=7.9$, $z_2'=5$, $\theta=0°$		$V_4=7.5$, $z_2'=5$, $\theta=4°04'$	$V_4=8.2$, $z_2'=5$, $\theta=-2°35'$
		$d_3=27.5$	$d_3=29.0$	$d_3=26.5$	$d_3=27.5$	$d_3=30.0$	$d_3=26.0$
	sec	sec	sec	sec	sec	sec	sec
11. Siroiwa	−0.04	0.04	−0.06	−0.01	−0.02	−0.19	−0.18
12. Kawamata	−0.02	0.25	−0.05	0.21	0.01	0.04	0.04
13. Isida	−0.02	0.32	0.01	0.27	0.07	0.10	0.10
14. Kaneyama	negligible	0.02	−0.05	−0.03	−0.05	−0.20	−0.19
15. Watari	〃	0.29	0.00	0.25	0.05	0.07	0.09
17. Miyatoko	〃	0.29	0.00	0.25	0.05	0.07	0.09

(V_4 in km/sec, z_2' and d_3 in km.)

Speaking of correction for height, it was not necessary for the shot point, because its height above sea level is 41 m and the head of explosives was 35 m deep below the surface of the ground.

As is apparent from the tables, except for a few stations all $O-C$ absolute values are less than 0.1 sec and can be regarded as random errors.

In Table 2, $O-C$ values at Sano and Tanakura are larger than 0.1 sec. It is supposed that at Sano the surface layer is thick and at Tanakura the travel time of the first motion was read too late, owing to its small amplitude.

In Table 11, for the most adequate values of $V_4=7.7$ km/sec and $d_3=27.5$ km, $O-C$ values attain 0.2–0.3 sec, except Siroiwa and Kaneyama. This is explained by the existence of a certain surface layer. If we assume a layer with velocity of 1.74 km/sec, as found at Hokoda shot point, thickness of 0.4 km is sufficient to explain them, which is supposed to be very probable.

10. Remarks to reflected waves

As stated in the former paper[11] at Sano a seismograph of the E. T. L.—M3 type for seismic exploration was used, in order to catch reflected waves from the Mohorovičić discontinuity. Three distinct phases obtained were 1 h 05 m 9.61 sec, 11.35 sec and 12.85 sec. On the other hand, travel times of reflected waves expected from calculations are 19.56 sec from the bottom of the P_1 layer and 7.38 sec from that of the P_2 layer. No phase corresponding to the former was observed and none corresponding to the latter identified, its time being nearly coincident with the commencement of the first refracted wave.

As for the reflected waves from the Mohorovičić discontinuity, the travel time calculated from the model in Fig. 10 is 11.27 sec. The difference from the observed value 11.35 sec is only 0.08 sec and the coincidence is very good. If we adopt the horizontal Mohorovičić discontinuity with $V_4=7.9$ km/sec and $d_3=27.5$ km, the coincidence is better.

A further remark should be added, because at this time a refracted S-waves are expected to set in. But as the apparent velocity of the phase due to these 12 components is 7.7 km/sec, where the apparent velocity of the initial phase is 5.9 km/sec, we can very probably conclude that this phase be due to P-waves reflected at the Mohorovičić discontinuity.

11. Remarks to gravity anomaly and the surface geology

The Bouguer anomaly of gravity near Hitati is very large in positive.[12] This fact corresponds very well to the supposed upheaval of the P_3 layer. In Fig. 11 the Bouguer anomaly in the profile Hokoda-Hitati is shown.

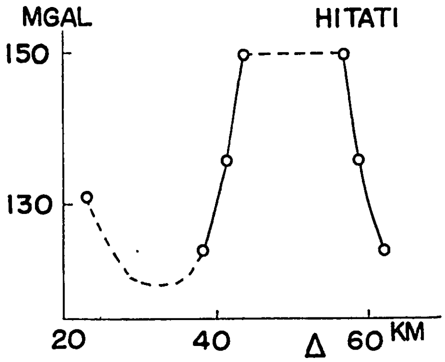

Fig. 11. Bouguer Anomaly in the Section of Hokoda-Hitati.

As for the surface geology near Hitati, a detouched layer called Hitati Palaeozoic layer is exposed.

One more characteristic feature shown in Fig. 10 is the structure near Tamagawa, Tamura and Siroiwa. Of course, as it is not necessary that the P_3 layer is literally exposed to the surface, the exact correspondence to the surface geology is not indispensable. This area belongs geologically

11) *loc. cit.*, 2).

12) C. TSUBOI *et al.*, *Bull. Earthq. Res. Inst.*, *Suppl. Vol.*, **4**, Part 7 (1956).

to the Abukuma mountain land and has not such a remarkable characteristic as the Hitati area and no visible fault was found. However, some geologists seem to suppose existence of faults in this area.

At any rate, the direct correspondence is not so good as in the Hitati area.

12. Conclusion

As often stated elsewhere, the principal objects of this observation were precise determination of several quantities concerning the Mohorovičić discontinuity and to find out the connection between the crustal structure in North-east Japan and in the northern part of Kwantô District. Results of analysis are shown in Fig. 10, and we could consistently connect the latter and get values about P_n more precise than hitherto obtained.

In summary, in the Kwantô area the first layer has a velocity of 1.74 km/sec with a thickness of 0.92 km and ceases to exist in the farther north of Hitati. The second layer has a velocity of 5.5 km/sec with a thickness of 4.3 km, however, its bottom surface begins to taper northward at a distance of $\Delta=40$ km from Hokoda, and near Tamura the third layer with velocity of 6.2 km/sec comes near to the earth surface.

In North-east Japan, except Siroiwa and Kaneyama the surface is covered by a certain thin layer and the second layer, corresponding to that of Kwantô area with velocity of 5.5 km/sec, has a velocity of 5.8 km/sec with thickness 4–8 km.

The velocity of P_n waves is 7.7 km/sec and the depth of the Mohorovičić discontinuity is 27.5 km under Hokoda and tapers northward with inclination of about 2°. The depth of the Mohorovičić discontinuity is verified by reflected waves observed at Sano.

From observations of the Nozori explosions and the first Hokoda explosion,[13] we derived velocity of 6.1 km/sec of the third layer and the depth of the Mohorovičić surface 25 km for the northern part of Kwantô District.

In the present case we have 6.2 km/sec instead of 6.1 km/sec and the depth of the Mohorovičić surface under Hokoda, 27.5 km, instead of 25 km. Therefore, a small correction to the structure of the northern part of Kwantô District may be necessary, but we think it trivial.

13) *loc cit.*, 1).

Hitati is a singular point and the third layer is supposed to be upheaved near to the surface of the ground.[1]

13. Acknowledgement

In conclusion, we wish to express our hearty thanks to the Research Group for Explosion Seismology who placed the data at our disposal. Also we are much obliged to Miss Yoriko Utida who prepared many text figures in a short time.

Postscript

After the completion of this paper, it was found that the name of the town near the shot point should be written "Hokoda" instead of "Hokota." But owing to the lack of sufficient time for correction, inscriptions in text figures are left as hitherto used.

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32. 第2回鉾田爆破観測から得られた地殻構造について

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第2回鉾田爆破の観測資料を解析した結果, Fig. 10に示されるような, 東北地方, 関東地方北部を結びつける地殻構造を得た. すなわち, 関東地方では, 第一層は速度, 1.74 km/s, 厚さ 0.92 kmで, この層は日立以北ではなくなる. 第2層は速度 5.5 km/s, 厚さ 4.3 km, 底面は $\Delta=40$ km の所から 3°15′ で傾き, 田村付近では速度 6.2 km/s の第3層が地表近くまで来ている. 東北地方では, 白岩, 金山以外ではうすい未知の表面層があり, 関東北部の 5.5 km/s の速度に相当するのは, 東北地方の結果を考えあわせると 5.8 km/s であり, 厚さ 4～8 km の程度と仮定した. P_n 波の速度は 7.7 km/s, Moho. 面の深さは鉾田直下で 27.5 km であり, 約 2° の傾斜で東北地方では浅くなつている. この Moho. 面の値は, また, 佐野で得られた反射波の走時からも妥当性を裏付けされた. 日立の方向だけは構造が別で, 日立では第3層が地表近くまで来ている. これは, 重力や, 地質の資料とも極めてよく調和する.

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(1) According to K. Kanai, Bull. Earthq. Res. Inst., **29** (1951), 505-509, at the depth of 440m 5.65 km/sec was found.