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61. *Crustal Structure in the Western Part of Japan Derived from the Observation of the First and Second Kurayosi and the Hanabusa Explosions (Continued).*

Part 2. Crustal Structure in the Western Part of Japan (Continued).

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Abstract

The crustal structure was revised by using the data of the second Hanabusa explosion as well as of previous Kurayosi and Hanabusa explosions. The velocities of 6.1 km/s and 6.4～6.7 km/s were determined with certainty. For the deeper layers, two models, Model 1 (1*) and Model 2, are compatible, being very similar to the old models. Model 1 and Model 1* have a layer with a velocity of 7.9～8.0 km/s while in Model 2 there is a layer with a velocity of 7.6 km/s and an additional layer with a velocity of 8.3 km/s.

1. Introduction

The crustal structure in the western part of Japan has already been presented by using the data obtained from the first and second Kurayosi explosions and the first Hanabusa explosion in 1963-1964.[1] The existence of the layer with a velocity of 6.1 km/s was established through the analysis of the first and late arrivals, especially late arrivals at distances larger than 150 km. The layer with a velocity of 6.5-6.6 km/s was also derived with a fairly large certainty. It is also worth noting that the apparent velocity higher than 8.0 km/s is determined definitely with good data at distant stations. However, at least two models are compatible for the deep crust in spite of data of good quality. It is necessary to have some additional data for the Hanabusa explosion to study the deep

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1) M. HASHIZUME, O. KAWAMOTO, S. ASANO, I. MURAMATU, T. ASADA, I. TAMAKI AND S. MURAUCHI, *Bull. Earthq. Res. Inst.*, **44** (1966), 109.

crust in more detail.

Therefore, observations of seismic waves generated by the second Hanabusa explosion were conducted at 1h 07m on November 2, 1966 as presented in a separate paper.[2] The purpose of this experiment was to supply additional data at larger distances for the Hanabusa explosion so that the layer with a velocity of 6.4–6.6 km/s and the structure of the deep crust could be studied in more detail.

In this paper, the crustal structure in the western part of Japan derived from the data not only of the second Hanabusa explosion presented in Part 1 (Continued)[3] but also of the whole previous explosions[4] along this profile is discussed.

2. Analysis of travel time graphs

The same assumptions or procedures with those in the previous paper[5] were adopted. That is,

1) The first and all late arrivals were picked up and classified into four grades by considering clearness of phases and time accuracy of identification.[6]
2) A homogeneous layered structure model was adopted.
3) Probable lines were fitted to observed data on the travel time graph with consideration of the quality of data. The record sections (Figs. 5 and 6) were used to correlate waves from point to point and to determine probable lines.
4) The fluctuation of travel times within ±0.1 sec, was assumed to be due to the inhomogeneity near the earth's surface or within the crust, or the change of thickness of surface layers. Therefore, no effort had been made to explain fluctuation of travel times as large as 0.1 sec, only by the change of thickness of surface layers.

Figures 1 and 2 give travel time graphs reduced with a velocity of 6.0 km/s obtained from all available data of the Kurayosi and the Hanabusa explosions. On the assumption of the homogeneous layered structure, the following two models, very similar to previous models[7], were derived through the above procedures. These two models suffici-

2) RESEARCH GROUP FOR EXPLOSION SEISMOLOGY, *Bull. Earthq. Res. Inst.*, **48** (1970), 1121.
3) RESEARCH GROUP FOR EXPLOSION SEISMOLOGY, *loc. cit.*, 2).
4) RESEARCH GROUP FOR EXPLOSION SEISMOLOGY, *Bull. Earthq. Res. Inst.*, **44** (1966), 89.
5) M. HASHIZUME *et al.*, *loc. cit.*, 1).
6) RESEARCH GROUP FOR EXPLOSION SEISMOLOGY, *loc. cit.*, 2).
7) M. HASHIZUME *et al.*, *loc. cit.*, 1).

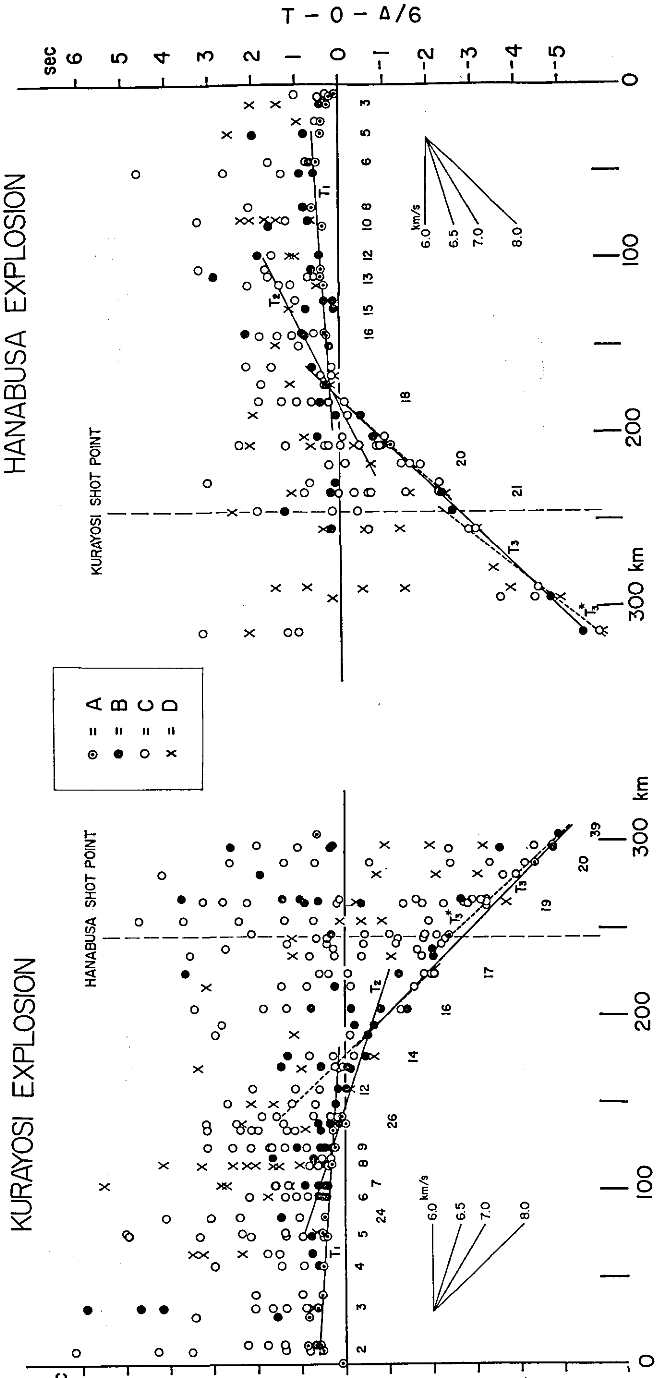

Fig. 1. Travel time graph for the Hanabusa and the Kurayosi explosions (Model 1 and Model 1*). A: very clear first arrivals; B: good phases; C: fairly good phases; D: doubtful phases; T_1, T_2, T_3: travel time lines for Model 1; T_1, T_2, T_3^*: travel time lines for Model 1*. Numbers below some of plots refer to the station numbers in Table 4a, b of Part 1 in the previous paper.[8)]

8) RESEARCH GROUP FOR EXPLOSION SEISMOLOGY, *loc. cit.*, 4).

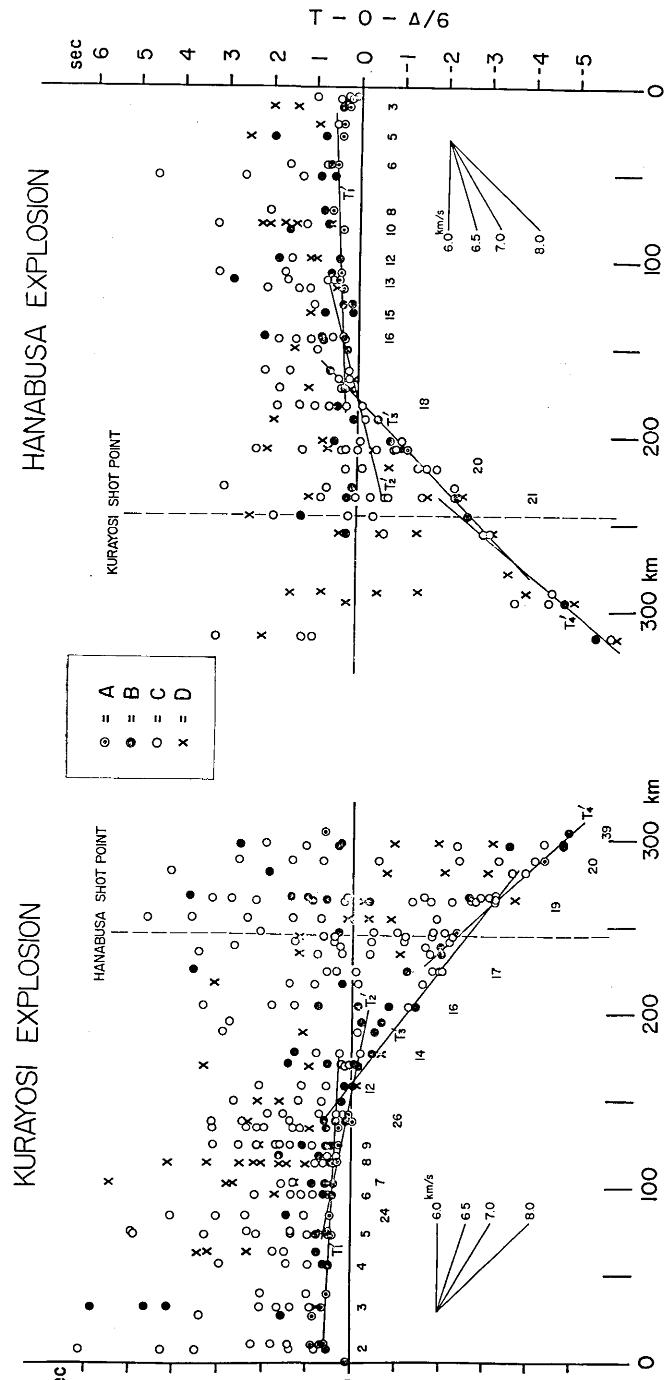

Fig. 2. Travel time graph for the Hanabusa and the Kurayosi explosions (Model 2).
A: very clear first arrivals; B: good phases; C: fairly good phases; D: doubtful phases;
T_1', T_2', T_3', T_4': travel time lines for Model 2.
Numbers below some of plots refer to the station numbers in Table 4a, b of Part 1 in the previous paper.[8)]

ently represent various kinds of layered structure models satisfying observed data.

Both models have a similar structure as far as the shallower part is concerned. That is, the first layer has a velocity of 5.5 km/s which is obtained clearly from the observation of the Hanabusa explosion at distances shorter than 20 km. This layer was assumed to exist through this profile. The velocity of the second layer, 6.1 km/s, is determined more definitely. The refracted waves through the layer with a velocity of 6.4–6.7 km/s, the 'basaltic' layer, appear as late arrivals on the travel time graph of the Hanabusa explosions, while the corresponding waves in the Kurayosi explosion give first arrivals. The crustal structures deeper than the basaltic layer differ between two models. This defference is due to that in the interpretation of travel times in the distance larger than 230 km as given in the following.

Model 1 (1*) (Fig. 1)

The formulas of travel times for each line fitted to observed data are as follows:

Kurayosi explosions	Hanabusa explosions
$T_0=\Delta/5.5$	$T_0=\Delta/5.5$
$T_1=0.67+\Delta/6.10$	$T_1=0.67+\Delta/6.10$
$T_2=1.97+\Delta/6.51$	$T_2=3.71+\Delta/6.82$
$T_3=6.95+\Delta/7.85$	$T_3=7.52+\Delta/8.00$
$(T_3{}^*=7.46+\Delta/8.01)$	$(T_3{}^*=7.58+\Delta/8.04)$

In the above, $T_3{}^*$ was derived regarding the systematic deviation of observed data in the distance larger than 230 km as real for the Hanabusa as well as for the Kurayosi explosions. This systematic deviation is interpreted as due to the local deep structure as shown by the broken line in Fig. 3 (Model 1*), while T_3 was obtained by fitting a line to the whole observed first arrivals in the distance larger than 180 km.

Model 2 (Fig. 2)

Travel times with a high apparent velocity in the distance larger than 230 km were interpreted as due to an additional deeper layer.

The formulas of travel times for each line are as follows:

Kurayosi explosions	Hanabusa explosions
$T_0'=\Delta/5.5$	$T_0'=\Delta/5.5$
$T_1'=0.60+\Delta/6.06$	$T_1'=0.60+\Delta/6.06$
$T_2'=1.20+\Delta/6.30$	$T_2'=1.84+\Delta/6.40$
$T_3'=4.90+\Delta/7.35$	$T_3'=6.94+\Delta/7.83$
$T_4'=8.35+\Delta/8.14$	$T_4'=9.35+\Delta/8.42$

The systematic delay of observed time from T_3' in the range 230–250 km for the Kurayosi explosions is interpreted in this model as being due to the shallow local structure. The introduction of the layer with a high velocity of 8.3 km/s in the distance larger than 250 km resulted in inserting the layer with a velocity of 7.6 km/s for the shorter distances, 170–250 km. In the old Model 2, 7.4 km/s was obtained instead of 7.6 km/s.[9)]

The crustal structure of Model 1 (1*) derived from the above formulas is shown in Fig. 3. In Model 1, the whole of the first arrivals in a distance greater than 180 km were fitted with an averaged line which gives delayed first arrivals in 230–280 km. In Model 1* the depth of Mohorovičić discontinuity is larger around two shot points and is smaller between them. The distribution of Bouguer anomaly does not agree with this symmetric feature of the Mohorovičić discontinuity, although the distribution of Bouguer anomaly and geological features agree qualitatively with the feature of Model 1* in the vicinity of Biwa Lake. In Fig. 4 the crustal structure is shown for Model 2. Model 2 was derived from the standpoint of reducing systematic deviation and fitting each line to earlier first arrivals. The latter standpoint is based on the idea that the real first arrivals sometimes are too small to be observed and also the first arrivals are usually delayed due to unknown surface layers if they exist. In this model, the velocity of 8.3 km/s has not been determined with sufficient data.

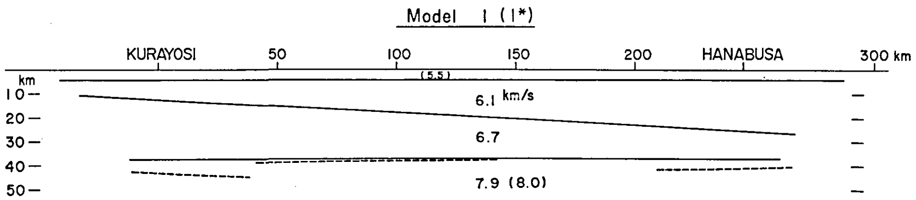

Fig. 3. Crustal structure of Model 1 (1*)

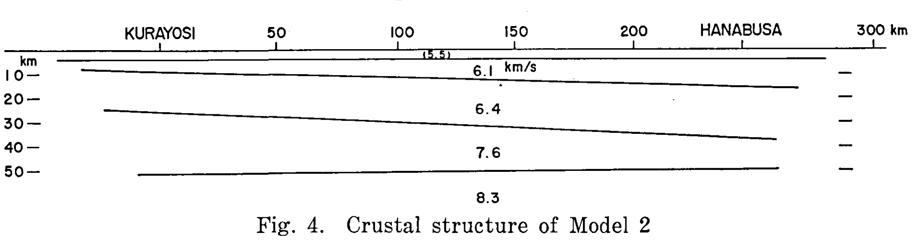

Fig. 4. Crustal structure of Model 2

9) M. HASHIZUME *et al.*, *loc. cit.*, 1).

Figure 5 gives record sections of the Kurayosi and the Hanabusa explosions together with lines of travel times for Model 1 and 1*. In Fig. 6, for Model 2.

3. Concluding remarks

The crustal structure in the western part of Japan was revised by supplementing the data of the second Hanabusa explosion to the previous data. The existence of the basaltic layer becomes more convincing. Also the apparent velocity higher than 8.0 km/s was derived from the data of the Hanabusa explosions as from those of the Kurayosi explosions. However, there are at least two possible models similar to the previous ones. These models were derived on the assumption of homogeneous layered structure. For the deeper layers, the fluctuation of travel times is fairly large in spite of reliable data. This is one reason why two models are compatible. It is desirable to study in more detail the velocity structure of the deep crust by using late arrivals. Also the explosions should be carried out for sufficiently long profiles at an appropriate place around the middle of or outside the region Kurayosi-Hanabusa.

In conclusion, we wish to express our sincere thanks to the members of the Research Group for Explosion Seismology for their fruitful discussions and advices. Our thanks are also due to Misses E. Iwata and Y. Okuda for their help in preparing tables, figures, and manuscripts.

A part of the computation of the crustal structure was carried out by an OKITAC 5090 at the Computation Centre of the University of Tokyo.

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61. 第1回，第2回倉吉爆破及び花房爆破観測より得られた西部日本の地殻構造（続）

第2部　西部日本の地殻構造（続）

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第1部（続）に与えられた第2回花房爆破の資料を加え，倉吉，花房における計4回の爆破の資料を用いて西部日本における地殻構造が改訂された．6.1 km/s 層と 6.4～6.7 km/s 層は，一そうよく

求められたが，地殻深部の構造については，2つのモデル，モデル1(または1*)とモデル2が可能である．モデル1または1*ではP_nとしては，7.9～8.0 km/s の速度である．モデル2では7.6 km/sと8.3 km/s の層が存在し，P_nが何れであるかは決定し得ない．モデル1*とモデル2は前回の2つのモデルに似ている．

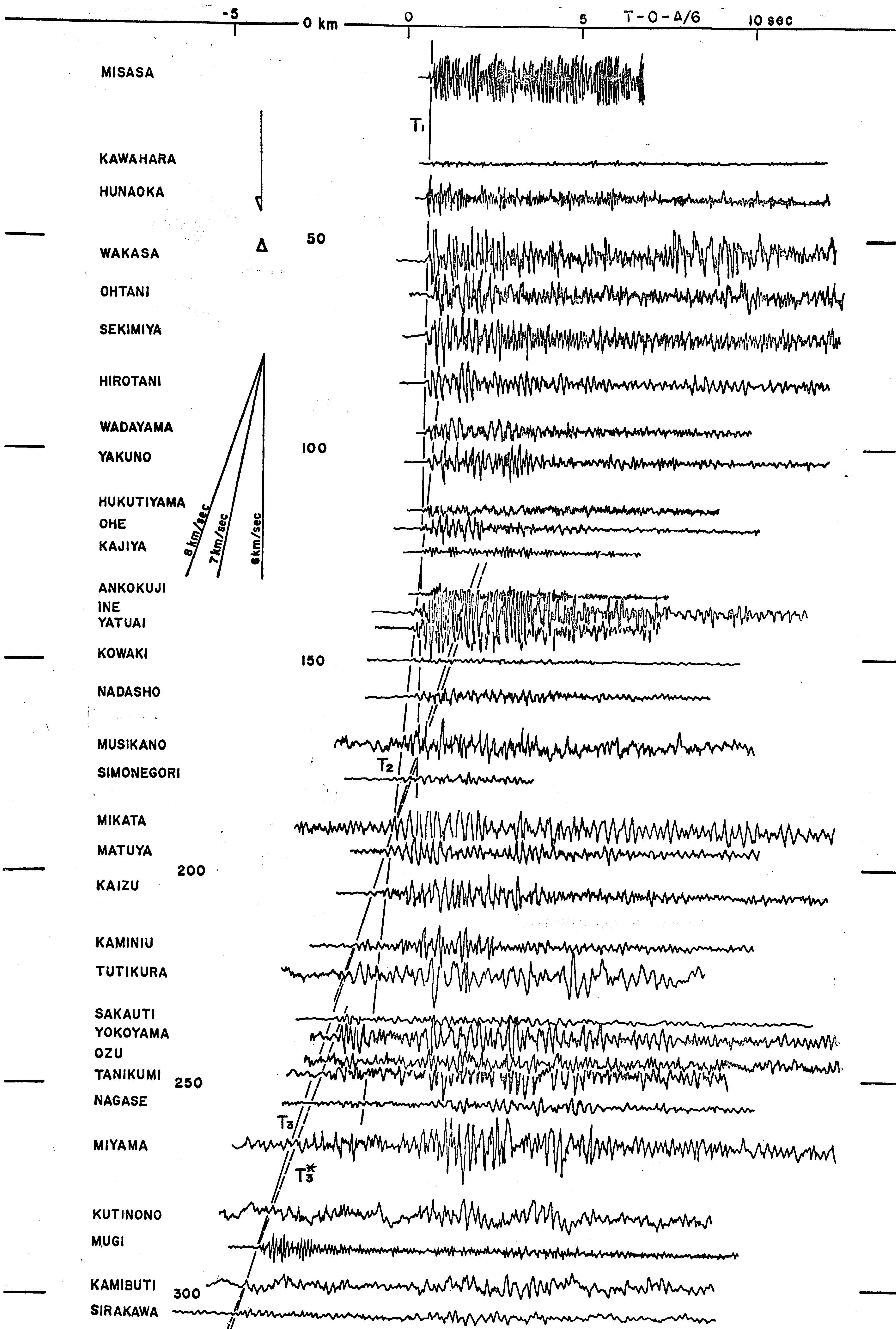

Fig. 5a. Record section of the Kurayosi explosions (Model 1 and 1*).

[Bull. Earthq. Res. Inst., Vol. 48, Pl. 26]

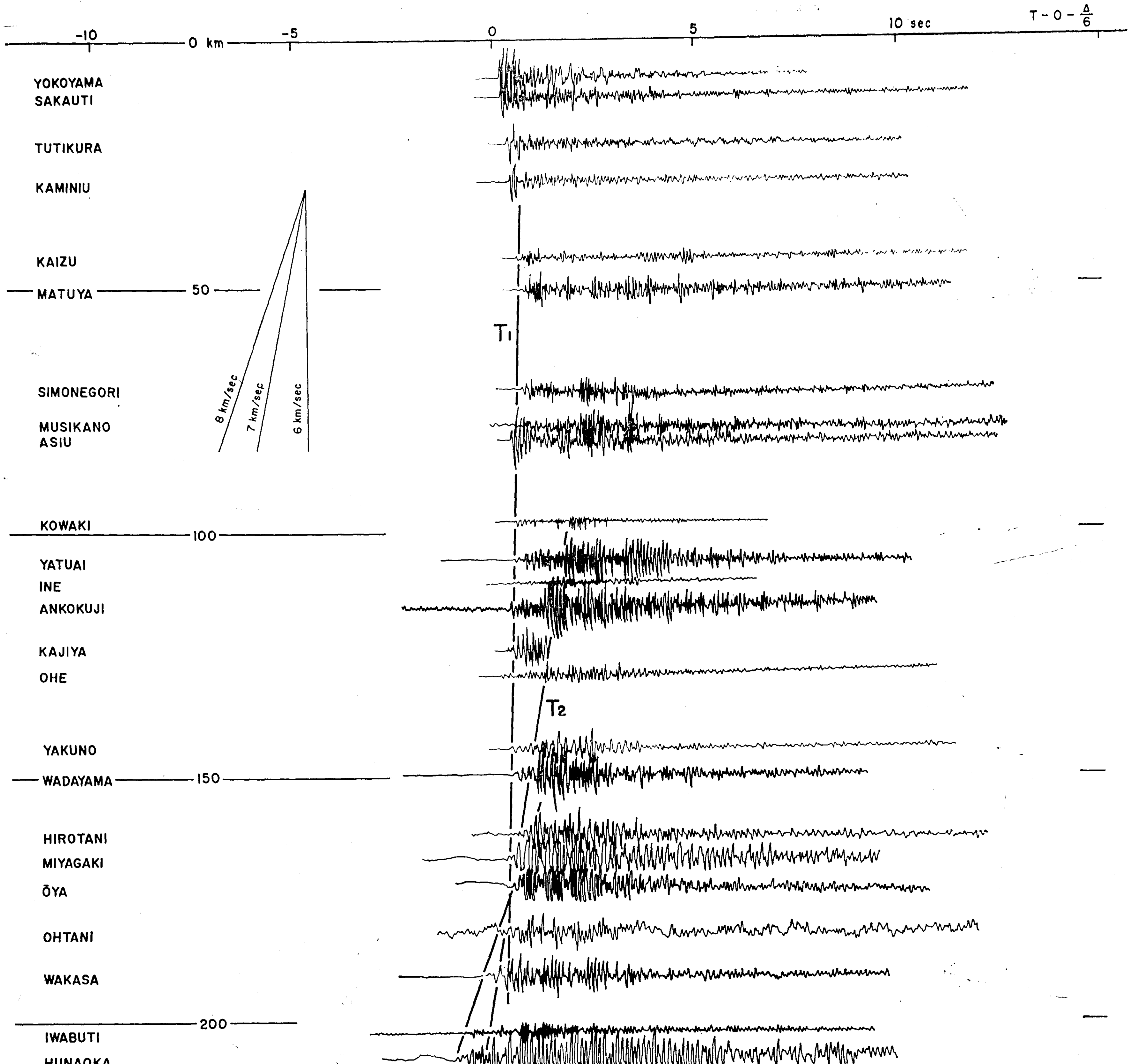

Fig. 5b. Record section of the Hanabusa explosions (Model 1 and 1*).

[Bull. Earthq. Res. Inst., Vol. 48, Pl. 27]

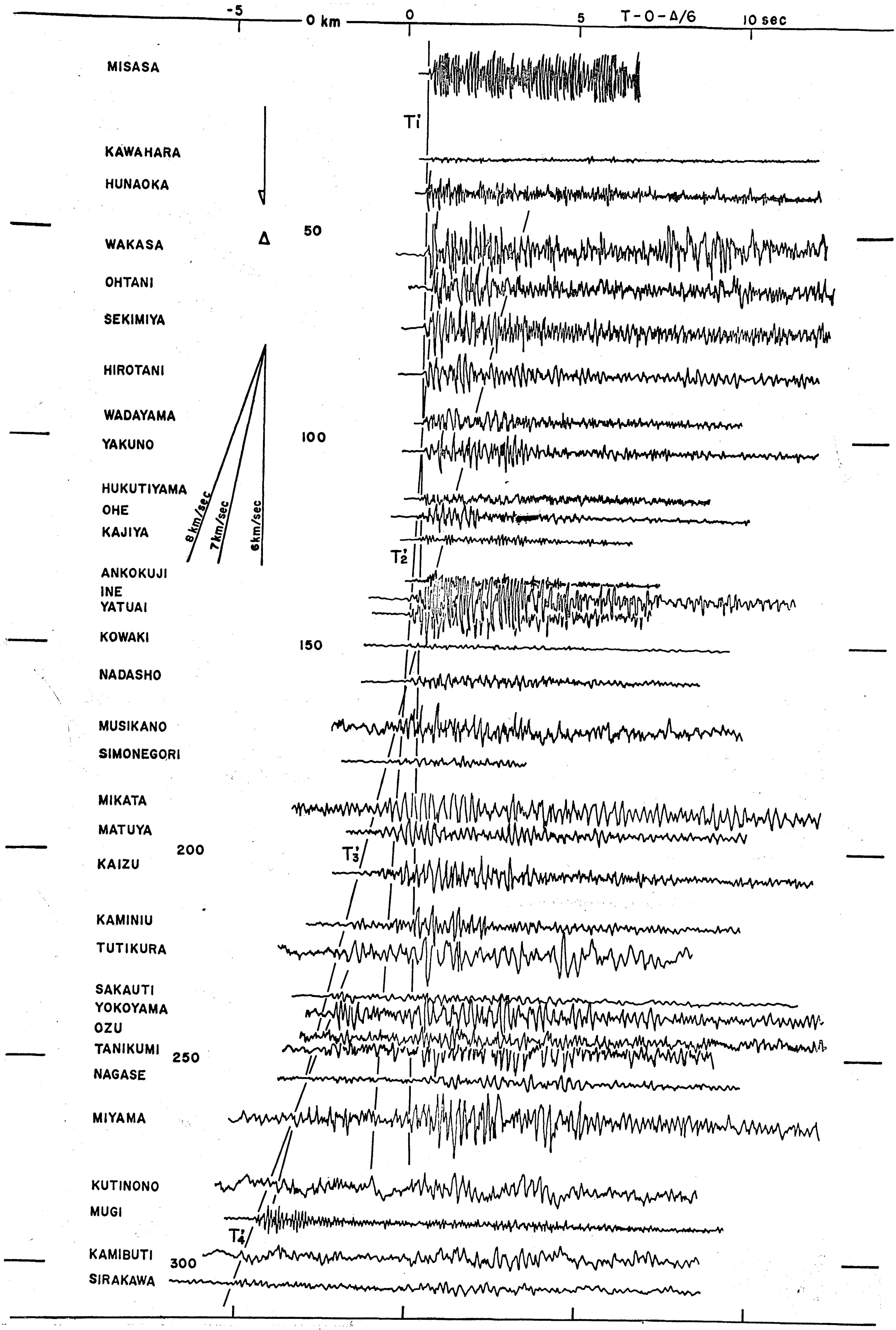

Fig. 6a. Record section of the Kurayosi explosions (Model 2).

(震研彙報 第四十八号 図版 佐々木・浅野・村松・橋爪・浅田)

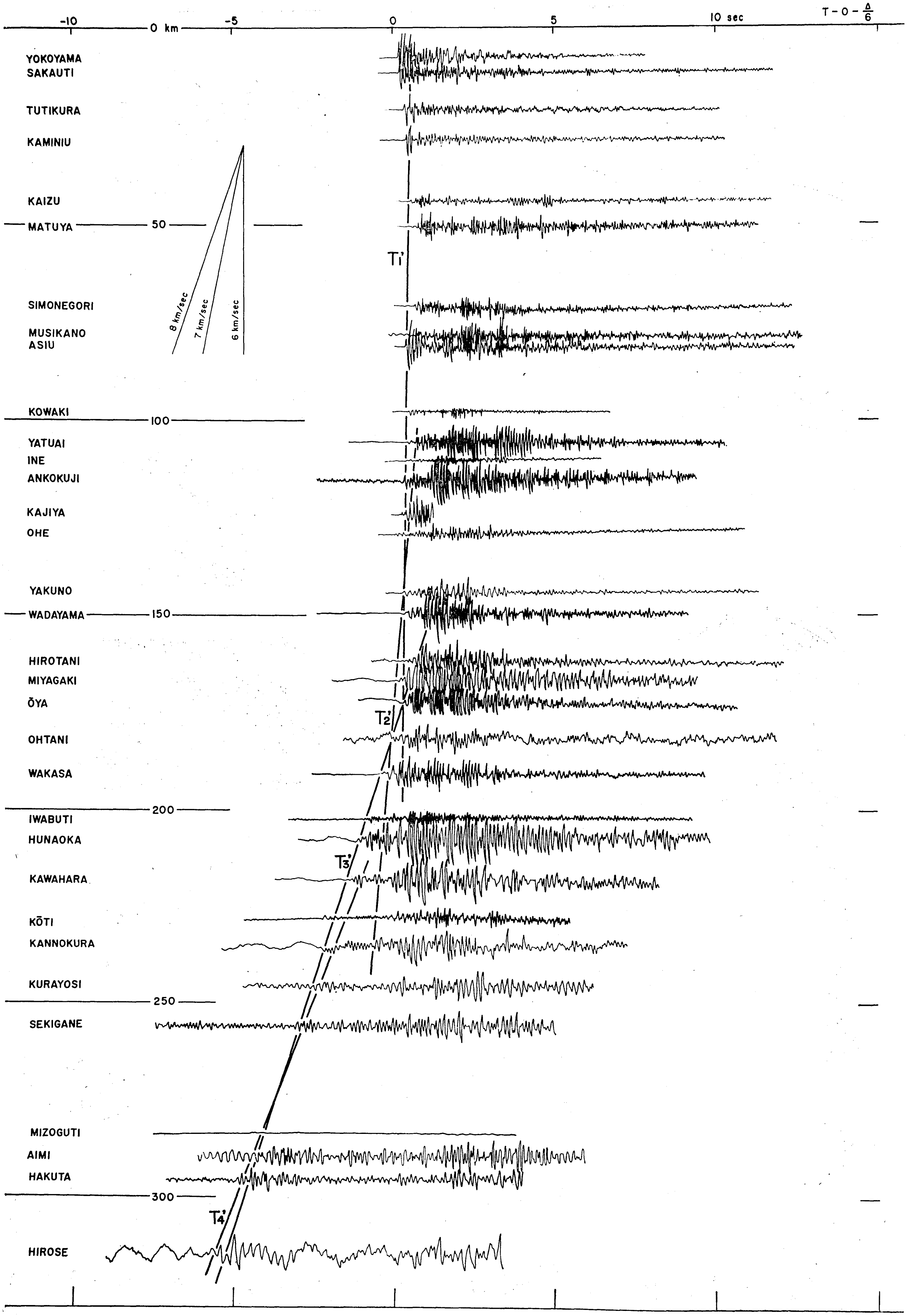

Fig. 6b. Record section of the Hanabusa explosions (Model 2).