URGENT REPORT ON THE CHIBAKEN-TOHHO-OKI EARTHQUAKE OF 1987*

by

Choshiro TAMURA[1] and Kazuo KONAGAI[2]

1. PREFACE

A powerful earthquake with the magnitude of 6.7 on the Richter scale occurred Thursday morning (11:08a.m.), December 17, 1987. The epicenter was located at 7km east off the Taitozaki on the eastern shore of the Boso Peninsula, Chiba Prefecture, and the focus was 58km beneath this point. An Intensity of V on the JMA scale was recorded in Choshi (Δ=56km), Chiba (Δ=48km) and Katsuura (Δ=24km), and the fairly wide area where an intensity of IV was recorded includes Ajiro (Δ=130km), Tateyama (Δ=66km), Mito (Δ=120km) and Kawaguchi-ko (Δ=130km)(Fig.1). Though this earthquake was said by many Tokyo and Chiba residents as the strongest one they had ever felt, the authors could see quite few damages in the narrow epicentral area ($\Delta \leq$20km), and the press and television toned down their reports on this quake before long. However, we found some damages in places on our reconnaissance. They would be evidences that the ground shook with remarkably great acceleration. The amplitude of the ground acceleration may have exceeded that in the Kanto Earthquake of 1923 in a moment. It is a common recognition to many researchers in the field of earthquake engineering that hardly any severe damage on a public structure can be seen in the area with an epicentral distance greater than 10km. Thus, it would be unforeseen case that an elevated railway bridge located about 80km away from the epicenter was severely damaged by the quake. These phenomena are suggestive of the peculiarity of this earthquake. This is urgent wrap-

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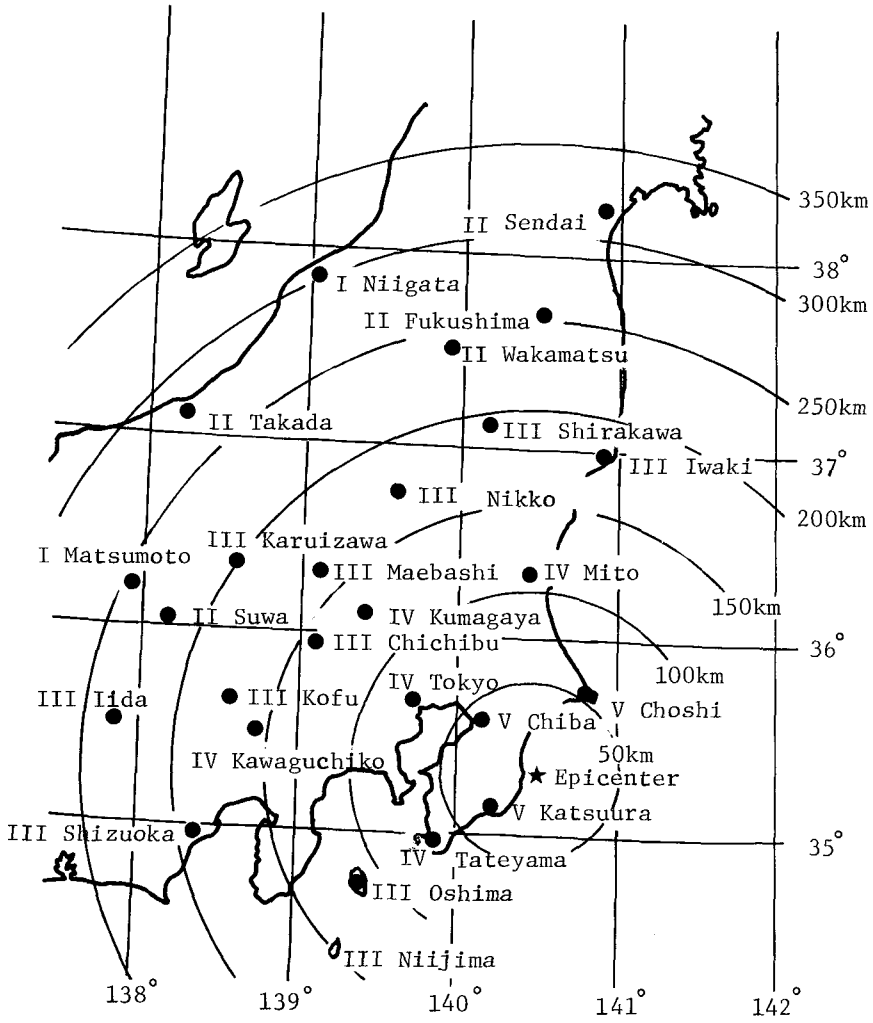
1) Prof., Institute of Industrial Science, Univ. of Tokyo
2) Assoc. Prof., Institute of Industrial Science, Univ. of Tokyo

* Temporary name in Japanese. "East off Chiba Prefecture Earthquake of 1987" is the literal translation of this name, and used in the Prompt Report on Strong-Motion Accelerograms, No.36, National Research Center for Disaster Prevention.

Roman numeral: Intensity in the JMA scale



Epicenter and Intensities (JMS)
(after"PROMPT REPORT ON STRONG-MOTION ACCELEROGRAMS No37, National Research Center for Disaster Prevention)

up of our findings obtained through the reconnaissance.

2. ELEMENTS OF THE EARTHQUAKE

The elements of this earthquake are as follows ;

Origin time : 11h 08m a.m., Dec. 17, 1987
Epicenter : Long. 140°29'E, Lat. 35°21' N
Focal depth : 58km
Magnitude : 6.7

The Japan Meteorological Agency (JMA) reported 99 aftershocks in the three hours after main quake. They includes 7 major shocks whose intensity on Japan scale was registered. However, the occurrence rate of the minor quakes decreased to 10 times/hours after 1:00 p.m. while it was 45 times/hours between 12:00 and 1:00 p.m.

The Earthquake Resistant Structure Research Center (ERS) at the Institute of Industrial Science (IIS), Univ. of Tokyo was succeeded in recording the ground tremor in the diluvial deposit at the Chiba Experiment Station (IIS) using an array of 36 three-component accelerograph networks, and also obtained records of response of weak model structures at this site. The deposit in this experiment station consists of a top soil layer, loam, clay and sandy clay layers with a deep sandy base underlayed. The maximum acceleration near the surface (1.0m beneath the G.L.) was 326gal in N-S direction and 216gal in E-W direction. These values are almost three times of those recorded at the depth of 40m. The strong tremor lasted about 7s. Findings obtained through the study of these records are reported in the other papers in this bulletin.

3. RECONNAISSANCE

After the earthquake, we surveyed the damaged area three times. The party for the reconnaissance consists of the following persons;

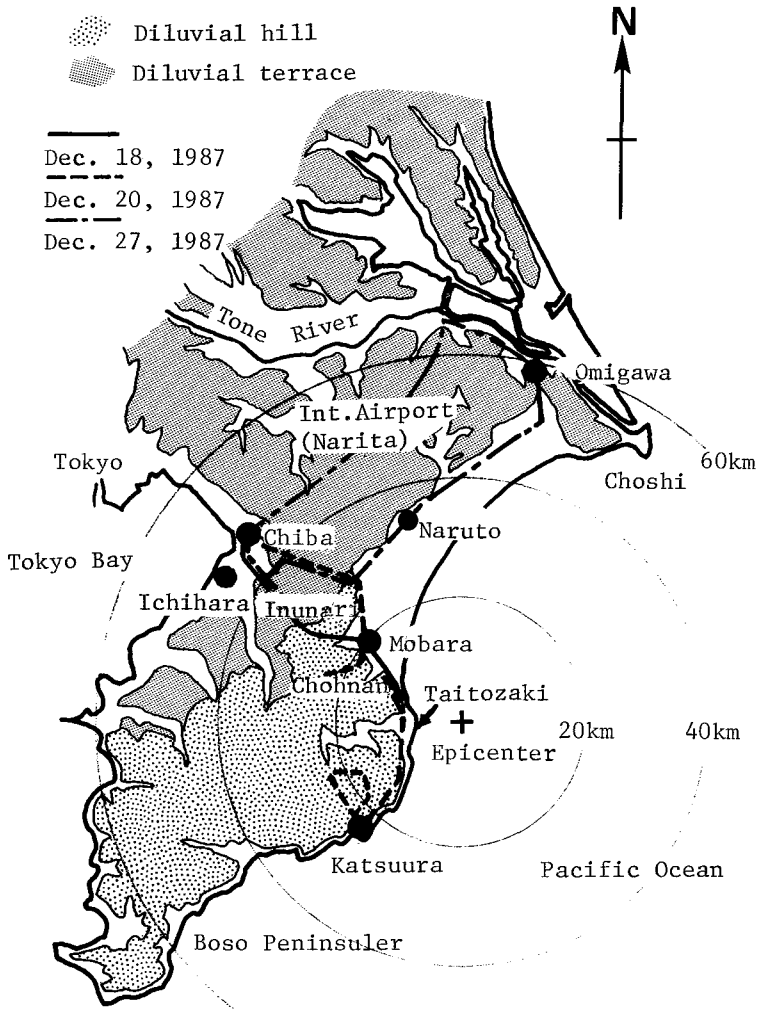


Fig. 2 Route of Reconnaissance

Shunzo	Okamoto	Prof. Emeritus, Univ. of Tokyo
Choshiro	Tamura	Prof., IIS, Univ. of Tokyo
Kazuo	Konagai	Assoc. Prof., IIS, Univ. of Tokyo
Takeyasu	Suzuki	Researcher, IIS, Univ. of Tokyo
Shinji	Takeuchi	ditto
Mitsuhiro	Inamori	ditto
Dong	Jun	Post graduate student, Univ. of Tokyo
Masaru	Noda	ditto
Zheng	Jingzhe	ditto
Kiyotake	Sakai	Technical assistant, IIS, Univ. of Tokyo
Toshihiko	Katagiri	ditto

The routes we took are schematically depicted in Fig.2.

* Buildings

One of the most conspicuous damages on structures are collapse of ridge tiles on roofs of wooden houses. Many of them can be seen in the area with the epicentral distance $\Delta \leq 50$km. We, however, found that quite few houses lost their roof tiles in the vicinity and the south-western area of the Taito-zaki, though the area is the closest to the epicenter in the Boso Peninsular. Many outcrops of mud rock or sand rock in this area show that the ground is firmly solidificated. This ground condition seems to have mitigated remarkably the damage on roof tiles. In the area encompassing the vicinity of the epicenter ($20\text{km}<\Delta<50\text{km}$), large regional deviation in a damage on roof tiles can be seen. It will be a general feature that there are many damaged houses on an alluvial formation near diluvial hills. In Chonan-Town located on a long and narrow valley, almost half of the whole houses (=3000) were rocked to loose their ridge tiles, and we could see that almost houses in Ozawa district were severely damaged. However, special attention should be paid on the fact that there are some evidences of severe tremor even on diluvial formations. Inunari is one of the villages on those hills. This village faces a prefectural highway connecting Chiba City and Mobara City, and is about 35km away from the epicenter. Almost ridge tiles fell onto the ground north-west side of these houses. In the grave yard near the village, all tombs were collapsed, and some of them

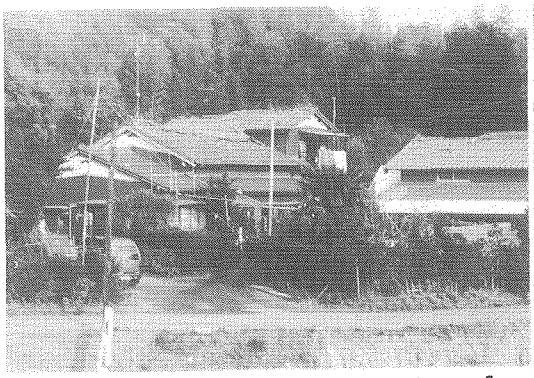


Photo. 1 Damage to ridge tiles of wooden houses(Chonan town)

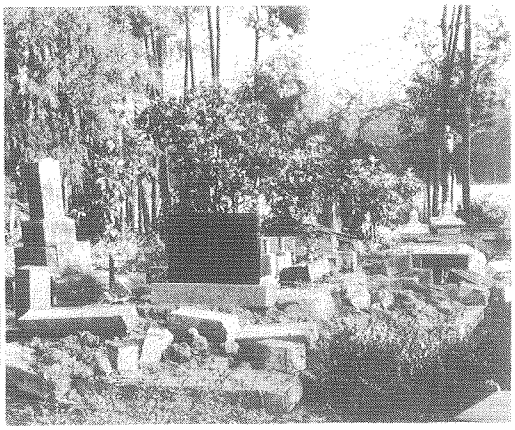


Photo. 2 Collapse of grave stones (Inunari village)

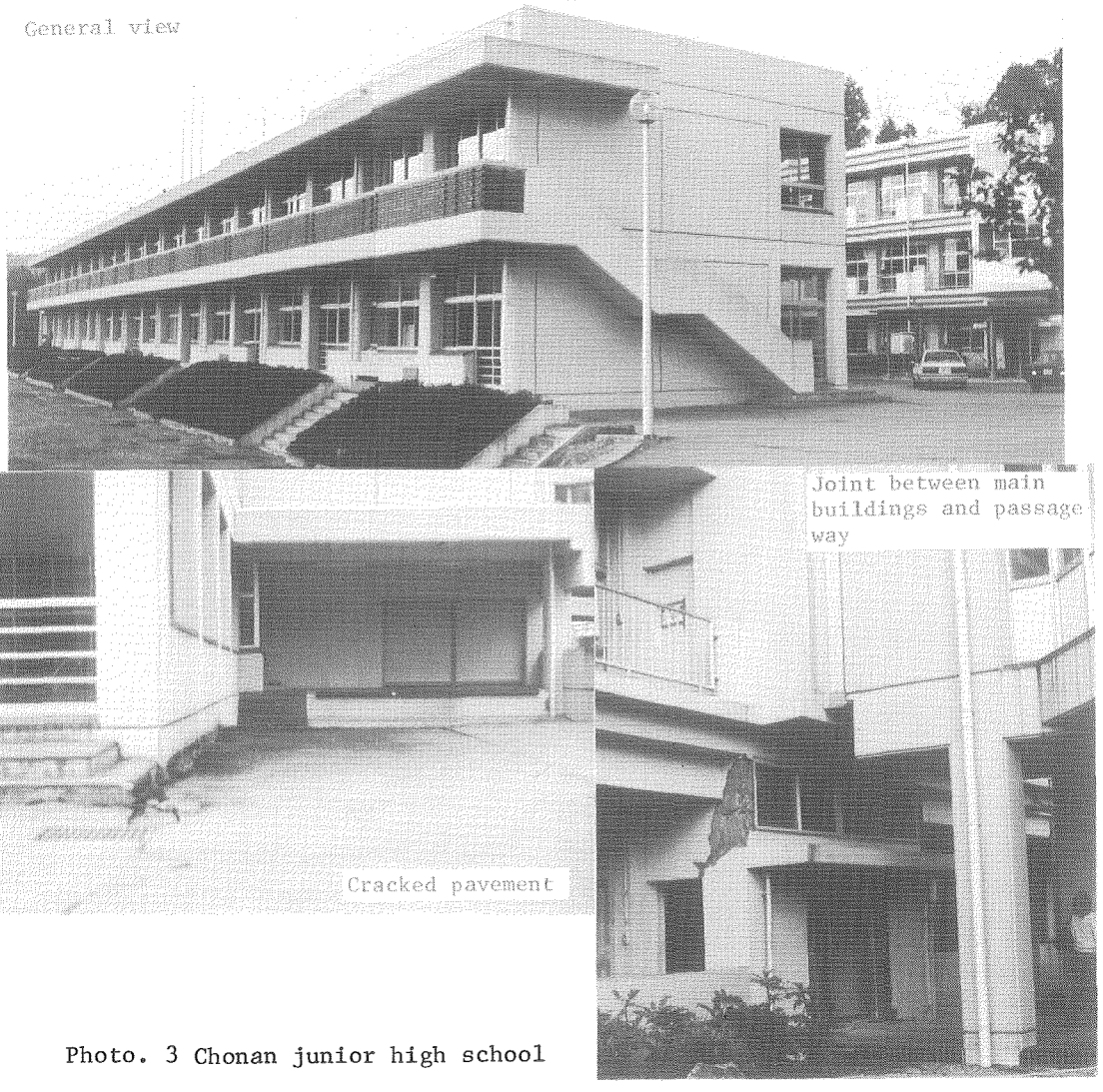


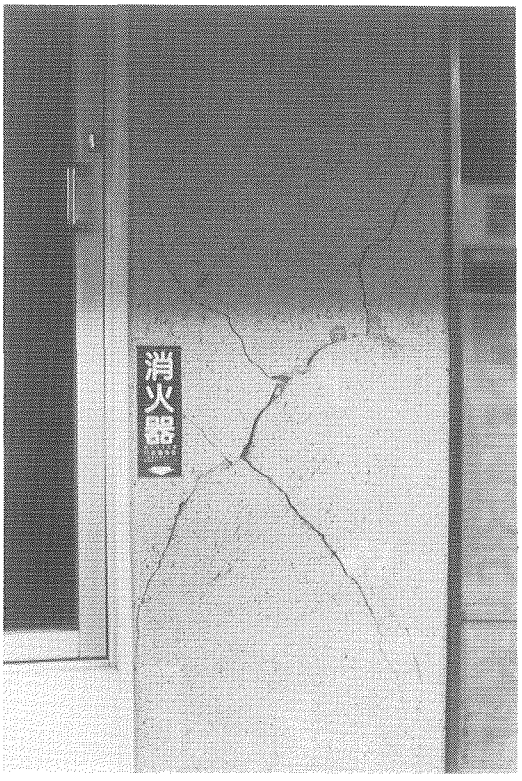
Photo. 3 Chonan junior high school

Photo. 5 Mobara city hall

The front of the city hall

Cracked wall

Photo. 4 X-shaped shear crack on a column in Chonan town hall



appeared their charneles, and we could see some evidences that the tomb stones had been shifted in north-west direction.

Quite few R-C buildings are severely damaged by the quake. The buildings of Chonan Junior-High School and the Chonan Town Office were examples of these few. Either of them was constructed over a cut terrace and sandy embankment on soft soil deposits. Chonan Town Office has a long rectangular base with its front entrance on its long side. The backside of this office underlays the cut terrace while front side was on sandy banking. X-shaped cracks on the walls parallel to the short side of this building is suggestive of a strong rocking motion of this building.

Mobara City Hall was also damaged by this earthquake. About 150 window panes with their frames fixed were broken. There were 17 conspicuous shear cracks on the walls, and an air conditioner was disordered.

* Dams and Embankments (Damage to Artificial Bankings)

In general, in spite of the strong tremor, hardly any damage on a civil engineering construction was observed in the vicinity of the epicenter, probably because of the shock of very short period. However the quake shook an elevated railway bridge in Miura City, Kanagawa Prefecture and a bank of the Tone River. The former structure is about 80km from the epicenter and the latter about 60km.

On Dec. 20, we inspected four earth dams in the vicinity. they are the Onjuku Dam (Δ=20km, 21m in height), Naguma Dam (Δ=18km, 18.5m in height), Azuma-the-First and the-Second Dam (Δ=20km, 22m (the first) and 21m (the second) in height) and Arakine Dam (Δ=24km, 34m in height). A witness, who happened to be just on the Onjuku Dam, put an emphasis on the strong vertical tremor of the embankment. Every road lamps on this dam was shaked with an amplitude of about 40cm or more. He saw minor ripples on the reservoir surface abated just before the strong quake, and after the severe tremor was over, the whole water surface was waving. We found an evidence of slight slippage at the movable support on the top of an intake tower bearing an access bridge. However this was the one and only evidence of the strong tremor we found through our inspection on the aforementioned 4 dams.

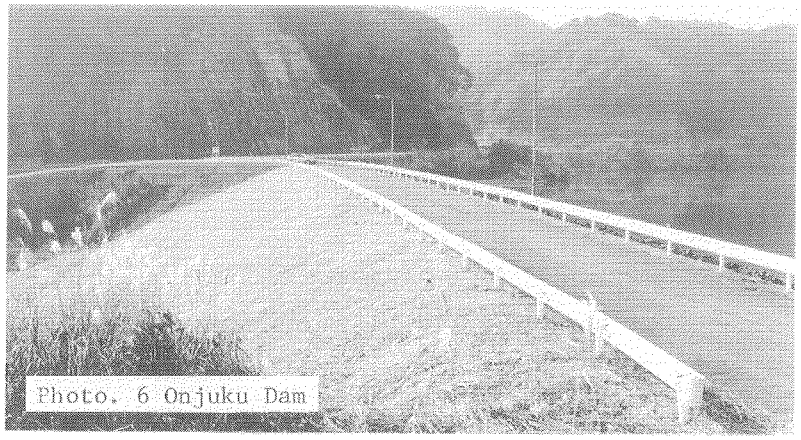


Photo. 6 Onjuku Dam

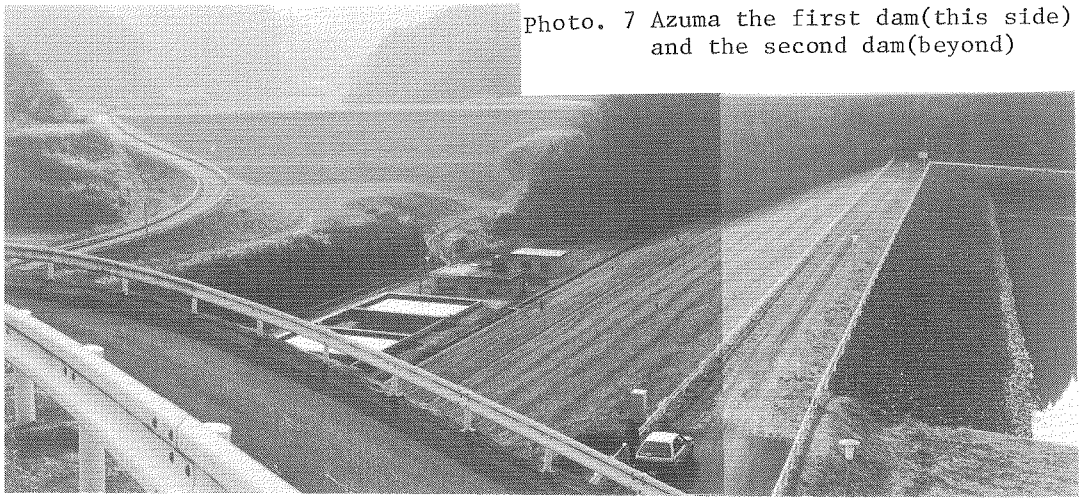


Photo. 7 Azuma the first dam(this side) and the second dam(beyond)

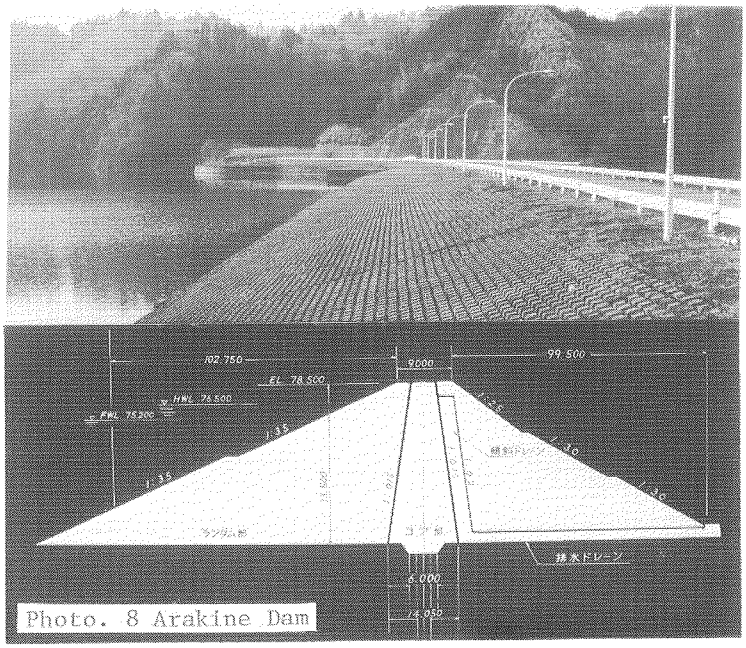


Photo. 8 Arakine Dam

On Dec. 27, we inspected the Nagara Dam (Δ=35km, earth dam, 52m in height) near the Inunari Village where some severe damages on houses and graves were seen. The schematic view of this dam was shown in Fig.3. We found some cracks on the pavement on the top of the dam, and a long and narrow soiled portion with width of about 10cm on the concrete wall of the spillway. This shows clearly that the embankment settled more than 10cm. The Moroichi Bridge crossing this spillway are pinned to abutments on both sides, and street drains on the abutments were crushed. However, there was no damage which brought the functional disorder into the dam.

The damaged portion of the bank of the Tone River we inspected lies between the Omigawa Bridge and Tomita district. The maximum horizontal acceleration of 185gal was recorded in this area. Damage to this banking was mainly a longitudinal fissure of pavements on this banking. Total length of these fissures twinning one another along the banking axis may have exceeded 2km, and the averaged width of the opened crack was about 1cm. We checked the toe of this banking slope, and could not find a clear evidence of failure.

In Manna region in Mobara City, the shoulder of a road was damaged by a slid of the slope with the height of around 5m. This road was banked up on a small valley, and the toe of this slope was bounded by a wet lotus field. The slid mass consists mainly of fine sand, and was oozing with water.

Damages to school grounds of sand banked up on soft soil deposits stood out clearly. The schematic map of the Nagara Junior-High School is shown in Fig.4. In this school, we could see a long cracks running across the school ground and reaching the access road. The half side of the ground which faces a rice field subsided to an extent of 7cm, and the thin steel tape inserted in the opened crack reached at the depth of 1.75m.

In the Chonan Junior-High School, the school ground constructed on a sandy banking with the height of about 5m was settled over the whole surface, and some evidences of liquefaction were seen in places. North part of this ground and the access road to school buildings were severely damaged by a slide of slopes(Fig.5). The slid area is about 25m in width and 30m in length. This slide resulted in an upheave of the tennis court

Photo. 9 Nagara Dam

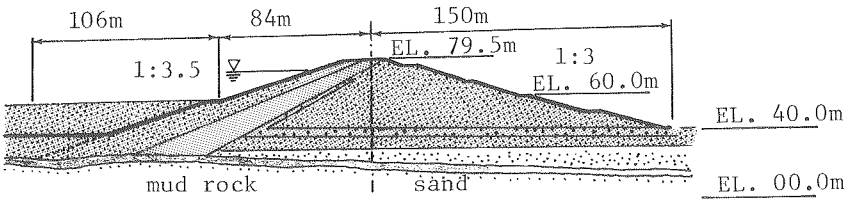


Fig. 3 Standard cross-section of Nagara Dam

Photo. 10 Backfill of spillway(subsided to an extent of about 10cm)

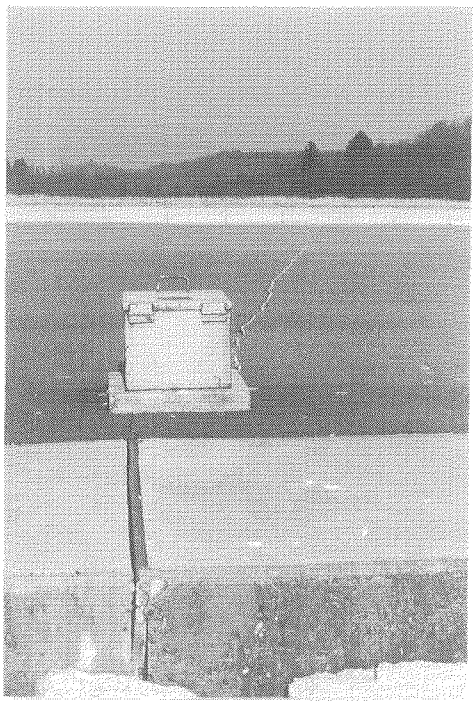


Photo. 11 Crack running across asphalt pavement at the top of dam from a piezometer box

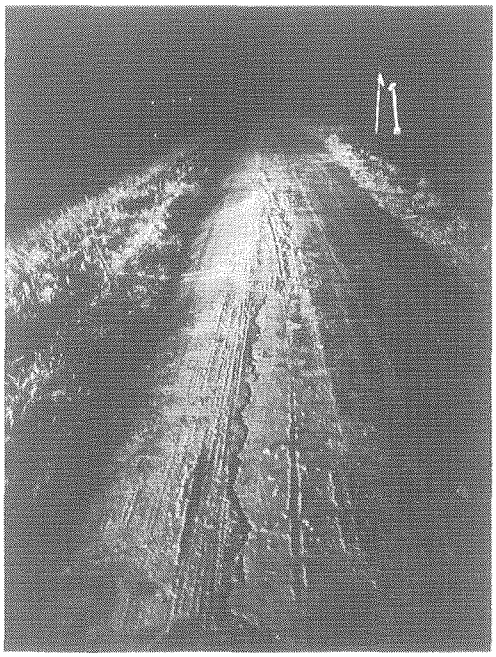


Photo. 12 Longitudinal crack on right side bank of the Tone River

Photo. 13 Collopse of a shoulder of road in Mobara city

Photo. 14 Cracks along the edge line of school ground (reclamated ground) and cracks on the slope

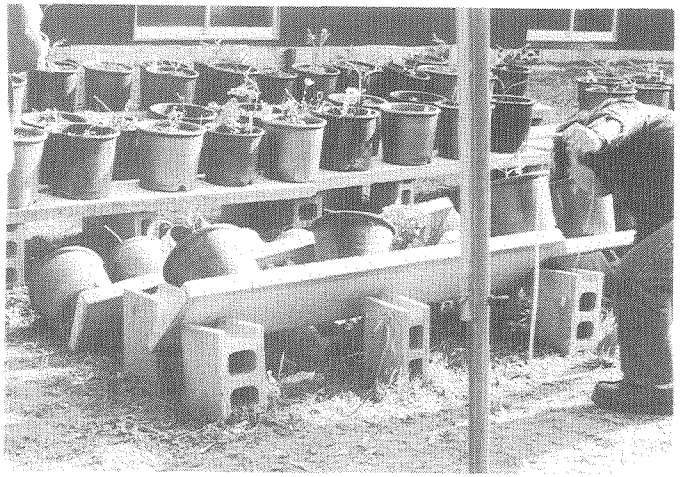


Photo. 15 Flowerpots fallen onto the ground (Nagara junior high school)

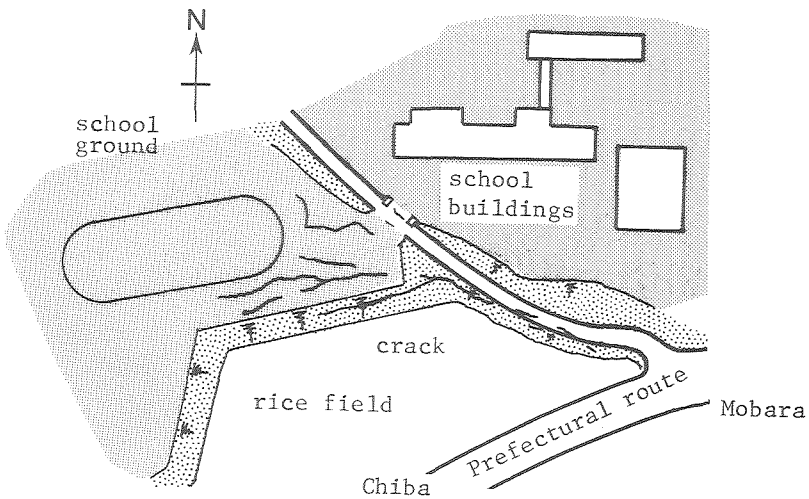


Fig. 4 Nagara junior high school

Photo. 16 Slide of slope of school ground
(Chonan junior high school)

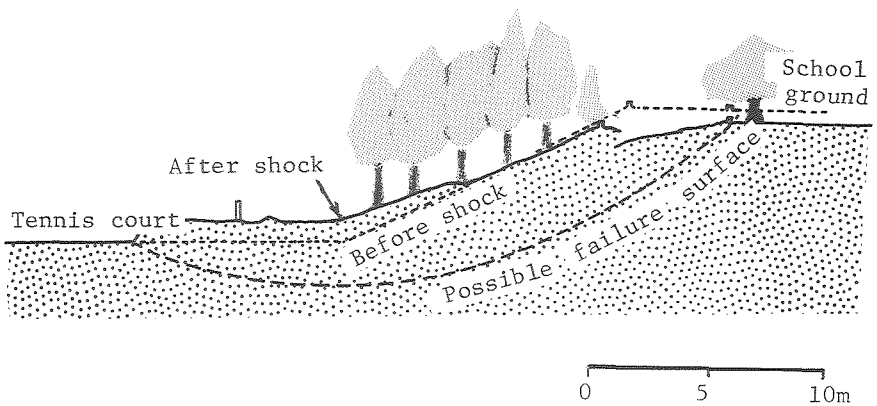


Fig. 5 Schematic cross section of damaged slope

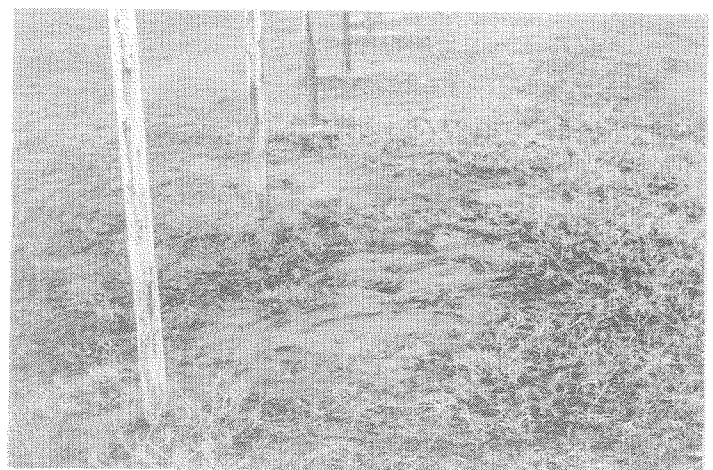


Photo. 17 Sand dunes due to liquefaction
on school ground

Photo. 18 Slope failure at Matsuo in Naruto town

Photo. 19 Stone gate of Washizu Shrine (The upper part fell down on the ground)

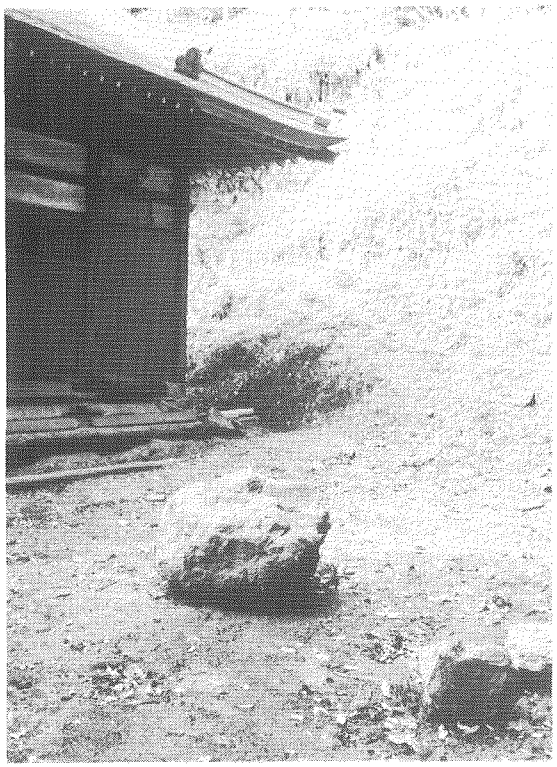


Photo. 20 Fallen stones by the shrine building

adjacent to the slope toe, and there were some sand boils on this upheaval, which must be an evidence that the banking was in remarkably wet condition.

* Slope Failures

Most of slope failures are concentrated in the valleys of many small tributaries, and boundary areas between diluvial terraces and widely spread alluvial low lands. Togane City and Naruto Town are representative towns in one of the later areas. We surveyed some slope failures which took place in Matsuo Town near the Naruto Town. The sites are fairly steep hill slopes with a gradient of around 60. The height of the terrace is about 30m. The collapsed material deposited on the lower concave slopes includes a lot of fine and wet sand particles. The deposited mass seemed to have slipped on a sand rock firmly solidificated or on hard clay. Some open cracks were observed along the slope shoulder on the surface of the terrace where soft humus is deposited. There are many other towns along the toe of this diluvial terrace. Oami Town is one of these towns and is closer to the epicenter than the aforementioned towns. However, we could hear little in reply to our inquire about occurrence of failures of slope.

In Hase region in Mobara City, a landslide took place. The collapsed zone are both sides of cutting in a tongue-shaped hill with the height of about 10m. Several stones with the radius exceeding 1m scattered on the road. The cut surface of the hill shows that the mass of rock of this hill belongs to mud silt sediment called "Kasamori Layer" which is not so hard. The fallen mass involving large stones must be a erosive surface of this rock. The road passing through the cutting leads to a small pond along the left hillside. The right-hand surface of the slope of this road was oozing with water, and the water ponded in the silty farm. This finding shows that the erosive surface of the hill was in moist condition.

The Washizu Shinto Shrine stands on a small terrace at the middle height of a diluvial hill in Mobara City. There were evidences of strong tremor in this shrine. The upper part of the stone gate fell down onto the ground. The stone steps on the hillside from this gate to the shrine building were settled, and several stones with radius of around 70~80cm were lying around by this building. It is obvious that they rolled down on

the rear hill slope to the terrace.

In the vicinity of the epicenter, few evidences of slope failure were observed. One of the few is the collapse of horizontally laminated rock cliff hanging over the sandy beach near the Taito Fishing Port (Δ=7km). Mud plates and sand plates solidificated lie one upon another, and belong to the so-called "Otashiro Layer". Since the rock is rather firmly solidificated in comparison with the aforementioned rock belonging to "Kasamori Layer", this collapse is suggestive of the strong tremor near the epicenter.

* Bridges

We could not find any severe damage on bridges. Most conspicuous evidence of quake observed is a slight settlement of approach. It was observed on the Nisshin Bridge and the Shouwa Bridge in Mobara City.

In Inunari village in Ichihara City, small evidences of strong tremor were seen on the pedestrian bridge crossing the prefectural highway connecting Chiba City and Mobara City. This is a simple-spanned steel beam supported on piers of steel pipe. The both piers were tilted a bit toward the highway. The concrete ring holding the pier at its base were cracked. And the floor slab was bent so that the center portion along the axis of the bridge was heaved a bit. We also could see a buckled portion on the lower franges of the bridge, though it is not confirmed it was resulted from the earthquake.

* Ports and Harbors

We surveyed two fishing ports in the vicinity of the epicenter. One is Taito (Δ=7km) and the other is Katsuura (Δ=24km). One of the quaywalls of the Taito Fishing Port was tilted forward slightly to an extent of 2 to 3cm which was followed by subsidence of the backfill. And this is one and only evidence of the quake we found.

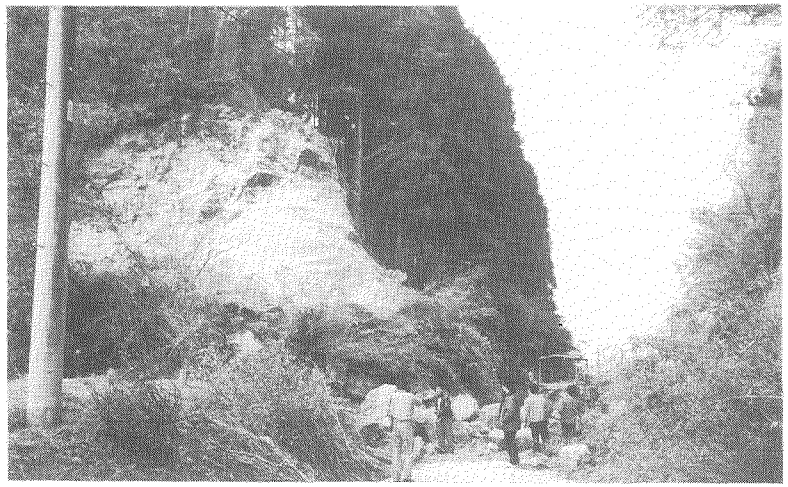


Photo. 21 Slope failure at Hase in Mobara city

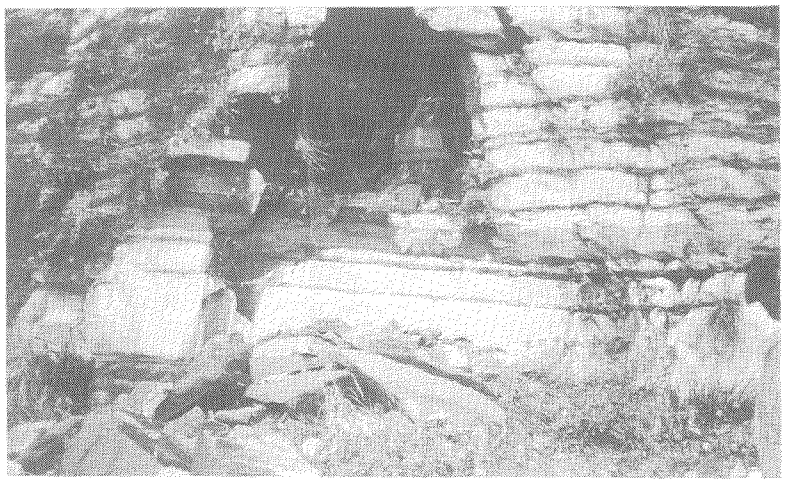


Photo. 22 Collapse of laminated rock near Taito fishing port

Photo. 23 Pedestrian bridge at Inunari village

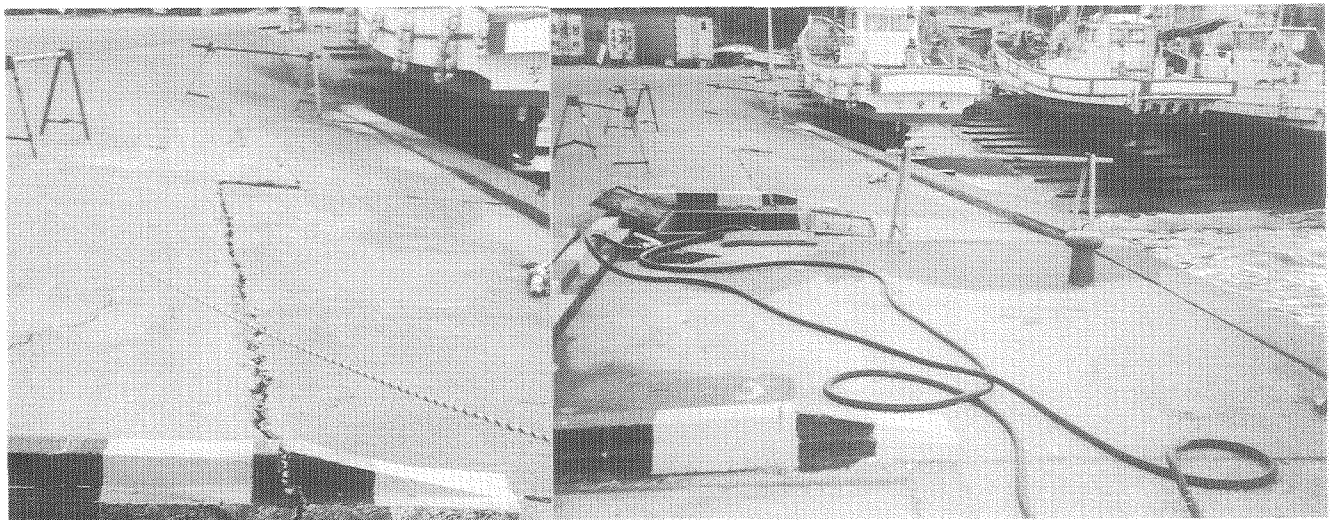
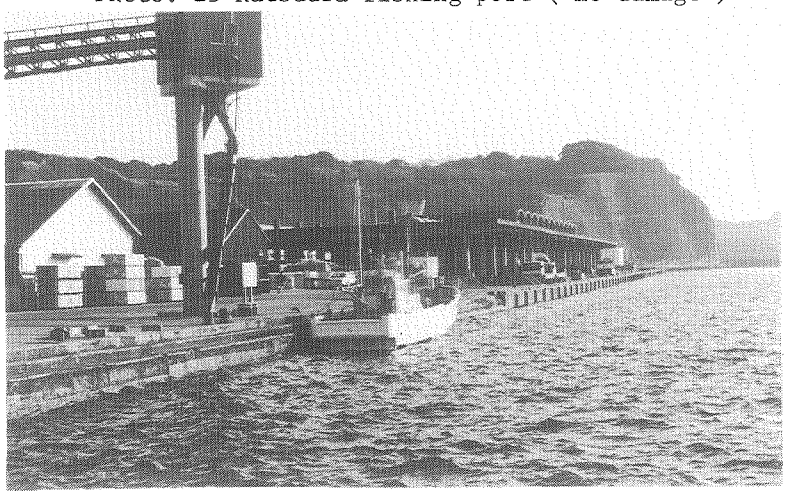


Photo. 24 Tilt of a quaywall and subsidence of backfill at Taito fishing port

Photo. 25 Katsuura fishing port (no damage)



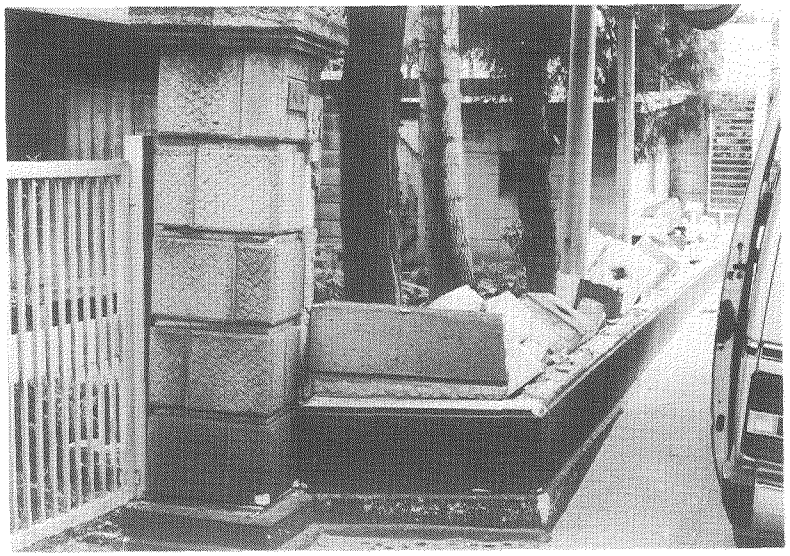


Photo. 26 Collapse of stone wall at Inunari villege

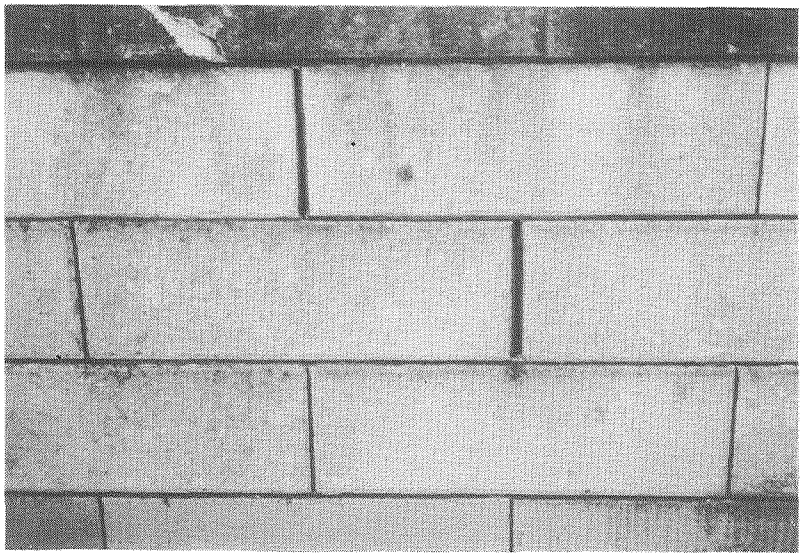


Photo. 27 Expanded stone block wall at Togoshi in Naruto town

Photo. 28 Collapse of grave stones in Ichihara city

* Others

Collapses of stone of concrete walls are also conspicuous. Distribution of the damages to these walls seems to have strong interrelation with those to ridge tile of wooden houses. In Ichihara City, it was reported that a collapse of a stone wall killed one person. In Inunari Village, a massive wall made of Ohya stone blocks cluttered the street, though there were deep scratches on each block to be cemented tightly. An interesting phemomenon was observed on a concrete block wall in Tagoshi region. This village lies along the boundary between a diluvial hill and widely spread alluvial low land. This wall was cracked and expanded in its longitudinal direction, which is normal to the terrace slope.

4. CONCLUDING REMARKS

Though the ground tremor by this earthquake is considered to have been fairly great especially in the vicinity of the epicenter, it is astonishing to see how small the damage to building and civil engineering construction is. On the other hand, there were exceptionally great damages in some areas far from the epicenter. Some severe damages to constructions seem to have resulted from nonuniform behavior of the ground supporting them. These phenomena show us the importance of geological and topographical effect, and urge us to study them keeping it in our mind that fairly high-frequency component of ground tremor showed up conspicuously in this earthquake, and may have affected the aforementioned phenomena. Our findings described above lacks deep considerations and discussions. However, we believe these findings are suggestive of fundamental mechanism of the appeared phenomena.

The authors are grateful to many related people and residents who have told us their experiences of this earthquake.