Geological conditions and soil deformations in the July 17, 2007, Chuetsu Off-shore Earthquake*
(Ver. 1.1)

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A powerful earthquake of M=6.7 occurred off the west coast of Kashiwazaki, Niigata Prefecture at 10:13 a.m. local time on July 17, 2007. The epicentral area is in a zone of slow and steady compressive tectonic movement. This movement has formed NNE-SSW-trending folds of sand, silt and mud rocks of tertiary geological time in areas spreading several tens kilometers east of Kashiwazaki. It was about three years ago, on Oct. 23, 2004, the Chuetsu Earthquake (Mid-Niigata Prefecture Earthquake) jolted one of these areas of active folding. In this earthquake of 2004, an abundant number of landslides in the epicentral mountain region forced the local authorities to suspend the operation of totally 233 segments of several prefecture routes and the national route No. 249.

Though the July 17, 2007, Chuetsu Off-shore Earthquake, has a similar tectonic mechanism in the active folding zone, geotechnical aspects of damage to houses and civil-infrastructures are largely different from those in the 2004 earthquake.

Fig. 1 compares the present satellite imagery in 2007 of Kashiwazaki (taken from Google Earth) and a topographical map of the same area in 1912. Kashiwazaki city spreads over a set of sand dunes, which has been elongated along the coast in such a way that it would bend mouths of both Ugawa and Sabaishigawa rivers southwest, two major rivers flowing into the Japan Sea. Sand, silt, mud and other suspended matters that waters of these two rivers have carried over centuries have been deposited south-east behind the sand dunes. **Fig. 1** shows that the old river trace of Ugawa had a meander near the south end of the sand dune and a lagoon at its mouth.

Fig. 2 is a map of cracks that appeared on pavements in the area enclosed with broken line in Fig. 1. Red and blue lines show respectively cracks opened (**Photo 1**) and compressed (including those colliding over the others, buckled up; see **Photo. 2**). Most clusters of opened cracks are seemingly found along ridges of the sand dunes while many compressed marks were found along toes of the dunes and some were found along an S-shaped sagged zone among the sand dunes.

Photo. 1: Crack opened along ridge of sand dune

Photo 2: Pavement buckled up

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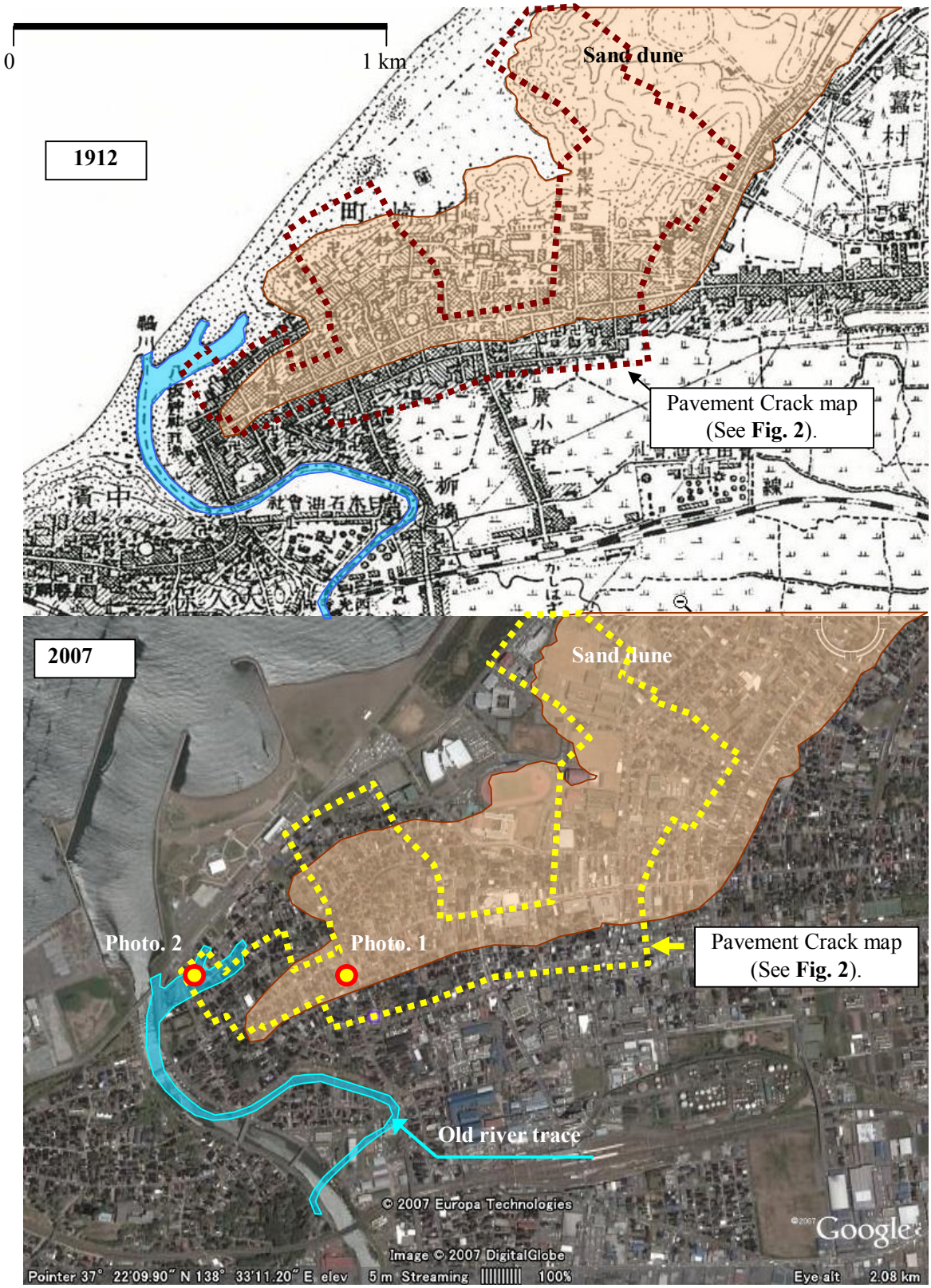

Fig. 1: Satellite imagery in 2007 of Kashiwazaki (from Google Earth) and a topographical map of the same area in 1912.

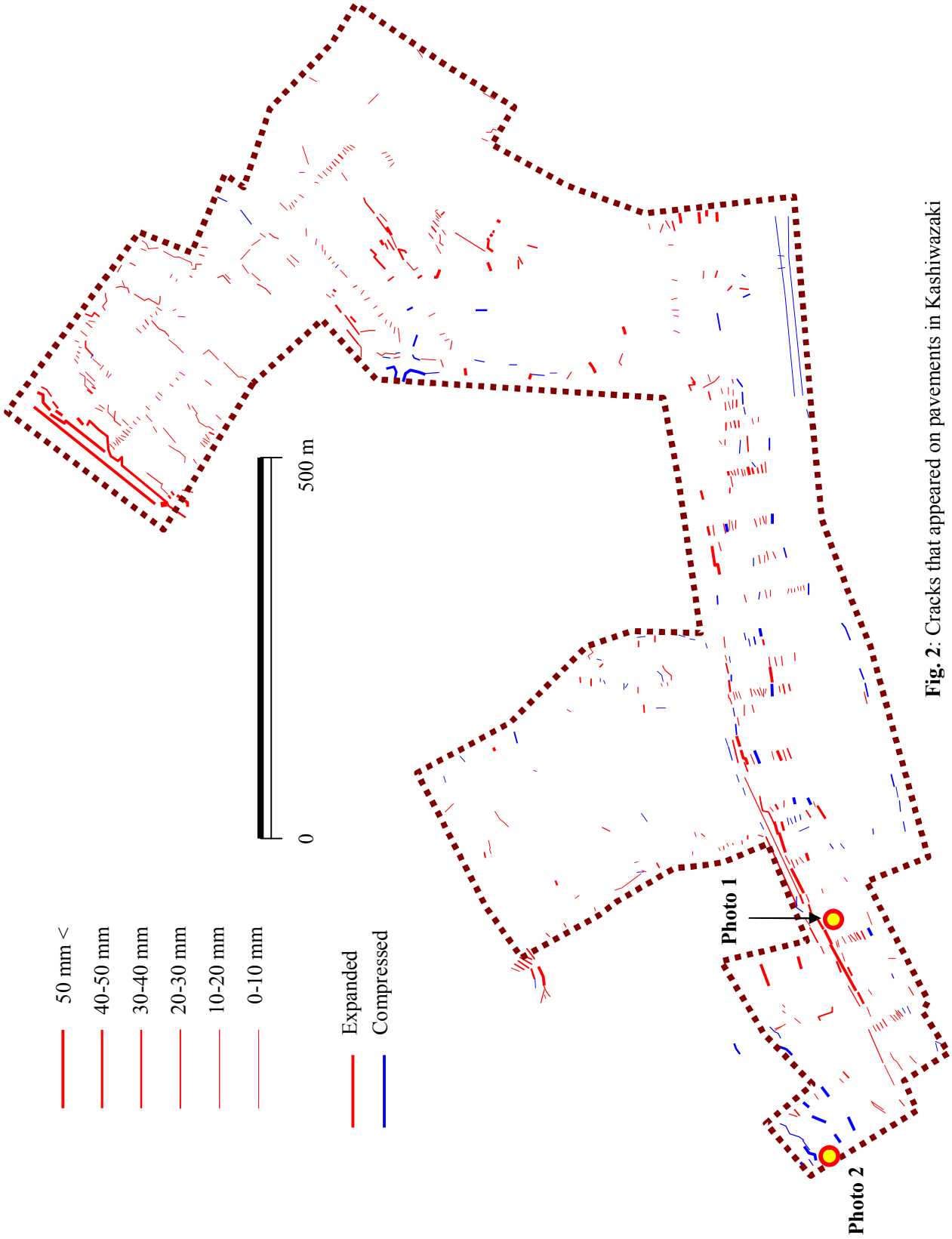

Fig. 2: Cracks that appeared on pavements in Kashiwazaki

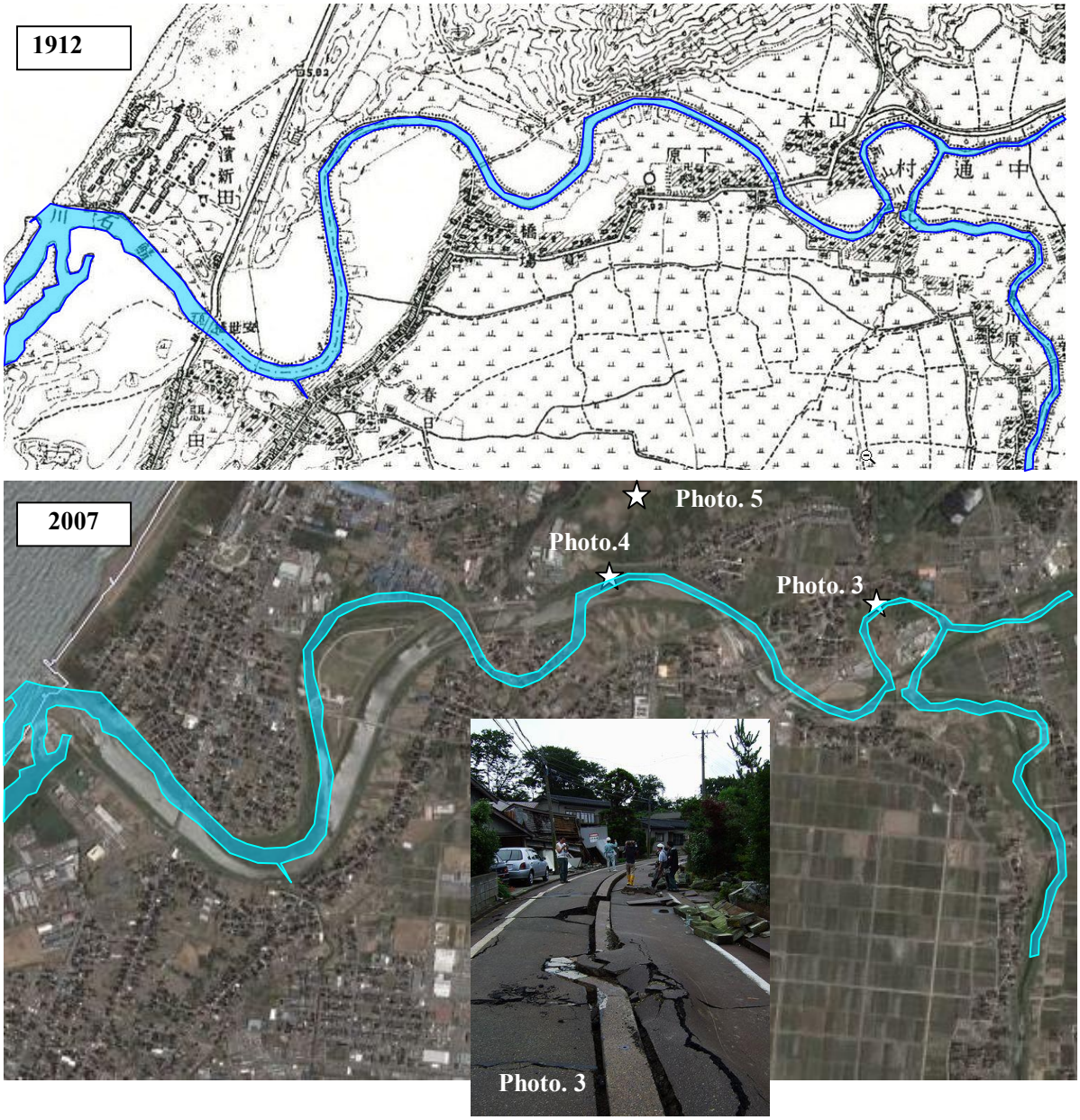

Fig. 3: Lower course of Sabaishi river, north of Kashiwazaki

Fig. 3 shows lower course of Sabaishi river in 1912 (above) and 2007 (below) respectively. Due to river improvement works, the present course has become shorter than that in 1912. Soil deformations are clearer along old river traces such as an old horse-shoe lake near Nakadori (**Photo. 3**). River erosion must have been clearly large on the outside of a river bend at the waste incineration plant of the city (**Photo. 4**). Immediately north of the plant, there is a sand dune of about 70m high above the sea level (**Photo 5**).

Photos 4 and **5**

A slope failure mass occurred at Oumigawa station of the JR Hokuriku railway, and covered its western approach (Photo 6). Water is seeping out along a layer boundary slightly dipping west across the entire terrace (see yellow arrows in Photo. 6 and Photo 7).

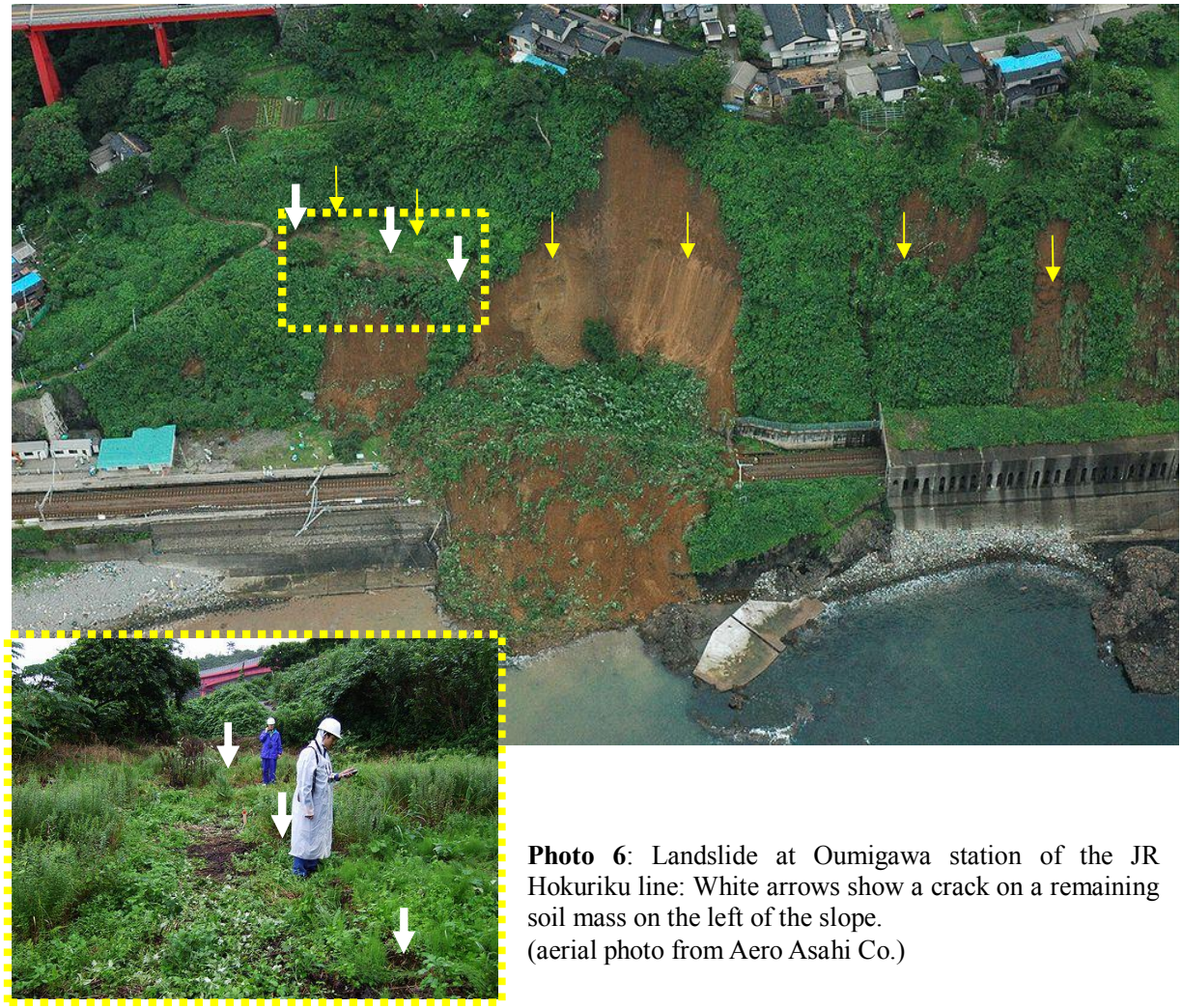

Photo 6: Landslide at Oumigawa station of the JR Hokuriku line: White arrows show a crack on a remaining soil mass on the left of the slope.
(aerial photo from Aero Asahi Co.)

At the time of our group's third visit to Oumigawa station on July 30, some recovery works have started and the soil mass covering the railway has been partially removed. The geological stratification was inferred from a close-up of the failure surface that appeared south behind the station (**Photo 7**).

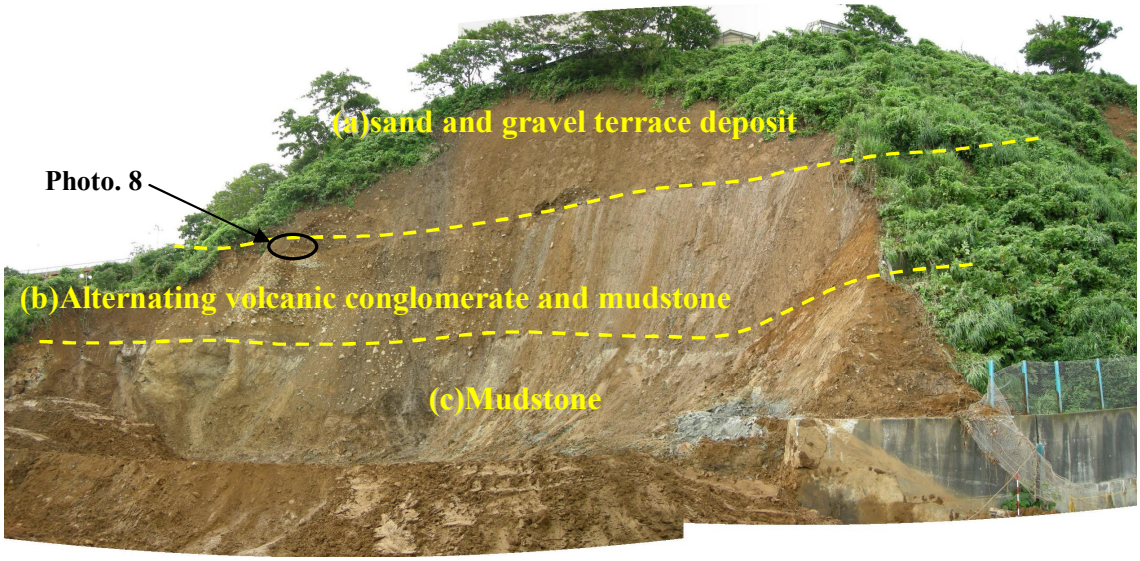

Photo 7: Failure surface with geological stratification.

There are three major geological formations exposed on the failure surface: (a) sand and gravel terrace deposit, (b) inter-bedding formation of volcanic conglomerates and mudstones, and (c) mudstone, from the top.

(a) Sand and gravel terrace deposit
This terrace deposits dates back to the geological time of about 0.11Ma (Kobayashi et al, 1995). Streaks from layer boundaries show that ground water is seeping out from the boundaries among the exposed geological formations (see **Photo. 9**). Yoneyama formation ((b) and (c) in **Photo 7**), immediately below the (a) terrace deposits, is inferred as a base rock of Pliocene period. It has a strike in nearly E-W direction and dips about 8 degrees to north (Kobayashi et al, 1995).

(b) Inter-bedding formation of volcanic conglomerates and mudstones
This inter-bedding formation consists mainly of volcanic conglomerate. Thin lenses of mudstone are found bedding in at some locations along the boundary between two formations (a) and (b) (**Photo 8**). These lenses are weathered, and are more compact than the overlying terrace deposit.

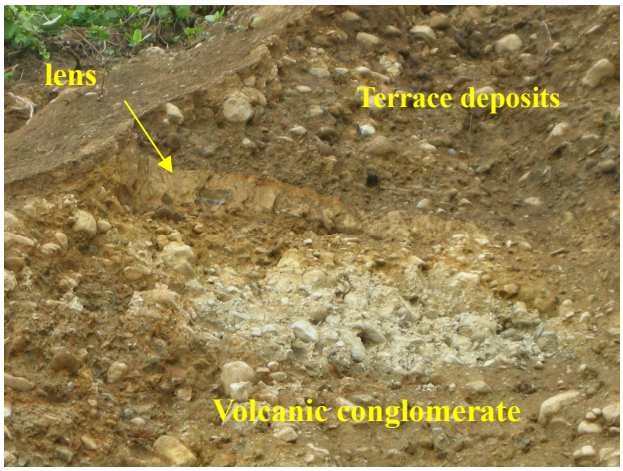

Photo 8: Thin lens of mudstone.

(c) Mudstone
The lower gray part is rather intact, but upper light-brown part is weathered. This mudstone is compact, and no clear bed is seen. According to cores taken from borings performed after the earthquake, there is volcanic conglomerate spreading beneath this mudstone formation, at about the same level as the railway elevation. This can also be inferred from the geological map.

With an infrared camera (NEC SanEi TH702MV), we took images of the whole failure surface. Blue to green streaks of underground water (20-25 degrees on Celsius scale) are found seeping out at some locations along two major boundaries among the geological formations. This information together with the geological information can be useful for the recovery works. E.g. drainage installations can be concentrated in areas where waters are seeping out.

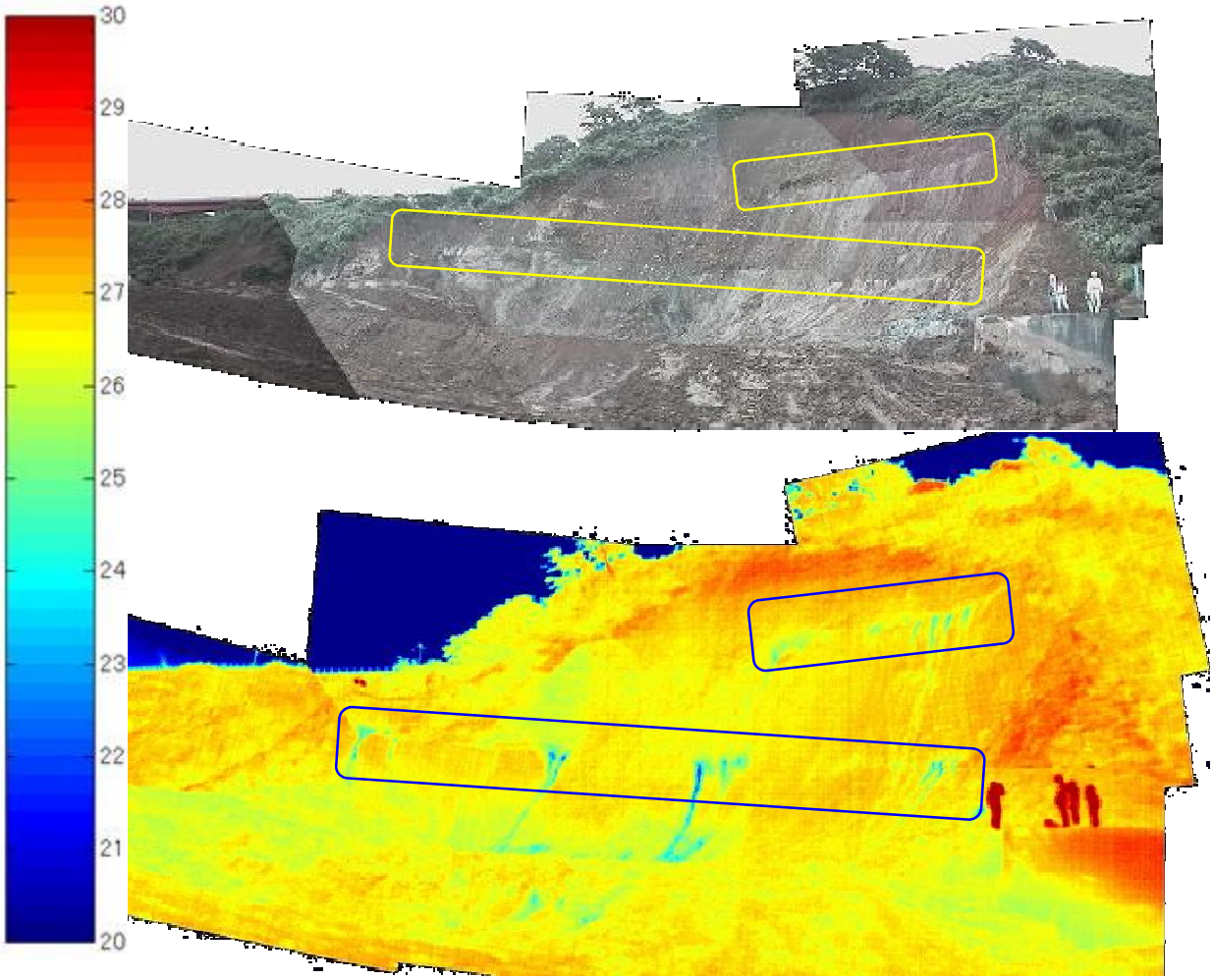

Photo 9: (a) normal and (b) Infrared image of slope surface. Color scale shows "degrees" on Celsius temperature scale.

References:

Kobayashi,I., Tateishi,M., Yoshimura,T., Ueda,T. and Kato,H. (1995) : Geology of the Kashiwazaki district, Geological Survey of Japan, 102p