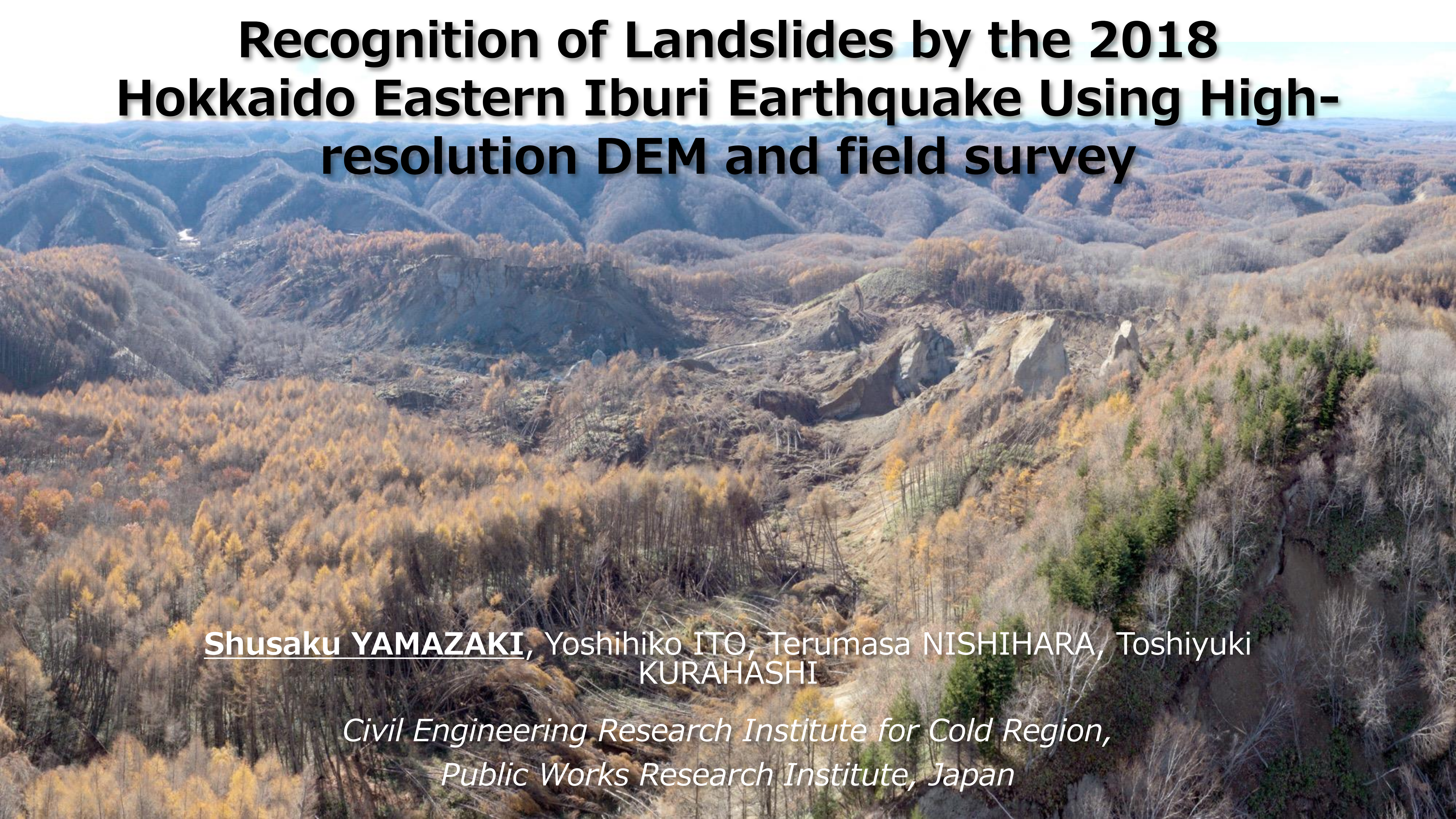
Recognition of Landslides by the 2018 Hokkaido Eastern Iburi Earthquake Using High-resolution DEM and field survey



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Introduction: the 2018 Hokkaido Eastern Iburi Earthquake

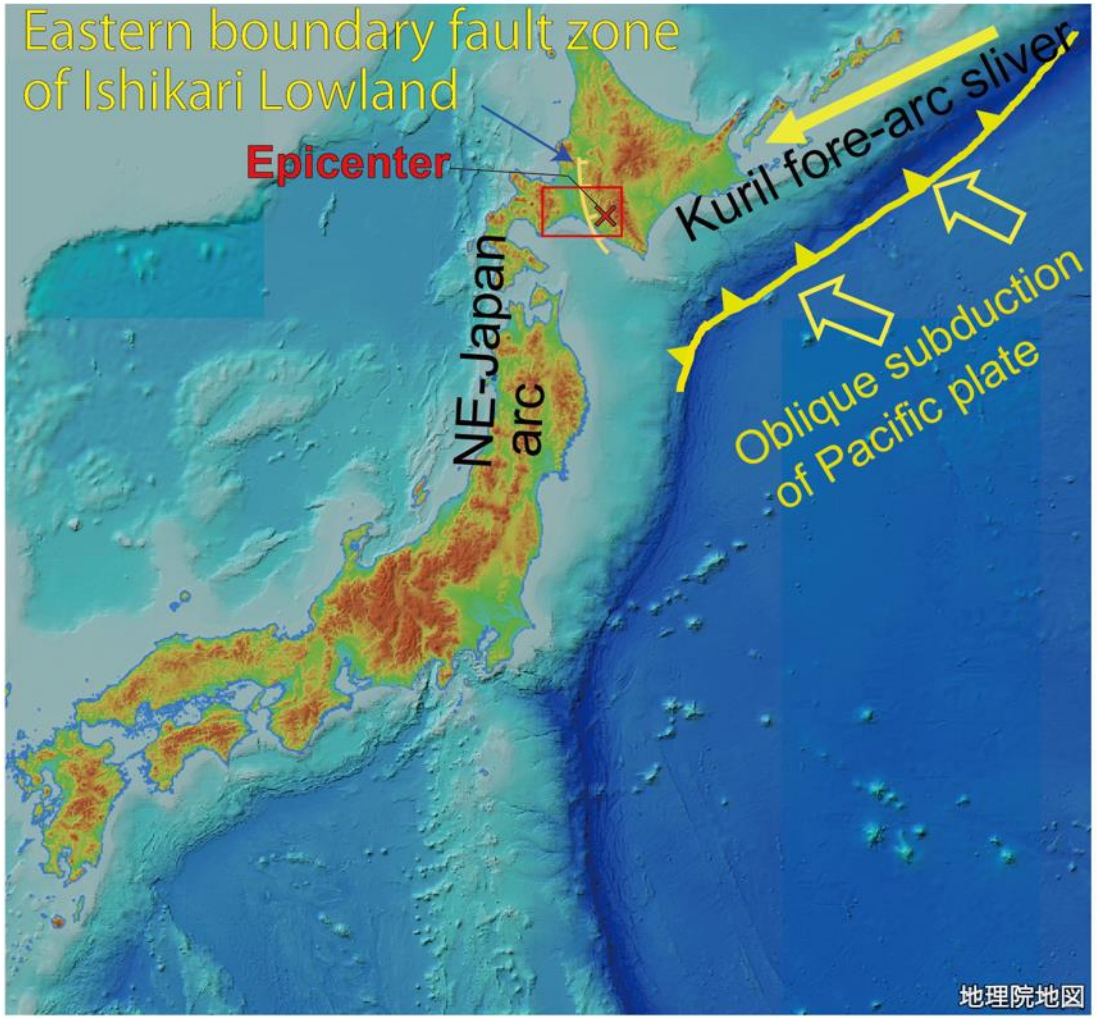


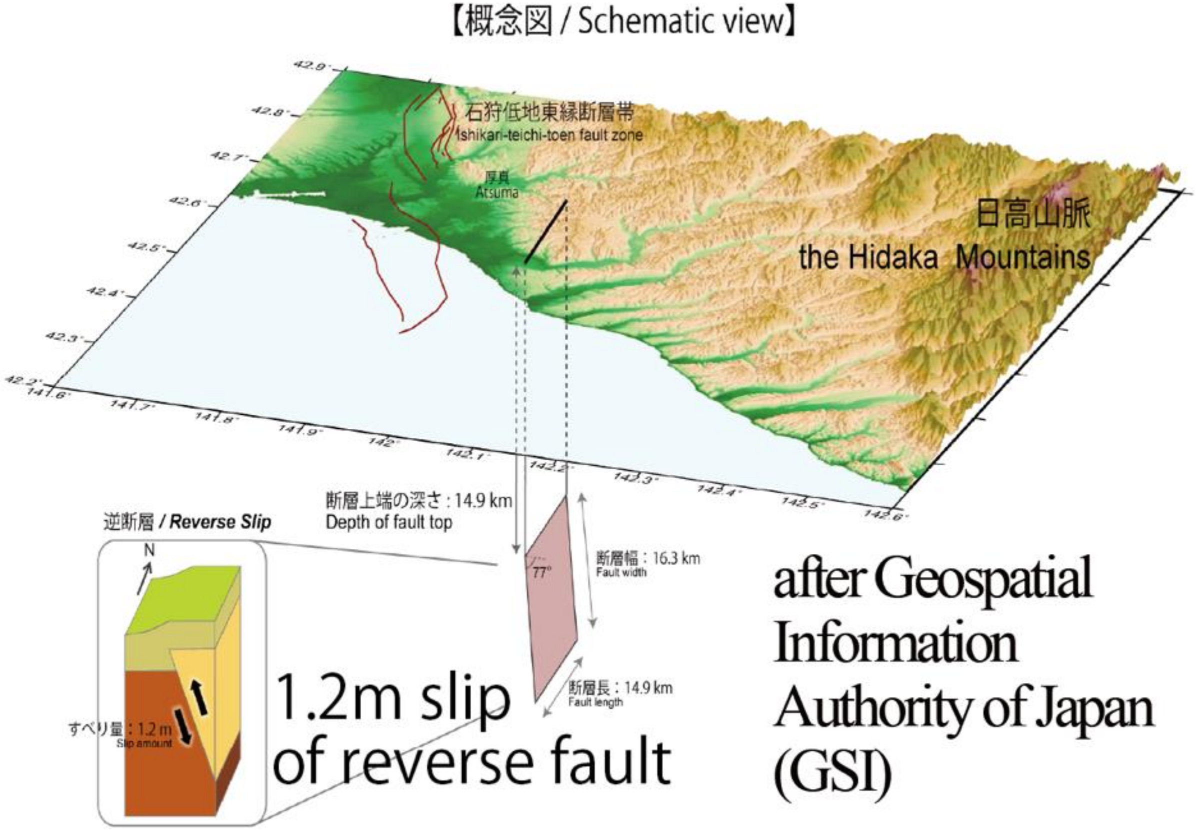
Fig. 1 Tectonic setting and schematic image of the souce fault

Date: 06-Sep-2018 AM 3:07

Epicenter : N42º 41.4, E142º 0.4”

Magnitude = 6.7(JMA)

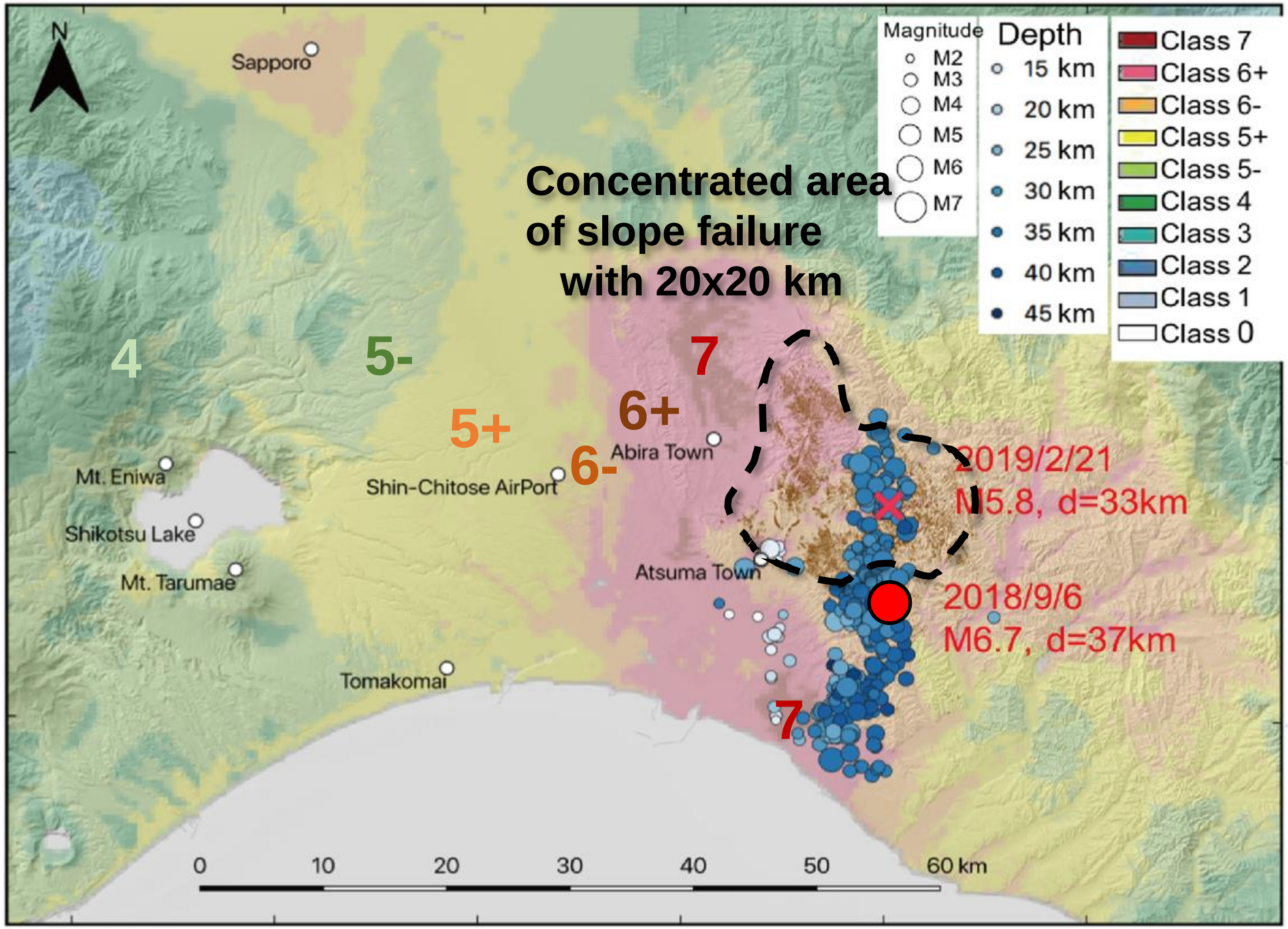
Source fault: reverse fault with 1.2 m slip at 37 km in depth



after Geospatial Information Authority of Japan (GSI)

Shake intensity and distribution of slope disaster

Estimated Seismic Intensity map by NIED
Epicenter from 2018/9/6 to 2019/3/31 by JMA



Brown color area is the trace result of failure slope by GIS japan (2018)

- Intensity Class 7 is first record in Hokkaido island, Japan.
- The earthquake induced >6000 landslides.
  - Slope failures by shallow landslide caused 38 casualties.
  - Deep landslides (rockslide) also occurred. The largest one stopped river and formed landslide dam.

Over 6000 slope disaster in the northern area of the epicenter

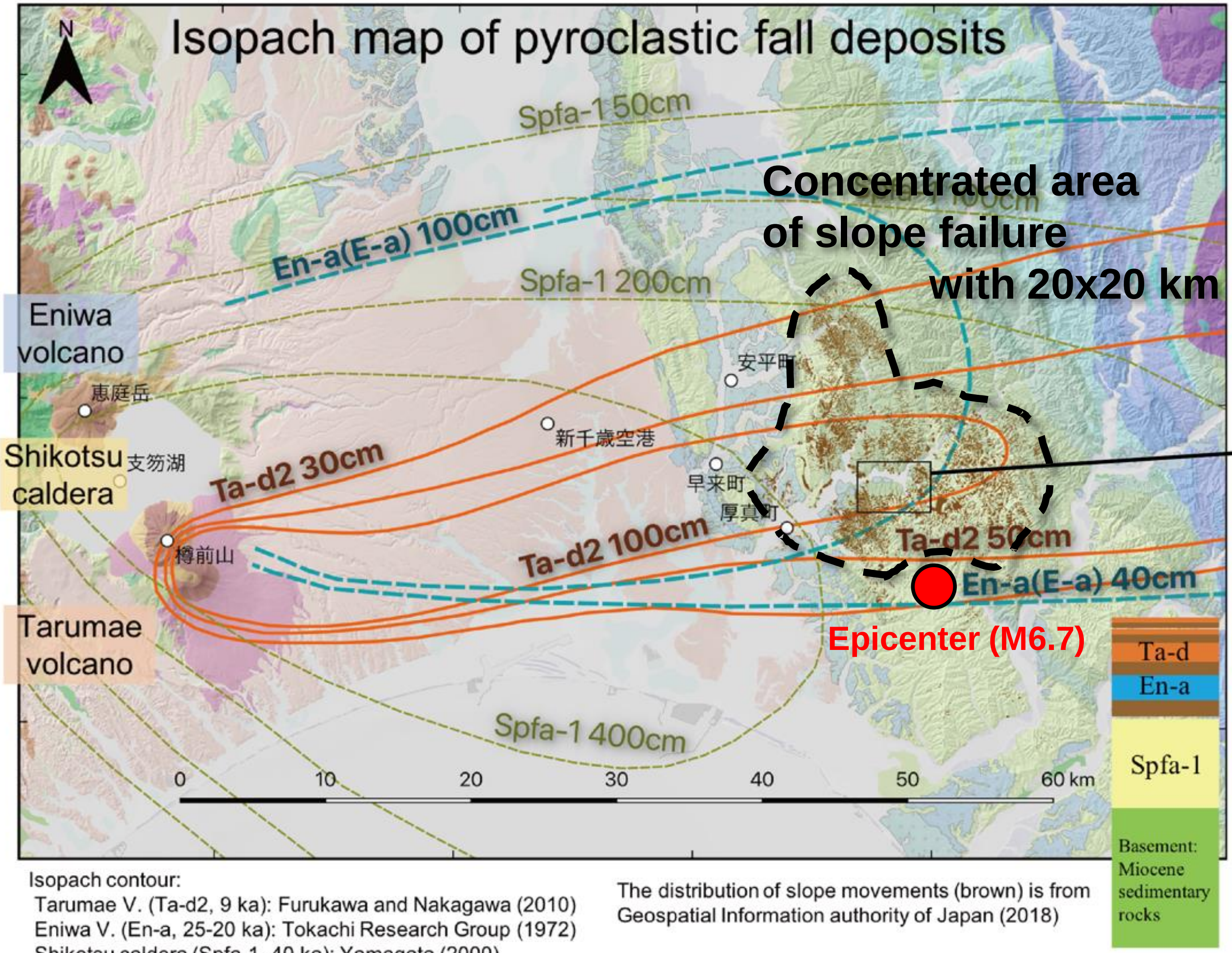


Fig. A Distribution of the shallow landslide and related pyroclastic fall deposits

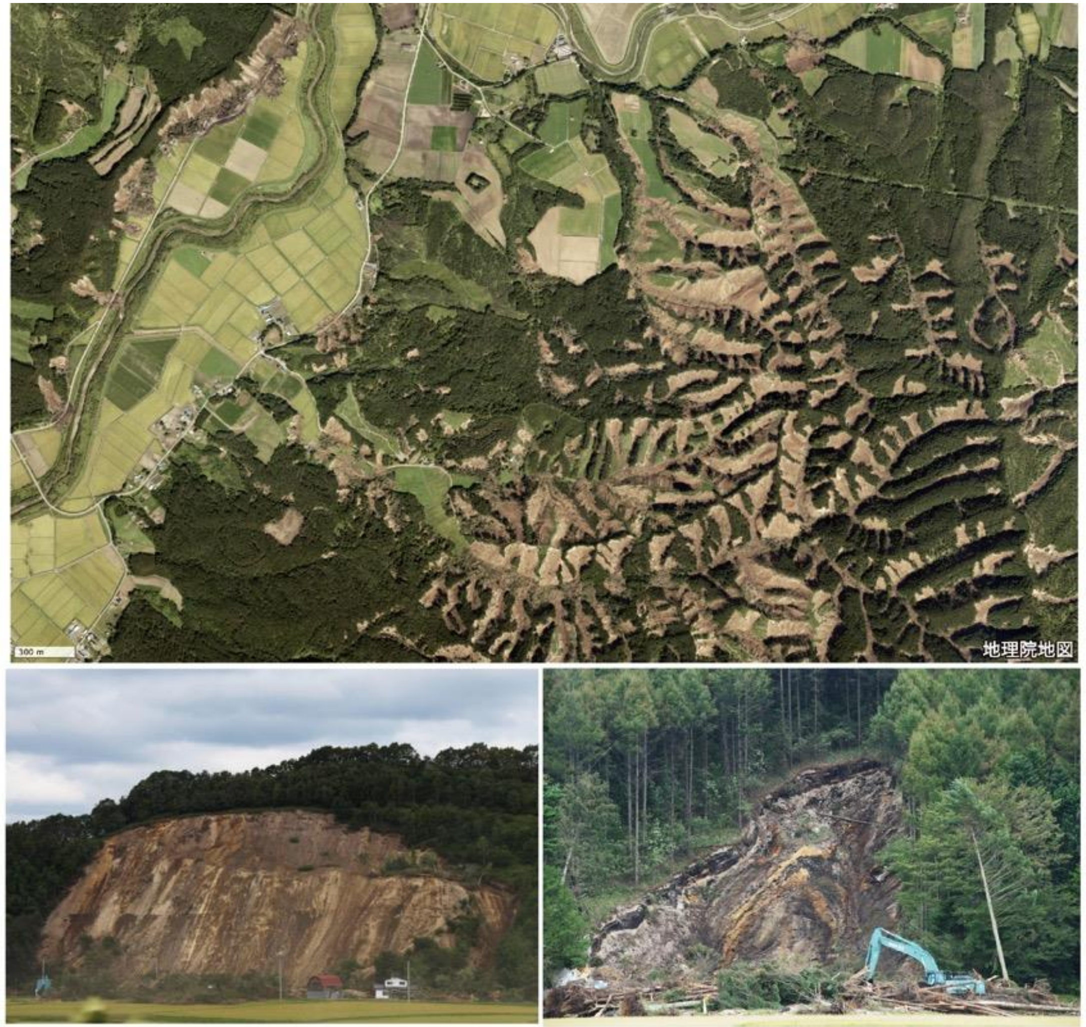
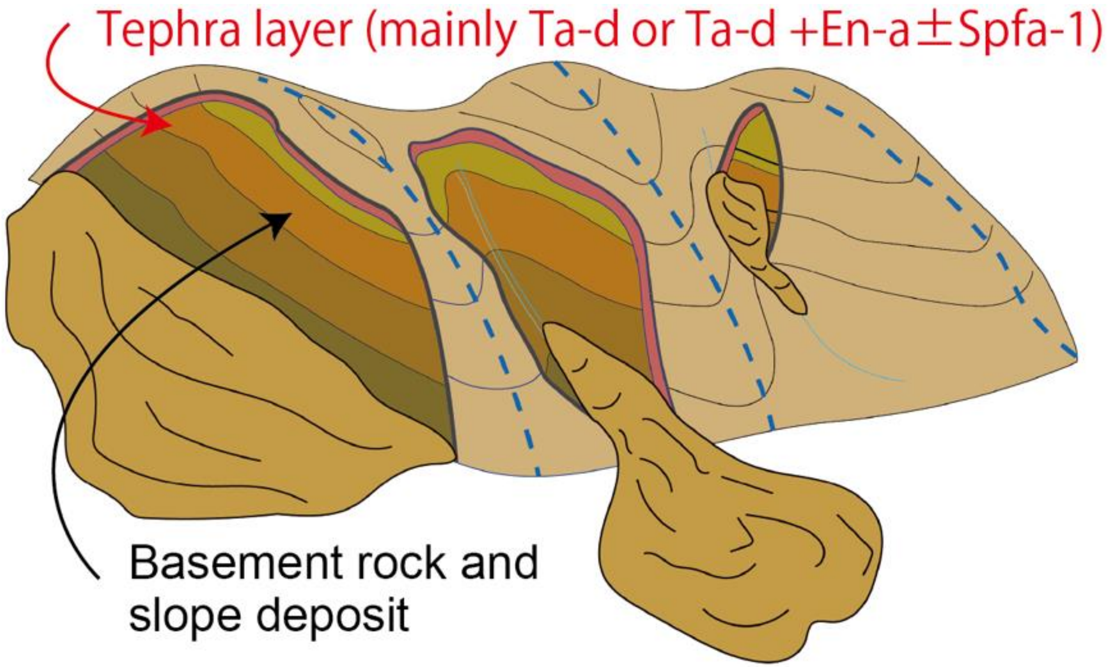


Fig. B Orthophoto image (upper; 5 days after the earthquake by GSI Japan) and photos of typical failured slope (lower).

Mechanism of the shallow landslide (Earthslide of tephra layers)

- The collapsed slope was covered by tephra layers from active volcano of Mt. Tarumae (Ta-d at 9ka) and partly with Mt. Eniwa (En-a at 20ka) and Shikotsu Cardera (Spfa-1 at 40ka) in the northern part.
- The occurrence of the shallow landslides seems to rapidly decrease with thinning of Ta-d layer to <1m thick.



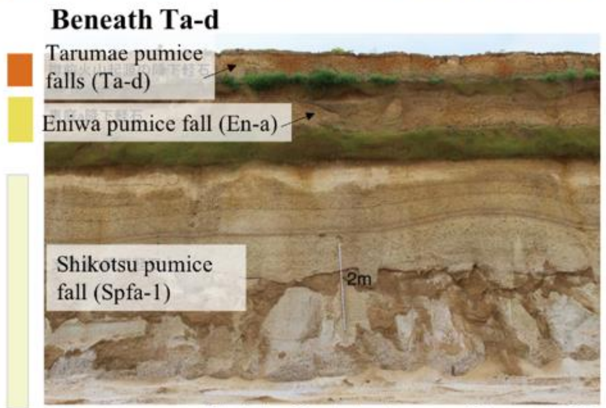
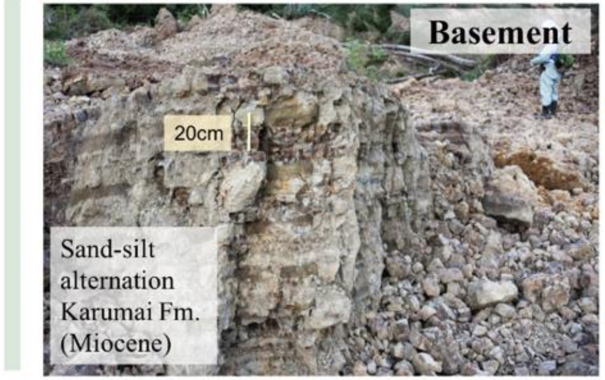
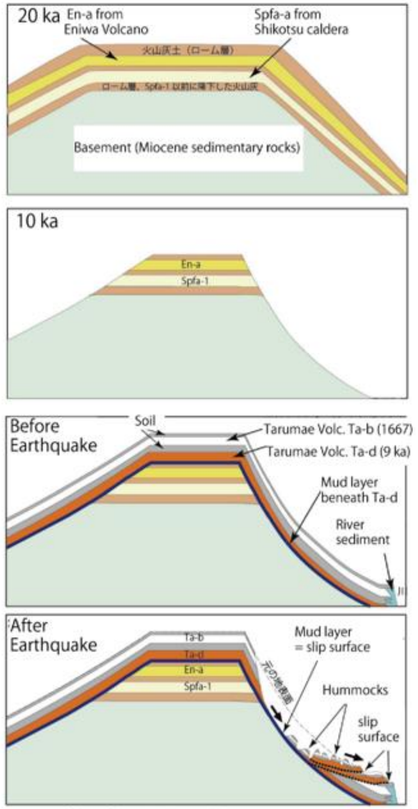


Photo by Geological survey of Japan, AIST
Location: west of Atsuma town office



Block in rock-debris avalanche by the huge land:



Process of slope failure in Atsuma Town
(after Figure 10 from Hirose et al. (Geological Survey of Hokkaido))

The largest rockslide body slid about 350 m

- A narrow ridge topography, with 300 m wide, 1 km long and 50-80 in height, slid down 350 m to valley as a slide block.
- Geostructure is typical dep-slope with 8-10º dip toward river-bed.
- The basement rock consists of marine sediments (shale, silt and sandstone) of Miocene.
- Formation of landslide dam
    - As a countermeasure, a new waterway was constructed by excavating the the slide block.

Deeper rockslides are also occured. However, their number and distribution is still unknown.

Fig. 3 UAV photo image of the huge rock slide in Hidakahoronai River.

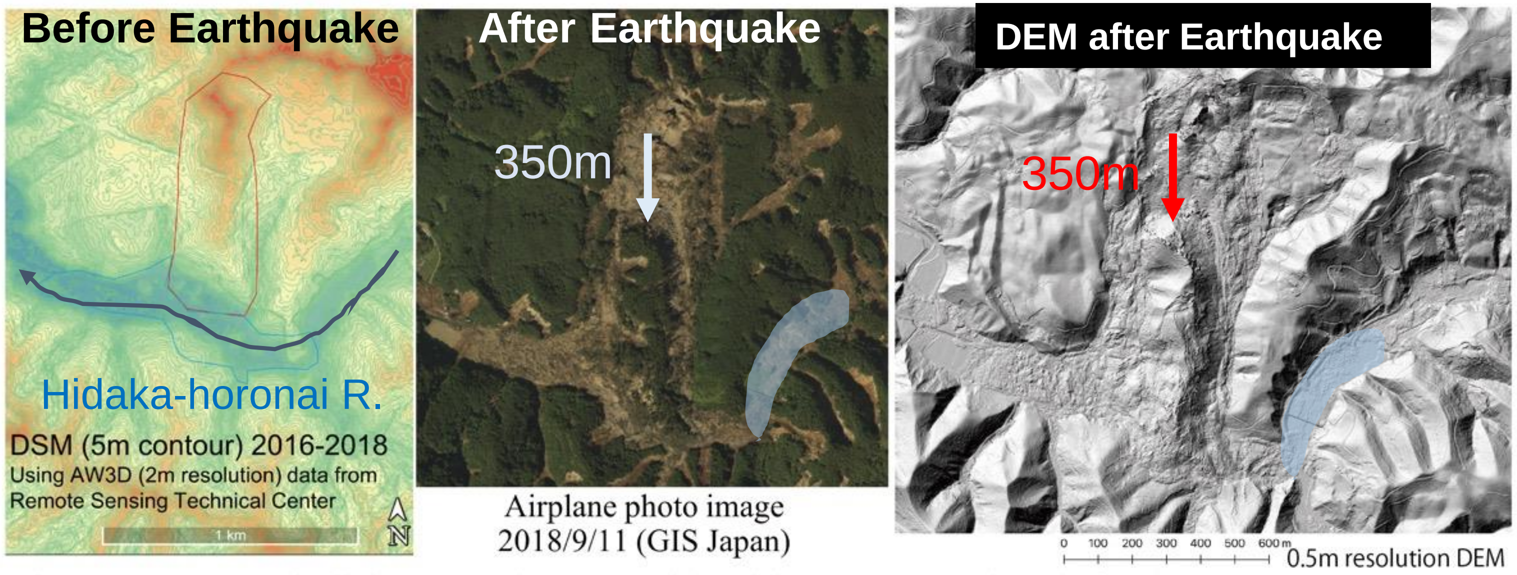


Fig. 4 Huge rockslide occurd at unstable ridge topography (left). Large movement can be detected using satelite or airplane photo image (middle). However, their detailed structure and small topography under vegetation can only be reorginized using high-resolution DEM data (right).

Motivation of this study

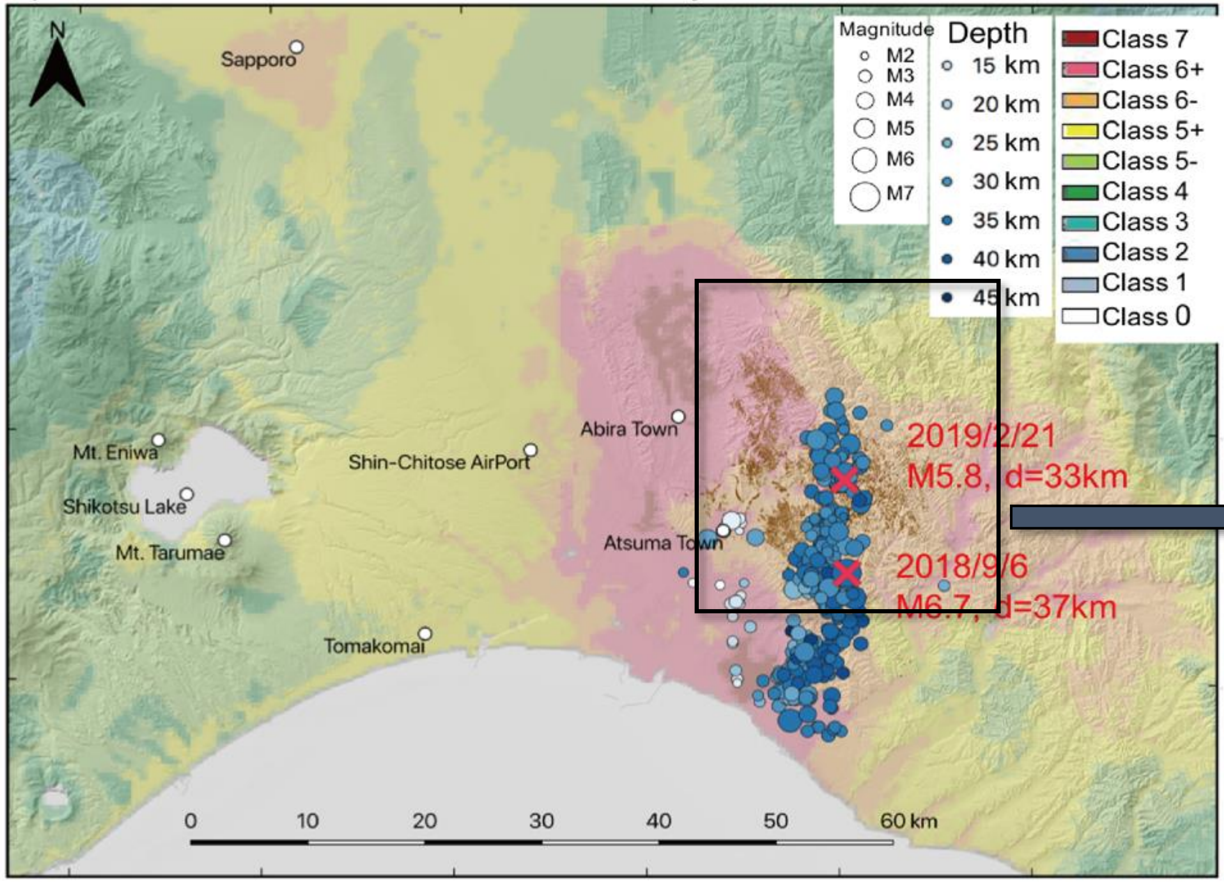
- The number and distribution of shallow landslides (earth-slide of tephra layers) can be analyze using airplane or satellite image.
- On the other hand, deeper landslide (rockslide) is difficult to identify its shape, size and distribution because of vegetation cover, except large moved rockslide. Limited number of rockslides still have been reported along a recovered road side.
- Therefore, we try to identify rockslide topography using 0.5 m resolution Digital Elevation Model (DEM) by aerial laser survey (provided by Hokkaido Regional Development Bureau).

Method: Recognition of rockslide using high-resolution DEM

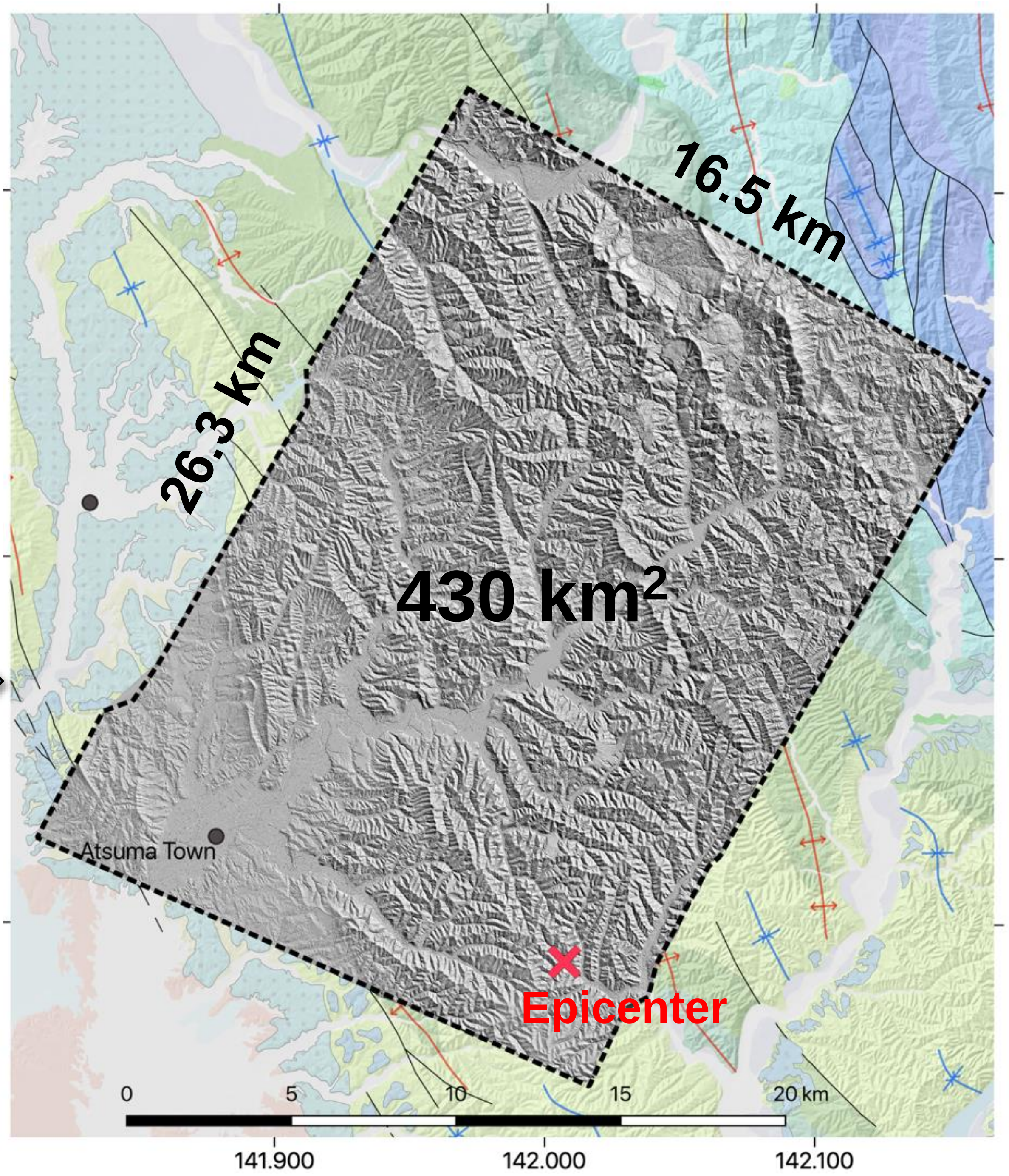
Result: over 200 earthquake induced rockslides are newly identified.

Studied area

Estimated Seismic Intensity map by NIED
Epicenter from 2018/9/6 to 2019/3/31 by JMA

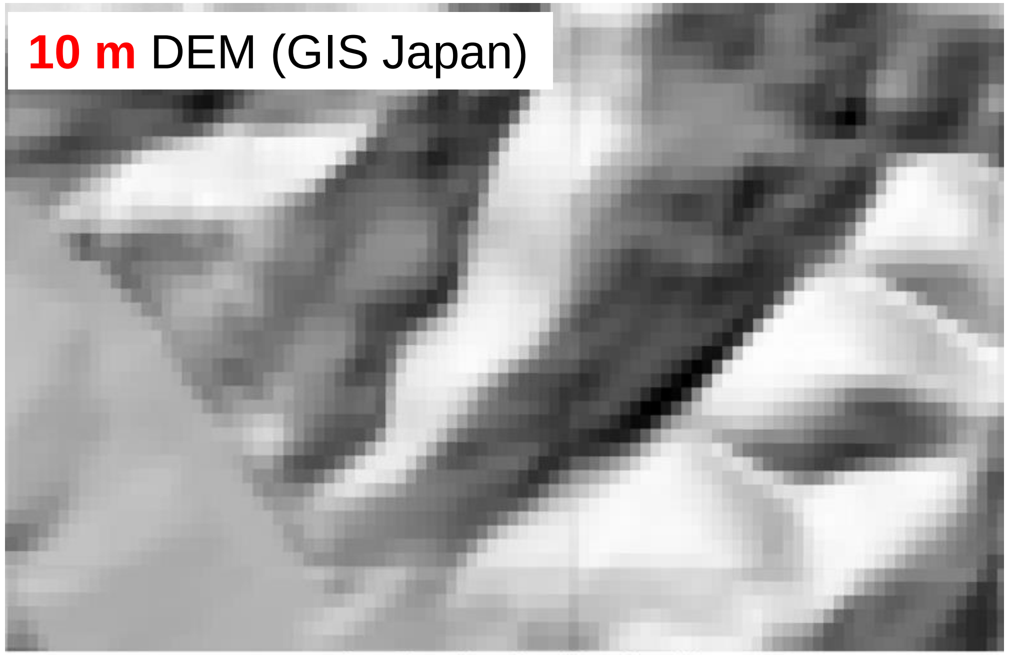


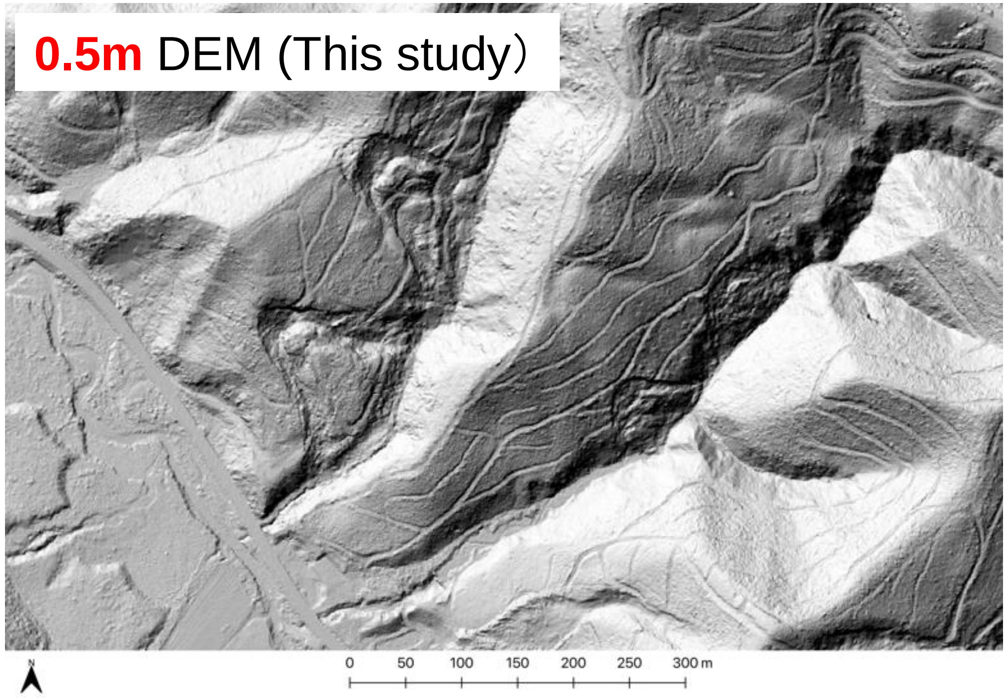
Brown color area is the trace result of failure slope by GIS japan (2018)

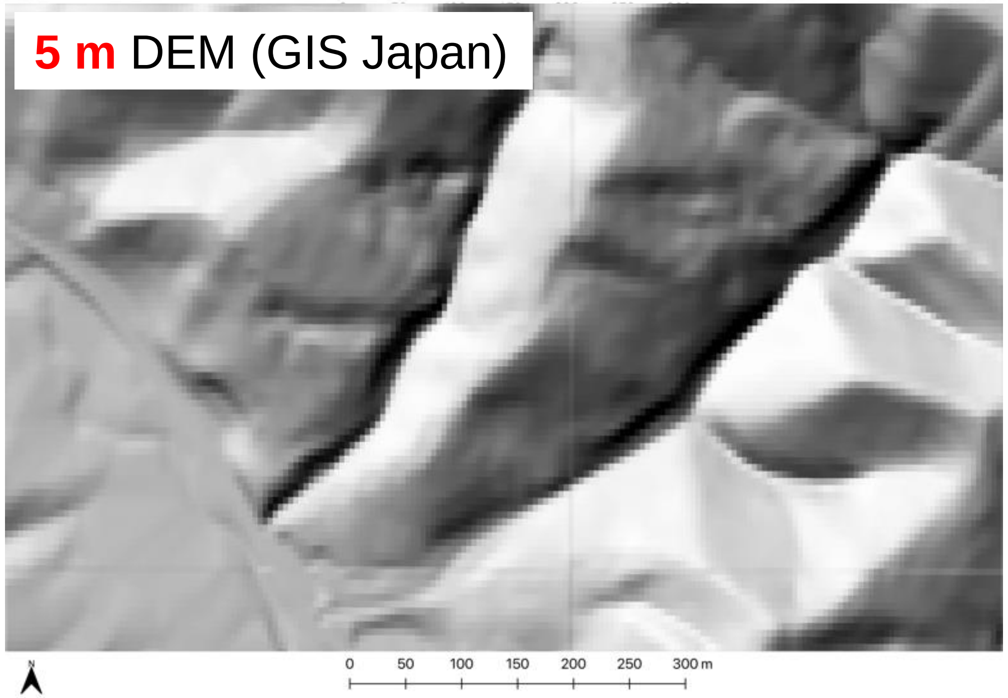


High-resolution DEM data

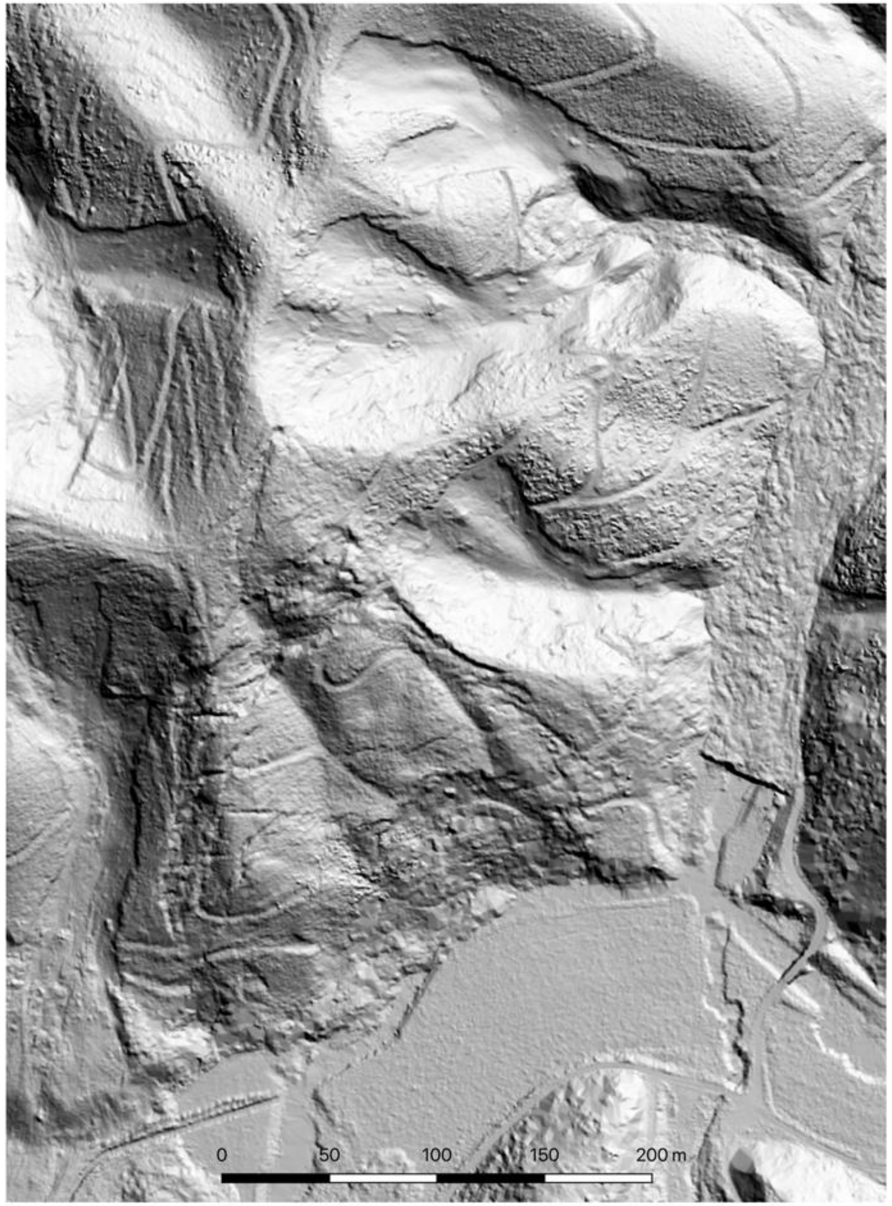
- DEM data of 0.5m in resolution and average point density of 22 points/m^2.
- Topographic analysis is used shaded-relief map which generate from DEM data in QGIS software.
- Microstructure with >1m in size, such as crack, step, rock block, mound, is clearly discriminable.



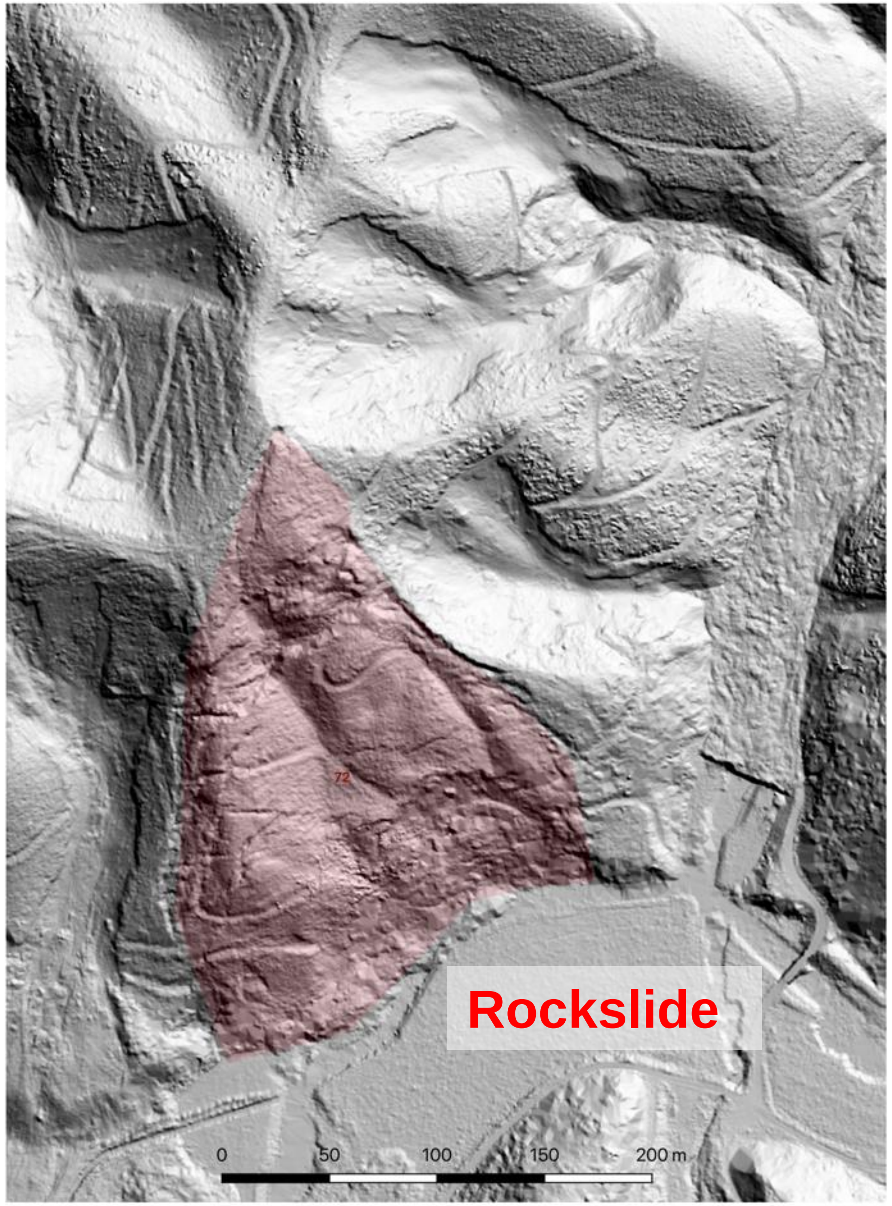




Potential of high-resolution DEM

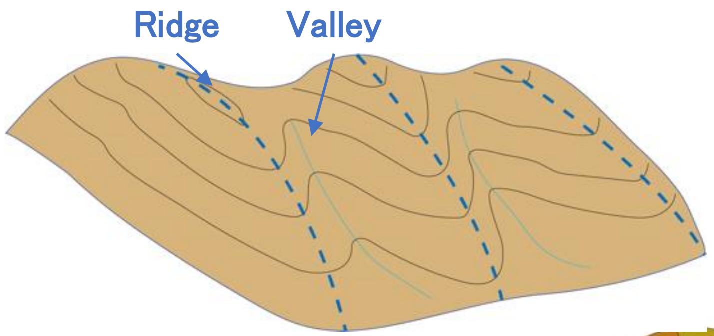


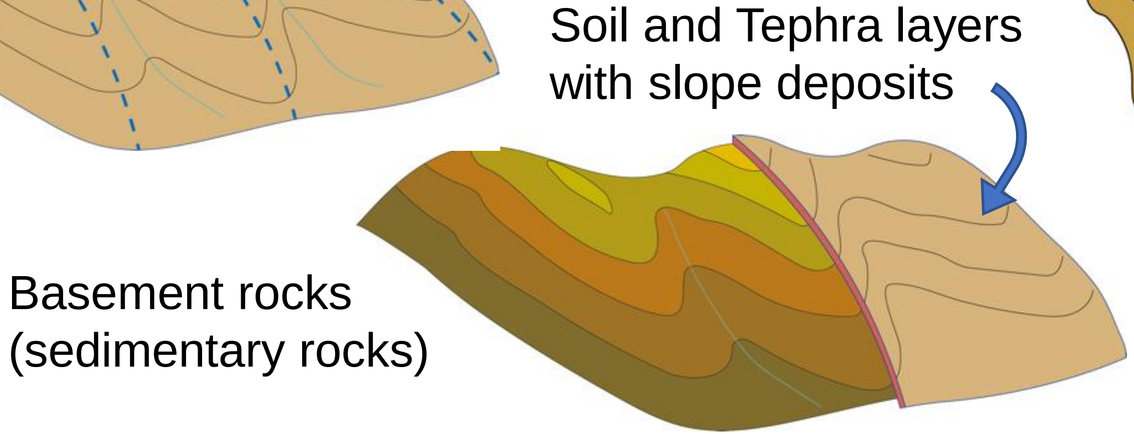
Potential of high-resolution DEM

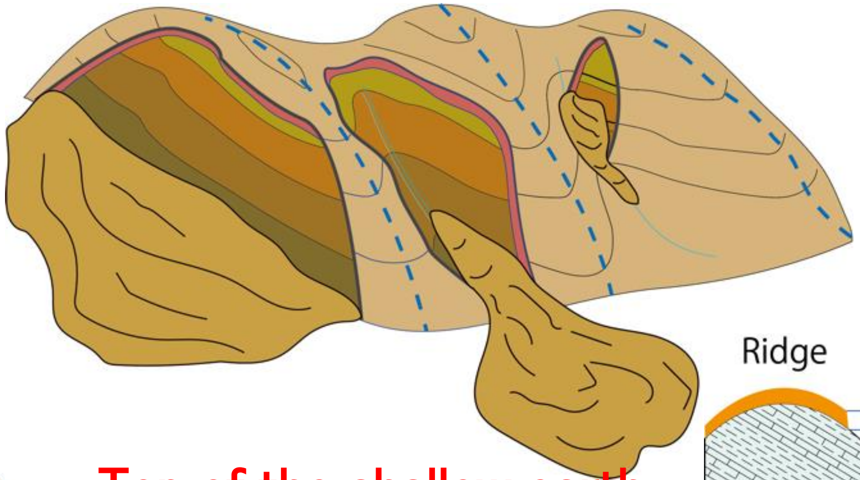


Criteria of rockslide identification in DEM data

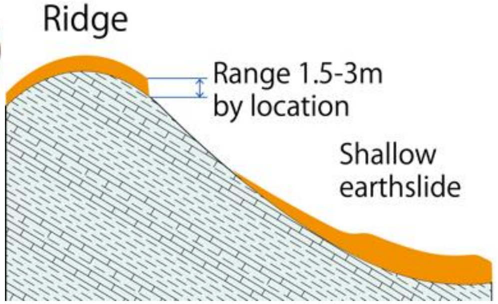
- Shallow landslide (earth-slide) of this earthquake is mostly defined by the slide or flow down of mantle bedded tephra layer with 1.5-3 m in thickness on the slope and top of failure area dose not over ridge topography.
- Mantle bedded tephra layer is not enough strong to drag the layer on the top of ridge.



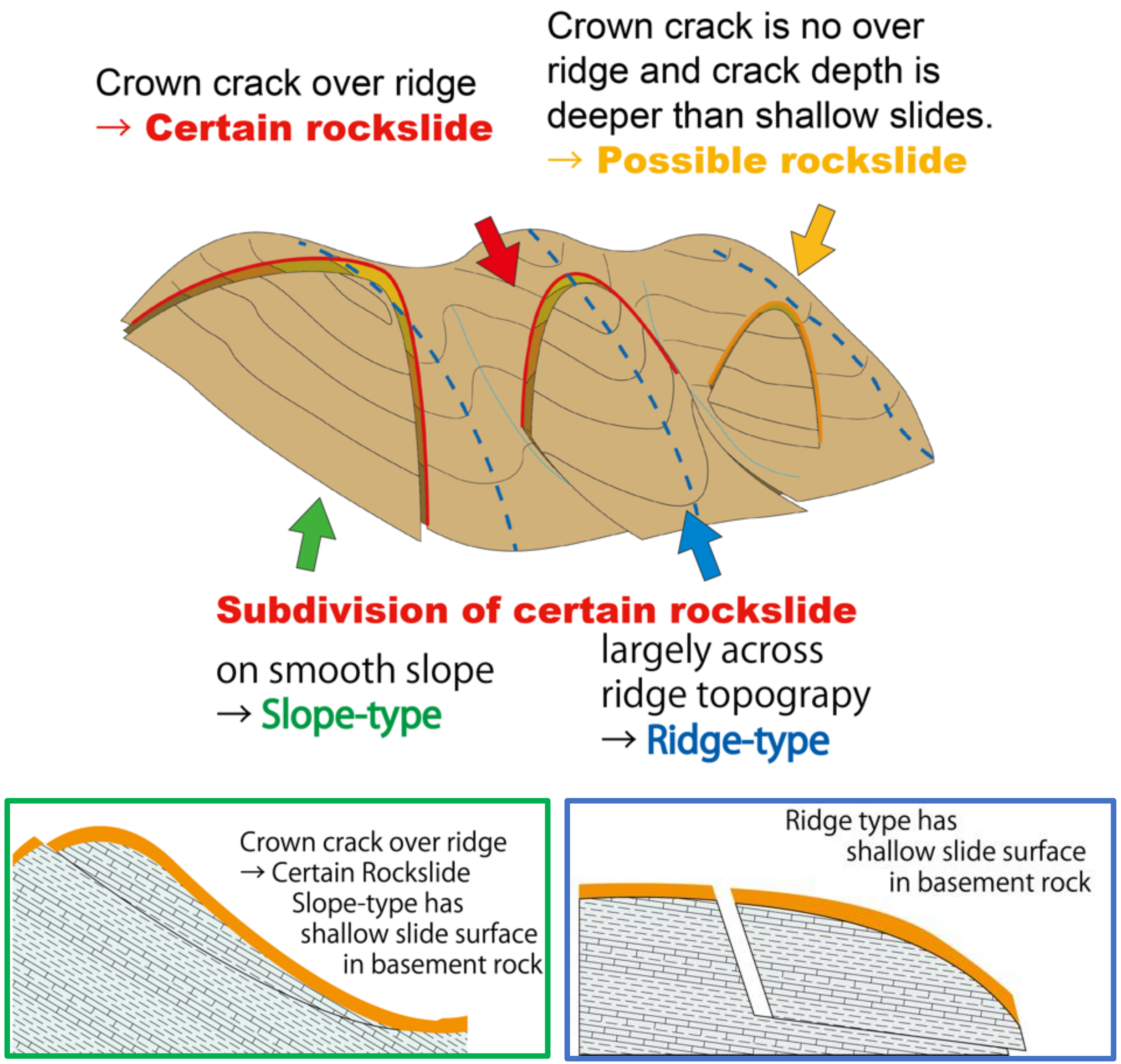




Top of the shallow earth slide never across the ridge line.



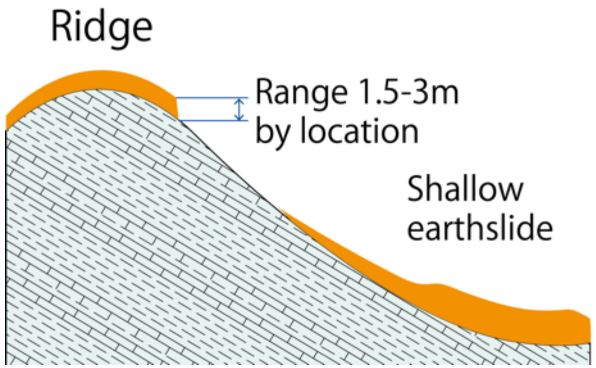
Criteria of rockslide identification in DEM data



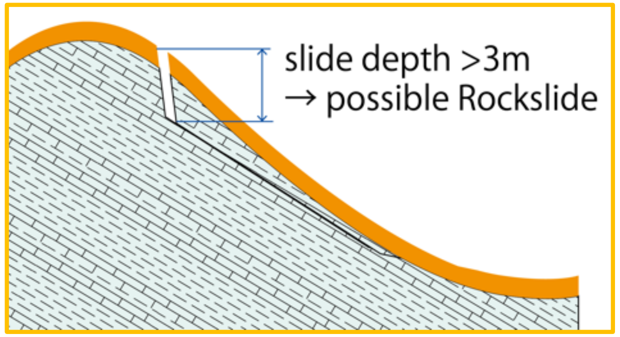
- **Certain rockslide** is defined by:
  ① Crown crack across ridge line
  ② And, crack deeper than 3m (or height of slide body).
- The **certain rockslide** is subdivided into 2 types:
  - **Slope-type** is defined as crack parallelly across ridge. It is relatively shallower rockslide on the single slope without valley formation.
  - **Ridge-type** is characterized as crack across ridge line with high-angle. The depth of slide surface of the ridge-type is relatively deeper than the slope-type.

Criteria of rockslide identification in DEM data

Shallow Earth-slide

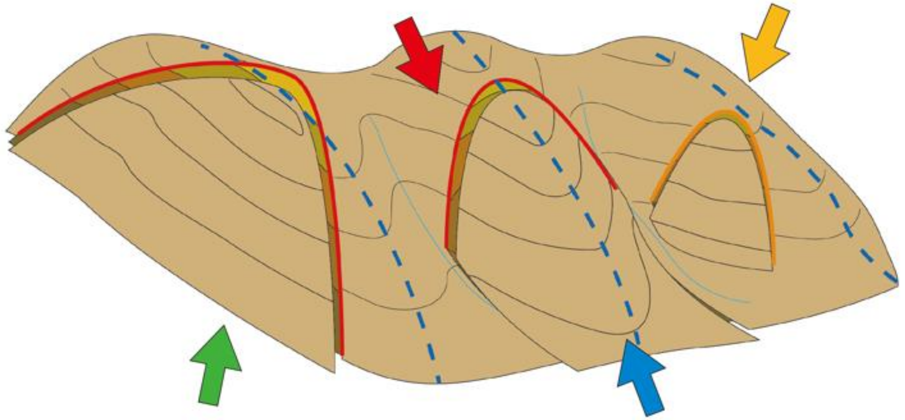


Possible Rockslide



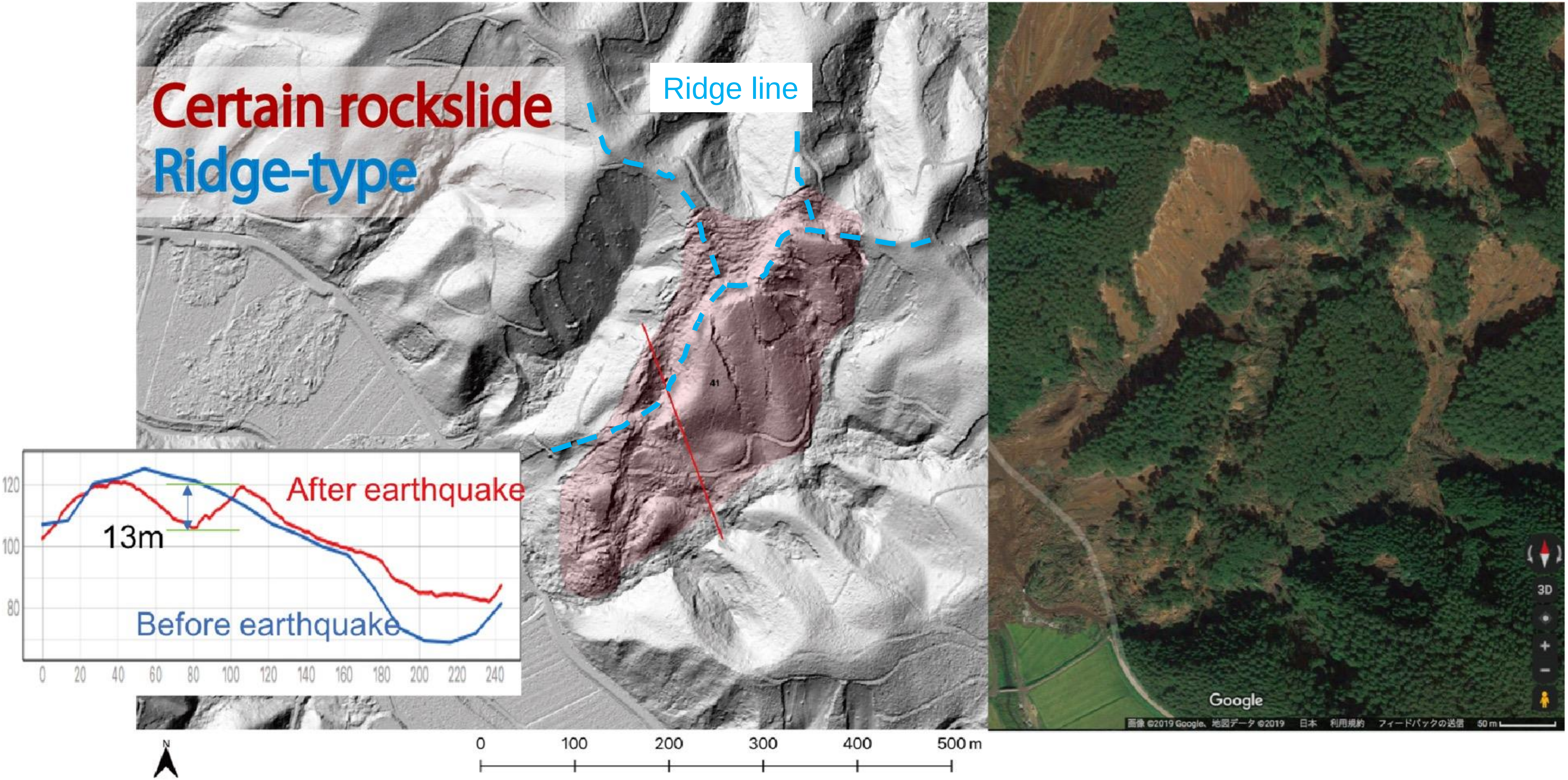
Crown crack over ridge
→ **Certain rockslide**

Crown crack is no over ridge and crack depth is deeper than shallow slides.
→ **Possible rockslide**

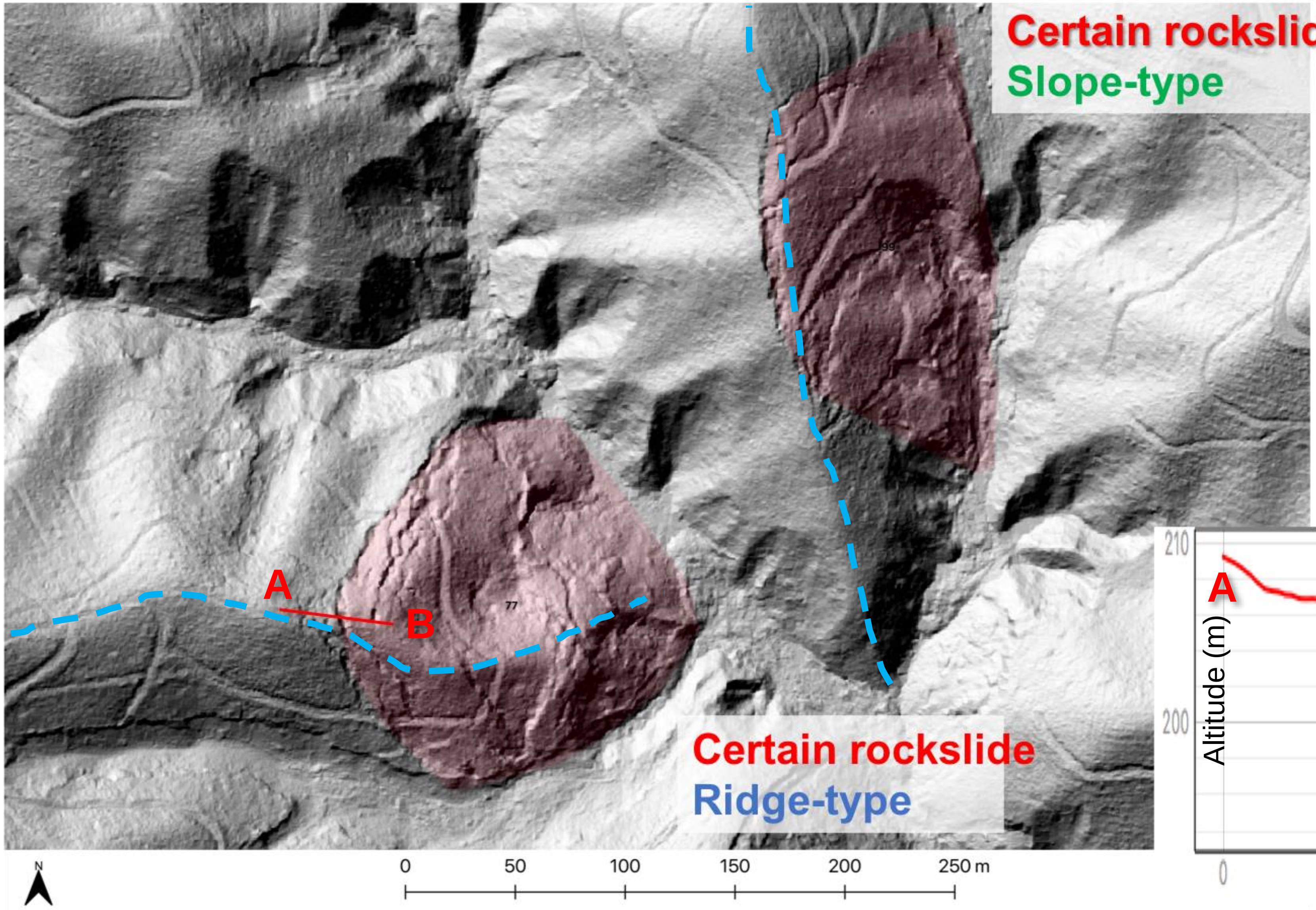


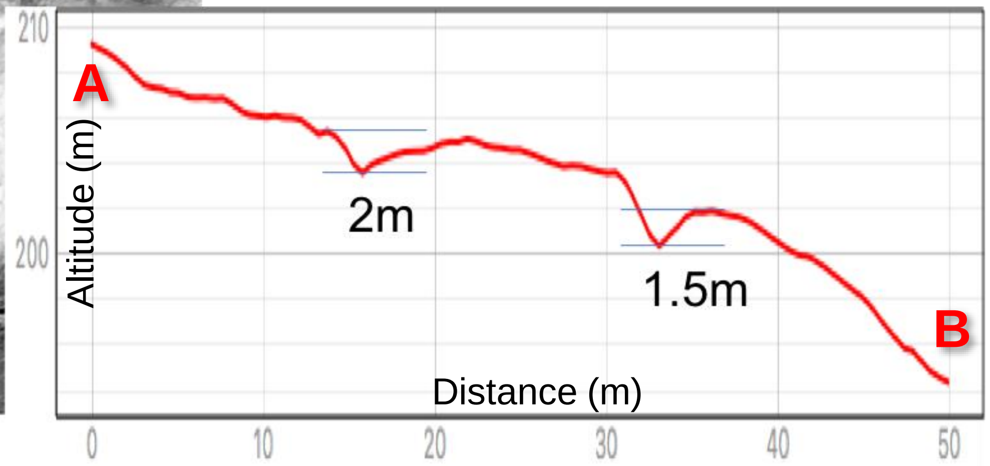
- **Possible rockslide** is defined by:
  - ① Crown crack <u>don't crossover ridge</u> line
  - ② Crack <u>deeper than an adjacent shallow landslide</u>, generally defined as >3m in depth.
- Possible rockslide is also classified into the slope-type.
- The depth of slide surface of the possible rockslide seems to be shallower than those of the certain rockslides.

Crown crack across ridge and >3m → Certain RS

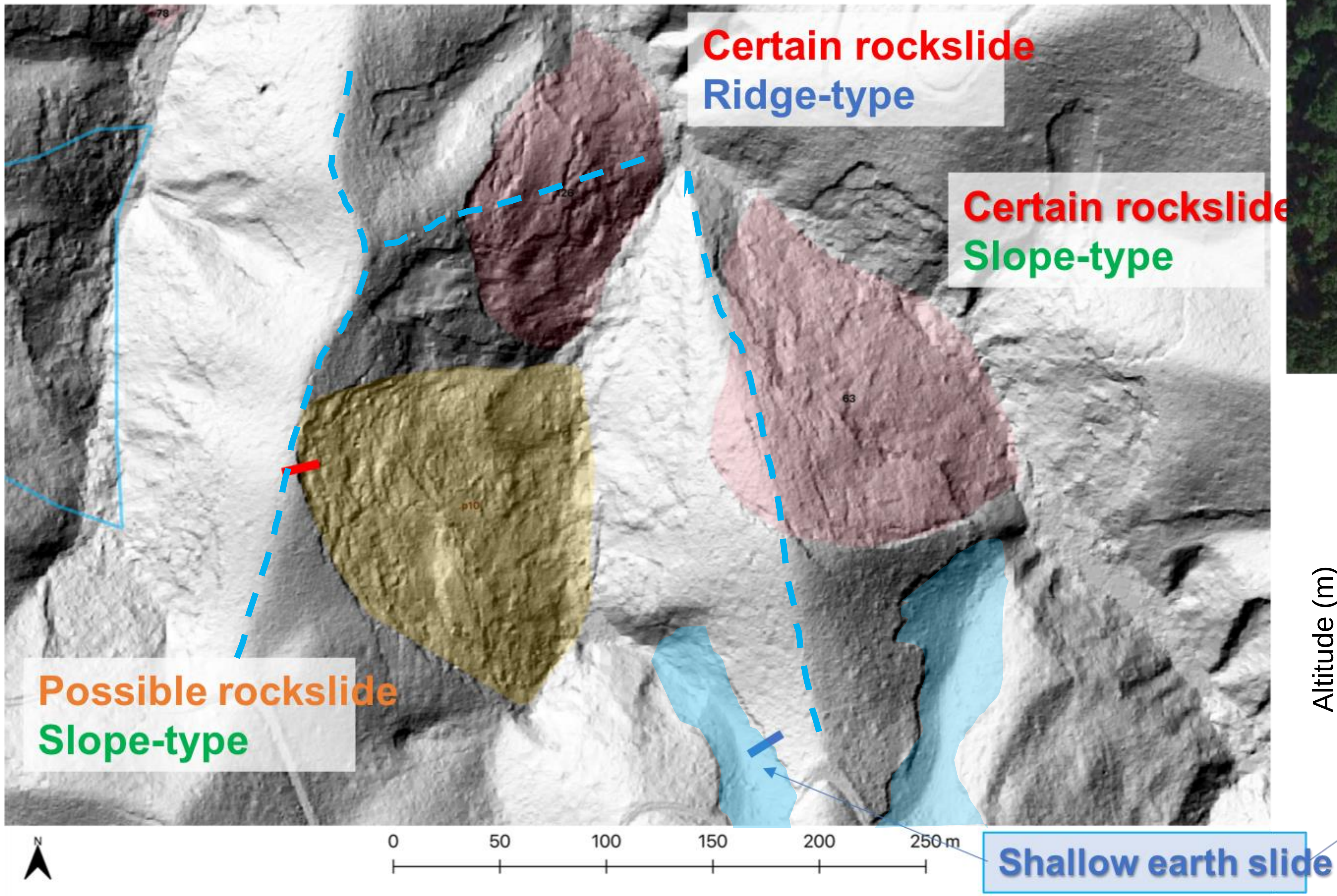


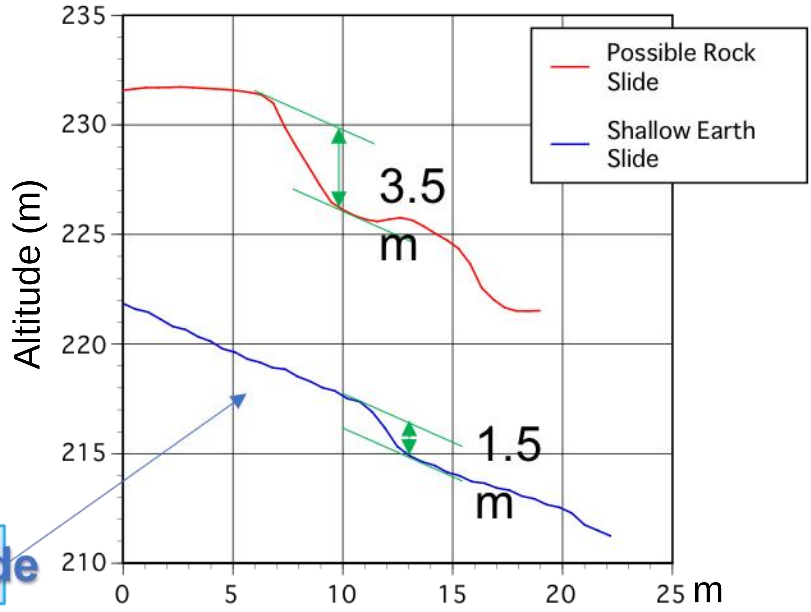
Crack across ridge, but crack depth <3m → Certain RS



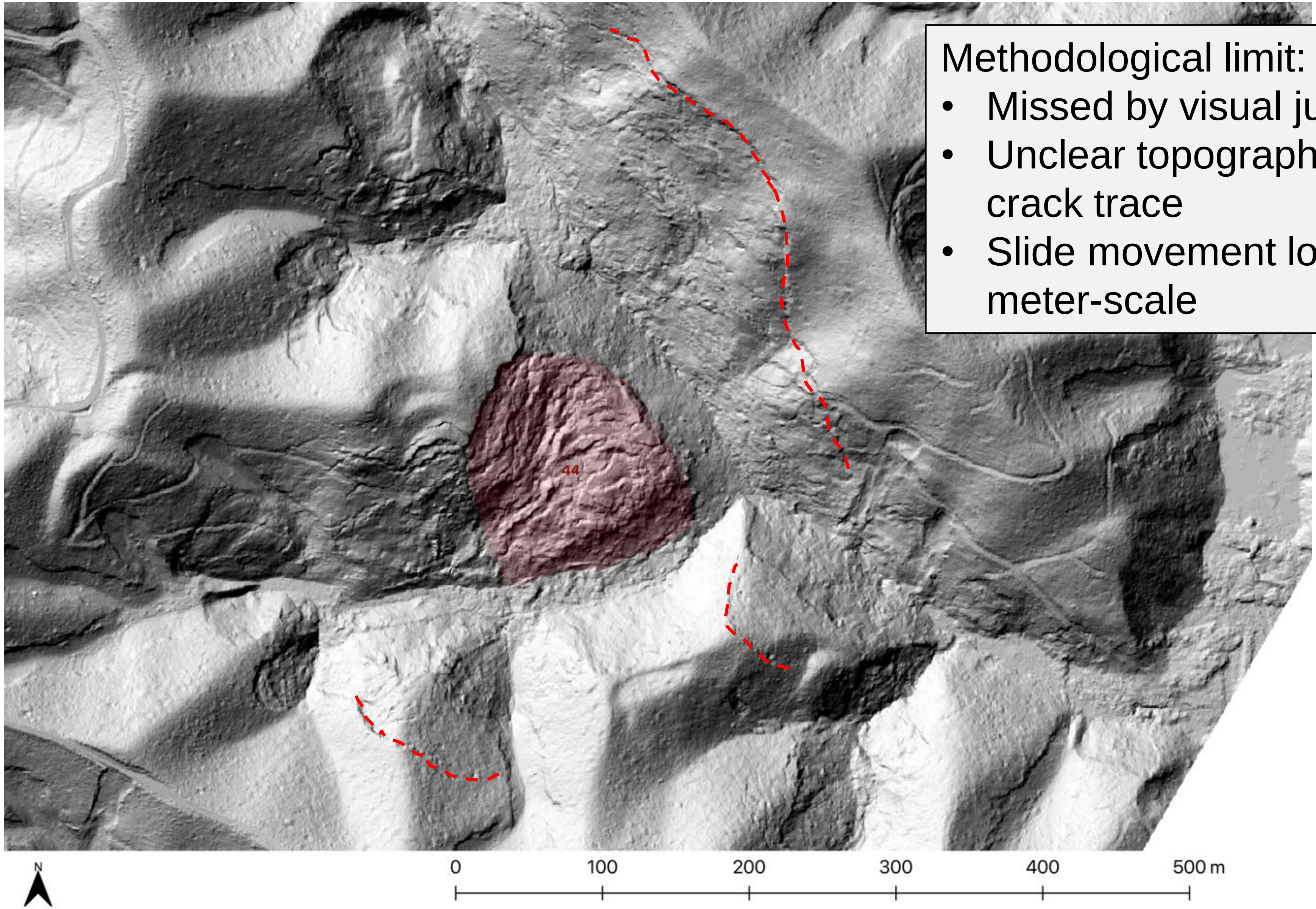


Crack not across ridge & deeper than near ES → Possible RS





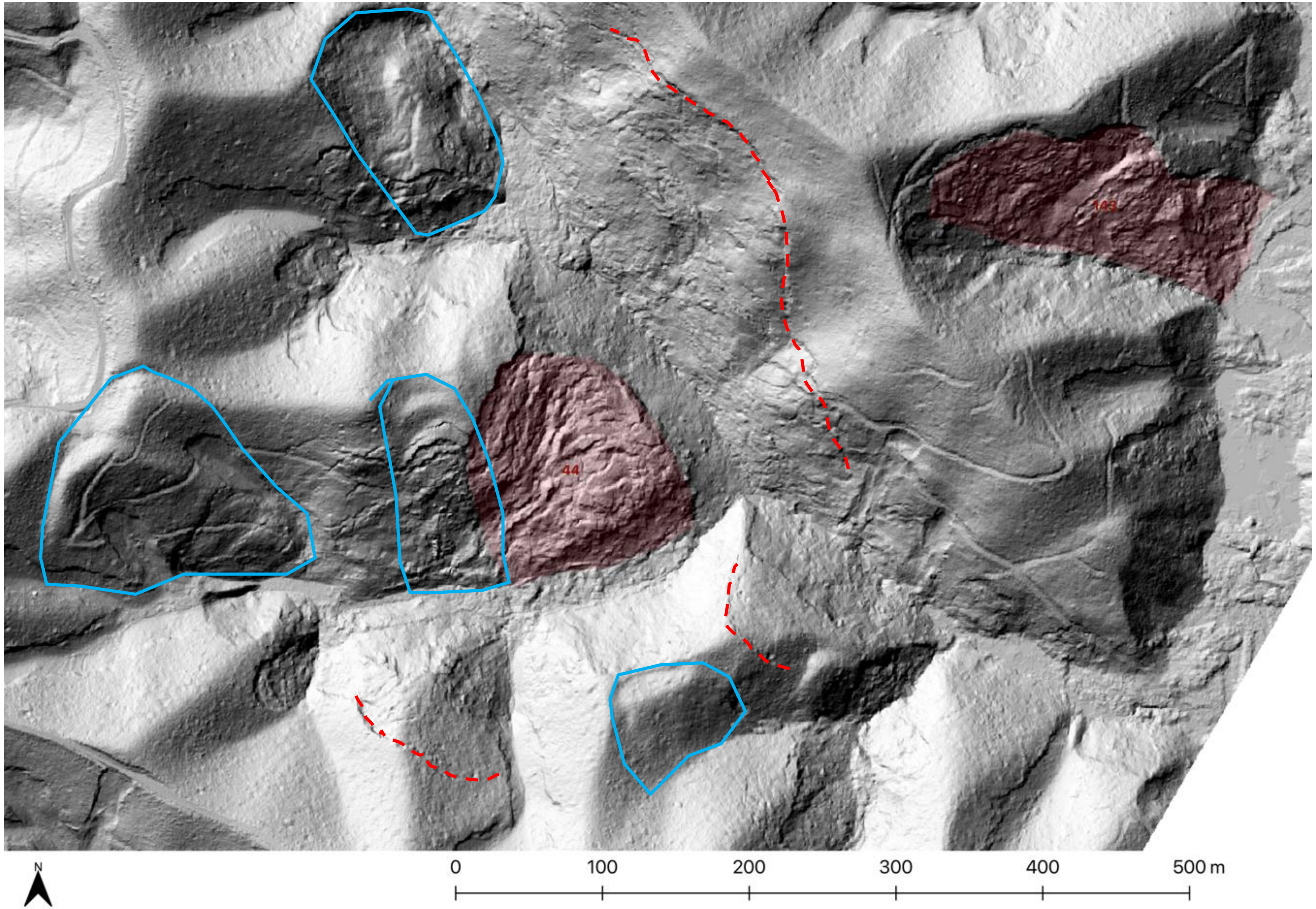
Unclear crack trace or crack depth <3m → unidentified



Methodological limit:

- Missed by visual judgement
- Unclear topographic change or crack trace
- Slide movement lower than meter-scale

Moved block with smooth surface → Old-landslide



Check the results in field

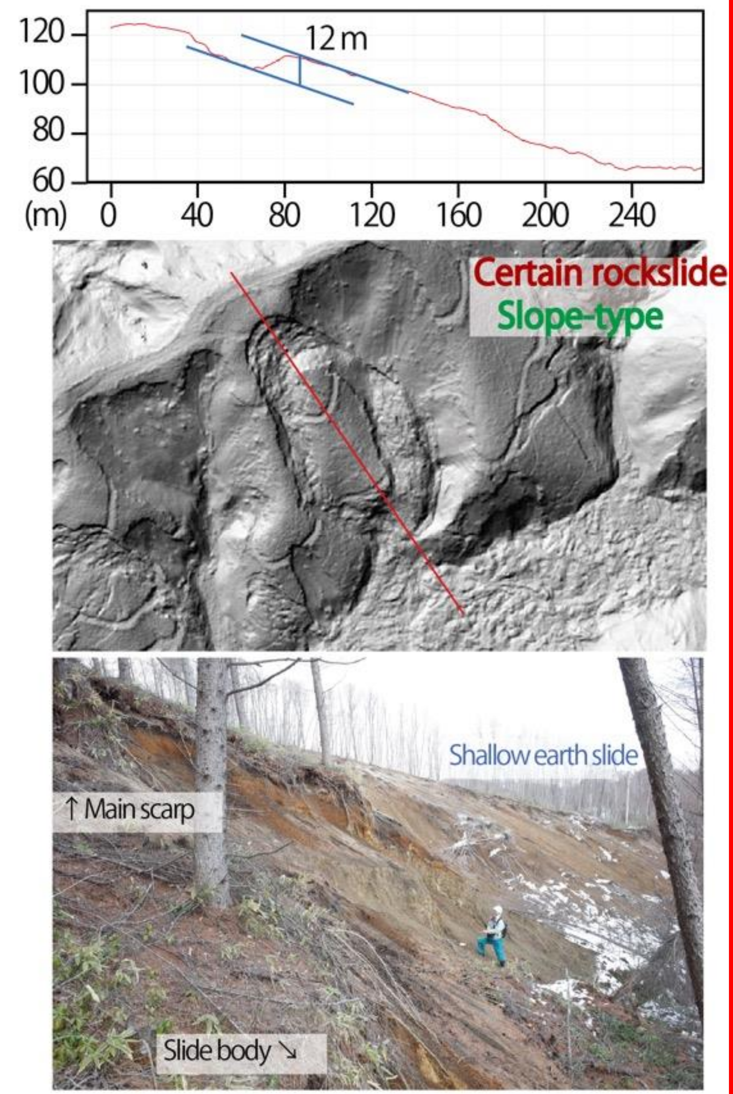


Fig. 13 Cross section, shaded-relief map, and photograph of the certain rockslide and earthslide.

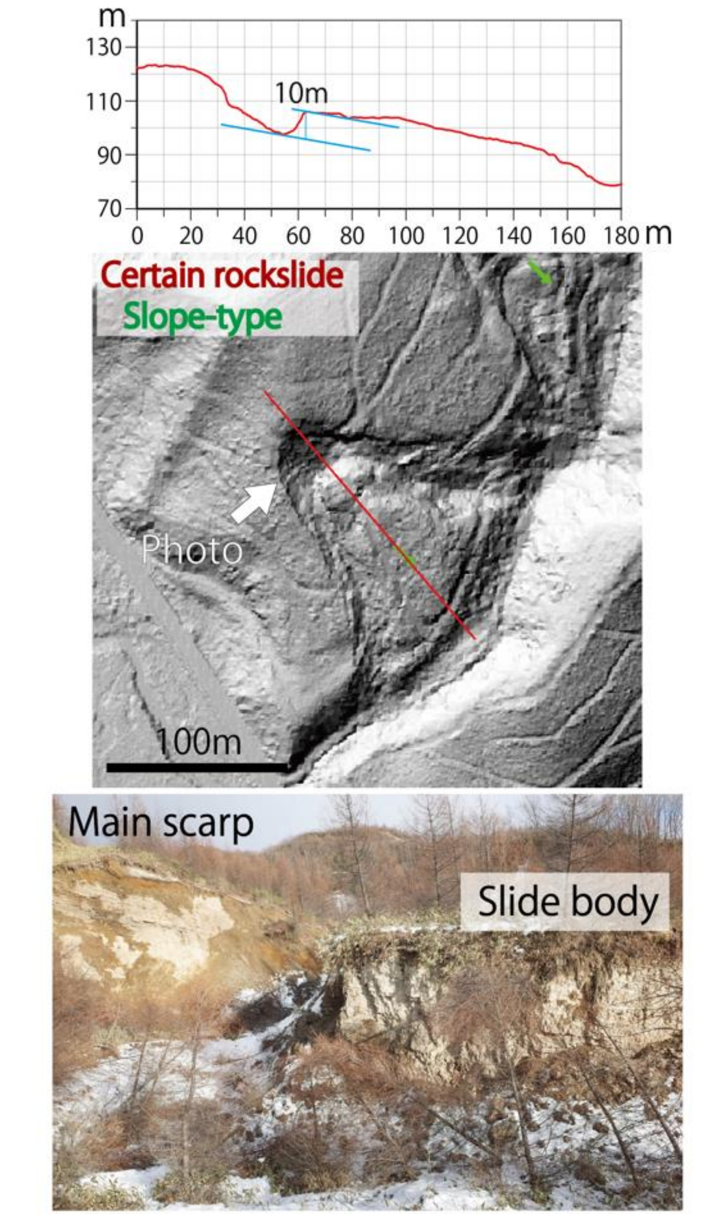
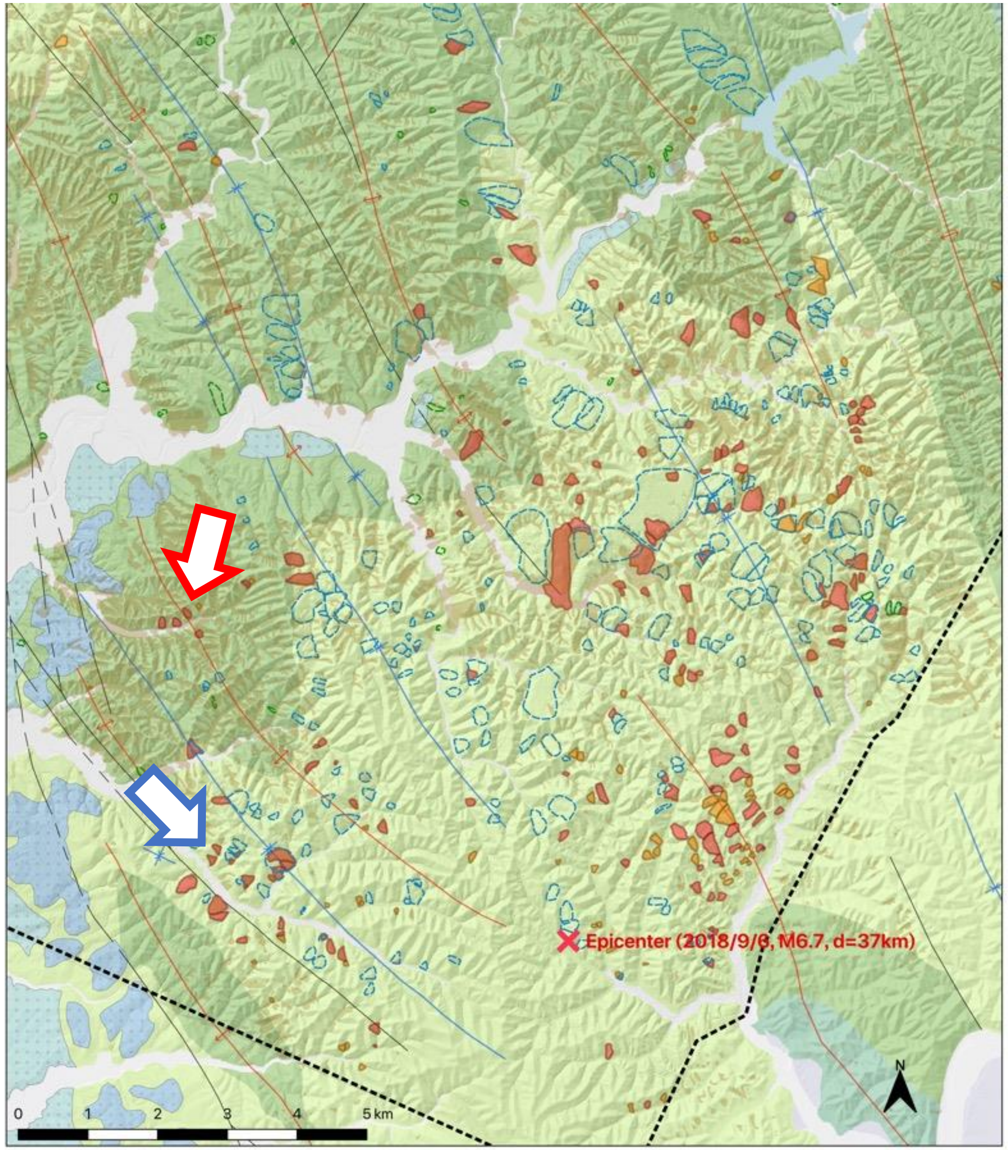
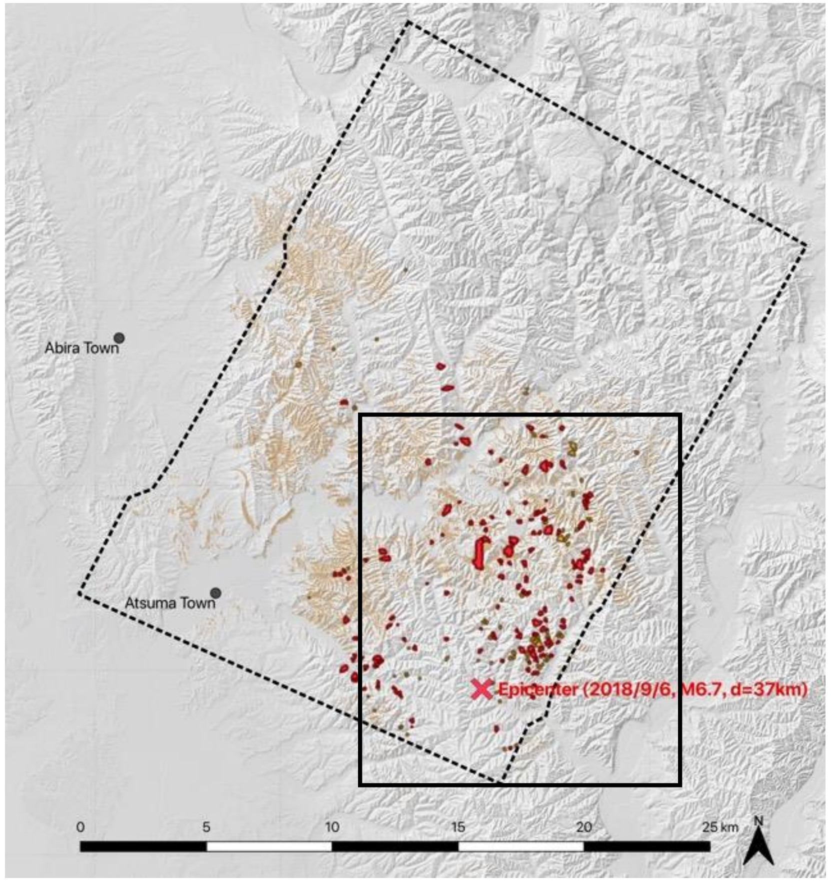


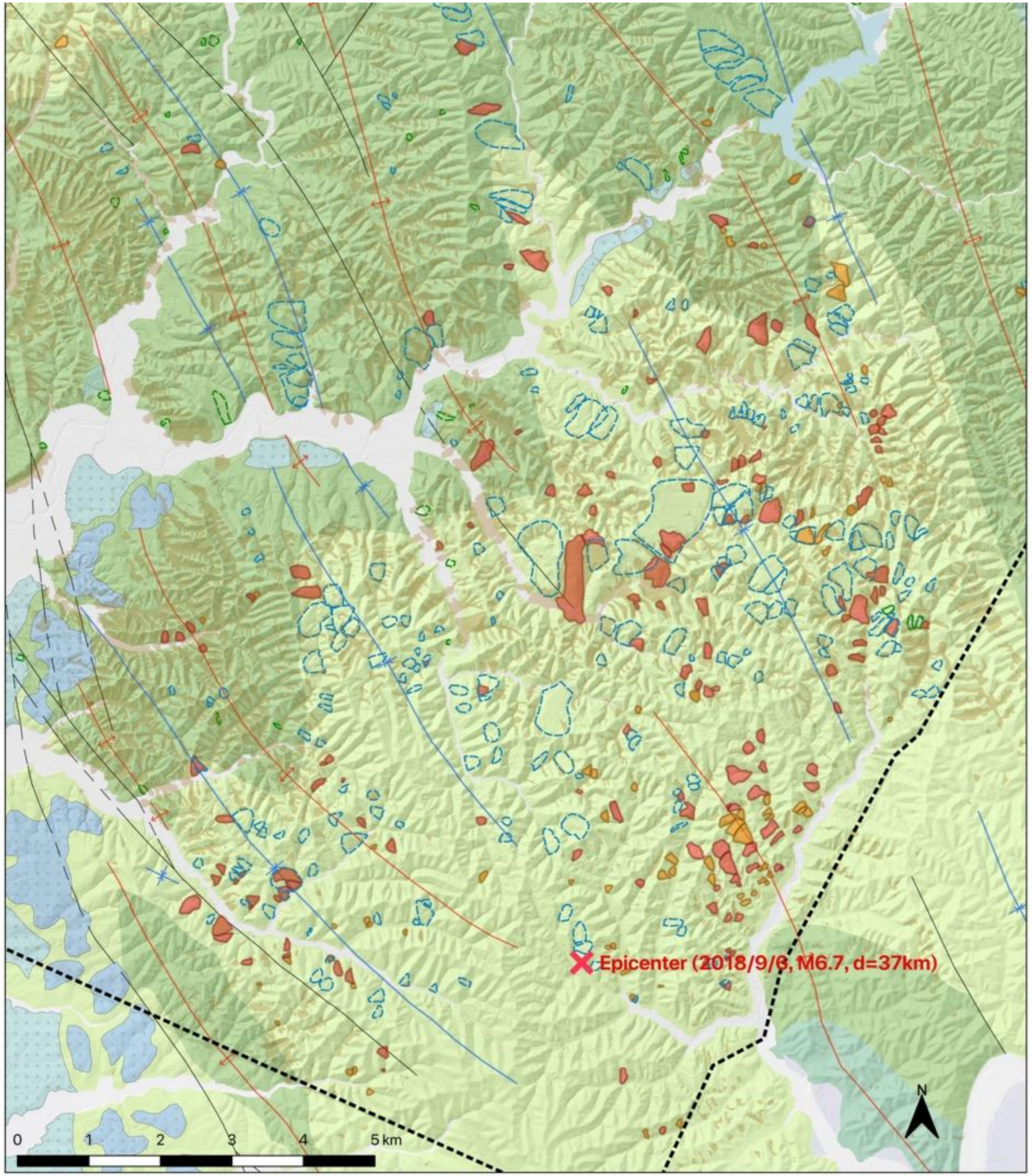
Fig. 14 Cross section, shaded-relief map, and photograph of the certain rockslide, top to bottom. The basement is consist of sand to silt stone of Miocene with gently dip down to the valley.



Result: distribution of certain & possible rockslide

- Identified total 232 locations
  - Certain rockslide = 151
  - Possible rockslide = 81





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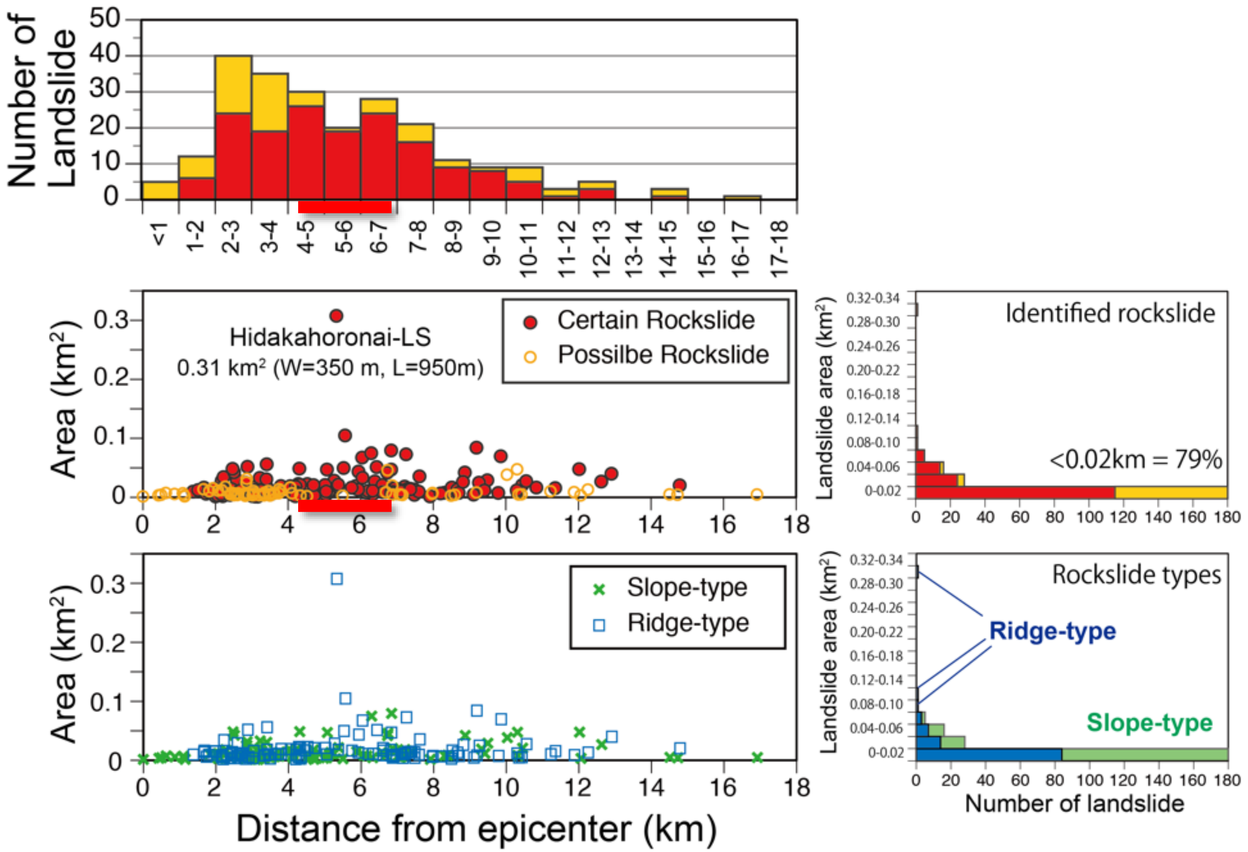

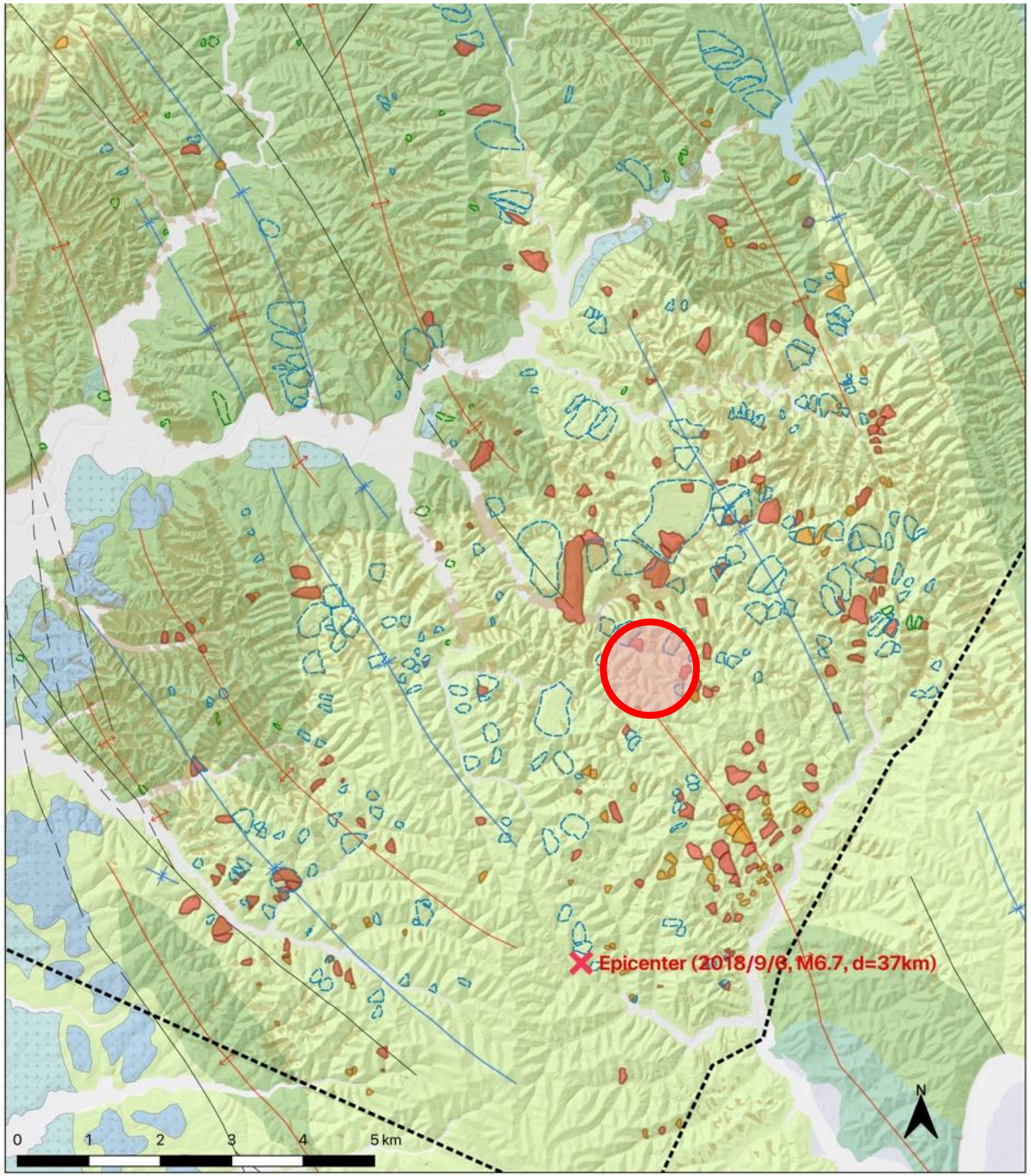

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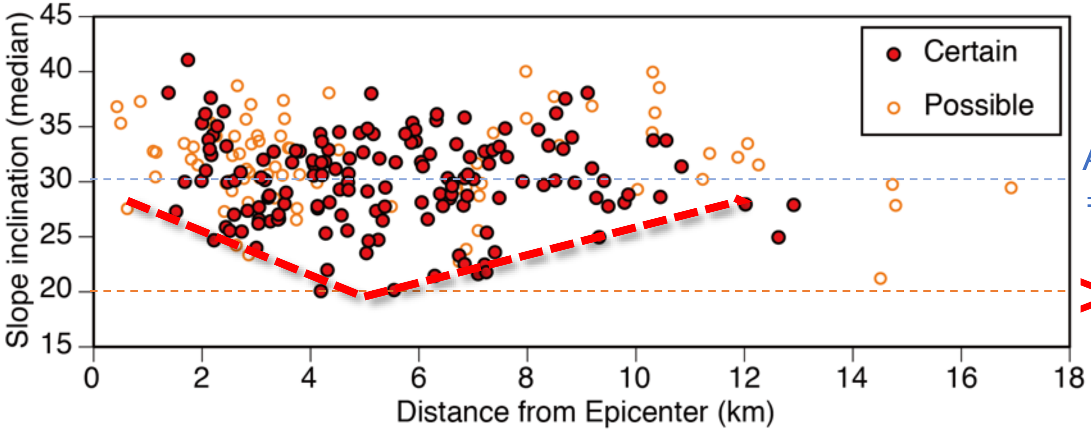
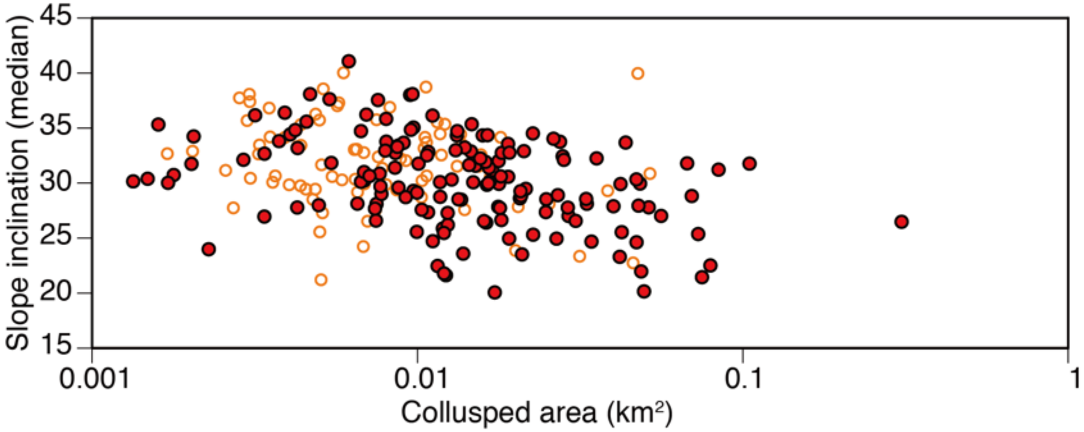
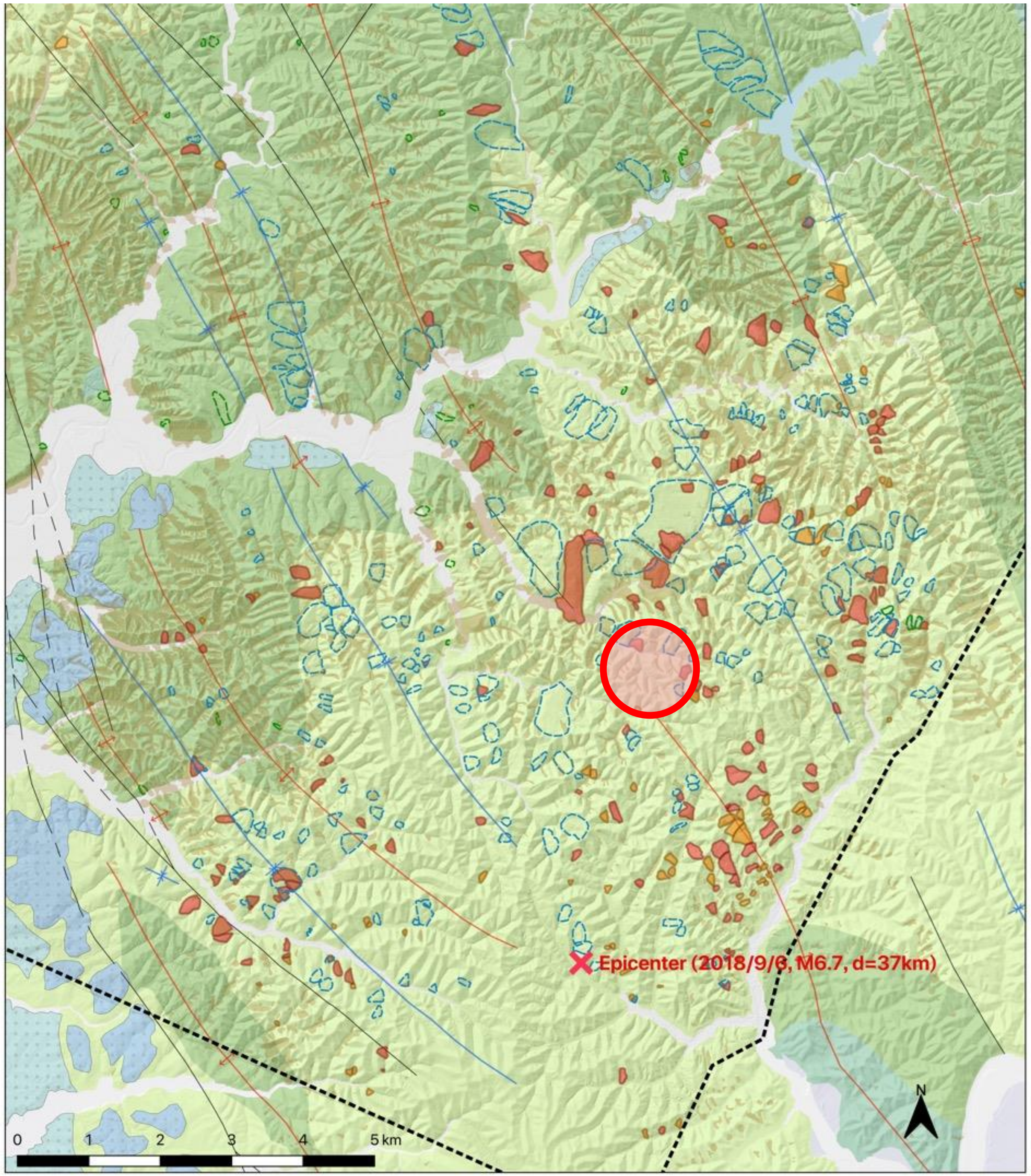


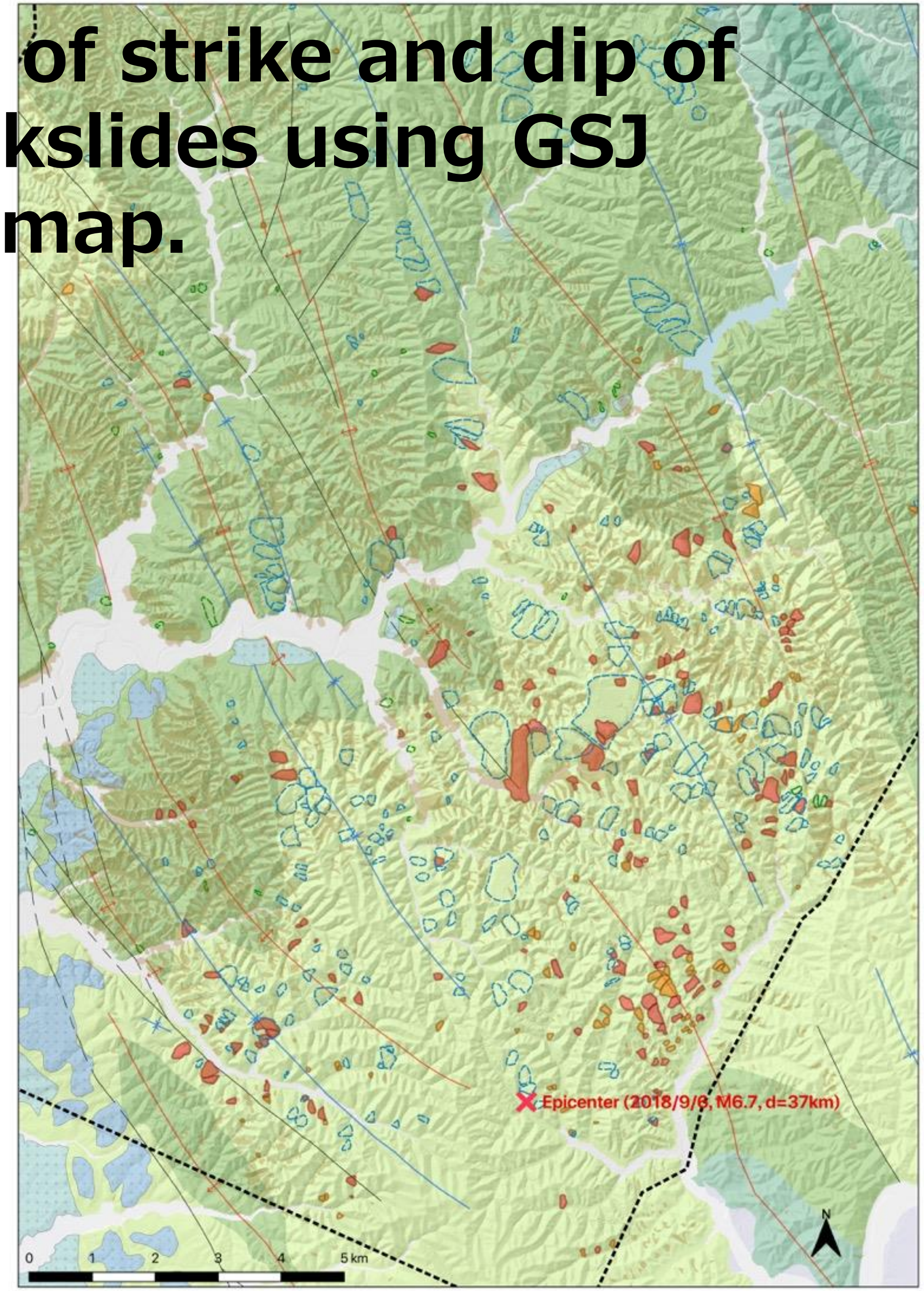
Average
≒ 30º

>20º





Estimation of strike and dip of certain rockslides using GSJ geological map.



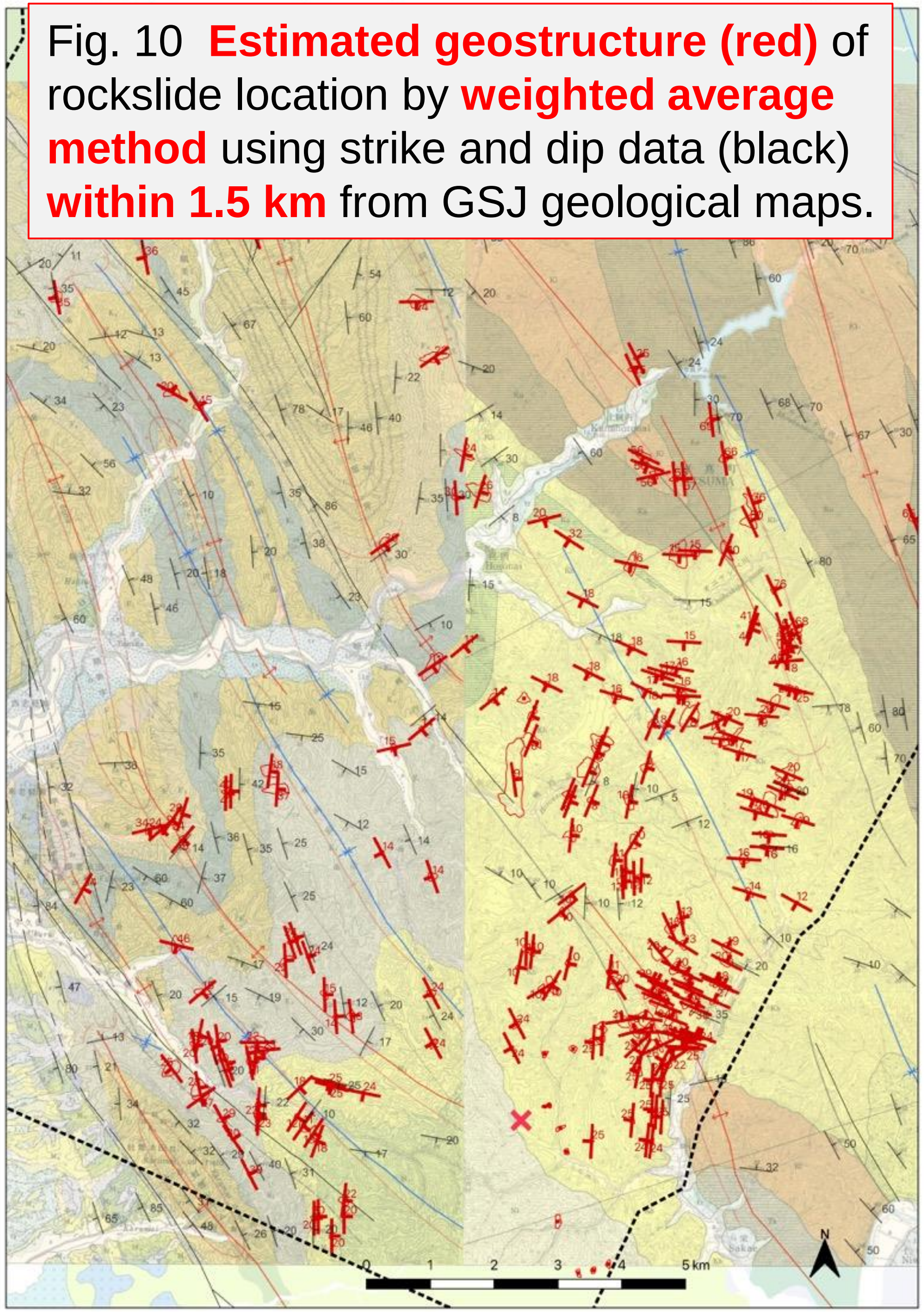


Fig. 10 **Estimated geostructure (red)** of rockslide location by **weighted average method** using strike and dip data (black) **within 1.5 km** from GSJ geological maps.

Estimation of strike and dip of certain rockslides using GSJ geological map.

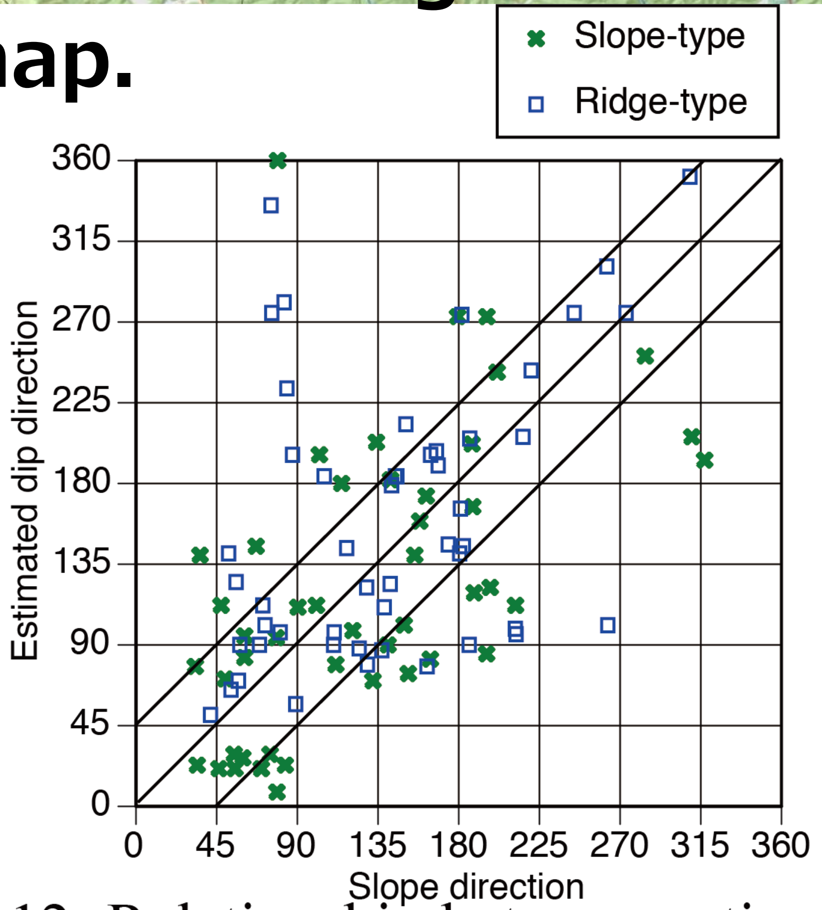


Fig. 12 Relationship between estimated rockslide dip direction and median slope tile amount. The area within the lines show the difference within 45° as dip or overdip slope.

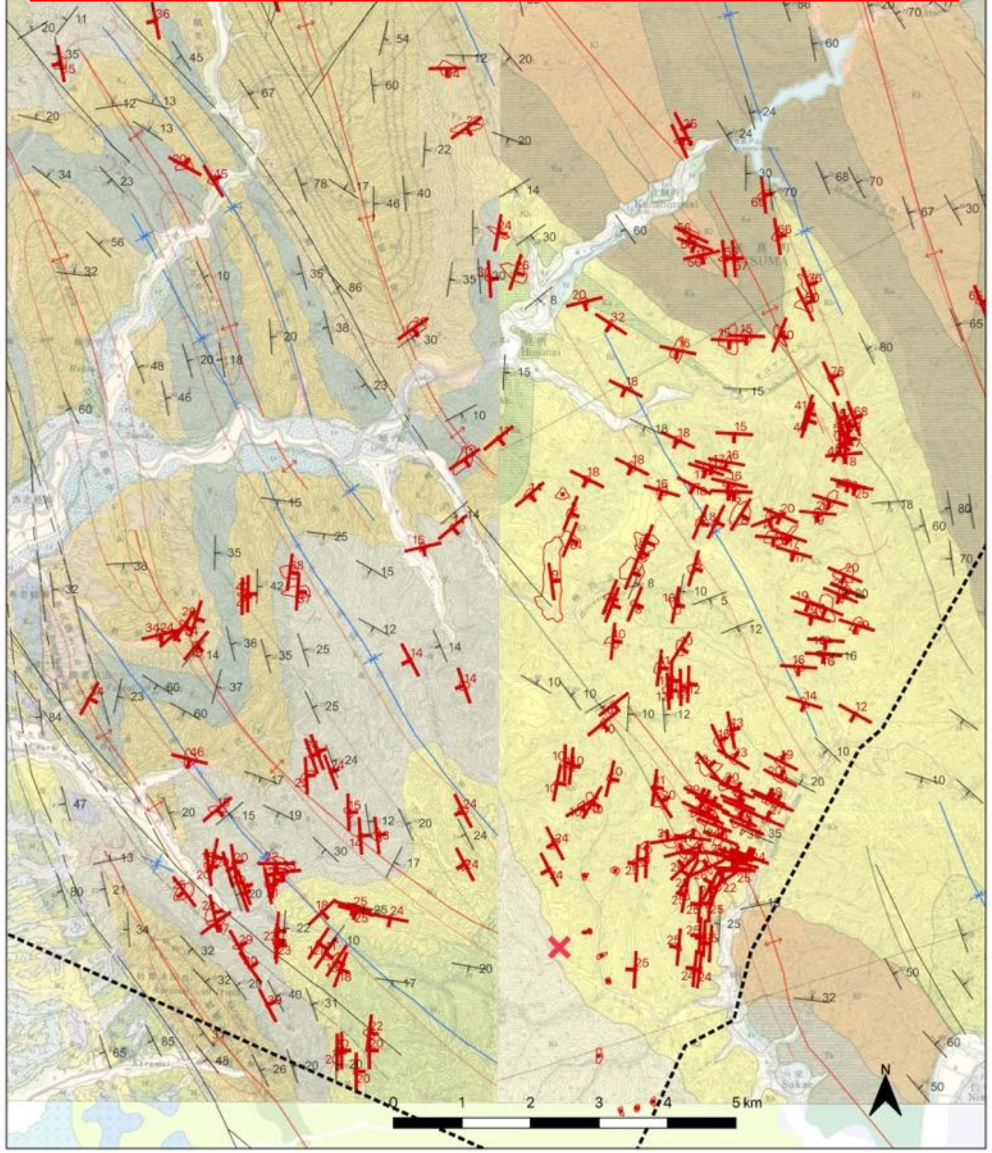


Fig. 10 **Estimated geostructure (red)** of rockslide location by **weighted average method** using strike and dip data (black) **within 1.5 km** from GSJ geological maps.

Summary and future subjects

- Landslide topography analysis using high resolution DEM has **newly identified at least 150 of the earthquake induced rockslides** around the epicenter of Hokkaido Eastern-Iburi Earthquake, Sep-2018.
- The distribution of the rockslides is the highest density at 4-7 km northeast of the epicenter. This possibly indicate that
  - （A）we success to accurate estimation of epicenter location or
  - （B） can detect differences of seismic response associated with basement rock lithology.
- Accurate comparison of the estimated geological structure and the slope is future subject.
- In addition, the distribution and shape of past landslide also, and they would be good data for discussing the interval of fault activity in this area.