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Muography as a novel complementary technique for geotechnical surveys

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Geotechnical applications of cosmic-ray muography

- Cosmic-ray muons can be utilized for **non-destructive and passive imaging** of Earth's subsurface and human made objects

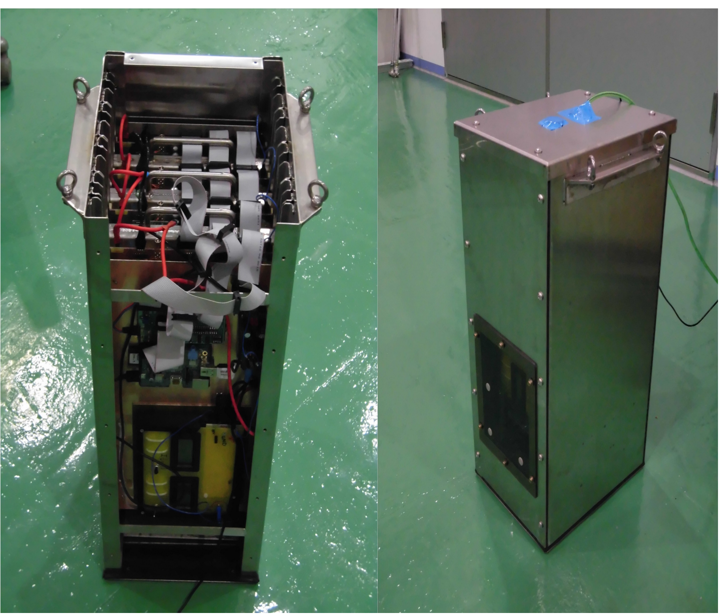
- **Geotechnical applications:**
  - Inspecting and monitoring of human-made structures
  - Improving the effectivenenss and safety of geotechnical work processes, such as tunnelling optimization or exploring abondand mines

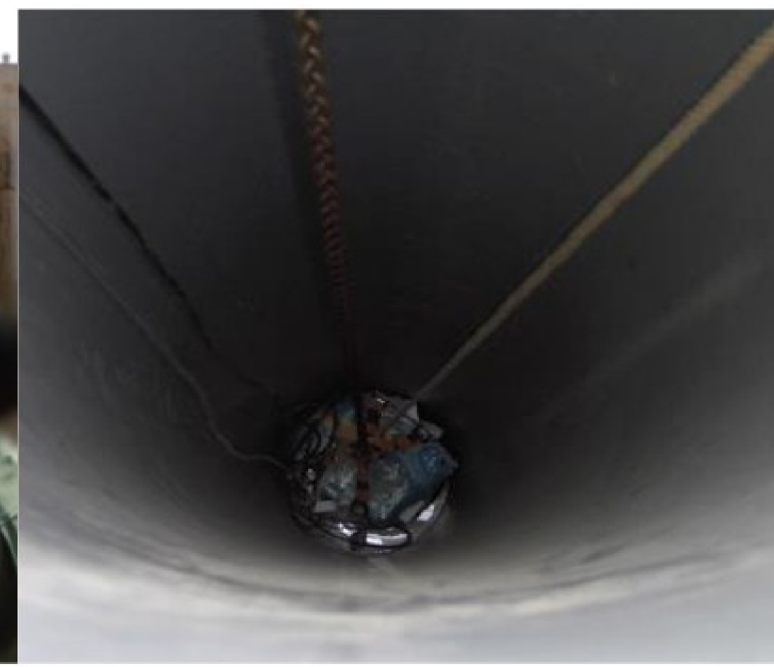
    (See further details in other talks in this session by Marko Holma et al., Mitro Juutinen et al., Simon Bouteille et al., Diletta Borselli et al.)

- This talk focuses on three possible targets of muography:
  1. buried pillars, 2. debris dams and 3. burial mounds

1. Muography of buried pillars

- Blind testing of Japanese Railway standard reinforced concrete pillar: Where is the bottom of the buried pillar?
- 15 days of data taking in a 3-meter-depth shaft
- AC supply + gas supply (1 Liter/hour flow of Ar + CO_2 (portion 80:20) was provided from a bottle installed on the surface
- Ethernet cable allowed remote detector control and data management



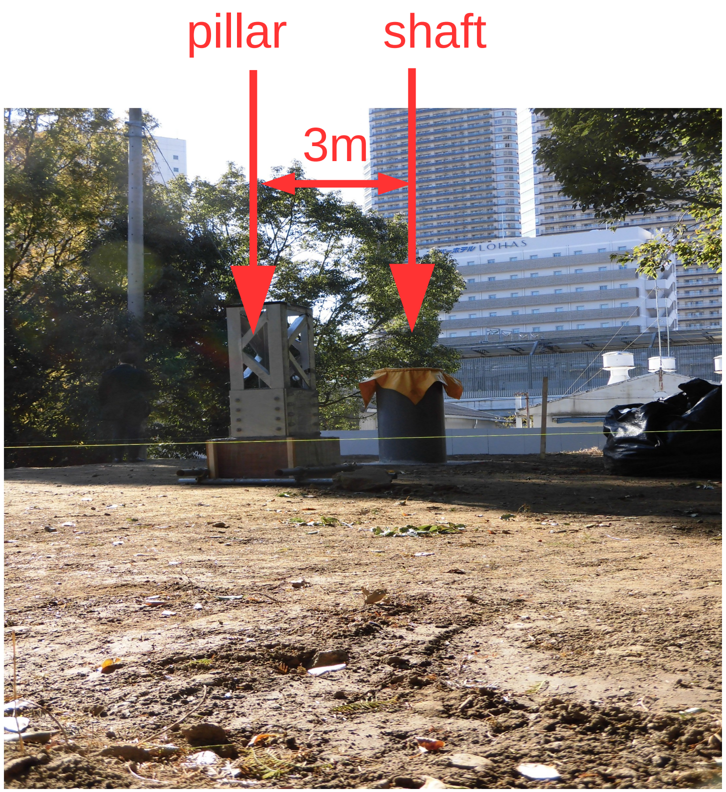


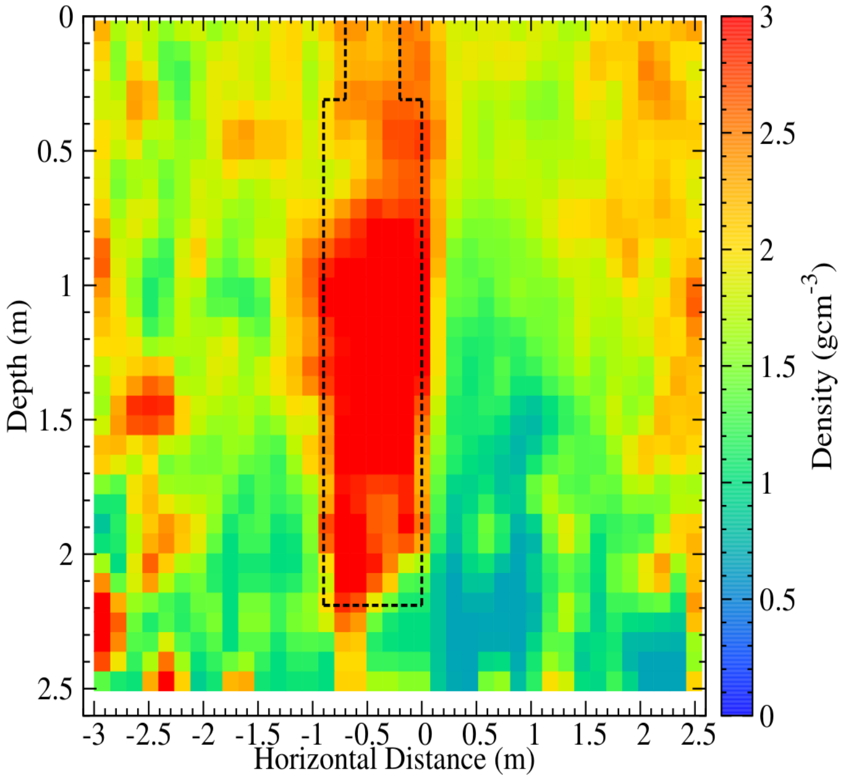
University of Tokyo, Wigner RCP, NEC

Oláh et al.: BUTSURI-TANSA, Vol.71 (2018) pp. 161-168 https://doi.org/10.3124/segj.71.161

1. Muography of buried pillars

- The buried pillar was imaged with a spatial resolution of 15 cm
- The bottom of the pillar was detected at a depth of approx. 220 cm (80 cm above detector's level)





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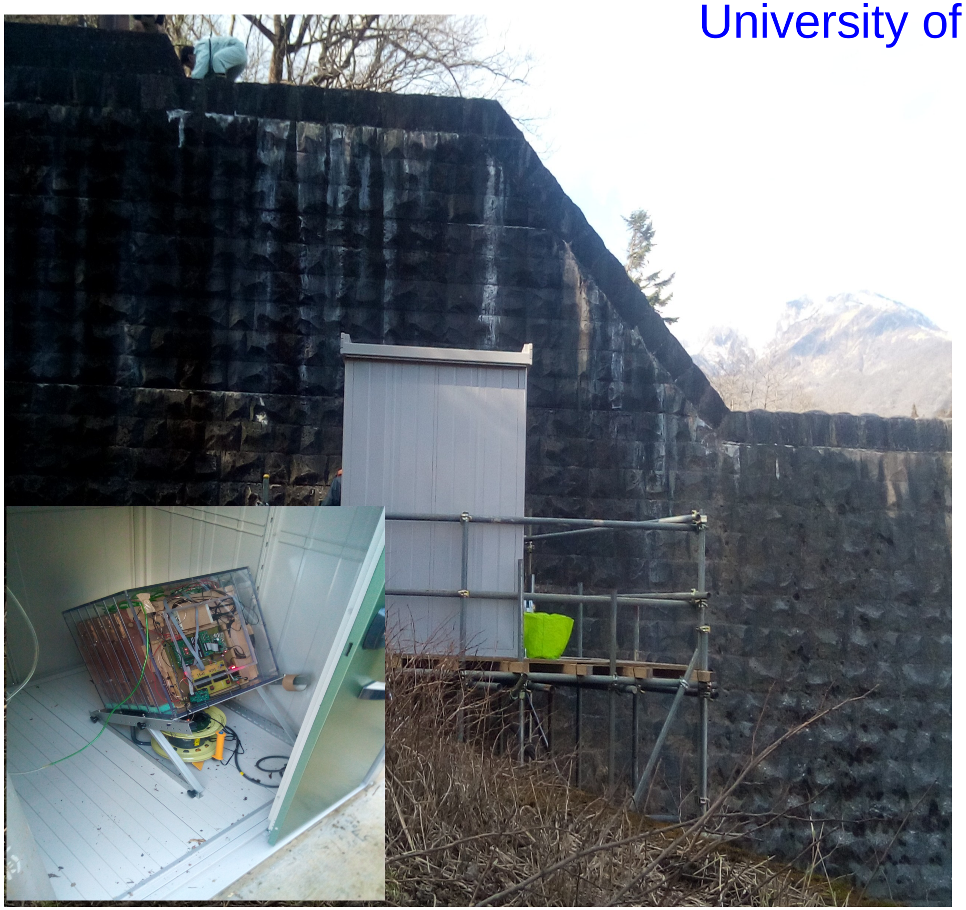
2. Muography of debris dams

- Debris dams control rivers in mountain area and protect the surrounding landscape
- Most of debis dams build 50+ years ago in Japan → inspection of dam structures required
- **Density image of Nikko dam was revealed no structural failure (3 weeks data collection)**



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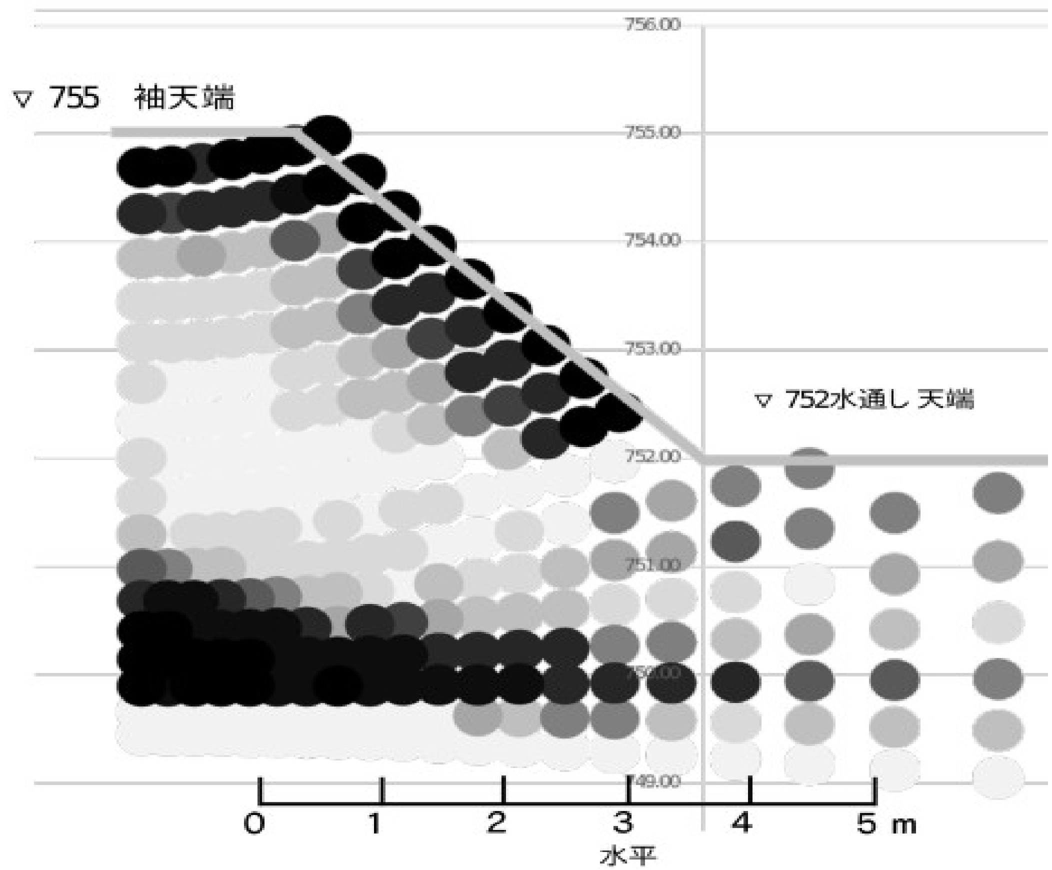
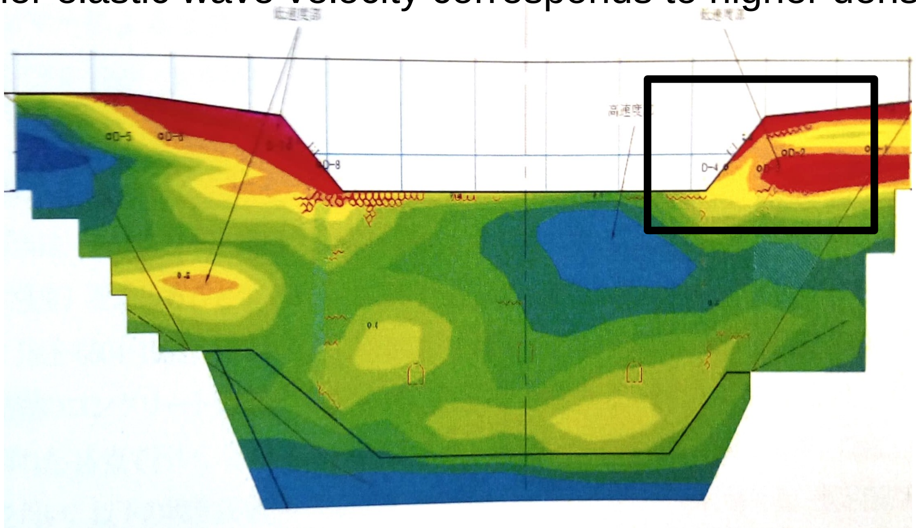


2. Muography of debris dams

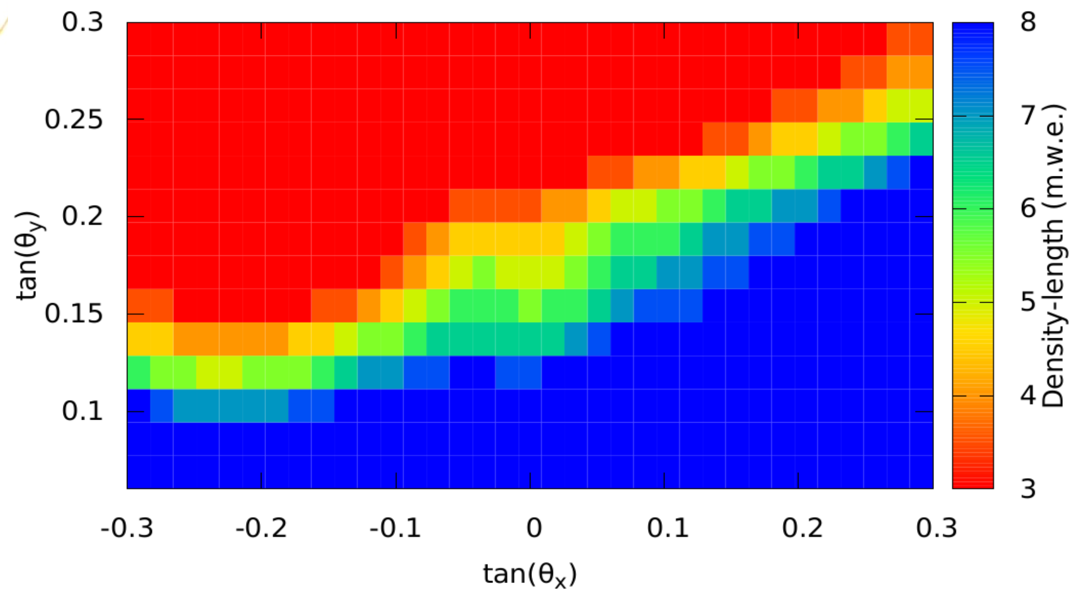
- Weak regions of Karasugawa dam (red coloured regions) were revealed by elastic wave tomography
- Preliminary result of (40 days) muography also shows lower density-length for the right side of the dam where a weak zone was found

Elasic wave tomography
(red and yellow → low elastic wave velocity,
green → medium elastic wave velocity,
blue → high elastic wave velocity)
higher elastic wave velocity corresponds to higher density)



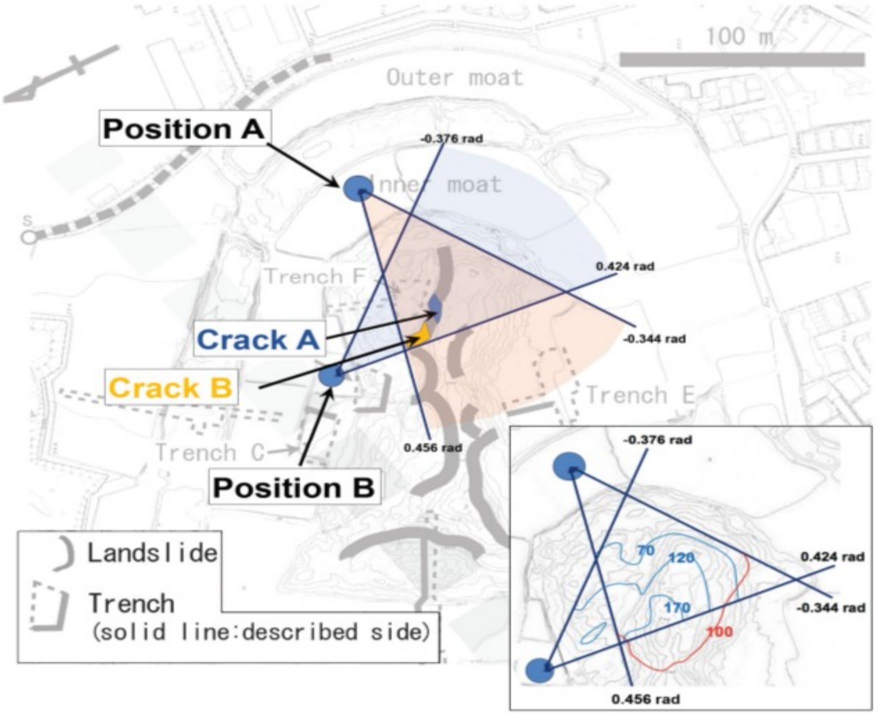
Source: Sabo FF

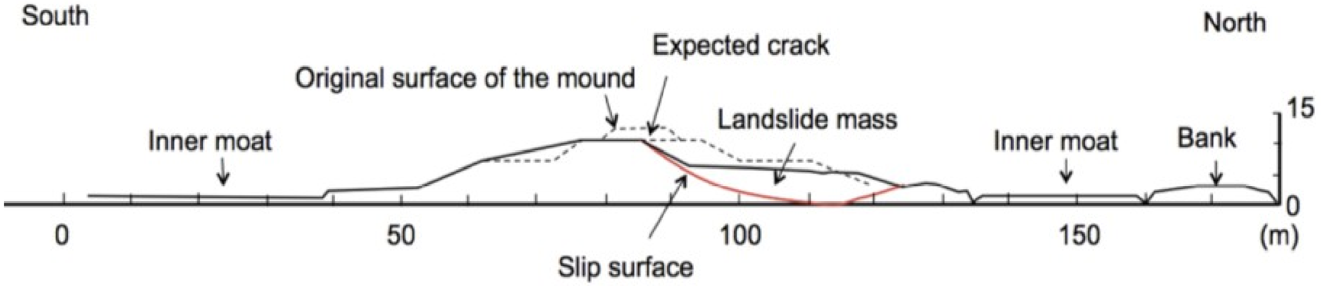
Muography preliminary
(image corresponds to the black rectangle in left figure,
pixel size corresponds to approx. 0.5 m x 0.5 m)



3. Muographic surveying of burial mounds

- Landslides were induced by 1596 Fushimi earthquake on Imashirozuka burial mound
- Imaging of the internal structureo of the kofun can provide information how the earthquake affected its structure
- Bi-directional muography measurements (Pos. A: 40 days, pos. B: 30 days)

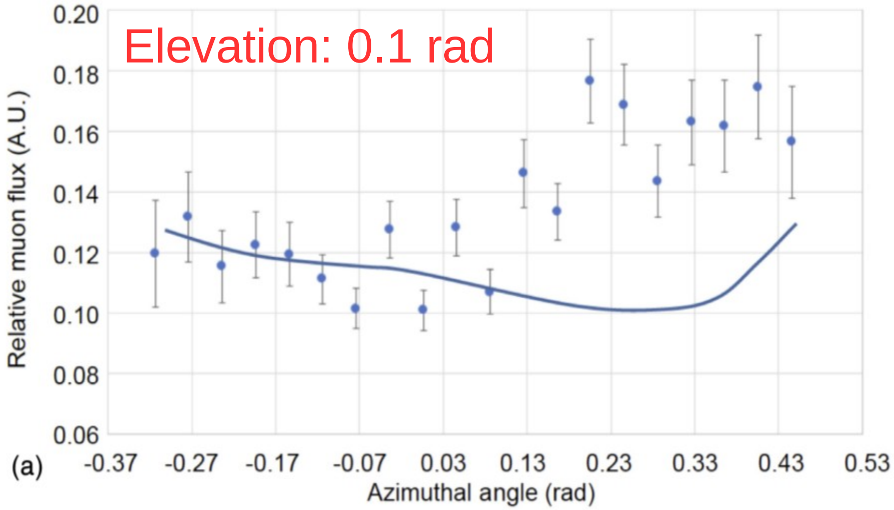


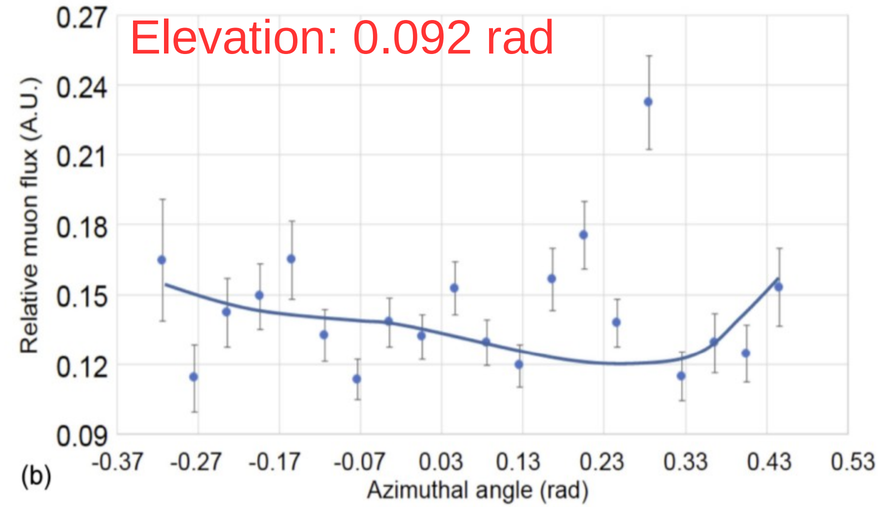


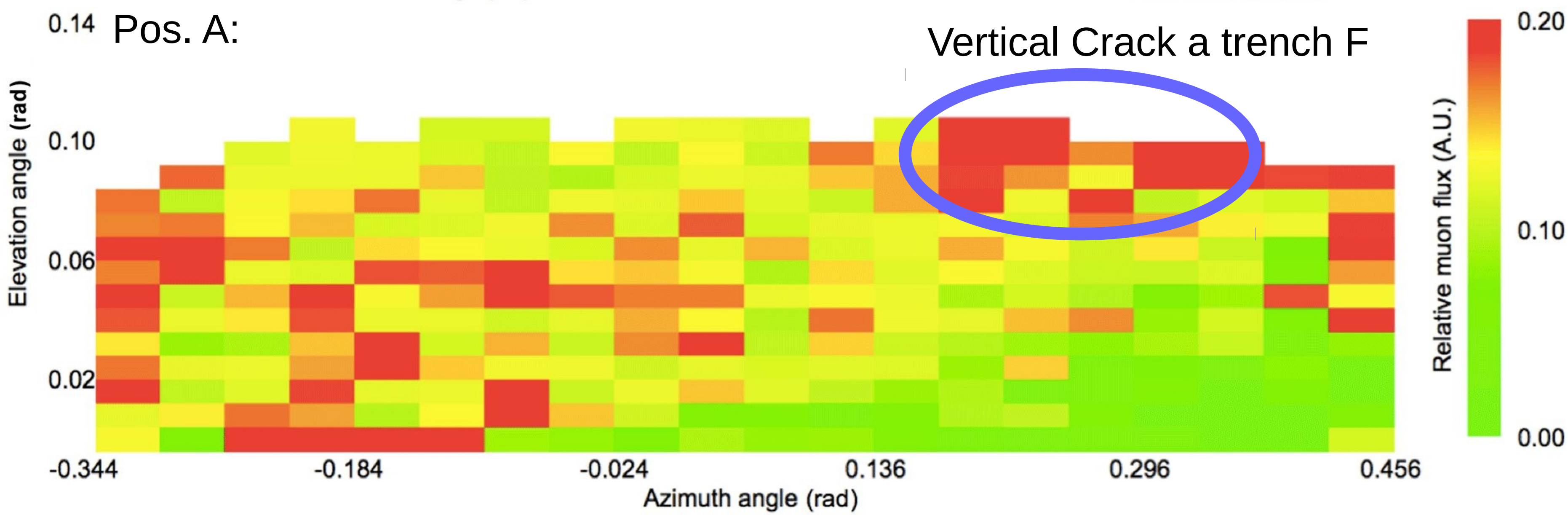
H.K.M. Tanaka, K. Sumiya, L. Oláh, GeoSci. Instrum. Meth. Data Syst., 9, 357 (2020)
https://gi.copernicus.org/articles/9/357/2020/

3. Muographic surveying of burial mounds

- Large-scale (4-8 m width) vertical crack is located behind the rotational landslide headscarp
- mound deformation that connected to the translational collapse process also occurred behind this rotational landslide → structural problem befor historic earthquake







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Conclusions

- Cosmic-ray muons allows non-destructive and passive inspection of different human-made structures
- Strengthening the intersectoral cooperations and further proof of concepts are required to make muography a complementary technique for geotechnical surveys

Thank you for your attention!

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