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新潟大学災害・復興科学研究所
共同研究報告書

GPR investigation of a large-scale volcanogenic flood deposit: the Numazawa Flood Extent
(火山性大規模洪水堆積物(沼沢洪水)の地中レーダ探査)

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研究要旨

After the temporary blockage of the Tadami River by an ignimbrite that originated from Numazawa Volcano (5,400 years ago), a consequent breakout flood swept the Tadami and Agano rivers, reaching the Niigata Plain more than 150 km downstream [1], in one complex event dominated by hyperconcentrated-flow transport. This flood was a single event and was characterized by mass transport of light volcanic pumice material. These materials can vary in density in contact with water, and change mode of transport during flowage due to water absorption in the pores. Because of those particularities, field investigation is essential to unveil the detailed dynamics of the event and how it flowed through the Tadami and Agano rivers. Following on previous years' collaborative research and an original research developed at Niigata University, this collaborative research project investigated the internal structures of the pumiceous flood deposits on a flood-terrace near Nozawa, in order to complete the work carried out in 2018 in the nearby locality of the investigated area. The research method combined GPR (Ground Penetrating Radar) and GNSS (Global Navigation Satellite System) investigation. Collected data were processed to obtain radar velocity and refracted and reflected dielectric intensities from which images of the subsurface, from which images of the subsurface structure were generated.

A. Aim of the study

The aim of the research was to expand the present understanding of how the breakout flood, which occurred 5,400 years ago, evolved during its flowage. The subobjectives are: (1) to confirm the flood extent as it has been previously described using mostly outcrops at different elevations along the valley slopes [1] and (2) to investigate the internal structure of the deposit to understand the changes in the modality of deposition following a downstream gradient in the Agano River. In [1], the author proposed a description of the event, which the present collaborative

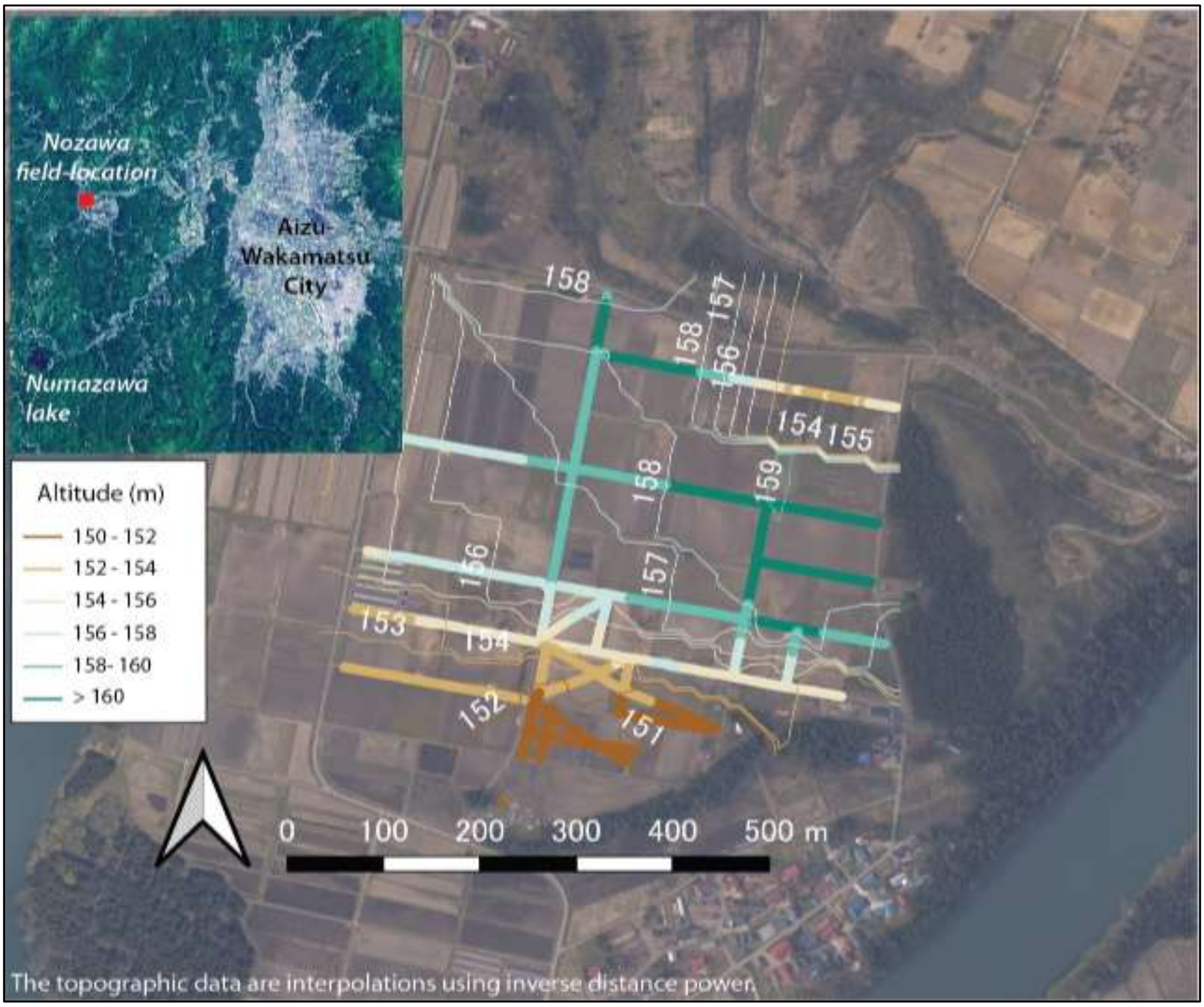

Fig. 1 Map of the field survey location (Red point on the location map) within a square of 500 m x 500 m and at elevation between 150-160 m a.s.l. The topographic values are interpolated from the topographic data measured along the thicker lines (the further away, the higher the probability of having errors).

study attempts to build on, by providing further spatial evidences using Ground Penetrating Radar (GPR).

The collaborative research of 2019-2020 concentrated on a flood-terrace within a meander loop of the Agano River at the locality of Nozawa, downstream of the urbanized center (Fig. 1), and downstream of the work done in 2018-2019 [2].

B. Methodology

The field survey is made of 48 GPR transects mapped using GNSS (Global Navigation Satellite System) and two CMP measurements, one along transect 16, and one at location 48 (Fig. 2-A). Technically, the methodology relies on a field survey GNSS PPK (Post-processing Kinetic), with a fix receiver and a mobile antenna placed on the GPR cart. The fixed GNSS antenna corrects its own position using three continuous GNSS of Yamato, Kaneyama and Kanose. Then, the fixed antenna data is used to correct the GNSS receiver on the cart, providing absolute values in x,y,z. The Ground Penetrating Radar is a Pulse-Ekko Pro® mounted on the company's "smart-cart" with 100 Mhz unshielded antennas. The smart-cart has a coding wheel to record the distance, on top of the GNSS receiver.

Both GPR and GNSS were kindly provided by the Research Institute for Natural Hazards and Disaster Recovery of Niigata University, and the GNSS data were processed at the institute and the GPR data was processed by the collaborative fund applicant.

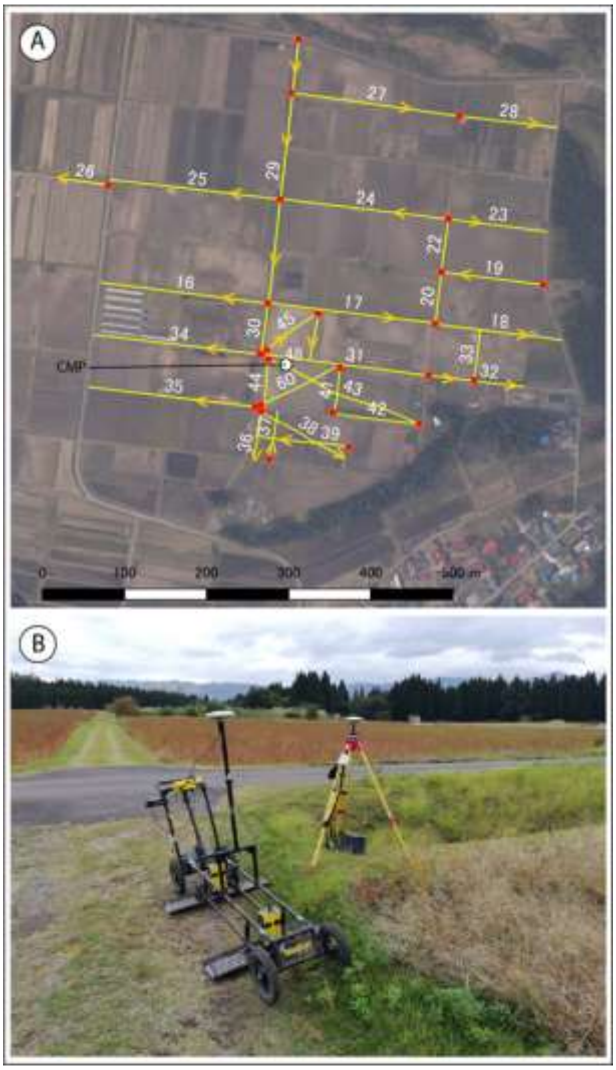

Fig. 2 Survey strategy on the flood terrace. (A) Location of the 48 transects (please note that No. 48 is the CMP location, and that the 48th transect was named transect 60 for convenience. (B) photograph of the GPR and GNSS system used in the present study.

C. Preliminary Results

Using the quadrangles of agriculture practices, the GPR results are spread over a 500 m x 500 m square with 5 or 6 E-W parallel transects and two main N-S transects. This was completed by local transverse transects. For the present report, the authors have selected three parallel transects following a general E-W orientation (transects 17, 24 and 27) the three measuring between 190 m and 200 m length reaching a depth of 12-14 m (data underneath is echo and signal noise). The transects are characterized by two different sets of horizontal layers. A first set located mostly underneath 8 m depth, with velocities at 0.08 to 0.09 m [ns^{-1}] in (A in Fig. 3) and 0.7 m [ns^{-1}] (B,C,D in Fig. 3). Velocities in the top layer D is around 0.7 to 0.75 m [ns^{-1}]. Underneath this two sets of layers, another set of layers exists and on transect 17 measures of velocities at 0.04 m [ns^{-1}] have been made locally. Among those units, UX1, UX2 and UX3 represent features with vertical "walls" and limits that can be filled with other material (UX2) and are kept as unexplained here. Furthermore, agriculture management structures also impact the result with the presence of a drain (the red hyperbola) that creates artificial disturbances in the surrounding units. In unit D, attributed to Numazawa flood deposit (based on one small outcrop and corroboration by the local farmers, as well as the material emerging through the soil at the surface) the GPR architecture shows sets of slightly undulated (with potential 2D wavelength of 50 to 75 m) sub-horizontal layers, as well as inclined layers that resemble units climbing over one another (transect 27 in fig. 3). The layers contain eventual clasts or blocks that are inferred to be of the same material as there is no clear variation in the signal amplitude between the surrounding substratum and the clast itself, so that the ratio between the relative dielectric permittivity of both

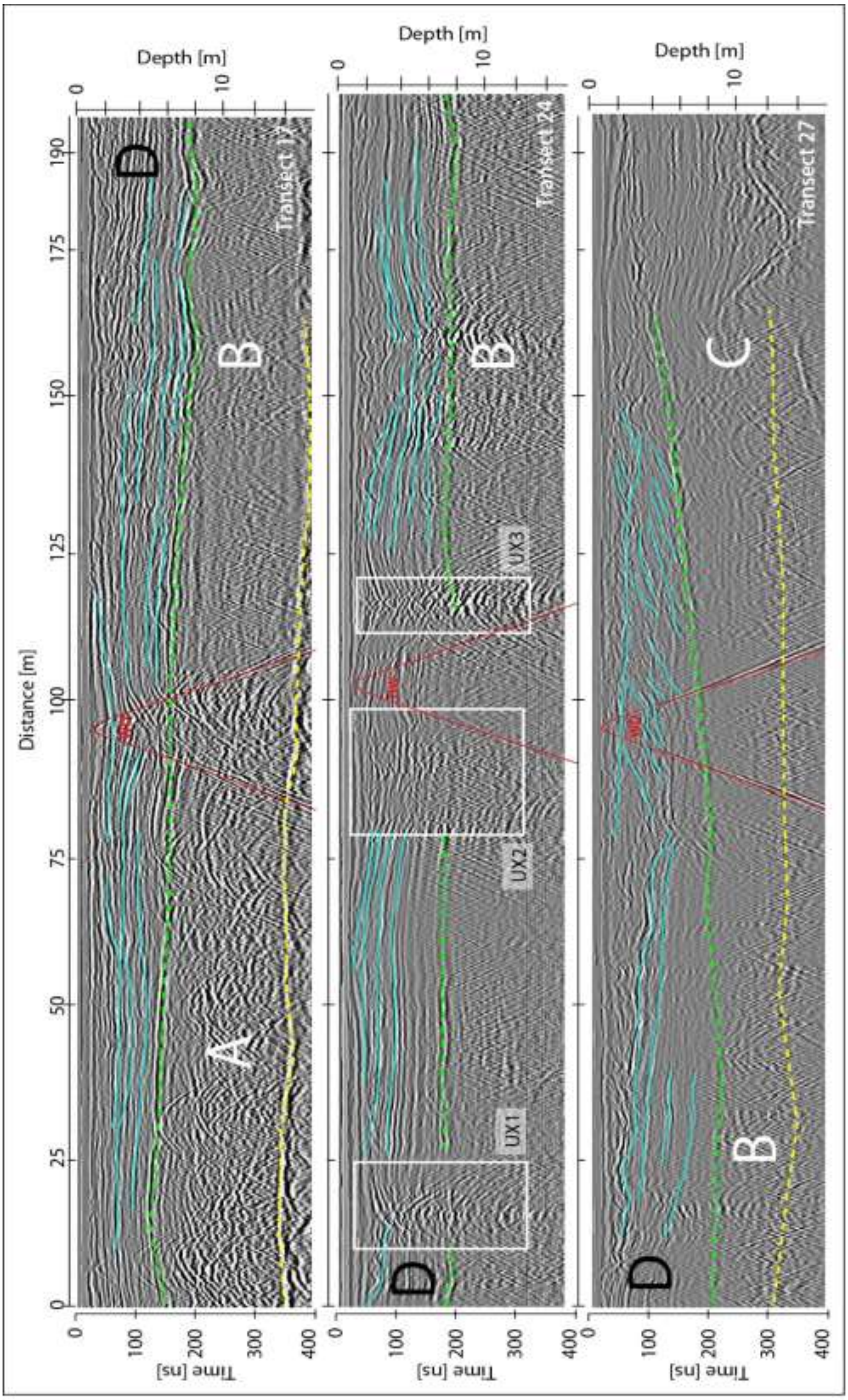

Fig. 3 Transects 17, 24 and 27 showing two to three types of substratum underneath the Numazawa-flood deposit (A, B and C). UX1, UX2 and UX3 are unexplained features with "vertical" limits more than 10 m deep, that could be some forms of excavation or cavity generated during deposition. One will notice the high number of punctual element in a dielectrically heterogenous matrix in A.

material is close to 1.

In details, between 0 and 50 m the units of the top layer D dip slightly towards the East, before slightly rising until 125 m where the units are then richer in clasts/blocks and through the depth of layer D. Along the all transect, there are the presence of punctual elements near the surface (< 2 m depth), which are ignored as they can and are most probably due to present-day activity. On transect 24, the units between 0 and 75 m form a set of sub-horizontal units with a slight slope towards the East and they are stacked over one another "regularly". The set of layers is not a simple repeat of a single unit because the variation of signal energy amplitude does not follow the energy decay curve. This set of layers is limited by two unexplained vertical limits at 10-15 m and at 75-100 m (UX1 and UX2). After 125 m another set of sub-horizontal layers is present but this time it dips towards a central point at ~160 m distance. At the convergence point, a set of reflectors (potentially clasts) dominates the visible geometry on the radargram. Finally, transect 27 displays a set of layers dipping from 0 m distance towards 75 m distance, with an important number of punctual elements/blocks in the first 2.5 m depth, like it can also be seen on transect 24 around the same distance. After 75 m distance and to the end of the transect a "pseudo-backset" (this is used here as a shape descriptor from the GPR data, not a term to take as a sedimentology concept) between 2 to 4 m depth. This set of units is truncated horizontally at 2 m depth, above which punctual elements make the structure of the data. One will notice that there is no apparent change of velocity nor signal amplitude, and it is most probable that the top unit is made of the same material than the one underneath the two meters limit.

D. Conclusions

Although a full picture will only emerge from the whole dataset, the present data shows (1) the data collection was successful and the GPR provided an image to a maximum depth of 12-14 m. The top layer (D) covers another set of material of unknown origin, that can be very rich in blocks or punctual elements (one can wonder whether there are wood debris trapped in a matrix explaining the high dielectric change in A, that looks like nothing else in B,C,D). Underneath those units one can find the bedrock that does not let the signal go through.

The structure of layer D is composed of sub-horizontal units with a very long wavelength, as well as shorter units that are apparently dipping towards the West (from the 2D transect, the real dipping could only be obtained from 3D data or excavation). The units incorporate blocks (punctual objects) that seem to be denser towards the top of D.

References

[1] Kataoka et al., 2008. GSA Bulletin 120, 1233-1247.

[2] Gomez and Kataoka, 2019. Collaborative Research Report. Research Institute for Natural Hazards and Disaster Recovery of Niigata University