



Deformations of a small mud volcano revealed by multi-temporal terrestrial laser scanning

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Activities of mud volcanoes are often regarded as signals of tectonics both in subaerial and submarine environments. Characteristics of mud volcanoes, including the composition of mud, water and gas, the underground structure, and the surface morphology, have often been investigated to reveal their activities. Here we explore the spatial variation in the deformation of a small terrestrial mud volcano, which has hardly been revealed without the use of high-resolution topographic measurements. The Murono mud volcano (north-central Japan) exhibits displacements of its ground surface morphology both by the earthquake events and in the inter-seismic quiescent periods. Multiple-time terrestrial laser scanning (TLS) was applied to detect the spatial variations in the ground surface deformations. After registering the point cloud data at different times using numerous points on unchanged reference features, deformations of the central zone of the mud volcano were detected at the scale of centimeters to decimeters, including both central uplift and peripheral subsidence with an elliptic spatial pattern. Open cracks on the central uplift area were also mapped, whose formation was successfully modeled with the displacement and stress fields estimated by the strong earthquakes. More gradual changes in the surface elevation of the mud volcano during the inter-seismic quiescent periods were also detected by the TLS data, and it was revealed that the spatial location of the center of uplift could have changed after an earthquake event.