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3D Geological Mapping of Central Tokyo

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Abstract

The Geological Survey of Japan (GSJ) carried out 3D geological mapping of central Tokyo. In this project, we performed surface-based geological modeling using borehole logs created by GSJ and also those provided by local governments as well as the development of the Web system for sharing 3D geoinformation. The 3D geological map of central Tokyo will be released on the "Urban Geological Map" website in a year. In this paper, we describe the current progress of this project.

Keywords: 3D geological map, borehole logs, geotechnical properties, Tokyo, voxel model.

1. Introduction

Recently there is growing demand for subsurface information to contribute to the evaluation of geological risk, such as liquefaction and amplification of ground motion, in urban areas in Japan due to frequent disasters caused by large-scale earthquakes. To meet this demand, GSJ has carried out a 3D geological mapping project since 2013. In the project, we create 3D geo-information based on detailed stratigraphic studies and on computer modeling of subsurface geological structures and make it open to the public on the Internet. To date, we have created a 3D geological map of the northern Chiba area, eastern part of Tokyo metropolitan area (Naya et al., 2018), and released it on the "Urban Geological Map" website (https://gbank.gsj.jp/urbangeol/index_en.html). As the next stage of this work, we are carrying out 3D geological mapping of central Tokyo, cooperating with the Civil Engineering & Training Center (CETC) of the Tokyo Metropolitan Government. In this paper, we describe an outline of the 3D geological mapping method and summarize the current progress of the work.

2. Methodology

The study area comprises the special wards of Tokyo, Japan (Fig. 1). This area geologically consists of three parts: upland with Pleistocene deposits, lowland with Holocene deposits, and reclaimed land along the coast. In this area, there are more than 60,000 borehole logs created for public construction works. The borehole logs are accumulated as XML files by CETC. Most of them have simple lithofacies descriptions and Standard Penetration Test results (SPT *N*-values). In our project, we utilize these borehole logs to assess the subsurface geology.

Figure 2 shows a flow diagram of the 3D geological mapping. In the mapping, we perform (1) establishment of a standard stratigraphic framework, (2) stratal correlation using borehole logs, (3) surface-based geological modeling, and (4) release of the map on the Internet. The details of each process are described below.

2.1 Establishment of standard stratigraphic framework

A standard stratigraphic framework beneath central Tokyo is established based on high-quality stratigraphic data obtained from drilling surveys and laboratory work by GSJ. The stratigraphic data includes detailed core descriptions such as sedimentary facies, tephra marker layers, and fossils, ^{14}C age measurement, and PS velocity and density logging.

2.2 Stratal correlation using borehole logs

Stratal correlation between borehole logs obtained from past construction work is carried out by adopting the standard stratigraphic fra-

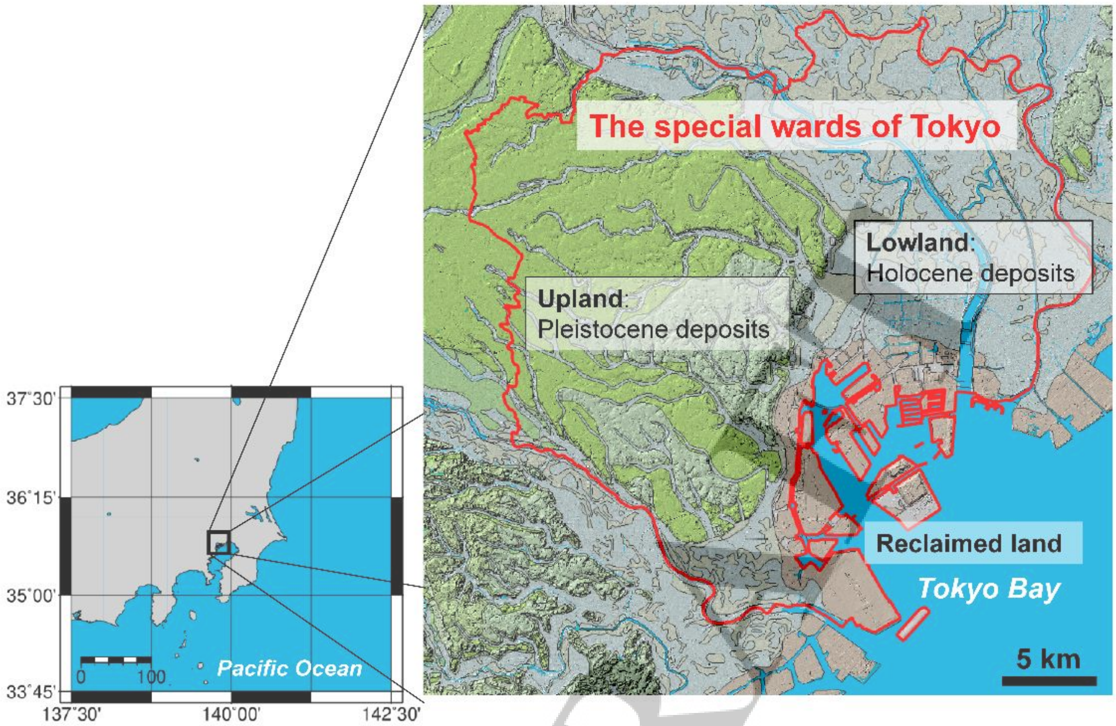

Figure 1: Study area. Solid red lines indicate the special wards of Tokyo, Japan. Base map is based on the Fundamental Geospatial Data (DEM 5-m-mesh Elevation) (Geospatial Information Authority of Japan, 2019) and the Seamless Digital Geological Map of Japan 1:200,000 (Geological Survey of Japan, AIST, 2020).

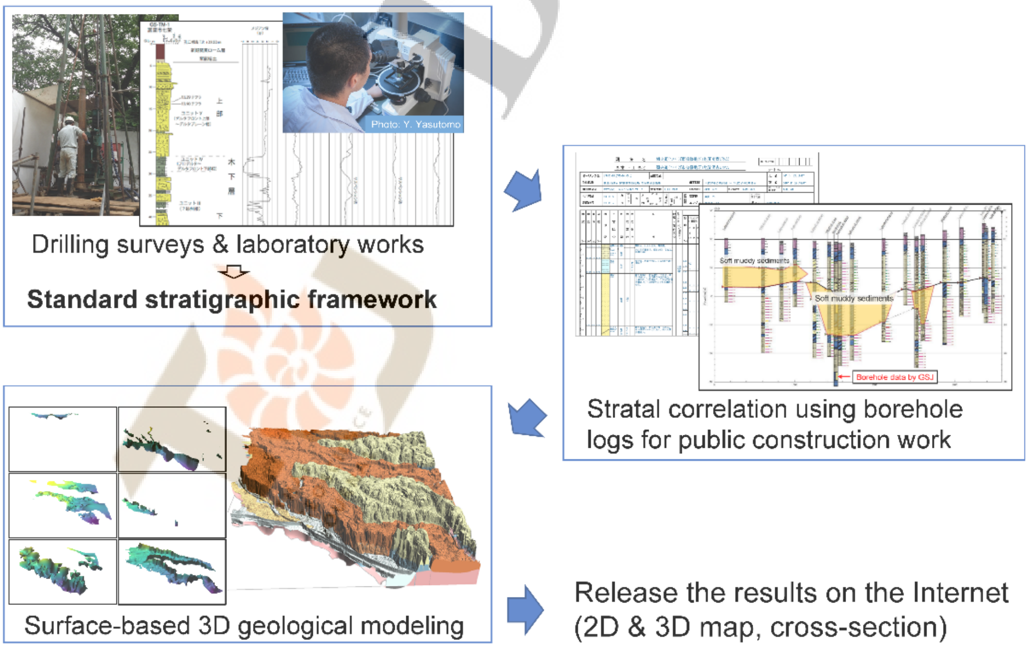

Figure 2: Flow diagram of 3D geological mapping.

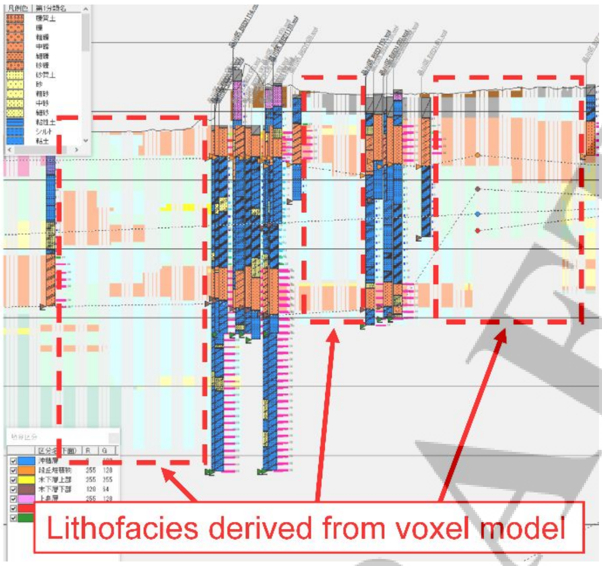

Figure 3: Example of stratal correlation with voxel model of geotechnical properties. Lithofacies derived from voxel model is displayed in broken red line frames.

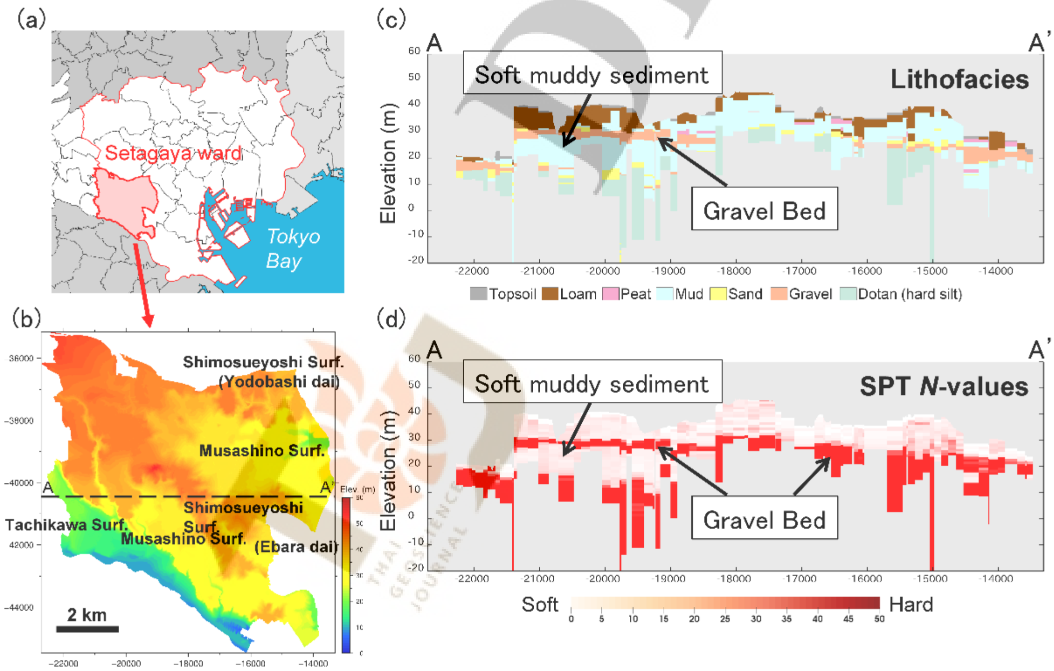

Figure 4: Example of vertical cross-section images of geotechnical properties in the upland area. (a) index map showing Setagaya wards, Tokyo, (b) topographical map, (c) cross-section image of voxel model of lithofacies, and (d) cross-section image of voxel model of SPT N-values. (a) was based on the National Land Numerical Information (administrative boundary) (Geospatial Information Authority of Japan, 2020). (b) was based on the Fundamental Geospatial Data (DEM 5-m-mesh Elevation) (Geospatial Information Authority of Japan, 2019).

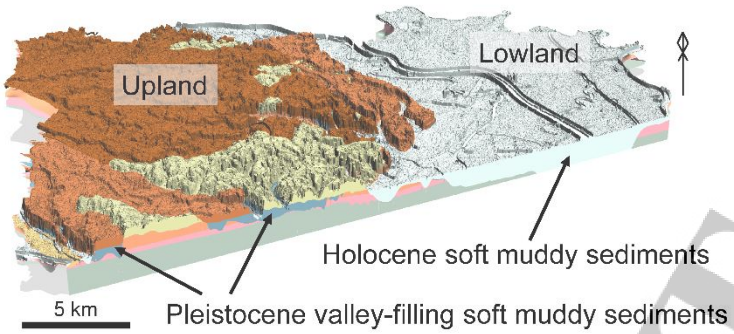

Figure 5: Provisional 3D geological model of central Tokyo.

-me work. In order to increase the efficiency of the stratal correlation process, voxel models of geotechnical properties, such as lithofacies and SPT *N*-values, are constructed from a large number of borehole logs based on Nonogaki et al. (2020) and are used as auxiliary data for the correlation process (Fig. 3).

2.3 Surface-based geological modeling

The Digital Elevation Models (DEMs) of the geological boundary surfaces are generated by the spline fitting method (Nonogaki, Masumoto & Shiono, 2012) using the results of stratal correlation. Additionally, based on Shiono, Masumoto & Sakamoto (1998), a surface-based 3D geological model is constructed by combining the DEMs with a consideration of the geological history.

2.4 Release on the Internet

The 3D geological model is available to the public on the "Urban Geological Map" website. On the website, the user can browse 2D and 3D geological map and borehole logs used for mapping as well as being able to create geological cross-sections along arbitrary lines.

3. Current progress

We constructed voxel models of lithofacies and SPT *N*-values to a depth of several tens of meters in the study area and finished stratal correlation of about 50,000 borehole logs. Moreover, we generated the DEMs of nine geological boundary surfaces using the result of stratal correlation and constructed a provisional 3D geological model of central Tokyo comprised of ten geological layers. The spatial resolution (grid size) of each DEM is five meters. Figure 4 shows the vertical cross-sections of the voxel models in Setagaya ward. The cross-sections reveal that soft muddy sediments, which have high risk of amplifying earthquake ground motion, underlay hard gravel bed in the upland area. Figure 5 shows a provisional 3D geological model of central Tokyo. The geological model also clearly shows the distribution pattern of some geological layers which have a risk of natural disasters.

4. Conclusions

The 3D geological map of central Tokyo is expected to contribute to increasing the accuracy of geological risk evaluation. Furthermore, it is also helpful for planning urban infrastructure, analyses of groundwater flow, and for the real estate business. The 3D geological map of central Tokyo will be released in 2021.

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