学 位 論 文 審 査 の 要 旨

博士（環境科学）　　氏 名 孟 宇

審査委員　主査　教授　渡邉　悌二
副査　教授　露崎　史朗
副査　准教授　早川　裕一
副査　教授　澤田　結基（福山市立大学都市経営学部）

学 位 論 文 題 名

Mapping periglacial landforms in Daisetsuzan National Park, Japan
（大雪山国立公園における周氷河地形のマッピング）

Periglacial regions are geomorphologically active and characterized by permafrost-related processes and frost activity, encompassing about 25% of Earth's surface. Freeze-thaw processes in these areas generate diverse periglacial landforms, which function as sensitive climate change indicators. Daisetsuzan National Park represents an exemplary mountain region where periglacial landforms have developed extensively. However, comprehensive high-resolution and accurate geomorphological data remain limited, constraining thorough understanding and analysis of these landforms.

This study addresses the research gap by selecting two areas in Daisetsuzan National Park. An uncrewed aerial vehicle (UAV) and Structure from Motion (SfM) methodology was used to conduct ultra-detailed mapping of periglacial landforms and analyze their morphological characteristics. This approach generated high-resolution orthomosaic images (2.0 cm/pixel for Area A and 1.8 cm/pixel for Area B) and digital elevation models (DEMs) (3.9 cm/pixel for Area A and 3.6 cm/pixel for Area B). These resolutions provide a robust foundation for identifying and analyzing landform features, even at the decimeter scale.

First, this study identified periglacial landforms in the study areas. Visual interpretation and Geographic Information System (GIS) technology were used to create detailed distribution maps of the landforms. Earth hummocks and nonsorted steps occupy the largest distribution area. Across the study areas, 18,838 individual earth hummocks were mapped over approximately 82,599 m^2, whereas nonsorted steps were mapped over 105,552 m^2 from 50 sites. Compared with maps created using traditional methods, these maps provided higher positional accuracy, more detailed landform classifications, and an expanded study area unconstrained by site accessibility.

The morphological features of landforms dominating the study areas' topography were analyzed to determine their relationship with topographical conditions using orthomosaic images and DEMs. Key morphological parameters and distribution characteristics, including slope, aspect, topographic wetness index (TWI), and Geomorphon Landforms, were examined.

For earth hummocks, the average length, width, and height were 1.22 m, 1.03 m, and 0.15 m, respectively. Statistical analysis revealed significant correlations between earth hummocks' morphological parameters and topographical factors, such as slope, aspect, and Geomorphon Landforms. The average

slope of distribution areas was 8.3°, mostly below 20°, and earth hummocks tended to develop in areas slightly elevated above the lowest gully bottoms. This study showed that earth hummocks are more densely distributed in areas with gentle slopes, suggesting the influence of local microclimatic and topographical factors on their formation.

For nonsorted steps, the average riser height, tread width, riser width, and terrace length were 0.20 m, 1.00 m, 0.73 m, and 5.08 m, respectively. The terrain analysis showed nonsorted steps were mainly on gentle slopes below 10°, around hiking trails in sparsely vegetated areas with low TWI values. This study found a significant positive correlation between riser height and slope, while tread and riser widths slightly decreased with increasing slope. The aspect distribution indicated nonsorted steps in Area A were oriented toward NNW, whereas those in Area B faced WNW. Geomorphon Landform classification identified "slope" as the dominant landform type for nonsorted step distribution.

Among other periglacial landforms, this study documented 2991 m of thermal contraction cracks, much longer than previously recorded. The intersection pattern between cracks and their slope location was analyzed. High-resolution UAV imagery confirmed the presence of sorted patterned ground, offering more detail than earlier field surveys. Insights into the interaction between thermal contraction cracks and nonsorted steps provided a clearer view of their formation sequence.

Findings of this study indicate that topographic parameters elucidate numerous characteristics of periglacial landforms, although these factors alone do not fully explicate their formation and evolution. This study utilized multidirectional hillshade maps to represent and classify landforms, emphasizing reliability. Object-based image analysis (OBIA), with higher accuracy, facilitates extraction of morphological parameters with greater precision and efficiency. The detailed workflow and methodologies can serve as a reference for analogous studies in other periglacial regions globally.

In addition to the excellent academic knowledge in this research, his academic records throughout the Ph.D. course are outstanding. Based on this evidence, the committee concluded that Yu Meng deserves to become a Doctor of Philosophy (Environmental Science).