論文の内容の要旨

論文題目　Morphometric analyses of Danxia landforms in China using GIS and DEMs

（デジタル地形モデルと地理情報システムを用いた中国丹霞地形の地形解析）

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The “Danxia landform” is an erosional landform type originally defined in China. It is characterized by red-colored sandstones and steep cliffs, and developed via long-term erosion. In recent years, the landforms have been receiving international attention and recognized as World Natural Heritage in 2010. Research on Danxia landforms in China so far has focused on the definition, classification, qualitative description and discussion about the origin of Cretaceous strata. Considering the lack of quantitative morphometric research on Danxia landforms, this research aims to provide quantitative and objective characterization of Danxia landforms using a large number of morphometric parameters derived from digital elevation models (DEMs), which have seldom been made in previous studies. The approach permits an objective comparison among Danxia landforms at different stages of geomorphic evolution; the differences in such stages have been stressed in the past descriptions of Danxia landforms. This study also investigates the relationship between the topography and geology using digital geological maps and GIS to evaluate the effects of bedrock lithology and structure on landform development.

This study investigates Danxia landforms in three areas in subtropical southern China: Chishui, Mt. Danxia, and Mt. Longhu. They are the sites of the archetypal Danxia landforms with the World Heritage status, having a monsoon climate, and characterized by different stages of landform evolution: young, mature and old. The use of the ASTER GDEM permitted detailed geomorphometric analyses in the three areas. Stream-nets and watersheds were extracted from the DEM using the threshold drainage area method. Basic properties of the stream-nets including Horton`s parameters such as drainage density, stream orders, the bifurcation ratio and the stream-length ratio as well as the data of stream orientation were derived. Basic morphometric properties of the watersheds such as mean slope and relative relief were also computed. The use of the MathWorks Matlab code allowed the derivation of the hypsometric curves and the hypsometric integral from the DEM. Longitudinal and transverse profiles of each watershed were also extracted. For a segment of a given river, the value of the stream length gradient (*SL*) index was obtained and for an entire reach the Hack profile was derived. Analysis was conducted on “anomalous points” where the height of a point along the river significantly differs from the height estimated from a power function fitted to the river longitudinal profile. Knickzones were also identified along the longitudinal profile of each stream by using the change rate of the stream gradient at different spatial scales. The transverse profiles were analyzed using parameters such as width, relief, slope, height, and their statistical

moments (standard deviation, skewness, and kurtosis). The obtained data allowed the investigation of relationships among the morphometric properties and those between topography and geology.

The results of various geomorphometric analyses show distinct differences in landform characteristics among the three areas related to the landform evolutionary stages. The obtained *HI* values have confirmed previously inferred geomorphic stages. Other parameters related to slope, relief and drainage density were also found to change with the landform evolutionary stage. Correlations between morphometric parameters effectively indicate topographic differences among the three areas according to the evolutionary stage.

Analyses of stream networks indicate that fault systems are responsible for the stream direction in Mt. Danxia, where fault density is high and the effect of overall topographic gradient is relatively weak. Hypsometric curves and hypsometric integrals (*HI*) of the watersheds are significantly affected by lithology. The *SL* index and Hack profiles also reflect lithology and fault distribution. Lithology differences also show their effects on knickzone distribution and forms. More knickzones are found in the typical red terrestrial sedimentary rocks. The locations of the anomalous points often correspond to those of the knickzones. In other words, the longitudinal profiles and the slope changes tend to change at the same points. In the Chishui area, difference in drainage density-slope angle relationship seems to reflect differing stages of channel development corresponding to relative watershed location. It was found that the watershed with the Type 4 drainage density–slope angle relationship in the Chushui area represent significantly different stages of evolution from those in Mt. Danxia and Mt. Longhu, in spite of some similarities topographic characteristics.

The relationships between the representative shape parameters of longitudinal/transverse profiles and watersheds have revealed that the number of positive correlations increases in the following order: Chishui, Mt. Danxia, and Mt. Longhu. With the advance of erosion, topography of Danxia landforms tends to exhibit stronger correlations between various relief, slope, height and dimensional parameters. It can be said that more organized topography is formed in the later stages.

The analyses using a large number of morphometric parameters conducted in this research permitted the detailed evaluation on the independence and effectiveness of each parameter. For example, *HI* was found to be independent of other parameters for any stages of landform evolution so future studies using a lesser number of parameters should include *HI*.

The results of this study were compared with a previously proposed model on the evolution of Danxia landforms. It was found that the differences in slope and relief among the areas with different evolutionary stages and change in drainage density are not well represented in the model. The effects of geological differences within an area also need to be included. This result, along with the other results obtained through this research, provides a guideline for future studies on Danxia landforms widely distributed in China.