Doctoral Thesis (Abridged)

博士論文（要約）

Analysis of Factors Controlling Erosion Rates on a Global Scale Using DEMs and GIS

（デジタル標高モデルと地理情報システムを用いた全球規模の侵食速度を規定する要因の検討）

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Understanding the mechanisms and controlling factors of erosion rates is of great importance as it is a vital component of both geochemical and sediment mass balance studies, and a deep understanding of these processes will enable a development of accurate landscape evolution models. During the past decades scientists have been studying and measuring erosion rates on local and global scales. A major objective of these studies was to try and discover the controlling factors of erosion rates. A variety of factors were identified ranging from slope and basin area, to precipitation and vegetation coverage. Due to limitation of available data in the past, the analysis tended to be relatively basic. Thanks to abundant newly obtained erosion rate data, combined with high resolution DEMs (Digital Elevation Models) on a global scale, a more complete and comprehensive analysis can be made, and correlations of erosion rates with factors related to basin morphometry, climate and tectonics are possible. This is the first comprehensive study to analyze erosion rate data derived from a number of different methods. Using a 1 arc second resolution on a global scale would significantly improve basin morphometry data, which has been identified as a major player in controlling erosion rates. The study is based on previously obtained and published erosion rate data, including those from ^{10}Be, a cosmogenic radionuclide, and sediment yield measurements published by the U.S. Geological Survey. In addition, open source data related to climate, tectonic plates, lithology, vegetation, fault distribution and peak ground acceleration (*PGA*) were obtained and correlated to the compiled erosion rate data. Analysis was conducted using ArcGIS 10.0, Python and JMP 13.0.0. In addition to looking at the full data set, it was also divided into sub data sets and each of them was analyzed.

All together 2683 data points in 211 basins were analyzed. The total area studied in this research represents about 10% of the surface of earth. The mean erosion rate for the whole data set is about 560 m/Myr and the data show a log normal distribution. Erosion rates for basins tend to be

larger than those for outcrops; sediment yields tend to measure faster erosion than ^{10}Be; sedimentary rocks generally erode faster than igneous rocks; small and wet basins tend to erode faster than large and dry basins; and rates measured close to converging type tectonic boundaries are usually larger than rates for diverging and transform types, and non-tectonic zones. The following five characteristics were identified in this research. 1) The most important factors within the basin morphometry category are relief and slope. However, their careful usage is recommended. Although in the bivariate correlation analysis, mean basin-wide slope correlates better than other slope related factors, it is a problematic parameter as it does not account for the complex morphology of a basin and slope distribution within a basin. This is prominent in basins that have steep slopes near river heads but wide depositional planes downstream. 2) Erosion rates are dependent on climate factors, in particular basin average yearly precipitation and annual precipitation range to which they are positively correlated. The latter reflects the element of seasonality and wet-dry cycles, which has been shown to accelerate erosion. 3) Examination of the correlation of erosion rates to vegetation types and coverage indicates that these factors do not directly affect erosion rates; rather, they represent a secondary effect dependent on precipitation. 4) Erosion rates are correlated with factors related to tectonic activity as they are positively correlated to peak ground acceleration (*PGA*), and are negatively correlated to distance to tectonic plate boundary. This might be an indirect dependence on tectonic activity, as the further away from a plate boundary, the more likely the basins are in a tectonically stable environment. 5) An analysis focusing only on tectonics-related factors shows strong couplings between *PGA* and distance to tectonic plate boundary, between basin slope and *PGA*, and basin slope and distance to tectonic plate boundary. This, together with the strong correlation of these factors with erosion rates, indicates that tectonic activity strongly affects erosion rates. The

precise way in which these are related is still difficult to determine but can be due to the combination of several factors: the effect of rock shattering due to ground motion, an effect of precipitation causing erosion and thinning of the crust which incites tectonic uplift through isostasy, and a relation through slopes as increased tectonic activity produces steep slopes. Although erosion rates are dependent on many different factors, this study emphasizes the importance of two factors in particular: precipitation and distance to tectonic plate boundary. Even though they are part of extensive systems and the precise way in which they affect erosion is complex, both are easily obtained parameters. The study also shows that using mean basin-wide slope as a predictor of erosion rates can be problematic as it does not properly expresses the complex morphology of basins and thus careful consideration should be taken when using this parameter.