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Relation between rock uplift and topography in asymmetric mountain ranges: Application to actual mountain ranges

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Nowadays, we have detailed information about topography for all over the world, while tectonic deformation is still not easy to estimate in most areas, even if we can use space geodetic techniques, such as GPS and InSAR. So, if we can quantitatively estimate tectonic movements directly from topography, it must be very useful.

There are many asymmetric mountain ranges in the world, such as the Himalayas. One of the main causes of the asymmetry is asymmetric rock uplift. Under asymmetric rock uplift and fluvial erosion, the erosion rate seems faster on the steeper side, if the other conditions, such as precipitation, are uniform. Hence, we can expect that the topographic axis migrates from the rock uplift axis toward the center of the range.

Using a stream erosion model, in which the erosion rate is proportional to the product of power functions of the drainage area (exponent m) and the channel gradient (exponent n), we quantitatively examined the response of topography to asymmetric (gabled) rock uplift. Particularly, we focused on the relation between the axes of rock uplift and topography.

So far (at JEPS 2004 and JPGU 2009), through the numerical simulation, we have shown that 1) the topographic axis always locates between the rock uplift axis and the center of the mountain range under a realistic parameter range ($m < n$), 2) the relation between the axes of rock uplift and topography is expressed by a logarithm function, especially the fitting by the logarithm function is nearly perfect for $m = 0.5$ and $n = 1.0$, and that 3) the location of topographic axis is controled by the pattern of rock uplift and the exponents m and n, and does not depend on the maximum uplift rate and the proportional coefficient of erosion rate.

Based on the obtained relation between the axes of rock uplift and topography, we estimated rock uplift distribution for the following three ranges; the Taiwan Central Range, the Hida Range, and the Suzuka Range. From the cross section of topography, we found that the topographic axis locates around 65 % from the west in each mountain range. Then, according to the simulation results, the rock uplift axis locates around 72 % from the west, if $(m, n) = (0.5, 1.0)$. When m/n is larger than 0.7, the rock uplift axis almost coincides with the topographic axis; more specifically, the offset between the both axes is less than 2 %. For smaller m/n, on the other hand, the offset between the both axes is larger. For example, when $m/n = 0.4$, which is reported for the Taiwan Central Range, the location of the uplift axis is 69 % for $n = 0.5$, 76 % for $n = 1$, and 90 % for $n = 1.5$. In brief, when the topographic axis locates around 65 %, the offset between the topographic axis and the rock uplift axis is small (about 5 % or less) except for the cases of smaller m/n and larger n.

In the Taiwan Central Range, from the metamorphic grade and thermochronological studies, we can infer that the offset between the topographic axis and the rock uplift axis is significant.

Therefore, we can expect that m/n is small and n is large in the Taiwan Central Range, though we perhaps need to consider the effect of horizontal rock movements there. In the Kinki Triangle, we observe many asymmetric mountain ranges, one side of which is bounded by active reverse faults. As shown in the simulation, actual topography is always affected by various random factors, such as initial topography. Therefore, if we obtain the rock uplift pattern for many mountain ranges in the Kinki Triangle, we can have more reliable estimates of the exponents m and n, because the conditions of erosion, such as precipitation, lithology and vegetation, are relatively uniform in the region.

Keywords: asymmetric mountain range, topographic evolution, rock uplift, active fault,
stream erosion model, Kinki Triangle