

Assessment of weathering grades for different chemical and geomechanical properties; A Sri Lankan case study
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Having a better understanding of the weathering grade of rock materials is highly beneficial in the perspective of civil engineering and geology. The classification of weathering grades can be performed based on the chemical, physical, mineralogical, textural and strength properties of rocks. Among those, the use of chemical components to classify weathering grades is not very promising for all types of rocks. Based on the mobility of elements various chemical indices for weathering grades have been formulated. Most of those indices are based on experiments of weathered acidic igneous rocks under humid and well drained environments. There are only a few indices formulated for sedimentary and metamorphic rocks, so the use of chemical weathering indices for the classification of weathered metamorphic rocks would not be convincing. However, the use of physical and strength properties for the assessment of weathering grades is comparatively convenient. A better variation of those properties with respect to weathering grades is resultant irrespective to rock type. Therefore, this study focuses on assessing weathering indices using physical, strength and chemical properties of a selected metamorphic rock and evaluating the correlation among the indices derived from those properties.

Fresh and weathered rocks of garnet-sillimanite gneiss were selected from the Samanalawewa Hydropower Project. Weathering grades were visually assessed initially, then confirmed with physical and strength properties using tests on dry density, water content, ignition loss, point load strength and slake durability. Whole rock geochemical data were used to calculate weathering indices.

Physical and strength properties show a marked difference with weathering grades. However, chemical indices are not very convincing. Silica-Titania, Product index and Ruxton ratio show a gradual variation with weathering grades. Mobiles index also shows an acceptable variation. However, the modified weathering potential index, which was formulated for metamorphic rocks, Parker index, which was formulated for all types of rocks, do not show a gradual variation with weathering grades. Chemical index of alteration and weathering (CIA and CIW) do not show a recognizable variation with weathering grades. Physical and strength properties show good correlation with most of chemical indices. In addition, most chemical weathering indices show good correlation with each other. The Lixiviation index is the one shows weak correlation with most of other chemical weathering indices. The failure of some indices in showing a good correlation can be accounted for the heterogeneity of garnet-sillimanite gneiss.

キーワード: Weathering grades, Rock weathering, Chemical weathering index
Keywords: Weathering grades, Rock weathering, Chemical weathering index

柱状節理の発達した花崗斑岩の皮殻を伴う球状風化過程 Spheroidal weathering process of granite porphyry with columnar joints to form core-stones covered with rindlets

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紀伊半島南東部の花崗斑岩山地には、厚い風化帯があり、花崗斑岩の基盤岩が直径 0.4-1.5 m の球形のコアストーンに風化し、コアストンの表面に鱗状の層(皮殻)が生じている。この風化現象は球状風化と呼ばれ、その際の皮殻は化学的風化によって剥離した結果であると古くから考えられている。しかしながら、皮殻形成の際の化学的変質に伴う物理的性質の変化や亀裂発達の過程は解明されていなかった。そこで、その中新世の熊野酸性岩類の花崗斑岩を対象にして、地表踏査と露頭観察、ならびに採取試料の表面観察と鉱物-化学的分析、物理的性質の測定を行った。その結果、次のように球状風化が進んでいることが分かった。花崗斑岩は 2-6 m 間隔のほぼ鉛直の柱状節理をもち、地表付近では、斜面に沿ったシーティング節理に切られて角柱のブロックになる。球状風化は、柱状節理やシーティング節理から褐色化(酸化)が進むことにより始まる。コアストンの半径に因らず、褐色帯は 2.5-5 cm の厚さであり、最もコアストーン側の皮殻が 3.5-5 cm の厚さであることから、褐色帯が約 5 cm の厚さを超えると剥離が生じると考えられる。薄片観察や X 線回折分析によれば、黄鉄鉱や緑泥石の酸化と水酸化鉄の形成が褐色化の際に生じる。褐色化が進むにつれて、細孔が水酸化鉄に充填されていることや微小亀裂が褐色前線と平行に形成されていることが紫外線照射のもとで行う蛍光観察によって明らかになった。また、褐色帯や皮殻内部に認められる亀裂は、鉄の水酸化物とパーミキュライトとの集合体に収束する傾向があり、0.5-2 cm 間隔で鱗状を成す。褐色帯では、P 波速度は最大 10% 速くなったが、褐色境界と平行な面の圧裂引張強度は低下した。これらの物理的性質の変化は、細孔充填と亀裂発達の影響であると考えられる。岩石の密度と化学組成を用いたマスバランス計算によれば、褐色帯や内側の皮殻では未だに体積膨張は認められなかったが、亀裂がさらに増加した外側の皮殻では 20%、マサでは 80 %、未風化岩よりも体積増加を示した。以上の結果は、亀裂発達と皮殻の剥離の原因が鉄の水酸化物の間隙への沈殿に伴う体積膨張であることを示唆している。また、マスバランス計算は化学成分が褐色帯と皮殻、マサで、構成鉱物の変化と調和的に溶脱されていることを示した。酸素の拡散と溶脱によって、コアストーンは皮殻を次々と生じて小さくなりつつ、節理に近い皮殻は斜長石を失い、内部に亀裂を発達させる。皮殻は最終的にマサになり、マサ中に皮殻に包まれたコアストーンが生じる。

キーワード: 球状風化, 風化皮膜, 花崗斑岩, 亀裂, 酸化, P 波速度

Keywords: spheroidal weathering, weathering rind, granite porphyry, crack, oxidation, P-wave velocity

石造建造物におけるバイオ風化とバイオプロテクションに関する議論 Regarding to the arguing issue; Bioweathering vs Bioprotection in stone historical buildings

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The Angkor complex is the one of the greatest cultural heritages in the world. It is constructed in the early 12th century, designated as a world cultural heritage by UNESCO in 1992. The temples at the Angkor complex are mainly made of sandstone and laterite. However, due to the tropical climate, plants, lichens and various microorganisms are growing well on the rock surface. Black crusts are also easily found on the stone surface. Biological factors are considered as a damage factors for the heritage. The studies suggested that how it can be removed without destroying the substrate efficiently.

We sampled Angkor sandstone covered by black crust at the Angkor Wat and Bayon temples, Angkor complex, and observed the section and the surface of the rock sample by using SEM. Surfaces of the samples are not polished in order to observe the original condition. The depth of the black crust is up to 1 mm. Many filamentous materials were found on the black crust. Average energy-dispersive X-ray spectroscopy data of the black crusts shows that over 70 % of the surface materials are compounds of carbon. And 15% of the mass are made of SiO₂. It seems that these materials are hyphae. The shape of the hypha is like a thread and its size is few μm in diameter and up to several centimeters in length. Black crusts are consisted of elements and compounds of carbon, Na, Mg, Al, Si, Cl, K, Ca, and Fe.

The answer of the controversy question "Do lichens on the historical building protect it or not?" is not fixed. It protects while weathers. It depends on the time scale and the surroundings. We have to focus on the timing of the lichen fall off. Under the lichen coverage, rocks may be protected. When the lichen fall off, it may have lower surface than lichen-free rock surface. Weathering is in progress and is a result of previous process under various facts, not only biological factors but wet-dry cycle, various salt and so on. This is the reason why it is hard to judge whether lichens should be removed or not. We have to check all the environmental data such as temperature, humidity, direction, insolation, rainfall frequency, human effect, weathering degree etc. and decide to remove or not. Therefore, field survey and evaluation standard are needed. Further research has to be continued to find out the better and proper way of conservation for the historical sites as Angkor monument.

キーワード: アンコールワット寺院, 石造文化財, 保存修復, 地衣類, 生物風化

Keywords: Angkor Wat, stone cultural heritage, conservation, lichen, biological weathering

Accumulation of radioactivity inside Yoshimi archeological heritage Accumulation of radioactivity inside Yoshimi archeological heritage

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The Hundred Caves of Yoshimi is a cluster of ancient grave caves dug on the cliff made of tuffaceous sandstone located in Yoshimi town, Saitama. It was designated as a national historic site on March 7, 1923. Built between late 6th century and late 7th century, the caves were initially made for only the blood royal and other big powerful families but later used for large scale of underground munition factory. At present, the area is used for tourist attraction. Continuous survey has revealed that the caves are heavily affected by salt weathering, mostly by gypsum. However, seasonal changes have also been observed in salt formation. As part of that survey, accumulation of natural radioactivity, significantly anomalous than background level, has been observed inside some of the caves of Yoshimi. The survey has been carried out to all accessible caves and radioactivity was measured by Horiba Radi PA-1000 radiation monitor within 2-5 cm of the wall. Radioactivity was found to be as high as 0.119 micro sievert per hour in some of the walls which is more than twice of the natural radioactivity found at the entrance of the area. This amount is marginally higher than the radiation dose limits for general public. Having similar rock type in all the caves, the reason of such accumulation of radioactivity is lichen formation in the inside walls which is a known bio-accumulator of radioactivity. Though studied walls are still out of reach of tourists visiting Yoshimi caves, spreading of lichen to other walls might increase the radioactivity risk. Such accumulation of radioactivity also needs to be considered if other caves are opened for tourists in future. Specific source of radioactivity also needs to be investigated through detail survey.

キーワード: Natural Radioactivity, Yoshimi caves, Weathering, Lichen, Bio-accumulator, Radiation dose
Keywords: Natural Radioactivity, Yoshimi caves, Weathering, Lichen, Bio-accumulator, Radiation dose

韓国マノ山における岩塊流の形成プロセス Formation processes of block stream in Mt. Maneo, South Korea

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This study revealed that formation processes of slope deposits include block stream near Mt. Maneo, South Korea. Using a satellite image reading from Naver site (<http://www.naver.com/>) and a field survey, we studied the positional relationship between the Mt. Maneo block stream and its surrounding terrain, as well as the general shape of the block stream. The satellite image scale was about 1:5000, which had a resolution sufficient to identify the block stream. Next, we superimposed the interpreted satellite image on a 1:25000 topographic map, and read the contour lines over the location of the block stream. The plan view of the block stream on Mt. Maneo has a belt-like shape. The top end of the slope is the steepest, having an incline of around 20 degrees. On examining the contour lines crossing the block stream, the contour lines in the top section are found to be more or less straight and represent an even slope with no obvious ridges or valleys. In the central part of the block stream, the contour lines are convex in the upslope direction, indicating a wide valley. In the lower section of the block stream, the contour lines are convex in the downslope direction, indicating the presence of a ridge.

A cross-section of the block stream is visible in the central part of the out crop and can be split into two parts: a matrix of fine-grained materials on the northwestern side, and a matrix-free deposit on the other side. For the purpose of this study with respect to sedimentary facies, we counted the sections having matrix as part of the block stream. In the matrix-free deposit section, blocks with a larger diameter tend to be concentrated in the lower portion. The overall cross section has an upward convex shape.

We observed ground water flow and soil saturation by five tensiometers. All observation points were located at the top of block stream. Depth of the tensiometers were about 30cm. Tensiometers were inserted fine slope deposits at the upper part of the block stream. Observation period was Jul. 9, 2014 to Jul.14, 2014. We observed that slope deposits were rapidly saturated associating with rainfall event. Rain fall event was occurred in Jul. 13, 2014. Rainfall amount was 30mm/day. All tensiometers responded this rain fall event. Suction was decreased very rapidly at this rainfall event. This means that saturation of soil layer occurred at the head of block stream associating with rainfall event. Water was concentrated in the valley created by this landslide. We can recognize from observation of suction that the unsolidified weathered fine-grained material forming the landslide block was washed out by this water flow, leaving only the core stones behind.

We believe that the area of the Mt. Maneo block stream is an old landslide site. This could have been a deep seated landslide that reached the deep weathering layer of the upper section of Mt. Maneo, and it is thought that a large section of the landslide block consisted of core stones and weathered fine-grained material.

キーワード: 岩塊流, 形成プロセス, 地すべり, 水文観測, 韓国, マノ山

Keywords: Block stream, Form processes, Landslide, Hydrological survey, South Korea, Mt. Maneo

上高地谷の幅の広い谷底における土砂収支に沖積錐が果たす役割
Roles of alluvial cones in sediment budget in the wide valley floor of the Kamikochi valley, central Japan

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The upper reaches of the River Azusa, flowing down in the Kamikochi valley in the Northern Japan Alps, central Japan, is surrounded by very steep mountain slopes and high mountains which elevation is higher than 2500m. There are many landslides on the steep mountain slopes, from which debris is supplied to the valleys of the tributaries of the upper River Azusa.

Alluvial cones are the most important features on the valley floor of the upper River Azusa. These are formed at each outlet of the tributaries. To clarify the roles of the alluvial cones in the sediment budgets of the upper Azusa basin, landforms of the alluvial cones were investigated and the sediment linkages between the tributaries and the main river were discussed.

Many debris flow lobes are distributed on the surfaces of the alluvial cones. This shows that the alluvial cones are formed by debris flow accumulation. Most of the alluvial cones have several levels of terraced surfaces. The cone of a tributary, Furuikezawa, has four levels of surfaces. Each surface is bordered by terrace cliffs of several meters high. While the most part of the lowest surface is covered with newly deposited gravels with pioneer trees younger than 70 years, the other surfaces are covered with mature forest, the age of some trees are hundreds of years, and dense forest floor vegetation. The channel of Furuikezawa directly connects with the lowest surface and the surface borders on the main river floodplain with dense riparian forest. The surface is not contact with the channel of the main river. The lower borders of the terraced surfaces are margined by terrace cliffs which stretch parallel with the direction of the valley of the River Azusa. Other alluvial cones in the Kamikochi Valley have such similar geomorphological characteristics.

These characteristics of the alluvial cone show the alternation of accumulation of debris flows on the cone surface and lateral erosion of the toe of the cones by the channel shift of the main river. The debris supplied from a tributary basin is stored as its alluvial cone deposits. When the channel of the River Azusa will be shifted to the alluvial cone, lateral erosion will occur at the lower end of it. As lowering of the base level the channel of the tributary begin downcutting and the alluvial cone surface becomes a terrace. Debris produced by the lateral erosion is transported downstream of the main stream.

During the time lag between debris supply to the cone and eroded away from the cone and transport downstream debris became easily breakable into fine materials.

Alluvial cones on a wide floodplain play important role on sediment transport link between mountain slope and valley floor. Produced debris from the mountain slopes is not transported directly downstream by the main river. That is an important factor in basin sediment budgets.

キーワード: 土砂移動プロセス, 沖積錐, 広い氾濫原, 土砂収支, 上高地, 中央日本

Keywords: debris transport process, alluvial cone, wide floodplain, sediment budget, Kamikochi, central Japan

走古丹バリアースピットの地形発達史から読み解く 根室海峡沿岸域の完新世海面変動と地殻変動

Geomorphological evolution of Hashirikotan barrier spits resulting from seismotectonics along the southern Kuril Trench

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An active barrier system is developed in the Nemuro Bay area along the Okhotsk Sea in eastern Hokkaido, Japan. This presently rare feature consists of a lagoon (the Furen-ko lagoon), a flood tidal delta, a barrier, and a tidal inlet that opens into the outer sea of Nemuro Bay and the Sea of Okhotsk. The Hashirikotan barrier spits are active in the northeastern part of the Furen-ko lagoon, and five spit branches (BS1~BS5) can be observed clearly. Using geomorphological, sedimentological, and ground-penetrating radar methods, we analyzed Holocene sediments near the Furen-ko lowland. We dated them using radiocarbon and tephrochronological methods. The Furen-ko barrier system has been established since 5.5 ka. BS1, the youngest spit was formed after the 17th century, and BS2 was caused by the last seismic uplift in the 17th century. BS3 was uplifted in the 12~13th century, and BS4 was caused by seismic uplift in the 9th century. These great earthquakes (Mw8.5~9.1) have occurred at an approximate 500-year interval along the southern Kuril subduction zone. Coastal areas were raised by 1~2 m during or just after the earthquakes due to postseismic displacement. Conversely, land subsidence has been ongoing at a rate of about 1.0 mm/year since the 17th century. We conclude that the geomorphological evolution of the Furen-ko barrier system has been controlled by the seismotectonics along the Kuril subduction zone.

キーワード: 地形発達史, 走古丹バリアースピット, 地震テクトニクス, 南千島海溝, 東北海道, 北部日本

Keywords: geomorphological evolution, Hashirikotan barrier spit, seismotectonics, southern Kuril trench, eastern Hokkaido, northern Japan

Measurement of changes in wall surface morphology in Yoshimi-Hyakuana cave by terrestrial laser scanning
Measurement of changes in wall surface morphology in Yoshimi-Hyakuana cave by terrestrial laser scanning

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Detection and quantitative evaluation of changes in surface morphology of rocks are crucial issue for the understanding of processes of weathering. Using terrestrial laser scanning (TLS) approach, detailed topographic measurements of wall surface morphology were performed repeatedly at a test site of Yoshimi-Hyakuana cave in Saitama Prefecture, central Japan. Time series of point clouds and digital elevation models (DEMs) were compared to each other, revealing the locations of centimeter-scale changes in the wall surface, likely induced by salt weathering. The spatial distribution of such surficial changes will be further assessed by continuous measurements, with appropriate accuracy assessments.

Keywords: TLS, weathering, point cloud, digital elevation model

中川低地北部の自然地層中に含まれる砒素を含有した間隙水について Arsenic contained in the pore water of the natural sediments in the northern part of the Nakagawa Lowland, Japan

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The Kanto Plain is the largest lowland in Japan. Marine sediments are found over a wide area here, even more than 50 km inland from the present shoreline, because of the global cyclic changes in sea levels. The dependence on groundwater to meet the water needs in this area is relatively high. In particular, groundwater is the source of approximately 40 % of the municipal water supplies. Arsenic levels, greater than those permitted by the environmental standards of Japan, have been detected in the groundwater of this area. Therefore, measurements were conducted to evaluate the occurrence of arsenic and other related elements in the pore water contained in the natural sediment layers. We measured the levels of various inorganic chemical substances, such as arsenic (As), iron (Fe), and sulfur (S), and major dissolved ions, such as sulfate (SO_4^{2-}), calcium (Ca^{2+}), and sodium (Na^+). The pore water was collected from sediment samples, obtained by drilling from the river bottom down to a depth of 44 m. The pore water samples were obtained immediately after the extraction of the sediments. The sedimentary facies shown in the vertical profile are continental, transitional, and marine, including two aquifers. The upper aquifer (15~20 m) contains fine to coarse sand, whereas the lower aquifer (37~44 m) contains fine to coarse sand and gravel. The concentration of arsenic and other inorganic elements was measured by an inductively coupled plasma mass spectrometer (ICP/MS) and an inductively coupled plasma atomic emission spectrometer (ICP/AES). The concentration of major dissolved ions was measured by an ion chromatograph analyzer. The total chemical element content was measured by X-ray fluorescence analysis, using solid sediment samples. We obtained the following results. The arsenic concentrations in the pore water of the marine silt and clay sediments (approximately 40 mg/L) were about five times higher than those in the continental sediments (approximately 8 mg/L). The highest concentration of arsenic (74 mg/L) was detected at a depth of 13 m, which is immediately above the upper aquifer. Visual observations confirmed oxidizing conditions for this level. Therefore, it points to arsenic being adsorbed to iron hydroxide in the sediments. In contrast, in the top part of the section, from the river bottom to a depth of approximately 3 m, the arsenic concentrations in the pore water were clearly high, and decreased gradually and continuously with depth. This is ascribed to the anthropogenic impact on the river.

キーワード: 重金属, 砒素, 水-岩石相互作用, 間隙水, 溶出, 汚染

Keywords: Heavy metal, Arsenic, Water-rock interaction, Pore water, Leaching, Pollution

漸化式モデルを用いた階段状岩石海岸地形の側方侵食速度の算出
A recursion model for calculating the original widths of narrow terraces and their lateral erosion rates on rock coasts.

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This presentation presents a new and simple recursion model for calculating the erosion rates of flights of narrow terraces under conditions of regular uplift. The general equations developed are: $\Delta x_n = \Delta x'_n + \Delta x_{n-1} - \Delta z_{n-1}/\tan\theta$, and $\varepsilon_n = \Delta x_n/t_n - t_{n+1}$, where n is the number of narrow terraces, Δx_n is the original width of narrow terrace n , $\Delta x'_n$ is the observed width of narrow terrace n , Δx_{n-1} is the original width of narrow terrace $n-1$ (one step below terrace n), Δz is the height of the narrow terrace, θ is the gradient of the slope, ε is the lateral erosion rate, and t is the time uplifted. The model can be used to calculate the lateral erosion rate if the widths of the present shore platform and of the emerged narrow terraces can be obtained, and where chronological control is available. Lateral erosion rates on the Ashizuri, Boso, and Kii peninsulas in Japan, as well as the Huon Peninsula in Papua New Guinea, were calculated using the model to be approximately 0.001, 0.2-1.0, 0.009, and 0.002-0.014 m/yr, respectively. These calculated values are in agreement with the rates of lateral erosion determined in previous studies.

キーワード: 岩石海岸, 漸化式モデル, 側方侵食速度
Keywords: rock coast, recursion model, lateral erosion rate

河川縦断形の発達プロセス：室内実験 Adjustment processes of river longitudinal profile: laboratory experiment

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平衡河川の縦断形は指数曲線的であるという認識が存在している。フィールドでは、地形が隆起しているにも関わらず、隆起と浸食がつりあう動的平衡状態へと向かう。しかし、岩盤河川において、平衡河川に至るまでの河川縦断形発達プロセスは明らかになっていない。本研究のモデル実験は、砂とシルトを混合させた実験物質で斜面を形成し、河川を開析させた。下流には、中央にスリットの入った堰を設け、流域のベースレベル低下を防ぐ。斜面の上から、10個のノズルによってミストを降らせる。パラメーターに海岸線を軸にしている傾動の速度と初期傾斜を持つ。傾動を行わず初期傾斜の依存を観察する実験と傾動を伴う実験を行った。結果は以下の通りであった。傾動を伴わない場合では、本流の下刻は二段階で進んだ。一度目の下刻は谷頭浸食が終わった時に抑制され、二度目の下刻は支流の成長による流量増加から起こったと考えられる。同じタイミングで、本流と支流の河床勾配の差によって合流部の下刻が進み、遷急点が発生した。また、安定した縦断形の勾配は初期傾斜に因らない。傾動を伴う場合では、最初は傾動の影響を強く受けるものの、数時間で浸食と隆起がつりあう動的平衡状態に至った。また、隆起速度をある時間で変更させると、それに合わせて浸食速度も変化し、それぞれの隆起速度で動的平衡状態に近づいた。河川地形は、隆起速度に応答して安定することが示唆される。傾動が伴う試行も伴わない試行も縦断形が平衡状態に至る以前に遷急点が確認されたことから、遷急点は平衡に至るまでのプロセスである可能性がある。

キーワード: 河川縦断形, モデル実験, 傾動隆起, 平衡河川

Keywords: river longitudinal profile, laboratory experiment, tilting uplift, graded river

流れ山の規模—頻度分布特性の地形学的意義 Magnitude-frequency distribution of hummocks and its geomorphological significance

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流れ山とは、火山体などで起こる巨大山体崩壊によって発生する岩屑なだれの堆積面上に形成される小丘状の地形のことをいう。本研究では、この流れ山の規模—頻度分布特性とその地形学的意義を検討した。

本研究で対象としたのは日本の16事例とフィリピンの1事例の計17事例であり、流れ山の規模(A:面積により代替)と頻度(N(x):累積個数)との関係は指数分布、

$$\log_{10} N(x) = a - b x \quad (1)$$

によってあらわされることが明らかとなった(吉田, 2015)。なお、aとbは定数である。

b値は事例ごとに異なっており、ほぼ1—2の範囲に含まれる。流れ山は、基本的には山体を構成していた一部が「岩屑なだれブロック」として芯部をなすことによって形成される起伏とみなしうる。そして一般には、流れ山は岩屑なだれの流走にともなってサイズを減じていくことが知られている(Yoshida et al., 2012)。したがって、流れ山の規模—頻度分布特性を示す回帰線の傾き(式(1)のb値)は、岩屑なだれの流走にともなう流れ山(またはその芯部となりうる岩屑なだれブロック)の縮小(または破壊)の過程を反映した特性値ということになる。その値の大小が意味することは、「規模の縮小にともなう頻度の増大」の程度が異なる、ということである。b値が大きいときには規模の縮小にともなう個数の増え方が急(大)であり、b値が小さいと逆に、規模の縮小にともなう個数の増え方が緩やかとなる。

上記の「規模の縮小にともなう頻度の増大」の程度は、事例間の物性に大きな相違がないと仮定すれば、岩屑なだれの運動特性に大きく依存していると推測される。それは、岩屑なだれが流動的であるほど、破碎が効果的に進み、規模が縮小していくばかりでなく頻度の増加率も大きくなると考えられるからである。そこで岩屑なだれの流動性を端的に示す等価摩擦係数(H/L)とb値との関係を検討してみたところ、両者間で強い相関がみられることが判明した。つまり、流動性が小さい(H/Lが大)岩屑なだれでは流れ山の規模—頻度分布においてb値は小さい傾向にあり、流動性が大きくなると(H/Lが小)b値は増加することが示され、上記の考えが指示される結果となった。

(文献) 吉田(2015) 日本地理学会 2015年度春季学術大会; Yoshida et al. (2012) *Geomorphology*, 136, 76-87.