NS111 LBA

EXFOLIATION IN MT.BUKHANSAN

NS111: Implications of Earth's Cycles
Minerva Schools at KGI

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Introduction

Last weekend I climbed up three peaks of Mt.Bukhansan: Bibong, Hyangonbong, and Boheyonbong to directly observe the morphologies of the granitic mountain. In this paper, I analyze studies about Bukhansan with reference to my in-situ observations to gain insights on how exfoliation contributes to Bukhansan's morphologies.

Setting up the stage

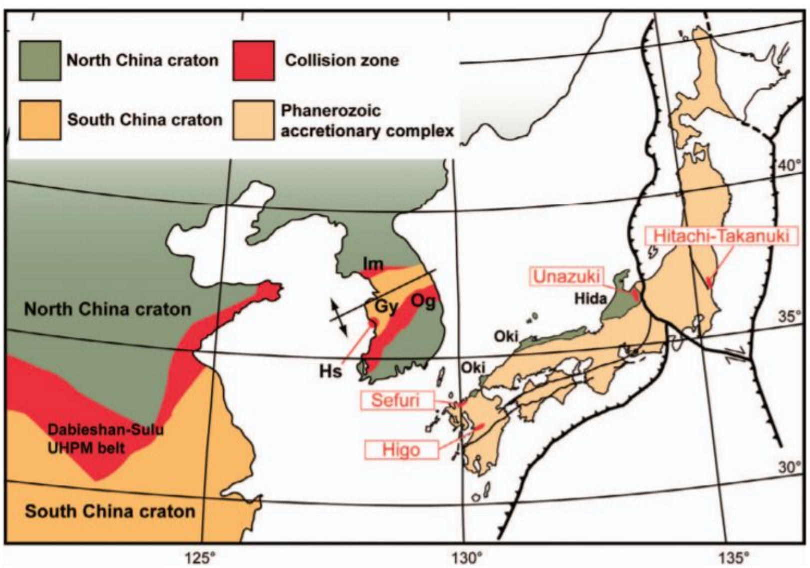


Figure 1. Korean Peninsula was formed by the continental subduction of North and South China cratons in the Middle Triassic (Omori et al., 2011, 42).

Figure 2. The surface of exposed granite at Bibong Peak. The lighter color indicates rich silica content.

Figure 3. The panorama from Boheyonbong peak. The batholiths of Gyeonggi Massif are visible (Kwon et al. 1999).

The geologic record shows that the Korean peninsula was formed 230 Ma ago due to the collision of North and South China cratons (Omori et al., 2011) (fig. 1). The unanimous distribution of granites in the Korean massifs (Kim et al., 2001) suggests seawater's presence for the sequential partial meltings to produce magma. Mt.Bukhansan is Seoul's igneous mountain located in Gyeonggi Massif and consists of Jurassic granites (Chough, 2012, 25). The three peaks' light-colored felsic appearance (figs.2 and 3) shows how the mountain has a plutonic origin where granites slowly cooled to form the batholiths (Kwon, 1999). The granitic peaks' formation in the Jurassic age is many years after the cratons' first collision. Since granites are where "many different melting and cooling events" (Langmuir, 2012, 201) end, the batholiths may have gone through multiple partial meltings before finally forming the peaks. One possibility is the purification of granites through the rock cycle.

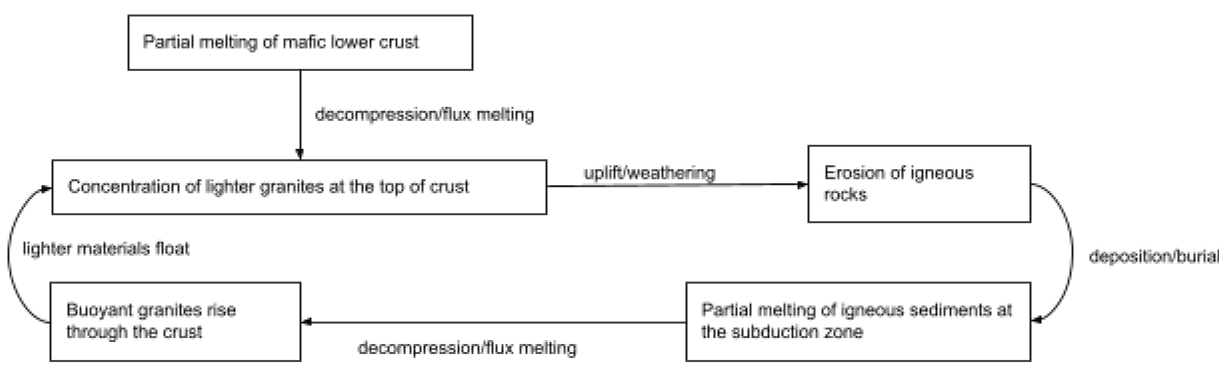


Figure 4. Purification of granitic material as a positive feedback loop.

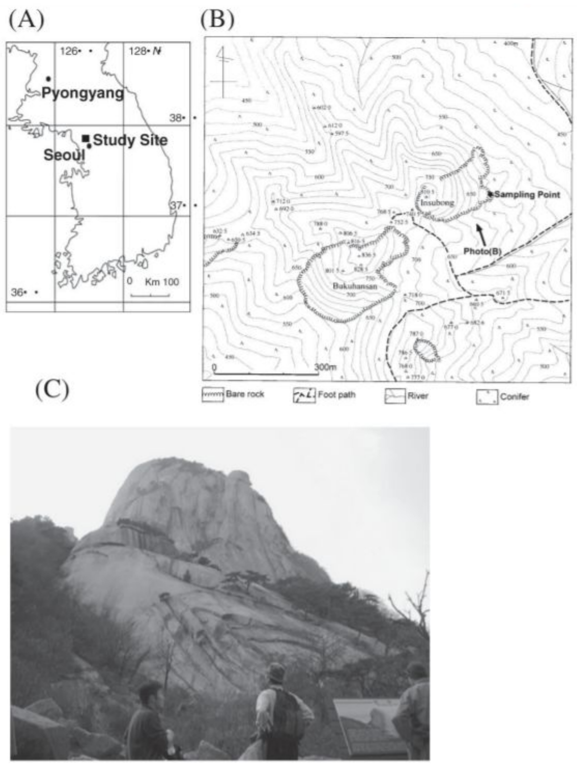
The felsic appearance of the peaks (figs.2 and 3) indicate the rich silicate composition. One possible explanation is the granitic purification by sequential positive feedback loops of partial melting. Through partial melting, less dense igneous rock separates away from the heavier rocks. The granites then go through uplifting, weathering, deposition before further condensing in the next partial melting. Repeating partial melting will separate materials with different densities more. Therefore lighter granites concentrate and "float on top of the mantle" (Langmuir, 2012, 201).[1] This purification cycle may explain the very light-colored peaks of Mt.Bukhansan (testable by measuring the composition of silicate (quartz), potassium (feldspar) and sodium (feldspar) which are unique to granites (Rauser, 2021)).[2][3]

[1] Granite's average density is approximately 2.75 g per cubic centimeter, whereas basalt's average density is 3 g per cubic centimeter (Korotev, 2021)

[2] #feedbacks: I extract part of the rock cycle to identify a positive feedback loop that can explain the production of felsic peaks of Mt.Bukhansan. I elaborate how repeated partial melting can lead to more purification of the granitic minerals. To respect the word count, I mention key features of the positive feedback and contain the nuance of the loop in the diagram (e.g. labeling nodes, elaborating edges with reference to the density).

[3] #planetaryformation: I consider how the production of batholiths in Mt.Bukhansan relates to the production of the Korean Peninsula, and analyze the role of partial meltings with reference to my own in-situ observations. I consider the geological time scale and identify a possible feedback loop that may have led to the purification of granites as a result of repeated partial meltings. Crystal composition is also mentioned to test my explanation.

Exfoliation



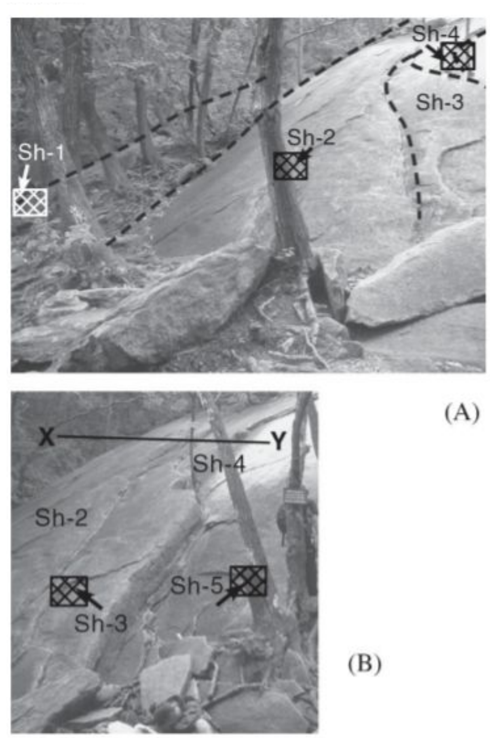


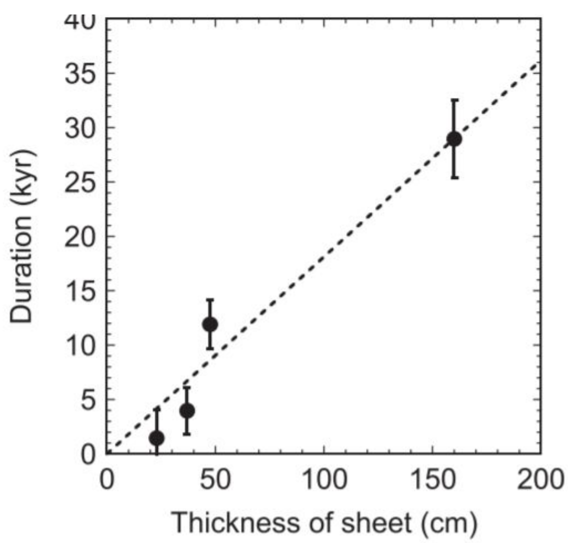
Fig.4 (left) Wakasa et al. studied exfoliation in Mt.Bukhansan (Wakasa et al., 2006, 1248).

Fig.5 (right) The photos from the sampling point. The effect of exfoliation is visible on the surface (Wakasa et al., 2006, 1249).

	Sh-1	Sh-2	Sh-3	Sh-4	Sh-5
Thickness of sheet (cm)	160	50	25	40	–
L_s value					
max.	415	519	600	640	738
min.	103	110	108	153	140
av.	228	279	321	384	455
SD	78	105	145	123	139

SD, standard deviation.

Table 1. The thickness and rebound strength of each sheet (Wakasa et al., 2006, 1250).



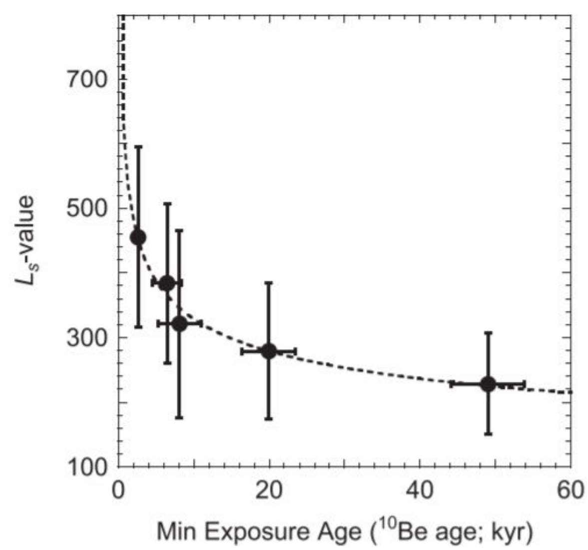


Figure 6 (left). The inverted slope (thickness/duration) indicates the average exfoliation rate of 5.6 ka (Wakasa, 2006, 1253).

Figure 7 (right). The reflected logarithmic graph shows the rapid reduction in the hardness during the early exposure (Wakasa, 2006, 1254).

Wakasa et al. (2006) estimated the rate of exfoliation in Mt.Bukhansan by cosmogenic nuclide analysis. Exfoliation is a form of weathering where rocks "scale off along joints, especially at corners and edges, and thereby develop(ing) bowlder-like form" (Blackwelder, 1925, 793) due to tectonic stress, temperature changes, or chemical alterations (e.g., hydration). The effect is seen worldwide commonly in granitic domes whose pressure is released when brought to the surface by uplifting, for example (e.g., Half Dome in Yosemite). Wakasa et al. measured each sheet's thickness alongside the rebound value (a proxy for the weathering strength) and the concentrations of the nuclides (fig.5, table 1). The duration of exposure was determined by transposing the following matrix product:

$$[N] = [P][t]$$

where N is the nuclide concentration, P is the nuclide production rate and t is the exposure duration. The result showed that the average exfoliation rate was 5.6cm/ka (the inverted slope of fig.6) which was significantly greater than 0.1-1cm/ka for rocks with no sheeting effects (indicating recent exposure/unloading). The study relies on a similar assumption as the law of superposition. The group implicitly assumed that the top layer was the eldest, with the later weathering causing the bottom layers' exposure. In contrast, the law of superposition assumes a positive association between depth and age. This paradox is reconciled with the law of uniformitarianism which ensures that the geological processes must remain the same in each underwater and above water conditions. For this study, we can assume that the exposed layers will weather whereas underwater layers would accumulate, thus causing the reversed association between age and depth. This study hints at the strength of combining absolute and relative dating. The relative dating with the weathering assumption is reinforced by measuring the concentration of cosmogenic nuclides. Furthermore, the study highlights how absolute dating is not limited to measuring the absolute time of a rock's birth, but also determining its growth rate. This combination was useful in this study because the cosmogenic nuclides start to concentrate once the rocks are exposed at the surface as most "cosmic rays do not penetrate deep into the earth's surface" (Davies, 2020). The specific value of exfoliation rate (absolute dating) strengthens the inference Wakasa et al. made from the surface textures (relative dating) when they compared to other "areas where sheet structures were absent or far less pronounced" (Wakasa et al., 2006, 1254). This exemplifies how having multiple lines of evidence can strengthen scientific arguments.[4]

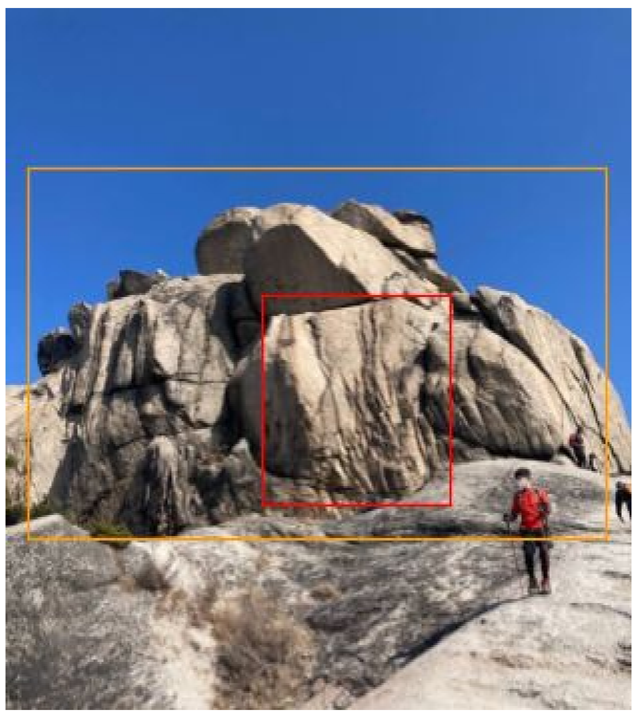


Figure 8. A possible sign of exfoliation (red and orange rectangles) near Hyangonbong peak.

[4] #plausibility: I analyze the underlying implicit assumption unique to the study group and contrast it with laws we identified in class. I also discuss how both relative and absolute dating can be combined to generate robust scientific inferences. In the later section, I identify how the assumptions can be applied to my observation in Mt.Bukhansan to validate my predictions.

During my hike, I also observed possible signs of exfoliation (fig. 8). The general cracks in the rock face (orange rectangle) indicated long weathering on possibly originally one giant rock (testable by sampling chemical composition from different parts of the rock face). Thinner sheets in the lower part (red rectangle) sign a frequent exfoliation. Since “trigger forces large enough to cause shedding are rare, ... a thin sheet will be shed than a thick sheet” (Wakasa et al. 2006, 1254), this part of the rock face may encounter more exfoliation than other parts inside the orange rectangle. To understand the cracks' precise formation, I can use cosmogenic nuclide analysis to infer how exactly exfoliation occurred.[5][6]

The granitic peaks of Mt.Bukhansan show a unique sample of the continental crust from millions of years ago, with the addition of later weathering effects.

Word Count: 820

[5] #ageandcomposition: I identify cosmogenic nuclide analysis as a specific type of absolute dating technique and analyze how its application in Mt.Bukhansan demonstrated the strength of absolute dating, supplemented by relative dating. This technique is compared to the relative dating and direct observations made on site, to analyze how multiple techniques can be integrated to strengthen inferences on metamorphologies.

[6] #critique: I analyze in length, the details of a specific study conducted at Mt.Bukhansan to discuss aspects of dating techniques. For example, I pick out one implicit assumption in the argument and consider its implication with reference to other laws. I further contrast the group’s findings to my own observations to further extract arguments about Mt.Bukhansan’s metamorphosis.

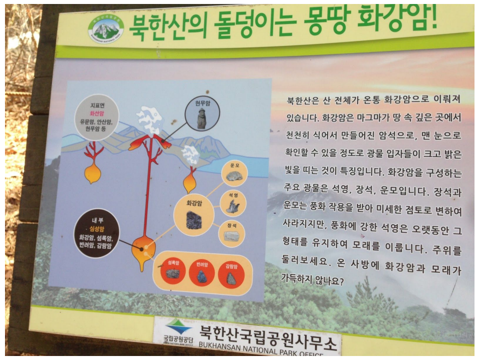


Figure 9. The tourist guide I found while walking on the trail. Asking a Korean classmate for translation first helped me realize that the mountain was granitic.[7]

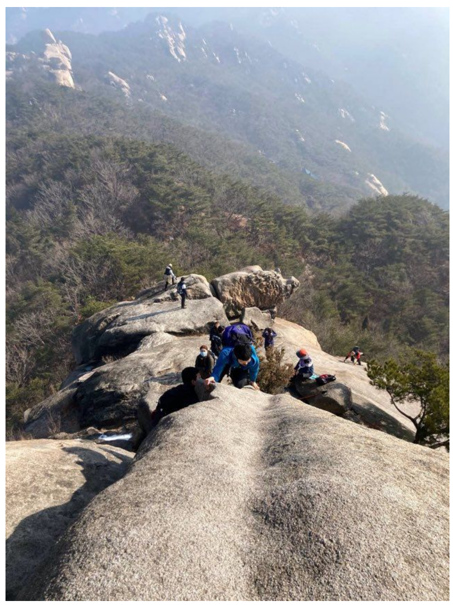


Figure 9. The person in the blue sweater is me. The rock was very slippery and steep, therefore I had no spare energy to look up at the camera. Having had introductory awareness about geology completely changed how I saw rocks along the trails.

[7] #constraints: despite the thorough research in the Claremont College and Google Scholars, I struggled to find English sources that described the geomorphology of Mt.Bukhansan in depth. To work around this language barrier, I used information in the tourist guide to first realize that the mountain was granitic then made informed inferences by referencing other materials that described analogous batholiths around the world, general granitic formation, proximate tectonic collisions. To ensure I'm not being a rockchair geologist, I tie back these online resources to my own observations from the mountain. The scholarly sources are listed in the references section.

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