

Blockfields of Seoraksan National Park: Age and Origin

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설악산 국립공원 지역 아고산대의 암괴원의 기원과 연대에 관한 고찰

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Abstract : On top of several peaks of Seoraksan National Park, many extensive blockfields are found. After initial report was made in year 2000, further field works and analysis of satellite image have been made. Blockfields on top of mountain peaks exhibit evidence of chemical weathering including gnammas and grooves. Also, several lichen colonies larger than 80 cm in diameter have been found on the surface of many blocks. High resolution IKONOS image has been used to delineate the boundary of blockfields which are hard to access during the field trip. Blockfields of Mt. Seoraksan lack fine material necessary for age dating and clay mineral analysis because they experienced long period of wash and erosion during the Holocene. The ages of blockfields seem to be pre-Holocene on the basis of size of lichen colony and weathering pits.

Key Words : blockfields, chemical weathering, lichen, IKONOS image, Pleistocene

요약 : 설악산 아고산대 지역에 분포하는 암괴원은 2000년에 보고 된 후, 아직 그 규모에 비해 많은 논의가 이루어지지 못하였다. 고산지형학과 주빙하 지형학 분야에서의 새로운 논의들을 소개하고 현지답사를 통해 확인한 새로운 논의점들을 소개하고자 한다. 항공사진에서 확인하기 어려운 분포지역과 관련된 정보는 IKONOS 위성영상을 통해 일부지역에서 확인할 수 있으며, 분포범위를 확정할 수 있었다. 현지조사의 결과 지의류의 성장이 암괴원의 화학적 풍화를 유발하고 있음을 확인할 수 있었고, 심층풍화와 관련된 절리구조가 아직도 중요한 것으로 파악된다. 외국의 대부분의 산정형 암해와는 달리 미립물질이 대부분 세탈되어 버리고 암괴만 남아, 화학적 풍화의 산물인 점토광물 등을 확인하기 어렵다는 점과 지의류의 성장속도와 풍화형의 발달정도로 보아, 홀로세 이전에 형성된 암괴원이 현재 기후하에서 생물학적 풍화를 받아 변형되는 것이라고 판단된다.

주요어 : 암괴원, 화학적 풍화, 지의류, 아이코노스영상, 플라이스토세

1. Introduction

On Hwangcheol peak and Guitaegicheong peak, large blockfields are found (Park, 2000). Since the first paper, new and diverse ideas on origin and age have been suggested in the field of alpine and periglacial geomorphology, and new findings from the field trip are reported and discussed. Ballantyne (1998) suggested the generic term of 'mountain-top detritus' which refers to the regolith cover that mantles summits and high plateaux in many mid-latitude mountain ranges.

Such regolith often takes the form of blockfields of coarse rubble, in which fine sediment is absent at the surface. Some authors have suggested that such blocks are essentially pre-Pleistocene in origin since blockfields contain some clay minerals indicative of chemical weathering. Alternative suggestion is that mountain-top detritus on mid-latitude mountains is formed by the breakdown of rock by frost weathering during the Pleistocene cold stages. The other possibility is that plateau blockfields have developed under severe periglacial conditions during the Late Wisconsin with

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the continued development during the Holocene.

2. Study Sites

1) Satellite image analysis

High-resolution satellite images have not been widely used in the field of geomorphology in Korea until recently. Seo and Park (2003) analyzed IKONOS image to survey the landform of transborder region of Goseong and to delineate the landform boundaries successfully. They have shown that satellite images of high resolution can be very useful to draw the boundaries of landform units and also the ecosystem boundaries.

Three band-IKONOS image for the study area was geo-rectified with digital topographic maps at the scale of 1: 5,000, from which digital elevation data were extracted at thirty meter interval using Erdas Imagine 8.4 and ArcInfo 8.0 software. All the DEM data and image data were edited with 3d-TIME software (three dimensional Terrain Image Model Environment, 3GCORE, Korea). Figure 1 is the screen captured image with a point of view of at 1,338 meter and yaw of 171.5 meter. The actual height of Hwangcheolbong is 1,318 meter. The Figure 2 is a zoomed shot for the study area with a viewpoint to the further south. The boundaries of blockfields can be distinguished by bare eyes in the screen and digitized with the actual photos taken during the field work (Fig.3). High resolution satellite image can give a great opportunity to get the boundary of blockfield before or after field work, partly because IKONOS image has a very high spatial resolution of one-meter, and partly because the rock sends different spectral signature from the surrounding vegetated area. Aerial photography has higher spatial resolution of below 30cm, however it is difficult to focus on study area (Fig 4). Since the aerial photography was taken for the purpose of generating 1:25,000 scale topographic maps, while IKONOS images can generate 1:5,000 scale ortho-image which can give us such

detailed images of study area as Fig. 1 and Fig. 2.

2) Geology and present climate

The blockfields are located in the subalpine peak where Cretaceous granite complex intruded the Precambrian metamorphic rock (Fig. 5). Bedrocks of Hwangchulbong and Guitaegichungbong peaks are granitic porphyry and medium grained granite respectively.

The annual mean temperature of the nearest manned weather station (Jungchungbong peak, 1676 m. a.s.l.), observed from the September, 1998, to August, 1999, is 3.2°C. The annual precipitation amounts to 1,487 mm. The minimum temperature of the coldest month (January) is sometimes below -26°C, the depth of frozen soil is probably over 1.6m considering the data presented by Kee(1999).

By definition, the term 'blockfield' is applied in geomorphology to a chaotic assemblage of fractured rocks in any flat lowland area in the polar regions or any high plateau or summit in temperate latitudes, where well jointed massive rock type outcrops. The blocks consist of local rocks, broken by frost from the subjacent bedrock and angular in form. The degree of angularity depends on the degree of chemical weathering. Sometimes the rocks are misleadingly round. These areas are good examples of mountain top detritus described by Ballantyne (1998). They occur in the main ridge of Taebaeg Mountain Range, where it appears that the accumulation has been taking place for a long time since the Pleistocene ice ages.

Numerous authors have interpreted the lower limit of mountain-top detritus as an erosional trimline that marks the vertical extent of the last ice sheets (Ballantyne,1998). However, the findings of this study indicate that such inferences require caution, as blockfields and other forms of mountain-top detritus have developed on certain lithologies, and direct evidence of ice sheet is not found in other part of the Republic of Korea.

There remains a big question as to whether the blockfields in Seoraksan Mt. are the relict landforms

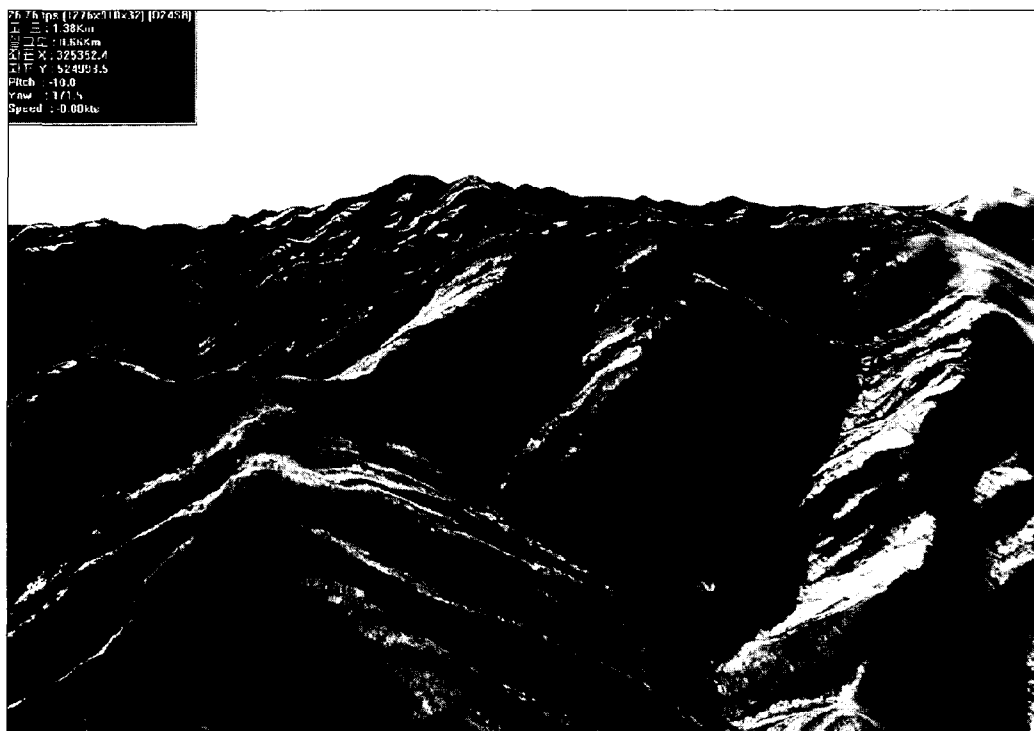


Fig. 1. Computer generated image of the study site, Hwangchulbong, Seoraksan, Korea. 1

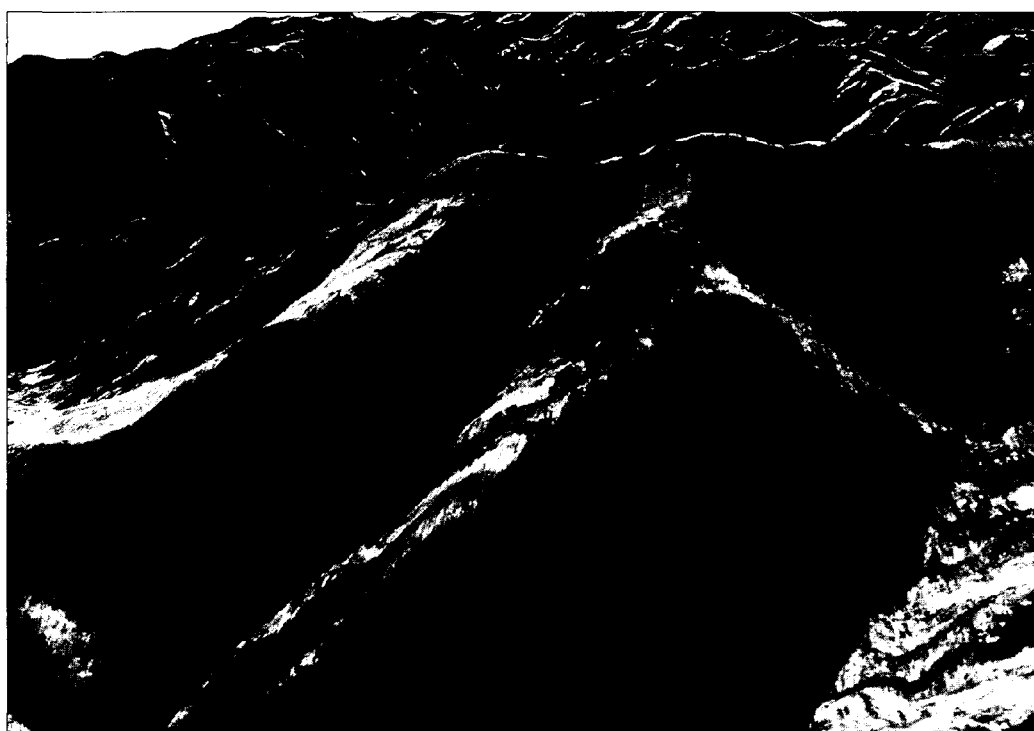


Fig. 2. Closer view of Hwangchulbong generated from IKONOS image.



Fig. 3. Panoramic view of Hwangchulbong site (Photo taken in Sep. 2003)



Fig. 4. Aerial photo of Guitaegichungbong site, in which blockfields can be barely identified

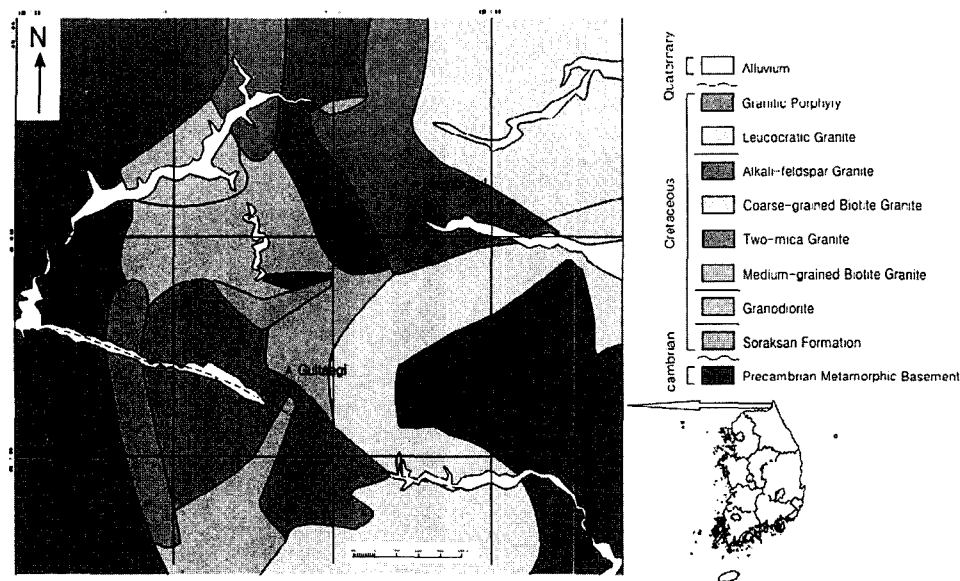


Fig. 5. Generalized geological map of the study sites

of colder Pleistocene Ages or they are still forming during the Holocene. In order to assess the possibility of blockfield formation, the freezing index has been calculated using recent climate data of the nearest weather station using the formula of Washburn (1979). Freezing index is a measure of the heat balance at the ground surface (surface index) or at a height of 1.5 or 1.8 m above it (air index). It is given in degree days of freezing. For °C

$$I = \int_0^t T dt$$

where I = index, T = mean temperature for a day as represented by (maximum + minimum temperature)/2, and t = the period. To compare the findings with the previous studies, daily temperature has been converted to fahrenheit scale, which has been commonly used for freezing index calculations

$$I = \int_0^t (T - T_0) dt$$

where T₀ = 32°F. Freezing index provides a measure of the severity of climate, and useful estimates for the depths of freezing and thawing.

Freezing air index has been calculated using a data set measured at a weather station located in the Daechungbong peak in Seoraksan Mt. For °C, freez-

ing index is -1,133 and for °F, it is -2,039. Compared with the Corte's air freezing index map, freezing index of Seoraksan Mt. is comparable to that of Canadian Prairie of today.

Another important controlling factor in forming blockfields is the frequency of freeze-thaw cycles. The weather collection period is too short and inaccurate that it is hard to tell the exact number of freeze-thaw cycles, because only maximum and minimum air temperature data are collected in that weather station. Weather station is maintained by the staffs of National Parks Authority instead of those of weather bureau.

In the absence of a comprehensive weather data, another estimate of the effective precipitation for the study site may be gained by using Lang's (in Evans *et al.*, 1999) simple formula

$$r/t$$

where *r* is the mean annual rainfall (precipitation) and *t* is the mean annual temperature.

A value of *r/t* < 40 indicates an arid climate, where as *r/t* > 160 indicates a perhumid climate where the effective precipitation is close to the mean annual

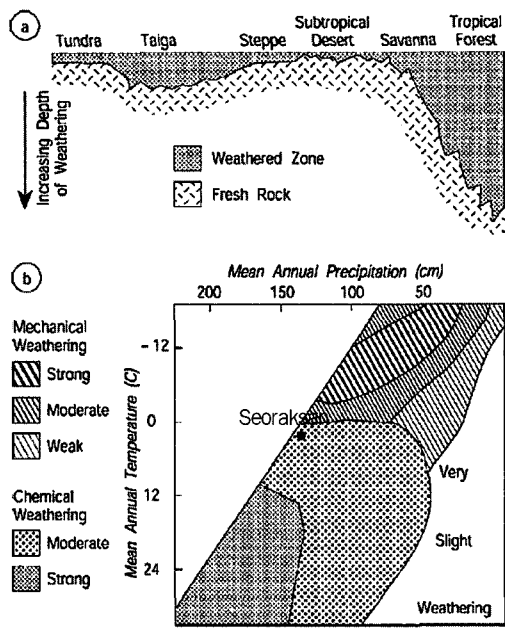


Fig. 6. Strakhov (1967)'s and Peltier (1950)'s diagrams: the world-wide distribution of weathering processes (in Andre., 2003, p. 154)

precipitation. Study sites in Seoraksan area possess the r/t values of ca. 465. Figure 6 gives an idea of weathering regime of Seoraksan in modern days.

3. Age and Origin

Two questions still need to be fully answered;

namely their age and origin. Three hypotheses provide alternative explanations, which are Postglacial, Pleistocene, Pre-Pleistocene. According to Rea *et al.* (1996), carbonate rock is one and only lithology where the potential for rapid freeze-thaw breakdown is feasible, therefore Postglacial origin is possible. Generally speaking, freeze-thaw processes do not seem to be powerful enough to produce such wide blockfields in Seoraksan area. As discussed earlier, the lithology of study area is medium grained granite and granite porphyry, which are very hard rocks. It doesn't seem to be possible that post-glacial physical weathering alone could produce profiles which are well over 2m deep in study sites.

As can be seen in pictures taken in Hwangchulbong area, present day chemical weathering must be so important in rock breakdown below a size controlled by main joints in the regions. Therefore, most deep weathering is thus the result of chemical action during periods when climate was warmer in these regions (Fig. 7).

The distribution of blockfields has been used to indicate limits of ice-cover, but as Embleton and King (1968) pointed out, it appears that such detritus in the region remain unaffected by the moving ice-sheet or it has not been ice covered. The length of time required for the blockfields in Seoraksan National Park to form varies considerably with rock-type as discussed in theoretical backgrounds. It also varies

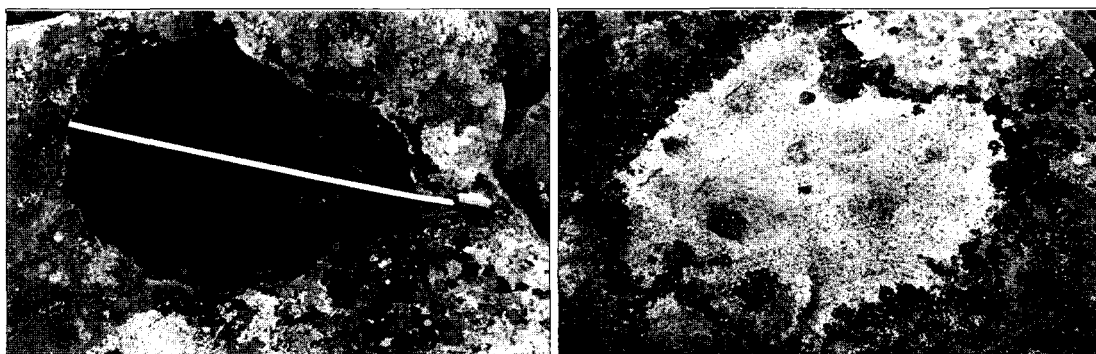


Fig. 7. Evidences of chemical weathering can be easily found on the surface of the blocks. Water and weathered material are present during the wet season

with climate and especially the number of significant oscillations through freezing point (frost cycles).

1) Lichens in the study area

Most people think that lichens are simple organism, and cannot tell lichens from mosses. In fact lichens are mini-ecosystem, consisting of at least two organisms: a fungus and a photosynthetic partner. The International Association of Lichenology defined a lichen as an "association of a fungus and a photo synthetic symbiont resulting in a stable thallus of specific structure" in 1982.

Lichens are known to play an important role in breaking down rock minerals both physically and chemically and contribute to soil formation. Physical weathering occurs mechanically through hyphae and rhizines simply growing through the rock resulting in the breaking up of minerals. This may seem an enormous task for such small organisms as lichens, however, their harmful effects on stone artifacts have been well known in 1980's in the field of preservation science (Min, 1985 and Min, *et al*, 1986).

Min *et al.* reported 1,968 pale green colored crustose type thallus and 237 dark gray colored crustose type thallus on the surface of the stone monuments within the royal tombs around the Metropolitan Seoul.

The weathering of mineral surfaces (mineral etching) occurs at the rock-lichen interface by dissolution and dislocation of the mineral structure resulting in a distorted mineral lattice (Aghamiri and Schwartzman, 2002). Continued etching will result in honeycombing of the mineral grains, making them extremely fragile and leading to their disintegration into finer particles. Some minerals even become totally depleted of all other elements except silicon, aluminum and iron.

Lichens are ubiquitous lithobiontic coatings, and they are able to tolerate the harshest temperature and moisture conditions on earth. Even in the Antarctic about 350 lichen species have been reported by the Korean scientists (Kordi).

They are dominant on over eight percent of the Earth's surface (Dorn, 1998). Foliose, fruitocose, and crustose lichens are all found on rock surfaces. In

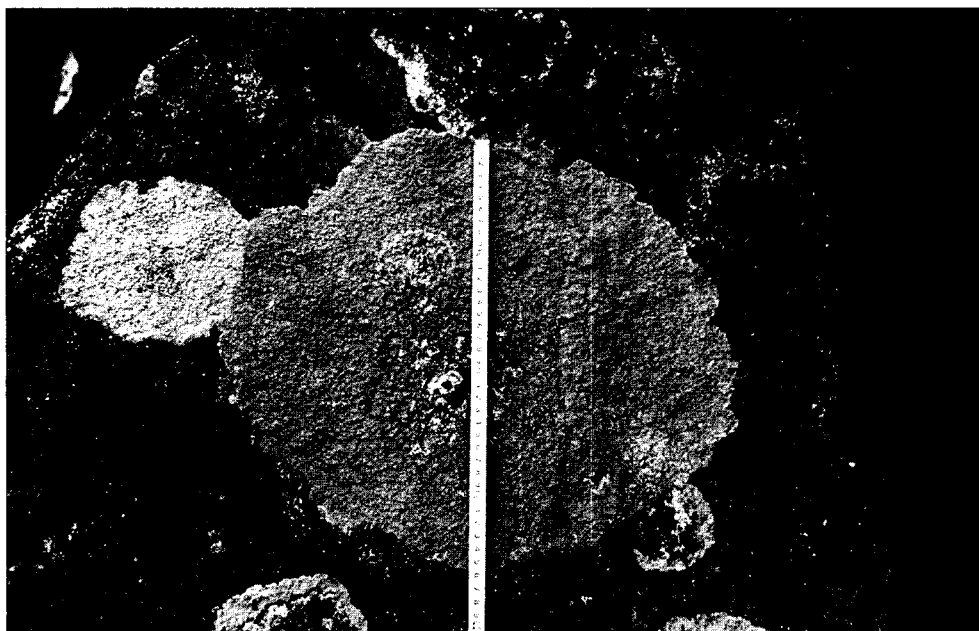


Fig. 8. Crustose type lichens are found on the surface of the blocks of Hwangchulbong site

Table 1. Lichen growth rates reported from various sources

Source	Growth rate(mm/yr)			Thallus axis used	Lag(yr)
	Early	(Linear)	Late		
Jaksh (1970)				Long	15
Jaksh (1975)		0.73		Long	<15
Gordon and Sharp (1983)		0.987		Long	15
Maizels and Dugmore (1985)		0.85		Long	20-25
Thompson and Jones (1986)	0.725		0.585	Short	
Kugelmann (1991)			0.44	Long	10
Guðmundsson (in press)		0.67		Short	19
Evans <i>et al.</i> 1999 (Bruarj kull)		0.51		Long	16
Evans <i>et al.</i> 1999 (south coast)		0.56		Long	>5
Evans <i>et al.</i> 1999 (south coast forelands)		0.8		Long	6.2
Min <i>et al.</i> (1986)				Long	

subalpine Soraksan areas, however, most of the lichens seems to be crustose type, a form that limits exposure to the atmosphere. As far as literature survey goes, lichen growth rates has not been reported in Korea, even though Min *et al.* (1986) measured the size of thallus on the surface of stone monuments around the Seoul, subsequent measurements had not been made since their pioneer study. Identification of lichens to the species level has not been made in this study due to the lack of expertise of the author. This study find that many lichen colonies of crustose type are larger than 80 cm in diameter.

2) Lichen-induced chemical weathering

Aghamiri and Schwartzman (2002) reported that elemental fluxes in runoff from cumulative and individual rain events of all the lichen mini watersheds were significantly greater than the elemental fluxes from bare-rock mini watersheds. The exceptions were Al^{3+} and Fe^{2+} of which high levels were found in the lichen thallus as a result of biological uptake of these two elements by lichens.

When they reproduced mini watershed study in the laboratory, the results were similar to those from the field studies. They showed significantly greater elemental flux from the lichen mini watersheds for K^+ , Na^+ , Mg^{2+} and Si than the bare-rock mini watersheds.

They also found that thin-section analysis showed a considerable thickness of weathering rind at the lichen-rock interface. Weathering rinds are clearly visible by bare eyes in the study area. The thin-section analysis has not been performed yet in the study area, however field study confirms that lichens do chemically and physically disintegrate the rock and contribute to the weathering process (fig. 7).

All findings from this study agree with findings by previous researchers mentioned above that lichens contribute to the weathering process. Further studies both in the field and laboratory, and a temperature measurement at the lichen-rock interface will likely support the outcome of this research and will enhance our understanding of biochemical and biophysical weathering by lichens (Aghamiri and Schwartzman, 2002).

As discussed earlier, study sites in Seoraksan area possess the r/t values of ca. 465, suggesting that the effective precipitation is close to the mean annual precipitation.

Even though original study has been done in Ireland, therefore, climatic conditions are very different from Korea, an assessment of modern day lichen growth rates in Seoraksan area may be possible using the growth rate prediction curve of Hamilton (1995):

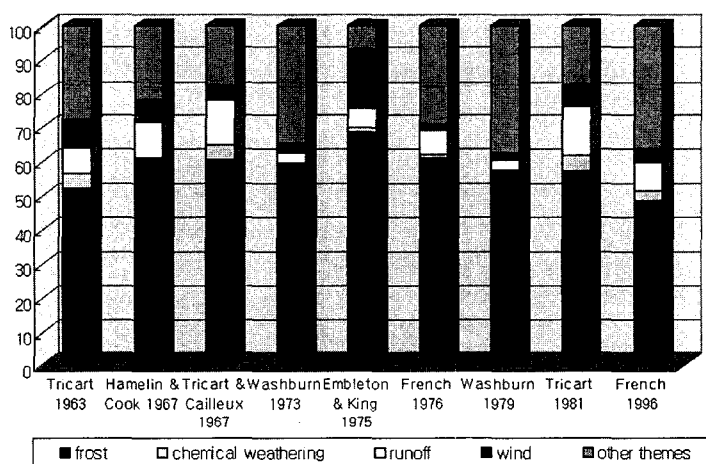
$$y = 2836.5x + 266.85$$

where y is the effective precipitation and x the growth rate (mm/year).

It is certain that the growth rate of the lichens is not linear. The growth rates follows a non-linear pathways depending on their growth stages, higher growth rate in the younger lichens and lower rates in older lichens. However, as growth curves cannot be determined at this point, linear growth pattern has been applied to determine the age of colony formation despite the many unanswered questions. Also, there is a big assumption that climate, especially precipitation has not been changed very much since the beginning of lichen colonization, which is very unrealistic.

A growth rate of 0.43 mm/year has been calculated from the Hamilton's formula, whereas maximum

size of thallus in study area is about 80 cm. Roughly speaking, it took more than 1,860 years to form lichen colonies around the Hwangchulbong site. At this point it is hard to determine whether growth curve of Hamilton can be directly applied in Korean Subalpine environment since no other scientific data for the lichen growth rate are available at this moment, and species of lichens have not been identified and compared with those of Ireland either. The absolute age that can be applicable and comparable to these sites has been recently published for the block streams of Mt. Maneo, southern part of Korea (Sung and Kim, 2003). From the analysis of cosmogenic ¹⁰Be and ²⁶Al, they suggested that block streams found in southern part of Korea have been stabilized since the Wisconsinan glacial stage but no later than 38ka.



	Tricart 1963	Hamelin & Cook 1967	Tricart & Cailleux 1967	Washburn 1973	Embleton & King 1975	French 1976	Washburn 1979	Tricart 1981	French 1996
other themes	27.7	22	17.6	34.8	6.7	28.8	37.5	16.7	36
wind	8.2	6.1	4.1	2.6	17.5	1.8	1.9	7.1	4
runoff	7.6	10.9	13.4	3.1	5.6	7	3.1	14.3	8.6
chemical weathering	4.3	0	4.1	0	1.5	1.1	0	4.8	2.5
frost	52.2	61	60.8	59.5	68.7	61.3	57.5	57.1	48.9

Fig. 9. The importance of frost-derived processes in the erosion system of cold nonglacial environments, based on the contents of periglacial textbooks 1963-1996 (redrawn after Andre 2003)

4. Discussions : Importance of Chemical Weathering

Despite a long published record of potential and actual chemical weathering in alpine environment, the nature and intensity of cold region chemical weathering remains little studied (Thorn *et al.*, 2001). It seems obvious that most of Korean geomorphologists believe that subalpine periglacial environments are dominated by mechanical weathering processes and experience low intensity chemical weathering regimes.

Recently Andre (2003) raised a critical question for the freeze-thaw mechanism, which has been regarded as controlling landscape evolution in periglacial areas. More ubiquitous noncold-related processes including biochemical weathering and rainfall-induced slope processes are systematically underestimated. In quoting French's 1996 edition of 'The Periglacial Environment', she argued that both the reality of frost-related mechanisms and their position within the hierarchy of processes interoperating

in periglacial environments definitely need clarification and revision.

In fact, there are ample evidence of active and fossil evidences of chemical weathering around the summit of Hwangchulbong peak and Guitaegichung peak including grooves, gnammas (weathering pit), and honeycombing due to the removal of lichen covers. Weathering pits and lichen growth may simply modify the surfaces of the blocks after the formation of blockfields, however, many blocks exhibit round corners, which indicates the deep chemical weathering. Even though further analysis of joint system is necessary, it seems realistic that main joint systems are derived from the deep weathering, although, newly formed angular joints are readily found within the blocks, which means frost shattering is still active in the region. Also fine materials with clay minerals in Guitaegicheong peak prove the wide-spread chemical weathering in the region. X-ray analysis for clay mineral identification and identification of lichens to the species level will be performed in the next stage of research even though in situ clay mineral is hard to



Fig. 10. In situ weathered blocks which show the joint system. These blocks have not been moved since their formation. Fine materials have been washed out.

find.

Physical weathering plays a critical role to form the blockfields in the region. Chemical weathering, however, deserves more attention to explain the formation and modification of widespread blockfields around the summit areas. Many of the block streams are formed or modified after their formation by the periglacial process such as solifluction and frost-shattering. The blocks found in the study sites have not been moved that far, and some of the blocks are connected to the basal rock as can be seen in Fig. 9.

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