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Morphology and Genesis of Block Fields on the Seoraksan National Park in Kangwon Province, Korea

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설악산국립공원에서 발견되는 암괴원에 관한 고찰

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Abstract : Mountain-top detritus type block fields are introduced in this article. Two main block fields in Seoraksan National Park are located in HwangChulBong Peak and GuiTaeGi Peak. They cover the entire summit areas and are random in direction. Even though the edges of blocks are still very sharp indicating the frost action due to freezing of water, the evidences of chemical weathering such as gnamma and grooves are also found on relatively flat surface of the individual blocks. Block fields in the Korean Peninsula have been regarded as relict landforms of periglacial environment during the Quaternary Ice Ages or even Tertiary. Many evidences, however, indicate that blocks may be forming and altered even under the modern climate conditions. Landsat-5 image analysis, using Hough transform techniques, does not show much lineament variation within the region.

Key Words : Seoraksan, block fields, chemical weathering, frost action, Hough transform

요약 : 본 논문에서는 설악산 아고산대에 나타나는 산성형 암괴원에 관한 여러 가지 논의를 제시하였다. 이 암괴원은 산악인들에게는 너덜지대로 널리 알려져 있었으며, 설악산의 북쪽 황철봉과 귀때기봉에서 대청에 이르는 서북주릉 상 화강암류의 기반암에 암괴원이 분포하고 있다. 이들 암괴원은 규모가 클 뿐 아니라 암괴상에는 풍화쇄설물을 가지고 있는 나마(gnamma)와 그루브(groove)를 비롯한 많은 화학적 풍화에 의한 미지형들이 발견되고 있어 한반도의 제4기 후반의 기후변화와 지형형성 영력을 연구할 수 있는 기후지형학적으로 중요한 연구지역이라 하겠다. 본 논문에서는 추후 발표될 암괴원의 성인과 고기후학적 의의에 관한 논의에 앞서 먼저 분포지역에 대한 소개와 몇 가지 이론적 고찰에 관하여 논의를 제한하고자 한다. 국내에서는 테일러스, 암괴류 등에 관한 논의가 상당히 이루어지고 있으나 암괴원에 관한 본격적인 논의는 아직 시작단계에 있다. Landsat 영상에 의한 구조선 분석 결과 구조선 밀도는 설악산 지역에서 큰 차이를 나타내지는 않으며, 암괴원은 대부분 화강암 지역에서 나타나는 것으로 판단된다.

주요어 : 설악산, 너덜지대, 암괴원, 풍화미지형, 기후지형학

1. Introduction

The Seoraksan National Park, located in the northern part of the Taebaek Mountain Range, is composed of the Precambrian gneiss, Mesozoic sedimentary rock, Mesozoic granite and Quaternary sediments (Fig. 1). Topographic analysis indicates that some remnant pieces of the original surface are found on the summit area of the Mt. Seoraksan ridge area. Characteristic porphyroblastic gneiss includes very large crystals of porphyroblasts, ranging 5 to 10 cm in diameter. The age of the gneiss is still not known, but older than Mesozoic granites, which intrude the gneiss. Radiometric dating indicates that Mesozoic granites are 70-130 ma old (Kangwondo, 1984).

Faults and joints are the structural elements of the area. One of the most prominent fault is the Hangyechon fault, which is prominent in the lineament diagram(Fig. 2) and forms a deep and wide stream along the Hangyechon valley. Near vertical joint system has influenced the formation of ragged topography of the area.

Block fields can be found in several locations; one

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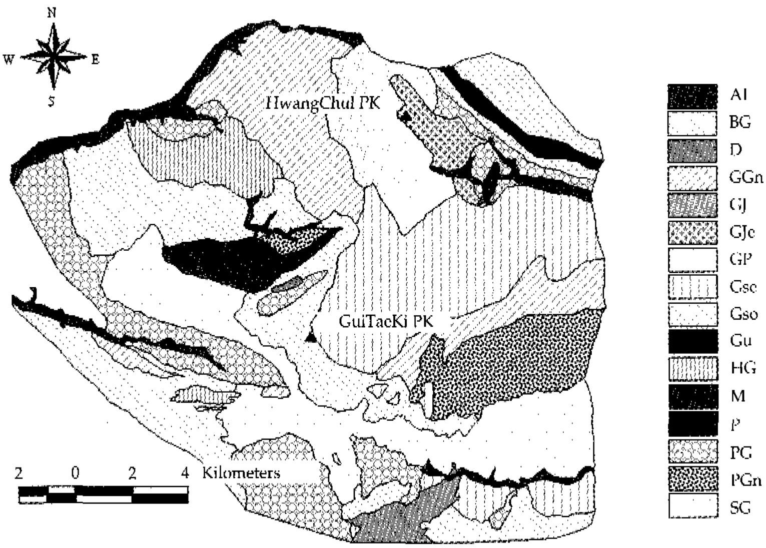

Figure 1. Geologic map of the Seoraksan National Park (redrawn after Kangwondo, 1984)

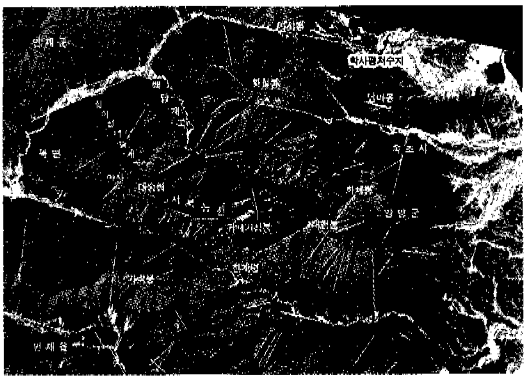

Figure 2. Lineament map after hough tansform of Landsat TM image

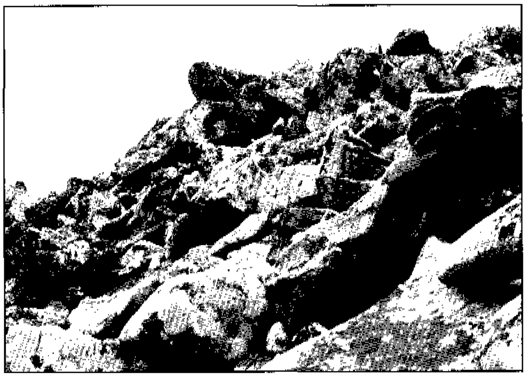

Figure 4. Close view of the block fields in GuiTaeGi Peak, developed on the Biotite granite

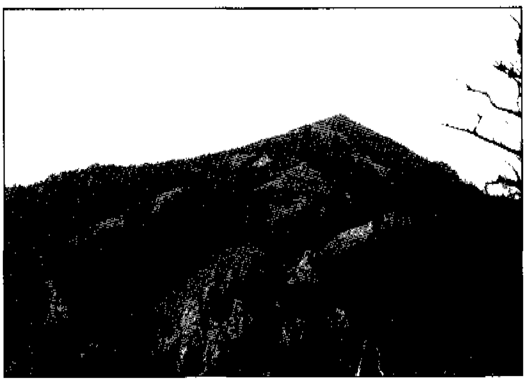

Figure 3. Panoramic view of the block field in GuiTaeGi Peak

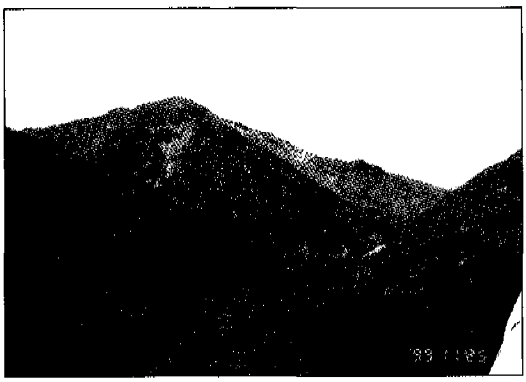

Figure 5. Panoramic view of the block field in Hwangchul Peak

Figure 6. Close view of the block fields in HwangChul Peak, developed on the Jeonggori granite

of them is near the top of the GuiTaeGi Peak (Fig. 3 and 4) and another is in the HwangChul Peak (Fig. 5 and 6).

2. Theoretical Discussions

1) Processes of Bed Rock Weathering by Frost Action

The disintegration of crystals and mechanical breakdown of rock by the freezing of water present within the pore spaces, joints and bedding planes are widely regarded as powerful geomorphic agents in periglacial environment. The block field is an extensive surface of angular rock fragments and is regarded as the most dramatic feature in periglacial environment, but has not been discussed in Korean literatures. Other periglacial landforms including talus, block streams and summit tors, and near vertical rock walls with extensive debris slopes beneath have been widely discussed compared with the block fields(Jeon, 2000).

Several different processes of cryogenic weathering have been proposed. The frost scaling is one of them, it is formed due to the formation of thin ice plates parallel to the rock surface. The second process, known as frost splitting of previously non-cracked rock, is a true bursting process and occurs only when frost affects all the faces of the block. Another process is frost wedging, which exploits pre-existing weaknesses such as cracks and joints in a rock. It has been well known that frost wedging predominates in siliceous rocks. Actually, several investigators stress the role of microfractures in bedrock as the method by which water penetrates bedrock and subsequently freezes to cause rock disintegration. However, the questions including when this cracking takes places and what

Table 1. Russian data concerning rates of bedrock weathering by frost action : (a) average thickness of disintegration layer for one freeze-thaw cycle in various rocks of different water saturation; (b) data on fissuring of feldspar sandstone in opencast mine, Taimyr, Siberia.

Rock, deposits	Average thickness of disintegration layer(mm)			
	Dry samples		Water-saturated samples	
	Range (mm)	Average (mm)	Range (mm)	Average (mm)
Granite	(6.4-8.6) x 10^{-5}	8.0 x 10^{-5}	(6.4-34.9) x 10^{-5}	14.5 x 10^{-5}
Weathered granite	(8.7-11) x 10^{-5}	10 x 10^{-5}	(10-32) x 10^{-5}	20 x 10^{-5}
Gneiss-granite, gneiss	(7.0-9.2) x 10^{-5}	8.0 x 10^{-5}	(7.0-9.9) x 10^{-5}	9.0 x 10^{-5}
Porphyry	(8.1-2.5) x 10^{-5}	11 x 10^{-5}	(3.1-92.4) x 10^{-5}	30 x 10^{-5}
Diabase	(0.8-8.3) x 10^{-5}	4.5 x 10^{-5}	(1.1-8.3) x 10^{-5}	4.5 x 10^{-5}
Metamorphic shale	(2.8-27) x 10^{-5}	12 x 10^{-5}	(8-35) x 10^{-5}	18 x 10^{-5}
Limestone	(3.8-7.3) x 10^{-5}	5.5 x 10^{-5}	(22.3-24.7) x 10^{-5}	23.5 x 10^{-5}
Sandstone	(4.0-7.1) x 10^{-5}	6.0 x 10^{-5}	(4.0-160) x 10^{-5}	48 x 10^{-5}
Limestone, dolomite	(400-1000) x 10^{-5}	600 x 10^{-5}	1-8.7	1.0
Marl	(400-1000) x 10^{-5}	600 x 10^{-5}	1-8.7	3.5

Source: French, 1996, after Konishchev and Rogov, 1993.

causes the cracking are still not clear. The average thickness of the disintegration layer for ice-saturated rocks during one freeze-thaw cycle ranges from a high of 3.5 mm in marl to a low of 30-50 x 10-5 mm in sand stone and porphyry(table 1, French, 1996). Clearly, rock type seems to be an important variable in addition to whether or not the rock is dry or water-saturated. French geomorphologists have also suggested that granular disaggregation caused by frost may detach mineral grains or mineral aggregates of granitic rocks that have been weathered to some extent.

Although surface scaling and frost splitting have been the focus of recent studies, these studies have not so far yielded definitive results(Clark, 1988). It is well-known that thin ice form in rock parallel to the freezing front in a manner similar to that which occurs in a soil, but less in known concerning bursting processes and frost wedging. In contrast to the physical process work, where many unanswered questions remain, considerable progress has been made by geomorphologists in the classification of rock frost shattering as a function of lithological and climatological parameters.

The term periglacial was introduced by Lozinski (1909) to designate the climate and climatically controlled features adjacent to the Pleistocene ice sheets. The use of term 'periglacial' has been expanded widely to designate nonglacial processes and features of cold climates regardless of age and any proximity to glaciers. According to Peltier's estimate, his periglacial morphogenetic region is characterized by an average annual temperature ranging from -15 to -1℃ and an average annual rainfall(excluding snow) range from 127 to 1397 mm. Peltier's diagram of morphogenetic regions, which has been widely reproduced, is reasonably consistent with these figures for the periglacial region except that the lower rainfall is given as 0 mm. French (1976) defined the periglacial domain as including all areas where the mean annual air temperature is less than +3℃. However useful for particular purposes, any such definition is arbitrary because the periglacial concept itself is sufficiently broad and imprecise to defy quantification.

The English term block field or the German terms Felsenmeer or Blockmeer are 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 types outcrop. Under frost riving with respect to hard rock in the same manner as frost heaving, intense shattering occurs and the landscape becomes a sea of jagged blocks and rock fragments. Exfoliation or spherical weathering may convert larger blocks into sub-rounded forms.

2) Periglacial Landform Studies: Historical Perspectives

In 1941 Lautensach reported the presence of striped terrace and turf-banked terraces at the Mt. Baekdoo. Kim(1966) reported the fossil involution at the slope of Mt. Acha in Seoul, however this report still remains to be supported by the other geomorphologists. Kim in 1970 reported the earth hummocks and turf-banked terraces in Mt. Halla. Chang(1983) reported the presence of a block fields at the bottom of a cliff at the Chottae-bong in Mt. Jiri. According to Chang's report, gneiss blocks are scattered at around 1680m a.s.l. on the slope angled at 7.5°. He regarded the observed angular blocks are frost-shattered mountain-top detritus which is originally core stone. According to same author, two high altitude terraces in Mt. Jiri (1600~1650, 1650~1700) are originated from the cryoplanation in periglacial environment(Chang, 1983).

In general, researches on debris slopes have not progressed much in terms of number of articles in Korea. On the contrary, in Europe, North America and even in Japan, the foci of periglacial landform studies are morphological and genetical ones respectively on talus, block stream and block fields. However, slope studies in Korea have been focused mostly on block stream and talus since 1980s (Jeon, 2000). The studies on block field are relatively small in numbers.

3. Results and Discussions

1) Methods of Study

Field measurement was carried out in Seoraksan area in Kangwon Province. Group of blocks on granite slopes are selected randomly. At GuiTaeGi site fifty blocks were selected and measured along the three axis. The lengths were measured in centimeters. And the mean lengths of each axis are calculated. Three sizes of some salt pan were also taken in the field. Grus sample had not been taken because it seems to be tampered by the human impacts such as cigarette butt.

In order to check the effects of rock types on the development of block fields, the rock types are identified in the field and cross-checked in the laboratory using geological map and microscopes. Geological map was drawn after the published map using ArcView 3.2 program.

One of the remaining question is whether the structural lineament may affect the distribution of block fields. Landsat-5 image, taken in 1989, has been analyzed using hough transform techniques.

2) Study Site

The block fields are located in the subalpine peak where Cretaceous granite complex intruded the granitic gneiss. HwangChul Peak is 1318 m. a.s.l and GuiTaeGi Peak is 1408 m.a.s.l. The annual mean temperature of the nearest weather station (Jungchungbong peak, 1676 m. a.s.l.), observed from the September, 1998, to August, 1999, is 3.2℃. The annual precipitation amounts to 1,487 mm. The minimum temperature of the coldest month (January) is sometimes below -26℃, the depth of frozen soil is probably over 1.6m. At this point, the data set for the depth of frozen soil has not been gathered. Kee(1999) reports that freezing depth in Taegwallyung Area is over 1.6m in his dissertation. Following figure is the climograph from the Daechungbog peak. The data period spans from Sep. 1998 to Aug. 1999.

3) The Length of Time to Form the Blockfields

By definition, the term 'block field' 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 outcrop. The blocks consist of local rocks, broken by frost from the subjacent bedrock and angular in form. The degree of angularity depends on the

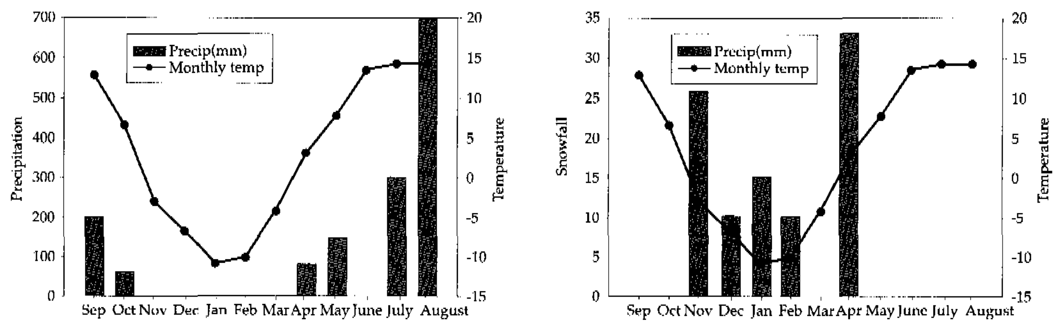

Figure 7. Climograph from the Daechungbong Peak (Sep.1998 - Aug.1999)

degree of chemical weathering. Sometimes the rocks are misleadingly round. These areas are good examples of mountain top detritus described by J. D. Ives(1958). They occur in the main ridge of Taebaek Mountain Range, where it appears that the accumulation has been taking place for a long time, including the Pleistocene ice ages.

As shown in figure 1, both areas are composed of granite. GuiTaeGi area is composed of biotite granite (BG, Fig. 8), and HwangChul Peak is composed of Geonggori granite(GJe) and granitic gneiss, where joint system are well developed(Fig. 9). Under frost riving, in the same manner as frost heaving, intense shattering occurred during the frequent freeze-thaw cycle. Moisture soaks down into joint, cleavage crevices or even into granular cleavages during the thaw season. In freezing season, it expands and causes the rocks to split. The role of freezing in mechanical weathering either in subpolar latitudes or at high altitudes has been well recognized.

The distribution of block fields has been used to indicate limits of ice-cover, but as Embleton and King(1968) pointed out, it appears possible such detritus 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 with climate and, especially the number of significant oscillations through freezing point (frost cycles). Dahl also finds evidence that some block fields in Norway have developed in the post-glacial, and therefore they cannot be used to indicate possible ice-free areas in the last glaciation. Rother(1965), however, explained the block formation in German uplands to be the products of Tertiary, and ascribed the block packing as fossil land relict landforms.

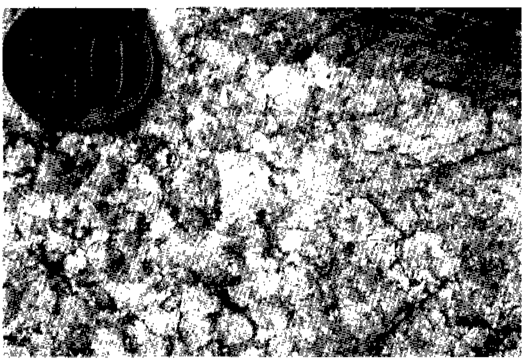

Figure 8. Closer view of biotite granite outcrop near HanGyeRyong pass

There remains a big question as to whether the block fields in Seoraksan Mt. are the relict landforms of colder time, probably Pleistocene Ages or they are still forming. In order to solve the problem the freezing index has been calculated using recent climate data of the nearest weather station (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 ℃

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

where I = index, T = mean temperature for a day as represented by (maximum + minimum temperature)/2, and t = the period. For the comparison' s sake, daily temperature has been converted to fahrenheit scale. For °F, which has been the most commonly used unit for freezing index

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

where T_0 = 32°F. Freezing index provides a measure of the severity of climate, and useful in 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 ℃, freezing index is -1133 and for °F, it is -2039. Compared to the Corte' s air freezing index map (Washburn, 1979), freezing index of Seoraksan Mt. is comparable to that of Canadian Prairie of today.

Another important controlling factor in forming block fields is the frequency of freeze-thaw cycles. The number of times the air temperature passes through the freezing point is not an adequate measure of the effectiveness of frost action. It is relatively well-known that thin ice occurs in soil parallel to the freezing front but less in known concerning bursting processes and frost wedging in a rock. The weather data is still not long and accurate enough to tell the exact number of freeze-thaw cycle since only maximum and minimum temperature data are collected in that weather station.

4) Salt Weathering versus Shattering: Unsolved Questions

There are many questions to be answered by the geomorphologists and Quaternary scientists. One of them is whether mountain top detritus type block

Figure 9. Joint-controlled block formation near the top of GuitaeGi Peak

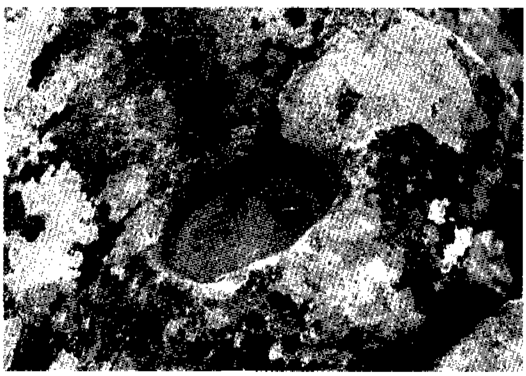

Figure 10. Gnamma developed on relatively flat surface of a block

fields are the remnant of Tertiary as was argued by Rother(1965) and Chang(1983). For several years the interaction between salt weathering and frost shattering has been a matter of great debate to geomorphologists. Unfortunately, this debate has not been discussed or introduced so far among the Korean geomorphologists. The conclusions of this research are contradictory as much as the two apparently contradictory pictures in the same mountain(Fig. 4 and 10). In figure 4, wedges of blocks are very sharp indicating frost shattering and no sign of chemical weathering, however gnamma and grooves (Fig. 10) developed on the relatively flat surface of the blocks indicates that chemical weathering plays a significant role in forming present landform.

Two points are very clear; first, a comparison between differing concentrations of salt; second, comparison between fresh and saline water. Lautridou(in Clark, 1988) summarized these two elements of the argument. The one group of scholars believe that frost is more efficient with low concentrations of salt in water, while at the opposite extreme the others believe in a higher efficiency with concentrated solutions. McGreevy claims that frost is more active with fresh water, while Litvan, Williams and Robinson propose great shattering of rock by frost with salt water. Fahey shows that aggregates or rock lose more debris with salt water than with fresh water as a result of hydration without freezing. Fahey also suggests that the amount of frost shattering does not depend on the presence of salts with freezing. These apparently opposing conclusions may be explained by differences in the conditions under which the freezing experiments were conducted. Because these two location are located on the ridges of the Taebaek Mountain ridge, these sites are equally affected by both maritime and continental type air masses. Further study is necessary on this topic.

Another question is whether exfoliation or spherical weathering may convert larger angular blocks into sub-rounded forms (Fairbridge, 1968) or, as Chang(1983) reported, the observed angular blocks are frost-shattered mountain-top round boulders, which have been deep-weathered during the Tertiary. Grooves and saltpans developed on top of several blocks may indicate that chemical weathering converts larger angular blocks into sub-rounded forms in block fields of Seoraksan Mt.

Table 2 summarizes the size characteristics of measured blocks on top of GwiTaeGi Peak. 50 blocks are chosen randomly and measured along the three axis. They do not show any directional or morphological tendency at all.

5) Lineament

Though a close examination of joint pattern and fractures in the fields is the most effective way of interpreting development of joint system. Interpretation of satellite images may help geomorphologists explain the lineament pattern. Therefore, the next question is whether the development of block fields is controlled by the density of lineament. Some of the high-frequency information on images is directional, like lineaments on satellite image data. Directional kernels can be used to enhance local image differences (Bonham-Carter, 1994).

The definitions of lineament are varied depending upon research goals and scientists. Lineaments can be defined as follows; lineaments are straight or gently curved, lengthy features of the Earth' s surface, frequently expressed topographically as depressions or lines of depressions. These are prominent on relief models, high-altitude air photographs, radar imagery, and satellite imagery. Among the various definitions, this study will follow the definition of lineament by Short and Lowan(Kang et al., 1991) to investigate lineament in Mt. Seoraksan area. Criteria applied in this study are as follows;

① lines of variable length, straightness and continuity which are differentiated by tonal contrast in image;

Table 2. Block size measured in GuiTaeGi Peak

Item	X	Y	Z
1	235	150	110
2	285	155	100
3	135	75	55
4	65	45	25
5	150	110	20
6	110	70	35
7	73	58	22
8	162	132	55
9	69	51	19
10	240	188	55
11	103	58	12
12	118	51	29
13	208	202	105
14	135	80	53
15	171	88	58
16	84	77	12
17	169	142	26
18	184	83	59
19	270	127	129
20	248	89	64
21	206	56	82
22	93	57	53
23	228	89	31
24	183	128	72
25	250	203	187
26	157	124	76
27	184	111	95
28	345	133	99
29	185	102	31
30	127	57	38
31	103	49	37
32	98	40	37
33	67	59	36
34	139	72	42
35	102	58	45
36	134	54	30
37	87	57	29
38	173	93	69
39	181	118	54
40	102	63	54
41	124	53	38
42	103	98	50
43	90	55	19
44	85	29	18
45	104	48	35
46	127	91	39
Average	151.9783	89.73913	53.02174

② tonal discontinuities;
③ bands of variable width which contrast in tone to the area immediately adjacent;
④ alignment of topographic forms;
⑤ alignment of drainage patterns;
⑥ association of vegetation along linear trends;
⑦ coalignment of cultural features(e.g. farms, road patterns, etc.) with underlying structural and/or surrounding topographical control.

The Hough transform is a technique which can be used to isolate features of lineaments within a satellite image. Because it requires that the desired features be specified in some parametric form, the classical Hough transform is most commonly used for the detection of regular curves such as lines, circles, ellipses, etc. A generalized Hough transform can be employed in applications where a simple analytic description of features is not possible.

The motivating idea behind the Hough transform technique for line detection is that each input measurement (e.g. coordinate point) indicates its contribution to a globally consistent solution (e.g. the physical line which gave rise to that image point).

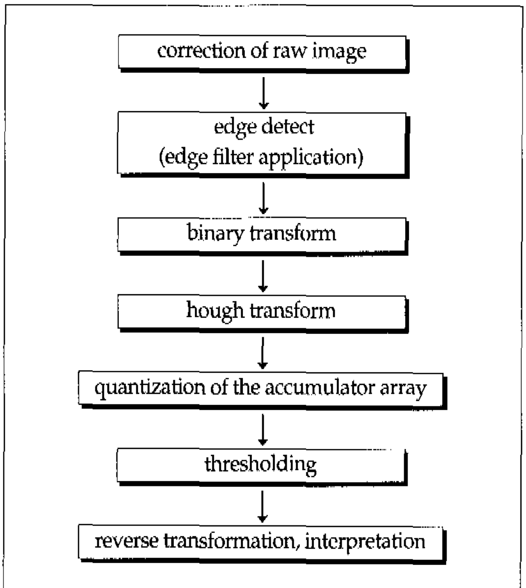

Figure 11. Hough transform procedure

As a simple example, consider the common problem of fitting a set of line segments to a set of discrete image points (e.g. pixel locations output from an edge detector). The diagram below shows some possible solutions to this problem.

In this study, Landsat-5 image, taken in Jan. 1989, has been analyzed. Hough transform has been found very effective to detect the lineament structures in Seoraksan area. As can be seen in figure 2, it seems the density of lineaments does not explain the formation of block fields. Actually this study cannot find big differences in lineament density throughout the area (Fig. 2).

However, the spatial resolution of 30m TM data is probably too low to detect the minor leneaments. One thing should be in mind that those which are detected as a lineament by Hough transform do not necessarily mean geological structures. Unfortunately, the detailed geological map of the area has not been published yet. Further study, therfore, using higher spatial resolution satellite image such as 1m resolution IKONOS image could enhance the capability of explanations.

6) Age Control

Absolute age has not been obtained for the block fields in the Seoraksan area at this moment. These sites lack the ideal material for the conventional dating techniques. Fine detritus, peat and humates for radiocarbon dating have been washed out, and soil development is almost none. However, there remains some possibility of radiometric dating including ^{10}Be dating for the blocks themselves, and lichenometric dating (Evans et al., 1999).

4. Conclusions

The block fields are located in the subalpine peak where Cretaceous granite complex intruded the granitic gneiss. HwangChul Peak is 1318 m. a.s.l

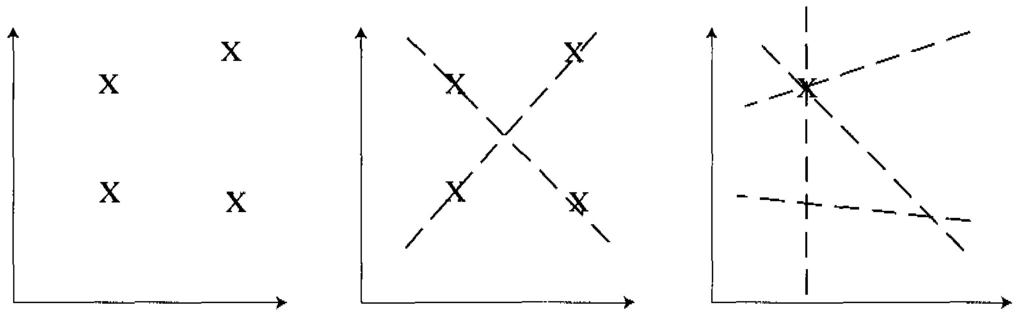

Figure 12. a) Coordinate points. b) and c) Possible straight line fittings.

and GuiTaeGi Peak is 1408 m.a.s.l. Both areas are developed on granite. GuiTaeGi area is composed of biotite granite, and HwangChul Peak is composed of Geonggori granite, where joint systems are well developed. Under frost riving, in the same manner as frost heaving, intense shattering occurred during the frequent freeze-thaw cycle under severe subalpine climate.

Freezing air index has been calculated using a data set measured at a weather station located in the Daechungbong peak in Seoraksan Mt. For ℃, freezing index is -1133 and for °F, it is -2039. The freezing index of Seoraksan Mt. is comparable to that of Canadian Prairie of today.

Gnammas and grooves developed on the flat surface of the large blocks indicate that chemical weathering converts larger angular blocks into sub-rounded forms in block fields of Seoraksan Mt. Landsat-5 image, taken in Jan. 1989, has been analyzed. Hough transform has been found very effective to detect the lineament structures in Seoraksan area. However, it seems the density of lineaments does not explain the formation of block fields.

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