

Variations of Clay Mineral Assemblage, Colour, and Microfossil Abundance in the Tertiary Sediments from the Pohang Area During Chemical Weathering*

Hi-Soo Moon**, Hyesu Yun***, Kyung Duck Min**,
Hyun Koo Lee*** and Jong Chun Lee*

ABSTRACT: Mineralogy, chemistry, physical property, and fossil abundance have been studied for the samples collected from three weathering profiles, two from the Duho Formation and one from the Hagejeon Formation in the Tertiary sediments in the Pohang area. The mineralogy of the samples from the Duho Formation shows somewhat different from that of the Hagejeon Formation. Kaolinite is more abundant and shows higher crystallinity in samples from the Duho Formation than those in the Hagejeon Formation, but clay mineral assemblage in each weathering profile remain fairly constant with depth. This difference in mineral distribution seems to be inherited from original source materials. It indicates that little or not severe leaching has been taking place in these three weathering profiles. Weathering indices indicate different degrees of susceptibility to chemical weathering in these two formations. The Duho Formation has a higher degree of susceptibility to weathering than that of the Hagejeon Formation which is mainly due to differences in clay mineral assemblages in both formations. A noticeable colour difference between oxidized and unoxidized zones in each profile can be easily recognized which is definitely due to different decomposition rate organic carbon by various oxidation state from surface to bottom of the profile. Weathering process have also intensively influenced microfossil preservation about up to 7-10 m in depth in the Duho Formation. Consequently, characteristics observed at weathering surface should be used as a subsidiary tool in setting geologic boundary or establishing formation. Great care must be taken to choose sampling site for microfossil study.

INTRODUCTION

The colour of sedimentary formations of the Pohang Basin is often quoted as characteristic features by various authors (Kim, 1965; Um et al., 1964). Um et al. (1964) described the colour of the Hakrim Formation as whitish brown, the Idong Formation as brown to whitish brown, the Duho Formation as showing the same colour as that of the Heunghae Formation. Kim (1965) characterized the Daegock Formation (Heunghae Formation) by light brown shale and mudstone, and light grey sandstone, the Eedong (Idong) Formation by light brown mudstone intercalated by grey mudstone. According to field observation of Yoon (1975), the colour of the Hagejeon (Hakrim) Formation is whitish grey, the Heunghae Formation dark grey (whitish-brown in weathered surface) and the Idong Formation whitish grey. He, further-

ermore, described the colour of the Duho Formation is more whitish than that of the lithologically similar to the Heunghae Formation, and considered that as differentiating characteristic. On the other hand, he recognized the actual colour of the Duho Formation is dark grey which can be bleached into whitish brown by weathering. The physical properties of sediments, especially of the Duho Formation, is also mentioned as lithologic characteristics (Yoon, 1975). The Duho Formation shows less developed bedding plane and conchoidal-like fracturing which are developed along the surface.

Generally, the Duho Formation is marked as fossil barren zone or very unfertile sediments in paleontological or stratigraphical works. Lee (1984) has described the Duho Formation as barren zone in his diatom research. You (1983) described only 5 species of nannoplankton, and could not find any silicoflagellates and ebridians, and Koh (1986) 9 species in rare occurrence. In contrast to these rare calcareous and siliceous microfossils, relatively abundant organic microfossils containing mostly pollen, spores and dinoflagellates are reported from the Duho Formation by Bong (1985), Yun (1981), Yi (1988),

* This paper was supported by NON DIRECTED RESEARCH FUND, Korea Research Foundation, 1989.

** Department of Geology, Yonsei University, 134 Shinchondong, Seoul 120-749, Korea.

*** Department of Geology, Chungnam National University, Daejeon 301-764, Korea.

and Mun(1990). Macrofossils which mainly consist of mollusca are also frequently described (Yoon, 1976; Kim and Yoon, 1978).

In describing lithologic characteristics, physical properties, and fossil occurrence of the formations in the Pohang Basin, they are remarkably varied in the Duho Formation depending on observers, fossil groups, and sample localities. These differences caused confusions concerning the lithostratigraphy and interpretation of paleoecology of the Duho Formation. These problems will be eliminated by clarifying the nature of the colour and its relationship to fossil occurrence. Among the post-sedimentary processes which affect the external features of sediments, weathering process seems to be most influential factor resulting such a variations. Therefore, such differences which vary with depth, and influences of weathering process on mineral assemblages, physical properties, chemical change, and fossil preservation are considered here, and its implication in stratigraphy, fossil preservation, and geologic mapping are discussed.

DESCRIPTION OF OUTCROP

A number of weathering profiles are cropped out on cutting faces for the constructional pur-

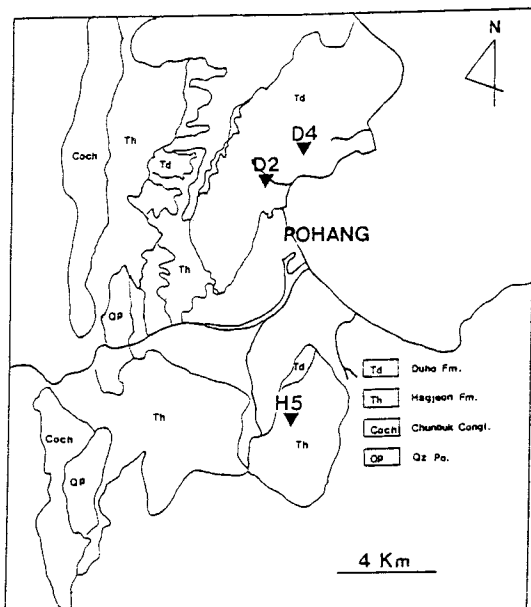


Fig. 1. Geologic map of the central Pohang Basin (after Yun, 1986) showing sampling sites for the Duho (D2 and F4) and Hagjeon (H5) weathering profiles

poses in the Pohang area. A series of weathered products and its fresh or less weathered rocks were collected from three outcrops of the Duho and Hagjeon Formations in the Pohang area (Fig. 1). Each outcrop shows a good weathering profile in terms of coherence, hardness, colour, and particularly sharp boundary between the oxidized and unweathered zone by distinct difference in colour. However, different weathering-degree scale can be easily recognized by hammer test. Scales of strength of samples (siltstone) range from "somewhat friable" in the weathered surface or near surface to "moderately strong" in the fresh siltstone at the bottom of the profile. But the strength of some part of the weathered surface along the fracture is harder than that of unweathered rock due to cementation by weathering process. Dry and wet colours of the samples from weathered surface to bottom show wide variation by rock colour Chart (Goddard *et al.*, 1980) from very pale orange to pale yellow brown or dusky brown.

Weathering depth is somewhat different from place to place particularly under the influence of the slope orientation and topography. The weathering depth of south facing slope ranges 2-4 meter in thickness whereas shallower depth on north facing slope. Generally, the steeper slope has thinner weathering zone than that of the gentle slope.

D-series samples were collected from the Duho Formation along the same stratigraphic horizon on the weathering profile to avoid confusion due to the different lithology (Fig. 2) at national grid 2333/2844. H-series samples from the Hagjeon Formation were collected from top to bottom of the weathering profile at national grid 2347/2737 because no lithologic variation can be observed in this outcrop. The former and latter were called the Duho and Hagjeon weathering profiles, respectively in this study. F-series of 3 samples are collected in the Duho formation at near Pohang city for the comparison with D-series. The first sample (F4-1) is collected at near surface and F4-2 and F4-3 samples are with interval of 10 and 6 m in depth, respectively.

SAMPLE PREPARATION AND ANALYTICAL METHODS

The bulk samples were saturated with water to identify wet colour and then dried at room temperature for three weeks to measure dry colour using a colour chart prepared by Goddard *et al.* (1980). Some portion of the dried samples were powdered in an agate mortar for X-ray diffraction (XRD), chemical analysis and size

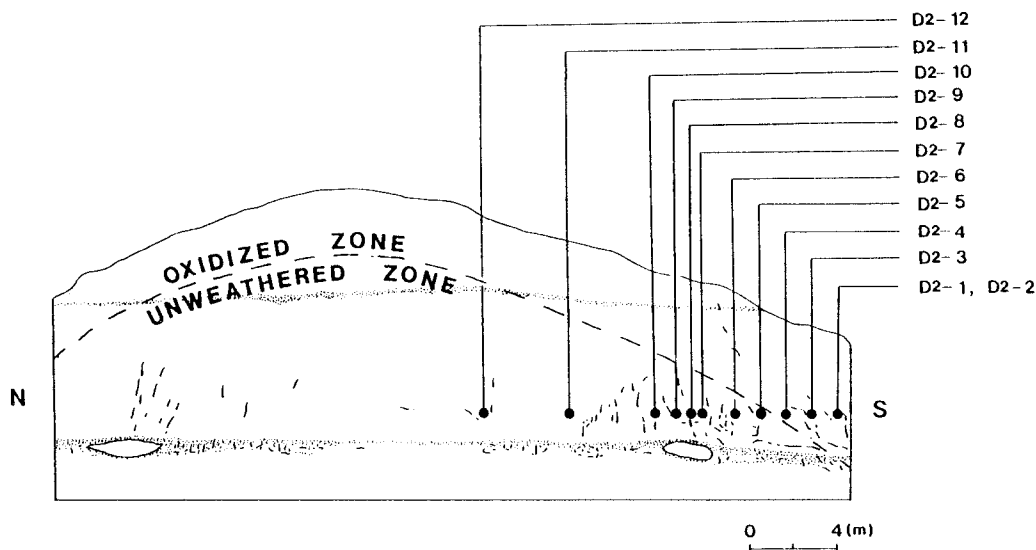


Fig. 2. The Duho weathering profile showing clear boundary (dotted line) between oxidized and unweathered zone and sampling sites. Dotted area indicates intercalated sandstone layer.

fraction.

Chemical analysis was carried out using a XRF except for H_2O which was determined by the conventional method (weight loss at $105^\circ C$). Total organic carbon (TOC) was determined using a Rock Eval I (Gwak et al., 1989). About 30 g of powdered samples were used for separation of under 2 micron size fraction by the conventional sedimentation method to identify clay mineral assemblages. Free iron was determined by the method of Mehra and Jackson (1960), and free alumina and silica by the method of Hashimoto and Jackson (1960) using rapid dissolution technique.

XRD measurements were carried out using a computer-controlled Rigaku diffractometer with a $Cu-K\alpha$ radiation and scan speed of $1^\circ/\text{min}$ for oriented slides and $2^\circ/\text{min}$ for randomly mounted samples over 2θ range $2-45^\circ$ with a graphite monochromator. XRD patterns of glycolated samples were also obtained.

The colour of the bulk samples were measured by the reflectance spectrophotometer (Photovolt Reflectometry Model 577). Even-grained powder samples (under 200 mesh in size) were used to make a press disk under uniform pressure in order to get a flat surface. Brightness was taken as the Y tristimulus value, and colour specification was made as the Commission Internationale de l'Eclairage (C.I.E.) system based on the values of X, Y and Z are called the tristimulus values corresponding to amber, green and blue. The results are plotted in chromaticity diagram after Grum and Bartleson (1980) and then

purities and hues were estimated from this diagram.

The samples for organic microfossils are processed by HF method processed by Evitt (1984). The residuals out of sample preparation contain microfossils and water. One droplet of residuals is strewn on a slide glass in a size of 40×22 mm, and the organic microfossils are counted under the microscope. It is presumed a residual droplet is taken in a same amount each time.

RESPONSE OF MINERALOGY IN THE WEATHERING PROCESS

The mineralogical assemblages of the bulk samples from two weathering profiles, the Duho (D-series) and Hageon Formation (H-series), were identified by XRD method. Some representative XRD patterns of the bulk samples are shown in Fig. 3. The mineralogy of D-series samples shows somewhat different from that of H-series samples. D-series samples consist mainly of quartz, feldspar and mica with appreciable amount of kaolinite and trace amount of smectite. The dominant minerals in H-series samples are also quartz and feldspar, but they contain appreciable amount of low cristobalite and relatively larger amount of smectite than those of D-series samples with trace amount of kaolinite. The difference in mineralogy of under 2μ size fractions of these samples is not distinct as shown in Fig. 4. The recognizable differences between these two size fractions are abundance of kaolinite and crystallinity of kaolinite which

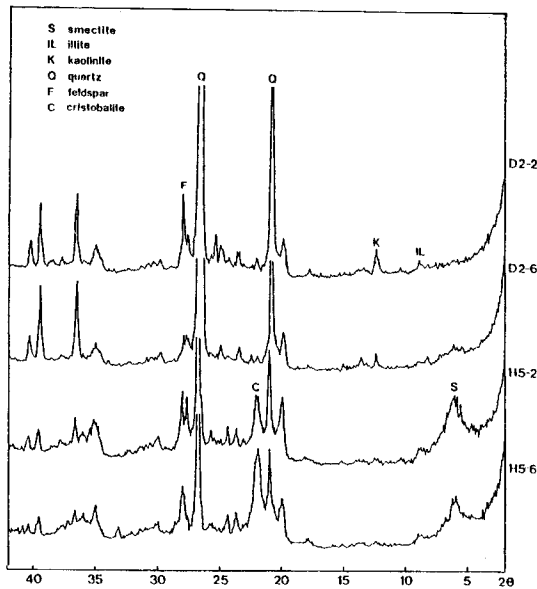


Fig. 3. X-ray diffraction patterns of some representative bulk samples from the Duho and Hageon weathering profiles. D2-2 and H5-2 were collected from weathered surface and D2-6 and H5-5 from the unoxidized zone in both profiles.

is hardly monitored from the bulk XRD data. However, it seems to be inherited from original samples. Kaolinite is more abundant and higher crystallinity in D-series samples than in H-series. But, kaolinite content just beneath the surface slightly increases in the D-series samples.

The clay mineral distribution with depth in weathering profile remains relatively constant, but the slight variation can be monitored. In H-series samples, quartz content decreases slightly as weathering depth increase. In D-series samples, kaolinite content decreases slightly as weathering depth increase. Such a relatively uniform clay mineral assemblage seems to reflect that little, not severe, leaching has been taking place in these weathering profiles. It results such a little change in chemical condition as shown in Table 1 and 2. The most common vertical variation of mineral distribution in weathering profile is that gibbsite and kaolinite at the surface grading downward to kaolinite and montmorillonite, respectively, are common trend (Loughnan, 1969). The difference in mineral distribution of these two weathering profiles does not agree with common trend as mentioned above. It suggest that this difference in mineral distribution seem to be inherited from original source material rather than alteration of

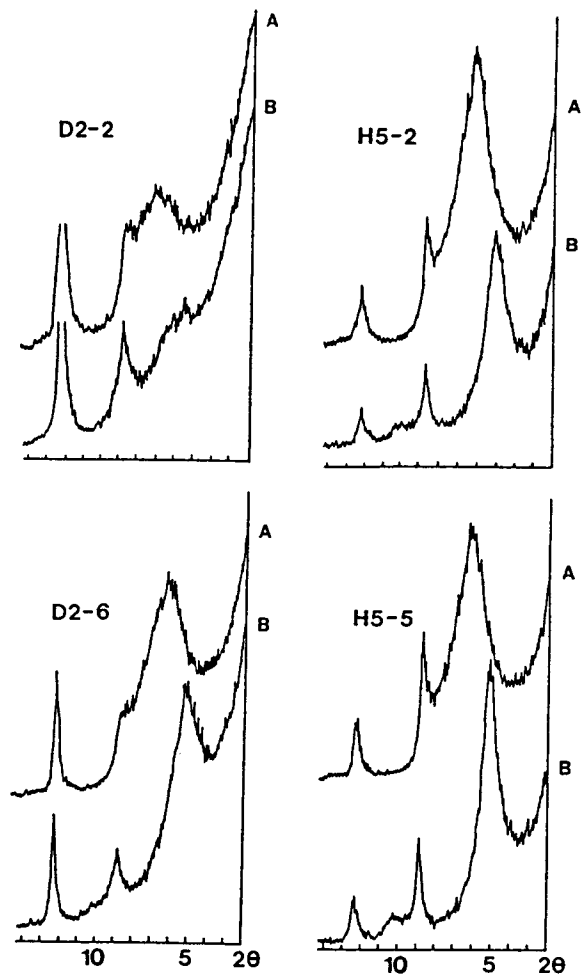


Fig.4. X-ray diffraction patterns of some representative <2 micron size fractions of samples from the Duho and Hageon weathering profiles. Upper traces are untreated oriented sam- and lower ones are glycolated.

weathering process. But, the slight increment of kaolinite content in D-series samples is resulted from loosing potassium or silica or both of them at these two weathering profiles. As a natural consequence, variation of kaolinite content of D-series samples is due partially to its neoformation from different minerals during the weathering process. It indicates that the direction of the weathering reaction of this area has been taking place toward kaolinite formation. Based on kaolinite stability field by Curtis and Spears(1971), kaolinite could be stable in pH range between about 4 to 8 with H_4SiO_4 con-

centration greater than 10^{-4} μ M.

Considering pH of rain water and ground water distributed in siltstone and clay is acidic and about 7, pH condition of the area is considered to be acidic to neutral. The presence of cristobalite in two weathering profiles, eventhough quantity varies in two profiles, suggest that the equilibrium solution of this environment has higher silica concentration and relatively lower base cocentration with definitely lower pH But not less than 4.

CHEMICAL CHANGE WITH DEPTH AND WEATHERING INDEX

Chemical Change with Depth

Chemical analyses of the bulk samples are tabulated in Table 1 and 2 with extractable iron, silica and alumina, and total organic carbon(TOC).

As mentioned in previous section, relatively constant mineral distribution in each weathering profile indicates little change in chemical condition as shown in Table 1 and 2.

Slight increment of kaolinite content in the weathering profiles as mentioned in previous section suggests that weathering reaction of these two profiles goes first to illite formation, and then to kaolinite formation. Generally, it was known that illite and kaolinite are formed as a weathering product from feldspar through the reaction with weathering agent in relatively low pH solution. It was also known that the reactions of illite and kaolinite formations from feldspar release of K and Si ion.

Major element chemistry(Table 1 and 2) shows no remarkable variations of silica and

Table 2. Chemical analyses of bulk samples from the Hagjeon weathering profile.

Sample Name	H5-2	H5-3	H5-4	H5-5
SiO ₂	59.75	66.01	62.37	60.18
Al ₂ O ₃	20.09	13.06	15.14	15.99
Fe ₂ O ₃	2.26	2.37	2.82	3.49
FeO	0.55	1.87	1.40	1.25
CaO	0.24	0.74	0.74	1.11
MgO	2.12	1.95	2.04	2.37
TiO ₂	0.95	0.54	0.68	0.71
Na ₂ O	1.27	1.06	1.16	1.20
K ₂ O	3.28	2.16	2.51	2.75
H ₂ O(-)	4.77	3.62	4.10	4.21
Ig.Loss	4.77	6.31	6.94	6.62
Total	100.05	99.69	99.90	99.88
Free Fe	0.41	0.65	0.54	0.17
Free Si	4.98	12.18	8.78	5.78
Free Al	0.70	0.38	0.38	0.38
TOC	0.30	1.40	1.74	1.23

potassium, which indicate that those ions are not wholly removed from this system but precipitated somewhere, and this can be monitored from the presence of low cristobalite. Considering solubility of aluminium and no variation of aluminium content with depth (Fig. 5), it is certain that no aluminium transported into solution. It leads to make a valid assumption that solution pH must be low, in other word, acidic but not extremely low. Smectite also can be formed during the weathering process, but it was not favorable under such an acidic environment for the formation of smectite. Therefore, smectite occurred in these weathering profiles are considered to be detrital sediments or authigenic minerals mainly or almost entirely from the original sediments. No other major element

Table 1. Chemical analyses of bulk samples from the Duho weathering profile.

	D2-1	D2-2	D2-3	D2-4	D2-5	D2-6	D2-7	D2-8	D2-9	D2-10	D2-11	D2-12
SiO ₂	77.64	73.98	79.70	77.90	79.11	78.32	80.63	79.01	78.19	75.63	75.70	70.83
Al ₂ O ₃	11.87	13.81	11.02	11.71	11.28	10.84	9.45	10.12	9.72	10.53	11.51	11.86
Fe ₂ O ₃	0.85	1.02	0.70	0.66	0.47	0.41	0.71	0.87	0.61	1.03	0.42	2.36
FeO	0.62	0.95	0.81	0.76	0.54	0.57	0.78	0.68	0.71	0.88	0.63	1.71
CaO	0.07	0.05	0.02	0.02	0.02	0.03	0.04	0.04	0.02	0.03	0.03	0.50
MgO	0.32	0.25	0.32	0.31	0.49	0.45	0.27	0.26	0.36	0.47	0.38	0.56
TiO ₂	0.47	0.63	0.46	0.43	0.42	0.41	0.40	0.46	0.38	0.43	0.47	0.48
Na ₂ O	0.87	1.03	0.31	0.67	0.68	0.99	0.45	0.39	0.74	0.44	0.66	0.73
H ₂ O(-)	1.54	2.09	1.50	1.60	1.52	1.52	1.39	1.40	1.45	1.44	1.52	1.63
Ig.Loss	1.81	1.66	1.47	1.57	1.68	1.85	1.35	1.46	1.38	1.46	1.56	1.47
	3.74	4.33	3.49	4.22	3.75	4.63	4.57	5.27	6.35	7.75	7.02	7.79
Total	99.80	99.80	99.80	99.85	99.96	100.02	100.04	99.96	99.91	100.09	99.90	99.92
Free Fe	0.22	0.54	0.36	0.41	0.16	0.19	0.45	0.49	0.40	0.61	0.16	0.18
Free Si	1.02	0.88	0.68	1.20	0.80	1.04	0.74	0.66	0.88	0.76	1.06	0.56
Free Al	0.48	0.42	0.32	0.34	0.32	0.28	0.24	0.22	0.26	0.22	0.30	0.30
TOC	0.42	0.60	0.65	0.80	0.97	1.18	1.21	2.85	2.47	3.20	2.64	2.38

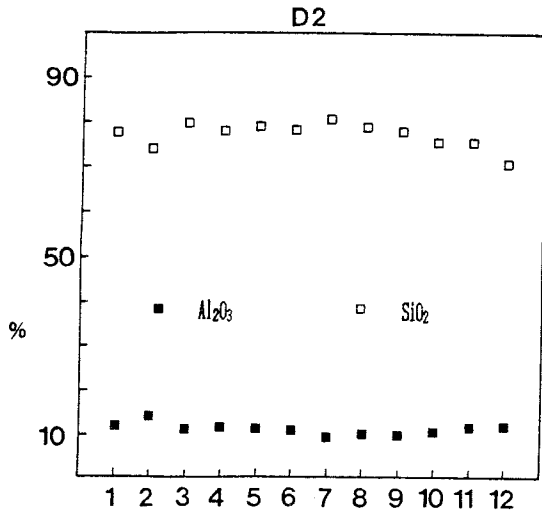


Fig. 5. Variation with weathering depth in alumina and silica for samples from the Duho weathering profile. Open square : SiO₂ and solid square : Al₂O₃.

except for H₂O(-) shows such an observable variation with depth in these profiles even though there is a distinct oxidation front in both weathering profiles. H₂O(-) was slightly decreased with increasing depth which reflects that the quantity of clay minerals whereas ignition loss increase with depth (Fig. 6). Further dissociation of clay aggregates and slight increment of clay content lead to increase H₂O(-) due to the size reduction, because size reduction increases surface area to hold more absorbed and inter-layer water of clay minerals. Such a tendency is closely related to little increment of clay minerals in the weathering surface or near surface. Judging from the mineralogical composition by XRD and chemical analysis, a notable increment of ignition loss with depth may be due to the increment of TOC with depth rather than the increment of hydrous mineral content.

Generally, it is understood that Al₂O₃ and TiO₂ remain constant during weathering process with normal chemical condition. Alumina content of the present samples from the Duho profile remains fairly constant. The average value of alumina of the unweathered samples from D2-6 to D2-11 was considered as an original one of this formation. Chemical analyses of samples from oxidized zone (D2-1 to D2-5) were recalculated, holding Al constant to average value of the unweathered samples (10.36 percent), and the results are tabulated in Table 3. It clearly shows that substance added in small but significantly is Fe₂O₃, and losing substances are SiO₂, FeO and H₂O(+) as expected. Variations of bases can not be monitored in this recalculated

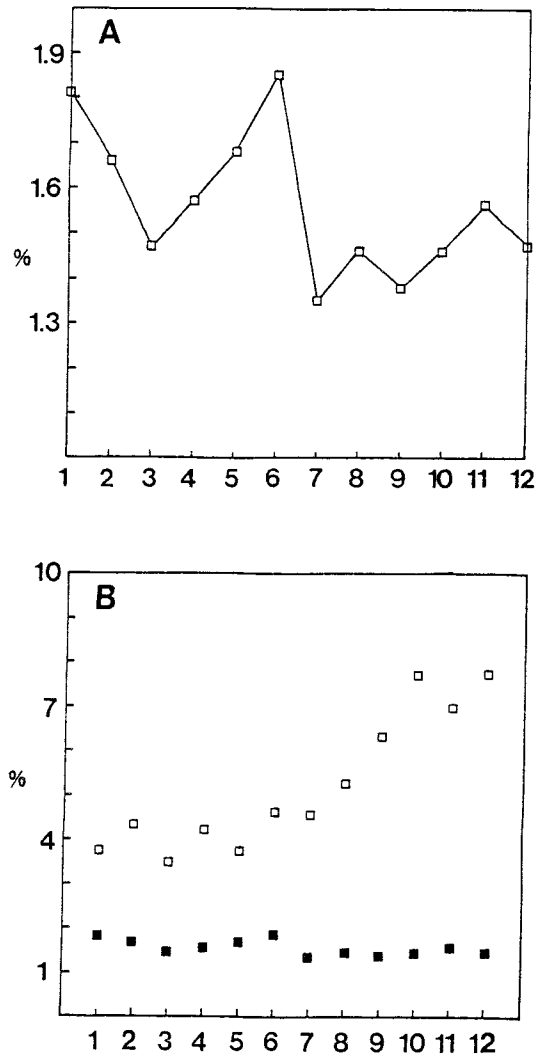


Fig. 6. Variation with weathering depth in ignition loss and H₂O(-) for samples from the Duho weathering profile. Upper diagram and lower one show variations in H₂O(-) and ignition loss, respectively.

results.

The measured free iron, silica and alumina are reported in Table 1 and 2. It is known that quartz and well crystallized clay minerals are generally unaffected using rapid dissolution technique, whereas non-crystalline silica, aluminium hydroxide, allophane, and very small particles of smectite and halloysite are dissolved (Schwertmann, 1979). Extracted values of free alumina and silica range 0.22-0.48 and 0.56-1.20 percent, respectively in the Duho weathering profile and

Table 3. Recalculated analysis from Table 1, holding Al constant to 10.36.

	D2-1	D2-2	D2-3	D2-4	D2-5	unwthd*
SiO ₂	67.76	55.50	74.93	68.92	72.66	77.91
Al ₂ O ₃	10.36	10.36	10.36	10.36	10.36	10.36
Fe ₂ O ₃	0.74	0.77	0.66	0.58	0.43	0.68
FeO	0.54	0.71	0.76	0.67	0.50	0.71
CaO	0.06	0.04	0.02	0.02	0.02	0.03
MgO	0.28	0.19	0.30	0.27	0.45	0.37
TiO ₂	0.41	0.47	0.43	0.38	0.39	0.43
Na ₂ O	0.76	0.77	0.29	0.59	0.62	0.61
K ₂ O	1.34	0.57	1.41	0.42	1.40	1.45
H ₂ O(-)	1.58	1.25	1.38	0.39	1.54	1.51
Ig. Loss	3.26	3.25	3.28	3.73	3.44	5.93
Total	87.10	74.87	93.82	88.34	91.81	99.99

Unwthd ; the average value of samples from unoxidized zone.

0.38-0.70 and 4.98-12.18 percent, respectively in the Hageon weathering profile. These results are plotted against with depth in Fig. 7, which indicates that little change or no leaching and little or no loss due to surface runoff have been taking place in this system. The relatively large amount of alumina and silica extraction in the Hageon profile can be explained as a greater dissolution due to appreciable amount of smectite being contained in the H-series samples.

Total organic carbon only varies systematically with depth, and it increases with increasing depth (Fig. 8). In the oxidation zone, TOC ranges less than 1 percent, but it increases up to 3.20 in the bottom of the Duho profile. Though the absolute amount of TOC in the H-series samples is

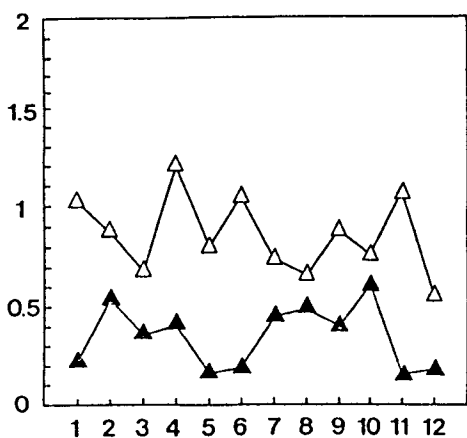


Fig.7. Variation with weathering depth in extractable silica and alumina for samples from the Duho weathering profile. Solid triangular; free iron oxide and open triangular; free silica.

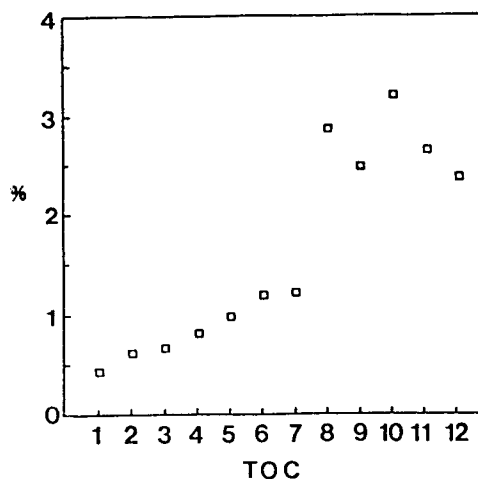


Fig. 8. Variation with weathering depth in total organic carbon for samples from the Duho weathering profile.

somewhat lower than those of the D-series samples, such a tendency was appeared. A noticeable difference in organic matters definitely is due to the different decomposition rate in relation with the various oxidation state from weathering surface to bottom of the profile. It is closely related with colour change of the samples, which will be discussed in later section.

Weathering Index

It is difficult to determine the grade of chemical weathering that has taken place in rocks, particularly in the less intensely weathered profile like the Duho and Hageon weathered profiles. However, major element chemistry of the bulk sample is the most widely used way of determining the grade of chemical weathering. Therefore, various weathering indices were calculated as a molar ratios on the basis of major element chemistry and tabulated in Table 4. The depth of oxidation front in both profiles varies depending on a number of factors such as lithology, orientation of slope, etc.. The depth of oxidation front of south facing slope is greater than that of north facing slope due possibly to greater annual temperature fluctuation and the relatively warmer condition. They promote the weathering reaction mainly by decomposition of organic matter. According to the chemical change as mentioned above, great variation of the weathering indices was not expected. In this study the authors employed the weathering potential index(WPI) and product index(PI) proposed by Reiche(1943), and some mole ratios suggested by Coleman(1982) to see a

Table 4. Molar ratios of some oxides of samples from the Duho and Hageon weathering profile.

	D2-1	D2-2	D2-3	D2-4	D2-5	D2-6	D2-7	D2-8	D2-9	D2-10	D2-11	D2-12	H5-2	H5-3	H5-4	H5-5
SiO ₂ /Al ₂ O ₃	11.10	9.09	12.27	11.29	11.90	12.26	14.48	13.25	13.65	12.19	11.16	10.14	5.05	8.58	6.99	6.39
SiO ₂ (Al ₂ O ₃ +Fe ₂ O ₃)	10.62	8.68	11.80	10.90	11.59	11.97	13.82	12.56	13.13	11.47	10.91	8.99	4.71	7.69	6.25	5.61
Parker's weathering index*	11.61	14.44	8.73	10.79	10.99	12.34	8.82	8.56	10.61	9.52	10.62	13.11	26.24	21.32	23.52	26.58
Reiche's weathering potential index**	2.71	3.22	1.98	2.46	2.69	3.00	2.00	1.95	2.54	2.45	2.59	3.79	8.44	7.53	8.26	9.66
Reiche's product index***	91.01	89.16	91.82	91.25	91.72	91.96	92.93	92.25	92.61	91.62	91.21	89.58	81.68	88.01	85.60	84.23

* : 100(K₂O/0.25+Na₂O/0.35+CaO/0.7+MgO/0.9), ** : 100(sum of bases-H₂O)/(sum of bases+SiO₂+R₂O₃), and *** : 100(SiO₂)/(SiO₂+R₂O₃).

quantitative variation of chemical weathering in these profiles.

The first two ratios in Table 4 should decrease on weathering due to the concentration of alumina in the weathering profile as expected. WPI are plotted against PI as shown in Fig. 9. WPI and PI also decrease on weathering. WPI decreases more rapid than PI due to the former reflects bases and crystal water as shown in formula in Table 4. Leaching of bases of this system is not detectable as mentioned earlier. The general relationship between WPI and PI is not applied to these samples. But, Fig. 9 shows the different degree of susceptibility to chemical weathering between two formations. The Duho Formation has a higher degree of susceptibility to weathering than that of the Hageon Formation, which can be explained by the difference of mineralogy and texture. The Hageon Formation contains greater amount of smectite which results decreasing permeability due to more dense packing or cementation by fine clay particles. Consequently, it leads to different rate of regional chemical weathering of both the Duho and Hageon profiles.

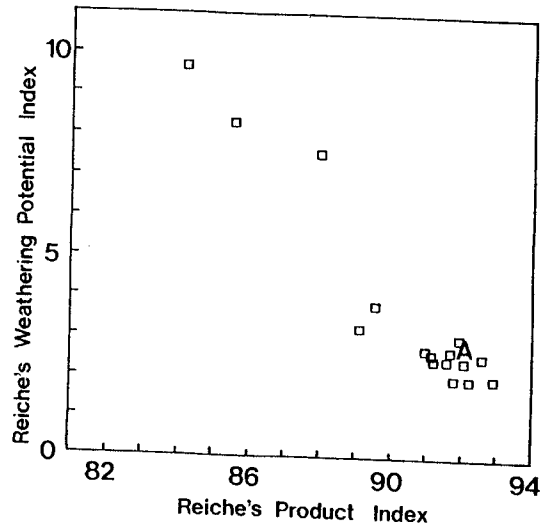


Fig. 9. Weathering data on the Duho profile plotted with respect to both weathering potential index and product index.

Table 5. Dry and wet color of the bulk samples from the Duho and Hageon weathering profile.

Sample	Dry color	Wet Color
D2-1	Very pale orange(10YR8/2)	Moderate orange pink(5YR 8/4)
D2-2	Very pale orange(10YR8/2)	Pale yellowish brown(10YR 6/2)
D2-3	Very pale orange(10YR8/2)	Moderate yellowish brown(10YR 5/4)
D2-4	Very pale orange(10YR8/2)	Pale yellowish brown(10YR 6/2)
D2-5	Very pale orange(10YR8/2)	Moderate yellowish brown(10YR 5/4)
D2-6	Pale yellow brown(10YR 6/2)	Moderate brown(5YR 4/4)
D2-7	Pale yellow brown(10YR 6/2)	Dark yellowish brown(10YR 4/2)
D2-8	Pale yellow brown(10YR 6/2)	Dark yellowish brown(10YR 4/2)
D2-9	Pale yellow brown(10YR 6/2)	Dark yellowish brown(10YR 4/2)
D2-10	Pale yellow brown(10YR 6/2)	Dusky yellowish brown(10YR 2/2)
D2-11	Pale yellow brown(10YR 6/2)	Dusky yellowish brown(10YR 2/2)
D2-12	Pale yellow brown(10YR 6/2)	Dusky brown(5YR 2/2)
H5-2	Very pale orange(10YR 8/2)	Dark yellowish brown(10YR 4/2)
H5-3	Light olive gray(5Y 4/1)	Dusk yellowish brown(10YR 3/2)
H5-4	Light olive gray(5Y 4/1)	Dusk yellowish brown(10YR 3/2)
H5-5	Light olive gray(5Y 4/1)	Olive gray(5Y 3/2)

CHANGE IN COLOUR AND MICROFOSSIL ABUNDANCE BY WEATHERING PROCESS

The colour of the bulk samples from two weathering profiles was measured by eyesight using a colour chart and reflectance spectrometer, and the results are listed in Tables 5 and 6. The measured colour by two different ways shows somewhat different results. The dry colour by eyesight is very pale orange (10YR 8/2) in both weathered profiles. The dry colour of the unweathered samples is pale yellow brown and light olive gray in the Duho and Hageion profile, respectively. The wet colour is darker than that of the dry colours as expected. It should be noted that the dry and wet colours by eyesight using a colour chart are rather qualitative than quantitative because it can be varied depending on the observer and limitation of colour appeared in colour chart. However, the colour difference between weathered and unweathered zones is so distinct that it can be easily recognized at exposed outcrops.

The colour was determined by reflectance spectrometer, Photovolt, to get a quantitative result using three different filters (amber, green and blue). The results are plotted in the chromaticity coordinate as shown in Fig. 10. Corordinate formulate for x, y and z are as follows: $x = X/(X+Y+Z)$, $y = Y/(X+Y+Z)$ and $z = 1 - (X+Y)$. From the enlarged portion of Fig. 10a, hue and purity of colour can be quantitatively determined. The hue is determined from a line drawn on the diagram from standard point

Table 6. Tristimulus values measured by reflectance spectrometer.

	Amber	Blue	Green	x	y	z	L*	a*	b*	
D2-1	49.0	32.1	44.3	0.354	0.348	0.298	72.43	4.47	15.55	34.9
D2-2	40.6	25.3	36.9	0.357	0.356	0.288	67.20	2.81	16.98	27.7
D2-3	48.1	31.5	43.0	0.355	0.346	0.299	71.55	5.86	14.90	31.3
D2-4	44.3	28.7	40.0	0.355	0.349	0.296	69.47	4.30	15.46	31.3
D2-5	41.4	25.6	37.0	0.360	0.353	0.288	67.28	4.73	16.61	28.9
D2-6	39.3	24.1	35.3	0.360	0.355	0.286	65.98	3.94	16.91	28.9
D2-7	39.0	24.4	35.4	0.357	0.355	0.289	66.06	2.99	16.53	28.4
D2-8	34.5	22.8	31.6	0.351	0.350	0.298	63.01	2.63	14.07	25.9
D2-9	31.9	22.8	29.9	0.343	0.346	0.311	61.57	1.18	11.58	24.7
D2-10	29.0	20.6	26.9	0.344	0.344	0.311	58.88	2.17	11.01	22.2
D2-11	27.2	19.2	25.5	0.344	0.348	0.309	57.56	0.91	11.47	21.0
D2-12	25.2	19.2	24.2	0.335	0.343	0.321	56.29	-0.48	9.27	19.7
H5-2	37.2	25.0	34.5	0.349	0.351	0.300	65.36	1.50	14.30	25.9
H5-3	25.6	18.2	24.5	0.341	0.351	0.308	56.58	-1.15	11.83	19.7
H5-4	21.0	15.5	20.0	0.338	0.346	0.316	51.84	-0.09	9.55	16.0
H5-5	24.6	19.9	23.9	0.329	0.338	0.332	55.99	-0.75	7.37	19.7

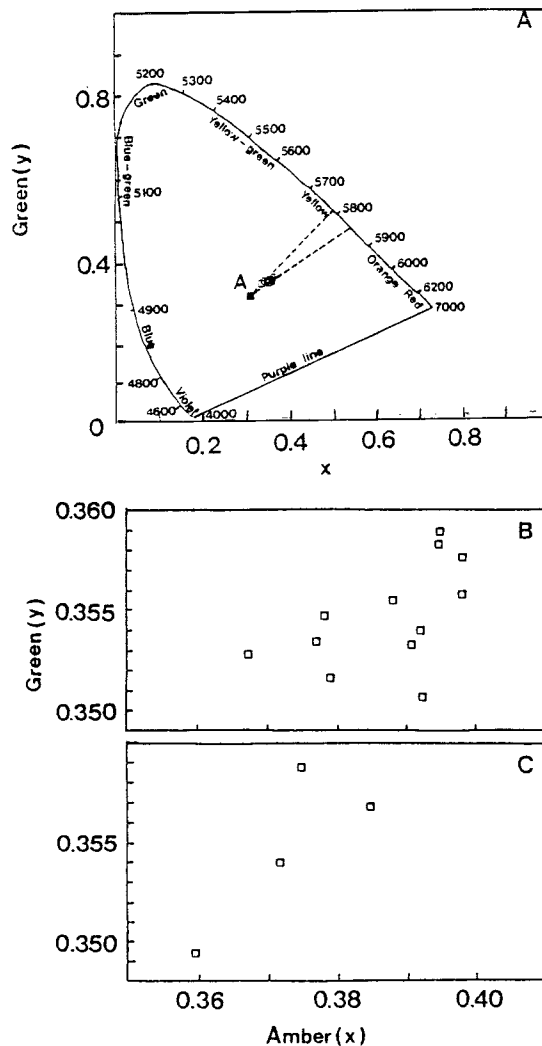


Fig. 10. CIE chromaticity diagram for A) samples from both the Duho and Hageion weathering profiles, B) enlarged portion of diagram for the Duho profile, and C) enlarged portion of diagram for the Hageion profile. It shows variation in colour with increase weathering depth.

(marked as cross in Fig. 10a) to the spectrum locus. The intersection is the dominant wavelength corresponding to our normal appreciation of the colour. The dominant wavelength is ranging approximately 5800-5840 Å corresponding to yellow to orange. It is quite similar to the colour we observed by eyesight even though the chromaticity coordinates do not allow the colour to be visualized exactly. CIE

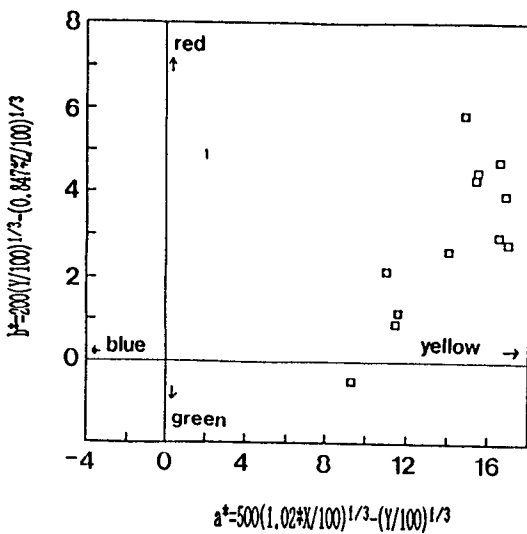


Fig. 11. Data plotted in the CIE L*a*b* colour coordinates for samples from both weathering profile showing relationship of colour.

L*a*b* shows more clearly colour difference with our normal appreciation of the colour. The quantities L*a*b* are defined for illuminant C as: $L^* = 116(Y)^{1/3} - 16$, $a^* = 500[(1.02X)^{1/3} - Y^{1/3}]$, and $b^* = 200[Y^{1/3} - (0.847Z)^{1/3}]$. The results are plotted in Fig.11. As expected, the light colour such as yellow is dominant in the weathered surface. The colour of samples in depth become

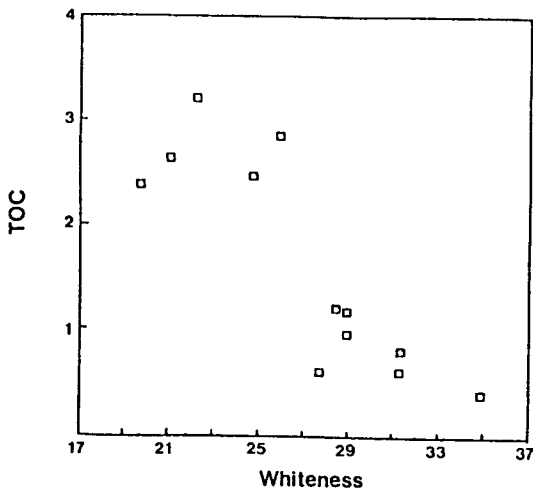


Fig. 12. Relationship between total organic carbon and whiteness showing good negative correlation.

es darker as increasing green component than those of samples from surface as shown in Fig.11. The colours of all the present samples have same hue but different purity relating to weathered depth. Whiteness was taken as the y trimulus value, and it decreases with increasing depth. It shows very good negative correlation with TOC(Fig.12) indicating that TOC is a main factor to affect the colour of the samples. It is worth to note that iron species ratio(FeO/Fe₂O₃) seems not to directly relate or affect to the colour of the samples.

According to colour measurement along the weathering profiles, there is a clear difference in

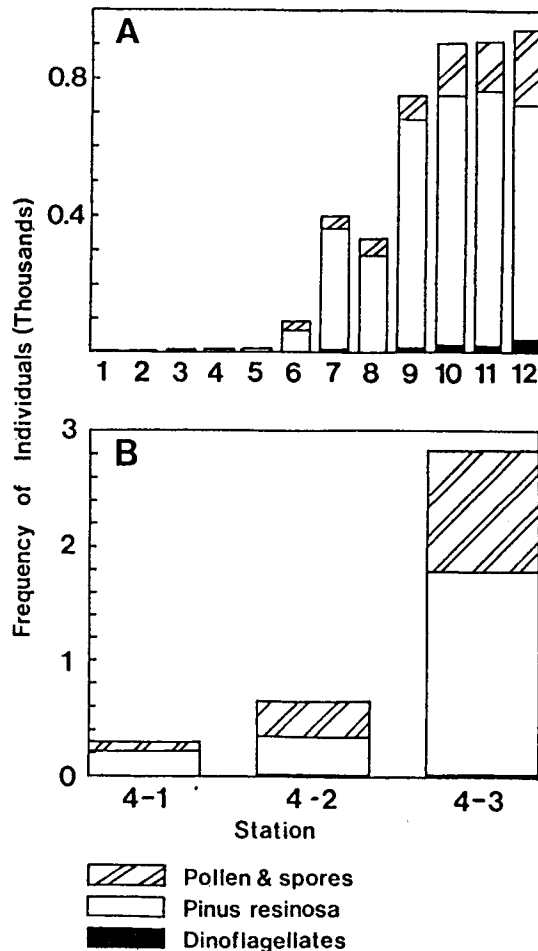


Fig. 13. Frequency diagram of micro-fossil occurrences in the Duho weathering profiles(A ; D-series samples and B ; F-series samples).

Table 7. Occurrence chart of the organic microfossils at each station.

Station	D2-1	D2-2	D2-3	D2-4	D2-5	D2-6	D2-7	D2-8	D2-9	D2-10	D2-11	D2-12	Total
Dinoflagellates						67	8	2	15	25	24	44	
<i>Pinus resinosa</i>						28	357	285	668	728	743	683	
Pollen & spore	5	6	9	11	14	28	38	50	70	153	144	220	
Total	5	6	9	11	14	95	403	337	753	906	911	947	4397

colour between weathered surface and unweathered part of the same horizon within the formation. It clearly suggests that the colour observed in the weathered surface can not be used characteristic features to differentiate concerning lithologic stratigraphy simply because it is false one and variable from place to place. The decomposition of organic matter is deeply influenced by texture, particle size distribution, permeability and topography such as gradient and orientation of slope, etc. (Jenny, 1980; Finney et al., 1962), and results various false colour.

The frequencies of micro-fossil occurrence from two weathering profiles are listed in Table 7 and plotted in Fig.13. Generally, number of fossil individuals successively increases regardless of fossil taxa from surface to bottom of profiles. Among the microfossils pollen and spores are very abundant, *Pinus resinosa* are dominant, and dinoflagellates cysts are less abundant. Its increasing rate of amount is also lower than that of pollen and spores. The microfossils begin to occur abundantly at the sampling sites D2-6 and D2-7 in the Duho section where pale yellow brown colour at dry sample or moderate brown colour starts to set (Table 6 and 7). In the Hagjeon section they occur abundantly first at depth of 10 m below the surface and its abundance abruptly increases at 16 m in depth.

CONCLUSION

Regarding microfossil preservation the weathering processes have intensively influenced about up to 7-10 m in depth from the surface in the Duho Formation, although it may vary from outcrop to outcrop, duration of exposure into the air, slope gradient, and orientation of weathering surface. Therefore, the minimum excavation depth for microfossil sampling should be 7-10 m to reach relatively fresh sediment containing organic microfossil groups. In case of calcareous microfossils it may be deeper due to mild resistance of its skeletons against weathering processes. Hence, the stratigraphic zonation by some authors that the Duho Formation is a microfossil barren zone should be rediscussed and possibility of microfossil preservation should

be retained at a deeply excavated outcrops.

As shown in colour change of the Duho Formation from surface to deeper part, the colour is not a primary and constant characteristics of the sediments, and could not be used as a diagnostic feature of a stratigraphic zonation. The colour change is mainly due to the decomposition of organic carbon by chemical weathering, and surprisingly iron species ratio ($\text{FeO}/\text{Fe}_2\text{O}_3$) seems not to significantly affect colour change in these weathering profiles. The chemical and mineralogical studies on the weathering profiles lead to conclusion that little change or no leaching has been taking place in both profiles. It may indicate that the erosional rate of these sedimentary formations is somewhat higher than that of well consolidated sediments. In terms of the degree of susceptibility to chemical weathering, the Duho Formation has higher degree of susceptibility than the Hagjeon Formation mainly due to mineralogical composition and its texture. The blocky fracturing nature of the Duho Formation which only occurs in a weathered light-brownish outcrop is also not an inheritant characteristics but secondary one. Consequently, these characteristics should be only used as a subsidiary tool in setting geologic boundary or establishing a formation.

ACKNOWLEDGEMENTS

The authors are grateful to Korea Research Foundation for financial support. Total organic carbon analyses of bulk samples were carried out by Dr. J.H. Oh of the KIER, and is gratefully acknowledged. We are also grateful to Dr. Y.S. Park of Chosun University for allowing us to use X-ray diffractometer. This paper was prepared as a part of the project "Biostratigraphic, chemostratigraphic, paleomagnetostratigraphic and tephrochronological studies for the correlation of Tertiary formations in southern part of Korea".

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浦項地域 第3紀層 堆積岩중 化學的風化作用이 粘土鑛物組成, 化學組成, 岩色 및 微化石 產出頻度에 미치는 영향

문희수 · 윤혜수 · 민경덕 · 이현구 · 이종천

요약 : 제3기 포항분지의 퇴적암류의 외견상의 특징은 비록 한 층준내라 할지라도 산출지, 즉 노두에 따라 다양하게 나타난다. 이러한 현상은 주로 화학적풍화작용에 의한 화학조성 및 광물조성의 변화와 미화석 산출빈도의 변화에 기인된 것으로서, 이는 암층서, 생층서 및 지질경계를 설정하는데 많은 혼동을 유발하는 원인이 되었다.

화학적 풍화작용이 제3기 포항분지의 퇴적암류에 미친 영향을 지화학적, 광물학적 및 미화석 산출빈도와 관계시켜 풍화심도에 따른 변화를 체계적으로 연구 하였고, 지질현상 해석에의 적용을 고찰하였다. 본 역의 화학적 풍화작용에 대한 감응력은 광물조성과 조직의 차이에 따라 변화를 보였고, 풍화대에서의 용탈현상이 미약한 것은 침식속도가 상대적으로 빠른 결과로 해석된다. 외견상의 가장 현저한 변화인 암색의 변화는 주로 유기물의 분해에 의한 결과이며, 미화석의 산출 또한 풍화 심도에 따라 큰 변화를 보여 풍화대 상부, 즉, 산화대에서는 산출이 극히 제한되고 특히 풍화작용의 감응력이 상대적으로 큰 두호층의 경우 그 영향은 더욱 현저하다. 그 영향은 지표로부터 7-10m에 이르러 포항분지의 경우, 지표 시료를 이용한 암층서 및 생층서 연구시 이들자료 해석에 큰 제한이 있고 주의가 필요함을 지시한다.