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Textures of Claystones and Their Genetic Significances in the Cheonunsan Formation of the Hwasoon Area

화순지역 천운산층 중의 점토암의 조직과 그 성인적 의미

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ABSTRACT : Textures of claystones of the Cheonunsan Formation in the Hwasoon area have been studied using optical microscope and electron microprobe. Microscopic images were observed under the optical microscope using the transmitted polarizing light from thin sections and under the electron microprobe using the back-scattered electron beam from the polished sections. Identification of minerals were made using X-ray diffraction analysis and chemical analysis by electon microprobe. Textural analyses show that the original sedimentary claystones rich in aluminium were subjected to metamorphism by which they changed to the metamorphosed claystone consisting mainly of chloritoid, quartz, andalusite and illite. Later intensive hydrothermal kaolinization of this metamorhosed claystones resulted in the formation of high-aluminous claystones rich in kaolinite exhibiting various complicated replacement textures.

요약 : 화순지역의 천운산층에서 산출하는 점토암의 조직을 편광현미경과 전자현미경을 사용하여 연구하였다. 현미경적 조직은 박편을 이용한 투과광으로 그리고 전자현미분석기에 의한 화학분석에 의하여 이루어졌다. 현미경적 조직 분석 결과는 알루미늄이 풍부한 원래의 퇴적기원 점토암이 변성작용을 받아 주로 일라이트, 석영, 홍주석 및 클로리토이드로 구성된 변성점토암으로 변했다는 것을 보여준다. 이 변성 점토암이 후에 광범하게 일어난 열수용액에 의하여 다양하고 복잡한 교대조직을 보이는 캐올리나이트가 풍부한 고알루미늄 점토암이 생성되었다.

INTRODUCTION

Claystones of the Cheonunsan Formation is highly aluminous showing 32～44% Al_2O_3 and thus it has been used for various industrial application including refractory bricks and ceramics.

The Cheonunsan Formation is the uppermost unit of the Kuam Group that is correlated with the Pyeongan Group of late Paleozoic Period. According to drilling data (Lee, 1991), the Cheonunsan Formation is divided into three members : the lower member consisting of thick greensh grey and purple coarse-grained sandstone with minor dark grey coaly shale, the middle member consisting of alternation of dark grey to black coarse-grained sandstone and black shale and sandy shale, and the upper member consisting of dark grey coaly shale, sandy shale and claystone with minor light grey coarse-grained sandstone, quartzite and quartz-muscovite schist. The rocks generally show more or less foliation due to regional metamorphism. The exact thickness of the formation is not known because of intense folding and faulting in the area.

Geology of the Hwasoon area was studied by many workers (Kim and Lee, 1962; Park et al., 1978; Seo and Baek, 1984). Origin of high-aluminous claystones was studied by Park et al. (1978, 1984) and the mineralogical study was carried out by Lee et al. (1986, 1988). Detailed mineralogy of claystones and their genesis was recently studied by Lee, S.-R. (1991). But detailed textures of claystones have not been studied yet.

The textural analysis of present claystones and their genetic significances are prerequisite for the study of the process of formation of claystones. Therefore, the present study aims to analyze the various features of textures of claystones and their genetic significances.

MATERIALS AND METHODS

Claystone samples were collected in the field considering their occurrence and mineralogical characters. Identification of minerals was made using X-ray diffraction and electron microprobe analysis.

X-ray diffration analysis was made using a Rigaku Geigerflex RAD3-C with Ni-filtered CuKa radiation. Microprobe analyses were obtained using a JEOL JXA 733 Superprobe equipped with Link wave dispersive spectrometer. Analyses were carried out using polished thin sections of claystone chips. Textural study was carried out under both the optical microscope using the transmitted polarizing light through thin sections and the electron microprobe fitted with a Link energy dispersive spectrometer using the back-scattered electron images (BSEI) from the polished sections. Detailed textures of fine-grained minerals were well manifested in the back-scattered electron images.

MINERALOGY OF CLAYSTONES

X-ray diffraction and electron microprobe analyses show that the claystones consist of kaolinite (20~70%), chloritoid (10~35%), quartz (up to 10%), illite (5~40%), andalusite (5~35%), pyrophyllite (up to 5%), carbonaceous material (up to 7%), rutile (trace) and dickite (up to 15%) (Lee, S.-R., 1991). According to Lee (1991) the carbonaceous materials are maturated to metaanthracite-semigraphite.

TEXTURES OF CLAYSTONES

Megascopic Textures and Structures

The claystones are usually dark grey to black in color due to their high contents of carbonaceous materials (up to 7%), but occasionally yellowish or brownish due to their low contents of carbonaceous materials.

The textures of claystones in hand specimen are massive or porphyroblastic. The massive claystones are abundantly found in the Cheonun mine, whereas the porphyroblastic clystones are abundantly found in the Byeogsong mine. However, gradation between two types of textures is observed in the field.

In the porphyroblastic claystones, the porphyroblasts range from fine-grained to several millimeters in size, exhibiting black or cream white color depending on their mineralogy. The cream white porphyroblasts consist of andalusite, whereas the dark grey to black porphyroblasts consist of kaolinite or chloritoid. Chloritoid or partly kaolinized andalusite porphyroblasts are generally round in shape. The matrix of the porphyroblastic claystones consists of illite, kaolinite and pyrophyllite with minor rutile.

The white thin veinlets usually less than 2mm in thickness are found parallel or perpendicular to the bedding in the claystone of the Cheonun mine. The minerals found in veinlets are dickite, nacrite, illite, pyrophyllite, quartz, siderite, goethite and hematite. They occur independently or in group. Especially the illite-rich claystones show distinct foliation.

Microscopic Textures

Microscopic observation on the relationship of constituent minerals of claystones reveals that the rock textures of the original sedimentary claystones have been considerably changed to those of the metamorphosed phase. The frequently observed textures are porphyroblastic and various replacement textures.

Porphyroblastic Texture

The back or white spotted claystones and even some of the massive claystones show well-developed porphyroblastic texture under the microscope (Fig. 1). Porphyroblasts consist of andalusite only, kaolinite only, chloritoid only, andalusite-kaolinite, and sericite-kaolinite. Matrix consists of illite, kaolinite, and pyrophyllite with minor rutile and diaspore. Porphyroblastic claystones show more or less foliation by parallel to subparallel arrangement of clay minerals in matrix, especially in the illite-rich matrix (Figs. 1 and 2).

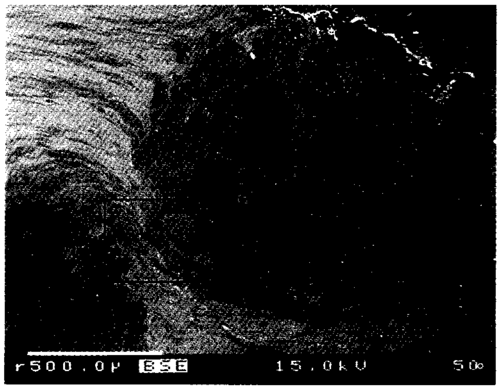

Fig. 1. Back-scattered electron image showing the pseudomorph of kaolinite (dark grey) porphyroblasts after andalusite in the matrix of illite (fibrous light grey). Relicts of andalusite (anhedral, grey) that escaped replacement are found in kaolinite porphyroblasts. Illite is also replaced by kaolinite along its cleavage. Note another later generatlon of illite vein in kaolinite porphyroblast, and the rutile veinlet (white) cutting illite and kaolinite.

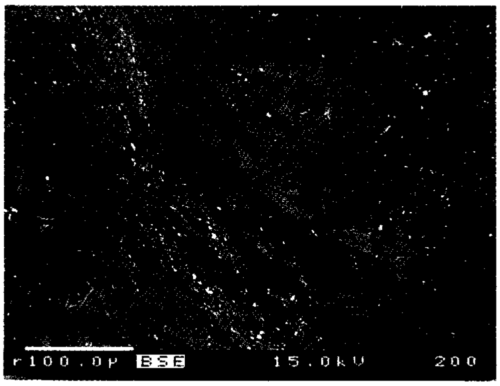

Fig. 2. Enlarged view of the rectangular part in Fig. 1. Note the replaced remnants of andalusite (grey) in kaolinite (dark grey) and tiny particles of rutile (white) in illite, andalusite and kaolinite.

Porphyroblasts are partly fractured and

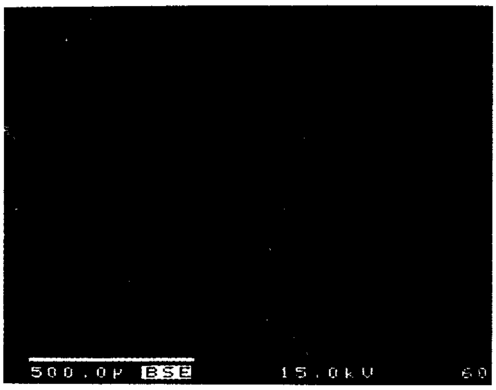

Fig. 3. Back-scattered electron image showing the pyrophyllite-kaolinite vein (dark grey) trending NS in andalusite (grey) near the center. Note the kaolinite veins cutting chloritoid and andalusite simultaneously. Distribution of rutile particls (white) suggests that they are not affected by the formation of kaolinite.

crushed indicating dynamic deformation. Andalusite porphyroblasts occasionally show hourglass structure due to the crossing arrangement of tiny carbonaceous materials.

Texture between Chloritoid and Andalusite

Chloritoid usually occurs as inclusions in andalusite. It shows embayment along its margin, suggesting the partial replacement by andalusite (Fig. 3). It is also observed that chloritoid is surrounded by kaolinite since andalusite has been replaced by kaolinite along the contact of both minerals.

Texture between Andalusite and Kaolinite

It is often found that andalusite porphyroblasts are pseudomorphously replaced by kaolinite (Fig. 1). The black poprphyroblasts seen with naked eye in handspecimen are made up nearly entirely of kaolinite or of andalusite core and kaolinite margin. Such a kaolinite porphyroblast with andalusite core has been formed from replacement of original andalusite porphyroblasts by kaolinite along their margins. The boundary between andalusite core and kaolinite margin is very irregular but considerably sharp. It is also found that andalusite relicts which escaped replacement by kaolinite are remained in the marginal zone of kaolinite porphyroblasts (Fig. 2).

Pseudomorphs of kaolinite after andalusite do not have their original shapes because they are considerably obliterated due to replcement by other later minerals. In some cases, andalusite grains show brecciated texture that the crushed fragments are surrounded and partly replaced by kaolinite. It is also observed that large andalusite porphyroblasts are cut by kaolinite veinlets (Figs. 3 and 5).

It is inferred that the replacement of andalusite by kaolinite took place in the following way as shown by Hemley et al. (1980).

$$\underset{\text{andalusite}}{2Al_2Si_2O_5} + SiO_2 + 4H_2O \rightarrow \underset{\text{kaolinite}}{Al_4Si_4O_{10}(OH)_8} \quad (1)$$

Texture between Chloritoid and Kaolinite

Chloritoid occurs as moderately sized porphyroblasts compared with large andalusite or kaolinite porphyroblasts. It is usually included in andalusite or kaolinite. It is often observed that chloritoid and andalusite are cut by kaolinite simultaneously along its cleavage or irregularly (Figs. 3 and 5). Presence of brecciated or twisted cleavages of chlorioid suggests dynamic deformation.

Texture between Andalusite and Pyrobphyllite

Andalusite is an abundant mineral of the metamorphosed claystone that has not subjected to later alteration. Pyrophyllite occurs not only in association with illite in the matrix of porphyroblastic and non-porphyrolastic claystones, but also in veinlets in andalusite or as selvages between andalusite and quartz veinlets in the andalusite- rich claystones. Pyrophyllite veinlets in andalusite (Fig. 3) as well as pyrophyllite selvage between andalusite and quartz are regarded to be the reaction product of andalusite with hydrothermal solution containing silica as shown in the following equation (Hemley et al., 1980).

$$\underset{\text{andalusite}}{Al_2SiO_5} + \underset{\text{silica}}{3SiO_2} + H_2O \rightarrow \underset{\text{pyrophyllite}}{Al_4Si_8O_{20}(OH)_4} \quad (2)$$

Texture between Pyrophyllite and Kaolinite

Association of kaolinite with pyrophyllite is always found near andalusite. Pyrophyllite in association with illite in the matrix of massive or porphyroblastic claystones might be a metamorphic product of clastic kaolinite and silica as follows:

$$\underset{\text{kaolinite}}{Al_2Si_2O_5(OH)_4} + \underset{\text{silica}}{2SiO_2} + \rightarrow \underset{\text{pyrophyllite}}{Al_2Si_4O_{10}(OH)_2} + H_2O \quad (3)$$

But it is also found that vein pyrophyllite in andalusite is replaced by kaolinite (Fig. 4). It is inferred that replacement of pyrophyllite by kaolinite took place by reaction of pyrophyllite with hydrothermal solution as follows (Thompson, 1970):

$$\underset{\text{pyrophyllite}}{Al_2Si_2O_{10}(OH)_2} + H_2O \rightarrow \underset{\text{kaolinite}}{Al_2Si_2O_5(OH)_4} + \underset{\text{quartz}}{2SiO_2} \quad (4)$$

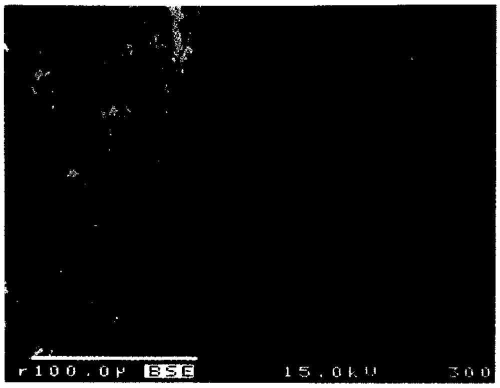

Fig. 4. Enlarged view of the rectangular part in Fig. 3. Note the partial replacement of pyrophyllite (slightly more grey than andalusite) by kaolinite (dark grey, containing the rutile (white) inclusions) along its cleavage.

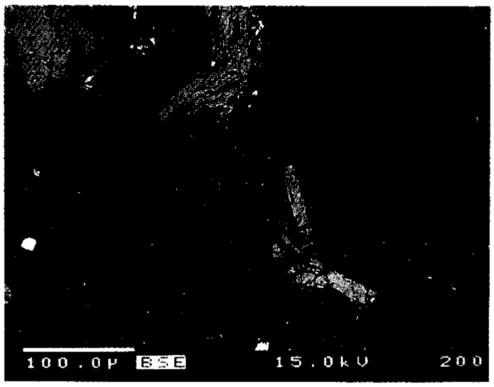

Fig. 5. Back-scattered electron image showing the replacement of chloritoid (light grey) and andausite (grey) by kaolinite (dark grey) along its cracks. White particles are rutile.

SiO_2 produced in the equation (4) might be consumed for the formation of kaolinite from andalusite. Kaolinite is also observed between andalusite and pyrophyllite which is developed along the contact of andalusite and quartz veinlets. It is inferred that this kaolinite might be the reaction product of andalusite or pyro-

Fig. 6. Back-scattered electron image showing the replacement of illite (light grey) by kaolinite aloung its cleavage.

phyllite with hydrothermal solution as shown in the reaction of either (1) or (4).

Texture between Illite and Kaolinite

Illite is abundant in the not high aluminous claystone. Illite flakes are aligned paralled to the foliation around the andalusite or kaolinite porphyroblasts suggesting its syntectomic nature (Fig. 1). It is abundantly observed from the back-scattered electron images under the electron microprobe that illite is replaced by kaolinite along its cleavage resulting in the fine alternation of narrow flakes of illite and kaolinite (Figs. 1 and 2). Replacement of illite by kaolinite might take place by reaction of illite with hydrothermal solution in the following way (Hemley and Jones, 1964).

$$\underset{\text{illite}}{2KAl_3Si_3O_{10}(OH)_2} + 2H^+ + 3H_2O \rightarrow \underset{\text{kaolinite}}{3Al_2Si_2O_5(OH)_4} + 2K^+ \quad (5)$$

Texture between Andalusite and Illite

Andalusite prophyroblasts are considerably fresh in the unaltered claystones, whereas they are deeply altered to other minerals, especially to kaolinite in the altered claystones. Therefore, the porphyroblasts of the present porphyroblastic claystones consist mostly of kaolinite. But the outer margins of kaolinite porphyroblasts are in contact with illites showing very irregular and complicated boundaries. It is inferred that such an irregular contact betwen kaolinite and illite are the heritage of the partial replacement of precursor andalusite by illite along its margin. But such an original texture has been considerably obliterated by intefisive kaolinitization of andalusite and illite.

Texture between Quartz and Kaolinite

It is observed that large quartz grain are replaced by kaolinite, leaving abundant large or small quartz islands within kaolinite.

Texture of Rutile

Rutile is very fine-grained and widely distributed as tiny particles or veinlets (Figs. 1 and 2) in kaolinite and illite. But rutile is also found within andalusite and chloritoid. Rutile particles in kaolinite are the heritage from the claystones befor kaolinitization.

DISCUSSION

Optical and electron microprobe observations show that the claystones are not homogeneous throughout the whole claystone mass in both the mineral composition and texture. Textural analyses suggest that the original metamorphosed claystone consisting of chloritoid, andalusite, quartz, illite, pyrophyllite, carbonaceous material and rutile have been deeply altered by later intensive kaolinitization. By this kaolinitization, the mineral composition and textures of the metamorphosed claystones have been considerably changed to the complicated new ones. It suggests that the intensive kaolinitization process resulted in the formation of the present high-aluminous claystones. It is inferred that the kaolinitization took place by hydrothermal process that occured extensively over the area. Widespread occurrence of well-developed kaolinite veinlets as well as the dickite or nacrite veinlets support the hydrothermal origin for the kaolinitization.

CONCLUSIONS

Textural analyses by optical and electron microprobe observations assisted by chemical analyses using electron microprobe show that the original clastic sedimentary claystones have been subjected to low-grade metamorphism by which they changed to metamorphosed claystones consisting chiefly of chloritoid, quartz, andalusite and illite. Later hydrothermal kaolinitization of the metamorphosed claystones resulted in the formation of the present high aluminous claystone rich in kaolinite.

ACKNOWLEDGMENT

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