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Characteristics of Uranium Minerals and Uranium Distribution of Fracture Zones of Uranium Deposits for Natural Analogue Study

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1. Introduction

It is essential to understand the mechanisms by which radionuclides move and delay in order to enhance the safety assessment of disposal site and public acceptance. To this end, a detailed study of the characteristics and behavior of radionuclides in fracture zones developed in an environment similar to that of disposal environments is needed [1]. Therefore, the objective of this study is to provide basic data necessary for understanding the behavior and delay of radionuclides through a natural analogue approach to the long-term behavior of radionuclides characteristics, which are the ultimate safety evaluation factors of deep geological disposal repository that go through evolution for tens of thousands of years or more, and to provide supplementary evidence related to the behavior of uranium minerals and uranium elements necessary for the construction of a safety case for disposal as well as predicting the long-term behavior of uranium in deep geological disposal environment.

2. Methods and Results

Geological, mineral, and geochemical characteristics data were obtained through various analysis of rocks obtained by drilling and field survey at the Hoenam-myeon study site in Boeun, Suyeong-ri and Birye-ri study sites in Geumsan, and Haso-dong, Daejeon. The characteristics of uranium minerals and the distribution characteristics of uranium in the fracture zones were investigated and analyzed for the rock samples from the uranium deposits study site. The Daejeon KURT site is a study site targeting granite, which is considered as a parent rock of future domestic deep geological repository. Data on the geological characteristics and the uranium distribution characteristics of drilling cores and groundwater samples of the KURT site were obtained.

2.1 Geological and Mineralogical Characteristics

The geological and mineralogical characteristics of the study sites were analyzed through field surveys and microscopic observations after rock sampling. This analysis aimed to determine the distribution characteristics of the fracture zones and the mineral occurrences within the rocks that comprise these zones. The fracture zones are mainly distributed in the coaly slate, where quartz and calcite veins have developed along the fractures or have undergone weathering and soil formation. The coaly slate within the fracture zones is mainly composed of coaly materials, quartz, and muscovite, while the weathered soil in the fracture zones is dominated by coaly material, quartz, clay minerals, barite, and iron oxides.

Table. 1. Mineral Composition of the Study Sites [2]

Rock mineral	phyllitic rock	arenaceous rock		black slaty rock			
		ser sch	hornf	blk sl	hornf	coaly sh	coal
quartz	+++	++++	++++	+++	++	++	++
sericite	++++	+++	++	++++	++	++	++
biotite	+++	+++	+++	++	+++	−	−
chlorite	++	++	−	++	+++	−	−
tremolite	−	−	−	−	−	+++	−
hornblende	−	−	++++	−	++++	−	−
microcline	−	−	−	−	++	−	−
clinozoisite	−	−	+++	−	+++	−	−
cordierite	++	−	−	−	++	++	−
apatite	+	+	+	+	++	++	−
tourmaline	+	+	+	+	++	−	−
sphene	−	−	+	−	−	+	−
zircon	+	+	+	+	++	+	−
magnetite	+	+	+	+	+	+	++
hematite	−	−	+	−	+	+	+
ilmenite	+	+	+	+	+	+	+
pyrite	+	+	+	+	+	+	+
charcopyrite	+	+	+	+	+	−	−
clay	−	−	−	+	−	++	++
U−mineral	−	−	−	−	++	++	++
V−mineral	−	−	−	−	−	++	++
Ba−mineral	−	−	−	−	−	++	++
coal(graphite)	−	−	−	++	−	+++	++++
average radioactivity (cps)	120~130	130~150		170~190	190~300	200~600*	600

ser: sericite, sch: schist, hornf: hornfels, blk: black, sl: slate, sh: shale
++++: Very much, +++: much, ++: some, +: little, −: absent
*: partly 2200~2400 cps

2.2 Uranium Minerals

The major uranium minerals identified in the rocks collected from the study site were uraninite, uranothorite, coffinite, francevillite, and brannerite. Ekanite and uranophilite are also occurred depending on the region. The species of uranium minerals, their frequency, grain size, and associated minerals varied by region. Notably, the frequency and grain size of uranium minerals were more prominent in the coaly slate and soils. Uranium minerals in coaly slate were associated with mainly coaly material, quartz, and muscovite, while in the weathered soil, they occurred with coaly material, clay minerals, iron oxides, and barite.

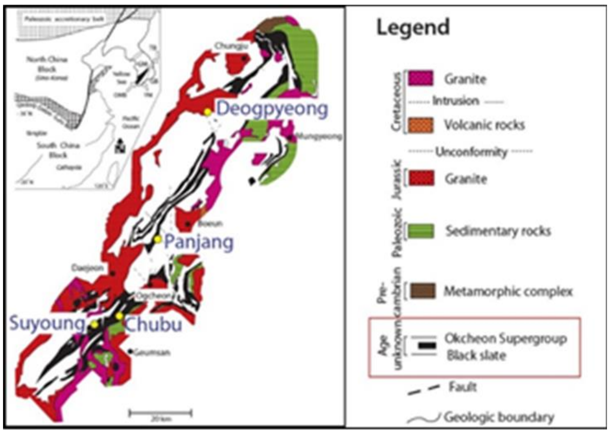

Fig. 1. Distribution of the U deposits in Okcheon Area [2]

2.3 Geochemical Characteristics of host rock

Geochemical analysis of rocks collected from the study sites showed that coaly slate in two study sites (Hoenam and Birye-ri study site), excluding Haso-dong, exhibited a negative Ce anomaly and a positive Eu anomaly. Additionally, redox-sensitive elements such as V, Mo, and U were enriched, while Mn was depleted, This suggests that uranium minerals were concentrated in a reducing marine environment rich in organic matter. On the other hand, the weathered soil showed high weathering and alteration index value, and the uranium content tended to increase with the increase of the weathering and alteration index. Furthermore, the uranium content showed a positive correlation with F_2O_3, P_2O_5, and TOC content, indicating that uranium in the rock was mobilized through weathering and mineralized by adsorption onto various ions in the soil.

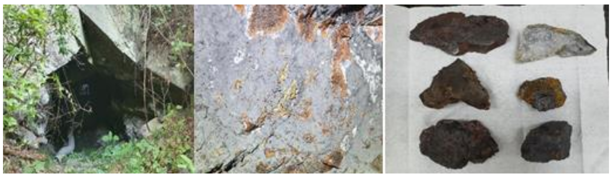

Fig. 2. Uranium-bearing rock sampling in the study sites (e.g. Birye-ri study site in Geumsan) [2]

2.4 Uranium Minerals from the KURT site

Uranium mineral from the KURT site, which is composed of representative domestic granitic rock, was estimated to be thorite or uranothorite, which has a slightly higher uranium content than the silicate mineral thorite, and was found to be less than 30 μm in apatite and boundaries of quartz and mica, feldspar, pyrite, and calcite. The KURT research site has not yet revealed a detailed investigation of uranium distribution characteristics in fracture zones and their correlations, but chemical analysis of groundwater collected by depth from deep boreholes revealed cases of high uranium dissolution characteristics in some depths.

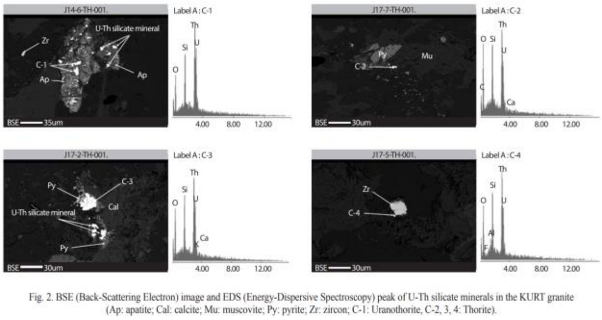

Fig. 3. BSE image and EDS peak of U-Th silicate minerals in the KURT (Ap: apatite, Cal: calcite, Mu: Muscovite, Py: pyrite, Zr: zircon, C-1: Uranothorite, C-2,3,4: Thorite) [3]

3. Conclusions

Study on U minerals and U distribution of fracture zones of domestic study sites was conducted to provide supplementary evidence on the uranium minerals and behavior of uranium elements necessary for safety assessment and safety case construction, as well as understanding nuclide behavior and delay process through a natural analogue approach to the long-term behavior of radionuclides, the ultimate safety assessment factor of deep geological repository. The results and data will be used as a natural analogue database of uranium behavior in Korea and as a supplementary input data for safety assessment and safety case construction.

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REFERENCES

[1] G.Y. Kim, D. Shin, S.-W. Jeen, M.S. Sim, S. Lee, J.-H. Ryu, A Report on the Characteristics of Uranium Minerals and Uranium Distribution of Fracture Zones of Uranium Deposits for Natural Analogue Study, KAERI/TR-10919/2024, 2024

[2] KAERI, Phase 1 Report on Development of a comprehensive performance evaluation scheme for deep geological disposal system- Natural analogue studies in the geological disposal system of radioactive wastes, 2024, KAERI/RR-5074/2024, 2024

[3] W.H. Cho, M.H. Baik, J.-H. Ryu, and J.K. Lee, Influence of Dissolved Ions on Geochemical Dissolution of Uranium in KURT Granite, JNFCWT wol.16, No. 3, pp.281-290, 2018