

# The Impact of Glaciation over the Stability and Long Term Post-Closure Radiological Safety of a Potential Deep Geologic Repository for the Permanent Disposal of Used Nuclear Fuels in the Republic of Korea

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## 1. Introduction

The Wurm Glaciation is the last glacial period of the Pleistocene between 115,000 and 11,600 years ago. The average annual temperature was cooler than the current one which altered the vegetation around the world. The glaciation covered around 30 % of the world when it reached the maximum capacity. It is believed that the area with the higher altitude than 40 was covered with the glaciers. The so-called Wisconsin glaciation and the Japanese Alps are good examples of the glaciation during the Wurm Glaciation. Certain mountains in Taiwan is known to be covered with glaciers at that time.

Recently, many geological evidences over the existence of glaciation in the mountainous areas of the Northern and the Mid-Korean Peninsula were reported. Mt Baedu on the border between the PRC and the DPRK, Kwanmo-Bong in Kaeman High Plateau, Mt Unjin in Hwanghae-Bukdo, and Mt Kumgang in Kangwon-do are identified as the areas with good evidences of glaciation during the last glacial period. Results show that glaciers existed in the mountainous area of the DPRK with the creation of cirques and striations during the migration of a group of glaciers or an individual one. But there is no study yet about the potential heights and volumes of the glaciers in those areas.

This leads to the uncertainties to screen in or out the so called the effect of ice age on a potential deep repository. Future follow-up studies are needed before the final FEP screening processes.

## 2. Glaciation in Korean Peninsula

In this section some of the results from studies over the glaciation in Korea Peninsula are summarized.

### 2.1. Glaciation in the ROK

There is a paper about the evidence of glaciation at Ogcheon System in Chungcheongnamdo in the ROK[1]. It is suggested by the authors that the evidences such as striations were created around 2.5 billion years ago during the Late Paleozoic Era. The origin of the glaciation on the Ogcheon case is suggested to come from the plate tectonics stating that a certain part of Korean Peninsula came from the Antarctica. There is no evidence of glaciation during the last glacial period yet in the southern part of Korean Peninsula.

### 2.2 Glaciation in the DPRK

#### *Mt. Unjin*

There has been many studies over the glaciation in the DPRK. The first study was done for Mt Unjin at the early 70's. The series of the follow-up studies[2] on the northern slope of Mt Unjin show that the glaciation occurred during the Wurm glaciation period.

#### *Mt. Baekdu*

Korea University studied the glaciation at Mt. Baekdu[3] where the latest volcanic activity occurred around 1,000 years ago. The mountain is covered with basalt and its metamorphic rocks. The area of Mt Baekdu, currently under the control of the PRC, has been actively investigated by the ROK and the PRC scientists[4,5] over the issues of glacier formation, retreat, and its migration. When the glaciation was at the maximum capacity during the Wurm Period, the entire Lake Chonji was covered with the ice cap. Due to the climate change, the ice gap was divided into valley glaciers. Later, individual glaciers started to migrate downward along the slope of the mountain. The recent studies focused on the U-shaped valley in the western Chonji area identified cirques created in the Holocene period and the altered geological landscape of the area during the migration of glaciers. The age of the ice age near Lake Choin was measured by C1-36 sampling from the sedimentary layer underneath the migration pathway of these glaciers. Results show that glacier migration happened between 90,000 and 26,000 years ago. This is the direct evidence of glaciation during the Wurm glaciation period in Korean Peninsula.

#### *Kwanmo-Bong*

Similar evidences were identified at Mt Kwanmo, the highest mountain in Kaema High Plateau. Many North Korean Pinaceae were believed to migrated from the northern area under the much harsh climate at that time. The climate at Mt Kwanmo during the last glaciation period is believed to be the boreal climate[4,5,6]. Many geological features to illustrate the glaciation such as cliques, rigged ridges and etc are identified in this area.

#### *Mt. Kumgang*

Recent studies show the strong evidence of the existence of glaciation during the Wurm Glaciation Period at Mt Kumgang[7,8.] The age of glaciation is around 28,000 years ago during the last glaciation period. Some glaciation striations were identified at Kuryongyon, Manpokdong and Sangpaltam valley. The beautiful landscapes of the Inner and the Outer Kumgang areas are believed to be created by the

migration of glaciers during the last glaciation period.

### 3. Impact of the Glaciation

When glaciers are formed due to the advent of the new ice age in the future, it shall impact the three aspects of a potential repository to be built in the ROK.

(1) Mechanical Stability: The first issue is whether the new glaciation shall disturb the mechanical stability of a proposed deep repository or not. Without the glaciation, the safety functions of the proposed waste containers shall be to withstand the mechanical burden of the geologic media above the emplacement holes and the swelling of the bentonite used as an engineered barrier. The lithostatic pressure shall be around 5 MPa if no high mountain exist. Also, the swelling pressure shall be additional 15-20 MPa. However, if there is strong formation of thick glaciers during the new ice age, it will upload additional pressure against the stability of a waste container embedded into a deep geologic medium. The impacts of the future glaciation are well recorded in many overseas studies[9]. According to the study by POSIVA, the safety function of the proposed waste container is designed to withstand the pressure of 60 MPa when the next glaciation occurs[10.]

(2) Migration Pathways: There is the other impact of the future ice age. The severe glaciation shall retreat the shores of the coastal areas where the potential repository is located. It shall alter the present ground water pathways and the saline water distribution.

(3) Food Chains: In addition, the advent of the ice age shall change the food chains under the current temperate climate to the boreal or tundra ones. The comprehensive studies over the long-term advent of the potential ice age are needed when there are many proven evidences of glaciation during the last 100,000 year time frame in the vicinity of a future proposed repository site.

### 4. Key Factors

#### Uncertainties in the Climatic Snow Lines

The cirque in Mt Unjin located at 38° 50', 126° 27' in Yonsangun Hwanghaebukdo indicates that the climate snow line lies at 700 meter altitude from the sea. The evidences of cirques, rigged ridges, and U shaped valleys at Kwanmo-Bong area, indicates the existence of the snow lines between 1,300 and 2,100 meter altitude. This strongly implies that glaciers in those spots are high mountain glaciers. However, the recent studies at Mt Kumgang shows the existence of the valley glaciation at about 100 meter above sea level in the Outer Kumgang and 500 meter in the Inner Kumgang. This shall create the uncertainty when the importance of the glaciation is evaluated from the future FEP(Features, Events, and Processes) screening.

#### Time of Glaciation

The studies show that the glaciation at mountains in the DRPRK occurred during the last glaciation period. There is no evidence of the glaciation during the Wurm Glaciation Period in the ROK yet.

### 5. Conclusions

Studies on the glaciation in the northern Korean Peninsula direct the strong evidence of the glaciation in mountainous areas during the Wurm Glaciation Period. However, there is uncertainty over the climatic snow lines in these areas. The follow-up studies are recommended to acquire data for the snow lines.

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