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Paleoseismological Study on the Mid-northern Part of Ulsan Fault by Trench Method
트렌치 조사에 의한 울산 단층 중북부의 고지진학적 연구

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요약 / ABSTRACT

The Korean historical literatures describe that great earthquakes with destructive damages occurred mainly in Kyongju-Ulsan areas during the period of 1 to 8 century and 16 to 17 century. It seems that the Ulsan fault system shows a little curved trend with N-S strike in the southern part and diverges into three directions from the mid-northern part of the fault. The dominant trends of the lineaments are NNE-SSW, NE-SW and NS directions. Trench excavation in the mid-northern part of the Ulsan fault shows thrust facies cutting slope deposit containing a compacted laminar structure whose origin may due to severe cryogenic activities of the last cold period(about 25000 B.P.). Detailed observation of the facies gives some evidences related to two earthquake episodes of thrust components along the Ulsan fault system. Fault outcrop and trench study suggest that Ulsan fault seems to be one of the active fault which has reworked several times even in the late Quaternary.

한국의 역사 문헌에 의하면 파괴적인 피해를 동반한 대지진들이 1-8 세기와 16-17 세기에 주로 경주와 울산 부근에서 발생했다. 울산단층 동부 지역에서의 선구조선들의 분포는 NNE-SSW, NE-SW, NS 성분이 우세하게 나타나며 울산단층은 중북부에서 세 방향으로 분기하는 단층계를 형성한다고 보여진다. 울산단층 중북부에서의 트렌치 조사에 의하면 본 단층은 마지막 빙기 (약 25,000 B.P)동안의 심한 결빙작용으로 나타난 엽리구조를 포함하는 사면 퇴적물을 절단하고 있으며 트러스트 성분의 단층운동이 2회 발생한 흔적을 보인다. 야외 노두와 트렌치 조사에 의하면 울산 단층은 제 4 기 후기 이후에도 여러회 활동한 단층으로 추정된다.

Introduction

The level of seismicity in the Korean peninsula is lower than that in northeastern China and Japan. However, some great earthquakes occurred through the historical time and triggered destructive damages. These earthquakes occurred mainly in Kyongju-Ulsan areas in the southeastern part of the Korean peninsula. The Korean historical literatures describe approximately ten earthquakes occurred in Kyongju-Ulsan areas and might have affected great damages such as house destruction, dead people, ground fissures, liquefaction and surface depression around the above cities. NNE-SSW trending Yangsan fault(about 200 km) and NNW-SSE trending Ulsan fault(about 60 km) are passing through these areas.

From the interpretation of aerial photograph these two faults show clear lineament and crosses around Kyongju city(Hoshino et al., 1984; Yoon and Kim, 1990). Along the coast of East Sea from Pohang to Ulsan city, higher middle and lower marine terraces are consecutively developed(Kim, 1973; Oh, 1977; Jo, 1980; Lee, 1985; Kim, 1990). From the study of these terraces, the northern part of middle terrace including Ulsan fault is relatively higher than the southern part, which indicates the existence of vertical displacement since the formation of middle terrace(Oh, 1977).

In order to clarify the fault characteristics related to great earthquakes, trench work was attempted in the mid-northern part of the Ulsan fault. The result of the work with some outcrops are introduced and discussed here. It provides important informations indicating the Quaternary faulting events along the Ulsan fault.

Characteristics of Korean Historical Earthquakes

Earthquakes that occurred in and around Korea have been described in old historical literatures such as Samkuksaki, Koreosa, Izoshillok, Seungjoungwon-ilki, Cheungbomunhyeon-biko and so on. The data cover almost two thousand years since 27 A.D.

A long term synchronous variation in seismicity since 1400 A.D. exists in the intraplate region from northeastern China to the Inner Zone of Southwest Japan through the Korean Peninsula(Kyung et al., 1996). The seismogenic stress field in this intraplate region may be formed under the common tectonic conditions due to the regional tectonic forces originating from the collision between the Indo-Australian and the Eurasian plates in the west and the combined effects of subduction of the Pacific and the Philippine Sea plates in the east, and the regional vertical force by upper mantle. The direction of the regional forces is almost paralled to the great circle connecting the eastern part of the Himalayas to Japan. The intraplate regions extending from northeastern China and the Korean Peninsula to the western part of the Inner Zone of Southwest Japan may be responding as a unitary block to the regional tectonic force and comprising a province with a common seismogenic stress field in the eastern part of Eurasian plate(Kyung et al., 1996).

The epicentral areas of great earthquakes are closely related to the areas with the composite conditions such as short distance to lineaments, relatively high gradient of Bouguer anomaly and low relief regions having high density of lineaments (Kyung and Lee, 1993; Kyung, 1993).

Some great earthquakes affected destructive damagae with dead people, induced ground fissures, surface depression, land slide, water spouting with sand or mud, and sand blows. The Korean literatures also show some description indicating the above phenomenon(Fig.1). Eight great earthquakes condensely occurred in and around Kyongju city(A.D. 34, 100, 123, 304, 471, 510, 630, 779). Especially, the Kyongju earthquake in 779 affected great damages with death of approximately one hundred people. The greatest earthquake(MMI X) in the Korean Peninsula occurred around the Ulsan city in 1643. It had large felt areas and triggered tsunami, liquefaction on the coast and destroy of some beacon houses.

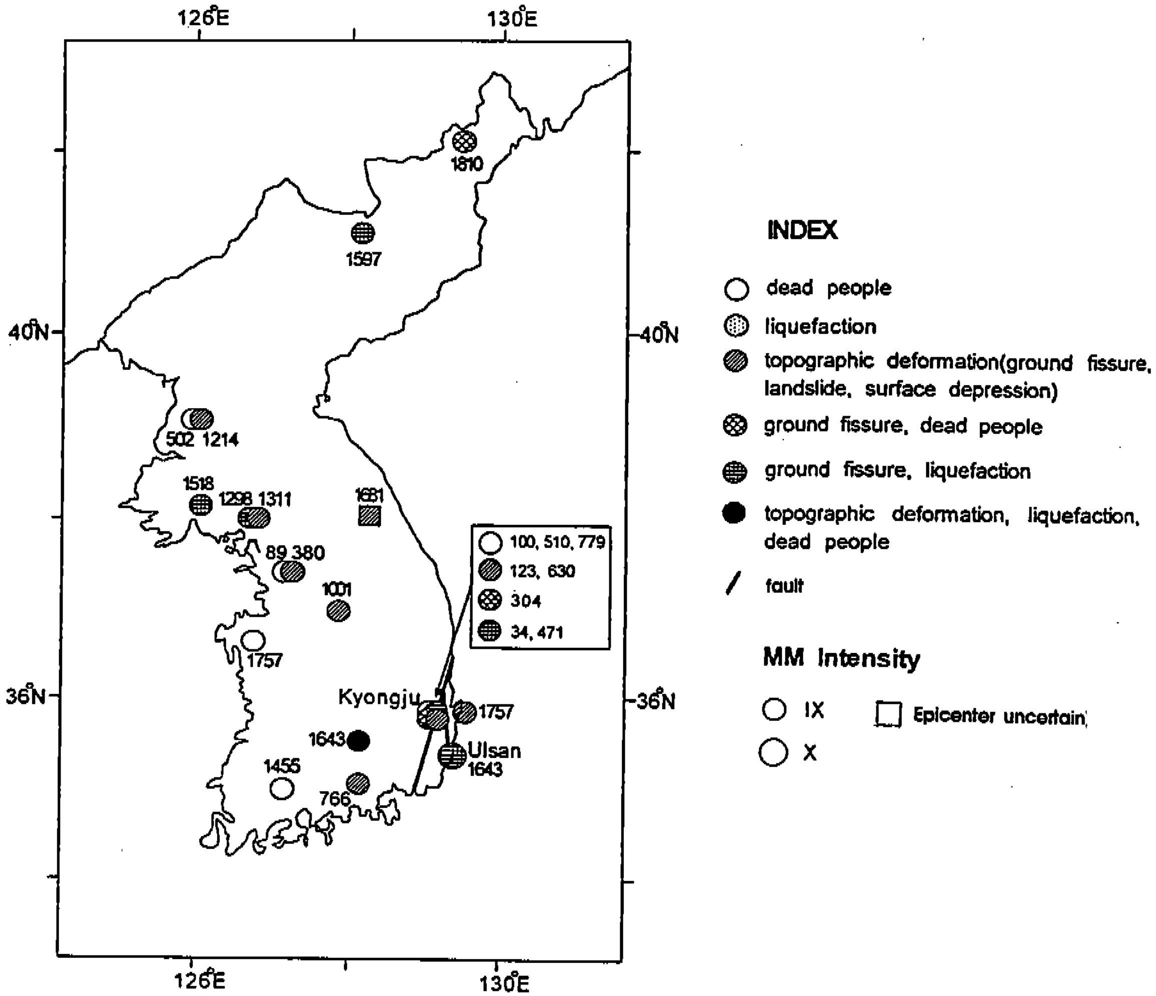

Fig. 1. Epicenters of great historical earthquakes(MM intensity≥IX) which triggered destructive damages in the Korean peninsula.

NNE-SSW trending Yangsan fault system and NNW-SSE trending Ulsan fault are passing through these areas. These two faults cross at the northeastern part of Kyongju city. It was suggested that Yangsan fault with right-lateral strike-slip component was repeatedly activated in the Quaternary era, even though its activity is low(class C)(Okada et al., 1994).

Geomorphological Characteristics and Interpretation of Lineament

In the eatern part of the Kyongju-Ulsan cities several mountains such as Mt. Toham, Samtae Peak, Mt. Tongdae and Mt. Muryong are consecutively connected in the N-S direction (Fig.2). The slope of the western part of these mountains is quite steep and shows fault scarp topography. Alluvial fan type terrace surfaces distribute along the western hill of the aligned mountains.

In the geological map of Choyang and Ulsan(scale : 1/50,000), upper Cretaceous granite and Silla formation of Kyongsang group distribute in the northern and in the southern part of the fault scarp, respectively. In the southern part of the mountain areas, Jeongja conglomerate of the Yeonil group is locally distributed. Sediments of river terrace and alluvium distribute in the lower part of the mountain. However, Ulsan fault were not clearly described in the geological map. It was suggested that the Ulsan fault is thrust fault with a low dip angle to the east and almost N-S strike(Okada et al., 1995).

The distribution of lineament was analyzed using the aerophotograph(scale : 1/20000) and topographic map(scale : 1/5000, 1/25000) which is published by National Geographic Institute(Fig.2).

Geomorphologically the Ulsan fault shows quite clear contrast between the east and the west side. As shown in Fig.2, the general trend of Ulsan fault shows NNW-SSE or N-S direction. It does not show a straight line but a little curved trend. The fault diverges into three trends such as NNW-SSE, N-S and NNE-SSW directions from the mid-northern part of the fault. Therefore, it can be called as Ulsan fault system. The NNE-SSW trending fault is quite clearly shown on the aerial photograph and passing through the Bulguk temple, eastern part

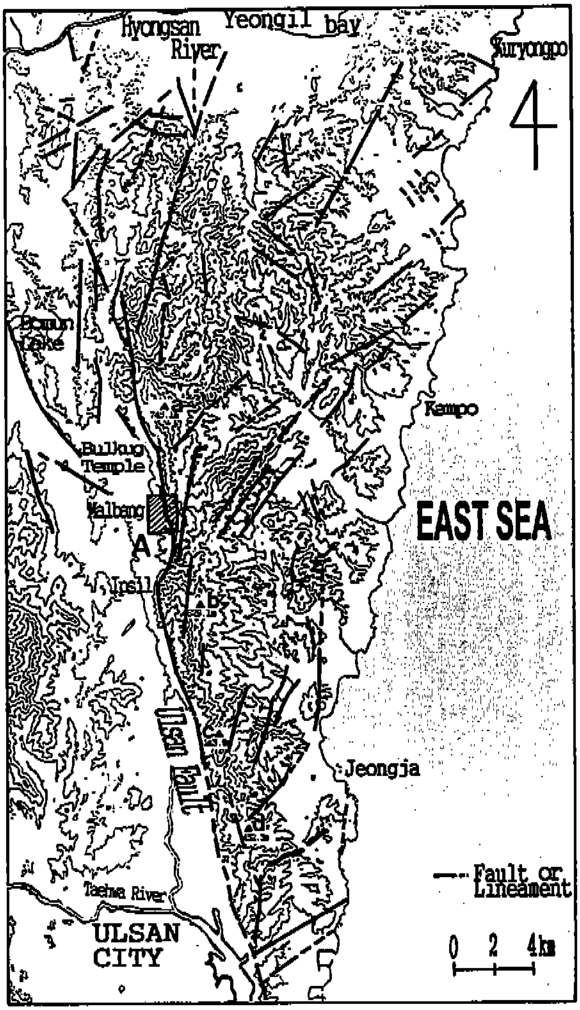

Fig. 2. Topographic map and distribution of lineament interpreted from aerial photograph(scale : 1/20000) in the eastern part of Ulsan fault system. The symbol is as fallows; a-Mt. Toham, b-Samtae Peak, c-Mt. Tongdae, d- Mt. Muryong. The symbol A indicates the study area.

of Deokdong lake and Yeongil bay. In the eastern part of the Ulsan fault system, the dominant trends of lineaments are NNE-SSW, NE-SW and N-S direction.

The natural topography almost disappeared in the Ulsan city due to the construction of many buildings and houses. However, in the eastern part of Ulsan bay, NE-SW lineaments are clearly shown. Several parallel NE-SW trending lineaments distribute dominantly from the east side of study area to the east coast area(Kampo).

Fault Outcrop

Field survey was attempted along the mid-northern part of the Ulsan fault In the study area(A region of Fig.2), dissected alluvial fan surfaces are well developed along the western hill of the mountain(Fig.3).

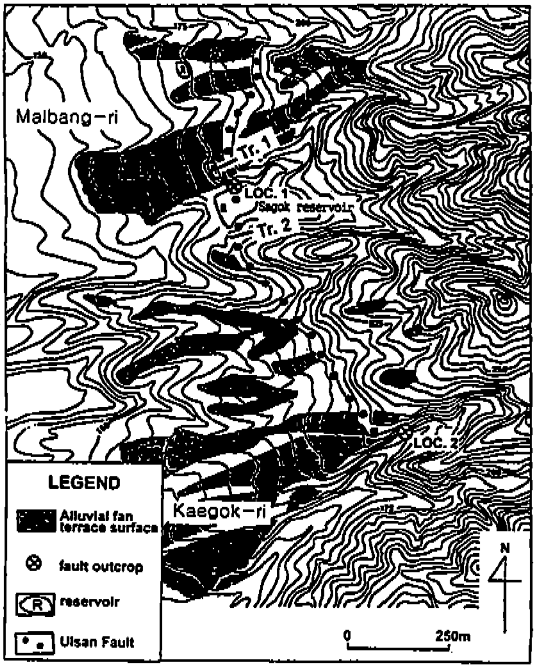

Fig. 3. Topographic distribution, locations of fault outcrop(Loc.1 and Loc.2) and trench site in the study area(Tr.1 and Tr.2).

Geomorphologically, the Ulsan fault represents a little curved trend which typically appears in case of thrust fault type. The westward gently dipping terrace surfaces are cut by the low fault scarplet at Malbang-ri area. The age of the alluvial fan is quite important to estimate the active age of the Ulsan fault. Fault outcrops were found on the northern wall of the Sagok reservoir in the eastern part of Malbang-ri, Waedong-up(Okada et al., 1995).

Fig.4 describes the top of the fault outcrop with 10m width and 4m thickness. The weathered granite is overthrusted above the gravel layer. The fault shows almost N-S strike and 25° -30° E dip with about 20 cm wide fault gauge zone. On the hanging wall about 3m thick granule-pebble and cobble-boulder(10-50 cm in diameter) layer covers unconformally the granite. The upper part consists of granule-pebble with silt layer and shows the graded bedding repeatedly. They were bent by fault movement. As it comes to the gauge zone the layer becomes greatly bent and some small minor faults exist.

On the foot wall, about 7m thick gravel layer mainly consists of cobble-boulder. However, the upper part is more fresh than the lower part. On the top of the outcrop, another thrust fault separates from the main fault. Therefore, the fault shows one fault plane on the lower part and separates into two or more minor faults on the upper part of the outcrop. It indicates that at least two faulting events have occurred along the fault since late Quaternary.

Another outcrop is seen on the northeastern part of Kaegok-ri area(Loc.2 of Fig.3). Fig.5 delineates the sketch of the fault outcrop at Kaegok-ri area. Here the granite is gently overthrusted above the some weathered gravel layer of the late Quaternary. The fault(f1) shows almost N-S strike and 25° - 30° E dip. Several faults with fault clay are shown within the granite of the hanging wall. It is covered with fresh gravel and humic layer(granule-pebble and cobble-boulder). The weathered gravel layer of

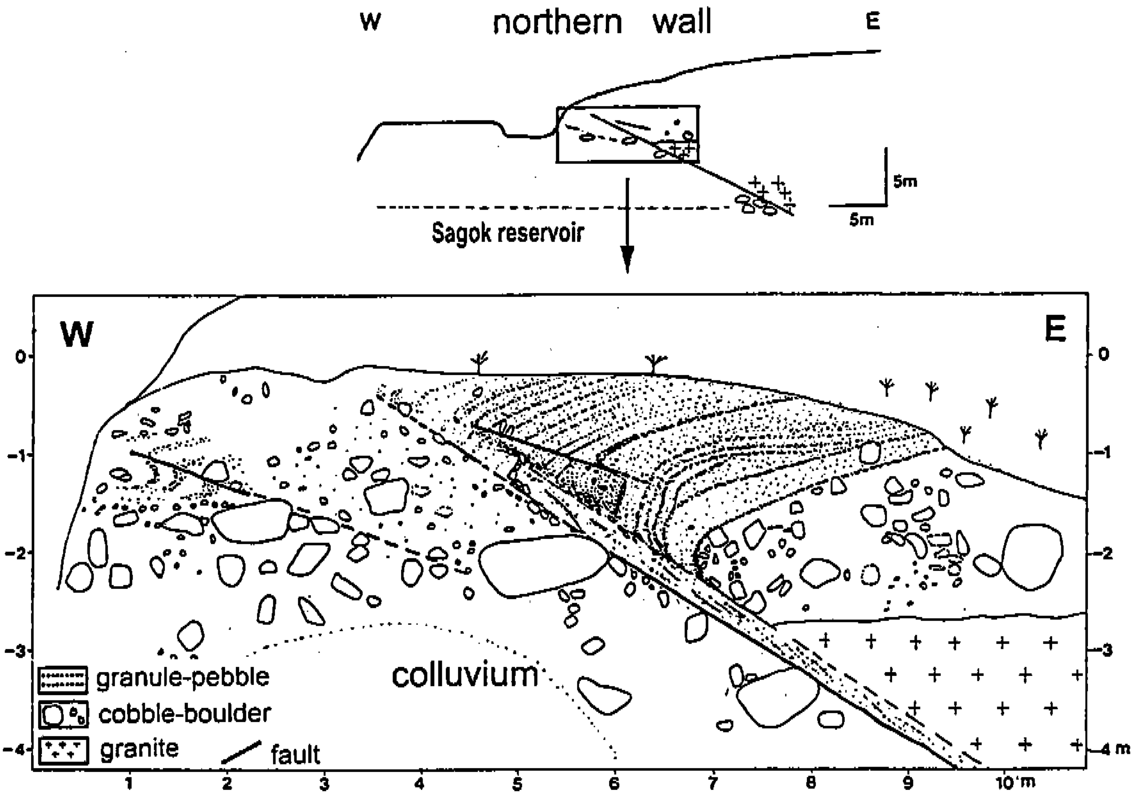

Fig. 4. Sketch of the top of the fault outcrop on the northern wall of the Sagok reservoir(loc.1 of Fig.3). Malbang-ri.

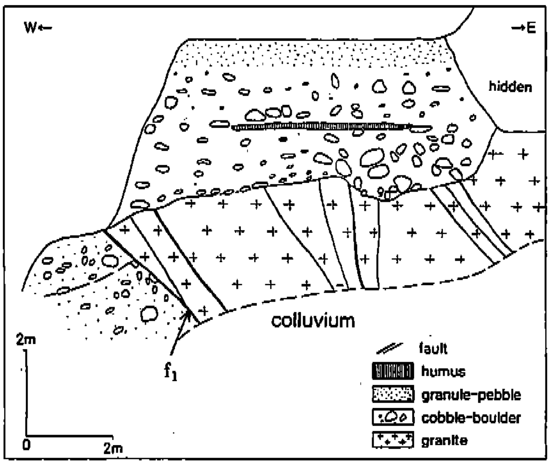

Fig. 5. Sketch of the fault outcrop at Kaegok-ri(loc.2 of Fig.3).

the footwall seems to be quite older than the fresh gravel and humic layer of the hanging wall. It is quite difficult to estimate whether the fresh gravel layer of the hanging wall is displaced or not by fault(f1) on the outcrop. However, the boundary fault(f1) between gravel layer and granite rock indicates the Late Quaternary fault.

Trench Study along the Ulsan Fault

Trench excavation was attempted across the Ulsan fault in the eastern of Malbang-ri. The trench site is located at 10m north of the fault outcrop(Tr.1 of Fig.3). Its surface is 1.5m higher than the surface of fault outcrop(Loc.1 of Fig.3). Fig.6 shows the sketch of the cross-section for the southern wall of the trench site. The hanging wall of the fault consists of highly weathered materials(mainly cobble-boulder) from the basement rock(granite) in the lower part and fine to coarse sand, granule-pebble, which alternatively accumulated, in the upper part. They were greatly bent along the fault. Here three episodes of faulting are identified in this trench site.

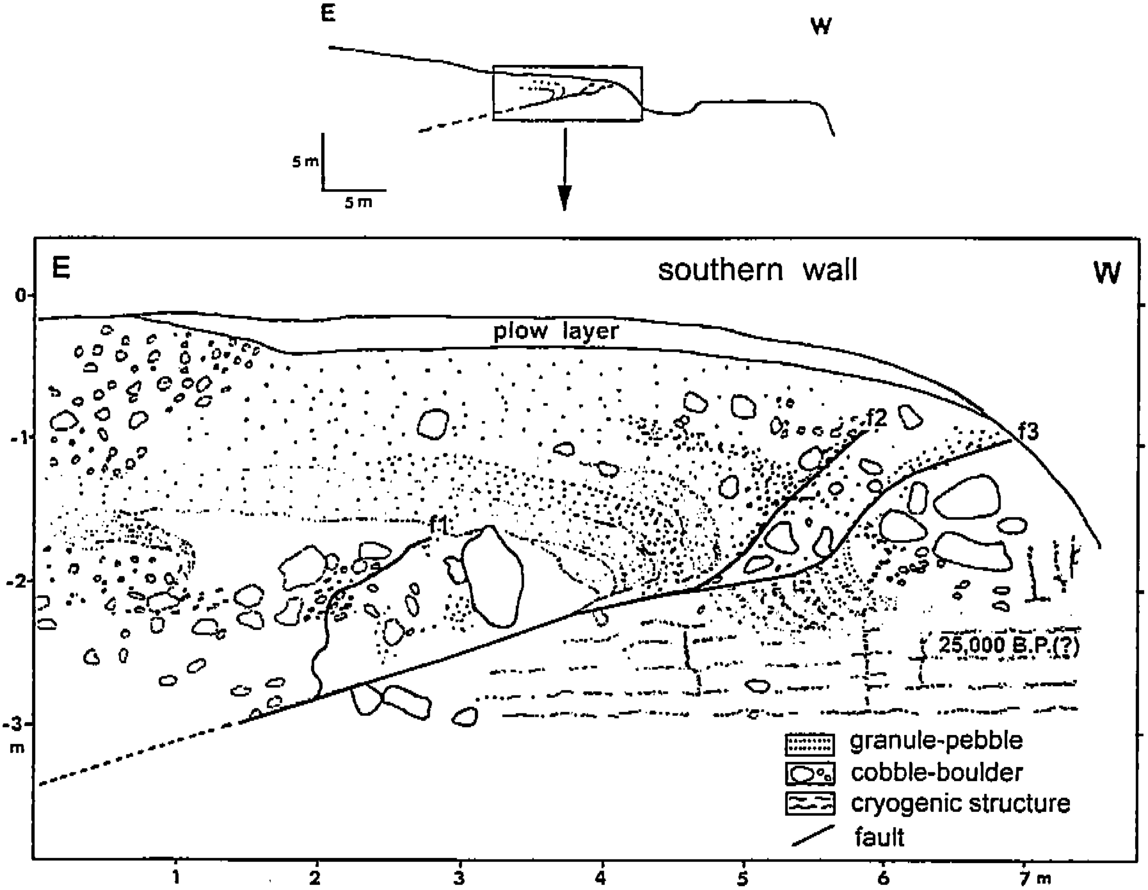

Fig. 6. Trench excavation and sketch of the southern wall across the low fault scarplet(Tr.1 of Fig.3).

The basement granite rock does not appear in the trench site. However, it seems that the granite may exist under the cobble-boulder layer of hangwall according to the informations offered from the outcrop of the same layer(Fig. 4). One fault line in the lower part of the trench site diverges into three faults on the upper part. The former fault(f1) within the cobble-boulder layer seems to be quite disturbed and show irregular line because of the later fault movement(f2, f3). On the foot wall of the fault, grayish white sand and reddish brown silt layer shows laminar and cryogenic structures in the lower part. The upper part was truncated by overthrust and delineates concave structure just below the fault(f3).

The facies of the foot wall deposits are characterized by the presence of the traces directly or indirectly related to a group of earth surface processes(millimetric laminar structure, vertical crack....). Such type of laminar structure in autochtone slope deposits frequently distribute in polar and sub-arctic regions. It is also found in a temperate zone whose paleoclimates in Quaternary glacial periods were quite colder than the present day. A consecutive investigations systhesizing the geographical field works and simulations with refrigerating system proved that the laminar structure can be developed by ice segregation in thin lenticular forms during the deep freezing period of soil(Oh, 1985; Oh, et al., 1987).

Cryogenic origin of the laminar structure is generally approved by geomorphologists and soil scientist who are interested in the earth surface processes of the cold and arctic region. The origin of the vertical cracks with decicentric interval, cutting laminar structure, is also proved cryogenic. The structures formed by cryogenic processes are conserved well unless they have been submitted to faulting, mass-movement or bio-pedological turbation(Oh, 1985; Oh, et al., 1987).

Another trench work was done at the southern part of Sagok reservoir(Tr.2). Here the fault was not found due to the limited dig. However, as shown in Fig.7, there exist several cryogenic structures accompanying vertical and horizontal graysh white sand and reddish brown silt layer with 1.5 m thickness. It seems that these structures were formed during the Late Würm under the cold climate environment.

In the Korean peninsula, cryogenic structures are observed in several slope deposits, as fossil form of the last cold period(Würm)(Oh, 1989, 1994, 1995). Carbon dating of the carbonated plant parcels in the laminar structure of the Kanweol area on the west coast shows 25060±250 B.P. or 23000 B.P.(Oh, et al., 1995). This data indicate that the age of its development do not go back to earlier than Late Würm in the Korean Peninsula.

The trace of overthrust obliquely cutting laminar structure in the study areas(Tr.1) is detected by discontinuity and disturbation of the cryogenic structure. Considering the results obtained from the cumulative researches on the cryogenic structures in the Korean peninsula, the associated overthrust faulting in our study areas can be dated back to Late Würm or Early Holocene. Therefore, at least two episodes of faulting have occurred since Late Würm along the Ulsan fault.

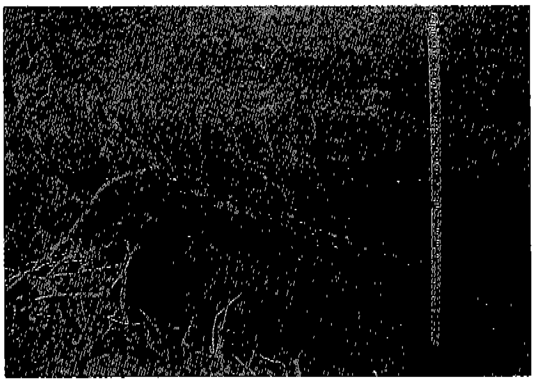

Fig. 7. Trench excavation at the southern site of Sagok reservoir(Tr.2). A lot of cryogenic structures are found in the wall of the trench site.

Conclusions

Great historical earthquakes condensely occurred in Kyongju-Ulsan areas. Geomorphologically, the Ulsan fault system represents a little curved trend with almost N-S strike in the southern part and diverge into three directions (NW-SE, N-S, NNE-SSW) in the northern part.

The dominant lineaments on the east side of Ulsan fault are NNE-SSW, NE-SW and N-S directions.

Trench study at Malbang-ri area shows that at least two events of faulting with thrust components might have occurred along the Ulsan fault since Late Würm(about 25000 B.P.). During the historical time the greatest earthquake(MMI X) in the Korean Peninsula occurred around Ulsan city in 1643. Even though some geological and geomorphological evidences related to the earthquake are not found at present, the earthquake may be related to the Ulsan fault. Ulsan fault may be an active fault which has moved several times since the late Quaternary. This study is the first attempt to explain the characteristics of active fault by paleoseismological viewpoint, and further studies are required in order to tackle the important problems about the active fault in the Korean Peninsula.

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