Comparison research on formation mechanism of frost crack and desiccation crack formed in the last glacial stage

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1. Introduction

Cracks are one of the causes disturbing Paleolithic horizon. Nevertheless, the formation mechanism of the cracks at Paleolithic sites is not clear. This research aims to clarify transitional characteristics of formation mechanism and the differences between frost cracks in high latitude area and desiccation cracks in middle latitude area.

2. Results of observation

In this research, I compared soil wedges in the Korean Peninsula, desiccation cracks in Honshu, and frost cracks in Hokkaido, all of that were formed in the last glacial stage. Observed spots are as follows: Donghodong at Daegu, Salle at Milyang, Shinsanri at Sangju, Joengjangri at Goechang, Dosan at Hwasun, Chongokni at Yoenchan, other archeological sites in the Korean Peninsular, Sarufutsu-mura, Bekkai-cho, Hokkaidaira at Mt. Daisetsu in Hokkaido, and Nagahara site in Osaka, central Honshu. In addition to observations at above spots, I observed microstructure of cracks with non-disturbed samples gathered at Shinsanri site and some others. Furthermore, I carried out grain analysis, volcanic ash analysis, rounded mineral analysis with samples from Joengjang, Dosan and Salle site.

According to French(1984) and others, typical ice wedges as periglacial phenomena are formed in continuous permafrost. When continuous permafrost thaws in warm climate, ice inside the permafrost melts. Part of materials from overlying active layer is depressed there and forms ice wedge casts. Ice wedge casts have upturned beds adjacent to casts. On the contrary, soil wedges are created because frost cracks, once opened in summer when the seasonal permafrost (frozen ground) melts, get buried in summer. Generally, they do not brake beyond the depth of the active layer. Soil wedges have down-turned

beds adjacent to wedges.

Frost crack casts cracks in Hokkaido

There are many crack casts in northern and eastern part of Hokkaido. The size of the largest crack I observed was 162cm in width at the crack brim, 10cm in width at 250cm deep from the brim, and continues even deeper. The crack filling has linear structure similar to foliation of common ice wedge and rip-up clasts from enclosing beds of the cast. The overlying bed is not well sorted and mostly estimated as the active layer. This crack appears in a large scale as an ice wedge cast, but has enclosing down-turned beds which are characteristic of soil wedge.

In other cases which I observed in Hokkaido, there are various scale and structure of the crack filling. Some of them have upturned beds and others have down-turned beds in enclosing materials. Some certain cracks has upturned enclosing beds with down-turned edges, other have small step faults which slipping down toward the center of the crack, and the others have blocked fillers. In addition, some of them, under the crack, have one or a few veins that filled with narrow mud film continue more than 150cm depth from the brim. Moreover, evidence of disturbed seasonal frozen ground layer as active layer is not recognized adjacent to lower part of cracks.

The formation age of these cracks at Sarufutsu-mura is estimated at after the Last Glacial Maximum, before 14,000 y.B.P. The ones at Bekkai-cho are estimated at later than 32,000 y.B.P. and earlier than 13,000 y.B.P.

Soil wedges in Korean Peninsula

Lee, D. (1978) describes that water movement had caused discoloration resulted in grey or yellowish grey of soil color of wedges, which formed soil wedges on the permafrost in cold climate.

There are four horizons of cracks at least at Shinsanri site, and two or three examples observed at other sites(Figure 1). Almost all cracks were narrow veins filled with thin clay film except brims at the opening. Around the enclosing zone of several centimeter width, however, iron oxide is leached out to light gray color in veins. Iron oxide deposit surrounds the light grey zone to make the narrow brown zone. Veins are emphasized with such coloration and giving impressions of being wide. It is caused by penetration of water transmitted through cracks. Moreover, there were some horizontal cracks in the upper part of enclosing beds.

In microstructure observation, width of cracks is less than 1 mm, and the narrowest less than 0.1 mm. When some of those seem to be wide are carefully observed, they actually consisted of more than several cracks piled up. It shows that cracks did not opened only one time, but repeated opening and closing many times. In addition, there are micro-slumping structures surrounding the brim, which is considered as evidence of cryoturbation. Upturned and/or down-turned structures in enclosing material, however, are not observed. The characteristics of horizontal cracks in the upper part of the enclosing beds, such as crack widths, piled up cracks and the colors, are the same as the vertical ones in microstructure.

Desiccation cracks in central Honshu

Desiccation cracks or sun cracks appeared from the layer above the Heianjingu volcanic ash layer (AT tephra ; ca.25000 y.B.P,, ca.28000 cal.B.P.) in the Uppermost Pleistocene. Their intervals are as narrow as up to 25cm and each width is also narrow. Mud curls are not observed. The color of filling materials from the upper limits up to 10cm below is light gray, and the lower part in dark gray. It is supposed that iron oxide and humic acid transmitted from the upper part of cracks to the lower part leading the cracks. In microstructure observation of the lower part of cracks, similar characteristics with the cases of Korean Peninsular are recognized, such as very narrow width, changes of color by penetration of water, piled up cracks and slumping like structure of cryoturbation. Furthermore, horizontal cracks are remarkable in the enclosing beds, which are compounded the same as vertical cracks. Most of the vertical cracks are younger than horizontal ones.

3. Discussion

Frost cracks in Hokkaido as above mentioned show both elements of soil wedge and ice wedge cast. I suggest that upturning and down-turning of the enclosing cracks are influenced by thawing duration and lithofacies of the enclosing beds. The down-turned beds of the largest one are thought that the fine sand forming the enclosing beds became saturated with melting water and could not support the crack wall, which let the beds gradually down-turn toward the inner crack. Therefore, these cracks can be defined as frost cracks which resembled ice wedge casts, even if they are not exactly the same.

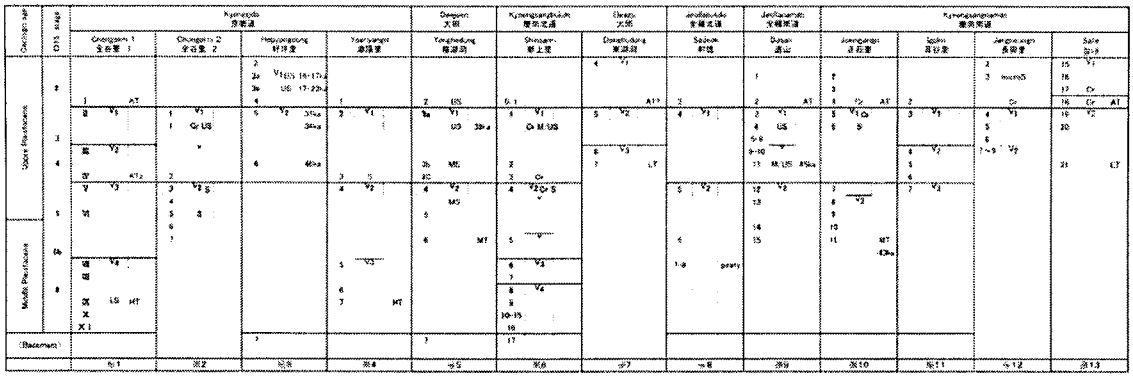

Figure1 Tentative plan of correlation to Korean Pleistocene with cracks

Dark gray zones show dark color zones of beds, light gray netlike zones show gravel beds. The left column of each site shows the stratigraphy of the site. The center columns show horizons of large and/or clear cracks(V) with crack number, small and/or unclear cracks(v), cryoturbation or disturbance of similar cryoturbation(Cr), stone tools(S) and their time; Upper Paleolithic(U), Middle P.(M), Lower P.(L), microlith(micro). The right columns show volcanic ash horizones: Aira-Tn(AT); Kikai-Tazurahara(KTz), terrace horizon: high terrace(HT); middle terrace(MT); low terrace(LT), and radiocarbon age.

※1; after Bae, K, Hong, M et.al. (2001). 2: Excavated 2004 by Seoul National University and the data by the author. 3; after Gijeon Institute of Cultural Properties (2004). 4; Excavated 2004 by Gijeon Instirute of Cultural Properties and the data by the author. 5; Data from Jungang Museum of Hanam University (2001) with additions by the author. 6; Excavated 2001, 2003 by Kyeongsangbuk-do Research Institute for Cultural Assets and the data by the author. 7; Excavated by Yongnam Institute of Cultural Properties and the data by the author. 8; Excavated 2003-2005 by Honam Cultural Property Research Center and the data by the author, 9; after Lee, G.(2002) with additions by the author. 10; Data from Kyeongnam Development Institute Center of History and Culture(2002) and Kim, J(2006) with additions by the author. 11; Excavated 2004 by Foundation of East Asia Cultural Institute and the data by the author, 12; Excavated 2001 by Pusan National University Museum and the data by the author. 13: after Cho, C.(2002)

On one hand, cracks called soil wedges in Korean Peninsular do not show the characteristics what French (1984) points out as those of soil wedges. On the other hand, many characteristics of the soil wedges in Korea Peninsular, such as narrow cracks, piled up cracks, existences of horizontal cracks, no deformation of the enclosing beds, color changes of the filler, and others are similar to those of so called desiccation cracks in central Honshu. Therefore, soil wedges in Korean Peninsular and desiccation cracks in central Honshu formed similar formation mechanism.

4. Further problems

Cracks in the Korean Peninsula and central Honshu show similar form, and both of them are thought as a kind of frost cracks formed in a cold climate. The structure of these cracks, however, is not the same as that of frost cracks with active layer in Hokkaido. Generally speaking, frost cracks are formed by thermal shrink and aridity, and the thermal shrink of sediments is the major cause of ice wedges. Therefore, cracks in Korea Peninsular and central Honshu leave the possibility to be defined as frost cracks of non-periglacial phenomena mainly formed by aridity, but not being the so-called desiccation cracks. This is a problem to be examined.

It is estimated that horizontal cracks, so as vertical cracks, are formed by aridity and the cause of formation could be the sedimentary structure. Cracks in both directions may have repeated opening and closing every year. Water transmitted through and invaded cracks along with clay when it is open, which caused the color change by leaching and deposition of iron oxygen and humic acid.

Crack formation mechanisms in both areas are similar. Nevertheless, it is thought that the difference of formation system originates from the difference between the causes of influence, high continental influence in Korean Peninsular and high marine influence in central Honshu. Figure1 shows the tentative plan of correlation to beds in Korean archaeological sites based on topography, characteristic lithofacies of dark zone and reddish brown zone, contents of volcanic glass and rounded quartz, radio carbon dating and so on (detailed explanation orally). Cracks in Korean Peninsular, wider and longer than those of central Honshu, had been formed with cryoturbation at the oxygen-isotopic stage (OIS) 2. The remarkable cracks may have not been formed in central Honshu at OIS 4 due to much rain or snow. So-called soil wedges in Korean Peninsular are estimated to have formed at the dry seasons or snow covering ground season of lower level of underground water. The cracks may have been affected by water infiltration in the rainy season or the snow thawing season. Theses correlation and formation mechanism has to be examed further.

References

Bea, K., Hong, M. et al.(2001) *The Chongok Pleolithic Site, report of test-pits excavation, 2000-2001.* 298ps.

Cho, C.(2002) The strata at Salle and Keumcheonri sites and their results of

physics and chemistry analysis. *Comparison study on the initial farming in Korea and Japan.* 223-245.

French, H.M.(1976) *Periglacial Environment.* Longman, London

Gijeon Institute of Cultural Properties(2004) Hopyongdong Paleolithic site in Namyangju; The guidance material of the 3rd excavation. 33ps.

Jungang Museum of Hanam University(2001) The material of the field briefing session of the Paleolithic site (Yunghodong) 3rd excavation in Teajeon Seokbong water purification plant construction project area. 14ps.

Kim, J.(2006) Environment of fluvial sedimentary deposits and palynological occurrence in the Geochang area. *The Korean Journal of Quaternary Research,* 20, 1, 39-50.

Kyeongnam Development Institute Center of History and Culture(2002) The excavation of Jeongjangri site, cultural site, Keochang; The material of the field briefing session. 23ps.

Lee, D. (1987) Stratigraphical Research of the Quaternary Deposits in the Korean Peninsula. *Korean Quaternary Research*, 3−20.

Lee, G.(2002)*Hwasun Dosan Palaeolithic Site.* 124ps.