Fossil Cryogenic Structures in the Terrace Deposit of the Oship River, Samchok, Korea

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In the deposits of the tributary terrace of Kosa-ri area, there appear fossil cryogenic structures (platy structures and silt caps) formed under periglacial environments during the late glacial period. The characteristics of terrace sediments and the stratigraphy with respect to the main-stream terrace show that the tributary terrace was also formed during the last glacial period. The fossil periglacial cryogenic structure seems to serve as a valuable index for terrace dating in Korea, where materials for the dating of river terraces are scarce.

The Distribution of Cryophilous Flora and Past Environment in the Korean Peninsula

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Most of the artic-alpine and alpine plants in East Asia are thought to have evolved from a montane flora originally established in the high mountains of central Asia (and in some cases, further afield) since the Miocene, but mainly during the Pleistocene. These plants repeatedly advanced downslope and southward as the climate deteriorated, notably during the Pleistocene, but retreated back upslope and northward during the alternate phases of climatic amelioration. The absence of major topographic barriers, and of extensive glaciation, coupled with the presence of a north-south orientation in the mountain ranges of both East Asia and Korea, facilitated the dispersal of arctic-alphine and alpine plants southward from the circumpolar area, possibly through the Maritime Territory of the USSR, and especially along the Sikhote-Alin Mountain Range, consequently giving rise to the rich arctic-alphine and alpine flora in Korea. This migration was also aided by the lowering of sea-level during the glacial phases of the Pleistocene, especially in respect of the areas now covered by the West Sea (Yellow Sea), and the Korean Straits between Korea and Japan.

Further, in repect of the processes of arctic-alpine and alpine species migration in the past, the Korean peninsula seems to have served as one of the major refugia for these species during both the glacial and interglacial periods, because of its easy access to the circumpolar area of East Asia, and the availability of its diverse environments and habitats ranging from coastal

lowlands to alpine zones, which encouraged their survival. The cold-phase pleistocene climates in the alpine zones of Korea seem generally to have been too cold and harsh for arctic-alpine and alpine plants to survive at high altitudes. Those plants, therefore, had to confine themselves to lower montane and/or lowland areas during these phases, possibly including coastal areas. It is likely that the lowlands of the Korean peninsula, possibly including the coastal lowlands, accordingly effectively became *primary* refugia for many of these species during the cold phases of the Pleistocene. Then, as the climate subsequently ameliorated, arctic-alpine and alpine plants moved upslope on to the mountain tops and northwards, and the range of thermophilous temperate and warm temperate plants was then expanded in the wake of this movement, to cover large areas of lowland and the lower mountains. The mountain tops of the Korean peninsula accordingly then proved to be important *secondary* refugia, certainly in the post-Devensian period. The present occurrence of six arctic-alphine species, in the alpine and subalpine zones of Korea, at the world's southernmost limit of their distribution (*e.g. Ledum palustre* var. *diversipilosum, L. palustre* subsp. *decumbens, Phyllodoce caerulea, Diapensia lapponica* subsp. *obovata* and *Empetrum nigraum* var. *japonicum*), and of another six species at the southernmost limit of their range in the East Asian continent (*e.g. Chamaedaphne calyculata, Dryas octopetals* var. *asiatica, Oxycoccus microcarpus, O. quadripetalus, Vaccinium vitisidaea* var. *minus* and *Linnaea borealis*) further promotes the idea of the existence of refugia for these species in particular in the Korean peninsula, both in the Pleistocene glacial phases and during the postglacial period.

At present, the estimated number of Korean arctic-alpine and alpine species is 419, and this includes 75 arctic-alpine species (*i.e.* 17 arboreal and 58 herbaceous spp.), 239 alpine species (*i.e.* 108 arboreal and 131 herbaceous spp.) and 105 Korean endemic alpine species (*i.e.* 58 arboreal and 47 herbaceous spp.). The occurrence of such a large number of arctic-alpine, alpine and endemic alpine species, which *in toto* form up to 10% of the total Korean flora, can be explained by the following reasons. First, there have been no catastrophic environmental events in the Korean peninsula during the Pleistocene such as the presence of a major glaciation, and consequently a long history of the flora is assured. Secondly, the unique geographic setting (a north-south linkage of mountain ranges both in East Asia nd Korea) has enabled smooth migrations of arctic-alpine and alpine plants from north to south to take place, with the onset of the Pleistocene cold phases. Thirdly, the existence of *c.* 79 high mountains (over 2,000m a.s.l. in height) in northern Korea, and of *c.* 264 high mountains of 1,500m to 2,000m a.s.l. in height, mainly in the north, but also in central and southern Korea, has ensured that isolated areas have been available for these species to colonise during interglacials, and the post-Devensian warming. Finally, the different climatic regimes present in the Korean peninsula today, particularly the predominantly continental one in the north, an intermediate one in the midlands, and a slightly oceanic one in the south and Cheju Island, have created a range of diverse climatic habitats in general and local environments in particular, which has encouraged the long-term survival of many of these species at all altitudes.

All the above situations (the frequent floristic movements between circumpolar East Asia and the Korean peninsula during the Pleistocene glacial phases, the existence of peninsular glacial refugia, the presence of easy access between mountains in the north and the availability of diverse habitats and environments for alpine flora, particularly in the north and the midlands of Korea) have resulted in arctic-alpine and alpine plants being dominant in the north and midlands of Korea, albeit on a disjunctive distributional basis. Thus, *c.* 71.7% of the total number

of arboreal arctic-alpine and alpine plants, *c.* 74.9% of the total number of herbaceous arctic-alpine and alpine plants and *c.* 61.7% of the totla number of endemic alpine plants are presen tin these two regions. The particular larger-scale disjunctive distribution of three arctic-alpine plants, *i.e. Diapensia lapponica* subsp. *obovata* between East Asia and Cheju Island, and *Empetrum nigraum* var. *japonicum* and *Luzula rufescens* between northern Korea and Cheju Island, further implies the possibility of a previous land connection between the mainland of Korea and Cheju Island during at least some of the cold phases of the Pleistocene glaciation. Taken as a whole, the disjunctive distributions of arctic-alpine and alpine plants in Korea is likely to be due to first, the downslope and southward expansion of these species towards the Korean peninsula from the arctic region as the Pleistocene glacial phases approached, and then their subsequent isolation upslope in mountain areas as the post-Devensian climatic amelioration followed; secondly, the expansion of forest tree communities on lowland and montane areas subsequent to the end of the Pleistocene has had the effect of dividing formerly continuous arctic-alpine and alpine plants into disjunctive areas on high mountains; and thirdly, the general disappearance or restriction of available habitats for arctic-alpine and alpine plants because of the post-Devensian climatic amelioration.

Depositional Environment and Genesis of Terrace Gravels in Reference to Gravel Shape and Base Level

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The present Naengcheon fluviatile gravels can be separated from the present Yangnam and Umok-dong beach gravels on the basis of bivariant diagram between mean roundness and mean Maximum Projection Sphericity (MPS), both of which are independent variables. The fluviatile gravels have consistently higher mean MPS and lower mean roundness than beach gravels. The terrace gravels in the Pohang Area were plotted on the MPS-roundness diagram. The result shows that terrace gravels derived from the Naengcheon valley are of fluvial environment, whereas those derived from Umok-dong and Yangnam coasts represent beach environment.

The Quaternary terrace gravels were formed by a cyclic fluctuation of the Quaternary base levels which had been progressively lowered down since the Neogene time. The fluviatile terrace gravels generated by the morphoclimatic valley degradation and subsequent valley aggradation, while the marine terrace gravels were formed by the standstill or progradation of the Quaternary paleoshoreline in response to the repetitive marine transgressions.