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The Alpine and Subalpine Geoecology of the Korean Peninsula

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韓半島의 高山과 亞高山의 地生態

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ABSTRACT

The geoecology of the alpine and subalpine belts of the Korean Peninsula, its component plant group, its environmental history, and climatic amplitudes of the arctic-alpine and alpine plants has reviewed and discussed.

The present-day alpine and subalpine landscapes are likely to have been formed during the post-glacial warming phase. The disjunctive distribution of many alpine and subalpine plants, however, suggests a former continuous distribution of these both locally and on a broader scale, their range extension downslopes and southwards during the Pleiostocene glacial phases, and the subsequent breakdown of a former continuous range into fragments as the climate ameliorated during the post-glacial warming phase. The presences of numerous arctic-alpine and alpine plants on the alpine and subalpine belts of the Korean Peninsula, are mainly due to their relative degree of sensitivity to high summer temperatures. The continued survivals of alpine species and landscape in Korea is in danger if global warming associated the greenhouse effect takes place.

Key words: Geoecology, Alpine and subalpine, Landscape, Environmental history, Climatic amplitudes.

INTRODUCTION

Despite the presence of a diverse and unique flora and vegetation in Korea, not very much is known about species composition, structure and species distributional patterns within it. Even less is known about these features for the alpine and subalpine belts of the Korean Peninsula.

In order to remedy this, and so as to meet the growing need for the investigation of the geoecology of the alpine and subalpine belts of the Korean Peninsula, its component plant group and the biogeographic interpretation of these elements, its environmental history of the cryophilous plants in Korea from the Carboniferous period of the Palaeozoic Era to the present-day, and climatic amplitudes of the arctic-alpine and alpine plants in connection with the sensitivity to high summer temperatures both on Mts. Sorak and Halla, the author have made these main themes of the present work.

Data sources for the designation of the alpine and subalpine belts have been collated from the previously published Korean floristic literatures, along with data on the worldwide distribution of arctic-alpine plants and also my own fieldwork data at Mts. Sorak and

Halla. For the reconstruction of past vegetational patterns, numerous macro- and micro-fossils of flora have been collected. Climatic data have been collated and compared with the horizontal and vertical distributional ranges of species.

THE DESIGNATION OF THE ALPINE AND SUBALPINE BELTS

On the basis of 204 evergreen plants from 146 sites, eight biogeographic regions of the Korean Peninsula (Kong, 1989), including the Northern Alpine Region and the North-South Subalpine Region were established. On the Northern Alpine Region and the North-South Subalpine Region, the arctic-alpine and alpine plants are found mainly in regions dominated by higher altitudes. Diverse life-form, such as shrubs dwarf shrubs, small shrubs and dwarf small shrubs, are predominant in the alpine and subalpine belts. Tree forms are rare in the Northern Alpine Region. Bamboos begin to appear in inland areas from the North-South Subalpine Region. Highly adaptive leaf trichome forms are found in the Northern Alpine Region due to the occurrence of arctic-alpine plants. The high proportion of revolute leaves in the Northern Alpine Region and the North-South Subalpine Region also relates to the existence of arctic-alpine plants. Arctic-alpine and alpine plants are dominant group in the north, but are confined to high altitudes in the south.

THE PALAEOECOLOGY OF THE ALPINE AND SUBALPINE BELTS

The examination of fossil evidences (Kong, 1991, 1992, 1994, 1995, 1996, 1997) indicates that *Pinus* date back to the Cretaceous period of the Mesozoic Era. Most of conifers such as *Juniperus, Picea, Abies, Larix, Taxus, Cephalotaxus, Tsuga* have been present from the Miocene period of the Cenozoic Era and *Thuja* date back to the Middle Pleistocene, and *Pinus pumila, P. sibirica* and *P. koraiensis* to the Upper Pleistocene. In the case of Korean dicotyledons, genera which often occur at present on the high mountains have been reported from the Cretaceous period of the Mesozoic Era *e.g., Salix, Acer* and so on during the Oligocene period of the Cenozoic Era, *Carpinus, Quercus, Betula, Rhododendron, Sorbus* during the Miocene period of the Cenozoic Era.

On the basis of present-day latitudinal distribution of arctic-alpine plants in Korea, their altitudinal ranges, the fossil evidence, the distributional patterns of circumpolar plants, and using all the evidence, the pattern of migration of arctic-alpine plants into the Korean peninsula have reconstructed(Fig. 1).

As the climated deteriorated during the Pleistocene cold phases, most of temperate trees would have shifted downward from the mountains and southward from the north. At the same time, cryophilous arctic-alpine and alpine plants moved downward and southward as well. During the Pleistocene cold phase, it is likely that the climate in high alpine belts of Korea was too cold and harsh for many arctic-alpine and alpine plants to survive. Therefore, arctic-alpine and alpine plants had to confine themselves to lower mountain and/or lowland areas, which effectively then became their primary refugia. Then, as the climate subsequently ameliorated, arctic-alpine and alpine plants moved back upslope to the mountain tops which proved to be important secondary refugia within the peninsula.

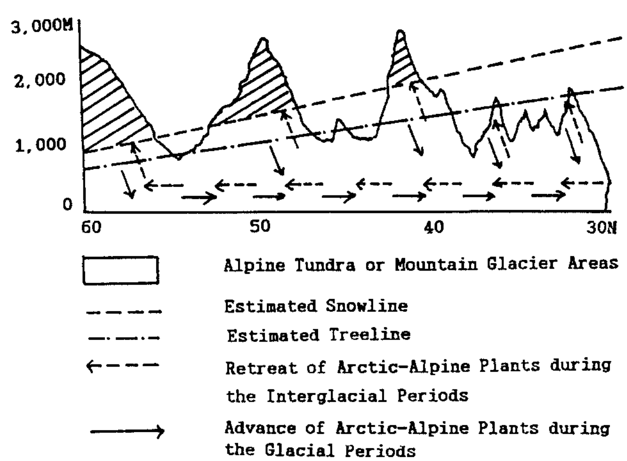

Fig. 1. Schematic diagram for the migration of arctic-alpine plants into the Korean Peninsula.

However, as the climates ameliorated during the post-glacial period, the temperate species both lowlands and mountain lands then became more common than arctic-alpine and alpine plants. As a result of the increased competition associated with this process, cryophilous retreated upward towards mountain tops, and the fragmentation of the arctic-alpine and alpine plant's distributional range took place in the Korean Peninsula. At present, therefore, arctic-alpine and alpine plants are mainly confined to the alpine and subalpine belts of mountains in Korea, along with specific-habitat-adapted species which grow below the alpine belt.

THE PHYTOGEOGRAPHY OF ALPINE AND SUBALPINE BELTS

The occurrence of a large number of arctic-alpine and alpine plants (*ca.* 367 spp.), which form up to 10% of the total Korean flora may due to first; the absence of catastrophic environmental events; secondly, the north-south linkage of mountain ranges in the peninsula which has enabled smooth migrations of the arctic-alpine and alpine plants from north to south to take place, with the onset of the Pleistocene cold phases; thirdly, the existence of large number of alpine, subalpine and montane areas, mainly in the north, but also in central and southern Korea which ensured that isolated spaces were available for these species to colonise during the Holocene period; and finally, the different climatic regimes present in the peninsula today, which has encouraged the long-term survival of these species at alpine and subalpine belts in recent times.

The occurrence of large numbers of arctic-alpine plants in the Korean Peninsula may be due to the following reasons. First, their arrival has been encouraged by frequent floristic exchanges with the Arctic regions of East Asia during the Pleistocene glaciations; secondly, many parts of Korea have served as primary lowland refugia for them during the Pleistocene glacial phases; and thirdly, during the post-Pleistocene warming, they have subsequently moved upslope to their present habitats in Korea's alpine areas. The appearance of the Korean alpine and endemic alpine species no doubt reflects the long-term isolation of species in the peninsula, and the local environmental peculiarities which have both accentuated this isolation and aided the development of genetic diversity (Kong, 1989).

Within the Korean Peninsula, seven major distributional patterns can be found from the arctic-alpine and alpine plants (Kong, 1989), *viz.*, species which present throughout the peninsula, species present from the north to the midlands, species occurring both in the north and in Cheju Island, but not in between, endemic species which present in the south and Cheju Island, species which are restricted solely to the north, species which are restricted to the midlands and species which is restricted to the Cheju Island.

In respect of the vertical distributional range relating to the means of the lower limits for the arctic-alpine and alpine plants for which data are available, four distinct divisions may be delineated, *viz.*, the altitudes of *c.* 500m to *c.* 1,000m a.s.l. which are dominated mainly by coniferous trees, at *c.* 1,000m a.s.l. in which endemic coniferous trees grow, from *c.* 1,000m to *c.* 1,500m a.s.l. in which coniferous and broadleaved trees mixed and from *c.* 1,500m to *c.* 1,800m a.s.l. and above, where communities are dominated by the evergreen broadleaved trees. The presence of arctic-alpine and alpine evergreen broadleaved trees at *c.* 1,500m to *c.* 1,800m a.s.l. or above, in which low summer temperatures and very cold winter temperatures prevail, is no doubt due to their physiognomic and ecophysiological adaptations against cold environments. Below the alpine belts, or in the south, where high summer temperatures prevail, these adaptions are disadvantageous to the survival of arctic-alpine and alpine evergreen broadleaved trees.

THE GEOECOLOGY OF THE SUBALPINE BELTS OF MT. SORAK

On Mt. Sorak, the leeward eastern slopes near to Taechongbong (1,708 m a.s.l.) are occupied mainly by

Betula ermanii var. *genuina*, and show no clear tree-line. However, the windward western slopes of Taechongbong, and the areas along the saddle between Taechongbong and Chungchongbong (1,676 m a.s.l.), both do display a local tree-line at *c.* 1,550 m a.s.l., comprised mainly of *Abies nephrolepis* and a few species, such as *Rhododendron* spp., *Quercus mongolica, Betula ermanii* var. *genuina* and so on; areas above the tree-line are dominated by *Pinus pumila*. The climatic tree-line, beyond which arboreal trees are generally unable to develop an erect tree form mainly as a result of prevailing climatic conditions, occurs at *c.* 1,700 m a.s.l., though a further local tree-line occurs at Chungchongbong at *c.* 1,650 m a.s.l. on the windward western slope of Taechongbong. The additional 100 m lowering of the local tree-line on the exposed col between Taechongbong and Chungchongbong down to *c.* 1,550 m a.s.l. is caused by the effects of strong winds on physical and physiological structures of trees at the col, and the damage which results from this.

The high-ground near to the summit of Taechongbong, and the saddle between Taechongbong and Chungchongbong in which snow is largely blown clear during the winter months, and this doubly emphasizes its coldness and aridity both winter and spring. Under these conditions, *Abies nephrolepis* krummholz there gives way to krummholz dominated by *Pinus pumila*. On the windward slopes, *Pinus pumila* shows distinctive morphological adaptation against freezing and desiccation. It tends to form a creeping trunk near to the ground surface, and only rarely exceeds a height of more than 5 cm above ground level. It has a compact crown, and a dense thicket of twigs and leaves, which together seem to contain the available heat, and to avoid excessive evapotranspiraton (Troll 1972, Holtmeier 1973, Ives 1978, 1980, Tranquillini 1979) and also, the presence of adventitious roots increases the chance of successful vegetative regeneration of the species in this harsh, short-growing-season environment. However, only a small additional rise in temperature may be sufficient to render *Pinus pumila* no longer viable in this locality (Kong & Watts, 1992). *Pinus pumila* and its habitat and subalpine landscape on Mt. Sorak are also endanger from excessive human trampling damage (Hugget 1995).

CONCLUSION

The present-day alpine and subalpine belts as well as relevant arctic-alpine and alpine plants and landscapes are likely to have been formed during the post-glacial warming phase. The existence of a north-south orientation of mountain ranges, and of scatted numerous mountains within the Korean Peninsula, along with the presence of different climatic regimes, enabling many arctic-alpine and alpine plant species to survive in the alpine and subalpine belts in both primary and secondary refugia during the both the glacial and interglacial phases, respectively.

The present occurrence of several arctic-alpine species, in the alpine and subalpine belts of Korea, at the world's southernmost limit of their distribution, and of another species at the southernmost limit of their range in East Asia further promotes the idea of the existence of refugia for these species in the Korean Peninsula. The presences of numerous arctic-alpine and alpine plants on the alpine and subalpine belts, mainly in the north, but also in the midlands, the south and Cheju Island are mainly due to their relative degree of sensitivity to high summer temperatures.

The disjunctive distribution of many alpine and subalpine plants, including *Diapensia lapponica* subsp. *obovata, Empetrum nigrum* var. *japonicum, et al* on the top of Mt. Halla, Cheju Island (Kong, 1998) as well as *Pinus pumila,* on the summit of Mt. Sorak, suggests a former continuous distribution of these both locally and on a broader scale, their range extension downslope and southwards during the Pleiostocene glacial phases, and the subsequent breakdown of a former continuous range into fragments as the climate ameliorated during the post-glacial warming phase. The continued survivals of these species and landscape in Korea is in danger if global warming associated the greenhouse effect takes place.

적 요

한반도 고산대와 아고산대의 지생태를 생물지리구별 식물종 구성, 환경변천사, 극지고산식물과 고산식물의 기온적 범위 등을 종합적으로 고려하여 분석, 재검토하였다. 현재의 고산과 아고산경관은 후빙기에 들어 형성된 것으로 판단되며, 오늘날 고산과 아고산지역의 산정을 중심으로 격리 분포하는 고산식물은 플라이스토세 빙기 중에는 산지를 중심으로 연속적으로 분포했던 것들의 후손으로 사료된다. 그러나 후빙기에 들어서 기온이 상승하면서 평야나 낮은 산지를 난대성 혹은 온대성 식물들이 차지하면서 고산식물의 연속적인 분포역이 차단되었고 현재에는 산정을 중심으로 고산과 아고산 식생 경관이 고립되어 출현하는 것으로 본다. 최근에 지구적인 현안으로 등장한 기온온난화가 계속될 경우 한반도의 고산지 식물과 경관은 위기에 처할 것으로 판단되어 이에 대한 연구가 시급하다.

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