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东北全新世乔木种类演化的区域差异及其迁移问题

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提 要

根据花粉等时线图和代表性剖面花粉资料, 总结了东北全新世主要乔木种类出现和发展的地区差异。三江平原和小兴安岭地区的栎属与松属的出现和发展分别比长白山地区推迟 1—2 千多年。这个时间上的差别说明它们可能有从南向北的迁移过程。不同乔木种类迁移的速率也不一样。初步估计的几种乔木迁移速率为: 栎属 250—590 m/a, 松属 150—580 m/a, 胡桃属 200—810 m/a。这种差异可能主要与种子大小、河流和地形等因素有联系。

关键词 森林演化 物种迁移 全球变暖 全新世 中国东北

REGIONAL DIFFERENCE IN HOLOCENE VEGETATIONAL CHANGE AND THE POSSIBLE MIGRATION OF MAJOR TREES IN NE CHINA

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Abstract

Regional difference in forest changes over Northeast China is investigated using the previously completed pollen isochrone maps and the data from a few representative profiles. During the Holocene, *Quercus* and *Pinus* seem to have appeared in the Xiao Hinggan Ling Range and the Sanjiang Pingyuan 1 000-to-2 000 years later than in the Changbai Shan. Little difference in the appearance times of *Ulmus* is found at the representative sites between north and south. It is therefore plausible that *Quercus* and *Pinus* may have experienced south-to-north

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migration after climate became warmer and more suitable for their growth. Estimated migration rates are 250- 590 m/a for *Quercus*, 150- 580 m/a for *Pinus*, and 200- 810 m/a for *Juglans*. The difference of the migration rates between the taxa may depend on such factors as the size and weight of seeds, distance of the profile sites from major rivers and specific topographical feature.

Key words forest evolution, migration of species, global warming, Holocene, China

1. Introduction

Great progress has been made in the studies of the Holocene palynology for Northeast China (Chen et al., 1977; Liu, 1988; Liu, 1989; Ren & Zhang, 1997; Ren & Zhang, 1998; Sun & Chen, 1991; Sun & Yuan, 1990; Xia et al., 1993; Xia, 1996). These studies, however, were mostly conducted on the basis of single sites, and the inter-site variation of the Holocene vegetational evolution has been scarcely exploited based on reliable radiocarbon dates. Pollen maps for the specific time slices show temporal and spatial change patterns of the Holocene vegetation over Northeast China (Ren, 1994; Ren & Zhang, 1998), and could provide a potential means for understanding the past vegetation dynamics (Webb, 1988; Huntley, 1990).

Pollen isochrone maps in a previous research (Ren, 1994), in combination with representative site pollen series, are used here to distinguish the regional difference in Holocene changes of major pollen taxa over Northeast China. Furthermore, the question of possible species' migration during the last ten thousand years is raised, and implication of the issue for global change is discussed.

2 Regional difference of changes in trees' abundance

A mapped summary of Holocene pollen data was made for Northeast China (Ren, 1994; Ren & Zhang, 1998). For that research work, a data set of 65 sites was used, and standardization was made to guarantee the inter-site comparability through recalculating the pollen percentages based on an united sum (Ren & Zhang, 1998). Isopolls were drawn for nine taxa and seven time levels, the isochrones were made for the nine taxa accordingly.

Marked difference in changes of the taxa, including total arboreal pollen (AP) can be seen in the region (Fig. 1). This difference indicates the diverged evolutionary paths of the species in the last ten thousand years. The most obvious divergence is found between south and north (also refer to Ren and Zhang, 1998). It is therefore reasonable to classify the whole region into three sub-regions from north to south.

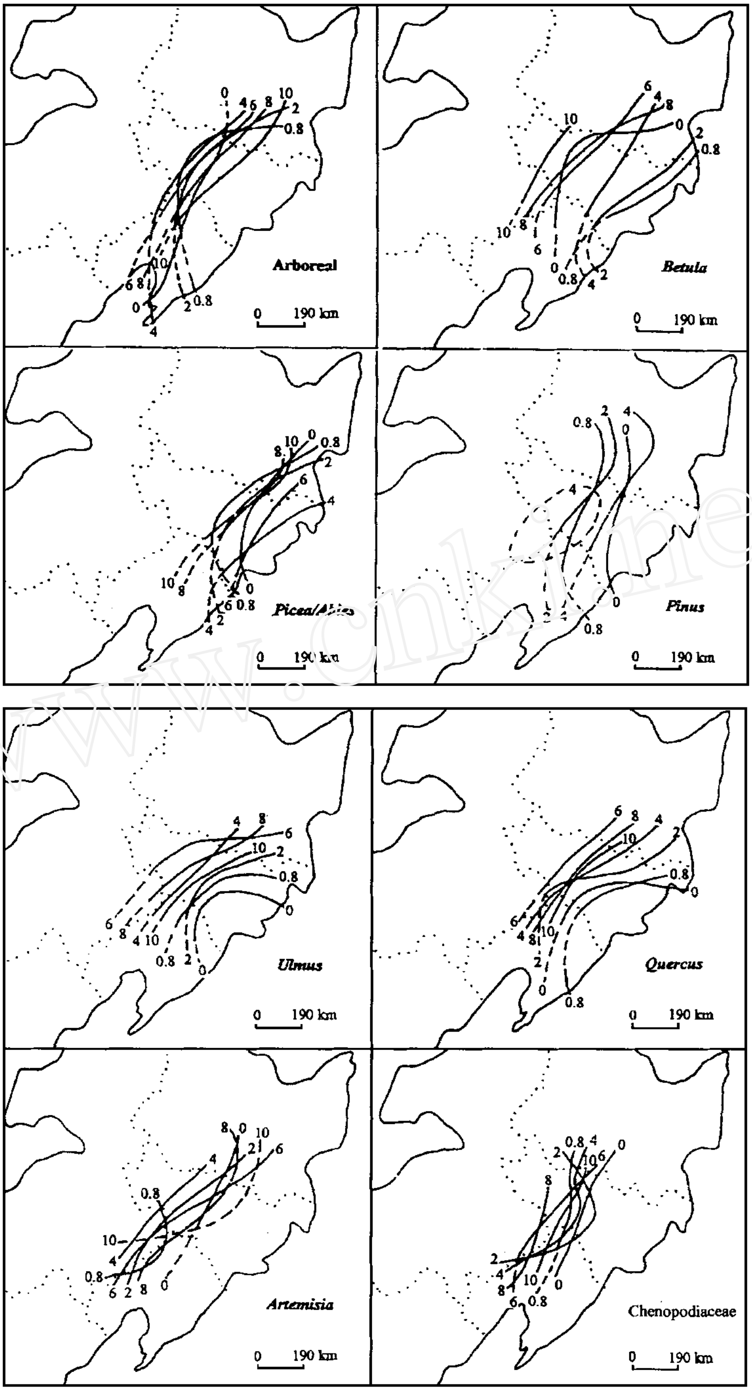

Fig. 1 Pollen isochrones of selected taxa for Northeast China. Specific isopolls were chosen to draw the isochrones. They are respectively 40 for Arboreal pollen, 30 for *Artemisia*, 20 for *Pinus*, 10 for *Betula*, and 5 for *Picea/Abies*, *Ulmus*, *Quercus* and Chenopodiaceae. The values represent radiocarbon ages in ka BP.

2.1 *Northern sub-region*

The sub-region consists of the Sanjiang Pingyuan and the Xiao Hinggan Ling Range. AP percentages remain relatively low from 10 ka BP to 6 ka BP, and keep increasing since 6 ka BP. The last 1 000 years witness the highest AP percentages for the Holocene period. *Betula* percentages are at very high level in the early Holocene throughout Northeast China, and decrease from the early Holocene to about 1 ka BP in the Sanjiang Pingyuan and the south. Increase in *Betula* percentages in the last 1 000 years over the northern and middle sub-regions may have been mainly caused by human interference. *Abies/Picea* percentages are low from 10 ka BP to 6 ka BP, and they increase generally since 4 ka BP. Change in *Pinus* percentages is very similar to that of *Abies/Picea*, with the most abundant population occurring at present.

In deciduous trees, *Ulmus* percentages reach the highest level between 8 ka BP and 6 ka BP, but it may exist early at 12 ka BP on the Sanjiang Pingyuan. The peak value of *Quercus* comes a little later, mostly from 6 ka BP to 4 ka BP.

2.2 *Middle sub-region*

Middle sub-region includes the Changbai Shan and the Songliao Plain. The AP percentages increase from 10 ka BP to 6 ka BP, and remain unchanged or slightly decrease since 4 ka BP. Changes in *Betula* and *Abies/Picea* percentages are similar to those in the northern sub-region. *Pinus* percentages also increase remarkably after 6 ka BP, but the highest value occurs about 1 ka BP rather than at present as in the northern sub-region. The time of the maximum for *Quercus* percentages is at about 6 ka BP, significantly earlier than in the north.

2.3 *Southern sub-region*

This sub-region is mainly composed of the Liaodong Peninsula. Before 6 ka BP, changes in AP percentages are parallel with that of the middle sub-region. Since 6 or 4 ka BP, however, AP percentages experience tremendous drop, though they obtain a rise once more at present. Change in *Pinus* percentages is characterized by a low value in the early Holocene and an obvious increase after 4 ka BP. Maximum of *Quercus* percentages occurred at 6 ka BP, and the afterward decrease in *Quercus* percentages is rather rapid. The decrease makes a large contribution to the late Holocene drop in the AP percentages

3 Issue of possible trees' migration

From the analyses of the data mapping, it is clear that the changing histories for *Quercus* and *Pinus* vary among the sub-regions. It seems that the changes usually start in the southern sub-region, and propagate toward north. As shown in previous studies, decrease in AP percentages after 6 or 5 ka BP in Northeast China may have been induced by human activities (Ren, 1994; Ren, 1999). The time difference in the initial decrease of the AP percentages could be explained by the northward spread of the early farmers (Ren, 1999). However, human interference with vegetation could not account for the difference of changes in trees' percentages in the first half of Holocene period. It may have been related to species' migration after the amelioration of climate.

In order to further investigate this problem, four pollen profiles are chosen and correlated. They come from Gushantun (Liu, 1989) and Dadianzi (Sun & Yuan, 1990) in the Changbai Shan (middle sub-region), and Qindeli and Chuangye (Xia, 1988) in the Sanjiang Pingyuan (northern sub-region) (Table 1). These profiles were all produced from peat land, well dated and analyzed, with good time resolution. Recalculation is made for pollen percentages using the same method with that in Ren and Zhang (1998) to enable the intersite comparability.

Table 1 Four representative Holocene pollen profiles from Northeast China

Site	Longitude (E)	Latitude (N)	Altitude (m)	Carbon dates	Authors
Qindeli	133.25	48.00	～70	5	Xia, 1988
Chuangye	134.25	48.17	～40	3	Xia, 1988
Gushantun	126.00	42.23	～500	4	Liu, 1989
Dadianzi	126.37	42.33	614	4	Sun et al., 1990

Fig. 2 gives the changes in pollen percentages of *Ulmus* (a), *Quercus* (b) and *Pinus* (c) for the four profiles. *Ulmus* pollen is under-representative for vegetation (Birks & Birks, 1980). If 1 % is thought as a threshold value for the presentation of *Ulmus*, it grew around the four sites throughout the Holocene, and perhaps existed early in the late glacial period or in the last glacial maximum.

For *Quercus*, the difference of change between south and north in early Holocene is significant. If we take 5 % as a threshold value for the presentation of *Quercus*, then the initial existence of *Quercus* was at 10.2 ka BP around Gushantun profile, at 10 ka BP or earlier around Dadianzi profile, at 9 ka BP around Qindeli profile, and at 6.2 ka BP around Chuangye profile. It is safe to say that at least by 10.2 ka BP, *Quercus* had grown in the Changbai Shan. In the Sanjiang Pingyuan, however, the appearance of *Quercus* seems much later than in the southern region. This temporal variation in initial growth may have been caused by the migration lag.

Straight distance between the two southern and two northern profiles is about 810-990 km. If the different changes between south and north results from species' migration, the migration rate of *Quercus* (mainly of *Quercus mongolica* in the concerned area) ranges from 250- 590 m/a in the early Holocene.

Fig. 2 (c) shows the changes in *Pinus* percentages for the four sites. Tremendous changes can be seen throughout the record period. Also obvious is the significant difference of the initial increase between south and north. *Pinus* pollen is over-representative in sediments (Birks & Birks, 1980; Li, 1993). If 20% pollen is taken as a threshold value

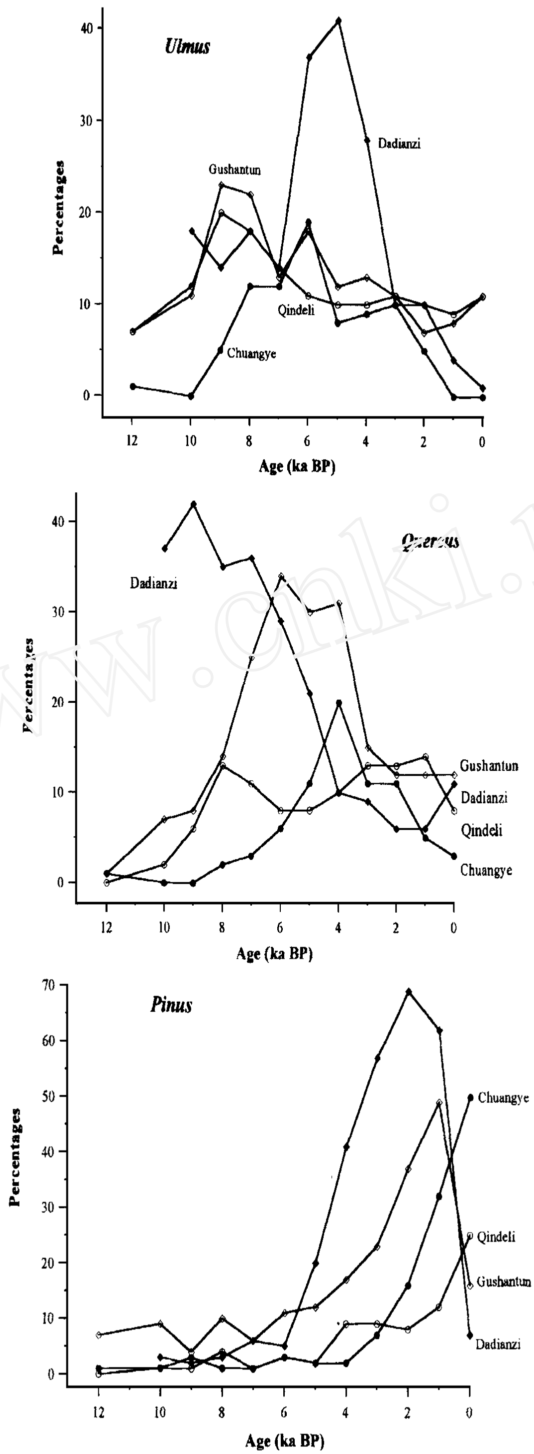

Fig. 2 Changes in pollen percentages of *Ulmus* (a), *Quercus* (b) and *Pinus* (c) at Gushantun and Dadianzi of the middle sub-region and at Qindeli and Chuangye of the northern sub-region. See text and table 1 for method and source of the data.

for existence of *Pinus* near the profiles (Li, 1993), it started to exist at 5 ka BP around Dadianzi, 3.5 ka BP around Gushantun, 1.8 ka BP around Chuangye and 0.5 ka BP near Qindeli. The initial growth of *Pinus* (dominantly of *Pinus koraiensis* in the Changbai Shan and the Sanjiang Pingyuan) near the two northern sites is 1.7- 4.5 ka later than near the two southern sites.

This temporal difference is most likely induced by the species' migration of *Pinus* from south to north. If the inference is correct, the estimated migration rates for *Pinus* are from 150 m/a to 580 m/a between the Changbai Shan and the Sanjiang Pingyuan.

Using the same method, I also estimate the possible migration rate for *Juglans* in the concerned region based on the four-site data (not shown in Fig. 2). It is from 200 m/a to 810 m/a, with a much larger range as compared with *Quercus* and *Pinus*.

4 Discussion and conclusions

As the ice sheets retreated and temperature rose rapidly in North America and Europe in the late glacial and early Holocene periods, terrestrial plants migrated northward from the ice age refuges in southern regions (Birks & Birks, 1980; Davis, 1983; Webb, 1988). China, including Northeast China, was not covered by ice sheet in the glacial period. Whether the plant migration occurred over the non-ice China is an untouched question though it is scientifically important in paleo-ecological and paleo-climatological studies of the late Quaternary. Deficient pollen data with good quality is the underlying cause for the situation.

Theoretically, it is possible that tree species migrated in non-glaciation areas during the post glacial period. This is because the plant migration does not only respond to the retreat of ice sheet in high latitudes, but also in the middle latitude regions such as Central Europe and the southern United States (Birks & Birks, 1980; Davis, 1983). If temperature experienced marked increase in East Asia as believed by Chinese Quaternary scientists, it is quite possible that tree species could migrate from the south to the north during the post glacial period.

This study is the first one to investigate into the issue of possible plant migration in China using pollen data. Although the data is still incomplete due to the lack of influx and macrofossil data, the preliminary analysis indicates that the terrestrial plant migration may have occurred in China, at least in Northeast China, during the early to mid Holocene period. The possible migration rates in Northeast China are estimated as 250- 590 m/a for *Quercus*, 150- 580 m/a for *Pinus*, and 200- 810 m/a for *Juglans*. It is unknown, on the ground of present data, whether *Ulmus* migrated from south to north as well. If it did, the migration rate of *Ulmus* would be most rapid among the concerned taxa.

Size and number of seeds, orientation of mountains, rivers and animals are all the important factors affecting the plant migration. For example, significant difference exists among the sizes of seeds of the arboreal taxa mentioned above. The cone of *Pinus koraiensis*, a dominant species in the Changbai Shan and the Sanjiang Pingyuan, is about 9- 14 cm long; whereas the nut of *Quercus mongolica* is only 1. 3- 1. 8 cm in diameter. The smaller size of seeds of some trees may have favored the northward spread when climate warmed in the early Holocene, because they could more easily be carried by animals and natural dynamics such as wind and flowing water.

In the Changbai Shan and the Sanjiang Pingyuan, rivers usually flow from south to north. This kind of rivers may also have helped in northward migration of plants. There is a possibility that nearness of the pollen sites to rivers in the north narrow the difference of the onset time of a species from that of the south. The nearness of the pollen sites to rivers, combined with the chance of landing for seeds on a specific place, may also account for the different initial times for *Quercus* to settle between Qindeli and Chuangye.

In spite of the large ranges of the estimated migration rates for each taxa, they indeed fall within the rational values. Researches from eastern North America and Europe show that the migration rate of the major trees is generally from 250m/a to 400m/a in the postglacial period (Davis, 1983; Huntley & Birks, 1983). For some frontier trees, the migration rate would be as high as 500- 1 000 m/a (Velichko et al., 1993). Considering the complex of the factors affecting plant migration and the limit of the available data, the estimation of the migration rates is really encouraging.

Presently an important problem facing human being is the possibly serious ecological disturbance induced by the future global warming. We need to understand how the biomes response to the global climate change, if the climate change is too rapid for the adaptation of ecosystems (Zhang, 1993). According to IPCC report (IPCC, 1996), global mean temperature will rise by about 2℃ by 2 100. Suppose that the future climate change of Northeast China can be represented by the global annual mean temperature, the northward movement of a specific isotherm, say isotherm of 6℃, will be 1. 0- 7. 0 km per year in Northeast China, much more rapid than the potential migration rate for almost all trees as estimated from the pollen data. Therefore, some of the tree species in the temperate forests of Northeast China will be endangered if climate continues to warm in the future centuries, even in absence of the direct interference of human activities.

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