A COMPARATIVE STUDY OF JAPANESE POLLEN RECORDS

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(*With 2 tables and 13 figures*)

I. Introduction

During the past twenty years which have elapsed since the introduction of pollen analytical method to Japan, a considerable body of work has been undertaken in this country.

But no general consideration based upon these studies has been done except the works about Hokkaido and South Saghalien in which T. Yamasaki and Y. Sasa (1933) discussed the climatic change since the Pleistocene in North Japan.[1)]

The difficulty of making any general consideration of this nature may be due to the following two points:

The investigated peats are comparatively restricted to montane bogs which are so young in their age of accumulation, that they show no remarkable changes in climate and forest succession. There are no evidences by which to estimate the peat ages; in this country the occurrence of glaciers is considered to be questionable and so we have no historical records of the post-glacial stages which are placed on an exact basis and absolute dating is given neither to the archaeological remains nor to the pollen records.

But it is clear that, during the period corresponding to the Quaternary Ice Age in Europe and America, a colder climate prevailed in this country as in other regions, though the occurrence of ice sheets may be a question at present. Plant remains indicating such a cold climate have been fouud in many places. (Miki 1950)

On the other hand the pollen records already published scarcely indicate any evidence of such a climate or extinct species. So the ages of these pollen records may be younger than the Quaternary Ice Age.

A vast number of pollen analytical studies of the post-glacial climate in Europe agree fairly well with those in America and the rest of the world and the absolute dating has been given in most cases. Then the pollen records in our country ought to represent a part of the common sequence of the post-glacial climates in the world.

If we are able to induce a common trend of forest succession from those pollen records published already and compare it with representative synchronized records from Europe and America, some absolute dates of these pollen records may be fairly elucidated.

This paper aims to elucidate the late-quaternary history of Japanese vegetation and establish its absolute dating by means of pollen analytical studies.

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1) According to T. Yamasaki and Y. Sasa (1938), the constitusion of the forest elements in the Pleistocene in Hokkaido was very differerent from the present one; the *Picea*>*Abies* forest prevailing in the Pleistocene is now converted into the *Picea*<*Abies* one. The *Picea*>*Abies* forest, on the other hand, has continuted to the present in the northern part of South Saghalien. For these reasons they estimated that no remarkable changes occurred in the flora and climate of Hokkaido and South Saghalien duringthe Late Quternary Age. But no pollen records of the Late Guaternary Age are yet published in Hokkaido, so that the comparison between these results and those obtained in this paper must remain for the future.

II. The station of pollen records

The following 22 stations lying between north latitude 30 degrees and 41 degrees are used in the present study. They include almost all the records published already for this area. (Table 1.)

The horizontal and vertical distributions of these 22 stations are indicated respectively in Fig. 1 and 2. In both figures each station is represented by an Arabic number assigned in Table 1.

Table 1. List of the station

No. of station	Bog name	Locality (Altitude)	Author	Note
1	Akamizusawa	1000m, Mt. Hakkoda, Pref. Aomori	J. Nakamura (1942)	Also by T. Jimbo ('32, '36, '48)
2	Senninta	1300m, Mt. Hakkoda, Pref. Aomori	〃 (〃)	
3	Yachi	780m, Mt. Hakkoda, Pref. Aomori	〃 (1949)	
4	Kamitashiro	1400m, Oze, Pref, Gunma	〃 (1951)	Also by S. Hori ('41) and J. Nakamura ('48)
5	Akatashiro	1400m, Oze, Pref. Gunma	〃 (Unpublished)	
6	Oomine	1254m, Mt. Oomine Pref. Gunma	S. Hori (1949)	
7	Yoshigadaira	1831m, Mt. Shirane, Pref. Gunma	〃 (〃)	
8	Sugadaira	1250m, Mt. Nekodake, Pref. Nagano	〃 (1948)	
9	Yashimagahara	1500m, 8km N.E. Ueda city, Pref. Nagano	〃 (1938)	Also by D. Numada and K. Tamata ('37)
10	Odoriba	1500m, 5km N. of Kamisuwa, Pref. Nagano	〃 (1940)	
11	Meike	1350m, Mt. Ontake Pref Gifu	D. Numada and K. Tamata (1937)	
12	Yakumogahara	920m, Mt. Bunadake Pref. Shiga	〃 (1936)	
13	Hacchodaira	800m, Kuta mura, Pref. Kyoto	〃 (〃)	
14	Sugawara	680m, Katsube mura Pref. Tottori	T. Yamasaki (1943)	
15	Boogatsuru	1000m, Mt. Kuju, Pref. Ooita	K. Miyai (1949)	
16	Kirishima	1301m, Mt. Koshikidake Pref. Miyasaki	〃 (〃)	
17	Hananoego	1600m, Mt. Yaedake, Yaku isl. Pref. Kagoshima	〃 (1938)	
18	Higashiakaishi	1100m, Mt. Higashiakaishi, Pref. Ehime	J. Nakamura (Unpublished)	
19	Noganoike	1294m, Mt. Noganoike, Pref. Tokushima	〃 (1950)	
20	Kamiike	430m, Kaminiro mura Pref. Kochi	〃 (Unpublished)	
21	Eranuma	10m, Hewa mura, Pref. Kochi	〃 (〃)	
22	Tochi	5m, Tochi mura, Pref. Kochi	〃 (1948)	

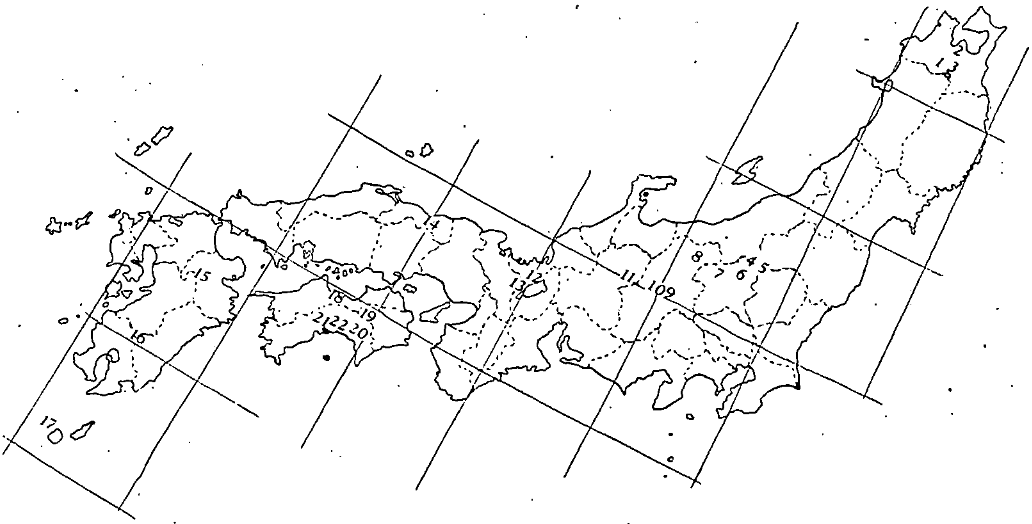

Fig. 1. Map showing the localities of the bogs, where the pollen records were obtained.

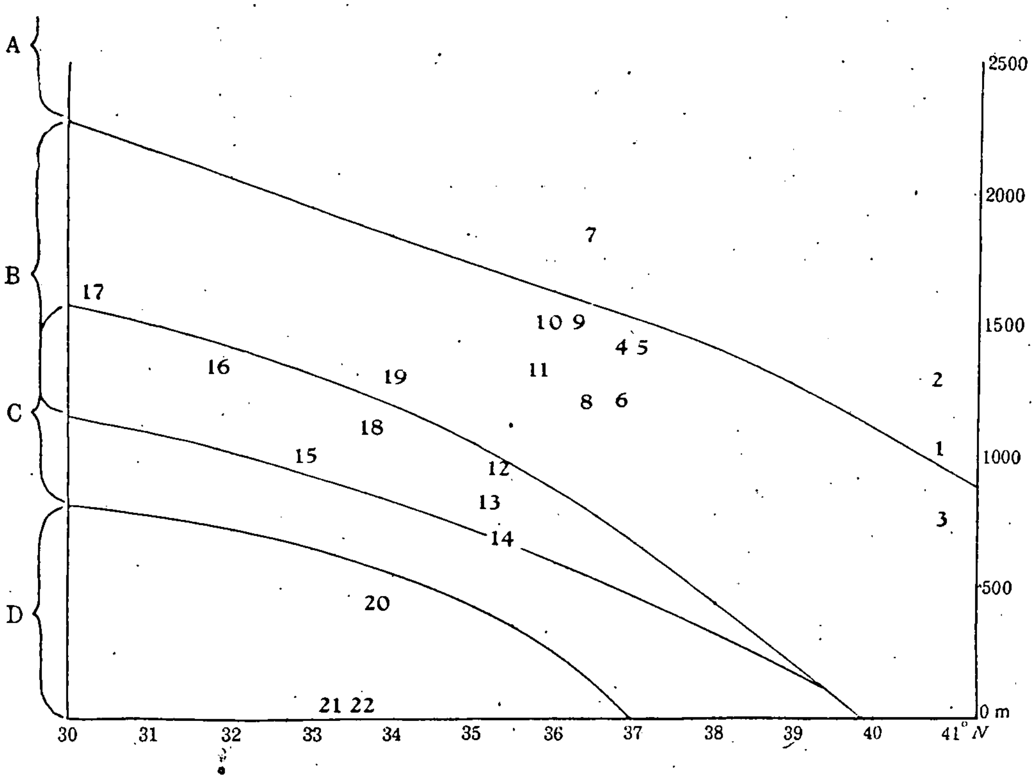

Fig. 2. Diagram showing the vertical distribution of the bogs with the forest zones in Japan.

A: Subalpine coniferous forest zone
B: Deciduous forest zone (*Fagus* forest zone)
C: Transition zone (*Abies firma-Tsuga Sieboldii* forest zone)
D: Ever-green broad leaved forest zone

III. Zoning of pollen diagrams

The lower layers of the pollen diagrams for Central Honshu, especially those of the Oze district may be little older than the others in their ages of deposition.

But even their diagrams must begin with the post-glacial period. since no deposits of the late-glacial period indicating the Dryas flora or the arctic climate have yet been found in this region,

We have now proposed a series of numbered zones, based directly on the records of Kamitashiro bog of the Oze district. These zones also are, however, based not only upon local correlations but also upon a consideration of the diagrams for the other localities. (Fig. 3)[1]

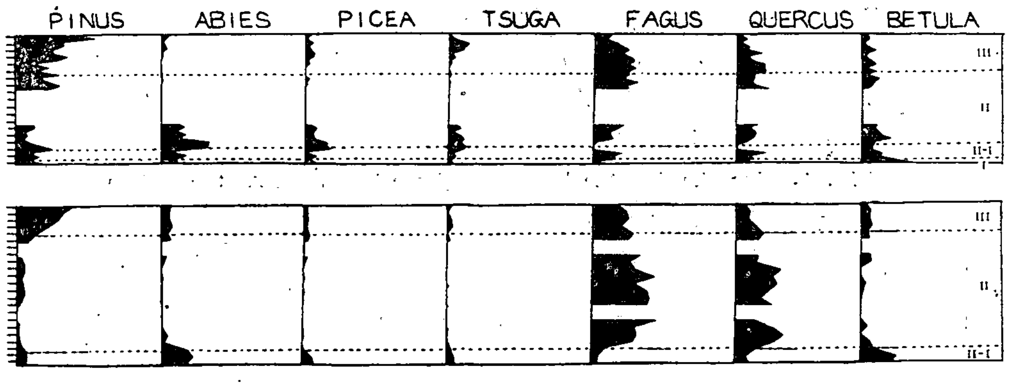

Fig. 3. Comparison of pollen diagrams at two stations in the Oze district: 4, Kamitashro and 5, Akatashiro.

R I zone: For this period evidence in the bog is very scarce, and it can be recognized with certainty only at the base of the Kamitashiro diagram. It appears there to be characterized by the dominance of conifers and birch (*Betula Ermanii* var. *communis* Koidz.) and the absence or very small amount of deciduous trees such as *Fagus* and *Quercus* is a remarkable fact. We tentatively suggest that this zone is a little lower in temperatur than to-day.

R I-II transition zone: The beginning of this period is marked by a sudden increase of *Fagus* and *Quercus* and the dominance of conifers alternates with that of trees several times during this period. R I—II is regarded as a transition zone between R I and the next R II. In climate it seems to be unstable.

R II zone: This period is marked by the preponderance of deciduous trees such as *Fagus* and *Quercus*, while conifers such as *Pinus*, *Picea*, *Abies* and *Tsuga* are relatively

1) The original diagrams are all simplified in the diagrams of this paper, which therefore do not indicate a complete pollen analysis of each station. Some pollen not considered important for comparative treatment have in some cases been omitted. Within a given diagram each column represents depth vertically, percentage horizontally. One degree of the vertical scale represents a depth of approximately 20cm, the total width of each column being reckoned as 100 per cent.

small in amount. It seems to be reasonable to recognize this period as a warmer stage than to-day and R II is widely recognizable elsewhere in Japan.

R III zone: The end of R II zone is characterized by the beginning of the steady rise in the curves of conifers and the decrease of *Fagus* and *Quercus*. This trend is maintained to the present day through the perid R III. Especially a well-marked increse of *Pinus* up to the living bog surface of the present day is widely recognizable throughout this country. This period probably represents a stage of decreasing warmth.

The diagrams of Akatashiro and Kamitashiro agree fairly well; obviously the lower layer of the former and the 1 m gap in the middle layer of the latter correspond respectively with R I–II and R II periods.

The Oze district (Station 4 and 5) is situated in the lower part of the subalpine coniferous forest zone or the upper part of the deciduous (*Fagus*) forest zone. Most pollen in their stations are derived either from the coniferous or from the deciduous forest zone and therefore a comparison of the frequency curve of total pollen derived from the former with that from the latter allows a clearer recognition of the changes in the vertical distribution of these forest zones and accordingly those in the climate. Thus the frequencies of main species belonging exclusively to each forest zone were respectively summed up on each level of the diagram and indicated in the following figures. (Fig. 4)[1]

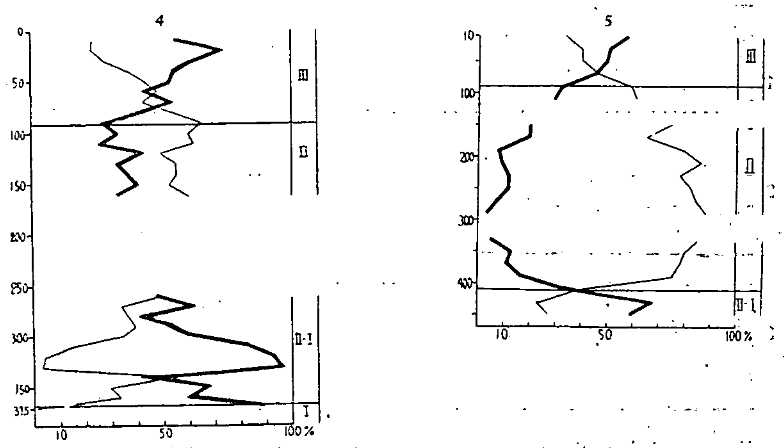

Fig. 4. Total frequency curves of the subalpine coniferous-deciduous forest elements of the Oze district: 4, Kamitashiro and 5, Akatashiro. Thick line, total frequency curve of Subalpine coniferous elements; thin line, that of deciduous elements. See further the text.

From these figures it is clear that R I, I–II, II and III correspond respectively with the coniferous forest stage, the coniferous-deciduous mixed forest stage, the deciduous forest stage and the coniferous deciduous mixed forest stage. In this way we can recognize a movement of these two forest zones and it is inferred that in the R II period the upper

1) It might be desirable to make curves which indicate the total frequencies of all pollen derived from each forest zone, but in this paper those which are relatively unimportant or distributed through both forest zones are conveniently omitted.

limit of the deciduous forest zone was about 200—300 m higher than the present.

IV. Grouped diagrams from, Shikoku and Kyushu

The above mentioned zoning is essentially based upon the oze diagrams. But the major zones can be easily matched in other parts of Japan. The results are broadly as follows:

A) Northern part of Honshu (Station 1—3) (Fig. 5,6)

As shown in Fig. 1 and 2, Station 1,2 and 3 are included in this region. Station 1 and 2 are situated in the lower and the middle part of the subalpine coniferous forest zone respectively, while Station 3 lies in the deciduous forest zone. But the diagrams for these three alike indicate the replacement of the dominance of the deciduous trees by that of the conifers in the upper layers. Furthermore it is note worthy that the diagram of Station 2 lying in the coniferous forest zone (1300 m in altitude) shows a preponderance of deciduous trees such as *Fagus* and *Quercus* in the lower layer. This fact probably indicates that at one time the deciduous zone reached the neighbourhood of this station, in other words, formerly the deciduous zone was 200 m higher.

From these considerations we are able to make the upper and the lower layers of the three diagrams belonging to Period R III and R II respectively.

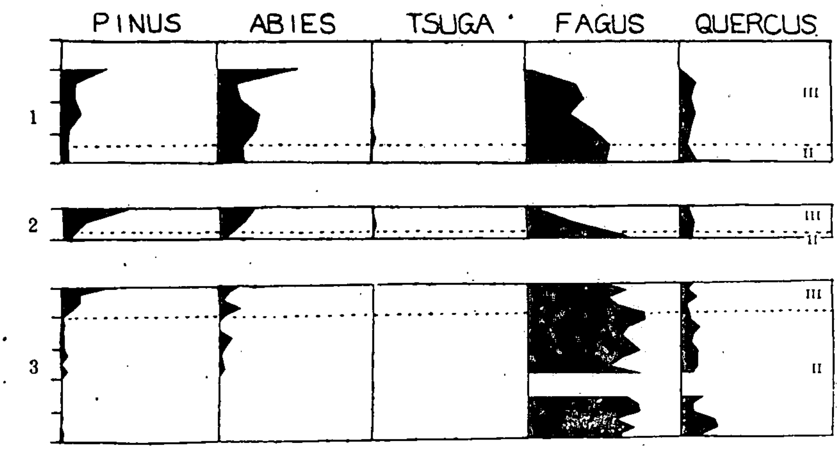

Fig. 5. Comparison of pollen diagrams at three stations in northern part of Honshu: 1, Akamizusawa; 2, Senninta and 3, Yachi.

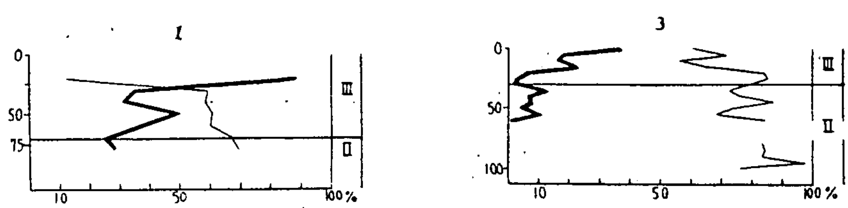

Fig. 6. Total frequency curves of the subalpine coniferous-deciduous forest elements: 1, Akamizusawa and 3, Yachi.

B) Central part of Honshu (Station 4—11) (Fig. 7,8)

The Oze district and the other stations in this region are all situated in the upper parts of the deciduous or the subalpine coniferous forest zone, and most deposits from this region are assumed to be older than those from the other regions.

From these diagrams it is recognized that in the upper layers conifers, especially *Pinus*, increase and deciduous trees tend to decrease upwards, while the middle and the lower lower layers correspond with the deciduous and the deciduous-coniferous mixed forest stages respectively.

At Station 6 the conifers are dominant throughout, but in the lower layer a dominance of the deciduous forest can be seen. This trend refers to a rise of the deciduous zone. Thus, in this station also we are able to recognize a pericd in which the upper limit of the deciduous zone was about 200—300 m higher than now.

At Station 9,10 and 11 the frequency of *Fagus* is consistently lower than that of *Quercus*. This fact is interesting, judging from the present distribution of *Fagus* which is scarce on the Pacific side as compared with the side of the Sea of Japan.

In this way the zoning which we have proposed is applicable to these stations as is shown in Fig. 7. As regards the age of their deposition, Station 4 is the oldest, Station 7 is the youngest, and the other come between them.

C) Wesetrn part of Honshu (Station 12—14) (Fig. 9)

The three stations (12—14) included in this region are all located in the montane coniferous forest zone (dominated by *Abies firma* and *Tsuga Sieboldii*) corresponding to the lower part of the deciduous forest zone. The subalpine coniferous forest which lies higher than the deciduous forest is not developed in this region.

Therefore it may be considered that the relatively high values for *Abies* and *Tsuga* in the lower layers suggest a rise of the montane coniferous forest zone accompanied by that of the deciduous forest. But these stations probably remained in the range of the deciduous forest zone although we are unable to elucidate the sequence of the vertical distribution of these species from the change in amount of *Fagus*.

Quercus is also unsuitable to elucidate such a sequence, since the oak pollen indicated in these diagrams originated from two different zones. Some are derived from such species as *Quercus crispula* in the upper deciduous forest and others from such as *Q. serrata* and *Q. acutissima* in the montane coniferous forest zone.

Cryptomeria is not quite suitable either, being distributed in its natural range from the middle part of the deciduous forest to the montane coniferons forest zone, but it is noticed to show a temporary increase before the maximum development of *Pinus* near the surface in all the diagrams of this region.

Accordingly, although we can not apply the coniferous-deciduous curves to this region, we may be able to distinguish R III and R II from the common trend of *Pinus* throughout this country and the abundance of *Abies* and *Tsuga* in the lower layers.

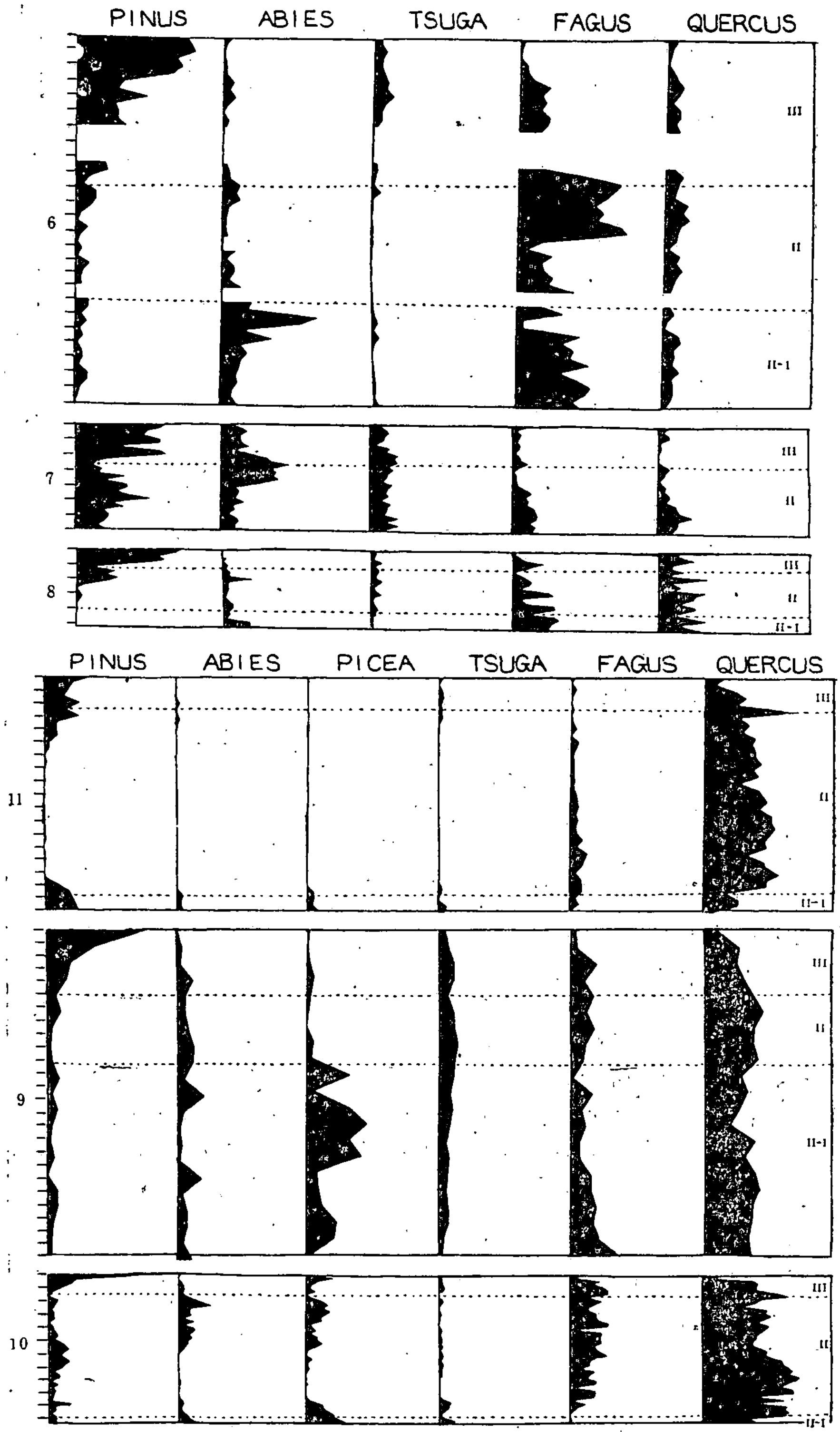

Fig. 7. Comparison of pollen diagrams at six stations in central part of Honshu: 6, Oomine; 7, Yoshigadaira; 8, Sugadaira; 9, Yashimagahara; 10, Odoriba and 11, Meike.

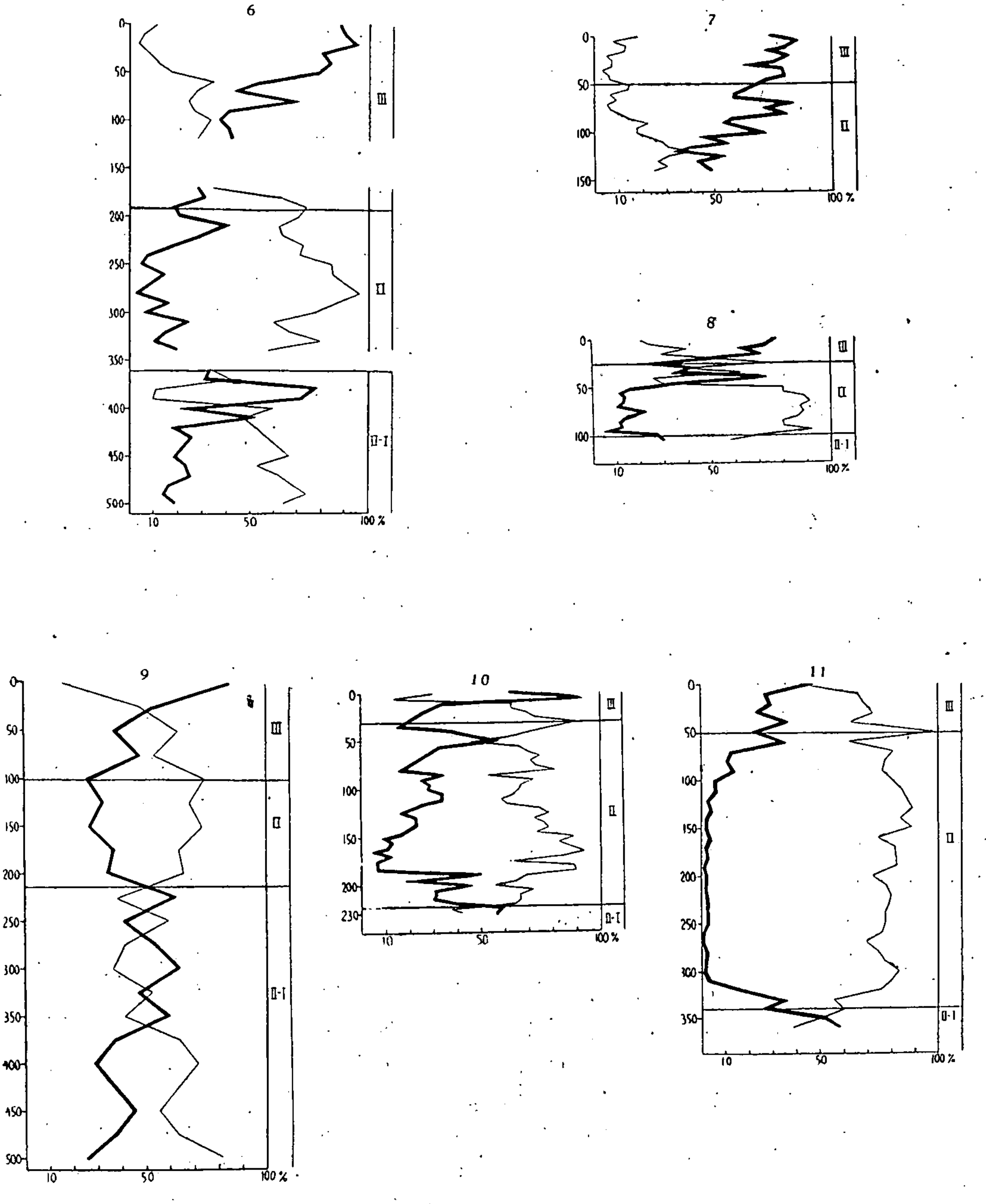

Fig. 8. Total frequency curves of the subalpine coniferous-deciduous forest elements: 6. Oomine; 7. Yoshigadaira; 8, Sugadaira; 9, Yashimagahara, 10, Odoriba; and 11, Meike.

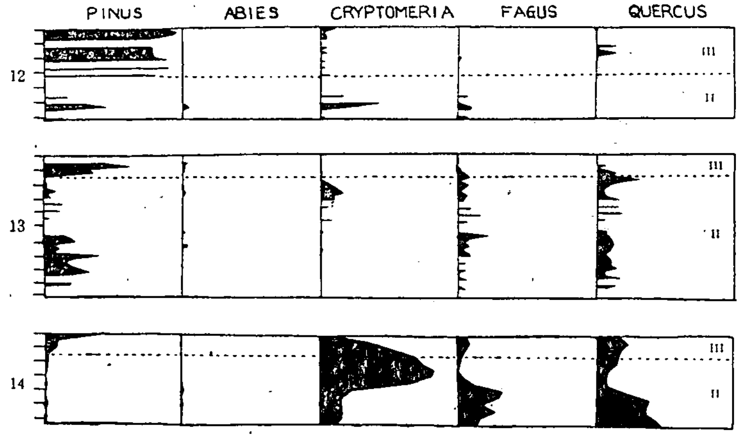

Fig. 9. Comparison of pollen diagrams at three stations in Western part of Honshu: 12, Yakumogahara; 13, Hacchodaira and 14, Sugawara.

D) Sikoku (Station 18—22) (Fig. 10,11)

The following five stations located on the Pacific slope in the range from 5m to 1294m above the sea level are used in the study of this region. Both Station 21 and 22 are situated in the evergreen broad-leaved forest zone (the warm temperate zone) which reaches from the sea shore to the montane coniferous forest zone. Station 20 is situated near the upper limit of the ever-green forest, and the rest (Station 18 and 19) in the middle or lower part of the deciduous forest zone. And so it is considered that *Abies* and *Tsuga* in the diagrams of Station 20,21 and 22 are mostly derived from *Abies firma* and *Tsuga Sieboldii* which dominate in the montane coniferous forest located at a higher altitude than these stations. *Quercus* again is not decidnous but ever-green dominating in the warm temperate forests. The increase of *Abies* and *Tsuga* in the upper layer, which results in the replacement of the abundance of *Quercus* by that of *Abies* and *Tsuga* in the upper layer, may suggest a descent of the montane and the deciduous forest zone. Such a descent of the forest zone during a relatively recent time is admitted over again by the appearance of *Fagus* in the upper layer of Station 20. And we must here add a fact that many leaves and trichcmes of some evergreen oaks such as *Q. gilva* and *Q. glauca*, are found in the lower layers of this station.

On the other hand, it is hard to elucidate the above mentioned migration of the forest zones by the sequences of *Abies*, *Tsuga* and *Fagus* etc. in the diagrams of Station 18 and 19, since *Abies* and *Tsuga* are derived from both forest zones. For instance *Abies* involves two species, *A. firma* and *A. homolepis*, the latter species being distributed mainly in the upper deciduous forest. *Tsuga*, as in the case of *Abies*, involves *T. Sieboldii* in the montane forest and *T. diversifolia* which ranges from the upper deciduous to the subalpine forest. As regards *Fagus* and *Quercus* their relations are the same as in the case of western part of Honshu.

As the result of these considerations we have tentatively divided the diagrams into periods as in Figure 10.

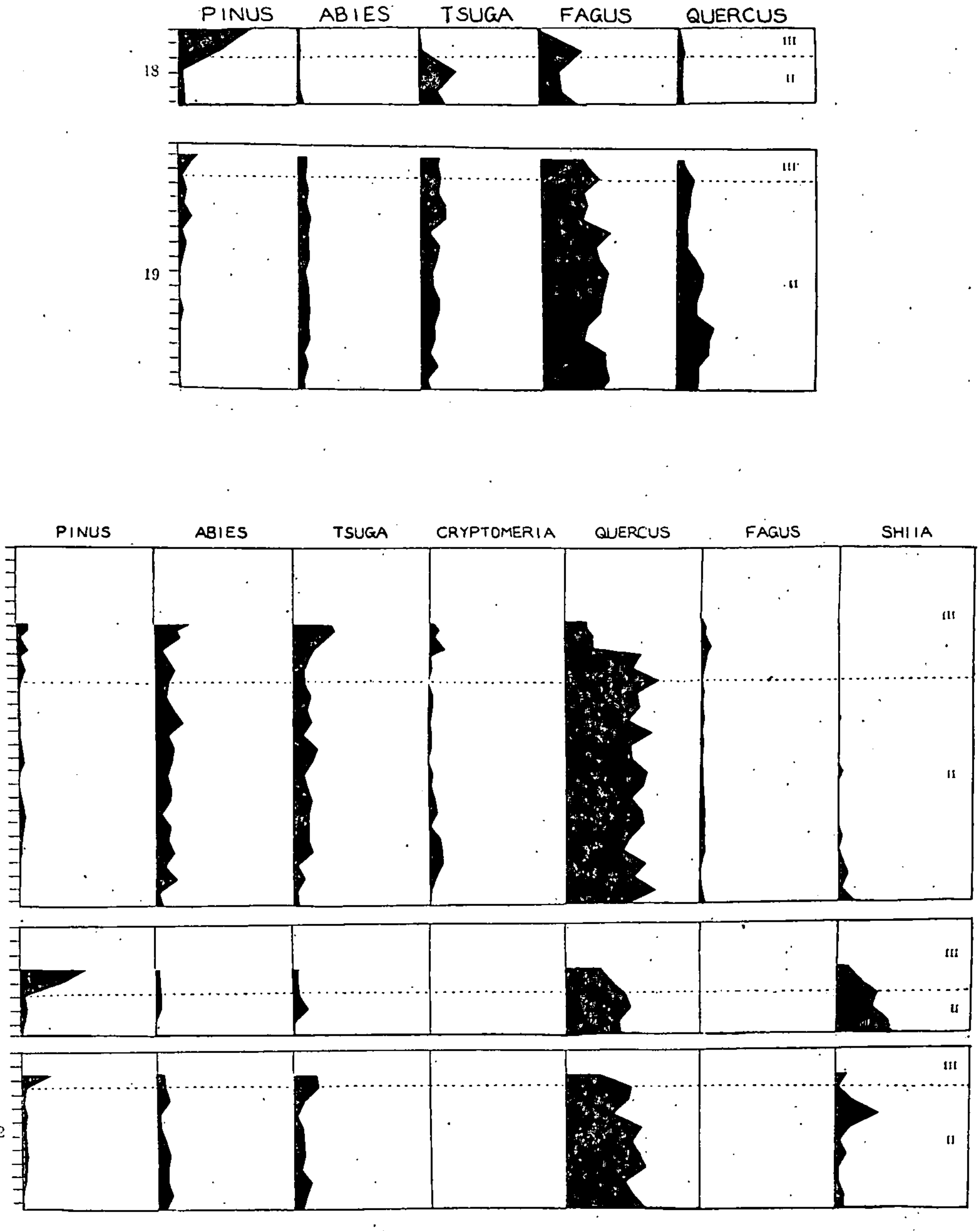

Fig. 10. Comparison of pollen diagrams at five stations in Shikoku: 18, Higashiakaishi; 19, Noganoike; 20, Kamiike; 21, Eranuma and 22, Toochi.

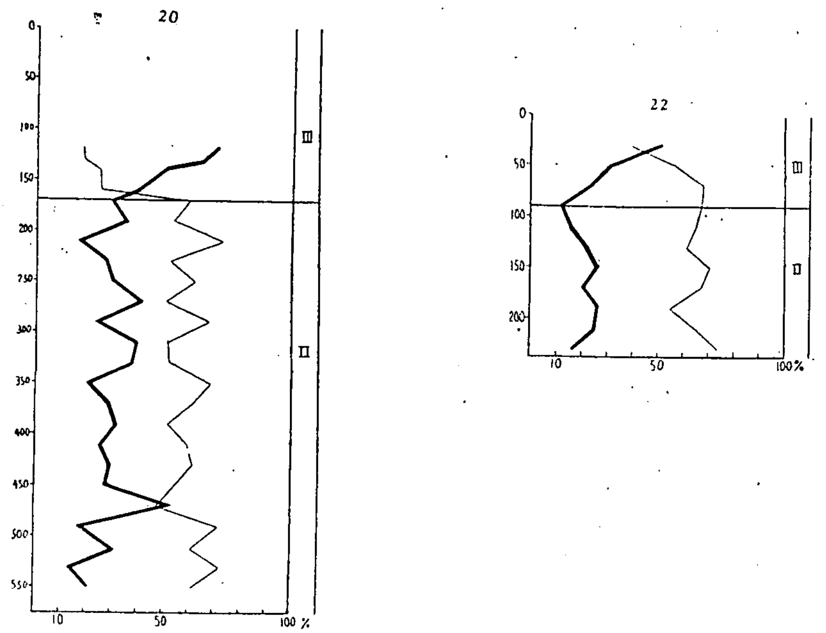

Fig. 11. Total frequency curves of the montane coniferous-ever-green broad leaved forest elements: 20, Eranuma and 22, Toochi. Thick line, montane coniferous elements; Thin line, ever-green broad leaved elements.

E) Kyushu (Station 15—17) (Fig. 12)

Two stations (Station 15 and 16) are located in Kyushu proper and Station 17 is in the Island of Yaku.

The two former stations lie in the deciduous forest zone and their vegetation is more or less affected by some volcanic activities.

As Miyai (1935) pointed out in Station 16 already, the preponderance of *Abies* and *Tsuga* in the lower layer indicates a rise about 300m of the montane forest zone up to the neighbourhood of this station. This suggestion agrees well with the increase of *Fagus* in the upper layers.

The diagram of Station 15 shows a sequence similar to that of Station 16, so we can divide them into RII and R III.

At Station 17 *Cryptomeria* is a dominant through its diagram, whilst *Fagus* and *Pinus* are not seen at all. According to the previous studies on the present vegetation on this island, *Cryptomeria* dominates on a slope ranging from 700 to 1600m above the sea level subordinating *Abies firma*, *Tsuga Sieboldii* and *Trochodendron aralioides* etc. Ever-green trees such as *Quercus* and *Shiia* are distributed on the lower slope.

In the diagram, such ever-gren broad leaved trees are predominant in the lower layers but give up their dominancy to conifers such as *Cryptomeria* and *Abies firma* etc. in the upper layers. It suggests a vertical movement of both forest zones in a range of 200—300m in altitude. From these facts it is concluded that the forest zones were at least

200—300m higher in the ever-green *Quercus* and *Shiia* forest stage than at any other time indicated in the diagram. The maximum development of *Cryptomeria* found in the middle layer is comparable to the similar stage in the upper layers of Station 12,13,14 and 20. On these grounds we may conclude that the zoning, which has been tried in Diagram 15 and 16, is applicable to this one also.

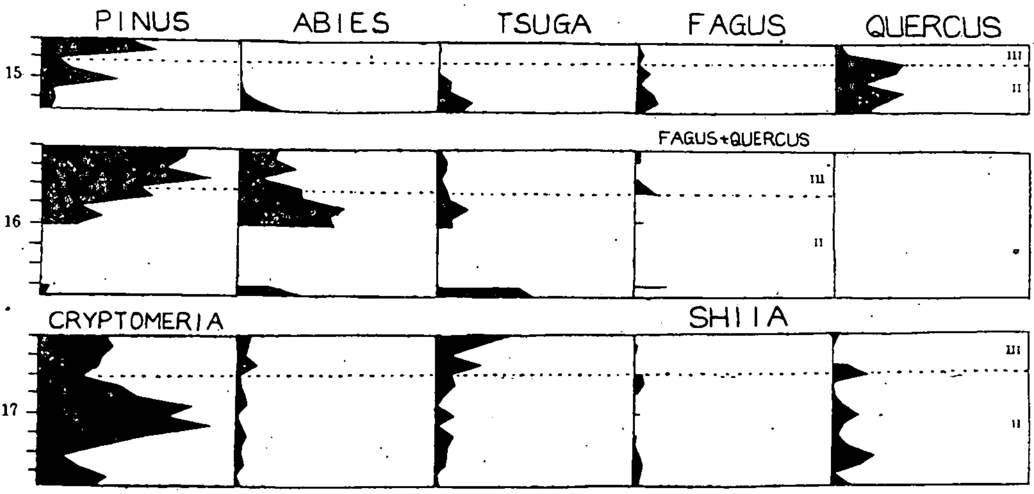

Fig. 12. Comparison of pollen diagrams at three stations in Kyushu: 15, Boogatsnru; 16, Kirishima and 17, Hananoegoo.

In this way our proposed zonations based on that of Kamitashiro were applied successfully to all pollen diagrams already described and their comparative ages of deposits were deduced from their results. Most basal deposits must be referred to the warmer and probably moister period R II, except those of central Honshu which are older than the others in their age.

V. Comparison with extra-Japanese records

As we have described. numerous pollen analytical studies on the post-glacial vegetation in the outsid of Japan agree well and their absolute dating has been fairly elucidated.

For instance, before the developement of pollen analytical method Blytt and Sernander proposed a scheme of the post-glacial climatic sequence for Sweden. With the extension of pollen analysis such a scheme has been applied unmodified to the whole of Europe. In Germany, Overbeck and Schneider (1938) divided the post-glacial period into 11 zones and achieved an absolute chronology covering this period. In England, H. Godwin (1940) divided successfully this period into 6 zones based on the deposits of East Anglia. In North America, on the other hand, Deevy (1948) and Sears (1942) from the Eastern region and Hansen (1947) from the Pacific coast region respectively have succeeded in their zoning of this period.

Before this von Post (1930) proposed a threefold division of postglacial period which is applicable to the whole of Europe.

1. The period of increasing warmth, characterized by the appearance and first increase

of relatively warmth-loving trees.

2. The period of the maximum warmth; the stage of culmination of these forest trees.

3, The period of decreasing warmth, characteristiezed by the decrease of these trees of the warm period and the appearance or the return of the dominant forest constituents of the present day.

The use of this scheme for the world as a whole has clear advantages over the preceding schemes, because the scheme is shorter and clearer than the others and avoids the complexity due to regional difference of forest elements. Recently von Post (1946)

Table 2.

Thousands of years before 1952	Blytt-Sernander zones	British Isles	N.W. Germany	New England	British Columbia	von Post zones
0 1 2	Subatlantic	Ⅷ *Alnus-Betula-Quercus*	Ⅺ *Fagus-Carpinus*	C3 *Quercus-Castanea*	Ⅲ *Tsuga-Pseudotsuga*	Ⅲ
3 4	Subboreal	Ⅷ – Ⅶ	Ⅹ *Fagus-Quercus* Ⅸ *Quercus*	C2 *Quercus-Carya*		
5 6 7	Atlantic	Ⅶ *Alnus-Quercus-Tilia*	Ⅷ *Tilia-Ulmus*	C1 *Quercus-Tsuga*	Ⅱ *Pseudotsuga-Tsuga*	Ⅱ
8 9	Boreal	Ⅵ *Pinus-Corylus* Ⅴ *Pinus*	Ⅶ *Corylus-Pinus* Ⅵ *Pinus-Corylus*	B *Pinus*	Ⅱ *Pseudotsuga*	Ⅰ
10	Preboreal	Ⅳ *Betula-Pinus*	Ⅴ *Betula*	A *Picea-Abies*		
11 12	Late glacial	Ⅲ Tundra Ⅱ (Alleröd) *Betula* Ⅰ Tundra	Ⅳ *Betula-Pinus* Ⅲ *Betula-Pinus* Ⅱ *Betula* Ⅰ Tundra	L3 L2 L1	Ⅰ *Pinus*	

Table 2. Postglacial pollen chronology for North America and Europe Chiefly after R. F.Flint and S.Deevy (1951), with additions: H.Godwin (1940,1951); H.P.Hansen (1947); O.H.Selling (1948) and F.Overbeck and S.Schneider (1938).

applied it successfully to many records derived from the Northern and the Southern Hemispheres. O. H. Selling ('48) also adopted this scheme to the Hawaiian pollen records and introduced an absolute chronology into the Late-Quaternary of the Hawaiian Islands.

Thus it is clear that the climatic sequence proposed by von Post is common and synchronistic all over the world. In this way it becomes possible to introduce an absolute chronology into the Late-Quaternay of a region lacking of any chronological evidences. The above-mentioned several schemes and their parallerization are shown in Table 2.

As shown in the preceding chapter, we have recognized the vertical movement of the forest zones in this country, and it is most reasonable to ascribe the vegetational changes reflected in Japanese pollen records to climatic changes which are common to this country, even though their local effects may vary. Therefore, we consider on the whole that the periods in our zonations (R I, II, III) proposed in this paper respectively correspond to von Post's period I, II, III.

Von Post (1946) divided the forest elements presented in his diagrams to the terminocratic and the mediocratic elements; the former means a preponderant species in period I or III and the the latter a predominating species in period II. Figure 13 shows the sequence of these two elements in the diagrams of four different sites of the world, including a result of the Oze district.[1)]

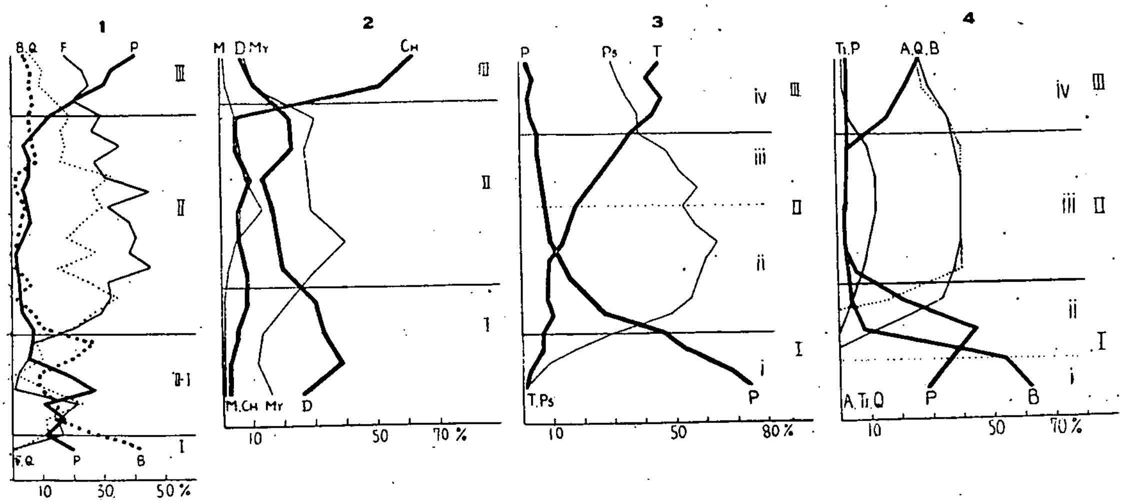

Fig. 13. Synchronized pollen diagrams from Hawaiian Islands, British Isles and Pacific coast of North America for comparison with the diagram of Oze.
1) Oze, 2) Hawaiian Island (W. Maui) after O.H.Selling (1948).
3) Pacific coast of North America after H.P.Hansen (1947).
4) British Isles (East Anglia) after H.Godwin (1940).
thick lines and thick dotted lines: terminocratic elements
thin lines and thin dotted lines: mediocratic elements
P : *Pinus*, B : *Betula*, T : *Tsuga*, Ch : *Chenopodium*, D : *Dodonaea*, My : *Myrsine*, M : *Metrosideros*, F : *Fagus*, Q : *Quercus*, Ps : *Pseudotsuga*, A : *Alnus*, Ti : *Tilia*.

1) Fig. of Oze is more or less schematically represented from the results of Kamitashiro and Akatashiro.

From these figures it is clear that the sequence of the Oze is the same as in other parts of the world.

VI. Consideration

As shown above, the influece of elevation upon the present distribution of forest types is so strongly marked that its effects must always be looked for in the pollen records of such a mountainous country as Japan. In a country of varying altitude the correlation of pollen diagrams from different sites is impossible without recognition of the altitudes of the various sites in relation to the altitudinal forest zones of the present and of the past. Moreover, the elements constituting the forests in south-west Japan differ considerably from those of north Japan and it is difficult to treat their vegetational developements in the same way.

But a comparison of many records with each other shows close agreement, indicating the vertical movement of the forest zones, and many changes in the horizontal distribution of the zones are deduced from the results of the vertical changes.

On this point our pollen records differ considerablly from those elsewhere; in Europe and North America many bogs lying on the low lands have been studied concerning the horizontal distribution of forest trees. But the studies of the Alps are more or less similar to those of Japan. With regard to the Alps detailed studies have been done by many workers in Germany and Switzerland. Among them Keller (1931) has shown that the forest zone was higher in von Post's period II than at any other time, and he effectively contrasted their altitudinal and temporal sequences on the north and the south slopes of the Alps. Firbas (1948) also has recognized a depression of 100—200m in altitude for the *Picea* forest on the north side of the Alps at a relatively recent time.

In our country Miyai (1935) has recognized a period during which the forest zones were about 300m higher in Kyushu. We have also concluded that in many diagrams the forest zones were at least 200—300m higher in the middle or the lower layers. If converted into temperature, it means some 1.0—1.5°C rise in average temperature.[1] And this value is considered to be applicable roughly throughout this country. In Europe it is supposed that the temperature of period II was 5°F higher than now.

Thus we recognize an invasion of the forest upwards as a main feature of period R II.

The most prominent feature of R III is a sudden increase of *Pinus* up to the surface. *Pinus* indicated in our diagrams involves several species. In the diagrams from the northern Japan it represents rather the sequences of *P. pumila* and (or) *P. pentaphylla* than that of *P. densiflora* which is always reflectd in the diagrams of the south-western Japan. According to Yoshioka (1949), *P. densiflora* which is predominant through the country at present is originally an edaphic climax forest constituent streching from the lower parts of the *Fagus* zone to the *Abies firma-Tsuga Sieboldii* forests. Its extensive distribution has generally considered as due to human activities such as plantation or desolation of lands. We also recognize such effects of human activities, but must add the

1) As the lapse rate of temperature 0.5°C is used here.

depression of temperature as another case of it, because *P. pumila* and *P. pentaphylla* have shown a remarkable increase in the untouched mountain regions also. In this connection, the invasion of *P. densiflora* to the low lands, especially in the south-western Japan, partly owes to the recent depression of temperature.

Then the diagrams indicating the periods of R II—I or R I are too scarce for a full discussion, for they are found only from the central part of Honshu. Neverthless the irregular succession of the coniferous and the deciduous trees may be recognized as an effect of transitional unstable climate between the cold period (R I) and the warm period (R II). Such an unstable climatic effect may also be seen more or less between R II and R III. In this paper R II—I has been considered as a transitional stage between R II and R I. We hold it convenient until the character of R I is elucidated in future. It is our opinion that it should be a part of either von Post's period I or II.

As in the case of R II—I, we must wait for a full discussion of R I until more sites are found. At present we distinguish it from the others, recognizing it as a portion of von Post's period I.

As regards the accumulation of peat now dealt with, it varies in thickness from 30 cm to 5.5m and it is not proportional to its age; the rate of peat growth largely depends upon its environment. In Europe, for instance, a peat (up to 10m thick) indicates a warmer climate at the lower limit, while others (up to 3m thick) rest directly on the moraines. Moreover, Selling (1948) has pointed out from Hawaiian diagrams that the bottoms of some peats (only 40—50cm thick) sre synchronous with Period I.

There remains to add a few words on the "Grenz Horizont". If our zonation is resonablly parallel to von Post's scheme, the recurrence surfaces of Granlund (1932) which are widespread in Europe may correspond to the layers of or near the lower parts of R III. Already Hori (1940) discussed the occurrence of such surfaces from the results of central Honshu, but we can hardly recognize such layers in other results. On the other hand it has been considered that in the North-west pacific states of U.S.A. such layers were less beveloped owing to the proximity of the Pacific. (Brooks 1950) Perhaps for the same reason such dry layers would be too insignificant to be recognized in our country, even if they had occurred durirg this period.

Finally the diagrams show that within the main periods the development has taken a complex undulating course and it will be possible to make a more detailed zonation of the Japanese Late Quaternary by means of pollen analysis. Such further discussion, however, is beyond the scope of the present investigation. This paper simply aims to deduce from the diagrams now dealt with some applicable features which may be used as a chronological scale.

VII. Summary

1) 22 pollen diagrams studied by many worekrs in Japan were used in establishing the main phases of the vegetational development.

2) The vertical migration of the forest zones was recognized from these diagrams. Such changes as are reflected in the diagrams are ascribable to climatic changes which are common through this country.

3) Taking an instance of the Oze district (1400m altitude) in central Honshu, we find three main and one trasitional period:

1. Cold period (R 1) The area of the subalpine coniferous forest was extended. Its lower limit was lower than it is now. This period was recognized only in Station 4.

2. Transition period (R I—II) The mutual replacement in dominance of the coniferous and the deciduous forest was seen several times during a relatively short time. This period seemed to be unstable in climate and was regarded as a transition period between R I and the next R II.

3. Warm period (R II) The subalpine forests were pressed back by the deciduous forests which became dominant. The upper limit of this forest was higher than now.

4. Decreasing warmth period (R III) This period is characterized by the fact that the deciduous forests have been invaded by the subalpine conifers. Sudden increase of *Pinus* up to the living surface is recognized through this country.

4) The above mentioned zonation is generally applicable to the other diagrams. Most bogs, except in the central part of Honshu, can be considered to have begun to accumulate during R II.

5) Our zonation may be synchronized with Late Quaternary pollen diagrams from Europe, North America and other regions. Since the European and the North American diagrams are dated, an absolute chronelogy can in this way be introduced into the Late Quaternary of Japan. R I corresponds to the end of the last Glacial period (von post's Period I). R II corresponds to the post glacial warm period (von Post's Period II), and R III to the cooler period (von Post's Period III).

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