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PALYNOLOGY OF THE LATE ELSTERIAN TO EARLY SAALIAN AQUATIC SEDIMENTS IN WESTERN LATVIA

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ABSTRACT. Palynological investigations into of the origin and composition of pollen in the aquatic intertill sediments of western Latvia in the Ziemupe-Jurkalne area indicate that these were laid down during a lengthy non-glacial interval of the Middle Pleistocene. Pollen and fossil data prove that sediment formation began in the subarctic conditions of the Late Letiza/Late Elsterian (Sudrabi Member) and continued through the Akmenrags/Holsteinian Interglacial into the subarctic conditions of the Kurzeme/Saalian glaciation (Jurkalne formation), including the first advance and retreat of the Baltic Sea. Nine pollen assemblage zones (PAZ I-IX) have been distinguished, suggesting three main types of vegetation on the mainland in the region, which reflect three different sets of climatic conditions:

1) periglacial (PAZ I);

2) temperate, (PAZ II-VI), of an interglacial cool – warm – cool climatic sequence;

3) open landscape vegetation, typical of cold arctic and subarctic early glacial climatic conditions during stadials (PAZ VII, IX) and sparse forest during the subarctic and boreal climate of the interstadial (PAZ VIII).

In the Akmenrags/Holsteinian Interglacial it was possible to cover an extended sequence of vegetational succession ranging from *Betula-Pinus* through *Picea-Ulmus-Tilia-Corylus-Alnus, Abies-Carpinus, Pinus,* and concluding with a *Betula-Alnus-Quercetum mixtum* period.

The Ziemupe-Jurkalne area is the most easterly one in the Baltic Sea basin where a pollen sequence characteristic for the Holsteinian Interglacial can be recognized in marine sediments.

KEY WORDS: marine, Pleistocene, Sudrabi, Akmenrags, Jurkalne, Holsteinian, pollen, western Latvia

INTRODUCTION

In western Latvia (Fig. 1) accumulated marine sediments were found in the Devonian bedrock of the Baltic depression. In spite of significant glacial and tectonic movements in this region, sediment sequences have been found which reflect almost the whole Holsteinian Interglacial cycle, as well as some interstadials. The intertill deposits were discussed and interpreted as being marine by Konshin *et al.* (1971), Charamisinava (1971), Danilans (1973), Seglins (1987), etc. From 1986 to 1989 the Geological Survey of Latvia carried out stratigraphic investigations in Western Latvia adjoining the Baltic Sea, as part of a regional mapping project. In association with these investigations six test-drilling cores in western Latvia were investigated palynologically.

RESULTS

Pollen data were compared and correlated with those from the nearest marine and continental sites. In the pollen diagrams nine pollen assemblage zones (PAZ I-IX) were distinguished (Fig. 2), all of which were encountered in the Akmenrags and Ozoli sections. In other sections the accumulation of sediments was apparently interrupted, as is indicated by sudden changes in the pollen composition and degree of preservation (PAZ II, V and VI). At Strante and Ulmale the sandy layers overlying zone V contained very few pollen grains, mostly of *Pinus*, and those which were present were torn or eroded.

SUDRABI DEPOSITS – LATE LETIZA/LATE ELSTERIAN

The Sudrabi beds consist of Late Letiza/Elsterian calcareous laminated clays which become silty towards the top. In addition to plant remains, fragments of mollusc shells, particularly *Portlandia arctica,* ostracods and foraminifers occur in the upper part (Seglins 1987), with diatoms (Seglins 1987) also present. A *Pinus-Betula nana-Juniperus-Artemisia* PAZ I has been distinguished in the diagram.

The abundance of palynomorphs in PAZ I is low (200 grains per 1 g of dry sediment). Tree and shrub pollen dominates with *Pinus* and *Betula* commonest, the latter mostly of *Betula nana* type. *Salix, Juniperus* and *Larix* pollen appears sporadically. Herb pollen is abundant,

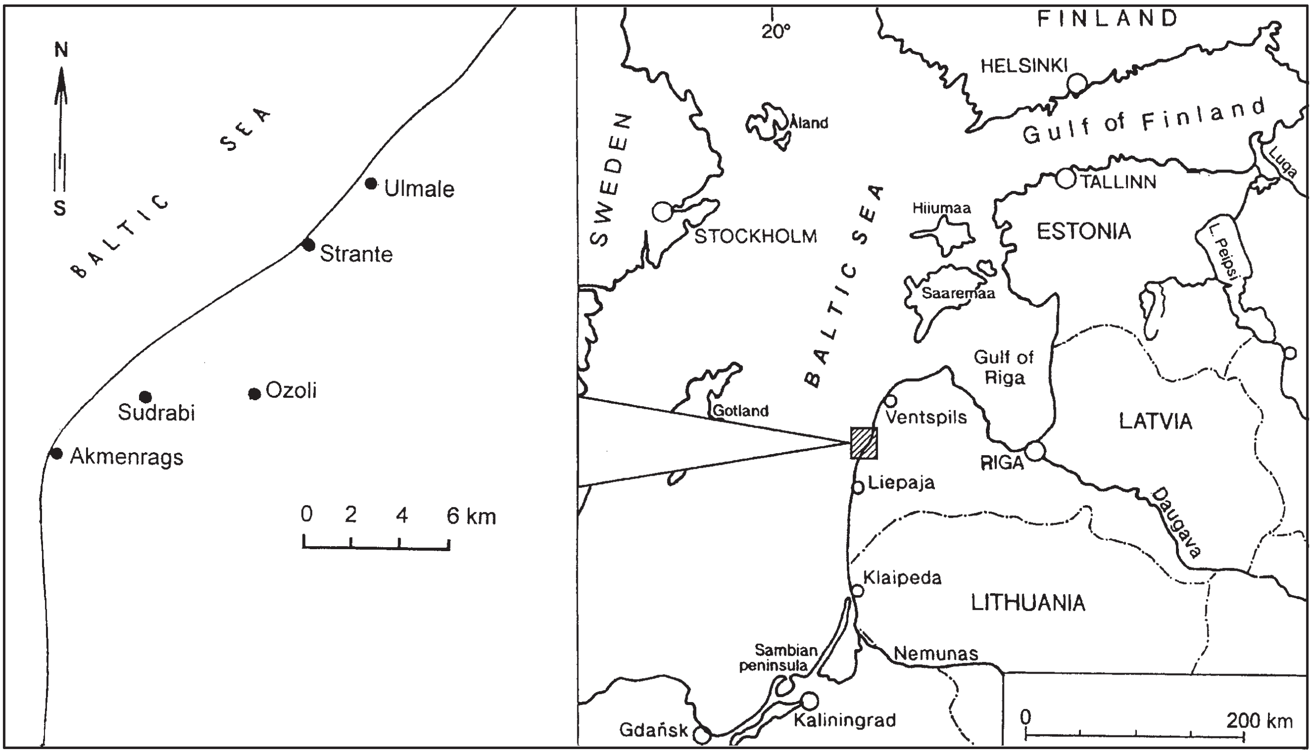

Fig. 1. Map of the investigated area. Solid circles show the location of the palynologically investigated test-drillings

represented mostly by *Artemisia* and Chenopodiaceae. Pollen and spores of plants indicating periglacial conditions are *Ephedra, Hippophaë, Selaginella selaginoides, Helianthemum, Dryas octopetala* and *Diphasiastrum alpinum*. The differences in pollen composition within the zone allow us to subdivide it into PAZ Ia-*Betula nana-Artemisia-Dryas* and PAZ Ib-*Pinus-Betula-Juniperus*-NAP. In PAZ Ia redeposited Pre-Quaternary palynomorphs such as *Taxodium, Sequoia, Ilex, Ostrya, Eucomia, Rhus, Nyssa, Pterocarya, Tsuga,* etc., are present. The upper boundary of PAZ I occurs at the level where pollen of a subarctic flora disappears and the values of *Picea, Alnus* and *Corylus* increase.

AKMENRAGS INTERGLACIAL – HOLSTEINIAN INTERGLACIAL

The Akmenrags Interglacial sediments (Seglins, 1987) occur throughout the area, with their upper surface at a depth of 40–55 m below the present sea level. They are rich in organic material, particularly plant remains, but also contain ostracods, foraminifers, diatoms and fragments of marine mollusc shells. Five pollen assemblage zones (PAZ II-VI) were distinguished in the Akmenrags Interglacial sediments (Figs 2, 3).

Betula-Pinus **PAZ II**. Tree pollen dominates. In some diagrams *Betula* dominates among the trees at the base, but its abundance decreases upwards. However, a *Betula* PAZ IIa zone can be distinguished with *Betula* pollen being represented only by tree species. A *Pinus* PAZ IIb is characteristic for all diagrams, although *Pinus* eventually decreases upwards. *Picea* and *Alnus* are present and gradually increase in abundance. Broad-leaved tree and *Corylus* pollen have continuous curves. The upper boundary of PAZ II is drawn where the abundance of *Alnus, Corylus* and broad-leaved tree pollen increases.

Picea-Ulmus-Alnus-Tilia-Corylus **PAZ III.** The sediments of this zone are particularly rich in organic material and palynomorphs. The abundance of *Picea* pollen increases rapidly and, in some sections, reaches its maximum. *Picea* sect. *Omorica* pollen is found from time to time but *Pinus* is less abundant, although *Pinus* sect. *Strobus* pollen is noted occasionally. *Alnus, Corylus* and Quercetum mixtum pollen culminates, *Carpinus* contributes up to 10%, while *Tilia* dominates among the broad-leaved trees, consisting of both *T. platyphyllos* and *T. tomentosa*. Small maxima of *Fraxinus* and *Taxus* are also noted in this zone. Additionally there are some differences among the sections investigated. Thus, broad-leaved tree pollen culminates at Strante and Ulmale before *Picea* reaches its maximum. At Akmenrags, however, the Quercetum mixtum pollen maximum divides the *Picea* curve into two maxima, but this is probably a local phenomenon. Spores of *Osmunda claytoniana* and *Osmunda regalis* are present.

The upper boundary of PAZ III is delineated at the level where the percentages of *Alnus, Corylus* and Quercetum mixtum decrease, and those of *Pinus* increase.

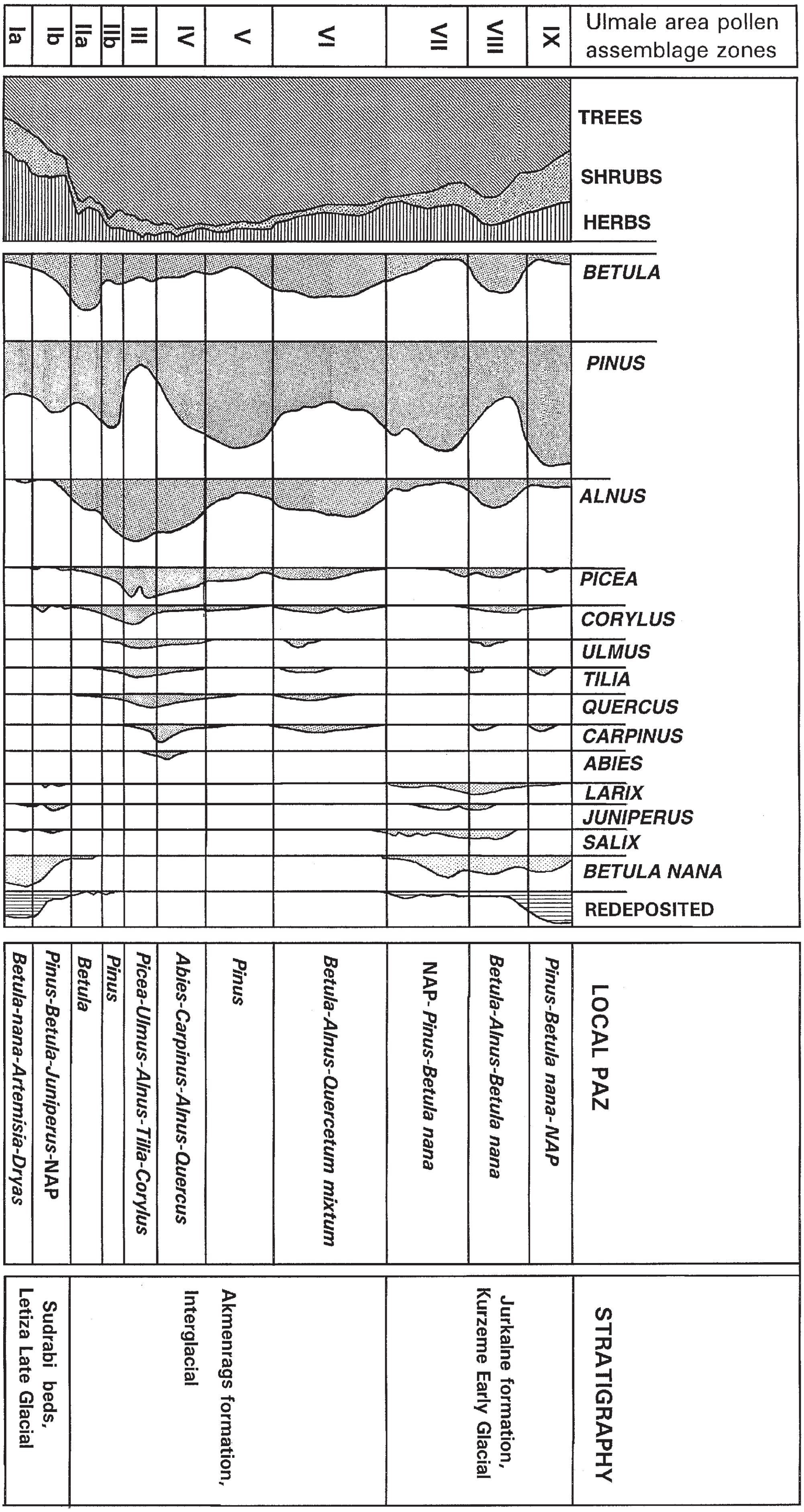

Fig. 2. Generalized pollen diagram of the Late Elsterian to Early Saalian sediments of western Latvia

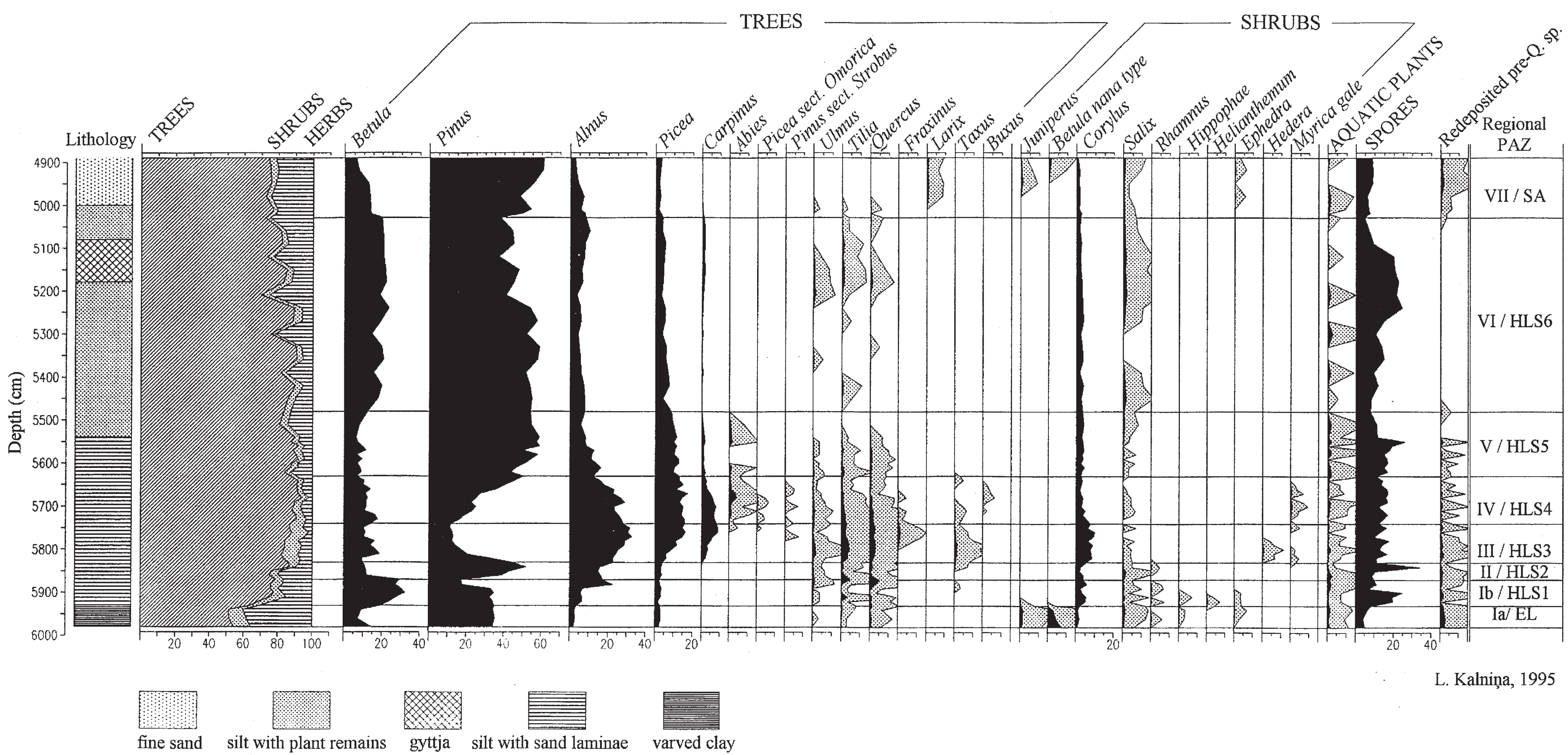

Fig. 3. Pollen diagram from the Ozoli site, reflecting vegetational development characteristic for the Akmenrags/Holsteinian Interglacial. Pollen percentages were calculated as Pollen sum =100%. Percentages of aquatic plants and spores were calculated from Pollen sum + the actual value of the microfossil =100%

***Abies-Carpinus-Alnus-Quercus* PAZ IV**. The role of coniferous trees increases, particularly *Pinus*, with *Abies (Abies alba* and *Abies* sp.) reaching its maximum. The percentages of *Alnus*, *Corylus* and broad-leaved trees decrease.

The upper boundary of PAZ IV is marked by the decrease of *Picea* and *Alnus,* and a significant increase of *Pinus* pollen.

***Pinus* PAZ V.** Palynomorphs decrease in abudance. Tree pollen is still dominant, but that of herbs, particularly Ericales and *Artemisia* increases. *Pinus* is the dominant tree with *Picea* decreasing , and *Abies* disappearing altogether. Even the percentages of *Betula* and *Alnus* decrease, and the presence of broad-leaved trees and relicts such as *Buxus* and *Pterocarya* is sporadic.

The upper boundary of PAZ V is determined by a decrease in *Pinus* and an increase in *Betula, Alnus* and herb pollen.

***Betula-Alnus-Quercetum mixtum* PAZ VI**. AP pollen decreases, while NAP increases, particularly Ericales and Cyperaceae. Among the trees, *Pinus* pollen decreases considerably, whereas *Betula* and *Alnus* pollen increases in abundance. Subarctic flora elements, e.g. *Dryas* and *Selaginella,* occur simultaneously with some broad-leaved tree pollen.

The upper boundary of PAZ VI, which coincides with the Akmenrags Interglacial/Early Kurzeme Glacial (Jurkalne deposits) boundary occurs where there is a marked a decrease in the total number of palynomorhs per 1 g of sediment and an increase in the representation of light demanding plants.

JURKALNE FORMATION (EARLY KURZEME/EARLY SAALIAN)

PAZ VII-IX are distinguished in the Jurkalne sediments, represented by fine to medium sand, less commonly by silt beds, containing plant remains.

NAP-*Pinus-Betula nana* PAZ VII. In the Akmenrags and Ozoli sections most of the sediments in this zone are sands, where palynomorphs are poorly preserved. *Pinus* dominates with some presence of *Betula* (mostly shrub types) and herb pollen, predominantly *Artemisia*.

***Betula-Betula nana-Alnaster*-NAP PAZ VIII**, corresponding to the silt interval overlying the sands, are relatively rich in palynomorphs with both pollen and spores being well-preserved. *Betula* pollen reaches its maximum and tree pollen becomes more species rich, with *Picea, Alnus, Larix* and occasional broad-leaved trees being represented. Among shrubs *Salix* forms a continuous curve. Herb pollen, domonated by *Artemisia* abunds, with Cyperaceae, Poaceae, Ericales and Chenopodiaceae also present in quantity.

The upper boundary of PAZ VIII coincides with the rise of *Pinus*.

***Pinus-Betula*-NAP PAZ IX**. *Pinus* pollen dominates, but *Betula* is also abundant and high values of Ericales and Polypodiaceae are characteristic. Though the poorly preserved pollens of *Picea, Carpinus* and Quercetum mixtum form continuous low abundance curves, so also do the Tertiary redeposited pollen, suggesting that all of them may have been redeposited.

DISCUSSION

Calcareous laminated clays deposited at the end of the Letiza (Elsterian) glaciation contain pollen suggesting the periglacial treeless vegetation of a subarctic climate on the adjoining mainland during the formation of the Sudrabi clays.

The pollen succession of the Akmenrags (= Holsteinian) Interglacial sediments suggests that the vegetation was dominated by pine and birch forest, with a gradually increasing incidence of *Picea, Alnus, Corylus* and broad-leaved trees. Climatic conditions during the Akmenrags Interglacial were favourable for the early immigration of *Picea* and *Abies.* The maximum extent of the *Picea* and *Abies* forest occured either before the climatic optimum or almost simultaneously with it. During the climatic optimum spruce forest with broad-leaved trees and an admixture of *Alnus, Corylus, Fraxinus* and *Taxus* was characteristic (Fig. 3). After the climatic optimum, in the late temperate stage, the values of *Carpinus* and *Abies* pollen increased. In the late temperate stage the pollen composition indicates a decrease in the incidence of thermophilous trees, suggesting gradual reductions in the temperature and precipitation.

The climate during the final phase of the interglacial was cooler that of the previous zone, but, obviously, with some short relatively warmer periods. This could help to explain the mixed vegetation of thermophilous and periglacial plants as indicated by the pollen in the sediments. Clusters of open forest were probably present in association with tundra vegetation.

The pollen from the Jurkalne Formation (Early Kurzeme, Early Saalian) shows elements of a subarctic flora. Open tundra-type vegetation was probably dominant on the land.

Pollen data from the investigated area were compared and correlated with the nearest contemporaneous interglacial pollen diagrams from marine sediments of the Kaliningrad District (Kondratiene & Gudelis 1983) and NW Europe (Erd 1970, Müller 1974, Ehlers 1983, Zagwijn 1992, Müller *et al.* 1995, etc.). The data have also been compared and correlate well with those from Hamburg-Dochenhuden (gho 4), where a complete Holsteinian sequence was recovered (Linke & Hallik 1993, Ehlers 1996). Therefore, the pollen data from the investigated area firmly demonstrate the existence of vegetation charasteristic of the Akmenrags/Holsteinian Interglacial as revealed by the marine sediments of the Holsteinian Sea in Western Latvia (Fig. 1).

CONCLUSION

The aquatic intertill sediments of western Latvia in the Ziemupe – Jurkalne area represent a lengthy non-glacial interval of the Middle Pleistocene. The pollen data prove that the vegetation in areas adjoining the sea during the Akmenrags Interglacial could be compared with that of the Holsteinian Interglacial. The Akmenrags Formation of marine intertill sediments, correlates with the Pulvernieki formation for continental sediments in Latvia and the Holsteinian Interglacial in NW Europe (Seglins 1987, Kalnina 1993, 1999, Dreimanis & Zelcs 1995). The pollen data suggest that the formation of the intertill sediments began in the late glacial episode of the Letiza (Elsterian) glaciation, and continued through the Akmenrags (Pulvernieki, Holsteinian) interglacial into the early part of the Kurzeme (Saalian) glaciation, taking in the first advance and retreat of the Baltic Sea. The data suggest three main pollen complexes, which reflect three different sets of climatic conditions:

1. A periglacial vegetation complex with relatively high frequencies of *Betula nana, Pinus* and herbaceous pollen, including a dominance of *Artemisia* and Chenopodiaceae.

2. Vegetation of a temperate climate as represented by PAZ II-VI, dominated by pollen of coniferous forest, with the following characteristics: the early appearance and significant values of spruce and the a simultaneous appearance of thermophilous deciduous trees, with the additional presence of *Abies*, *Picea* sect. *Omorica, Pinus* sect. *Strobus, Buxus, Osmunda claytoniana* and *Ligustrum.* An interglacial cool – warm – cool climatic sequence is suggested by the above pollen complex.

3. The pollen spectra from PAZ VII, VIII and IX suggest an open landscape vegetation, typical for cold arctic and subarctic early- or late- glacial climatic conditions.

The palynological data showing a pollen sequence characteristic for the Akmenrags/Holsteinian Interglacial, together with carpological (Cerina 1993) and palaeontological data (Danilans 1973, Seglins 1987), prove convincingly that the central part of the Baltic Sea basin was occupied by salt water during the Holsteinian Interglacial. The Ziemupe-Jurkalne area investigated is the most easterly one in the Baltic Sea basin in which marine Holsteinian sediments have been recognized.

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