ABOUT THE INTERPRETATION OF THE PALEOGEOGRAPHIC DATA

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ABSTRACT

Paleoecological reconstruction and the use of numeral modelling for estimating the influence of humans on natural geoecosystems, as well as compilation prognoses for describing the dynamics of complex landscapes are to be studied here. As a rule reconstructions are based on classical principle of actualism. In this article some additional principles to the method of actualism are formulated, which must be accounted for the interpretation of analytical data.

The last decades have witnessed a progressive increase in the influence of human activities, the anthropogenic factor, which along with natural processes, has lead to the development of the landscapes of today. Extensive fundamental studies are needed to distinguish between the consequences of these two influential processes in describing the state of a definite natural system and its development tendencies. Two main approaches may be used. The first is based on a comparison of the state of the studied anthropogenically affected landscape system or component, with an area similar in its natural conditions, but anthropogenically unaffected. This approach may give good results in case of certain landscape forms, but is limited by the difficulties of finding similar natural systems.

Scientifically more correct, but requiring considerably more work, is the approach based on the investigation of the development of the studied ecosystems. This approach foresees the reconstruction of the main characteristics of ecosystems under different environmental conditions (temperature, moisture, hydrological regime, biogeochemical matter cycle, salinity etc). Using paleogeographical data, it is possible to find a time interval in the past when the external conditions ruling in a given area were similar to the present ones. The paleobotanical and -faunistical material saved in the sediment complexes formed during that time interval allows us to reconstruct the biological composition and structure of the ecosystem. The chemical composition characterizes the biogeochemical matter cycle of the system under environmental conditions similar to the present ones. The chemical composition characterizes the background state of the given system, against which we can estimate the changes, characteristic of the actually existing ecosystems. The difference between the actually existing, and the hypothetic ecosystem, has been caused by the influence of human activities on the formation of the present system. The methodological scheme of studies is presented in figure 1.

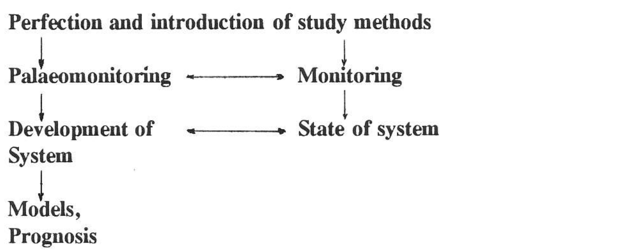

Fig 1. Principal scheme of numerical modelling of dynamics of geosystems.

Using the obtained reconstructions, it is possible to prognosticate the development of an ecosystem in case of certain scenarios connected either with climatic changes or human activities. Water level changes caused by either drainage of floods, changes in the physico-chemical conditions of environment when acidic or alkaline agents are added, changes in the oxygen regimen of water-bodies as a result of eutrophication etc, might serve as examples.

On the whole, such paleogeographical reconstructions and prognosis, as well as the widely used bio- and climatostratigraphic methods of dividing and correlating sediments are based on classical principle of actualism. At that, the principle of actualism is often viewed very narrowly, which inevitably leads to the comparison of disparate things, and from there on to artificial correlations or reconstructions.

The following presents some additional principles to the method of actualism, formulated on the bases of concrete examples.

The principle of cause-consequence adequacy

In all kinds of reconstructions we actually study the consequence evoked by a cause and saved in one way or another. However, quite often the result may be evoked by different causes or a complex of causes (fig 2). In paleoclimatic reconstructions, for instance, such sources of information as glacier dynamics, pollen spectra, change of the oxygen isotope ratio in calcareous sediments etc are usually used. Articles can often be met where all those data are being compared to prove that the past temperatures really varied in the indicated way. In fact, in all three cases we deal with rather complicated causes. Thus, in addition to temperature changes, the changes in the amount of precipitations and the circulation mechanism, displacement of ice masses etc are also important in the activation of glaciers.

Pollen diagrams indicate changes in the state of vegetation which, besides changes in the temperature, may also result from landscape development, hydrological regime, soil genesis, and so on. Delta ^{18}O variations in lake lime are determined by temperatures in the water body during the formation of lime (ie in summer), evaporation, circulation of water masses. So, on the whole, it is not recommended to compare mechanically the generalizations obtained by these methods as reflections of paleotemperatures.

The principle of similar natural conditions

Violation of this principle is evidently the most common one. It is typical that pollen diagrams are correlated in spite of the location or character of the

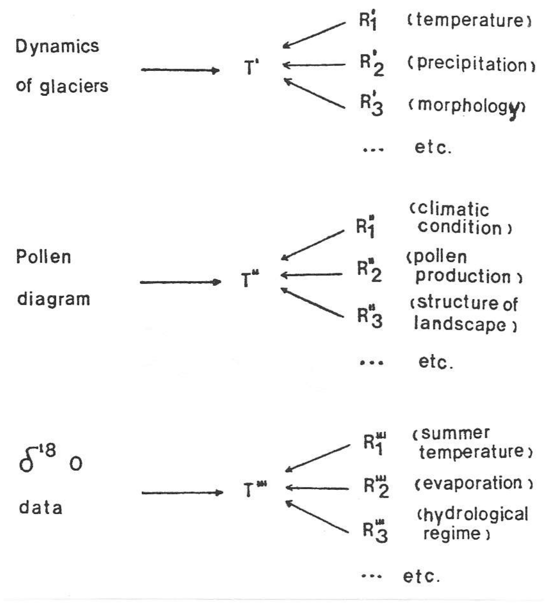

Fig 2. The same result may be evoked by different causes (R), what must be accounted in reconstruction of palaeotemperatures (T) using different sources of information.

object used in sediment analyses. It's clear that the objects compared should be located on landscape of similar type, in similar climatic conditions etc.

It's also very typical that this principle is violated in the geochemical study of landscapes. There are even cases in the literature when increases of SO_2 concentration in the atmosphere have been used for background in the analogical value above the Antarctic glacier shield as an area less of all influenced by human activity. No attention at all has been paid to the meteorological regime as well as the existence of natural sources of sulfur.

It is most important that this principle be followed while estimating the anthropogenic influence on any natural system. The essence of this principle is easy to understand depicting schematically landscapes as systems, the development and state of which are determined by the matter cycle and energy flow (fig 3).

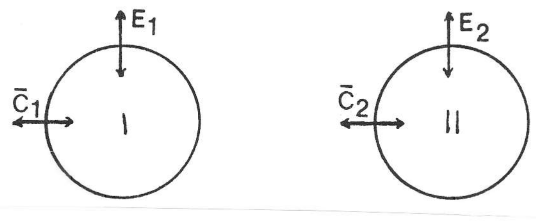

Fig 3. It is possible to compare only such systems, which have the comparable processes of matter cycle ($\bar{c}_1 = \bar{c}_2$) and energy flow ($E_1 = E_2$).

The principle of similarity of development tendencies

directly results from the previous one. It's not enough that the present conditions are similar. To apply the principle of actualism it is necessary that the systems should have undergone similar development to reach the current state (fig 4). The application of this third principle is very difficult as it presumes knowledge of the development tendencies of the system, which in many cases is the aim of the studies. However, success here may be achieved through cooperation of paleogeographus and stratigraphus.

A most vivid example of complicatedness is the correlation of the development stages of the Baltic Sea. Basing the correlations mainly upon such paleoecological indicators as changes of salinity and temperature, reconstructed either by faunistic or pollen analyses of the sediments, local schemes have been obtained which correlate badly between themselves. The confusion has evidently been caused by differences in the parameters of glacioisostatic uplift, which considerably change the state of local ecosystems.

The same reason also leads to the senselessness of interregional comparison of water level or precipitation regime reconstructed on the bases of water level changes in lakes. It also seems that some contradictions in the estimation of the extent of climatic optimum in various regions have been caused by the different changes of climatic conditions at the Ancylus Lake stage. Calculations indicate that at that time the Baltic Sea was totally covered by ice during the winters, which made the climatic conditions near the basin more continental. As the influence of the water body could not extend more than 50-100 km from the coast, the development of the climatic characteristics of the lake and marine stages differed in space.

The principle of hierarchic correspondence of external factors

This question is also reduced to the demand of comparing equal phenomena. As the development of natural conditions is determined besides global or regional factors also by the local ones, it's necessary to choose corresponding spatial systems for the description of processes of different levels (fig 5). For example, oceanic deep sediments from the equatorial zone are the most suitable object for the study of global climatic changes. On the level of hemi-

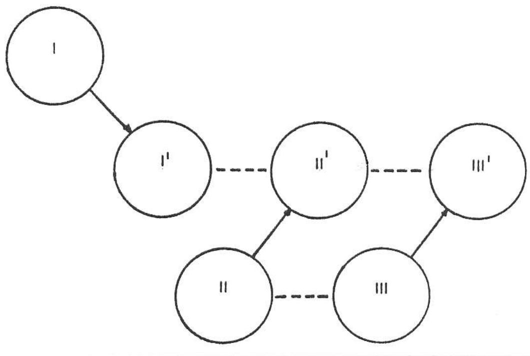

Fig 4. It is possible to compare only such systems, which have the analogous history of development (II'and III')

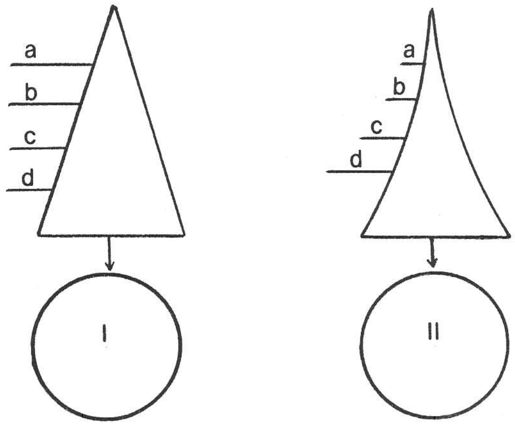

Fig 5. The development of systems I and II has been influenced by different hierarchic factors. In case I the global factor (a) is more important then in case II where the local factor (d) is dominating

spheres climatic conditions can be reconstructed, for instance, by the analysis of the Antarctic or Greenland glacier ice. At that, these reconstructions must not at all correspond to each other. Data on the glacier ice from Spitsbergen or Arctic Canada fit here still less, as the formation of their composition was considerably influenced by local factors.

Pollen from the Baltic Sea bottom deposits reflects mean changes in the development of communities in a big area. In addition to this the pollen spectra of samples from different sites reflect the peculiarities of the sedimentation process. Corresponding diagrams on the basis of sediments from a big bog massif or small kettle hole give and idea of the influence of areas of hundreds or a couple of square kilometers on the development of regional processes. Interpretation is considerably complicated by the long-distance-transported pollen, the share of which depends on atmospheric processes and structure of landscapes.

The above examples vividly show the necessity of complex approach in carrying out paleogeographical reconstructions and compiling prognoses. During the last years we have been trying to perform corresponding studies in NE Estonia, where numerous bogs and lakes can be found in the Kurtna Kames field. The program of the study of sediments consists of biostratigraphical, geochronological, paleobotanical, limnological, geomorphological, hydrological and geochemical investigations. We try to reconstruct the development of natural systems and to detect the mechanisms leading to the change of one or another parameter.

Based on the results we reconstruct the state of natural systems during the following time intervals: 8000 BP when the landscape structure had been formed in its main features, the migration of plant cover had finished; 5000 BP - the end of glacioisostatic uplift, the Holocene Climatic Optimum; 3500 BP the natural conditions were comparable to the current ones. The analysis of the cause - consequence relations allows us to find out the dominating factors important in the development of the landscape element. Comparison with the present day gives us an idea of the influence of human activities, and allows us to distinguish between the anthropogenic and natural factors. On the basis of correlative relations it is possible to prognosticate in landscape developments in case of different development scenarios.

Studying current processes and long-term developmental tendencies of different landscape elements (lake, fen, bog) in dependence on the changes of natural conditions it is possible to find the dominating processes influencing the development of corresponding geoecosystems, as well as the final result of their influence (tab 1).

These conclusions are based mainly on the comparison of geochemical parameters of current deposits with those of the deposits formed in analogous natural conditions (3500 BP) and in the changes of community and structure of different systems.

The annual amount of atmospherically imported elements, for example, has increased in general 10-1000 times during the last 25-30 years, which has led to the rise of their concentrations in the surface layers of raised bogs by 10-15 times. Raised bog ecosystems are degenerating in NE Estonia due to the increase of pH and mineralization.

As active infiltration of chemical elements into the depth of the deposit takes place in fens, it would be expedient to study the possibilities of using fens for the regeneration of waters with a certain composition (Punning 1990).

Table 1. Main factors of anthropogenic influence and their consequences on the state of natural systems of the Kurtna Kames field area

System	Factor	Consequence
Bog	Pollutant (minerogenic matter)atmospheric influx	Increase of mineralization Changes in community Changes in structure Degradation
Lake (closed)	Drop of water level	Increase of nutrient content Increase of trophicity Erosional processes Increase of O_2, seperation of H_2S Degradation
Lake (drainage)	Influx pollutants by water	Increase of pollutant content Formation of secondary pollution sources
Fen	Rise of water level	Increase of toxicant influx

References

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