The problems of the orbital theory of paleoclimate: new way for their solution.

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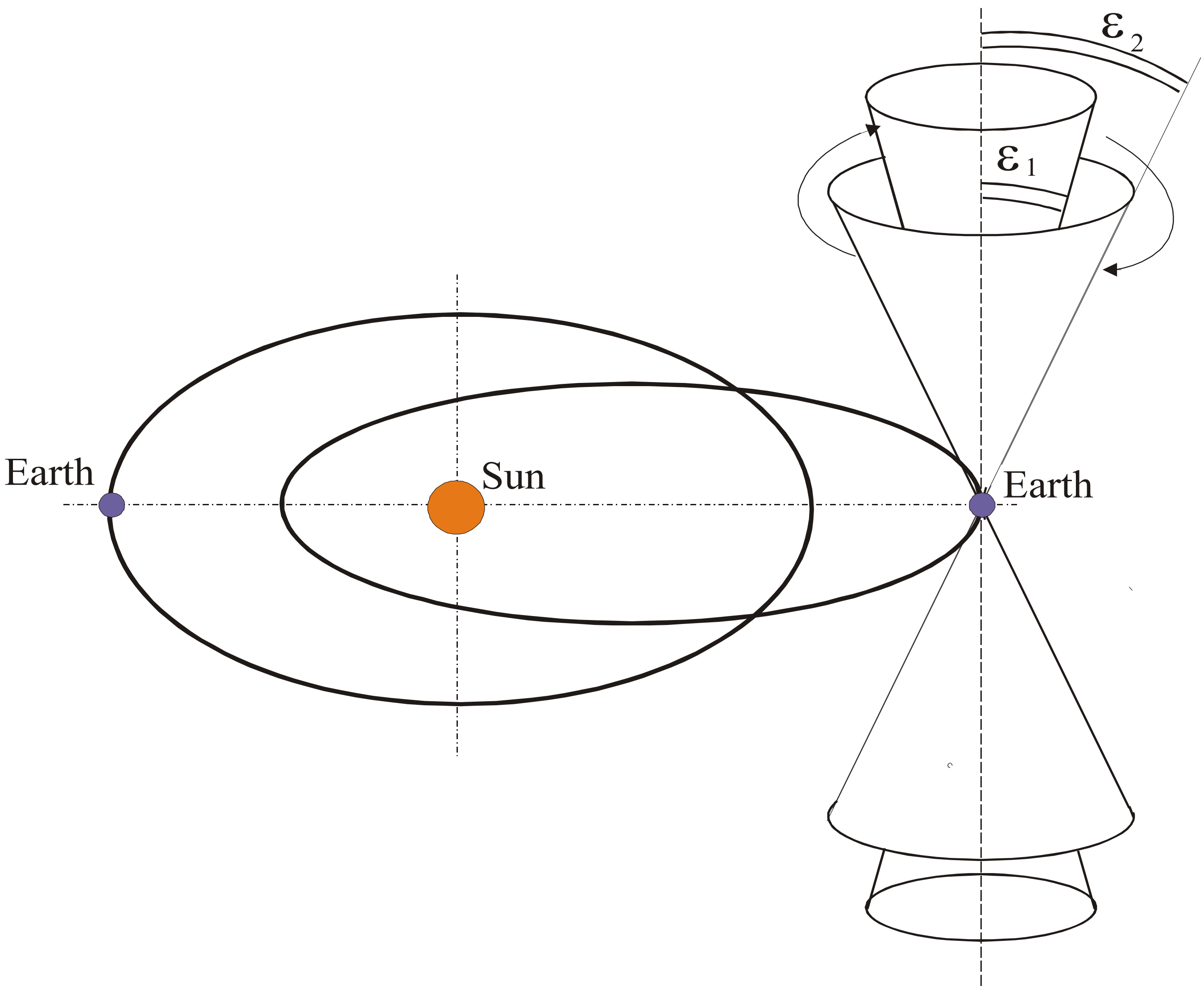

Fig. 1. Orbital elements of the Earth characterizing spatial variations in its orbit and direction of its axis. The elongation of the Earth's orbit is expressed by the eccentricity $e = \frac{\sqrt{a^2 - b^2}}{a}$, where a and b are the lengths of the semimajor and semiminor axes of the orbit ellipse. If the orbit is circular, $e = 0$ ($a = b$, the Sun is at the circle center). The oblateness of the ellipse is controlled by the length of the semiminor axis b, whereas the length of the semimajor axis is constant. So, the maximum limit of e is 1 (if b diminishes to 0). The decreasing of e leads to decreasing of the annual insolation of the whole Earth. The axial tilt ε (obliquity) varied from about 22° to 24.5° over the last million years. Variations in ε do not change the total annual insolation of the Earth but mainly redistribute it over latitudes. Thus, an insolation increase at high latitudes (as the angle ε increases) will be accompanied by its decreasing at the low latitudes, and vice versa. Decrease of ε results in a colder climate of the Earth, due to high latitudes albedo positive feedback. The arrow shows the precession of the Earth's axis in space. Precession changes the seasonal insolation contrasts between opposite hemispheres. So, if one Hemisphere climate is characterized by a relatively long cool summer and soft short winter, the other would be characterized by stronger seasonal contrasts: a long cold winter and a hot short summer, and vice versa. The yearly average variation of the precession insolation is zero *at any latitude*; i.e., an increase in the summer insolation is compensated for at any latitude by a decrease in its winter amount, and vice versa.

Spectral analysis of the oxygen isotope data of deep-sea cores, carried out by J. Hays, J. Imbrie, and N. Shackleton in 1976 supported the orbital hypothesis of paleoclimate, which proposed the connection of the global climate oscillations, such as glacial-interglacial cycles, with the Earth's orbital elements variations (Fig. 1). This hypothesis was suggested by J. Adhémar in 1838. Many scientists did their contributions in the elaboration of the orbital theory of paleoclimate (OTP) after that time. J. Croll (1864-1875) and M. Milankovitch (1930-1941) works are the most famous among them. Milankovitch theory is commonly adopted now as analogue of the OTP.

However, empirical data reveal considerable inconsistencies of the Milankovitch theory. The main of them are the following.

(1) The climatic cyclicity for the Brunhes chron is primarily governed by a 100 ka periodicity, attributed to eccentricity variations, whose immediate impact is disregarded in the Milankovitch theory.

(2) According to empirical data, glacial events fall on eccentricity minima, whereas under the Milankovitch theory these are mainly coupled to eccentricity maxima.

(3) About one million years ago, the dominant climatic periodicity switched from 41 ka to 100 ka, which is at odds with the Milankovitch theory, because the variation periods of orbital elements suffered no significant changes at that time.

It seems logical, that a theory, which contradicts to empirical data, is wrong. Consequently, the Milankovitch theory should be rejected, as was done with regard to it 50 years ago, as well as with regard to Croll's theory about 100 years ago. However, our predecessors turned out more consistent than our contemporaries in 1980s, who attempted to "modernize" the Milankovitch theory. One of the main points of the modernization was in using the monthly, or daily summer insolation at 65° N latitude, instead of half-year insolation used by Milankovitch. Such modernization created new contradiction between theory and empirical data – the inconsistency between the highest amplitude of precessional harmonic of the insolation forcing (monthly or daily

65°N insolation variations) and the lowest amplitude of the 23-ka harmonic of paleo-climatic $\delta^{18}O$ record (fig.2 a,b). (So, it may be assumed as a mirror reflection of the 100-ka problem in precessional band).

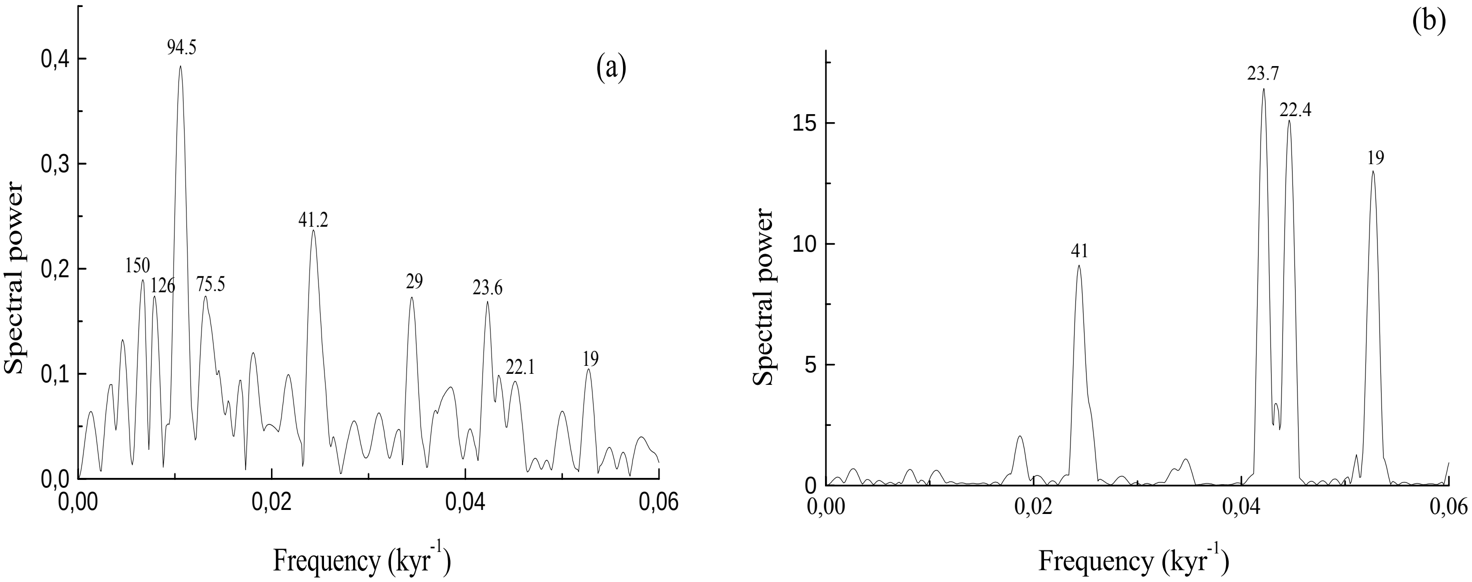

Fig. 2. Spectrograms of: (a) core MD 900963 oxygen isotope record for the last 910 kyr (raw data are from Bassinot et al., [1994]); (b) July 65°N insolation for the last million years (insolation values are from Berger and Loutre [1991]. The numerical values near peaks of each spectrogram denote the most important corresponding periods in kyr. The time scale for the oxygen isotope record was elaborated by the author [Bol'shakov, 2003].

However, the more logic way for solving the problems of Milankovitch theory is critical analysis of basic assumptions of the Milankovitch theory and exposing its main drawbacks, which should be taken into account in process of further work.

Here, I have to pay attention to the wide spread opinion among them who did not read attentively (or did not read at all) the publications of J. Croll and M. Milankovitch. They believed that it was Milankovitch who was the fist to suppose the connection between orbitally induced variations of insolation and global climatic oscillations. Such position often based on the pronouncement of J. Imbrie and K.P. Imbrie (1986): "Within a few years the international scientific community came to accept the basic tenet of the Milankovitch theory: that major changes in global climate – at least during the Pleistocene Epoch – were caused by orbitally driven changes in the earth's radiation budget". This pronouncement is not exact – that major changes in global climate were caused by orbitally driven changes in the earth's radiation budget – is the orbital hypothesis of paleoclimate; the last was the basic tenet of **the all versions** of the orbital theory developed by many predecessors of M. Milankovitch (J. Adhemar and J. Croll among them). However, it is well known, that, in spite of the same basic tenet the theories of Milankovitch's predecessors were refused. Consequently, when analyzing the Milankovitch theory, we should analyze the **peculiarities of exactly**

this theory, but not the orbital hypothesis, which validity was proved by the data of Hays et al. So, the Milankovitch theory should be regarded as one of the versions of the orbital theory in which calculated summer half years variations in insolation at 65° N believed to represent directly global climatic changes (glaciations and interglaciations) in the Northern Hemisphere for the last million years, i.e. the deepest minima of the insolation curve correspond to glaciations.

Such analysis performed by me, revealed

the next main drawbacks of the Milankovitch theory:

(a) In determining the paleoclimatic significance of rigorously *quantified* insolation oscillations, related to variations of a set of orbital elements, Milankovitch disregarded the *qualitative* differences between these oscillations. It is meant here that eccentricity variations force changes in the *annual* mean heat inflow to the *whole* surface of the Earth. However, obliquity and precession variations virtually *do not change the annual* insolation received by the *whole* Earth, merely causing energy redistribution through latitudes and between the seasons, respectively (see capture to Fig.1). These significant qualitative differences of insolation changes, forced by different orbital elements, were ignored in the Milankovitch theory. This circumstance alone suffices to discard the quantitative indices (calculated by Milankovitch in order to evaluate insolation changes) as being *a realistic* measure of global climatic impacts from variations of the respective orbital elements.

(b) The very technique of assessing the paleoclimatic significance of the variations in insolation incident on the upper boundary of the atmosphere, based on calculating these variations over particular caloric half-years and geographic latitudes, does not stand up under scrutiny. Indeed, one cannot reasonably assume that for a half-year insolation influences global climate, and for another half-year it does not. Likewise, it makes no sense to believe that insolation at a single given latitude governs global climate changes within the entire continuous and interrelated Earth climate system. The viability of this approach is further challenged by the fact already mentioned that half-year precessional variations of insolation, as well as insolation variations due to changes of the angle ε at high and low latitudes, occur in opposite phase.

(c) Another drawback is Milankovitch's failure to account for a set of diverse terrestrial feedbacks, or, more exactly, the fact that he accounted for them in a much less meticulous or mathematically rigorous manner (as compared to his calculation of insolation variations), and which he saw as being much less important than Croll did more than fifty years prior to him. (According to Milankovitch, the half-year insolation at individual latitude plays the decisive role in climate (temperature) changes. So, the changes in temperature at low latitudes should be similar to insolation changes, which driving by precession at these latitudes. In this way, because summer and winter "precession" insolations change in opposite phase, summer temperatures at low latitude should decrease, and winter temperatures should increase during glaciations; the opposite temperature changes should take place during interglaciations [Milankovitch, 1930]. However, according to empirical data, summer and winter temperatures changed in phase during global climate changes).

J. Croll was the first who took into account the positive terrestrial feedbacks, which amplified climatic influence of variations in insolation. In my opinion, his discovery is an outstanding achievement of theoretical paleoclimatology. According to Croll [1875], it is due to positive feedbacks, that the *annual temperature* of the hemisphere with an excessively long and cold winters, decreases – *in spite of hot summers accompanying long cold winters*. (Such seasonal contrasts take place, when the value of eccentricity is especially high, and driven by precession winter soltstice of the hemisphere under consideration occurred far from the Sun near aphelion).

Currently, the fact that feedbacks are prerequisite to transform weak insolation signals to global climate changes is acknowledged commonly. The well-known example of the common acknowledgment of the positive feedbacks importance is the wide discussed problem of the climatic influence of greenhouse gases. (Moreover, some researchers believe that there may exist independent, not forced by insolation, *self-sustained* oscillatory global climatic processes governed by feedbacks through interactions in the system ocean–land–atmosphere–cryosphere).

It is common knowledge that there exist different terrestrial feedbacks, some of these being not only *positive* (due to albedo changes following changes in the volume of ice and snow and vegetation cover of the planet or changes in the atmospheric content of greenhouse gases), but also *negative*, e.g., due to strengthening of circulation in the atmosphere, tending to reduce the longitudinal temperature gradients, which increase during glaciation events.

There are good reasons to assume that these types of feedbacks exert different relative influences on orbital signals, caused by variations in individual orbital elements. Thus, the positive feedback controlled by albedo changes (primarily at high latitudes of the Earth) will most likely provide the strongest amplification for the insolation signal due to variations in the axial tilt, whose largest relative changes are also related to high latitudes. Changes in the rate of atmospheric circulation, involving changes in temperature gradients between high and low latitudes, would likely exert the most influence (negative feedback) on the same insolation signal. The feedback induced by oscillations of the atmospheric contents of greenhouse gases is most likely to exert the strongest influence (relative to the other orbital signals) on the *direct* (not connected with precessional modulation) eccentricity signal, changing the annual mean insolation of the whole Earth. Nevertheless, the strongest feedback influenced the obliquity and eccentricity signals in the Pleistocene, is connected with albedo of snow and ice cover. The less clear mechanism of precessional influence on global climate, associated, in particular, with paleomonsoons, may have a regional rather than a global significance, and, hence, it may exert its specific influence through terrestrial feedbacks on the precessional insolation signal.

Therefore, the linear amplification of insolation signals, postulated by the Milankovitch theory, is not grounded well enough. This is further evidenced by the fact that Milankovitch's followers had to adopt, to be consistent with empirical data, the mechanism of "non-linear amplification" for the eccentricity-induced insolation signal. Furthermore, the same set of empirical data suggests the absence of the linear amplification postulated by these authors for those insolation changes due to variations in the axial tilt and precession as well. Thus, the insolation curve of Milankovitch, and, especially, of Berger and Loutre for 65°N show that the dominant contribution comes from precession, whereas the 41-ka component, attributed to the axial tilt, prevails over the 23-ka one in the most proxy paleoclimatic records (see: fig 2 a,b). For these reasons, it was concluded by me that mechanisms of amplification are neither "linear" nor "non-linear", but "individual" for each orbital element variation.

A rigorous account for a variety of feedbacks is thus among the pivotal prerequisites for elaboration of the orbital theory of paleoclimate. *It is precisely by taking into account how these feedbacks operate through time and space that one can solve the problem of zero annual mean insolation changes (related to variations in the axial tilt and precession) over the entire Globe.* This would require developing a realistic and accurate mechanism for climatic influences from variations in *each of orbital elements*, primarily precession.

Table. "Values of the orbital parameters and 65°N June insolation (in Wm^{-2}) used in…" (according to Loutre and Berger, 2000, Table 2)

	Eccentricity	Perihelion	Tilt	Insolation
Cold orbit	0.07	Winter solstice	21.50°	403.2
Cool orbit	0.04	Winter solstice	22.45°	440.9
Present	0.016724	4 January	23.45°	477.6
Warm orbit	0.04	Summer solstice	24.45°	554.2
Hot orbit	0.07	Summer solstice	25.00°	602.3

It should be noted, that the *idea that precession is the main driver for global climate change,* has been developing by Adhémar, Croll, Milankovitch and his present adepts over a period of 150 years. The paper of Loutre and Berger (Geophys. Res. Lett. V.27, No.6, 2000) may be referred as an example of this idea. The scheme of the influence of orbital parameters on the Earth's climatic conditions is putting in their paper (see table). According to this scheme, the highest value of the eccentricity (0.07) is consistent as with cold, so with hot climate conditions.

However, this is not right. According to well-known paleoclimatic data [Hays et al., 1976; Johnson, 1982; Imbrie et al., 1993], glaciations of the last million years are consistent only with low values of the eccentricity. High values of eccentricity are correspondent to interglaciations.

Thus, the idea that precession variations were the main driver of the Pleistocene global changes appears to be wrong also, because it is not supported by paleoclimatic data. For this reason, the increased attention to the climatic influence of the mean annual obliquity insolation, paid in publications of Paillard (2001), Raymo and Nisancioglu (2003), Loutre et al. (2004), Huybers and Wunsch (2005), has been justified. It would be well then, if the attention of investigators would concentrate not only on the obliquity, similarly to the past situation when only precession assumed to be the main driver of global climatic changes. There are all reasons to hope that understanding of necessity of taking into account the changes in all orbital elements insolation and corresponding feedbacks comes before the end of the 21st century.

It should be noted that *semiquantitative scheme of global climatic dynamic (paleoclimatic curve) may be constructed without calculation of insolation variations* [Bol'shakov 1998-2003]. A simplified approach to constructing a paleoclimatic curve draws on commonly accepted qualitative mechanisms for the forcing of climate oscillations by a set of orbital elements, assuming that cooling is caused by (a) a decrease of the eccentricity e of the Earth's orbit, (b) a decrease of the tilt angle of the Earth's axis ε, and (c) an increase of the relative distance between the Earth and the Sun, as expressed by the value of precession index $e \times sinw$ (where w is so called *longitude of perihelion measured from the moving vernal equinox*), in the summer in the Northern Hemisphere. The curves showing the changes of all three orbital elements over the last million years, plotted so that their minima correspond to cooling events (by taking $e \times sinw$ with a minus sign). It is sensible to assume that time intervals when the integrated variations of all three orbital elements are the lowest will fall on glacial events. However, before adding all three curves in order to find these integrated minima, the curves should be normalized, because their variation amplitudes are different. As a result, each normalized curve for a varying orbital parameter will plot within ± 1 on the ordinate axis, with negative values, as agreed at the beginning, corresponding to cooling events. Then, a different climatic significance coefficient was attributed to the normalized variations of each particular orbital element.

This was performed in compliance with empirical paleoclimatic data, which suggested that different periods of climate changes had different amplitudes (intensities) of these changes. The most marked climate changes of the last million years have a periodicity of ca. 100 ka, which is ascribed to eccentricity variations. This is the reason why the largest climatic significance coefficient, equal to 1, was adopted for the eccentricity curve. Climatic significance coefficients for the other two orbital elements were found by trial-and-error so that to achieve the best fit between the resultant integrated curve and those available reliable oxygen isotope (OI) curves that have a sufficient resolving power, and which currently provide the most trustworthy records of global climate changes. These coefficients proved to be 0.7 for ε and 0.4–0.55 for ($-e \times sinw$). The integrated curve thus obtained (Fig. 3), called the "orbital climatic diagram" (OC diagram) [Bol'shakov, 2000; 2001], represents an expected climatic effect from insolation variations related to all three orbital elements, or, in other words, the conventional relative probability ΔP of cooling (for negative ΔP) and warming (for positive ΔP). We interpret the deepest ΔP minima as matching probable glaciations. The best match between the glaciations of the oxygen isotope curve and the OC diagram is achieved at $\Delta P \leq -0.5$ (Fig. 3). Note that the OC diagram is, by and large, a *theoretically* constructed diagram, inasmuch as its creation draws on (a) the general theoretical mechanisms of global climate effects of variations in orbital elements, (b) theoretical calculations of these variations [Berger and Loutre, 1991], and (c) the theoretically validated possibility that the climatic significance attributed to the variations in individual orbital elements are considered in a different way than in the Milankovitch theory.

Comparison of the OC diagram and oxygen isotope curves shows a rather good fit, especially for OI stages 1–5, 7, 12–15, and 17 (Fig. 3). All but one glaciation event (matching oxygen isotope Stage 6) over the last million years can be identified. Noteworthy is that the OC diagram maximum matching the 19^{th} oxygen isotope stage falls between 770 and 790 ka, in good agreement with the new age determination for the Matuyama–Brunhes magnetic reversal, which passes inside the 19^{th} OI Stage.

Apparently, there are some misfits between the theoretically constructed OC diagram and oxygen isotope curves. The most distinct ones are (a) the mismatch of the OCD minimum between 190 and 140 ka and OI Stage 6 glaciation and (b) the mismatch between the low value of the OCD maximum at ca. 410 ka and the high peak on the OI curve, identified as the 11^{th} OI stage. These discrepancies are most likely due to the eventual self-sustained oscillations, mentioned above, in the system cryosphere–hydrosphere–lithosphere–atmosphere [Bol'shakov, 2000], considered by many researchers. Assumedly, the period of these oscillations may be ca. 100,000 years. These oscillations, forced by insolation variations and associated primarily with the waxing and waning of glaciers and the World Ocean temperature, in view of their enormous inertia, may have changed the amplitude of global climate oscillations and, to some extent, possibly stabilized this amplitude relative to the amplitude of the forcing insolation signal—in particular, for oxygen isotope Stages 6 and 11.

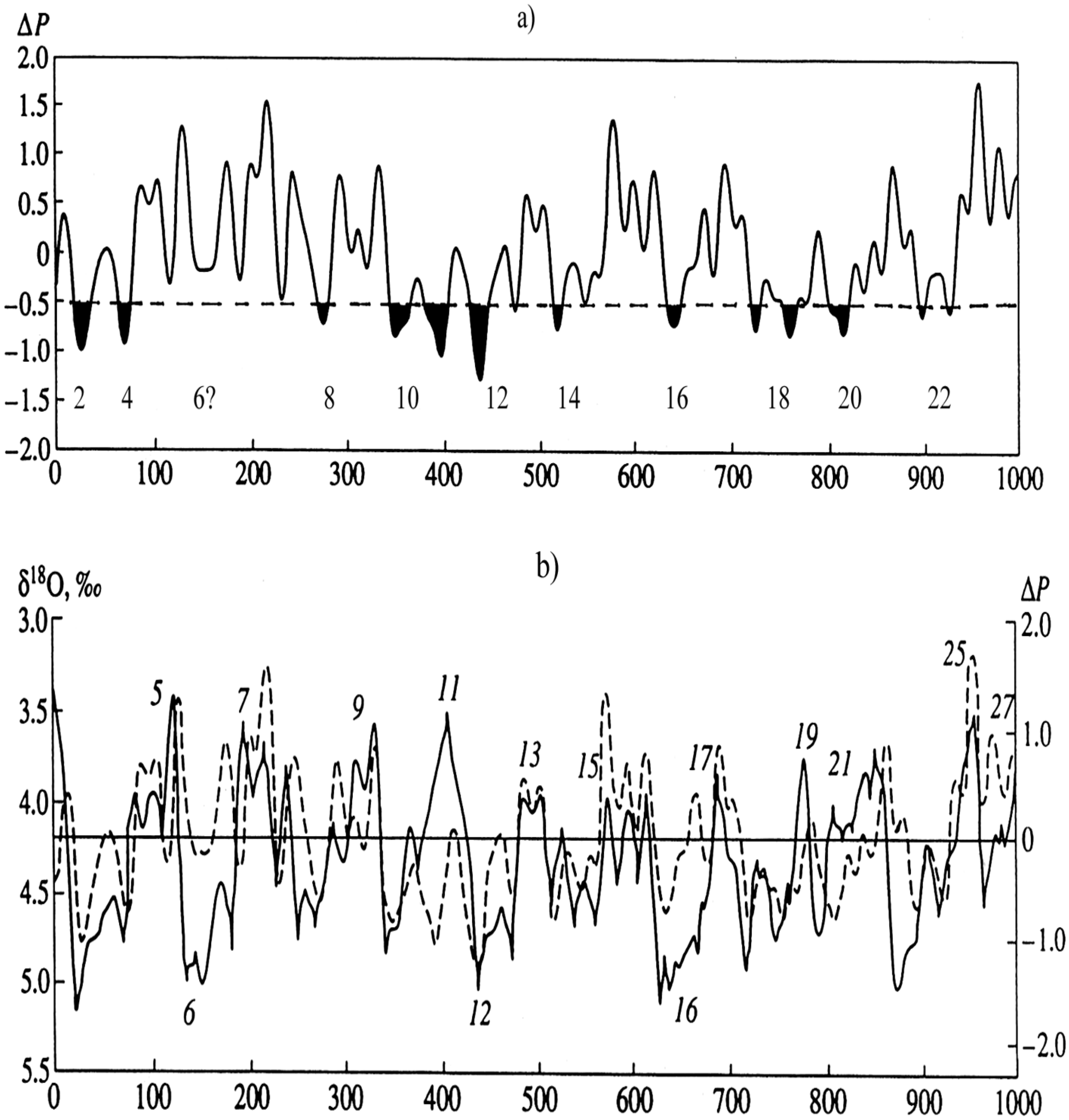

Fig.3. (a) The orbital climatic diagram (OCD) constructed for the ratio of climatic coefficients 1:0.7:0.55. Shaded area with ΔP<-0.5 are interpreted as periods of the most probable glaciations. The numbers near shaded areas denote the corresponding oxygen-isotope (OI) cold stages. (b) Comparison of the OCD (the dashed line) with the OI curve of Shackleton (1995). The OI record is represented by the SPECMAP scale in the 0÷620-ka interval and further by column 677. The figures above and below the OI curve represent the numbers of OI stages. The abscissa shows time (kyr B.P.).

The changes of global albedo may be the base of a simple qualitatively explanation of the dynamic of the whole Phanerozoic climatic changes characterized by the orbital periodicities.

For instance, mid Pleistocene transition may be connected with so called parametric resonance mechanism. According to this mechanism, the changes of external conditions cause the changes in the parameters of the system into account and its resonance frequencies. In my terms, the change in external conditions is the unidirectional cooling in the time interval from 2 to 1 Ma, which set in as early as the Eocene. This must have led to a change in the volume of high latitude glaciers and, consequently, to a change in their inertia. The likely mechanism of change in the rhythmicity of climate oscillations at 1 Ma may thus be presented as follows.

Prior to 1 Ma ago, ice volume was not large enough, and the planet surface temperature not low enough, to ensure ice growth to dimensions comparable to the Pleistocene sheet glaciation. Hence, the change in the volume of glaciers clustered at high latitudes was governed by a relatively short period forcing from the axial tilt, in accordance with the empirically discovered, 41 ka periodicity of this change. Long-period forcing from eccentricity variations and its related global oscillation of the planet temperature proved to be too weak to cause the waxing of ice sheets. This is the reason why the corresponding 100-ka period variations were not pronounced in climate records of this time interval. Over time, with progressive global cooling, glaciers kept growing as well.

Conceivably, at 1 Ma the planet surface temperature and the mass of glaciers at high latitudes became critical with respect to the influence from insolation changes, forced by eccentricity variations. In this case, the "eccentricity forced" temperature drop was sufficient to prevent glaciers that propagated from high latitudes from melting at lower latitudes. On the other hand, with increasing mass and area of glaciers, positive feedbacks due to albedo and the atmospheric content of greenhouse gases also increased, in turn to boost the advance of glaciation; naturally, the time constant of glacier waxing and waning increased, too. In my opinion, it was the interplay of these three factors that determined the new glaciation periodicity for the last million years. Therefore, the dynamics of development of global glaciations over the last two million years has been mainly determined by a combined impact from eccentricity and obliquity variations, amplified by the influence of positive feedbacks, modulating the general trend of global cooling. (Similar mechanisms for the "mid Pleistocene transition," calling for a global increase in ice volume as a principal factor, were proposed by the other researchers as well. However, these mechanisms do not invoke as decisively the governing role for the insolation signal forced immediately by eccentricity variations).

According to above simple scheme, further increase in ice volume will result not only in glacier expansion, but also in an increased period of glacier oscillations. Therefore, an eventual expansion of the global glaciation should involve a climatic manifestation of a longer, 400-ka eccentricity cycle, which has not occurred for the past 2 Ma. It is such the case, that was supported by the published data suggesting that the maximum phase of the Permo-Carboniferous glacial age was characterized by the 400-ka climate cyclicity of the World Ocean level [Heckel, 1986; Veevers, Powell, 1987]! (It is common knowledge that the Permo-Carboniferous Gondwanan glaciation was vaster than the Pleistocene one, reaching as far south 30°S latitude.) Hence, these data can be taken to support the here proposed mechanism linking insolation oscillations forced by variations in the axial tilt and eccentricity, changes in the ice sheet volume, and the cyclicity of ice waxing and waning.

The above suggests an exclusive role for the ice sheet volume (and albedo feedback) in how the orbital periods of insolation variations manifest themselves in climate cycles. Hence, the lack of ice should bring about essentially different climate oscillation mechanisms. Assumedly, contrary to many researchers' opinion, *the direct forcing of eccentricity and obliquity variation during the thermal ages* (or when global ice volumes are essentially smaller than in the Pleistocene) *will be absent in paleocli-*

matic records. This inference is further supported by the largely empirical data. Thus, the Mesozoic, the Eocene and Miocene have mainly 23-ka (precession) climate oscillations, modulated by eccentricity variations. No independent manifestations of the other orbital cycles have been recorded. The conclusion of Herbert and Fisher [1986] about the direct manifestation of 100 ka eccentricity variations in the Cretaceous sedimentary records is most probably a mistake of interpretation, as was shown by the author [Bol'shakov, 2003].

CONCLUSION

The analyses of the historical development of the orbital (astronomical) theory of paleoclimate let us to receive some results, many of them are not yet commonly adopted. It has to be stated that the creation of the orbital theory of paleoclimate is far from being complete, despite the efforts of many generations of researchers over the past century and a half. The Milankovitch theory is merely a version of the orbital theory of paleoclimate, each existing version having its own concept, its advantages and drawbacks, and, as it turned out, considerable inconsistencies with empirical data.

The main problems of the modern versions of the orbital theory are the problems of the "100-kyr periodicity" and "mid-Pleistocene transition". Solving of these problems needs to have clear notions about transformation of the input signal (orbitally driven variations in incident insolation) into output signal (time series of climatic indices). However, up to now there are different opinions about the composition of the input signal, which is used for paleoclimatic modeling, or for interpretation of paleoclimatic data. The majority of authors use monthly or daily insolation at 65°N for these purposes. In other words, they disregard the qualitative difference between insolation signals of different orbital elements. It should be noted also that the potentiality of feedbacks transforming the insolation signals into global climatic changes are learned very poor. Some authors don't take into account the negative feedbacks in the Earth's climatic system. The primacy and power of the greenhouse gases feedback are widely debated up to now.

It has also been shown that widely used insolation curves for individual latitudes and half-years, let alone months or days, taken individually, bear no paleoclimatic implications and are of no use to paleoclimate modeling.

Forecasting global climate change based on paleoclimate models where the input signal is a monthly let alone a daily mean insolation incident on the upper boundary of the atmosphere at a single arbitrarily chosen latitude (usually 65°N), would hardly make sense. This is because creating a paleoclimate model involves establishing the mechanism for transforming the input (insolation) signal to the output signal. However, the input signal in this case *does not fully reflect* the changes in the solar radiation incident on the Earth and *really* influencing the Earth's climate. Hence, a mechanism for transforming an inadequate input insolation signal to real climate changes would itself be inadequate.

It may be concluded also, that the calculations of orbitally caused insolation changes, as performed by Milankovitch, *outstripped their time*. Making a full use of these calculations requires a steadfast identification and validation of the concrete mechanisms for transforming orbitally forced insolation variations to global climate changes. In this way I see the solving of the modern problems of the orbital theory of paleoclimate.

Our considerations indicate quite unmistakably that the total insolation change resulting from variations in all three orbital elements determines the cyclicity and trend of climate changes, while the cycles themselves (i.e., the shape of the empirically obtained paleoclimatic curves) are mainly determined by the mechanisms of influence from various feedbacks. The set of these feedbacks and their influence may change through time and space.

So, constructing a rigorously quantified model would require taking into account time- and space-continuous insolation changes (i.e., such as could be calculated following the Milankovitch method, but additionally integrated over the year and over all the latitudes), while also accounting for terrestrial feedbacks, which can be of either a global or regional character. It is only by using these really globally operating factors that one may quantify the degree of global climate forcing from variations in orbital elements and the various feedbacks. In particular, this applies to variations in albedo of the Earth surface and in the atmospheric concentration of greenhouse gases, which is currently a burning issue to the forecasts of global climate change.

Elaboration of the paleoclimatic model consistent with this idea is a very difficult problem. However, this way of investigating the mechanisms of the past global climatic oscillations seems to be the only logical and consistent one. Our consideration let us to propose an internally consistent overview of climate oscillations (ranging in period from several tens to several hundreds of thousand years) not only for the Quaternary, but also for the older geological periods of the Phanerozoic.