The Gravitational Power Originating the Earthquakes and the Dansgaard-Oeschger Catastrophic Events

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Abstract

The planetary Gravitational power, derived from the *pushing gravity* in the frame of the Micro-quanta paradigm, opens new insights on the physics of solar planets. It has been observed in the past that the infrared internal emission from the giant solar planets is much higher (7-10 times) than the emission of bodies cooling in space. This agrees with the predicted Gravitational power, which in the case of the Earth results about 60 times the classical heat flow estimated through the temperature gradient within the continents. This bias points out once again the problem of the high terrestrial seismic activity that can hardly be attributed to the thermal stresses produced by the classical heat flow crossing the crust. The new Gravitational power is able to explain both the seismic activity and the oscillations of the surface temperature, such as the rapid warming named Dansgaard-Oeschger events, which are recorded from 11.500 yr up to 45.000 yr B.P. in the Ice-cores obtained by drilling in Greenland and Antarctica. In the long term these temperature oscillations combine with the Earth's radiation cooling to originate the Glacial Eras lasting about 100,000 years.

Keywords: Pushing gravitation, Gravitational power on planets, Planetary physical evolution

1. Introduction

Before the Modern Era the cause of the earthquakes was attributed to some volcano's eruptions, mountain slides, collapse of natural caves, etc. When the Earth became considered as a sphere with hot viscous core and a thin solid crust, which transmits tensile and shear stresses, some intuition arose about the linkage between hot mantle and crust about the origin of earthquakes. After the tragedy of the 1906 S.Francisco earthquake, Henry F. Reid explained that the earthquakes are due to rock's deformation, which suddenly fractures generating vibrations due to the elastic energy accumulated ("elastic rebound"). R.Mantovani, a precursor of modern geophysics, wrote in 1889 that the fractures of the crust were due to the Earth's expansion which was probably responsible (Mantovani, 1909) for the removal of continents. This idea was developed by Alfred Wegener in the theory of "continental drift", whose final version was published in English (Wegener,1924) some years before his death. However only in the '50s the discovery of the mid Atlantic Ridge revealed the seafloor spreading that originates the removal of continents. More recently many seismic submarine faults have been discovered which delimit several "plates" on the crust. This gave rise to the theory of *plate* tectonics, where plates undergo slow motions that produce earthquakes due to friction between them. However plate tectonics encountered adverse arguments by S.W.Carey, which gave rise to the renewed hypothesis of "expanding Earth" in the book bearing the same name (Carey,1976). In a further book Carey pointed out that the expansion implies the additional hypothesis of an increasing planetary mass.

This is only a brief and incomplete commentary in homage to the pioneers of geophysics. Notwithstanding the efforts, the knowledge of our planet is still unsatisfactory. Today science has taken the observations to the frontier of the Universe, but the physics of the planet under our feet remains somewhat mysterious.

The advances of seismology suggested that the most important cause of earthquakes resides on the high thermal gradients within the crust, which produce differential expansion of the rocks with consequent sudden fractures emitting elastic waves. Thus the seismic activity shows an energetic counterpart due to the passage across the crust of some thermal power, as it is confirmed by the temperature gradients (equal to about 28°C/km on the average) measured in boreholes within the *continents*. It is conceivable to calculate, assuming the heat conductivity measured for various rocks, the heat flow escaping from the continents. Assuming tentatively that

the heat flow by conduction holds also for the ocean seafloor, classical calculations showed a total thermal power from the Earth $P \approx 4.4\times10^{13}$ watts (Stein C., 1995).

However the assumption about the oceans appears unreliable because it neglects the completely different heat transfer conditions due to the hot magma escaping from the seafloor through new fractures signalled by frequent earthquakes. This explains the dynamic behaviour of the crust which appears *everywhere* remarkably seismic. The US Geophysical Service data show about 8 earthquakes per day, mostly under the oceans, with Richter magnitude not less than 4. Then the thermal power has to take into account the high heat transfer between the hot magma and the oceans. The evidence of a higher thermal power escaping from the planet puts the problem of individualising the proper internal heat source. So, it appear necessary to point out physical phenomena that imply planetary power emissions well beyond the classical heat flow due to both the cooling of a hot body in space and the heating due to radioactive nuclei decay.

2. Effects of the new Gravitational power on the Earth

In a preceding paper (Michelini, 2010a) it has been found that as the cold Bok's globules, that give rise to young stars, also the planets receive a gravitational power from the interaction between particles and the Micro-quanta flux that is assumed to fill the space according to this new physical Paradigm (Michelini, 2010b).

Some few words about the new physical Paradigms. The most significant considerations on these physical tools have been expressed by Thomas S. Kuhn: <<*Revolutionary changes involve discoveries that cannot be accommodated within the concepts in use before they were made*>>. Most of Kuhn's epistemological thought may be found in the book "The Structure of Scientific Revolutions" (T.S.Kuhn,1962).

Any new paradigm have to fulfill the Principles of physics, but its *proof* comes from plane explications of some unsolved phenomena. The paradigm of Micro-quanta has been extensively adopted (Michelini, 2010b) to explain several phenomena yet unsolved, as well as some theoretical problems which arise from the inadequacy of the current paradigms to give the physical basis of both the inertial forces and particle masses.

The old paradigm of Newton's gravity produces some unphysical concepts such as the unlimited gravitational collapse, a situation in which the laws of physics do not hold. This inconvenience vanishes in the new *quantum gravitation* theory (Michelini, 2010b) named "pushing gravity" to distinguish from the Newton's "pulling gravity" that relies (as well as General relativity) on the concept of "gravitational mass". Let's now recall the gravitational power given up to planets (Michelini, 2010a)

$$P_{gr} = 2.95\times10^{-9} G\, c \int_0^R 4\pi\, r^2 \left\{ \delta^2(r) / \left[T(r) A(r) \right]^{1/2} \right\} dr \tag{1}$$

due to the energy transferred towards dense matter by the collisions with micro-quanta. The Earth gravitational power results about $P_{gr} \approx 2.6\times10^{15}$ watt. About 99% of this power is generated within the *fluid* core (i.e. Fe-Ni core plus mantle), producing a small temperature rise during the time Δt (years)

$$\Delta T_{in}(t) = 3.2\times10^{7}\, P_{gr}\, \Delta t / C_p\, M_{in} \approx 1.73\times10^{-5} \Delta t\ ^{\circ}C \tag{2}$$

where $C_p \approx 800$ J/kg°C is the core average specific heat and $M_{in} \approx 5.9\times10^{24}$ kg is the core mass. The above model takes into account that the heat internally generated cannot flow by conduction across the crust wall because the temperature gradient within the crust does not practically vary during million years. However the gravitational internal heating is able to produce a non negligible expansion of the core volume V_o

$$\Delta V_o(t) = 3\, \alpha_c\, \Delta T_{in}(t) V_o = 5.19\times10^{-5} \Delta t\, \alpha_c\, V_o \tag{3}$$

where α_c is the expansion coefficient of the fluid core. The increased volume $\Delta V_o(t)$ pushes on the crust, expanding elastically its radius till the stress within the rocks reaches the tensile strength σ_*. Considering the small thickness of the crust, the expansion produces an average tensile strength σ_* within the *effective* cross section of the crust. Correspondingly the elastic expansion of the crust volume V_{Cr} reaches the critical value

$$\Delta V_* = 2\, (\sigma_* / E)\, V_{Cr} \tag{4}$$

After how much time the stress attains the tensile strength? The fragmentation of rocks occurs at time $\Delta t = t_*$ when the increased core volume $\Delta V_o(t_*)$ equals the critical crust expansion ΔV_*

$$\Delta V_o(t_*) = 5.19\times10^{-5}\, t_*\, \alpha_c\, V_o = 2\, (\sigma_* / E)\, V_{Cr.} \tag{5}$$

Since stresses grow gradually, fractures will first take place where the stress reaches the local tensile strength. Because the rocks floating on the mantle are similar between them, their tensile strengths may be put equal to the average value $\sigma_* \approx 10^7$ N/m^2 shown by Jeffreys. It is then conceivable that the fragmentation gives rise to magma escaping primarily from the seafloor, thus warming the oceans and the solid crust within a "short " period of time.

Putting in eq.(5) the volume ratio $V_o/V_{Cr}=108$ and recalling the expansion coefficient $\alpha_c \approx 2\times10^{-5}$ of the hot core constrained within the crust assumed by Jeffreys (1970), one gets

$$t_* \approx 10^7 / 560 \times 10^{-10} E \tag{6}$$

Assuming the elasticity modulus of the rocks at Mohorovic's depth equal to $E \approx 1.2\times10^{11}$ according to K. Bullen (1963), one obtains the time $t_* \approx 1488$ yr. Considering an uncertainty of about 10% both in the expansion coefficient and in the average tensile strength, the time t_* agrees with the periods comprised between 1200 yr and 1700 yr, as recorded in the Ice-core (Fig.1). The figure of 1500 yr is the typical period attributed in the literature to the Dansgaard-Oescher events (Dansgaard et al., 1989).

3. The heat flow produced by an internal heat source

Let's recall that the Mohorovic's discontinuity is about 40÷60 km under the continents, whereas under the oceans it is about 6÷12 km. This may explain why fractures frequently appear on the seafloor. Though the classical calculations of planetary heat flow consider only the heat received by conduction from the seafloor, it is nevertheless a common opinion that this contribution is high. Considering for instance the average contributions of insolation and atmospheric agents in Antarctica, it has been shown that the *basic* temperature (Michelini, 2010a) of the site Vostok was in the past about 200 °K, that is near the average annual temperature (209°K) measured in that place during the last decades. The ice-core recorded temperature oscillations have to be added to this temperature. Any region/latitude on the Earth has its basic temperature which undergoes oscillations due to climatic perturbations as well as to an internal *generation* of heat. Since the Greenland GISP2 ice-cores were extracted in the northern hemisphere at the same latitude (about 80°) of the Vostok site, the basic temperature in the past of the Greenland site is assumed to be the same as for Vostok site. When the internal heat source is lower than the classical heat flow (4.4×10^{13} watts), it shows no effect on the usual heat ejection by conduction from planet. When the internal source is much higher than 4.4×10^{13} watts, then the exceeding power must be transferred up to the *free* surface (mostly *ocean* surface) through some particular physical mechanism.

In general a small increase of the surface temperature ΔT_{sur} much less than the basic temperature T_B, corresponds to the specific emission power

$$p \cong 4\kappa\varepsilon\, T_B^3\, \Delta T_{sur}. \tag{6a}$$

If we know the average surface temperature $\Delta T_{sur}(t)$ linked to the $\delta^{18}O$ oscillations over a time much greater than the D-O period, we may likely obtain the specific emission due to the internal heat source. Considering the graph of Fig.1, where the maximum warming amplitude is about 8°C (R.Alley, 2000), one may obtain a specific emission $p \approx 5\div6$ w /m^2.

Today the thermal emission coming from internal Earth is not yet known from *IR* measurements, contrary to the giant planet observations. This is probably due to difficulties to obtain the average value from the variable data of total *IR* emission measured by the orbiting satellites.

However the presence of high seismic activity under the seafloor and correlated magmatic fractures heating the oceans and producing tsunami, supports the above found infrared emission, which is of the order of that predicted (5.2 w/m^2) by the planetary Gravitational power P_{gr} reported in the preceding paragraph.

4. The analysis of the Greenland Ice core data

The rapid warming events were firstly described by W.Dansgaard et al.(1993) tanks to the results of two Ice cores (GRIP and GISP2) drilled in central Greenland. Meese, Gow et al.(1997) studied on the GISP2 ice-core the correspondence between ice-layers and depth, that revealed large and abrupt climate changes with nearly regular period up to 45 kyr B.P. From these data S.Rahmstorf considered the record of the $\delta^{18}O$ from 50 kyr up to 10 kyr B.P., as shown in Fig.1, where the D-O events (marked with red dots) present a rapid temperature increase, of the order of several degrees in some decades.

At first, the "regular" timing of the D-O events was attributed to some unknown astronomical phenomenon. But the oscillatory modes within the Earth system are expected to be (Rahmstorf, 2003) far more irregular. Since the sequence of events shows also multiple intervals of 3000 and 4500 years it was confirmed that the physical cycle is about 1500 years, but sometimes an event or two are skipped. The characteristic timing of a list of 13 D-O

events between 11500 and 45000 yr B.P. have been analysed by this author showing that the most probable period is 1470 years, but the standard deviation attains 8%. This work analysed also several technical problems that intervene in the Ice-core temperature dating, normally given by layer-counting through the oscillations $\delta^{18}O$ of the oxygen isotope. After showing that dating of the GISP2 core is more accurate than the original GRIP core, the author concluded that the events are paced by a "regular" 1470 year cycle. The deviations from this period were attributed to three causes: 1) the presence of some climate "noise", 2) random variations of the physical "clock", 3) the accuracy of the layer-counting, since each Ice-core presents in general only portions that can be accurately layer-counted.

In our present work, the so-called "regularity" of the cycle is reduced to its real significance. The triggering cause resides in a physical property of the planet. The constant generation of internal Gravitational power causes a core expansion pushing on the elastic solid crust, which attains the tensile strength. This is denounced by the periodic rock fractures conveying hot magma towards the surface, producing abrupt warming of climate. So the "clock" of the D-O events is of statistical nature involving elastic dilatation and tensile strength of the rocks. We have to remark that some minor rises in temperature (which depend on regional crust fractures) happen before the D-O event (see Fig.1) during the crust cooling phase, which initiates when the escaping magma flow stops. So the events' timing appears linked to the statistical occurrence of the triggered fractures.

The number of small warming preceding the D-O jump is responsible of the disappearing of one or two D-O events, because the heat subtracted by the small warming events to the core expansion explains why sometimes the expected D-O event (whole crust fracture) cannot take place.

The "regularity" of the rapid warming events disappears beyond 46 kyr B.P. as described in Fig.2 by the $\delta^{18}O$ data elaborated on the GISP2 ice-core up to 90 kyr (Stuiver & Grootes, 2000). Although the D-O warming events do not show any periodicity, they maintain the $\delta^{18}O$ jumps around $3.9°/_{oo}$. The gradient of the $\delta^{18}O$ rise is around $7{,}8°/_{oo}$ per century, while after the peak the $\delta^{18}O$ slowly declines of about $0.14°/_{oo}$ per century.
Let's notice that the $\delta^{18}O$ jumps are nearly equal between them, showing that the D-O warming is due to the repetition of the same phenomenon. As later explained in Sec.7, the D-O events recorded in various hemispheres appear to be synchronous, a fact that confirms the fracture of the *whole* crust.

The intrusion of about 3×10^{16} m^3 of hot magma heating the crust during a few decades appears to be a catastrophic event. The continents undergo some new shaping. Most of the magma escapes from the seafloor. The direct damage of earthquakes to the human world will be probably not greater than the damage of related tsunami. The level of the earthquakes (Richter magnitude) should be very high.

After the last D-O event, occurred 11,500 yr ago, the GISP2 oscillations of $\delta^{18}O$ result less than $2°/_{oo,}$ declining towards $1°/_{oo}$ (Fig.2). Referring to Greenland, these small oscillation signal "small" escapes of magma (in respect to that involved in the D-O events) which repeat at a rate of 5÷6 per millennium. Their impact on human world would not probably be catastrophic.

With this mechanism the planet is able to transfer across the crust the "excess" heat to be radiated in space.
The irregularity of the D-O events recorded more than 46 kyr ago (Fig.2) depends on the chemical-mechanical characteristics of the ancient crust. Rocks in different physical states show different tensile strength. So they attain the *whole* crust fracture after different time periods.

When the surface temperature shows little oscillations for a long time around a *maximum* (as shown in Fig.2 during the last 10,000 yr) the internal Gravitational power is ejected towards the surface by a continuos cycling of small crust fractures. In these conditions the D-O events cannot take place.

5. How much heat can be transferred by the intruded magma?

The critical value of the crust elastic expansion equals from eq(4) $\Delta V_* \approx 8.3\times10^{14}$ m^3. Let's consider an ideal D-O event where no magma escapes during the period before that event. We have now to verify if the mass of magma occupying the volume of 8.3×10^{14} m^3 may be able to give the crust the heat $Q = 3.2\times10^7 P_{gr}\, t_* = 1.22\times10^{26}$J that the core accumulated during the time t_*. The balance is

$$Q = 1.22\times10^{26} \approx 8.3\times10^{14}\, 4100\, C_M (1200 - T_x) \qquad (7)$$

where $C_M \approx 980$ J/kg°C is the specific heat of magma, whose density is about 4100 kg/m^3 and T_x is the average temperature of the fractured crust that receives heat from hot magma, whose average temperature during travel through the fractures is assumed around 1200°C, considering the temperature of lava escaping from surface fractures. Substituting these values in eq(7) one gets negative values of T_x. This absurdity signals that the actual volume of the fractures filled by magma is obviously larger than the critical expansion ΔV_* of the elastic crust.

This fact appears intuitive since the mass of escaping fluid that fills the fractures depends on the pressure accumulated before the collapse. The internal magma increments the expansion rate when the elastic crust collapses.

H.Jeffreys (1970) showed that a fluid planet cooled by convection on a thin crust shows a *free* expansion coefficient

$$\alpha_f(r) = [C_p\, \delta(r) / T(r)]\, dT/dp \tag{8}$$

that can be adapted to a gravitational body by substituting $dp = -\, g(r)\, \delta(r)\, dr$. Thus we obtain the equation

$$\alpha_f(r) = -\, [C_p / g(r)\, T(r)]\, dT/dr \tag{8a}$$

where $C_p \approx 800$ J/kg°C is the Earth core average specific heat and $g(r) = 9.8$ is the acceleration of gravity at the core-crust interface. To give an idea, substituting in eq(8a) some values of the temperature gradient [derived from current Earth studies] calculated at the magma-crust interface, one gets

$$\alpha_f \approx (1 \div 4) \times 10^{-4}\ /°C. \tag{8b}$$

Another approach is based on the bulk modulus (K) of fluids through the equation

$$dp\ /K = -dV/\ V = 3\ \alpha_f\, dT \tag{9}$$

that gives

$$dT/dp = 1/3\ \alpha_f\, K$$

which can be substituted in eq(8) to obtain an expansion coefficient

$$\alpha_f = [C_p\, \delta/\ 3\ T\ K\ ]^{1/2}. \tag{9a}$$

Putting the bulk modulus K equal to the *bulk pressure* of magma calculated at depth of about 270÷150 km and substituting the other quantities calculated at the magma/crust interface, one obtains

$$\alpha_f \approx (3 \div 4) \times 10^{-4}\ /°C\ . \tag{9b}$$

This *free* expansion coefficient of hot magma is notably higher than $\alpha_c \approx 2 \times 10^{-5}$ assumed when the core is constrained within the elastic crust. In fact when the crust is fractured, magma expands freely under the transient overpressure. Fluids, as the high temperature core is, show in general high expansion coefficients. For instance, water at 20°C shows $\alpha_w = 2.3 \times 10^{-4}$ /°C. Let's write the First principle for the core mass during the crust collapse, recalling that the ΔQ received from Gravitational power in a few decades (collapse) is negligible. So the expanded magma ΔV_M is linked to the core cooling (ΔT_{in} is negative) by the heat balance

$$\Delta Q/\ V_o = C_v\, \delta_{av}\, \Delta T_{in} + (p_o + \Delta p)\, \Delta V_M / V_o \approx 0 \tag{10}$$

where $C_v = C_p / \gamma \approx 620$ J/kg°C is the specific heat at constant volume, p_o is the gravitational pressure of the crust upon magma, Δp is the transient compression after collapse, $\delta_{av} = 5565$ kg/m^3 is the average core density. Due to the transient triggered by the crust breaks, magma enters the fractures with velocity dependent on the local transient pressure, which can be put equal to the gravitational pressure p_o multiplied by a factor $\chi \approx 2$.

Let's now recall that the expanded magma ΔV_M depends on the core coefficient $3\alpha_f$ of expansion by volume

$$\Delta V_M / V_o = 3\ \alpha_f\ \ \Delta T_{in} = 3\ \Delta R_f / R. \tag{10a}$$

Substituting the volume ratio in eq(10) and rearranging, we obtain the free expansion coefficient

$$\alpha_f = C_v\, \delta_{av}\ / 3(1+\chi)\, p_o \approx 3.8 \times 10^{-4}\ /°C.$$

The agreement with the range of values given by eq(8b) and eq(9b) entitle us to calculate the volume of escaped magma. From eq(3), recalling the calculated period t_*, we obtain the increase of the core temperature $\Delta T_{in} = 2.57 \times 10^{-2}$ °C, that substituted in eq(10) give us

$$\Delta V_M = C_v\, \delta_{av}\, \Delta T_{in}\, V_o / (1+\chi)\, p_o \approx 3.3 \times 10^{16}\ m^3\ . \tag{11}$$

How much time the escape of 3.3×10^{16} m^3 of magma lasted ? The heat transfer to the crust seems to cease when the D-O recorded temperature is maximum. But magma escapes in a short time, during the transient overpressure originated by the elastic crust compression.

Let's calculate the cross section of the fractures at time t_* when the elastic crust collapsed. At this time eq(5) points out that the core expansion equals the critical crust expansion

$$\Delta V_* / V_o = 3\ \alpha_c\, \Delta T_{in} = 3\ \Delta R_* / R.$$

The radius increment of the elastic crust results $\Delta R_* / R = 5.2\times10^{-7}$, so we may calculate the total cross section of fractures open to the escaping magma

$$\Delta S_{Cr} = S_M = 8\,\pi\, R\, \Delta R_* = 5.2\times10^{8}\ m^2.$$

Assuming a magma velocity of the order of $v \approx 0.5 \div 1$m/sec in the average flow rate

$$q_M = v\, S_M = \Delta V_M / \Delta t_{int}$$

one may calculate the duration of the magma intrusion in the crust

$$\Delta t_{int} = \Delta V_M / v\, S_M \approx 2 \div 4 \text{ yr.}$$

The thermo-hydraulics part of the D-O event is short. Of course the surface temperature requires some decades to reach the peak, as recorded on the ice-cores, due to the slow diffusion of heat across the crust.

Let's now repeat the check of eq(7) using now the volume ΔV_M to verify the congruence between the mass of escaped magma and the heat actually transferred to the crust with an appropriate temperature difference. Of course we continue to refer to D-O events without any temperature drift before the warming jump, so the balance is

$$Q = 1.22\times10^{26} \approx \Delta V_M\, 4100\, C_M\, (1200 - T_x). \tag{12}$$

This equation shows that the average temperature of the receiving rocks results $T_x \approx 280$°C, so the great part of heat is given up to rocks at about 10 km depth. Since the small crust thickness under the oceans is likely bored by the fracture shock, magma transfers directly heat to the ocean water. The time needed to heat the oceans is less than the time needed to heat the crust. This explains why this mechanism is efficient in transferring the excess heat on the ocean surface.

A remark on the radius thermal expansion. From eq(10a) one gets the radius increase in the D-O warming event

$$(\Delta R_f / R) = \alpha_f \Delta T_{in} \approx 1\times10^{-5} \tag{12a}$$

that is the radius increases of about 60 metres. But, due to the planet isostasy, the radius decreases simultaneously of the same quantity. In fact the volume of magma intruded in the crust *is subtracted* to the core volume, thus lowering the whole crust *floating* on the mantle. The intrusion of magma, which condenses at increasing volume, produces local compressions of the crust, which may give rise to mountain chains. In any case the D-O events happen with conservation of the planet mass.

6. The temperature oscillations on the surface

The physical cycle here described needs to verify the surface temperature oscillations recorded on the Ice cores. Due to thousand fractures during the collapse, the internal heat in excess is transferred to the crust within some decades. Let's assume that the whole Gravitational heat (Q) generated in the Dansgaard period is transferred to the whole crust mass (M_{Cr}) producing an average temperature increment

$$\langle \Delta T_{Cr} \rangle = Q / C_{Cr} M_{Cr} \approx 3°C \tag{13}$$

where M_{Cr} equals about 3.8×10^{24} kg and the average specific heat is $C_{Cr} \approx 1060$ J/kg°C. One has to note that $\langle \Delta T_{Cr} \rangle$ is less than the surface temperature jump ΔT_{sur} of the D-O events. R.Alley (2000) recalled that a dramatic warming event involved about $\Delta T_{sur} \approx 8$°C in Greenland. The crust's average $\langle \Delta T_{Cr} \rangle$ is sensibly less than the surface peak ΔT_{sur} because a fraction of magma rises up to the surface with temperature around 1800°C (as the volcanic lava shows), so 1 ton of this magma gives the upper (more chilly) rocks more heat than it gives the deeper layers. When the warming stops, the surface temperature starts to decrease slowly. As a consequence the crust layer undergoes a temperature cycling that increases a little and successively reduces the radius.

7. D-O events at different hemispheres: are they synchronous?

The peak temperature of the D-O events is not uniform on the surface as shown comparing the same D-O events recorded in different regions of Greenland. For instance the peak shown in Antarctica are less pronounced. Obviously this may depend on the regional presence of large fractures conveying magma. This fact explains the different temperature peaks, but not the differences of the D-O event timing detected in different hemispheres. It has been found that the D-O events recorded on the Greenland GRIP core show different dating than Bird and Vostok cores in Antarctica. According to Alley R. (2000), "the ice isotopes indicate an antiphase behaviour, with Bird warm during the major events when Greenland was cold; dating control is not good enough to determine the phase of the smaller events". On the other hand, Bird and Vostock also contain indications of events that may be correlative to nearly all of the Greenland events (Blunier T. et al. 1998).

The problem of accurate phasing of the D-O events pertains to specialised geophysicists.

Recently a group of physicists (Raisbeck et al. 2007) tried to solve the problem starting from a completely different point of view. It is known that the ^{10}Be isotope is not present on the Earth. The only traces have been recovered from the slight cosmic rain of this isotope. In 5 ice-cores of EPICA and Vostok drilled in Antarctica it was recorded a ^{10}Be peak 41 kyr B.P.. Since the Earth surface is exposed to the same ^{10}Be rainfall it is immediate to try to obtain a synchronisation based on the ^{10}Be peaks recorded on ice cores. The advantage of this method is that the ^{10}Be is recorded in the ice, rather than in the ancient gases trapped within ice. This makes this method independent of the climate because the current dating, that gives rise to troubles in the synchronisation of Greenland and Antarctica cores, is mostly based on the peaks of some atmospheric gas, such as methane.

The most reliable peaks of ^{10}Be have been identified in several ice cores from Antarctica and Greenland around 41 kyr ago, so that the authors elaborated an experimental technique that enables to use the scarce strips of ice-cores (that are lost in the measurement) to maximise the method accuracy. The paper reports that the D-O event N.10 observed in Greenland resulted synchronous with the ^{10}Be peak, which in turn resulted synchronous with the Antarctic counterpart of the D-O event.

The synchronism of the regional D-O events supports that the triggering cause may be the sudden whole fracture of the elastic crust due to the internal push of the expanding core.

This mechanism does not require the constancy of the D-O period.

When some partial fractures, signalled by the small size of δ^{18}O oscillations, are present within the interval of about 1500 yr, it is likely that the expected D-O event does not take place, because the heat subtracted by the fractures reduces the core expansion and prevents the stress in the crust to attain everywhere the tensile strength of rocks at the expected time..

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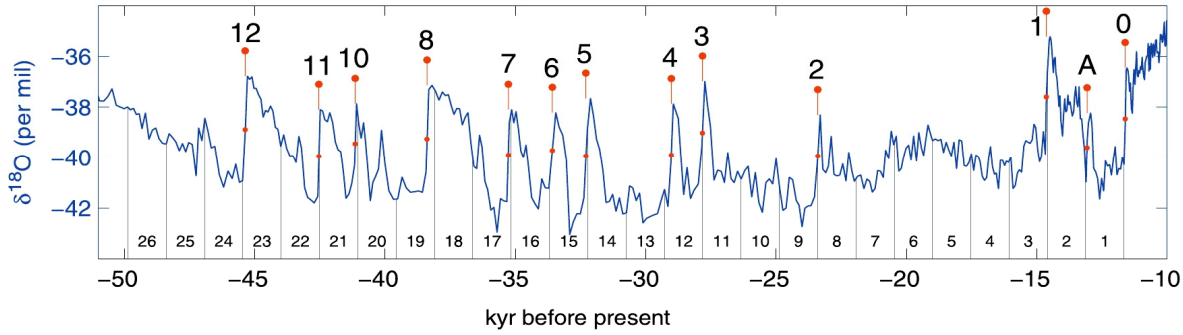

Figure 1. Dansgaard-Oeschger warming events in the second half of last glaciation recorded from the GISP2 Ice core (Courtesy of Dr. S. Rahmstorf)

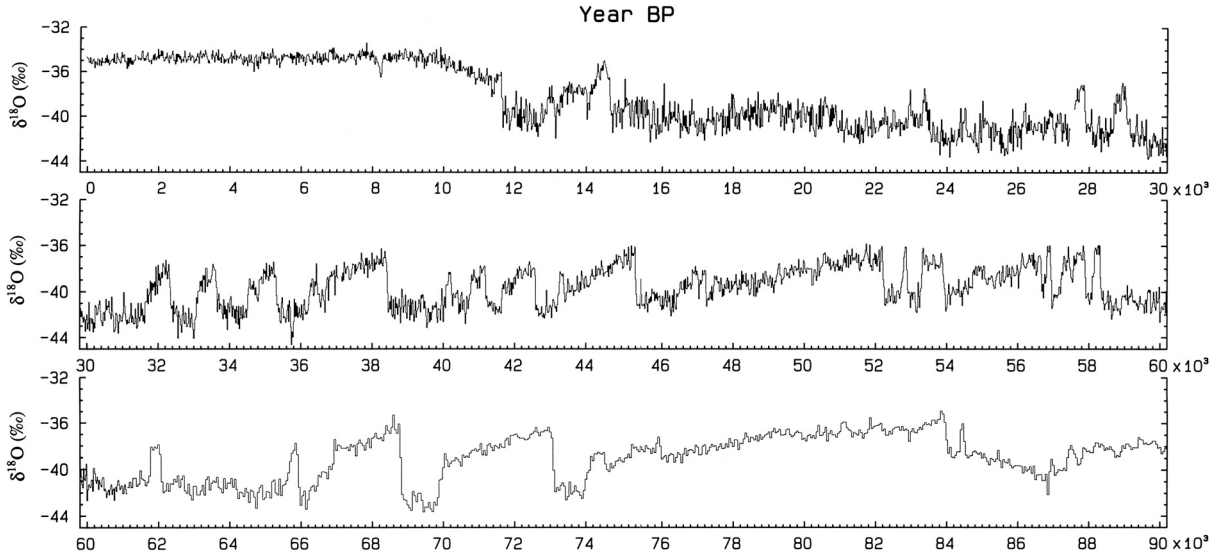

Figure 2. Graphs of $\delta^{18}O$ recorded up to 90 kyr obtained from GISP2 Greenland ice-core (M. Stuiver, P. Grootes, 2000)