TERRESTRIAL, SOLAR AND GALACTIC ORIGIN OF THE EARTH'S GEOPHYSICAL VARIABLES

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ABSTRACT. The terrestrial paleoclimatic records and explanations are much more uncertain than generally claimed. Similarly, the understanding of the solar physics and variations are still very limited. The galactic variables with solar-terrestrial impact are hitherto almost unexplored. Nevertheless, we can provide examples of terrestrial geophysical variables that originate, or seem to originate, also from solar and galactic forces.

Introduction

It is a main problem in Earth's geology and physics to identify and separate effects caused by changes within the Earth itself and those caused by external forces like planetery constellations, solar activity, galactic situation, general changes within the Universe and galaxy, etc., as illustrated in Fig. 1. There seems to be examples of all the main possible causes, a few of which will be discussed here.

Unfortunately, astronomers and paleoclimatologists usually 'do not speak the same language', which makes evaluation and understanding of results in the other discipline very hard. It is quite clear, however, that both disciplines still have a long way to go before satisfactory records, interpretations and explanations have been achieved.

OMNIS VOLVAT (everything moves)

The Universe expands or oscillates. Our galaxy, the Milky Way, moves with a speed of about 290 km/s towards the Andromeda Galaxy. It turns around its center at about 320 km/s at the position of our solar system, so completing a full revolution in about 200 m. yr. The Sun is said to experience a 'random motion' towards Vega at about 19.3 km/s. It is sometimes claimed, however, that the Sun in fact moves in a spiral around Sirius. The Earth, like the other solar planets,

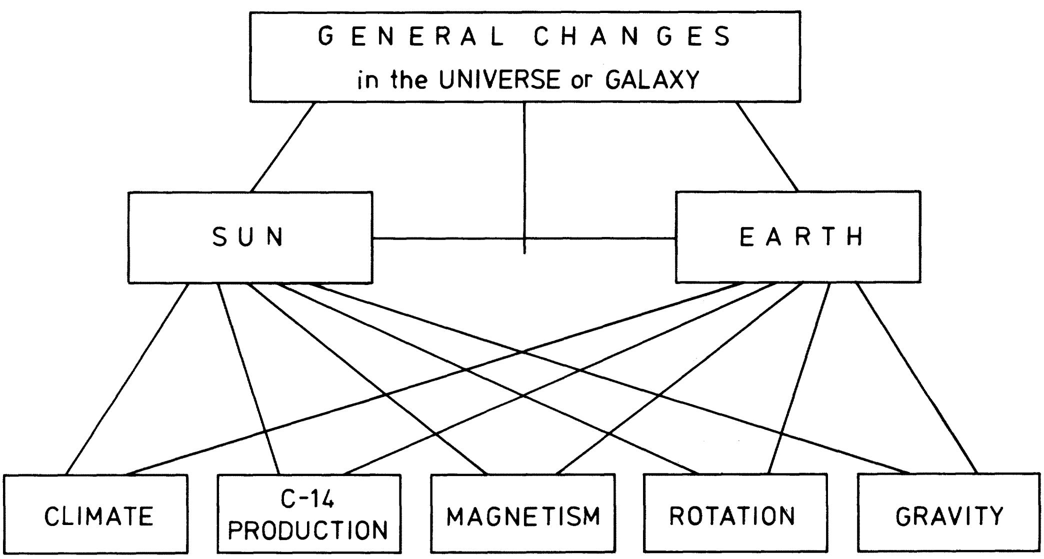

Fig. 1. Some Earth's geophysical variables (at the base) and their possible maine sources of driving forces.

moves around the Sun in elliptic spirals (the Earth at an average orbital velocity of about 29.8 km/s). The Earth and the Moon are constantly revolving around their common center of gravity, the barycenter.

With all these motions, it would be a miracle if the Earth's evolution would have been a static-mechanical one and not a dynamic and dynamically varying evolution.

The gravity, conservation of momentum, the magnetic fields, the ionization of interstellar and interplanetery plasmas, the cosmic rays, etc., are all factors that may link the motions together in a complex interaction of forces and effects (cf. Fig. 8).

SOLAR LUMINOSITY CHANGES

In order to explain the terrestrial paleoclimatic records we often turn to the Sun and its possible changes in luminosity, the so-called 'solar constant'. It is, for example, interesting to note that Wigley (1980) stated that 'the 100000-year cycle could be a solar luminosity cycle, but a better explanation is the eccentricity cycle' (cf. below).

The most striking and well-known example of changes in the solar activity is the sunspot changes. The sunspot cyclicity has been claimed to have been identified in many different terrestrial records.

The Sun's 5-minute oscillation seems now to be well established (Claverie *et al.,* 1979; Jager, 1980). However, the driving mechanism that maintains the pulsation and prevents dissipation is still unknown (Gough, 1979).

Direct measurements of the luminosity ('solar constant') over a period of 30 months indicate an increase of 0.4% (Willson *et al.*, 1980). Whether this is a random fluctuation, a non-random short-period change or a part of a long-term change is unfortunately impossible to distinguish at present.

Eddy (1977) postulated a significant decrease in the Sun's radius during the last centuries. However, Shapiro (1980) found 'no indication of any significant changes in the diameter of the Sun' from 1736 to 1973.

As mentioned by Jager (1980), the four major planets may affect the Sun's center of gravity in a way that it is registered in the sunspot activity, (cf. Figs. 2 and 8).

Dearborn and Blake (1980) showed that structural changes of the superadiabatic zone will

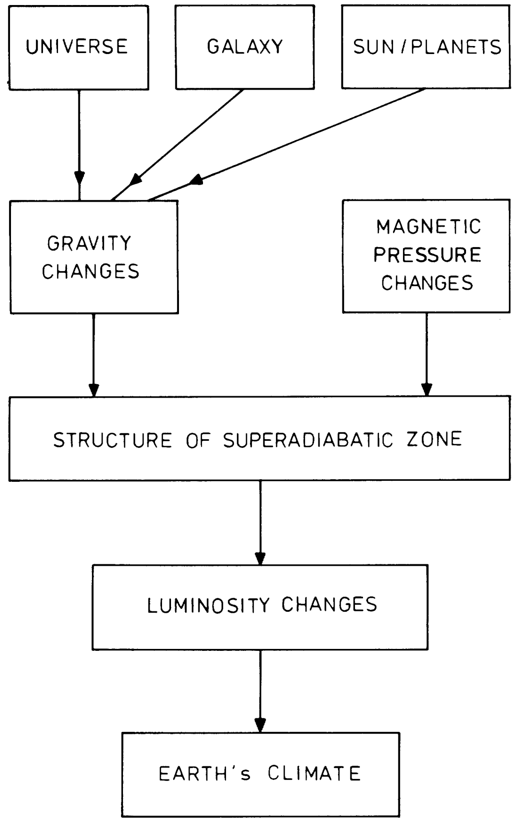

Fig. 2. Forces likely to give rise to structural changes in the Sun and by this luminosity changes.

cause luminosity changes. They claimed that 'magnetic pressure changes' were capable of inducing such changes. Gravitational changes should have similar effects, as illustrated in Fig. 2.

EARTH'S ORBITAL GEOMETRY CHANGES

The changes in the Earth's orbital geometry, i.e. in the Earth/Sun constellation, due to the cyclic changes in eccentricity, obliquity and precession (the so-called 'Milankovitch variables') have been claimed to control the Earth's climate and to be 'pacemaker of the ice ages' (Hays *et al.,* 1976). These variables have been treated quite mechanically and hence claimed to provide an absolute chronology (cf. e.g. Milankovitch, 1941; van Woerkom, 1953; Verneker, 1972; Berger, 1978).

However, the orbital geometry variations are neither fully and finally shown to be 'pacemaker

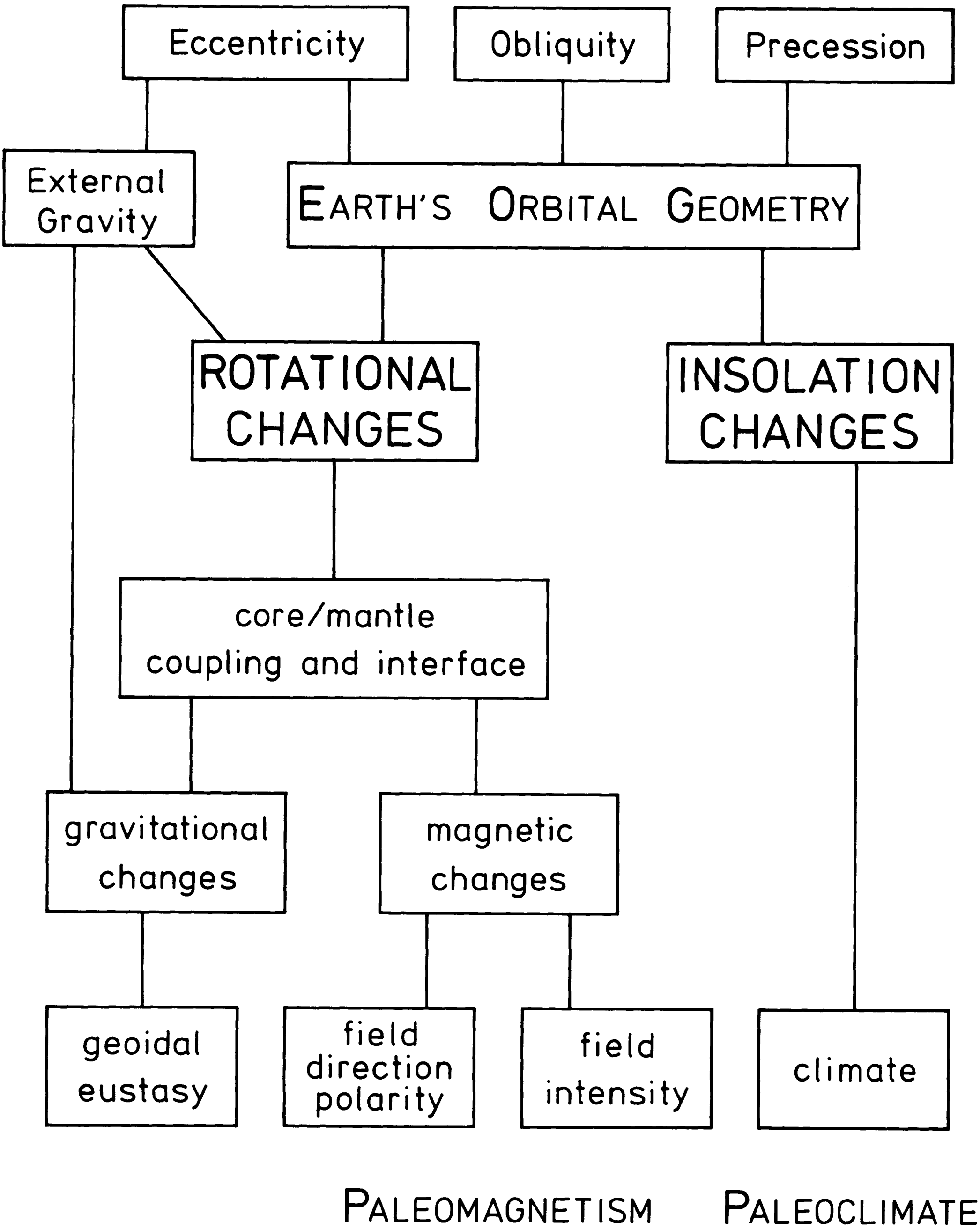

Fig. 3. Multiple effects of the so-called Milankovitch variables (cf. Mörner, 1978a, 1981a). The Earth's 'external gravity' may, of course, be influenced by many other factors (cf. Fig. 8).

of the ice ages' (Broecker, 1978; Mörner, 1978a, 1980a, 1981a), nor are they a basis for an absolute chronology.

Mörner (1978a, 1981a) showed that the so-called Milankovitch variables have, in fact, multiple effects as illustrated in Fig. 3. Analyzing the

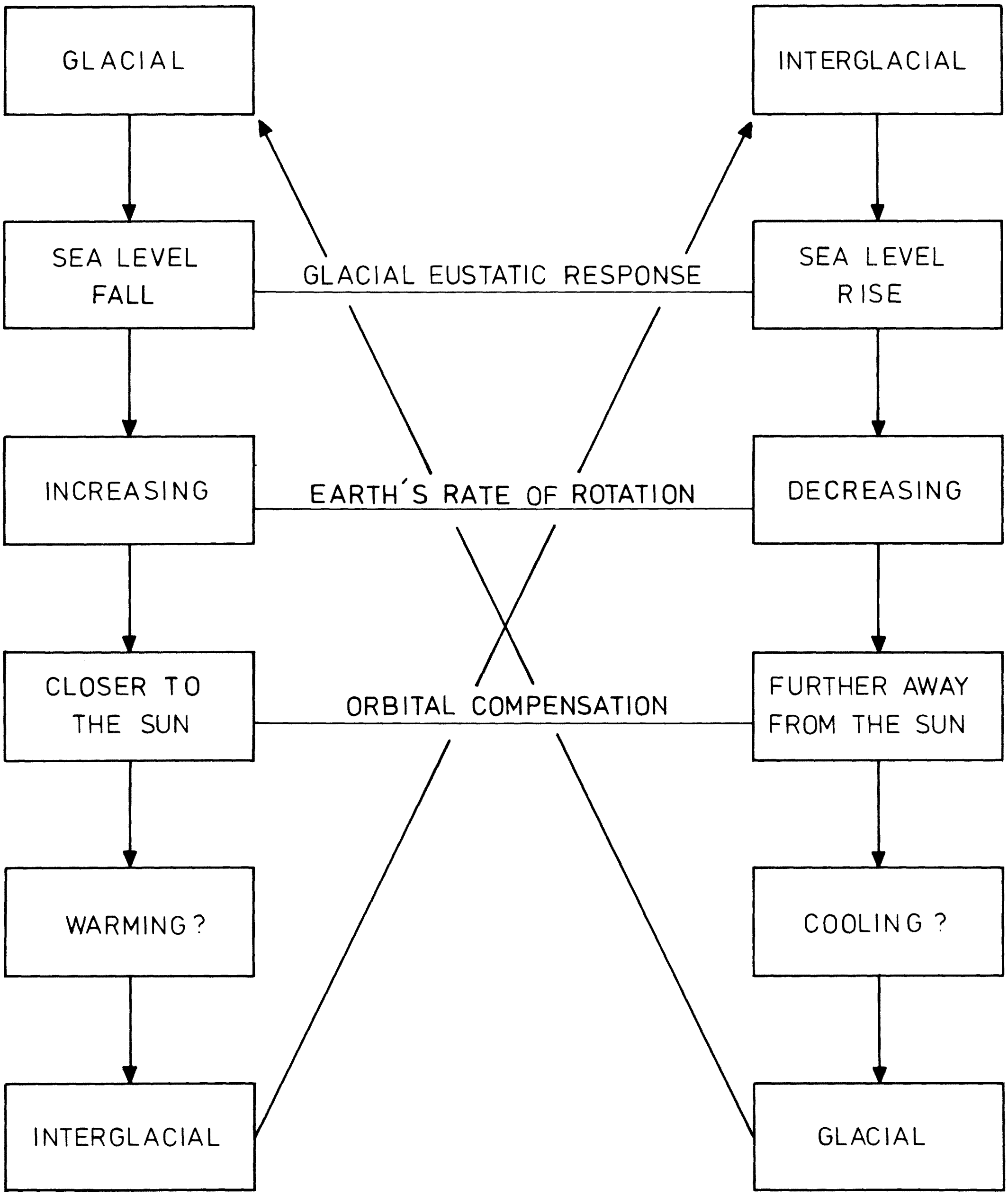

Fig. 4. Due to the conservation of momentum, changes in the Earth's rate of rotation must be compensated by the orbital geometry and/or velocity. Consequently, the major glacial-eustatic fluctuations may lead to warmings and coolings that, theoretically, may well give rise to glacial/interglacial alternations. However, this has not been considered in the Milankovitch theory.

effects of the planetary motions and constellations, Mörth and Schlamminger (1978) concluded: 'thus arises the possibility that the Milankovitch variations influence climate by a gravitational mechanism'. Furthermore, Broecker (1978) concluded: 'It is difficult to see how insolation cycles which are dominated by frequencies near 20000 and 40000 years and which

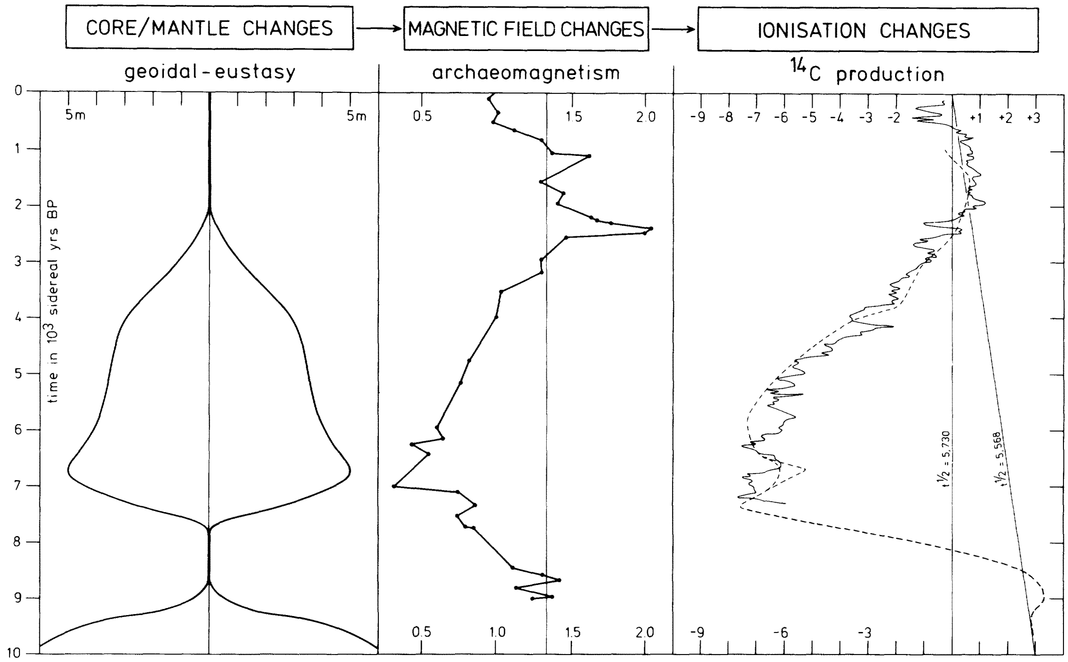

Fig. 5. The correlations established between the main Holocene geoidal-eustatic cycle of Mörner (e.g. 1978a), the archaeomagnetic cycle of Bucha (e.g. 1970) and the main atmospheric ^{14}4C-production cycle of Suess (1970) indicate a mutual orgigin. According to this, the core/mantle changes affect the geoid at the same time as they affect the geomagnetic field, which controls the incoming cosmic rays and hence the ionization and atmospheric ^{14}C-production (cf. Fig. 6) as disussed by Mörner (e.g. 1980a).

are not in phase between the northern and southern polar regions, could produce polar cycles which have the same amplitude, are in phase, and appear to be dominated by the 100000 year cycle'.

Changes of the geometry of the Earth's orbit (like the other planetary orbits) will lead to changes in the Earth's orbital velocity and/or rate of rotation. Similarly, the Earth's rate of rotation cannot change without compensational adjustments of the Earth's motion in its orbit (velocity and/or geometry). This means that the Earth's orbital elements cannot be analyzed simply mechanically, and hence that they do not provide an absolute chronology.

Because of the glacial eustatic fluctuations in sea level between glacial and interglacial periods, the Earth's radius changed by about 100 m. This is enough to change the rate of rotation (cf. e.g. Dicke, 1966). The rotational changes must be compensated by the orbital velocity and/or radius. One may therefore hypothesize that the Earth's climate could be strongly influenced by this in some sort of feed-back mechanism, as illustrated in Fig. 4.

TERRESTRIAL GRAVITATIONAL CHANGES

One of the most important terrestrial results is the recording of significant gravitational changes, i.e. deformations of the geoid, with time (Mörner, 1976, 1978a, 1980a, 1980b, 1981a, 1981b, 1981c, 1981d; (Newman *et al.*, 1980).

The terrestrial reference levels seem to undergo constant changes. This is indicated by tide gauge data, some repeated levelling records and some repeated gravity profiles, and suggested by many other records (cf. e.g. Mörner, 1981e). The Holocene sea level records give evidence partly of short-time geoid oscillations (Mörner, 1976, 1980a, 1981c, Fig. 1; Newman *et al.*, 1980), and partly of a long-period geoid cycle of about 5000–8000 year (Fig. 5; Mörner, 1976, 1978b, 1980a, Fig. 10). The Late Cenozoic sea level records also give evidence of significant geoid changed. These changes, like the Holocene ones, seem always to be linked to geomagnetic changes (cf. Mörner, e.g. 1976, 1978a, 1980a). During the Cretaceous (i.e. 135–64 m. yr. ago), the global sea level records, furthermore, provide evidence of gravitational waves that migrate latitudinally

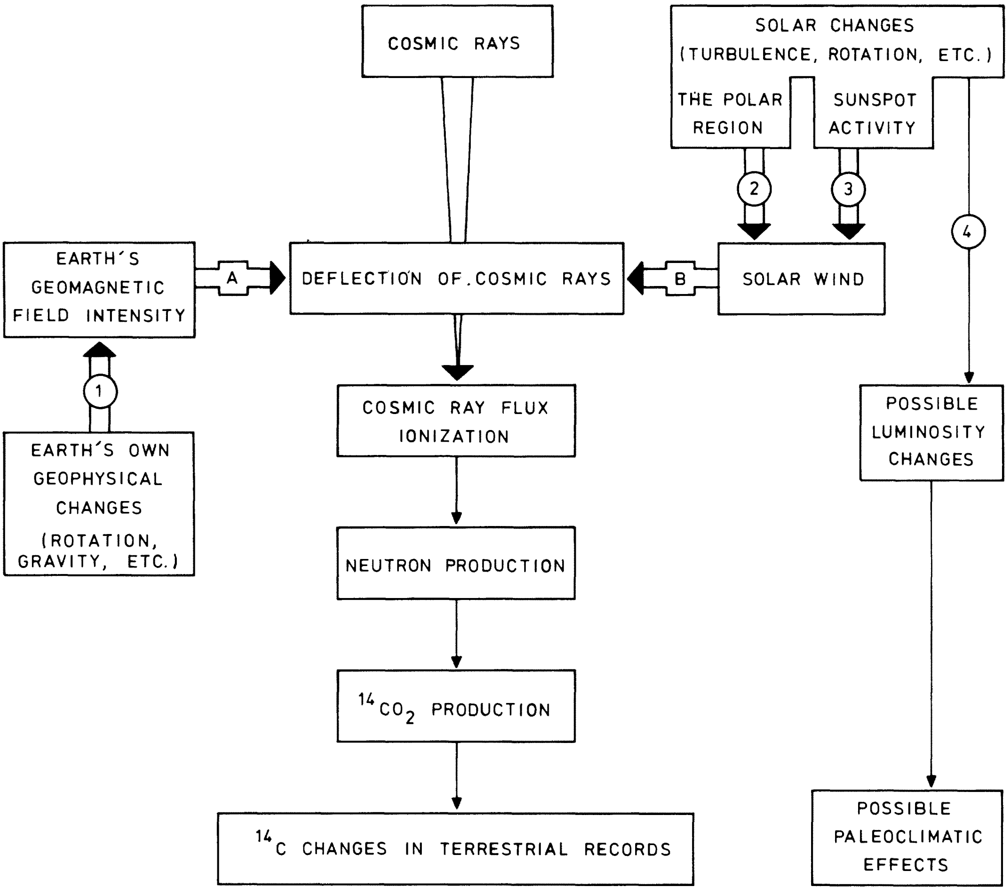

Fig. 6. The 'internal' (A) and 'external' (B) ways of controlling the incoming cosmic rays and hence the atmospheric ^{14}C-production. (1) is caused by 'internal' geomagnetic field changes in the order of 5000–8000 yrs (Fig. 5; Mörner, e.g.e 1978a, 1980a). (2) is caused by 'external' solar changes in a combination of solar wind effects both from the sunspots and the Sun's polar regions (Stuiver and Quay, 1980; Stuiver, 1980). (3) is caused by 'external' sunspot activity (Stuiver and Quay, 1980; Stuiver, 1980; Burchuladze *et al.*, 1980). (4) represents the possible simultaneous paleoclimatic effects via luminosity changes due to the solar changes (Gough, 1980). These independent luminosity changes may explain why short-term cycles (11, 22, etc. years) seem well-established in some terrestrial records without exhibiting clear correlations with the ^{14}C-variations.

with time, i.e. experience some sort of gravitational drop-motions (Mörner, 1980b, 1981b). The same waves are identified in the Pliocene and most probably also in the Miocene (the other epochs are not yet analyzed). A 100000 year geoidal-eustatic cycle is identified in the Albian (Mörner, 1980b) and seems to give final evidence that the 100,000 year cycle (so well-established in the Pleistocene) really affects the geoid as proposed by Mörner (1976, 1978a).

These gravitational changes must be linked to fundamental geophysical changes, where changes in the 'external gravity' (cf. Figs. 3 and 8) is one factor (cf. Mörner, 1978a, 1981a).

COSMIC RAYS AND ^{14}C-PRODUKTION

Eddy (1977) proposed that there is a direct correlation between sunspot frequency and atmospheric ^{14}C-production. Mörner (1978a, Fig. 7, 1978c, Fig. 4) showed that the ^{14}C-production changes could be caused both by 'external' (the solar activity) and 'internal' (the Earth's geomagnetic field intensity) factors (cf. Fig. 6), and suggested that the former applied for the short-term fluctuations and the latter for the long-term Holocene cyclic changes (Fig. 5). Stuiver and Quay (1980) and Stuiver (1980) provided firm and final evidence for the relationship between solar activity changes and ^{14}C-production variations, and proposed a convincing mechanism for these correlations (Stuiver and Quay, 1980). This mechanism seems to be responsible for the fluctuations with periodicities of up to about 200 years (Stuiver, 1980, Fig. 2A). Stuiver (1980) also demonstrated that there is 'a complete absence of a direct relationship between the solar Q and climatic changes'.

The variations in the Earth's own geomagnetic field intensity have obviously controlled the long-term ^{14}C-production as illustrated in Fig. 5. The simultaneous cyclic deformation of the geoid (left curve in Fig. 5) indicated that the Earth was subjected to a cyclic rotational (with differential effects on the core and the mantle) or gravitational force (Mörner, 1978a, 1980a).

Fig. 6 illustrates the double origin, i.e. partly the 'external' via the solar wind and partly the 'internal' via the geomagnetic field intensity, of atmospheric ^{14}C-production changes.

Fig. 6 also includes a line for possible luminosity changes in accordance with the statements by Gough (1980) that the luminosity 'easier gets out' an sunspots and that 'bursts of the magnetic field increase luminosity'.

COSMIC RAYS AND NO_3-PRODUKTION

The establishment of four NO_3 spikes in an Antarctic ice core record (Rood *et al.,* 1979) was originally interpreted as effects of known galactic supernovae. However, Stothers (1980) objected that these spikes rather were the effects of giant solar flares (2–3 times the ordinary major flares). These two alternative mechanisms are illustrated in Fig. 7.

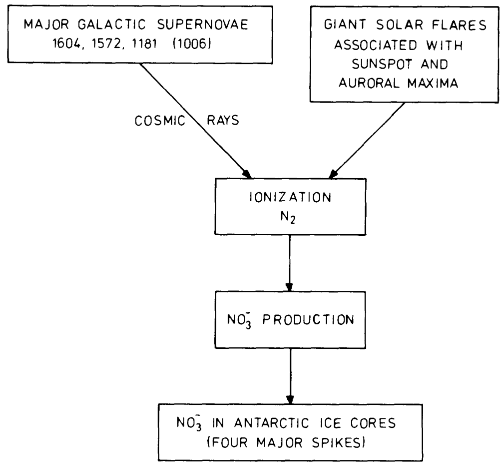

Fig. 7. The 'galactic' (Rood *et al.*, 1979) and 'solar' (Stothers, 1980) ways of explaining the four No_3 spikes recorded in the Antarctic ice cap.

LONG-TERM PHASE COHERENCE OF SOME CYCLES

The 11-year and especially the 22-year sunspot cycles are identified in varves-sequences representing the entire Phanerozoic (Anderson, 1961) and the upper Precambrian (Williams, 1981). The 11-year sunspot cycle is established in paleomagnetic records of varves of 10000 and 13000 years age in Scandinavia (Mörner, e.g. 1978d) and also in Permian varvites in Brazil (Ernesto and Pacca, 1981).

The half-cycle of about 10000 years responsible for the regular alternations between 'colder' and 'warmer' periods in the Late Cenozoic, is a fundamental cycle, but is not clearly identified back in time (perhaps due to the fact that it is generally too short to be recorded in unvarved sediments and too long to be present in varved sediment sequences).

The '100000-year cycle' is well established in the Late Cenozoic. It is also found in sedimentological alternations back in time, e.g. at about 64 m.yr. (Mörner, in prep.) and at about 100 m. yr. (Mélières, 1979) and in geoidal-eustatic changes at about 100 m.yr. (Mörner, 1980b).

GALACTIC CONTROL

It is obvious that the position of our solar system in our galaxy will affect the solar-terrestrial variables on a long-term basis. The gravity forces which the solar system is subjected to, will, for example, change with the vertical and horizontal position of the Sun within the galaxy. The Earth's orbital eccentricity and velocity changes with time indicate that the Earth's spiral motion around the Sun is subjected to gravitational forces from one side. The Sun's motions should be subjected to and affected by the same forces.

Fig. 8 illustrates some lines of complexity and interaction between galactic, solar, planetary and terrestrial variables.

The mere fact that the sunspot cycles and the 100000-year cycles have very long phase coherences may be taken to suggest an origin outside our own solar system.

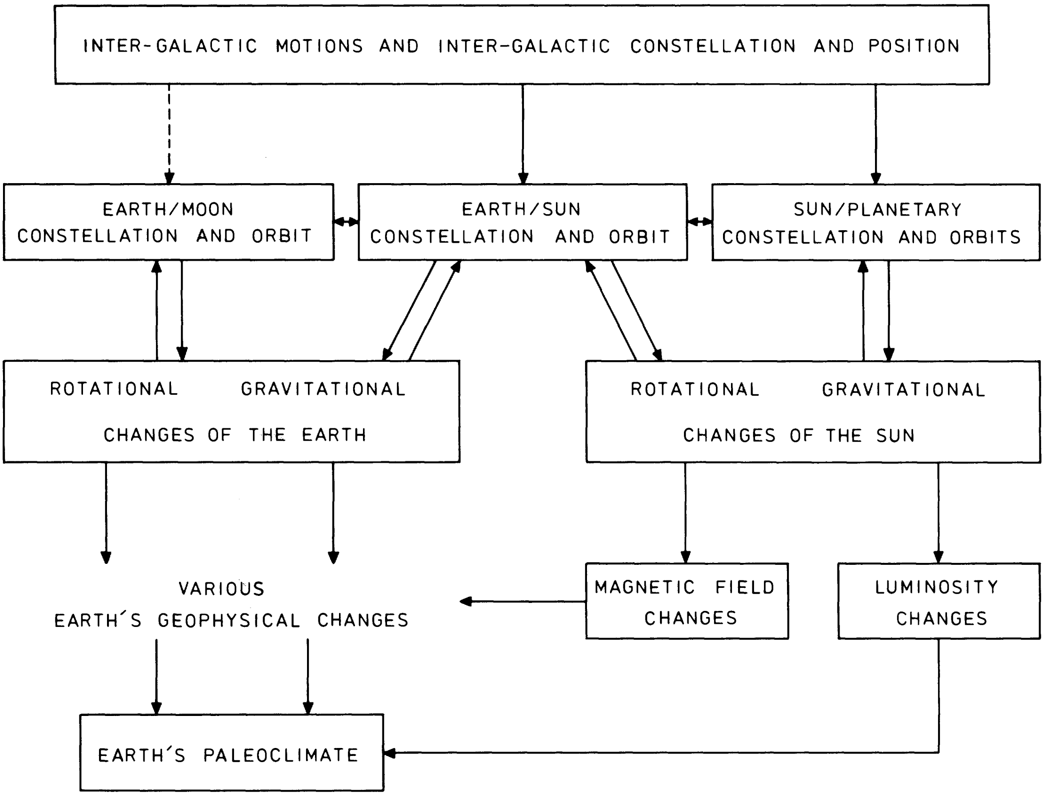

Fig 8. Some lines of complex interaction between galactic, planetary, solar and terrestrial forces and their possible impact on Earth's paleoclimatic changes.

The gravitational vibration, or drop-motion, established during the Cretaceous and the Pliocene seems hard to explain by forces within our own solar system. They rather remind of stellar pulsations (cf. Gough, 1979).

According to Wing (1959), 'some of our solar-terrestrial cycles may be related to some sort of cosmic waves of extrasolar origin'. Wing (1961) noted that the sunspots exhibit a 'latitudinal passage' with time towards the equator. He claimed that the same was true for different terrestrial data, suggesting a common behaviour 'passing ripplelike or wavelike over the solar and terrestrial spheres'.

FINAL REMARKS

The terrestrial records are not at all as complete as often is suggested, and especially not as easily interpreted as, for example, claimed when it concerns the 'Milankovitch variables' (cf. e.g. Hays *et al.,* 1976). Similarly, we still seem to know quite little about the Sun's internal structures (cf. Gough, 1979), general behaviour and changes with time. Hence, the driving mechanisms must remain uncertain and hypothetical. A few examples have been given of changes originating from terrestrial, solar and galactic forces. The main message may thus be that there are examples of all these main sources of driving-mechanism-forces. Moreover, the key-words seem to be 'complexity' and 'interaction'. (For further discussions on the terrestrial, solar and planetary changes on their interaction, cf. Mörner, 1984).

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