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Influence of Solar Luminosity Variation on Glaciations and their Significance for Time Shifting of Termination-II

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ABSTRACT. Calcite speleothems luminescence depends exponentially upon soil temperatures that are determined primarily by solar visible and infrared radiation. Microzoning of the luminescence of speleothems is therefore used as an indirect Solar Insolation (SI) proxy index.

We measured a luminescent solar insolation proxy record in speleothem (JC11) from Jewel Cave, South Dakota. This record was dated by six TIMS U/Th dates with 2 sigma error of 0.8–5.5 ka. It covers 89,300-138,600 years BP with high resolution (34 years) and precision of measurements better than 1%. It reveals determination of millennial and century cycles in the record. This record exhibits a very rapid increase in solar insolation at 139 ± 5.5 ka (2 sigma error) responsible for the termination II. This increase precedes the one suggested by the orbital theory with about 10 ka and is due to the most powerful cycle of the solar luminosity with duration of 11.5 ka superposed on the orbital variations curve. Solar luminosity variations appear to be as powerful as orbital variations of solar insolation and can produce climatic variations with intensity comparable to that of the orbital variations.

KEY WORDS: speleothem luminescence, solar insolation, orbital variations.

Introduction

M. Milankovitch demonstrated that orbital variations of the Earth's orbit cause significant variations of the amount of solar radiation received by the Earth's surface (solar insolation - SI). Scientists believe that glacial periods (ice ages) result from such variations.

Recent measurements of cave deposits from Devils Hole (DH), USA, which is the best dated paleoclimatic record, demonstrated that the end of the former glaciation (Termination II) came 10,000 year earlier than suggested by the orbital theory.

So far, there was no quantitative proxy record able to demonstrate how big the variations of solar luminosity were in geological time scales.

Methods and material studied

Calcite speleothems (stalagmites etc.) usually display luminescence which is produced by calcium salts of humic and fulvic acids derived from soils above the cave. These acids are released by the decomposition of humic matter. Rates of decomposition depend exponentially upon soil surface temperatures that are determined primarily by solar infrared radiation. So the microzoning of the luminescence of speleothems can be used as an indirect Solar Activity (SA) index (Shopov, 1987).

Time series of the SA index "Microzoning of Luminescence of Speleothems" are obtained by Laser Luminescence Microzonal Analysis (LLMZA) of cave flowstones (Shopov, 1987). LLMZA allows measurement of luminescence time series with duration of hundreds of thousands years.

Results and analyses

Jewel Cave, South Dakota, USA (Shopov et al., 1998; Stoykova et al., 1998). This record covers the interval of 89,300–138,600 years BP (Fig. 1b) with high resolution (34 years) and precision of measurements better than 1%. It reveals determination of millennial and century cycles in the record.

We extracted orbital variations from the JC11 record by a band-pass Tukey filter set for frequencies of 41, 23 and 19 ka. So the remaining signal contains only SL self-variations. The most powerful cycle in this record with a period of 11.5 ka appears to be a bit more powerful than the precession cycle and a bit less than the total orbital component of the SI variations.

This TIMS U/Th dated JC11 record exhibits a very rapid increase in solar insolation at 139 ± 5.5 ka BP (95% confidence level) responsible for the termination II. This increase precedes the one suggested by the orbital theory by about 10 ka and is due to the most powerful cycle of the solar luminosity with a period of 11.5 ka superposed on the orbital variations curve. This cycle was found previously to be the most intensive one in the $\Delta^{14}C$ calibration record and was interpreted to be of geomagnetic origin. Our studies suggest that this is a solar cycle modulating the geomagnetic field. The Devils Hole ^{18}O record suggests that termination II occurred at 140 ± 3 ka BP. It follows precisely the shape of our experimental solar insolation record. This result is confirmed by another U/Th dated luminescent solar insolation proxy record in speleothem from Duhlata Cave, Bulgaria (Fig. 1c), 10,000 km from the JC11 site. These records suggest that the solar luminosity contribution to the solar insolation curves has been severely underestimated.

The orbital theory has two presumptions:

1. Solar luminosity is constant over geological periods of time.
2. The Earth behaves as an absolutely solid body independently of the orbital variations.

Recent studies demonstrate that neither of these presumptions are precise. Direct satellite measurements of the solar constant demonstrated that it varies with time by as much as 0.4% during the observation time span (Hickey et al., 1980), but there are experimental data suggesting that it varied much more widely over geological periods (Stuiver et al., 1989).

In order to compare quantitatively the intensities of all cycles presented in our data we designed a special algorithm and a relevant computer program, which plots the periodogram in coordinates.

Intensity/Period Cycle: periodograms calculated for the JC11 luminescent record demonstrated that the 11,500-year cycle has the intensity of several orders of magnitude higher than the observed century and sub-century cycles.

The best theoretical calculations of the orbital variations of the solar insolation have been made by Berger (1978, 1992). His theoretical curves explain about 1/2 of the signal in the existing proxy paleotemperature records (Imbrie et al., 1993) derived from sea cores and polar ice.

The increase in ice volume and related sea-level change during glaciations produces changes in the inertial moment of the Earth and resulting changes in the speed of Earth's rotation (Tenchov et al., 1993). Orbital variations cause also some deformation of the solid Earth and redistribution of the Ocean masses (Moerner, 1983). As a result, theoretical curves can be used only for qualitative reference. For quantitative correlation it is necessary to use experimental records of solar insolation as these contain also variations of the solar luminosity and number of others not covered by the orbital theory.

Conclusions

Solar luminosity variations contribute to Earth's heating almost as much as the orbital variations of the Earth's orbit (Milanko-'itch cycles). Their most prominent cycle (with a period of 1,500 years) must be also taken into account for a proper ex-lanation of the timing of the last deglaciation. Speleothem :cords (being the best dated paleoclimatic records) may serve

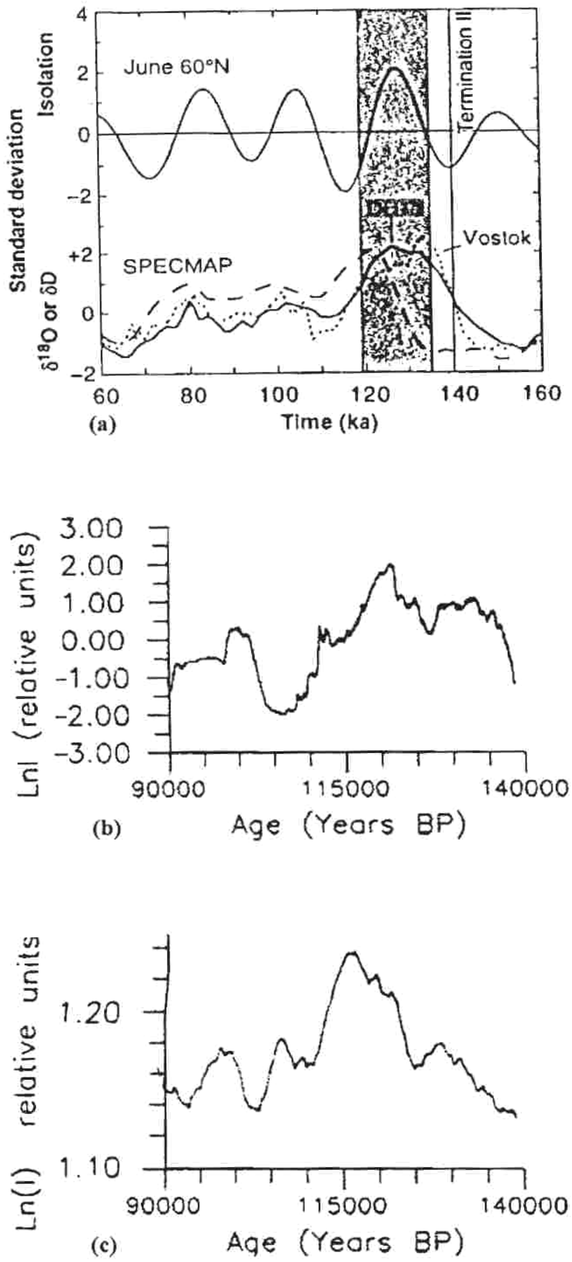

Fig. 1. (a) The theoretical insolation curve compared to Devils Hole (DH-11), Vostok, and SPECMAP stack stable isotope curves (Winograd et al., 1992). Shading represents high sea-level stands (at or above modern levels). (b) Jewel Cave (South Dakota) JC11. It is TIMS U/Th dated at 6 points with 2σ error varying from *0.8 ka (for 89.3 ka BP) to 5.5 ka (for 138.7 ka BP).* (c) Duhlata Cave (Bulgaria), DC-2 luminescence Solar Insolation proxy record. It is TIMS U/Th dated at 4 points with 2 σ error varying from 1 ka (for 89.3 ka BP) to 23 ka (140 ka BP).

as a reliable tool for studying the mechanisms of formation and precise timing of glaciations.

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The Magneto-Susceptibility Event and Cyclostratigraphy (MSEC) Method Used for Paleoclimate Estimates and Correlations at Archaeological Sites in Europe: Results for the Middle to Upper Paleolithic

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Over the last 20 years, MS measurements of sediments have been used in paleoclimatic studies of loess (summarized by Heller and Evans, 1995) and as a paleoclimate proxy in marine limestones and shales (for example, Crick et al., 1997; Ellwood et al., 1999). In unconsolidated samples like those excavated from archaeological sites, MS works as a proxy for climate because climate controls the magnetic properties of deposited sediments, primarily as the result of pedogenesis (see Mullins, 1977, for an early summary). The result is higher production of magnetic minerals such as maghemite, magnetite, hematite, or possibly ferrimagnetic sulfides (Stanjek et al., 1994; Ellwood et al., 1997) in soils and corresponding increases in MS during periods when climate is relatively warm, assuming that moisture is available for pedogenesis. Work by Tite and Linington (1975) and Singer and Fine (1989) showed that climate (both temperature and moisture) can have a significant effect on the MS, and that in general, warmer/wetter conditions enhanced the MS signature during pedogenesis. Besides maghemite, Maher and Taylor (1989) have shown that magnetite is readily produced during soil formation. (Much of the work concerning the production of ferrimagnetic minerals in soils has been summarized by Fassbinder et al., 1990).

For paleoclimate studies, MS, independent of other measurements, has been shown to be very sensitive to subtle changes in total iron concentration of sediments (Banerjee, 1996). Thus, the addition to sediments of maghemite or magnetite increases the MS. Furthermore, the authigenic production of maghemite produced by pedogenesis appears to be relatively stable chemically (Mullins, 1977), resulting in a stable MS signature that is preserved in sediments.

Soils that are formed through pedogenesis outside caves and shelters, along with their magnetic constituents, are eroded and deposited within caves or deep rock shelters by wind, water and other processes. This produces a signature of climate that potentially can be identified by measuring the MS. One test of this model is an evaluation of the within-site MS correlation power. After performing such tests at a number of open air and cave sites, we believe it is clear that excavation units from the same locality can be correlated using MS variations (Ellwood et al., 1994, 1995, 1996, 1997). At these sites, small-