Neotectonics,

the new global tectonic regiment during the last 3 ma and the initiation of ice ages

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Abstract

It recently became evident that the globe experienced a significantly changed tectonic regiment from about 3.0 Ma onwards. This puts the term "neotectonics" in quite a new perspective. We are now able to identify the last 3 Ma as characterized by generally intensified tectonic activity. This period may hence be looked upon as a special "neotectonic period". Large areas were rapidly uplifted between 3.0 and 2.5 Ma. This led to a seemingly more general lowering of the ocean floor due to an adjustment of the geoid-oceanoid level. The tectonic reorganization 3.0-2.5 Ma ago led to the initiation of global ice ages, the first one of which occurred at about 2.3 Ma.

Introduction

The term "neotectonics" originates from Russina nomenclature (Mescherikov, 1968; Fairbridge, 1981), where it was used to denote crustal movements during the Neogene and Quaternary periods (i.e. from the Miocene onwards). In the rest of the world the term has been used to denote upper Cenozoic young and on-going tectonics (Mörner, 1989; INQUA 1978–1993;Vita-Finzi, 1986), or the period when tectonic conditions of present-day-typ began (Mörner, 1989). In most cases, there were no real grounds for separating a general lower boundary at which "neotectonics" could be said to have commenced globally. In the Meditarranian region, however, a new prevailing tectonic regiment seemed to have bagun at about 3.0-2.5 Ma ago when the northward push of the African plate seemed to have been significantly intensified inducing new tectonic conditions not only within the Mediteranian region but also far up in northern Europe (Mörner, 1989, 1986, 1987a). In a global context, the time base for a meaningful application of the term "neotectonics" seemed to vary greatly over the globe and rather be of local to regional character.

In recent years, the picture has changed rapidly and significantly. We are now able to identify a thoroughly revised senario which puts the term "neotectonics" in quite new parspectives.

Observations

At the INQUA XIII Congress in Beijing in 1991, we had a special session on "the uplift of the Tibetean Plateau". The material presented showed that the plateau is a young geological pheature formed during the last 3 Ma (Mörner, 1992). Between 3.0 and 2.5 Ma, the region rose by about 1.5 km from a level of about 1.0-1.5 km to a level of about 2.5-3.0 km (Fig. 1). By this, a plateau was formed with secondary effects both on the

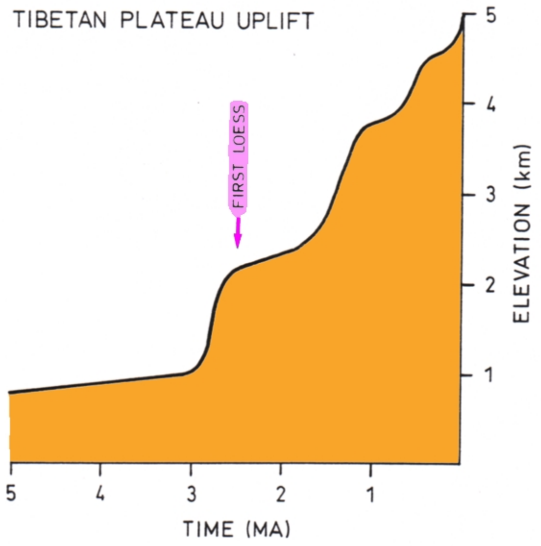

Fig. 1. Uplift of the Tibetan Plateau according to data presented at the INQUA XIII Congress in Beijing 1991 (Mörner, 1992). A major uplift phase occurred at about 3.0-2.5 Ma. The initiation of Chinese loess deposition began at about 2.5 Ma closte to the Gauss/Matuyama boundary.

atmos-pheric and ocean circulation (Mörner, 1992; Ruddiman & Raymo, 1988; Ruddiman et al., 1989; Kutzbach et al., 1989; Ruddiman & Kutzbach, 1989)). The first Chinese loess deposition – indicative of glaciation – began at about 2.5 Ma (Fiig. 1). This illustrates the close link that existed between plateau formation and change in climatic regiment.

The remarkably rapid and large uplift of the Tibetan region between 3.0 and 2.5 Ma opened new perspectives (Mörner, 1992). This event coincided well with the changes in tectonic regiment in the Mediterranean region (Mörner, 1986, 1987a) and over Europe (Mörner, 1992; Cloething et al., 1992) which might imply that the entire old Tethyan region experienced compres-sion and increased closing forces. At about the same time, a number of continetal basins were formed or drastically deepened (Artyushkov, 1993). The Bajkal basin, for example, subsided by about 1-1.5 km. Similarly, the Tyrrhenian Sea deep-basin is younger than about 3 Ma. The North Sea basin also experienced a considerable subsidence (Cloething et al., 1992).

The Bogota high plain did not exist before about 2 Ma (van der Hammen et al., 1973) indicating that, at least, the northern part of the Andian Cordillera underwent a considerable uplift at about 3-2 Ma. The same seems to be true even for other parts of the South American Cordillera although we still lack enough good a dating control. The same could be said about parts of the North American Cordillera, especiallt the southern parts which definitly includs quite young parts. At about the same time, the Panama Istmus came into being closing the Balboa Strait and having significant effects on the ocean circulation (Mörner, 1978; Sikes et al., 1991). The Sierra Nevadan, Colorado Plateau, Basin and Range, Rocky Mountains and High Plains of the west, seem all to have experienced a significant uplift in late Cenozoic time (Ruddiman & Raymo, 1989).

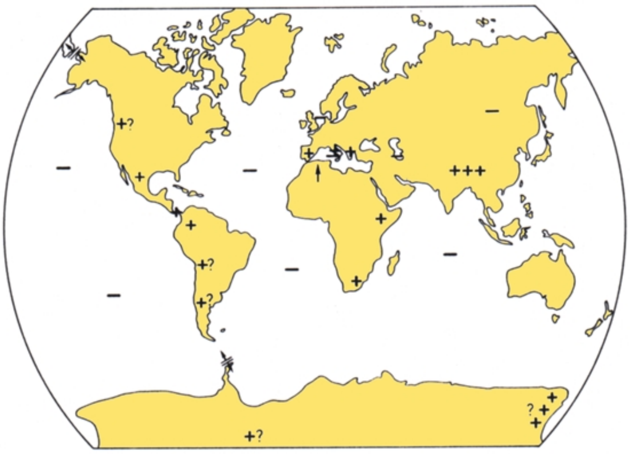

Fig. 2. Global tectonic activities in the time rage 3.0–2.5 Ma (cf. Table 1); + for uplift, – for subsidence, arrows for horizontal motions, opposed arrows for opening of straits.

The Bransfield Strait between Antarctica and the South Shetland Island did not exist some 4 Ma ago (Jeffers et al., 1991; González-Ferrán, 1991). This has quite a significance both for the oceanic circulation and for the glacial ice cover. It has even been proposed that the Transantarctic Moun-tains went up by 2-3 km at 3.0-2.5 Ma (McKelvey et al., 1991).

South Africa went up by about 0.9 km about 2.5 Ma ago (Patridge & Maud, 1987). The Ethiopean Plateau is relatively young, too. Paleobotanic evidence indicate a change from low-land to high-land some 2-3 Ma ago. In West Africa, the northward push of the African plate is seen in a series of E-W faults of Pliocene age all the way south to the Bay of Guinea (Mörner, 1992).

This implies that the period 3.0-2.5 Ma marks the onset of a general tectonic reorganization (Fig. 2). The available data are summarized in Fig. 2 and Table 1.

Regional geoid–oceanoid deformation

The uplift of large land area must, of course, have been balanced by subsidence in other areas. Any earth movements lead to the redistribution of mass and must hence affect the geoid configuration (Mörner, 1987b, Fig. 8a1). Besides the formation of a number of inland basins, there seems also to have been a more general lowering of the ocean floor (Mörner, 1992); or rather the so-called "oceanoid" (Alessandrini et al., 1987). Available oxygen isotope records of bentic forams indicate a significant shift in their mean trends to heavier values between 3.0 and 2.5 Ma (Fig. 3). In view of the strong uplift of the Tibetan Plateau (Fig. 1) and several other areas of the globe (Fig. 2), it seems highly likely that these shifts represent a general lowering of the ocean floor, i.e. an adjustment of the oceanoid level.

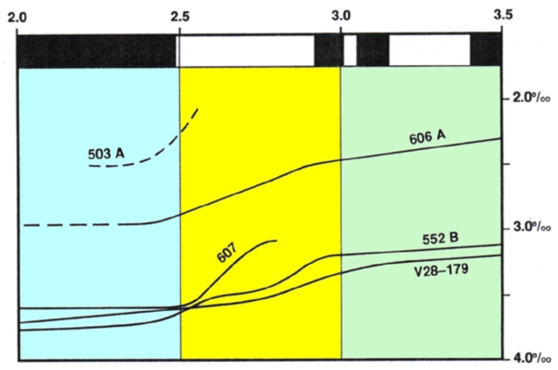

Fig. 3. The shift in mean oxygen isotope level in the period 3.5-2.0 Ma for 5 deep-sea cores covering this interval. Between about 3.0 and 2.5 Ma, there is a general shift – in the range of 0.5 %o – to heavier values. We interprete this as an effect of a general ocean floor subsidence.

New perspectives

The new perspectives in view of "neotectonics" is, of course, that a new tectonic regiment of global dimentions was induced 3.0-2.5 Ma ago. Consequently, we have now real reasons to talk about "neotectonics" not only in the vague sence of "young", "on-going" and "potentially active" tectonics but in the sence of the new tectonic style that has set the tectonic characteristics of the last 3.0 million years. We may now talk about a "neotectonic period" with reference to the last 3 Ma.

Initiation of global ice ages

The recorded tectonic reorganization was directly linked to the initiation of global Ice Ages and interjacent interglacial alternations (Mörner, 1992) hence confirming the proposition of Ruddiman & Raymo (1988).

It is, of course, of fundamental importance that the global tectonic reorganization between 3.0 and 2.5 Ma also led to the initiation of the Ice Ages that have characterized Earth's history for the last 2.5 Ma (Fig. 4). The new atmospheric and oceanographic circulations induced by the tectonic reorganization must have generated a new situation where the forces of the Milankovitch variables could be amplified so that they from 2.5 Ma onwards led to the alternations between glacial and interglacial conditions that set the character of the Quaternay period (Mörner, 1992; Ruddiman & Raymo, 1988). Increased land surface relief by uplift of the Tibetan Plateau and large parts of wetern North America generates amplified tropospheric planetary waves and monsoon-type circulation around the high areas (Kutzbach et al., 1989) which leads to winter cooling and summer drying over large areas (Ruddiman & Kutzbach, 1989). Raymo & Ruddiman (1992) proposed that the uplift caused increased erosion and weathering that consumed $CO2$ the lowering of which affected global climate. We cannot see this as a major cause and believe that it was the changes in atmospheric and oceanographic circulation that were the ultimate reason

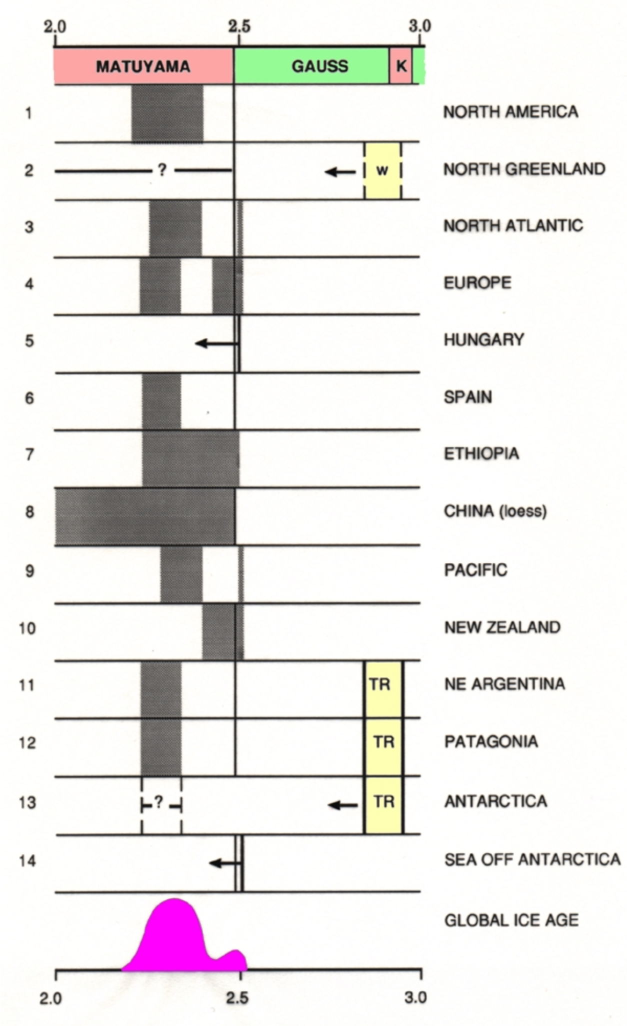

Fig. 4. Chronostratigraphic position of the first major cooling or glaciation as established in a number of key localities all over the globe. Time is given in Ma for the period 2.0-3.0 Ma in relation to the corresponding magneto-stratigraphic subdivison. A cooling and glaciation of global extension is recorded in the time span 2.5-2.3 Ma. It represents the first Quaternary-type Ice Age; commensing just below the Gauss/ Matuyama boundary and reaching a full ice age of global dimentions at around 2.3-2.4 Ma (basal curve).

for the initiation of a global ice age at 2.5 Ma and the subsequent alternations between glacial and interglacial periods.

It should be noted that the initiation of Patagonian ice ages (Mörner, 1991) was fully time equivalent to the initiation of northern hemisphere continental glaciations (Fig. 4).

Conclusions and proposition

The use of the term "neotectonics" should be restricted to phenomena of the last 2.5-3.0 million years with its first phase represented by the general tectonic reorganization that took place during the relatively short period of 3.0-2.5 Ma ago. There were also subsequent periods that seem to represent periods of more generally intensified tectonic activity, viz. at around 1.6 and 0.8 Ma.

At any rate, we are now able to identify the 3.0-2.5 Ma period as a period of considerable tectonics activity more or less all over the globe, marking the onset of a new tectonics phase in Earth's evolution; the neotectonic period.

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