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SHORT NOTE

Intraterrestial stresses caused by the decreasing spin angular momentum of the Earth

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RESUMEN

Debido a imperfecciones de la rigidez de la Tierra existe un desfase de la respuesta hidrostática al momento angular decreciente de su rotación. Las desviaciones de la forma y estructura requeridas por la condición de equilibrio hidrostático representan fuentes de energía potencial que alimenta los movimientos tectónicos.

PALABRAS CLAVE: Origen del tectonismo, imperfecciones elásticas.

ABSTRACT

Because of the virtual rigidity of the planet Earth its hydrostatic response to the continuously decreasing spin angular momentum is lagging. The departures of the planet's actual shape and structure from the ideal shape and structure as required by hydrostatic equilibrium may be a source of potential energy for intraterrestial and, ultimately, crustal unrest.

KEY WORDS: Quasi rigidity, causes of tectonism.

INTRODUCTION

The purpose of this paper is to suggest a primary cause for the directly, as well as indirectly, observed crustal movements -both continuous and catastrophic-that have characterized the history of the planet, and are commonly attributed to forces of thermal origin-specifically, to the heat emitted by decaying radioactive elements in the mantle.

If the shape and structure of the planet had always been maintained in hydrostatic equilibrium with the continuously decreasing spin angular momentum, all past geoids would have been perfect ellipsoids of rotation, progressively less flattened as the spin angular momentum decreased. The crust -except where disturbed from without by meteorite impacts- as well as all subcrustal formations would have been uniformly thicker at lower latitudes than at the poles. The surface of the planet would have been completely covered by water, uniformly deeper at the equator than at the poles, and seasonally frozen above near-polar latitudes. No forms of life, other than aquatic, could ever have evolved.

However, because of the planet's virtual rigidity, instantaneous hydrostatic equilibrium is never quite achieved. Invariably, there is a significant time lag between the actual shape and structure, and that required by hydrostatic equilibrium at the time of observation.

Among the presently observed departures from the ideal shape and structure as required by hydrostatic equilibrium are:

a) an excess in the degree of flattening of the planet; significantly 0.417 percent;

b) triaxiality of the reference ellipsoid; the difference between the longer and the shorter axes across the equator is approximately 120 meter;

c) the pear-like shape of the planet;

d) various gravity anomalies;

e) the asymmetrical distribution of continental and oceanic crust;

f) topographic variations ranging from 8848 m above to 10 912 m below the reference geoid.

The principal mechanisms by which the hydrostatic shape and structure are continuously being approached include intermittent orogenic and epeirogenic crustal movements and tectonic adjustments, as well as continuous differentiation and outgassing. These processes would have been much more active in the distant past than they are at the present, because, in the past, the above listed departures from equilibrium were more pronounced than they are today.

It is known than the spin angular momentum of Earth has continuously decreased-most probably at a decelerating rate-to its present value of 5.91×10^{23} kgm^{2}s^{-1}. It is also commonly agreed that the planet was at no time in a completely molten state. It is plausible to assume that the protoplanet, as it envolved from the stellar nebula destined to become the solar system, was initially a relatively thin and rapidly spinning spiral disk, the radius of which may have exceeded its thickness by a factor of up to 10^2. At some early stage, as a consequence of a decreased spin angular momentum, this thin, semi-rigid and flexible spinning disk, composed essentially of fused dust, would have become structurally unstable; it eventually would have buckled and rapidly collapsed to form an initially structureless quasi-pear shaped mass of which the presently observed subtle departures from hydrostatic equilibrium remain as vestiges or traces of formerly much more pronounced departures from the ideal shape and structure. In this scenario the center of the protoplanetary disk might have evolved to become the southern end of the geographic axis. One may plausibly argue that the planet still retains some memory of its long ago transition from a flat disk to a quasi-global structure -a memory which is gradually fading and is, by now, admittedly quite faint.

Because of the planet's virtual rigidity, its hydrostatic response to the continuously decreasing spin angular momentum is not instantaneous but lagging most of the time (Hoffer 1995) resulting, in effect, in a directed stress acting along the geographic axis; a stress which is one of the most significant primary sources of potential energy for intraterrestial and, ultimately, crustal unrest.

SOME QUANTITATIVE ASPECTS

Seismic studies indicated that the elastic properties of the mantle are comparable to those of steel. Using a Young's modulus of 2×10^{11} Pa, it is thus possible to estimate the sustained tensile stress currently acting along the geographic axis as 3×10^6 Pa, or some 30 atmospheres. It is also possible to estimate the time required for the elastic potential energy to be transformed into kinetic energy and finally dissipated as heat. The present discrepancy between the observed and the hydrostatically required degree of flattening -1/298.247 and 1/299.49 respectively-amounts to 0.415 percent. The observed progressive increase in the duration of an average days is 10^{-3} seconds per century, or an aggregate of 36 seconds per century; -that is, a time discrepancy of 1.14×10^{-6} percent per century. Assuming that the decrease in the flattening ought to progress at a rate comparable to the deceleration of the angular speed (and also that the rate of deceleration remain essentially constant), one would expect the time lag in the present degree of flattening to correspond to 3.65×10^5 centuries (at least), or some 40 million years. That is, if there were to be from now onward no further decrease in the angular speed, it would take the planet (at most) some 40 million years to reach complete hydrostatic equilibrium. Conversely, the present degree of flattening would correspond to the hydrostatic equilibrium of some 40 million years ago; that is, the middle of the Tertiary period.

DISCUSSION

The gradual decrease in the flattening of the spheroid has to be accompanied by the gradual shrinkage of the equatorial bulge (with the concomitant deceleration of the precession of the equinoxes), a change in the curvature of the planet's surface, as well as by the shrinkage of the total surface area of the planet even if its volume were to remain constant. In fact, continuous outgassing and recrystallization would independently tend to contribute to a reduction in volume and, thus, to a further reduction of the surface area. This implies not only that the average rate of subduction of crustal matter must exceed the average rate of generation of new crust, but it also makes the concept of a hypothetical supercontinent ("Pangea") breaking up into dispersing fragments an unlikely scenario. On the contrary, it is more likely that independently evolving blocks of sialic crust or islands of varying sizes and shapes, while approaching one another from all directions simultaneously, tended to rotate so as to align their opposing edges in an effort to minimize the surface energy of the planet[1]. Initially, centrifugal forces would tend to draw such islands toward the equator; but as the angular momentum continues to decrease, these islands would be less restricted in drifting toward higher latitudes. Invariably, collisions between such islands would create bridges -some temporary, some permanent- facilitating the migration of land-based forms of life and resulting eventually, after compounded collisions and mergings, into the two (unequal) supercontinental masses of the eastern and western hemispheres.

The fossil record of early primitive forms of life on Earth suggests a global proponderance of shallow seas covering the planet's surface in late Precambrian and early Pa-

[1] Hence, the intriguing so-called "fit" between the coasts of western Africa and eastern South America, which is often cited as compelling evidence for the split-up of the assumed supercontinent.

leozoic times. This would appear to confirm that essentially the same amount of H_2O that is available today was distributed over the larger surfaces of the planet in the distant past.

SUMMARY

The principal causes of intraterrestial instability are stresses due to the effective rigidity of the planet's materials and the consequent time-lag in their response to continuously changing enviromental conditions. While the bulk of the planet constantly seeks to reach hydrostatic equilibrium as the spin angular momentum constantly decreases, the movements of continental crust seek to achieve a distribution such as to minimize the surface energy of a constantly decreasing planetary surface.

Orogenic processes involving local buckling and folding of the crust are natural inevitable consequences and concrete evidence for the gradual shrinkage of the surface.

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