THE HIDDEN OCEAN ON THE TOP OF THE CORE
AND THE GEOMAGNETIC SECULAR VARIATIONS

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NASA Grant NAG 5-2953
Project Period 6/15/95 - 9/14/98

Final Technical Report

The goal of this project under Grant NAG 5-2953 was to establish the fundamentals for the dynamics of a stably stratified layer at the top of the core, adjacent to the core-mantle boundary (CMB). This (still hypothetical) layer has a density that differs very little (about 1% or less) from the equilibrium value corresponding to the adiabatic gradient in the bulk of the core. The hydrodynamical properties of this specific region, however, differ drastically from those of the bulk of the Earth's core because of a very large Archimedean (buoyancy) force acting there. The new model of this layer has been established, as a result of the project development under Grant NAG 5-2953. This model brings my previous model (assuming the density change across the layer about 10^{-4} parts or less (Braginsky, 1993)), in correspondence with recent results of seismological investigations, which suggest about 1% depletion in density at the top of the core. The properties of the lighter fluid layer are very close to those of the Earth's oceans. That is why this layer is called the Hidden Ocean of the Core in (Braginsky, 1993), or the Stratified Ocean of the Core (SOC) in the papers published under Grant NAG 5-2953. Oscillations with periods from diurnal to decades, similar to those observed in the Earth oceans and ttmosphere, were considered in the project.

The new model of the light layer has a sharp density drop on the boundary with the bulk of the core, and a homogeneous internal density gradient. The CMB, placed at a radius R_1 , is the bottom of the layer (the bottom of the ocean); its top merges with the bulk of the core at the radius $R_S = R_1 - H$ where the density excess, C, drops to the negligibly small value $C_0 \sim 10^{-8}$ characteristic for the bulk of the core. A linear C(r) dependence is assumed: $C = -(C_S + (C_H/H)(r - R_S))$. The characteristic parameters of the simplest SOC model are its thickness, H, and the Brunt-Väisälä frequency, $N = (gC_H/H)^{1/2}$. The jump of the density excess at the top surface of the layer, C_S , is the third (additional) parameter. A comparison of the theory of MAC oscillation in the layer (Braginsky, 1993) with observations made it possible to estimate two main parameters of the layer: $N \sim 2\Omega$, and $H \sim 80$ km, here Ω is the

Earth's speed of daily rotation. The third parameter, C_S , is estimated according to the seismological results.

Several theoretical consequences of this model have been investigated under Grant NAG 5-2953.

During the first year of the grant (June 15, 1995 - June 14, 1996) the PI worked on the physical mechanisms which determine the high frequency dynamics of the stratified ocean of the core (SOC). These mechanisms can support oscillations and waves of various forms and with periods ~ 1 day. The folowing waves were considered using a simple planar model: inertial waves in the core, internal waves in the SOC, and surface internal waves on the boundary between the SOC and the bulk of the core. All these waves are very similar to their counterpart existing in the "common" ocean on the surface of our planet. The most interesting new effect is a strong decay of the internal waves in the core due to Joule heat production in the thin magnetic diffusion layer on the boundary between the SOC and the bulk of the core.

During the second and the third years of the grant PI was working on the dynamics of much slower SOC oscillations - with decade periods. The theory of axially symmetric oscillation (period = 65 yr) of the global length scale was considered previously by Braginsky (1993). Under Grant NAG 5-2953 PI considered the local waves in the SOC depending on longitude, with the length scale of order of 10^3 km and periods of order of decades. The governing system of equations for these waves was obtained, which is similar to the equations of the nearly geostrophic dynamics broadly used in the atmospheric science and oceanology. This provides us with a simplified model of the waves, which reveals their qualitative features without going into significant mathematical complications. The possibility of existence of such waves in the SOC with the eigenperiods in decade interval was shown, the dispersion equations were obtained and the form of the waves was established as well. These waves are akin to the Rossby waves (also named planetary waves) well-known in oceanology and meteorology. These waves in the SOC are, however, significantly modified and experience a rather strong decay, due to the influence of the core's magnetic field. It looks likely that these magnetic Rossby waves are responsible for a significant part of the geomagnetic secular variations. A further investigation and comprehensive understanding of these waves in the Earth core is necessary both for the correct interpretation of the observational secular variations, and for obtaining the velocities on the surface of the Earth core from the geomagnetic observations.

The core-mantle coupling, which originates from the interaction of the surface flow with the topography of the core-mantle boundary, is strongly influenced by the stably stratified layer. Its existence makes possible a new effect, namely the topographic core-mantle coupling arising due to generation of motion resembling the magnetic Rossby waves in the stably stratified layer by a zonal flux of the core fluid over the CMB topography. This effect was considered by PI, and it was shown that this process produces a topographic coupling which can be much stronger than a commonly estimated coupling due to the mantle electrical conductivity. A simple expression was obtained, and a qualitative explanation was given to the resulting topographic tangential stress on the core-mantle boundary.

The fundamentals of the dynamics of a stably stratified layer at the top of the core was established during the work under Grant NAG 5-2953, but the existence of such an "Ocean" opens a new chapter in the dynamics of the core with a lot of problems waiting for solution. The PI tried also to consider the influence of the stratified ocean on the penetration of the geomagnetic secular variations from the bulk of the core to its surface, and to investigate the influence of the SOC on the Chandler Wobble and the Earth's nutations, but these studies are not finished yet. The future research of the SOC should be oriented towards the confirmation of its very existence. For this purpose we should find a large enough number of observable effects for which a theory of the SOC can be compared with observations, thus making it possible to estimate and cross-check the parameters of the stratified ocean at the top of the core

Results obtained under Grant NAG 5-2953 were presented at the AGU Meeting in San Francisco (1997), and at the IAGA Scientific Assembly, Uppsala, Sweden (1997), and published in the following papers supported by the grant NAG 5-2953 : S.I.Braginsky. "Magnetic Rossby waves in the stratified ocean of the core and topographic core-mantle coupling", and S.I.Braginsky. "Dynamics of the Stably Stratified Ocean at the top of the Core".

No patents or inventions resulted from this effort.

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