TOPOGRAPHY OF THE THERMAL BOUNDARY LAYER AT THE BASE OF THE MANTLE

MARCO VIA GEOLOGY 393 THESIS I
Adviser: Proff. SASWATA HIER-MAJUMDER
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IMPORTANCE OF PROJECT

•To understand better the Earth's thermal evolution
•It will help to confirm or deny the theory of convection cells in the mantle

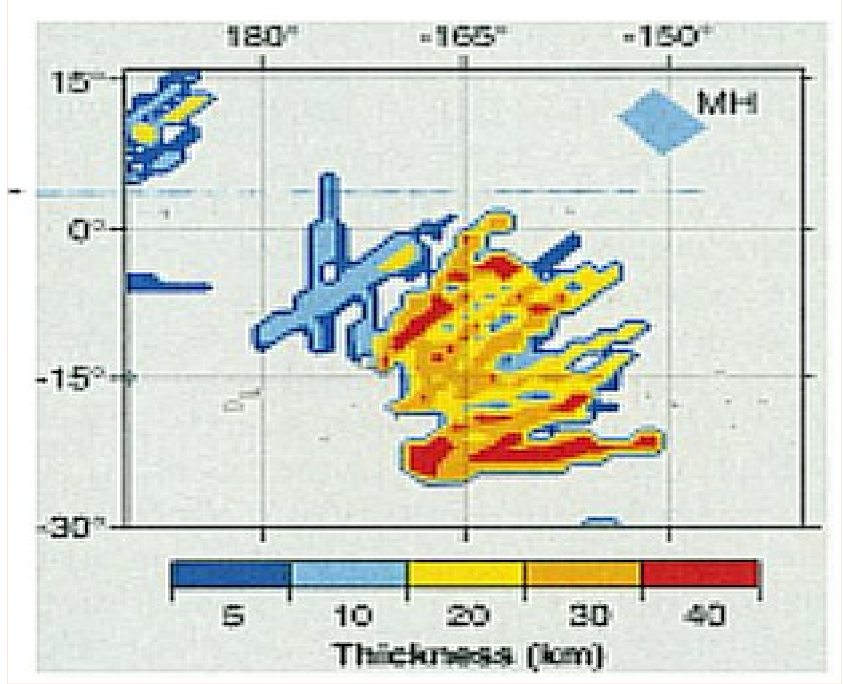
TERMINOLOGY

• TBL: Thermal Boundary Layer
• ULVZ: Ultra low velocity zone
• CMBL: Core mantle boundary layer

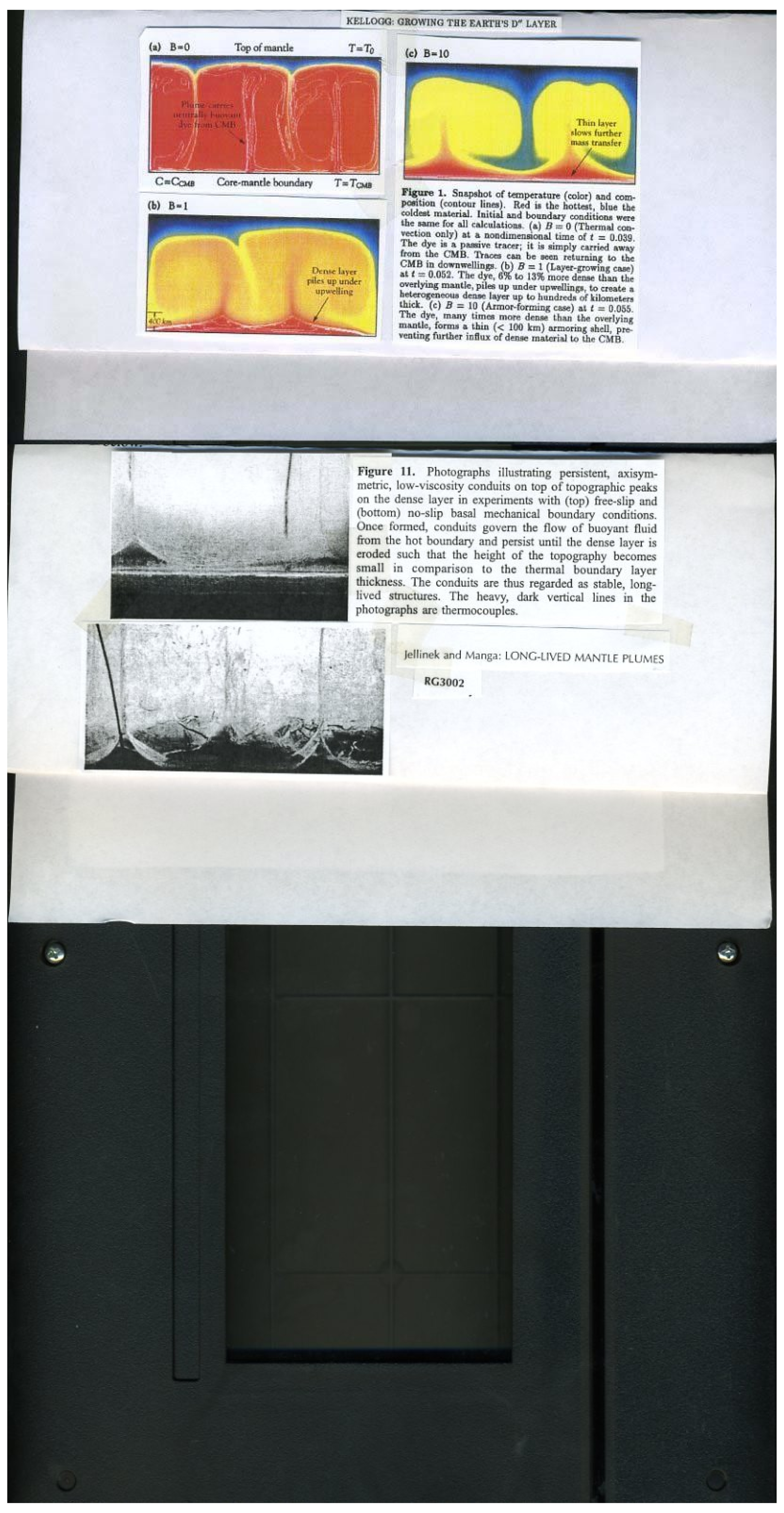
·BACKGROUND

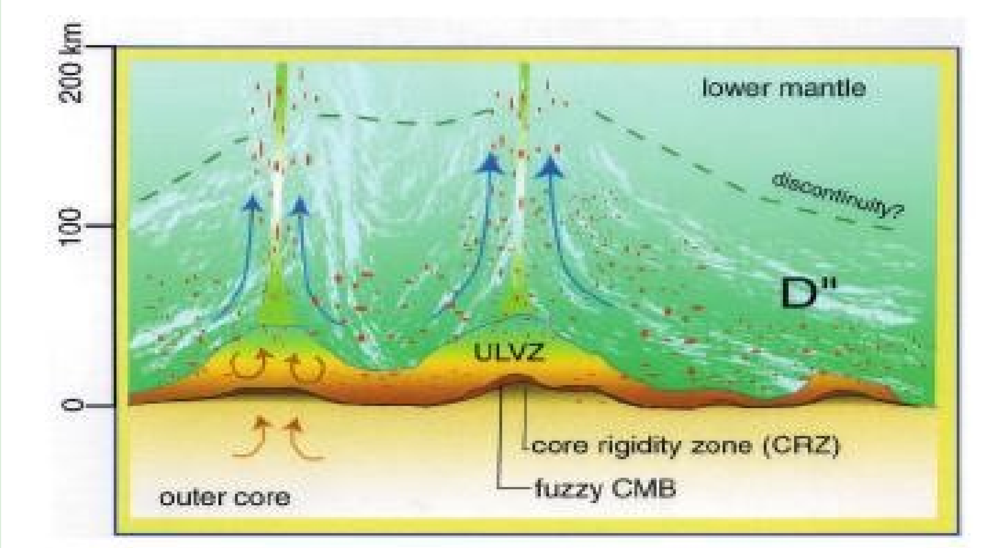
• There is strong evidence through seismic data of the existence of a layer with an uneven topography known as D"
• This layer seems to have different composition than the lower mantle and/or outer core
• There is still some limitations as to whether D" covers the outer core in its entirety or just in some areas

Red = reduction by 30% in the velocity or P- waves
(Williams, et al 1996)

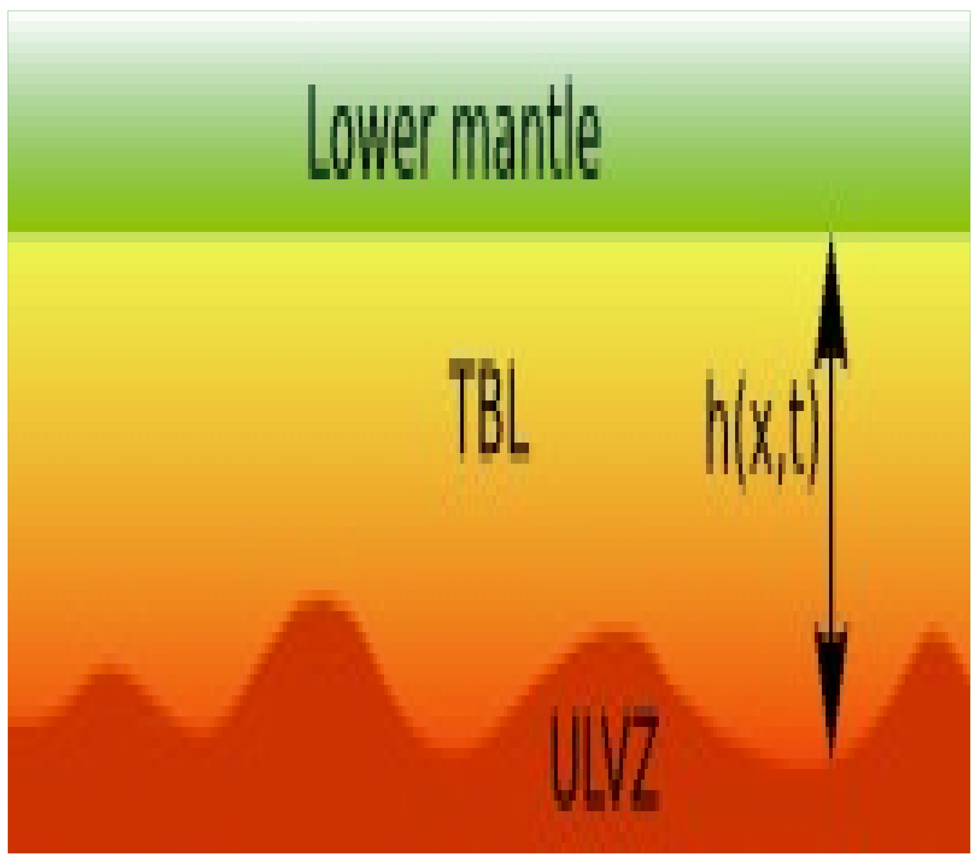


• Two- dimensional and three-dimensional numerical experiments have generated plumes
• The thermal convection systems used were under steady state conditions
• Two fluids with different viscosities were used



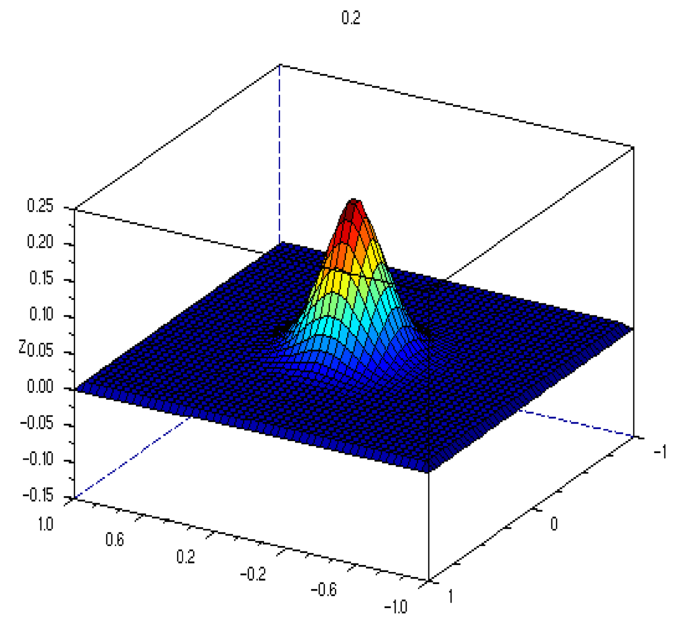


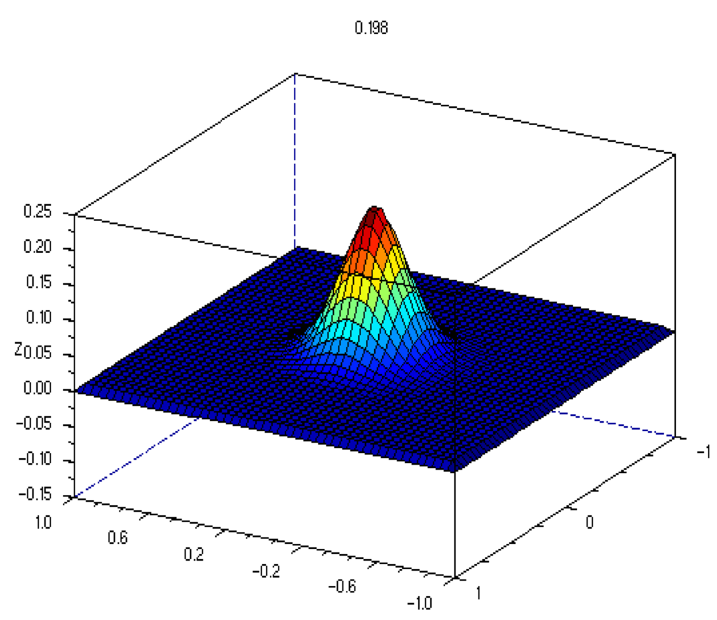
Application of the Lubrication theory



Partial numerical results as iteration number is changed for different times, viscosities, and densities of the dense fluid layer.

Stable topography
Changing the iteretion number while keeping the other variables constant, the viscosity values changes and the formation of an stable topography occurs





POSSIBLE RESULTS

• Once the ULVZ becomes stable the TBL fluid will start to form a plume
• The plume will be stable enough t

• Laboratory experiments have also produced plumes in a system with two fluids with different viscosities

HYPOTHESIS

• The core mantle boundary layer CMBL has an uneven topography
•Observations from numerical and experimental results show that it is necessary an uneven topography to form plumes.
•The stability of plumes seems to be close related to a definite topography

ASSUMPTIONS

•Treat the thermal boundary layer as a thin fluid (TBL)
•Treat the ultra low velocity zone (ULVZ) as a denser fluid
•No interchange of materials between the outer core and the ULVZ
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CALCULATIONS

• Mass conservation

$[\partial \tilde{u}/\partial z^2 = (\rho g/\mu)\, \nabla_H * h]$ -(1)

Where: $\partial \tilde{u}/\partial z^2$=Shear stress (vector equation)/ viscous resistance

$(\rho g/\mu)\, \nabla_H * h$=gradient pressure on the system.

∇_H= is the horizontal gradient operator. Defined parallel to the walls of the narrow TBL

$\partial h/\partial t + \nabla_H * q = Q\delta(x - x_o)$ -(2)

Q is the mass flux into the plume conduit (vol/unit time)
Equation (2) is the mass balance equation of the system
Where q= the volume flux per unit channel area

If: q= int. 0 to h (u dz) -(3)

The term on the right is a sink term of the fluid layer, indicating suction of material into the plume channel
Solving for equation (1) integrating twice, using the following boundary conditions;

$\partial u/\partial z = 0$ and u = 0 at z=0

$\partial h/ \partial t + g\nabla_H h^{4}/(24v)$ -(4)

Combining equations (2) and (4) we obtain

$(\partial h/ \partial t)+(g/24v)(\nabla_H^{2} h^{4})=Q\delta(x - x_o)$ -(5)

equation 5 is a PDE for h, which we need to solve with an initial condition and boundary conditions.

After solving the equations, the non-dimensionalization technique was applied to the results.
BegiDemonstrate Feasibility with:

H=Lh*

Where L is a constant and h* is a non-dimentional variable
Also we have these known variables:

$t= (L/u_o)t^*$

$\nabla_H^{2}=(1/L^2)\nabla^*$

$\delta=(1/L^2)\ \delta^*$

Dropping the asterisks:

$\partial h/\partial t+(\rho g L^2/24\ \mu V_o)\nabla_H^{2} h^{4}=(Q\delta/U_o\ L^2)$

Defining $L^2=Q/U_o$

then: $\partial h/\partial t+(\rho g Q\nabla_H^{2} h^{4})24\ \mu V_o=\delta$ -(6)

$I= \rho g Q\nabla_H^{2}\ h^{4}$ (Intrusion term)

Discretizing this equation we have:

$[k = - (\Delta t/d^2)\, I]$ where I=sigma term

REFERENCES

• Olson,P. 1990
• Jellinek and Manga 2004
• Garnero, E. 2000
• Kellog, L. 1997