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Experimental presentation of plate subduction using paraffin wax

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Experimental approaches using analogue materials have been widely used to understand kinematic behaviors of tectonic plates. Previously molten paraffin in a tank inside a hot water bath has been used. Although tectonic plate-like behaviors, such as inclined subduction and trench migration, have been observed, the “plate” in this case was too thin to reproduce the lithospheric strength and the heat balance through the thermal boundary layer of the Earth. In order to simulate the plate and its motion as a well-developed thermo-mechanical boundary layer on top of vigorously convecting mantle, we have developed a tank apparatus and performed preliminary experiments using paraffin wax.

To control the complex heat and convection processes and for easy observation we constructed a glass tank with an inner size 120x23x4cm. The walls are constructed from double pane glass with panes separated by air gap to reduce heat loss, and reinforced with aluminum plates and bars. The paraffin was melted from bellow by a copper heat-sink containing 24 ceramic heating elements. To reduce heat loss to the back wall, the wall was isolated with 8cm thick foam. At the boundary layer where the paraffin wax was sticking as it cooled down we applied NiCr wire heater to the inner walls. All heating sections were controlled by variable controllers. We cooled the top layer of the wax with a cold air flow carefully controlled with thin foam plates from a vat filed with liquid Nitrogen.

The biggest challenge was the “frosting” effect especially on the front uninsulated wall that prevented the “subduction” of the forming “crust” to deeper levels. External wall temperature was 65 ℃, 70 ℃ was measured at the boundary level by the wire heater, while the wax inside the tank was at 80 ℃. Some external force was necessary to initiate a start of subduction. The maintenance of balance between the various heaters, the wall temperature, the wax temperature and the cooling rate was critical for the successful completion of the experiment.

We observed continuous subduction and clear “crust” forming with subsequent “subduction” . We can say that our experiment properly reproduces the general features of plate motion of the earth. Artificially fracturing or weakening the boundary layer and applying a vertical, downward external force were required to initiate subduction in addition to collision of the plates. The thickness of the plate was the primary parameter controlling subduction behavior and plate motion. The plate showed elastic and plastic behavior depending on its thickness and temperature. A cold and thick “plate” did not subduct even after applying an external force, and formed a stagnant lid. A hot and thinner “plate” did not show continuous subduction behavior, plate motion stopped soon after subduction was initiated, possibly because the slab pull force from the thinner partially subducted slab was too weak. Our experiment results suggest that the driving force of subduction and plate motion is slab pull, not the thermal convection of the molten paraffin or ridge push. We will present photos and videos of the observed processes.

Improvements to the tank and heating elements design are necessary to provide better and easier control over the experiments.

Keywords: analogue experiment, plate subduction, paraffin wax, glass walls tank, slab pull