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This Week's Citation Classic

McKenzie D P, Roberts J M & Weiss N O. Convection in the earth's mantle: towards a numerical simulation. *J. Fluid Mech.* **62**:465-538, 1974. [Depts. Geodesy and Geophysics and Appl. Mathematics and Theoretical Physics, Univ. Cambridge, Cambridge, England]

Numerical experiments on convection in fluids, heated either from below or from within, provide a guide to the type of circulation likely to occur in the Earth's mantle. They also allow the gravity field and surface deformation to be obtained, which can be compared with observations. [The *SCI®* indicates that this paper has been cited over 140 times since 1974.]

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"Mantle convection has long been believed to be the energy source for continental drift, though the precise connection between the two was not understood. Starting in 1967, plate tectonics showed how the detailed structure of ridges and island arcs could be produced by the rigid motion of a few thin spherical caps. Once these results were accepted, it was clear that most features on the ocean floor were only indirectly relevant to the circulation of the mantle, though convection was still needed to maintain the motions. As a result, by 1969 we had very few observational constraints on mantle motions.

"The best way to proceed seemed to me to be to study the fluid dynamics of many types of convection driven by different forms of heating and to attempt to understand why they behaved as they did. What little we knew about mantle convection showed that the convection was vigorous, and therefore that the analytical techniques so extensively developed by mathematicians would be of little use. This left a choice between laboratory experiments and numerical solution of the governing equations. Numerical techniques looked more hopeful, partly because the gravity field could easily be calculated, and had been widely observed, and partly because Nigel Weiss, who was also at Cambridge, had long been interested in the numerical solution of the equations governing thermal convection. He and one of his students, Dan Moore, had developed efficient and accurate numerical methods for the purpose, and were interested in the geophysical problem. Jean Roberts carried out the production runs. All the work was done at Cambridge, England.

"I suspect the paper is widely quoted (though I wonder if it is as widely read!) because it reviewed the observations relevant to mantle convection in terms of plate tectonics, and then went on to use the numerical solutions to discuss likely flow geometries. A controversial proposal was that the circulation which maintains the plate motions is restricted to the outer 700 km of the mantle. This suggestion was widely attacked, especially in the US, but has recently been confirmed by geochemical observations.[1,2] Even more recently it has become possible to map the circulation directly,[3] and it is just as complicated as the numerical solutions suggested."

1. **O'Nions R K, Evensen N M & Hamilton P J.** Geochemical modeling of mantle differentiation and crustal growth. *J. Geophys. Res.* **84**:6091-101, 1979.
2. **Jacobsen S B & Wasserburg G J.** The mean age of mantle and crustal reservoirs. *J. Geophys. Res.* **84**:7411-27, 1979.
3. **McKenzie D, Watts A, Parsons B & Roufosse M.** Planform of mantle convection beneath the Pacific Ocean. *Nature* **288**:442-6, 1980.