Ancient Crusts Workshop - Houston Feb 79., Lunar and Planetary Institute, Houston.

PLATE TECTONICS ON THE EARLY EARTH; W.S.F. Kidd and Kevin Burke, Department of Geological Sciences, State University of New York at Albany, Albany, NY 12222

Heat escapes from terrestrial planets both by conduction through the surface and by convection. On earth's surface the plate structure of the lithosphere with its associated volcanism and the occurrence of volcanoes unrelated to plate structure are the most obvious indications of convection within. On the moon although convection may persist today, the absence of any volcanism younger than about 3 b.y. means that there is no superficial sign of young convection. On this evidence the moon could have completed its convectional evolution mainly during the time of high impact flux (> 4 b.y.). This process would have needed to concentrate the moon's heat generating nuclides close to the surface so that conduction could suffice to remove heat generated later in lunar history.

On Mars there is evidence of both early and later vulcanism (although how late vulcanism persisted is not yet clear) so that convection, on the basis of superficial evidence, persisted for longer than on the moon. Because there is only local evidence of compressional and strike-slip motion on Mars the strong evidence of rifting can be interpreted as implying that the planet came close to, but did not develop, a plate-structured lithosphere. Mars appears to have been generally able to dissipate its convective heat through sporadic vulcanism.

On Earth (1) about one-third of the heat presently being generated escapes through the cooling of ocean floor as it ages, another third by conduction through the ocean floor and the rest by conduction through the continents in which there is a high concentration of heat-generating nuclides at shallow depths. Evidence of high sea levels during the last 0.6 b.y. has been interpreted (1) as showing that at some times in the past up to half of all the earth's heat production was lost by the aging of ocean floor.

During the Archean two or three times as much heat was being generated in the earth and the absence of evidence of extensive continental melting (2) shows that heat did not escape along much steeper conductive gradients than at present. Evidence of incessant widespread sporadic vulcanism is also lacking so that increased convection with more effective cooling of aging lithosphere appears the most likely way by which the extra heat was removed.

Plate tectonics is the heat dissipating convective process that operates on earth today, and we have suggested (3) that Archean rocks and structures can be interpreted as products of plate tectonic processes. More active plate tectonics could have satisfied the heat dissipating requirements of the early Earth.

Some Archean geologists have been reluctant to interpret the rocks they study as products of plate tectonic processes and some alleged plate tectonic interpretations of the Archean appear unrealistic to us. This seems to be partly through a lack of familiarity among students of the early Earth with the way in which plate tectonics has operated during later times and limited acquaintance with the kinds of rocks and structures it has produced. A major specific problem has been that many Archean geologists interpret greenstone-belts as structurally simple whereas plate tectonic interpretations, emphasizing horizontal motion on the Earth's surface, require them to be structurally complex as Ramsay (4) long ago demonstrated for the Barberton mountain land.

The plate tectonic process on Earth embodies, as an essential part, the convective return of hydrated lithosphere to the mantle. Partial melting at or above subducted hydrated lithosphere is the process that produces the calc-

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alkaline rocks characteristic of convergent plate boundaries and many have pointed out that lateral accretion of such arc material made at convergent boundaries is a feasible way of building continents. These observations suggest a possible answer to the question: "When did plate-tectonics begin?" One answer could be "As soon as water, sufficient to partially hydrate descending convective material, existed on the Earth's surface, because from that time on calc-alkaline rocks are likely to have been erupted." We suspect that water existed on the Earth's surface from early in its history - certainly long before the ~3.8 b.y. oldest rocks were formed. From the time that there was water on the Earth's surface there seems little likelihood that terrestrial petrology much resembled that of the moon. Instead of high alumina basaltic and anorthositic highlands the Earth would have produced calc-alkaline arcs, microcontinents and continents.

(1) Turcotte, D.L. and Burke, K., 1978. Global Sea-level changes and the thermal structure of the earth. Earth Planet. Sci. Lett. 41, 341

(2) Burke, K. and Kidd, W.S.F., 1978. Were Archaen continental geothermal gradients much steeper than those of today? Nature, 272, 240.

(3) Burke, K., Dewey, J.F. and Kidd, W.S.F., 1976. Dominance of horizontal movements, arc and microcontinental collisions during the later permobile regime, pp. 113-129 in The Earth History of the Earth (ed. B.F. Windley) Wiley, London.

(4) Ramsay, J.G., 1963. Structural investigations in the Barberton Mountain Land, eastern Transvaal. Trans. Geol. Soc. S. Africa 66, 353.