AXIAL FOCUSING OF SEISMIC ENERGY FROM A LARGE IMPACT ON EARTH: PRELIMINARY NUMERICAL SIMULATIONS; M.B. Boslough and E.P. Chael, Sandia National Laboratories, Albuquerque, NM 87185.

We have proposed a hypothesis and performed preliminary proof-of-principle simulations for the coupling of energy to the earth's mantle from a major impact by axial focusing of seismic waves. Because of the axial symmetry of the explosive source, the phases and amplitudes are dependent only on ray parameter (or takeoff angle) and are independent of azimuthal angle. For a symmetric and homogeneous earth, all the seismic energy radiated by the impact at a given take-off angle will be refocused (minus attenuation) on the axis of symmetry, regardless of the number of reflections and refractions it has experienced. Mantle material near the axis of symmetry will experience more strain cycles with much greater amplitude than elsewhere, and will therefore experience more irreversible heating. This mechanism may give rise to an isostatic instability leading to uplift, rifting, or volcanism. The situation is very different than for a giant earthquake which has an asymmetric focal mechanism and a larger area. It should be noted that our hypothesis is fundamentally different from those proposed by others [e.g. 1-4] which involve melting and excavation at the impact location.

Along with the appreciation of the importance of impact events on the earth's evolution, there has been increasing speculation that energetic collisions have been responsible for processes as varied as continental flood basalt eruptions, mantle plumes, continental rifting, and geomagnetic pole reversals. The link between impacts and such geophysical processes was first discussed by Seyfert and Sirkin [5], who suggested that impact-induced mantle plumes could be a mechanism for initiating the breakup of plates. Burek and Wanke [6] listed correlations between known Cenozoic impacts and geomagnetic field reversals, unconformity ages, shifts in paleotemperatures, and tectonic episodes. They suggested that major impacts could generate shock-induced phase transitions in the upper mantle, disrupting a delicately-balanced stability down to the core-mantle boundary. Rampino and Strothers [7] proposed a quasi-periodic correlation between mass extinctions and major continental flood basalt volcanism over the last 250 million years and attempted to explain it in terms of episodic showers of impacting comets. Connections between impacts and the internal workings of the earth are supported by correlations of the ages of tektites from strewn fields with geomagnetic field reversals [8], and by a reversal associated with sediments deposited immediately after the impact that formed the Ries Crater [9].

A causal link between major impact events and global processes would probably require a significant change in the thermal state of the earth's interior, presumably brought about by coupling of impact energy. One possible mechanism for such energy coupling from the surface to the deep interior would be through focusing due to axial symmetry. Antipodal focusing of surface and body waves from earthquakes is a well-known phenomenon [10] which has previously been exploited by seismologists in studies of the earth's deep interior [11,12]. Antipodal focusing from impacts on the moon, Mercury, and icy satellites has also been invoked by planetary scientists to explain unusual surface features opposite some of the large impact structures on these bodies [13,14]. For example, "disrupted" terrains have been observed antipodal to the Caloris impact basin on Mercury and the Imbrium basin on the Moon. Very recently there have been speculations that antipodal focusing of impact energy within the mantle may lead to flood basalt and hotspot activity [15,16], but there has not yet been an attempt at a rigorous model.

For the preliminary seismic modeling, the impact was represented as a vertical point force applied at the earth's surface as a delta function in time. The impactor was assumed to yield an

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impulse of approximately 3 x 10^{24} dyne sec, as an estimate of a K/T-sized impact. Synthetic displacement and strain records were generated for such a source by summing the normal modes of the elastic earth model 1066A of Gilbert and Dziewonski [17]. We used the attenuation profile of the model PREM [18] to determine Q values for the 1066A modes. We assumed a vertically-directed point source, so we included only spheroidal modes in the synthetic seismogram calculations. Toroidal modes are not excited by a vertical point force. All spheroidal modes with periods greater that 45 seconds were summed for the synthetics.

The synthetic signals yield estimates of the peak strains at any location in or on the earth. Strains at the surface near the antipode (angular distance = 180^o) are orders of magnitude higher than those over most of the rest of the earth's surface. Figure1 demonstrates that focused arrivals have much greater amplitudes than direct arrivals at the core-mantle boundary. The direct arrival can be seen for a point directly beneath the impact, followed by a long high-amplitude focused trace. Figure 2 plots the peak strains as a function of depth beneath the antipode of the impact, from the surface to the core-mantle boundary. It can be seen that peak strain amplitude varies by two orders of magnitude, and is largest at the top. This would imply that most of the energy is focused at shallow depths. Future work will model the impact using shock-dynamics codes to determine how the impact generates seismic waves.

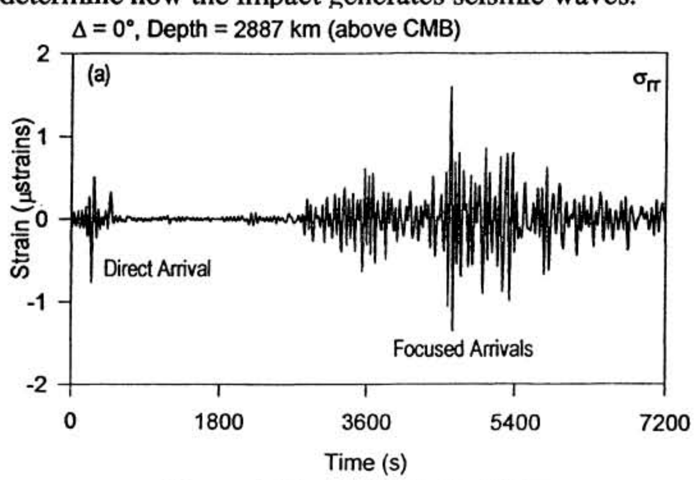

Figure 1. Synthetic strain history

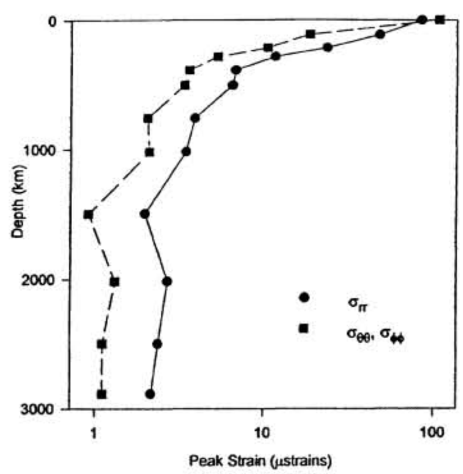

Fig. 2. Peak strain along antipode

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