Bulletin of the Seismological Society of America, Vol. 75, No. 3, pp. 891–892, June 1985

REPLY TO H. ACHARYA'S "COMMENTS ON 'SEISMIC POTENTIAL ASSOCIATED WITH SUBDUCTION IN THE NORTHWESTERN UNITED STATES'"

By Thomas H. Heaton and Hiroo Kanamori

Subduction in the northwestern United States presents us with a dilemma. Although there is good evidence of 3 to 4 cm/yr of convergence between the Juan de Fuca and North American plates, the occurrence of either historic or instrumentally recorded shallow thrust earthquakes is remarkably low. Why aren't there more earthquakes? Aseismic slip along the entire plate boundary provides a convenient explanation for this dilemma. Aseismic slip appears to be the predominant mode for plate interaction for many subduction zones. However, the Juan de Fuca subduction zone is clearly different from the most common class of aseismic subduction zone that is characterized by the subduction of very old oceanic lithosphere (Heaton and Kanamori, 1984). We noted that, in general, the subduction of young lithosphere is characterized by strong interplate seismic coupling. The Juan de Fuca subduction zone can be considered as an end member in that it involves some of the youngest subducted lithosphere observed anywhere. This, in itself, suggests that the Juan de Fuca subduction zone belongs in a class (perhaps aseismic) by itself. However, there are several other localities where comparably young crust appears to be subducting. These are southern Chile between 42° and 45° south latitude, Colombia near 2° north latitude, and the Rivera plate off western Mexico. All of these regions are seismically active and, in the case of Colombia and southern Chile, have involved earthquakes with energy magnitudes of 8.8 (1906) and 9.5 (southern half of the 1960 rupture zone), respectively. Furthermore, these regions of Colombia and southern Chile do not have bathymetric trenches, and there is no significant seismic activity deeper than 100 km observed on their Benioff-Wadati zones.There is also evidence that these regions have experienced significant periods of seismic quiescence. The NOAA catalog shows a remarkable absence of shallow activity between 41° and 45° south latitude along the Chile trench for at least 30 yr prior to the 1960 M_W 9.5 Chilean earthquake. Unfortunately, this catalog is not sufficiently complete to allow a comparison of seismicity at small magnitude earthquakes. However, at a magnitude cutoff of 6, the rate of seismicity in the 50 yr preceding the 1960 earthquakes in the region between 41° and 45° south latitude seems comparable to that reported for the Juan de Fuca subduction zone's 150-yr history (the Juan de Fuca convergence rate is about one-third that of southern Chile).

Acharya (1981) has estimated that 1.8 cm/yr of aseismic slip on the Juan de Fuca subduction zone is indicated by the rate of historic volcanism observed in the Cascade ranges. The formula he uses is

$$AS = 5.55N + 0.83,$$

where AS is the aseismic slip rate (cm/yr), and N is the number of eruptions per year per 1000 km of trench. Although this relationship may be approximately valid for many subduction zones, it leads to the conclusion that the calculated aseismic slip must always be greater than 0.83 cm/yr, regardless of the plate convergence rate or the volcanism rate. For the Juan de Fuca subduction zone, Acharya's estimated aseismic slip value, 1.8 cm/yr, is not much larger than this minimum

value. Furthermore, a model in which the Juan de Fuca subduction zone is strongly coupled would require an absence of Cascade-type volcanism. However, Cascade-type volcanism is common in regions of great subduction earthquakes. For example, the volcanism rates in Colombia and southern Chile are similar to that observed in the northwestern United States when scaled for convergence rate. Thus, it is difficult to interpret the presence of such volcanoes as evidence that large earthquakes will not occur.

We feel that the basic problem remains. How can there be convergence at 3 to 4 cm/year and such a remarkable historic paucity of shallow thrust earthquakes? Lacking direct evidence of great prehistoric earthquakes or of aseismic slip, we have no clear answer to this question, and we reiterate our previous conclusion: "Although we cannot completely rule out the possibility that the plate motion is being accommodated by aseismic creep, we find that the Juan de Fuca subduction zone shares many features with other subduction zones that have experienced great earthquakes . . . and there is sufficient evidence to warrant further study of the possibility of great subduction zone earthquakes in the Pacific Northwest."

References

Acharya, H. (1981). Volcanism and aseismic slip in subduction zones, *J. Geophys. Res.* **86,** 335–344.

Heaton, T. H. and H. Kanamori (1984). Seismic potential associated with subduction in the Northwestern United States, *Bull. Seism. Soc. Am.* **74,** 933–941.

U.S. Geological Survey
Earthquakes, Volcanoes and Engineering

525 South Wilson Avenue
Pasadena, California 91106 (T.H.)

Seismological Laboratory
California Institute of Technology
Pasadena, California 91125 (H.K.)

Manuscript received 29 January 1985