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Non-closure of the geologically instantaneous global plate motion circuit: Implications for plate non-rigidity

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Global plate motion models such as NUVEL-1 provide rigorous tests of the assumption of plate rigidity and appear, at first glance, to strongly validate that assumption. But the complex interactions of the plate circuits in such global models can hide important inconsistencies. Here we make a straighforward comparison of Pacific-North America motion estimated through three nonoverlapping sets of data: (1) plate motion data (spreading rates, fault azimuths, and slip vector azimuths) along the Pacific-North America boundary, (2) space geodetic data, and (3) plate motion data along the Pacific-Antarctic-Nubia-North America plate motion circuit. We find that all three estimates are inconsistent with one another and, in particular, the plate circuit results are highly inconsistent with the two directly estimated results, being both of the wrong magnitude and in the wrong direction. The inconsistency is large and described by an angular velocity of non-closure with a magnitude 0.11 ± 0.03 degs/Myr (95% confidence limits). Projected into the Gulf of California, the non-closure is a velocity of 12 ± 3 mm/yr toward 196. If not owing to an unrecognized systematic error, this non-closure is presumably caused by non-rigidity of one or more of the North American, Nubian, Antarctic, and Pacific plates. We consider several hypotheses to explain the inconsistency. We can conceive of no plausible diffuse plate boundary to explain the difference. In particular, deformation in western North America is excludable as the cause of the difference as both direct plate motion data and space geodetic data differ highly significantly from the predictions from the circuit. The bias in rates of seafloor spreading caused by outward displacement of magnetic anomaly reversal boundaries (DeMets and Wilson, 2005) is in the right direction but can account for only 15% of

the inconsistency. Much of the inconsistency may be explainable, however, by horizontal thermal contraction of oceanic lithosphere, especially of the young Pacific plate lithosphere flanking the Pacific-Antarctic Rise and East Pacific Rise. This young lithosphere includes a continuous band connecting Baja California to the Pacific-Antarctic Rise. The expected contraction rate of this young lithosphere is the right order of magnitude to explain the discrepancy. If this hypothesis is correct, simple plate tectonic predictions may need to be corrected by models fully incorporating the horizontal thermal contraction of the lithosphere to obtain the accuracy needed for some plate recontructions and for comparisons with space geodetic data.