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Geologically current plate motions

Charles DeMets,[1] Richard G. Gordon[2] and Donald F. Argus[3]

[1] Department of Geoscience, University of Wisconsin-Madison, Madison, WI 53706, USA. E-mail: chuck@geology.wisc.edu
[2] Department of Earth Science, Rice University, Houston, TX 77005, USA
[3] Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, USA

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SUMMARY

We describe best-fitting angular velocities and MORVEL, a new closure-enforced set of angular velocities for the geologically current motions of 25 tectonic plates that collectively occupy 97 per cent of Earth's surface. Seafloor spreading rates and fault azimuths are used to determine the motions of 19 plates bordered by mid-ocean ridges, including all the major plates. Six smaller plates with little or no connection to the mid-ocean ridges are linked to MORVEL with GPS station velocities and azimuthal data. By design, almost no kinematic information is exchanged between the geologically determined and geodetically constrained subsets of the global circuit—MORVEL thus averages motion over geological intervals for all the major plates. Plate geometry changes relative to NUVEL-1A include the incorporation of Nubia, Lwandle and Somalia plates for the former Africa plate, Capricorn, Australia and Macquarie plates for the former Australia plate, and Sur and South America plates for the former South America plate. MORVEL also includes Amur, Philippine Sea, Sundaland and Yangtze plates, making it more useful than NUVEL-1A for studies of deformation in Asia and the western Pacific. Seafloor spreading rates are estimated over the past 0.78 Myr for intermediate and fast spreading centres and since 3.16 Ma for slow and ultraslow spreading centres. Rates are adjusted downward by 0.6–2.6 mm yr^{-1} to compensate for the several kilometre width of magnetic reversal zones. Nearly all the NUVEL-1A angular velocities differ significantly from the MORVEL angular velocities. The many new data, revised plate geometries, and correction for outward displacement thus significantly modify our knowledge of geologically current plate motions. MORVEL indicates significantly slower 0.78-Myr-average motion across the Nazca–Antarctic and Nazca–Pacific boundaries than does NUVEL-1A, consistent with a progressive slowdown in the eastward component of Nazca plate motion since 3.16 Ma. It also indicates that motions across the Caribbean–North America and Caribbean–South America plate boundaries are twice as fast as given by NUVEL-1A. Summed, least-squares differences between angular velocities estimated from GPS and those for MORVEL, NUVEL-1 and NUVEL-1A are, respectively, 260 per cent larger for NUVEL-1 and 50 per cent larger for NUVEL-1A than for MORVEL, suggesting that MORVEL more accurately describes historically current plate motions. Significant differences between geological and GPS estimates of Nazca plate motion and Arabia–Eurasia and India–Eurasia motion are reduced but not eliminated when using MORVEL instead of NUVEL-1A, possibly indicating that changes have occurred in those plate motions since 3.16 Ma. The MORVEL and GPS estimates of Pacific–North America plate motion in western North America differ by only 2.6 ± 1.7 mm yr^{-1}, $\approx$25 per cent smaller than for NUVEL-1A. The remaining difference for this plate pair, assuming there are no unrecognized systematic errors and no measurable change in Pacific–North America motion over the past 1–3 Myr, indicates deformation of one or more plates in the global circuit. Tests for closure of six three-plate circuits indicate that two, Pacific–Cocos–Nazca and Sur–Nubia–Antarctic, fail closure, with respective linear velocities of non-closure of 14 ± 5 and 3 ± 1 mm yr^{-1} (95 per cent confidence limits) at their triple junctions. We conclude that the rigid plate approximation continues to be tremendously useful, but—absent any unrecognized systematic errors—the plates deform measurably, possibly by thermal contraction and wide plate boundaries with deformation rates near or beneath the level of noise in plate kinematic data.

Key words: Plate motions; Planetary tectonics.