GPS MEASUREMENTS OF CRUSTAL DEFORMATION IN EASTERN INDONESIA AND PAPUA NEW GUINEA

By

Colleen W. Stevens

An Abstract of a Thesis Submitted to the Graduate
Faculty of Rensselaer Polytechnic Institute
in Partial Fulfillment of the
Requirements for the Degree of
DOCTOR OF PHILOSOPHY
Major Subject: Geophysics

The original of the complete thesis is on file
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Rensselaer Polytechnic Institute
Troy, New York

April 1999
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Abstract

Here we present crustal velocities from Global Positioning System (GPS) measurements made between 1991 and 1997 at 56 sites throughout eastern Indonesia and Papua New Guinea (PNG). From these measurements, we interpret the relative motions of the plates and fault slip rates in the region.

Only a small amount of the Pacific-Australian plate convergence is accommodated at the New Guinea Highlands fold and thrust belt although it stands out as a major structural feature. East of 138° E, most of the plate convergence is taken up on faults lying north of the northern coast of Irian Jaya, including the New Guinea trench. West of 138° longitude, however, plate convergence drives rapid west-southwest motion (about 80 mm/yr) of the Bird's Head microplate relative to southern Irian Jaya. As a result, the Bird's Head continental crust is being subducted at about 50 mm/yr below the Banda Sea at the Seram trough, and only a small portion of the convergence is taken up between Bird's Head and the Pacific plate.

Pacific-Eurasian plate convergence is fully accommodated within the northern Molucca Sea. Southward, however, approximately 30% of this convergence is transferred to north-south convergence at the North Sulawesi trench by the rotation of the East Sulawesi microplate. The Banda Sea comprises a large shear zone. Left-lateral shear in the Banda Sea is accommodated differential motion between at least three crustal slivers.

Eurasian-Australian plate convergence is fully accommodated at the Java trench near Java. Eastward along the Banda arc, however, from Timor to Aru, Australian-Eurasian plate convergence is not actively accommodated at the Timor and Aru troughs. Instead, the Banda arc islands have been accreted to the northern margin of the Australian plate, and the boundary separating the plates has jumped to the north, probably to the Wetar backarc thrust, where several large thrust earthquakes have occurred in recent years. West of the island of Timor, near 121°E, a north trending left-lateral shear zone with a slip rate of about 50 mm/yr is required to accommodate this differential motion.

Yearly GPS measurements on a small-aperture array crossing the fault from 1992-1995 indicate that the left-lateral strike-slip Palu fault in central Sulawesi slips at a rate between 26 and 46 mm/yr with a locking depth between 2 and 8 km. From the measured slip rate and the historic seismicity of the fault, we estimate the Palu fault currently has stored enough strain to produce a $M_w > 7$ earthquake. The Palu and other nearby faults accommodate rapid clockwise rotation of nearly 4°/Ma of East Sulawesi relative to eastern Sunda. The rotation of East Sulawesi transfers east-west shortening between the Pacific and Eurasian plates to north-south subduction of the Celebes Basin beneath Sulawesi.

In Papua New Guinea, earthquakes and geodetic evidence are used to infer the presence of a low-angle, mid-crustal detachment fault beneath the Finisterre Range that connects to a steep ramp surfacing near the Ramu-Markham Valley. Waveforms of three large (M_w = 6.3 to 6.9) thrust earthquakes that occurred in October 1993 beneath the Finisterre

Range 10 to 30 km north of the valley reveal gently, north-dipping thrusts at about 20 km depth. GPS measurements show up to 20 cm of coseismic slip across the valley requiring that the active fault extend to within a few hundred meters of the Earth's surface beneath the Markham Valley. Together these data imply that a gently north-dipping thrust fault in the middle or lower crust beneath the Finisterre Range north of the valley steepens and shallows southward forming a high-angle ramp fault beneath the north side of the Markham Valley. Waveforms indicate that both the ramp and detachment fault were active during at least one of the earthquakes. While the seismic potential of mid-crustal detachments elsewhere is debated, in Papua New Guinea the detachment fault shows the capability of producing large earthquakes.

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