MONITORING SEISMICITY AND SURFACE DEFORMATIONS IN THE NEW HEBRIDES ISLAND ARC

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During the past 5 years Cornell University and the Office de la Recherche Scientifique et Technique Outre-Mer (ORSTOM) have conducted studies of seismicity, surface tilting and uplift in one of the major oceanic subduction zones of the southwest Pacific, the New Hebrides Island Arc. The program has included operation of temporary networks of seismographs, some of which included University of Texas OBS stations, a permanent network of 18 stations installed in 1978, and measurements of tilt with bubble-level tiltmeters and relevellings of benchmark arrays. In a related project the pattern of late Quaternary uplift and tilting of coral terraces in the area is being determined.

The seismicity of the New Hebrides is characterized by the frequent occurrence of large (magnitude 7-8) earthquakes, often remarkably clustered in time and space, rather than by the occasional occurrence of great earthquakes. The record for this century suggests a possible repeat time of about 30 years for rupturing of the plate boundary. The area focused upon in our studies, the central New Hebrides, spans a length of about 500 km along the arc. The northern part, including Santo and northern Malekula islands, ruptured during two major sequences of earthquakes in 1965 and 1973-74, while the southern part, including southern Malekula and Efate islands, has not ruptured by large earthquakes during probably at least the past 30 years. A primary question is whether the southern area is in a pre-seismic phase of a cycle of major earthquake occurrence or whether slippage of the plate boundary is accommodated without large earthquakes. We are investigating this question through comparative study of the two areas.

The thrust zone of contact between the convergent plates in the northern area may be wider than that in the southern area because of the anomalous morphology of the Central New Hebrides, where the islands of Santo and Malekula are in positions normally occupied by a trench. The topography of the D'Entrecasteaux "Fracture Zone", subducted beneath parts of Santo and Malekula, controls the locations of the areas ruptured in 1965 and 1973-74.

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That topographic feature also has clear expressions in the focal mechanisms and space-time pattern of occurrence of intermediate depth earthquakes, and in the pattern of uplift and tilting of blocks in the upper plate on Santo and Malekula islands.

The southern "unruptured" area includes the transition between the anomalous morphology of the central New Hebrides and the more typical island arc-trench system of the southern New Hebrides. Major transverse bathymetric features are associated with the northward termination of the trench between Efate and Malekula Islands. This region is the locus of several striking features of the seismicity. A remarkably high and nearly constant rate of seismicity (mb greater than about 4.5) has persisted there during the past 20 years. This contrasts with the generally lower rate in the north and in several other parts of the arc where strong fluctuations in activity are related to the occurrence of large earthquakes. Focal mechanism solutions and accurate depths for the larger events of 1963-1978, in combination with data from local networks, delineate the inclined plate boundary beneath Santo. In contrast most of the data for the Efate region indicate a more diffuse distribution of seismicity with significant activity in the upper plate. The largest earthquakes caught so far in our program occurred in a sequence of 4 events (Ms = 5.9 - 6.2) in the Efate area between September 1978 and September 1979. The largest of the four was preceded by a foreshock sequence, but the others were not. Well-defined features of the time-space development of foreshocks, aftershocks and related swarms in the sequence, together with aspects of previous seismicity, indicate a persistent and localized structural feature in the transition region north of Efate which plays an important role in the pattern of seismicity.

Tilts on Efate and Santo Islands are reliably determined during the past 5 years by 12 relevellings each of 1 km arrays of benchmarks. The Efate measurements show a large consistent tilting of 5-6 microradians upwards towards the anomalous area north of Efate. Much of this tilting seems to have taken place during a 1.5 year interval prior to the 1978-79 sequence. In contrast, the Santo measurements show little accumulated tilt, although a 3-4 microradian pulse-like signal can be tentatively correlated with the Efate signal.

Thus, although the various data for the Efate area may be interpreted as precursory or pre-seismic phenomena - e.g. increased loading of a locked fault zone - there is also the possibility that the mode of plate boundary slippage is governed by specific morphological and structural features and may vary significantly along the arc. Even if the fraction of seismic relative to aseismic slippage is large and does not vary along the arc, the nature of a pre-earthquake phase may still be governed largely by the specific structural complexities.