ANALYSING EARTHQUAKE HAZARD IN PAPUA NEW GUINEA

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ABSTRACT

After an understanding of the regional seismicity and tectonics has been gained, the second stage for an earthquake hazard study is largely concerned with calculation of ground motion recurrence, representing the hazard due to shaking by seismic waves. Other earthquake hazards, such as liquefaction, surface rupture, landslides, and tsunami, are treated separately. Two main models required to compute ground motion recurrence are a seismotectonic model that specifies the assumed distribution of earthquake magnitude recurrence of earthquakes, and a ground motion model that specifies the expected ground motion from the earthquakes.

The four-stage Cornell method uses a seismotectonic model consisting of earthquake source zones that are small enough to allow the assumption of uniform seismicity, specified by the rate of occurrence of earthquakes larger than a specified magnitude, the relative number of small to large earthquakes (the b value), and the maximum credible magnitude for each source zone. The zones represent regional areas, volumes, or active faults. In this study the source zones are all volumes within a series of depth layers. Future work will increase the resolution of the seismotectonic model by adding specific active faults.

By utilizing available data and the use of improved methods, the earthquake hazard of Papua New Guinea (PNG) was determined. Based on the Cornell method, the results of this work will form the basis for the replacement of the existing outdated hazard maps.

EARTHQUAKE HAZARD AND DATA ANALYSIS

Previous work

Brooks (1965) was the first to analyse seismic hazard of the PNG region using earthquakes from 1906 to 1959, to estimate recurrence intervals of larger earthquakes, and represented hazard with intensity maps for recurrence intervals for 25, 50 and 100 years.

Studies were later undertaken to support building codes for earthquake design of bridges (Beca *et al*, 1976), and for buildings (Jury *et al*, 1982). These included peak ground acceleration maps for a recurrence interval of 20 years, and a seismic zonation map based on these estimates. The hazard and vulnerability aspects of both are now in need of revision.

Denham et al. (1993) gave a review of earthquake risk in the Southwest Pacific region, including PNG, in the Technical Planning Volume for the Global Seismic Hazard Assessment Project (GSHAP) undertaken for the United Nations International Decade of Natural Disaster Reduction. McCue (1999) used available ground motion recurrence calculations to contour the PNG map incorporated into the GSHAP map of global hazard.

Utilizing the magnitude 7 earthquake record since 1900, Ripper and Letz (1993) determined return periods and probabilities of occurrence of these earthquakes in normalized 10,000 km^2 areas of PNG. The return periods for magnitude 7.0 earthquakes for Bougainville Island, New Britain, Huon, West Bismarck, North Sepik and Ramu seismic zones are only 37, 60, 81, 88, 125 and 125 years respectively.

Amongst others, the seismic hazard was determined for the urban centre of Lae (Ripper and Anton, 1995), sites of national projects such as the Lihir Gold Mine (Anton and Ripper, 1999), while Ripper and McCue (1983) determined the seismic hazard of the Papuan Fold and Thrust Belt.

Since the 1970s, other seismic hazard analyses have been undertaken for various sites in PNG, particularly dams, mines and petroleum facilities. These have been mainly based on the limited and imprecise earthquake catalogue, without detailed consideration of geology and geophysics.

Earthquake hazard analysis

The hazard maps are produced using the four-stage process Cornell method.

In the first stage is the development of a seismotectonic model, which attempts to anticipate the distribution of earthquakes over the next few tens of years. This is largely based on previous seismicity, with additional constraint from geological and geophysical data. The earthquake source zones used in a Cornell seismotectonic model are defined as being areas or volumes that are assumed to have uniform seismicity for the ground motion recurrence calculation. Some zones represent regions of faulting or deformation, while other zones are used to represent transitions in levels of activity, from high to low. When active faults are identified within a zone and used within the model, the earthquakes assumed to be on each fault are subtracted from the background area or volume source zone. The zones developed for this project (Figures 1 and 2) are more detailed than used in past studies.

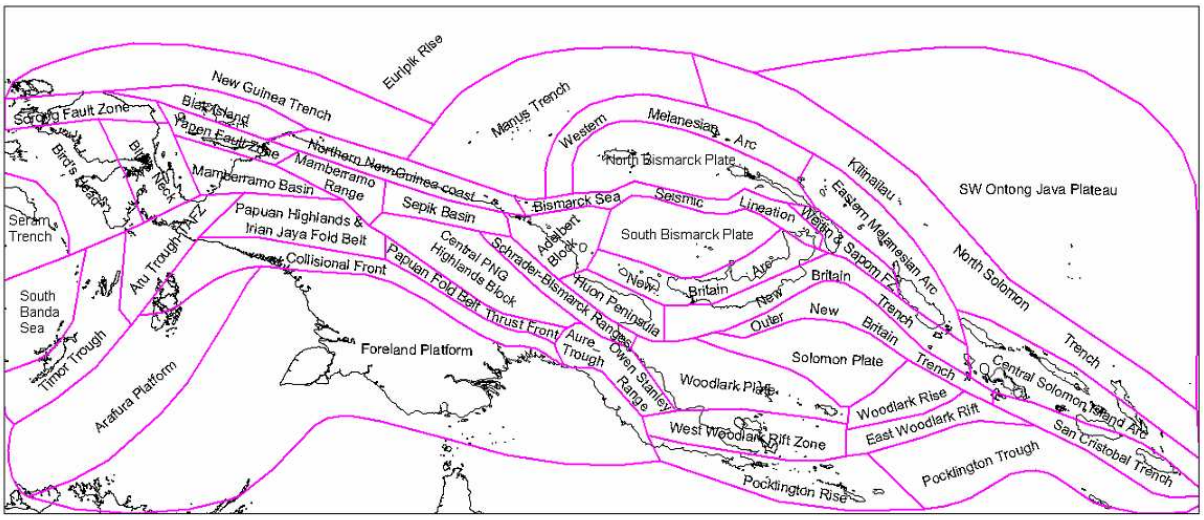

Figure 1. The seismotectonic model PNG1 shallow seismicity zones, to a depth of 35km.

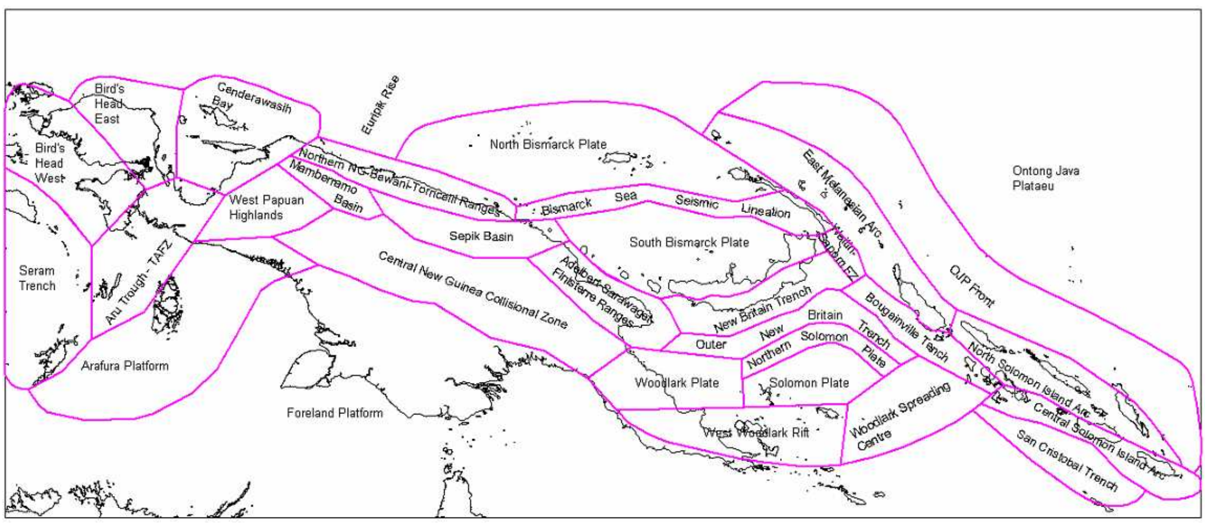

Figure 2. The source zones for depths from 35 to 70 km. Deeper levels are also involved in the hazard analysis, (6 layers in total).

The second stage involved quantifying the seismicity in each of the source zones, giving the rate of earthquake activity as a function of magnitude, with key parameters defining the relative numbers of small to large earthquakes, and the maximum credible earthquake magnitude in each zone. Quantification considered earthquake clustering, and sequences including foreshocks and aftershocks were identified.

Stage three involved the specification of the ground motion from an earthquake as a function of distance, magnitude and other parameters. Ideally, attenuation functions are derived from local empirical data. This requires considerable instrumentation that is not installed in most places, and is very limited in PNG. This means that attenuation functions derived using data recorded in other places that are geologically and tectonically similar must be chosen and used until local data are available for the derivation of a local attenuation function. The applicability of such functions was checked with a few local data available. Local attenuation affects estimates of local earthquakes, especially smaller events, so variations affect the magnitude estimates of the earthquakes in the catalogue as used in stage one.

Spectral ground motion recurrence was computed in stage four by integrating the probabilities of motion from all earthquakes in space (longitude, latitude and depth), magnitude (from negligible to maximum credible), and frequency of motion. Software used was EZ-FRISK program (McGuire, 1993), as used for the GSHAP project. The four stages were further developed to produce hazard maps in an iterative process.

Resources used

Earthquake data for the PNG region from the International Seismological Centre (ISC) bulletin and from the Port Moresby Geophysical Observatory (PMGO) were utilized. The data include comprehensive earthquake hypocenter and intensity databases, as well as a collection of accelerograms recorded on medium or soft foundation. Some of these records have been analysed by the then Bureau of Mineral Resources, Geology and Geophysics (now Geoscience Australia) and others have been analysed by PMGO (Ripper, 1992).

Data now available includes some strong motion data that has been collected by PMGO in the 1970s and 1980s. RVO have data collected in the 1990s and by Lihir Gold Mine in the early part of 2000s through their collaboration with CSIRO. Some data were collected by the Seismology Research Centre (SRC) and BMR during their occupation of sites at the Panguna Mine site on Bougainville and at the Yonki Dam, in the 1980s. Other data included geology and geophysics obtained from the former Department of Mining, as well as topographic and geographic. The geology data includes Quaternary fault lines while the geophysics includes gravity and magnetic.

Seismic acceleration attenuation relationships for the entire PNG region will be derived from analysis of the accelerograms and synthesized with the distribution of seismicity, geology and tectonics of the region to produce a new map of seismic zoning.

Preliminary hazard for Lae

The first test of model PNG1 was the application to the city of Lae.

Nine seismic zones in layer 1 of the seismotectonic model PNG1 were combined with six zones from layer 2, five from layer 3 and seven from layer 4 to determine the PGA as a function of return period (Figure 3), uniform probability response spectra for selected return periods (Figure 4), and an example of magnitude-distance deaggregation for motion of 1.0 second period and a return period of 975 years (Figure 5). The determinations are based on magnitude 5.0 earthquakes and larger, and incorporate all source zones that are within 300 km of Lae, in northeastern New Guinea.

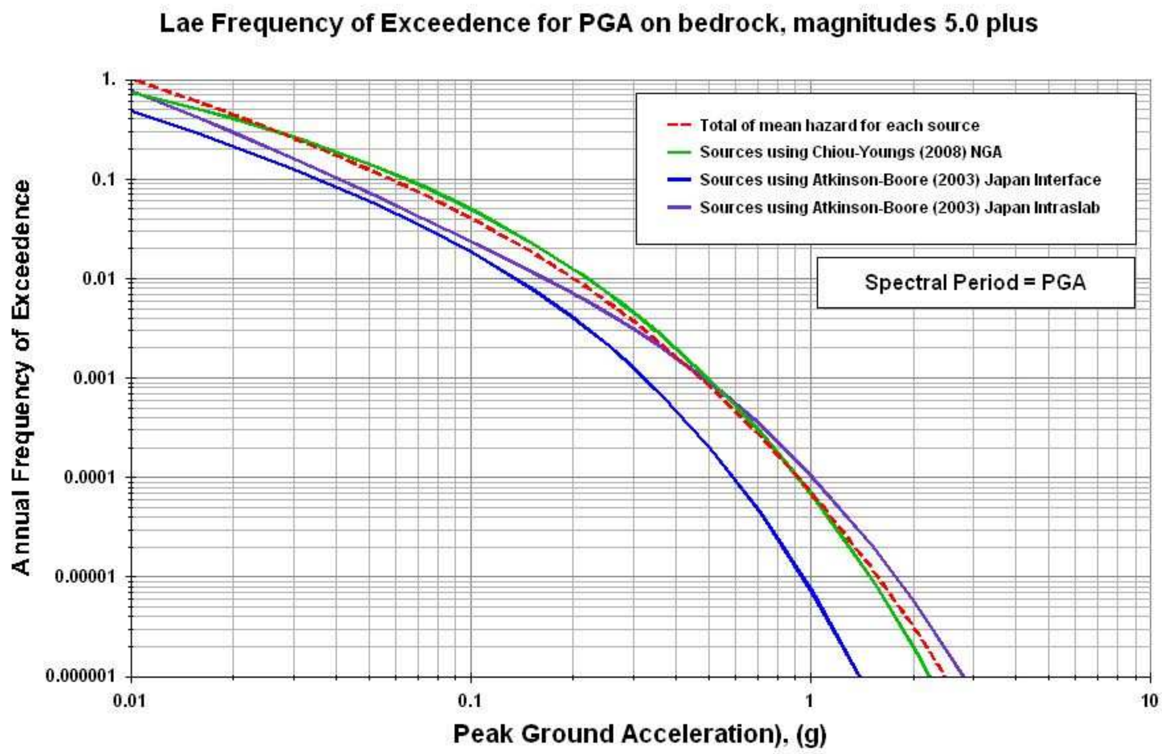

Figure 3. Peak Ground Acceleration at Lae varying with return period.

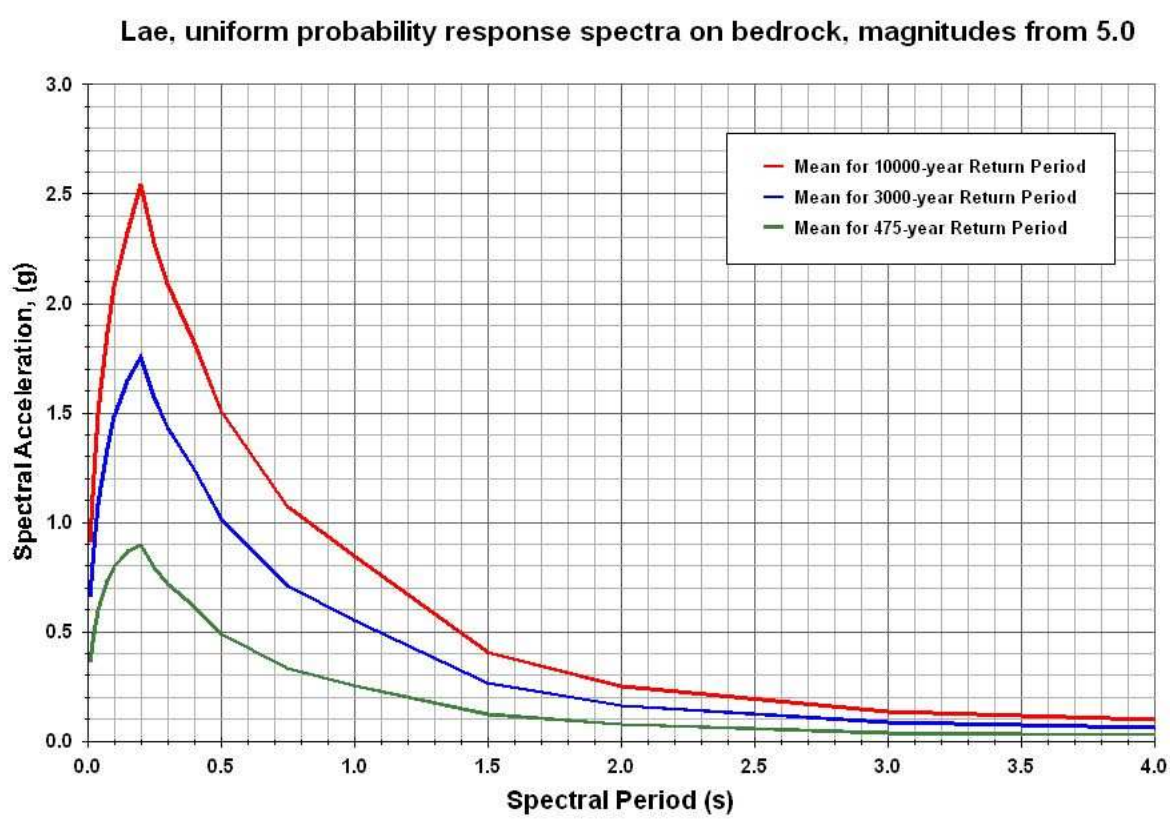

Figure 4. Uniform probability response spectra for Lae.

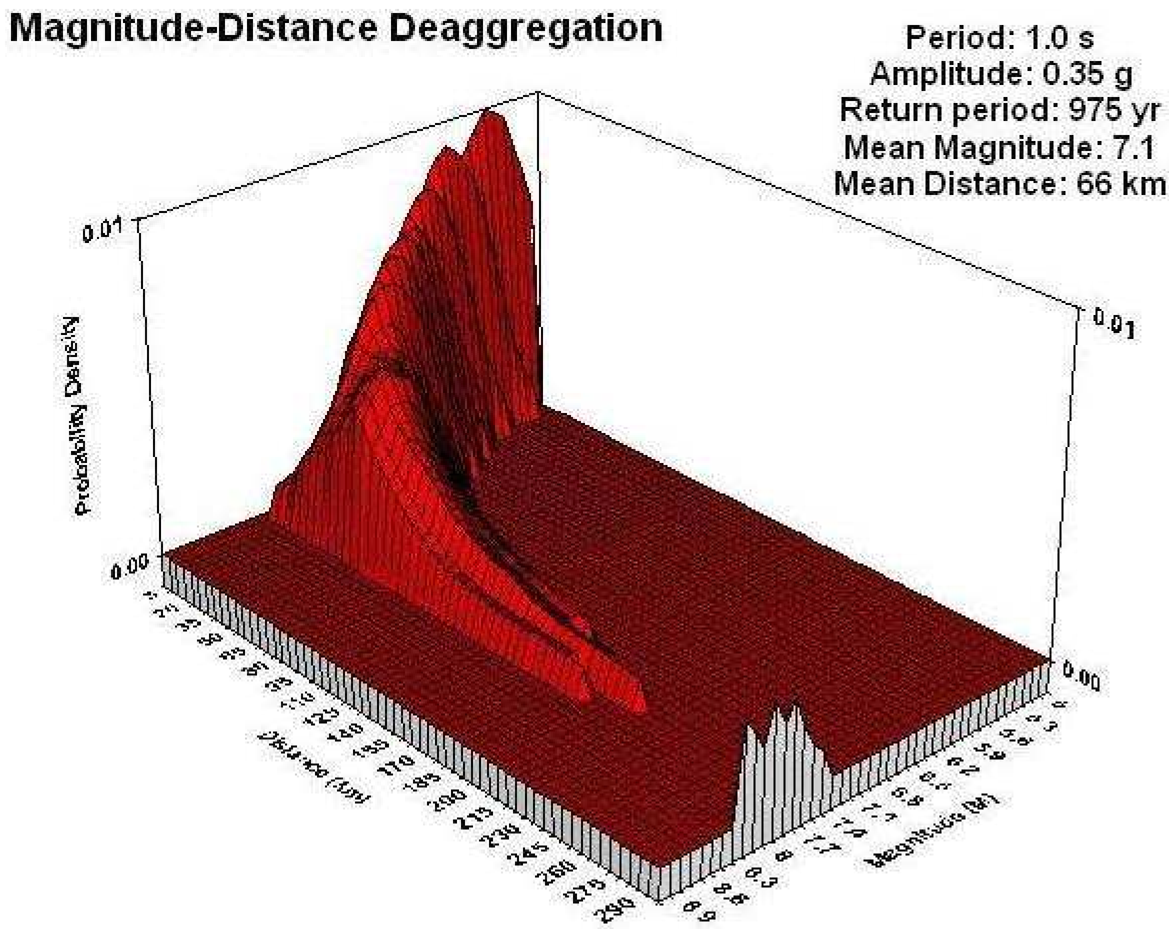

Figure 5. Magnitude-distance deaggregation for Lae.

CONCLUDING REMARKS

The earthquake hazard in PNG is being determined, with the seismotectonic model having been developed and seismicity in source zones quantified.

Most earthquakes in the PNG region occur along tectonic plate boundaries and along zones of plate deformation where stress has built up. As well, earthquakes associated with volcanic activity occur well away from the plate margins along volcanic arcs. It must be noted, though, that volcanic earthquakes and volcanic activity both occur as a result of tectonic forces in the earth. Accompanying hazards in tsunamis, landslides and floods do result as consequences of these tectonic events.

While earthquake hazard is recognized as significant, proper determination of hazard parameters is required to update previous work as data now becomes available. Producing modern hazard maps to replace old maps now becomes an achievable goal. Being situated in an earthquake prone region, PNG has a significant earthquake hazard. It is envisaged that the results of this study will assist in mitigating the effects of future disastrous events in the region.

ACKNOWLEDGEMENTS

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