SEISMIC HAZARD IN NORTHERN CENTRAL AMERICA

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SUMMARY

In regions where the seismicity rate is low, or where recent crustal movements are poorly known, like in Northern Central America, it is necessary to use a probabilistic approach in order to calculate the Seismic Hazard. To calculate the hazard, we first defined a site of interest, and then described a nearby zone in which earthquakes occur. We estimated for each source zone the probability of occurrence of future earthquake with a given magnitude and within a given time period. For numerical calculations, we use the computer code SEISRISK III, developed by Bender and Perkins (1987). The code, as input entries, requires a table of attenuation of peak ground accelerations, a definition of seismic source zones and the corresponding rates of seismicity. Also are required a threshold and a maximum magnitude. In order to obtain a feasible estimate of the hazard we followed the logic tree approach (Cáceres and Kulhánek, 1999). The results are expressed in a series of maps of expected Peak Ground Acceleration (PGA) for 60% and 90% probabilities of nonexceedence in a 50-year interval, which corresponds to return periods of 100 and 475 years, respectively. The highest PGA values of 0.4g (90% probability of nonexceedence) are expected along the borders of Honduras-Guatemala and Honduras-El Salvador. Along the Swan fracture zone, a maximum acceleration of around 0.3g is expected. However, if we concentrate on a given source zone, like the Swan fracture zone, the seismic history is incomplete. In order to accommodate for this, we focus on the slip rate of this zone. From comparing moment release of earthquakes with expected moment release from plate motions we obtain a potential maximum moment deficiency as well as a recurrence period for a given magnitude. The techniques we use involve body wave inversion of ten earthquakes along the Swan fracture zone which gives us the fault width, as well as summing the total moment for earthquakes along the Swan fracture zone.

INTRODUCTION

A simple way to try to assess the seismic hazard would be to compile seismicity maps and look for areas with a lot of earthquakes and those with just a few. That would give us how prone an area is to be affected by earthquakes. In order to obtain a measure of seismic hazard in areas where the seismicity rate is low, or where recent crustal movements are poorly known, it is necessary to use a probabilistic approach such as that proposed originally by Cornell (1968) and modified by others.

SEISMIC HAZARD

The probabilistic seismic hazard assessment (PSHA) is a computation of probabilities of occurrence of given levels of ground motion caused by earthquakes at a given site per unit time (McGuire, 1993). To calculate the hazard, we first define a site of interest at a point or in a small area. We then describe a nearby zone in which earthquakes occur. This source zone defines an area in which earthquakes are assumed to have an equal probability of occurring at any point within this area. For each source zone, we compile a sub-catalogue of recent

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earthquakes that have occurred within the zone. We estimate for each source zone the probability of occurrence of future earthquakes with a given magnitude and within a given time period. In Honduras, tectonic and geological data are scarce so that it is difficult to develop a plausible model of the region. In order to obtain a feasible estimate of the hazard, we use a methodology based on the logic tree. Northern Central America is located at the north-western edge of the Caribbean plate (CARIB), which along with Nicaragua, El Salvador and southern Guatemala form the Chortís block (Donnelly et al., 1990) **(**see Figure 1).

To implement the formalism of a logic tree we define the source zoning, the attenuation relationship, the threshold and maximum expected magnitudes as the node-elements for the logic tree. Each element is described below. As attenuation model we adopted the model of Schnabel and Seed (1973). The uncertainty in the threshold magnitude, that ensures the completeness of the seismic catalogue, was modelled with two values: M=4.0 and M=5.2. Two levels of the maximum expected magnitude were examined. We selected the upper bound magnitude to be the largest observed magnitude plus half of a magnitude unit. Summarising, we developed 16 different scenarios for each of the two return periods studied. Finally, seismic hazard calculations were expressed in terms of contour maps with 60% and 90% of non-exceedence probability in 50 years, corresponding to 100 and 475 years return periods (Figure 2 shows a 475 years return period). As anticipated, the highest expected acceleration for the 100-year return period is observed in and near areas of seismic sources with a high rate of seismic activity, especially along the subduction zone. For longer return periods the expected accelerations increase along the Swan fracture zone and the Motagua-Polochic fault zone where the largest earthquake (1976, Mw=7.6) of the sub-catalogue occurred.

Present results are given as probabilities of non-exceedence of ground motion acceleration. There are a number of factors that influence their accuracy. The short-time span of the available earthquake catalogue is fundamental. Prediction for time intervals longer than, say, twice the length of the catalogue provides highly unreliable results.

One disadvantage of the PSHA is that the concept of a “design earthquake” is lost; i.e., there is no single event that represents the earthquake threat at, for example, the 10,000-yr ground motion level.

Another drawback in the PSHA is that depends very much on the length and quality of the seismic catalogue used. If this catalogue is not representative, in time and space, for the region of interest, underestimation or overestimation of the levels of hazard may occur. Therefore, we try to abridge this problem by constructing a physical model of the seismogenic sources upon their size and recurrence periods for earthquakes. The model is constructed from plate motions. As a first attempt we make a model of the Swan transform fault, northern Central America (Figure 1), which is one of the boundaries between the North America plate and the Caribbean plate.

In estimating the slip deficit, through moment deficiencies; and the area of a fault that has not rupture, the maximum credible earthquake can be calculated (McGuire, 1995). Since the seismic moment is the best way to describe the size of an earthquake on a given fault, it provides an important link between geologic and seismicity data (Youngs and Coppersmith, 1985).

It is recognised now that some sections of plate boundaries are deficient in their seismic moment release as compared with plate tectonic estimates. The ratio of the seismic moment release rate over the moment rate calculated from the slip rate from plate motions gives an important measure of either the amount of slip along a plate boundary or amount of slip due to slow aseismic sliding. To calculate the seismic moment release, we compile a catalogue for the fault, lasting 26 years(1973 to 1999) and then we convert all magnitudes to moment magnitude Mo through the formulae derived by Ekström and Dziewonski (1988) and the formulae presented by Kulhanek (1997). After the conversion of magnitudes and the summation of the seismic moments contributed by all earthquakes in the catalogue, we obtain a seismic moment release from earthquakes as

$M_o = 1.9X10^{18}\,Nm$ per year. To calculate the moment rate from plate tectonics we use the formula : $M_o = \mu DLW$, where μ is rigidity, D is fault displacement, L is fault length and W is the width of the fault.

The relative velocity of the Caribbean plate with respect to North America plate is 1.11 cm (DeMets et al. 1990). The length of the Swan fracture zone is 595Km (Rosencrantz and Mann, 1991). By means of teleseismic body waves inversion techniques (McCaffrey et al., 1991) of ten events, we estimate the width of the fault as 20Km. We find, therefore, that $M_o = 4.4X10^{18}\ Nm$.

Taking the rate of the Seismic moment from earthquakes and from plate motions we find that there is a deficiency of $\chi = \frac{1.9X10^{18}}{4.4X10^{18}} * 100\% = 43\%$.

The current deficiency may imply that, in the near future, a proportion of the moment deficiency may be released by earthquake movement. If all the moment deficiency would be released by a single event, the $2.5X10^{18}\,Nm$ would correspond to an $M_w = 6.3$ earthquake.

This deficiency is located in two segments of the fault, (Figure 3). In order to improve this calculations we plan to extend the length of the investigated time span as far as earthquakes records in the area allow.

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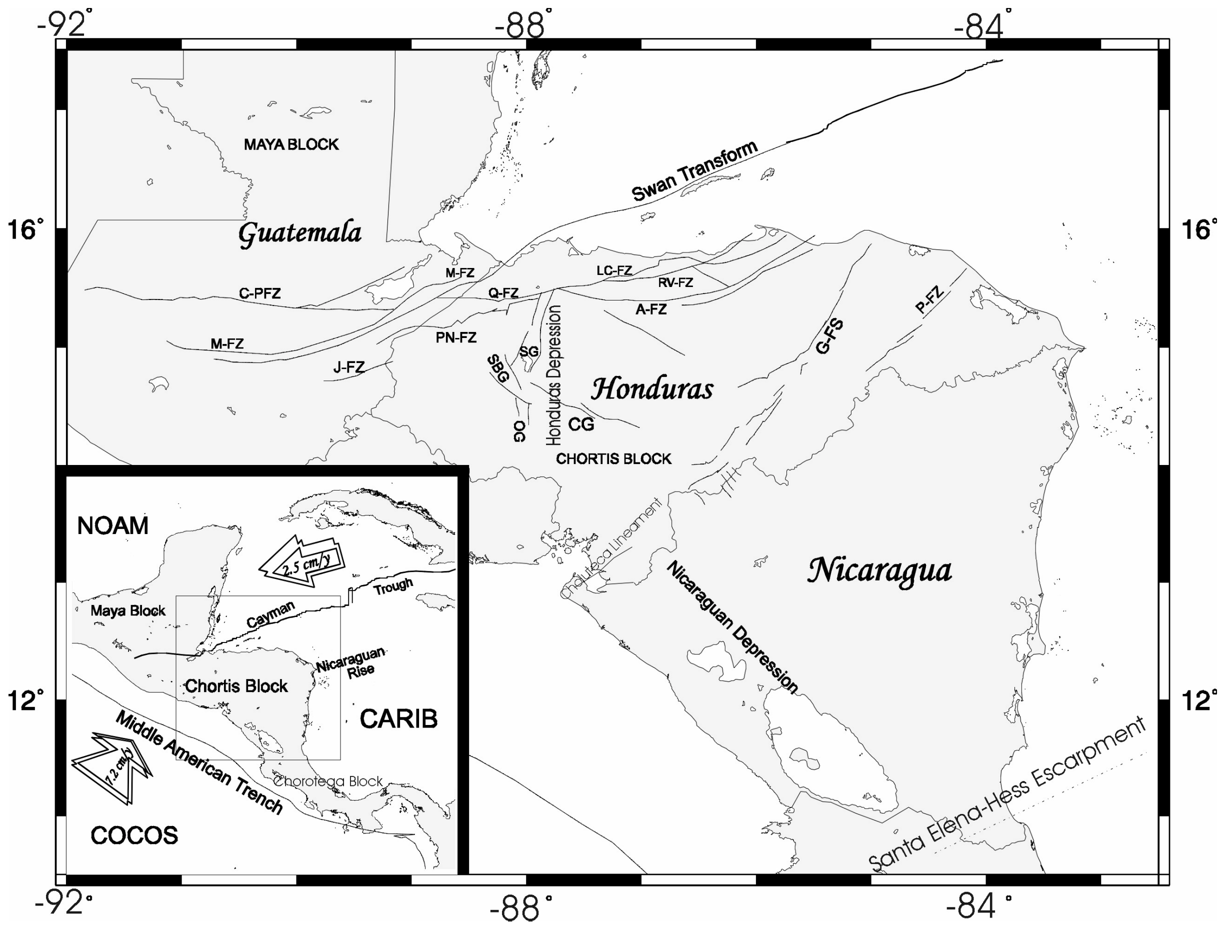

Figure 1. Tectonic setting of northern Central America after Finch and Ritchie(1991).
(AFZ), Aguán fault zone; (C-PFZ), Chixoy-Polochíc fault zone; (JFZ), Jocotán fault zone; (LCFZ), La Ceiba fault zone; (MFZ), Motagua fault zone; (PFZ), Patuca fault zone; (PNFZ), Pueblo Nuevo fault zone; (QFZ), Quimistán fault zone, (RVFZ), Rio Viejo fault zone. (CG), Comayagua graben; (OG), Otoro graben: (SBG), Santa Bárbara graben; (SG), Sula graben. The inset shows the Chortis block of the Caribbean Plate (after Case and Holcombe, 1980).

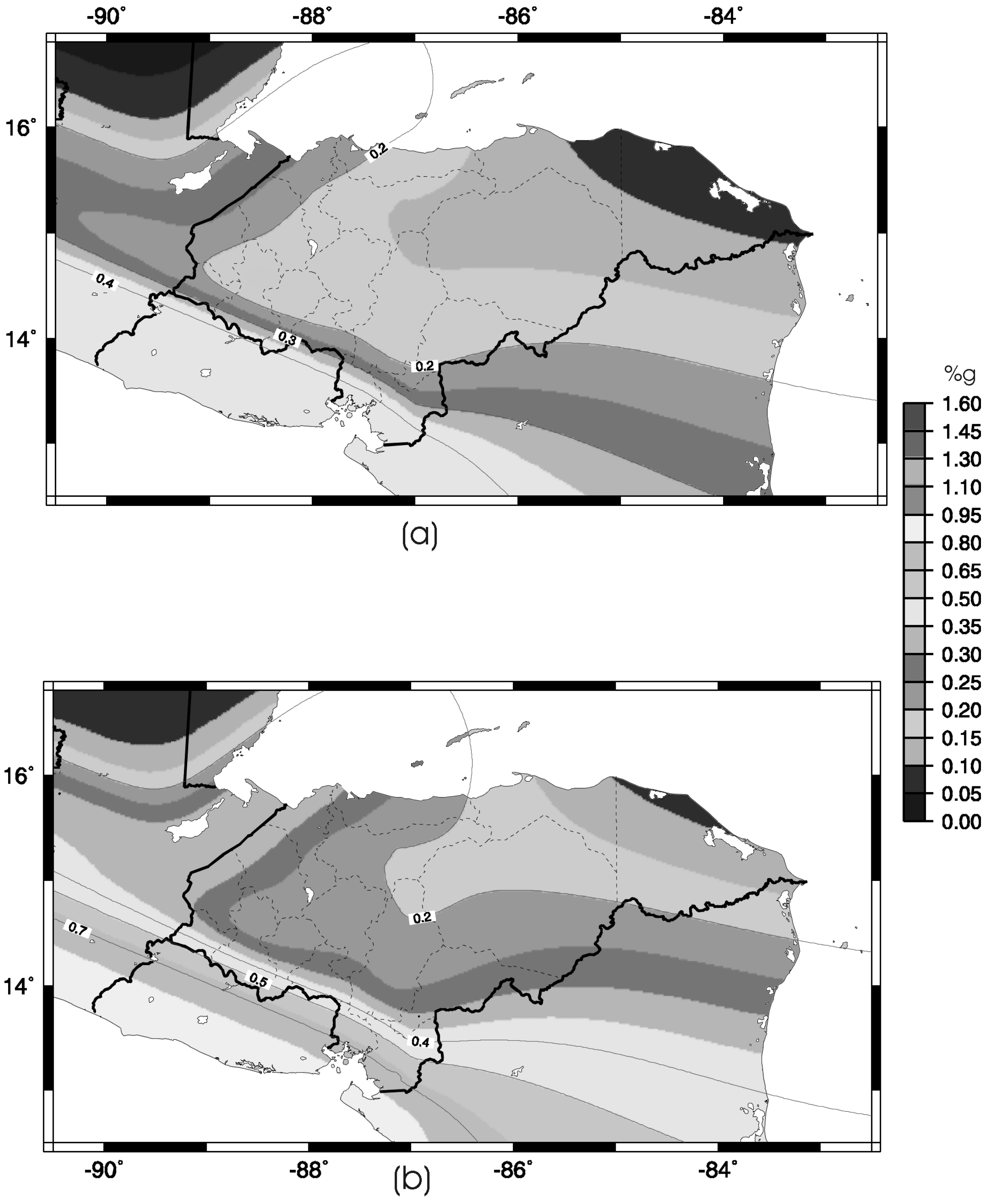

Figure 2. Poissonian estimate seismic hazard map for Honduras and its vicinity. Return period = 475 years (0.1 probability of exceedance in 50 years) and ground accelerations are in ratios of g. (a) PGA with zero variability. (b) PGA with variability σ = 0.6.

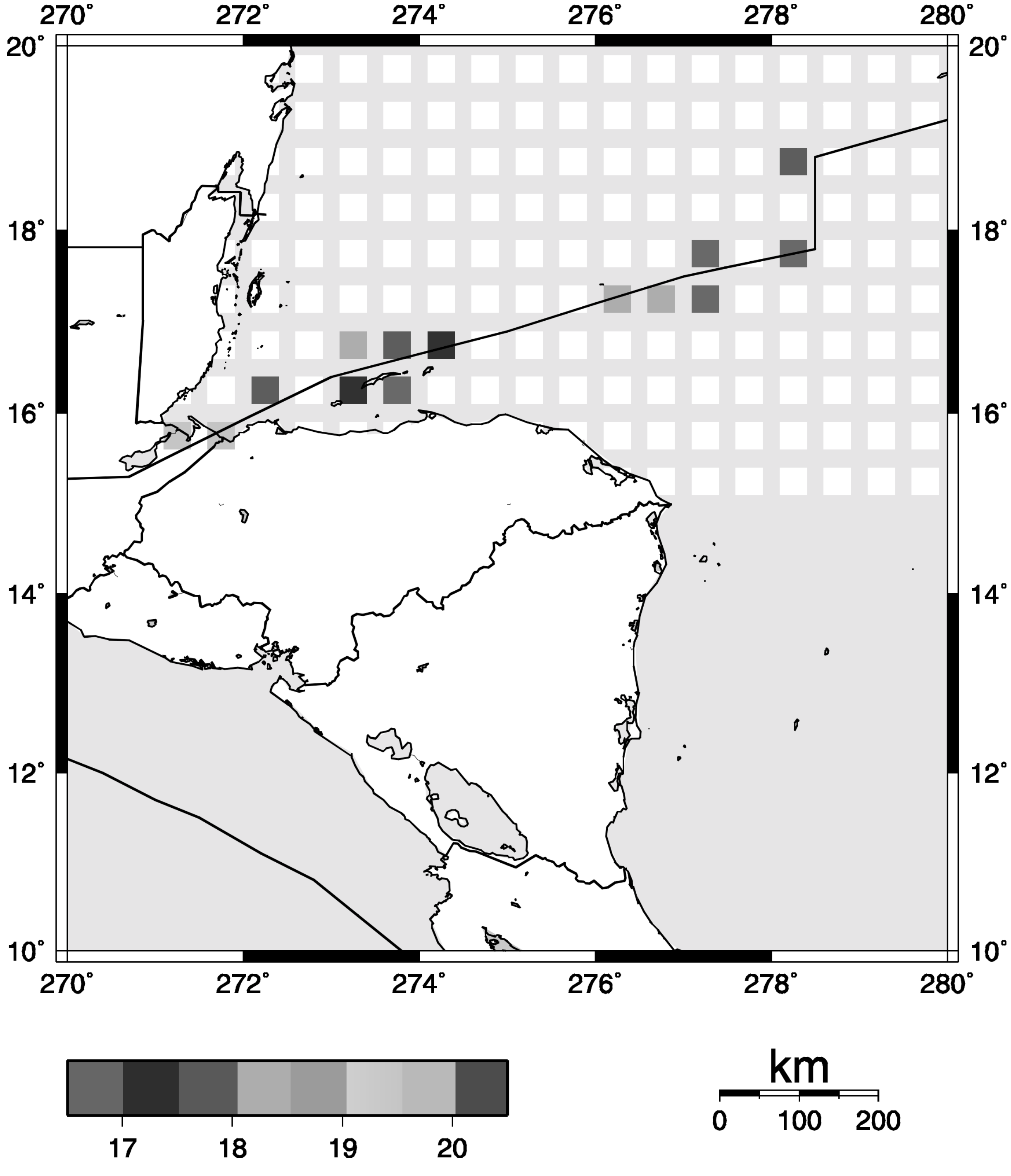

Figure 3. Seismic Moment from earthquakes for the period 1973 to 1999.

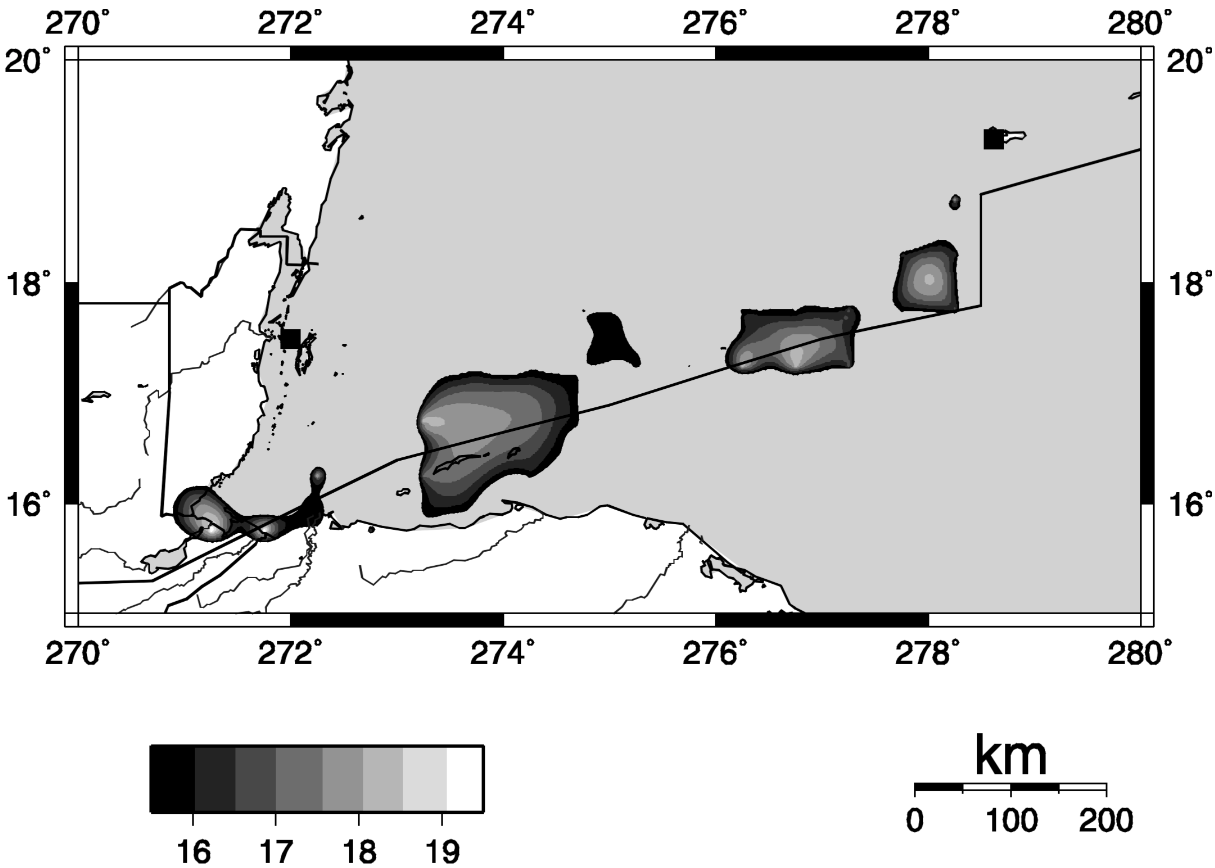

Figure 4. Seismic moment deficiency for the period 1973 to 1999.