Bulletin of the Seismological Society of America, 90, 4, pp. 859–869, August 2000

Minimum Magnitude of Completeness in Earthquake Catalogs: Examples from Alaska, the Western United States, and Japan

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Abstract We mapped the minimum magnitude of complete reporting, M_c, for Alaska, the western United States, and for the JUNEC earthquake catalog of Japan. M_c was estimated based on its departure from the linear frequency-magnitude relation of the 250 closest earthquakes to grid nodes, spaced 10 km apart. In all catalogs studied, M_c was strongly heterogeneous. In offshore areas the M_c was typically one unit of magnitude higher than onshore. On land also, M_c can vary by one order of magnitude over distance less than 50 km. We recommend that seismicity studies that depend on complete sets of small earthquakes should be limited to areas with similar M_c, or the minimum magnitude for the analysis has to be raised to the highest common value of M_c. We believe that the data quality, as reflected by the M_c level, should be used to define the spatial extent of seismicity studies where M_c plays a role. The method we use calculates the goodness of fit between a power law fit to the data and the observed frequency-magnitude distribution as a function of a lower cutoff of the magnitude data. M_c is defined as the magnitude at which 90% of the data can be modeled by a power law fit. M_c in the 1990s is approximately 1.2 ± 0.4 in most parts of California, 1.8 ± 0.4 in most of Alaska (Aleutians and Panhandle excluded), and at a higher level in the JUNEC catalog for Japan. Various sources, such as explosions and earthquake families beneath volcanoes, can lead to distributions that cannot be fit well by power laws. For the Hokkaido region we demonstrate how neglecting the spatial variability of M_c can lead to erroneous assumptions about deviations from self-similarity of earthquake scaling.

Introduction

The minimum magnitude of complete recording, M_c, is an important parameter for most studies related to seismicity. It is well known that M_c changes with time in most catalogs, usually decreasing, because the number of seismographs increases and the methods of analysis improve. However, differences of M_c as a function of space are generally ignored, although these, and the reasons for them, are just as obvious. For example, catalogs for offshore regions, as well as regions outside outer margins of the networks, are so radically different in their reporting of earthquakes that they should not be used in quantitative studies together with the catalogs for the central areas covered.

In seismicity studies, it is frequently necessary to use the maximum number of events available for high-quality results. This objective is undermined if one uses a single overall M_c cutoff that is high, in order to guarantee completeness. Here we show how a simple spatial mapping of the frequency-magnitude distribution (FMD) and application of a localized M_c cut-off can assist substantially in seismicity studies. We demonstrate the benefits of spatial mapping of M_c for a number of case studies at a variety of scales.

For investigations of seismic quiescence and the frequency-magnitude relationship, we routinely map the minimum magnitude of completeness to define an area of uniform reporting for study (Wyss and Martyrosian, 1998, Wyss *et al.,* 1999). Areas of inferior reporting (higher M_c), outside such a core area, are excluded because these data would contaminate the analysis. In seismicity studies where statistical considerations play a key role, it is important that results are not influenced by the choice of the data limits. If these limits are based on the catalog quality, then improved statistical robustness may be assured. For this reason we routinely map the quality of the catalog for selecting the data for our studies of seismic quiescence; however, homogeneity in M_c does not necessarily guarantee homogeneity in earthquake reporting, since changes in magnitude reporting influence the magnitude of homogeneous reporting (Habermann, 1986; Habermann, 1991; Zuniga and Wyss, 1995; Zuniga and Wiemer, 1999).

Our estimation of M_c is based on the assumption that, for a given, volume a simple power law can approximate the FMD. The FMD (Ishimoto and Iida, 1939; Gutenberg and