PAD-1.0 Portuguese Accelerometer Database, CD-ROM Edition

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INTRODUCTION

Mainland Portugal, located in the vicinity of the Azores-Gibraltar plate boundary, is exposed to large magnitude (**M** 8.0–8.5) distant interplate earthquakes and moderate magnitude (**M** 7.0) local intraplate earthquakes. Such events, although infrequent, are relevant in terms of seismic hazard assessment and risk management, in particular in the Lisbon metropolitan area and the Algarve region (Vilanova and Fonseca 2007). The Azores archipelago, located at the North America, Eurasia, and Africa triple junction, is the source location of frequent low-magnitude events and seismic swarms and occasional moderate (**M** 7.0) magnitude earthquakes. Figure 2(C) shows the general tectonic setting of the above-cited regions.

Under the framework of the European Commission Project NERIES (Network of Research Infrastructures for European Seismology), the Portuguese accelerometer database PAD-1.0 was organized in a MySQL server and compiled in a CD-ROM edition. For each waveform, PAD-1.0 includes relevant information on the earthquake parameters, recording stations, and recording instruments, and a simple query interface allows users to select data that fulfills specific requirements. The search interface and the data request follow very closely the format implemented at the Internet site for the European Strong-motion Database (http://www.isesd.cv.ic.ac.uk/; Ambraseys *et al.* 2002).

The publication of ground-motion data is generally recognized as an important step toward understanding ground-motion properties worldwide (*e.g.*, Theodulidis *et al.* 2004). This work represents a first effort toward the organization and dissemination of the Portuguese accelerometer database.

ACCELEROMETER NETWORK

The first strong-motion instruments installed in Portugal were a Japanese SMAC accelerograph on the north pier of Lisbon "25 de Abril" bridge and a SMA-1 Kinemetrics accelerograph at Pico Island (Azores) during the 1960s. These analog instruments provided records on photographic paper for the 1969 M_S 8.0 St. Vincent earthquake, the 1973 Pico Island crisis, and the 1980 **M** 6.9 Terceira Island earthquake.

The currently operating accelerometer network consists of a set of 32 instruments permanently installed at selected sites, 80% of which are run by Instituto Superior Técnico (IST). Most stations are equipped with GeoSIG SSA-320 force balance tri-axial accelerometers with GSR12, GRS16, or GSR18 digital converter. In addition, there are two Kinemetrics ETNA tri-axial episensor force-balance accelerometers and one Terra Technology integrated digital seismograph (Model IDS-3602) installed. The stations operate in triggered recording mode, with threshold values depending on the station's noise level.

A total of 13 IST instruments are deployed in central and southern Portugal plus 12 in the central group of islands in the Azores archipelago. Figure 1 shows the stations' location. The majority of instruments (about 70%) are installed in the ground level of low-rise buildings (up to three stories). A small number of instruments are deployed in higher levels of taller buildings or in specific structures to evaluate their seismic response. Most stations (73%) are settled in stiff geology sites (classified either as rock or stiff soil).

The instruments were in general funded by research projects, either national or European, and the network has been running with minimum maintenance costs. Besides limited coverage, the main network drawbacks at present are the lack of common timing (GPS) and telemetry to a central station. This last aspect implies not only that there is no real-time access to the data for most stations, but also that data are stored in the instrument memory, meaning that relevant ground motions may not be recorded if the instrument memory fills up.

DATABASE STRUCTURE

The database was implemented in MySQL, a widely used relational database management system (http://www.mysql.com). MySQL server is available as open-source free software and is supported by a large number of system platforms (Windows, Mac OS X, Linux, etc.). Five tables, named according to the information they contain, form the database: three independent tables, *event*, *station*, and *instrument*; and two linked tables, *wave* and *stationlog*. The *event*, *station,* and *instrument* tables describe, respectively, the recorded earthquake characteristics, the database stations, and the instruments. The *sta-*

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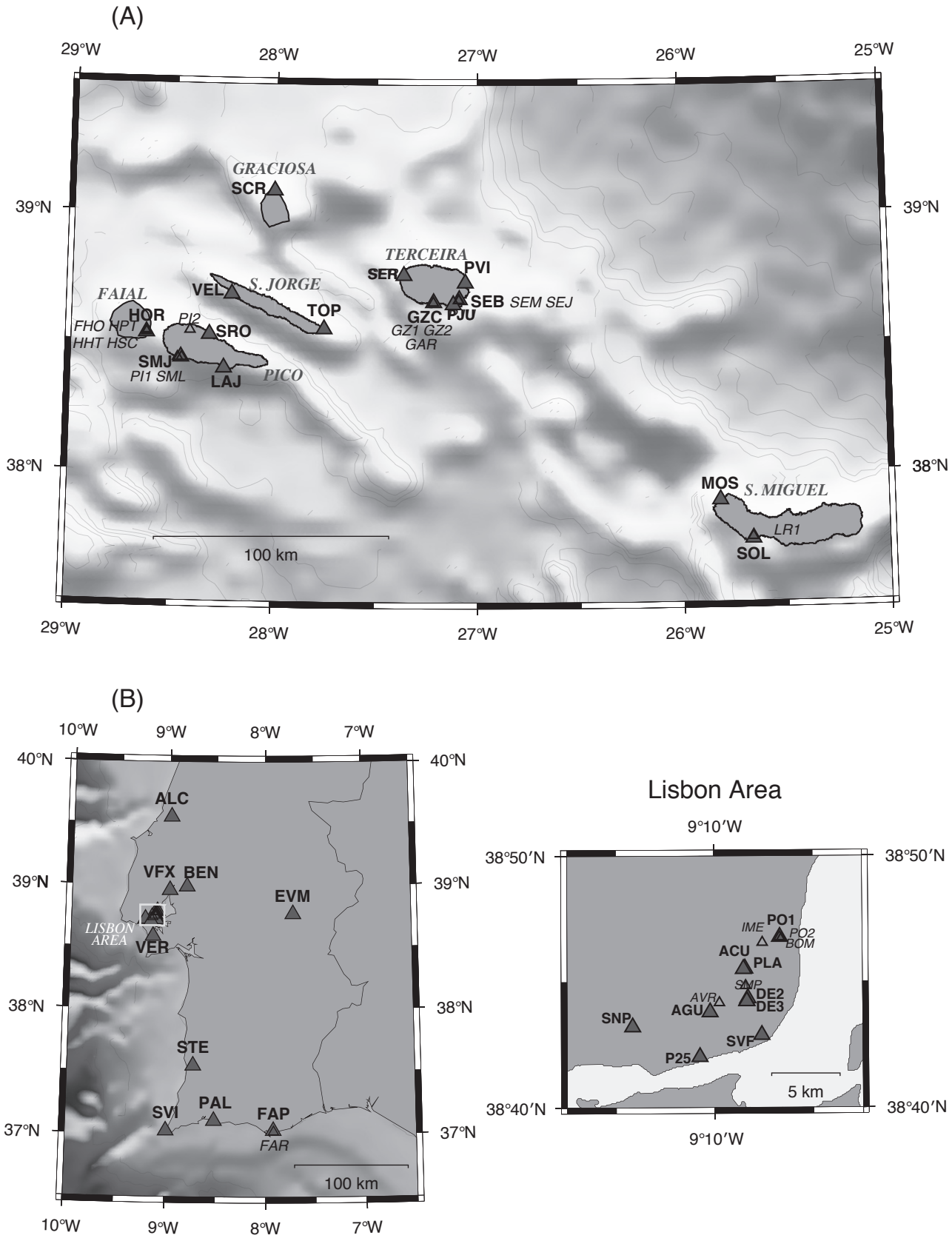


▲ **Figure 1.** Accelerometer stations in Portugal: (A) Azores archipelago; (B) Mainland; gray and open triangles represent, respectively, active and disabled stations. Codes for disabled stations are displayed in italic. Azores island names are displayed in bold italic. Offshore contour spacing is 250 m in (A) and 1,000 m in (B).

tionlog table gathers information on the installation, removal, and orientation of instruments within a station, and the *wave* table describes the characteristics of the recorded accelerogram.

The information on earthquake characteristics is primarily based on the International Seismological Centre (ISC) online Bulletin (http://www.isc.ac.uk). In this case ISC appears as the reference. If the assigned value was not computed by ISC, the agency that reported it is appended inside brackets. As secondary sources for earthquake data we used the Instituto de Meteorologia (IM), Lisbon, annual bulletin and monthly preliminary bulletin; the Sistema de Vigilância Sismológica dos Açores (SIVISA) preliminary bulletin; the Instituto Geográfico Nacional (IGN), Madrid, bulletins; and the Nunes *et al.* (2004) CD-ROM catalog. Figure 2 shows the seismicity recorded by the Portuguese accelerometer network during the period 1969–2006.

The most critical station characteristics are the underlying geology, the building type, and the level at which the instrument is installed. The shear-wave velocity profiles for the upper 30 m are not available for the stations, and in general the classification relies only on surface geology characterization from geological maps in the case of mainland Portugal (Serviços Geológicos de Portugal 1992), and on the Forjaz *et al.* (2001) classification for the Azores islands. For the building type classification we use a letter indicating the construction type according to Mendes-Victor *et al.* (1994), followed by the number of stories (including ground floor). The level indicates the building story where the instrument is deployed. Most instruments are installed at the ground level (around 70%), but in some cases upper stories (or underground levels) were used.

The wave-file ascii format is based on the format of Ambraseys *et al.* (2002). Each *xyz* record component is stored in a separate file with suffix *x*, *y*, or *z* appended to the wave-file name and extension ".raw", since the data are unprocessed. The file's header is divided in three blocks. The first block keeps information about earthquake, wave, station, and instrument; the second block keeps the time information (currently only internal clock time is available), the units and a reference; and the third block is used for comments and processing history. The wave data follows in one column and the file ends with the string STOP.

DATA PROCESSING AND CHARACTERISTICS

The database contains records from 1969 to 2006. The 1969-02-28 event, registered in an SMAC instrument, is one of the first accelerometer records acquired in Europe. The other analog records, from 1973-11-23, 1980-01-01, and 1998-07-09 earthquakes, were made on a Kinemetrics SMA-1 accelerometer. The data from the 80-mm film was recovered by manual digitalization of five-times-magnification paper copies. The main references for analog records are Marécos and Castanheta (1970), Ravara and Duarte (1975), Oliveira (1992), and Oliveira (2008). Regarding digital data, we converted original binary files to ascii files using each manufacturer's software (for the vast majority of files we used GeoSIG software ALLView to perform the conversion to ascii). The force balance accelerometers, GeoSIG model SSA-320, have a bandwidth from DC to 50 Hz, so correction for instrument response is not necessary in order to achieve reliable high-frequency motions. The low-frequency filtering, particularly relevant for displacement histories, is a matter of much debate, depending on the data frequency content, the signal-to-noise ratio, and the characteristics of the recording instrument, and should be performed individually for each waveform (see Akkar and Bommer 2006 for a discussion on this issue). All time histories presented in PAD-1.0 are unprocessed, and therefore users should apply their own correction procedures according to their needs.

Figure 3 shows the distance-magnitude distribution for all database records. In general, only low-magnitude earthquakes ($\mathbf{M} < 5$) were recorded in the near-field (distance below 10 km). In the Azores archipelago, **M** 5–6 earthquakes were recorded within 10–100 km from the source, but in mainland Portugal, records from earthquakes with $\mathbf{M} > 5$ correspond to source-site distances larger than 60 km. The largest peak ground acceleration (PGA) value recorded for mainland Portugal corresponds to the M_S 7.8 1969-02-28 earthquake (27.8cm/s^2). The largest PGA value recorded corresponds to the M_S 6.8 1998-07-09 Azores earthquake (399.3cm/s^2).

THE GRAPHICAL INTERFACE

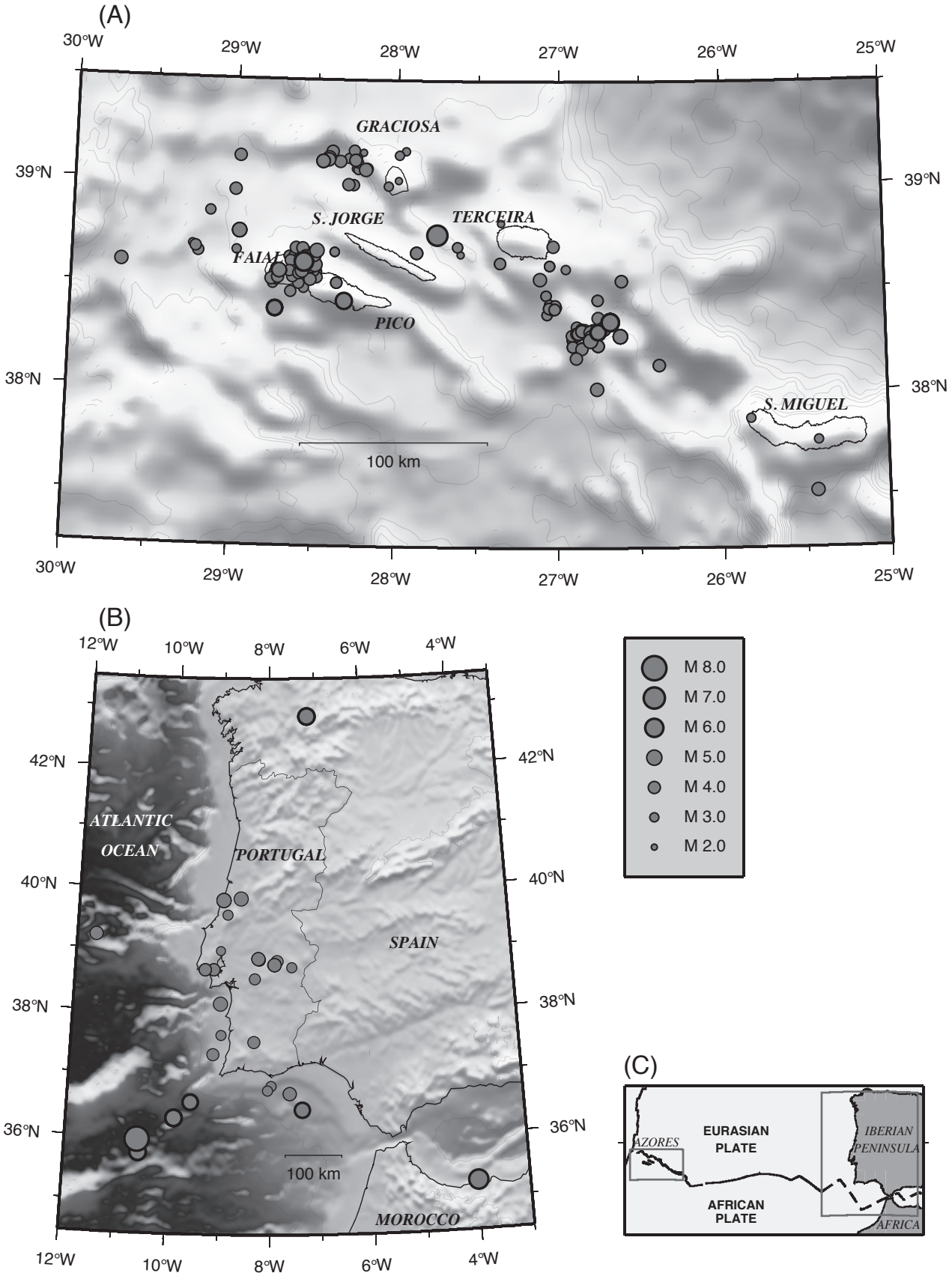
The PAD-1.0 CD-ROM provides a user-friendly TCL-TK graphical interface based on the web interface of Ambraseys *et al.* (2002), which allows users to retrieve data that fulfill specific requirements. A search can be carried out on earthquake, station, and waveform characteristics, and descriptive fields like earthquake region, station geology, or building type display a menu. The query results are shown in a new window and users can select, through checkboxes, the files to download. No software has to be installed in the user's computer and no commercial database software is necessary, since both the MySQL server and the graphical interface run from the CD-ROM. Figure 4 shows a screen-shot of the graphical interface query and results windows.

The graphical interface runs on Windows and Mac OS X (Intel) operating systems. Users of other operating systems cannot run the graphical interface but can retrieve information on the existing waveforms through a tab-delimited file. Also, the database tables can be downloaded and used in any MySQL installation.

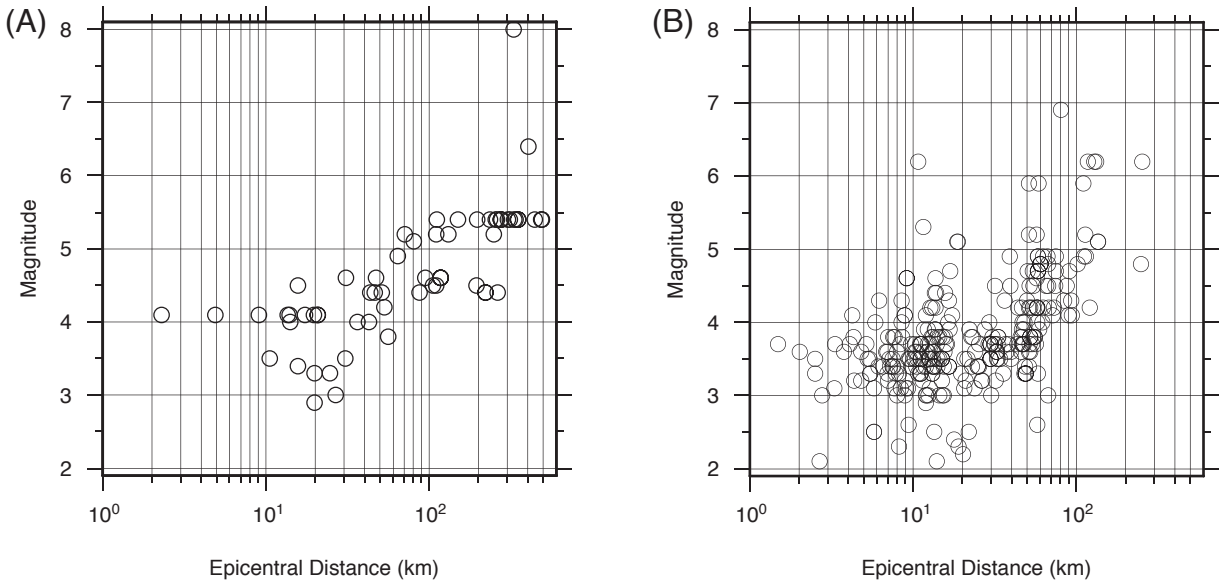
DISCUSSION AND PERSPECTIVES

The publication of the PAD-1.0 CD-ROM is the first effort toward the organization and dissemination of the Portuguese accelerometer database, which includes data from regions under different tectonic regimes (*e.g.*, extensional, compressional) and crustal rheology, and can be useful in a variety of academic and applied studies. The main drawback of the present data set is the absence of GPS timing of waveforms.

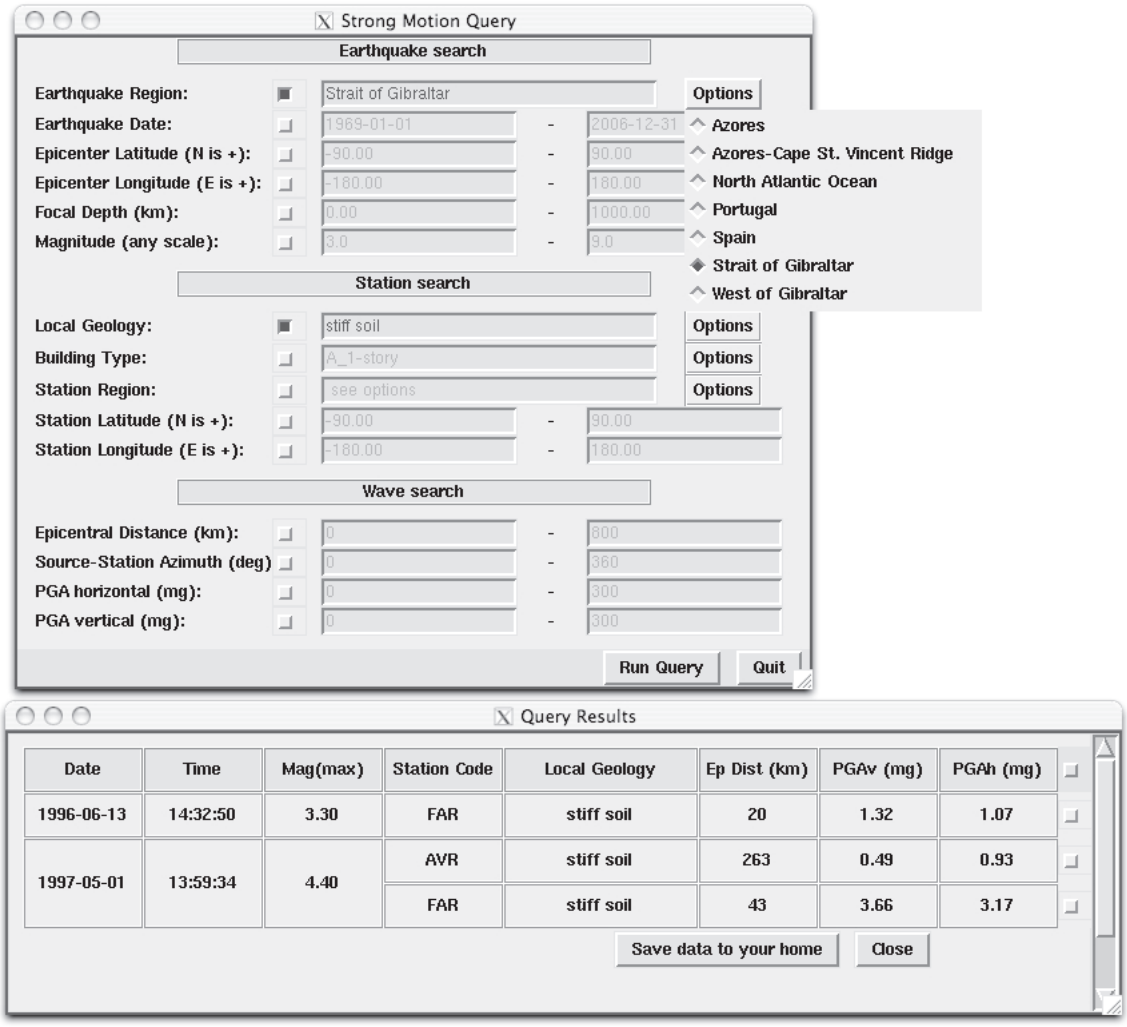
The PAD-1.0 database was prepared as a preliminary step for a Portuguese contribution to the NERIES project and it



▲ **Figure 2.** (A) Seismicity recorded at Azores archipelago; (B) Seismicity recorded at Mainland Portugal; (C) General tectonic setting of both regions. In (A) and (B) the magnitude indicated is maximum magnitude; the contour spacing is 250 m in (A) and 1,000 m in (B).



▲ **Figure 3.** (A) Distribution of magnitudes with distance for mainland and (B) Azores islands.



▲ **Figure 4.** PAD-1.0 graphical interface.

represents raw data only, meaning that the user will have to process the data according to his or her specific needs. The file format used in PAD is one column ascii format (with a fixed header) and can easily be transformed into another ascii format, such as NERIES format. A study of the ground-motion data set is currently being performed within the NERIES project and engineering parameters (PGA, PGV, PGD, Arias intensity, Trifunac duration, CAV, Housner intensity, pseudo-velocity response-spectra) are being computed according to a standard processing procedure (baseline correction and high-pass filtering at 0.1 Hz).

The Portuguese accelerometer network is currently being upgraded by the Scientific Re-equipment Program, Portuguese Science Foundation (FCT), which aims to improve different types of seismic networks and cooperation and data sharing among the operating institutions. The Instituto de Meteorologia, the government institution for seismic monitoring, is complementing the seismic network with accelerometers and 16 new strong motion stations equipped with AC-63i GeoSIG accelerometers, GPS timing, and ADSL connection to a central station, which will be deployed by IST in mainland Portugal (eight stations) and the Azores islands (eight stations). The existing IST stations will be upgraded with larger memory capacity and ADSL connections. All station sites will be subjected to geological and geotechnical evaluation to comply with the most recent recommendation for site classification (EC 8, 2004), since in its current stage PAD-1.0 includes only generic surface-geologic classification. These improvements will certainly have a strong impact on the quality and number of records available in subsequent versions of the database.

The PAD-1.0 CD-ROM is freely available as an ISO-file download at the Web site http://sismologia.ist.utl.pt/pad/pad.iso (a limited number of copies are also available by request).

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