REGIONAL SEISMIC DATABASE FOR SOUTHWEST CHINA

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ABSTRACT

We have built a database of high-quality 3-component digital broadband and short-period recordings from 23 stations of a regional digital seismic network in southwestern China. There are frequent natural earthquakes and man-made seismic activities in the region, which provides an immense amount of data for regional seismic studies. The database contains mainly the regional digital broadband waveform data recorded at the newly implemented regional digital seismic network. Each seismic station in this network has digital broadband seismographs and short-period seismographs with 16-bit A/D converters, as well as data processing and transfer facilities. The bandwidth of the digital broadband seismograph is about 20 sec - 25 Hz. The major specifications of the instrument are: (1) sensitivity of $1\sim2x10^{-8}m.s^{-1}$/LSB; (2) dynamic range greater than 90dB, (resolution equal to or greater than 2^{-15} for 16 bit); (3) linearity greater than 10^{-3}; (4) time error less than 1 ms. The center of the regional digital seismic network has the function of seismic data collection, storage, processing and maintenance.

This study will report on the seismic characteristics of regional phases in the region. Multimax has obtained and examined the digital waveform data for over 900 seismic events recorded by the regional digital seismic network. We also performed detailed time- and frequency-domain analyses of local and regional signals detected from events for which some ground-truth information about the seismic sources may be known. Our preliminary analyses of the waveforms have shown that such data provide insights to the studies of the excitation and propagation of regional phases in the region. These studies include seismic event locations, Pg/Lg spectral ratio, coda attenuation, identification, and regional structure model from tomographic inversion.

KEY WORDS: regional seismic characteristics, regional digital seismic network, regional broadband waveform database, ground truth

OBJECTIVE

Introduction

The Lg/Pg ratio has been shown to improve in discriminant performance as the frequency content increases, with frequencies higher than 5 Hz, leading to good separation of explosion and earthquake populations in most regions where it has been tested (National Research Council, 1997). For example, in their study of discrimination between Nevada Test Site (NTS) explosions and earthquakes, Walter *et al*. (1995) noted improved performance at higher frequencies. Other examples are the regional discrimination study of explosions and earthquakes in the eastern United States and in southern Russia by Kim *et al*. (1993, 1997), who observed significantly improved discrimination capability of the amplitude ratio P/Lg in the 5- to 25-Hz band than in the lower frequency bands.

Several recent studies (e.g., Baumgardt and Schneider, 1997; Rodgers and Walter, 1997; Walter *et al.* 1997) have observed significant variability of regional phase ratios, such as Pn/Lg or Pg/Lg, which are generally powerful regional discriminants. Their characteristics vary significantly from one tectonic or geographic region to another and may also be strongly dependent on frequency (e.g. Baumgardt and Der, 1994). Southwestern China is known to have complex geology with large Q variations (e.g. Qin and Kan, 1986), so that several

combinations of distinct source and receiver regions will need to be calibrated. It is important to understand and quantify these differences in order to accomplish improved regional discrimination in a region of complex geology, such as southwestern China.

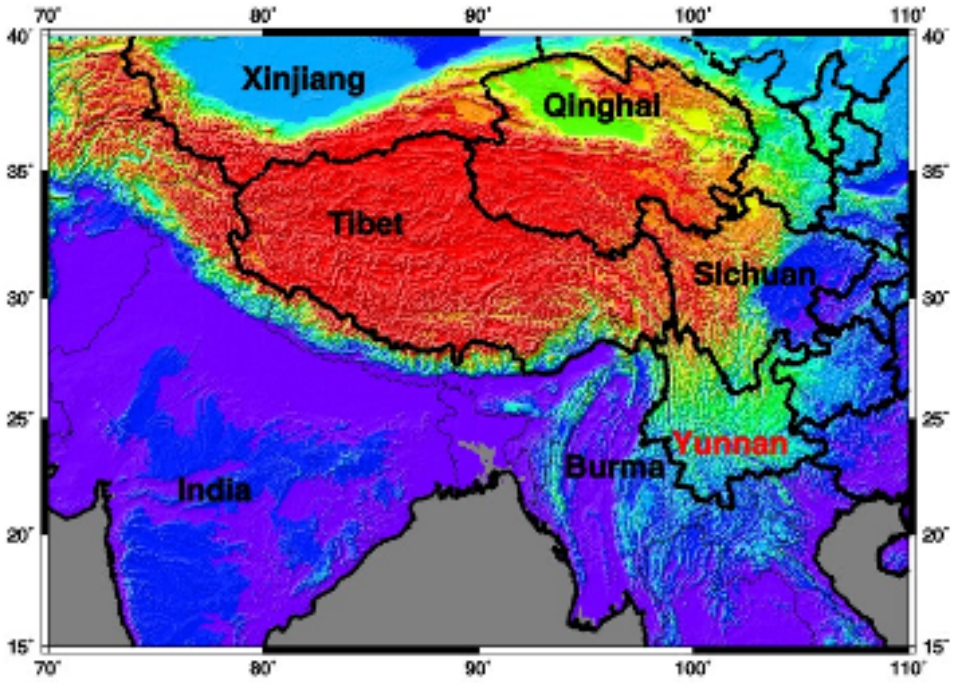

Figure 1. Yunnan and its surrounding area.

Yunnan Province is located at the south segment of the North-South Earthquake Zone in China, close to the Himalaya Orogenic Belt (Figure 1). Tectogenesis is strong in the region. Long and deep earthquake faults criss-cross and spread over almost the entire region, and strong earthquakes occur frequently. As one of the most seismogenically active regions in China, western Yunnan is an earthquake prediction experiment field operated by the China Seismological Bureau. There is a well-developed seismic network in the region and a large volume of seismic data has been collected. Considerable efforts have been made on the study of the geological and geophysical features in the region. Wang, et al. (1994) investigated the 3-D velocity structure under Kunming seismic network and found an uplift of Moho in central Yunnan. They also found that the Red River Fault cuts through the Moho discontinuity. Liu, et al. (1993) studied the 3-D crustal and upper mantle structure in Yunnan and the vicinity and found that there are strong correlations between the upper crustal structure and the topography in the region. Complex crustal velocity structures, including a low-velocity plume and low-velocity layers were also revealed in the study. Lin, et al. (1993) found significant lateral heterogeneity in the crustal structure in western Yunnan based on several DSS profiles. They concluded that the velocity in the crust increases from south to north. Regional seismic characteristics in such an area are of high interest for discrimination studies.

Technical Objectives

The challenge for nuclear explosion monitoring and treaty verification will be to maintain reliable discrimination of small seismic events in diverse regions of the world by using sparsely distributed recording stations. At regional distances, Lg is often the largest seismic phase from both explosion and earthquake sources and may sometimes therefore be the only reliably observed phase from small events. The ratio of S- to P-wave energy (or Lg/Pn and Lg/Pg for regional data) has so far been found to be the most promising regional discriminant for earthquakes and explosions. Use of broadband data, whenever available, will allow us to investigate how low- and high-frequency data may be combined to enhance regional discrimination. The spectral characteristics of regional phases are known to vary drastically from one region to another. It is

therefore important to investigate the variability of regional discriminants in a geologically complex region such as southwest China. Results of the proposed research will lead to more effective and reliable discrimination of small events in various geological settings.

The objectives of this project include: 1) Construction of a digital seismic waveform and ground truth database for southwest China; 2) Regional discrimination studies, including location, spectral ratio, coda, and structure tomography (combined with other projects); and 3) Product delivery. Currently the project is in the middle stage. In the next section, we will mainly discuss the construction of the waveform database and preliminary analyses of the spectral ratio. The tomography results are to be presented separately.

RESEARCH ACCOMPLISHED

The Waveform Database

We have constructed a database of digital waveforms recorded by both the regional digital broadband network and the portable seismic arrays.

Data Recorded at the Regional Digital Broadband Network

In their 1995 Five-Year-Modernization Plan, the Chinese government has proposed efforts to upgrade the Chinese Digital Seismic Network. Additionally, certain regional analog stations should be upgraded to digital recording format. The Chinese Digital Seismic Network consists of national digital seismic networks, regional digital seismic networks, portable digital seismic networks, regional seismic arrays and digital strong earthquake networks. A regional digital seismic network has 30 digital broadband seismic stations, including telemetric ones. The bandwidth of the digital broadband seismograph is about 20 sec - 20 Hz (Figure 2). Each seismic station has digital broadband seismographs and short-period seismographs with a 16-bit data sampling board, data processing and transfer facilities. The major specifications of the regional digital seismographs are: (1) sensitivity of $1\sim2\times10^{-8}$ m.s^{-1}/LSB; (2) dynamic range greater than 90dB; (3) resolution greater than 2^{-15}, 16 bit; (4) linearity greater than 10^{-3}; (5) time error less than 1 ms. The center of the regional digital seismic network has the function of seismic data collection, storage, processing and maintenance.

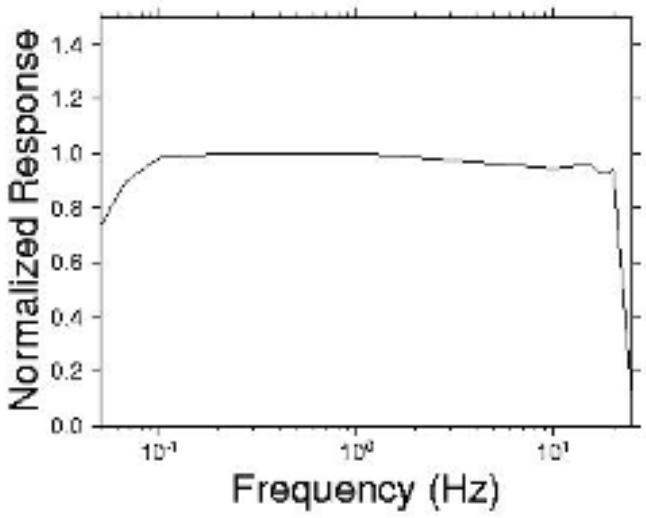

Figure 2. Instrument response of the digital broadband seismographs used in the regional digital seismic network in Yunnan, China.

Twenty-three digital broadband seismographs have been implemented in the Kunming regional digital seismic network in recent years (Figure 3). This is the first fully functional regional digital seismic network in China that provides high-quality continuous 3-componant digital broadband waveform data. The seismographs are

velocity recording with a 50-Hz sample rate, 16-bit sampling board. The network has been in operation since 1997 and a large volume of good quality digital seismic data have been collected. Multimax has obtained and examined the digital waveform data for over 900 seismic events recorded by the Yunnan regional digital seismic network. This is the first time that the high-quality regional digital broadband waveform data from China are available to U.S. seismologists. Figure 4 shows a comparison of the events recorded at this regional network with those reported by the International Seismic Centre, the International Data Centre, and the Institutes for Research in Seismology DMC for the same period. Clearly, the regional network has a much better coverage of the regional seismic events, which are very important for regional seismic studies.

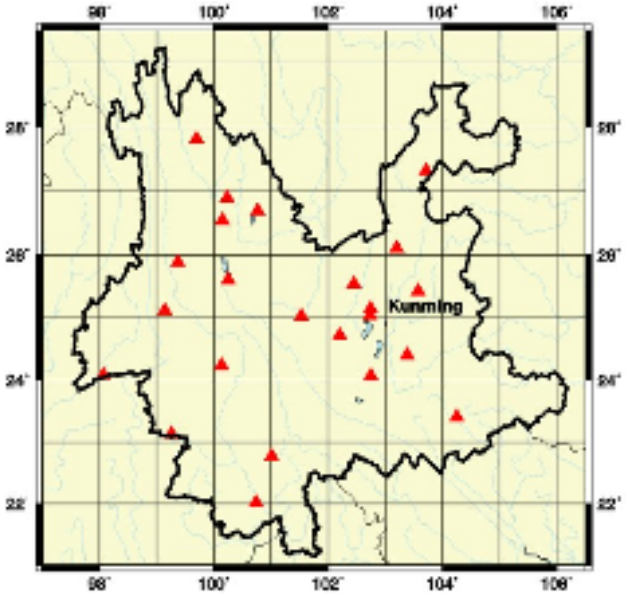

Figure 3. The digital broadband seismic network in Yunnan.

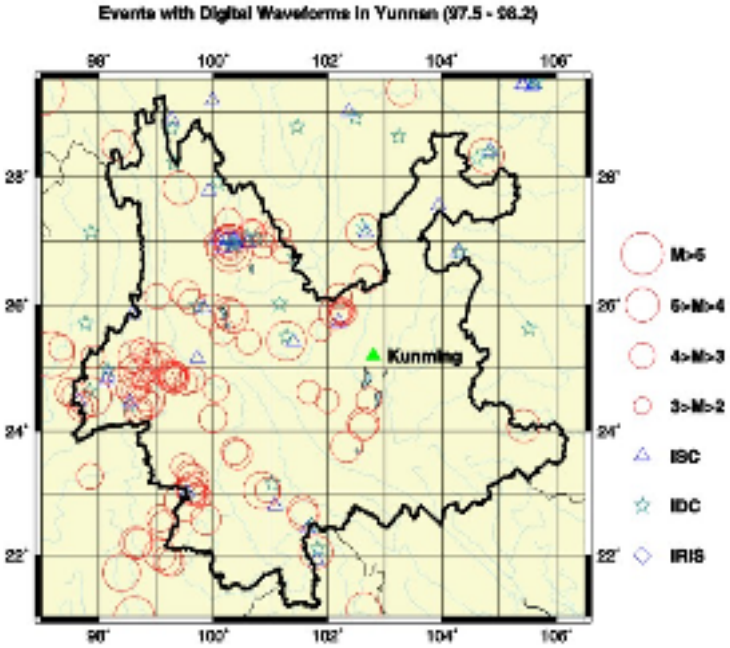

Figure 4. A comparison of the regional events recorded at the Yunnan digital network and those reported in several other global catalogs.

As an example, Figure 5 shows the vertical component of the waveforms recorded by the regional network for a M5.5 local earthquake. A typical 3-component waveform recording for a local event 110 km away is shown in Figure 6. We have established a data retrieval mechanism to access the digital broadband data from the regional digital seismic network through our Chinese collaborators. Over 30,000 waveforms with the same quality have been obtained in this project. There are an abundance of seismicity and mining activities in Yunnan, which provides a valuable data source for the study of regional seismic discriminants.

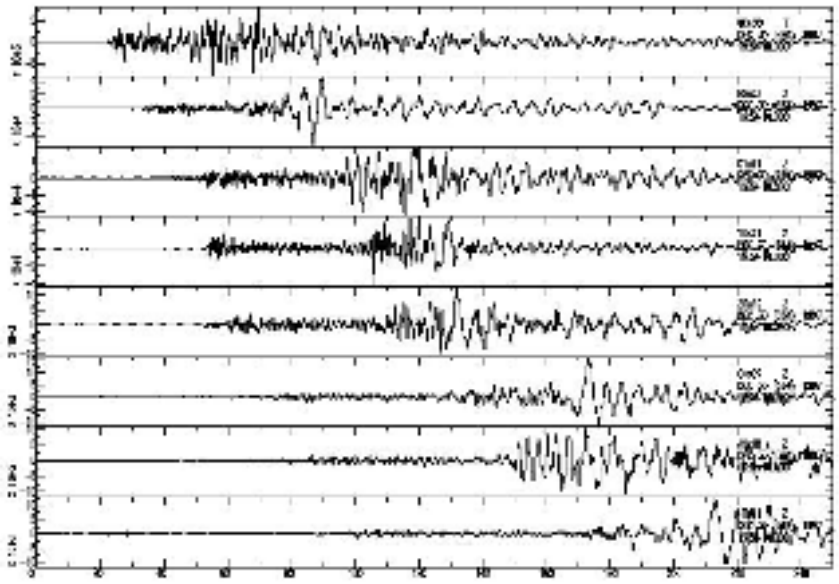

Figure 5. The vertical component of the waveforms of a M5.5 event recorded at the regional digital network.

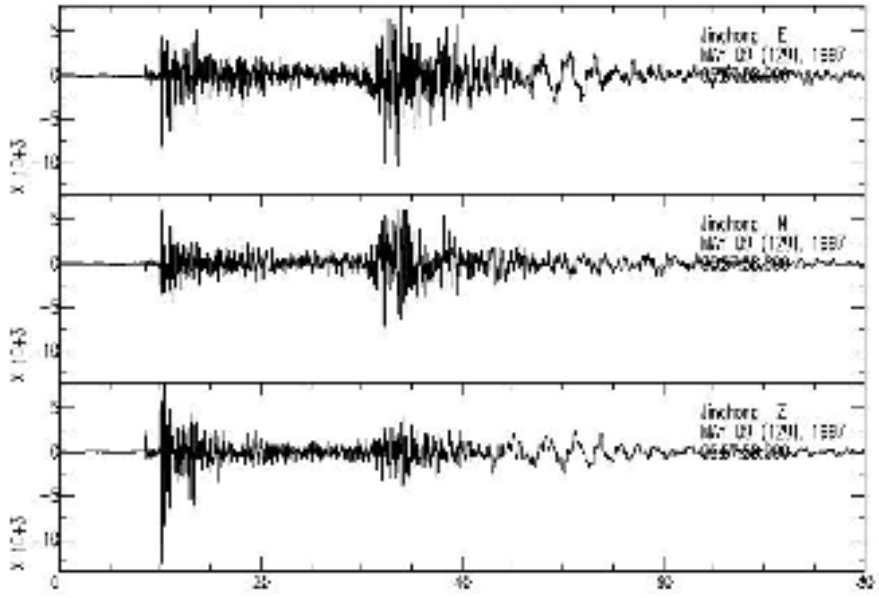

Figure 6. An example of 3-component waveforms of a local event (110 km away) recorded at one station of the regional digital network.

Data Recorded by Portable Broadband Arrays

We have also collected the waveform data recorded at two portable broadband seismic arrays for seven underwater or underground explosions and four local earthquakes. All explosions are controlled ones in southwest China, and are about 1,000 kg TNT. Figure 7 shows the waveform of one underwater explosion

recorded at the portable broadband array. These controlled explosion data are high-quality ground truth information. Figure 8 shows the waveform of a local earthquake recorded by a similar portable array in the same area of the explosions. Such data sets provide very good opportunities for discrimination studies.

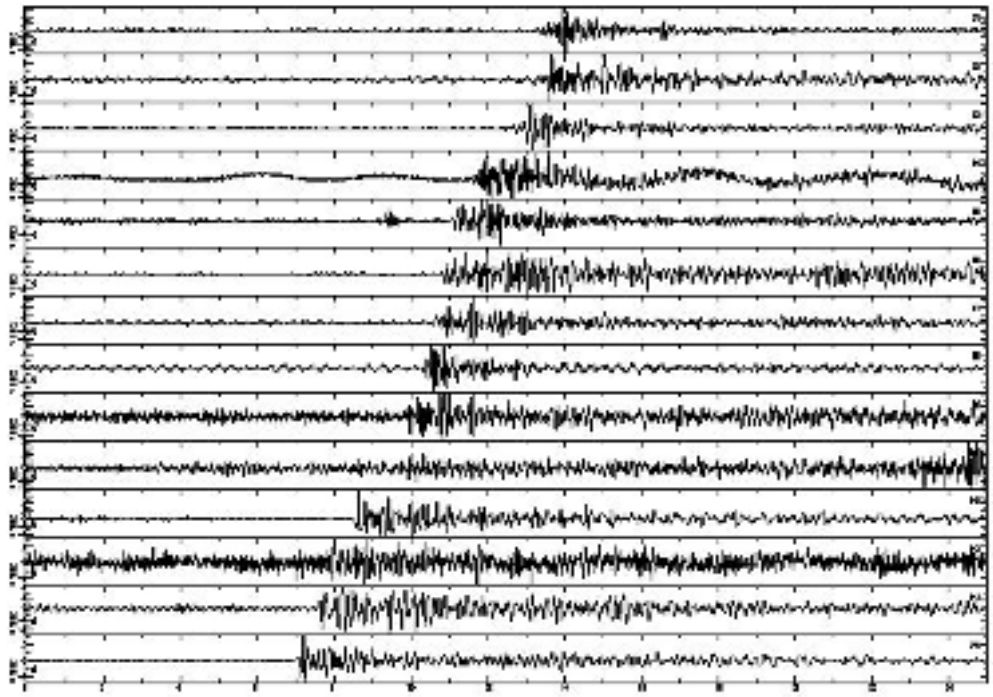

Figure 7. The vertical component of waveforms of an underwater explosion recorded by a portable broadband seismic array.

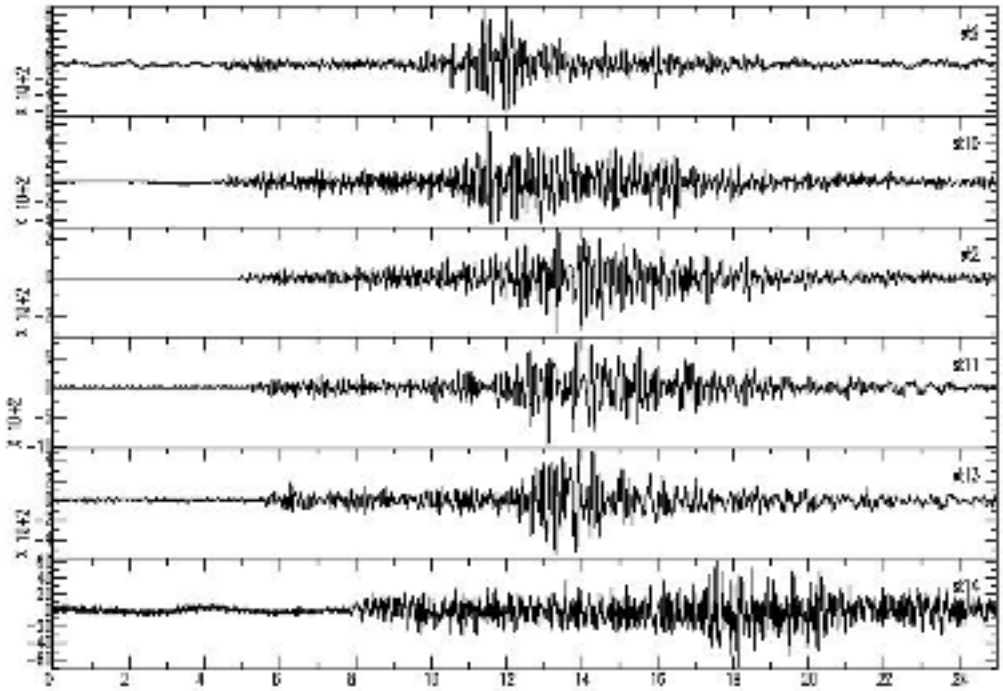

Figure 8. The vertical component of waveforms of an earthquake recorded by a portable broadband seismic array in the same area as the explosion shown in Figure 7.

Preliminary Analyses on the Data Set

Most of the waveform data have been reduced to absolute ground velocity in m/sec. The digital data so reduced are quality controlled, have their P and S-arrival times picked, and are filtered in narrow frequency bands. Then the spectral analysis is conducted in each frequency band. A table is finally created for further multivariate statistical analysis from each filtered waveform which contains event-station information, peak filtered motion, smoothed Fourier velocity spectra, duration, and signal envelope information. To give an example of the spectral analysis, the spectral ratio for a local earthquake and a local explosion are shown in Figure 9 and Figure 10 respectively. All the phase picks are also assembled together with other data obtained by Multimax Inc. into a comprehensive bulletin for the region.

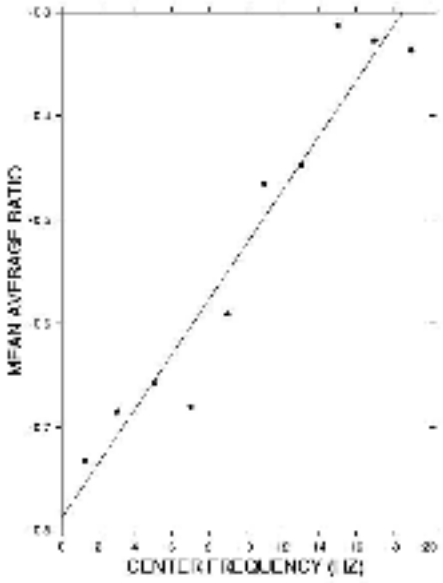

Figure 9. Spectral ratio of Pg/Lg for an earthquake.

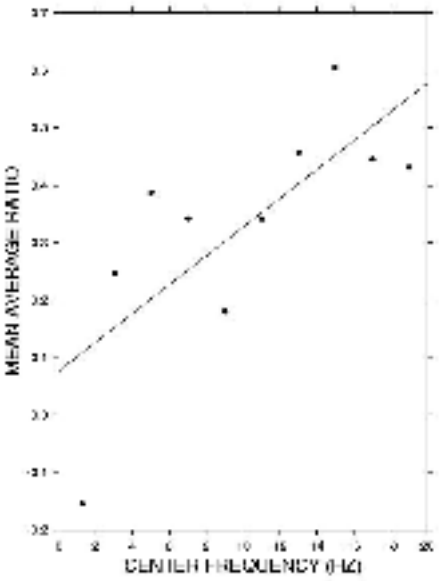

Figure 10. Spectral ratio of Pg/Lg for an underground explosion. Note the difference from the previous figure.

CONCLUSIONS AND RECOMMENDATIONS

In summary, we have accomplished the following tasks in the first stage of this project for studying the regional seismic characteristics in southwest China:

1. **Compiled a regional waveform database**. This is the first digital waveform database from China regional networks. Currently, over 30,000 waveforms reduced to the absolute ground velocity have been archived in the database.
2. **Assembled local bulletins with arrivals and phase picks**. Such bulletins have much better coverage than the national or global bulletins. They are very useful in re-location and tomography studies.
3. **Obtained ground-truth information for seven local explosions**. These data contribute tremendously to the regional discrimination studies.

Preliminary analyses show that these data are of high quality and have broad research applications. Further researches in the next stage will include

1. Evaluate various available parameters for their discrimination capability.
2. Magnitude and distance corrections (Yazd, 1993; Raoof *et al*., 1999; Malagnini, 1999).
3. Multivariate analyses (e.g. Gupta *et al*., 1984; Fan and Lay, 1998).

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