Geological Society of Malaysia Annual Geological Conference 2002
May 26 – 27, Kota Bharu, Kelantan, Malaysia

Detection of seismic phases from a major earthquake on a local seismogram

CHE NOORLIZA LAT

Geology Department, University of Malaya
50603 Kuala Lumpur, Malaysia

Abstract: A study was undertaken to investigate how a local seismogram records a major earthquake. The earthquake chosen was the one that shook Afghanistan's Hindu Kush region on the 3rd of March, 2002 at 12:08:22.9 UTC. This major magnitude 7.4, intermediate depth, tremor killed about 150 people. This intriguing earthquake was preceded by another earthquake of magnitude 6.2 at 12:08:12.3 and followed by several large aftershocks in the same day. The data used is from the NEIC website and the FRIM station. Several phases were successfully identified from the local seismogram, including multiples and depth phases.

INTRODUCTION

An earthquake produces seismic waves in several phases that arrive at seismographs at different times depending on their individual path and speed. These phases can be seen on seismograms across the world if the energy released is sufficient to transmit the signal (Bolt, 1982).

This paper is a descriptive seismological exercise to see how much information could be obtained with a local seismogram recording a major earthquake. Several factors were considered in choosing the earthquake:

1. Size: The earthquake needs to be large enough for the phases to still be recognizable on the seismogram even after travelling a great distance. Major earthquakes release huge amounts of energy that enable the corresponding signals to travel and be detected around the world.
2. Distance: The further an earthquake is from the recording station, the easier it is to decipher the seismogram. Each phase from the earthquake arrives with a sufficient time lapse between them thus making the seismogram "cleaner" and the phases easier to recognize.

Based on these factors, the magnitude 7.4 Hindu Kush earthquake of March 3rd 2002 was chosen. Magnitude 7 earthquakes are rare, occurring less than 20 times a year statistically (NEIC, 2002).

THE EARTHQUAKES

At about 4:38 pm (local time) on a Sunday afternoon, the inhabitants in Hindu Kush were shaken by a large earthquake. This tremor was followed by a larger mainshock about 10 seconds later. The epicentre of the mainshock, occurring at 12:08:22.9 GMT, was located by the US National Earthquake Information Centre (NEIC) at longitude 70.42° E and latitude 36.54° N. The epicentre is 240 km north-northeast of Kabul as shown in Figure 1. The earthquake originated at a depth of about 256 km, which is classified as an intermediate-depth focus. What makes this earthquake more interesting was the foreshock occurring at 12:08:12.3 with a magnitude of 6.2 at a focal depth of 252 km. There were also four aftershocks recorded later that day with magnitudes of 3.8 to 4.4 and similar intermediate focal depths. These considerably large earthquakes, fortunately, only killed about 150 people, mostly from secondary effects of landslides. Statistically, earthquakes of intermediate depth, such as these, have caused fewer casualties as the energy tends to dissipate before it reaches the surface. In comparison, the shallow earthquake of 26/03/02 in the same area killed more than 3000 people from structural failures even though it was a lot smaller at magnitude 5.9.

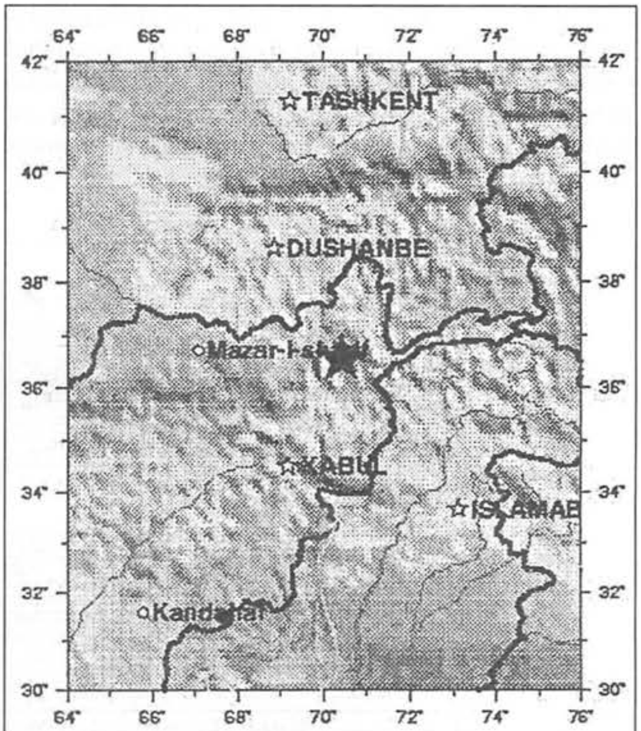

Figure 1. Location of the Afganistan earthquake epicentre (12:08:22.9 pm, March 3, 2002) (NEIC, 2002).

The Hindu Kush region of Afghanistan has always been a seismically active region. Most of the earthquakes are of shallow to intermediate depths (surface to 330 km deep). Situated in an area where the Eurasian plate subducts under the Indian plate a rate of about 4.4 cm a year (NEIC, 2002), this region is constantly under deformation, producing several large to major earthquakes every year.

MALAYSIAN SEISMOLOGICAL NETWORK

The Malaysia Seismological network is composed of twelve stations scattered throughout the Malay Peninsula, Sabah and Sarawak. These stations are managed by the Seismological Division of the Malaysia Meteorological Services under the Ministry of Science, Technology and Environment. There are five stations in the Peninsula, which are located in Ipoh (IPM), Kluang (KLM), Kuala Terengganu (KTM), Petaling Jaya (KLM) and Kepong (FRM). There are three stations in Sarawak and four in Sabah.

The seismogram used for this paper is from Kepong station (FRM), located in the Forest Research Institute of Malaysia (FRIM) which was obtained from the Seismological Division office located in Petaling Jaya. The seismogram from the Petaling Jaya station could not be used because the signal was marred by excessive noise from ceaseless traffic activity within the vicinity of the seismometer. The short period Kinemetrics seismometer at FRIM, with granite as its foundation, is capable of detecting vertical components only. Its purpose is mainly to detect local earthquakes, and not teleseisms (earthquakes of great distance). Ideally, we would need a broadband or a long period, three component seismometer with a digital recorder to be able to identify the phases of earthquakes and thus be able to determine epicentres with ease and clarity. Unfortunately, this is not available at the moment.

DISCUSSION

The objective of this paper is to analyse the seismogram from FRM and identify the seismic phases associated with the earthquakes in the Hindu Kush region.

Some phase onsets were immediately noticeable on the FRM seismogram during the initial observation. The phase identification was difficult due to several factors, including the following facts.

1. There was only one seismogram with a single (vertical) component to analyse.
2. There are actually two sets of seismic phases from two different earthquakes on the seismogram which makes the interpretation more complicated. One earthquake phase might enhance or cancel the corresponding phase from the second earthquake depending on whether they are in-phase or out-of-phase with each other.
3. There are errors associated in reproducing the records and reading of the seismic phases.

The phase picks are shown in Figure 2; subscripts 'fs' are used for phases associated with the foreshock and 'ms' for mainshock. The first phase, denoted P_{fs}, was the P wave from the magnitude 6.2 earthquake, arriving at 12:15:55.8s with the origin time 12:08:12.3s. The travel time for P_{fs} was 7 minutes 43.2 seconds. The second phase corresponded to the P wave from the mainshock (origin time 12:08:22.9s), picked at 12:16:05.7s. The travel time for this phase, denoted as P_{ms}, was 7 minutes 42.8 seconds. These times agreed with the estimated arrival time of the P wave at around 8 seconds (NEIC, 2002). Using these P arrival times and the depths of the earthquakes, we can determine the distance of at about 44° to 45° (1° ~ 110km). The S wave from the mainshock (S_{ms}) came in at 12:22:28.5s as a small but distinguishable signal. The S-P time is about 6 minutes 23 seconds.

The pP phase from the mainshock could be seen

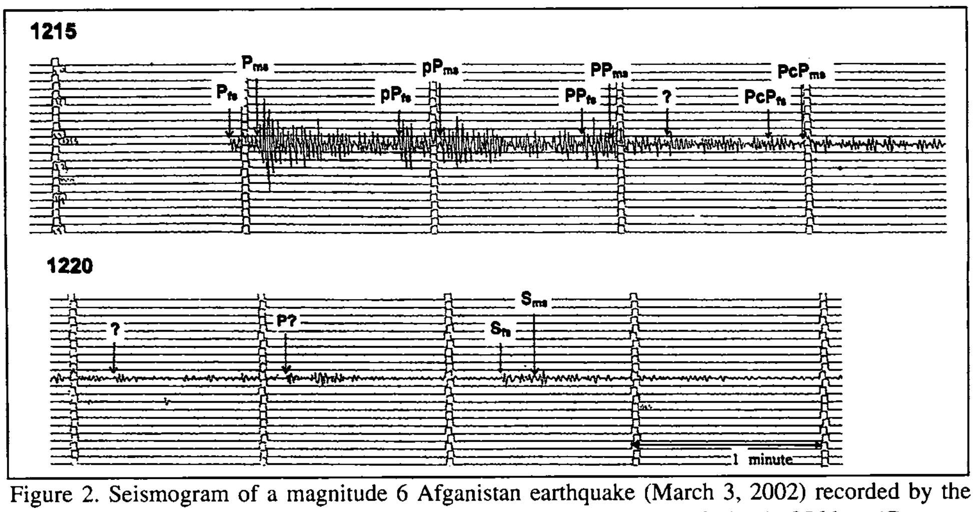

Figure 2. Seismogram of a magnitude 6 Afganistan earthquake (March 3, 2002) recorded by the vertical-component short-period seismograph at FRIM, Selangor. D=45°, depth=256 km. (Courtesy of the Seismological Division, Meteorological Services Department, Malaysia)

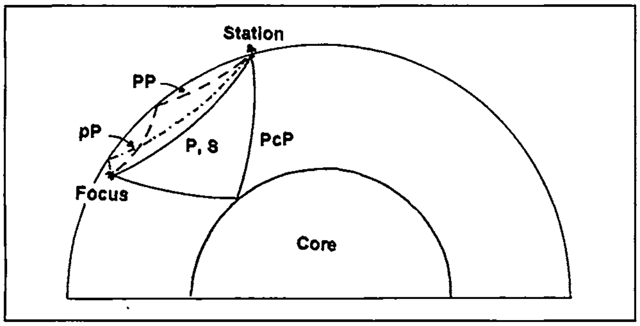

Figure 3. The paths for seismic phases P, S, pP, PP and PcP (after Richter, 1958).

arriving at 12:17:03.0s; this seismic wave being a depth phase that travels from the focus to the surface before arriving at the station (Fig. 3). It arrived a little later than P. Another phase that could be seen was PP, which came in at 12:17:52.0s. PP is the P wave that reflects once off the surface, about half way to the station. The pP phase is usually sharper and clearer than the PP phase (Richter, 1958). The P wave that bounces off the core, called the PcP phase, was supposed to arrive at 12:18:55.0s but there was only a weak signal at this particular time on the seismogram. Each of these phases has a "twin" phase arriving about ten seconds earlier; these earlier phases being from the 6.2 foreshock.

There are also other phases on the seismogram that are not identifiable. These phases do not coincide with any phases listed in the Jeffreys-Bullen earthquake list (Jeffreys & Bullen, 1967) for an earthquake from 45° distance and 256 km depth. These seismic phases (labelled "?") may be from the Hindu Kush earthquakes or other earthquakes that occur that same day. Detailed, comprehensive studies are needed to identify these unknown phases.

The signal arriving at 12:21:07.5s (labelled as P?) is from another earthquake and probably not from the Hindu Kush region. The Hindu Kush earthquakes have P arrival times of about 7.75 minutes. No significant earthquakes from Hindu Kush region occurred at 12:13:23.5 that day to trigger this signal. The frequency content of this earthquake also differs from the characteristics of the Hindu Kush earthquakes. Higher frequencies are usually associated with local or regional earthquakes. Unfortunately, the origin of this earthquake cannot be determined with only one record.

SUMMARY

This study shows that it is possible to analyse the local seismograms for earthquakes provided that there is sufficient energy for the waves to provide a signal. Right now we are limited to single component, analog stations but in the future we will be able to gain more information from MMS's broadband, three-component seismometers and digital recording/playback capabilities. These future stations will also be useful in analysing not only local earthquakes but also large earthquakes from anywhere around the world. We would have a better idea on the path taken by the signals from the focus to the seismometer.

The signal from this particular Afghanistan earthquake retained most of its energy making it relatively easy to analyse. If the path was through water, the signal might be damped or loose its energy faster It is interesting to be able to "see" these depth phases as they were seen by pioneering seismologists while investigating the existence of the earth's internal structures.

ACKNOWLEDGEMENT

The author expresses gratitude to Mr. Low Kong Chiew, the Director of the Seismology Division, Malaysia Meteorological Services, and his staff, for all the data and help given. Utmost thanks also go to the University of Malaya for providing the research facilities.

REFERENCE

BOLT, B.A., 1982. Inside the Earth. W. H. Freeman and Company. 191p.

JEFFREYS, H. & BULLEN, K.E., 1967. Seismological Tables. *In: Ruth Simon's Earthquake Interpretations*, 1981. William Kaufmann Inc, 150p.

NEIC, 2002. National Earthquake Information Centre, Golden, Colorado, U.S.A. URL: http://neic.usgs.gov.

RICHTER, C.F., 1958. Elementary Seismology, W. H. Freeman and Company, 768p.