BARKHAN (BALUCHISTAN) EARTHQUAKES OF JUNE 26 AND JULY 12, 1999: SOURCE PROCESS FROM TELESEISMIC BODY WAVES

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Abstract

Source process of the June 26 and July 12, 1999 earthquakes, which occurred in the eastern part of Kirthar Fold Belts area near Bakhmar in the province of Baluchistan, were studied using the teleseismic body waves recorded at the IRIS Global Seismographic Network. The P and S waveforms of these events were inverted to double couple source using the method of Kikuchi and Kanamori. The estimated average of seismograph stations is good enough to resolve some details of heterogeneous moment tensors. Mechanism of the earthquakes were plotted to have information about the orientation and length of the fault involved. It was found that the movement on the eastern section of the Kirthar thrust was responsible for these earthquakes. The focal mechanism solutions show thrust faulting. The strike, dip and slip of the causative fault of the June 26 earthquake are respectively 243°, 90° and 98°. The seismic moment is estimated as M0 = 2.3 x 1021 Nm for June 26 and M0 = 3.3 x 1021 Nm for July 12, 1999. The solution of the event is compared with fault plane solution derived from first motion polarity data recorded by local seismic network, USGS and also with the Harvard CMT solution. The moment tensor solutions is in agreement with these obtained from first motion polarity, USGS and CMT solutions.

Geology and Tectonic features

June 26, 1999, a moderate earthquake of magnitude 5.7 (m) occurred in the Kirthar-Baluchistan zone of sparsely populated region of Baluchistan as shown in Fig. 1. Another event with same size (m = 5.5) and location occurred on July 12, 1999. Geologically epicenter area is bounded in the west by the left-lateral strike slip zone of Kirthar fault belts and towards northeast it is bounded by the oblique dip of the Kirthar Range. It is an inverted structural basin with high angle reverse faults (Ahmad and Ali 1991) existing in seismic manner almost parallel to each other. Fig. 1-2 shows the main thrust fault in the region named as Pakhtak Range, Kirthar thrust, Karahi thrust, Chigan thrust and Zhob valley thrust (Rakher and Raza 1995).

Aftershocks Distribution

First mainshock was followed by about 15 aftershocks of magnitude ≥2.0 within four days of the occurrence of the main shock. The largest being of magnitude 5.8 which occurred on June 30, 1999 almost at the same location (Fig. 3). Hypocentral locations of the aftershocks were determined with the help of computer code HYPO71 (Lee 1989) using body waves data recorded by local seismic network. The spatial distribution of the well-recorded aftershocks forms a cluster just NE of the main shock (Fig. 3). On July 12, 1999 the region was rocked again by another earthquake of magnitude m = 5.5 located at almost same location at 29.59°N and 69.33°E (Fig. 2). This earthquake was followed by about 30 aftershocks between July 13 and July 27. The largest being of magnitude 5.0 occurred on July 28, 1999. The spatial distribution of the well-recorded aftershocks forms a cluster just NE of the main shock (Fig. 4).

Data Analysis

The teleseismic broadband data set used in this study were retrieved from Data Management Centers of Incorporated Research Institute for Seismology (IRIS-DMC) in the epicentral distance ranging between 30° and 90°. In this distance range, the waveforms are not contaminated by strong upper mantle or core phase. The azimuthal coverage is good enough to resolve some details of the moment release distribution. The teleseismic body waves data were appropriately windowed for each station before P-wave arrival or S-wave arrival. The continuum contained in this time window is adequate enough to resolve the source process. The records were convolved into discrete spectra and subjected to linear and non-linear filtering. We used S-wave velocity as 6.7 km/s, S-wave velocity as 5.2 km/s and density 2.8 g/cm3. The instrumental response were removed by subtracting the poles and zeros of the system frequency response. The source time function is expressed by the amplitudes of the series of overlapping symmetrical triangles. Their amplitudes were adjusted for geometrical spreading and for attenuation parameter (using Butterfield’s 1982) operates with m* = 1 for P* and m* = 4 for SH. The BI velocity model is adopted as velocity structure under all receivers. A rupture velocity was set at 3.2 km/s, which gives start time at each sub-fault.

Method of Analysis

Inversions of teleseismic data of Kirthar and Karah oasis (1992 and 1993) were used to study source parameters of June 26 and July 12, 1999 Bakhmar earthquakes. It uses the far field body waves to invert seismic moment tensors. In 1991, the method was further improved so that subevents with varying mechanism can be used and source time function need not be fixed. Rupture pattern is determined in series of sub-events, which are distributed over fault plane. Each sub-event is represented by (m, g, w) where m is the seismic moment and g stands for the characteristics of the source (location, time history, local mechanism, onset time).

When we consider point source that is, it is much smaller compared with the source length and epicentral distance, then the displacement field at point p is written as

\[ u(p) = \frac{1}{4\pi} \int_{V} \frac{\mathbf{m} \cdot \nabla \delta \mathbf{r}}{|\mathbf{r}|^3} dV \]

where \( \mathbf{m} \) is the displacement field at point p, \( \mathbf{m} \) is the double couple point source and \( |\mathbf{r}| \) is the distance between the location of the source and the point p.

References

