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Estimation of Source Parameters of Local Earthquakes in Jammu and Kashmir, India

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***Abstract*:** The local earthquake events recorded north of Panjal thrust (=Main Central thrust) and Main Boundary Thrust (MBT) by the four broadband seismological observatories located at Jammu, Poonch, Doru and Bani in Jammu and Kashmir from January to May, 2012 have coda magnitudes ranging from 1.7 to 3.8 were used to compute source parameters namely; seismic moment, source radius, and stress drop. These source parameters were computed with the help of Seisan software following Brune's source model. The seismic moments calculated for these events range from $4.47x10^{18}$ to $6.31x10^{21}$ dyne-cm; source radii from 0.45 to 2.08 km and stress drops from 0.08to 28.4 bars.

Index Terms: Earthquake, seismic moment, source radius, stress drop, coda magnitude.

I. Introduction

The Himalaya originated due to continental collision between the Indian and the Eurasian plates that took place during the Late Cretaceous to Early Eocene times[1-2]. This orogenic process continues even to date, as is indicated by significant number small and moderate earthquakes and neotectonic movements along the thrusts and faults in the region[3]. The active tectonic movements along the faults provide direct evidence of lithosphere deformation and the evolving seismo-tectonic setup in the region. The northwestern Himalaya is broadly divisible into four east-west trending linear belts which at the northwest end take a turn to the southwest and form the Western Syntaxis (= Jhelum Syntaxis). These tectonic belts from north to south are i) Karakoram belt, ii) Indus-Shyok belt, iii) Main Himalayan belt and iv) Frontal fold belt. Western Syntaxis and the two re-entrants, the broad Chenab re-entrant near Reasi, Jammu and Kashmir and the sharp Ravi re-entrant near Dalhousie in Himachal Pradesh., have played major role in the configuration of these tectonic units. Jammu and Kashmir has experienced number of devastating earthquakes in the past. According to the seismic zonation map of India, the region under study falls in seismic zones IV and V. We have installed a seismological network of four Broad Band Seismic (BBS) Observatories under the MoES funded project at Duru (in Kashmir region), Poonch, Jammu and Bani (in Jammu region) which is operational since 2009. The entire State of Jammu and Kashmir is flanked by number of faults and thrusts some of them being considered very active (e. g. Main Boundary Thrust (MBT), Murree Thrust (MT) and Panjal Thrust (PT)). Most of the earthquakes are generated by the fault movements[4]. The seismic activity in the Jammu and Kashmir region is largely concentrated along the MBT and PT. Most of these earthquakes have focal depths in the upper 40 km of the crust. Majority of the past earthquakes have occurred between Outer Himalaya and Middle Himalaya within the northwestern Himalaya.

Estimation of source parameters provides important information for assessment of seismic hazard analysis of a region. Several workers[07-21] have made notable contribution in the field of source parameters study following Brune's theory[5-6] which describes the far-field displacement amplitude spectrum as the physical process that release energy at source. We also followed Brune's model[5-6] for estimation of source parameters on local seismic events that occurred from January to May 2012 in Jammu and Kashmir region.

II. DATA SET

The digital data record used in the present study were acquired from the seismic network of four broadband seismograph in the region operational since 2009 at Jammu University Campus (Lat. $32^0$43.139′ N, Long. $74^0$52.052′ E), Poonch (Lat. $33^0$46.233′ N, Long. $74^0$06.415′ E), Doru (Lat. $33^0$34.79′ N, Long. $75^0$14.005′ E) and Bani (Lat. $32^0$41.050′ N, Long. $75^0$48.282′ E) (Fig. 1). All the events used for this analysis were recorded by these stations from January to May, 2012 and are shown in Figure 1.

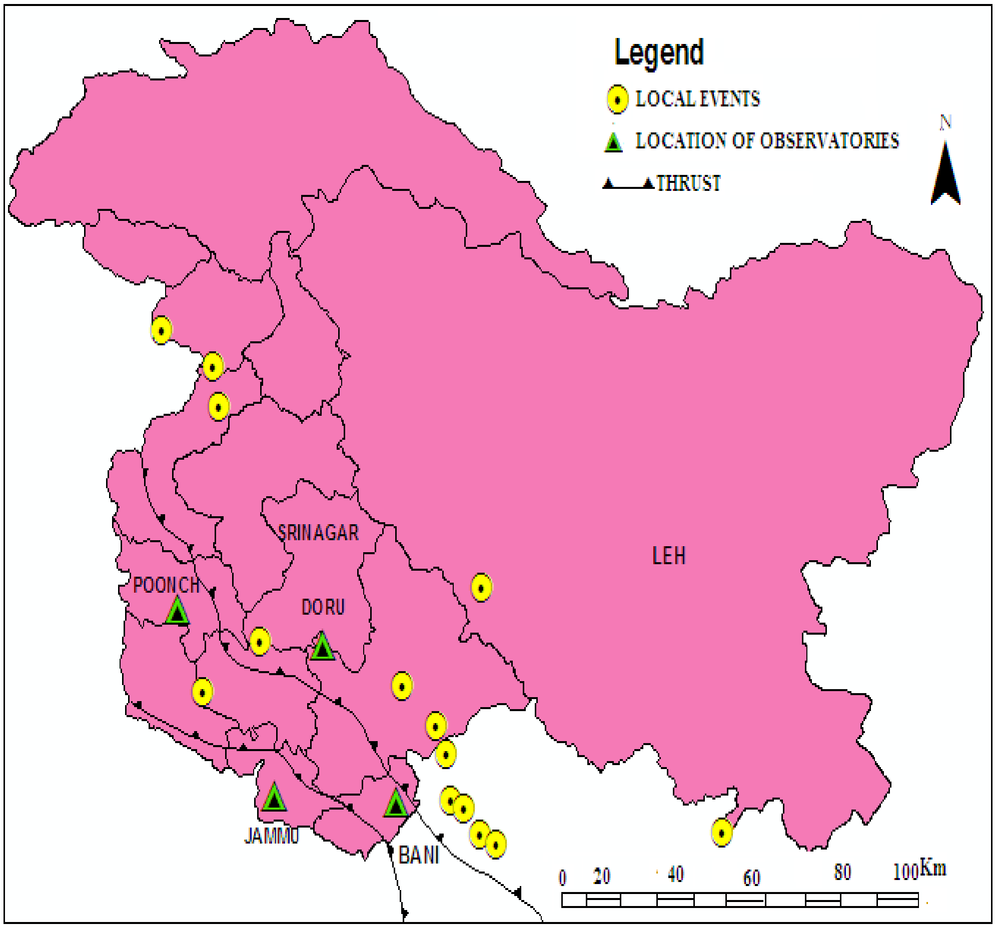

Fig. 1 Map showing the location of Seismic Observatories and local events recorded by these observatories.

III. METHODOLOGY

The P-wave and S-wave arrival time data (phase-data) of fourteen local earthquakes were measured from the digital seismograms obtained from seismological stations. The HYPOCENTER computer program[22] was employed for locating these local earthquakes and computations were carried out adopting the earthquake analysis software SEISAN[23].The digital waveform data recorded from the four stations were converted into respective ground velocity and then rotated to obtain ground velocity in vertical, transverse and radial direction in order to obtain the arrival of phases directly from the source to observatories. The integration of the corresponding velocities gives the displacement waveform. The Shear Horizontal(SH) part of the signal was transformed to frequency domain to get displacement amplitude spectrum. The low frequency spectral level (Ω_0) and corner frequency (f_c) were estimated from the displacement amplitude spectra. A frequency dependent attenuation ($100f^{1.02}$) [24] correction for the Himalayan region was applied. The source parameters: seismic moment, source radius and stress drop were calculated using the following expressions:
Following Kellis-Borok[25] the seismic moment is estimated from the value of Ω_0 as:

$$\text{Seismic Moment, } M_o = 4\pi\rho\beta^3 R\Omega o \,/\, R_{\theta\phi} S_\alpha \qquad (1)$$

Here ρ is the average density (=2.67 g/cm3), β is shear wave velocity in the source zone (=3.92 km/sec)[26], R is the hypocentral distance, $R_{\theta\phi}$ is the average radiation pattern (=0.63), S_a is free surface amplification (=2).

The source radius and stress drop are estimated followingBrune's model[5-6] as:

$$\text{The source radius, } r = 2.34\,\beta / 2\pi f_c \qquad (2)$$

$$\text{The stress drop, } \Delta_\sigma = 7\, M_o / 16\, r^3 \qquad (3)$$

An example of recorded digital waveforms of an event is shown in Figure 2. The rotated transverse component of time history at a station along with its Shear Horizontal (SH) part marked by arrows and its displacement amplitude spectrum is shown in Figure 3.

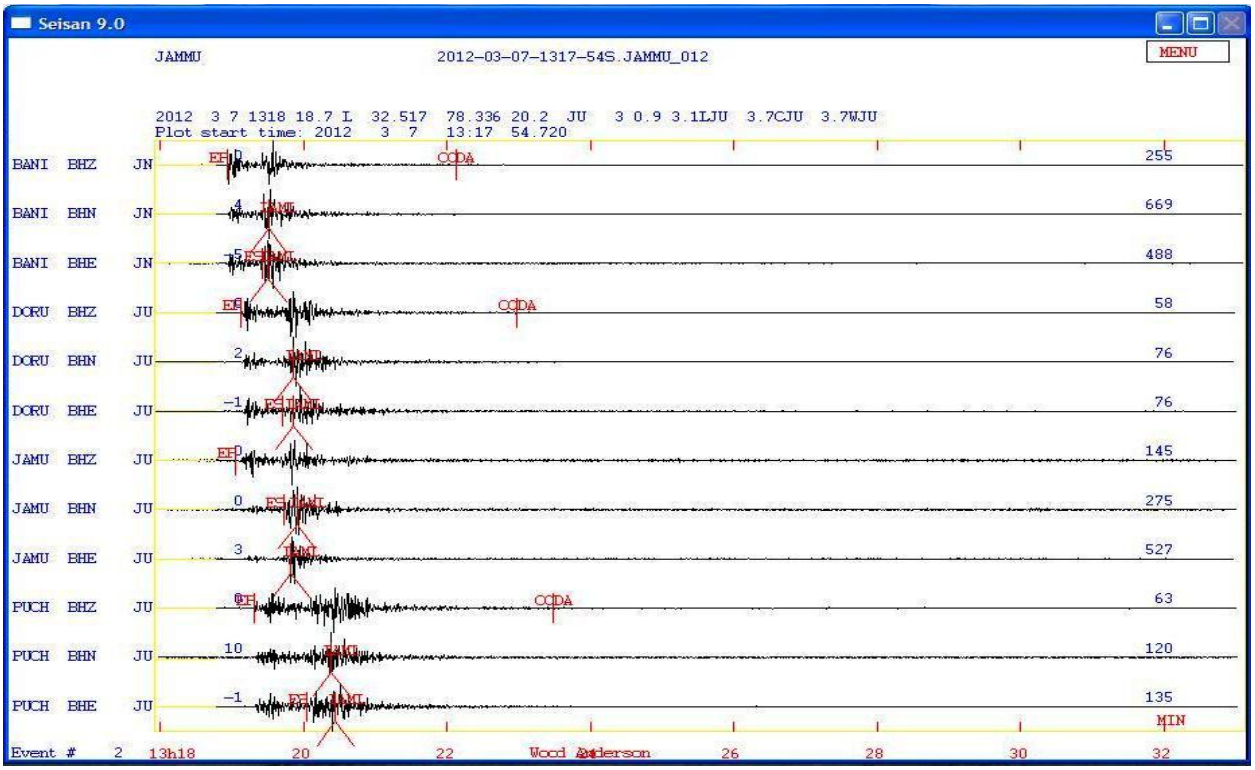

Fig. 2: Waveforms of an event recorded by seismic network of Jammu University

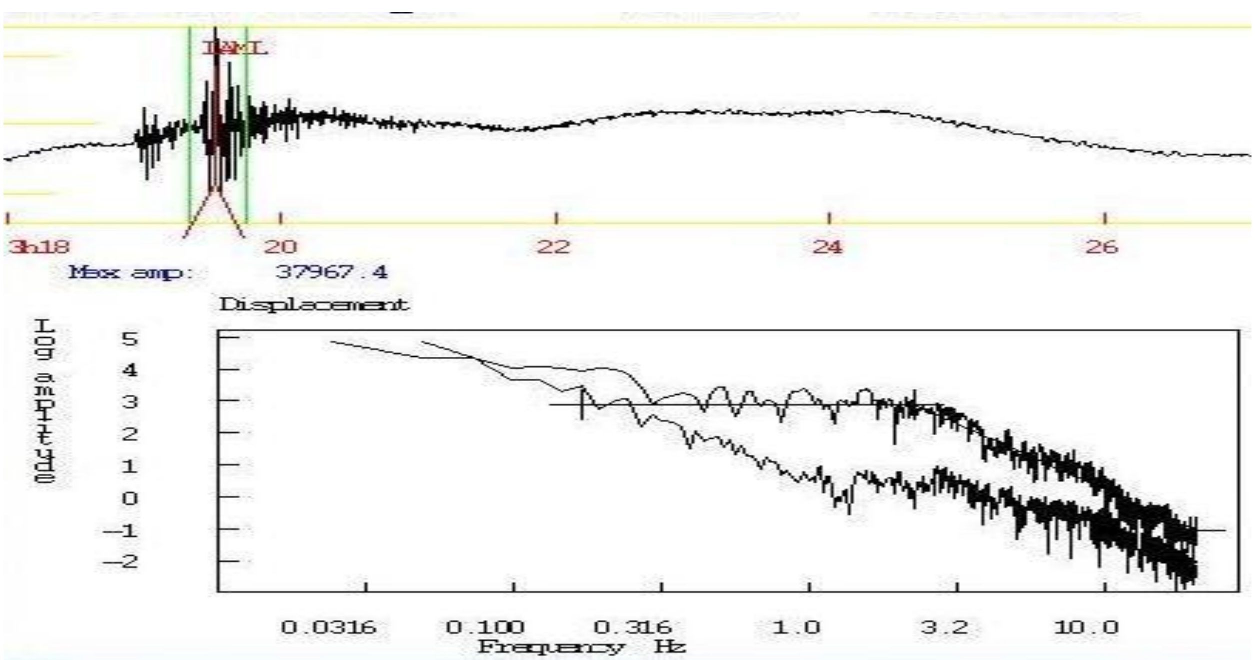

Fig. 3: The rotated transverse component of an earthquake and its Shear Horizontal (SH) part shown in upper part of the figure and the displacement amplitude spectrum along with marked low frequency spectral level and high frequency spectral decay above f_c in the lower part.

IV. RESULTS AND DISCUSSIONS

The estimated source parameters namely seismic moment, source radius and stress drop along with their hypocentral parameters of the fourteen local seismic events are given in Table 1.

Table 1: Showing Location of Earthquakes and source parameters of the events recorded by the Jammu University Seismic Network during January-May, 2012

S.No	Date yyyymmdd	UTC Time HH:MM:SS.s	Latitude	Longitude	Coda Magnitude	Seismic Moment M_o (dyne-cm)	Stress Drop (bars) σ	Source Radius (km)
1	20120104	16:31:18.54	33.593	74.759	3.7	$4.47x10^{21}$	28.4	1.21
2	20120206	00:16:49.18	33.118	76.123	2.1	$5.01x10^{19}$	0.5	0.504
3	20120221	19:55:48.20	35.354	74.003	2.9	$2.82x10^{20}$	4.2	0.5842
4	20120225	21:41:18.27	32.966	76.200	1.7	$4.47x10^{18}$	0.31	0.5
5	20120307	13:18:18.73	32.518	78.332	3.8	$6.31x10^{21}$	7.0	2.08
6	20120402	06:30:17.42	32.260	74.242	2.4	$5.01x10^{19}$	1.1	0.8
7	20120405	22:34:56.02	34.920	74.447	3.0	$3.98x10^{20}$	3.8	0.6
8	20120406	10:54:48.08	32.502	76.464	2.6	$1.0x10^{20}$	1.5	0.8
9	20120424	01:52:48.74	33.898	76.482	2.3	$3.55x10^{19}$	2.5	0.5
10	20120426	22:34:01.69	32.704	76.235	2.0	$1.26x10^{19}$	0.08	0.5
11	20120501	21:36:26.76	35.144	74.396	3.0	$3.98x10^{20}$	4.61	0.456
12	20120503	14:44:56.99	33.349	75.851	2.2	$2.51x10^{19}$	0.18	0.5
13	20120506	05:43:3.43	32.650	76.337	2.5	$7.08x10^{19}$	1.5	0.5
14	20120510	01:05:20.10	33.315	74.317	2.1	$1.78x10^{19}$	0.12	0.5

The estimated seismic moment ranges from $4.47x10^{18}$ to $6.31x10^{21}$ dyne-cm and coda magnitudes of these events ranges from 1.7 to 3.8. The corner frequencies range from 0.63 Hz to 3.0Hz, and source radii calculated for these events ranges from 0.45 to 2.08 km. The stress drop of these events varies from 0.08 to 28.4 bars. These results are similar to the results obtained through earlier studies elsewhere in the Himalayan region[20, 27].

V. CONCLUSION

The estimated source parameters for the fourteen local events ($1.7 \leq M_D \leq 3.8$) recorded by the four seismic observatories installed in Jammu and Kashmir is the first such study carried out in the region. These source parameters have an importance in providing basic information for the assessment of seismic hazard in the region which experienced an earthquake of M_w=7.6 in 2005 taking a toll of about 87000 lives across the Line of actual Control in Jammu and Kashmir and Pakistan. Epicentres of these events located north of Panjal Thrust (PT) and Main Boundary Thrust (MBT). The seismic moments calculated for these events range from $4.47x10^{18}$ to $6.31x10^{21}$ dyne-cm; source radii from 0.45 to 2.08 km and stress drops from 0.08 to 28.4 bars which are similar to the events recorded in other parts of the Himalayan regions.

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