Journal of Nepal Geological Society, 1997, Vol. 15, pp. 45-51

Source parameters estimation of the 1980 Bajhang Earthquake, far western Nepal

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ABSTRACT

The Bajhang earthquake of 1980 is one of the moderate magnitude earthquakes in the Himalaya that has been investigated by many researchers. The methods used by them for determining source parameters vary from the use of the first motion data to the waveform modeling. The ambiguity in focal mechanisms determined by different processes has been resolved by comparing the synthetic seismograms generated using wave number integration technique with those observed at the Global Digital Seismograph Networks (GDSN). The earthquake source parameters determined are found to be as follows: Dip=26°, Strike=290°, Rake=90°, Depth of focus=20±5 km and source time function=7 (2,3,2) seconds.

INTRODUCTION

The Bajhang earthquake of 1980 has drawn attention of many researchers in the world (Ni and Barazangi, 1984; Singh, 1985; Sipkin, 1987; Choy and Engdahl, 1987; Lyon-Caen and Molnar, 1989). The event having its body wave magnitude 6.1 and surface wave magnitude 6.5 had affected an area of 12000 km^2 (Singh, 1985). The tectonics of the epicentre region (Fig. 1) has been explored by many investigators (e.g., Seeber et al., 1981; Khattri and Tyagi, 1983; Baranowski et al., 1984; Ni, 1989; Molnar, 1990; Khattri et al., 1993; Yu et al., 1995).

One of the reliable methods used in order to estimate the earthquake source parameters is the waveform modeling that requires the generation of synthetic seismograms with the appropriate earth model. Various approaches are taken in order to generate such seismograms. In this method, the wave number or the frequency integral is evaluated first (Chapman, 1978). If the wavenumber integral is evaluated first leaving the frequency integral, it is known as the spectral method (Langston and Helmberger, 1975; Hermann, 1978; Mueller, 1985). If the frequency is integrated, first it is called slowness method (Burdick and Orcutt, 1979). In this study, the wave number integration method has been used to generate synthetic seismograms of the long period P waves. High quality digital observed seismograms from the Global Digital Seismograph Networks are used in this investigation.

THEORY INVOLVED

As the seismogram is the net effect of source, medium and instrument systems, the synthetic seismogram is expressed as the convolutional output of the responses of all these systems:

$$r(t) = s(t)* s^c(t)* r^c(t)* i(t)$$

where, s(t) describe the seismic radiation at the focal sphere,
$s^c(t)$ and $r^c(t)$ are the impulse responses in the source and in the receiver region respectively,
q(t) is the Q factor in time domain
i(t) is the instrumental response and * denotes convolution

METHODOLOGY

The source crust response is estimated according to Hudson (1969a,b). The source crust is composed of horizontally isotropic, homogeneous layers. Each layer is characterized by the P and the S wave velocities, the density and the thickness. The source

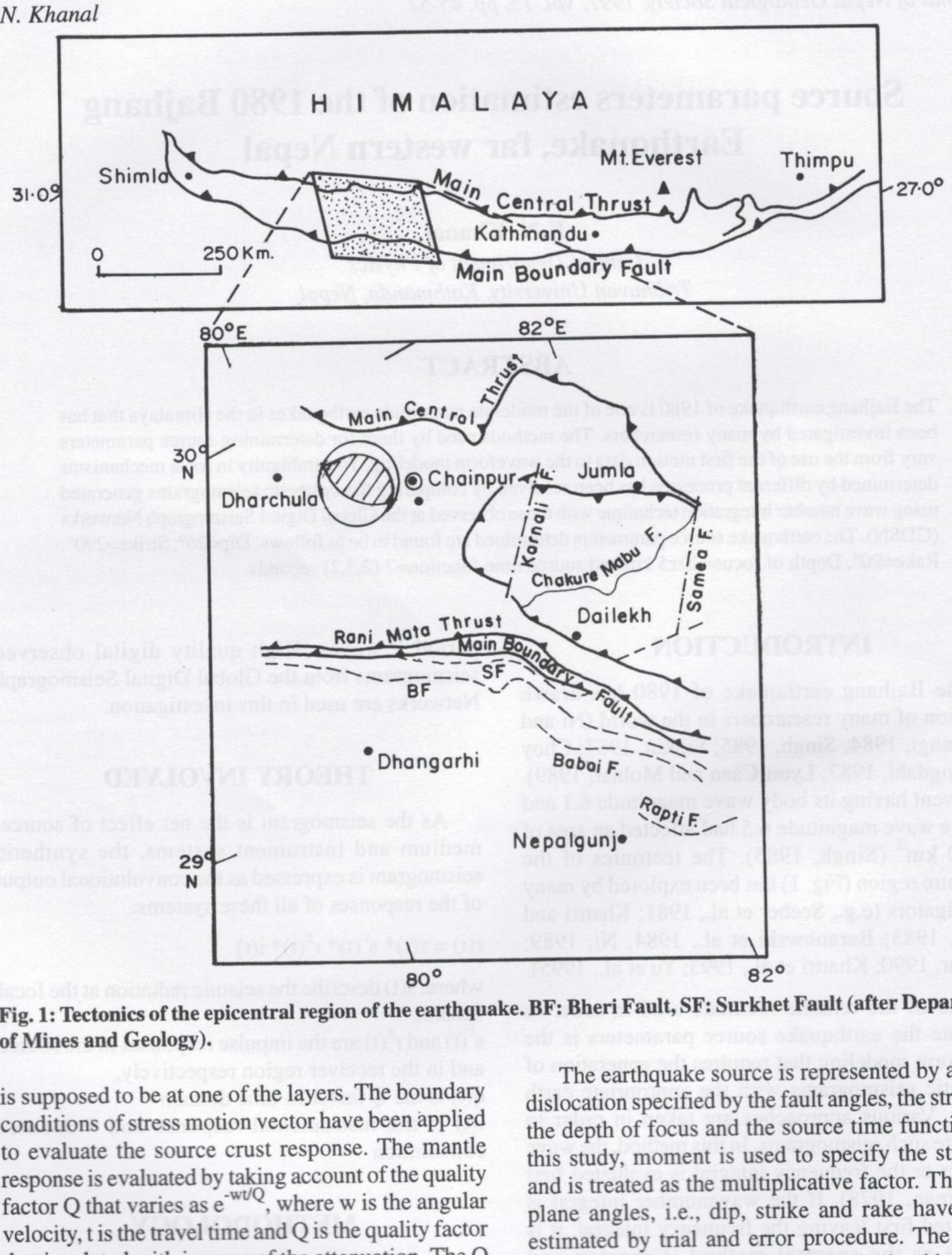

Fig. 1: Tectonics of the epicentral region of the earthquake. BF: Bheri Fault, SF: Surkhet Fault (after Department of Mines and Geology).

is supposed to be at one of the layers. The boundary conditions of stress motion vector have been applied to evaluate the source crust response. The mantle response is evaluated by taking account of the quality factor Q that varies as $e^{-wt/Q}$, where w is the angular velocity, t is the travel time and Q is the quality factor that is related with inverse of the attenuation. The Q value for the P waves is used as given by Langston and Helmberger (1975). The receiver crust transfer function is estimated by propagator matrix method of Haskell (1953). The appropriate transfer function of the instrument system is used.

The earthquake source is represented by a point dislocation specified by the fault angles, the strength, the depth of focus and the source time function. In this study, moment is used to specify the strength and is treated as the multiplicative factor. The fault plane angles, i.e., dip, strike and rake have been estimated by trial and error procedure. The initial estimate is done using the values obtained by other investigators. At the beginning, the source time function is estimated from the empirical values of the dimension of the source according to Kasahara, 1981 (Table 1).

Table 1: Earthquake hypocentral parameters and magnitudes

Date	Origin Time	Latitude °N	Longitude °E	Body wave magnitude (mb)	Surface wave magnitude (Ms)	Depth H(EDR)
1980:7:29	14:58:40.8	29.598	81.092	6.1	6.5	18

Source: Earthquake data reports of United States Geological Survey

The observed seismograms used in this study are those recorded at seven stations (Fig. 2): GUMO (Guam, Merina Island), NWAO (Narogen, Australia), GRFO (Grafenberg, Germany), TATO (Taipei), CTAO (Charter Tower, Australia), MAJO (Matsushire, Japan) and KONO (Kongsbarg, Finland). The station parameters that include the location of epicenter and the azimuth (or back azimuth) are estimated assuming a symmetric spherical earth (Richter, 1958). These parameters are presented in Table 2.

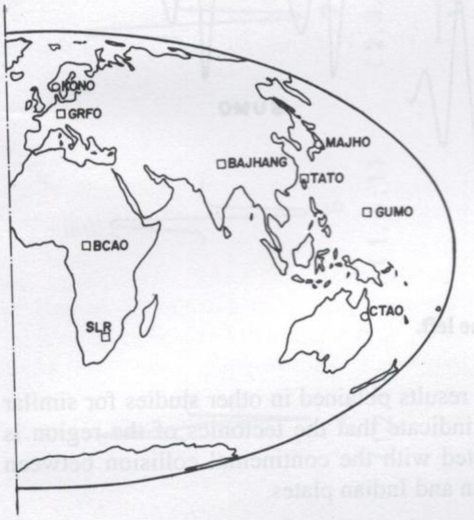

Fig. 2: Various digital stations used for the study.

Among the various velocity models (Barazangi and Ni, 1982: Ni and Barazangi, 1983; Hirn et al., 1984; Chander et al., 1986) used on trial basis showed the model of Hirn et al., 1984 produced comparatively better result The model is given in Table 3.

Table 3: Velocity model of the (source crust)

Vp (km/s)	Vs (km/s)	Density (gm/cc)	Thickness of layers(km)
6.0	3.45	2.7	20
6.4	3.75	2.9	35
8.0	4.82	3.3	—

RESULT

The location of the earthquake epicentre along with the tectonics of the region is shown in Fig. 1. From the digital observed seismograms (Fig. 3) the source parameters are estimated as strike=290°, dip=26°, rake=90°, duration of source time function =2,3,2 (7) seconds and depth of focus=20±5 km. Fig. 4a shows the total duration of the rupture of seconds fits the rupture of the earthquake Fig. 4b shows a linear dependance between duration of source time function and the period of the waves.

Table 2: Stations parameters

Station	Epicentral Distance, Degree	Azimuth, Degree	Back Azimuth, Degree	Take Off Angle, Degree	Phase Velocity, Km/sec
GUMO	60.69	90.51	296.55	24.5	14.5
NWAO	71.29	148.48	327.21	21.7	16.2
GRFO	55.24	312.32	96.38	26.0	13.7
TATO	92.56	286.61	31.4	11.5	
CTAO	80.01	120.08	306.72	19.2	18.2
MAJO	47.67	65.87	260.99	28.1	12.7
KONO	55.55	324.48	90.79	25.9	13.7

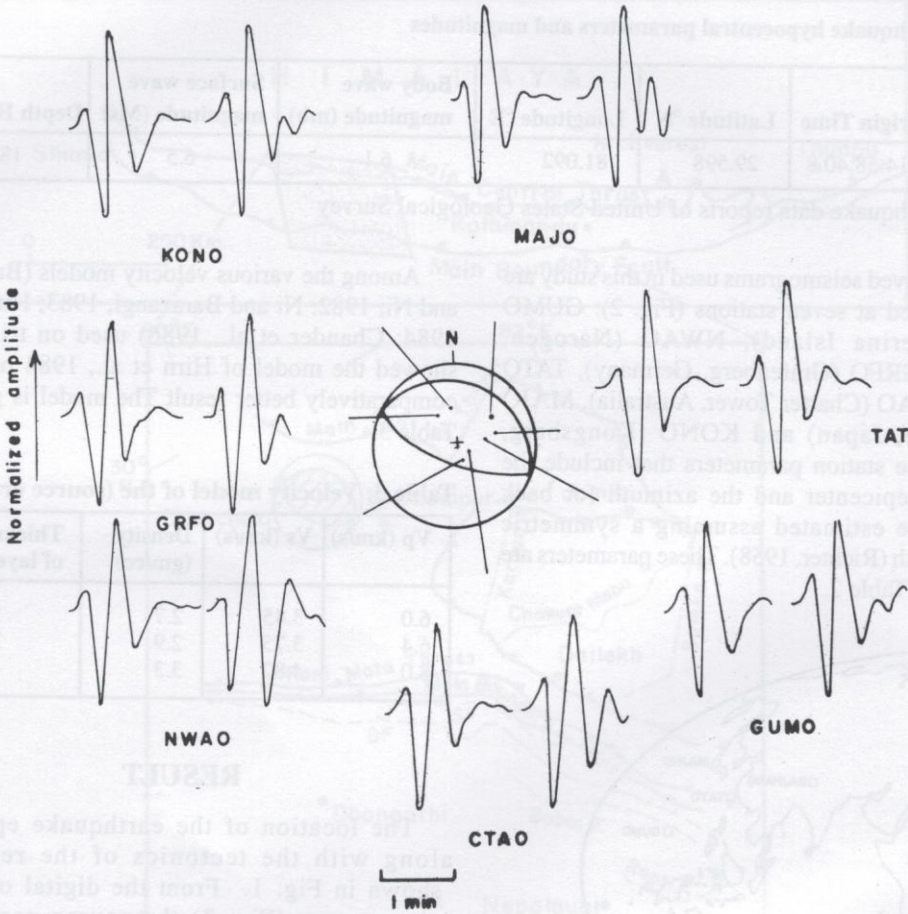

Fig. 3: Synthetic and observed seismograms. Synthetics are on the left.

DISCUSSION AND CONCLUSIONS

A comparison between synthetic and observed seismograms (Fig. 3) shows that there are some differences in the period and first peak to peak amplitude of the waves which may be due to various factors including the very simple receiver crust model and the inadequate path effects taken into consideration.

The shape of the seismograms are also dependent on fault plane parameters. The angles specifying the earthquake source are resolvable only up to an angle of ±5 in this study. The period of the waves match good indicating that the duration of source time function taken into account is appropriate. Although the tectonics of the region cannot be explained in terms of the fault plane solution of a single event but the results obtained in other studies for similar events indicate that the tectonics of the region is associated with the continental collision between Eurasian and Indian plates.

In this study, the depth of focus has not been resolved properly. Choy an1d Engdhal (1987) treat it as a complex event and estimate the depth of focus equal to 27 km. Sipkin (1987) estimates only 17 km, whereas Ni and Barazangi (1984) estimates the depth to be only 15 km. Earthquake Data Report reports the depth of the event as 17 km. On the other hand, International Seismological Summary has estimated 23 km whereas from this study the depth has been constrained to be at 20±5 km. It is believed that the estimation of 20 km made in this study is not away from the real value (Baranowski et al., 1984).

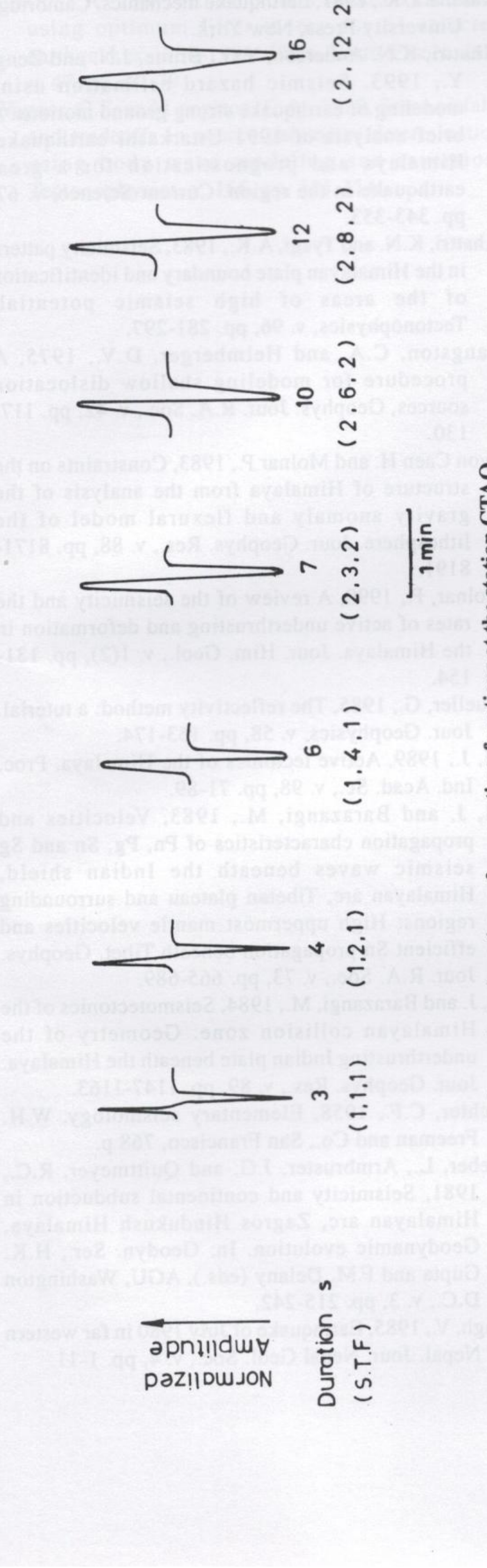

Fig. 4a: Seismograms generated for various durations of source time functions at the station CTAO.

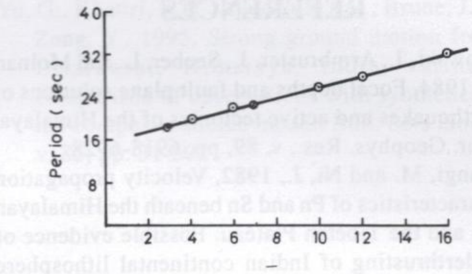

Fig. 4b: Relation between the duration of source time function and the periods of the waves.

One of the significant differences that occurs in the body wave modeling is in between the depth of focus and the source time function (e.g., Christensen and Ruff, 1985). In some cases, it is possible to fit observed data using a deep source with a short source time function as well as a shallower source with a longer time function (Wagner and Langston, 1989). This ambiguity can be resolved based on external information. The relationship between the magnitude and the duration of source time function can also be established from the rupture length and the rupture velocity (Kasahara, 1981). In the present investigation, the duration of source time function has been fixed from the curves obtained at various durations (Fig. 4a). For the earthquake of this magnitude, the duration is of about 7 seconds.

Fig. 4b shows the relation between the period of the waves and duration of the source time function. A linear relation has indicated that the longer the duration of source time function i.e., the longer the slip of the fault the longer will be the period of the wave. It is based on the practical experience.

ACKNOWLEDGEMENTS

The author expresses his gratitude to Prof. K.N. Khattri, Emreritus Scientist and Dr. V.C. Thakur, Director, Wadia Institute of Himalayan Geology for their suggestion and help during this work. He is also thankful to the unknown reviewer. Revision of the work was done when the author visited WIHG under scientific exchange program between RONAST and INSA during October, 1995 to April, 1996.

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