Paper No. 161, Bull. ISET. Vol. 12, No. 4, December 1975, pp. 155-160

FAULT PLANE SOLUTION FOR KINNAUR EARTHQUAKE OF 19 JANUARY, 1975

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INTRODUCTION

Earthquakes are not new to the people of Himachal Pradesh. The state nestles in the highly seismic belt of the Himalaya. One of the most severe historical earthquake devastated area around Kangra in 1905. Recently on 19th January, 1975 the adjacent areas of Kinnaur and Lahaul—Spiti districts were badly rocked. Although this recent earthquake was a midget in comparison to the great Kangra shock, it has nevertheless left an expanse of considerable damage and loss of life in its wake. The shaking of the ground was experienced over a wide area that encompassed places as far as Delhi, 450 km away from the epicenter.

Earthquakes have attracted the attention of the most discerning of scientists and engineers all over the world. Their main concern is to clearly understand the processes that cause earth-tremors and thereby devise ways and means to mitigate their disastrous results.

According to the modern concept of the origin of an earthquake, its immediate source lies in the sudden release of elastic strain energy accumulated in the rock masses in the form of a catastrophic fracture of the earth's crustal layers. The sudden slip on the fault generates seismic waves which propagate outwards. A study of the nature of these waves that emerge at the surface permits the determination of the fault surface which often lies at considerable depth in the earth without producing any trace on the surface. The fault plane studies of earthquakes also allow the determination of the direction of relative displacement of the faulted blocks as well as the directions of principal stresses. In this investigation we present the fault plane solution of the Kinnaur earthquake and examine the relationship of this event with the tectonics of the area.

The hypocentral coordinates of the main Kinnaur earthquake are as follows:

Date: 19th January, 1975
OT: 08H02M 02.53S
Latitude 32.455°N; Longitude 78.430°E
Depth of focus $H=37$ km
Magnitude $M_S=6.8$

SEISMO-TECTONIC SETTING OF THE AREA

The area of the present investigation lies in the Himalayan tectonic zone noted for high seismic activity, and is shown in Fig. 1. The dots represent the earthquake epicenters which outline the southern edge of the Himalyan tectonic province. The thick lines represent major thrusts which characterise the entire Himalayan zone. The hatched areas show the meizoseismal zones of the great earthquakes that have devastated the area in the historical past.

A detailed tectonic picture of the area is shown in Fig. 2. It will be noted that the southern edge of the Himalayas are laced by numerous thrusts that follow the general NW-SE trend. Further to the north west, the well known Main Central Thrust (MCT) is exposed. In between the above mentioned thrusts, around Leo, a series of north-south trending faults have been mapped (Gansser, 1964). The epicenter of the main Kinnaur earthquake and its aftershocks are seen to cluster in the vicinity of these faults. The location of the great Kangraearthquake of 1905 is also shown in this figure.

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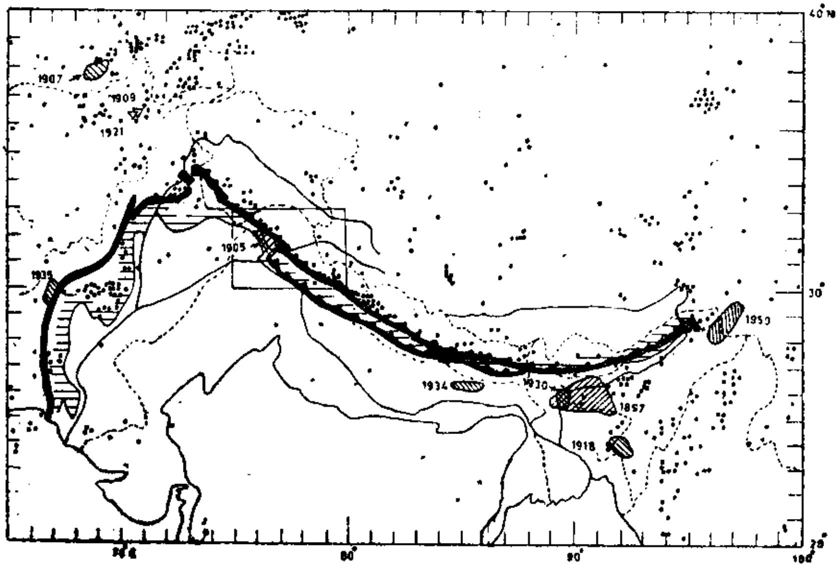

Fig. 1. Seismicity map of Himalaya and adjoining areas. The Meizoseismal areas (MMV) of great earthquakes is shown by hatchure areas. The major Lineament/Thrust are shown by thick lines. The area of present investigation is shown by the inset (after K.H. Jacobs, 1975)

Recent geological investigations of the area following the earthquake have revealed that the N-S trending faults in the meizoseismal area are characterised by the occurrence of thermal springs and gypsum deposits (Singh et al., 1975). These bear testimony to the active status of these faults.

THE FAULT PLANE SOLUTION

In order to derive the source mechanism of an earthquake, the actual process at the source is mathematically modelled by a dislocation surface across which there is a discontinuity of displacement. This permits a theoretical calculation of the radiation pattern of the elastodynamic field around the assumed dislocation. A matching procedure in which the theoretical radiation patterns are compared with the observed ones allows the selection of the appropriate fault model (Ben-Menahem and Singh, 1972; Khattri, 1973). There are several techniques for accomplishing this.

The method used in the present analysis utilizes the observed world pattern of the sense (compression or dilatation) of the initial wave motions. Theoretical studies have demonstrated that the space around the fault plane is divided by two orthogonal planes into four quarter spaces. The sense of initial motion longitudinal waves in these spaces is alternately a compression and dilatation. The fault plane coincides with one of the orthogonal planes while the other is termed as the auxiliary plane. The inferred axes of compression (P) and tension (T) make angles of 45° with the strikes of the orthogonal planes.

In order to render tractable the problem of determining the orthogonal planes from global observation data, the initial motion data are first projected on to an imaginary sphere, called the focal sphere, that surrounds the hypocenter. The data points are then plotted on an equal area projection to reduce the three dimensional space data on to a two-dimensional map. Two orthogonal great circles are drawn

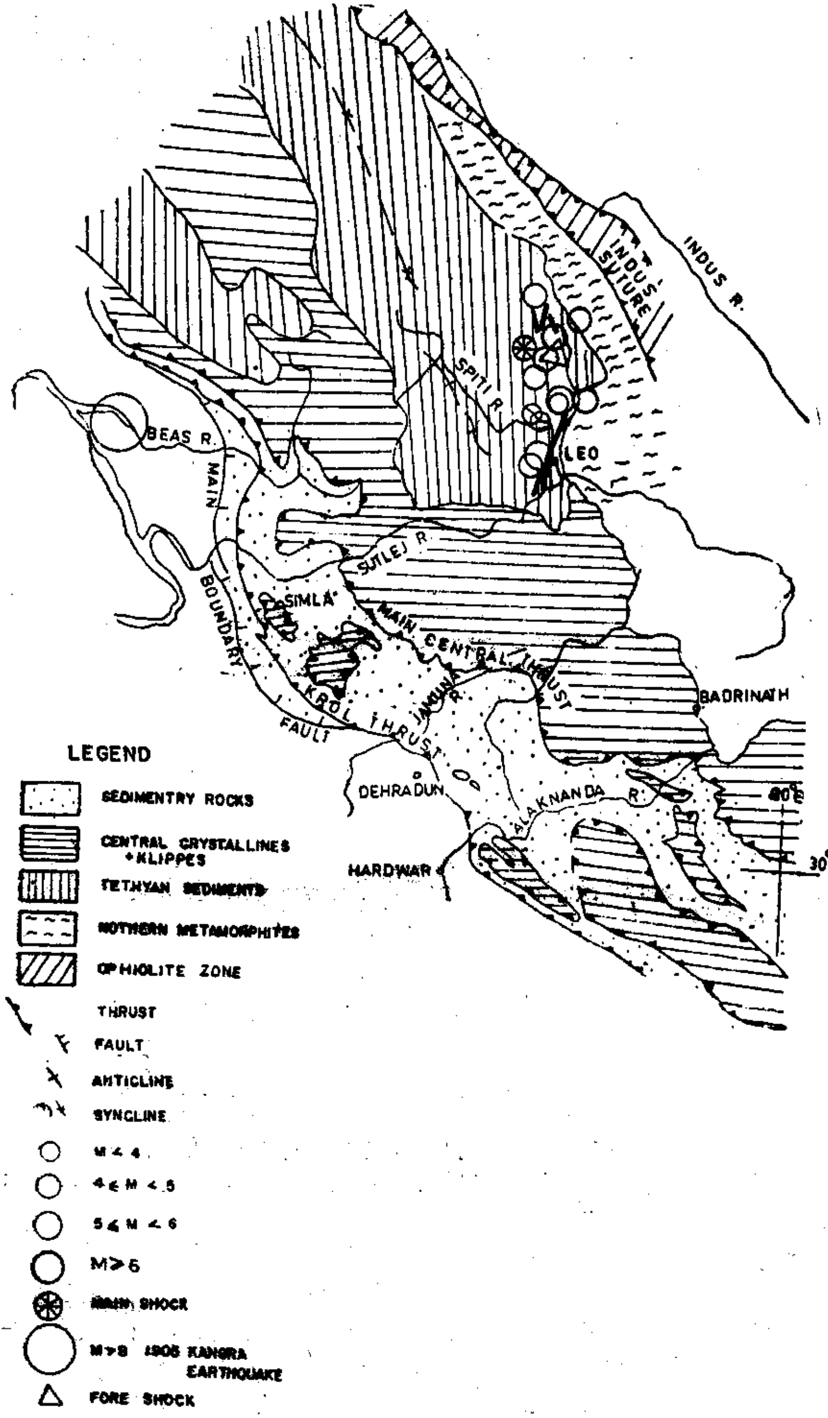

Fig. 2. The generalised geological map of the area. The epicentres of the Kinnaur main earthquake and its after shocks. The geology is after Gansser (1964).

separating the observed fields of dilatations and compressions into four regions. The fault plane solution for the Kinnaur earthquake determined in this way is illustrated in Fig. 3. The data used in this study were taken from the epicentral determination reports

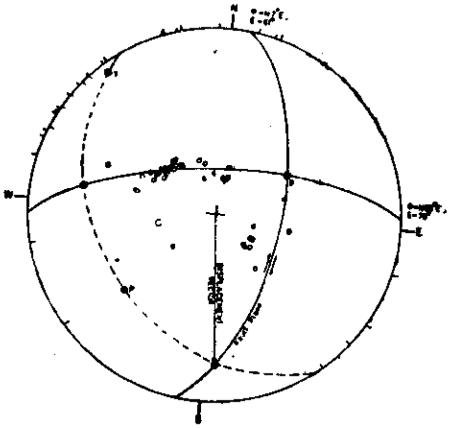

Fig. 3. Fault plane solution 19 January 1975 Kinnaur earthquake. The open circles show dilatation, closed circles compression, half circles represent stations reporting emergent P phases, full circles impulsive P phases.

(EDR) issued by the National Oceanographic and Atmospheric Agency (USA). The two orthogonal planes that fit the data are as follows:

Plane I: Strike=N 7°E; Dip=60°E
Plane II: Strike=N86°E; Dip=70°N

The other parameters of the fault plane solution are given below:

	Azimuth	Plunge
P axis	226°	35°
T axis	318°	3°
B axis	57°	53°
Displacement Vector	176°	20°

It may be noted that the initial motion data are not completely consistent. Such discrepancies are mostly ascribable to incorrect reading of the initial motion by station operators. In most cases such inconsistencies can be eliminated by a seismologist himself reading the seismograms. But unfortunately the present investigators have uptil now failed to obtain the actual seismograms.

THE FAULT PLANE

The ambiguity in the choice of the fault plane out of the two orthogonal planes is inherent in the method used here, and ancilliary information is needed to select the correct plane.

Often such information as the tectonic fabric of the area, or the alignment of a seismic zone parallel to one of the orthogonal planes allows this choice to be made with certainty. A powerful method is to examine the spatial distribution of the after shocks which define the fracture zone. The isoseismals of intensity maps also reveal the strike of the fault causing the earthquake.

The aftershocks of the Kinnaur earthquake are remarkably well aligned in a N-S direction (see Fig. 2). The N-S trending geologically mapped faults coincide with the after shock seismic zone. The isoseismals (see Fig. 4) also show a N-S trend (Singh et al., 1975). All the above evidences put together, inevitably lead to the conclusion that the fault plane during the Kinnaur earthquake is defined by the north trending orthogonal plane of the fault plane solution. An isometric view of the inferred earthquake fault is shown in Fig. 5. The relative slip on the fault plane is a combination of strike and dip slip, the former being more dominant. The eastern block has moved southward relative to the western block. The length of the fault, estimated from the extent of the after shock zone is approximately 100 km. Seismological data have shown time and again that the main earthquakes are located at one end of the fault zone, a phenomenon in evidence in the present instance also. A conlusion that flows from this observation is that the fracture probably propagated from the main shock towards its southern tip.

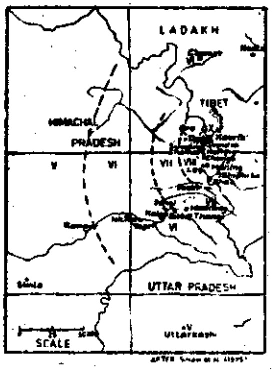

Fig. 4. **Isoseismals of Jan. 19, 1975 Earthquake on M.M. Intensity Scale.**

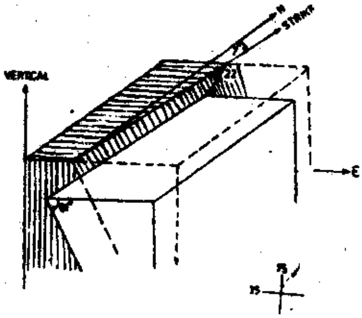

Fig. 5. **Orthographic View Showing the Orientation of the Fault Plane and Displacement on it.**

The axis of compression aligns in an approximately NE-SW direction i.e., across the axis of the Himalaya in this region. This result is in conformity with the relative motion of the Indian plate with respect to the Eurasian plate which is in an approximately NE direction (Le Pichon, 1968).

DISCUSSION AND CONCLUSIONS

The evolution of Himalaya and current deformation taking place there as evidenced by high seismicity is ascribed to the collision of the Indian and Eurasian lithospheric plates which are converging on each other in an approximately NE–SW direction (e.g. Isacks et al., 1968; Le-Pichon, 1968; Valdiya, 1973). The crustal shortening that is brought about by this collision is considered to be chiefly by way of the underthrusting of the Indian plate below the Eurasian plate (e.g. Valdiya, 1973, Molnar et al., 1973). The surface mapping of the great thrusts and folds along the Himalyan chain as well as the alignment of the seismic zone parallel to it are features upon which the above conclusions are based. These are further supported by a large number of earthquake fault plane solutions pertaining to the Himalayan region (Fitch, 1970, 1972; Molnar et al., 1973; Rastogi et al., 1973). However a number of geological studies have also shown that in addition to the thrusting process, a number of pre-Himalayan lineaments trending in the NE-SW direction are still perhaps tectonically active (Valdiya, 1973; Krishnaswamy et al., 1970; Mithal, 1968). Several earthquakes fault plane investigations have led to the same conclusion (Khattri et al., 1974; Ichikawa et al., 1972) and the present earthquake is yet another evidence of this activity. The inference to be drawn is that the entire process of earth strain release in Himalayas is rendered extremely complex by the interaction of pre-Himalayan lineaments with the stress fields along the Himalayan plate boundary. The generalized conclusions drawn from regional studies can not provide enough data to help understand the problems of a local area such as the Bhakra[1]. In order to be able to reconstruct the stress pattern in an area, it will be necessary to study a large number of tremors.

ACKNOWLEDGEMENTS

We are grateful to Shrimati Amita Sinvhal and Shri Rakesh Mithal for their help in the preparation of this paper. The authors had valuable discussions on the subject with Prof. R. S. Mithal, Dr. A. K. Jain and Shri S. Singh.

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[1] Where civil projects are planned.