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Geological Interpretation of Earthquakes Data of Zindapir Anticlinorium, Sulaiman Foldbelt, Pakistan

Muhammad Iqbal[1] and Dietrich Helmcke[2]

ABSTRACT

The present study is focused on the distribution of earthquakes occurred in the area of Zindapir Anticlinorium and its relationship with the basement of the Indo-Pakistan Plate. Such information regarding the involvement of basement in structural deformation is crucial for understanding the tectonics of an area.

Review of the published data shows that in the area of the Zindapir Anticlinorium, the basement of the Indo-Pakistan Plate occurs at a depth of 10 km, whereas the current study, based on occurrence of earthquakes between 1966-1994 reveals concentration of high magnitude earthquakes at a depth of more than 30 kilometers. It suggests that the basement of the Indo-Pakistan is involved in structural deformation of Zindapir Anticlinorium and its surroundings.

INTRODUCTION

The Sulaiman Foldbelt, a north-south trending mountain chain is situated in the middle of the country with three fold physiographic division; namely the Sulaiman Foldbelt in the west, the Indus Foredeep in the middle and Punjab Platform in the east (Figure 1). The Sulaiman Foldbelt consists of shale, limestone, and sandstone strata of Mesozoic and younger age. Zindapir Anticlinorium is an integral part of the Sulaiman Foldbelt. It is marked by low altitude rocks, which are built up of Paleocene through Plio-Pleistocene marine sediments of the Indo-Pakistan Plate and is overlying by thick Siwalik. Alluvial deposits brought by Indus River and its tributaries cover the Indus Foredeep and the adjoining west dipping Punjab Platform.

Field observations indicate that the structures style of Zindapir Anticlinorium is characterized by high angle faults. These faults are generally north-south trending. Additionally at places en-echelon features and splay faults, which truncate the regional fault obliquely are noticeable.

Based on interpretation of earthquakes data supplemented with the field observations it is considered that basement of the Indo-Pakistan Plate in the region of the Zindapir Anticlinorium is involved in the structural deformation of the region.

1 Hydrocarbon Development Institute of Pakistan, Islamabad.
2 Photogeology and Remote Sensing Department, Institute of Geology and Dynamics of the Lithosphere (IGDL), George August University Gottingen, FR of Germany.

PREVIOUS WORK

The previous work focused on the tectonic aspects of the Sulaiman Foldbelt is discussed below.

Hunting Survey Corporation (HSC, 1961) with the help of aerial photographs carried the first comprehensive and integrated geological investigation in the region, providing foundations for the stratigraphic and structural geological framework.

Abdel - Gawad (1971) suggests that the change in structural style within the Balochistan Arc is dominated by a system of high angle wrench faults, trend north northeast-south southwest, parallel to the Kirthar and Sulaiman ranges, which he named the Kirthar and Sulaiman Wrench Zone.

Hemphill and Kidwai (1973) mapped Bannu and Dera Ismail Khan area in the northern pocket of the Sulaiman Foldbelt and recognized strike-slip and thrust faults.

Rowlands (1978) interpreting the LANDSAT images of the region with special reference to the area surrounding the Kingri Fault, south- west of the Zindapir Anticlinorium, suggests that the major structures of Balochistan Arc are large scale left-lateral strike-slip faults with concomitant thrust faulting associated with the collision of the Indian and Eurasian plates.

Niamatullah et al., (1989) working around Gogai village about 100 km in northwest of Duki, Balochistan, propose the emplacement of nappe structures during Middle Eocene to Early Oligocene time. They suggest that stratigraphic sequences comprising Triassic and younger strata thrust upon Ghazij Shale and subsequently folded during Plio-Pliestocene time forming duplex structures.

Banks and Warburton (1986) presented thin–skinned tectonics (Passive- Roof Duplex) model responsible for structural deformation in the Kirthar and Sulaiman foldbelts. This concept became very popular among petroleum geologists till 2000 when one of the authors himself negated their previous model of Passive-Roof Duplex-1986.

Humayon et al. (1991), Jadoon et al. (1994), conducted structural interpretation of the eastern & central Sulaiman Foldbelt, respectively based on surface geology and seismic analysis. According to the mentioned researchers the sedimentary strata detached from the basement with a floor thrust in Paleozoic strata (duplex sequence occurs in Jurassic and older strata) and roof-thrust (upper detachment) in Cretaceous (Sembar Formation) except in the frontal part of the Sulaiman Foldbelt where it occurs in Eocene sequences.

Bannert et al., (1989), Bannert and Raza (1992), Bannert et al; (1992, 1995), Bender and Raza (1995), suggest that the oblique collision of the Eurasian and Indo-Pakistan plates caused the development of large scale; N-S running,

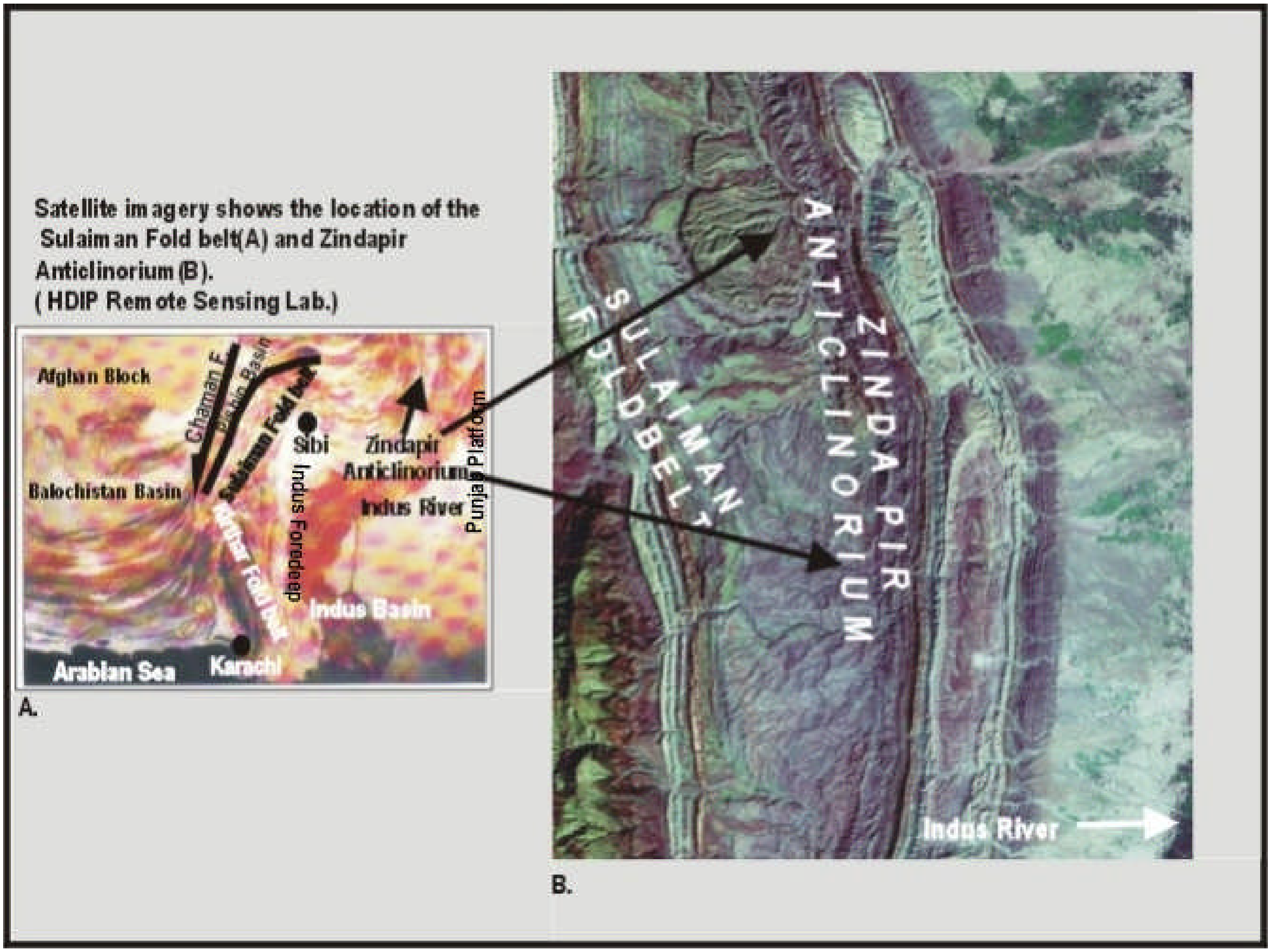

Figure 1- Satellite image showing the Western Foldbelt and Zindapir Anticlinorium.

left-lateral strike-slip faults in the basement beneath the present day re-entrants which are responsible for the segmentation of the Indo-Pakistan Plate.

Coward (1994) discussed two possible models; thin-skinned and inversion tectonics, for the structural deformation of the Sulaiman foldbelt. The author realizes the spectacular role of the inversion tectonics (thick-skinned tectonic). According to the mentioned author the uplift within the foldbelt from a regional is generated by reversal of deep-seated, steep, originally extensional faults that have been reactivated and thrust and involved basement

Ali et al. (1995) suggest that the Sulaiman Foldbelt is deformed as a result of wrench tectonics.

Iqbal and Ali (1996 unpublished reports) and Iqbal and Helmcke (1997), consider that Zindapir Anticlinorium is developed as Positive Flower Structure due to left-lateral strike-slip movement.

EARTHQUAKES DISTRIBUTION AND INTERPRETATION

American Council of National Seismic System (ACNSS) offers the worldwide CNSS Earthquake Catalogue of raw data for earthquakes distribution along with depth and magnitude. The earthquakes data (1964-1996) for the area between N 29^{o}.00 to 32^{o}.00 and E 69^{o}.00 to 71^{o}.00 (Zindapir and surroundings) is presented in table 1. This is the area roughly lying on topographic sheets 39 I, J and K in scale 1:250,000 of Survey of Pakistan. The said data is geologically interpreted in this paper.

Based on the seismic interpretation of Humayon et al., (1991, Fig.10), the basement in the region of Zindapir Anticlinorium occurs at a depth of about 10 kilometers (Figure 2). The mentioned contribution of Humayon et al., (1991) is helping hint for structural understanding of the area.

Table 1. Raw data of recent earthquakes of Zindapir area from CNSS Earthquake Catalogue (only bold-marked data are plotted in figures 3 and 4).

S.No.	Date	Time	Latitude	Longitude	Depth (Km)	Magnitude
1.	**07.02.1966**	**06:57:01.40**	**30° 06′**	**70°12′”**	**24.00**	**4.80**
2.	**07.02.1966**	**07:28:19.00**	**30°18′**	**70 0′**	**43.00**	**4.70**
3.	**07.02.1966**	**08:38:10.50**	**30°06′**	**70°0′**	**9.00**	**4.70**
4.	**08.02.1966**	**05:53:05.20**	**30°12′**	**70°06′**	**6.00**	**5.10**
5.	**04.03.1966**	**06:01:01.00**	**30°06′**	**70°0′**	**3.00**	**5.00**
6.	**25.04.1966**	**18:11:56.60**	**30°06′**	**70°0′**	**33.00**	**4.70**
7.	**13.05.1966**	**23:12:35.40**	**30°0′**	**70°0′**	**26.00**	**400**
8.	**24.05.1966**	**04:35:24.90**	**30°0′**	**70°0′**	**26.00**	**3.90**
9.	08.12.1966	02:07:07.30	29° 24′	70°0′	31.00	5.10
10.	**25.04.1966**	**07:36:36.20**	**30°49′48”**	**70°19′48”**	**23.00**	**4.90**
11.	10.09.1970	02:42:20.90	29°54′	70°23′24”	20.00	4.90
12.	05.06.1972	11:52:52.70	29°4612′	70°18′36”	27.00	4.80
13.	27.06.1972	06:39:44.40	29°4124”	70°16′12”	12.00	5.50
14.	27.06.1972	10:48:55.60	29°45′	70°16′12”	8.00	5.40
15.	27.10.1980	20:12:12.30	29°12′36”	70°08′24	33.00	5.10
16.	03.11.1980	21:44:03.80	29°15′	70°04′12”	33.00	4.70
17.	04.11.1980	15:35:25.00	29°10′48”	70°04′48”	33.00	4.90
18.	26.12.1982	13:10:15.42	29°41′29”	70°0′36”	3.00	4.60
19.	29.12.1982	15:21:20.95	29°57′36”	70°10′48”	33.00	5.00
20.	12.04.1984	16:14:59.91	29°57′36”	70°15	33.00	4.5
21.	**05.05.1985**	**19:34:59.35**	**30°46′12”**	**70°17′24”**	**33.40**	**5.30**
22.	**06.05.1985**	**03:04:22.71**	**30°53′24”**	**70°16′12”**	**36.60**	**5.60**
23.	**06.05.1985**	**03:27:00.68**	**30°47′24”**	**70°20′24”**	**34.10**	**5.10**
24.	**08.05.1985**	**17:10:41.28**	**30°54′36”**	**70°18′36”**	**33.00**	**5.40**
25.	**10.05.1985**	**01:56:23.20**	**30°52′48”**	**70°27′36”**	**33.00**	**4.40**
26.	**19.01.1986**	**14:45:47.27**	**30°48′36”**	**70°36′**	**33.00**	**4.90**
27.	28.06.1988	18:47:49.34	5624′	70°55′48”	52.10	4.70
28.	**27.01.1989**	**23:13:13.86**	**30°36′**	**70°16′12”**	**33.00**	**4.70**
29.	16.11.1990	04:18:23.44	29°52′48”	70°34′48”	33.00	4.70
30.	**14.01.1991**	**09:12:40.08**	**30°22′12**	**70°07′48”**	**33.00**	**4.40**
31.	**17.02.1992**	**09:09:05.14**	**30°12′36”**	**70°43′48”**	**33.00**	**4.00**

The earthquakes data is plotted and evaluated at LANDSAT TM-5 image (Figure 3). The depth of the earthquakes and its magnitudes have been plotted in cross section along 30^o latitude for the area of Zindapir Anticline (Figure 4).

Most of the data represent earthquakes deeper than 10 km depth. Whereas as earlier said in Zindapir area 10 km is the approximate depth of basement (Figure 2). Only some hypocenters are located at depth less than 10 km. This is very important information for structural interpretation such as present day deformation is basement involved or deformation above the basement postulated by Humayon et al. (1991) and Jadoon et al. (1994) is, therefore, in question.

The seisomotectonic study conducted by by Verma et al., (1980) suggests that the Sulaiman Range and its eastern foreland are at present mainly affected by strike-slip faulting. Focal plane solution of nearly all earthquakes that were investigated (Figure 5) indicates left-lateral sense of motion and is in good agreement with the northward drift of India.

CONCLUSION

The review of published data shows that the basement occurs approximately at a depth of 10 kilometers in the region of the eastern mountain front of the Sulaiman Foldbelt in Pakistan. Whereas the earthquakes distribution data reveals that the majority of high magnitude earthquakes concentrate at a depth range of 30-35 kilometers. Thus, it is evident that the basement is involved in structural deformation of the Zindapir Anticlinorium. It is further vetted by focal plane solution, which seconds that the area is deformed by strike-slip deformation (Verma, 1980).

In the light of the above findings it is concluded that due to deformation in the basement, the pre-existing deep-seated faults have been reactivated and give rise to “Positive Flower Structure”at the surface. The existence of Zindapir Anticlinorium is an evidence of the proposed concept.

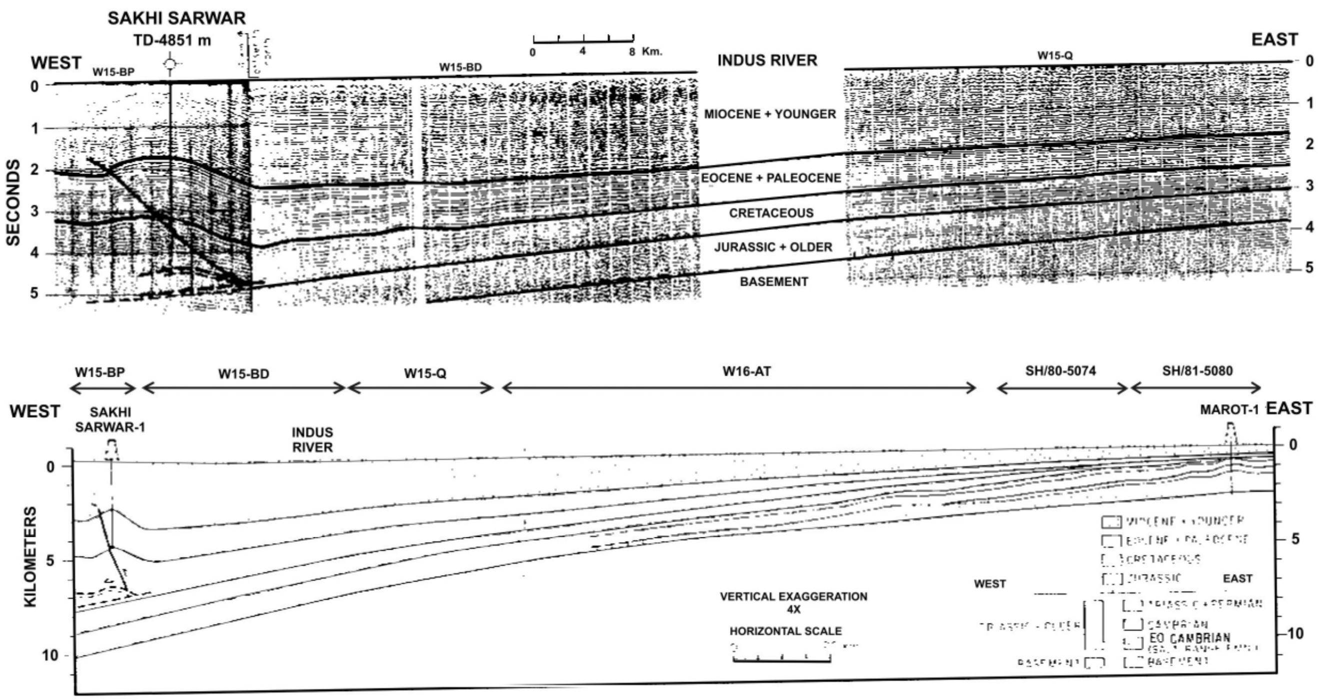

Figure 2- Seismic lines showing the west dipping basement of Indo-Pakistan Plate between the area Punjab Platform in the east and Sulaiman Foldbelt (Sakhi Sarwar-1) in the west (after Humayon et al., 1991).

This is worth consideration finding from tectonic point of view and Exploration Geologists may look into their strategic exploration planning.

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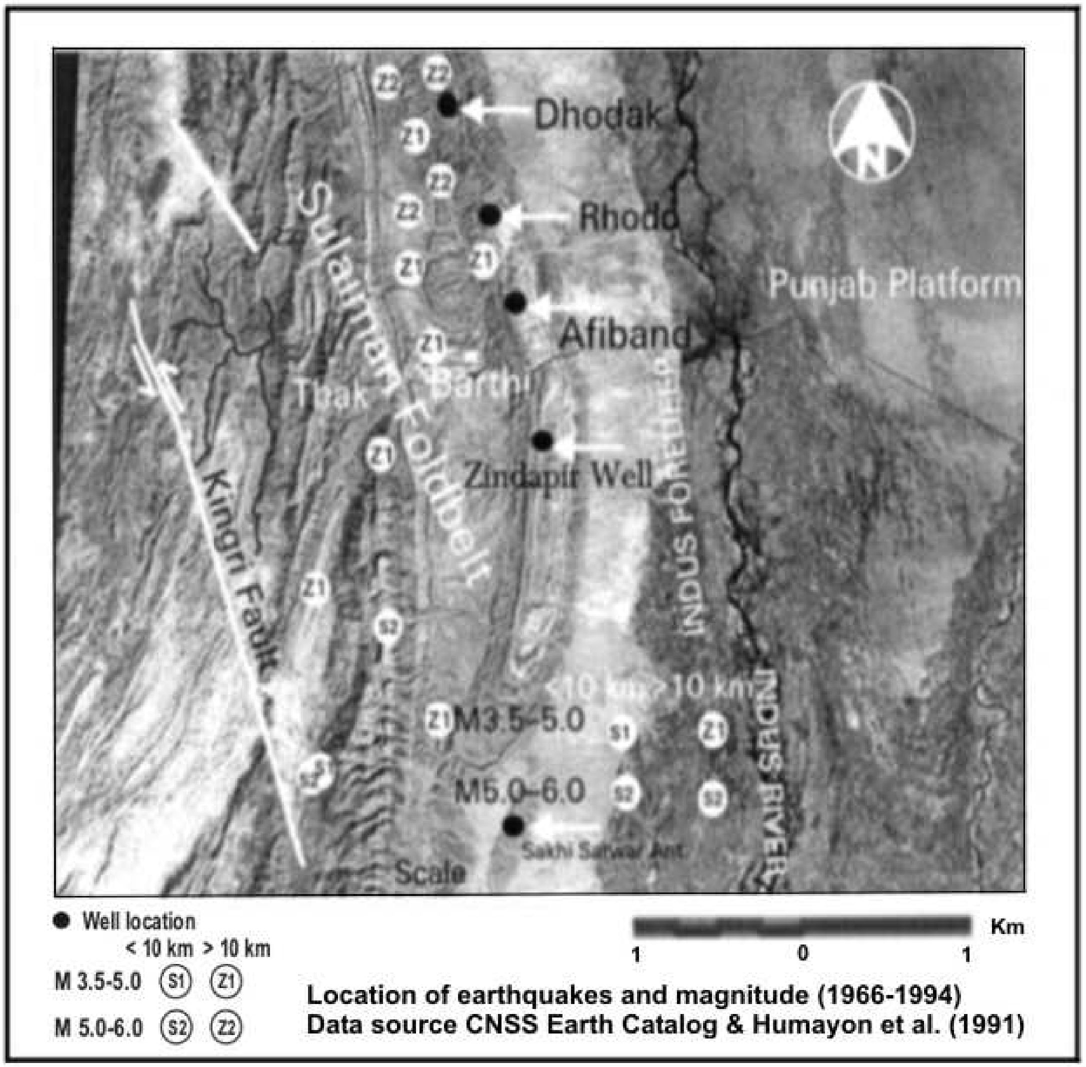

Figure 3- Shows the distribution of earthquakes and its magnitude (after Iqbal & Helmcke,1997-unpublished data).

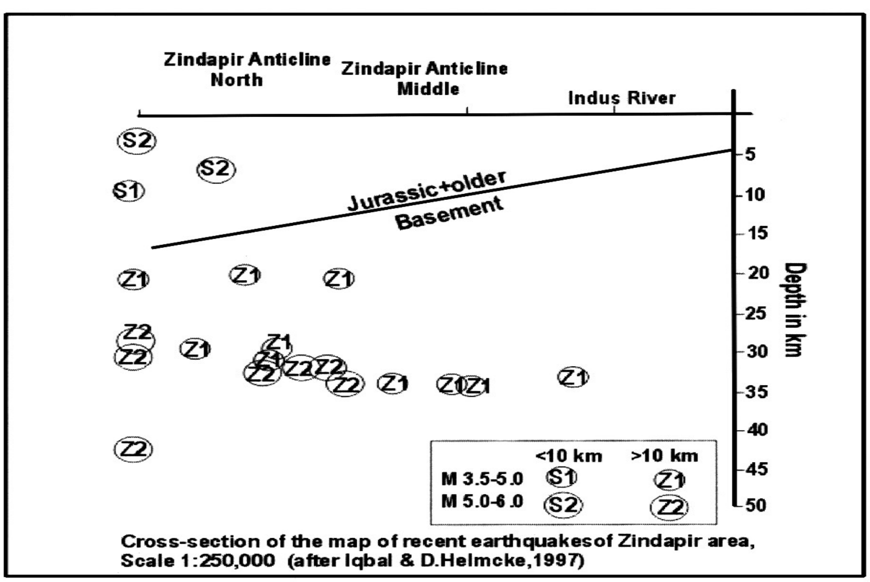

Figure 4- Plotting of the distribution of earthquakes, its magnitude and depth in the region of Zindapir Anticlinorium.

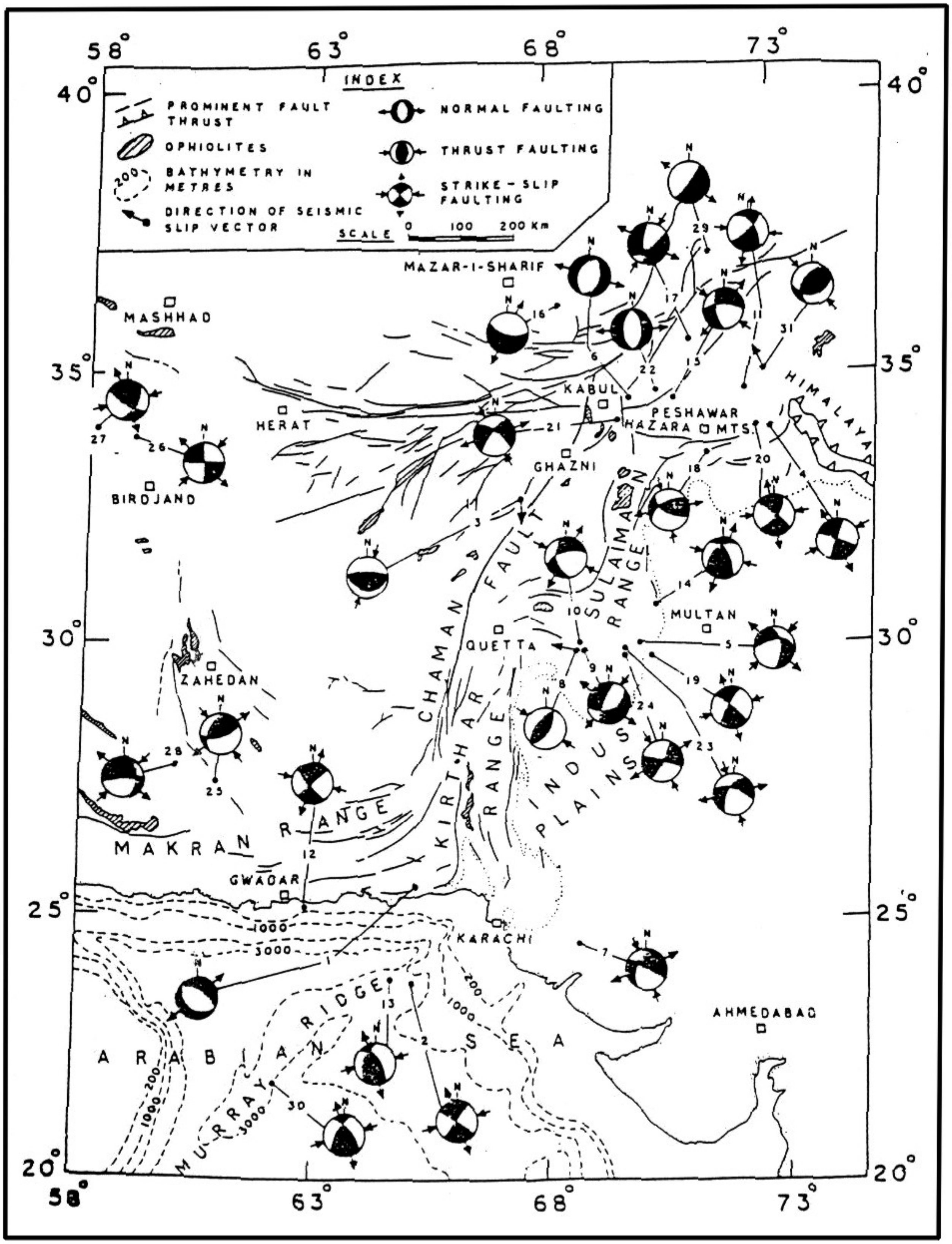

Figure 5: Schematic orientation of nodal planes of earthquakes at Pakistan (Verama et al., 1980). The nodal planes at Zindapir point to earthquakes, which belong to strike-slip faulting.

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