Pakistan Journal of Hydrocarbon Research
Vol.12, (January 2001). p.73-80, 6 Figs.

Correlation of Structural Lineaments with Oil Discoveries in Potwar Sub-Basin, Pakistan

Muhammad Iqbal[1] and S. Manshoor Ali[1]

ABSTRACT

The Potwar sub-basin is located in the foothills of western Himalayas. It is developed as a result of continent to continent collision between the Indian and Eurasian plates. This sub-basin is one of the major oil and gas producing-region of the country. Clastics of Cambrian, Permian, Jurassic, Paleocene, and carbonates of Permian, Paleocene, and Eocene are producing reservoirs. Fractured Eocene carbonate reservoirs (Sakesar & Chorgali) are the main producing horizons in the region. Shale of infra-Cambrian-Cambrian, and Paleocene are the main source rocks in the area.

Interpretation of satellite data for lineament analysis coupled with stress models indicate that 63% of oil and gas fields fall along and 37% within 2-5 km radius of extensional lineaments and their corresponding open fractured zones developed due to various stress regimes. It is therefore suggested that exploration for hydrocarbon may be targeted in the strike extension of the mentioned lineaments in areas where optimum conditions for hydrocarbon generation exist.

INTRODUCTION

The Potwar sub-basin is a part of the foreland fold and thrust belt located at the northern rim of Indian Plate in the foothills of western Himalayas in Pakistan.

It is bounded in the north by Kala Chita-Margala Fault Zone. In the east by left-lateral strike-slip Murree-Jhelum Fault system and in the south by Salt Range Thrust whereas in the west it is bounded by right-lateral Kalabagh strike-slip fault and merges into Kohat Plateau in the northwest (Figure 1).

Merin and Moore (1986) working on the relationship of lineaments and occurrence of hydrocarbon in Denver Basin, Wyoming USA, have established a direct relationship between hydrocarbon occurrence and lineaments.

According to these workers fractured zones are generally associated with lineaments, which serve as pathways for migration and subsequent accumulation of hydrocarbons.

This research paper is an attempt based on similar approach in Potwar sub-basin, Pakistan by interpreting lineaments sets and identifying leads for hydrocarbon exploration.

LANDSAT MSS (black & white) images were analyzed using various geological criteria. The drainage pattern was particularly focused. The lineaments derived from interpretation of the satellite data were studied in conjunction with the developed theoretical stress models to know the relationship between lineaments and discovered oil and gas fields. The findings are quite encouraging.

STRATIGRAPHY

The Potwar sub-basin is filled with more than 9000 m thick sediments of marine clastic and carbonate origin of Precambrian through Eocene and fluviatile deposits of Miocene- Pliestocene age. The thick pile of sediments is deposited in response to various tectonic events through geologic time. These tectonic pulses have also given rise to a number of unconformities. The generalized stratigraphy of the area is given in figure 2.

HYDROCARBON POTENTIAL

The Potwar sub-basin is one of the major hydrocarbon producing province of the country. Multiple reservoirs of carbonate and clastic sediments of Cambrian through Miocene age occur. In total 11 reservoirs are known to be productive.Out of these fractured carbonates of Sakesar and Chorgali units are the major producing reservoirs.

A brief description of these major reservoirs is as follows. The Sakesar limestone is light yellowish-gray, massive and partly dolomite and locally contains chart concretions. In the eastern and central Salt Range the Sakesar limestone is conformably overlain by yellowish-gray, silty reddish, partly dolomitic thin bedded limestone of Chorgali formation (Jurgan et al., 1988).

Shale of infra-Cambrian – Cambrian (Salt Range) and Paleocene (Patala Formation) are the main source rocks in the area.The average geothermal gradient in the region is 2°C/100 m and the depth of oil window occurs in the range of 2500-5000 m (Khan & Raza, 1986).

STRUCTURAL SETTING

The Potwar sub-basin is fault bounded basin.The basin is filled with thick syntectonic molasses sediments derived from the rising Himalayas.

Presently two fold division is envisaged for the Potwar sub-basin. That is the northern Potwar deformed zone (NPDZ) and the platform zone (Figure 1). The NPDZ is lying in south of Kala Chitta Margala Hills. It is structurally complex zone. In this area Tertiary rocks are exposed along a series of south verging thrust faults.

The platform area is mainly covered with thick fluviatile sediments of Siwalik Group (Chinji, Nagri, and Dhok Pathan formations). These sediments have been folded along with underlying marine sediments of Indian Plate as a result of

[1] Hydrocarbon Development Institute of Pakistan, Islamabad.

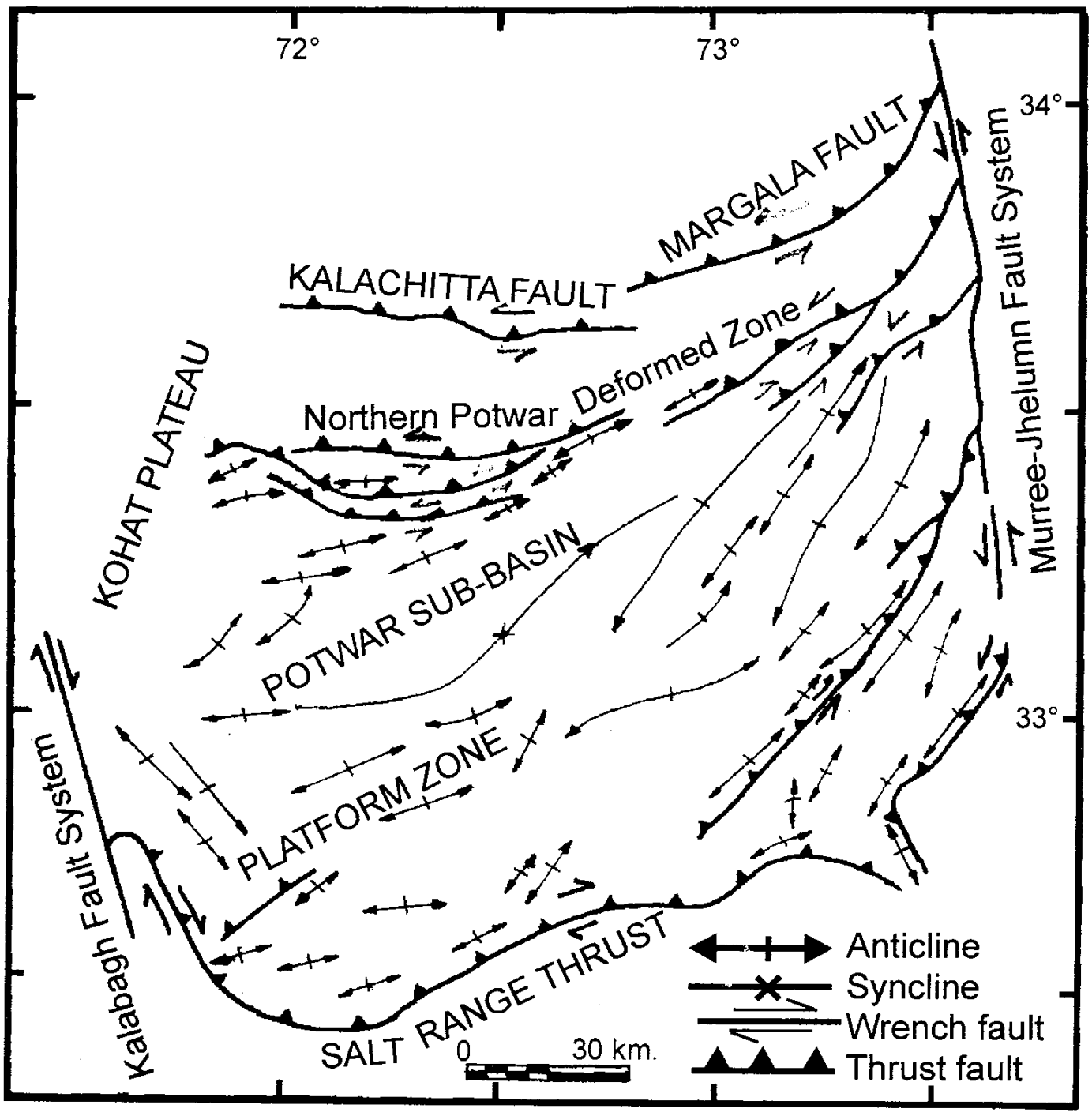

Figure 1- Map showing structural elements in Potwar sub-basin, Pakistan.

the latest Tertiary tectonic movements. The folded structures are generally oriented in sub-latitudinal fashion (Khan et al., 1986). The extreme eastern, southern, and northern parts of the basin are intensely deformed, but towards west through its central part the intensity of deformation is diminishing. The platform area in the south merges into Salt Range uplift.

According to our interpretation the present structural pattern in the Potwar sub-basin is the response of left and right-lateral strike-slip movements initiated during Late Tertiary time along Murree- Jhelum and Kalabagh fault systems in the east and west, respectively.

The structural elements developed due to left-lateral strike slip movement along Murree- Jhelum fault system are the east-west to northeast-southwest oriented thrust faults and associated left- lateral en-echelon folds while the structural elements developed in response to right- lateral Kalabagh strike- slip fault system are the northwest and east-west oriented right- lateral en-echelon folds and east west trending Salt Range thrust (Figure 1). Some of the thrusts of Murree –Jhelum fault system, which are visible on surface in the northeast, probably extend in the subsurface forwards the central part of the sub-basin.

APPLICATION OF SATELLITE DATA AS AN AID TO HYDROCARBON EXPLORATION IN POTWAR SUB-BASIN

The study is based on analogous exercise undertaken in Denver basin, Wyoming USA by Merin and Moore (1986). Their interpretation reveals that the lineaments which have extensional regimes served as pathways for hydrocarbon migration and storage in carbonate reservoirs of Niobrara Formation of Late Cretaceous age.

O' Leary et al., 1976 defined lineament as a map-able, simple or composite linear feature of the earth surface, whose parts are aligned in rectilinear or slightly curvilinear relationship and which differs distinctly from patterns of adjacent features and which presumably reflects subsurface phenomena. It has long been recognized that lineaments on the surface of the earth are the expression of the zones of weakness, fracturing, and structural displacement

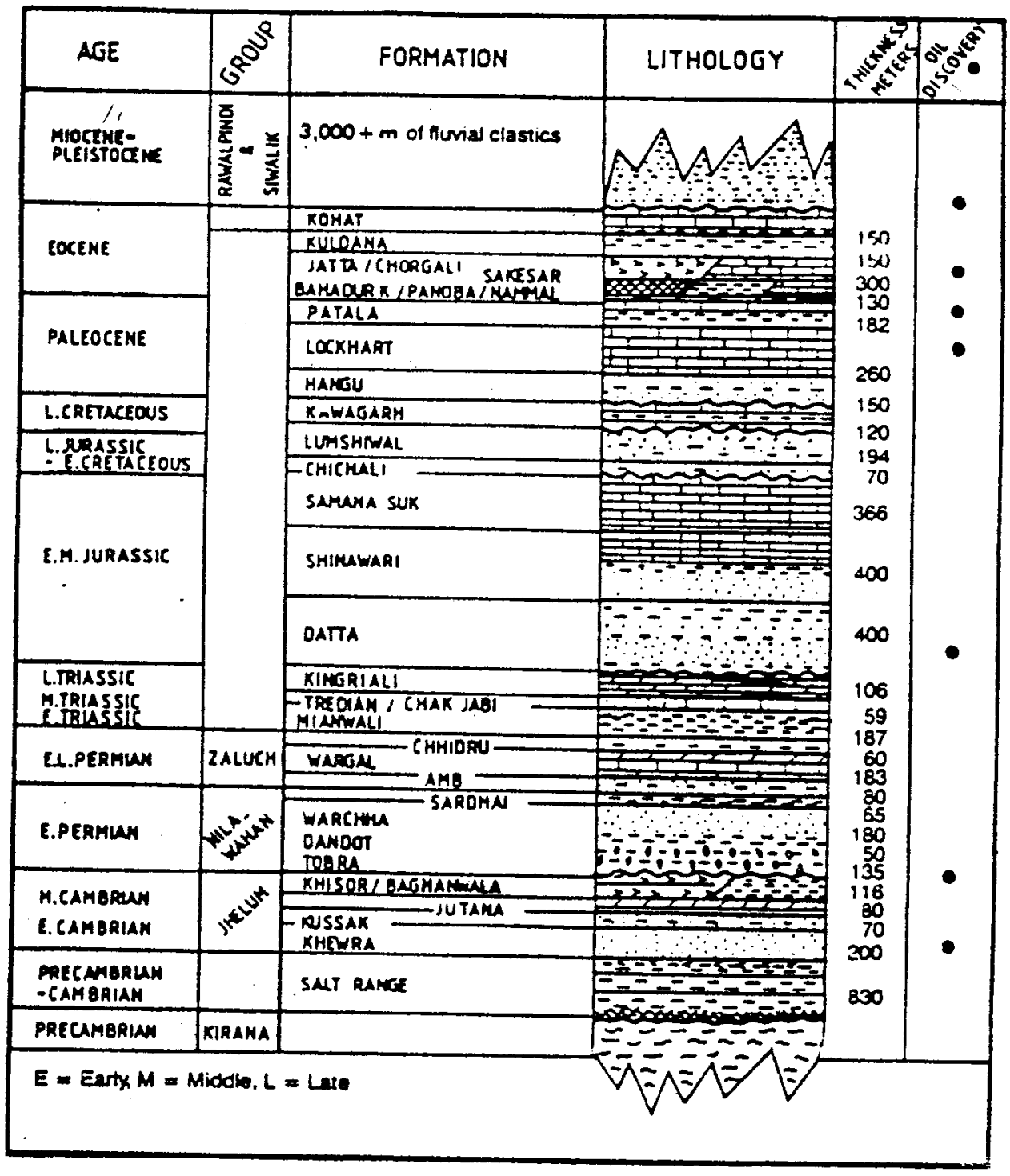

Figure 2- Generalized lithostratigraphic coloumn of Kohat-Potwar depression. (After Khan et al., 1986).

brought by tectonic activities in the earth crust. Thus it reveals the hidden architecture of the basement rocks with its reflection in the sedimentary cover (Numan & Bakose 1997).

Interpretation of images and aerial photographs for lineament study is very interesting exercise. Lineaments can be derived from any image as change in relief or tone along straight, curved or even circular lines. In the Potwar sub-basin, lineaments have been inferred from linear arrangements of streams (drainage), and linear offset of trends and regional trends.

As earlier mentioned that Eocene carbonate rocks are the main reservoirs in the area. These rocks despite poor primary porosity are producing hydrocarbon commercially. Which is due to fracture controlled secondary porosity. Since lineament pattern directly corresponds to fractured patterns in the subsurface. Therefore, the potential of Eocene reservoirs in various parts of the sub basin is assessed through the following approach.

1: to determine whether the oil and gas fields are associated with lineaments and corresponding fractures, if so,

2: to determine the lateral extent of those lineaments, along which the fractured zones may serve as potential reservoirs.

The study indicates that during Late Tertiary time the principal horizontal stress (PHS) which is responsible for the development of lineaments was generated from two different directions; as

1: North- South
2: Southeast- Northwest

North-South directed PHS which is the result of compression due to left-lateral strike-slip movement along Murree-Jhelum fault system has created various sets of northeast and northwest trending lineaments, more prominent in the eastern part of the study area (Figure 3).

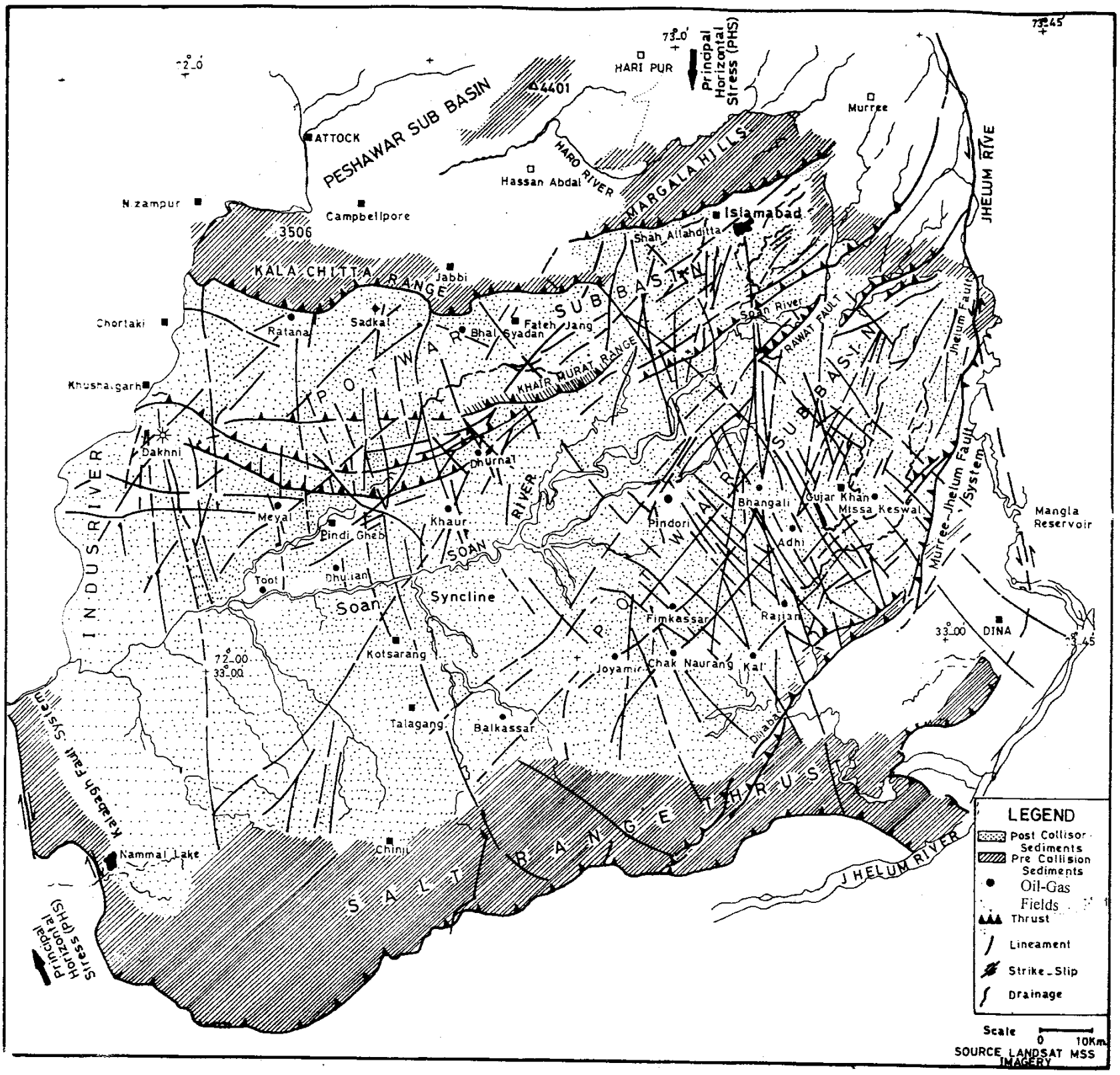

Figure 3- Alignment of oil/gas fields with lineaments and stress regimes in Potwar sub-basin, Pakistan.

Our stress model (Figure 4) shows that as a result of north to south directed PHS, a thrust regime with right-lateral strike-slip component is developed in the northwest oriented lineaments while a left-lateral strike-slip regime is created in the northeast oriented lineaments (Figure 4a).

On the other hand southeast to northwest directed PHS which is the result of compression due to right-lateral strike-slip movement along Kalabagh fault system has created numerous sets of north south and east west oriented lineaments which are more pronounced in the western part of the Potwar sub-basin (Figure 3).

According to stress model (Figure 5) an east-west trending thrust regime with right-lateral strike-slip component and north- south oriented left-lateral strike-slip

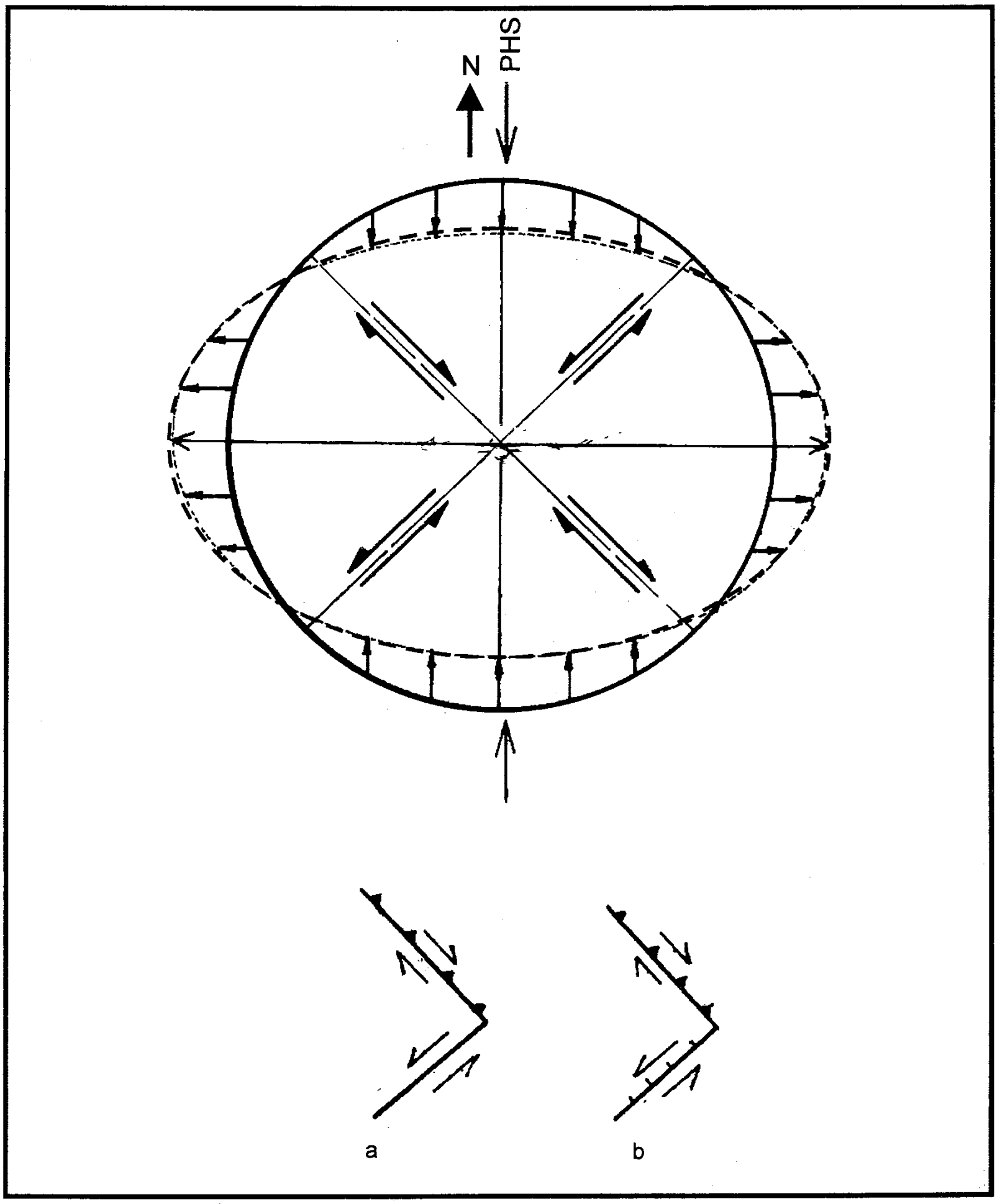

Figure 4- Stress model showing:
a) Theoretical motion in response of north to south directed principal horizontal stress
b) Theoretical motion subject to westward rotation of the principal horizontal stress.

regime is created in response to southeast- northwest directed PHS (Figure 5a).

According to our interpretation both principal stress regimes were subsequently rotated towards west, thus creating extensional features in the northeast- southwest and north- south oriented lineaments and their corresponding fracture zone (Figures 4b&5b). These extensional features, according to our interpretation, served as pathways for migration and accumulation of hydrocarbon in the Eocene reservoirs of the Potwar sub-basin.

The study indicates that out of nineteen oil and gas fields (47% of the total fields, namely Dhurnal, Khaur, Joyamir, Fimkassar, Bhangali, Chak Naurang, Adhi, Missa Kiswal, and Kal fall on northeast- southwest oriented extensional

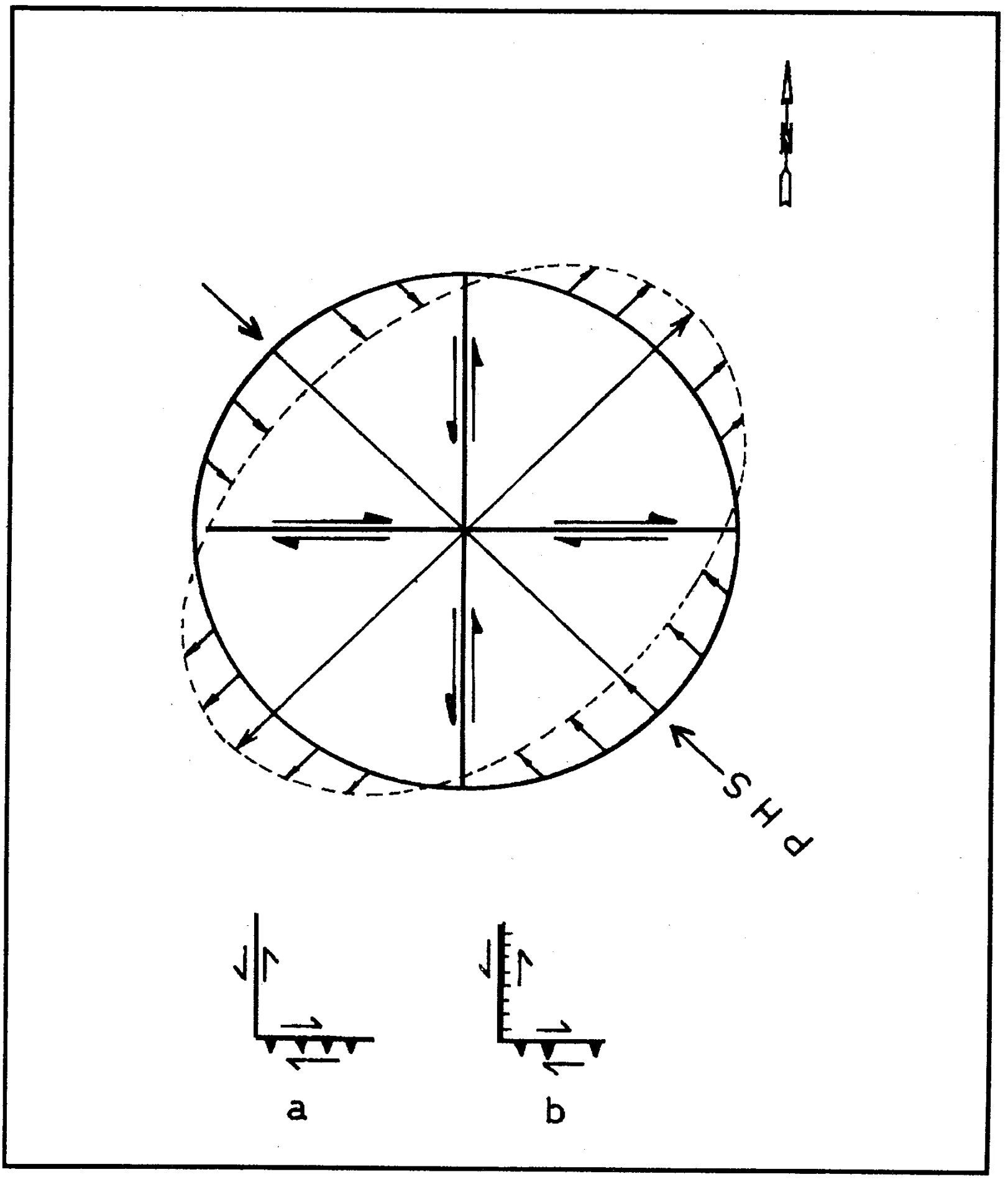

Figure 5- Stress model showing:
a) Theoretical motion in response of southeast to northwest directed principal horizontal stress,
b) Theoretical motion subject to westward rotation of the principal horizontal stress.

lineaments. Whereas Balkassar, Pindori, Rajian, and Bhal Sydan (21% of the total fields) are within 3-5 km radius of the lineaments. This means that 68% of the total fields are associated with northeast-southwest oriented lineaments (Figure 3).

In the western part of Potwar sub- basin Meyal, Dhakni, Ratana (16% of the total fields) fall on the north- south extensional lineaments whereas Toot, Dhulian, and Sadkal (16 % of the total fields) lie within 2-5 km radius of the lineaments. Thus 63 % of the fields fall on northeast-southwest and north- south extensional lineaments and 37 % within 2-5 km radius.

In Denver Basin, 69 % of producing fields are located along northeast-southwest trending extensional lineaments (Figure 6). This figure closely corresponds to our statistics in Potwar sub-basin where 63 % of the total fields fall on northeast- southwest and north- south oriented extensional lineaments.

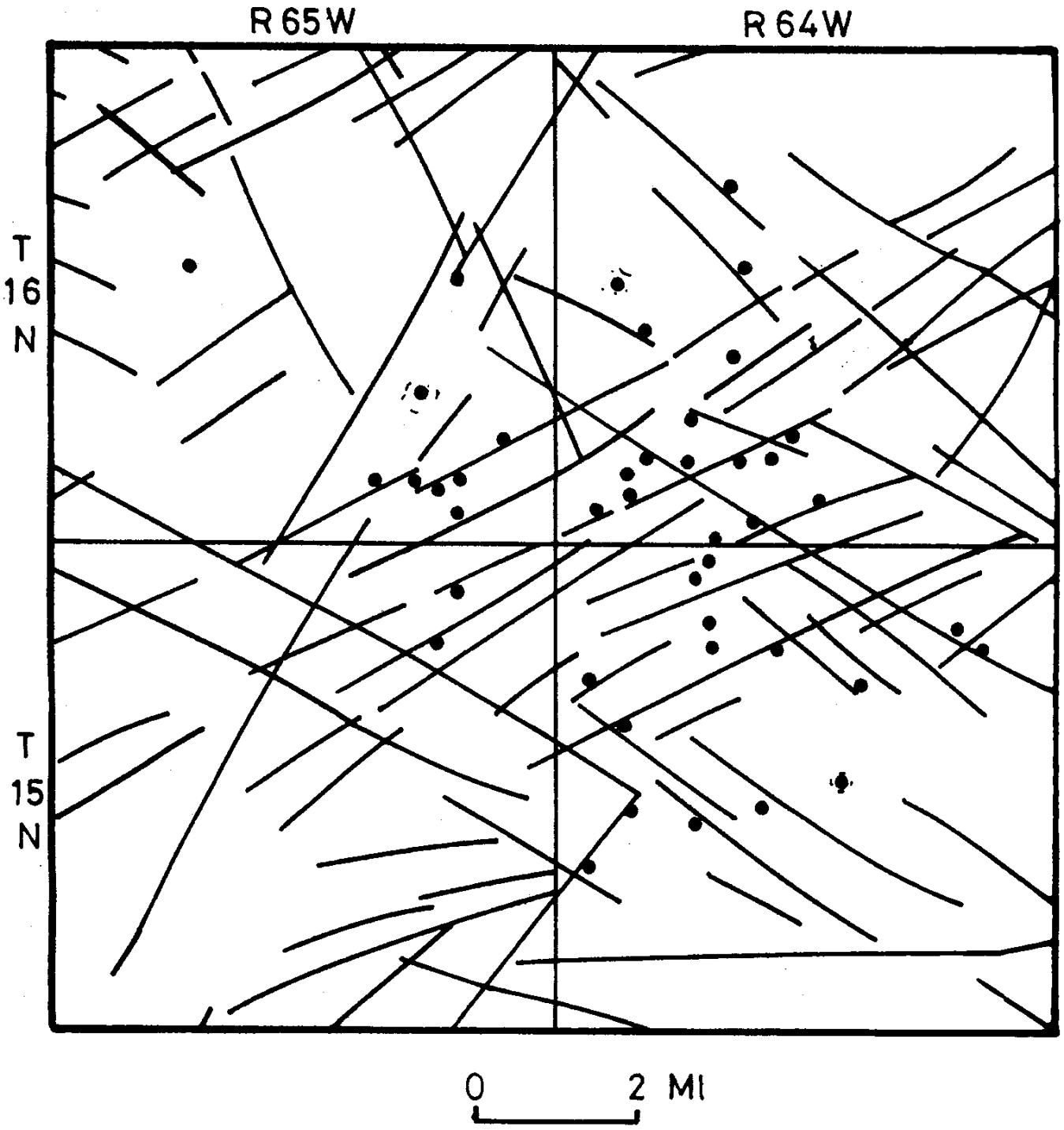

Figure 6- Distribution of lineaments and oil wells in Silo field area. Laramie County, Wyoming. (After Merin and Moor, 1986).

CONCLUSION

Based on interpretation of satellite data and structural analysis of stress models it is concluded that in Potwar sub-basin:

1. The producing Eocene carbonate reservoirs are fed through fractures associated with northeast-southwest and north- south oriented extensional lineaments.

2. The future exploration , therefore may be targeted in the strike extension of these lineaments particularly in the area where optimum conditions for hydrocarbon generation exist.

REFERENCES

Jurgan, H., G. Abbas and M. Mujtaba, 1988, Depositional environments and porosity development in Lower Eocene Limestone formations of the Surghar Range, Salt Range, and Potwar Basin, Pakistan: HDIP-BGR internal report.

Khan, A.M. and H.A. Raza, 1986, The role of geothermal gradients in hydrocarbon exploration in Pakistan: Journal of Petroleum Geology, v.9, no.3, p.245-258.

___, R.Ahmed, H.A. Raza and A. Kamal, 1986, Geology of Petroleum in Kohat Potwar Depression, Pakistan: AAPG Bull., v.70, no.4, p.396-414.

Merin, I. S. and W.R. Moor, 1986, Application of landsat imagery to oil exploration in Niobrara Formation, Denver Basin, Wyoming: AAPG., v.70, no.4, p.351-359.

Numan Nazar M.S. George and B. Bakose, 1997, Lineaments: questions on the vercity of their relationships in the western and southern deserts of Iraq in ITC Journal, 1997-1, p.41-47.

O' Leary, D.W., J.D. Friedman and H.A. Pohn, 1976, Lineaments, Linear, Lineation: Some proposed new standards for old terms: Geological Society of America Bulletin, 87, p.1463-1469.