e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
Volume:03/Issue:06/June-2021 Impact Factor- 5.354 www.irjmets.com

STRUCTURE ANALYSIS OF NAR ANTICLINE, DISTRICT KOTLI, AZAD JAMMU AND KASHMIR, PAKISTAN

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ABSTRACT

The integration of structural geological data with the stratigraphy of Kotli area to look into the geometrical analysis in sub-Himalayas, Pakistan. Precambrian to recent rock sequence are present in a deformed state in the area due to Himalayan orogeny. Deformation is the result of the northeast to southwest Himalayan forces, induced different structures in folds and faults. Nar anticline, Gulpur syncline, Khuiratta anticline and Rajdhani syncline are the main fold, whereas Bajwal thrust, Kajlani, and Panjan Fault are the main faults in the area. Folds are open to gentle in nature, northeast or southwest verging and northwest or southeast plunging. The Nar anticline is doubly plunging anticline, contain Chinji Formation and Nagri Formation in the core and Dhok Pathan Formation lies laterally at hinges. Chinji Formation exposed on the surface as Dhok Pathan Formation, and Nagri Formation eroded from the crust to form erosional inlier. The sandstone of Nagri Formation from Nar anticline can act as a source rock. The area provides a good understanding of petroleum prospect; however, detailed research will be needed to understand the relationship between secondary porosity and permeability of the area.

Keywords: Structural Analysis, Nar Anticline, Doubly Plunging, Petroleum Prospect, Thrust Fault.

I. INTRODUCTION

The research area is located in sub-Himalayas, Pakistan. A significant structure is the Hazara Kashmir Syntaxis (HKS) in the north of the study area. The folding of thrust sheets forms the HKS. These thrust sheets are trending northwest in the western limb to the northeast-trending thrusts in the eastern limb. The thrust sheets include Main Boundary Thrust (MBT) and Punjal Thrust (PT), which bend along the HKS (Sana & Nath, 2016). The western limb of the HKS, MBT and Salt Range Thrust (SRT) (Grelund et al., 2002) are displaced by transform fault called Jhelum Fault (JF), parting a sinistral sense of slip. The area is highly deformed due to the Himalayan orogeny (Malkani, 2017).

Stratigraphically, the Kashmir basin is comprised of Precambrian to Recent rocks, as shown in (Malkani & Mahmood 2017). Precambrian Dogra Formation is the oldest Formation in the sub-Himalayas region. The Cambrian Muzaffarabad Formation overlies Dogra Formation and underlies Paleocene to Eocene Formations. Both upper and lower contact of the Muzaffarabad Formation is unconformable. Paleocene to Eocene rocks include Hangu Formation, Patala Formation, Margala Formation, Chorgali Formation and Kuldana Formation. Miocene Murree Formation and Kamlial Formation conformably overlies by Kuldana Formation.

The exposed stratigraphic sequence in Nar, Bratla, Bajwal and Kajlani areas is Miocene rocks of Himalayan molasses. This molasse sequence includes the Rawalpindi Group and Siwalik Group. There is a gap in deposition between Precambrian to Cambrian, Late Cambrian to Permian, Pliocene to Pleistocene and Pleistocene to recent. These depositions are formed in the Kashmir basin, which is characterized by a regional unconformity. Sedimentary nature rocks of cover sequence of Tertiary period preserved well records of Himalayan orogeny and often folded and faulted as a result of this orogenic event. The Nar anticline is a northwest to southeast trending fold located in sub-Himalayas near Kotli city. The development of this anticline is by the bending of Chinji and Nagri Formation as a result of Himalayan orogeny. In the northeast limb of Nar anticline is followed by Gulpur Syncline and southwest followed by Rajdhani syncline. The Bajwal Fault cuts the northeastern limb of Nar Anticline. During folding and faulting by regional and or local tectonics, the rocks experienced fracturing.

1.1. STUDY AREA

The research area is located in District Kotli of Azad Jammu and Kashmir (AJK), Pakistan (Figure 1). This section is about 200 square kilometers along the eastern limb of HKS, approximately 23 kilometers southwest of Kotli city. The area is shown on topographic sheet No. 43G/15 of Geological Survey of Pakistan (GSP) between Latitude 75º 45' 00'' E to 74º 00' 00'' E and Longitude 33º 30' 00'' N to 33º 15' 00'' N (Plate 1.1).

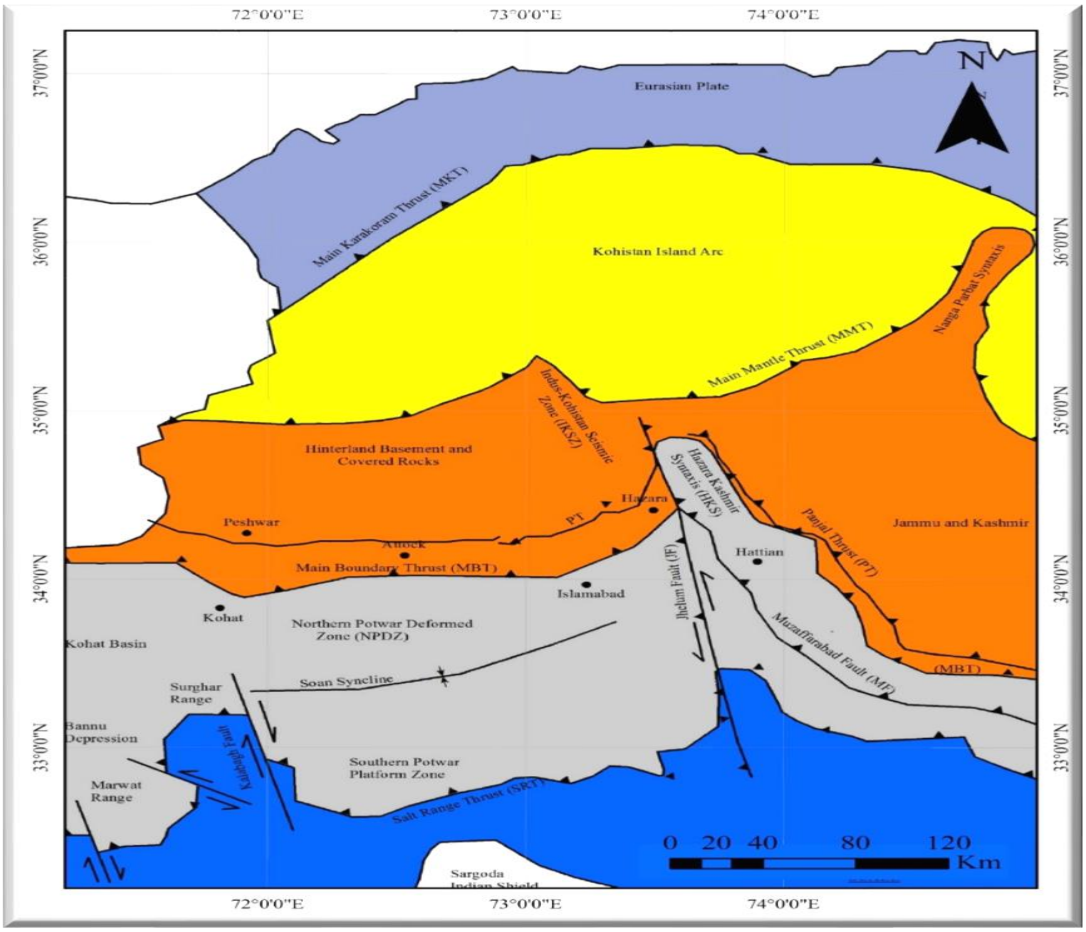

Figure 1: Tectonic map of the study area modified after (Avouac et al., 2006). The study area is marked by square.

1.2. REVIEW OF LITERATURE

Different scholars contribute their effort to understand more clearly the geology of AJK. The earliest geology explained by the pioneer geologist Lydekker (1876, 1883) carried out the geological field to established rock units at Hazara and Kashmir.

Reconnaissance work in the Kotli area has been carried out by Middlemiss (1896). Wadia (1928) describes the geology of Kashmir and the adjacent regions initially. Further, Abid et al., (1983) discussed the geochemical and petrology of sandstone from Siwaliks and drove its relationship with the Himalayan orogeny. Ashraf and Chudrary (1984) study the lower Siwaliks sandstone petrographically, chemically and spectrochemically and established that these rocks' sediments derived from crystalline and sedimentary rocks the north in the Pir Panjal ranges.

Baig and Lawrence (1987) worked on structures in the area and described the sedimentary sequence that is highly deformed due to Himalayan orogeny. Hashmi and Pervez (1993) accomplished reconnaissance to explore base metals in the area of Kotli District. The structural, stratigraphy and petrographic work on some parts of Kotli is done by Ashraf et al. (1983).

Rustam et al. (2003) studied with the help of residual gravity data to investigate the geological structure present in the core of HKS. GSP and Azad Kashmir Mineral and Industrial Development Corporation geological mapping of the area at 1:50,000 scale (Akhtar et al., 2004). Islam (2006) gave structural, stratigraphic and tectonic research data of Kotli and Mirpur area. Shahabaz et al. (2011) has also documented stratigraphy and structural features of District Kotli.

Work done on structural and fractural analysis of sandstone of Nagri Formation on both limbs of Khuiratta Anticline is by Virk (2015). The authors do the analogous nature of efforts of fracture in diverse basins of Pakistan. Jadoon et al (2005) work on fracture analysis of surface and subsurface reservoirs rocks in Kohat and Potwar plateau. The research was done on the effects of mega shear fractures on Loti anticline present in the lobate of Sulaiman Fold and Thrust Belt by Khan et al., (2012).

1.3. OBJECTIVES

The project area is favorable for petroleum exploration. It has all the petroleum paly as compare to sub-Himalaya. However, the specific objective is to understand as follows:

- Update the existing geological map of the research area to understand lithological variation
- To prepare the structural geological map
- Developed cross-section to determine the structural geometry of folds
- To identify different types of faults in the research area
- To prepare the π and β diagram to analyze the folds
- To identify the direction of compressive forces

II. METHODOLOGY

The fieldwork of three months took place to complete the detailed investigation of the study area. The data collected from the field and pre-existing geological maps were organized, analyzed and digitized in different tables, diagrams and maps. Detailed geological fieldwork was carried out to get geological information. The acquired geological data includes information on structures, stratigraphy and complete geological mapping (Plate 1). The structural data consists of the attitudes of the bedding and joint surfaces, which were collected during the field with the help of Brunton compass. Contours of the study area constructed with the help of the Arc GIS tool using 12.5m Digital Elevation Model data. The lithological data collected in the field was utilized in Arc GIS 10.4 software to prepare the geological maps of the Nar anticline. The geological cross-sections constructed across the strike of the fold axis from different locations of the Nar anticline. The attitude of folds was measured and plotted on stereonet through Stereonet software.

Table 1: Stratigraphic sequence of Project area

Formation	Age	Type Locality	General Description
Quaternary Alluviam	Recent	Kotli	Consists of silt, gravel and unconsolidated deposits of clay
.... Unconformity................................			
Dhok Pathan Formation	Late Miocene	Kotli	Gray, fine to medium-grained, medium to thick-bedded sandstone with clay and siltstone, sandstone 50% and clays 50%.
Nagri Formation	Late Miocene	Kotli	Greenish gray to light gray, massive medium to coarse gained sandstone, siltstone and mudstone. The sandstone alternates with clays. It includes 30% clay and 70% sandstone.
Chinji Formation	Middle to Late Miocene	Kotli	Red to purple, greenish-gray, ash gry sandstone and siltstone, purple and reddish-brown mudstone. 60% clays and 40% sandstone.

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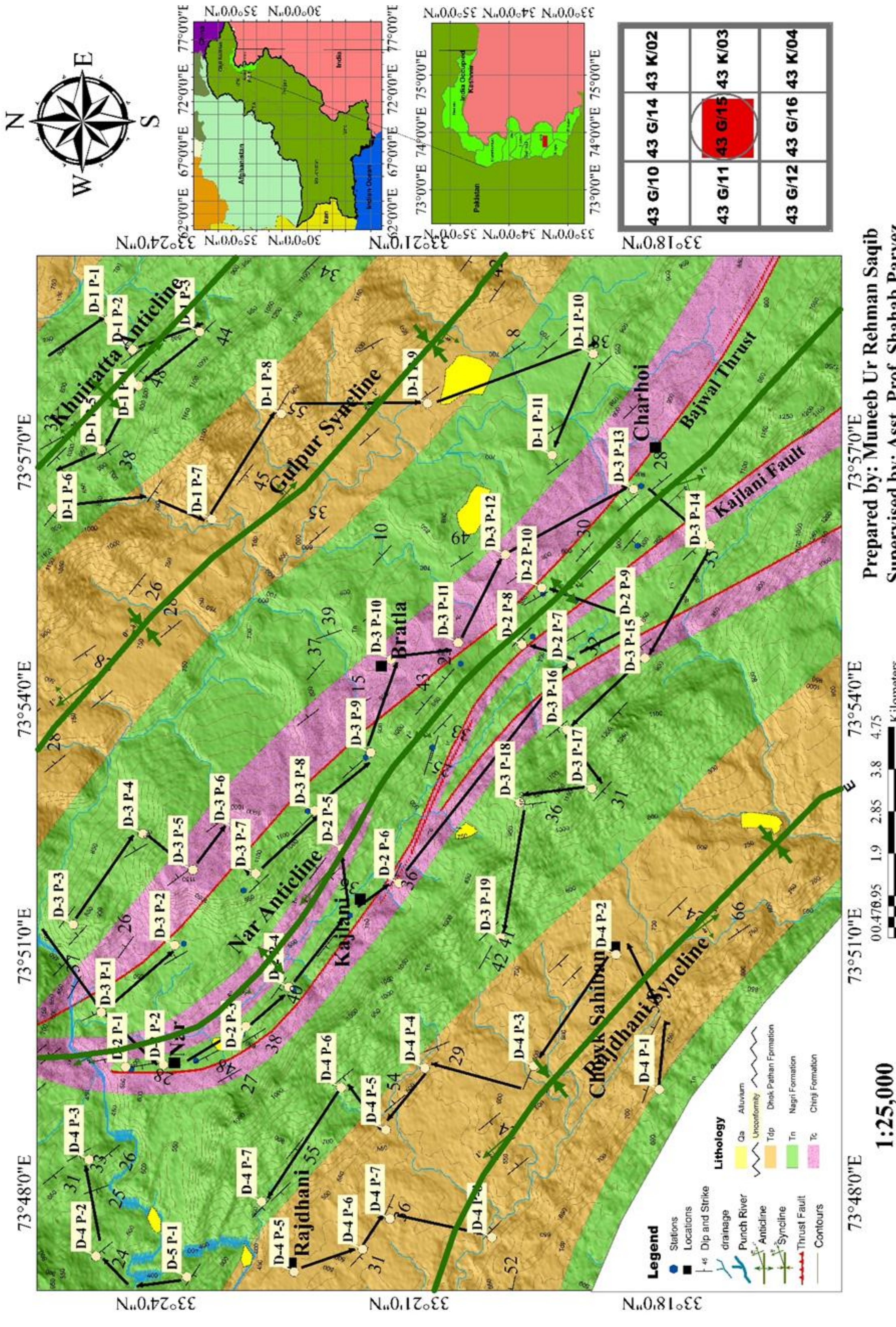

Plate 1: Route traverse map of Nar, Rajdhani- Khuiratta areas, District Kotli, Azad Kashmir, Pakistan

III. STRUCTURAL GEOMETRY

The Project area is located at the margin of the eastern limb of HKS. In the past, as a result of collision Himalayas are formed. In contrast to the above statement, the northward moving Indian plate first collided with Kohistan-Ladakh Arc (KLA) ~ 65 Ma/~50 Ma, and then both KLA and Indian plate collided with the Karakorum block (a part of the Eurasian plate) around ~50 Ma/~40 (Chatterjee et al., 2017& Chatterjee & Bajpai, 2016). Another model shows the northward movement of the Indian plate at a rate of 15-20 cm/yr to the north around 80 Ma and decreases around 52 Ma at a rate of 5 cm/yr. However, there are some controversies regarding the time the events take place. The collision of the Indian plate with the Eurasian plate produced extensive forces. To accommodate these forces, different fold and thrust belts were formed (Davis and Lillie, 1994).

The sedimentary sequence from Precambrian to Cenozoic is multiply deformed (Baig et al., 2010). The strike of folds present in the area is northwest to southeast with a dip either southwest or northeast. The faults are northwest to southeast trending and northeast dipping. However, some faults are the back thrust which dips the southwest.

This section deals with the geometry of the different structures of the project area. Structurally, the project area contains different folds and faults. Folds are Anticlines and synclines. The detailed description of these folds is as follows;

3.1. FOLDS

Folds are the main structures in the project are comprising of anticlines and synclines. These folds are northwest-southeast trending open to gentle in nature. These folds show right step form of pattern from southwest to northeast. The structural data of these folds is represented by stereo-plotting and π-β diagrams (Appendix-1). The major-folds in the project area are Rajdhani-syncline, Nar-anticline, Gulpur-syncline and Khuiratta-anticline.

3.1.1 Nar Anticline

The Nar anticline is a regional-well exposed structure in the study area. The strike of the fold is northwest to southeast. It is well exposed in Kajlani, Bratla and Charhoi areas and extends up to 20 km along the strike (Plate 2; Photo 1).

It is considered that the folding of these strata is due to the impact of solid compressive forces generated from Himalayan orogeny. These forces influence the formation to yield folds. The northeast and southwest limbs of the Nar anticline are faulted. The Bajwal fault cuts the northeastern limb, whereas the southwestern limb is cut by the Kajlani fault (Plate 2, 3, 4 & 5). The strike of the northeastern limb ranges from N26°W to N55°W, whereas the strike of the southwestern limb varies from N18°W to N47°W. The dip of the northeastern limb varies from 28°NE to 43°NE whereas the dip of the southwestern limb ranges from 22°SW to 37°SW (Table 2).

The trend of the anticline varies from 164° to 338° whereas plunge varies from 01° to 03°. It is doubly plunging fold (Plate 2, Figure β1, β2, β3, β4, β5 and β6). The attitude of the axial plane ranges from N22°W/88° SW to N39W/87°SW. The data shows that anticline is open to gentle, northeast verging and northwest or southeast plunging. The maximum-density of fold-axis is 58.3% at 132.0/0.0 and pole to axial-plane is 64.8% at 44.0/0.0 (Table 2; Plate 2; Image 1).

3.1.2 Gulpur Syncline

The Gulpur syncline is located northeast of the Nar anticline (Plate 2). The fold axis of the Gulpur syncline is almost parallel to Nar anticline's fold axis and follows the regional structure (Plate 2). The Dhok Pathan Formation is present in the core, where the Nagri Formation lies on the limbs. The attitude of the southwestern limb is varying from N40°W to N55°W/28°NE to 42°NE. The attitude along the bedding of the northeastern limb ranges from N35°W to N55°W/ 26°SW to 45°SW. The trend and plunge of the syncline varying from 129° to 323°/00° to 02°.

The attitude of the axial plane is N37°W to N55°W/ 85°NE to 89°NE, and the interlimb angle ranges from 105°-120° (Table 2, 3 & 4). The Gulpur syncline is a southeast plunging fold. Based on the interlimb angle, the fold is classified as open to gentle fold. The maximum density of the fold axis is 91.4% at 136.0/0.0 and the pole to the axial plane is 47.2% at 040.0/0.0 (Table 2; Figure 3).

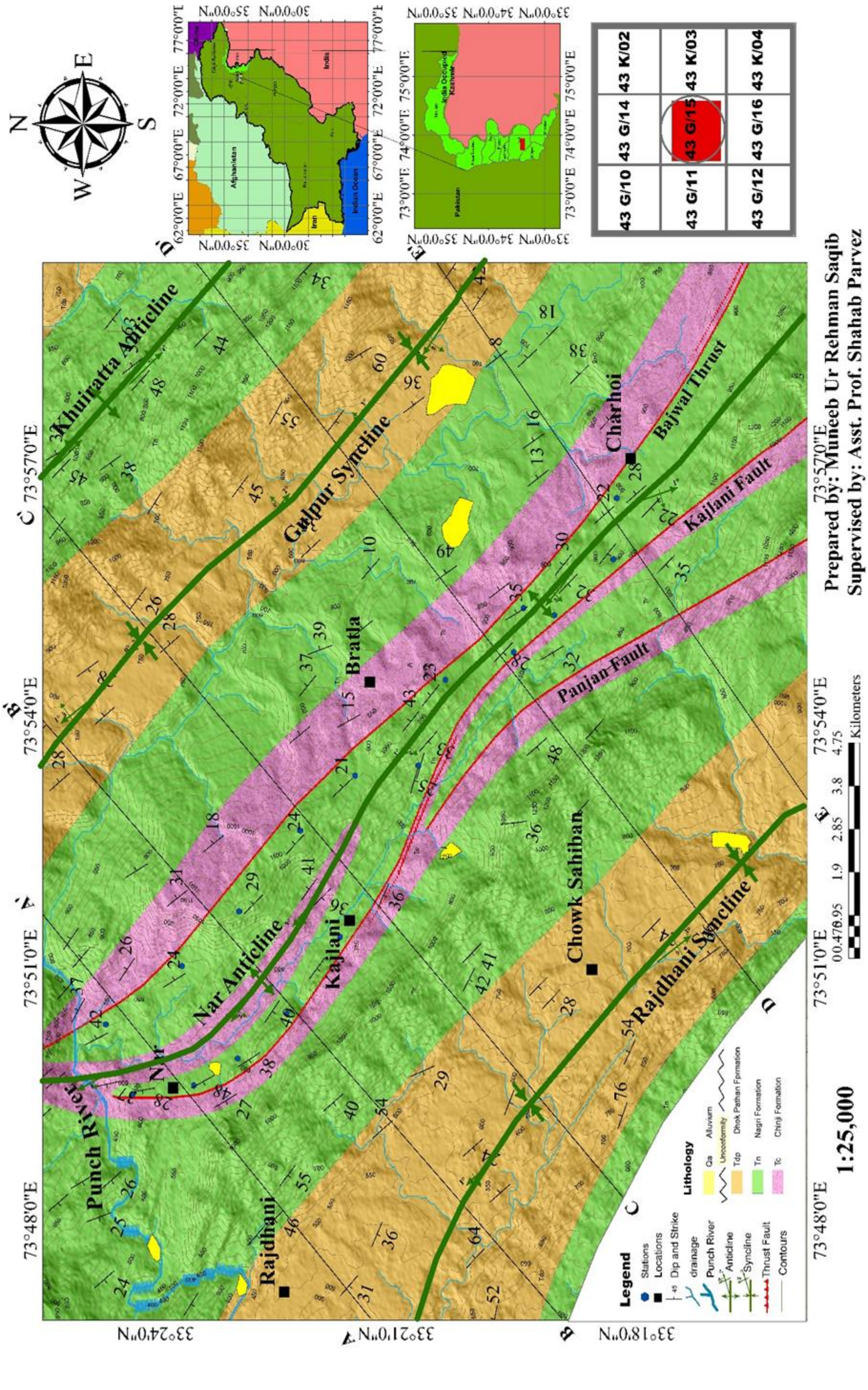

Plate 2: Structural map of Nar Anticline, Nar-Charhoi areas, district Kotli, Azad Kashmir, Pakistan.

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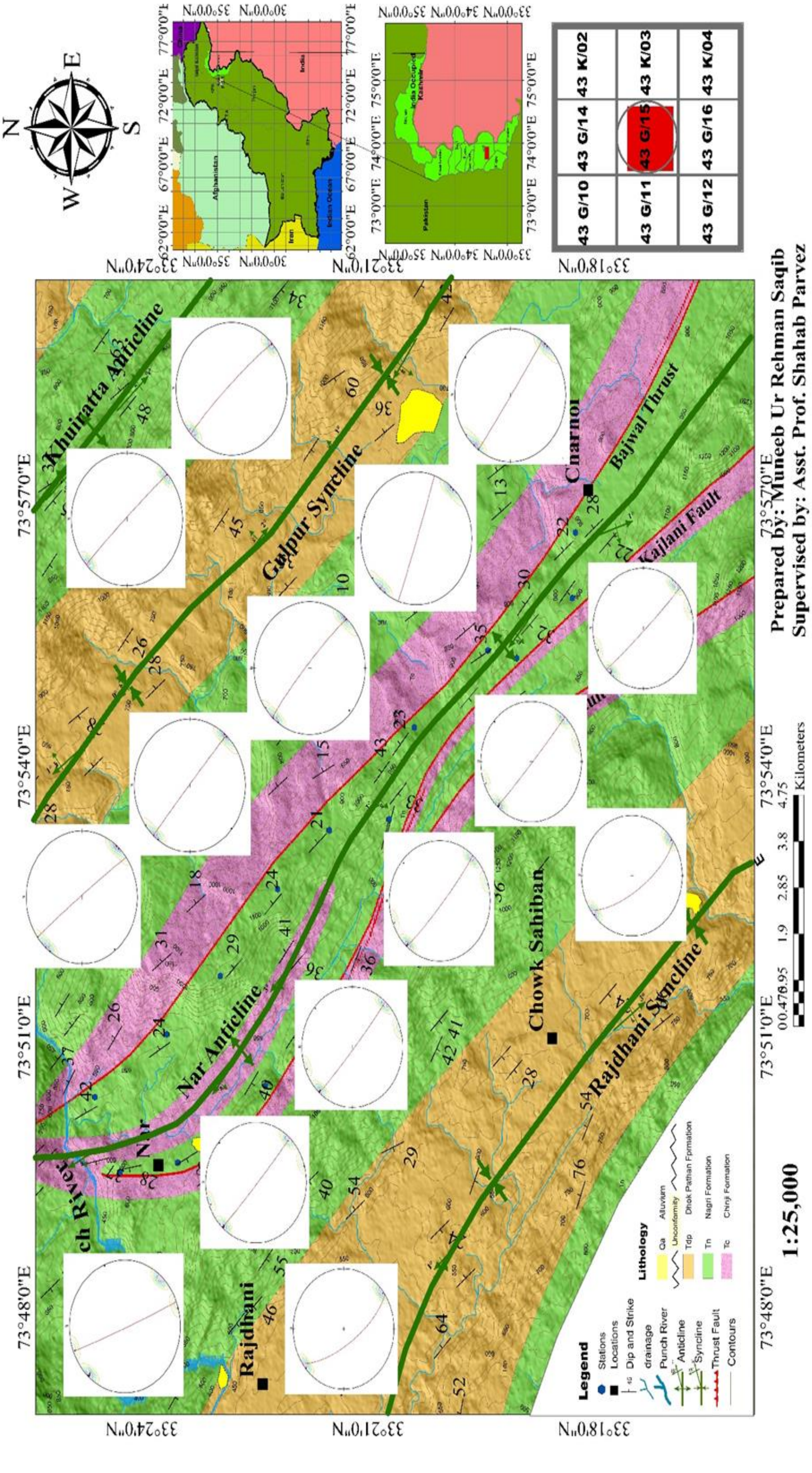

Plate 3: Study area map showing pole to axial plane and pole to fold axis diagrams of Nar anticline and associated.folds..

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Table 2: The data shows the distribution of folds in the study area.

Fold	Northeastern Limb		Southwestern Limb		Fold Axis		Axial Plane		Interlimb Angle	Fold Type
	Strike	Dip	Strike	Dip	Trend	Plunge	Strike	Dip		
Nar Anticline	N26° W	42°NE	N18° W	37°SW	338°	03°	N22° W	88°SW	101°	Open Fold
	N55° W	38°NE	N40° W	33°SW	312°	05°	N48° W	88°SW	109°	Open Fold
	N53° W	41°NE	N44° W	36°SW	311°	03°	N49° W	87°SW	104°	Open Fold
	N50° W	43°NE	N47° W	33°SW	311°	01°	N49° W	85°SW	104°	Open Fold
	N50° W	30°NE	N45° W	32°SW	312°	01°	N48° W	88°SW	111°	Open Fold
	N40° W	28°NE	N45° W	22°SW	164°	01°	N43° W	87°NE	130°	Gentle Fold
Gulpur Syncline	N35° W	28°SW	N40° W	30°NE	323°	01°	N37° W	88°NE	115°	Open Fold
	N48° W	26° SW	N50° W	28° NE	311°	00°	N49° W	89°NE	126°	Gentle Fold
	N50° W	45° SW	N45° W	35° NE	132°	02°	N48° W	85°NE	101°	Open Fold
	N53° W	29° SW	N50° W	31° NE	129°	01°	N51° W	89°NE	120°	Open Fold
	N55° W	40° SW	N55° W	42° NE	305°	00°	N55° W	89°SW	98°	Open Fold
Khui Ratta Anticline	N40° W	42°NE	N45° W	45°SW	137°	2.4°	N43° W	88°NE	93°	Open Fold
	N37° W	52°NE	N46° W	49°SW	137°	02°	N43° W	85°NE	100	Open Fold
Rajdhani Syncline	N45° W	24°SW	N35° W	66°NE	143°	03°	N35° W	69°SW	90°	Open Fold
	N41° W	54°NE	N40° W	24°SW	319°	01°	N38° W	77°SW	98°	Open Fold

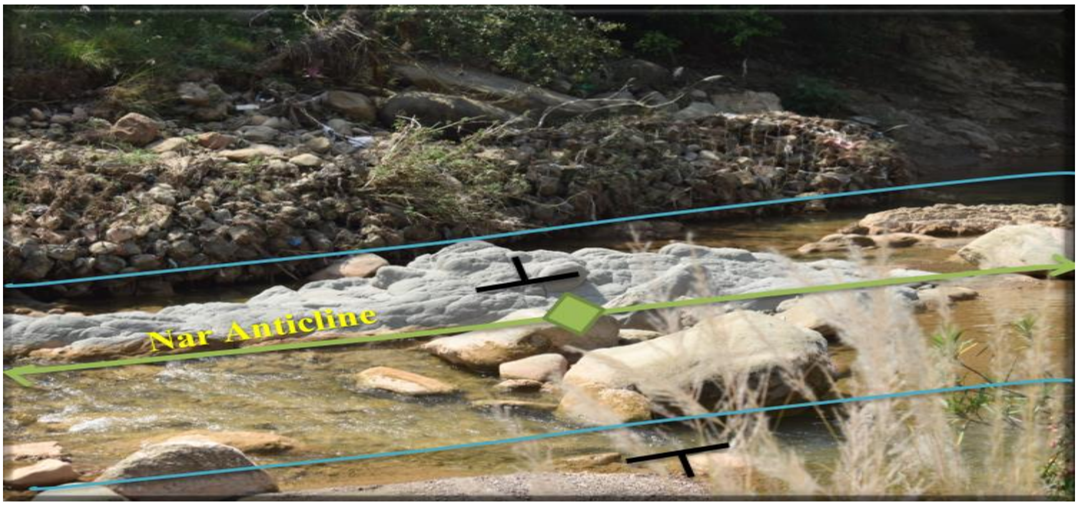


Photo 1: Showing Chinji Formation exposed at the core of Nar anticline, photo facing east.

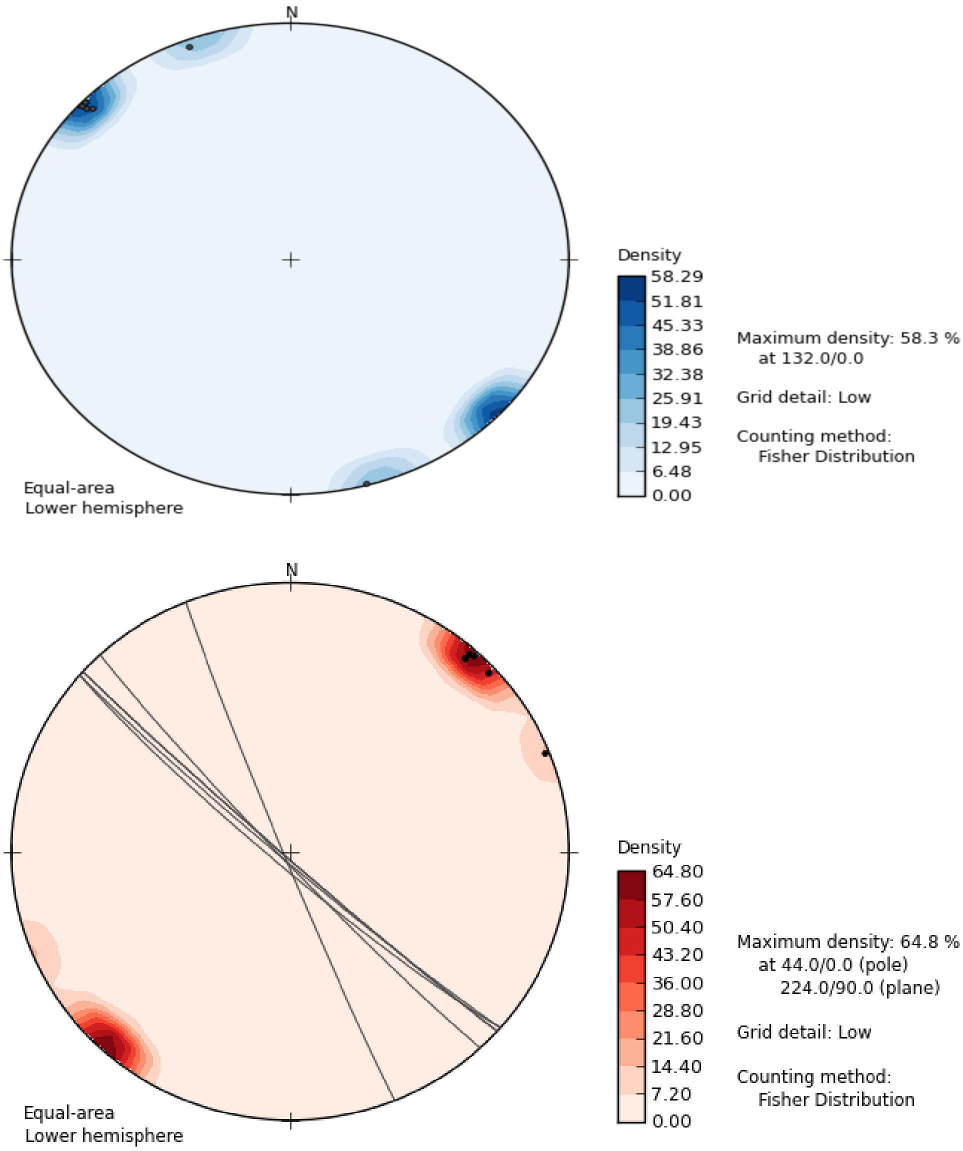


Figure 2: Geometric features of Nar anticline. a) Fold axis of Nar anticline; b) poles to axial planes of Nar anticline. Great circles indicate the mean attitude of axial planes; equal-area lower hemisphere plot with north at the top; the number of measurements is 7. Data are listed in table 2.

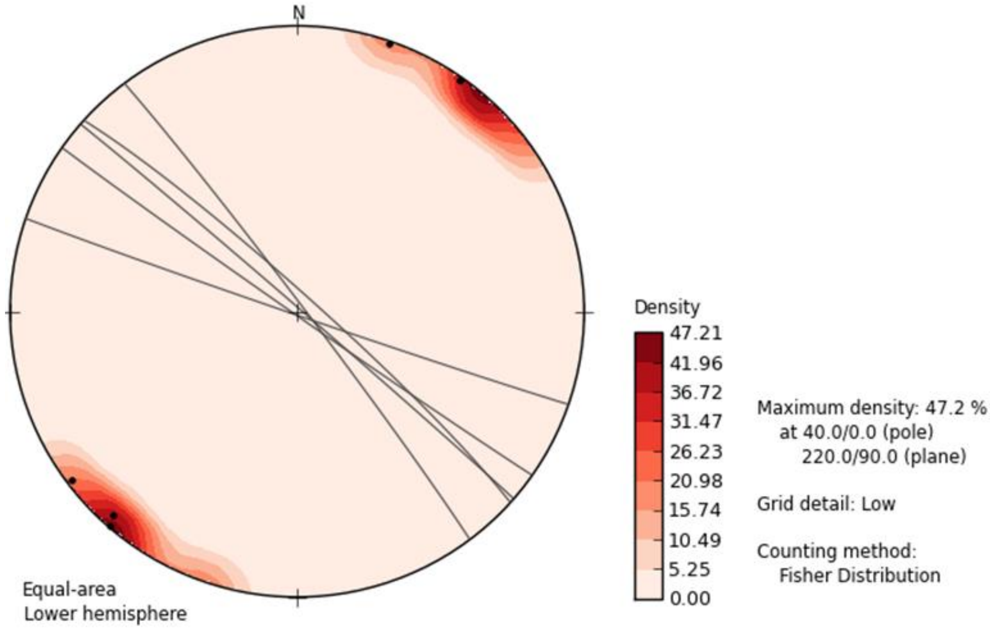
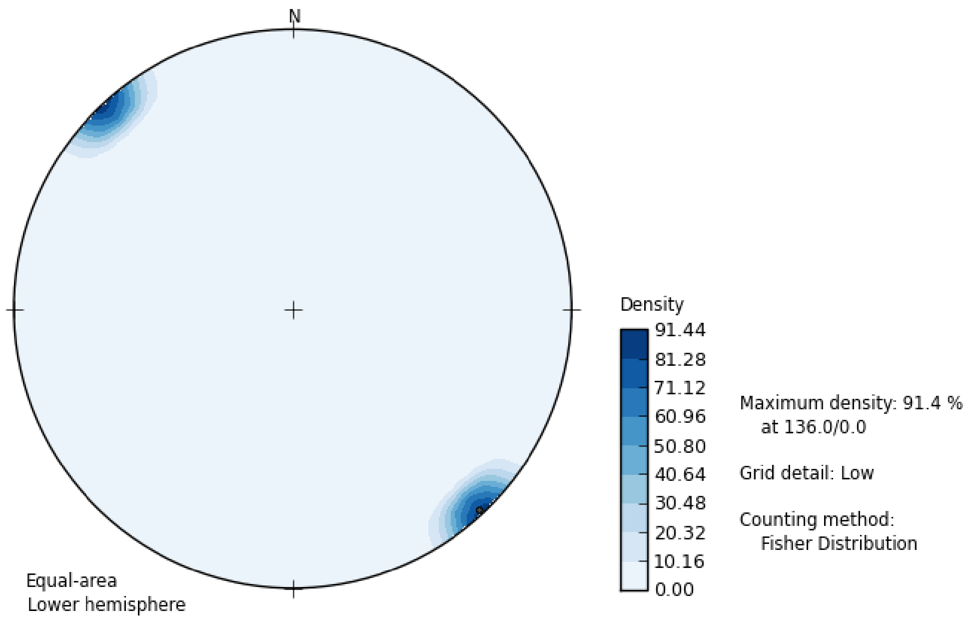


Figure 3: Geometric features of Gulpur syncline. a) Fold axis of Gulpur syncline b) Poles to axial planes of Gulpur syncline; Great circles indicate the mean attitude of axial planes; equal-area lower hemisphere plot with north at the top; the number of measurements is 5. Data are listed in table 2. Trend and plunge are ranging from 143°-319°/ 1°-3° and the interlimb angle varies from 90°-98°.

3.1.3 Khuiratta Anticline

The Khuiratta anticline lies at the northeastern side of the Gulpur syncline (Plate 2). The trend of the fold axis is northwest-southeast. The anticline is formed due to the folding of the Nagri Formation on the surface, whereas the Chinji-Formation lies in the core (Plate 2, 3, 4). The bedding attitude of the anticline along the northeastern limb is N37°W/52°NE, whereas the southwestern limb is N40°W/42SW°. The trend and plunge of the fold are 02°/137°. The attitude of axial plane is N43°W/85°NE. The interlimb angle of the fold is 93°-100° (Table 2; Figure β12 and β13). The axial trace of anticline on the surface is parallel to the regional structure. The structural interpretation demonstrates that the Khuiratta-anticline is southeast-plunging, southwest verging fold. Based on the interlimb angle, the fold is classified as an open fold. The maximum density of the fold axis is 91.4% at 136.0/0.0, whereas the pole to the axial plane is 80.0% at 228.0/0.0 (Table 2; Figure 4).



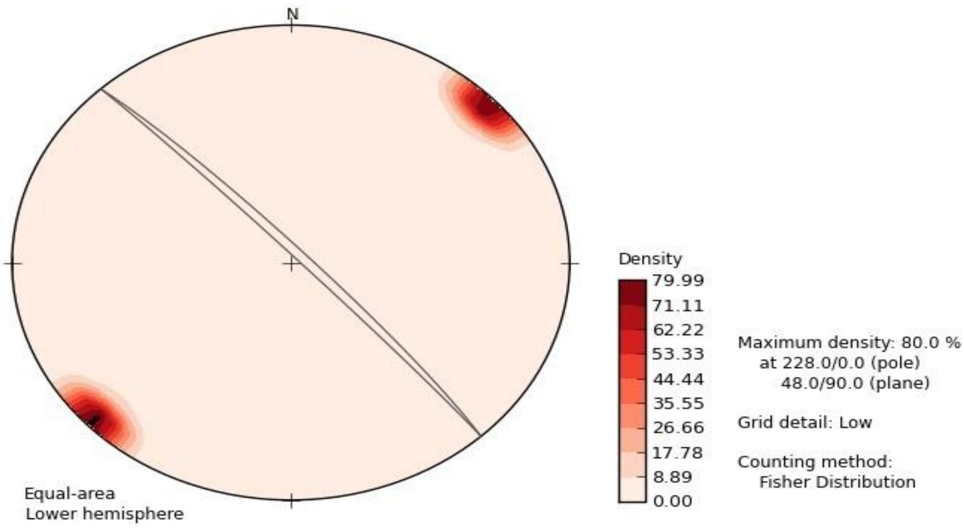
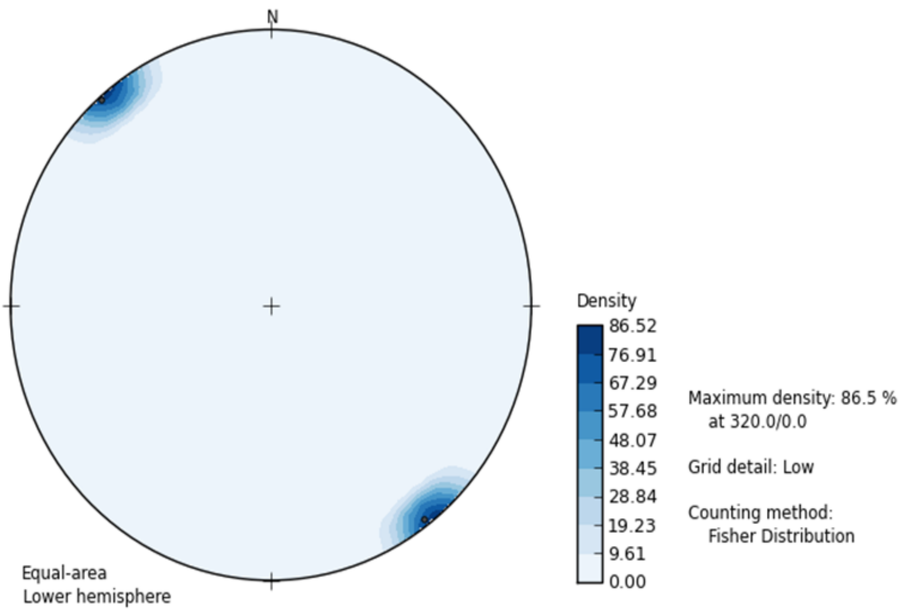


Figure 3.3 Geometric features of Khuiratta anticline. a) fold axis of Khuiratta anticline; b) Pole to the axial plane of Khuiratta anticline. Great circles are from 24°SW to 54°NE whereas the strike of the northeastern limb is ranging N35°W to N40°W and dip is from 66°SW-24°SW. The structural data depict Rajdhani syncline as northeast verging southeast or northwest plunging fold. The data of interlimb-angle shows that the fold is an open fold,.indicate the attitude of axial planes; equal-area lower hemisphere plot with north (N) at top. Data are listed in table 2.

3.2.4 Rajdhani Syncline

The Rajdhani syncline is exposed on the southwest of Nar anticline (Plate 2). The syncline is produced by the buckling of Dhok-Pathan-Formation, Nagri-Formation and Chinji-Formation. The core of the syncline contains Dhok-Pathan Formation, while limbs contain Chinji Formation and Nagri Formation (Plate 2,3 and 4). The attitude of the southwestern limb is N41W to N45°W/ 24°SW to 54°NE whereas the attitude of the northeastern limb is N35°W to N40°W/66°SW-24°SW. The maximum density of fold-axes and pole to axial-plane is 86.5% at 320.0/0.0 and 67.7% at 50.8/14.4, respectively (Figure 5).



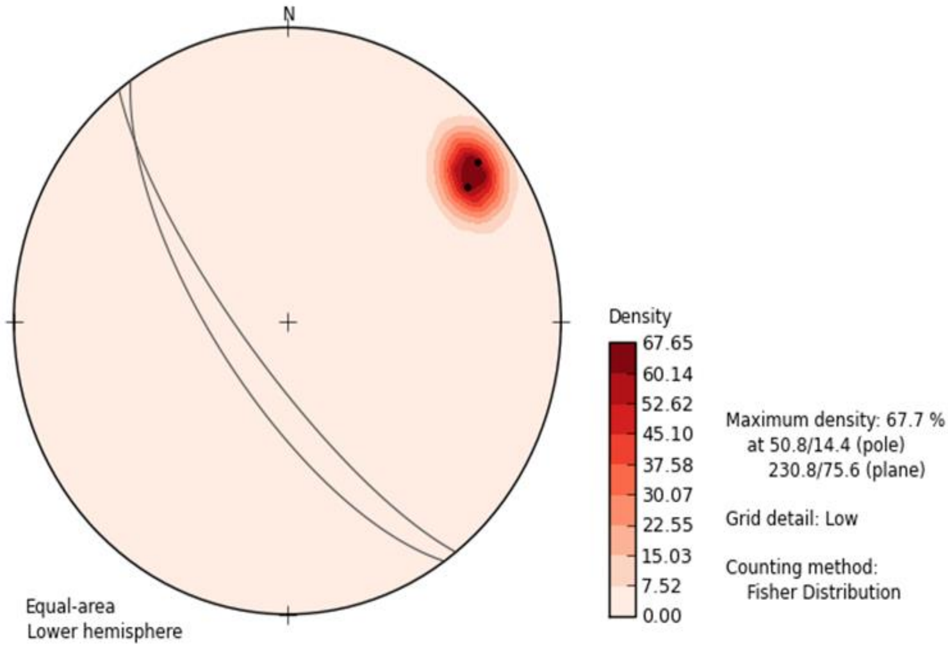


Figure 5 Geometric features of Rajdhani syncline **a)** Fold axis of Rajdhani syncline; **b)** poles to axial planes of Rajdhani syncline. Great circles indicate the mean attitude of axial planes; equal-area lower hemisphere plot with north at the top; the number of measurements is 2. Data are listed in table 2.

3.2. FAULTS

In the project area following thrust and back thrust are present, which are:

- Bajwal fault
- Kajlani fault
- Panjan fault

3.3.1. Bajwal Thrust

The Bajwal thrust is a regional fault in the area. The fault is the northwest to southeast trending fault, which emplace Chinji-Formation on the Nagri-Formation. Shearing, crushing and drag folds are present along the fault zone (Image 2). the deformation along this fault is six meters. It is a thrust fault with the attitude of the fault plane is N44°W/ 38°NE. (Plate 2, 4, 5 & 6).

Photo 2: Photograph showing Chinji Formation (a) thrust over the Nagri Formation (b) Bajwal thrust. Note; Drag folds are present in the hanging wall of Bajwal thrust, photo looking southeast.

3.3.2. Kajlani Fault

The Kajlani fault develops along the southwestern flank of the Nar anticline. The fault is well exposed near Nar police station. Kajlani fault is a back-thrust fault (Plate 2, 4, 5 & 6). The fault emplaces the Chinji Formation on the Nagri Formation. It shows listric behavior. It a pseudo normal on the surface. The shearing, crushing and drag folds are present (Figure 4; Plate 2, 4 & 5 Photo 3).

Photo 3: The photograph showing Kajlani fault. The Chinji Formation (a) thrust over the Nagri Formation (b). Drag fold can be seen on the upper left corner of the photograph, photo looking northwest

3.3.3. Panjan Fault

The southwestern flank of the Nar anticline is faulted by Panjan fault, considered the splay of Kajlani fault. The fault more or less runs parallel to the Kajlani fault. The thrust emplaced the Chinji Formation on the Nagri Formation (Plates 2; 4, Photo 3). The fault is characterized as a reverse fault. The dip of fault exceeds 45°. The drag folds are found along the fault, as shown in photo 3.

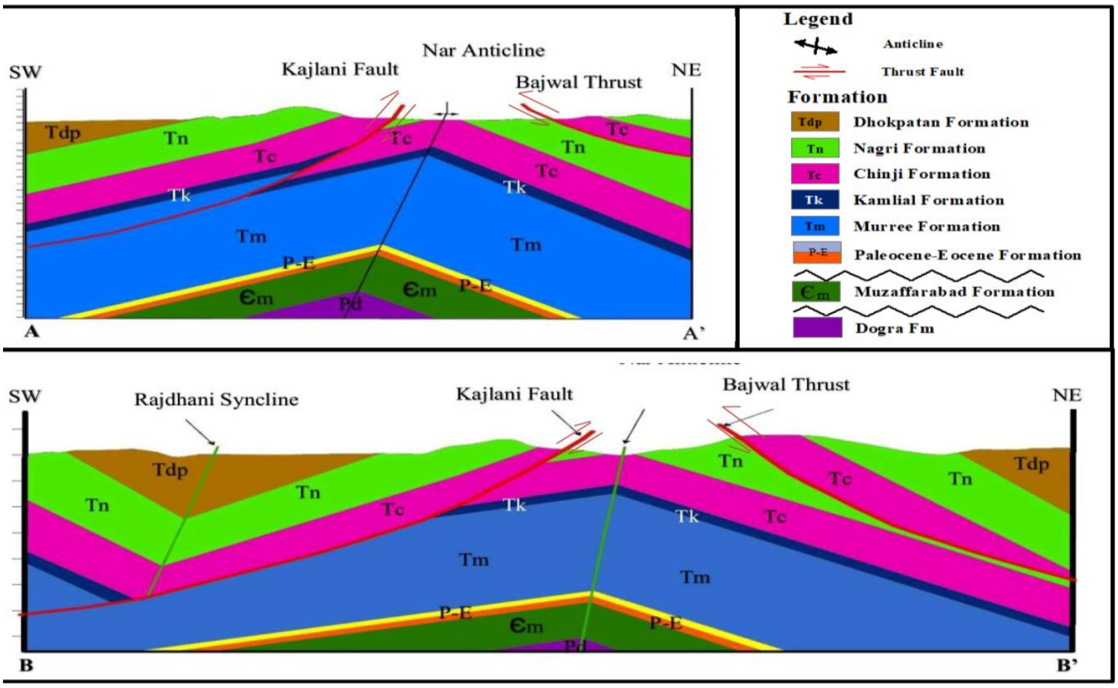


Plate 5: Structural cross-section of Rajdhani, Nar and Kajlani area, District Kotli, Azad Jammu and Kashmir, Pakistan.

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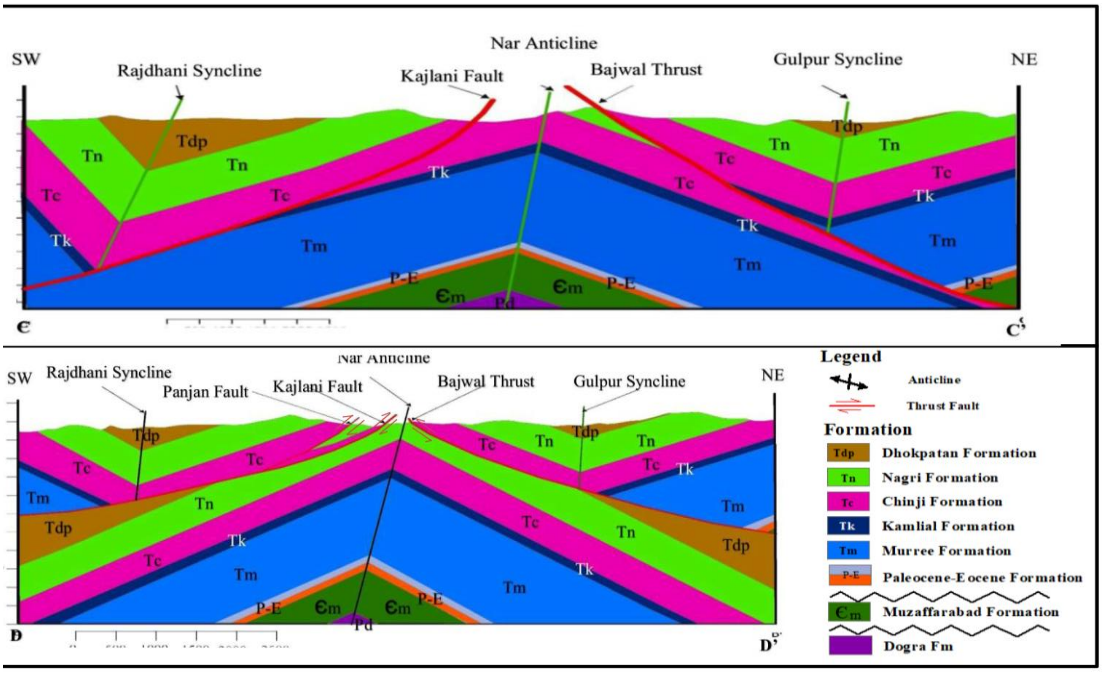

Plate 6: Structural cross-section of Chowk Sahiban, Bratla and Charhoi area, District Kotli, Azad Jammu and Kashmir, Pakistan.

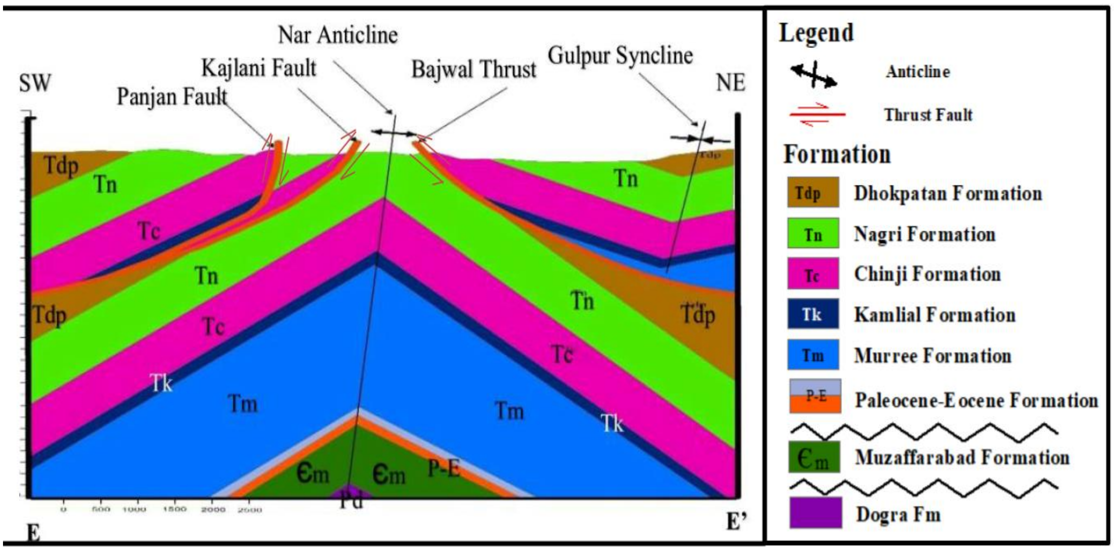

Plate 7: Structural cross section of Panjan and Charhoi area, District Kotli, Azad Jammu and Kashmir, Pakistan.

IV. DISCUSSION & CONCULSION

The Nar anticline located in the Kashmir fold and thrust belt (Figure 1). The Kashmir fold and thrust belt lies in the east of the Hazara Kashmir Syntaxis.

The Tertiary to Recent sedimentary sequence of the molasse is exposed in the area (Table 1). Sedimentary sequence in the area is fractured and buckled throughout the Himalayan orogeny. The main folds are; Nar anticline, Gulpur syncline, Khuiratta anticline and Rajdhani syncline (Plate 2). These folds are commonly NW-SE trending having SE or NW plunge.

The local cross folding in the area may rise distinction in fold trends (Baig et al., 2008). The axial plane of fold dips either NE or SW. The angle between limbs are ranges from 101° to 130° (Table 2). Fold is categorized as open to gentle geometry based on interlimb angle, whereas the attitude of flanks shows asymmetric folds (Plate 4 and 5; Cross sections).

The flanks of the Nar anticline are locally fractured along faults (Plate 2). The significant faults are Bajwal thrust, Kajlani fault and Panjan Fault (Plate 2). The Bajwal thrust lies at the northeastern limb also parallel to the fold axis of Nar anticline (Plate 4; Cross-section CC'). The Kajlani fault and Panjan fault run parallel to the fold axis along the southwestern limb of the Nar anticline.

The Nar anticline is one of the best-exposed anticlinal structures in the Kashmir fold and thrust belt (Wadia, 1928). It is selected for detail geometrical analysis. The Nar anticline is folded by the buckling of Precambrian to Recent rocks such as; Dogra Formation, Muzaffarabad Formation, Paleocene-Eocene sequence, Kuldana Formation, Murree Formation, Kamlial Formation, Chinji Formation, Nagri Formation and Dhok Pathan Formation. The Paleocene-Eocene sequence includes the Hangu Formation, Patala Formation, Margalla Hill Limestone and Chorgalli Formation. Dogra Formation to Kamlial Formations is not exposed in the core, where the Chinji, Nagri and Dhok Phatan Formation are well exposed on the hinges. Nagri and Dhok Pathan Formation are conserved along the strike of the flanks of Nar anticline and eroded from the hinge, leading to exposure of Chinji Formation at the core of the anticline (Plates 3,4 & 5).

These rocks have been eroded upstream in the area to form the erosional curve due to tectonic uplifting similar to the Tattapani anticline (Saqib, 2012). This erosion leads to form an erosional inlier. Similarly, this type of inlier is also found in the area of Muzaffarabad, in the core of the Hazara Kashmir Syntaxis (Baig et al., 1991). However, Wadia (1928) reported this type in the Jammu area.

Miocene Chinji Formation having sandstone and clays are conformably overlain by the clays and sandstone of Nagri Formation. Further Nagri Formation is overlain conformably by thick sandstone of Dhok Pathan Formation.

The Patala Formation can play source rock for petroleum potential in the Kashmir fold and thrust belt. The clays of Chinji Formation have the potential to act as cap rock to trap the hydrocarbons. This interpretation is supported by the study of structural traps of Kohat, Potwar and Salt range basins. In the Potwar basin, the Miocene rock shows potential reservoir rocks (Zahid et al., 2014). However, the shales of the Patala Formation also act as source rock in Kohat and Potwar basins (Shami and Baig, 2002; Zahid et al., 2014). In these basins, the shales and clays of Kuldana Formation and Murree Formation cap the reservoir and source rocks of the sequence of the Paleocene-Eocene rock.

The Sedimentary cover sequence from Precambrian to Resent in the area is distorted. This sequence in the Kashmir fold and thrust belt is folded and faulted during Himalayan orogeny. The Nar anticline is a regional structure. The different data from the field is integrated to deduce the following conclusion:

1. The folds in the area are primarily broad and are open to gentle folds.
2. The axial plane of the Nar anticline is plunging on both NW and SE sides.
3. The verging of the axial plane is towards the northeast.
4. The exposed sandstone of Nagri Formation at the anticline is porous and can play an essential role in hydrocarbon migration
5. The faults in the area are thrust faults and enhanced the secondary porosity and permeability
6. The Patala Formation can act as a source and charge the formation; the clays of Chinji Formation can act as a caprock.
7. The Orientation of the fold axis shows that the principal direction of stress is from northeast to southwest.
8. The anticline is formed as a result of the northeast to southwest compressional forces.

ACKNOWLEDGEMENTS

We are thankful to our parents, teachers and friends for believing in us and standing by us in the difficult times in our life.

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APPENDIX-I

L1=N18°W/37°SW
L2= N26°W/42°NE
Fold Axis=03°/338°
Axial Plane=N22°W/88°SW
Interlimb Angle=101°
Type of Fold= Open Fold

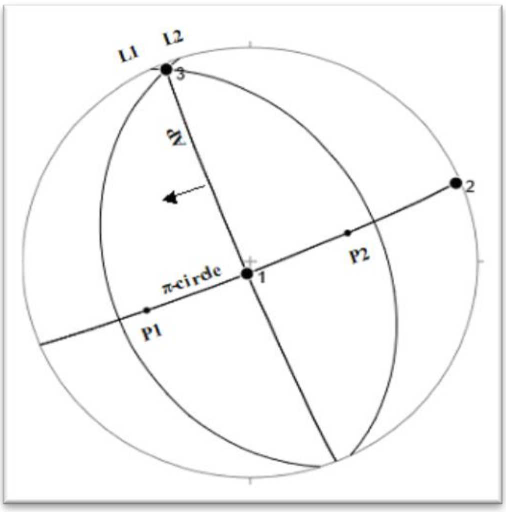

Figure β1 β-π diagram of Nar anticline.

L1= N40°W/33°SW
L2= N55°W/38°NE
Fold Axis=05°/312°
Axial Plane=N48°W/88°SW
Interlimb Angle=109°
Type of Fold=Open Fold

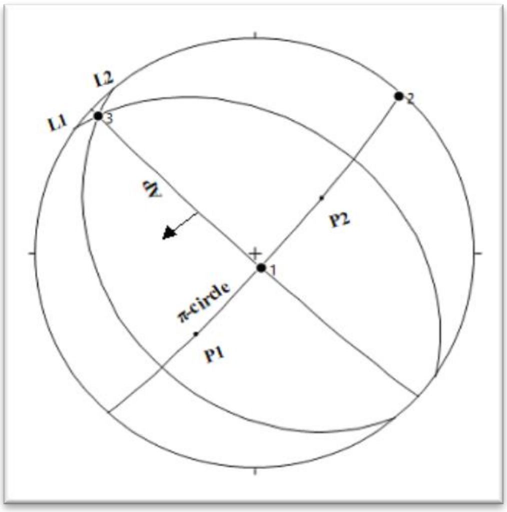

Figure β2 β-π diagram of Tattapani anticline.

L1=N44°W/36°SW
L2=N53°W/41NE°
Fold Axis=03°/311°
Axial Plane=N49°W/87°SW
Interlimb Angle=104°
Type of Fold= Open Fold

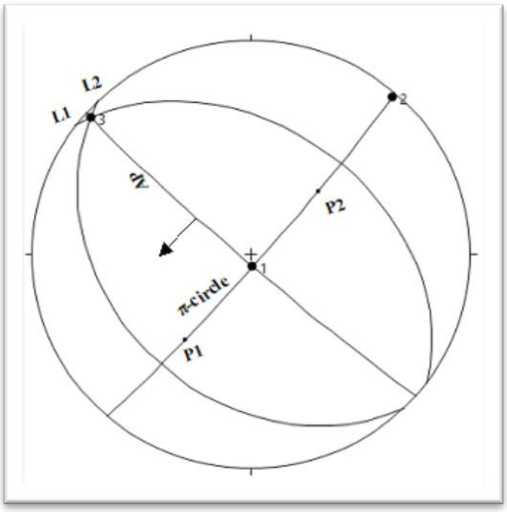

Figure β3 β-π diagram of Nar anticline.

L1=N47°W/33°SW
L2=N50°W/43°NE
Fold Axis= 01°/311°
Axial Plane=N49°W/85°SW
Interlimb Angle=104°
Type of Fold= Open Fold

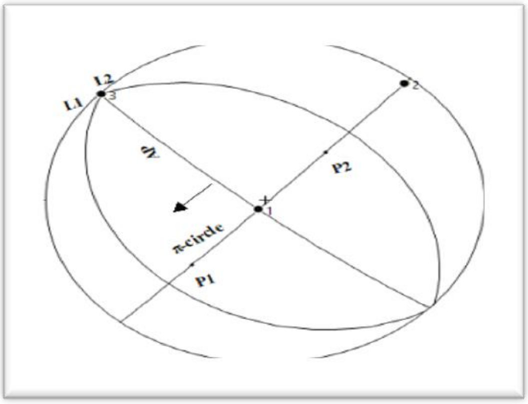

Figure β4 β-π diagram of Nar anticline.

L1=N45°W/32°SW
L2=N50°W/30°NE
Fold Axis=01°/312°
Axial Plane=N48°W/88°SW
Interlimb Angle=111°
Type of Fold=Open Fold

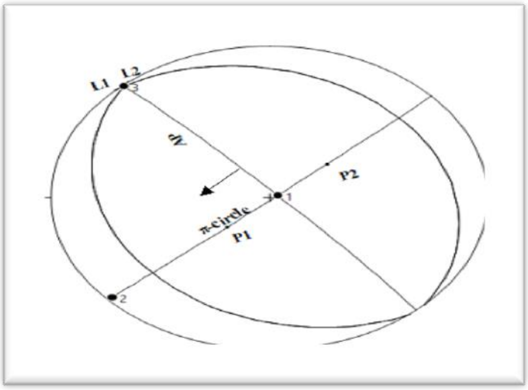

Figure β5 β-π diagram of Nar anticline.

L1=N45°W/22°SW
L2=N40°W/28°NE
Fold Axis=01°/164°
Axial Plane=N43°W/87°NE
Interlimb Angle=130°
Type of Fold=Open Fold

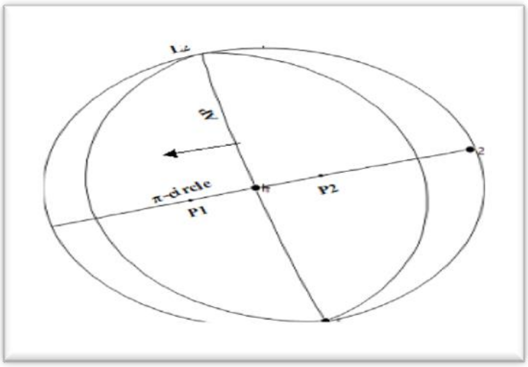

Figure β6 β-π diagram of Nar anticline.

L1=N40°W/30°NE
L2= N35°W/28°SW
Fold Axis=01°/323°
Axial Plane=N37°W/88°NE
Interlimb Angle=115°
Type of Fold= Open Fold

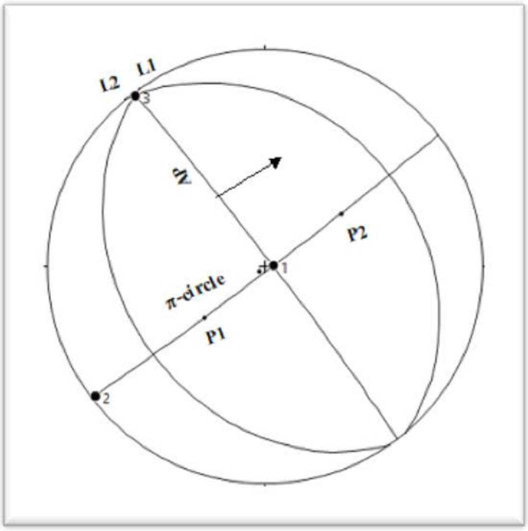

Figure β7 β-π diagram of Gulpur syncline.

L1=N50°W/28° NE
L2= N48°W/26° SW
Fold Axis=00°/311°
Axial Plane=N49°W/89°NE
Interlimb Angle=126°
Type of Fold= Open Fold

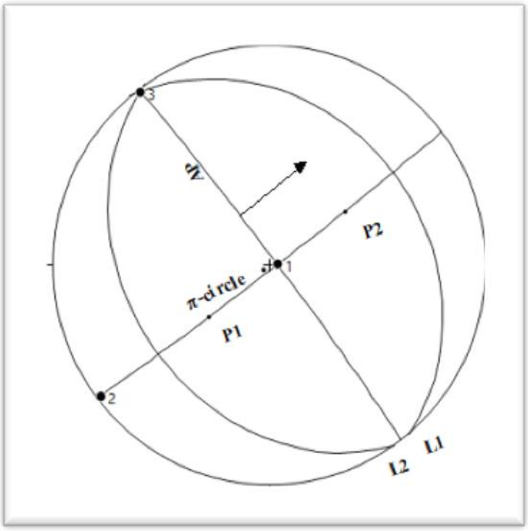

Figure β8 β-π diagram of Gulpur syncline

L1=N45°W/35° NE
L2= N50°W/45° SW
Fold Axis=02°/132°
Axial Plane=N48°W/85°NE
Interlimb Angle=101°
Type of Fold= Open Fold

e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
Volume:03/Issue:06/June-2021 Impact Factor- 5.354 www.irjmets.com

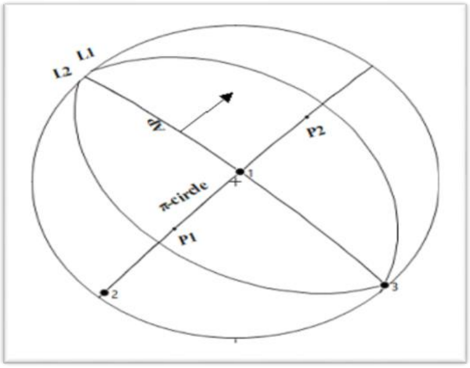

Figure β9 β-π diagram of Gulpur syncline.

L1=N50°W/31° NE
L2= N53°W/29° SW
Fold Axis=01°/129°
Axial Plane=N51°W/89°NE
Interlimb Angle=120°
Type of Fold= Open Fold

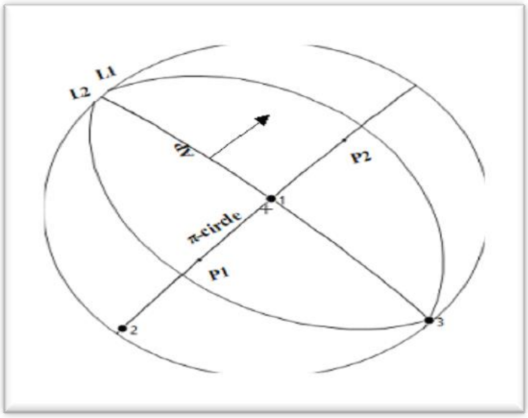

Figure β10 β-π diagram of Gulpur syncline.

L1=N55°W/42° NE
L2= N55°W/40° SW
Fold Axis=00°/305°
Axial Plane=N55°W/89°SW
Interlimb Angle=98°
Type of Fold= Open Fold

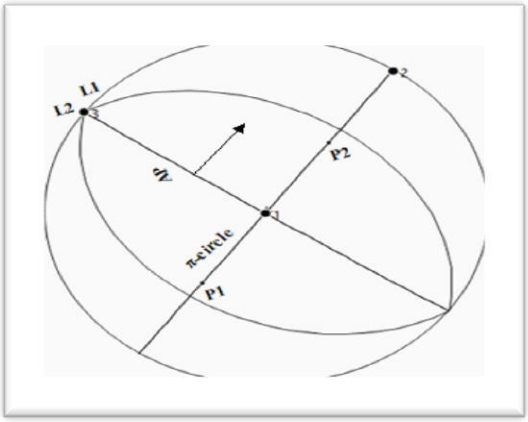

Figure β11 β-π diagram of Gulpur syncline.

L1=N45°W/45°SW
L2= N40°W/42°NE
Fold Axis=2.4°/137°
Axial Plane=N43°W/88°NE
Interlimb Angle=93°
Type of Fold= Fold

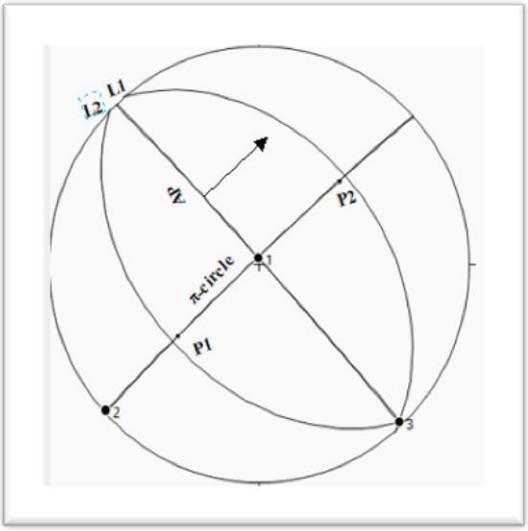

Figure β12 β-π diagram of Khui Ratta anticline.

L1=N46°W/49°SW
L2= N37°W/52°NE
Fold Axis=02°/137°
Axial Plane=N43°W/85°NE
Interlimb Angle=100.1
Type of Fold= Open Fold

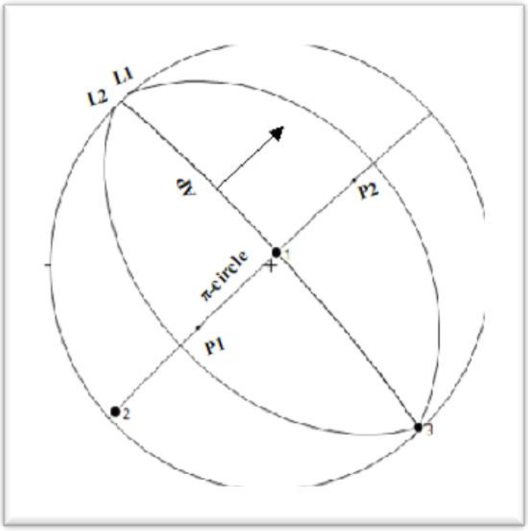

Figure β13 β-π diagram of Khui Ratta anticline.

L1=N45°W/24°SW
L2= N35°W/66°NE
Fold Axis=03°/143°
Axial Plane=N35°W/69°SW
Interlimb Angle=90.3°
Type of Fold= Open Fold

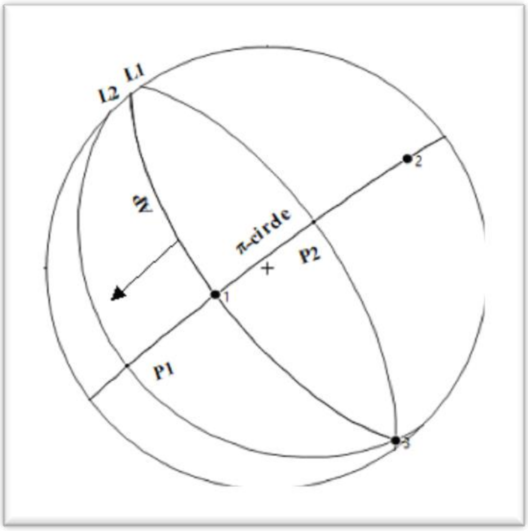

Figure β14 β-π diagram of Rajdhani syncline.

L1=N40°W/24°SW
L2= N41°W/54°NE
Fold Axis=01°/319°
Axial Plane=N38°W/77°SW
Interlimb Angle=98
Type of Fold= Open Fold

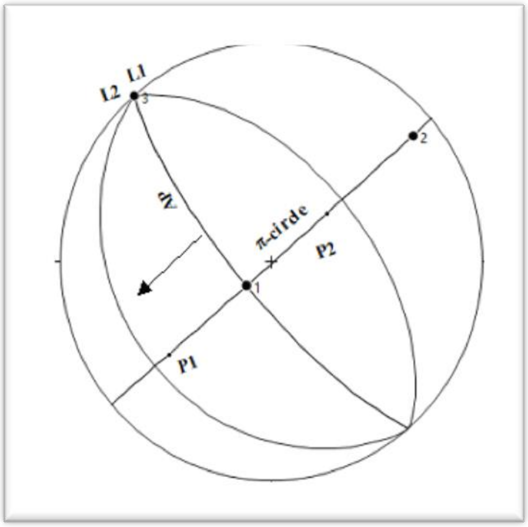

Figure β15 β-π diagram of Rajdhani syncline