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Role of Rose Diagrams in the Interpretation of Geologic Structures: A Review

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Abstract

Rose diagrams are essential tools in geology for visualizing the orientation of geologic features such as fractures, faults, and joint sets. These diagrams help in understanding the spatial distribution and statistical properties of these features, which are critical for interpreting tectonic settings and geological history. This paper provides an in-depth analysis of the roles of rose diagrams in geologic interpretation, detailing the principles behind their construction and use, the procedures for creating them, and their application in various geological contexts.

Keywords: *Rose diagrams, geologic interpretation, lineaments, Bida Basin, tectonic settings, geologic structures.*

1.0 Introduction

1.1 Definitions and Importance of roles diagrams

A rose diagram, also known as a wind rose, is a circular histogram that displays the frequency of data along different directions (Davis, 2002; Ramsay & Huber, 1983).Its primary application is in the visualization of directional data, which makes it a valuable tool in various geological fields (Boggs, 2011; Fetter, 2001).The rose diagram's ability to represent data directionally and cyclically enables geologists to understand and analyze patterns that would be difficult to discern from raw data alone. This essay explores the application of rose diagrams across different geological disciplines, including structural geology, sedimentology, paleontology, hydrogeology, and environmental geology.

Geology structures refer to the features and arrangements of rocks and sediments that result from geological processes. These structures can form in various ways, including through tectonic activity, sedimentation, erosion, and volcanic activity. (Ananaba & Ajakaye, 1987; Udensi et al., 2003).

1.2 Types of Geology Structures

Here's a comprehensive overview of the major types of geological structures:

Folds: Folds are bends in layered rock strata resulting from compressional forces. They can vary greatly in size from microscopic crinkles to large mountain ranges. Key types of folds include:
i. Anticlines: Upward-arching folds with the oldest rocks at the core.
ii. Synclines: Downward-arching folds with the youngest rocks at the core.
iii. Monoclines: Step-like folds where layers are tilted in one direction.
iv. Overturned Folds: Folds where one limb is tilted beyond the vertical.

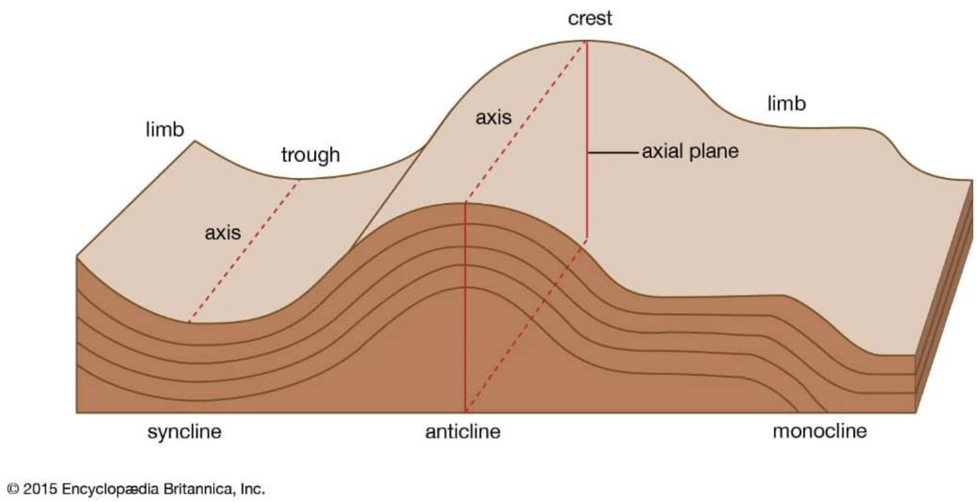

Fig. 1: Types of folds (adapted from Encyclopedia Britannica (2015), Fold types, https://www.britannica.com/science/folds#/media/1/211999/5532)

Faults: Faults are fractures in the Earth's crust along which movement has occurred. They are classified based on the direction of displacement:

i. Normal Faults: Occur under tensional forces, where the hanging wall moves down relative to the footwall.

ii. Reverse Faults: Result from compressional forces, with the hanging wall moving up relative to the footwall. If the angle is low, it is called a thrust fault.

ii. Strike-Slip Faults: Horizontal movement along the fault line, classified into right-lateral (dextral) and left-lateral (sinistral) based on the relative motion.

iii. Oblique-Slip Faults: Have both vertical and horizontal movement.

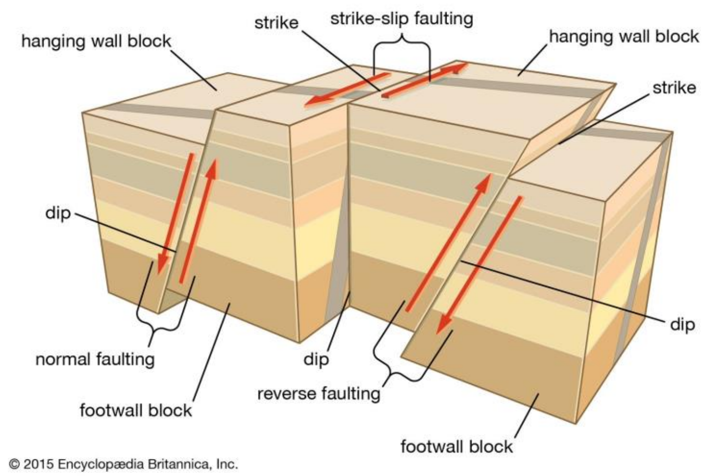

Fig 2: Types of fault (adapted from Encyclopedia Britannica (2015), fault types in tectonic earthquakes. https://www.britannica.com/science/fault geology#/media/1/202708/1423

Joints: Joints are fractures in rocks where there has been no significant movement parallel to the fracture surface. They can form due to:

i. Tensional Stress: Often forming perpendicular to the direction of the least principal stress.

ii. Cooling and Contraction: Seen in volcanic rocks as they cool and shrink, creating columnar jointing.

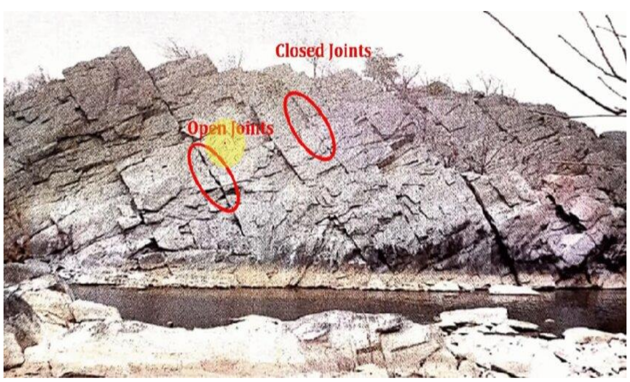

Fig 3: Closed and open joints (adapted from Analyzing the shear strength of jointed magmatic rock mass excavatability using the hybridization of metaheuristic model of ELM-SVM - Scientific Figure on ResearchGate. Available from: https://www.researchgate.net/figure/Closed-and-open-joints-in-rock_fig4_363732837).

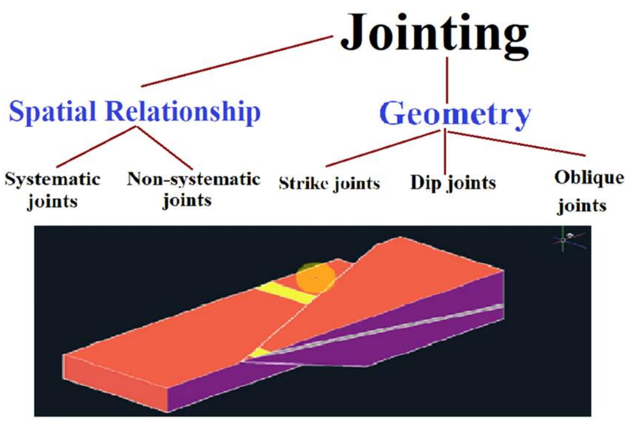

Fig 4: The strike of the joint is parallel to the dip direction of the rock(adapted from Analyzing the shear strength of jointed magmatic rock mass excavatability using the hybridization of metaheuristic model of ELM-SVM - Scientific Figure on ResearchGate. Available from: https://www.researchgate.net/figure/The-strike-of-the-joint-is-parallel-to-the-dip-direction-of-the-rock_fig5_363732837

Unconformities: Unconformities represent gaps in the geological record where rock layers have been eroded or where deposition was absent for a period. Types include:

i. Disconformity: A gap between parallel layers of sedimentary rocks.

ii. Angular Unconformity: Where tilted or folded sedimentary rocks are overlain by younger, more flat-lying strata.

iii. Nonconformity: Occurs between sedimentary rocks and older igneous or metamorphic rocks.

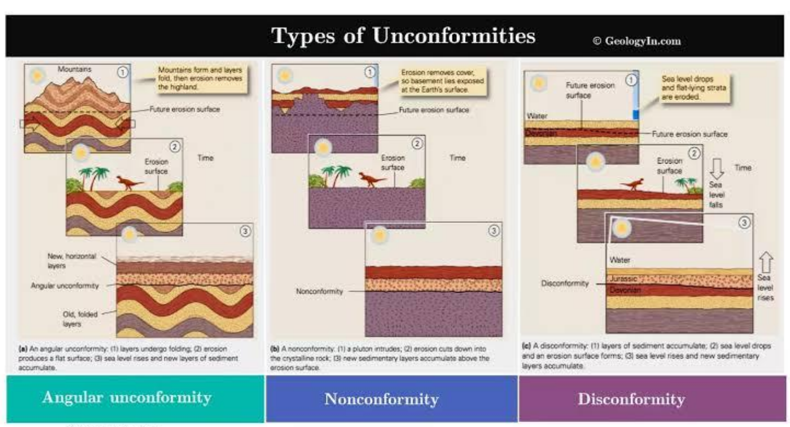

Fig 5: Types of Unconformities are Angular unconformity, Disconformity, and Nonconformity (adapted from Geology in (2015). Types of unconformity. Retrieved from https://www.geologyin.com/2015/10/types-of-unconformities.html)

Intrusive Igneous Structures: When magma intrudes into pre-existing rocks and solidifies, it forms various structures:

i. Dikes: Tabular bodies of igneous rock that cut across pre-existing layers.

ii. Sills: Tabular bodies that intrude parallel to existing layers.

iii. Laccoliths: Dome-shaped intrusions that cause the overlying rocks to arch upward.

iv. Batholiths: Large, irregular masses of intrusive igneous rock that form the cores of many mountain ranges.

Extrusive Igneous Structures

These structures result from volcanic activity:

i. Lava Flows: Sheets of lava that have erupted onto the Earth's surface.

ii. Volcanic Cones: Formed from accumulated volcanic debris, such as cinder cones, shield volcanoes, and stratovolcanoes.

iii. Lava Plateaus: Extensive, flat areas covered by lava flows.

Sedimentary Structures

These are features within sedimentary rocks that form during or shortly after deposition:

i. Bedding and Stratification: Layers of sediment that are deposited over time.

ii. Cross-Bedding: Inclined layers within a bed, indicating sediment was deposited by wind or water currents.

iii. Ripple Marks: Small ridges formed by water or wind action on the sediment surface.

iv. Mud Cracks: Polygonal cracks formed when muddy sediment dries and contracts.

Metamorphic Structures

Structures formed in rocks subjected to high pressures and temperatures, leading to recrystallization:

i. Foliation: Planar arrangement of mineral grains or structural features within a rock.

ii. Schistosity: A type of foliation characterized by the parallel arrangement of platy minerals.

iii. Gneissic Banding: Alternating light and dark bands of minerals in a metamorphic rock.

Tectonic Structures

Large-scale structures resulting from plate tectonics, including:

i. Orogenic Belts: Mountain ranges formed by the collision and compression of tectonic plates.

ii. Rift Valleys: Large depressions formed by the extension and thinning of the Earth's crust.

iii. Transform Faults: Major strike-slip faults that accommodate horizontal movement between tectonic plates.

Landforms

Surface features shaped by geological processes:

i. Mountains: Elevated areas formed by tectonic forces, volcanic activity, or erosion.

ii. Valleys: Depressions carved by river erosion or glacier movement.

iii. Plateaus: Elevated flat areas formed by volcanic activity, uplift, or erosion.

iv. Basins: Low areas often filled with sediments, formed by subsidence or erosion.

1.3 Application of Rose Diagram in Different Geological Fields

1. Structural Geology

i. Fault and Fracture Analysis

In structural geology, rose diagrams are extensively used to analyze the orientation of faults and fractures within rock masses. By plotting the strike of faults and fractures, geologists can identify predominant orientations and understand the stress regimes that influenced the rock formations. This information is crucial for seismic hazard assessment, mining operations, and understanding tectonic processes.

ii. Fold Axes and Lineation

Rose diagrams also help in visualizing the orientation of fold axes and lineations. Fold axes are the imaginary lines that run along the crest of a fold, while lineations are linear features within the rock. By plotting these features, geologists can infer the direction of tectonic forces and the deformation history of the region.

iii. Joint Set Analysis

Joints are natural fractures in rocks that do not show significant displacement. Analyzing the orientation of joint sets using rose diagrams helps in understanding the mechanical behavior of rock masses and their response to stress. This is particularly important in engineering geology for the stability analysis of rock slopes, tunnels, and other structures.

2. Sedimentology

i. Paleocurrent Analysis

In sedimentology, rose diagrams are commonly used for paleocurrent analysis. By plotting the orientation of sedimentary structures such as cross-beds, ripple marks, and flute casts, geologists can infer the direction of ancient water or wind currents that transported the sediments. This information helps in reconstructing past depositional environments and understanding sediment transport processes.

ii. Grain Orientation

The orientation of elongated grains, such as pebbles or fossils, can be plotted on a rose diagram to infer flow directions during sediment deposition. This is particularly useful in fluvial and deltaic environments where the flow direction influences sediment sorting and distribution.

iii. Facies Analysis

Rose diagrams assist in facies analysis by visualizing the directional properties of sedimentary features within a facies. This helps in understanding the depositional environment and the processes that controlled sedimentation.

3. Paleontology

i. Fossil Orientation

In paleontology, rose diagrams are used to analyze the orientation of fossil remains within sedimentary rocks. The orientation of fossils, such as shells or bones, can provide insights into the depositional environment and the post-depositional processes that affected the fossils.

ii. Trace Fossils

Trace fossils, or ichnofossils, are geological records of biological activity. Rose diagrams can be used to analyze the orientation of trace fossils such as burrows, tracks, and trails. This helps in understanding the behavior of ancient organisms and their interaction with the sedimentary environment.

iii. Bioturbation Structures

Bioturbation refers to the disturbance of sedimentary deposits by living organisms. Analyzing the orientation of bioturbation structures using rose diagrams helps in understanding the direction of organism movement and the environmental conditions that influenced their behavior.

4. Hydrogeology

i. Groundwater Flow Direction

In hydrogeology, rose diagrams are used to visualize the direction of groundwater flow. By plotting the orientation of hydraulic gradients, geologists can understand the movement of groundwater within an aquifer. This information is crucial for groundwater resource management, contamination studies, and the design of groundwater extraction systems.

ii. Fracture Flow Analysis

In fractured rock aquifers, rose diagrams help in analyzing the orientation of fractures that control groundwater flow. This is important for understanding the hydraulic properties of the aquifer and for designing effective groundwater monitoring and remediation strategies.

iii. Well Orientation

Rose diagrams can also be used to analyze the orientation of wells in a study area. This helps in optimizing well placement for groundwater extraction or injection, and in understanding the spatial distribution of groundwater resources.

5. Environmental Geology

i. Pollution Dispersion

In environmental geology, rose diagrams are used to analyze the dispersion patterns of pollutants in the subsurface. By plotting the direction of contaminant plumes, geologists can understand the factors controlling pollutant migration and design effective remediation strategies.

ii. Erosion and Deposition

Rose diagrams help in understanding the direction of erosion and deposition processes in a study area. This information is crucial for managing soil erosion, designing erosion control measures, and understanding sediment transport processes in rivers and coastal areas.

6. Coastal Geology

In coastal geology, rose diagrams are used to analyze the orientation of coastal features such as dunes, beach ridges, and shoreline trends. This helps in understanding the processes that shape the coastline, such as wave action, longshore currents, and wind direction.

7. Geotechnical Engineering

i. Rock Mass Characterization

In geotechnical engineering, rose diagrams are used to characterize the orientation of discontinuities within a rock mass. This information is crucial for designing stable slopes, tunnels, and foundations. By understanding the orientation of fractures, engineers can assess the potential for rockfalls, slope failures, and other geotechnical hazards.

ii. Soil Anisotropy

Rose diagrams can also be used to analyze the directional properties of soils, such as the orientation of soil particles or the direction of stress within the soil mass. This helps in understanding soil anisotropy and designing appropriate geotechnical structures.

iii. Structural Stability Analysis

By plotting the orientation of structural features such as joints and faults, rose diagrams help in assessing the stability of engineered structures in rock masses. This information is crucial for designing safe and stable structures in areas prone to geological hazards.

8. Petroleum Geology

i. Reservoir Characterization

In petroleum geology, rose diagrams are used to analyze the orientation of fractures, faults, and bedding planes within a reservoir. This helps in understanding the reservoir's structural framework and optimizing the placement of wells for hydrocarbon extraction.

ii. Fracture Networks

Rose diagrams help in visualizing the orientation of fracture networks within a reservoir. This information is crucial for understanding the permeability and flow characteristics of the reservoir, and for designing effective hydraulic fracturing strategies.

iii. Wellbore Stability

By analyzing the orientation of stresses around a wellbore using rose diagrams, geologists can assess the stability of the wellbore and design appropriate drilling strategies. This helps in minimizing drilling problems and optimizing hydrocarbon production.

2.0 Historical Development of Rose Diagram in Geological Studies

A rose diagram, also known as a wind rose or polar plot, is a circular histogram used in geological studies to represent the frequency and orientation of directional data, such as geological structures, wind directions, and wave heights. The development of rose diagrams in geological studies can be traced through several key historical milestones, reflecting advancements in geological understanding, data analysis, and visualization techniques.

Early Beginnings

The concept of representing directional data graphically can be traced back to early meteorological studies. In the 19th century, wind roses were used by meteorologists to display the frequency and direction of winds at various locations. This concept was later adopted by geologists and engineers to analyze directional phenomena in the earth sciences.

Adoption in Geological Studies

In geological studies, rose diagrams began to gain prominence in the early 20th century. Geologists recognized the value of these diagrams for visualizing the orientation of various geological features such as fractures, joints, faults, and bedding planes. The ability to represent the directional frequency of these features helped in understanding the tectonic forces and stress fields that shaped rock formations.

Advancements in Data Collection and Analysis

With the advent of more sophisticated field instruments and techniques, geologists were able to collect more accurate and extensive directional data. The introduction of the Brunton compass in the early 20th century revolutionized field geology, allowing geologists to measure the orientation of rock structures with greater precision. This increase in data quality and quantity necessitated better methods for data visualization and analysis.

Computational Era and Software Development

The latter half of the 20th century saw significant advancements in computing technology, which greatly influenced the development and use of rose diagrams in geological studies. The introduction of computer software for geological data analysis allowed for more complex and precise rose diagrams to be generated. Programs such as RockWorks, Stereonet, and other geological software packages provided tools for creating rose diagrams from large datasets, enhancing the ability of geologists to analyze and interpret directional data.

Visualization and Interpretation

Modern rose diagrams are often integrated with other geological visualization tools, such as stereonets and contour plots, to provide a comprehensive view of directional data. They can be customized to display various statistical measures, such as mean direction, circular variance, and confidence intervals, allowing for more interpretations of the data.

Example of a rose diagram

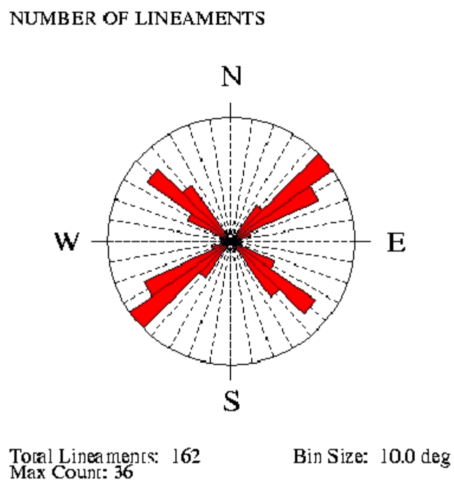

Fig 6: Rose diagram of the faults and joints of the structures of the same area (adapted from Mavrantza, O.D. & Argialas, Demetre. (2003). Implementation and evaluation of spatial filtering and edge detection techniques for lineament mapping - Case study: Alevrada, Central Greece. Proceedings of SPIE - The International Society for Optical Engineering. 10.1117/12.463275)

2.1 Principles of Rose Diagrams Construction

1. Orientation and Frequency:

The basic principle of a rose diagram is to illustrate the frequency of orientations of geological features. Data is grouped into bins corresponding to specific angular intervals (usually 10° or 15°). Each bin represents a range of directions.

The length of each segment (spoke) in the diagram is proportional to the number of data points that fall within that angular interval. The more data points in a specific direction, the longer the spoke.

2. Circular Layout

The circular layout of the rose diagram allows for an intuitive visual representation of directional data. The center of the circle represents zero frequency, and the distance from the center indicates increasing frequency.

This format is especially useful for visualizing data that does not have a single predominant direction but is distributed around a circle.

3. Symmetry and Patterns:

Rose diagrams can reveal patterns and symmetries in geological data. For instance, if data points are evenly distributed around the circle, it indicates no preferred orientation. Conversely, clusters of long spokes in specific directions indicate predominant orientations.

2.2 Fundamentals of Rose Diagram

Here are the fundamentals of rose diagram

1. Basics

i. Circular Format: A rose diagram is plotted on a circular grid, with directions (usually compass directions) radiating out from the center.

ii. Bins: The circle is divided into equal angular bins or sectors. Each bin represents a specific range of directions.

iii. Frequency Representation: The length of each bar (or the area of each sector) represents the frequency or magnitude of data within that directional bin.

2. Components

i. Axes: The central point of the diagram is the origin, with radial lines representing different directions.

ii. Bars or Sectors: Each bin has a bar or sector that extends outward from the center. The length or area of these represents the data magnitude.

iii. Labels: The diagram may have labels indicating the directions (e.g., N, NE, E, etc.) and sometimes the magnitude scales.

2.2.1 Basic Components of a Rose Diagram in Geology

1. Direction:

Represents the orientation of geological features relative to the cardinal directions (e.g., North, East, South, West).

The diagram is circular, with each section or "petal" representing a specific direction or orientation, usually in degrees from true north (e.g., 0° to 360°).

2. Magnitude:

Indicates the degree of prevalence or concentration of the geological features in a specific direction.

In geology, magnitude might correspond to the frequency or density of features, such as the number of faults or the extent of bedding planes in a given direction.

3. Frequency:

Shows how often the geological features occur within different directional ranges.

The length of each petal in the rose diagram reflects the frequency of features in that directional segment. Longer petals indicate a higher frequency or concentration of geological features aligned in that direction.

2.2.2 Reading a Rose Diagram in Geology

1. Direction: Each petal points in a specific direction and represents the orientation of geological features like faults or rock layers.

2. Magnitude: The length of each petal indicates how significant or dominant that direction is in terms of geological features.

3. Frequency: The width and number of petals show how common the features are in different directions. More or wider petals in certain directions suggest a higher frequency or density of features oriented that way.

By analyzing a rose diagram, geologists can infer patterns and trends in geological structures and their orientations, which helps in understanding geological history and processes.

3.0 Interpretation Geological Structures using Rose Diagrams

1. Orientation and Frequency:

i. Orientation: The diagram is divided into segments, each representing a range of directions (usually in degrees from North).

ii. Frequency: The length of each segment indicates the frequency of features in that particular direction. Longer segments mean more features oriented in that direction.

2. Dominant Directions:

The directions with the longest segments indicate the dominant orientations of the geological features. For instance, if the longest segment points towards 30° and 210°, it suggests that most features are oriented in these directions.

3. Symmetry and Patterns:

i. Symmetry: Symmetrical patterns might suggest certain geological processes. For example, a symmetrical pattern around a central axis might indicate tectonic stress fields.

ii. Clustered Patterns: Clustering of segments in specific directions can indicate consistent geological forces acting in those directions.

3.1 Correlation of Rose Diagrams With Geological Features

The correlation of Rose diagrams with geological features involves interpreting the orientation and frequency data to understand the underlying geological processes and structures. Here's how Rose diagrams correlate with specific geological features:

1. Fractures and Joints:

i. Correlation: The directions with the highest frequency in the Rose diagram correspond to the predominant orientations of fractures and joints.

ii. Geological Implication: These orientations can indicate the stress fields and tectonic forces that created the fractures. For example, a predominance of north-south orientations might suggest a specific tectonic regime.

2. Faults:

i. Correlation: Rose diagrams can display the orientation of fault lines in a given area.

ii. Geological Implication: The orientations help identify the type of faulting (e.g. strike-slip, normal, reverse) and the principal stress directions during fault formation.

3. Foliation and Lineation:

i. Correlation: When applied to foliations (planar features) and lineations (linear features), Rose diagrams highlight the dominant orientations.

ii. Geological Implication: This can provide insights into the deformation history and metamorphic processes affecting the rock units.

4. Sedimentary Structures:

i. Correlation: Rose diagrams are used to analyze the orientation of cross-beds, ripple marks, and other sedimentary structures.

ii. Geological Implication: The dominant directions often indicate the paleocurrent directions, helping to reconstruct ancient depositional environments.

5. Veins and Dikes:

i. Correlation: Rose diagrams can show the orientations of veins and dikes within a rock body.

ii. Geological Implication: The data can reveal the pathways of mineralizing fluids and magmatic intrusions, as well as the stress regime at the time of their formation.

6. Geomechanical Analysis:

i. Correlation: In engineering geology, Rose diagrams can be used to understand the orientation of discontinuities that might affect rock stability.

ii. Geological Implication: This information is critical for designing stable excavations, tunnels, and foundations.

Example Correlations

1. Fracture Patterns in a Quarry:

i. Rose Diagram: Shows a dominant orientation of 90°-270°.

ii. Geological Feature: Indicates a major set of east-west trending fractures, possibly due to regional compressive stress.

2. Paleocurrent Directions in a Sedimentary Basin:

i. Rose Diagram: Displays multiple peaks indicating currents flowing from the northeast and southeast.

ii. Geological Feature: Suggests a deltaic environment with sediments transported by rivers flowing from these directions.

3.2 Advantages and limitations of Rose Diagrams in Geological Structures

Advantages

1. Visual Representation: Rose diagrams provide a clear and intuitive visual representation of the orientation of geological structures such as joints, faults, and lineations.

2. Pattern Recognition: They help in identifying patterns and trends in data, which can be crucial for geological interpretations.

3. Directional Data Analysis: Useful for analyzing directional data, such as wind directions, paleocurrents, and stress fields.

4. Comparison: Allow for easy comparison between different datasets or different geological features within the same dataset.

5. Data Summarization: Summarize large amounts of orientation data in a single, comprehensive plot.

6. Quantitative Analysis: Facilitate quantitative analysis of the frequency of occurrences in different directions.

7. Communication: Enhance communication of complex geological data to non-specialists through an easily understandable format.

Limitations of Rose Diagrams

1. Data Overlap: Overlapping of data points can obscure details and make interpretation difficult.

2. Resolution Issues: The resolution of the diagram depends on the chosen bin size, which can affect the accuracy and clarity of the displayed information.

3. Subjectivity: The interpretation of rose diagrams can be somewhat subjective, depending on how the data is grouped and displayed.

4. Data Representation: Can misrepresent data if not properly scaled or if the bin size is inappropriate for the dataset.

5. Limited to Planar Data: Primarily effective for planar data; not suitable for three-dimensional data without additional processing.

6. .Simplification: Simplifies complex geological data, which can sometimes lead to loss of important nuances.

7. .Circular Histogram Limitations: Similar to limitations of circular histograms, such as issues with binning and angular data treatment.

3.3 Procedures For Creating Rose Diagrams

3.3.1 Data Collection for Creating Rose Diagrams

Field Techniques for Measuring Orientation of Geological Features

I. Strike and Dip Measurements:

Instruments Used:

i. Brunton Compass: A highly accurate compass used by geologists for measuring the strike and dip of rock layers. It helps in determining the orientation of planar features like bedding planes, faults, and joints.

ii. Clinometer: Often integrated into the Brunton compass, this instrument measures the angle of dip.

Procedure:

i. Strike: Place the edge of the compass along the line of the feature. Rotate the compass until the bubble level is centered to determine the strike, which is the compass direction of a horizontal line on the plane.

ii. Dip: Measure the maximum angle of descent of the plane relative to the horizontal using the clinometer.

2. Measuring Lineations:

Instruments Used:

i. Geological Hammer: Used to expose fresh surfaces or align the compass.

Compass with Sighting Device: For accurate measurement of linear features such as mineral alignments or fold axes.

Procedure:

Align the sighting device with the linear feature and read the azimuth. The plunge can be measured with the clinometer.

3. Recording Fault Data:

Instruments Used:

Fault-Gouge and Slickensides Analysis Tools: Tools to examine the characteristics of the fault surface.

Field Notebooks and Cameras: For detailed recording and visual documentation.

Procedure:

Measure the orientation of the fault plane and any linear features like slickensides using the compass.

Document the sense of movement, dip direction, and angle.

4. Measuring Joint Sets:

Instruments Used:

Joint Measuring Templates: Predefined templates to record joint orientations systematically.

Protractors and Rulers: To measure angles and distances on exposed rock surfaces.

Procedure:

Use the templates to trace the orientation of joints.

Measure the spacing, aperture, and orientation relative to other features.

3.3.2 Tools and Instruments in Data Collection

1. GPS Devices:

Purpose: To record the precise location of measurements, ensuring accurate mapping and correlation of data points.

Usage: Marking the location of each measurement for integration into geological maps and databases.

2. Digital Clinometers:

Purpose: For more accurate and faster measurements of dip angles.

Usage: Often connected to mobile devices for immediate data recording and analysis.

3. Total Station and Theodolites:

Purpose: High-precision instruments for surveying and measuring angles in the field.

Usage: Used in creating detailed topographic maps and for aligning geological features accurately in three dimensions.

4.0 Case History

Case Study of Parts of Southern Bida Basin, Nigeria and the Surrounding Basement Rocks (Megwara & Udensi 2014). Structural Analysis Using Aeromagnetic Data-Case Study of Parts of Southern Bida Basin, Nigeria and the Surrounding Basement Rocks.)

4.1 Background

The southern Bida basin section of the study area (Figure 2) is Cretaceous (136^{o}65 Ma) and forms part of the larger Bida basin. In the basin section, the Pre-Cambrian (4600^{o}570 Ma) to lower Paleozoic (570^{o}500 Ma) basement gneisses and schist is overlain by alternating shales, siltstones, claystones and sandstones (Obaje, 2009; Obaje et al., 2011). The sandstones (Nupe) consist of slightly cemented fine to coarse grained sandstones and siltstones with interbedded thin beds of carbonaceous shales and clays. The basin consists of the basal Lokoja Formation, overlain by the Patti Formation and capped by the Agbaja Formation. The basal Lokoja Formation is a sequence of matrix supported conglomerates and sandstones overlying the Pre-Cambrian to lower Paleozoic basement. Depositional environments are predominantly within fluvial systems of a continental setting. Patti Formation consists of dark grey carbonaceous shales; mudstones and siltstones representing flood plains to shallow marine deposits with likely organic rich intervals. Agbaja Formation is made up of ferruginised oolitic and kaolinitic mudstone of a marginal environment (Akande et al., 2005). The surrounding Pre-Cambrian basement rocks consist of a suit of Pre-Cambrian gneisses, migmatites and metasedimentary schist crosscut by intrusive granitoids (Shekwolo, 1992). The Pre-Cambrian basement rocks experienced severe deformation during the late Pan-African phase, and developed megashears that were reactivated during the late Campanian-Maastrichtian (Braide, 1990). The gneisses and metasedimentary schist are found mostly as flat lying outcrops (Shekwolo, 1992).

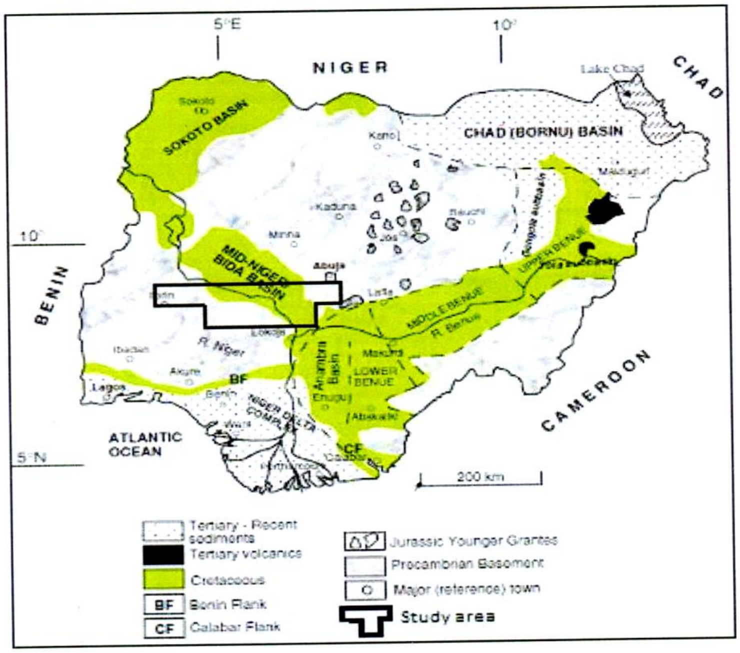

Figure 7: Geological map of Nigeria showing the study area (Megwara & Udensi 2014; Obaje, 2009)

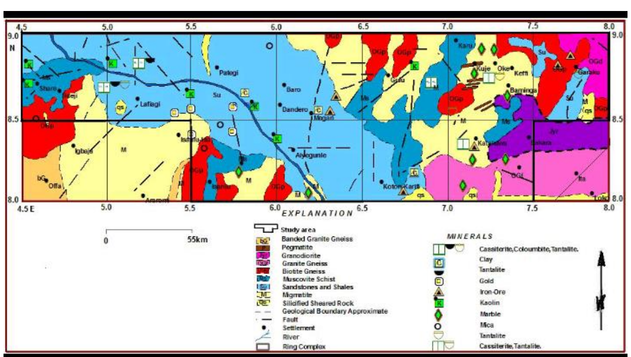

Fig 8:Geological and mineral map of the survey area (Megwara & Udensi 2014). Structural Analysis Using Aeromagnetic Data-Case Study of Parts of Southern Bida Basin, Nigeria and the Surrounding Basement Rocks. Earth Science Research)

4.2 Methodology

i. Regional residual separation: The study area does not have complex geology and it has spatial extent, thus, it seemed plausible to assume that the regional field is a first order polynomial surface. The regional magnetic field data was separated from the residual magnetic field data using the Robust Polynomial Fitting method. Residual magnetic field data was obtained as the deviations of the fitted plane surface from the total magnetic intensity.

ii. Werner deconvolution: The equations for the total magnetic field due to thin sheets and the edges of a thick body (Werner equations) is used to compute the depth to the top, susceptibility contrast, and the dip of these features from a given total magnetic field profile. The term Werner deconvolution refers to a set of algorithms whose feature is the linearization of a two-dimensional (2–D) inverse problem for the parameters of a magnetic dike or contact by clearing the denominators of the rational functions that describe their anomalies (Hansen & Simonds, 1993; Kilty, 1983).

iii. Euler deconvolution: The Euler deconvolution method is based on Euler's homogeneity equation; an equation that relates the magnetic field and its gradient components to the location of the source, with the degree of homogeneity n, which may be interpreted as a structural index (Thompson, 1982). The structural index is a measure of the rate of change with distance of a field. For example, in a magnetic field a narrow two dimensional dike has a structural index of n = 1, while a vertical pipe gives n = 2. A solution is recorded if the depth uncertainty of the estimated depth is less than a specified tolerance and the solution is within a limiting distance of the centre of the data window. When the process is stopped, a database file containing the depth solution is obtained as output.

iv. Linear structures mapping using Landsat data: Landsat Thematic Mapper (Landsat-TM) imagery covering the survey area was obtained from the Global Land Cover Facility and used to map linear features in the study area. The raw data was geo-referenced using the coordinates of the topographic sheets covering the research area. Image enhancement operations carried out include contrast stretching, spatial filtering and edge detection, which were done to enhance sharpness of the satellite image for better visual interpretation, reduce noise in the image and aid structural interpretation.

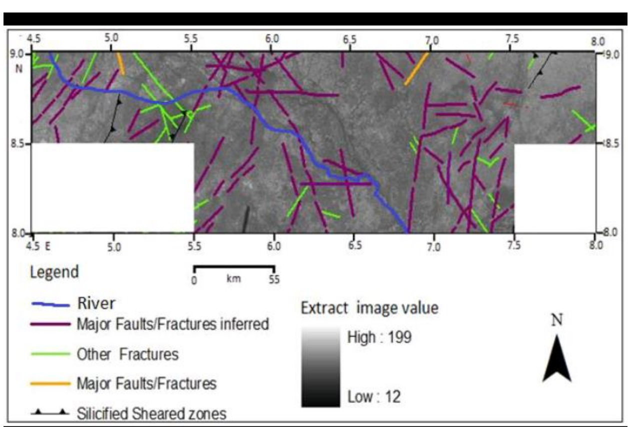

Fig 9: Lineaments generated from Landsat thematic mapper image of the study area: highlights eastwest, northwest southeast and northeast southwest directions of linear structures (adapted from John U. Megwara & Emmanuel E. Udensi (2014).

Structural Analysis Using Aeromagnetic Data-Case Study of Parts of Southern Bida Basin, Nigeria and the Surrounding Basement Rocks. Earth Science Research).

v. Rose Diagram construction: the rose diagram of lineaments in the study area was generated from Landsat data, the Rose diagram generated from Landsat data; also highlights a dominant north northeast – south southwest direction of linear structures.

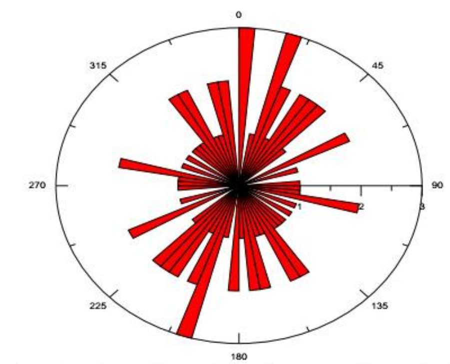

Fig 10: Rose diagram of lineaments in the study area generated from Landsat data (Megwara & Udensi 2014).

Structural Analysis Using Aeromagnetic Data-Case Study of Parts of Southern Bida Basin, Nigeria and the Surrounding Basement Rocks. Earth Science Research).

4.3 Results and Discussion

The general trending fabric of TMI anomalies is the northeast-southwest direction. The TMI values range from a minimum value of 7630 nano tesla to a maximum value of 7930 nano tesla. Since sedimentary rocks are characterized by low susceptibility values, a northeast-southwest trending magnetic high anomaly occurring at the central part of the basin section results from underlying magnetic basement rocks. The residual magnetic field indicates a general trending fabric of anomalies in the northeast-southwest direction, having magnetic values ranging from a minimum of 458.15 nano tesla to a maximum of 129.12 nano tesla. The survey area is not vast in expanse; both first and second order regional magnetic field contours are linear; a first order regional magnetic field was adopted for this study. The regional magnetic field shows contour lines trending in a dominant northwest southeast direction; and this is in agreement with trend of the basin. There is no significant difference between the features of both first and second order residual magnetic field anomalies; a first order residual magnetic field was adopted for this study. Rivers courses in the survey area are structurally controlled; trending mainly in the northwest southeast and northeast southwest directions. The Rose diagram generated from Landsat data; also highlights a dominant north northeast south southwest direction of linear structures.

5.0 Conclusion

Rose diagrams are graphical tools used in geology to represent the orientation of geological structures, such as fractures, joints, or sedimentary layers. They display the frequency of features' orientations as petals radiating from a central point, with petal length proportional to frequency. Principles include data collection (measuring strike or dip angles), data plotting (grouping orientations into bins), and diagram interpretation (identifying dominant directions and patterns). Procedures involve accurate field measurements, statistical binning of orientation data, and plotting using specialized software or manual methods. Rose diagrams help visualize structural trends and geological processes.

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