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Assessment of Deformation Patterns on Pan-African Basement Rocks of Keffi Area (Sheet 208NE), Central Nigeria

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Abstract- ***The study analyzed field structural measurements and aeromagnetic data over parts of Keffi, central Nigeria, to assess surface deformational signatures and deep buried lineaments associated with the Pan-African structural system. The lithomorphology of the area reveals a cluster of reconstituted geomorphological terrains, initiated by the collage of multiple tectono-deformational dynamics. These are characterized by polydeformed phyllitic schist, biotite granite with patches of granodiorite, porphyroblastic and migmatized gneisses, among other minor lithologies, all of which formed primarily during the Pan-African tectonics. The analysis of aeromagnetic data shows lineaments that are linear to curvilinear, predominantly in NE-SW directions, with a marginal NW-SE trend. The NE-SW lineaments exhibit significant lengths, measured in thousands of meters, and crisscross other trends. These lineaments are correlated with trends of structurally controlled pegmatite, stretched phenocrysts, xenoliths, and magmatic enclaves on granitic plutons. Field data reveals ductility defined by foliation, lineation, and minor shear zones that cluster around NW-SE, NE-SW, and a faintly superimposed E-W trend. These structures are defined by concordant and discordant mineral growth and the transposition of stratigraphic fabrics. The intensity of the deformation varies, ranging from mere schistosity to well-developed gneissoid structures in some components of the rocks. Foliation displays polyphase deformation and reveals lateral disparity, indicating a bulk directional rock deformation pattern parallel to plutons and gradational around contacts with gneisses. Meanwhile, lineation shows a single-phase deformation predominantly in the NE-SW direction. The brittle system exhibits NE-SW, NW-SE, and E-W trends of fracture surfaces defined by a sinistral strike-slip displacement system. This deformation pattern occurred during the later stage of an active deformational phase and was accompanied by the release of remnant fluids trapped within the cooling granitic rocks, as well as recovery attempts of the rocks under plastic stresses. This phase is chronologically the most recent in the deformation of the rocks in this area. The Pan-African tectonics in this region are considered to be interactively pervasive in nature and have significantly influenced magmatic and thermometamorphic activities.***

Indexed Terms- Pan African Tectonics, Basement Complex, Deformation

I. INTRODUCTION

1. Regional Tectonic Setting

The study area extends approximately 900 km² and lies between latitudes 8° 45′ - 9° 00′ N and longitudes 7° 45′ - 8° 00′ E in central Nigeria. It occupies a strategic location in the regional tectonic setting owing to Ferre et al. (1996) Western Nigerian Terrane (WNT) and Eastern Nigerian Terrane (ENT) which made it a tectonic transient site sandwiched between two regions with contrasted geological phenomena. The structural system of this area contributed significantly to general tectonic system of central Nigeria that does not only show inferences on mineral deposits but also on seismic activity (Goki et al., 2020; David et al., 2022; Goki and Umbugadu, 2022). Thus, understanding the nature and pattern of these deformations will provide a better understanding of the geologic environment, as it relates to the search for natural resources within the Nigerian basement complex.

The rocks of this area belong to an imaginary regional basement complex slab, widely considered to be part of the Northcentral Basement Complex block. It has been generally distinguished from other geological environments by distinctive, though arguably lithostratigraphic and metamorphic grades, as well as local structural and deformational histories. Its formation may likely not differ from the Ajibade et al. (1987) collision of the passive West African Craton and the active Congo Craton that birthed the Trans-Saharan belt (Fig. 1). This belt is reasonably tied to the Pan-African tectonics (750 and 500 Ma) (Booth, 1991; Ferre et al., 2002; Caby, 2003), an event characterized by terrane amalgamation, among many other geological events typical of collisional plate interactions (Black et al., 1994; Ferre´ et al., 1996), including high-grade metamorphism, multiple structural deformations characterized by mega fault systems and thrust-nappe development (Caby & Boesse, 2001). Polydeformed and, in some places, glacially disposed rocks of the migmatitic and banded gneiss complex, comingled with varied grades of schistose rocks and numerous granitic intrusions, are the major rock types that characterize the belt (Burke et al., 1976; Black & Liégeois, 1993; Deynoux et al., 2006).

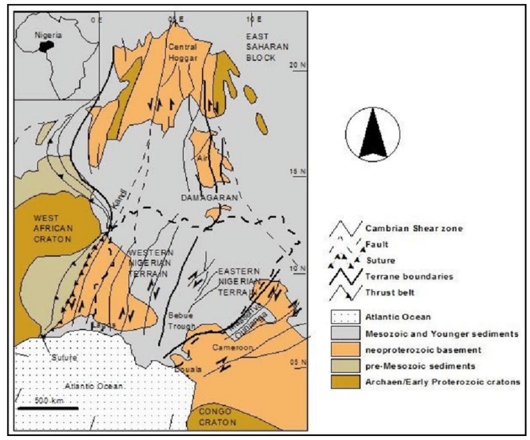

Fig. 1: Geological sketch map of the Hoggar–Aır–Nigeria province showing the Neoproterozoic Trans-Saharan belt resulting from terrane amalgamation between the cratons of West Africa and Congo and the East Saharan block (Ferré, et al, 2002)

II. METHODS

Prior to field mapping, aeromagnetic data for the area was processed and used to enhance structural and regional patterns. Generally, at low magnetic latitudes, correlating anomaly maxima and disposed magnetic sources are often difficult to link. Tilt derivatives tend to coincide with local maxima in the original input grid above magnetic sources. This technique has been useful in enhancing linear trends with specific spatial orientation including those of low amplitude as it acts as a type of automatic gain control. The TMI map was subjected to further enhancement and the result is presented as a tilt derivative map.

Field mapping was designed to get data on the physical characteristics of lithology and the overall nature and pattern of the deformation on a scale of 1:50,000. Field structural features such as faults, joints, lineation, foliation, folds, cleavages, banding, layering, and flows mostly known to have close affinity with tectonics or direct manifestation of crustal deformation patterns played significant roles in this study. These features were mapped, measured and characterized. The structural patterns were plotted using Stereoplots.

III. LITHO-MORPHOLOGY OF THE STUDY AREA

The study area comprises composite lithological outcrops typical of the Nigerian Basement Complex (NBC) rocks; undoubtedly related primarily by prehistoric geomorphological dynamics and/or tectono-deformational history. Most of these perceived relationships are driven by the cumulative effects of multiple tectonic events that defined the evolution of the Nigerian Basement Complex. Generally, the area is characterized by isolated high-standing rocks of the granitic suite emplaced amidst low-lying plains of migmatite-gneiss and schist complex. The plutons are largely biotite granite but show traces of transitional granodioritic composition. Four outcrops are conspicuous and varied in vertical and lateral extent, as well as local internal variation in petrophysical characteristics. The plains of the plutons and granitic gneisses are characterized by phyllitic schist and migmatitic gneisses (Fig. 2). The phyllitic Schist occurs generally as finely-grained with glossy reflection to the West of the study area seemingly caused by dominant presence of more biotite mica; and pale to the east with presence of more muscovite. Other minerals include quartz and feldspar of higher proportions. The rock is bedded to the West and resembles beds most likely to have been inherited from its protolith as evidenced by the localization of fracture surfaces. The rock exhibits no dipping stratigraphic foliation whose trend coincided parallel with the alternating bands of the compositional variation in the rock except where lithologically controlled ptymgtitic vein cut across both bedding plains and the foliations. Lineation is defined by pockets of strained blasts in no definite pattern and plunges between 5º - 20º. Others are mostly defined by patches of crystalline basement that seem to be inclusion in the rock. They are stretched along the foliation and bedding plains (plate 1a). Migmatized Biotite-Hornblende Gneiss (MBHG) dominantly occupies the NW region of the study area and continues into a more granitic-dominated area. The rocks vary between biotite, hornblende gneisses (BHG), and migmatized gneiss (MG). The BHG is dominant in the group and is characterized by a series of segregated mineral bands typical of the NBC gneisses. They developed in minor proportion within Keffi town but became prominent from the plains of Maloney hills and spread toward Jigwada to the north and Abuja to the West. The rocks are usually stretched mostly in the NE-SW direction as represented by numerous boudinage of quartzofeldspathic compositions (Plate 1c).

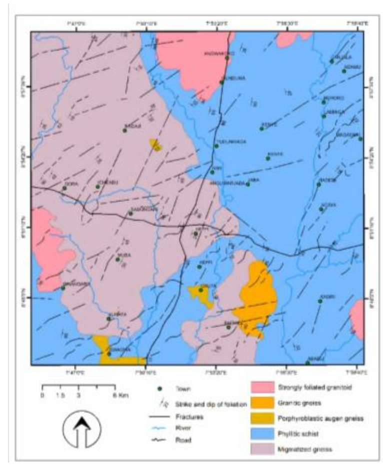

Fig 2: Simplified lithostructural map of the study area. The map was drawn based on field observations and the lithological boundaries was a computation radiometric responses, while the superimposed lineaments were derived from aeromagnetic

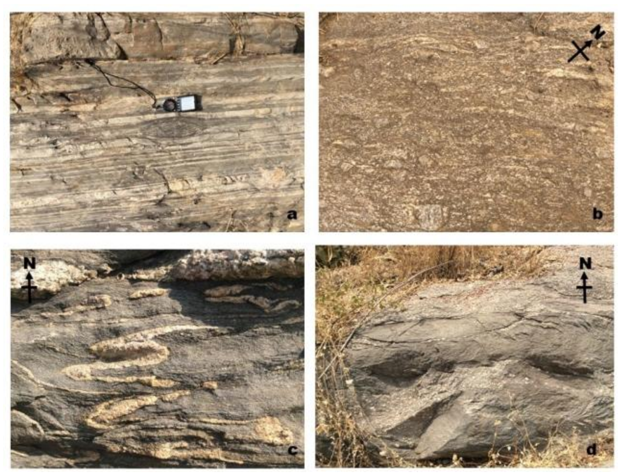

Plate 1: collection of rocks distribution of the study area. (a) phyllitic schist (b) porphyroblastic gneiss (c) migmatized gneiss (d) contact interaction between magmatism gneiss

These rocks are found to harbor patches of inter-fingered phyllitic schist (Plate) sometimes homogenously deformed by brittle systems usually infilled by pegmatitic materials. MG occurs in small proportion and commonly found around area of massive thermal activities associated with large 'pegmatitic granite'. There are signatures of partial fusion thought to have stemmed from the reaction of pervaded thermal fluid into the BHG. This resulted in the enfolded streak of quartzofeldspathic materials displayed on the rock (Plate 1c). The rocks of this suite are generally medium to coarse-grained and contain abundant quartz and feldspar.

Porphyroblastic gneiss occurs in the study area as low lying un-foliated metamorphic rock mapped in different locations. Both locations share matching granitic composition and appearances with mineralogy that includes majorly feldspar, quartz, biotite, and hornblende in non-equal proportions. Lineation is dominantly the deformational signatures recorded on the field. However, these varied in trends across each outcrop and are associated with sketchy fracture surfaces on the rock particularly around Gauta town (Plate 1b). These fractures mostly trend in ESE-WNW directions with near-vertical dips in many instances. These structures are commonly infilled by pegmatitic materials in sharp contact. The rock is characterized largely by strongly lineated porphyroblasts set in an uneven proportion of quartz-feldspar groundmass in association with flowage biotite among other minor minerals. On average, the size of the porphyroblasts ranges between 0.5cm and 3cm in stretched directions and about 0.5 and 1cm in width. Around Ungwan Madugu (Plate), stretched lineation and xenoliths predominantly show N-S while the other two locations show NE-SW trends. The xenoliths are also deformed and lightly resorbed in a manner similar to the host rock mineral porphyroblasts. Tanko, et al, (2015) reported the Peraluminous bulk composition of the rocks; which is coincidently the known rock chemistry associated with the magmatism of Pan-African collisional granitoids. Thus, it may not be speculative to suggest a protolithic rock that is likely associated with early magmatism of the Pan-African tectonic and the anatectic deformation thereafter.

Other minor lithologies include pegmatite, veinlets of quartz, aplite and quartzofeldspathic dykes. The pegmatite occurs as ridges and veinlets in patterns that are typical of structural controlled emplacement with some crosscutting of the foliation of enclosed rocks. The major ridges are hosted within the NE-SW foliated and migmatized gneisses. Their contacts with the host outcrops are sharp but slight dipping ones were also mapped. Three major pegmatitic trends were mapped on the field corresponding to NW-SE, NE-SW, and others. The NW-SE (315° - 344°) trends mostly occur in ridges with an average estimated width of between 10 and 20 meters but lack sufficient surface outlook except at a few locations where it outcrops. Pegmatites of this category are devoid of magma involvement but rather significantly show evidence of hydrothermal mineralization of mineable muscovite, Lapidolite, feldspars, tourmaline, and beryl among others. It is hosted dominantly within the southern limit of migmatized biotite-hornblende gneisses and occurs in veinlets mostly between 1-2 inches in width within phyllitic schist and granitoids. There seems to be a distinctive variation in the formational history of structures that controlled pegmatite emplacement and that of the hosted rocks, suggesting two unalike fractural episodes. Most of the ridges are currently been mined by artisanal miners around Betti, Angwan Chediya, Rugan Sadauna and Angwan Maikai. The NE-SW (035°-050°) pegmatite occurs largely as massive ridges with sufficient surface outcrops dominantly around Bagaji, Gora, Yelwa Salua and Rimi all within the migmatized gneisses-dominated region. This set of pegmatite constitutes a major source of thermal injections suspected to have contributed to the localized migmatization of the gneisses. They bear feldspar, quartz, mica, and hornblende in non-mineable proportions and varied in grain size distribution significantly with the aforementioned. Feldspar occurred as phenocrysts with maximum grain estimated at between 5-7cm and biotite and tourmaline displaying lenticular grain shapes in nature. They display sheet emplacement and their trends correspond with stretched porphyries on the pluton. The other sets of pegmatite are those whose trends are within E-W and N-S. The E-W trends occur up to one meter in width and are mostly pervasive. Evidence of gradational margins was noticed and thought to have been caused by coherently high-temperature solvent fluids disseminating through the host rocks. This process also created mutilation in the physiochemical properties of host rocks. They are common on porphyroblastic gneiss and plutons and are dominated compositionally by quartz, with little of feldspar and a relative trace of muscovite while biotite was absent. The N-S trends are relatively minor and commonly occur as veinlets on plutons and phyllitic schist and are in close association with aplitic veins. Quartz vein occurs in lesser proportion comparatively with others and shows a crescent outlook taking the shape of the Kokona pluton. Aplite veins were mostly mapped on the pluton and are the more affected by the structural disposition. Quartzofeldspathic veins are common of the veinlets after pegmatitic. Most of these veinlets were mapped on almost all outcrops with some crosscutting two rock types mostly around plutons.

IV. RESULTS AND DISCUSSION

4.1. Aeromagnetic data

The aeromagnetic data of the area is presented as a Total Magnetic Intensity (TMI) map (Fig. 2). The intensity map is grouped into three broad bands based on their amplitude. A qualitative evaluation of these groups reveals significant variations in magnetic intensity, indicative of basement topographic variations. This category shows magnetic responses in the range of about 20nT – 52nT. It has a dominant presence in the south to southwestern region, spreading in elongated patches amidst other highly superimposed anomalies to the east and reasonably to the northern region. This set of signatures correlates reasonably with the plain of the Maloney hills and areas associated with granitic plutons. This anomaly is considered the magnetic background value of the area.

The second category occurs in lesser proportions, with magnetic values in the range of -182nT to 19.9nT, represented by a blue color code. This category corresponds with low-lying porphyroblastic gneiss and pegmatitic veins. The evaluation of these categories provides insights into the magnetic and geological characteristics of the study area, indicating variations in basement topography and the presence of different geological formations. The third category is represented dominantly by the reddish color northeast trending anomaly. It has magnetic value between 52nT and 255nT. This category superimposes the earlier mentioned anomalies in some location with straight and sharply terminated contact suggesting structurally controlled boundaries. This suggests that the TMI anomalies are strongly influenced by the regional tectonic.

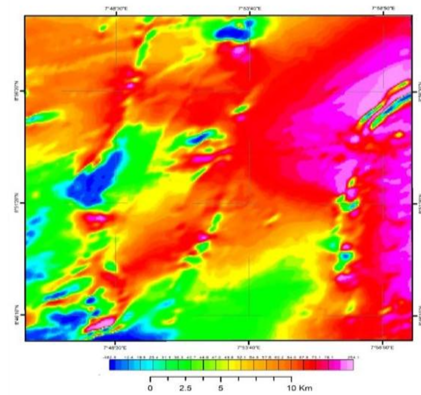

Fig. 2: Total Magnetic Intensity map of study area. Note: the colors variation represents the grouping of magnetic anomalies

The map (Fig. 3) shows two elongated classes of magnetic anomalies both showing dominant NE-SW and marginal NW-SE trends. These anomalies display negative polarity which seemingly denotes voided buried fracture surfaces or fracture surfaces infilled with materials of poor magnetic properties. Similarly, the positive anomalies show a narrow elongated pattern and compressed anomalous bodies. The narrow and elongated tally with some of the negative anomalies in outlook and lateral extents thus, suggesting structural surfaces healed by magnetically rich properties, while the compressed bodies are indicative of lithological controlled boundaries. Generally, the constricted pattern of the anomalies, the strength of the magnetic field, and the lateral extent of these features correspond to deep-seated signatures most likely resulting from geological lineaments that acted as a magmatic conduit during the emplacement of some plutons and some dykes alike

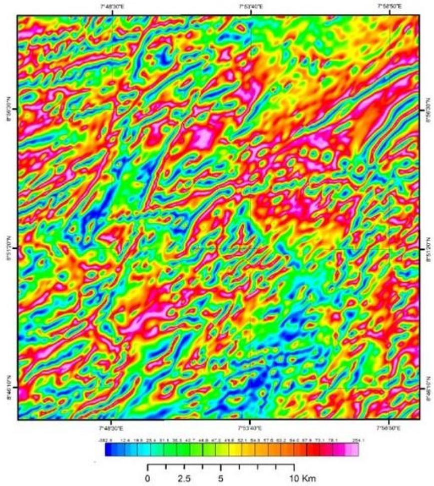

Fig. 3: Tilt derivative map of the study area

4.3. Aeromagnetic Lineaments

Aeromagnetic studies are widely known geophysical tools whose applications span a wide range of geological studies, particularly in litho-structural and deep-seated crustal tectonic studies (Al-Zoubi and Avraham 2002; Hatcher, et al, 1981; Al Amoush, et al, 2013). Its application in these studies is basically to help delineate as well as check the continuity of the subsurface lineament masked by denudation processes. The result of the aeromagnetic evaluation is presented as a Total Magnetic Intensity map (TMI). The map was further subjected to signal analysis, particularly tilt derivatives.

About 120 lineaments were extracted from the further enhancements of aeromagnetic data using tilt derivative (Fig. 4). These sets of data represent both superficial and deep-seated structures mostly masked by loose soil and vegetation. They occur in linear to curvilinear outlooks dominantly in NE-SW trends and a marginal NW-SE direction. These trend correlates well with the trends of fractures observed on the lithologies; this therefore shows that the aeromagnetic lineaments of the study area are geological deep-seated continuous fractures. The NE-SW lineament sets are the most frequent and show significant extent measured in thousands of meters, and have been seen to have cut across the other trends. They represent the deep-seated extensional fractures and these trends correlate well with the alignment of plutons, stretched phenocrysts, xenoliths, and magmatic enclaves. Other lineaments within this set displayed a tilt toward the ENE-WSW direction and are related to the NW-SE trend occurring largely earlier than the NE-SW but are remolded by the activities related to the latter.

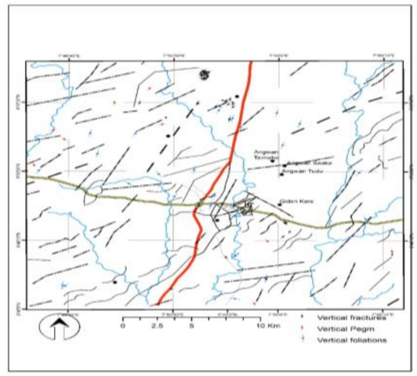

Fig. 4: Distribution of Aeromagnetic Lineament of the study area

4.4 Field Structural Deformation

The deformational study of the area was carried out systematically on a scale of 1:50,000 using collaborative data sets generated from direct field measurements. These processes provided data sets that are comparable in direction with aeromagnetic lineaments even though they varies in significance. Generally, two deformational styles (ductile and brittle) were studied across the lithologies; both defined the dynamic interaction between deformation, crustal reactions, and emplacement. However, for convenience, each structure is discussed as mapped.

4. 4.1 Ductile Deformation

4.4.1.1 Foliation

The ductility in the deformational pattern of the study area is defined by the behavior of foliation and lineation patterns. The foliations are defined by the development of both metamorphic fabrics generated by mineral growth and transposition of stratigraphic fabrics. This data shows the relationship that is both concordant and discordant in instances suggesting deformational fabrics that are sequential in history. Foliation extends in intensity from a mere to a well-developed schistosity among metasedimentary rocks to the banding gneisses and development of gneissiod structures in some components of the granitic rocks. The metamorphic rocks dominantly show poly-phased planar surfaces that signify multiple phases of ductile activity that are not necessarily of great age differences but rather related to adjustment in successive events particularly those developed around the pluton contact zone. The phyllite shows lateral foliation disparity that apparently reveals bulk directional rock deformation patterns parallel to plutons and gradational around contacts with orthogneisses.

Generally, foliation clusters around trends that correspond to NW-SE (D1), NE-SW (D2), and a ghostly superimposed E-W (D3); and each of these trends is knotted to a deformational phase (Fig. 5). D1 has a dominant streak in the southern portion of the study area with a NW – SE. This cluster is relatively the oldest recorded deformation in the area. It has less proportion and corresponds largely with trends of mineralized pegmatite. They are cut and twisted in many locations where foliations of the NE-SW trend show great dominance. This cluster obviously predates the NE-SW trends and contributed to the development of planes of weaknesses in the basement complex.

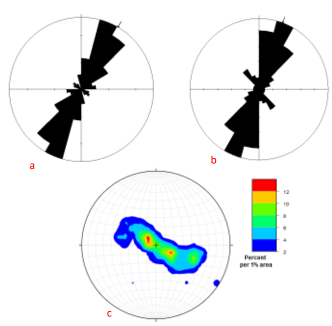

Fig. 5: plots foliation trends in the study area (a) Ross plot of strike and dip of dipping planes on gneisses and schists (b) Ross plot of strike and vertically dipping planes on gneisses and schists (c) Contour plot of strike and dip of foliation planes measured on gneisses and schists in the area

D2 has NE-SW trends and was mapped across all metamorphic rocks in the study area. This trend corresponds to the regional foliation phase generally reported across the Nigerian basement complex and closely related in timing with the emplacement of the plutons. Where it showed an area of influence, it contributed significantly to the development of crenulation on the rocks. This trend is pervaded, extends longer in length, and ranges between near horizontal planes to vertically dipping sets to NW and SE at close proximity with the plutons and prominent around Maloney hills. The NE-SW trends were truncated and crisscrossed by superficially grumbled magmatic dykes of mafic and pegmatitic composition around plutons contact. Averagely, the foliation trend ranges between 010° - 056° and marginally 216° - 358° and coincides comparably with the longer axis of phenocryst, maximum stretches of xenoliths and magmatic enclaves, and the geometry of some plutons. This foliation plane represents a regional ductile deformation regime that is likely contemporary with magmatic emplacement episodes. D3 has E-W trends and occurs at an angle perpendicular to the pluton at close proximity and is characterized by short foliation length mostly of thickened biotite flakes and reworked quartz and feldspar mineral grains lineation. They are obvious products of the realignment of the NW-SE and NE-SW trends generated by mutilation in the tectonic pattern. The formation of this foliation trend was synchronous with folding activity. The timing is during active emplacement disposition where further space was needed. The formation of the vertically dipping N-S trend foliation set cloud not be isolated as they were comingled with both aforementioned trends however, they are largely linked with a near cold state extensional deformation that probably resulted in the formation of the vertical dipping N-S joints planes on the plutons

3.4.1.2 Lineation

The rocks of the study area showcase a NE-SW lone-phased lineation trend defined by stretched Boudin's line, elongated mineral grains, alignment of phenocrysts, magmatic enclaves, and xenolith (Fig.6). This trend also corresponds with D2 foliation planes and some jointing system on the rocks. On the pluton, lineation is recorded on the feldspar-rich porphyries and stretched xenoliths and enclaves preserved on the rock. They are oriented along the NE (012° - 064°) axis of the pluton with complementary pockets of SE and SW trends, particularly on Gunduma and Dagwal. This lineation pattern is reflective of a viscous state pluton response to a relatively single-phased applied stress field owing to deficient records of possible porphyries rotation amidst the melts sequent to total solidification. The pockets of minor trends registered may likely be related to some chamber-magma dynamics. The superficial geometry of the porphyries plunges between 10° and 40° but dominantly around 20° which tallied with the two-stage vertical reverse faulting caused plunges reported on the NE-SW trending Maloney Hills (Goki & Umbugadu, 2022).

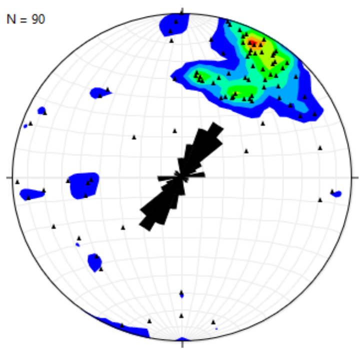

Fig. 6: Plot of trend and plunges of lineation. The general orientation is indicated by the rossete plot

3.4.1.3 Minor shear zone and folds

Field evaluation did not show the existence of regional extent shear zones and folding within the study area. However, evidence of minor zones of heterogeneous strain accumulation and pockets of pulverized minerals crystal zones are prominent (Plate 2). The shear zones commonly developed on phyllitic schist and the plutons. Those of the plutons are largely attributed to solid-state deformations that are typical of temperatures below 500°C (Gapais, 1989), while those associated with phyllitic schist are likely remnants of constricted strain. Also, two minor fold types (flow and ptygmatic folds) were mapped on the field. Both were found around the aureole at the largest width (short axis of the ellipsoidal shape) of the pluton which seems to be the direction of maximum pressure during active emplacement setting. The fold axis paralleled the wall of the pluton and seems to be associated with the formation of the marginally E-W trends foliation planes. They are expected to have been formed during further inflation of the pluton chambers in a most likely 'push-apart' scenario after outgrowing its pre-emplacement spaces

Plate 2: Relict of ductile deformation of the rocks of the study area. (a) Remnant of folding on phyllitic schist around Gwandara pluton. (b) Constricted shearing on the Gwandara pluton. (c) Leucocratic vein wobbled by shearing into near boundins on migmatized gneiss

4.4.2 Brittle Deformation

Fractures are groups of structures that define brittle deformation and are represented by varied degrees of lineaments, faults, and joint systems. These surfaces are grouped into wetted and dried fracture surfaces. The wetted are those surfaces characterized by infilled of quartzofeldspathic, quartz, or pegmatitic veinlets (Plate 3). Other includes aplitic veins and minor mafic dykes. They are associated with both joints and minor faults in the area. The wet joints were identified with consistent trends corresponding to NE- SW, NW-SE, and E-W trends, while the dry joints share similarities in trends but seem longer in extent than the wetted ones. They are common on the plutons and mostly are associated with exfoliation. The NE-SW joints pattern is mostly a wetted group characterized by continuously slim linear to curvilinear surfaces common on plutons and occurs in a group of closely spaced joints that give some outcrops a narrow ridges-like outlook. The E-W joints group is poorly developed and is mostly dried. They were recorded only on Dagwal among plutons but also show localized and closely spaced patterns to form zones of 'fracture cleavage' on the phyllitic schist. They are associated with pure quartz crystallization. NW-SE trend joints are generally pronounced and commonly associated with pegmatite.

The fault of this group shows records of considerable displacement ranging in centimeters to meters in some locations and is typified by sinistral strike-slip faults. This structural relationship occurred across all lithologies but was conspicuous on plutons and granitic gneiss. They are mostly wetted with similar material earlier mentioned and are likely to have occurred in a later stage of an active deformational phase accompanied by releases of remnant fluids trapped within the cooling rocks, and/or recovering attempts of rocks under plastic stresses. They occurred in trends similar to the wetted joints but the N-S trend predominates. The dried fault surfaces also share similarities with the wetted group but show dominate trends around E-W. They also show considerable displacement but their planes are only filled with debris. They likely occurred in a passively stable post-tectonic environment under the influence of activities related to isostasy and denudation processes that defined the topography of the area. This is chronologically the most recent phase of deformation of rocks around this area.

Plate 3: Distribution of fracture surfaces (a & c) wetted strike-slip displacement healed by quartzofeldspathic material (b) dry strike-slip minor fault on Dagwal Pluton (d) Array of wetted joint system on Gunduma pluton

V. DISCUSSION

The structural analysis of faults and lineaments within the study area reveals several key insights into the geological history and processes that have shaped the region. The identification of sinistral strike-slip faults, both wet and dry, in various lithologies and their dominant trends suggest a complex deformational history influenced by varying tectonic forces and environmental conditions.

The wet faults, typified by their similar material composition and occurrence within cooling rocks, indicate an active deformational phase characterized by the release of remnant fluids and plastic stress recovery. The predominance of N-S trends within these faults highlights a significant directional influence during this phase. On the other hand, the dried fault surfaces, with their E-W dominant trends and debris-filled planes, suggest a more passive post-tectonic environment. This phase is likely influenced by isostasy and denudation processes, which have played a crucial role in defining the topography of the area.

The aeromagnetic lineaments further complement the structural findings by revealing deep-seated extensional fractures predominantly in NE-SW and marginal NW-SE orientations. The correlation of these trends with lithological features such as plutons, phenocrysts, xenoliths, and magmatic enclaves underscores the significance of these lineaments in understanding the geological continuity and extent of fractures within the region. The NE-SW lineament sets, being the most frequent and extensive, highlight the deep-seated tectonic activities that have shaped the region's geological framework.

The presence of wetted joints and dried joints systems, as observed in field occurrences, provides other evidence of the varying environmental conditions and tectonic influences that have affected the region. The NE trending joints on Kokona pluton and the E-W trending quartz-infilling joints reflect the diversity in joint systems and their material compositions. The minor strike-slip faults, both dried and wet, further illustrate the complexity of the faulting mechanisms and their interactions with the surrounding lithologies.

In conclusion, the study of faults and aeromagnetic lineaments within the region offers valuable insights into the tectonic history, deformational phases, and environmental conditions that have influenced the geological evolution of the area. The findings highlight the significance of directional trends, material compositions, and tectonic influences in shaping the structural framework of the region. Further research and analysis are essential to deepen our understanding of these geological processes and their implications for the broader geological context.

CONCLUSION

The study of the structural geology of the area reveals intricate details about the region's tectonic history. The presence of both wet and dry sinistral strike-slip faults with distinct trends and material compositions offers a glimpse into the varying phases of deformation. Aeromagnetic lineaments further highlight the deep-seated extensional fractures and their correlations with lithological features. These findings underscore the significance of directional trends and tectonic activities in shaping the geological framework of the area. Continued research is necessary to explore these processes and their broader implications.

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