Quest Journals
Journal of Research in Environmental and Earth Sciences
Volume 10 ~ Issue 4 (2024) pp: 16-20
ISSN(Online) :2348-2532
www.questjournals.org

Research Paper

Comparing relative strain in Precambrian rocks around Girar using Fry method

Ankita Shrivastava*, A.K. Shandilya
Department of Applied Geology, Dr. Harisingh Gour Vishwavidyalaya, Sagar (M. P.) – 470003
**Corresponding Author*

ABSTRACT: *The finite strain analysis of major rocks deposited at different times in the Bundelkhand craton, around Girar area is done in this work, in order to make a comparison about the strain acquired by them after their deformation. To accomplish the objective of work, Fry method is employed as this approach is procedurally simple and new to the area of study. The lithostratigraphic units on which strain estimation is done are the Fuchsite-bearing quartzite of Mehroni Group (Archean), the Paleoproterozoic Bijawar sandstone and Mesoproterozoic quartz-arenite of Lower Vindhyan in ascending order. The values of aspect ratio (R) of strain ellipse calculated from the Fry plots of Fuchsite quartzite ranges from 2.09-1.588 averaging 1.839. For the Bijawar sandstone, values of R vary between 1.88-1.437 with an average of 1.658 whereas for the Vindhyan rocks R values lies in the range of 1.483-1.192 with an average of 1.365. These values of aspect ratio (R) suggest that the older Mehroni sediments are more strained compared to the Bijawar sandstone while the Vindhyan quartz-arenites are showing least deformation.*
Keywords: Strain analysis, Fry Method, Deformation.

R*eceived 02 Apr., 2024;* ***R****evised 11 Apr., 2024;* ***A****ccepted 13 Apr., 2024*

I. Introduction

Understanding the deformation such as intensity, orientation and amount of strain, experienced by the rocks in an area can easily be done by determining and evaluating the finite strain data. Various methods for determining the amount of strain exist such as Rf/ϕ method (Ramsay, 1967), Fry method (Fry, 1979; Erslev, 1988), Panozzo method (Panozzo, 1983, 1984) and Feret diameters method (Lapique et al., 1988). These methods require various different parameters to characterize the shape or location of the strain markers. Here, in this work, Fry method is used for determining the finite strain accumulated overtime by focusing on three major rocks exposed in the area. This kind of study in the study area using center to center Fry method is new and the reason for adopting this method to determine finite strain developed on these rocks in response to the stresses that had worked on them from time to time is multifold. Firstly, there has been no recent study of finite strain on these lithostratigraphic units and secondly, this method is applicable to a wide range of situations (e.g., Lacassin and Van den Driessche, 1983; Ramsay and Huber, 1983; Seno, 1992; McNaught, 1994; Srivastava, 1995; McNaught, 2002; Gonzalez-Casado et al., 2003; Genier and Epard, 2007; Long et al., 2011).

The study area is located around Girar village of Mehroni tehsil of Lalitpur district and falls under Survey of India Toposheet No. 54L/15. Strain analysis for three distinct lithounits observed in the area namely, the Archean Fuchsite-quartzite, the Paleoproterozoic Bijawar sandstones and the Mesoproterozoic Vindhyan siliciclastic sediments is done on the basis of strain data generated using Fry method and an attempt has been made to compare the strain/stress encountered by these chronologically different lithounits and how they behaved in response to those stresses.

II. General geology

The area of interest lies on the Southern fringe of the exposed part of Bundelkhand craton around Girar area covering the villages of Kurrat, Baraitha and Karrai. The major litho-stratigraphic units in this area includes the Bundelkhand granitic and gneissic complex with older crustal enclaves represented by Mehroni Group and associated metavolcanics of Archean age, the Paleoproterozoic rocks of Bijawar Group, the lower Vindhyan rocks of Mesoproterozoic age (Chatterjee et al., 1971; Crawford, 1970; Prakash et al., 1975). There are marked unconformities between these three different litho-units and also within them particularly in Bijawar and

Vindhyan rocks. When considered as a whole Bundelkhand craton has been intruded by more than six generations of granite in the form of batholiths within the rocks of Mehroni Group of Archean age. Structurally, the terrain of Bundelkhand craton was exposed to multiple deformational episodes and shows poly-metamorphic nature (Bhattacharya, 1985,1986; Roday et al., 1995).

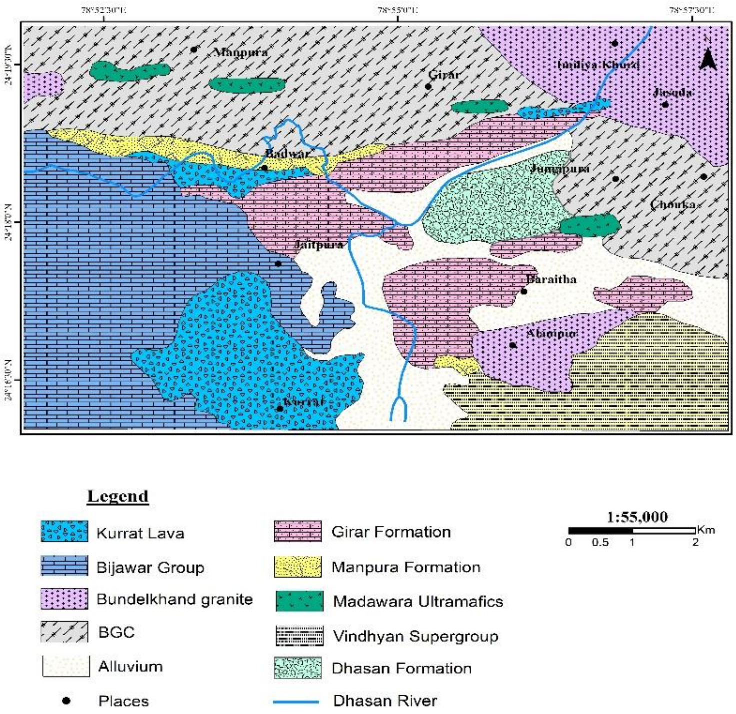

Figure 1: *Geological map of Girar area, Sonrai sub-basin, Madhya Pradesh (modified after Singh et al., 2011)*

The Mehroni group comprises of BIFs particularly banded hematite quartzite and banded hematite magnetite quartzite (Singh, 1999; Singh And Slabunov, 2013). Fuchsite quartzite and metabasites. The BIFs and Fuchsite bearing quartzite shows evidences of polyphase deformation (Prakash et al., 1975; Roday et al., 1995). Bijawar rocks in the area, represented by the sediments of Sonrai sub-basin which includes ferruginous sandstone, gritty sandstone, shales and carbonate facies along with subaqueous volcanism preserved in the form of Kurrat pillow lava (Prakash et al., 1975; Roy et al., 2004), also show some serious evidences of deformation. The other major litho-unit exposed in the study area is the Vindhyan supergroup particularly Lower Vindhyan sediments in the form of sandstone, shale and limestone. These predominantly siliciclastic sediments do not show any major deformational feature.

Table 1*: Lithostratigraphy of Girar area, Sonrai sub-basin (Modified after Prakash et al., 1975; Roy et al., 2004)*

Age	Litho-stratigraphic unit	Lithology
Mesoproterozoic	Vindhyan Supergroup	Sandstone, shale and limestone
---------- Unconformity ----------		
Paleoproterozoic	Bijawar Group	Ferruginous shale, sandstone, carbonate and volcanics
---------- Unconformity ----------		
Archean	BGC	Granite and genesis
---------- Unconformity ----------		

Archean (Supracrustal)	Mehroni Group	BIFs, fuchsite quartzite, metabasites

III. Methodology

For the estimation of deformation experienced by these lithounits, forty-eight North oriented representative samples are collected during the field phase of this study, out of which twenty-five samples are carefully selected for the preparation of oriented thin sections for microscopic studies. Five thin sections of Vindhyan quartz-arenite and ten each of Bijawar sandstone and Mehroni Fuchsite quartzite are thoroughly studied under the petrographic microscopic. The estimation of strain developed in these chronologically different lithologies is done using the Fry method (Fry, 1979). This method uses the relative movement of rigid grains with respect to each other to yield a central vacancy which reflects the finite strain ellipse. The center of grains is plotted with respect to each other to generate a central lacuna in order to analyze the strain developed by the rocks in response to the stresses applied during the deformational episodes. Fry method is then applied on the all thin sections of each of the lithounits studied for this work. Five thin sections of Vindhyan quartz-arenite along with ten sections each of Bijawar sandstone and Fuchsite rich quartzite of Mehroni group are studied using this method for finite strain analysis. Ten microphotographs are made from each thin section and their respective Fry plots are generated.

A comparison is made about the relative amount of strain developed by these rocks on the basis of the central lacuna identified on each of the Fry diagrams. The major and minor axis lengths of the strain ellipse are measured and their aspect ratio (R) is calculated for the interpretation of the strain developed on them. The formula used to calculate the value of R is,

Aspect ratio (R) = length of major axis/length of minor axis

The values of R ratios are then averaged to generate a single R ratio for each of the three lithostratigraphic units to determine the eccentricity of their strain ellipsoid. The different R ratios are used for the interpretation of the stresses observed by these units and a clear comparison is made about their deformational history.

Table 2: *Values of aspect ratio (R) generated after Fry analysis*

S. No	Litho-unit	Thin Section No.	No. of Fry plots	Average R value of each thin section	Average value of R for each Litho-unit
1	Vindhyan Quartz-arenite	14 a	10	1.385	**1.365**
2	Vindhyan Quartz-arenite	14 b	10	1.334	
3	Vindhyan Quartz-arenite	14 c	10	1.315	
4	Vindhyan Quartz-arenite	14 d	10	1.409	
5	Vindhyan Quartz-arenite	14e	10	1.382	
6	Bijawar Sandstone	4 a	10	1.648	**1.658**
7	Bijawar Sandstone	4 b	10	1.585	
8	Bijawar Sandstone	4 c	10	1.560	
9	Bijawar Sandstone	4 d	10	1.727	
10	Bijawar Sandstone	4 e	10	1.496	
11	Bijawar Sandstone	5 a	10	1.636	
12	Bijawar Sandstone	5 b	10	1.642	
13	Bijawar Sandstone	5 c	10	1.6.57	
14	Bijawar Sandstone	5 d	10	1.785	
15	Bijawar Sandstone	5 e	10	1.844	
16	Fuchsite Quartzite	8 a	10	1.764	**1.839**
17	Fuchsite Quartzite	8 b	10	1.846	
18	Fuchsite Quartzite	8 c	10	1.826	
19	Fuchsite Quartzite	8 d	10	2.090	
20	Fuchsite Quartzite	8 e	10	2.000	
21	Fuchsite Quartzite	9 a	10	1.714	
22	Fuchsite Quartzite	9 b	10	1.809	
23	Fuchsite Quartzite	9 c	10	1.823	
24	Fuchsite Quartzite	9 d	10	1.727	
25	Fuchsite Quartzite	9 e	10	1.788	

IV. Result and Discussion

The Precambrian rocks around Girar can be generally classified in to three distinct domains namely the Bundelkhand granite with older supracrustal enclaves of Mehroni, Bijawar Group and Vindhyan Supergroup of Archean, Paleoproterozoic and Mesoproterozoic respectively. The present work is mainly focused on the general estimation of strain in these rocks through Fry plot method. Fuchsite quartzite from Mehroni, ferruginous sandstones of Bijawar Group and quartz-arenites of Vindhyan Supergroup has been considered for the strain estimation.

The Fry plot analysis of Vindhyan rocks reveal a range of the aspect ratio (R) ranging from 1.483-1.192 with an average of **1.365**. For the Bijawar sandstone the R values vary between 1.88-1.437 averaging **1.658**. Fuchsite quartzite show a variation of R from 2.09-1.588 with an average of **1.839**. If the aspect ratio is considered as a tool for strain intensity, then it is clear from the aforementioned estimates that the rocks can be compared in terms of the extent of deformation. The oldest rocks (Archean) of Mehroni represented by the Fuchsite quartzite shows the highest average aspect ratio of 1.839 whereas the youngest rocks (Mesoproterozoic) of Vindhyan has the least average aspect ratio of 1.365. The Bijawar sandstones of intermediate age show similar average aspect ratio of 1.658 which is lesser than Mehroni and greater than Vindhyan.

The present work therefore provides the quantitative estimation of strain from Girar area for the first time. More work however, is required in future to enhance our understanding of deformation of these rocks.

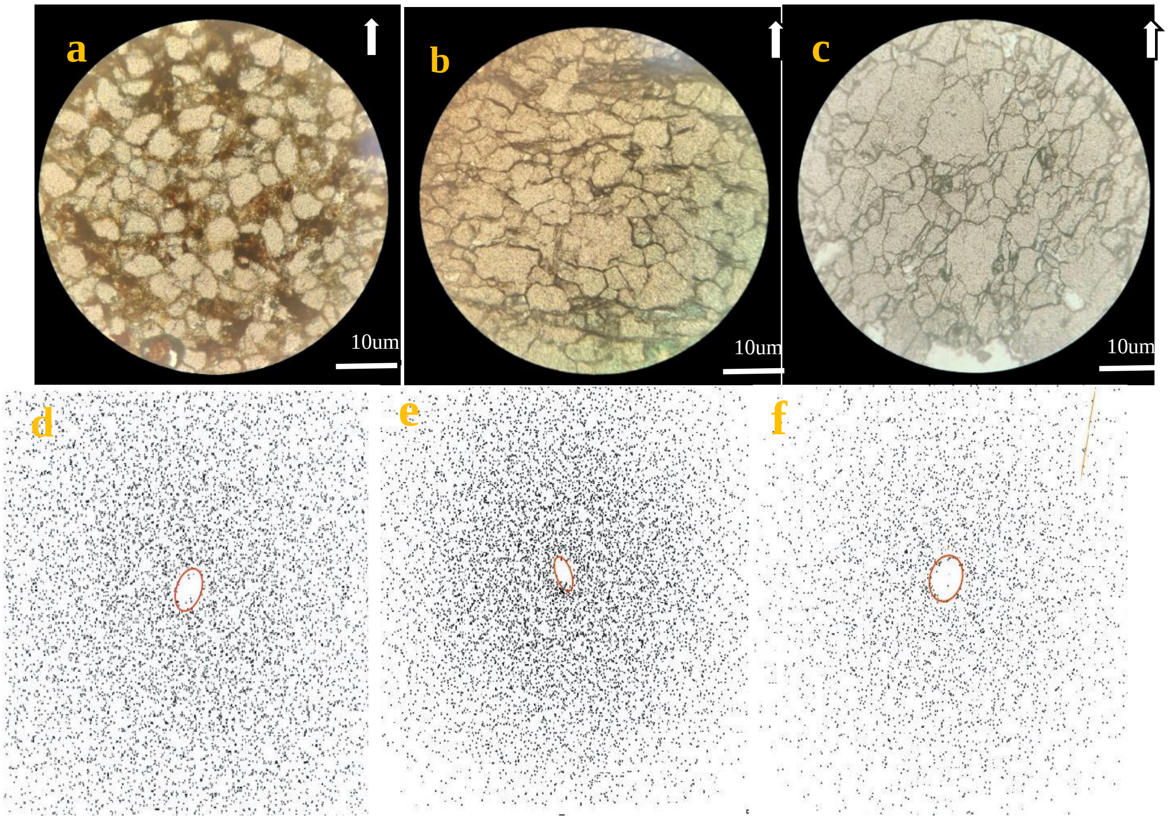

Figure 2: (a), (b) and (c) show photomicrographs of Bijawar sandstone, Fuchsite quartzite and Vindhyan quartz-arenite, respectively whereas (d), (e) and (f) show their respective Fry plots (Fry, 1979) with strain ellipse represented by a central vacancy.

V. Conclusion

The findings of strain analysis of these chronologically distinct litho-units using Fry method are in concurrence with the general understanding about the deformational history of various stratigraphic units within the Bundelkhand craton. The oldest unit represented by Fuchsite quartzite of Mehroni supracrustals (Archean) is most deformed unit out of all the three studied in this work. The Paleoproterozoic Bijawar sandstones are relatively less deformed than the Fuchsite-bearing Archean quartzite but still shows clear evidences of multiphase deformation whereas the youngest litho-unit of Vindhyan quartz-arenites are more or less undeformed. A correlation between ages of rocks and degree of deformation in the area of study, can be further strengthened on the basis of the findings of this work. It can be suggested that most of the large-scale deformational episodes within the craton in general and study area in particular were over before the onset of Vindhyan sedimentation.

Acknowledgements

The authors are sincerely thankful to The Head, Department of Applied Geology, Dr. Harisingh Gour Vishwavidyalaya, Sagar for providing all the necessary facilities to carry out this work. I express my heartfelt gratitude to my supervisor, teachers and friends for all the support and guidance they have provided me with during this work.

References

[1]. Basu, A.K., (1986): Geology of parts of the Bundelkhand Granite Massif. Rec. Geol. Surv. Ind. 117 (2), pp. 61-124.
[2]. Basu, A.K., (2001): Some characteristics of the Precambrian crust in the northern part of Central India. Geol. Surv. Ind., Spl. Pub. No.55, pp. 182 204.
[3]. Bhatt, Suresh & Singh, Vinod. (2021). Tectonic Evolution of Babina–Prithvipur Crustal Shear Zones, Bundelkhand Craton, India: Implications of Shear Indicators. 10.1007/978-981-16-4122-0_11.
[4]. Chatterjee, N.D., 1972. The upper stability limit of the assemblage paragonite+ quartz and its natural occurrences. Contributions to Mineralogy and Petrology, 34, pp.288-303.
[5]. Chatterji, G.C., Ray, D.K. and Banerjee, P.K. (1971): Stratigraphicsub-division and nomenclature of the Precambrian rocks of India. Rec. Goel. Surv. Ind., V. 101, Pt. 2, pp. 1-14.
[6]. Crawford, A.R. and Compston, W., (1970): The Age of the Vindhyan System, Quart. Jour. Geol. Soc., London.
[7]. Dunnet D and Siddan AWB 1971 Non random sedimentary fabrics and their modification by strain; Tectonophys. 12 307–325.
[8]. Elliot, D. (1970). Deformation of finite strain and initial shape from deformed elliptical objects. Geol. Soc. Amer. Bull. Vol. 81, p. 2221-2236.
[9]. Fry (1972, 1979) Fry N 1978 Construction and computation of 3-D progressive deformation; J. Geol. Soc. London 135 291–305.
[10]. Fry, N., 1979. Random point distributions and strain measurement in rocks.Tectonophysics 60, 89-105.
[11]. Genier, F. and Epard, J.L., 2007. The Fry method applied to an augen orthogneiss: Problems and results. Journal of structural Geology, 29(2), pp.209-224.
[12]. Ghosh S K 1993 Structural Geology: Fundamentals and modern developments (Oxford: Pergamon Press) 598 p
[13]. Hanna S S and Fry N 1979 A comparison of methods of strain determination in rocks from SW Dyfed (Penbrokeshire) and adjacent area; Tectonophys. 5 315–319.
[14]. Jhingran, A.G., (1958): The problem of Bundelkhand Granites and Gneisses : Presidential Address, Section Geology and Geography, 45th. Ind. Sc. Cong., Madras.
[15]. Long, J.J. and Imber, J., 2011. Geological controls on fault relay zone scaling. Journal of Structural Geology, 33(12), pp.1790-1800.
[16]. Mark McNaught. (1994), Modifying the normalized fry method for aggregates of non-elliptical grains, Journal of Structural Geology, Volume 16, Issue 4, Pages 493-503.
[17]. McNaught, M.A., 2002. Estimating uncertainty in normalized Fry plots using a bootstrap approach. Journal of Structural Geology, 24(2), pp.311-322.
[18]. Medlicott, H.B. (1859): On the Vindhyan rocks, and their associates in Bundelkhand. Mem. Geol. Surv. Ind., V. II, Pt. 1, pp. 1-95.
[19]. Mishra, R.C., (1975): New data on the geology of the Bundelkhand Complex of Central India. Recent Researches in Geology, Hindustan Publishing Corpn. India, V. II, pp. 311-346.
[20]. Mishra, R.C., and Sharma, R. P., (1974): Petrochemistry of Bundelkhand Granites and associated rocks of Central India. Indian Mineralogist, V. 15, pp. 43-50.
[21]. Mondal, M.E.A., Zainuddin, S.M., (1996): Evolution of the Archean Paleoproterozoic Bundelkhand massif, central India-evidence from graniatoids geochemistry. Terra Nova V.8, pp.532-539.
[22]. Pascoe, E.H., (1950): A manual of the Geology of India and Burma. V. I., Govt. of India Press, 483p.
[23]. Pati, J.K., and Mamgain, V. D., (1996): A note on the occurrence of Orbicular Rocks in Bundelkhand Grnaitoid Complex. Geol. Soc. India, Vol. 48, pp. 345-348.
[24]. Prabhat, Prashant & Singh, Vinod & Dinkar, Gautam Kumar. (2011). Tectonic Environment of Proterozoic Rocks of Berwar Formation, Lalitpur District, Uttar Pradesh, India.
[25]. Prakash, Ravi, Singh, J.N. and Saxena, P.N., (1975): Geology and mineralization in the southern parts of Bundelkhand in Lalitpur dist., U.P. Jour. Geog. Soc. Ind., V.16(2), pp. 143-156.
[26]. R. E. Bevins, Magmatism in Relation to Diverse Tectonic Settings, by R. K. Srivastava and R. Chandra. A. A. Balkema, Rotterdam, 1995. 462 pp. £60., Journal of Petrology, Volume 38, Issue 1, January 1997, Pages 165–166.
[27]. Ramsay, J. G. & Huber, M. I. 1984. The Techniques of Modern Structural Geology, Volume 1: Strain Analysis. Academic Press, London. 307 pp.
[28]. Robin Lacassin, Jean Van Den Driessche. (1983). Finite strain determination of gneiss: application of Fry's method to porphyroid in the southern Massif Central (France), Strain Patterns in Rocks, Pergamon, p. 245-253.
[29]. Roday, P.P. Diwan, P. and Singh, S., (1995): A kinematic model of emplacement of quartz reef and subsequent deformation pattern in the Central Indian Bundelkhand batholith. Proc. Indian Acad. Sci. (Earth Planet Sci.), V. 104 (3) pp. 465488.
[30]. Roday, P.P. Diwan, P. and Singh, S., and Pal, A., (1993): A two-stage modal for the development of Karitoan shear zones, Lalitpur district, U.P., Central India. Jour. Geol. Soc. Ind., V. 42, pp. 481-492.
[31]. Sarkar, Amitabha, Bhalla, J.K., Bishui, P.K., Gupta, S.N., Singhai, R.K. and Upadhyay, T.P. (1995): Tectonic discrimination of granite rocks: Situation on the Early Proterozoic Bundelkhand complex, Central India. Ind., Minerals.
[32]. Saxena, M.N., (1957): Structural study of Bundelkhand granites and associates rocks. Indian Mining Journal, V. 5, p. 9.
[33]. Seno, T., S. Stein, and A. E. Gripp (1993), A model for the motion of the Philippine Sea Plate consistent with NUVEL-1 and geological data, J. Geophys. Res., 98(B10), 17941–17948.
[34]. Sharma, K. K, (1998): geological evolution and crustal growth of the Bundelkhand craton and its relict in the surroundings 33-43.
[35]. Singh, V.K. and Slabunov, A., 2015. The Central Bundelkhand Archaean greenstone complex, Bundelkhand craton, central India: geology, composition, and geochronology of supracrustal rocks. International Geology Review, 57(11-12), pp.1349-1364.
[36]. Singh, Vinod & Slabunov, Alexander & Svetov, Sergei & Rybnikova, Zoya & Nesterova, Natalya & Gogolev, Maksim & Sibelev, Oleg & Chaudhary, Neeraj. (2018). Occurrence of Archean Iron Bearing Rocks from Babina, Mauranipur and Girar Area of the Bundelkhand Region: As Potential Reserves. 3. 108-113. 10.31031/AAOA.2018.03.000564.