Strain analysis and stratigraphic status of Nongkhya, Sumer and Mawmaram conglomerates of Shillong basin, Meghalaya, India

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Shillong basin, one of the Purana basins of the Indian peninsula is situated in the central and eastern parts of the Shillong plateau of NE India. Metasedimentary and metavolcanic rocks of the basin are of Mesoproterozoic age and lithostratigraphically belong to Shillong Group (erstwhile Shillong series) comprising Lower Metapelitic Formation (LMF) and Upper Quartzitic Formation (UQF). A long, persistent, faulted and tectonically attenuated conglomerate known as Nongkhya–Sumer–Mawmaram-conglomerate separates these two formations. In the present work, quantitative strain analyses of the pebbles of Sumer, Nongkhya and Mawmaram conglomerates of Ri-Bhoi and West Khasi Hills districts of Meghalaya are carried out using manual and computerized programmes. Eight different techniques for intrapebble, interpebble and bulk rock strain estimation are applied and results are compared systematically. Sumer and Mawmaram conglomerates bear the testimony of broadly flattening type of deformation ($0 < k < 1$) while Nongkhya conglomerate shows constriction type ($1 < k < \alpha$). The change in strain ellipsoid shape from Nongkhya to Mawmaram area is accompanied by a change of fabric from $S < L$ to $L < S$ tectonites. Affinity of rotational strain is more in Nongkhya conglomerate as compared to Sumer and Mawmaram conglomerates. The compactness of pebbles is high in case of Nongkhya conglomerate and low to moderate in Sumer and Mawmaram conglomerates indicating high strain in Nongkhya conglomerate (northeastern part of Shillong basin) relative to Sumer and Mawmaram conglomerates (southwestern part of Shillong basin). Thus strain magnitude increases from SW to NE direction of the Shillong basin.

The tectonostratigraphic status of these conglomerates suggest that the Sumer and Mawmaram conglomerates were initially a part of one conglomerate horizon of interformation type between LMF and UQF of the Shillong Group. With progressive deformation, the northeastern part of the Sumer conglomerate suffered tectonic attenuation and separation and eventually thrusted over the Basement Gneissic Group (BGG) as a tectonic mélange. This sector of the conglomerate is known as Nongkhya conglomerate. The tectonic configuration of the Nongkhya conglomerate is the effect of right and left lateral strike slip movement of Sumer conglomerate at Sumer and Adabasti points, respectively. This is a positive signature of post D_3 deformation on the Sumer conglomerate. The regional sigmoidal pattern of the interformational conglomerate broadly correlate with the Tyrsad-Barapani Shear Zone (TBSZ) of sinistral nature.

1. Introduction

It is customarily accepted that the strain of a body is simply the change in size and shape that the body has experienced during deformation. When the rocks along with the initial structures have been deformed, a fascinating record of the strain distribution throughout the rock can be obtained

Keywords. Strain analysis; Sumer–Nongkhya–Mawmaram conglomerate; tectonic mélange; Meghalaya.

from the deformed structures. Different techniques computing finite strain analysis of different strain indicators and their host have been used for a long time. Out of various strain indicators such as ooids, spherulites, alteration spots, radiolarian shell, foraminifera shell, worm burrow, pebbles of the conglomerate, brecciated mass, augens, ribbon quartz and amygdules, etc., pebbles of deformed conglomerates are considered as one of the most reliable tools to compute the dimension, orientation and allied different parameters to quantify finite strain. Pebbles of the conglomerate, although they are not initially spherical have an initial preferred dimensional orientation in the undeformed state. When deformed with the host rock they display significant stretching and rotational habits. The long axes of the pebbles lie parallel to the direction of tectonic transport while the short axis coincides with the perpendicular direction of the plane of schistosity (Stephanson and Johnson 1976). It is observed that the conglomerates of the Shillong basin are highly deformed and the pebbles show different stages of ellipticity, 'S' and 'Z' pattern rotation. The main emphasis of the present work is to estimate interpebble, intrapebble and bulk rock strain of the three selected notable conglomerates namely Nongkhya conglomerate, Sumer conglomerate and Mawmaram conglomerate of Shillong basin and also to ascertain their stratigraphic status.

2. Geological settings

Shillong plateau is approximately 300 km long (E–W) and 100 km wide (N–S). It singularly represents a Precambrian cratonic block of NE India. The plateau is tectonically detached from the Indian peninsula by the Garo-Rajmahal tectonic graben (Eremenco *et al* 1969). This vibrant plateau covers 47,614 km^2 area and is roughly confined between latitudes N 25°12′ and N 25°45′ and longitudes E 91°30′ and E 92°20′. This sector is at present tectonically sensitive and seismically very active due to continued north-northeastward counterclockwise movement of the Indian plate producing severe compression tectonics (Harijan *et al* 2003; Ramesh *et al* 2005). The plateau lies between the Himalayan belt in the north and Indo-Myanmar mobile belt in the east and has experienced compressive tectonic forces from orthogonal directions of two orogenies. Johnson and Alam (1991) have suggested that the Shillong plateau was uplifted due to collision of the Indian and Tibetan plates during Cenozoic period. Chatterjee *et al* (2006) have opined that the Shillong plateau was a part of the Indian shield since Mesoproterozoic time and was close to the Australo–Antarctica block, evidenced from Neoproterozoic–Cambrian paleomagnetic reconstruction of the Rodinia supercontinent. They suggested monazite dates from Goalpara Hills and Garo Hills around Sonapahar area as 1596 ± 15 Ma and 500 ± 14 Ma, respectively. According to them, Prydz Bay Suture possibly passes through Shillong Meghalaya Gneissic Complex with the western boundary of the suture between Garo-Goalpara and Sonapahar area. There is a great deal of confusion regarding the naming of this Precambrian cratonic block of NE India. Different workers used different names such as Assam Plateau (Ahmed 1981), Assam Meghalaya Plateau (Sarma and Dey 1996), Meghalaya Plateau (Nandy 2001) and Meghalaya Shillong Gneissic Complex (Chatterjee *et al* 2006). However, by and large the name Shillong plateau is still used because of its international status.

The study area belongs to Shillong basin, which occupies about 2500 km^2 area of the central and eastern parts of the Shillong plateau and confined dominantly to Meghalaya and partly to Karbi Anglong district of Assam. Metasediments and metavolcanic rock associations are the main components of the Shillong basin of Mesoproterozoic period (Mitra 1998a) and lithostratigraphically they belong to Shillong Group (Shilong Series of Medlicott 1869). The Shillong Group comprises metapelites, quartzites, metadolerites and conglomerates and they are intruded by Neoproterozoic granite plutons. The Shillong Group (SG) is divided into two formations – Lower Metapelitic Formation (LMF) and Upper Quartzitic Formation (UQF). The LMF is named as Tyrsad Formation (Barooah and Goswami 1972), Barapani Formation (Ahmed 1981) and Manai Formation (Bhattacharjee and Rahman 1985). The UQF is named as Shillong Formation (Barooah and Goswami 1972; Ahmed 1981) and Mawphlang Formation (Bhattacharjee and Rahman 1985). Metadolerite (erstwhile Khasigreenstone of Medlicott 1869) is found in the form of sills and dykes in both the formations. The rocks of the basin area are regionally metamorphosed under greenschist facies to lower part of amphibolite facies (Mazumder 1986; Devi and Sarma 2006). Neoproterozoic granites (e.g., Mylliem pluton, Kyrdem pluton and South Khasi pluton) were intruded into the Shillong basin in the form of plutons, which have been dated as 607 ± 10 Ma (Crawford 1969); 885–480 Ma (Ghosh *et al* 1991, 1994; Bhattacharyya and Ray Barman 1998) and they form another formation namely "Mylliem Formation" (GSI 1972). Granite gneiss of BGG from Patharkhang area of West Khasi Hills district of Meghalaya has been dated as 1714 ± 14 Ma indicating Paleoproterozoic age (Ghosh *et al* 1994).

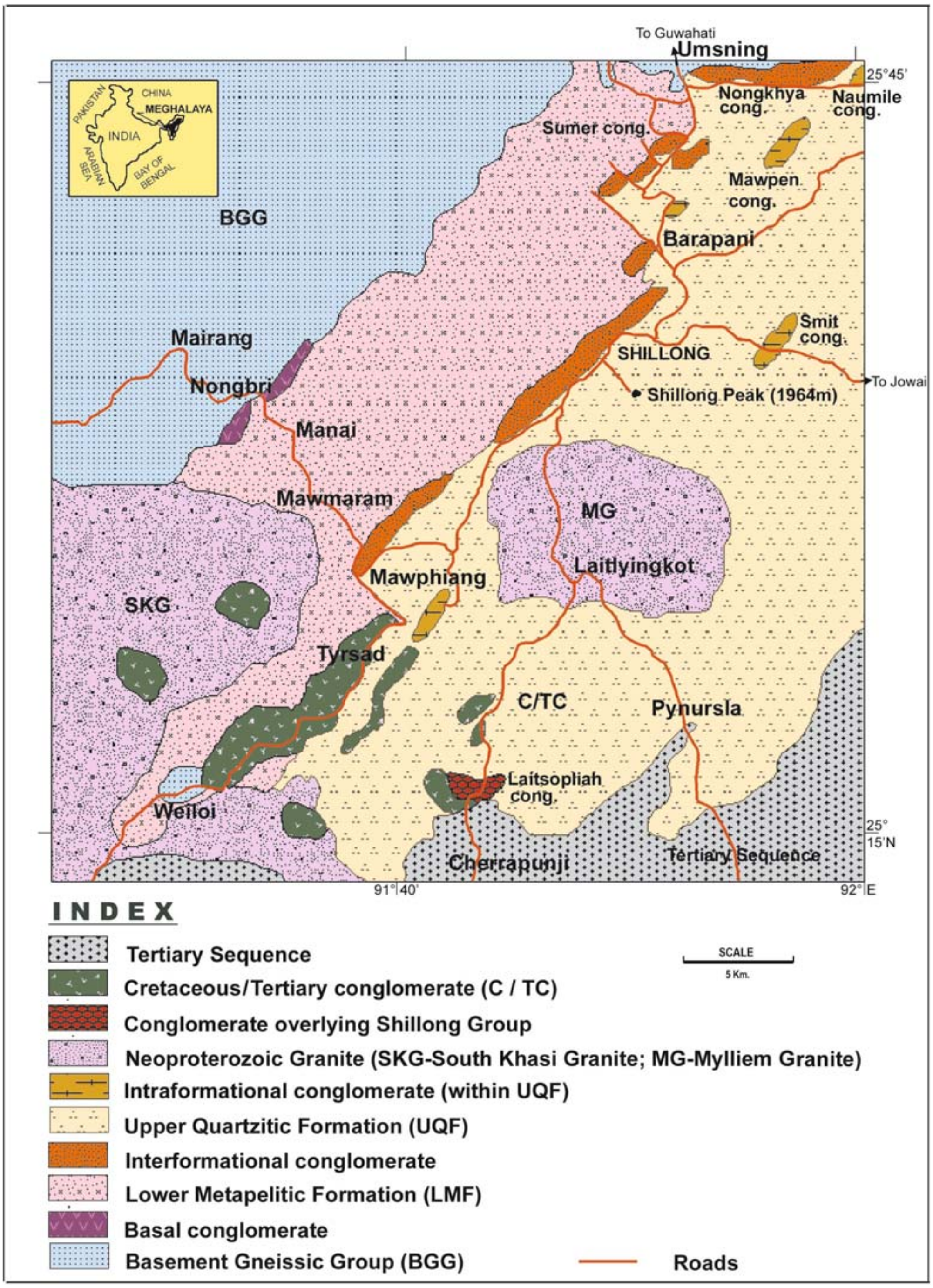


Figure 1. Geological map of the Shillong basin (after Devi and Sarma 2006).

Bidyananda and Deomurari (2007) have estimated the zircon age date from a few basement gneissic rocks (1.5–2.6 Ga), metasedimentary quartzite of Shillong Group (1.4–1.9 Ga) and a charnockite (1.0–1.3 Ga) from Shillong plateau, which proves the signature of Archean basement. A mere one or two radiometric data may not be sufficient to prove logically that the basement is Archean. However, the covered Shillong Group of metasediments has been dated as 1530–1550 Ma (Mitra 1998b).

Nongkhya, Sumer and Mawmaram conglomerates are the three notably persistent conglomerates of the Shillong basin. There exist various problems addressing the stratigraphic relationship of these conglomerates. Therefore, in the present work, these conglomerates are mapped in detail to assess their significant status in the Proterozoic stratigraphy and to work out strain and tectonic history (figure 1). The location and lithologic characters of these conglomerates are discussed in brief.

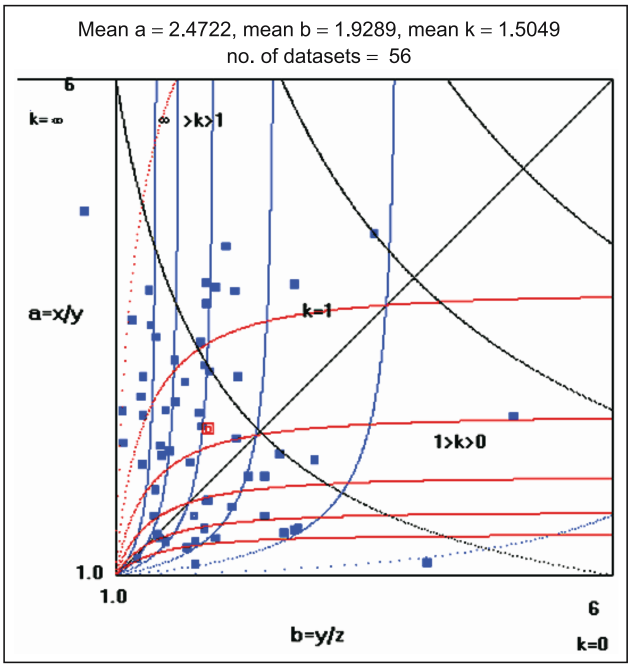


Figure 2. Flinn plot for Nongkhya conglomerate.

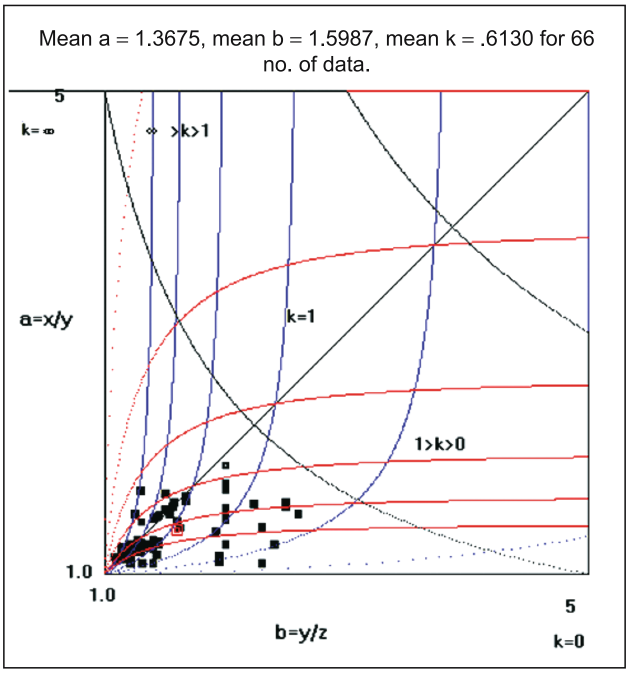


Figure 4. Flinn plot for Mawmaram conglomerate.

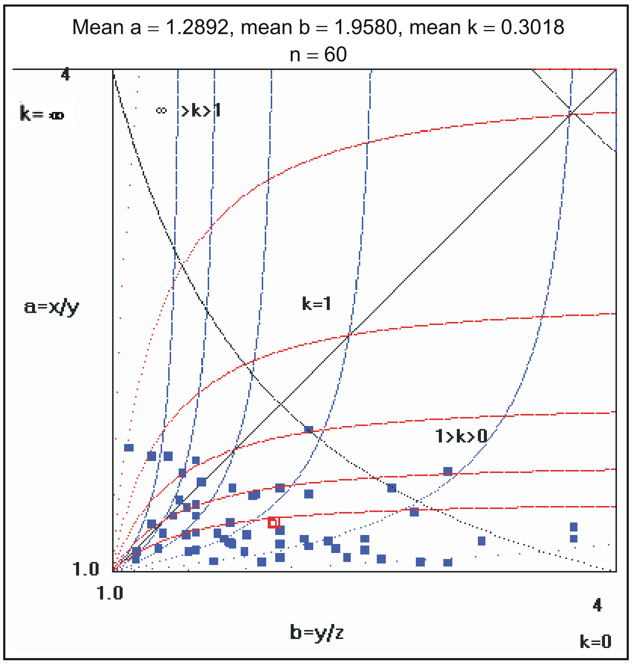


Figure 3. Flinn plot for Sumer conglomerate.

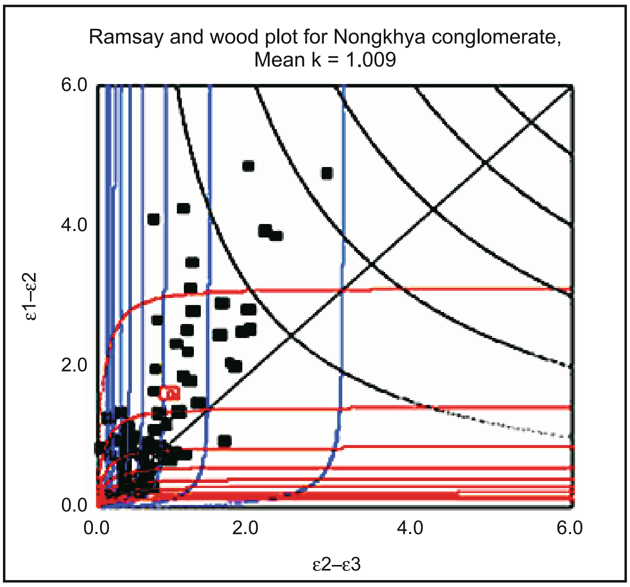


Figure 5. Logarithmic Flinn plot for Nongkhya conglomerate.

2.1 *Nongkhya conglomerate*

Nongkhya conglomerate is exposed around Nongkhya village, 4 km (N 25°44′.8″ : E 91°55′.17″) from Umsning along E–W trending Umsning–Jagiroad road of Ri-Bhoi district of Meghalaya. This approximately 100 m thick conglomerate hill unconformably overlies (angular unconformity) the underlying Basement Gneissic Group (BGG). The rock is highly weathered on the exposed surfaces and most of the pebbles are washed away leaving behind prominent hollows. The generalized strike of the conglomerate is E–W showing dip towards south. The stretching effect is more conspicuous. When measured they are found 2–4 cm in breadth and 7–9 cm in length. Some pebbles are measured up to 22 cm in length. The conglomerate is highly sheared with well-developed shear planes trending NW–SE and dipping towards NE. The shear foliation anastomosses round the pebbles. This conglomerate bears neither gneissic pebbles nor any evidences of autoclastic product of BGG;

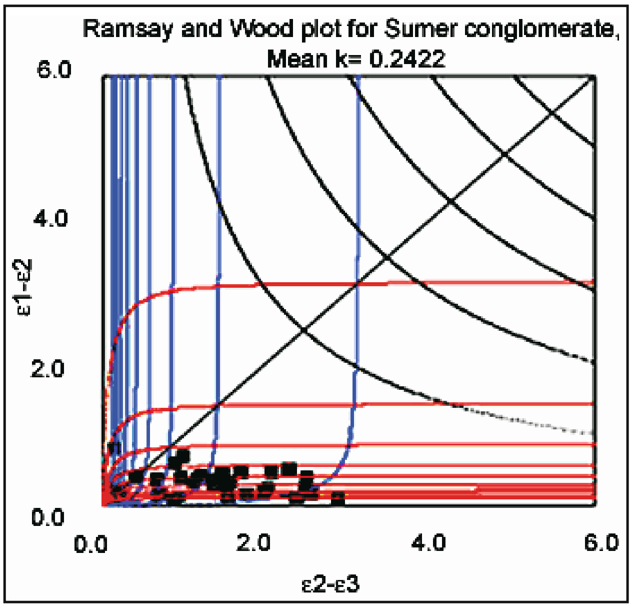


Figure 6. Logarithmic Flinn plot for Sumer conglomerate.

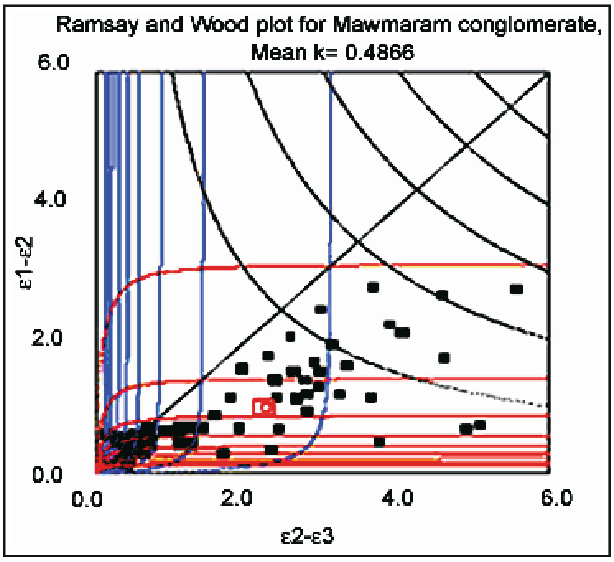


Figure 7. Logarithmic Flinn plot for Mawmaram conglomerate.

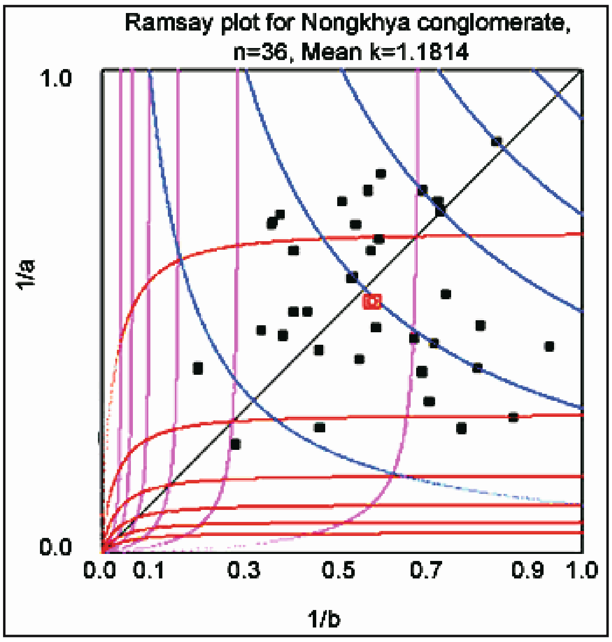


Figure 8. Ramsay's plot for Nongkhya conglomerate.

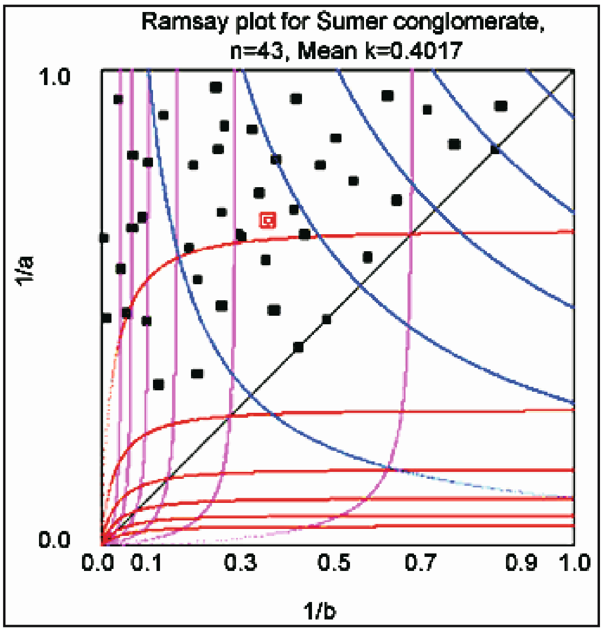


Figure 9. Ramsay's plot for Sumer conglomerate.

rather they contain metapelitic (phyllitic) pebbles, metadolerite and quartz pebbles and the matrix is made up of psamopelitic materials.

2.2 *Sumer conglomerate*

Sumer conglomerate is exposed along Kyrdemkulai–Sumer and Sumer–Umbir road of Ri-Bhoi district. The conglomerate stands out as a prominent ridge along the Umbir–Sumer section. The gradational character of the conglomerate is observed and the top gradually grades into fine-grained gritty quartzite. This conglomerate is very persistent showing variable thickness ranging from 300 m to 100 m and is faulted dextrally and sinistrally at a number of places (figure 1). The Umbir–Sumer road passes through the Sumer conglomerate about 3 km (N 25°40′.52″ : E 91°51′.8″) from Umbir and thereafter carries on along the interface of the conglomerate and the underlying Lower Metapelitic Formation. Similarly from Sumer point on NH-40 to Kyrdemkulai, the road passes through the interface between conglomerate and metapelitic formation. The conglomerate totally disappears at NH-40 at Sumer

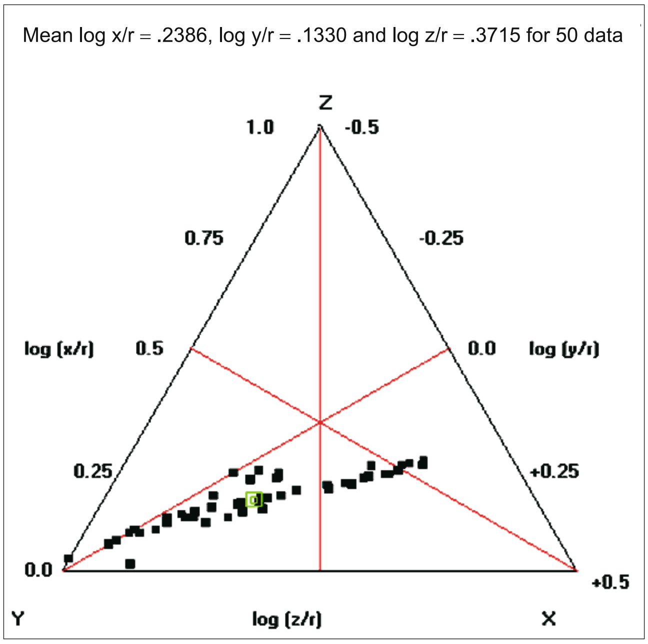


Figure 10. Burns and Spry plots for Mawmaram conglomerate.

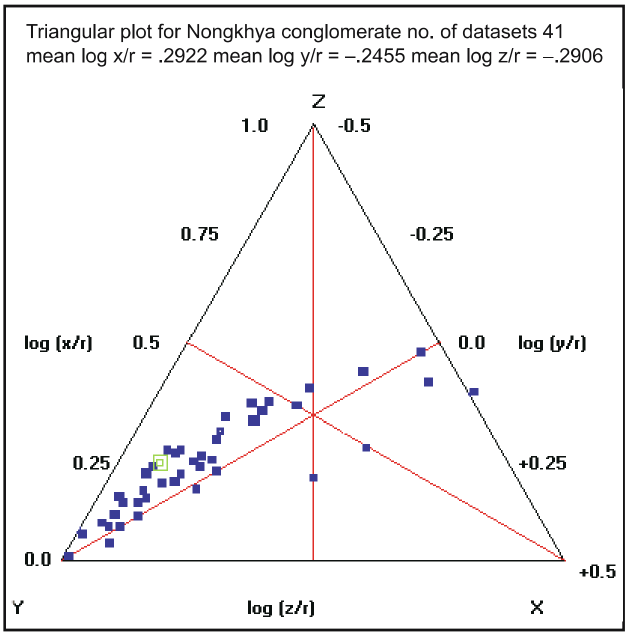


Figure 11. Burns and Spry plots for Nongkhya conglomerate.

point (N 25°41′42.0″ : E 91°54′28″) and is dextrally shifted 0.8 km towards Shillong. The fault plane trends roughly N–S. The schistosity or shear foliation is marked in the conglomerate and it varies from 040° to 065° dip being 30° to 60° due SE. Small subsidiary shears (< 10 cm) almost parallel to the strike direction of the conglomerate (NE–SW) are observed and they are transected by another set of NW–SE shear. According to Ahmed (1971) and Mazumdar (1976), the Sumer conglomerate is the base of Shillong Group and separates BGG from overlying SG. Mazumdar (1986) further stated that the schistose rocks around Umsning and Sumer belong to schistose member of the gneissic complex.

2.3 *Mawmaram conglomerate*

Mawmaram conglomerate is exposed near Sohiong–Mawmaram villages about 27 km from Shillong (N 25°30′.7″ : E 91°42′.05″). The 30 m thick conglomerate is very coarse, compact and composed mostly of quartz, metapelite (quartz-sericite schist) and quartzite pebbles. It separates UQF from LMF of the SG and shows a regional NE–SW trend. Matrix is psamopelitic and partly psamitic. The conglomerate extends further in NE direction and is exposed near Krang along Mawmaram–Umium road section. At Mawlendep the conglomerate is not traceable due to thick forest and inaccessibility. However, satellite imagery, hill morphology and isolated exposure of lithounits indicate that the Sumer conglomerate is the extension of Mawmaram conglomerate.

3. The structural framework of the basin rocks

The Shillong basin stands out as an intracratonic basin showing linearity in NE–SW direction. The rocks of the basin are affected by multi-deformational episodes imprinted in the form of planar, linear and other mesoscopic to macroscopic fold structures. The generalized attitude of the lithosetting is NE–SW showing steep to moderate dip towards SE but nonlinear transformation on different scales is obvious from different sectors. Ahmed (1971), Barooah (1976) and Bhattacharjee and Rahman (1985) have studied the metasediments and metavolcanic litho association and all of them opined that the rocks are affected by phases of multiple deformation. Recently Sarma *et al* (1998, 2001b), Goswami and Sarma (2001), have deciphered multideformational episodes associated with metamorphism. Sarma (2001), Devi and Sarma (2006) and Sarma and Devi (2006) suggested that the rocks of the Shillong basin have undergone four phases of deformation in LMF (MD_1–MD_4) and three phases of deformation in UQF (QD_1–QD_3).

Mitra (1998a) has established four phases of folding associated with planar and linear structures from metapelites of the Sohiong area of east Khasi Hills district of Meghalaya and suggested that first three phases are co-axial in nature showing generalized NE–SW trend while the fourth phase is characterized by conjugate and/or chevron folds which intersect all the earlier phases in the NW–SE direction.

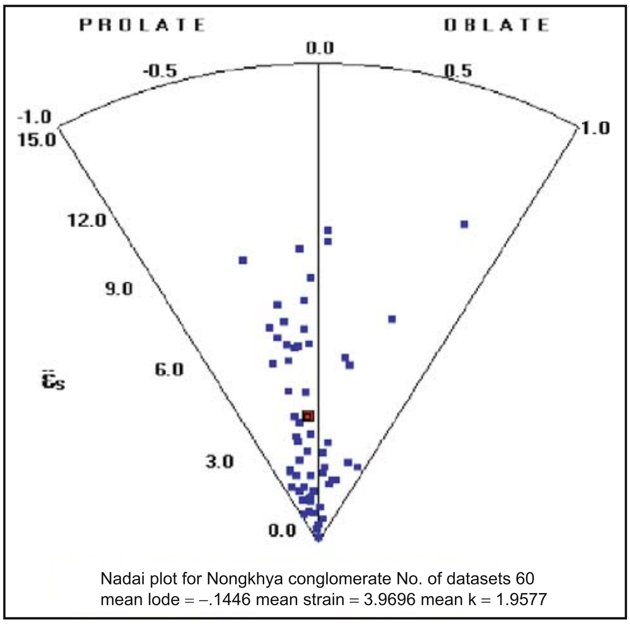


Figure 12. Nadai plot for Nongkhya conglomerate.

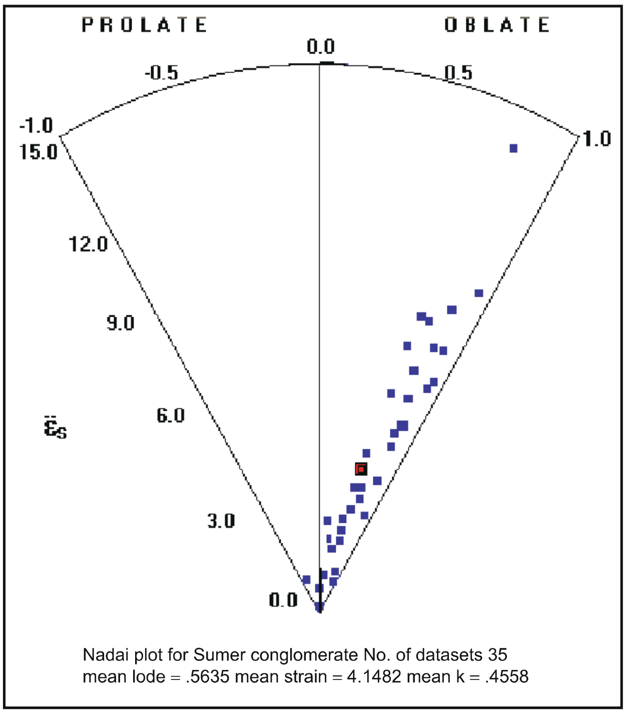


Figure 13. Nadai plot for Sumer conglomerate.

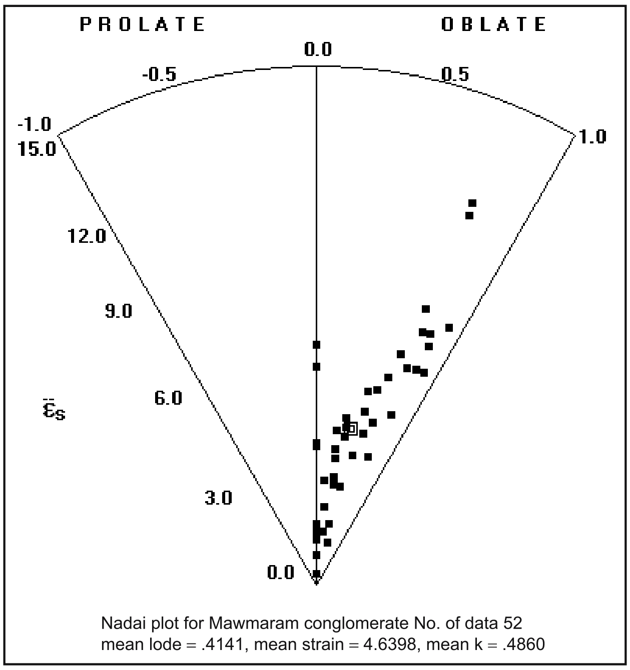
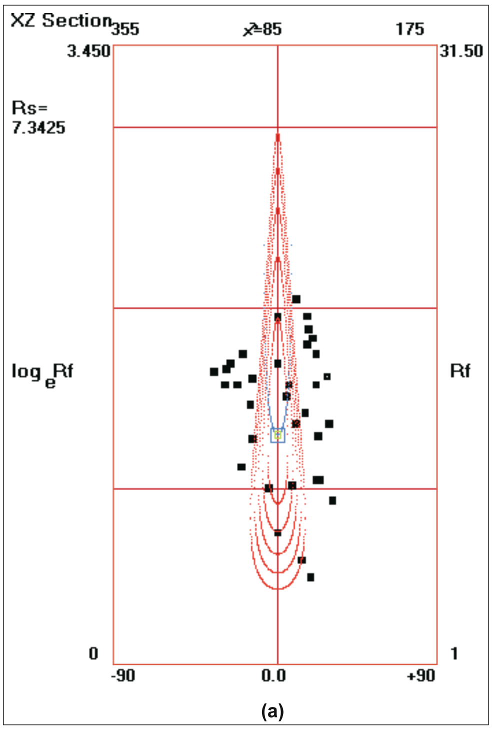


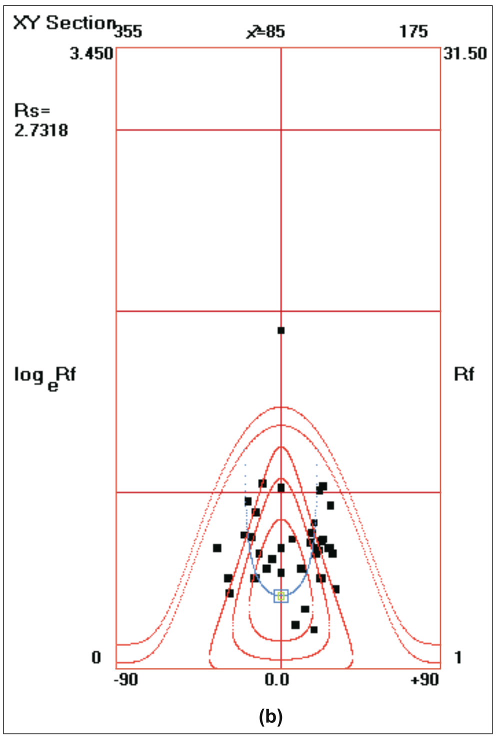
Figure 14. Nadai plot for Mawmaram conglomerate.

The first tectonic episode (MD_1) of LMF is imprinted in the form of tight, isoclinal, rootless folds (MF_1) with attendant axial plane foliation (MS_1). This deformation has not been recorded in the UQF. First and second phases are considered to be coaxial and the third phase is not coaxial; rather it transects the earlier two phases at high angle in the NW–SE direction. The earliest deformation in QD_1 in UQF results anticlines and synclines of asymmetric nature and they can be correlated with second phase deformation of LMF (MD_2). Third phase folds MF_3 of LMF have superposed on earlier structures, trend being recorded as NW–SE and the folds are generally of warp type resulting in the formation of dome and basin structures (type 1 interference pattern of Ramsay 1967). Conjugate folds seem to be mistaken as generations. Microstructural behaviour of the LMF around Mawmaram–Sohiong–Manai area has been studied by Sarma *et al* (2003) and their three phases of ductile and one phase of brittle deformation are correlated with the mesoscopic structural fabrics determined by Sarma *et al* (2001a, 2001b) from Ri-Bhoi district of Meghalaya. Fourth phase (MD_4) is brittle type and results faults and fractures on regional scale. Numerous mesoscopic faults are observed. Thus, third and fourth phases of deformation of LMF (MD_3 and MD_4) are correlated with second and third phases of deformations of UQF (QD_2 and QD_3). Devi *et al* (2009) have discussed the microstructural behaviour of the metapelites of Sohiong–Mawmaram area of west Khasi Hills district and established four phases of deformation. This multideformational setting and associated greenschist to later part of the amphibolite facies metamorphism of the Shillong basin is established based on laboratory and field observations with 3cs (care, caution and control).

4. Pebble characteristics and orientation

The conglomerates are oligomictic to polymictic in nature. Sumer conglomerate comprises quartz, quartzite, vein quartz, crenulated metapelitic and carbonaceous shale pebbles set in an arenaceous and partly psamopelitic matrix. The ductility contrast between the pebbles and matrix is low. The pebbles reflect more or less ellipsoidal shape with long axis ranging from 0.6 to 14.5 cm. The pebble-matrix ratio is approximately 60:40. Pebbles of the Mawmaram conglomerate are almost identical to that of the Sumer conglomerate although





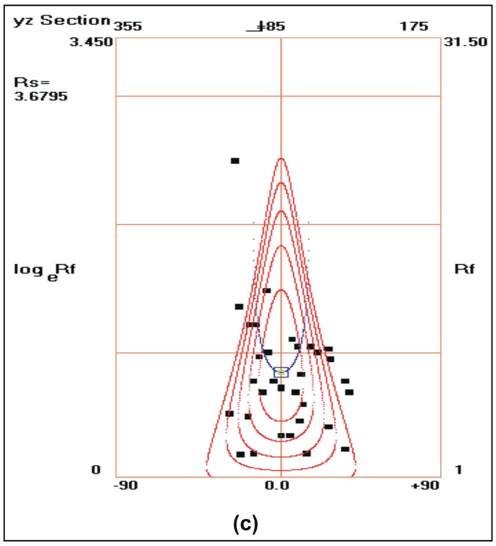


Figure 15. R_f/ϕ plots in XZ, XY and YZ sections of Nongkhya conglomerate.

the former is relatively coarser than the latter. On the other hand, the pebbles of the Nongkhya conglomerate are highly stretched, coarse-grained and comprise polycrystalline quartz, vein quartz, metapelitic clast, rarely metadolerite and feldspars set in a matrix of fine grained quartz and phyllosilicates. Some of the pebbles are measured up to 24 cm in length and are about 5 to 8 cm in width. The ratio of the major axis to minor axis of the pebbles varies from 2:1 to 6:1. Orientation of the long axes of pebbles varies from E–W in Nongkhya and Sumer to NE–SW in Mawmaram. The generalized strike is ENE–WSW, dip being dominantly towards SE at high-to-moderate angle. Plunge of the strained pebbles varies from 15° to 45° due SW and/or SE directions.

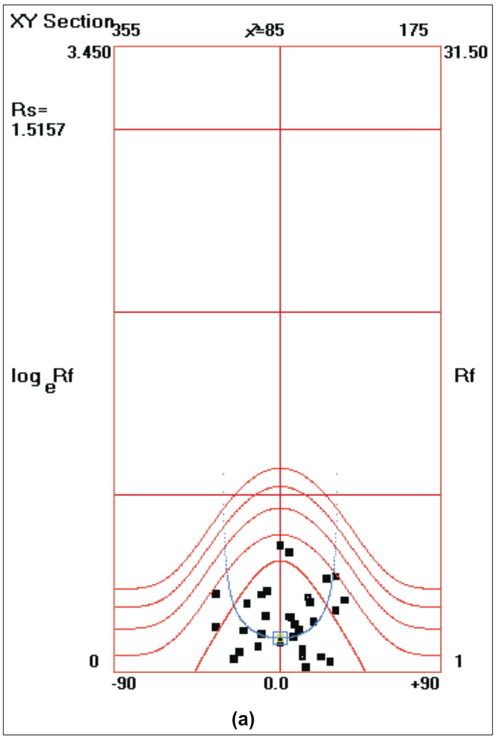
5. Strain analysis and methodology

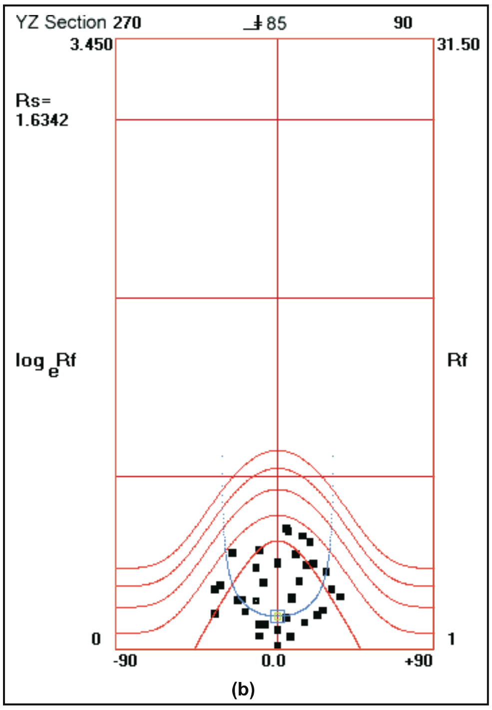
Out of the various techniques of strain measurement documented all over the world, eight methods were adopted to measure the inter-pebble, intrapebble and bulk rock strain of above three deformed conglomerates. The methods are namely:

(1) Flinn plots (Zingg 1935; Flinn 1962),
(2) Ramsay and Wood plot (Ramsay 1967; Ramsay and Wood 1973),
(3) Ramsay's plot (Ramsay 1967),
(4) Logarithmic Triangular plot (Burns and Spry 1969),
(5) Nadai's plot (Hsu 1966; Hossak 1968; Nadai 1963),
(6) R_f/ϕ plots (Ramsay 1967; Dunnet 1969; Dunnet and Siddan 1971),

(7) Algebraic method (Shimamoto and Ikeda 1976), and
(8) Fry method (Fry 1978, 1979; Hanna and Fry 1979).

Different strain plots for these methods are prepared following the colourful and versatile Windows based software, the "Sixstrain" developed by Roday (2003). A large number of exposures of conglomerates were studied in the field and the





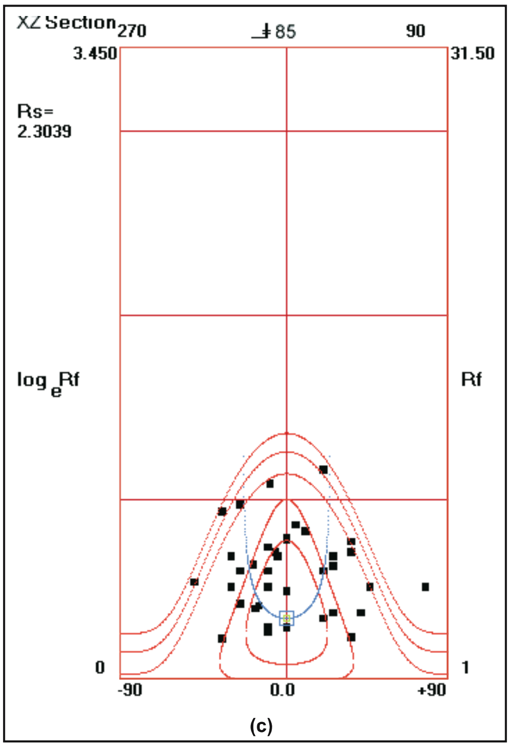


Figure 16. R_f/ϕ plots in XY, YZ and XZ sections of Sumer conglomerate.

lengths of the X (long), Y (intermediate) and Z (short) axes of the deformed pebbles were measured directly or with the help of transparent overlays and enlarged photographs. Both oriented and unoriented samples were collected and also studied in thin sections. Oriented samples were sawn in the laboratory along XY, XZ and YZ directions and relatively small pebbles were measured directly. The principal elongations $1 + e_1$, $1 + e_2$ and $1 + e_3$ were calculated by dividing the lengths of X, Y and Z-axes by 2. Axial ratios (R_f) of different sections, viz., XY, YZ and XZ as well as the orientation of major axes of the pebbles with respect to the reference line (ϕ) were measured. The data relating to the values of X, Y and Z-axes or $1 + e_1$, $1 + e_2$ and $1 + e_3$ were entered in data entry field of the software.

In the Flinn diagram, it is observed that the Nongkhya conglomerate has the characteristic mean k-value greater than 1 indicating the constrictional field (prolate) while Sumer and Mawmaram conglomerates have the contrasting k-values less than 1 defining flattening field (oblate). In some cases, Mawmaram conglomerates has an affinity for plane strain where $k = 1$ (figures 2–4). In Ramsay and Wood plot as well as in Ramsay's diagram k-values show similar significance like Flinn plots (figures 5–9). In the Logarithmic Triangular plot of Burns and Spry (1969) most of the plots of the Nongkhya conglomerate

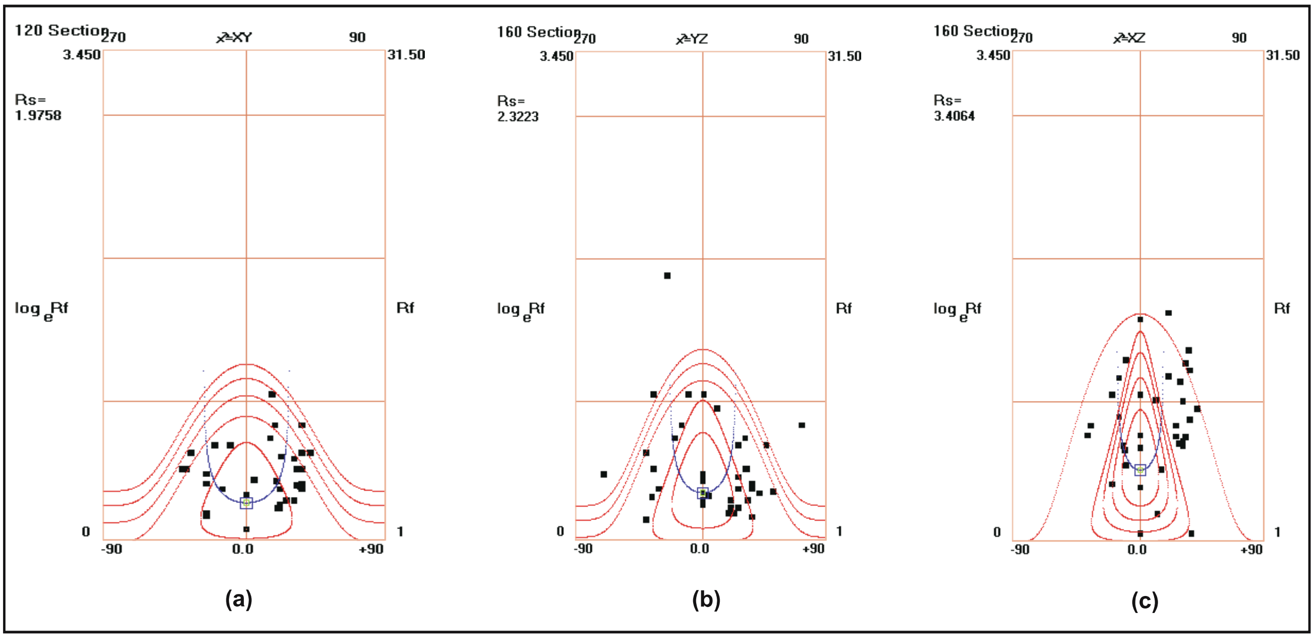


Figure 17(a–c). R_f/ϕ plots in XY, YZ and XZ sections of Mawmaram conglomerate.

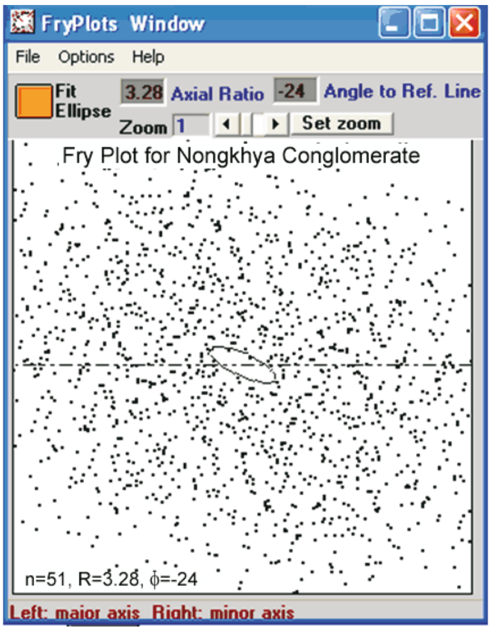


Figure 18. Fry plots for Nongkhya conglomerate.

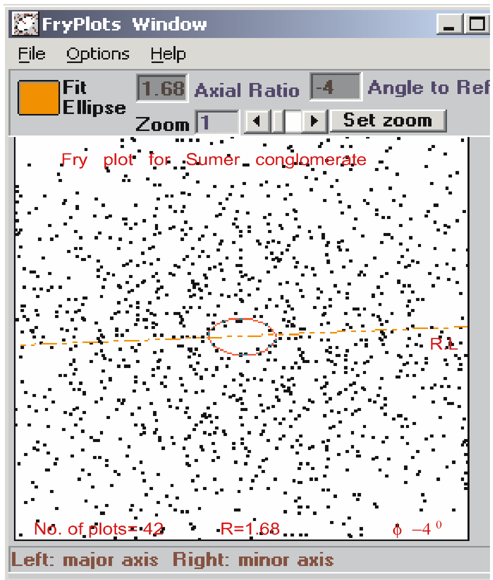


Figure 19. Fry plots for Sumer conglomerate.

fall in the constriction field while the majority of the plots for Sumer and Mawmaram conglomerates are plotted in the field of flattening (figures 10 and 11). The data relating to the strained pebbles of Nongkhya, Sumer and Mawmaram conglomerates were plotted in the graph of Hsu (1966) and the values of mean lode, mean strain and mean k were computed. It is observed that mean values of the parameters of Nongkhya conglomerate fall in the prolate field while they fall in the oblate field in case of Sumer and Mawmaram conglomerates (figures 12–14). From graphical plots of R_f vs. ϕ (Method 5) finite strain (R_s) values were determined by visual best fit into the standard curves of Dunnet (1969). Entering the values of R_f and ϕ of the strain markers of the three different sections, viz., XY, YZ and XZ into the data entry field of Sixstrain software for R_f/ϕ, the values of mean max.R_f, mean min.R_f, max.F(2ϕ) and mean R_s are computed. The tectonic strain ratio R_s estimated on three different planes of the conglomerates are shown in the table (figures 15–17) for comparison.

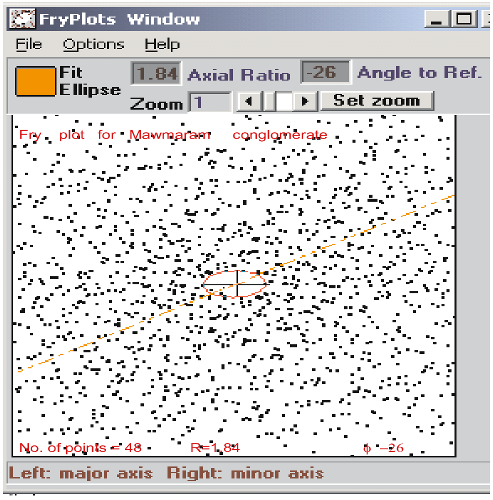


Figure 20. Fry plots for Mawmaram conglomerate.

In the Shimamotto and Ikeda's algebraic method the shape and orientation of the pebbles were estimated using algebraic formulas in terms of matrices on the basis of the values of R $(= R_f)$ and θ $(= \phi)$. From the estimated strain values it is observed that the ratio of the lengths of the principal axes in case of Nongkhya conglomerates is 3.69 whereas Sumer and Mawmaram conglomerates show variations from 1.65 to 2.09. The tabulated strain ratio can be correlated with that of Mawmaram conglomerate as defined by Devi *et al* (2006). Fry's maps were prepared using computerized procedures ("GeoFry plot" by Holcombe 1999 and "Fry programme" by Roday 2001) both from field photographs (enlarged) and field transparent overlays of the pebbles of the conglomerates as per methods suggested by Twiss and Moore (1992) and Ghosh (1993). The plots thus prepared show an elliptical vacant area of no concentration around the central point (figures 18–20). The long and short axial length and orientation with respect to reference surface are measured directly. The average ratio of long axis to short axis in Nongkhya conglomerate is 2.36 while that of Sumer and Mawmaram conglomerates are 1.59 and 1.965, respectively.

Results of all the methods showing various calculated parameters for the three different conglomerates were tabulated systematically in table 1. Separate plots were also prepared manually for all the methods and the computed results are compared with the manual plots. It is observed that the differences whatsoever are very negligible.

Table 1. *Comparison of strain parameters of different methods for the conglomerates.*

Methods	Computed parameters (only the mean value)	Nongkhya cong.	Sumer cong.	Mawmaram cong.
Flinn	a = X/Y	2.323	0.946	1.076
	b = Y/Z	1.8635	1.8125	1.677
	k	1.288	0.5435	0.578
Ramsay and Wood	lna	0.53	0.8095	0.958
	lnb	0.53	1.136	1.2385
	k	1.691	0.409	0.6905
Ramsay	1/a	0.614	0.643	0.755
	1/b	0.405	0.498	0.605
	1/ab	0.321	0.353	0.447
	k	0.791	0.539	0.388
Burns and Spry	Log X/r	0.446	0.112	0.194
	Log Y/r	−2.18	0.228	0.1055
	Log Z/r	−0.443	−0.159	0.287
Nadai	Lode	0.086	0.463	0.53
	Strain	2.982	3.824	5.517
	k	2.309	0.437	0.336
R_f/Φ	Strain in XY	2.74	1.635	1.865
	Strain in YZ	3.572	1.715	2.054
	Strain in XZ	7.163	2.051	2.7095
Fry	Strain ratio	2.36	1.59	1.965
Algebraic method	Strain ratio	3.69	1.65	2.09

6. Discussion and conclusion

From the above strain estimation it is clear that Nongkhya conglomerate has the characteristic k-values of constrictional field (prolate type) while Sumer and Mawmaram conglomerates have the contrasting k-values defining flattening field (oblate type). The change in strain ellipsoid shape from Nongkhya to Mawmaram area is accompanied by a change of fabric from $S < L$ tectonites to $L < S$. Majority of the strain data in the flattening field for Sumer and Mawmaram conglomerates hints foliation dominated fabrics. On the other hand, plots for the Nongkhya conglomerate fall in the constriction field indicating dominance of linear fabrics. Variation in k-values from flattening to constriction ($k > 1$) field also suggests a simple shear mechanism. The k-values of Mawmaram conglomerate show higher affinity towards plane strain as compared to Sumer conglomerate. Fry's map of Nongkhya conglomerate indicates that the long axes of the elliptical vacant area maintain subparallelism to the long axes of the pebbles and low angle with the reference line (interfaces of QS_1), which in turn indicates rotational strain (Toriumi *et al* 1988) and non-coaxial and rotational movement during progressive deformation (Sarma *et al* 2001a, 2001b). In case of Sumer and Mawmaram conglomerates the affinity to rotational strain is less as compared to that of Nongkhya conglomerate. Magnitude of the strain is controlled by the compactness of pebbles (Patel and Jain 1994) and accordingly compactness favours high strain effect in Nongkhya conglomerate and low to moderate strain effect in Sumer and Mawmaram conglomerates. Thus it is apparent that the strain magnitude is increasing from SW to NE.

As regards stratigraphic status of the Nongkhya, Sumer and Mawmaram conglomerates it is suggested that originally all the three conglomerates were one horizon separating the northwestern block (LMF) from the southeastern block (UQF) of Shillong basin on the regional scale and stands as interformational type. In case of Sumer and Mawmaram conglomerates it is apparently clear but Nongkhya conglomerate overlies quartzofeldspathic gneiss of the BGG and thus separates UQF from the basement behaving like a basal conglomerate. The study reveals that no basement gneissic pebbles are observed in the Nongkhya conglomerate, rather the conglomerate bears the evidences of metapelitic pebbles, metadolerite pebbles and show similar character of psamopelitic matrix like Sumer and Mawmaram conglomerates of interformational status. Hence, absence of gneissic pebbles and/or any gneissic character, presence of metapelitic pebbles, intensive shearing evidences in the BGG and discordance of lithological layering cum pervasive shear foliation of BGG with Nongkhya conglomerate are the diagnostic features to accept that Nongkhya conglomerate is the continuation of Sumer and Mawmaram conglomerates and thus deserves interformational status. With progressive deformation, northeastern part of the Sumer conglomerate signatures sinusoidal curvatures, faulted sinistrally and tectonically emplaced over the BGG as a tectonic mélange. Therefore, Nongkhya conglomerate is more strained as compared to the other two due to severe tectonic impacts over the basement complex (tectonic decollement).

Imprints of D_1 deformation is registered only in the Lower Metapelitic Formation of the basin and it is absent in Upper Quartzitic Formation as in the case of most of the Proterozoic belts elsewhere. The D_2 deformation was initiated under NW–SE compression and results the formation of shortening of the lithoassociation in the form of anticlines and synclines in the entire basin area. The D_3 deformation under NE–SW compression stress develops cross fold (dome and basin structures) on different scales. Asymmetry of the D_3 fold indicates sinistral nature and subsequently along the short limbs a lot of N–S and NW–SE trending faults are observed. Sumer conglomerate depicting an angular unconformity is dextrally faulted along the N.H-40 (N–S) and the displacement is about 0.8 km. The faulted block of the eastern part is gradually attenuated and takes a turn towards NW and disappeared at 1 km SE of Sumer point. The right lateral shifting of Sumer conglomerate along N.H-40 (N–S direction) near Sumer and left lateral movement near Adabasti and Umsning (NNW–SSE direction), emplacement of the conglomerate over the basement gneisses near Nongkhya, are some of the positive signatures of post D_3 deformational event. The tectonic configuration of the Sumer and Nongkhya conglomerate thus may be justified as a cause and effect of strike slip movement. The sinistral nature of overall lithosetting around Sumer and Nongkhya area and intensive shearing of the pebbles of the conglomerate in a sinistral motion near Nongkhya may be broadly correlated with adjacent sinistrally moving Barapani–Tyrsad ductile shear zone.

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