PART I

INTRODUCTION

An important tectonic element in the Precambrian belt of Singhbhum, Eastern India, which has attracted the attention of many eminent geologists mainly due to the presence of important economic mineral deposits, is an east-west trending arcuate belt, usually referred to as "Singhbhum shear zone", that runs for more than 160 km. from Baharagora in the east to Chakradharpur in the west (Fig. 1). Dunn (1929), and Dunn and Dey (1942) laid the foundation of geology of this region. Later workers have studied in details the different aspects of geology, e.g. economic geology, structural geology etc. in the several areas in the Precambrian belt of Singhbhum. However, most of them have broadly accepted the tectonic set-up proposed by Dunn and have invoked the presence of some sort of structural and/or metamorphic discontinuity between rocks within and outside the "shear zone". It is true that some of them, e.g. Sarkar and Saha (1963), Banerjee (1969, 70), have differed from Dunn's interpretation of overthrusting along the inverted limb of an anticlinorium, but they all agree that a "shear zone" does exist and the rocks within it show certain structural peculiarities absent in those outside it.

So far, the detailed structural investigations in Singhbhum have mostly been carried out in the metamorphic terrain north of the "shear zone", but structural studies on modern lines within the "shear zone" itself have rarely been attempted. Previous geological works within this belt were mostly confined to a description of only
the broad structural features along with reports on petrology and economic geology. Recently Bhattacharyya (1967) made a study of the minor structures within a small part of the "shear zone" near Kudada, south of Tatanagar, and his observations and conclusions were different from those of the earlier workers. In the year 1968, the present author, on a suggestion from Dr. D. Mukhopadhyay of Presidency College, Calcutta, studied the structures within a part of the "shear zone" near Sini and noted that these broadly tally with the pattern observed by Bhattacharyya in the Kudada area. These findings created a renewed interest about the "shear zone" and highlighted the necessity of a new systematic work with a view to reveal the tectonic significance of the "shear zone".

With this aim in view, the author undertook a detailed investigation of the central part of the "shear zone", from Rakha Mines in the east to Sini in the west, covering a strike length of about 40 km. The greater part of the area has been mapped in detail on a scale of 4 inches to a mile. During this investigation particular attention was paid to the small-scale structures like minor folds, lineations etc. with the hope that the study of their geometry, distribution in space and inter-relation would provide clues to the tectonic evolution of this belt.

The picture that will be presented in this thesis on the basis of this study will differ substantially from that of the earlier workers, and it is the author's contention that the existing ideas on the tectonic significance of the "shear zone" need reconsideration.
Previous Works

The first geological work in this region dates back as early as 1823 when Dr. Voysey made a geological traverse from Chakradharpur through Saraikela to Kuilapal. His work was published in 1844. Later publications by W. Jones, J.C. Haughton, Emil Stoehr, V. Ball, L.L. Fermor etc. mainly deal with the account of economic minerals like Gold, Copper etc. (summarised in Dunn, 1929; and Dunn and Dey, 1942). The first detailed work in this region was by Dunn (1929). He described the rocks in North Singhbhum as belonging to Iron-Ore series. In his opinion the Iron-ore series of rocks were first thrown into "broad folds associated with mountain building movements". "Following this severe orogenic folding and possibly as a later result of the constant overfolding from north to south, the shear zone east of Chakradharpur along the south side of the great geanticline, came into existence". "The overthrusting along the shear zone accounts for the close proximity from the unaltered to the highly metamorphosed rocks in the eastern part of the area. West of Chakradharpur, where acute folding takes the place of shearing, the rapidity of this change is, of course, not so pronounced". (1929, pp. 147-149).

In a later publication Dunn and Dey (1942) presented in detail the geology and petrology of Eastern Singhbhum and surrounding areas. The previous publication included the portion of the "shear zone" between Chakradharpur and Sini (West of longitude 86°00') and the later one deals with the part of the "shear zone" from east of Sini upto Baharagora thus covering the major part of the present area of investigation. Dunn and Dey (1942) divided the Iron-Ore
Series into two stages. The rocks that occupy the core of the geo-
anticline north of the "shear zone" were grouped within the Chaibasa
Stage and the rocks within the "shear zone" and south of it were
assigned to the younger Iron-Ore Stage. In Dunn and Dey's view the
shear zone "has formed along the overfolded southern limb of the geo-
anticline". It strikes almost due east from Narainpur (22°45';
86°00') to Rangamatipahar (22°40'; 86°18'), then taking a decided
turn to the southeast along the northeast foot of the hills through
Rakha Mines (22°38'; 86°22') and Badia (22°29'; 86°28'). Within this
thrust-zone the rocks have been very severely sheared, even granites
have been mylonitised, over a width varying between a few yards to
even 3 miles. The thrust-zone represents the end-stage in the over-
folding of the geo-anticline, a well defined bed of quartz granulite
(varying to quartz-schists) in the mica schists of the geo-anticline
very clearly delineates the increasing acuteness of the folding as
the zone of overthrust is approached." (P. 300). "Along the thrust
belt the Chaibasa stage has been successively thrust over Iron-Ore
stage rocks, Dhanjori quartzite-conglomerate, and lava". (P. 316)

Sarkar and Saha (1962) suggested that the "Singhbhum shear
zone" represents a tectonic boundary between two intersecting oroge-
ic belts. An earlier orogeny called "Iron Ore Orogeny" (2700 m.y.,
Sarkar, Saha and Miller, 1969) affected the rocks to the south,
and a younger orogeny called "Singhbhum Orogeny" (1550 to 850 m.y.,
Sarkar and others, 1969) affected the rocks to the north.

In the opinion of Gaal (1964) metasediments of the Chaibasa
stage around Rakha and Galudih region represent 'metamorphosed
flysch deposits' which were subjected to two deformational episodes.
During the main phase of movement, the Chaibasa "metaflysch" were
thrown into open symmetrical folds, which later on warped up in the Singhbhum anticlinorium. During the second phase of movement, the Chaibasa "metaflysch" was overthrust towards SSW. The vicinity of the thrust-zone is characterised by strong shearing, A-tectonites and imbricate structure.

At Rakha-Galudih region, he had recognised three tectonic zones. The area north of Railway line between Rakha Mines and Galudih is the 'Zone of the B1 + B2 tectonites', where B1 is the axis of major fold on SS=S1 (Bedding) and B2 is the axis of minute folding and puckering of mica sheets on S2 (flow cleavage and rarely fracture cleavage). The region between south of this and north of "shear zone" is the 'zone of B2+ A tectonites', A being the downdip lineation, marked by slickenside and parallel orientation of the mineral components on S2. In this zone, moving southwards "one can recognise amongst the shear planes S2 a gradually decreasing number of bedding planes SS=S1". He considered the "shear zone" as the 'zone of the A-tectonites'. "Within the shear zone one can observe only the lineation along the dip direction."

Around Jaikan, he has reported the presence of "a strong sheared and imbricated sequence of low grade metamorphosed clastic sediments" overlying unconformably the Singhbhum Granite to the south and underlying the B.H.Q. and mica schists to the north. In his opinion these clastic sediments represent the 'ancient molasse' which were accumulated after the main phase of the orogeny in foredeep, south of the rising mountain chains. During the second phase of movement, it was overthrust by the older rocks from the NWE. "While the overlying rocks are characterised by A + B tectonites,
the clastic sedimentary series consists exclusively of A-tectonites".

Gaal suggested that molasse has a wide lateral occurrence both to the east and west of Jala
tan.

Naha (1965) studied the structure of the region around Galudih-Ghatsila. For the region north of the shear zone he suggested, "the presence of a series of compressed folds diverging in trend and plunge with axial culminations and depressions, arcs and divergences". In his opinion thrusting occurred at a later stage of folding in the southern part of the region. "Though there is a definite surface along which one block has ridden over another, a considerable portion of the total strain was released through small amount of slip on slip planes distributed through a zone 2 to 3 miles wide" (P. 60). Regarding the nature of secondary planar structures, he wrote that passing from north to south, "the axial plane schistosity is first gently folded, and finally transposed into an attitude parallel to the shear planes." On his map he had shown all the secondary planar structure on Subarnarekha and north of it as belonging to axial plane schistosity (S2) and those immediately south of it as transposition and slip schistosity, slickensides and shear planes (S3).

Banerjee (1964) from his work in the Kudada area suggested that "there is normal order of superposition in the metasediments starting from the Singhbhum Granite border to the south (south of Kudada) upto Tatanagar to the north across the shear zone. The rocks in the area, on either side of the shear zone, show a uniform structural plan characterised by a cross-folded pattern in the major and minor scales, shearing being a late superposition on the structural plan." He refuted Sarkar and Saha's (1963) contention of two intersecting orogenies along the shear zone. On the contrary, he proposed
that "there is only one visible orogenic trend in the area which is approximately ESE-WNW, local variations affected by a cross trend approx. NE-SW. The available evidences indicate that these two trends are more or less concomitant and the result of a single orogeny in Singhbhum" (Banerjee, 1964).

In later publications (1969, 70) Banerjee proposed a new history of evolution of shear zone. "The shear zone can neither be regarded as a zone of overthrusting along which older rocks were thrust over younger rocks (Dunn & Dey, 1942), nor merely as a tectonic boundary separating two intersecting orogenic belts (Sarkar and Saha, 1963). It has had a complex geological history, spread out over a long period of time." (Banerjee, 1969). In his opinion the "shear zone" around Sini-Saraikela region bears the sign of "overprinting of, at least, six tectonic events" (Banerjee, 1970). The first tectonic event was the formation of a deep seated fracture that probably extended up to the upper part of the mantle as evidenced by extensive occurrence of basic rocks together with some ultrabasic rocks along the shear zone. As a consequence, the northern block began to subside and receive sedimentation of Chaibasa stage with conglomerates at the base. This earliest event represent the "closing stage of Iron-ore Orogeny" (2700 m.y). The next four events represent "successive warning stages during the Singhbhum Orogeny" (1550 to 850 m.y.). At first, the Chaibasa stage rocks were deformed along WNW-ESE trend which is "slightly askew to that of original fracture" and as a result of reverse faulting and shearing, the Chaibasa stage rocks mounted over the Iron-Ore stage rocks. During the next phase "the pile of metasedimentary and metavolcanic rocks were compressed against the Singhbhum granite massif to the
south and were regionally cross-folded about NNE-SSW trending axes. The next two events are characterised by transverse faulting indicated by shifts of conglomerate horizon, followed by movements along a late plane of shearing running east-west, parallel to the line of original deep seated fracture. "The later movements had dislocated the earlier transverse faults. The last event represent a stage of resumption of movements along the old line of fracture during later times, probably ranging between late Tertiary to Recent." On the map, Banerjee (1969) has delineated northern and southern boundary of the "shear zone". But the basis of such clear cut boundary has not been clarified.

In an area around Gamharia, the deformation and metamorphic history has been studied by Roy (1966a, 1969), and Sen and Chakraborty (1967). According to Roy, the rocks around Gamharia have been involved in more than one metamorphic and deformation episode. The earliest diastrophic structures are the "folds on stratification with roughly E-W trend. The folding was accompanied by formation of an axial plane foliation." "The foliation plane \( S_2 \) shows folding on mesoscopic scale and fanning on regional scale." In his opinion, "the deformation of the axial plane foliation is by the continuation of the same movement which gave rise to folds on stratification." "The shear zones are characterised by mylonitization of the rocks and transposition of earlier planar structure to form \( S_3 \) shear planes" (Roy, 1966). "The dominant linear structures present on these planes—mineral lineation, streaking, grooving, major axis of deformed pebbles and axis of small scale folds and puckers are all parallel to striae on slickensides, and thus indicate the direction
of tectonic transport" (Roy, 1969, p. 103). He has delineated the southern boundary of the "shear zone" on the basis of the southern limit of recognisable mylonitic rocks. The northern limit of the "shear zone" has not been defined clearly, but on his map (Roy, 1966) all secondary planar structures to the south of an approximate E-W line, 1 km. north of Kuku Dungri, has been shown as slip schistosity and those to the north of it as axial plane foliation.

Regarding metamorphism, he suggested that "the metamorphism is broadly coeval with the folding movements and predates the shearing movements which initiated the retrogressive metamorphism" (Roy, 1966a).

Chakraborty and Sen (1967) have recorded two distinct metamorphic events for rocks in an area around Gamharia. Regional metamorphism was concomitant with the formation of axial plane schistosity ($S_2$), the folding of $S_2$, but predated the transposition schistosity ($S_3$) which is parallel to axial planes of $S_2$ folds. The retrogressive metamorphism, in their opinion, was later than $S_3$.

**Scope and procedure**

The main purpose of the investigation was to elucidate the tectonic history of the "Singhbhum shear zone". For this purpose, after a preliminary survey, the author selected four sectors within the "shear zone" around Sini, Kuku Dungri, Jaikan and Rakha Mines (Fig. 1). In these sectors, the areas lying on either side of the "shear zone" had also been mapped to compare the structures within and outside the "shear zone". Besides, reconnaissance work along some traverses near Kudada, south of Tatanagar, had been undertaken. The Kudada area was previously mapped by Bhattacharya (1967). The present work confirms the main conclusions of Bhattacharya.
In the field lithology of the individual exposures was studied and all the structures noted and measured. Particular attention was paid to the interrelation of the minor structures of different generations. The structural data were plotted on equal area projection diagram to elucidate the geometry.

A large number of thin sections of the rocks have been studied under microscope. The purpose of the study was two-fold, firstly, to record the aerial variation of the mineral assemblages, and secondly, to make a careful textural study and to work out from this the relation between deformation and crystallisation history.

It will be evident from later discussion that the author found no objective criteria on the basis of which the limits of a "shear zone" can be demarcated on the ground. When the term "shear zone" is used in this thesis it refers to a belt as delineated by the previous workers (Dunn, 1929; Dunn and Dey, 1942; Roy, 1966,69; Banerjje, 1964, 69, 70, etc.). In the opinion of the author the "Singhbhum mineralised belt" is a much more objective description of this tract than "Singhbhum shear zone."
Fig. 2: Compositional banding defined by alternate light and dark coloured bands in an exposure of banded quartzite near Tama Dungri.

Fig. 3: Photomicrograph of a banded quartzite from Sini, showing compositional banding defined by concentration of granules of apatite and opaque-ores. Section cut perpendicular to bedding in Plane polarised light, mag. X 26.
Fig. 4: Exposure of chlorite schist, showing alternate phyllosilicate-rich and quartz-rich bands. Location: North of Tama Dungri.

Fig. 5: Photomicrograph showing compositional banding of coarse grained quartzose, very fine grained quartzose and phyllosilicate-rich bands. Crossed nicols, mag. X 35.