A NEW OROGENY IN THE PRE-CAMBRIAN TRACT OF THE NORTHERN SATPURA-RAJGIR OROGENY

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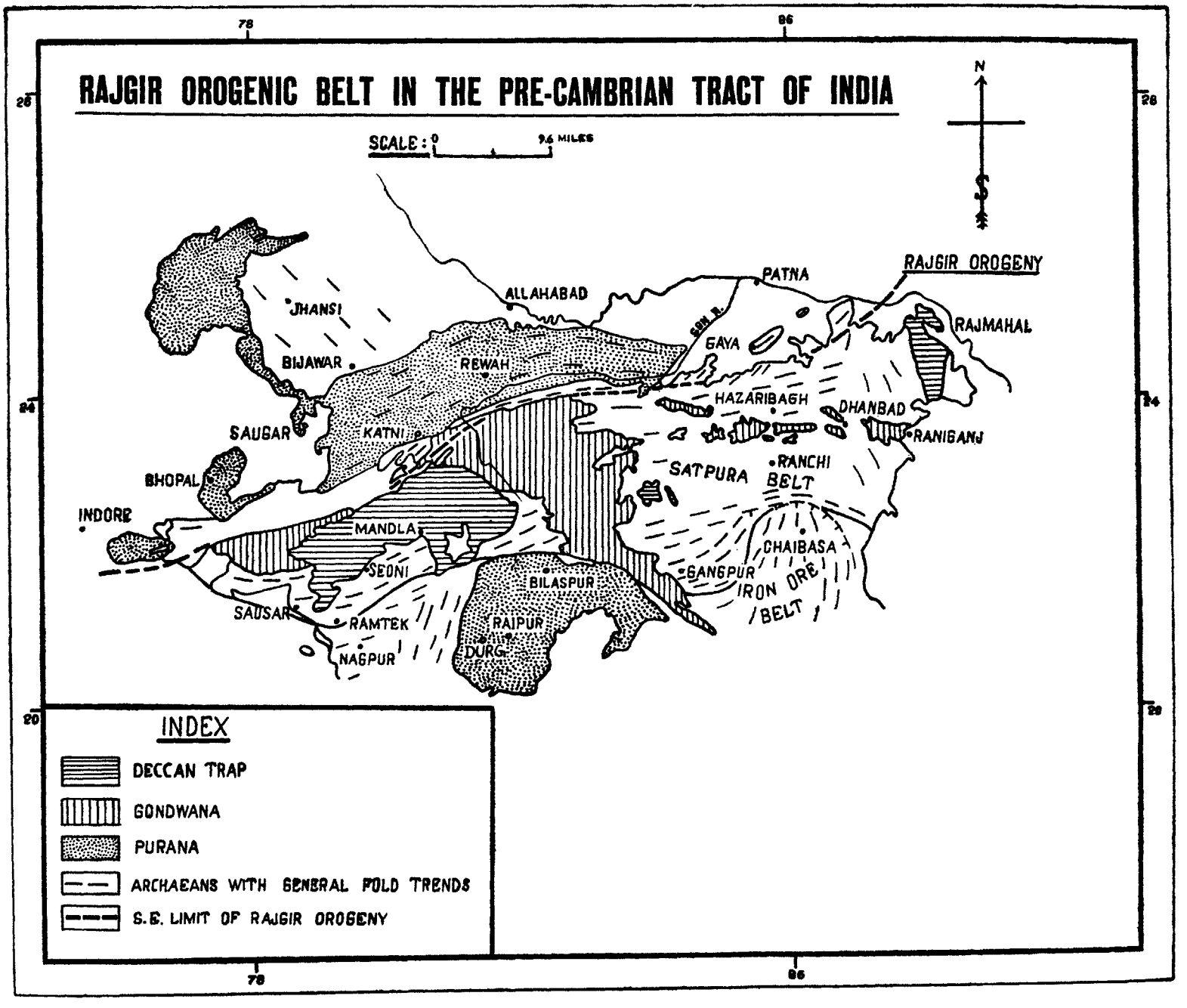
The narrow elongated belt of the sub-metamorphic series, occurring as detached outcrops in Bihar, the principal hills of which are those of Rajgir, Sheikhpura, Luckeesarai, Kharagpur, etc., forms, with the Son and the Narbada Valleys, an orogenic entity, which has been named after the key area around Rajgir. This was previously included under the Satpura Orogeny by Holmes, but is now found to be post-Satpura and pre-Vindhyan in age.

INTRODUCTION

The first systematic attempt to correlate the pre-Cambrian formations of Peninsular India was made by Fermor (1936). The demarcation by him of the regions into the charnockitic and the non-charnockitic, and his correlation with the help of the banded iron ores and manganese ores with marble (based on the assumption that certain periods of Archaean history were characterized by special types of sediments), do not find much support from modern workers. In those days, tectonic and geochronological information were not available to the extent that they are today, and, therefore, his proposal for correlation was probably the best suited at that time.

In the recent past, an entirely different approach to the problem of correlation was made by Holmes (1949, 1950 and 1955), followed by Krishnan (1953), Aswathanarayana (1956), Sarkar (1957-1958), Sarkar and Saha (1962 and 1963) and Sarkar *et al.* (1964). From the geochronological data recorded for radioactive minerals which originated during the closing stages of several of the major pre-Cambrian orogenic cycles of Peninsular India, and from the evidence provided where a younger orogenic belt cuts across an older one, Holmes (1955) formulated a succession of diastrophic cycles. These constitute, according to him, a skeleton framework within and around which many of the pre-Cambrian formations of India and Ceylon can be classified and correlated.

The regional strikes are generally N.N.W.–S.S.E. for the Dharwar belt, N.E.–S.W. for the Aravalli and the Delhi belts, N.E.–S.W. for the Eastern Ghats belt, E.N.E.–W.S.W. for the Satpura belt and N.W.–S.E. for the


RAJGIR OROGENIC BELT IN THE PRE-CAMBRIAN TRACT OF INDIA
SCALE : 0 96 MILES
N
78
86
26
24
20
28
24
29
RAJGIR OROGENY
PATNA
ALLAHABAD
JHANSI
BIJAWAR
REWAH
GAYA
SON R.
RAJMAHAL
HAZARIBAGH
DHANBAD
RANIGANJ
SAUGAR
KATNI
BHOPAL
INDORE
SATPURA
BELT
RANCHI
CHAIBASA
MANDLA
SEONI
BILASPUR
GANGPUR
IRON ORE
BELT
SAUSAR
RAMTEK
RAIPUR
DURG
NAGPUR
INDEX
DECCAN TRAP
GONDWANA
PURANA
ARCHAEANS WITH GENERAL FOLD TRENDS
S.E. LIMIT OF RAJGIR OROGENY

Godavari and the Mahanadi belts; though locally, some of these belts show considerable variations in strike. As a sequel to the joint work by Sarkar *et al.* (1964) about eight different pre-Cambrian diastrophic metamorphic cycles in all have been recognized between 600 m.y. and 3,000 m.y. Similar belts have been demarcated also from the Shield areas of Canada (Wilson 1954), Africa (Holmes 1951), Australia (Hills 1956), the Baltic (Polkanov and Gerling 1960), the Ukraine (Vinogradov *et al.* 1960), Scotland (Gilleti *et al.* 1961) and other regions.

The Satpura belt has been divided into (i) northern, and (ii) southern parts (Krishnan 1953). The northern Satpura is mainly seen from Jabalpur eastwards along the Son Valley. The southern part of the Satpura orogenic belt passes through the Nagpur-Chhindwara-Bhandara-Balaghat regions of Central India and the Gangpur-Singhbhum region of Chota Nagpur. The original idea of Holmes (1955) that the pre-Cambrian terrain of the Satpuras belongs to one orogenic belt with only one period of major granitic activity is not tenable now. More recent structural and stratigraphic studies in the Satpura belt by Sarkar, Saha and their co-workers have led to the recognition of more than one distinct orogenic belt in the region. In the pre-Cambrian tract of Singhbhum and adjacent areas (Sarkar and Saha 1963) two orogenic belts have been worked out. The N.N.E. trending Iron Ore Orogeny (= Eastern Ghat Orogenic Cycle) in the south is separated by a prominent thrust zone from the E.-W. striking Singhbhum Orogeny (= Satpura Cycle or Aravalli Cycle). Similarly, in the Bhandara and Durg-Balaghat areas (Sarkar 1957) of Maharashtra and Madhya Pradesh, three different diastrophic cycles, *viz.* Sakoli (= Satpura), and Nandgaon and Khairagarh (= Delhi) orogenies, separated by long time intervals, have been recognized.

Evidence of Discordance between the Northern and the Southern Satpura

Out of the areas originally included within the Satpura Orogenic belt by Holmes (1955), the following have remained for more critical evaluation:

(*a*) a Northern Satpura region including the sub-metamorphic belt of the Kharagpur, the Seikhpura and the Rajgir hills of Bihar, and the Son and the Narbada valleys; and

(*b*) a Southern Satpura region including the metamorphic series of Ranchi, Hazaribagh, Kodarma and Saugar, etc.

In general, the two belts of Satpura differ vastly, in regional tectonics, in lithology and in metamorphic facies as enumerated below:

Northern Satpura Region	*Southern Satpura Region*
General lithology	
(i) Lithology consists of a great series of phyllites and quartzites with basic to ultrabasic intrusives and minor emplaced granitic bodies. In the south-western portion of the series limestone is present.	(i) Lithology of the Kodarma mica-belt and of other adjacent areas consists of inter-bedded mica-schists, quartzites and para-amphibolites (including calc-silicate granulites), together with a number of small ortho-amphibolite bodies. The Sausar series rocks mainly include metamorphosed pelitic, psammitic and calcareous sediments rich in manganese ores. Basic intrusive rocks are less common. In these areas, all gradations from schists—injection-gneisses—migmatites—migmatitic granites are recognizable.
Facies of metamorphism	
(i) Slightly metamorphosed, maximum up to the 'green schist' facies of metamorphism.	(i) Highly metamorphosed from amphibolite to granulite facies of metamorphism.
(ii) Small-scale generation of granites by magmatism and metasomatism.	(ii) Large-scale generation of granites by magmatism and metasomatism.
Tectonics	
(i) Primary sedimentary structures conspicuous. Foliation is lamination-foliation.	(i) Only relics of primary sedimentary structures visible. Foliation is cleavage-foliation.
(ii) Regional trend is N.E.–S.W. which is oblique to the E.W. trend of the southern Satpura in the N.E. and S.W. parts of the region.	(ii) Regional trend is E.–W. to E.N.E.–W.S.W.

(iii) The rocks are essentially characterized by $\beta \wedge \beta' \perp \beta''$ tectonites. β and β' are synchronous and β'' is superimposed. The $\beta \parallel \beta' \perp \beta''$ tectonic character of the rocks observed in the S.W. portion of this belt is due to basement control of the older rocks.	(iii) The tectonic character of the rocks varies from $\beta \parallel \beta'$ to $\beta \parallel \beta' \perp \beta''$ and $\beta \wedge \beta'$ to $\beta \wedge \beta' \perp \beta''$. β' and β are synchronous and β'' is superimposed. This variation is due to the influence of the younger orogeny in the border regions.
(iv) Folds are generally asymmetric, isoclinal to overfolds.	(iv) Folds are generally isoclinal, overfolds to recumbent.
(v) Folds vary in style from parallel to disharmonic.	(v) Folds highly variable in style: cleavage, Chevron, conjugate, convolute, ptygmatic and intrafolial types.
(vi) Much less folded because of the non-existence of nappes and folded thrusts. Faults $\parallel$ to B, B' and B'' are present.	(vi) Highly folded due to the presence of folded thrusts and nappes.
(vii) The main forces of orogenic movements were from S.E. to N.W.	(vii) The main forces of orogenic movements in the Kodarma and adjacent areas and in the Sausar belt were from N. to S. and from S. to N. respectively.

The observations, enumerated above, of discordances in regional tectonics, in lithology and in metamorphic facies between the Northern and the Southern Satpura regions have led the author to make the suggestion that the former represents a younger orogenic belt, the sediments of which were deposited in the active belt adjoining the already stabilized continent to the south-east. The orogeny postulated has been named the *Rajgir Orogeny* (map) after the key area around Rajgir, in Patna District, Bihar, which lies twenty-eight miles to the north of the Bagai-Gupa-Laleni Marrhi metamorphic belt (Western part of the mica-belt of Bihar). Only a brief summary of the work on the regional tectonics, age and correlation, with especial reference to the key area, will be attempted here; further details are under investigation.

Tectonics of the Key Area: Rajgir Series

By the use of top and bottom criteria such as cross-bedding, ripple-marks and graded bedding in the rocks, the stratigraphic sequence has been worked out as follows:

Soft phyllites	Soft phyllites.
	Silt stone.
	Black quartzite.
Quartzites	White and grey quartzites (bottom of the white quartzite is gritty).
	Ferrugineous quartzite.
Hard ferrugineous phyllites ..	Hard and Ferrugineous slate and phyllite with ferruginous band.

A single S_1 (bedding) surface has been affected by three generations of folds. S_2—β, S_3—β' and S_4—β'' represent the axial planes and the axes, respectively, of the first, the second and the third generations of folds. S_1 and S_2 are the most prominent S-surfaces. The distinction between S_3 and S_4 cannot be made by mere inspection either since they have failed to develop or since they are too obscure to permit measurement of their orientations.

The over-all structure consists of two canoe folds that lie en/echelon along a major tectonic trend. The N.E.–S.W. trending long axis of the canoe fold is oblique to the major E.N.E.–W.S.W. tectonic line and appear as cross-fold along it. The major synclinal fold first plunges downwards and then upwards. Anticlinal and synclinal cross-folds have developed parallel to the culmination and to the depression, respectively, of the plunge of the major fold. Several faults that have been located trend more or less parallel to the cross-folds directions.

The major synclinal fold of Rajgir has been traced up to Giriak, a distance of nearly six miles. To the west of Rajgir, the trend of the fold axis gradually changes towards the S.W. and its south-eastern limb especially can be traced for nearly thirty-two miles up to Bodh Gaya. This fold opens towards Gaya, where granitic rocks have extensively developed. In the south-eastern part of the main fold, a number of less extensively developed folds parallel to the main trend are present.

Detailed statistical analysis of the structural geometry has revealed that the body is pervaded by complex noncylindroidal folds which have developed in three generations. The earliest plane noncylindrical folding is represented in general by an E.N.E. axial trend. The pattern of distorted earliest folds is less regularly preserved. The second generation of folds is slightly inclined to the first with N.E. axial trends and is also plane non-cylindrical. The youngest generation of plane cylindrical folds runs in a N.W.–S.E. direction, plunging moderately S.E., the axial planes dipping

moderately towards the east. The orientation of individual folds within B and B' are generally plunging normal; although plunging inclined and horizontal inclined folds are not uncommon. B'' folds are mostly plunging inclined. The first and the second generations of folds are synchronous, and the third generation of folds has formed at a slightly later stage of deformation. The rocks may be termed as $\beta \wedge \beta' \perp \beta''$ tectonites with triclinic symmetry. All these folds belong to a single orogeny.

The N.E.–S.W. Rajgir orogenic trend cuts across the E.–W. regional trend of the Bagai-Gurpa-Laleni Marrhi metamorphic belt, consisting of regionally metamorphosed (up to more or less the almandine-amphibolite facies) interbedded mica-schists, quartzites and para-amphibolites (including calc-silicate granulites), together with a number of small ortho-amphibolite bodies and migmatites and granitic rocks. Intensive megascopic fabric analysis (Das 1962) indicates that the rocks of this belt were folded into B-folds during the Satpura orogeny, having a general trend in an east-west direction, with axial planes dipping north, and varying in character from isoclinal, asymmetrical to overturned and at places recumbent types. The overturning is usually towards the south, with a low plunge towards the east. These folds constitute the Gurpa-anticlinoria. The amount of cross-folding in the belt increases from south to north. The N.W.–S.E. superimposed folds, plunging moderately S.E. with axial planes moderately dipping east, have formed subsidiary culmination (anticlinal cross-fold) and depression (synclinal cross-fold) in the northern parts; and they especially tally with the youngest generation of folds of the Rajgir regions. Therefore, the *Rajgir orogeny* has left its impression on the 'stabilized' region to the south-east.

Correlation

The rocks of the slate-quartzite series (Medlicott 1868) appear in detached outcrops, more or less isolated, in the deposits of the Gangetic plain of Bihar; the principal of these hills being those of Rajgir, Sheikhpura, Luckeesarai, Kharagpur, etc. In the south-west, closely related sub-metamorphic rocks are also present along the southern side of the Son and the Narbada valleys. The continuity of the sub-metamorphic belt is broken only very locally ($83° \times 24°$). We find all along this narrow elongated belt, the same stratigraphic series, tectonism of the same orientation and style, and structural trends often parallel to the axis of the belt. The various other phenomena that generally accompany in the initial stages such as basic and ultra-basic magmatism followed by metamorphism, formation of granites and mineralization of orogenic deformation are more or less well displayed in this belt. All these do indicate an orogenic entity.

Throughout the greater portion of their southern boundary, the

sub-metamorphic rocks are in contact with a great expanse of metamorphic and gneissic rocks, which terminate near Raj Mahal and extend continuously for nearly four hundred miles to the W.S.W. where they pass under the great Deccan trap outcrop of the Mandla plateau. The two belts generally have discordant trends. Since the synoptic N.E.–S.W. regional trend of the sub-metamorphic belt intersects the over-all regional E.–W. trend of the metamorphic belt, therefore, the former orogenic belt is younger than the latter.

Age

The metamorphic belt extending through Sausar-Ranchi-Hazaribagh-Kodarma falls under the Satpura Orogeny, the age of which has been fixed at 864–993 m.y. (Sarkar *et al.* 1964). This represents the lower age boundary of the Rajgir Orogeny. Further, the sub-metamorphic rocks are overlain by the Vindhyans (Pascoe 1950), the age of which has been fixed at < 600 m.y.; therefore, the *Rajgir Orogeny* should be older than the Vindhyans, *i.e.* more than 600 m.y. So, provisionally, the *Rajgir Orogeny* may be correlated with the Delhi Orogeny (735 m.y.). The Slate-quartzite series of the Monghyr District (Monghyr Orogeny), studied recently by Sarkar *et al.* (1964), falls under the *Rajgir Orogenic* belt of the author which has been dated as 420–358 m.y. by them, *i.e.* Silurian-Devonian in Holmes's scale. The age given by them seems to be much too low unless they are inclined to push the Vindhyans up much higher in the stratigraphic scale.

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