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PART V — BIHAR

By

DIRECTOR GENERAL

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FOREWORD

The total geological environment of a nation is its greatest resource. In it are comprised the minerals and fuels for industry, soil to till and water for irrigation and power. The optimum utilisation of these resources requires careful planning based on a scientific assessment and inventory. This assessment is the responsibility which the Geological Survey of India bears.

Minerals as ores and as raw material for chemicals and fertilisers are the most immediately recognised component of a country's geological resources. Since Independence, the emphasis has been on extensive prospecting and intensive exploration to prove reserves that could feed a growing economy. Against the background of systematic geological mapping of the country, this programme of mineral resources evaluation along with geotechnical studies for hydroelectric power generation, flood control, irrigation, water supply and urban expansion has also participated in development planning of the States.

This series of publications embodies concise, up-to-date accounts of the geology and mineral resources of the States and an analysis of their potential significance. Each part in the series covers one State and accompanies the geological and mineral map of that State to form a complete document for full benefit of the reader.

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Director General,
Geological Survey of India.

Calcutta,
The 7th February, 1974

CONTENTS

I. INTRODUCTION

The state of Bihar, being richest of all the states, so far as the mineral resources are concerned, is geologically most important and commands a great attention. Bihar state has an area of about 172,000 sq. km. Out of this about 80,000 sq. km. area is covered by Gangetic alluvium in the northern part and about 92,000 sq. km. is occupied by hard rock in the south. Till the time of Independence (1947) only about 55,000 sq. km. area was systematically mapped, while over 32,000 sq. km. area has been mapped since Independence. The alluvial areas of North Bihar, which were given lower priority in the mapping programme, so far, has recently been taken up for detailed study and mapping on various scales. Bihar State claims to be a store-house of minerals. It has remained till now the only state where uranium and copper ores are being produced. Several other important minerals, like coal, iron-ore, limestone, mica, kyanite, china-clay and bauxite are produced in the state. The total production of minerals in the state values over 30 per cent of the country's production.

The state attracted the attention of a number of British geologists, notable among them are T. W. H. Hughes (1866-'72), V. Ball (1867-'81), F. H. Hatch (1901), A. Jowett (1925), C. S. Fox (1923, 1930) and J. A. Dunn (1929-41). Among the Indian Geologists names of S/Shri A. K. Dey (1942), M. K. Roy Chowdhury (1958), D. R. S. Mehta (1957, 1963), A. B. Dutt (1963), H. S. Pareek (1965), T. M. Mahadevan (1967) and S. R. A. Rizvi (1972), deserve special mention. Besides the above, a large number of geologists have worked on the structure, stratigraphy and economic minerals of the state, and it is beyond the scope of this book to name all of them.

V. Ball (1881) was first to describe the geology of Singhbhum and Manbhum districts. Dunn (1929-41) carried out detailed work in the Singhbhum and surrounding areas, and has given a detailed description of his work in his memoir volumes 54, 63(pt III) and 69(Pt I & II). He has also described the economic geology and mineral resources of the state in his memoir volume 78. A large part of the state has been systematically mapped in the recent years by S. N. P. Srivastava (1952-55, 1958-60), U. Prasad (1962-73), A. N. Sarkar (1966-73), B. P. Bhattacharya (1964-73) and others.

The coalfields of Bihar have remained through ages the places of special attraction. T. W. H. Hughes (1866-67; 1870-'72) was first to give accounts of Jharia, Bokaro, Karanpura, Deoghar and Itkhori coalfields, while V. Ball (1867, 1872, 1880) described the Ramgarh, Chope, Auranga and Hutar coalfields. Later Albert Jowett (1925) discussed the geological structure of Karanpura coalfields in the memoir volume 52. Geology and coal resources of Jharia coalfield was revised by C. S. Fox in 1930, and later on by D. R. S. Mehta and B. R. Narayan Murthy in 1957. D. R. S. Mehta and others have also revised the geology of Karanpura coalfield. The petrographic studies of the coals of Karanpura coalfield have been made in detail by H. S. Pareek (1965). A. B. Dutt (1963) has revised the geology of Bokaro coalfield, while S. R. A. Rizvi (1972) has described in detail the geology and sedimentation trends of Palamau coalfields. As a results of the detailed work carried out in the coalfields by the Geological Survey of India, new coal seams were discovered, many blocks in Jharia, Bokaro, Ramgarh and Karanpura coalfields were recommended for exploitation, and the inferred reserves of coal in Bihar are now estimated to be 35,258 million tonnes against 20,000 million tonnes of pre-Independence days.

The pioneer workers on the iron-ore deposits of Bihar are F. G. Percival (1931), H. C. Jones (1934) and J. A. Dunn (1935). The bauxite deposits of the state have been examined and described in detail by Dr. M. K. Roy Chowdhury in his memoir volume 85 (1958). W. S. Sherwill (1851), A. Smith (1899), T. H. Holland (1902), A. A. C. Dickson (1907), A. F. Dixon (1913), G. H. Tipper (1920), C. S. Fox (1930) and J. A. Dunn (1940) are the earlier workers on the mica-fields of the state. Recently the geology and petrology of the mica-pegmatites in Bihar has been studied and discussed in detail by T. M. Mahadevan and J. B. P. Maithani (1967). A large number of geologists have carried out work in the Singhbhum copper belt.. J. A. Dunn (1937) was the first to give a full account of the history and geology of the copper deposits. Among the younger officials, names of N. K. Mukherjee, B. K. S. Dhruva Rao, A. B. Saha, K. R. Parthasarathy, R. S. Sharma, M. M. Sengupta, etc. may be mentioned. The base metal occurrences of the other parts of Bihar comprising mainly the districts of Bhagalpur, Santal Parganas, Hazaribagh and Palamu have also been studied in detail mainly by the young geologists, the major contributions are of S/Shri A. K. Sen (1962-64), S. R. A. Rizvi (1963-65), N. Chakravarty (1965-68), S. K. Ghosh (1964-68), U. Prasad (1964-69, 1971-73) and others. The asbestos occurrences of the state have been studied in detail by S. N. P. Srivastava (1956-59, 1963-64), and later on, by R. N. Prasad (1966-68). Srivastava (1968) has given an exhaustive description of all the occurrences of asbestos.

II. Physiography

The state of Bihar extends from the foot of the Himalayas in the north to the hill-ranges on the border of Orissa in the south and can be physiographically divided into two broad divisions, viz., (1) the Chotanagpur plateau region of central and south Bihar, and (2) the Gangetic plains of north Bihar, with a fringe of the Himalayan foot hills and the *Terai region* in the extreme north-west.

The Chotanagpur plateau represents a vast area from the westernmost part of Bihar to the border of West Bengal in the east, and continues somewhat further into West Bengal. This plateau can be divided on the basis of physiographic consideration into the Ranchi Plateau and the Hazaribagh Plateau. The former is the main plateau with general elevation of about 600 m. (m.s.l.) in Ranchi district, and has a flat to gently undulating topography with occasional ridges. To the north of Ranchi plateau, and separated from it by the Damodar valley, is the Hazaribagh plateau which extends in the north upto its dissected edge in Koderma area and in the east into Santal Parganas district. The Ranchi plateau gradually slopes down towards south-east into the hilly and undulating region of Singhbhum, which is actually the prolongation of the Chotanagpur plateau. North of Tatanagar the Dalma hills rising about 500-600 m. from the plains, forms a prominent E-W trending hill range, flanked on either side by easily denuded phyllite and mica schists occupying the lower plains. The highest peak is 924 m. from mean sea level. South of the Dalma ranges lie the undulating plains of Singhbhum. The Rajmahal hills lying in Santal Parganas and Bhagalpur districts are made up of Jurassic basalt flows and occupy a tract 130 km × 40 km in area, with north-south elongation. The Rajmahal hills form a plateau with a scarp on its western side and slopes towards Gangetic plains on the east and north. The Rajmahal hills may represent a hinge zone between uplift to the southwest and subsidence towards east and north (Dunn, 1942). The thickness of the sedimentary cover increases towards east to over 3000 m. probably as a result of step faulting (Krishnan, 1968).

The Chotanagpur plateau as a whole represents a denuded old land surfare. Broadly speaking, the Chotanagpur plateau as well as the lower plains to the east mainly consist of granitic rocks with associated metamorphic and basic igneous rocks, and large areas of Gondwana rocks constituting the coal fields of Bihar along linear tracts demarcated by faults on either side.

The Gangetic plains : North of the Chotanagpur plateau the Gangetic plains occupy a vast area in north Bihar as well as some tracts to the south of Ganga. The alluvial deposits are of variable but unknown maximum thickness which may be of the order of several thousand metres. South of Ganga, the alluvium cover gradually thins and ultimately abuts against the rock outcrops at the fringe of the southern stable land. Under this cover of alluvium lies a deep structural trough, having a WNW-ESE trend and a general slope of 1° to 3° from south to north. There are a few transverse ridges also present in this basement. The basements is further signified by both longitudinal and transverse faults, and some of them are loci of earthquakes (Krishnan, 1960).

III. Geology

A. Stratigraphy

The Archaean metamorphites with associated intrusives, and the sedimentaries belonging to Vindhyan and Gondwana systems and the associated intrusives and extrusives, comprise the most predominant hard rocks in the

State. They include diversified litho-units and are confined to the Chotanagpur Peninsular mass. The rest of the area, about half of the surface area in the State, is occupied by Quaternary sediments of Recent to the Sub-Recent age. A narrow fringe of area, in the northern-most part is underlain by loosely compacted sediments belonging to Siwalik group of rocks. The Archaeans are represented by various types of schists, gneisses, granulites, quartzites, metabasics and other basic intrusives and granites, in general. The Vindhyans comprise calcareous and arenaceous sediments, whereas the Gondwanas are represented essentially by alternations of argillaceous and arenaceous sediments, containing within their pile a number of coal seams. Conglomerates and conglomeratic sandstones, clay, graywackes and calcareous sediments represent the Siwaliks, and the flood plain deposits and some piedmont deposits, comprising the Quaternary sedimentaries in the state.

A generalised stratigraphic succession is indicated below :

Age	*Formations*
Recent	Newer alluvium
Pleistocene	
Tertiary	
Lower-Middle	
Jurrassic	
Upper Carbonifesous to Triassic	Gondwanas
Upper Precambrian	Vindhyans
Lower Palaeozoic	
Archaean (Precambrian)	Pre-Cambrian metamorphics, igneous itnrusives, metavolcanics and sedimentaries.

Archaeans :

The correlation of the Archaeans occurring in different parts of Bihar is not yet authentically possible, and so the Pre-Cambrian geology is described below under separate headings based on the areal distribution.

Singhbhum : The Archaean rocks of Singhbhum can be broadly divided into two facies, an unmetamorphosed one in the south and a metamorphosed one in the north, separated by a major shear zone known as the Singhbhum copper belt. Two lesser zones of shear occur further north, one along the northern border of the Dalma hills and the other still further north along the southern boundary of the Chotanagpur granitic terrain. These three zones are parallel to each other and to the Satpura strike prevailing in southern Bihar.

Based on the latest available data, the geological succession in Singhbhum are as follows :—

Newer dolerite
Arkasani granophyre, Soda-granite, Kuilapal granite
Chotanagpur granite-gneiss
..............Dhanjori Orogeny..............
Pyroxene granite-granophyre
Gabbro anorthosite (Vanadiferous magnetite in places)
Dhanjori stage (Kolhan series ?)
Turbidite sequence with quartz conglomerate
....
Singhbhum granite
Iron-Ore series
Granites and pegmatites
Older Metamorphics

Santhal Parganas, Hazaribagh and Ranchi districts : The northern most shear zone in Singhbhum, as mentioned above, separates the gneissic terrain to the north from the schistose rocks of Singhbhum. The various types of granite-gneisses occurring north of this shear zone are known collectively as the Chotanagpur granite-gneiss, which occupies an immense tract to the north of the belt of the Dharwarian rocks of Singhbhum and Gangpur (Orissa). The Chotanagpur granite gneiss thus characterises a distinct and important geological province and extends from the border of West Bengal in the east to the western border of Bihar with Uttar Pradesh and Orissa. Therefore, the geological features of Santhal Parganas, Hazaribagh, Ranchi and parts of Palamau and Singhbhum are comparable to certain extent.

The geological succession of the Archaean rocks, as revealed by the recent studies by the Geological Survey of India in Santhal Parganas district, is given below :—

Late to post-tectonic instrusions	Pegmatites and veins quartz
Syntectonic intrusives	Metadolerite and ortho-amphibolite. Anorthosite (sporadic) Meta-gabbro, meta-norite and granulitic meta-nortie. Pyrozenite (sporadic)
Para-metamorphics subjected to granitisation.	Granite-gneisses (Chotanagpur granite gneiss), khondalitic schist, charnockitic gneiss, amphibolite, felspathic quartzite, calc silicate rock etc.

The para-metamorphics and the syntectonic intrusives have been highly deformed and complexly folded. The mineral paragenesis of the rock-types indicate very high grade of metamorphism, belonging to the hornblende-granulite subfacies condition.

In Hazaribagh district, west of Santhal Parganas, the para-metamorphic rock-types become more schistose in nature. The prevalent rocks are mica schists, granite gneisses, amphibolite, quartzite, quartz-mica schist, schistose calc-silicate rock etc. which are intruded by meta-basic rocks, metadolerite, meta-gabbro, ortho-amphibolite. The grade of metamorphism is distinctly lower than in Santhal Parganas region and has rarely reached the sillimanite-orthoclase subfacies condition belonging to the amphibolite facies. Mica bearing pegmatite bodies of different dimensions occur extensively in Hazaribagh district, particularly around Koderma area, and also in the adjacent parts of Gaya and Monghyr districts. They are associated with vein quartz and generally occur in the mica schist country. The general strike of foliation is E-W.

In Ranchi district the predominant rock-type is the Chotanagpur granite gneiss within which bands and enclaves of mica schist, feldspathised mica schist, quartzite, calc-silicate rock epidiorite etc. occur. Metamorphism has reached upto sillimanite-orthoclase subfacies condition near Ranchi and further east, flanked by decreasing grades on either side. In Palamau district the Archaean rock-types are more or less similar to those of Ranchi, but in addition graphitic schists also occur. There are several bands and lenses of metamorphosed and crystalline limestone extending in a belt from Ramgarh westward upto Daltonganj. These are often magnesian and impure.

Monghyr and Bhagalpur districts : In parts of Monghyr district, Dharwarian rocks characterised by low grade metamorphism, *viz.* phyllites, schists etc. along with thick quartzite formations, occur. Chotanagpur granite-gneisses, occurring in southern part of Monghyr district, continues eastward into parts of Bhagalpur district.

Vindhyans :

The Vindhyan rocks are confined to a small area in the extreme western part of the state, mainly to the north of the Son river in Shahabad district and also in northwestern part of Palamau district. The upper Vindhyans are found on the north of Son river and form the eastern end of the Kaimur plateau. Towards east the maximum width of the lower Vindhyans narrows down to less than 3 km near Sasaram. The geological succession of the Vindhyans of Bihar is given below :—

UPPER VINDHYANS	Kaimur Series	Upper	Dhandraul quartzite Scrap sandstone & conglomerate
		Lower	Bijaigarh shales Upper quartzite & sandstone Lower quartzite & shales

.... Unconformity ....

LOWER VINDHYANS	Semri Series	Rhotas Stage	Alternating limestone & shale
		Kheinjua Stage	Glauconite beds (sandstone) Fawn limestone Olive shales
		Porcellanite Stage	(Porcellanites & silicified rock
		Basal Stage	Kajrahat limestone Basal conglomerate & Quartzite

The Rohtas Stage supports a flourishing lime and cement industry in Bihar. The Susnai breccia horizon occurring between the upper quartzite and lower quartzite in the lower Kaimur, has not been developed in Bihar, although this horizon is present in Mirzapur district, U.P. The Bijaigarh shales are carbonaceous, pyritiferous and points to a reducing environment of deposition.

Gondwanas :

The Gondwana group of rocks occur in the form of chain of outliers, the most important of which trend along an E-W belt, and conform approximately to the courses of Auranga and Damodar valleys. They comprise a number of detached coal fields from Hutar coal field in the west through Auranga, Karanpura, Bokaro, Ramgarh, to the Jharia and Raniganj coal fields in the east. Deoghar, Giridih and Rajmahal coalfields are also located in this main east-west chain. In the Rajmahal coalfield, the Gondwana rocks occur in a N-S belt.

The geological succession of the Gondwana group of rocks occurring in Bihar is as follows :—

	Rajmahal Series Supra-Panchet (Mahadeva Series) Panchet Series
.... Unconformity	
DAMUDA SYSTEM	Raniganj Series Barren Measures (Iron-stone shales) Barakar Series Karharbari Series
.... Unconformity	
	Talchir Series

The Talchir Series consists of a basal tillite or boulder bed succeeded by greenish colour needle shales and sandstone. Plant fossils occur in the upper part only at a few places, viz., Rikba (Karanpura), Latehar (Auranga), Nawadih (Hutar) etc.

The Damuda System, overlying the Talchir Series attains a considerable thickness and is of great economic importance because of occurrence of coal. This system comprises four series, viz., Karharbari, Barakar, Barren Measures and Raniganj.

The Talchir Series is succeeded with a distinct unconformity in the Giridih coal field by the Karharbari beds consisting of pebbly grits and sandstones attaining as thickness of 60 m. to 120 m. and containing intercalated coal seams, two of which are important and are being worked. This series has been recognised in the Karanpura, Hutar and Daltongaj coal fields.

The Barakar Series consists of white to fawn coloured sandstone, grits (conglomeratic and pebbly in some cases) and shale beds, attaining a maximum total thickness of 750 m. in the Jharia coalfield, where the series is exposed to the fullest extent. The series contains considerable carbonaceous matter in the form of seams, lenticles and streak. A total of 75 m. coal occurs in the total thickness of 600 m. strata in Jharia coalfield. Occasionally very thick seams occur in the Barakar Series, such as the Kargali seam of Bokaro coalfield which is about 30 metres thick.

The Barren Measures, about 600 m. thick, intervening between the Barakar and Raniganj Series in the Jharia coalfield is entirely barren of coal seams. Streaks of carbonaceous matter, however, are present. Lithologically the Barren Measures consist mainly of sandstone which is less coarse than in the underlying Barakar Series. The Barren Measures are equivalent to the Ironstone shales (420 m) of the Raniganj coalfield of West Bengal.

The Raniganj Series, typically developed in the Raniganj coalfield area of West Bengal, attaining a thickness of more than 1000 m, is thinner in Jharia coalfield and is about 570 m thick. Lithologically, the series consists of sandstones and shales. Coal seams occur only in Raniganj coalfield. The sandstones of Raniganj Series are definitely finer grained than in the Barakar Series.

The Panchet Series succeeds the Raniganj Series with an unconformity and in some cases overlaps the Barakars. The series comprises greenish, buff brownish sandstones and shales in the lower part and greyish micaceous, feldspathic sandstones and shales, in the upper part. This series is typically developed in the Panchet hill which is a prominent landmark.

In the Damodar valley, the *Mahadeva Series* is known by the vague term "Supra-Panchet". The Dubrajpur sandstones occurring in the Rajmahal hills are also correlated with the Mahadeva Series.

The *Rajmahal Series* is represented by the 450 to 600 m of predominantly basaltic lava flows (the Rajmahal traps) with intercalated carbonaceous shales and clays, some of which are silicified and porcellanoid. The total thickness of these intercalated sedimentary beds is only 30 m, each bed being 1.5

to 6 m thick. The intertrappean sediments between the lower four or five flows contain plant remains, fossil woods and unioids.

Rajmahal traps and related rocks :

In the Rajmahal hill ranges the Gondwana rocks are succeeded by 10 lava flows interbedded by four intertrappean beds composed of tuff, clay and ash. The lowest lava flow is acidic (dacite) and the rest are basaltic in composition. Andesite dyke has also been reported to occur as cutting across some of the flows. The chemical analyses show certain trends of variation in the Rajmahal traps and also that they belong to the calc-alkaline suite of igneous rocks and are characterised by alkaline and siliceous enrichment. The andesite and dacite could have been derived at depths from the primary basaltic magma by the process of crystallisation-differentiation aided by assimilation of the crustal rocks rich in silica, alumina and/or magnesia.

The dolerite dykes intruding into the lower Gondwanas in the Damodar valley coalfields and other eastern coalfields, are considered to be related to the Rajmahal volcanic activity and therefore, these can in general be correlated with the Rajmahal traps. It is also opined by some workers that the Deccan traps might have originally extended as far east as Lohardaga in Ranchi district where the outliers have been completely lateritised. However, laterite and bauxite ore found to be directly capping the gneissic and other metamorphic rocks in the Lohardaga area and gradual lateritisation of these rocks has also been seen. The lamprophyre (mica-peridotite) dykes and stills found in the Damodar valley coalfields and other areas are also of much the same age as the Rajmahal traps, though their origin is still not definite.

Siwaliks :

The Siwaliks occur in the extreme northwest corner of the state, in Champaran district. The formations include calcarenite, fossiliferous calcilutite, concretionary or sponzy limestone, impure limestone, sub-greywacke, conglomeratic sandstone, variegated clay, boulder conglomerate, red clay etc. These rock types of the Siwalik group have been correlated with Surma, Tipam and Dihing series of Assam and with lower, middle and upper Siwalik formations of the Punjab Himalayas on the basis of lithologic similarities, palaeontological evidence and heavy mineral association.

Tertiary gravels

Along the eastern border of Singhbhum and forming the edge of the coastal plains, gravels occur standing nearly 100 m above the sea level. These gravels are thought to be of late Tertiary age. Their present altitude suggests a more or less recent uplift.

Laterite

High level laterites are found to occur extensively capping the Netarhat and other groups of plateau in the western part of Ranchi district and adjacent areas of Palamau district. These laterite formations are generally thought to represent completely lateritised trap rock. Gradual thinning of the trap rock from the western part of Ranchi district towards east is noticed, and in the eastern part most of the laterites lie directly on the granite gneisses. Laterite derived from the Rajmahal traps occurs in the Rajmahal hills area overlying the trap rocks.

Alluvium

The Gangetic alluvial deposits can be broadly classified into two types, viz. older alluvium and newer alluvium. The sediments of older alluvium belonging probably to Pleistocene age occupy higher grounds and form terraces. These consist of coarse gravels and ferruginous fines containing abundance of calcareous nodules. The newer alluvium occurring in the lower grounds consists of a thick sequence of clay, silt and fine sands. Unlike the older alluvium these contain a high proportion of carbonaceous material and are rich in water content. Included in the Newer Alluvium are some 'fans' or piedmnot flood plain deposit, occurring in the northernmost fringe of the alluvial tract. The Quaternary sediments, though apparently barren of any economic mineral deposits, are rather rich in groundwater and alkali salts.

B. STRUCTURE

From the point of structure, the State can be divided into two broad tectonic divisions, viz., (1) the Gangetic plains of north Bihar with a fringe of the Himalayan foot hills and *Terai* region in the extreme north and north-west, and (2) the Chotanagpur plateau region of south Bihar. The Gangetic plains form a part of the Indo-Gangetic fore-deep region of the Indian sub-continent and seem to have formed by earth movements of global dimension during the Himalayan orogeny. The Chotanagpur plateau represents a part of the Indian Peninsular Shield—a stable cratonic block of the earth's crust.

Tectonically, the plateau region can be divided into seven domains, and the structure of the entire area may be described under the following heads :

(a) *Area to the south of Singhbhum shear zone*

The Pre-Cambrian metamorphics of Singhbhum belong to two tectonic domains separated by a prominent shear zone (termed 'Copper Belt Thrust by Dunn and Dey, 1942) running for more than 160 km. The shear planes have an overall northerly dip but regionally they form a sweeping curve with northward convexity. This shear zone separates two orogenic belts—the E-W striking younger Singhbhum orogenic belt in the north and the NNE-SSW trending older Iron-ore orogenic belt in the south (Sarkar and Saha, 1962). The low grade metamorphic facies of the Iron-ore orogenic belt were involved in polyphase deformations, but the folds have prominently NNE to NE axial plunge and converge with the shear zone in Chakradharpur area.

(b) *Area to the north of Singhbhum shear zone*

The Singhbhum orogenic belt to the north of the Singhbhum shear zone consists of a gre-anticline (Dunn and Dey, 1942) or the Singhbhum anticlinorium (Sarkar and Saha, 1962), which is followed to the north by the Dalma syncline. The general axis of the ge-anticline swerves from an E-W trend in the west to SE in areas occurring to the south-east, while the general axis of the Dalma syncline is mainly E-W, the Singhbhum shear zone occurring along the overturned southern limb of the ge-anticline. There are also evidences of later cross folds within tthe Singhbhum ge-anticline. The Dalma shear zone (Dunn and Dey, 1942) occurs along the inverted northern limb of the Dalma syncline and is followed to the north by another lesser shear zone along the southern boundary of Chotanagpur granitic terrain. The Dalma syncline shows evidence of refolding in the tortuous nature of its axial trace.

(c) *Chotanagpur granite gneiss terrain*

The Chotanagpur granitic complex with associated meta-sedimentaries occupying a vast tract in Bihar from Palamau district in the west to Santal Parganas district in the east has been subjected to three superposed fold movements giving rise to macroscopic structural domes and basins on the regional foliation in eastern part with a general N-S strike in Santal Parganas, while in the middle and the western parts falling in Hazaribagh, Ranchi and Palamau districts the superpositon has been less intense and the general strike in those parts is mainly E-W. The earliest folds were on bedding giving rise to regional foliation which was again folded on E-W trending axes, subsequently distorted locally by superpositon of still later folds. The axial trend of these later folds is E-W in the western part falling in Palamau and Ranchi district (Jha and Sarkar, 1967; Sarkar, 1968), while it swerves through ENE and NE in the middle part falling in Hazaribagh district and ultimately becomes NNE in the northeastern part falling in Santal Parganas district (Bhattacharyya, 1967-1972; and Prasad, 1969-1971). This swerving of the axis of these later folds might be due to another younger deformation. The Chotanagpur granitic complex occurring in the southeastern part of the tract falling in north Singhbhum was however, involved in two generations of folding, both with general E-W trends of axes (Sarkar, 1971). Of these, the folds of the first generation have steeply dipping axial plane towards south where the axial plane of the second generation folds dips towards north at low angle.

(d) *Gaya-Rajgir-Monghyr belt*

The meta-sedimentaries in this belt having NE to ENE trend have undergone two fold movements (Prasad, 1969-70; Sarkar and Basu Mallick, 1973). Th earlier of the two was more intense and led to NE-SW trending upright folds on bedding, while the later movement resulted in WNW trending folds. The faults and fractures in this area are geometrically related to the major fold pattern and are extension, shear or release fractures and faults. The hot springs in Rajgir area (middle part of the belt) occur mainly along the release faults at the quartzite-phyllite contact.

(e) *Vindhyan terrain in Palamau and Shahabad districts* :

The Lower Vindhyans south of the Son river (Palamau district) are folded into upright anticlines and synclines with low axial plunge towards ENE. The beds are low dipping (10°-30°) with general ENE-WSW strike. Strike faults of regional dimensions are common. The Upper Vindhyans occurring to north of the Son River (Shahabad district) are either horizontal or sub-horizontal without any significant deformation.

(f) *Gondwana group coalfield areas* :

The Gondwana group coalfield areas occupy E-W trending belts in Auranga and Damodar valleys. The rocks were deposited in tectonic troughs having faulted margins. The beds dip, in general, towards the fault with greater throw at low to moderate angles. Transverse faults, strike faults and oblique faults are very common.

(g) *Rajmahal Trap area* :

The traps along with inter-trappeans are mostly horizontal in attitude and were not involved in any folding movement. These traps extend to the east and south-east, but have been faulted down and covered by Cretaceous and Tertiary strata in the Ganges delta.

C. GEOLOGICAL HISTORY

The Older Metamorphics of Singhbhum district are believed to be the earliest rocks exposed in Bihar (Jones, 1934). Dunn (1940), however, considered them as forming parts of the Iron-Ore Series. Dunn and Dey (1942) believed both the low and high grade facies of north Singhbhum as broadly stratigraphically equivalents; the juxtaposition of the low-grade and high grade rocks according to them was brought about by the Copper-Belt thrust. Sarkar and Saha (1962) and subsequently Sarkar, Saha and Miller (1969) on the basis of reinterpretation of structure in some areas coupled with geochronological data have, however, suggested a revised geological history of Singhbhum. According to them the relevent Ar/K data indicate that the orogenic movements in south Singhbhum (Iron-Ore orogeny) closed at 2,700 m.y. and are much older than the orogenic movements in north Singhbhum (Singhbhum orogeny) which closed at 850 m.y. The end of the Iron-Ore orogeny was marked by the intrusion of the Singhbhum granite, whereas in the later period of the polyphase deformation and metamorphism in north Singhbhum (Singhbhum orogeny), large-scale granitisation took place. The Newer Dolerites, occurring as dykes in the Singhbhum Granite, are the latest intrusives of the area.

After the polyphase movements and metamorphism, igneous intrusions and metasomatism, and upliftment of the pre-Cambrian rocks of south Bihar, the area became a stable and cratonic block. This was followed by a prolonged period of denudation and a number of sedimentary basins were formed on the denuded surface. In the south Singhbhum district rocks of Kolhan group were deposited in Algonkian time. Similarly in the western part of the State (Palamau and Shahabad districts), the Vindhyan rocks were deposited in the basins formed on old denuded surface. These rocks were then folded, though the forces at play had much less intensity than that in the early pre-Cambrian era.

After the deposition of the Vindhyan rocks in the west and their uplift into land, there was a great hiatus in the geological history of the State. At the end of the Palaeozoic era, a new series of changes took place, which was mainly manifested by gravity block faulting in the Chotanagpur granite terrain. As a result of this block faulting, a number of basins were formed in an E-W belt. A new era (Gondwana) began with a glacial climate when a glacial boulder bed (Talchir) was deposited. The bulk of the strata which followed the glacial conditions was laid down as thick supergroup of fluviatile and lacustrine deposits (Damudas) with intercalated plant remains that ultimately converted into coal seams. The succeeding beds (Panchets) were laid down in flood plains and shallow lakes, and are free of carbonaceous matter. This was followed by deposition of sediments (Mahadevas) in arid climate. Then transverse faulting took place in the sediments of Gondwana basin in post-Panchet and pre-Mahadeva time, and a few in post-Mahadeva time. During the Rajmahal time, the crust seems to have experienced tension resulting in outpouring of vast quantities of lavas and volcanic material in the Rajmahal area.

After the eruption of the Rajmahal traps, the plateau region of Bihar did not experience any major geologic activity, excepting that in the eastern border of Singhbhum a gravel bed was deposited in late Tertiary time. In the north-west (Champaran district) the Siwalik group of rocks was deposited at the foot of the Himalayas in the depression which is a part of the fore-deep formed in the Indian Sub-continent after the third and perhaps the most violent Himalayan movement during the middle Miccene period. Extensive lateritisation in some parts of the plateau region during the Pleistocene period and formation of north Bihar plains by filling up the fore-deep during Pleistocene-Recent times by alluvial material have completed the picture of the State.

IV. Mineral Resources

APATITE

Apatite mineralisation is found along the Singhbhum Copper Belt, over a 60 km long zone, associated with schistose rocks of the Iron-Ore Series. The mineral occurs as a constituent of veins and lenses containing apatite and magnetite in biotite-chlorite rock. The deposits occur as fissure veins, replacement veins, disseminations or foliation fillings. The bulk of the apatite is, however, expected from fissure veins. Individual veins vary in width from 0.61 metre to 10.5 metre. The P_2O_5 content in the belt varies from 11 to 29.24 per cent.

The apatite zone from Itagarh (21°35′ : 86°25′) to Rajdah (22°41′ : 86°17′) is called the "Nandup Sector", that from Rakha Mines (22°38′ : 86°22′) to Dhobani (22°03′ : 86°27′) is known as the "Pathargora sector", and the third from Mosaboni (22°31′ : 86°28′) to Khejurdari (22°24′ : 86°34′) is designated as "Sunrgi Sector". A total reserve of 1.5 million tonnes containing 10 to 25 per cent P_2O_5 down to a depth of 30 metres has been estimated in the three sectors.

ASBESTOS

Occurrences of asbestos in Bihar are almost entirely confined to the Singhbhum district and are associated with Pre-Cambrian basic and ultrabasic rocks of Iron-Ore Series and the Dalma Lavas. The majority of the deposits are of amphibole variety. Chrysotile variety occurs at Roro (22°39′30″ : 85°39′00″), Nurda (22°20′ : 85°44′), Kalimati (22°16′00″ : 85°45′30″), Bichaburu (22°17′30″ : 85°48′00″), Gitilata (22°40′00 : 86°11′30″), and Manpur (22°36′ : 86°16′), and in very subordinate quantities at Barabana (22°37′ : 85°56′), Butgora (22°33′30″ : 86°20′30″), Duyarsini (22°35′ : 86°14′), and Digarsai (22°34′30″ : 86°15′00″) associated with the tremolite variety. Chrysotile is also noted in the chromite bearing areas of Jojohatu (22°32′ : 85°38′). Important deposits of tremolite asbestos are located near Barabana (22°37′ : 85°56′), Sarangpos (22°35′ : 85°55′), Nutandih (22°51′ : 85°18′), Bamanjhar (22°27′00″ : 86°13′30″)—Harina (22°31′ : 86°14′) area, Lailam (22°29′) : 86°11′) — Telingkocha (22°29′00″ : 86°11′30″) area, Jirka (22°49′30″ : 86°22′00″), Chardiha (22°23′00″ : 86°17′30″), Gamarkocha (22°33′ : 86°17′) Sarjori (22°32′ : 86°20′), and Lapaibera (22°52′30″ : 85°56′30°).

Roro hill deposit is under active exploitation by M/S Hyderabad Asbestos Cement Products Ltd. In the underground mine a 45 cm thick zone comprising several thin, veinlets of chrysotile asbestos is found continuing for about 122 metres in length. The probable reserves of asbestos estimated at Nurda, Manpur, Sarjori, Kalimati-Bichaburu, and Lailam-Telingkocha area are 1600 tonnes, 5000 tonnes, 26,000 tonnes, 1225 tonnes and 40,000 tonnes respectively upto a depth of 30 metres; and at Gitilata, Nutandih, Bamanjhar-Harina, and Lapaibera are 22,000 tonnes, 22,500 tonnes, 62,400 tonnes, and 22,000 tonnes respectively upto a depth of 15 metres.

BARYTES

Narrow veins and lenticular patches of barytes are reported from Kolpatka (22°22′ : 85°06′), Pradhanpali (22°20′ : 85°06′), Dhanapal (22°19′ : 85°06′) and Chaurarapa (22°25′ : 85°08′) in Singhbhum district, and from Tati-Silwai (22°23′ : 85°27′), Bahea (23°23′ : 85°30′), Bongaibera (23°03′ : 85°03′), Ulatutoli (23°23″:'85°28′), Tiliajaratoli (22°23′ : 85°31′), Beniajaratoli (23°22′ : 85°32′) Supatoli (23°22′ : 85°53′) and Karamtoli (23°18′ : 85°03′) in Ranchi district. Thin veinlets of barytes are also found within silicified shales belonging to Lower Vindhyan near Singhitali (24°24′30″ : 83°34′ 30″) in Palamau district. At Kolpatka barytes occurs in discontinuous lenticular patches associated with sericite-schist, and the probable reserves are estimated at 4100 tonnes. Near Tati-Silwai, the barytes veins are found in a zone 2.5 km long and 200 metre wide. The individual veins are only few centimetres thick and have been worked out upto 5 to 6 m depth. They appear to be lenticular and are not traceable over long distances. Near Singhitali, north of Bhaunathpur, in Palamau district, thin veinlets of barytes occur associated with quartz-veins in silicified shales and dolomitic limestones. Probable reserves of barytes in this area have been estimated at 33,000 tonnes upto a depth of 1.5 metres.

BAUXITE

Extensive deposits of bauxite are found in the plateau areas of Ranchi and Palamau districts, associated with high level laterite. Besides, minor deposits are reported from Monghyr and Rohtas districts. The area was geologically mapped by Dr. M. K. Roy Chowdhury of Geological Survey of India between 1943 and 1947.

Ranchi-Palamau district :

Some of the important deposits in Ranchi district are Bagru hill (Dudmatia Pat) (23°29′ : 84°36′), Jarda Pahar (23°05′ : 84°10′), ridge between Gharghuta Nadi and Barkadih (23°00′ : 84°10′), Luchutpat (23°13′ : 84°15′), Gorapahartoli (23°22′ : 84°15′), Sukhwapanitoli (23°19′ : 84°21′); Chhattasarai (23°18′ : 84°18′3, Gurdari (23°28′ : 84°14′), Kujam (23°18′ : 84°18′) etc. The important deposits in the Palamau district are in Chiro (23°27′ : 84°01′)—Kukud (23°29′ : 84°00′) and Orsa (23°24′ : 83°59′) areas of Jamira Pat plateau. These areas individually are estimated conservatively to contain reserves varying from 50,000 to 2.5 million tonnes of bauxite of all grades.

The reserves of bauxite of high grade containing over 50% Al_2O_3 were tentatively estimated by Roy Chowdhury (1958) at about 9 million tonnes in the Ranchi district and 1.7 million tonnes in the Palamau district.

Detailed proving of some of the unleased deposits of bauxite have been taken up during recent years. These deposits are Hanrup (23°24′ : 84°00′), Chandipat (23°18′ : 84°11′), Lupungpat (23°13′ : 84°17′), Bhaglatoli (23°12′ : 84°16′), Jarda Pahar (23°05′ : 84°10′). Kabragat (23°23′ : 84°26′), Dhuluapat 84°23′ : 84°31′), Dipakujam (23°18′ 84°18′) and Barkadih (23°00′ : 84°10′). A tentative indicated reserves of 12.83 million tonnes, so far, have been estimated in the above deposits.

Monghyr district :

In 1941, A. M. N. Ghosh of G.S.I. recorded the occurrences of bauxite in Kharagpur hills, Monghyr district. Four significant deposits, namely the hills of Khapra, Maruk, Maira and Thadi have been found here, of which the deposit at Maruk is the most promising. The total tentative reserves of various grades estimated in the four hills are of the order of 1.5 million tonnes of which Maruk hill deposit alone contains 1.11 million tonnes.

BERYL

Beryl is found in some pegmatites in the mica fields of Hazaribagh and Monghyr districts and are worked either along with mica or separately in some cases. The Atomic Minerals Department of the Atomic Energy Commission is at present the sole purchaser of beryl.

CASSITERITE

Sporadic occurrences of cassiterite have been recorded at Nurungo (24°10′ :86°08′3. Chappatand (24°42′ : 85°54′); and Pihra (24°39′ : 86°48′) in found at Kusmita (22°05′ : 85°45′)—Gurgaon (24°30′ : 84°28′) and Kachanpur (23°34′00″ : 85°41′30″) in the Gaya district, Nurungo deposit was worked in the past, and according to Oates an inclined shaft has gone upto a depth of 187 m. Detailed investigation aided by drilling in the area in the recent years could not establish strikewise or dipwise extension of cassiterite mineralisation. Quartz-magnetite rock and loose crystals of magnetite located at few spots at Chappatani showed only traces of tin. Minute grains of cassiterite are sparsely distributed in aplites, pegmatites, quartz veins and also in the country rocks at Chakrabandha and Kanchanpur areas. Tin bearing garnets occur in the form of small lenticular pockets within quartz-sericite-sillimanite-mica-schist at Bhaknahwa and Dhanras hills in the Chakrabandha area.

CHROMITE

Small deposits of chromite are confined to the southern part of Singhbhum district in Bihar. Such deposits are located in the hills of Roro-buru, Chitungburu, Kimsiburu, Kittaburu and Jojohatu. Small occurrences are also found at Kusmita (22°05′ : 85°45′)—Gurgaon (22°25′ : 85°10′3″) Tonto (22°-20′ : 85°35′) and Janoa-Ranjrakocha (22°31′ : 85°38′) areas. The tentative possible reserves in the various areas have been estimated as follows :—

Roro area	90,000 tonnes
Karakata Kuti hill	1,00,000 tonnes
Kusmita-Gurgaon area	1,68,000 tonnes
Janoa-Ranjrakocha area	16,560 tonnes
Tonto area	5,400 tonnes

The deposits are rather scattered and small and the grade is generally inferior, (30-40% Cr_2O_3). Many of the deposits have been prospected by private parties but abandoned afterwards.

CLAY

China clay :

Bihar is an important producer of china-clay in India. Extensive deposits of koalion of fairly good quality are found in Karanjia (22°12′ : 85°44′) Dumaria (22°10′ : 85°55′) and Sararia (22°16′:85°43′) areas in Singhbhum district. Other important deposits are noted at Patharghatti (25°20′ : 87°16′) and Samukhia (24°57′ : 86°52′) in Bhagalpur district; Haridih (23°27′ : 85°47′) and Sursu (23°27′:85°43′) in Ranchi district; and Mangalhat (25°04′:87°47′), Manjhitola (24°19′:87°24′) and Pond Dongri (24°59′ : 87°23′) in Santal Parganas district. Besides the above, a number of other occurrences are located in Dhanbad, Gaya, Hazaribagh, Palamau, Santal Parganas, and Singhbhum districts.

In the Singhbhum district large quantity of clay has already been worked out in the Karanjia area, though about 400,000 tonnes of clay may still be available from this place. In the Dumaria area, the total reserves of crude clay in all the localities combined together will be more than 1,287,000 tonnes, while in the Sararia area the total reserves of clay after washing is expected to be about 58,400 tonnes.

The china-clay deposit at Patharghatta, Santal Parganas district which is under lease to M/S Bengal Potteries Ltd., has clay zone of about 12 metres thickness that varied at places to more than 20 metres. The reserve of crude china clay of this place was estimated at about 1,80,000 tonnes with about 15 per cent recovery on washing. Several outcrops of Barakar sandstone with a clayey matrix occur near Mangalhat, Santal Parganas district, and are under lease to the Rajmahal Glass Sand and Kaolin Company.

Fire Clay :

Fire clay in Bihar generally occurs as beds associated with the coal seams in the Gondwana rocks. In the Jharia coal field the fire clays are found near Jharia (23°40′ : 86°25′), Pathardih (23°40′ : 86°26′), Chanderpura (23°45′ : 86°07′), Lutipahari (22°47′ : 86°12′), Tetulmari (23°49′ : 86°21′), Kenduadih (23°42′:86°23′), and Chasnala (23°35′: 86°10′). These clays are of fairly good refractory quality. The gross reverses of fireclay in Dhanbad district has been estimated at about 7.2 million tonnes upto depth of 6 m.

In Hazaribad district several seams of fire clay suitable for refractory purposes, are located near Mandu (23°48′:85°28′), Karo 23°47′:85°59′), Bermo (23°47′:85°56′), Gumia (23°48′: °50′) and Lioyo (23°48′:85°48′) in Bokaro coalfield; and near Devalgara (23°51′:84°58′), Barkuta (23°53′ : 84°58′), Ray (23°53′:84°56′), Bachra (23°41′: 85°05′) and Kurlonga (22°52′:84°57′) in North Karanpura coal field. In the Bachra block of NCDC good quality fire clay was estimated by G.S.I. to be about 7.9 million tonnes. In the South Karanpura coalfield, fire clay beds are found near Argada, Good fire clay seams are also found in the Ramgarh, Daltonganj and Hutar coalfield. Considerable deposits of fireclay are found in Santal Parganas district near Dukatia (25°03′ : 87°23′) and in other places in the Hura coalfield. The clay at Dukatia is highly plastic and resistant upto 1400°C, and fires pale white. Estimated reserves are about 1.8 million tonnes.

COAL

Coalfields of Bihar are mainly located in the valleys of Damodar and Koel. The Damodar valley comprises Raniganj, Jharia, East and West Bokaro, North and South Karanpura and Ramgarh coalfields; and the Koel valley consists of Auranga, Hutar and Daltonganj coalfields. Besides these, the other coalfields are Chope-Itkhori, Giridih, Deogarh and Rajmahal. The total inferred reserves of coal in Bihar, as worked out recently by Task Force on Coal and Lignite, for seams 1.2 m. and above in thickness and upto a depth of 600 m, amount to about 35,258 million tonnes. Brief descriptions of the coalfields are given below:—

Raniganj coalfield : A small part of this coalfield, lying west of the Barakar river, falls in Bihar. In this area only Barakar seams have developed, viz., Pusai, Kalimati, Bindabanpur, Gopinathpur, Laikdih and Shampur.

Jharia coalfield : It extends over an area of about 450 sq. kms and is the most important coalfield of the country, being the storehouse of prime coking coal. It consists of eighteen regionally persistent coal seams in the Barakar measures numbered I to XVIII from bottom to top. The lower seams (below X seams) are generally of inferior quality in comparison to the upper seams. The coals are largely of low moisture (less than 2%), medium volatile and caking type. The Raniganj measure coals show a lesser development and are generally of high moisture (> 2%), high Volatile, and are tentatively grouped as semicoking coals. The total gross reserves for different types of coal, as estimated recently by the Task Force on Coal and Lignite, is about 12,817 m. tonnes.

East Bokaro, covering an area of 207 sq. km., is highly potential as it shows the development of a number of thick seams, viz., Karo (17-53 m.), Bermo (4-16 m.) and Kargali (20-45 m.). The coal may broadly be classified as of medium coking variety. The total reserves of coal amount to 1992.9 m tonnes.

West Bokaro, occupying an area of about 154 sq. km, consists of thirteen regionally persistent seams, numbered I to XIII from bottom to top. The coals are of medium coking type in seams V, VI and VIII, whilst the other seams contain semi to weakly coking coal. The reserves, as estimated by the Committee on Assessment of Reserves, are 3323 m. tonnes.

North Karanpura coalfield : This covers an area of about 1239 sq. kms. Generally, the coals are non-coking, high in moisture and ash percentages, except in the eastern part where medium coking (high ash) coals are available. The gross reserves for both medium coking and non-coking coals for seams 1.2 m. and above in thickness and upto a depth of 600 m., are 8668.7 m. tonnes.

South Karanpura coalfield : This field, covering an area of about 194 sq. km., has altogether 44 seams, the most important of which are Argada seams (maxm. thickness 54.2 m.) and the Sirka seam (16.7 m.). This field contains large reserves of non-coking and inferior grade coals, suitable for power generation. The total reserves of coal amount to 4446.7 m. tonnes.

Ramgarh coalfield : The coalfield covers an area of about 98 sq. km. It contains medium coking coal with usually low moisture ($> 2\%$) and fairly high caking indices in the main Ramgarh sub-basin, and coals of high moisture ($< 2\%$), high volatile and weakly caking type in the Mahuatogri-Gohardhara sub-basin. The total reserves of coal are to the order of 936 m. tonnes.

Auranga coalfield : A few seams are present, out of which one seam, the Bagdaga seam, attains a thickness of about 14 m. The coal is of inferior type. A gross reserves of 118 m. tonnes, for seams 1.2 m. and above in thickness and upto a depth of 600 m., has been estimated for this field.

Daltonganj coalfield : Coal seams are restricted to the Karharbari formation in the central part of this coalfield. The coals are of non-coking superior quality. The reserves as estimated amount to 87.9 m. tonnes.

Hutar coalfield : The coal is in general of non-coking, inferior quality, with very high moisture. A gross reserve of 80.7 m. tonnes of coal has been estimated.

Chope-Itkhori coalfield : This is a very small field. The coals are generally of high moisture type. A tentative gross reserve of 20 m. tonnes can be expected from this field.

Girdih coalfield : This small coalfield (about 28 sq. km. in area) contains superior quality, strongly coking coal, though its resources are almost exhausted. The latest reserve position is 37.3 m. tonnes for both prime coking and medium coking coals.

Deogarh group of coalfields : Three isolated patches of coal measures, *viz*. Jainti, Saharjuri and Kundit Kuriah are found. The coal seams are generally 1-3 m. in thickness and, in general, contain non-coking, relatively low ash coal. The reserves, as estimated, amount to 38.3 m. tonnes.

Rajmahal coalfield : Five isolated patches of Barakars occur along the western fringe of the Rajmahal Hills, and are described as Hura, Chuperbhita, Ranchwara, Mahuagari and Bramhani coalfields. The seams in all these fields rarely attain a thickness of more than 8 m. and are in general of inferior quality. Large reserves, amounting to 2682 m. tonnes have been estimated for these fields.

COPPER

Most important deposits of copper are occur in Singhbhum Copper Belt, which is a shear zone that extends for over 160 km. with an arcuate trend in the southeastern part of the Singhbhum district. Within this Belt, copper mineralisation is relatively more well developed and persistent in Mosaboni (22°31′ : 86°28′), Badia (22°32′ : 86°27′), (22°29′30″ : 86°26′), Pathargora Surda (22°33′ : 86°26′), Rakha-Roam-Siddheswar (22°38′ : 86°24′), Tamapahar blocks at the east of Jamshedpur-Hatha road, where the shear zone is narrower, more well defined and intense. Westwards the Turamdih (22°45′ : 86°12′), Nandup (22°44′ : 86°12′) and Bayanbil and Ramchandra Pahar (22°43′ : 86°13′) blocks show quite good intensity of mineralisation, though loades are more wide and concentration of values comparatively less. Besides these there are smaller occurrences at Mahuldih (22°44′ : 86°09′), Kudamdiha (22°47′ : 85°50′), Barachakri (22°45′ : 85°45′), Galudih (22°47′ : 85°44′), Durarpuram (22°46′ : 85°34′) and other places.

The major copper mineral, chalcoyprite, along with other associated sulphide minerals like pyrite, pentlandite, bravoite, violerite etc. occur as impersistent veins, patches, disseminations etc. in different types of host rocks, including sheared soda granite, as in Mosabani and Badia Mines, and quartz-chlorite-schist, granular quartz-biotite-chlorite rock etc. in Rakha, Tamapahar, Turamdih and other deposits. Nickel and Molybdenum occur as significant minor metal in these ores. The Indian Copper Corporation Ltd. works the deposits at Mosaboni, Badia, Surda and Pathargara. Nickel is being obtained as a bye-product. The total reserve of "proved' ore in the Mosaboni, Badia, Surda and Pathargara mines of Indian Copper Corporation Ltd. has been about 4 million tonnes with 2.3% copper grade at the end of 1965.

The old Rakha mines area and the adjacent Road-Siddheswar Block have been explored in detail by the GSI, where "proved" and "probable" ore reserves has been established at about 63 million tonnes with 1.57% copper grade. This deposit is being developed by Hindusthan Copper Ltd. in Public Sector. The Tamapahar block at its west have also been explored in detail by GSI, where about 16 million tonnes of copper ore with about 1.40% copper grade has been established. At the western part of the Belt, the Turamdih block is being explored in detail by GSI through intensive drilling and underground opening. The interim estimate places the ore reserve here at about 12 million tonnes with 1.62% copper average grade. Development of this deposit is under consideration by Hindusthan Copper Ltd. Regional assessment of adjacent Nandup, Bayanbil and Ramchandra Pahar areas have indicated promising results, but further detailed work would be necessary before firmly establishing their potentialities. Assessment of other copper occurrences in the Singhbhum Copper Belt is being continued by the GSI.

Copper ore associated with lead and zinc sulphide minerals occur at several localities of Hazaribagh, Santhal Parganas, Gaya and Palamau districts. These occurrences have been under investigation by the GSI, but so far no workable deposit has been established. At Baraganda (24°05′ : 86°03′), where an old copper mine exists, the mineralisation has been tested by intensive drilling over 1.1 km. length. The lodes of copper mineral, chalcopyrite, occur in chlorite-biotite schists, forming part of a shear-zone. A total of 5 individual copper lodes have been delineated. Chalcopyrite forms the dominant mineral with sporadic lead and zinc sulphide minerals. The lodes are impersistent, and the total potentiality of about 0.6 million tonnes of copper ore with 2.3% copper grade have been estimated over the whole strike length. The deposit is not considered suitable for economic mining.

FELDSPAR

The pegmatites of Bihar Mica belt contain certain amount of potash feldspar. Both white and pink feldspars occur at Gawan (24°37′:85°55′), Dhab (24°35′ : 85°46′), and Saphitola (24°35′ : 85°40′) areas in Hazaribagh district. Occurrences of feldspar have also been located in Bandhakharo (24°06′ : 85°57′), Pihra (24°38′ : 85°48′), Sisri (24°35′ : 86°04′), Marpa (24°98′ : 85°31′) Harichatan (24°98′ : 85°35′), Chichaki (24°07′ : 85°57′), Bakradih (24°10′ : 85°58′), Kubadih (24°11′ : 85°56′), Kodarma (24°28′ : 85°35′), and other areas in the Hazaribagh district. Pegmatites are being worked for feldspar at Bandhakharo. Some large pegmatites consisting almost entirely of potash feldspar occur to the north of Jainti (22°04′ : 85°41′) in the Singhbhum district. Occurrences have also been reported from a number of localities in Dhanbad, Santal Parganas and Monghyr districts.

Tentatively, 1725 tonnes of good quality pink feldspar have been estimated from 26 pegmatites veins of Kodarma area. In Tisri area, good workable deposits of pink potash feldspar, occur around Gankura (24°35′ : 86°00′) and Khajuria (24°32′ : 86°06′). Feldspars from a few veins from Gandkura area are good quality suitable for electrical insulators.

GOLD

Gold bearing quartz veins have been reported from a number of localities in the Singhbhum district, namely Kundarkocha (22°28′ : 86°15′), Lawa (23°01′ : 86°05′), Mysara (23°03′ : 86°00′) Pahardia (22°30′ : 85°42′), Sonapet (22°53′ : 85°40′), Ankua (22°18′ :85°16′), Sausal (22°37′ : 85°17′), Barachakri (22°45′ : 85°45′), Bhatardari (22°42′ : 86°11′) and Digarsia (22°34′ : 86°15′). It has also been reported from Sithaura (25°00′ : 85°25′)

in the Patna district. Almost all the occurrences have been investigated by G.S.I. during recent years. The economic workability and potentiality of these occurrences have established. Gold particles are found also in the sands of a number of rivers of south Bihar of which Gurra, South Koel, Sanjai, Sono and Subarnarekha are more important. None of the alluvial gold deposits offer scope for large scale extraction by modern methods.

GRAPHITE

In Bihar, graphite occurrences are found mostly in the Palamau district. The important occurrences are Sokra (23°58′ : 84°08′) Khamdih, (23°58′ : 84°13′), Bhang (24°03′30″ : 84°19′30″), Mamoman (23°37′30″ : 84°12′30″), Parasia (24°04′ : 84°19′), Arapur (24°14′00″ : 84°02′30″), Mahugain (24°03′ : 84°04′), and Ledwakhar (23°55′00″ : 84°12′30″). The grade of graphite at Sokra and Khamdih varies from that of 45 per cent to 75 per cent fixed carbon. In most of the occurrences graphite occurs as disseminations in graphite schists, and the graphite content varies from 15 to 30 per cent. The graphite reserves in Bihar have tentatively been calculated to 2.14 million tonnes upto a depth of 20 metres with average graphite content of 15 per cent in the rock.

IRON-ORE

Iron-ore, associated with a group of rocks known as the Iron-Ore Series, consisting mainly of banded hematite-quartzite and shales with intercalations of lava flows and tuffs, occurs in a series of ridges with NNE-SSW strike, extending from the south-western part of Singhbhum district in Bihar to the adjoining Keonjhar and Sundergarh district in Orissa. Workable deposits of iron-ore found in Bihar are around Noamundi (22°09′ : 85°29′), Notuburu (22°18′ : 85°22′), Jamda (22°10′ : 85°25′), Gua (22°13′ : 85°23′), and other areas. The aggregate proved and indicate reserves of iron-ore in Bihar and Orissa are of the order of 4,880 million tonnes.

In addition to the Iron-Ore Series in south Singhbhum, iron-ores have also been found at Jhilingburu (22°12′ : 85°23′), south of Gua, with the Kolhan Series of rocks. Iron stone and hematite, occurring as nodules in the Barakar rocks, have been noted at Rajbar (23°47′ : 84°39′), Balunagar (23°50′ : 84°41′) and Morwai (23°46′ : 84°07′) in the Palamau district.

Deposits of magnetite occur between Dhadkidih (22°45′ : 86°06′) and Khejurdari (22°24′ : 86°34′), closely associated with the copper belt of Singhbhum. It has been mined in Singhbhum near Kudada (22°42′ : 86°12′). Magnetite is also abundant in the apatite-magnetite rocks near Patharghara (22°32′ : 86°27′), Kumaria (22°44′ : 86°09′), Ramchandra Pahar (22°43′ : 86°13′), Khariatola (22°32′ : 86°27′), Kanyaluka (22°29′ : 86°31′), Badia (22°29′ : 86°28′), Sungri (22°27′ : 86°27′) and other areas. It also occurs in the

Palamau district near Gore (23°38′ : 83°58′), and Biwabathan (23°55′ : 84°03′)

KYANITE

There are several deposits of kyanite in the Singhbhum district, out of which the deposits at Lapsaburu (22°48′ : 86′44′), Kanyaluka (22°29′ : 86°31′), Mohonpur (22°34′ : 86°32′) — Uparsoli (22°34′30″ : 86°33′00″), Ghagidih (22°15′ : 86°11), Shirbai - Dungri (22°20′30″ : 86°39′00″) and Jotipahar (22°19′ : 86°40′) are important. Kyanite occurs in the above deposits as massive kyanite and kyanite-quartz rock. Bladed kyanite has been recorded at Khejurbahar (22°30′00″ : 84°58′30″) in Ranchi district, and between Belbhinda (24°49′ : 86°27′) and Bhikha (24°50′ : 86° 30′) in Monghyr district.

Indian Copper Corporation Ltd. holds the lease of Lapsaburu area, and has estimated the reserves of marketable grade kyanite to the order of 310,556 tonnes containing 60-64 per cent Al_2O_3 down to a depth of 1.76 metres. The probable total reserves of kyanite, estimated by the Geological Survey of India recently with 30 per cent kyanite, in Kanyaluka, Shirbai Dungri and Jotipahar are to the order of 0.27, 60 and 4.7 million tonnes respectively.

LIMESTONE AND DOLOMITE

In Bihar limestone deposits occur in Rohtas, Palamau, Hazaribagh, Ranchi, and Singhbhum districts, and belong to the Vindhyan and Archaean ages.

In the Rohtas district, the limestone occurrences belong to the Vindhyan age and occur over a length of 75 km. between Jaradag (24°32′ : 83°32′) and Ramdhira (24°47′ : 84°01′). On the basis of detailed sampling nearly 12 million tonnes of Steel Melting Grade and 48 million tonnes of B.F. grade in addition to 30 million tonnes of cement grade limestone have been estimated by Nautiyal *et al.* from exposed areas lying between Ramdhira and Harriara (24°32′ : 83°36′). The total reserves of limestone in the soil covered areas of Ausane valley are to the order of 7.5 million tonnes of B.F. grade and 2.2 million tonnes of S.M. grade. Limestone of Vindhyan age have also been reported from Chapri (24°24′ : 83°34′), and Bajetoli (24°24′ : 86°36′) near Bhaunathpur in Palamau district. The total reserves of different grades of limestone around Bhaunathpur is expected to be about 18 million tonnes. Limestone of Panda valley, Palamau district, also belong to Vindhyan age, and has been prospected by the Geological Survey of India. The quality of this limestone conforms to the specifications for B.F. grade and cement grade. The total reserves, so far prospected north of Nawadih, is 3,000,000 tonnes.

Archaean limestone and dolomites, most of which are coarsely crystalline, are exposed as sporadic outcrops associated with phyllites and schists at several localities within a radius of 16 to 42 km. from Daltonganj and Latehar in the

Palamau district. In the Hazaribagh district crystalline limestone deposits occur between Babhana-Hoyar-Khalari (23°38′ - 23°40′ : 85°00′ - 85°04′). At Khalari limestone is massive, and is suitable for the manufacture of cement. In the Singhbhum district limestone deposit occur intermittently for over 48 km. long belt from Chaibasa to Jagannathpur, and thence to Kotagarh and are of Kolhan age. The large deposits are being worked for the manufacture of cement after beneficiation.

Dolomitic limestone occurs interbedded with the Iron Ore Series near Putada Spring (22°34′ : 85°49′), Ghatkuri (22°17′ : 85°24′) and Patung (22°22′ : 85°24′) in the Singhbhum district. It is also reported from Bakoria (23°53′30″ : 84°18′), Kauria (23°59′ : 85°06′30″), Pahargarwa (24°13′ : 83°58′), Sagardinua (24°00′ : 83°55′), Tulsidamar (24°19′ : 83°32′) and other areas in Palamau district, and from the top of the Rohtas stage near Banjari (24°41′ : 83°59′) in Rohtas district. The dolomitic rocks of Tulsidamar and Kauriya areas in Palamau district conform to the specification for B.F. grade but they are not suitable as flux material due to their crystalline nature. Tentative reserves at Tulsidamar and Kauriya areas are of the order of 10 million tonnes and 35,000 tonnes respectively.

MANGANESE ORE

In Bihar manganese ore is mined in Gua (22°13′ : 85°23′), Ghatkuri (22°18′ : 85°24′) and other areas in South Singhbhum. The ore minerals are mostly psylomelane, braunite, cryptomelane and pyrolusite. Deposits have also been recorded from Leada Buru (22°28′ : 85°23′) and from Lanji (22°49′ : 85°35′) in northern Singhbhum. Manganese ore occurs as scattered debris at Mirgitanr (22°43′ : 86° 29′) and Basadera (22°40′ : 86° 30′) in north-eastern Singhbhum, but no workable deposit exists. Other occurrences are recorded at Jhatijharna (22°42′ : 86°33′), Lakhaisini Pahar (22°42′ : 86°34′) and Hatibari (22°36′ : 86°39′), but are of no economic importance.

MICA

Nearly the entire production of mica in Bihar comes from the well known 'Bihar mica belt', which extends from Gaya district in the west across Hazaribagh and Monghyr districts into Bhagalpur district to the east. The width of the belt varies from 26 to 32 km, while the length is about 145 km. Concentration of mica in the mica belt is found mainly in the Koderma Reserve Forest area and the maximum production of mica has come from this area. Other mica producing localities are Chatkari (24°35′ : 85°35′), Domchanch (24°25′ : 85°40′), Dhab (24°35′ : 85°46′), Gawan (24°37′ : 83°35′), Tisari (24°35′ : 86°04′) etc.

Shiv Shankar, Bendro (Jamuria Surangi), Pokharia, and some other mica mines, falling in Hazaribagh district, are worth mentioning mines. Mica pegmatites in these mines occur usually as concordant lenticular bodies and occasionally as pipe-like bodies. They essentially contain quartz, feldspar and muscovite with accessory minerals as tourmaline, garnet, beryl or apatite. Mica lodes are observed to display wide variation in their disposition. Although they occur mostly within the pegmatite body, they also occur within the schists of the country rock near the pegmatite body. Mostly mica is concentrated at the contact of the pegmatite body with the host-rock. The lodes of mica are usually 0.5 to 1.5 m. thick and traceable for more than 5 metres in many cases. Mica occurs as books, which vary in size from 15 to 30 cm. across, bigger size upto as much as 1 m. across is also not uncommon. Mica in Bihar is chiefly of ruby variety, but limited quantities of green, white and brown micas are also present

OCHRE

Occurrences of red and yellow ochres are widely scattered in Bihar, mainly associated with the basic igneous rocks and phyllites of the Archaeans, and with the laterites. Ochres of various shades are reported from Kubasa (22°57′ : 85°48′) and Ray (23°41′ : 85°04′) in Ranchi district; Goikkera (22°31′ : 85°23′), Kuira (22°32′ : 85°31′), Mangru (22°29′ : 86°16′), Metiabandi (22°23′ : 86°38′), Dharadih (22°43′ : 86°32′) and other areas in Singhbhum district; and Madpa (24°38′ : 83°30′) and Chathans (24°38′ : 83°40′) in Shahabad district. Ochres are also known to occur in association with clay deposits of the Rajmahal hills. Deposits of lithomarge which might be suitable as yellow ochres occur below the laterites on the small plateaux of western Ranchi. Carbonaceous phyllites found near Papirda (22°57′ : 85°39′) and Kudda (22°57′ : 85°50′) are possibly suitable as a black pigment.

PYRITE

The chief source of sulphur is the iron pyrite deposits near Banjari (24°41′ : 83°50′) in Shahabad district. Pyrite also occurs along with copper and other sulphides in the copper and other base metal deposits in Singhbhum and other districts. There are nine known pyrite exposures extending over 102 sq. km area, occurring within a radius of 16 km from Amjhore (24°43′ : 83°59′). The upper 16 metres of the Bijairgarh shale horizon, below the contact of overlying scrap sandstone, shows disseminations, crystals and stringers of pyrite particularly along the planes of stratifications.

The pyrite bed in the Amjhore area, which varies in thickness from 0.55 to 1.04 m. is very consistent in relation to grade and structural behaviour. The sulphur content of the pyrite bed varies from 35.08 per cent to 44.66 per cent (with average. 41.23 per cent). Detailed investigation carried out in the area established that the proved/probable reserves of Amjhore pyrite deposit area are of the order of 77 million tonnes with an added assurance of readily available pyrite resources of the order of 313 million tonnes from the adjoining Budhua and Rhotas blocks.

Pyrites, Phosphates and Chemicals Ltd., a Govt. of India undertaking, commenced mining activities in 1961 in the Amjhore area. The composite reserve figures of the explored parts of Amjhore area, including areas explored by I.B.M. & P.P.C. Ltd., come to about 20.91 million tonnes, out of which 12.55 million tonnes are the recoverable reserves.

QUARTZ AND SILICA SAND

Occurrences of quartz are reported from Pradhankhanta (23°46′ : 86°31′) and Poddardih (23°49′ : 86°44′) areas in Dhanbad district; Chonthis (24°30′ : 85°47′),, Barai (24°03′ : 85°50′), Birmalli (24°14′ : 85°57′), Balia (24°04′ : 85°33′), Karma (24°25′ : 85°46′), Bachaidih (24°15′ : 85°46′) and many other places in Hazaribagh district; and Bagmara (22°42′ : 86°14′), Ghagidih (22°45′ : 86°11′), Tetoposi (22°43′ : 86°01′), Urga (22°44′ : 86°02′), Porloyang (22°40′ : 85°48′), Bicha Gutu (22°39′ : 85°48′) and other areas in Singhbhum district. Transparent to transluscent crystals of quartz varying in lengths from fractions of a cm. to maximum 20 cm. occur near Majhitola (24°19′ : 87°24′) in Santal Parganas, and near Khaira (24°05′ : 85°36′) in Hazaribagh district. Rosy quartz is found at Bansidih (24°22′ : 85°45′), Rangamati (24°30′ : 85°57′), Naitanr (24°23′ : 85°42′), Bijaia (24°17' : 85°34′), Chandedih (24°26′ : 85°33′) and other areas in the Hazaribagh district.

Quartzite from the Kharagpur hills, about 11 km from Jamalpur (25°18′ : 86°29′), is being used for the manufacture of silica bricks. The flaggy quartzite from the above hills southwest of Kewal (24°39′ : 86°30′) is suitable as furnace lining. Sericite-quartz schist occurring at Biridihtoli (23°08′ : 85°50′), Singhbhum distrist, is worked for use as lining in Besssemar converters.

Silica sand is the main constituent in making glass and should contain an absolute minimum of such impurities as harmful to the resulting glass. River sands found in Bihar are relatively high in iron and are capable of producing only cheap glass, such as green bottle glass. In the Rajmahal hills near Mangal Hat (25°04′ : 87°51′), and at Patarghatta Hill (25°20′ : 87° 16′), white Gondwana sandstones belonging to the Damodar Series are found to yield a sand which, after crushing, washing and sieving, is suitable for the manufacture of glass of ordinary quality.

TALC AND STEATITE

The occurrences of talc and steatite have been noted in the Dhanbad Hazaribagh, Ranchi and Singhbhum districts. They have been reported from the Pandra Kisment Estate (23°48′ : 86°47′) near Sijua (23°53′ : 86°43′) in

Dhanbad district, and near Kuddadih (22°53′ : 85°48′) and Bandudih (22°53′ : 85°50′) in Ranchi district. In the Hazaribagh district deposits of talc and steatite (soapstone) .occur as lenses in the neighbourhood of Parashath Hill near Chailmo (24°04′ : 86°04′), Jangidirt (24°05′ : 86°02′), Jaridih (24°05′ : 86°05′) and other places. They have also been located around Dondlo (24°07′: 85°52′), Kasitoli (24°08′ : 85°53′), Bagro (24°09′ : 85°46′), Bijaipur (24°11′ : 85°59′), Kusumarja (25°06′ : 85°56′) and other areas.

In the Singhbhum district Fermor reported the occurrence of steatite at Turamdih (22°43′ : 86°11′) and Kudada (22°42′ : 86°12′). A fairly large deposit of soapstone and talc schists is found in the hills northwest of Bhitardari (22°41′ : 86°11′). Parallel with copper belt, extending west to east across Singhbhum into southeastern Dhalbhum, there is a series of soapstone and talc-schist deposits. The deposits of talc rock, near Khejurdari (22°24′ : 86°33′) and Digha (22°39′ : 86°36′), are exploited at present. Steatite schists occur near Bara Mirgilandi (22°17′ : 85°42′) and Nurda (22°20′ : 85°44′). The occurrences of talc schists have also been reported from Rakha Mines (22°38′ : 86°22′), Manpur ((°36′ : 86°16′), Kundarkocha (22°27′ : 86°15′), Raghabdih (22°31′ : 86°07′), Baharagora (22°16′ : 86°43′), Gumtibera (22°34′ : 86°24′), Kamrora (22°43′ : 85°20′), Mahulisal (22°28′ : 86°34′) and other areas. The steatite deposit near Karlabera (22°24′ : 86°31′) is 93 m. long and 5 m wide.

URANIUM ORE

Singhbhum district in Bihar has so far remained the only place in the country where uranium ore is being produced. Occurrence of uranium in the Singhbhum district was first reported in 1921 by the Geological Survey of India. However, comprehensive study on the uranium mineralisation was taken up from 1950 onwards by the Atomic Minerals Division and the work is still in progress. Uranium mineralisation occurs discontinuously in the metasediments at several places in the Singhbhum Copper Belt, the important among them are at Jaduguda (22°38′ : 86°23′), Narwa Pahar (86°16′30″ : 22°42′00″). Bhalko-Kanyaluka (22°29′ : 86°31′), Tamadungri (22°40′ : 86°00′), Dhantuppa (86°32′ : 22°26′) etc.

At Jaduguda uranium occurs associated with hard, compact and somewhat competent mylonitised chlorite-sericite-schist and granular rock. The grade of ore in general increases with depth, the better grade of ore being found below 300 metre depth. The lode is about 5 metre thick and persistent upto a depth of 600 metre without any marked change of lithology and structural features. Indicated ore reserves at Jaduguda are estimated at 2.8 million tonnes with an average grade of about 0.08% uranium oxide (Wadia and Dar, 1961). The deposit at Narwa Pahar is also another large occurrence among the presently known zones of uranium in Singhbhum district. Here, uraninite occurs as fine disseminations in highly crushed and mylonitised chlorite-sericite-schists. At

Dhantuppa (Khadandungri) the uraniferous lodes, are in the form of lenticular bodies and are associated with apatite and magnetite. The tentative reserves of uranium ore in the Singhbhum belt have been placed at 20-25 million tonnes (*op. cit.* Bhola *et al.*, 1966).

Besides Singhbhum district, small amounts of uranium bearing minerals also occur in the pegmatites in the mica-belt of Gaya, Hazaribagh and Monghyr districts. Besides, inland placer deposits with columite-tentalite, uraniferous allanite, cassiterite, barite etc. have been discovered over an extensive area in the older alluvium of sub-recent age in Ranchi, Purulia and other adjoining districts of Bihar and West Bengal

VANADIUM

Vanadium is known to occur in the Singhbhum district of Bihar around Dublabera (22°29′ : 86°17′), Lango (22°30′ : 86°18′), Sindurpur (22°28′ : 86°15′), and Kumhardubi (22°17′ : 86°19′). The ore occurs in the form of veins and lenses within gabbro and ultrabasics. It consists of a fine mixture, mainly of magnetite ilmenite, hematite, and coulsonite (an iron-vanadium oxide). Rutile and goethite also occur occasionally. The vanadium oxide (V_2O_3) content of the ore varies from 0.50 to 4.84 per cent, and analyses showing as much as 8 per cent have been recorded. Some of the deposits have been worked by the Dublabera Mining Co.

GROUNDWATER

About half of the State to the south of the Ganga is occupied by hard rocks belonging mostly to Archaeans and Palaeo-Mesozoics (including Gondwanas), and these hard rocks bear groundwater only in their weathered top portion which rarely exceeds 10 metres. Joints and cracks in hard rocks also contain groundwater. Potentiality of water in hard rocks is sufficient and can serve the domestic requirements.

The vast area covered by alluvium (geologically of Recent to Holocene age) in this State is the main storage of groundwater. Major part of it lies in the North Bihar and a minor portion in the South Bihar bordering the course of the Ganga. Potential granular zones consisting of sands, gravels, pebbles etc form good aquifers within this alluvial body. These aquifers sustain large scale integrated development of groundwater in the State for irrigational and industrial purposes. Where artesian condition prevails in the aquifers, as in North Darbhanga and Muzaffarpur, water gushes out in pressure.

MINERAL WATER

There are a number of hot springs in the State viz. Rajgir group of springs in Nalanda district; Sitakund group in the Monghyr district; Surajkund group in Hazaribagh district; and Tatapani and other hot springs in Palamau district. These hot springs discharge water throughout the year, with varying yield and temperature ranging from 38° to 60°C. Some of the springs of Rajgir and Surajkund yield hot water rich in sulphurous gas and Radon and are well-known from time immemorial for their curative values.

Besides these, a number of cold springs yielding cold water occur at a number of places along the "Main Boundary Fault" zones between the Archaeans and Gondwanas.

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