MEMOIRS

OF

THE GEOLOGICAL SURVEY OF INDIA,

VOLUME LIII.

THE STRUCTURE AND CORRELATION OF THE SIMLA ROCKS. BY GUY E. PILGRIM, D.SC., F.G.S., F.A.S.B., *Superintendent, Geological Survey of India,* AND W. D. WEST, B.A., *Assistant Superintendent, Geological Survey of India.* (With Plate 1.)

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Vol. XI, 1878.

Part 1.—Annual report for 1877. Geology of Upper Godávari basin, between river Wardha and Godavari, near Sironcha. Geology of Kashmir, Kishtwar, and Pangi. Siwalik mammals. Palæontological relations of Gondwana system. 'Erratics in Punjab.'

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Vol. XVI, 1883.

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Part 2 (out of print).—Synopsis of fossil vertebrata of India. Bijori Labyrinthodont skull of Hippotherium antilopinum. Iron ores, and subsidiary materials for manufacture of iron, in north-eastern part of Jabalpur district. Laterite and other manganese-ore occurring at Gosulpore, Jabalpur district. Umaria coal-field.

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Vol. XVII, 1884.

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Vol. XX, 1887.

Part 1 (out of print).—Annual report for 1886. Field-notes from Afghanistan: No. 4, from Turkistan to India. Physical geology of West British Garhwal; with notes on a route traversed through Jaunsar-Bawar and Tiri-Garhwal. Geology of Garo Hills. Indian image stones. Soundings recently taken off Barren Island and Narcondam. Talchir boulder-beds. Analysis of Phosphatic Nodules from Salt-range, Punjab.

Part 2.—Fossil vertebrata of India. Echinoidea of cretaceous series of Lower Narbada Valley. Field-notes: No. 5—to accompany geological sketch map of Afghanistan and North-Eastern Khorassan. Microscopic structure of Rajmahal and Deccan traps. Dolerite of Chor. Identity of Olive series in east with speckled sandstone in west of Salt-range in Punjab.

Part 3.—Retirement of Mr. Medlicott. J. B. Mushketoff's Geology of Russian Turkistan. Crystalline and metamorphic rocks of Lower Himalaya, Garhwal, and Kumaun, Section I. Geology of Simla and Jutogh. 'Lalitpur' meteorite.

Part 4 (out of print).—Points in Himalayan geology. Crystalline and Metamorphic rocks of Lower Himalaya, Garhwal, and Kumaon, Section II. Iron industry of western portion of Raipur. Notes on Upper Burma. Boring exploration in Chhattisgarh coal-fields (Second notice). Pressure Metamorphism, with reference to foliation of Himalayan Gneissose Granite. Papers on Himalayan Geology and Microscopic Petrology.

Vol. XXI, 1888.

Part 1.—Annual report for 1887. Crystalline and metamorphic rocks of Lower Himalaya, Garhwal, and Kumaun, Section III. Birds-nest of Elephant Island, Mergui Archipelago. Exploration of Jesalmer, with a view to discovery of coal. Facetted pebble from boulder-bed ('speckled sandstone') of Mount Chel in Salt-range, Punjab. Nodular stores obtained of Colombo.

Part 2 (out of print).—Award of Woolasten Gold Medal, Geology Society of London, 1888. Dharwar System in South India. Igneous rocks of Raipur and Balaghat, Central Provinces. Sangar Marg and Mohowgale coal-fields, Kashmir.

Part 3 (out of print).—Manganese Iron and Manganese Ores of Jabalpur. 'The Carboniferous Glacial Period.' Pre-tertiary sedimentary formation of Simla region of Lower Himalayas.

Part 4 (out of print).—Indian fossil vertebrates. Geology of North-West Himalayas. Blown-sand rock sculpture. Nummulites in Zanskar. Mica traps from Barakar and Raniganj.

Vol. XXII, 1889.

Part 1 (out of print).—Annual report for 1888. Dharwar System in South India. Wajra Karur diamonds, and M. Chapter's alleged discovery of diamonds in pegmatite. Generic position of so-called Plesiosaurus Indicus. Flexible sandstone or Itacolumite, its nature, mode of occurrence in India, and cause of its flexibility. Siwalik and Narbada Chelonia.

Part 2 (out of print).—Indian Steatite. Distorted pebbles in Siwalik conglomerate, "Carboniferous Glacial Period." Notes on Dr. W. Waagen's "Carboniferous Glacial Period." Oil-fields of Twingoung and Beme, Burma. Gypsum of Nehal Nadi, Kumaun. Materials for pottery in neighbourhood of Jabalpur and Umaria.

Part 3 (out of print).—Coal outcrops in Sharigh Valley, Baluchistan. Trilobites in Neobolus beds of Salt-range. Geological notes. Cherra Poonjee coal-field, in Khasia Hills. Cobaltiferous Matt from Nepál. President of Geological Society of London on International Geological Congress of 1888. Tin-mining in Mergui district.

Part 4 (out of print).—Land-tortoises of Siwaliks. Pelvis of a ruminant from Siwaliks. Assays from Sambhar Salt-Lake in Rajputana. Manganiferous iron and Manganese Ores of Jabalpur. Palagonite-bearing traps of Rájmahál hills and Deccan. Tin-smelting in Malay Peninsula. Provisional Index of Local Distribution of Important Minerals, Miscellaneous Minerals, Gem Stones and Quarry Stones in Indian Empire: Part 1.

Vol. XXIII, 1890.

Part 1 (out of print).—Annual report for 1889. Lakadong coal-field, Jaintia Hills. Pectoral and pelvic girdles and skull of Indian Dicynodonts. Vertebrate remains from Nagpur district (with description of fish-skull). Crystalline and metamorphic rocks of Lower Himalayas, Garhwál and Kumaun, Section IV. Bivalves of Olive group Salt-range. Mudbanks of Travancore coast.

Part 2 (out of print).—Petroleum explorations in Harnai district, Baluchistan. Sapphire Mines of Kashmir. Supposed Matrix of Diamond at Wajra Karur, Madras. Sonapet Gold-field. Field notes from Shan Hills (Upper Burma). New species of Syringosphæridæ.

MEMOIRS

OF

THE GEOLOGICAL SURVEY OF INDIA

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VOLUME LIII.

THE STRUCTURE AND CORRELATION OF THE SIMLA ROCKS. BY GUY E. PILGRIM, D.SC., F.G.S., F.A.S.B., *Superintendent, Geological Survey of India*, AND W. D. WEST, B.A., *Assistant Superintendent, Geological Survey of India.* (With Plate 1.)

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CONTENTS

EXPLANATION OF PLATE I.

Geological map of the Simla Hills.

FIG. 1.—Section along the line C-C.
„ 2.—Section along the line A-A.
„ 3.—Section along the line B-B.
„ 4.—Section along the line D-D.

LIST OF TEXT FIGURES.

MEMOIRS

OF

THE GEOLOGICAL SURVEY OF INDIA.

THE STRUCTURE AND CORRELATION OF THE SIMLA ROCKS.

BY GUY E. PILGRIM, D.SC., F.G.S., F.A.S.B., *Superintendent, Geological Survey of India,* AND W. D. WEST B.A.,[1] *Assistant Superintendent, Geological Survey of India.* (With Plate 1.)

I.—INTRODUCTION.

Scope of the present investigation.

During the spring and early summer of 1925 the authors made a rapid reconnaissance survey of the country lying between the Kalka-Simla motor road and Chakrata hill-station, in the course of which several new geological facts came under their notice, which led them to an interpretation of the structural and homotaxial relations of the rocks of that region, different in many respects from that which has hitherto been accepted. During the corresponding period of 1926 work in the area was resumed by the junior author, the senior author being unfortunately unable to participate owing to absence on leave. While the second season's work entirely confirmed the previous conclusions as to the geological structure, yet it introduced modifications, of which the most important was the recognition of the Chail series, the existence of which had not previously been suspected. This was due to the detailed geological

[1] The second author alone is responsible for the sections dealing with the petrology and metamorphism of the area.

mapping in which the junior author was engaged; in fact he is almost entirely responsible for the actual boundaries of the various geological formations in the eastern portion of the map forming Plate I. In 1927 both authors were separately engaged in mapping the outlying parts of the Simla district, the senior author taking the country west of the Kalka-Simla motor road and north-east of Simla, and the junior author the country between the Kalka-Simla motor road and the Giri river.

Reasons for early publication.

In spite of the fact that we are unable to present a detailed geological map of the whole area under consideration, yet there are reasons why the publication of the results so far obtained should not be delayed until such a survey can be accomplished. In the first place that and the petrological work will take a considerable time to finish. In the second place Simla itself, as the summer capital of the Indian Empire, attracts such numbers of visitors, that it seems a pity that geologists who may have opportunities of working in its immediate neighbourhood should lack the information which might render that work more valuable. Moreover, the geological classification of the Simla rocks, if fairly well established, as the authors hope to do in the following pages, will undoubtedly provide the key to, or at any rate have an important bearing on that of the whole Sub-Himalayan tract from the Indus to the Brahmaputra, many portions of which will, it is hoped, engage the attention of the Geological Survey during the next decade.

Maps used in the survey.

The whole area has been mapped, though in some cases only approximately, on the very excellent Survey of India maps on a scale of 2″ to the mile. It is covered by sheets 311, 312, 313, 334 and 335. From these the geological map forming Plate I on a scale of ½″ to 1 mile has been reduced. This contains the names of all the localities mentioned hereafter; these have been arranged alphabetically with their latitude and longitude at the end of the paper.

Classification of the rocks.

In reviewing the previous geological work done in this part of the Himalayas, it will be necessary to refer to all the rock groups by name, and it seems most convenient to set these forth at the commencement, using the new classification and correlation which we have adopted, the reasons for which will appear in due course.

II.—CLASSIFICATION OF THE SIMLA ROCKS.

DAGSHAI SERIES—	
Purple sandstones and clays (brackish water deposits)	LOWER MIOCENE.
? *Unconformity.*	
UPPERMOST SUBATHU BEDS—	
Purple sandstones and grits	UPPER OLIGOCENE.
Unconformity.	
SUBATHU SERIES—	
Shales, limestones, carbonaceous beds	MIDDLE EOCENE.
Basal pisolitic laterite.	
Unconformity.	
KROL SERIES—	
(1) Massive blue limestone.	?
(2) Red shale.	
(3) Limestone and shale.	
Unconformity.	
KROL SANDSTONE—	
Sandstone, readily decomposing into dusty sand	LOWER GONDWANA.
INFRA-KROL BEDS—	
Shaly slates, with beds and lenticles of hard brown quartzitic grit	
BLAINI LIMESTONE—	
Pale pink magnesian limestone (=Mandhalis of Jaunsar)	
BLAINI CONGLOMERATE—	
Boulder beds ; slates with pebbles (glacial)	
Unconformity.	
SHALI LIMESTONE AND SLATES—(Position uncertain).	
SIMLA SERIES (Infra-Blaini)—	
(1) Dark unaltered slates, and micaceous sandstones	DOGRA SLATES (LOWER PALÆOZOIC).
(2) Limestone with pseudo-organic structure (Kakarhatti and Naldera Limestones). (?=Deoban Limestone)	
Unconformity.	
JAUNSAR SERIES—	
(1) Pale, sub-schistose slates	PURANA.
(2) Much crushed micaceous slates and phyllites.	
(3) Purple phyllites and conglomerate.	
(4) Purple, green and grey quartzites, pebbly in their. upper portion.	
(5) Slates with slaty cleavage and vein quartz.	
Unconformity.	

CHAIL SERIES—

(1) Light grey and brown schistose slates and quartz-schists — PURANA.

(2) Slightly talcose flaggy quartzites and quartz-schists.

(3) Talc-schist bed (30 to 40 feet thick).

(4) Slightly puckered grey phyllites.

(5) Grey slates with interbedded banded crushed limestones.

Unconformity.

Intrusion of Chor granite accompanied by intense folding and high grade metamorphism.

Olivine dolerites are intruded both into the granite as well as into the Jutogh series.

JUTOGH SERIES (Order of superposition uncertain)—

(1) Quartzites and schists — ARCHÆAN (?).

(2) Crushed and banded dolomitic limestone, generally carbonaceous and often containing actinolite.

(3) Carbonaceous slates and phyllites (often garnetiferous). (Jakko slates).

(4) Quartzites and mica-schists. (Boileaugunge beds). (Hornblende schists and gneisses are frequently intruded).

III.—MEDLICOTT'S AND OLDHAM'S VIEWS ON THE GEOLOGICAL STRUCTURE.

A bibliography of the published papers on the geology of this region will be found at the end of the paper (p. 139). No serious attempt to work out its geology was made until H. B. Medlicott studied it and published his results in 1864 in a memoir "On the Geological structure and relations of the southern portion of the Himalayan range between the rivers Ganges and Ravee." This memoir, the first to deal with the geology of the great mountain chain in a truly scientific fashion, displays the author's powers of observation, originality and critical judgment in a degree that leaves us astounded in admiration of his genius. This is evident when one realizes, not only that it laid the foundations of our knowledge of Himalayan structure, which remain as firmly established to day as when Medlicott enunciated his theories; but also that his correlation and nomenclature of the rocks of the Simla area have

Previous work in the area: Medlicott.

undergone no material alteration at the hands of subsequent writers. McMahon, R. D. Oldham and Middlemiss have extended Medlicott's observations in the area between Simla and Nepal, and have correlated more widely than he attempted to do, but Medlicott's classification of the various rock systems formed the basis of their work, and is still our accepted standard. A perusal of Hayden's "Geology of the Himalaya" (1907-08) convinces us that, however remarkable the fact, this is no more than the truth.

Medlicott's classification of the rocks at Solon.

We have accepted the geological succession given by Medlicott for the formations extending from the Krol limestone down to the Simla (Infra-Blaini) slates. It must be understood, however, that this acceptance applies only to the type area near Solon, since we do not universally agree with Medlicott where he correlates certain rocks at Simla and elsewhere with the Krol and Infra-Krol. The evidence for the geological succession was found in the valley of the Blaini river, north-west of Solon, where Medlicott shows clearly (pp. 25-30) that the sequence is as follows in descending order.

Upper Krol, dense blue limestone.
Middle red shale.
Lower Krol, thin-bedded, clear blue limestone, replaced occasionally by indurated well-bedded marls.
Krol sandstone, a coarse quartzose sandstone, often decomposing into a dusty sand.
Infra-Krol, shaly slates, often carbonaceous, with beds and lenticles of a hard brown quartzitic grit.
Blaini, siliceous limestone, from 15 to 20 feet thick; a boulder bed consisting of pebbles generally of quartzite scattered either plentifully or sparsely through a fine gritty slate.
Simla or Infra-Blaini, well-bedded grey slates without sandstone lenticles or carbonaceous matter.

Value of the Blaini for correlation.

Considering only the pre-Tertiary rocks of the area, it is at once apparent that Medlicott and all subsequent geologists have found in the Blaini beds the most important clue towards unravelling the structure of an area in which the entire absence of fossils and the close similarity which rocks of different ages bear to one another present difficulties of no ordinary magnitude. The present writers form no exception to this rule. It is not too much to say that, were it not for the peculiar and unmistakable character of the Blaini conglomerate and its often associated limestone we should have little hope of correlating these rocks successfully. R. D. Oldham has mapped a band of Simla slates between Solon and Barog, forming the core of an anticlinal fold having Infra-Krol beds on one limb and Blaini beds on the other. The further evidence that the Simla slates are stratigraphically lower than the Blaini beds is to be found at Simla, where these slates are exposed in all the valleys on the east and north of the station (*see* R. D. Oldham's map, *Rec. Geol. Surv. Ind.*, XX, p. 143, (1887)) and all along the road from Sanjauli bazaar to Mashobra. They are everywhere clearly overlain by Blaini limestone and conglomerate.

R. D. Oldham: Relation of the Simla series to the Blaini.

We have briefly stated the evidence for Medlicott's conclusion that the Simla slates form the lowest member of a succession passing up through the Blaini and Infra-Krol into the Krol. and, as before remarked, we take this as the basis for our further research. At the same time, in view of the intense disturbance which we are convinced that the type area north of the Solon ridge has undergone, we feel that it would be more satisfactory to have the relations of these rocks confirmed by a detailed survey of that area, of which our time did not permit.

Contrast between the rocks of Simla and Solon in regard to metamorphism.

It is a noteworthy fact that none of the rocks so far mentioned is truly metamorphic. Not only are there no secondary minerals developed, but further, the Simla, Blaini and Infra-Krol series, though containing rocks often resembling slates, have no slaty cleavage and we have found no evidence of any planes of crushing which do not coincide with the planes of bedding; neither is there any crystalline structure or evidence of flow in the limestones; while the Krol sandstone is obviously not a metamorphic quartzite. It is as well to insist upon this point, because the rocks to which we shall next refer, show all these features in a more or less marked degree. Medlicott has described these rocks as exposed at Simla sufficiently precisely to show that he was fully cognisant of the lithological difference. R. D. Oldham, in his paper on Simla (1887, p. 143) and Hayden in an unpublished geological map of Simla and Jutogh on a scale of 16 inches to 1 mile have described and mapped them in sufficient detail to make the relations of their various outcrops perfectly clear. The rocks in question rest on the Blaini series. The dips are nowhere very high, and there is no superficial reason to suspect overfolding or reversed faulting, the only faults which Oldham has mapped being minor ones of the normal or step type. Following Oldham, we may trace the following apparent sequence *ascending* from the Blaini.

R. D. Oldham's classification of the Simla rocks.

Blaini boulder bed.

Bleach slates.

Blaini boulder bed.

Blaini limestone.

Black carbonaceous limestone and shale, much crushed and folded on a minute scale.

Carbonaceous, slaty, garnetiferous schists (Jakko beds).

Garnetiferous quartz and mica schists, in places passing into a quartzite (Boileaugunge quartzites).

Limestone, sometimes carbonaceous, much crushed and folded on a minute scale, with secondary minerals (Prospect hill beds).

Hornblende schist (Prospect Hill beds).

Jutogh beds, consisting of three bands of limestone, separated by carbonaceous schists and quartzites (Oldham correlates these with the single band of limestone on Prospect Hill, but offers no explanation of the absence of the hornblende schist at Jutogh).

Approaching Simla from the S.W., Medlicott states (p. 37) that the Simla slates near Kiarighat are overlain first by a blue limestone which he considered to be Blaini and then by a series of slaty schists and sub-schistose flags. In his text he leads us to suppose that he correlates these with the Jakko slates; he remarks that they pass up into the Boileaugunge quartzites of Tara Devi, these being overlain by the Jutogh beds already mentioned. He has, however, mapped them as Simla (Infra-Blaini) slates; altogether he does not seem at all easy as to their exact correlation or their relations to other portions of the Solon-Simla section. In any case Medlicott came to the conclusion (1) that the Simla section is comparatively undisturbed, the whole forming in effect a shallow synclinal, uninterrupted except by stepfaults, (2) that the superposition of these

Medlicott's views on the rocks S.W. of Simla.

Medlicott's views on the Simla section.

metamorphic rocks on the Blaini series represents their real succession, and he is therefore forced to correlate them with the Infra-Krol and Krol series of Solon (p. 34). The black crystalline limestone and the Jakko schists are thus the equivalent of the Infra-Krol carbonaceous slates; the Boileaugunge quartzites represent, though in an immensely greater thickness, the Krol sandstone; while the Jutogh and Prospect Hill limestone with its interbedded schists and quartzite becomes a variant facies of the Krol limestone.

R. D. Oldham's adoption of Medlicott's view.

Hypothesis of an igneous intrusion to explain the metamorphism.

The same correlation of these rocks was adopted by R. D. Oldham (1887, p. 143). To explain their metamorphism he invokes the agency of an igneous intrusion. As there is no trace of such igneous rock at Simla, he suggests after Medlicott that it formerly overlay the metamorphosed beds, but has now been entirely denuded; or alternatively that the intrusion is still buried beneath the surface. In either case the intrusive mass must have exercised a selective action, since the Blaini and Simla series are unaltered.

The authors' unwillingness to accept the igneous hypothesis.

Even before they left the Kalka-Simla motor road, the authors were little disposed to accept this explanation of the facts for the following reasons:—

(1) Since Oldham's account of the geology of Simla was written it has on the one hand become generally accepted that an intrusive mass alone is incapable of producing such wide-spread metamorphic effects as we see here; on the other hand, while regional as opposed to thermal metamorphism is recognized as a usual phenomenon produced by intense pressures applied at a considerable depth over a big area, there is a disinclination, to say the least, to regard such metamorphism as selective, except in a very minor degree.

Different constitution of the Simla and Solon rocks militates against their correlation.

(2) The supposition that the original constitution of the Simla rocks, even before metamorphism, represented merely a local facies of the typical Krol and Infra-Krol series, as seen at Solon, presents difficulties. It must be recalled that the outcrop of the Krol limestone extends from the River Ravi at

least to the River Jamna, that is to say, over a distance of some 200 miles, within which its character remains essentially the same. Since the constancy of the Krol limestone over great distances is so marked, it seems hardly credible that within the few miles that separate Simla from the Krol hill, the massive blue limestone should have been replaced merely by a few thin bands of highly carbonaceous limestone and that the rest of the formation should have become argillaceous or sandy. The greatly increased thickness of the Krol sandstone, on the assumption that it is the same as the Boileaugunge quartzite, is also noteworthy, and has been the subject of comment both by Medlicott and Oldham.

(3) It is inconceivable to us that the structure of the Simla beds should be so simple as Medlicott and Oldham have assumed. Medlicott was the first to point out that the Tertiary rocks of the Himalayas are extraordinarily disturbed and are traversed repeatedly by longitudinal reversed faults, which often extend for hundreds of miles. Similar high dips and sharp folds and faults also exist in the outcrops of the typical Simla (Infra-Blaini) and Krol series, as Medlicott and Oldham have recorded. At Simla, however, we have, according to their assumption, a gentle syncline broken only by minor step faults.

Simplicity of the Simla section as assumed by Medlicott incompatible with our ideas of Himalayan structure.

On the face of things, therefore, the authors were prepared to find that so far from the Simla metamorphic rocks being newer than the Simla slates and the Blaini beds, they are really much older, and have been thrust over the latter along a nearly horizontal plane; and further that they are not a regular stratigraphical sequence but represent a group of less than half the thickness predicated by previous authors and repeated several times by a series of recumbent folds.

Alternative explanation suggested by the authors.

Overthrusting.

The fault or faults postulated show four outcrops in the neighbourhood of Simla: the first crossing the N.E. foot of Jakko and running approximately through Annandale, and north of Jutogh; the second just north of Kathlighat railway station; the third south of Kathlighat railway station, and exactly 14½ miles from Simla on the motor road; the fourth on the ridge above Kiarighat and crossing the motor road 15⅜ miles from Simla. Although these four fault traces are disconnected in the immediate neighbourhood of Simla, yet it will be shown that the first two of them are linked up to form a continuous closed outcrop, representing one and the same fault; while the third and fourth traces belong to distinct faults. The carbonaceous limestones and schists thus become the oldest beds of the area, being brought up against the Blaini beds on the north; and on the south against another series of rocks intermediate in age between the Jutogh carbonaceous series and the Simla slates; this series is represented by the phyllites, quartz-schists and quartzites exposed between mile-stone 14½ and Kathlighat. These are in their turn thrust over a still newer series but older than the Simla slates, the last of the three older series being finally thrust over the Blaini, or where the Blaini is missing over the Simla slates.

On this hypothesis it is quite natural that these older rocks should have undergone a regional metamorphism prior to the deposition of the Simla slates, and that the latter should not, therefore, have been affected by it. Equally do the other difficulties inherent in Medlicott's and Oldham's correlation vanish with this new interpretation of the structure. One sentence in Medlicott's memoir is worth quoting, as it seems to show that he envisaged some such explanation of the structure as we have now proposed. It occurs on page 36 of his memoir: "*To account for a state of things so apparently anomalous and incompatible with the generally received notion of metamorphic action, one is at first tempted to look for grand inversion of the strata.*" We, however, fail to understand his reasons for rejecting it.

Confirmation of the new hypothesis by sections in the Chor area.

Plausible as our hypothesis seems, merely from a consideration of the section on the Kalka-Simla motor road, it receives yet further support, when the sections between this and the Tons river are studied. At the present stage it would be premature to do more than present an outline of the geology of the area as a whole, since the authors have studied closely only limited portions of it, and they feel sure that a thorough and complete geological survey would be likely to alter their ideas as to details of structure and correlation. Nevertheless, seeing that their observations entirely support the views mentioned above, it will be advantageous to publish them at once.

Continuation of the Solon rocks to the south-east; The Giri fault.

South-east of Solon rises the hill known as the Khanog. This presents approximately a synclinal structure, the highest beds exposed being the Krol limestone, which presents all the typical features of this formation, passing down through sandstone into the Infra-Krol shales both on the N.E. and S.W. Near Solon these have been mapped by R. D. Oldham on a sheet which has never been published.

Medlicott draws attention to an anticlinal fold at Kandaghat in Infra-Krol rocks (pp. 36, 37, section on p. 24), with an ascending sequence on the S.W. limb into the typical Krol series of the Krol hill, while on the N.E. limb the ascending sequence is interrupted by a thrust fault running through Kandaghat and down the Ashni river by which the Simla slates are thrust over the Infra-Krols. We agree with Medlicott that these rocks agree precisely in lithological composition with the Simla slates of Simla and have no doubt as to the correlation. A continuous succession of these beds is exposed between Kandaghat and Kiarighat. They were continuously traced to the S.E. across the Kawal river. This river cuts through the ridge of Krol limestone, which continues to the S.E. all along the right bank of the Giri. The peculiar weathering of the Krol limestone which forms the upper half of the ridge is unmistakable; structurally the feature is a continuation of the Krol hill. The dips are high, but presumably the Simla slates form an anticlinal fold and the N.E. limb of this anticline is faulted against more Simla slates with a N.E. dip. These rocks consist of well-bedded slates, showing no real metamorphism, without any vein quartz and entirely unassociated with quartzites. This fault runs from Kandaghat along the right bank of the Ashni river, crosses the Kawal river about a quarter of a mile above its junction with the Giri, and continues along the right bank of the Giri. Medlicott has named it the Giri fault.

Section in the Kawal river.

The structure of this area is clearly revealed by examination of the section in the Kawal river which cuts right across the strike.

Below Riwari typical carbonaceous Infra-Krol slates are seen, dipping down-stream. On going up-stream these rocks are seen to overlie the Blaini beds by Khaltu ($\frac{1}{4}$ mile S.W. of Kuhat), though only the boulder beds were seen. Beneath these there comes a thick development of the Simla slates which are seen for a long way, until they are suddenly cut off by a strike fault. This crosses the river where the tributary from Bag comes in, and has the effect of bringing up the Infra-Krol slates again to the south-west, which now occupy the bed of the river for some way. About half way between the sharp bend by Sanjet and where the main road crosses, the Blaini beds are seen once more, represented here by both the limestone and the boulder bed. As before they are underlain by the Simla slates.

Returning to Riwari and going down-stream, the Infra-Krol are seen to dip beneath the Krol sandstone, south of Dabrech, and the latter soon gives way to the Krol limestone. These beds, however, evidently occupy the core of a fold, for after about 300 yards they are overlain by the Krol sandstone, which in turn passes down under the Infra-Krol slates. Further down these Infra-Krol are succeeded by the Simla slates, about S.W. of Mareog, the Blaini being entirely missing.

Throughout this length of the river the dip varies between N.E. and E.N.E. Due south of Mareog, however, the dip turns over to the S.W., remaining thus until about 200 yards before the Giri, when, after first becoming horizontal, the beds turn over so as to dip to the N.E. once more.

Across the Giri, all the way up to Dudham, the dip remains N.E., and at Dudham this great thickness of Simla slates is overlain by the Blaini beds, as described below. It should be mentioned that in these Simla slates, further north-west, a boulder bed was found forming the narrow tongue of land that projects into the Giri river just opposite the camping ground at Karganu. It is not certain whether it represents the Blaini; but if it does then it must owe its presence here to a sharp fold which brings down the Blaini into the Simla slates.

Figure 1 is a diagrammatic section across the strike, along the line of the Kawal river and across the Giri to Dudham :—

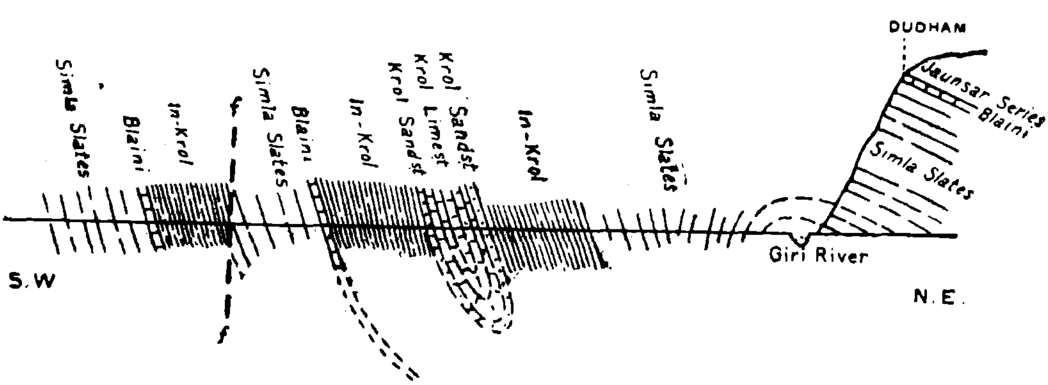

FIG. 1.—Diagrammatic section along the Kawal river. Distance about 6 miles. Vertical scale exaggerated.

We clearly have a syncline of Krol and Infra-Krol overturned to the south-west, followed by an anticline of Simla slates and Blaini, the northern limb of which is overlain by the Jagas (Jaunsar) beds. But, as Medlicott long ago pointed out, the great thickness of Simla slates below Dudham necessitates a fault, with an upthrow to the north-east, and it was this fault which he named the Giri fault. It evidently crosses the Kawal about a quarter of a mile above its junction with the Giri, and is no doubt responsible for the non-reappearance of the Blaini beds there. A simplified section across the strike here may be given :—

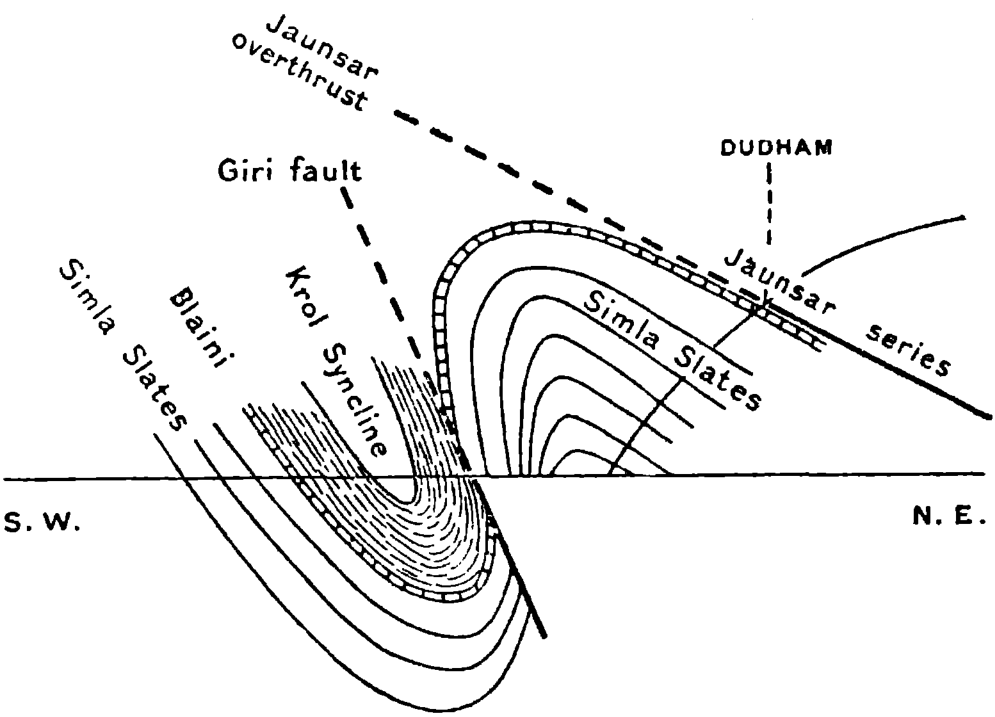

FIG. 2.—Diagrammatic section to show the structure in Fig. 1.

It seems likely that the overfolding and thrust faulting were directly induced by the main overthrusting, the evidence for which we shall put forward in the following pages; the two events were doubtless more or less contemporaneous.

IV.—EVIDENCE FOR THE OVERTHRUSTING HYPOTHESIS NOW ADVOCATED.

(i) Argument based on lithological succession across the strike.

Section across the Dudham ridge.

At Dudham, on the crest of the ridge, just above and to the east of the Giri, the regular succession of Simla slates is overlain by two outcrops of Blaini conglomerate separated by some 150 feet of bleached slates, which represent the bleached slates of Simla, mapped by Oldham. The upper of the two conglomerate outcrops is associated with some 15 feet of a pale pink limestone. The fragments in the conglomerate are mainly slate, but there is also some quartzite.

The Jagas (Jaunsar) series.

The beds strike obliquely across the ridge, having a general dip to the N.E. or E. Proceeding up the ridge from Dudham, the Blaini beds are succeeded by a few feet of red shale and these by grey slates, the whole amounting to some 200 feet. Above these are a series of quartzites some beds in which are schistose. These pass into a crushed conglomerate, consisting of quartz and slate boulders often of large size and flattened, embedded in a purplish slaty matrix (36/939). The boulders are very numerous and make up by far the larger portion of the rock. These beds pass into purple phyllites. The highest beds of the series are seen at the village of Nigaili just south of peak 6,594; these are very pale cream and lavender talcose schists, occasionally carbonaceous.

Between Dudham and Jagas, as one ascends the spur, the following sequence is seen, the beds having generally an easterly or north-easterly dip:—

Jagas (Jaunsar) series—

Light-yellow and lavender phyllites carbonaceous in places.
Purple phyllites and crushed conglomerates.
Massive white quartzites.
Brown slates.
Massive white quartzites.
Light green-brown slates.
Dark slates.
Quartzites.
Light and dark slates.

Blaini beds—

Red shales.

Blaini limestone.
Upper boulder bed.
Bleach slates.
Lower boulder bed.

Simla slates.

The brown slates and the light green-brown slates are both true slates, and show their original bedding markedly oblique to the present cleavage.

To these beds we originally gave the name of the Jagas series, but we have considerable evidence for correlating it with a part at any rate of Oldham's Jaunsar series which we restrict to the quartzites and slates, excluding from it the limestones and volcanic (?) beds which Oldham has included with them. If this correlation is correct, then the name Jagas may be abolished. In any case they are undoubtedly the same as the outcrop which overlies the Simla slates between the Ashni river and the ridge over Kiarihat, with which they have been traced into continuity. The most characteristic resemblance is to be found in a conglomerate described by McMahon (1877, p. 205) in the gorge of the Ashni river, just below the junction of the Tandalail stream, about 4 miles E.S.E. from Kiarighat; it contains "*white quartz eggs*" and passes into a quartz sandstone. McMahon correlates it with the Blaini conglomerate, but the absence of the generally associated limestone is itself significant. Furthermore the matrix of the boulders is not slaty but is on the contrary a fine grit or quartzite. This bed is undoubtedly the equivalent of the crushed boulder conglomerate of the Dudham ridge, and it also seems identical with a rock which occurs in what is certainly the Jaunsar series just west of the Tons, all along the Chandpur-Shalai ridge, as well as in Bawar-Jaunsar itself. The Jaunsar series, however, varies rapidly in character from place to place, and we find it often difficult to say how far beds met with in different sections represent the same horizon.

The Jagas (Jaunsar) conglomerate.

About 3 miles east of Dudham in the Gatogara *nala*, which is a small tributary of the Pervi, the beds just described are overlain by a typical outcrop of Blaini conglomerate and limestone. Resting on the Blaini are a series of silvery grey phyllites, slightly talcose flaggy quartzites and quartz-schists.

Continuation of the Dudham section to the north-east.

Further up the Pervi and round the village of Rajgarh these latter rocks are overlain by black carbonaceous slates, amongst which one most characteristic feature is a black slaggy-looking rock, pitted by small cavities, evidently once occupied by minerals (36/948). These are seldom preserved, but have been found *in situ* in a few places, amongst which Prospect Hill at Simla may be mentioned. These carbonaceous slates are well exposed round Rajgarh and above it on the way up to the crest of the Sain Dhar. Interbedded with them are quartzites and a carbonaceous limestone which is never more than 6 feet thick (36/950), but which recurs at several levels in such a way as to suggest that there are many recumbent folds in the section. Evidence of sharp folding is actually visible in some places. That these are the same as the Jutogh and Prospect Hill beds does not admit of doubt. Oldham has placed similar beds, which he saw at various localities between here and the Tons, in his "Carbonaceous System" with which he has included the Jakko and Annandale carbonaceous slates and schists, and has therefore correlated them with the Infra-Krol and Krol.

Identity of the rocks at Rajgarh with those of Simla; Oldham's "Carbonaceous System": Jutogh series.

In this section we have as at Simla a series of metamorphic beds resting on an ascending sequence of Simla slates to Blaini, but in this case also we cannot see that it is possible to explain them on the hypothesis that the metamorphic beds are the altered representatives of the Infra-Krol and Krol series. In the first place there is no limestone whatever in the thick series of quartzites, slates and phyllites which crop out between Dudham and the Gatogara *nala*, although as we have seen, just across the Giri to the south-west, limestone is the most important feature of the Krol formation.

Impossibility of correlating the supra Blaini rocks of the Dudham section with the Infra-Krol and Krol.

They are equally distinct from the Jakko carbonaceous slates, the Boileaugunge quartzites and the Jutogh beds in the neighbourhood of Simla, which Medlicott correlated with the Infra-Krol and Krol, not only in their less degree of metamorphism but also lithologically. Moreover it is significant that only a few miles away, at Rajgarh, a series of beds exist which exhibit most of the features typical of the beds at Simla just mentioned, but they do not rest on the Blaini as at Simla but are separated from them by two sets of beds which are equally unlike either of the others.

Before giving the explanation which we ourselves consider the only one capable of adequately satisfying the observed facts, it will be as well to refer to certain other features of the section which have not as yet been mentioned.

The Chail series.

It has been stated that between the outcrop of Blaini in the Gatogara *nala* and the carbonaceous slates of Rajgarh, which we may call the Jutogh series, a series of talcose quartzites, quartz-schists and phyllites occur to which we give the name Chail series. Though we regard them as older than the Blaini and Jagas series, their distinctness as regards degree of metamorphism from many of the beds of the Jagas (Jaunsar) series is not on the face of it very obvious. It is true that there are marked differences between the quartzites of the two groups. In the Jagas series the quartzites invariably show the original clastic structure of the rock, and the constituent grains have suffered no re-crystallisation. In fact they are not really quartzites at all, for they never show a siliceous cement. They are either sandstones or grits. In the Chail series, on the other hand, the quartzites have been re-crystallised, and the quartz grains are seen as a mozaic of quartz with no interstitial spaces. More commonly these Chail rocks have a slightly schistose structure, due to the development of new sericite or muscovite between the quartz grains.

Differences between the Jaunsar and the Chail quartzites.

The Chail talc-schist band.

At the same time the existence of a peculiar band in this series, which one of us has traced for long distances and has found to possess a marked individuality and constancy, has proved as in the case of the Blaini, for similar reasons, of the utmost assistance in identifying the series and unravelling the structure. This is a rock which may be termed a talc-quartz-schist, but which for convenience will be referred to as a *talc-schist* (37/619). Never more than 30 or 40 feet thick, it yet persists over a large area with little or no change. It has a very characteristic appearance, and can often be seen from a long way off; for on account of its bright silvery colour, both the outcrop and the debris below it flash out in the sunshine. It is a comparatively soft rock, due to its content of talc; and rather friable, owing to the presence of thin lenticles of quartz. In addition to the talc, the rock is invariably full of little black specks, embedded in the talc. Under the microscope they are seen to be magnetite. This band has been traced from south of Chail, in Patiala, to the southern side of the Chor mountain; but it has been found to extend, though in a less typical form, beyond the Ashni river, and across the Kalka-Simla cart road. Its value, however, was not at first recognised, and for that reason it was not mapped further north-west.

Gatogara "window" in the Chails showing the Blaini overlying the Jagas (Jaunsar) series.

The outcrop of Blaini in the Gatogara *nala* mentioned above (page 15), although it separates the Jagas (Jaunsar) from the Chail series, is not of great lateral extent, and is overlapped to the south-west by the Chail series, which everywhere else about here rests directly on the Jagas series. The Blaini beds occur in the form of a very gentle anticline, the beds dipping beneath the Chail rocks both up and down stream. The diagrammatic section in figure 3, along the stream, explains the structure seen here.

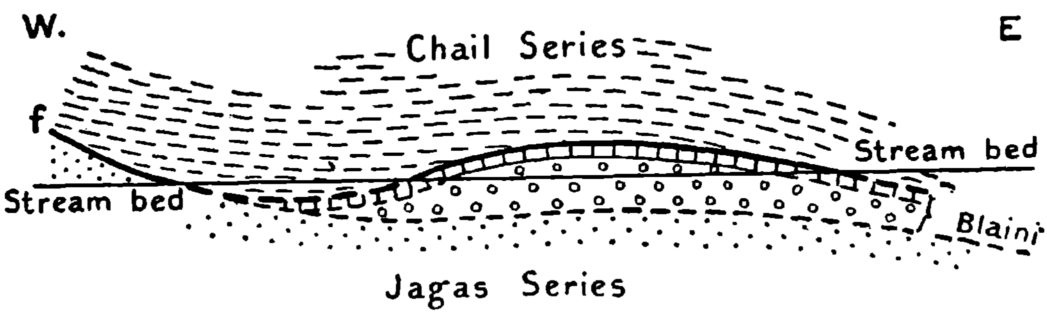

FIG. 3.—Diagrammatic section along the Gatogara stream. Distance about 1 mile.

The authors' interpretation of the Dudham section.

We consider that this section can only be explained on the supposition that there are three series of entirely different ages, all older than the Simla slates, exposed between Dudham and Rajgarh: (1) the carbonaceous slates, limestone and quartzites of Rajgarh—the Jutogh series, which is the oldest; (2) the talcose quartzites, schists and phyllites of the Chail series; (3) the quartzites, conglomerate, slates and phyllites of the Dudham ridge—the Jagas (Jaunsar) series, which is the youngest of the three. The Blaini series was deposited unconformably on the Jagas series after previous denudation of the Simla slates. Finally three overthrust faults pass through the area, one near Dudham separating the Jagas (Jaunsar) series from the Blaini and Simla series, the second in the Gatogara *nala* separating the Chail series from the Blaini and Jagas series, and the

The three main overthrusts.

third near Rajgarh separating the Jutogh carbonaceous series from the Chail series.

It will be convenient to refer to these three overthrusts, which are of enormous lateral extension, in the subsequent portion of this paper as the Jaunsar, the Chail, and the Jutogh faults respectively.

(*ii*) Argument based on unconformity.

Cutting out of the Blaini beds to the north-west.

The evidence for the overthrusting which we assume to have occurred does not, however, rest alone on the single section which has just been described. One of us has traced the Blaini outcrop from Dudham to the north-west. It crosses the Giri one mile above Karganu and tongues up that river occupying an even wider outcrop than might have been expected owing to a slight change from a north-easterly to a south-westerly dip. It is remarkable that Medlicott missed this exposure, as he evidently did through his statement (1864, p. 41) that the only rocks seen all the way along the Giri from Kot to Karganu are the Simla slates. On the Giri the Blaini is developed as typically and in as great thickness as at Dudham. Between this point and Kiar situated on the south-westerly flowing portion of the Ashni river, it is cut out, member by member, against the overlying Jagas (Jaunsar) series, which differs only in detail from the beds exposed on the Dudham ridge.

This is best shown by a number of parallel sections, showing the thickness of the various beds that go to make up the Blaini.

—	*Kakana.*	*E. of Kargal.*	*Kargal.*	*W. of Kargal.*
Blaini limestone . . .	..	15	3	missing
Red shales . . .	15	..	..	..
Upper boulder bed . .	45	few feet	few feet	missing
Bleach slates . . .	50	150	130	?
Lower boulder bed . .	20	few feet	20	?

	Karog	*Chhob*	*Kharanji*	*Kiar*
	15	missing	missing	Blaini entirely missing
(*continued*)	..	..	..	
	?	few feet	missing	
	?	200	fairly thick	
	?	few feet	missing	

The Blaini outcrop has also been traced in a south-easterly direction from Dudham. At the latter place their thickness is about 150 feet. Thence they continue to crop out in a regular way just below

Hion and just above Shalamun and then for a long way a little above the road to Rajgarh. The two sections showing the thickness of the individual beds at Shalamun and a little west of Badgala prove that the bleach slates are thickening in this direction and that both the upper and lower boulder beds are more developed than they were on the west side of the Giri.

	Shalamun	*W. of Badgala*
Blaini limestone	15	15
Upper boulder bed	65	45
Bleach slates	(about) 150	245
Lower boulder bed	60	55
	290	360

High up above Shalamun, towards Nigaili, a small outcrop of a boulder bed was seen. It is difficult to understand its position here if it represents the Blaini, but it was not closely investigated.

At Badgala and on either side of the Sheola gorge they are of equal thickness. Here they are repeated by thrust faulting. Between the Jagas and the Blaini series in the latter locality a highly carbonaceous shale associated with a limestone occurs, which the junior author thinks may be a representative of the Infra-Krol and Krol (*see* p. 26).

The Jaunsar thrust demonstrated by the unconformity of the Blaini.

The gradual dying out of the Blaini against the Jagas (Jaunsar) series as we proceed north-westward from the Sheola gorge to Kiar on the Ashni is clear proof of an unconformity. This is alone needed to render it certain that the Jaunsar thrust, of which the probability was inferred on other grounds, has a real existence.

A section through the Jagas (Jaunsar) series which is exposed on the Ashni river affords also very important evidence. This will now be described.

Section in the Ashni river.

The Ashni is an important tributary of the Giri river, the two joining at Karganu. About one mile east of Kandaghat, on the Kalka-Simla railway, the Ashni river makes a right-angle bend, and it is above this bend that the Jagas beds are well exposed, for the river here runs directly across the strike, and has cut down deeply into the Simla slates and Jagas (Jaunsar) beds.

Where the Ashni takes a southerly bend, by Kiar, there is a very typical development of the Simla slates, which have a steady north-easterly dip of about 40°. They are succeeded upstream, apparently conformably, by the Jagas (Jaunsar) series, which continue to crop out for about a mile. The basal beds of this series are here reddish-purple phyllites, a type of rock which persists for a considerable distance to the south-east (36/918 and 36/942). A characteristic feature of this rock is the presence in it of slickensided surfaces. These may occur along the dip plane, or at an angle with it, and are easily recognised by their green colour, due to the production of a thin film of some mineral where the rock has evidently been sheared. The rocks themselves are true phyllites, for they have undergone sufficient low grade dynamic metamorphism to have new mica (sericite) produced in them.

Character of the Jagas (Jaunsar) series: contrast with the Simla series.

These Jagas (Jaunsar) rocks then, in their degree of metamorphism, are in marked contrast to the Simla beds below, which are not even in the condition of true slates.

Further up the Ashni, these purple phyllites are succeeded by a thick mass of purple and white quartzites, generally purple, which in their upper part contain occasional beds of phyllite. The dip is uniformly to the north-east at about 30°-40°.

About 150 yards before the big tributary from Chail, these beds become conglomeratic, though at first the pebbles are quite small. At the same time the quartzites begin to show marked false-bedding, and further up one gets a rock which consists of bands of conglomerate in a purple falsebedded quartzite, a typical shallow-water deposit. The pebbles in the conglomerate are in the main of milk-white quartz, and hence are very conspicuous. These are the "white quartz eggs" referred to by McMahon (*see* p. 15 above). On the average they are about 1″ in diameter, though they sometimes reach up to 3″ or 4″. In addition there are pebbles of purple quartzite, and also fragments of slate, which in places are so abundant that they give the rock a semi-schistose character (36/923). The rocks now have a higher dip, though still to the north-east.

The Jaunsar conglomerate.

On reaching the stream from Chail, a complete fold in these rocks is very clearly seen in the west bank, with the result that further up the river one gets a repetition of the rocks seen below, conglomerate beds being succeeded by purple quartzites and some phyllites. Only

The Jaunsar outcrop an isoclinal fold.

part of the sequence, however, is repeated, for a little before the second tributary from the south-east these Jagas beds are abruptly cut off, and their place is taken by the Chail series of rocks.

Further evidence for a fold is afforded by the section seen along the bridle path to Chail where it leaves the main road and descends to the right bank of the Ashni. Along here some distinctive soft light coloured slates are seen to be repeated. Along the same path, just before the river is reached, are some carbonaceous slates. We believe these to belong to the Jagas (Jaunsar) rocks, and to abut directly against the Chails, though the structure just here is not quite clear.

A diagrammatic section of the beds is represented in fig. 4.

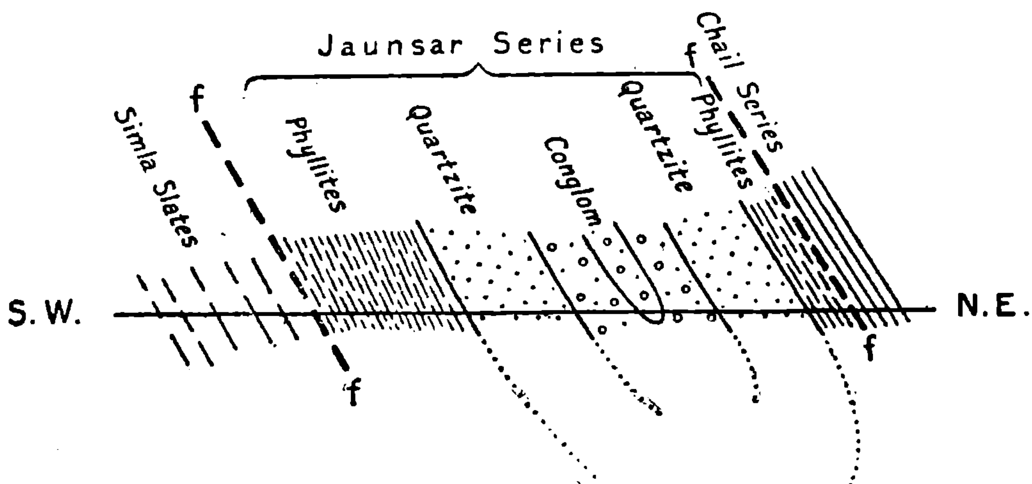

FIG. 4.—Diagrammatic section along the Ashni river. Distance about 1 mile.

It is clear that we are dealing with something in the nature of a thrust fault. If the fold had been a normal one we should have had first a repetition of the whole of the Jagas beds, followed by the Simla slates once more.

The Chail thrust demonstrated by the Blaini window and by the dying out of the Jaunsar series.

An unconformity can equally be demonstrated between the Chail and the Jagas series. The relic of Blaini in the Gatogara *nala*, intervening between the Chail and the Jagas series, is one evidence of this. Further proof of it is, however, seen at Rana Ghat on the left bank of the Giri. The broad outcrop of the Blaini in the bed of the Giri above Karganu has been mentioned on page 19. It does not in fact give place to the underlying Simla slates until just below Sargaon. This outcrop of the Blaini with the underlying Simla slates has been traced into direct continuity with the corresponding outcrop at Simla (page 84).

The southern boundary of the Blaini has also been traced a long way to the north-east. From below Lakhoti to the east of the Giri the Blaini outcrop rises rapidly, and eventually reaches Rana Ghat. Up to this point the Blaini has been persistently overlain by the Jagas series. But from now on *the Chail series rests directly on the Blaini, and the Jagas beds are entirely missing.* The Blaini is now overlain by the same beds for a long way; the outcrop runs roughly as follows, past Dhaila, Pal, Dhamla, Kufar, Chala, Pabhech, and so on across Pain Kufar Dhar, as is shown on the map. This is as far as it has been followed. The rocks have a very gentle dip to the east, though at times they are practically horizontal.

It is thus quite clear from what has been said above, that the base of the Chail series also marks the position of an important unconformity; for while in one place these rocks overlie the Jagas beds, elsewhere they are seen resting directly on the Blaini. Throughout, however, the basal beds of the Chail series remain the same, being the slightly puckered grey phyllites.

Actual base of the Chail series not exposed in this area.

It is true that these phyllites do not represent the actual base of the Chail series; for we shall show (pp. 91—93) that from the Ashni river westward a lower horizon comes in, consisting of slates with lenticular bands of limestone. In the area to the north-east of Simla, where another outcrop of the Chails occurs quite disconnected with the one with which we are now dealing, this limestone horizon assumes a prominence which it does not possess elsewhere (pp.). Its absence here may perhaps be accounted for by original overlap, but in any case, it does not affect the argument for unconformity which is based on the beds which we actually see.

Jutogh thrust demonstrated by the dying out of the Chail series.

It finally remains to show that the third overthrust postulated, that which we have called the Jutogh thrust, also coincides with a marked unconformity.

In Patiala the uppermost rocks, namely the Jutogh series, are only seen at the highest points of the district, by the station of Chail itself, and again about 3 miles further north.

Chail.

The Chail outcrop is the most typical, including the carbonaceous limestone (36/932) and the 'pitted' rock. The former is well exposed just below and to the west of the tennis courts, and again along the cart road leading to the Resident's house, along the north-east side of hill 7,394. At Bhalawag the limestone is not seen, but the 'pitted' rock occurs. These rocks are not again seen until the flanks of the Chor mountain are reached, appearing above the Chail beds at Chayal; and from there south-eastwards they are extensively developed as the highest beds surrounding the Chor granite. Displaying, as has already been indicated, a markedly higher grade of metamorphism, and characterised by being richly carbonaceous, these rocks are easy to distinguish from any that occur below, and the boundary can be put down in the field with precision.

Chayal.

In the Chayal district above mentioned, and for a long way to the north-east towards Dhanech, these carbonaceous rocks appear always to rest upon the same beds, those which have been taken as the top of the Chail series; though it can never be certain that these beds are always of the same thickness. Traced to the south, however, the course of the boundary is of some interest. At Chayal the whole of the lower series appears to be present, and the same holds good for a mile or two further south. Beyond this, however, the boundary gradually transgresses across the outcrop of the lower beds, until almost the whole of the Chail series is cut out. This is best brought out by studying the relations between the boundary and the talc-schist band; for the latter is a very constant horizon and one which is easily identified. In the vicinity of Chayal there may be as much as 800 feet of strata between the talc-schists and the base of the Jutogh series. On the ridge between Jagas and hill 6,742, there is probably not more than 500 feet. A mile-and-a-half south of this, a little south-east of Tikar, the thickness is about 300 feet. All along it is the upper beds of the Chail series that are disappearing.

Jubal spur.

Further south the network of *nalas* has rather obscured the rocks by depositing gravel, but there is evidence to show that the two horizons are gradually approaching. The maximum transgression is seen where the spur running out north-west from Jubal crosses the main road. Here the *talc-schists and the boundary of the Jutogh series are actually only a few yards apart*, and are only separated by a few feet of the talcose quartzites. While this is the nearest that the two approach, for some little way now, past Kohlan, there is not much change. Along here, then, with the exception of the salc-schists and the grey phyllites below, the whole of the Chail series is missing.

Beyond Kohlan the two horizons which we have been following gradually diverge again. On the spur on which Ghusan is situated, there is a thickness of about 600 feet of rock intervening, the same rocks that were previously seen in the Chayal area. The ground between here and Kohlan, is unfortunately obscured by gravel; but the spur mentioned above rises above the gravels, and thus affords useful evidence.

Ghusan spur.

The greatest thickness of the Chail rocks is seen further on by Bhalag, where there must be at least 1,500 feet of rock where there were only 600 feet at Ghusan and a few feet near Kohlan, evidence which speaks for itself. Beyond this the thickness again diminishes, and on the Shamra-Kufar ridge there is probably not more than 600 feet above the talc-schists.

Bhalag.

Shamra-Kufar ridge.

V.—THE THREE OVERTHRUSTS TRACED EASTWARD THROUGH THE CHOR AREA.

We shall now follow these three overthrusts eastward, until we join the district of Bawar Jaunsar (Chakrata), of which Oldham (1883) has given a geological sketch. The evidence on which we rely for the correlation of the formations which occur in the Simla area with those in Oldham's area will thus appear.

From south of Jubal the Jutogh thrust can be approximately traced along the base of the precipitous cliffs which form the summit of the range which runs above the Giri and parallel to it. It crosses the spur on which Bhalag is situated about 500 feet below the summit of peak 6,297. Here the carbonaceous limestone is well displayed at the base of the band. The same bed of limestone is seen again just above Kuftu, and can be traced almost continuously to the col known as Piriya Ghat, and beyond along the south side of the 6,792—5,630 spur to the stream due west of 5,083. The whole way the limestone band occurs at the base of the Jutogh series, and below it comes the Jutogh thrust. The limestone along here is less crystalline than where seen on Jutogh or on Sain Dhar, and no amphibole is developed in it.

Jubal to Piriya Ghat.

The Chail and Jaunsar thrusts are less easily traced, since to the south-east of Thor they evidently run rather close to the Giri river, and hence are much obscured by the gravels and sub-recent beds of the Giri valley. Both thrusts have been followed as far as Thor, but on the Ghusan spur only the Chail thrust was seen.

South-east of Thor.

Before leaving this area we may refer to some interesting structures which are developed in the Blaini beds in the Sheola Khala.

South-east from Dudham the Blaini beds are developed normally to within a mile north-west of Badgala. But further on, between Badgala and Thor, some slates and a massive limestone come in for a short way between the Blaini limestone and the Jaunsar series. The slates are in places carbonaceous. Though both of these new rocks are comparatively thin, and in places much contorted, it is just possible that they are the Infra-Krol and Krol, coming in in their normal position above the Blaini, while everywhere else along this section they have been cut out. The limestone is best seen N.E. of Badgala, where it forms some precipitous cliffs.

The Blaini traced to the south-east.

Possible representative of the Krol and Infra-Krol.

The structure to be described is best seen in the Sheola Khala where it flows south-east of Kanhech. Here, after turning sharply to the west, it cuts its way through a narrow gorge, and runs across the strike. By the village of Sandra, south-east of Kanhech, is a fine exposure of the Blaini limestone. The prevailing dip here is nearly due east, so that the slope below Sandra, eastwards to the stream is a dip slope and is made entirely of the Blaini limestone. An enlarged sketch-map is given in fig. 5, as it is impossible to show the smaller features of the outcrop on the half-inch map.

Development of the Blaini in the Sheola river.

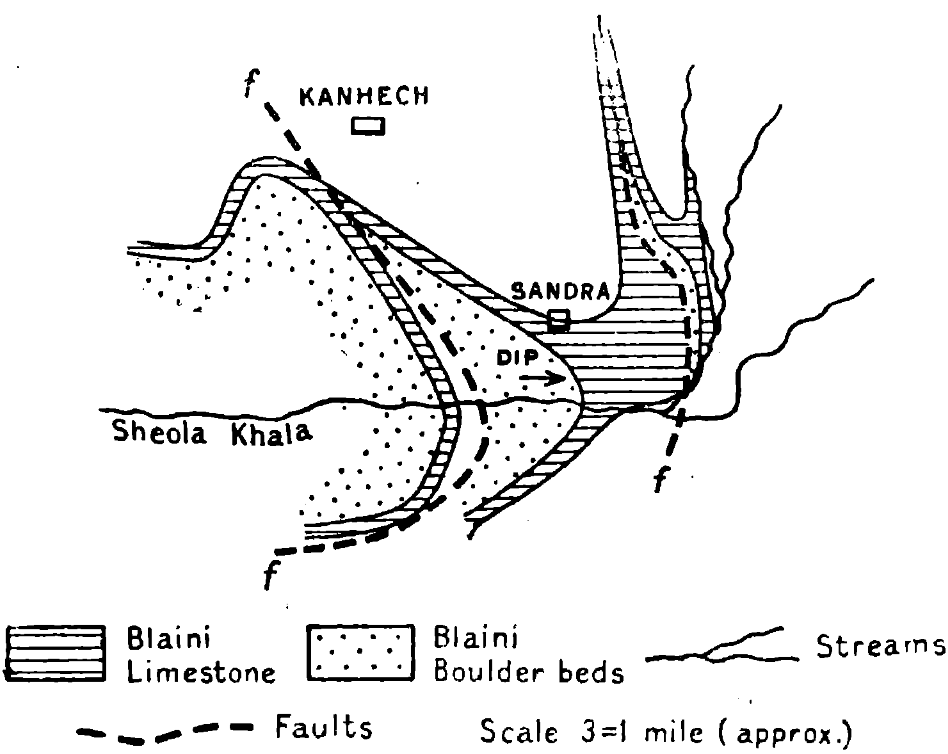

FIG. 5.—Plan showing geological structure near Kanhech.

This outcrop of the Blaini limestone is underlain by a good development of the boulder bed. In the tributary *nala* that flows down from the S. W. side of Gatoli there is seen a small fault, running N.N.W.-S.S.E., with an upthrow on the north-east side. It is not an important fault, and the hade is probably about vertical, but it may be regarded as symptomatic of what is seen further west. The limestone on the upthrow side is well seen forming the long, narrow peninsular of land between the two streams. The boulder bed is seen immediately beneath it, while on the west side of the tributary is the other band of limestone on the down-throw side.

Minor overthrusting in the Blaini.

Continuing down the main *nala* after it has turned sharply to the west, by taking a narrow path in the cliff along the south side several hundred feet above the stream, we first cross the main band of the limestone and then come upon a thick development of the boulder bed. The limestone can be seen running up the opposite cliffs towards Kanhech. After proceeding about a quarter of a mile from the bend a second band of limestone is encountered, coming up almost vertically from below. Its counterpart is seen on the opposite cliffs, running up towards Kanhech, apparently meeting the other band below that village. One suspects at first a fold of Blaini limestone, with a core of boulder bed; but on continuing along the path this is seen to be impossible, for the boulder beds are again seen beneath the second band of limestone. In addition, after the two beds have apparently joined below Kanhech, they can be seen continuing for a long way as one band, which would be most unlikely on the supposition of a fold.

Examination of the beds high up above the path along which we have come, by the gap in the Dangara spur, reveals that here also the two limestone bands come very close together. But it is quite clear that it is the lower band which continues, while the first band stops abruptly just before the gap. This is best shewn by a sketch of the cliffs as seen from the opposite side given in fig. 6; these are 600 or 700 feet high. The same phenomenon can be seen on the other

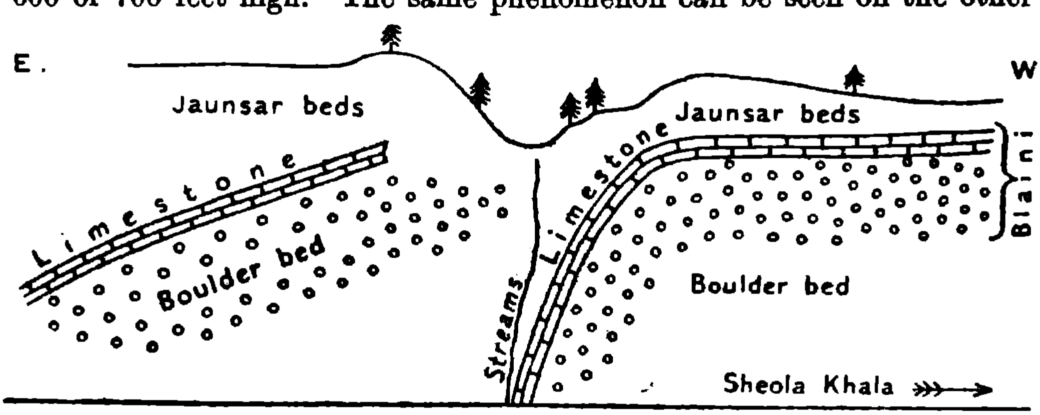

FIG. 6.—View (in section) of the cliffs on the southern side of the Sheola stream. About ¼ mile from E.-W.

bank of the *nala*, below Kanhech, only there it is not so clear which band continues.

It is evident, then, that we are dealing with a fault; and, moreover, a thrust-fault, which has evidently been induced by the main overthrust which comes just above.

Below Kanhech the two limestone bands, where they meet, practically lie on top of each other. It has already been mentioned that in this area the Blaini beds are overlain by some carbonaceous slates and a light grey limestone, which were tentatively correlated with the Infra-Krol and Krol. And it is in keeping with the structures developed here, that these rocks, immediately beneath the **Jaunsar** overthrust, are intensely folded and cleaved.

Similar overthrusting at Badgala.

While the evidence for the minor overthrusting of the Blaini beds is most convincingly seen in this section in the Sheola Khala, the same structures are developed further northwest near Badgala. Unfortunately the geology just here has not been completely elucidated; only part of a day was available for examining the ground here, and the cliffs on either side of the upper part of the Kiar Khala are almost perpendicular. It is clear, however, that the Blaini has been repeated here also by similar thrust-faults, only there are two or three of them. The effect is best seen along the Larab spur on which a temple is situated, but further down. The Jaunsar overthrust comes a little above the temple, while further down the spur the Blaini beds are repeated three or four times. Generally the boulder bed is seen also. The exposures, however, are not good, and had it not been for the fine section in the Sheola Khala, described above, the significance of this repetition might have been missed.

A diagrammatic section across this area will best show the structures developed, and is given in fig. 7.

FIG. 7.—Diagrammatic section along the Larab spur. Distance about 4 miles.

This area provides, in fact, a typical example of 'imbricate' structure, so well developed in the North-West Highlands of Scotland, beneath the great overthrusts; and it affords a good example of the effects of the overthrusting upon the rocks immediately below.

Position of the three overthrusts between Piriya Ghat and the Giri river.

We will now return to the section seen by Piriya Ghat.

Below the Jutogh series, which ends just north of the col, come some very thin-bedded grey slates, talcose quartzites and talc-schists. These are obviously the Chail series. They give place southwards to a great thickness of quartzites. Between these two sets of beds the Chail fault must run, although it has not actually been traced into continuity with that fault in the Jubal area. Amongst the quartzites on the descent to Kufar from peak 6440 are traces of a conglomerate of quartz pebbles in a slaty matrix, which is probably the equivalent of the purple conglomerate of the Dudham ridge.

At Kufar itself there are some intensely crushed conglomerate beds which are now in the form of talc-schists or phyllites of a silvery purple colour and with the quartz pebbles somewhat lenticular in shape (36/985). Below these comes a great thickness of schistose slates or phyllites generally of a dirty brown colour and often with a marked lustre which shows up in the sun. In addition there are a few bands of grit and lower down some quartzites. The Blaini beds are eventually reached at about 700 feet above the Giri river. Here is evidently the position of the Jaunsar fault.

Unfortunately, owing to lack of time, the area immediately to the north-west could not be examined, so that there is actually a gap of country, around Mangan and Ladib, which has not been seen. Nevertheless, it will be apparent from the description of the beds given above, that there is a very close resemblance between these beds by Kufar, and the Jagas (Jaunsar) rocks further north-west. Moreover, they are on the direct strike of those rocks where they were last seen, and they are overlain by the Chail series and underlain by the Blaini beds. If this correlation be correct, then we may say that the Jagas series are certainly the equivalents of Oldham's Jaunsar series; for from now on they have been traced more or less continuously to the Bhangal valley, which Oldham visited and briefly mentioned in his paper of 1888, and where typical Jaunsar beds are seen (*see* p. 37).

Reasons for the general absence of higher horizons than the Blaini in the sections so far described.

So far the Blaini is the highest horizon represented on the outcrops of the Jaunsar and Chail faults if we except the possible occurrence of Infra-Krol and Krol near the Sheola Khala (page 26), while the Chail beds are the highest horizon met with against the Jutogh fault. It is impossible for us to state whether the absence of the newer beds is due to the intensity of the thrust which has raised these beds far above the level of denudation, or whether the folds are as a whole not very deeply buried. Possibly both factors have played a part in the result. The sections now to be described afford strong evidence that farther eastward newer horizons occur on both the fault lines.

We have already described (pp. 11-13) a section which occurs on approximately the same strike much further to the northwest, in the Giri below Dudham and up the Kawal river, a north-easterly flowing tributary of the Giri, and we have reason to believe that along the Palor river from its confluence with the Giri up to the village of Tikari much the same structures have been developed.

Section on the Palor river.

In the Palor river the Jaunsar beds are seen typically developed W.N.W. of Tikari. Where the river turns sharply to the south-east, a thick bed of purplish conglomerate dipping north-east forms the south-west bank, while further up the river, below Ghutrog, are massive quartzites. Below this point for a little way the river itself offered insuperable obstacles to our progress, but we have seen the ground just east of it. Here we find that the Jaunsar beds are underlain to the south-west by a thick succession of dark grey to black thin-bedded slates, and there can be little doubt that these are the Simla slates. They are very well seen along the Palor just before it joins the Giri, where they have a fairly constant north-easterly dip. In the Giri the beds appear to be vertical.

Nowhere along here was any Blaini seen; but Medlicott, on page 43 of his memoir, mentions an outcrop of Blaini at the confluence of the Palor and Giri rivers, and refers to it as occurring at the base of a normal Krol—Infra-Krol succession above the Giri to the south-west. Owing to the depth of water we were unable to cross the Giri here; but a rock looking very like the Blaini limestone was seen on the south-west bank above the river, and was no doubt the Blaini referred to by Medlicott.

From the flat ground on either side of the river where the camping ground of Palar is located, a series of dark grey slates is well exposed for a considerable distance up the river dipping N.E. like the Jaunsars just mentioned.

Our interpretation of this section is embodied in figure 4 of Plate I, but the evidence on which it is based will be more conveniently considered later (p. 34).

From this point going eastward a certain change takes place which has been noticed by Medlicott, but which he has in our opinion failed to interpret successfully. On page 44 of his memoir he says "*From the confluence of the Palar and the Giri the hills on the left of the Giri are composed of the Krol and Infra-Krol rocks instead of exclusively the great Infra-Blaini* (*Simla*) *series. The Blaini conglomerate is found high on the summits over Railu and Shengri ; more to the east in the same line it is met with in the gorge north of Gailu and in the gap between Geruani and Juin. From Shengri to the Olong peak the section is very similar to that between Kiari and Tara Devi ; schistose slates, graphitic, micaceous or quartzose, alternate, with a variable low northerly dip.*" There is no doubt whatever that the uppermost 1,000 feet of the peaks 6756 and 6960 consist of the Krol limestone in its most typical form. Even the red shale bed occurs between the upper and lower limestone. Numerous step faults break up the continuity of the outcrops in a manner precisely similar to what is the case in the outcrops near Solon, which R. D. Oldham has mapped in considerable detail. Our work has shewn that the Krol limestone passes down into Infra-Krol beds and that below them comes the Blaini. On the northern side of peak 6756 the Krol limestone is overlain by pale-coloured slates, in one place carbonaceous, and micaceous, schistose beds, which appear to represent the Infra-Krol though they are by no means typical. These beds are succeeded still further north by two thin outcrops of the Blaini conglomerate and limestone, between which beds somewhat similar in character to those in contact with the Krol occur. The repetition of the Blaini must be due to a minor reversed fault. Traced below the road, the upper band of Blaini is at first somewhat discontinuous, but later becomes easier to follow, eventually crossing the top of hill 5738. It is here seen to have an E. S. E. dip, while the Infra-Krol rocks close by dip to the N.N.W. The reason becomes apparent when one traces the Blaini beds down the south-west side of the hill, when they are seen to turn right over and assume

Change in the character of the outcrops east of the Palor river.

The Krol limestone of Soat Hill.

The Blaini outcrop around Soat Hill.

once more their northerly dip. We are evidently dealing with a local fold, the actual structure being shown in figure 8.

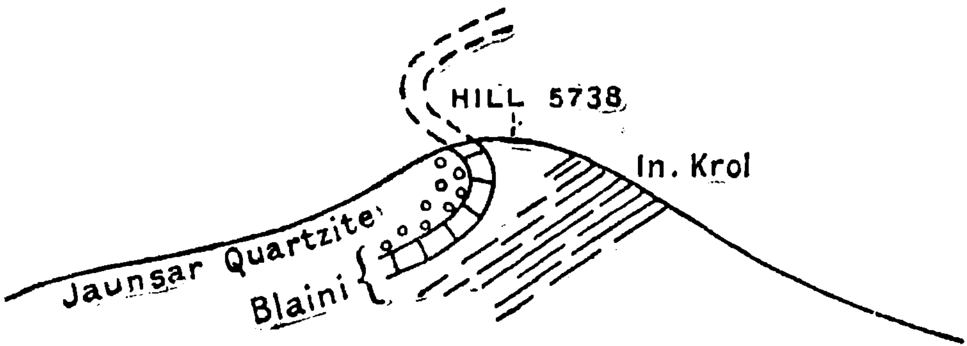

FIG. 8.—Diagrammatic section through hill 5738.

The Blaini now runs down below Sangrah, nearly to Tikari, where, however, there is a sharp overfold and the outcrop turns right back for a little way. This kind of thing now happens for some way,—sharp overturned folds, though, owing to lack of time the outcrop could not be followed the whole way. The lowest point it reaches is where the road from Lagnu to Tikari crosses the stream. From here it can be followed to where it cuts the spur by Paura, and then southwards and along the north-west side of Rerli, cutting the spur a couple of hundred yards west of Rerli, and then running south-eastwards; further than this it was not followed.

It will thus be seen that these Blaini beds have bent right round. Always they have the Infra-Krol slates on top of them (stratigraphically) and various members of the Jaunsar series below them. Whereas by Madoli the whole succession was inverted—the Blaini above the Infra-Krol, and the latter above the Krol—, at Rerli the right order is seen with the Blaini dipping beneath the Infra-Krol and Krol. Thus in making this big sweep round the beds have turned right over and the structure is obviously a syncline overturned towards the south or south-west. This syncline is, however, not entirely simple, but includes a number of smaller folds, and is more properly a synclinorium, as represented in Plate I, figure 4.

Returning to the outcrop on the Madoli-Ludihana road, the Blaini beds are overlain by light brown phyllites succeeded by grey slates and massive white quartzites. Vein quartz in abundance is present and lithologically the beds are quite similar to those seen on the Palor and their correlation with the Jaunsar series does not seem

Jaunsar beds on the Seat-Olong road.

doubtful. Their outcrop extends as far as peak 6306, and we see no reason why they should not represent the north-eastern limb of the overturned syncline mentioned above, the sequence of the beds being of course inverted. The Jaunsar outcrop on the Palor will then be a similar overturned syncline, the only difference between the Palor and Soat sections being that the beds which occupy the core of the syncline in the former case do not reach a higher horizon than the Jaunsar, while in the latter they include not only Blaini but also Infra-Krol and Krol, unconformably deposited on the Jaunsars. The difference is easily accounted for by the denudation of a fold pitching strongly to the south-east.

Synclinal structure of the sections on the Palor and the Soat-Olong road.

The boundary between the Jaunsar syncline and the Simla slates on the Palor river is obviously the trace of a thrust plane, probably that of the Jaunsar thrust. In order that the parallel between this and the Dudham section should be complete we should have an outcrop of Blaini between the Jaunsars and the Simla series. We saw, however, no evidence of this on the Palor, if we except a block of Blaini conglomerate not *in situ*, which may after all have fallen from the Blaini outcrops on the high ground to the east of the river. In any case the cutting out of the Blaini against the thrust would not be an unusual phenomenon in the circumstances.

The Jaunsar thrust on the Palor.

If the outcrop of the Simla slates on the Palor is an anticline, the south-western limb of the fold is complete, since it includes the Blaini outcrop mentioned by Medlicott on the Giri and the ascending sequence through the Infra-Krol to the lofty Krol peaks on the right side of the Giri.

Disappearance of the Giri thrust.

It is evident that in this case there is no room for the Giri thrust (*see* page 13) which must have been entirely overlapped by the Jaunsar thrust. The stages leading to this overlap would possibly be found in the country between the Palor and the Kawal rivers which we have had no opportunity to examine. Plate I, figure 4 shows the structure as we understand it.

The remaining part of the section between Soat and Olong peaks is far more difficult to understand. The Jaunsar outcrop is succeeded to the north-east of peak 6306 by a series of cream-coloured talcose quartzites and schists of an extremely powdery consistency. That

The Chail series on the Soat-Olong road.

these belong to the Chail series is suggested by our recognition of the typical talc-schist of the Chails on the spur just west of Tirmalga, to the north-west of the Madoli-Olong road. The latter has not, however, been traced into continuity with the beds which we are now considering. Above Ludihana the powdery quartz schists are overlain by a series of dark slates (37/10), obviously the same as the similar beds which we have seen on the Palor (p. 30); these in their turn are overlain by some 200 feet of limestone with some phyllites; in places these are carbonaceous, but not invariably so. They form the upper portion of Olong peak and we have no doubt as to their correlation with the Jutogh series. The junction between them and the dark slates mentioned marks the trace of the Jutogh thrust.

From their position one would infer that the dark slates and the powdery schists are Chail beds but their character and sequence does not conform with that of the Chail series as described above (p. 17). The powdery schists may indeed be at approximately the same horizon as the Chail talc-schist, but in none of the sections seen further to the north-west do such slates occur at higher stratigraphical levels. On the other hand in the typical Chail area a series of puckered phyllites, which are equally unlike the dark slates now in question, underlie the talc-quartz schists. In a later portion of this paper, however, (pp. 91-93) a still lower horizon of the Chails will be described consisting of dark grey cleavage slates with interbedded limestone. These begin to come in west of the Ashni (p. 23) and are found in their greatest development in the country to the north-east of Simla. Apart from the absence of limestone these slates of Olong and the Palor show a distinct resemblance to the lowest Chail horizon referred to. We suggest then that the dark slates below Olong belong to an older horizon than the powdery schists and that the puckered phyllites are missing. A hint of some such change as this in the character of the Chails is perhaps conveyed by the occurrence of limestone which seems to be identical with the Chail limestone associated with slates as we approach the Tons (p. 37), and also by our failure to recognize the puckered phyllites in that area. Since the dark slates are not found between the powdery schists and the Jaunsars on peak 6306, we must suppose that the Chail outcrop represents an overturned syncline of which the south-western limb has largely been cut out by the Chail thrust, the trace of which we raw just to the north-east of peak 6306. The section in Plate I, figure 4 has been completed in accordance with the view here expressed, but we are far from claiming that our interpretation of the structure has been satisfactorily demonstrated and between Olong and peak 6306 it must be regarded as provisional.

Medlicott's correlation of the Olong limestone with the Krol untenable.

The occurrence of typical Krol limestone at the top of a descending sequence through Infra-Krol and Blaini into a metamorphosed series of rocks (Jaunsars) undoubtedly supports the authors' main hypothesis, which it is the object of this paper to establish. The existence of the still more metamorphosed series apparently superposed on the sequence referred to, points very clearly to the metamorphosed rocks being older than the Krol and having been brought into their present position by two thrusts, the Chail and Jutogh thrusts respectively. The sudden replacement of the typical clear blue Krol limestone by crushed, often carbonaceous limestone, which Medlicott supposes to have taken place (p. 44), is here rendered even more improbable than at Simla.

Krol limestone traced eastward.

This great outcrop of Krol limestone can be followed continuously eastward to Guma peak. Here although much of the limestone is of the usual Krol type, it is mixed with a very sandy variety in which the sand grains stand out distinctly on the weathered surface. This sandy facies of the Krol is particularly interesting, because limestone of an identical type occurs both on the top of Juin Hill as well as farther to the east across the Tons river, 6 miles S.E. of Chakrata hill-station on the Mussoorie road (p. 49). It is, therefore, valuable as evidence for our correlation of the latter outcrops with the Krol.

The sections further east on the line of the Jaunsar thrust, seen between Juin and Soat peaks, exactly reproduce that which has been described in the latter locality. East of Tikar, the spur on the north side of the Tikar-ka-Khala is formed of the Krol limestone dipping north. In the tributary *nala*, immediately east of and below Tikar, this Krol limestone is seen to be overlain by a rather thin development of the Infra-Krol slates, while overlying them comes the Blaini. This consists of the limestone below, rather thin, with a much crushed boulder bed above. These are succeeded by a thin bed of schistose phyllites, followed by the main Jaunsar quartzites. The dip is northerly.

Now one mile further east, on the ridge by the upper hut called Ugrech the same section is seen, only here the Blaini beds have been entirely cut out, and the Jaunsar series are seen resting directly on the Infra-Krol. A similar section is seen on Pulilani Dhar, a little further east. Each occurrence serves to confirm more strongly the magnitude of the unconformity before the deposition of the Krol limestone.

It should be mentioned that Medlicott refers to the Blaini as being found 'in the gap between Geruani (Chabdhar) and Juin'. If by this he means Pulilani Ghat, then it must be said that careful search on more than one occasion failed to reveal any trace of the rock. If, however, he means further east, then he may be right; for although this ground has not been examined, the Blaini comes in again in force on Juin and north of it.

It seems fairly certain that the Krol limestone rests unconformably on the Jaunsar series, consisting of quartzites, slates, and micaceous phyllites, with much vein quartz, and is folded in with it at least three times in a series of isoclines.

Section on Juin Hill.

The highest point of Juni Dhar is formed of typical Infra-Krol, and so is the little hill half a mile east, just above the camping ground. These beds, with a northerly dip, overlie the Krol limestone which forms hill 8493, Juin Hill. They are themselves overlain on the north by the Blaini beds, which are twice seen cutting the road. Here, however, the Blaini seem to be upside down, the boulder bed being on the side nearest the Infra-Krol.

Direction of the three overthrusts east of Chabdhar.

From now on our lack of acquaintance with the country prevents us from indicating with any degree of certainty the lines taken by the three overthrusts which we have been endeavouring to trace. The Jaunsar overthrust is evidently to the south and not far from the Giri. The Chail overthrust is probably on the northern side of the Bhangal valley. The occurrence of the talc-schist at Lana, as indicated by a specimen of Oldhams, gives us a hint as to its position. The uppermost overthrust, that at the base of the Jutoghs, runs north and below the top of the ridge between Chabdhar and Haripur. It is highly probable that the Chail and Jaunsar thrusts bend round to the north, like the Jutogh thrust since the general dip of the beds is to the west on both sides of the ridge which runs approximately north and south from Chandpur, its highest point.

However the structure is by no means simple and there is undoubtedly frequent isoclinal folding. In reality a geological map of this band would be extraordinarily complicated, since our observations show that not only does the Krol limestone rest unconformably on the Jaunsars, as we have already mentioned, but so also does the Blaini and possibly patches of Simla slates as well. Between Juin Hill (8493) and the Bhangal river we have found no less than three outcrops of Blaini limestone, accompanied by slates which are probably also Blaini, though they are not invariably pebbly.

Blaini unconformable on the Jaunsars at Chandpur.

At Chandpur the Blaini is clearly unconformable on the Jaunsar series. Here a step fault with a throw of some 200 feet has displaced two identical sections which show an unconformable passage from typical micaceous phyllites, with abundant vein quartz, of the Jaunsar series up into slates without pebbles. These slates gradually become more pebbly and finally pass into the most typical Blaini conglomerate, while the topmost beds are clear, pale pink Blaini limestone. The total thickness of Blaini here is about 500 feet.

Descending section in the Jaunsars from the Chandpur ridge to the Tons river.

The Chandpur ridge descends steeply, in most cases precipitously, to the Tons river and everywhere is exposed what has all the appearance of a regularly descending sequence. We have already mentioned that the highest beds of this series exposed at Chandpur are micaceous phyllites with vein quartz which have every appearance of identity with the purple phyllites of Jagas and the Dudham ridge and are thus high up in the Jaunsar series though probably not the highest horizon of all. These rest upon a great thickness of quartzites of purple, green and grey tints. Here and there in this series, but always in their upper portion is a conglomerate composed of rounded pebbles of quartz of about the size of a hen's egg. Reference is made to this bed elsewhere (p. 15). These quartzites are underlain by a great thickness of grey slates with vein quartz and showing evidence of planes of bedding which do not coincide with the planes of cleavage. The section has been best observed between Shalai and the Tons, where Oldham (1887, p. 158) has also partially described it. We have also seen its upper part farther north in a descent of the cliffs N.W. of Chandpur.

Supposed Chail limestone at the base of the Jaunsar section at Bansa.

In the former, at the village of Bansa, the slates rest on about 300 feet of a blue limestone, in places earthy, in others yellow often finely banded, and showing signs of having been severely crushed, with the fine bands often contorted (36/721). The contortion of the bands, induced by crushing probably when in a plastic condition, give it an unmistakeable affinity to a limestone which has been found above the Nauti river north-east of Simla and between Fagu and Theog. This is described on page 114, and its correlation with a similar limestone at the base of the Chail series north and south of Sairi seems almost certain. Although the minute folds give it some resemblance to the Jutogh limestone, yet its non-carbonaceous character, the absence of secondary minerals, and its generally less metamorphosed condition preclude any real relationship. Its resemblance to a band of limestone which crops out 3 miles S.E. of Chakrata on the Mussoorie road (see p. 47) is very marked. It is possible that some of the slates which overlie the crushed limestone are also Chail and should be correlated with the dark slates below the summit of Olong hill mentioned on page 34. The limestone is succeeded by pale-coloured earthy phyllites and then another thinner band of limestone. R. D. Oldham has chiefly relied on this section when he decided that limestone occurs at the base of the Jaunsar series "*if indeed it do not belong to a different system altogether*" (Oldham, 1887, p. 158; 1888, p. 131). It is interesting to remember that Oldham formerly (1883, p. 193) held a different opinion as to its stratigraphical position in the series, when he had only observed the beds east of the Tons. The apparently contradictory character of the sequence in the two areas rather invites the idea that the sections are not always straightforward, but that older beds have been thrust over newer ones so as to give the appearance of a conformable succession.

Supposed Chail limestone thrust over newer beds,—Mandhali series.

The crushed limestone rests on a series of beds which though greatly disturbed present an altogether newer and less altered appearance than the beds which apparently overlie them. These are purple and dark-grey gritty sandstones, which are so unaltered that they might almost be mistaken for Dagshais (36/720). Interbedded are shales full of mica flakes; a characteristic purple shale occurs frequently at different levels, and is a clear evidence of folding.

Beds in the Tons correlated with the Simla series.

At a still lower level and forming cliffs along the Tons river are dark-grey slates which are very similar to the Simla slates. An outcrop of limestone occurs on the left bank of the Tons near Kwanu forest rest house which appears either to be interbedded with or folded in with the dark grey slates. This is of an entirely different character to the crushed limestone in the hills on the right of the Tons and approximates to the Krol. This limestone will form the subject of some further remarks on page 50.

Section down the Naihna-Kharkan spur.

A similar section is seen further north down the Naihna-Kharkan spur. Typical Jaunsar beds are met with along the top of the ridge to Naihna, including the same much crushed purple conglomerate that occurs at Kufar. The dip along here is south-west. On descending the spur to the east, the finely banded crushed limestone of Bansa is seen between Sakhaoli and Thumari (36/984), resting apparently upon a bed of clear blue limestone, rather resembling the Krol. Below Thumari there is a sudden change to the much newer rocks, mostly brown and bright-red sandy shales, generally nearly vertical, striking N.W.-S.E., and so in striking contrast to the gentle dip of all the rocks above. Further down, at Kharkan, the dip of these newer rocks is much lower. At about 4,400 feet, along the road to Minas, these rocks are seen resting on the Deoban limestone, which is seen for the rest of the way down to the Tons.

Mandhali series.

Apparently these purple and grey grits and shales belong to Oldham's Mandhali series, as we have found similar beds elsewhere which Oldham has mapped as Mandhali. He has indeed coloured this very patch on the Tons as Mandhali (1883, map).

Section further north at the head of the Sainj river described by Oldham.

Very few conclusions can be drawn with certainty from the scattered observations on the area west of the Tons going towards the Chor. Oldham (1887, p. 158; 1888, p. 137) has described a section on the eastern flank of the Chor mountain at the head of the Sainj river in which *the Mandhali or Blaini rests unconformably on a massive limestone similar in character to the Deoban, fragments of which they contain, and underlies, apparently with perfect conformity black carbonaceous slates, which again underlie a great thickness of quartzites and schists undistinguishable from the Boileauganj quartzites of Simla.* Medlicott (1864, p. 43) refers to a section also near the head of the Suinj below Baluk (evidently Bhalu of the $\frac{1}{2}''$ map), in which the dark, carbonaceous schists and limestone rest on the Deoban limestone. Of course both Medlicott and Oldham regard the carbonaceous beds as Infra-Krol, but, as we have produced evidence to show,

Section at Baluk described by Medlicott.

this correlation is untenable, and we are dealing with the Jutogh or oldest series of the area. The Blaini conglomerate and an associated pink limestone were also identified by McMahon (1877, p. 210) in the bed of the Shallu river where the Simla-Chakrata road meets it east of Chepal. He also mentions that it is overlain by black Infra-Krol slates, from which it would appear that the Jutogh thrust runs through this point.

Section on the Shallu river described by McMahon.

That the junction between the crushed limestone of Bansa and the purple and grey grits and shales marks the trace of a thrust fault is certain. That it is one of the three main thrusts described above is much more open to doubt. On the supposition that it is one of these, then it can only be the Jaunsar thrust. Its northerly or north-westerly direction is in accord with that shown to be followed by the Jutogh thrust, so that if future mapping of the intervening area should prove that it links up with the thrust trace on the Palor, the last position in which the Jaunsar thrust was recognized, the result could not be regarded as unexpected.

The Bansa fault possibly identical with the Jaunsar thrust.

So far the oldest horizon observed in the case of the overthrusting mass at the Jaunsar fault is the Jaunsar, but if the conjecture made above prove correct, then a lower horizon in fact the lowest stage of the Chails comes in, for between Bansa and the Chandpur ridge we undoubtedly have a descending section from the Blaini through the Jaunsars into Chail limestone. Whether any of the upper stages of the latter series are missing and consequently there is an unconformity, our observations do not enable us to say with certainty. The course of this and of the other thrust planes northward must equally be left for future mapping to determine.

Older beds exposed at the base of the Jaunsars in the neighbourhood of the Tons.

VI.—THE CHAKRATA AREA.

When we cross to the east of the Tons river, we are in the Chakrata district, the geology of which has been described by Oldham under the name of Bawar Jaunsar. Our own examination of this country was but cursory; it is necessary, however, to touch on it lightly, not only because it completes the evidence for the correlation of the Jagas series of the Chor and Simla areas with Oldham's Jaunsars, but also because certain of the rocks and sections which we saw exhibit a parallel to those of the main area with which this paper deals and throw some light on the correlation of and the relations between many of the rock groups of the latter region.

The Jaunsar series.

First as to Oldham's Jaunsar series:—The views expressed by that author in his later papers differ from those suggested to him by his earlier examination of the Chakrata rocks, particularly regarding the sequence of the constituent portions of the Jaunsar series. His final conclusions seem to have been published in 1888 (p. 131); here the Jaunsar series is classified into three divisions:—

(1) The lowest consisting of a great thickness of grey slates containing towards their upper limit a band of blue limestone some 300 feet thick; he hints at the possibility that these may not belong to the Jaunsar series at all;

(2) A middle division of red quartzites and slates;

(3) An upper division of traps and volcanic ashes.

Correlation of the Jagas series with one division only of Oldham's Jaunsar series.

It is with the second of these three divisions that we correlate the rocks to which we originally gave the name of the Jagas series, and which we have recognized continuously from the Simla area right into Chakrata. Associated with the quartzites are the highly characteristic conglomerates, which Oldham does not mention specifically in the passage quoted above, but which undoubtedly occur in his Jaunsar series as exposed between the Chandpur ridge and the Tons (*see* above p. 37).

Lower division of Oldham's Jaunsars probably to be correlated with the Chails.

With regard to the remaining two divisions, we have already stated (p. 37) our belief that the limestone included in the lowest division as seen at Bansa is identical with that which occurs in the Simla area and belongs to the lowest horizon of the Chail series so far recognized by us. In the Bansa section there are no underlying slates, the limestone being thrust over much newer beds. We have not in fact come across slates in this position, either in the Chakrata or the Tons area, so that we can express no opinion as to whether they do or do not correspond to the cleavage grey slates which are associated with the Chail limestones in the country to the east and north-east of Simla (*see* page 114); the suggestion is at any rate a plausible one.

The volcanic beds of Oldham's Jaunsar series.

The volcanic lavas and ashes which constitute Oldham's upper division have provided us with a problem, of which, with our inadequate knowledge of the eastern part of this area, we cannot offer an entirely satisfactory solution. We have nowhere found any beds of this description in association with the quartzites and phyllites of the Jaunsar series as exposed between Simla and the Tons river. We have been equally unsuccessful in finding any volcanic rocks amongst the specimens collected by Oldham from the Chakrata and Bhangal areas, which have remained stored in the museum in Calcutta. Those labelled as "trap rock" or "ash" appear when examined in thin sections under the microscope either to contain no volcanic matter, or where their igneous origin is probable they seem identical with the hornblende-schists of the Jutogh series and are not Jaunsar, as in fact Oldham himself has recognized by labelling them as "Infra-Krol".

Thus Nos. 6,869 and 6,870 from Arayan and Ludhia respectively in the Bhangal valley might be more appropriately described as quartzitic grit. No. 6,875 above Pab in the Bhangal valley seems to be identical with a quartz-schist from the Chail series; No. 6,871 from Ludhia in the Bhangal valley answers in its outward appearance to the description given by Oldham (1887, p. 157) of "a specimen preserved in the Imperial Museum in Calcutta, where portions of two distinct lava flows are seen to include between them a string of well-rounded water worn pebbles . . . . of vein quartz". This is obviously a portion of a conglomeratic band out of the Jaunsars, and no trace of volcanic matter is visible under the microscope; since, however, Oldham did not quote the registration number of the specimen to which the passage refers, it is permissible to doubt whether the specimen before us is one and the same as that one.

Supposed glacial conglomerate of the Jaunsars.

On the same page on which Oldham's description just quoted occurs, mention is made of another conglomerate from Lana, "consisting of rounded waterworn boulders of quartzite embedded in a fine grained red-coloured schistose matrix." This Oldham considers to be of glacial origin and assigns it to the Jaunsar series. A specimen now in the Museum, No. 6,877 labelled "matrix of conglomerate;

near Lana" may represent the schistose portion of the outcrop described in the passage quoted. Assuming that it is really the rock to which Oldham refers, we cannot of course offer any comments on the suggestion that it is glacial, but the resemblance of the schist to the characteristic talc-quartz-schist of the Chails is so close that we can hardly doubt their identity. In that case the outcrop at Lana represents a portion of the Chail series thrust over Jaunsars. The same explanation will apply to No. 6,875 and other specimens, apparently assigned by Oldham to the upper division of the Jaunsar series, but which agree better with rocks belonging to the Chail series.

Intrusive dolerites.

Rocks of a doleritic type are undoubtedly intrusive in both the Jaunsar and Chail series in the Chakrata area, judging both from Oldham's specimens and from our own field observations. We have elsewhere (p. 127) commented on the resemblance of these to dyke-rocks in the area north-east and east of Simla.

Restriction of the name Jaunsar series suggested.

On the whole we cannot regard it as likely that any considerable portion of the rocks of the Chakrata area outside of Oldham's middle division of the Jaunsar series really belongs to that series. If this proves to be correct the designation of "Jaunsar series" must be restricted to Oldham's middle division of quartzites and slates. In any case, even should we regard the question of the possible existence of volcanic beds in a higher horizon of the Jaunsars as still *sub judice*, it does not vitiate the nomenclature of "Jaunsar" for the Jagas beds which we have adopted throughout this paper.

The Mandhali series.

We may next summarize the facts at our disposal relating to the Mandhali series. Oldham has described these (1888, p. 136), "*as consisting of quartzites, slates, limestones, conglomerates and boulder beds in the most variable proportions*". Elsewhere (1883, p. 196) he remarks that "*in Southern Jaunsar* [Chakrata] *the majority of the beds are not conglomeratic at all*"; in northern Chakrata, where conglomerates are most abundant, they rest unconformably on the Deoban limestone and contain numerous fragments of that series. Oldham finally decided that the Mandhalis were identical with the Blaini (1887, p. 137). Regarding, as we do, the Blaini and Infra-Krol as one series of which the Blaini proper is at the outside 500 feet thick and generally much less, it seems to us more reasonable that the upper part of the Mandhalis should be correlated with the Infra-Krol.

Possibly represent both the Blaini and the Infra-Krol.

The fact that the Mandhalis on the Tons rest on a series of slates which are indistinguishable from the Simla slates tends to confirm Oldham's correlation of at any rate their lower part with the Blaini. We failed, however, to find much resemblance between the Mandhali outcrops mapped by Oldham in the southern half of the Chakrata district, and those of the type area further north. In the latter, in the Dhara Gad, just below Pateuri, there is a good outcrop of these beds, showing a bed of cream limestone (36/731) resting on a boulder bed (36/727), the former greatly resembling the Blaini limestone. But we found no such beds further south. The general character of the Mandhali and the Blaini, however, especially the glacial origin of the boulder beds in both of them, and the similarity of the sections in which both of them occur raises their correlation into the region of certainty.

Character of the Mandhalis differs in the north and south of the Chakrata district.

Although there are but few pebbles in the Mandhalis on the Tons, yet we have found one or two fragments of slate and quartzite near Kwanu. Further, we may say that our observations in the northern part of the district entirely confirm Oldham's opinion that the Mandhalis rest unconformably on the Deoban limestone.

We have been tempted, as Oldham was at first, to correlate the Deoban limestone with the Krol, with which it has many characters in common. The fact that the Mandhali (Blaini) boulder bed where it is in contact with the Deoban seems to contain pebbles of it, must, however, put this correlation out of the question. Moreover the prevalence of thin shale bands interbedded with the limestone is a character which the Krol does not possess. Neither are the pseudo-organic structures, common in the Deoban, found in the Krol. On the southern side of the great hill of Deoban limestone which rises above the valley of the Amtiar river, which runs down from the Chakrata ridge into the Tons, everything seems to point to the Deoban overlying a series of quartzites which cannot be anything but Jaunsar. There is probably a slight fault, as Oldham has concluded, but the displacement is not likely to be great. We arrive, therefore, at the conclusion that the Deoban limestone is intermediate in age between the Blaini and the Jaunsars. The only series with which we are acquainted, that occupies this position is the Simla slates. In the type area of the Simla slates north of Simla on the Naldera ridge a clear blue limestone occurs in lenticles of about 100 feet in thickness, interbedded with the Simla slates and probably near their base. This limestone is de-

The Deoban limestone.

The Deoban limestone possibly to be correlated with the Naldera and Kakarhatti limestones of the Simla series.

scribed in greater detail on page 113; it contains pseudo-organic structures. We have little doubt of the identity of this bed with a limestone which Medlicott (1864, pp. 54, 55) has recorded a few miles north of Subathu; this is known as the Kakarhatti limestone; the senior author has followed it continuously as far as Erki. It is beyond a doubt interbedded with the Simla slates and it is characterised by pseudo-organic structures. It is conceivable that these two limestones may be correlated with the Deoban. The pseudo-organic structures in them are, however, different from those which are found in the Deoban limestone, and lithologically they are dissimilar. The great difference in the thickness of the limestone in the two cases is perhaps of less importance.

Or with the Shali limestone.

It is more tempting to correlate the Deoban with the great Shali limestone (page 120). The age of this is, however, equally uncertain, though there is a possibility that it may be slightly later than the Simla slates. Lithologically, however, there is even less resemblance between the Shali and the Deoban limestones than there is between the latter and the Naldera limestone.

No evidence that the Deoban limestone is in contact with the Simla slates.

We have unfortunately no evidence that the Deoban limestone is in contact with the Simla slate series. The dark-grey slates on the Tons which we have correlated with that series do indeed underlie a small outcrop of limestone, which on the northern side is in contact with Mandhalis. There is, however, no certainty that this limestone is Deoban, since there is at least an equal chance that it may be an outcrop of Krol resting unconformably on the Simla slates. Other outcrops of this limestone are found on the same strike to the east of the Tons, but the section is too folded and complicated for a single traverse to clear up the structure successfully. The lowest beds seen are Jaunsar

Jaunsar quartzites west of Chakrata station.

quartzites which, as we have already mentioned, crop out on the whole of the hillside between the Disau-Haju ridge and the Amtiar; a narrow band of them occupies an anticlinal fold at Gubah. But from the fact that this limestone is in contact, sometimes with the Jaunsar quartzites, sometimes with the Mandhali grits, sometimes with splintery shales, we are rather more inclined to think that these outlying patches are not Deoban but Krol.

Although the Jaunsar quartzites are exposed in the valleys west of Chakrata, yet they are not found in Chakrata itself. Throughout the whole length of the ridge on which the station is built from the foot of Deoban Hill down to the toll bar at Kailana there are slates exposed. These are quite unaltered and present quite a different appearance to the older series which we know as Jaunsar. It is possible that these belong to the Simla series. Originally Oldham (1883, p. 193) included these unaltered slates in his Jaunsar series. Whether he retained the same idea after his later work we are unaware.

The rocks of Chakrata station.

Whereas on the west of the Tons the strike of the rocks is almost N. and S. that on the east of the Tons is almost E. and W. It seems, however, to be bending round to N.W.-S.E.; this being the strike of all the rocks seen in the southern part of Chakrata and in the hills south of Kailana on the Mussoorie road. What may be the explanation of this curvature in the strike we cannot conjecture.

Alteration of the strike in the Chakrata area.

Our observations in the Chakrata area are too scattered to enable us to present a detailed idea of the geological structure, but we seem to have a generally descending section from the fault on the west bank of the Tons at Bansa, where the crushed limestone is exposed. This section seems to be extraordinarily complicated by unconformities and overlap. Limestones which we have no hesitation in regarding as Krol rest on the Mandhalis and also on altered beds which can only be Jaunsars. It is, however, worth devoting some space to a description of a section which was seen on the road from Chakrata to Mussoorie, which seems to throw some light on the relation of the Chail to the Jaunsar series.

Section on the Chakrata-Mussoorie road.

The rocks throughout Chakrata and Kailana as far as the toll bar are mainly steeply dipping dark-grey slates, with occasional purplish, sandy or shaly beds, which are evidently folded repeatedly. Most of them resemble the Simla slates, with, perhaps, infolded bands of Mandhali. At the toll bar we pass into older-looking slaty beds, with vein quartz which we correlate with the Jaunsar series. Close here is an outcrop of the crushed limestone, of which the relations to the other beds are obscure. On the summit of peak 7152 quartzites crop out with a N.E. dip, and the outcrop continues for some distance along the road. They are both of a granular as well as a non-granular type. They overlie a series of much distorted grey slates, with very numerous blackened joints, containing frequent interbedded bands of quartzite and quartz-schist. In their lower portion they become very schistose and micaceous and contain abundant vein quartz. They are markedly different from any of the rocks seen in the station of Chakrata and we are inclined to assign them to the lower part of the Jaunsar series. On the col between peaks 6925 and 6658, about half way between miles 33 and 34, there is an open anticlinal fold; the beds on the col represent the core of the anticline, and, therefore, are obviously older than the quartzite slate series which has just been described, and newer than a series of quartzites which are exposed in the deep valleys on either side of the col. The rocks on the col are easily distinguished from those above and below them by the fact that they consist of a bed of blue, banded limestone, very much crushed and semi-crystalline in places and displaying minute foldings. In the latter character this limestone shows some similarity to the limestone of Annandale and Jutogh, and to the black limestone which has been frequently mentioned in these pages. In fact it was at first thought that it belonged to the Jutogh series and this provisional identification is mentioned in the Annual Report of the Geological Survey of India for 1926 (*Rec. Geol. Surv. Ind.*, LX, p. 22). It is however distinguished by being less altered and not carbonaceous. It seems to be identical with the limestone at Bansa on the west bank of the Tons, which underlies the Jaunsar slates and quartzites (page 37) and, as we have remarked above, it seems probable that in both cases the limestone is to be correlated with the Chail limestone. About 100 feet of this limestone is exposed on the col; it dips about 20° to the S.W. and is overlain by calcareous slaty phyllites which are occasionally carbonaceous. As we have remarked it passes down into quartzites, one bed of quartzite in contact with it being much blackened.

Supposed Chail limestone beneath the Jaunsars south of Chakrata.

Underlain by quartzites.

On the N.E. limb of the anticline we had expected to find the limestone and phyllites coming between the lower quartzites and the Jaunsar slate series; no trace of them is, however, seen, the junction between the lower quartzites and the Jaunsar slates being per-

Unconformity between the limestone and the Jaunsars.

fectly clear. We cannot avoid drawing from their absence the inference that the Jaunsar slates rest unconformably on an older series, which was partially denuded before the deposition of the later beds. This lends additional support to our identification of the limestone as the Chail series, since it is evidently entirely distinct from the Jaunsar. The sequence of beds is then as follows :—

(1) Phyllites.
(2) Limestone.
(3) Quartzites.

We are, however, unable to offer any suggestions as to the correlation of the thick series of quartzites which underlie the crushed limestone. In neither of the areas in which the basal limestones of the Chail series occur is there any such series of quartzites. A thin band of quartzite has indeed been found west of Simla and south of Halog (page 99), but it is believed that this belongs to the Jaunsar series and is not related to the Chail limestones. Figure 9 is a diagrammatic section across the area just described.

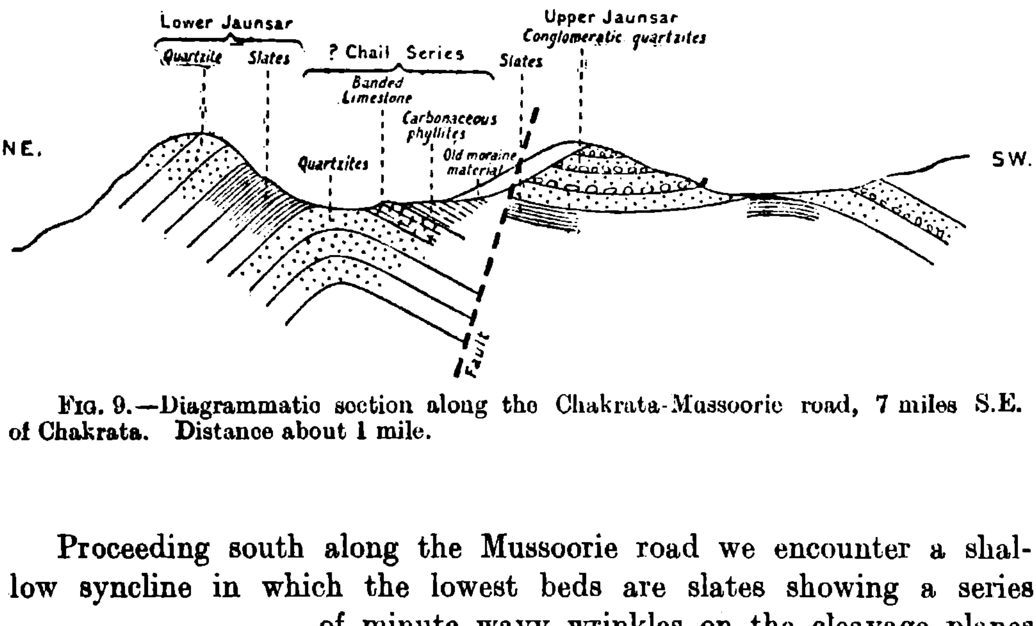

FIG. 9.—Diagrammatic section along the Chakrata-Mussoorie road, 7 miles S.E. of Chakrata. Distance about 1 mile.

Continuation of the section to the south.

Proceeding south along the Mussoorie road we encounter a shallow syncline in which the lowest beds are slates showing a series of minute wavy wrinkles on the cleavage planes due to crushing. This feature was noticed in more than one place in the Jaunsar series to the west of the Tons. On the slates are quartzites, in which conglomerate bands with quartz pebbles similar to those seen on the Chandpur ridge (p. 37) are conspicuous. Since the quartzites seen on peak 7152 north of the limestone contain no such conglomerate bands, we consider that the quartzites south of the limestone belong to a newer horizon than the others and that a fault separates them from the limestone and phyllites which we assign to the Chail series.

The same limestone crops out on the road west of Thana. Here also its dip is S.W.; it is probable that the outcrop could be continuously traced between the two points. The limestone was not, however, seen on the main motor road to Kalka, except at the toll gate, as mentioned above. At the brewery the Mandhalis were seen, so that it is possible that the crushed limestone at the toll gate represents the same outcrop and that the fault runs close below peak 7152.

Chail limestone on the cart road near Thana.

On the Mussoorie road, south of the shallow syncline mentioned above, the beds again turn over and we gradually pass from the quartzites into pale-coloured or mottled slaty beds with vein quartz. Quartzites again occur beyond these without any change of dip and then grey micaceous phyllites which closely resemble the highest horizon of the (Jaunsar) series seen above Jagas, while occasional pale-yellow, soft schists remind one of the beds of Nigaili. We now pass into a clear blue limestone just beyond mile 30; this occupies a broad patch with a low dip, all around the top of peak 6958; it rests on some yellow earthy arenaceous beds which intervene between the limestone and the pale yellow schists mentioned above. This limestone is quite distinct from the older limestone on the col north of peak 6658; portions of it are very sandy and the sand grains standing out on the weathered surface present a peculiar appearance which leads us to correlate it unhesitatingly with the similar limestone which occurs on Guma peak and Juin, and which is undoubtedly Krol. South of peak 6958 the limestone is overlain by massive quartzites which pass into dark slates. As we ascend towards peak 7632 the latter become very schistose, siliceous and splintery and simulate fossil wood. The correlation of these beds is uncertain; but they certainly belong to a different and no doubt older horizon than the Jaunsar beds exposed to the north of the Krol outcrop. It follows that they must have been thrust over the Krol limestone by a reversed fault. Considerable quantities

Krol limestone on the Mussoorie road.

Overthrust by older beds (?) Jaunsar series.

of limestone were seen on both sides of the Amlawa *nadi*, round about the village of Koruwa, and also on the old road W.S.W. of peak 6174. Oldham has mapped limestone east of Uproli and again to the north. It is probable that all these are Krol, and a continuation of the same outcrop which has just been described. It is not necessary that it should be perfectly continuous or regular, since by hypothesis the Krol limestone has overlapped unconformably on to the Jaunsars exposed to the N. and N.E. of it. The limestone which we saw on the Disau ridge (p. 39) is approximately on the same strike, and it is not impossible that an examination of the intervening area might disclose other patches. At Disau it would seem that both the Blaini and the Simla slates are present, and that denudation has not taken place to the same extent as we believe to have been the case on the Mussoorie road.

Krol limestone at Uproli and elsewhere east of the motor road.

Considerable outcrops of limestone occur round Sahiya; Oldham has mapped a large outcrop of it on approximately the same strike at Udpalta and has continued it up to the Tons river. South from Sahiya we have a long succession of Jaunsar quartzites and slates with a gentle northerly dip; amid this are one or more outcrops of intrusive "syenite" (sic Oldham). On the path east of Dhaira and before reaching the top of the ridge, is a black limestone with little blebs of dark quartz. This limestone was again seen on the motor road about 55·2 miles, at the sharp bend. It seems to be interbedded with rocks of a Mandhali type, amongst which are coarse grits and in one place a grey, slaty bed with bouldery fragments which closely resembles the Blaini conglomerate. The cliffs on the east far above the road present just the appearance of the Krol limestone. The structure is far too complicated to be mapped on a rapid traverse such as ours. The beds between Kalsi and mile 56 seem to belong exclusively to the newer series, and represent outcrops of the Simla slates, the Mandhali (Blaini and Infra-Krol) and the Krol, repeated by folding. Just after entering Kalsi we pass on to bright-red shales, which have been mapped by Oldham as Nahan, but which the senior author has no hesitation in regarding as Dagshai, as a result of his very careful work on the rocks on the west of the Kalka-Simla motor road, and which he hopes to

Krol limestone at Sahiya.

Mandhali beds north of Kalsi.

Dagshai beds at Kalsi.

describe at a future date in a memoir on the Tertiaries of the Sutlej valley.

Bawar series.

We have so far made no reference to the Bawar series, because our observations do not allow us to correlate it definitely. Originally Oldham regarded it as Tertiary (1883, p. 197), but at a later date mainly on account of a section on the Lambatach ridge (1888, p. 136) he referred it to his "Carbonaceous series". In the latter section a "glassy quartzite" correlated by Oldham with the Chakrata outcrop of the Bawar series does not come far below "carbonaceous slates and limestone" which are obviously Jutogh, but it is impossible to say whether a thrust separates the two beds. In any case the metamorphosed character of the Bawar series is indicative of an early epoch, and it can hardly be doubted that whether they are Chail or Jutogh a closed thrust trace separates them from the younger rocks, which underlie them on all sides.

VII.—THE JUTOGH SERIES AND ASSOCIATED ROCKS OF THE CHOR AREA.

Before we trace the three overthrusts mentioned above in the opposite direction, that is from the Giri and Ashni rivers towards the north-west into the Simla area, it will be as well to finish with what we may term the Chor area, since we find here the clearest evidence for the structure and correlation of these rocks that we wish to establish. So far we have only considered in detail the outcrops which lie on the southern and eastern, that is to say on the foreland side of the Jutogh thrust. We will now proceed to the consideration of the various rocks which lie on the hinterland side of that thrust.

The Jutogh series of the Chor area probably isolated within the uppermost overthrust trace.

Although we cannot assert that the Jutogh thrust continues to the north and north-east of the Chor mountain so as to join up with the points at which we left it on the western and eastern sides of that mountain, yet it seems to us probable that such is the case. At any rate we have no reason to believe that any other rocks than those of the Jutogh series occur within the thrust trace where we have definitely established its existence, so that the probabilities are in favour of the Jutogh outcrop in this area being just as isolated as is undoubtedly the case in the Simla area and in the much smaller area immediately surrounding the station of Chail.

Since the great intrusive mass known as the Chor granite is one of the most conspicuous portions of this area, this will first be briefly described.

The Chor gneissose granite.

The Chor granite forms the higher parts of the mountain of that name, which is a prominent feature of the district to the south-east of Simla, attaining an elevation of 12,000 feet.

Medlicott's views on the origin of the Chor granite.

Medlicott's views on its origin seem to have been rather undecided. The somewhat obscure way in which he writes makes it difficult to understand what his conclusions were. Apparently he discarded the idea of its origin from 'fluid intrusion', while, to use his own words again, he seems to have been 'in favour of a faulted elevation and semi-intrusion', whatever that may mean.

McMahon's views on the Chor granite.

Later, McMahon wrote extensively on the gneissose granites of the Himalayas, including the Chor granite. While he first regarded the granite as representing highly metamorphosed sediments (1877, pp. 216, 223), he later discarded this idea and concluded that the granite had been intruded into its present position (1882, p. 40).

Middlemiss's view.

In a later paper (1883, pp. 102-106) he summarised his views on this question of the origin of the Himalayan gneissose granites. He concluded that the gneissose granites of the Chor, Dhaoladhar and Dainkund, were all of one age, essentially the same rock and all definitely of igneous origin. He referred their intrusion to a Tertiary period, coincident with the uplift of the Himalayas, a view which is not supported by our more recent work. It may be mentioned in passing that this view of the age of the granites was upheld in Hayden and Burrard's book on the Himalayas (1907-08, p. 219), though it was not supported by Middlemiss, (Middlemiss, 1896, pp. 274-278, and McMahon, 1897).

Outward appearance.

The granite of the Chor Mountain (36/691) is a porphyritic biotite-granite, containing abundant phenocrysts of orthoclase, almost invariably twinned on the Carlsbad law. These phenocrysts often occur up to 2 inches in length. In addition to the quartz and felspar, the only other mineral that is easily seen in the hand specimen is biotite, in which the rock is very rich. Two average specimens gave a specific gravity of 2·70.

A marked characteristic of the granite is the foliation that has been developed in it. This shows itself most clearly in the arrangement of the orthoclase phenocrysts and of the biotite. In the least foliated varieties, the orthoclase crystals are scattered about the rock anyhow, their axes pointing in all directions. In such a rock the biotite, while it has a certain parallel disposition, tends to occur irregularly.

As the foliation of the rock increases, so the orthoclase crystals take on a parallel orientation, their longer axes being roughly parallel. In the most foliated varieties these crystals lose their sharp outline and have instead a rounder appearance, the rock being sometimes almost like an augen-gneiss, the 'eyes' being the orthoclase phenocrysts. In such a rock the mica is closely wrapped round the orthoclase, and elsewhere occurs in thin parallel strings.

Such then is the outward appearance of the rock. It was, of course, this foliated character which misled geologists into regarding it as a gneiss of sedimentary origin.

Microscopic characters.

Under the microscope the larger phenocrysts are seen to be mainly orthoclase. They commonly contain abundant inclusions of the groundmass, such as flakes of biotite, and in addition numberless little crystals of zircon and some apatite are seen scattered about the crystals.

The felspars of the groundmass are chiefly orthoclase and oligoclase, the latter sometimes showing albite twinning.

Quartz is the most abundant mineral, occurring in strings of small grains, which, together with the mica, sweep round the phenocrysts, enclosing them as lenticles; one phenocryst if it is a big one will go to form a lenticle, but one or two phenocrysts if they are small.

Biotite is the predominating mica, generally of a greenish-brown, but sometimes of the more typical red-brown colour. It rarely occurs in large crystals; more often it is seen as a thin string of little flakes.

Muscovite only occurs in subordinate amount, sometimes in medium-sized flakes and sometimes as a fine sericitic aggregate.

Sphene is quite abundant.

Another constituent which is almost universally present is a yellow-brown crystal, nearly always divided into a dark interior zone and a light outer zone. So far as can be said at present, the two appear to be epidote and allanite, the latter being the cerium-bearing epidote.

Xenoliths.

In certain parts of the granite, notably on its eastern side, xenoliths are fairly abundant. These seem to be of two kinds:—'accidental xenoliths' and 'cognate xenoliths'. The former are clearly portions of the country rock which have been caught up by the magma, and rocks such as quartzites and garnetiferous schists can still be recognised. The 'cognate xenoliths' betray their origin by containing some of the large twinned orthoclase phenocrysts of the parent rock. They differ from the latter, however, in being quite basic, and are almost black in colour. It is hoped to make a more complete investigation of these xenoliths in the future.

Geological relations of the granite to the surrounding rocks.

Such then is the rock itself. As regards its geological relations to the surrounding rocks, these are not so clear as might be wished, owing to the fact that the junction is commonly obscured by fallen boulders of the granite. While it is true in general that on the southern slopes the strata dip gently towards the granite, so that on the south-west side of the granite the prevailing dips are to the north-east, while on the south-east side they are north-west, at the same time no such simple relation is seen close up to the granite. On the west side of the granite, near Topi, the neighbouring rocks, right up to their contact with the granite, are almost everywhere horizontal, with the granite forming the higher slopes above them. On the Didag-Balogti spur the relations are not clear, but again the granite appears to rest on the gneisses. On the Nauraghat spur there is direct evidence of a discordant junction. The edge of the granite is about a quarter of a mile north of Nauraghat. Along the road from Sotani to Naura the prevailing dips are south and south-east, and the rocks appear to be striking north-east directly towards the granite. Due north of Nauraghat, the rocks have sometimes a northerly dip, but elsewhere it is again south-east.

Thus although on a broad view it might be said that the rocks on the south side of the granite have a dip towards the granite, closer examination shows that the relations are not really so simple.

The north side of the granite has not yet been examined by the authors, but Medlicott states most explicitly that the strata here have a northerly dip, and that they overlie the granite, which dips beneath them (1864, pp. 41, 42). In accordance with this northerly dip, which, though varying from place to place, may be said to be the prevailing dip of the whole area, the southern sides of the mountain are more steeply scarped than the northern.

It is of interest to note that on the very top of the mountain occur relics of the coarse garnet-gneisses which are found in the Jutogh series, and which may be presumed to have formed the roof of the intrusion.

The granite an intrusive laccolith.

It thus appears that we are dealing with a large intrusive laccolith, which has a gentle northerly dip, and has evidently been intruded up from the north, into the Jutogh series.

The foliation of the granite contemporaneous with its intrusion.

As regards the foliation of the granite, there seems to be little doubt that this feature was not the result of metamorphism after the solidification of the granite. This is most conclusively shewn by the fact that where the granite is most foliated the parallelism of the phenocrysts is most marked. Now if the granite had been intruded and cooled down under tranquil conditions, the phenocrysts would have been scattered about in all directions, with no particular orientation, as indeed they are in the less foliated varieties. If subsequently the rock had been subjected to metamorphism after it had become solid, the felspars would in the main still have retained their original directions, but would have shewn signs of crushing and other cataclastic effects, those which were most parallel to the strike of the crust-movements being least affected. Complete parallelism could only be attained if the whole rock became fluid, a condition which must be beyond the compass of metamorphism. (The possibility of complete fusion must in any case be excluded, because the rocks adjacent to the granite shew no evidence of it.) But in actual fact, except for certain strain phenomena shewn by the optical properties of the quartz, cataclastic affects are entirely absent; and though the mica is sometimes seen to be bent, following the general flow lines around the phenocrysts, it never presents the appearance of having been fractured subsequent to its crystallisation.

It is clear, then, *that the foliation must have been developed at the time of intrusion and crystallisation*, by pressure resulting from the crust-movements that were then in operation, presumably the same as those that caused the intrusion of the granite. All the evidence points to any parallelism there is among the minerals being due to flow prior to the final consolidation of the rock. The point is an important one; for on its correctness depend certain arguments which are used in determining the sequence and time-relations of the various events.

The olivine-dolerites.

We may now pass on to describe a small number of fresh, basic, igneous rocks, which occur as dykes cutting the Jutogh series and the Chor granite.

No reference to them appears to have been made by Medlicott, unless the 'dense hornblendic trap-rock' described as occurring near Banallah and Sohana, on the west flank of the Chor, refers to the dolerite which does occur there.

In 1887, however, C. A. McMahon published a paper entitled 'Some notes on the Dolerite of the Chor', in which he describes the petrography of some of these rocks.

In this paper McMahon refers to six localities, but it is almost certain that one of them is a mistake, that at Naura. Apart from the fact that his description of the locality is at fault, prolonged search in this area failed to reveal the slightest trace of any such rock, either *in situ* or as boulders. The particular locality, however, is notable for its abundant dykes of hornblende-schist, and it may be that he has mistaken one of these for the dolerite, though he gives a petrographical description of a dolerite.

In addition to these five localities, the same rock has been seen in four other localities, namely, (1) on the S.W. spur, Kheri-ki-Dhar, by a small pond about one mile east of Chorwa Hatti, cutting the gneisses (36/954); (2) further up the same spur, just before Bajni, cutting the granite (36/689); (3) where this spur reaches the top of the Chor by Setambu, also cutting the granite (36/692); and (4) on the west side of Sharah Dhar, one of the spurs running south from Nauraghat, about half a mile east of Bhangari, cutting the gneisses. In this latter place two varieties occur (36/965-967).

Thus we see that the outcrops of this rock (including the five described by McMahon) are entirely confined to the area of the granite and the older rocks associated with it, above the uppermost overthrust. They have never been seen in the Chail or Jaunsar series below, an observation which will be referred to later. On the other hand they do not appear to have been seen anywhere in the Simla-

Jutogh area, so that they seem to be confined to the vicinity of the Chor granite, with which perhaps they have some genetic connection.

In the above-mentioned paper McMahon drew attention to the close similarity of all these rocks, and, no doubt correctly, regarded them as belonging to one set of intrusions.

The rock is easily recognised in the field, for its marked freshness, great hardness, and the ringing sound it emits when struck with a hammer, all serve to distinguish it from any other rocks of the district.

The petrography of these rocks has already been described in some detail by McMahon.

In the *hand-specimen* they are seen to be very fresh, black, moderately coarse-grained rocks, weathering to a rusty brown colour, and having a high specific gravity, the rock at Setambu being 3·04. The grain varies considerably in coarseness. In places it approaches a gabbro in this respect; elsewhere it is more like a medium-grained dolerite. In the last locality mentioned above, by Bhangari, both varieties occur close together. While the rock is generally even-grained and non-porphyritic, in some varieties relatively large crystals of felspar occur, giving a semi-porphyritic character to the rock. The dyke at Bajni is of this type.

Under the microscope, an average specimen is seen to be a holocrystalline rock, composed essentially of plagioclase felspar, augite, and olivine.

The felspars in all these rocks are characterised by a faint clove-brown tint. This unusual appearance is so characteristic that on this ground alone one would be justified in placing all these rocks into one group. It is a feature which was remarked upon by McMahon, when he first described these rocks, and he attributes it to a content of iron. A detailed description will not be given in this place. It may be said, however, that the felspars correspond to an acid labradorite plagioclase, and that they are invariably idiomorphic towards the augite. The latter is generally quite colourless. It tends to occur in separate allotriomorphic grains rather than in plates, but sometimes a sub-ophitic structure is developed with respect to the felspars. The olivine, like the felspars, is very characteristic, being highly charged with a fine magnetite dust, giving many of the crystals a grey-black colour under the microscope. Though it occurs in all the dolerites that have been examined from the south side of the Chor, according to McMahon it is absent from the two specimens which he collected from the north-east side. As might be expected with a presumed high content of iron, the olivine crystals show a negative birefringence.

In accordance with the description given above, they should be called olivine-dolerites:

The hornblende-schists.

In this section we have to deal with igneous rocks of pre-metamorphism age, which are now seen as hornblende-schists and amphibolites. It will be convenient to refer to them here.

These rocks were briefly described by McMahon in his paper on the 'Dolerites of the Chor' (1887), wherein he refers to those seen by Nauraghat, where they happen to be unusually abundant.

Occurrence.

As compared with the dolerites they are quite common; but, as is the case with those rocks, they are confined in their distribution to the oldest, uppermost rocks, the Jutogh series, though they do not appear to cut the Chor granite. The main point, however, is that they are never seen cutting the underlying Chail or Jaunsar series. In fact it is impossible to conceive of them doing so; for they are the products of high grade metamorphism, and could not occur in rocks that showed little metamorphism.

Perhaps the commonest way in which they occur is as dykes cutting the neighbouring strata transgressively. On all sides of the Chor Mountain they are seen with this relation, so that there is no need to specify any number of cases. One, however, may be mentioned where this relation is very well displayed. Just south of Nauraghat, is a thick band of white dolomitic marble. Intruded into this rock, between the two roads to Bandal and Manal, are two dykes of hornblende-schist (36/696), and they both cut the marble almost exactly at right angles to the strike. In other places these rocks are seen to occur parallel to the bedding of the sediments, in the form of sills if they are regarded as intrusive.

All, however, have one feature in common, namely, a very limited extent. Rarely can a band of the rock be traced for more than a hundred yards. This is not due to poorness of exposures, for the rock can quite commonly be seen to end abruptly. Further, they none of them seem to follow any rule as regards their direction, but are scattered about at all horizons, some concordant, some transgressive.

These rocks, though they occur in considerable abundance, do not vary greatly in character, the two types, hornblende-schist and amphibolite, differing chiefly in the former being schistose, while the latter are more massive and granular. Felspar is sometimes abundant and sometimes comparatively scarce.

Character.

Another variety which is commonly seen is a garnet-bearing rock in which the garnets are very abundant and sometimes up to an inch in diameter, though generally they are about a quarter of an inch in diameter. This type of rock is seen on Prospect Hill (36/660-663), and is referred to by both Medlicott and Oldham (1887, p. 148). Throughout the Chor area also this rock is quite common.

In a typical specimen of these hornblendic rocks the hornblende is by far the most abundant constituent. It is generally a pale green colour, with the following pleochroism :—

$\mathfrak{a}$ = pale brown
$\mathfrak{b}$ = brownish-green
$\mathfrak{c}$ = bluish-green

It usually has a rather high extinction angle, 19° measured from the slow direction, with negative birefringence.

Pyroxene seems always to be quite absent.

The colourless minerals are almost entirely plagioclase and quartz. The former is commonly twinned on the albite law, with a maximum extinction of 26°, and a refractive index higher than the balsam. Hence it is probably a basic andesine. There is nearly always a certain amount of quartz present, and it may be quite abundant, though it is not always easy to distinguish it from untwinned albite, which may be present.

The only other constituents which are invariably present are sphene, a very common mineral in all hornblende-schists, and an iron ore, generally in ragged crystals.

In some specimens, notably one from Shangin, N.W. of Taradevi, and in certain parts of the Prospect Hill rock, zoisite or a colourless epidote are abundant.

The Prospect Hill rock is really very complex. In places the garnet is abundant, sometimes uniformly distributed, elsewhere in thin streaks in the rock, while often it is entirely absent. In one variety quartz is very prominent together with colourless epidote, while hornblende occurs only in certain bands.

Apart, however, from special variations such as these, the rocks are on the whole quite similar, and it would seem that they belong to one suite. Hence whatever origin can be determined for some of them, can probably be applied to the whole suite.

From what has been said above, then, it seems likely that the whole suite of rocks are of igneous origin, and it is clear that at least a large proportion of them are intrusive rocks. The question arises as to whether some of those with concordant relations may not represent lava-flows. But the fact that they are seen at all horizons in these older rocks, that they can never be traced for any great distance, and that so many of them are seen to have discordant relations, would seem *to point to their all being intrusive igneous rocks*, some dykes and some sills, but probably none of them lava-flows.

Metamorphism of the Jutogh series.

Metamorphism of the Jutogh series; its radiation from the Chor granite.

The most striking feature of these rocks is their much more metamorphosed condition as compared with all the other rocks of the district. This metamorphism undoubtedly radiates from the great intrusive granite mass of the Chor, its intensity varying inversely as the distance of the rock in question from the Chor. This phenomenon as observed by us is completely in accord with Medlicott's general observations as described on pages 40 to 43 and 45 to 47 of his memoir. It must be clearly understood, however, that if Medlicott intends to include the Chail and other rocks on the outer side of the Jutogh overthrust in the same generalization then we cannot endorse it. The Chail series is undoubtedly less metamorphosed than the Jutogh series, and the Jaunsar series than either of the other two; but the degree of metamorphism displayed by corresponding rocks in both the Chail and Jaunsar series does not vary from place to place except accidentally, and we believe that their metamorphism has no genetic connection with that shown by the Jutogh series, which as we have seen is separated from them by an overthrust. Thus, considering merely the Jutogh series, our examination of the older rocks which are closely associated with the Chor granite, incomplete as it was, yet did indeed reveal a fairly regular concentric arrangement of the secondary minerals about the granite; we can, therefore, hardly doubt that the intrusion has exercised quite an appreciable effect on their grade of metamorphism.

We did not originally intend to give a detailed description of the metamorphism of these rocks until a greater area had been surveyed and until more time had become available for determinative work. The metamorphism as we interpret it, however, is of importance in determining the age and sequence of some of the major events, and it is therefore necessary to refer to it briefly in this paper. As it is also of considerable interest, a preliminary account may not come amiss.

In discussing the metamorphism, attention is mainly confined to the older rocks comprising the various members of the Jutogh series; though certain comparative observations will also be made upon the metamorphism displayed by the Chail and Jaunsar series.

The metamorphism essentially regional.

Examination of these older rocks reveals at once the fact that the metamorphism displayed about the granite is essentially of a regional type, and is not purely thermal. This is clear, firstly from the type of rock produced, highly foliated gneisses and schists; and secondly from the type of mineral formed, in particular staurolite, chloritoid, and chlorite, minerals which are almost wholly confined to the crystalline schists, and never observed in ordinary contact metamorphism. Moreover, these Jutogh rocks always show a moderate grade of metamorphism over the whole of their outcrop, in places far from the Chor granite, and it seems clear that the granite has only been a modifying factor, with its local influence impressed upon the regional metamorphism.

Contemporaneous with the intrusion and foliation of the granite.

Again, the granite itself is often highly foliated, and, as discussed on page 55, the foliation was evidently impressed upon it at the time of its intrusion and subsequent crystallisation. We therefore have strong evidence that the granite was intruded at a time of important earth-movements; and the additional observations, that there is a definite relation between the granite and the grade of metamorphism, and that the metamorphism as a whole is essentially regional in type, point to the conclusion that the earth-movements which produced the foliation in the granite, and indeed probably caused its intrusion, were the same as those that produced the regional metamorphism of the whole area in which the Jutogh series existed.

We know that regional metamorphism is connected with periods of extensive earth-movement, when the crust is in a disturbed state, and that the same commonly applies to the intrusion of igneous material. In view, therefore, of the facts noted above, it does not seem unduly speculative to conclude that the intrusion of the Chor granite, and the main regional metamorphism, were products of the same earth-movements, and had thus a close genetic relation.

Increase of metamorphism about the granite due to heat produced by its intrusion.

From the type of metamorphism developed, it is evident that conditions of both high stress and fairly high temperature prevailed throughout the region; and we may confidently ascribe the increased metamorphism about the granite to the increase of temperature consequent upon its intrusion. Not only can one discern a general increase in the grade of metamorphism of the Jutogh rocks on approaching the granite, but certain metamorphic zones can be laid down, the distribution of which shows a definite relation to the granite mass. The importance of this, and the reason why it is necessary to refer to it briefly in this paper, is that it sets a limit to the date of the recumbent folding. It seems to us to show that the date of this folding cannot be later than the high grade metamorphism.

Character of the sediments an important factor in the degree of metamorphism.

Before proceeding further with the description of the metamorphism, an important factor must be mentioned; it is necessary, in discussing the grade of metamorphism, and in making any attempt to lay down zones of metamorphism, to take into consideration the composition of the sediments. It is obvious that composition must play an important part in determining the formation of the various minerals. Further only certain types of sediment are of use in following out the progressive metamorphism. A large number of sedimentary rocks exist in a state of 'false equilibrium', particularly calcareous sediments; and it only requires a small rise of temperature to set off a reaction, which, in proportion to the lack of equilibrium, will proceed with corresponding rapidity. Only the fine-grained argillaceous sediments can be regarded as in a state of equilibrium. It is, therefore, in these rocks that successive zones of metamorphism can most easily be traced, especially in the earlier stages.

For these reasons, in studying the successive grades of metamorphism about the Chor granite, the zoning, in so far as it can be effected, must be confined to one particular type of sediment. Fortunately the pelitic type is fairly abundant and it can be picked out for the purposes of zoning. Even so, however, there is considerable variety amongst this type of rock such as the schists associated with the Boileaugunge quartzites, and those associated with the carbonaceous band—two varieties of pelitic sediment, of which the second is very markedly ferruginous. Such differences of composition afford interesting comparisons. Thus in one variety a particular mineral may come in earlier or later than it does in another, or it may be completely absent. And, although a given mineral may be developed in rocks of different composition, its appearance may not denote the same temperature in both cases. This principal is well exemplified in our own area, where the ferruginous type of pelitic sediment is not isogradic with the normal type.

The Chor granite has merely modified the regional metamorphism.

Although the influence of the Chor granite is quite clear, its effect is only to be regarded as a modifying one; for the regional metamorphism of the same rocks far away from any granite mass, as at Simla, has already reached the garnet zone, at least so far as the schists associated with the Boileaugunge quartzites are concerned. In the case of the carbonaceaous rocks this is not so and garnet does not appear until within the immediate vicinity of the granite.

Zones of metamorphism established by Barrow in the S. E. Highlands of Scotland.

Before proceeding to describe the zones and their distribution, reference may be made to two important papers published many years ago by George Barrow (1893 and 1912). In these papers Barrow describes an area of Dalradian rocks in the S. E. Highlands of Scotland, which has suffered regional metamorphism. Associated with them are numerous granite intrusions, some of the 'Older Granites' of Scotland. Owing to the completeness of the evidence, the advancing metamorphism can be followed out from the lowest to the highest grades, and in general the zones are related to the distribution of the granite.[1] Such zones are characterised by different mineral assemblages, and in particular by the

[1]According to Tilley this is not always so. See *Quart. Journ. Geol. Soc.*, LXXXI, p. 107, 1925.

incoming of some distinctive new mineral, corresponding to the lowest temperature at which such a mineral can form. Such an index mineral may or may not continue to figure in the higher zones; but it is its occurrence on the border of the zone which is the significant point.

Working in this way, and confining himself to argillaceous rocks he has established six zones, characterised by the incoming of the minerals chlorite, biotite, almandine garnet, staurolite, kyanite and sillimanite. The latter is Barrow's highest zone mineral. Staurolite, however, is only found in sediments fairly rich in iron.

Returning now to our own area, it will be seen that the range of metamorphism is here confined within much smaller limits. In those schists associated with the Boileaugunge quartzites, the two zones of garnet and staurolite are well developed, while one lower zone, which can best be described as being without garnet, is also sometimes present. While biotite often occurs in this latter zone, it is more commonly absent, the most distinctive mineral being muscovite.

Range of metamorphism in the Chor area.

In the case of the rocks associated with the carbonaceous band, the garnet zone is much more restricted, and only occurs in the immediate vicinity of the granite. Prior to this is a zone characterised by the presence of the mineral penninite, and less commonly by chloritoid. The feature of this zone is the occurrence of the penninite and chloritoid in fairly large porphyroblasts, set in a fine matrix. It may be called the penninite or chlorite zone. Below this is the zone of white mica, which may be said to represent the normal grade of metamorphism presented by these rocks away from the influence of the Chor granite.

Metamorphism of pelitic type of sediments.

We shall now describe briefly the metamorphism of those sediments of normal pelitic type, such as the Boileaugunge schists.

In following out the advancing metamorphism, owing to the folding, one cannot always keep to the same horizon. This, however, is not of much consequence, so long as one can pick out rocks of the same pelitic type, having approximately the same composition. Thus, as we shall show later (p. 110), the rocks above the upper carbonaceous band (the upper mica-schist of Hayden) are probably a different horizon from those that occur between the two bands. But the type of rock is the same, quartzites and mica-schists; so that for our purposes they may be treated as the same.

In the Simla-Jutogh district the schists of the Boileaugunge series are well displayed on Jakko, and again on Jutogh. In the intervening area, on the ridge, the quartzites mostly predominate. As is well known from the observations of Medlicott, Oldham and other authors these schists are often already in the garnet stage; but, although this mineral is sometimes abundantly developed, more especially on Jutogh, it is mostly in small crystals, as compared with those seen near the Chor granite. A typical specimen of these rocks (36/667) is composed mainly of quartz, in small interlocking granules, with large films of white mica wrapping round them. Biotite also occurs but it is quite subordinate in amount. Garnets of a pale pink colour, may be abundant. Sometimes they show good shapes, and their great crystallising strength is revealed by the way they have pushed everything else aside when they were growing. Quite commonly, they seem to have been shattered, and the cracks have subsequently been filled in with quartz. Such, then, is the type of rock seen in this area, away from any visible outcrop of granite.

Metamorphism of the gneisses and schists in the Simla area.

Let us now compare the same rocks in the Chor area, with those of Simla. The progressive metamorphism is most clearly revealed on the spurs that radiate out to the S.W., W.N.W., and N.W. These three spurs are clearly shewn on Medlicott's small scale map. On the 1" map they are the three spurs named Kheri-ki-Dhar, Banali-Dhar, and Pain Kufar Dhar.

In the Chor area.

Summarily it may be said that the most obvious changes observed in the field as one approaches the granite are, (1) increase in the size and abundance of the garnets, (2) the incoming of staurolite, (3) increase in the size and abundance of the staurolite, (4) disappearance of the staurolite.

It was mentioned just above that the garnets that occur in the same rocks away from the granite are generally small, about 1/20" in diameter. On approaching the granite, however, they rapidly assume large proportions, up to ¼" in diameter, and become so abundant that in places the ground is strewn with them like gravel on a garden path. Not only have the garnets become larger and more abundant, but the muscovite has likewise increased in size; all this points to the prevalence of a higher temperature, resulting in an increased amplitude

Garnet zone.

of diffusion, and hence in a greater coarseness of grain. These rocks (36/960) often have a striking appearance owing to the abundance of the muscovite, which is a light golden colour, and in the absence of vegetation the whole hillside flashes out in the sunshine.

As compared with the garnet zone away from the Chor granite, biotite is now more prominent, though always subordinate to the muscovite. Felspar also now begins to come in. A feature of many of the garnets is the way they have been shattered, and the cracks filled in with quartz These latter sometimes show a remarkable arrangement within the garnets, being arranged in a kind of S-shaped way, as though the crystal had been rolled along or had suffered a small rotation while being fractured.

Sometimes large porphyroblasts of chlorite, probably penninite, are found developed in these rocks, but they are not as common as in the carbonaceous schists, to be described below.

Staurolite zone.

Over all this area the incoming of staurolite can be fixed on the ground with precision. Though almost exactly the same colour as the garnet, it is easily recognised by its prismatic habit. At first it is in comparatively small crystals, which are not very abundant. But on approaching the granite they increase both in size and abundance, until they become almost as common as the garnet, and are sometimes seen up to an inch long. While garnet continues to be present in this higher zone, it is not now so abundant as before. Nor, again, is the muscovite quite so coarse as it was in the garnet zone. The staurolite, where typically developed, shows the faces of the prism zone, and the face (101) is also commonly present. In places, and especially on Banali-Dhar, by the village of Banali, twins of the St. Andrew's Cross type are common, though usually only half the twin is developed, giving the appearance of an arrow head. These staurolite-garnet-schists (36/958) are very coarse rocks, and are commonly characterised by being full of thin sheets of milk-white quartz.

In staurolite-gneisses in other parts of the world, the staurolite, while appearing as good crystals in the hand-specimen, under the microscope is seen to be full of inclusions, commonly quartz, which make up more than half the crystal; or it may be destroyed to form white mica by alteration. Our own staurolite crystals, however, are very different in this respect, being remarkably fresh and free from inclusions, though they may be somewhat shattered.

In the staurolite zone muscovite becomes somewhat less abundant, while porphyroblasts of oligoclase and perhaps albite are quite common. Albite and oligoclase are also seen as small crystals in the groundmass, but it is doubtful if there is any potash felspar in these rocks.

It has already been emphasized that it is the incoming of a zone mineral which is the important point. Such a mineral when once formed may continue to exist in the higher zones, or it may be confined to its own zone. Thus we see garnet continuing into the staurolite zone. In the case of staurolite, however, it would seem to be otherwise, this mineral apparently having a restricted distribution. For as one approaches the granite staurolite dies out, and nowhere do staurolite-schists occur adjacent to the granite. It would thus appear either that staurolite has a definite temperature range, outside which it is not able to exist; or possibly that its existence is determined by the presence of shearing stress, so that at higher temperatures, where shearing stress may be presumed to become less effective, it ceases to appear.

Distribution of the staurolite zone.

The following sketch-map shows the distribution of the staurolite zone on the three spurs where it has been determined:—

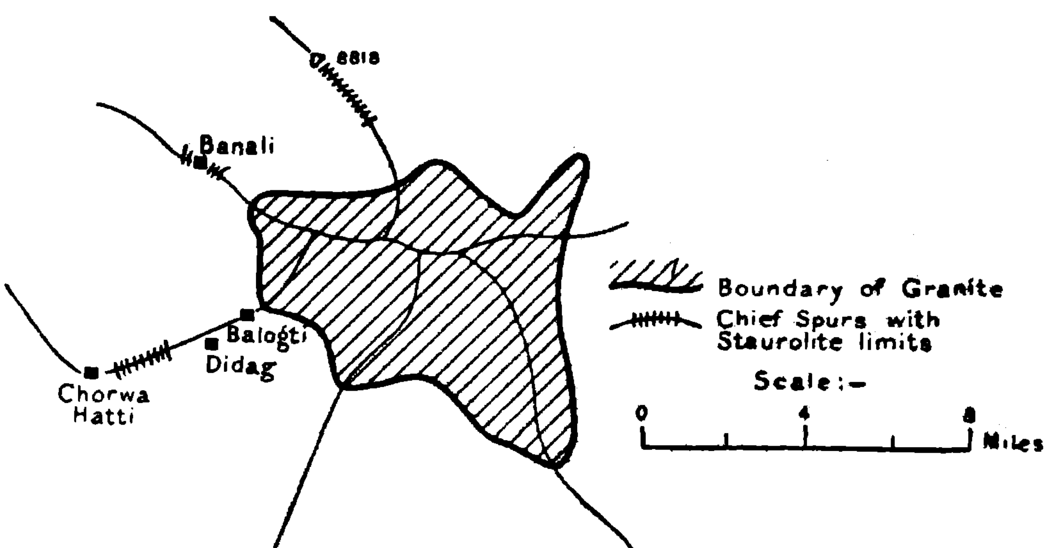

FIG. 10.—Sketch map showing distribution of the staurolite zone round the Chor granite.

From this it is seen that the zone most closely approaches the granite on the middle spur or Banali Dhar, though even here its upper limit is still about 1½ miles from the edge of the granite.

Although staurolite thus dies out before the granite is reached, garnet continues to be present, sometimes abundantly, right up to the boundary with the granite, the rocks then being very coarse.

Neither kyanite or sillimanite are ever seen here, though it may be mentioned that sillimanite apparently occurs around some of the granites of British Garwhal, which are probably the same age as the Chor granite. (Middlemiss 1888, p. 25.)

Metamorphism of the carbonaceous beds.

Having thus described very briefly the metamorphism displayed by the Boileaugunge schists, we may now turn our attention to the carbonaceous beds, the other part of the Jutogh series which best shows progressive metamorphism.

Garnet zone.

It has already been indicated that in these rocks the garnet zone has a much more restricted distribution; and it seems to be generally true that the advancing metamorphism has throughout been delayed to a very marked extent, as compared with its progress in the schists of the Boileaugunge series, described above. That is to say, the two series are not isogradic. Sometimes this distinction is strikingly shewn. At Punnar the carbonaceous beds are not garnetiferous; but immediately one gets into the Boileaugunge schists above, even while the rocks are still slightly carbonaceous (for there is a gradual transition), garnet at once becomes abundant. Why there should be this distinction is not evident.

In these carbonaceous rocks three zones are clearly marked out:—

(1) Zone of white mica.
(2) Zone of penninite.
(3) Zone of garnet.

Comparison between the zones of metamorphism in the schists and the carbonaceous beds.

In comparing the distribution of these zones with those of the Boileaugunge schists it appears that when the latter are in the early stages of the garnet zone these carbonaceous rocks are in zone (1). When the others are in the later stages of the garnet zone and in the staurolite zone, then zone (2) is developed in these rocks. Zone (3), that of garnet, is only developed in the immediate vicinity of the granite, while the staurolite zone is never developed; though in view of the composition of the rocks one would have expected it, had a sufficiently high temperature prevailed, for they are very ferruginous, as one is made to realize by the red colouration around the springs that issue from them. It is possible that the band never approaches sufficiently close to the granite for staurolite to form. In describing these three zones, then, it must be remembered that we are dealing with a distinctive type of sediment, often richly carbonaceous and highly ferruginous.

Muscovite zone.

In the *first zone*, the only distinctive mineral seen in addition to abundant quartz is muscovite. It occurs in lenticular bundles wrapping round the quartz, and it is interesting to note that the carbonaceous element is wholly confined to this mica (36/976-977).

Penninite zone.

The *second zone* is a very characteristic one, for the rocks commonly contain large prophyroblasts of a mineral which seems to be closely allied to penninite (36/943-945). It has the characteristic indigo-blue interference tints of that mineral, due to the very low birefringence, and approximately the same specific gravity and hardness. It differs, however, in having a somewhat higher refractive index, that for penninite being 1·578 while this is about 1·64.

In addition to this mineral, another mineral is sometimes found which is much harder and has a higher specific gravity (36/947). It most nearly approximates to ottrelite, and like that mineral it has great crystallising strength, pushing everything else aside as it grows, and taking not the slightest heed of the schistosity of the rock. The refractive index is again about 1·64, while that of ottrelite is 1·73. The mineral in our rock, however, seems to contain no manganese.

The abundant development of penninite in these rocks, and to a less extent of chloritoid, is clearly related to the abnormal composition of the sediment. The latter mineral, especially, is characterised by a high iron content, and we have already stated that the rocks in question are markedly ferruginous. A remarkable feature of the porphyroblasts of penninite is that they seem to grow with little or no disturbance of the rock. Instead of pushing the rock aside while growing, they seem to grow around the rock particles. One can often see the grain of the rock running right through some of the crystals that are perhaps only half formed, though already showing very definite and clear cut edges. Fully-formed crystals are nearly always full of inclusions of quartz, especially the penninite; and one may attribute its formation to the very basic nature of these minerals. It no doubt represents that excess of silica in the composition of the rock not required by the penninite.

It is hoped to make a more complete investigation of these minerals in the near future, as they are very abundant and present several features of interest. Their optical properties are unfortunately obscured by the abundant carbonaceous material. Both these minerals are easy to recognise in the field.

Garnet zone.

In the *third zone* muscovite is less abundant than before; this zone is easily recognised by the presence of garnets large enough to identify in the field. In addition to the incoming of garnet, the penninite still persists. Further we now find abundant biotite developed, in addition to the muscovite (36/962).

In order to render the areal distribution of these zones more easily understood, we reproduce in figure 11 a sketch-map of the west and south-west sides of the Chor mountain, showing its main spurs. The area occupied by the granite is shewn by shading, and the uppermost carbonaceous band is also indicated.

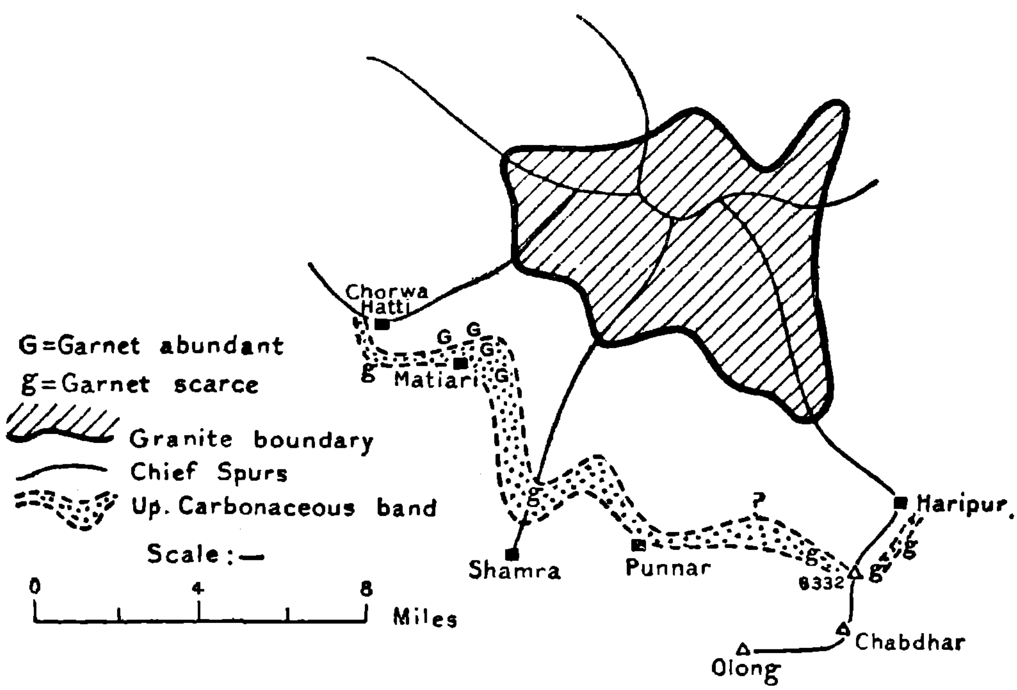

FIG. 11.—Sketch map showing the development of garnet in a carbonaceous band of the Jutogh series in relation to the granite.

The map has been drawn for the purpose of shewing the relation between the development of garnet in this upper carbonaceous band, and the proximity of the Chor granite. This has been done by lettering, a capital *G* indicating abundant garnet, and a small *g* scarce garnet. It will at once be seen that where garnet is abundantly developed the *band approaches most closely to the granite*; while as the band leaves the vicinity of the granite garnet dies out altogether. The connection between the development of garnet and the proximity of the band to the granite is too clear to be missed, and is eloquent of the part played by the granite as a modifying influence in the general regional metamorphism. Where the band sweeps north by Charna it has not yet been examined in detail, and hence it is not possible to say if garnet is abundant or scarce. But it is probable that it is only moderately developed, since further west, where the band passes to the north of Punnar, no garnet at all is to be seen, only penninite.

Distribution of the garnet zone.

These remarks as to distribution apply solely to the upper band of these rocks, which, owing to the configuration of the ground, crop out most closely to the granite. In the lower band garnet is almost completely absent, and was only seen in two places, and then only locally developed and in small crystals:—one just north of Gadol, due south-west of the Chor, at the top of the lower band; the other in the hills just above Chayal, on the west side of the Chor.

The distribution of penninite, though no less conclusive, is not so easy to demonstrate on a sketch map. In the Simla-Jutogh area this mineral seems to be entirely missing in these rocks, and a like remark applies to the outcrop of the same rocks at Chail, in Patiala.

Distribution of the penninite zone.

Further south-east, towards the Chor, the same rocks are next met with in the Haban-Chayal area. We are now very much nearer the Chor granite, and already both penninite and garnet are developed. Confining our attention to penninite, this mineral is now seen for some way. By Rajgarh it is sparingly developed, while in addition chloritoid is also found here. In the upper band the penninite is now seen continuously, and at Matiari is very abundant together with garnet, as shewn in the sketch map above.

In the lower band, continuing south-east from Rajgarh this mineral is seen above Kohlan, but further than this it does not occur, that is to say neither by Tikri, Gadol, Kanhar, Manal, S. of Shamra, Bahin, on Olong, nor on Chabdhar.

Now a glance at the map will shew that the line of outcrop of this lower band, following the places mentioned above, does on the whole very slowly diverge from the boundary of the Chor granite.

Irregularities in the distribution of the zones.

At the same time it is not easy to explain why the mineral is fairly abundant at Kohlan, but is not seen by Kanhar, where the band is somewhat nearer the granite. In fact there seem undoubtedly to be some irregularities in its development; though the general statement that it is only developed within the influence of the Chor granite is correct and none the less significant. Further the isothermal surfaces, resulting from the interaction on the one hand of the general temperature prevailing throughout the region, and on the other hand of the localised but higher temperature of the granite, may not have been very simple, and will have depended partly on the shape of the granite, concerning which we at present have little knowledge, at any rate as regards its underground extension. If the assumption made in the section on the granite be correct, that it is a huge sill or laccolite, which came up from the north or north-east, one cannot tell how much further south it may once have extended. By hypothesis it could not have been so very far above the present land surface, prior to its removal by denudation. From these and like considerations, we need not be surprised if irregularities occur in the distribution of our zone minerals; that is to say irregular as regards their relation to the boundary of the granite as now seen at the surface.

Metamorphism of the Chail and Jaunsar series.

The metamorphism of the younger rocks, designated as the Chail and Jaunsar series, is most conveniently considered here, although as we have shown they are separated by the uppermost overthrust from the Jutogh series, the metamorphism of which we have discussed in the preceding pages. The contrast in the two cases is very striking. The Jutogh rocks not only display recumbent folding, but also a high grade of metamorphism that has required both high temperature and high stress for its formation. Moreover it is abundantly clear that the increase in metamorphism is related to the granite mass.

On the contrary in the case of the younger underlying rocks, those which have been brought forward by the two lower overthrusts, the effects of high temperature are no longer to be seen. Instead, the dynamic factor has been the preponderating influence; and, whereas in the upper rocks we find the formation of schists and gneisses with high temperature minerals, in these rocks the effects of crushing and shearing are most in evidence, yielding such rocks as phyllites, slates, sericite-schists, talc-schists and the like. Certain other effects are only seen localised about particular horizons, such as the crushed conglomerate or mylonite which occurs just below the middle overthrust.

Moreover, in these rocks, we no longer have evidence of recumbent folding. Where the rocks have yielded, it has taken the form of reversed faults, and small overthrusts, the latter well seen in the Blaini beds beneath the lowest overthrust, near Badgala.

In the Chail and Jaunsar series, a phyllite with an incipient puckering, seen as a kind of wavy corrugation on the cleavage surface, with abundant sericite, is a very common variety of rock. A conglomerate occurring in the Jaunsar series near Kufar (36/985) shows the effects of intense crushing, the pebbles, which are mostly of hard quartzite, being sheared and drawn out, the chief mineralogical changes being localised about surfaces of friction.

All these rocks have been described above under their appropriate headings, and need not be referred to in detail again. It is of interest, however, to note the new minerals which have been formed,—sericite, talc, haematite, and chlorite; that is to say products which are formed by the breaking down of minerals by reactions which are essentially exothermic, corresponding to Van Hise's katamorphism. Moreover they are all minerals which are placed by Grubenmann in his upper or epi zone, which is formed under the conditions of high shearing-stress and low temperature.

This then concludes our account of the metamorphism.

From the evidence available, it seems fairly clear that the metamorphism of the Jutogh rocks must have taken place towards the end of or just after the main recumbent folding. For had the folding taken place after the metamorphism, the effects of the latter would not have shewn the same orderly arrangement in space which they undoubtedly do. Had the metamorphism taken place prior to the recumbent folding, we should have found it impossible to make out any zonary arrangement. We might, for example, have found that the lower carbonaceous band and its associated rocks were as highly metamorphosed or more metamorphosed than the upper band. As it is we see that the grade of metamorphism is related to the nearness of the granite, and its distribution has not been affected by the folding.

We are forced to conclude, therefore, that this recumbent folding cannot have taken place at the same time as or have had any connection with the later movements which were the cause of the overthrusting, and which were clearly later than the metamorphism.

Not only is the metamorphism of some importance, in determining the order of certain events (summarised on pp. 128—131); it is also of interest in seeming to support the general principle emphasised by Harker, that metamorphism generally takes place at a time when the earth's crust is in a disturbed state, and when the temperature gradient prevailing has little relation to the depth, especially if the metamorphism is accompanied by igneous intrusion (Harker, 1918). This is in disagreement with Grubenmann's supposition that both temperature and shearing stress during metamorphism are roughly functions of depth beneath the surface. In our own area we find that the highest grade metamorphism on the west and south sides of the Chor Mountain, for reasons already given, actually occurs highest in altitude.

Stratigraphy of the Jutogh series of the Chor area : recumbent folding.

Having dealt thus briefly with the lithology and metamorphism of the uppermost or oldest zone of the Chor area it remains to describe the stratigraphical relations of the various outcrops of the Jutogh series in that area, so far as our work enables us to arrive at definite conclusions. The most important result which emerges from our observations is the existence of recumbent folding in the Jutogh series, and our line of argument will be mainly directed towards the demonstration of this phenomenon. It should be stated that in this Chor area the subdivision of the Jutogh series into the carbonaceous beds and the Boileaugunge beds has only been made over a limited area, so that on the map the sub-divisions end abruptly.

Rajgarh and Sain Dhar sections.

We have already stated that the rocks at Rajgarh and on the ascent from that village up to the crest of the Sain Dhar south of peak 5740 may be correlated without much question with the Jutogh series. The black crystalline carbonaceous limestone is very well seen where the road from Rajgarh reaches the crest of Sain Dhar (36/679). Here the limestone contains abundant crystals of amphibole, which weather out on the surface of the rock. Generally they are arranged in radiating bundles, and owing to the carbonaceous character of the rock they are quite black. The limestone is interbedded with quartzose schists, muscovite-schists and some darker slates. There is also a yellow, much decomposed rock containing flakes of a pale green mica. It is quite a thin band, but it has been found in association with the black limestone and the carbonaceous slates by hill 7020 on the Nauraghat-Shamra spur, and increases the certainty of our correlation of the latter outcrops.

The evidence for the recumbent folding in the Jutogh series, as we shall show, is very strong, and the correlation of these highly metamorphosed limestones, slates, schists and quartzites of the Chor area with those of Simla and Jutogh cannot be doubted.

Repetition of the beds.

No doubt can be entertained as to the repetition of the carbonaceous rocks in numerous sections which we have seen; the bands are identical in every detail including carbonaceous slates, carbonaceous limestones, and some extremely characteristic carbonaceous ash beds, slaggy and pitted with small holes, from which some mineral has evidently been removed.

At Rajgarh, the repetition of the carbonaceous band is to be seen in the surrounding hills, the intervening rocks being massive quartzites, which clearly represent the Boileaugunge quartzites. The latter are well seen on the south-west side of Sain Dhar.

Figure 12 is a sketch showing the hills to the west of Rajgarh looking north-east up the Sheola Khala, from the neighbourhood of Dharoti. The sketch shows roughly the distribution of the rocks, and in particular the repetition of the carbonaceous beds.

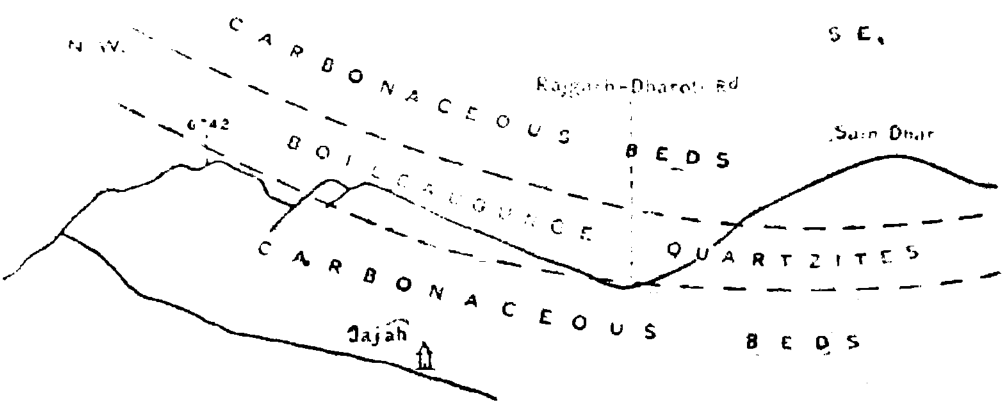

FIG. 12.—Sketch of the hills near Rajgarh showing the distribution of the Jutogh beds, with faulting omitted. Distance across about 3 miles.

It might however be argued that the repetition of the beds is due not to folding but to reversed faulting, or rather overthrusting, seeing that for long distances the northerly dip of the beds is so gentle that the strata are practically horizontal. This possibility is at once precluded after detailed examination of each outcrop.

Section from Chabdhar northward.

The section which affords the clearest proof of the recumbent folding is seen on the north-south ridge running from hill 8218 known as Chabdhar.

The detailed sequence of the beds between Chabdhar and hill 8112, a distance of 3½ miles direct, is as follows:—(Corresponding beds in the two outcrops are indicated by the same number).

	North.
(1) Lower limestone (with slate bands)	Hill 8112
(2) Carbonaceous slates	
(3) Upper limestone (with abundant mica)	
(4) Carbonaceous slates (pitted)	Hill 8332
(5) Garnetiferous schistose carbonaceous slates . . .	From Dum-ke-Bagh to the foot of Hill 8332.
(6) Boileaugunge quartzites and schists, thick . . .	(From Dum-ke-Bagh to the foot of Hill 8332.)
(5) Slightly carbonaceous mica schists	(From Dum-ke-Bagh to the foot of Hill 8332.)
(4) Carbonaceous slates (pitted)	..
(3) Upper carbonaceous limestone (micaceous) 100 feet .	Chab Dhar.
(2) Carbonaceous slates, 50 feet	
(1) Lower carbonaceous limestone with slate bands 250 feet .	
Slightly carbonaceous schistose slates	South.

The two limestone bands differ markedly from one another and these differences are readily distinguishable in both limbs of the fold. The only difference between the beds in the two limbs consists in the grade of metamorphism which they exhibit. Thus the upper band shows a development of garnet in its lowest bed which is absent from the highest bed of the lower band; amphibole is sometimes present in the limestone of the upper band, but was not seen in the lower band. As has been explained above when discussing the metamorphism of the area, such differences are perfectly natural considering how much nearer the upper band lies to the Chor granite.

This section, therefore, shows very clearly that there is a long almost horizontal fold in the Jutogh rocks, of which the core consists of Boileaugunge quartzites.

Further north along this ridge, beyond hill 8112, there is a gentle northerly dip, and the upper carbonaceous band is succeeded by garnet-mica-schists, gneisses and quartzites up to Haripur. The authors have not examined this part in detail, but along the ridge running east from Haripur they found two separate beds of the carbonaceous slates and limestone, separated by quartzites and dark grey phyllites. If these latter correspond to the massive quartzites seen between Dum-ke-Bagh and hill 8332, then they have got very much thinner. It may be that the fold is closing in this direction, so that the quartzites occupying the core of the fold are dying out. This, however, cannot be decided until further mapping has been done. The lowest outcrop of the carbonaceous rocks is underlain by dark grey phyllites, which are possibly the Chail series. They are probably the same as those which have been described in a similar position on page 23 where their correlation is discussed.

Nauraghat-Shamra section.

Similar evidence of recumbent folding, though not quite so decisive, is seen on the spur running south from Nauraghat through Shamra to Kufar. South of Nauraghat are two bands of white marble separated by quartzites, garnetiferous mica-schists and gneisses. The second marble band is succeeded to the south by quartzites and schists and then follows the sequence of rocks which is tabulated below. The numbering, as before, denotes the beds which are assumed to correspond. The dip is low to the N.N.E. Immediately below the lowest limestone comes the thrust plane on Pyriya Ghat which separates the Jutogh from the Chail series as mentioned on page 34. The centre of the fold must come a little north of Shamra.

	Quartzites.	North.
	Carbonaceous slates (including yellow rock with green mica).	Chaur Dhar.
(1)	Carbonaceous limestone, thick	
(2)	Carbonaceous slates, thick	Δ 7211
(3)	Carbonaceous limestone, thin	
(4)	Quartzite, thin	
(5)	Pitted carbonaceous slates, thin	
(6)	Massive quartzites, thick	
(7)	Chlorite-schists	Immediately above Shamra.
	Schistose slates	
	Quartzites	
(7)	Chlorite-schists	
	Grey schistose slates	
	Schistose slates and quartzites	
(6)	Massive quartzites, thick	Δ 6792
(5)	Pitted carbonaceous slates, thin	
(4)	Quartzite, thin	
(2)	Carbonaceous slates, thick	
(1)	Carbonaceous limestone, thick	
	OVERTHRUST.	
	Grey slates	Pyriya Ghat.
	Talcose quartzites	
	Talc-schists, etc.	South.

The evidence of repetition here, in conjunction with the other evidence, dispels any remaining doubt.

Complexity of the folding.

In the sequence of these beds as given above, one particular difference in the two limbs of the fold is worth considering. Whereas in the upper limb there are two bands of limestone, in the lower there is only one. The former seem to be the same bed repeated by folding. Where this same limb is continued to the east, above Punnar, three similar beds of limestone are seen. Now none of these beds show the marked differences that are seen in the two beds of limestone by Chabdhar, the first recumbent fold described above. It is thought, therefore, that in this area by Shamra and Punnar there is only one band, and that where it is seen more than once it is due to repetition by folding. Though the large-scale recumbent folding is clear from the distribution of the major rock divisions, each fold is in reality very complex, there being a number of secondary folds developed. The diagram in figure 13 will help to make this clear.

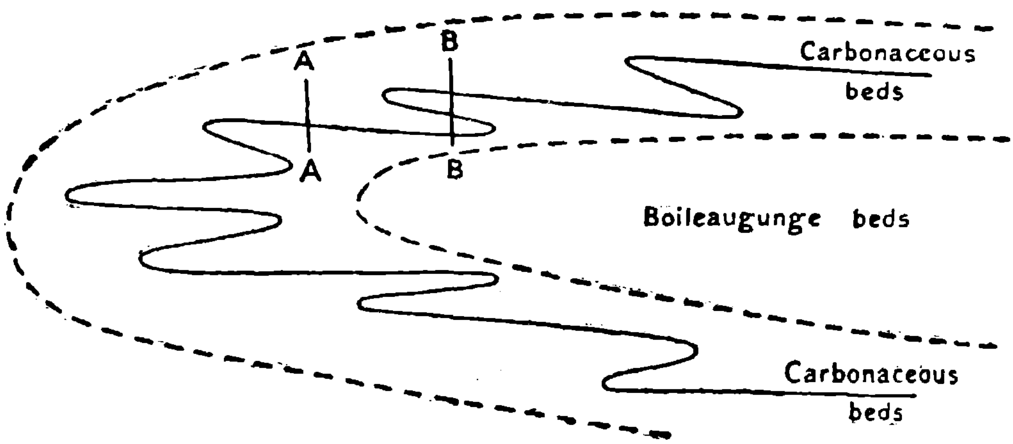

FIG. 13.—Diagrammatic representation of the folding in the Jutogh series.

The thick line represents a particular horizon in the carbonaceous beds, say the limestone. The dotted line gives the limits of the carbonaceous beds as a whole. The complete fold is shewn, though the left half where the fold is supposed to close is of course up in the air and not seen. Now if a certain section happens to cut the band as at A. A. then only one bed of limestone is seen. But if it cuts it at B. B. then three beds will be seen in the one section. The former corresponds to what is seen in the lower limb, south of Shamra; while the second may represent the section seen above Punnar.

White marble beds.

Mention has been made above (p. 77) of two bands of white marble between Nauraghat and hill 7020. The southernmost of these crops out nearly half a mile north-east of hill 7096; it is some 50 feet thick and contains crystals of green actinolite, tremolite and little granules of iron pyrites (36/695 and 36/700). Alternating quartzites and garnetiferous mica schists separate it from another band half a mile south of Nauraghat; this outcrop is broader than the former one but is probably no thicker, since it is somewhat folded. Hornblende schists, clearly intrusive into the marble, in some cases running across the strike, in others forming thin streaks interbedded with it, are very abundant here. On the next high ridge running north and south, east of the one which we examined, Medlicott mentions a band of coarsely crystalline white limestone near Chorna (1864, p. 44). A similar band of white marble with tremolite occurs a little south-west of Didag. The junior author has investigated this in some detail and is referred to below.

Probability that the white marble is merely a local variant of the carbonaceous limestone.

The entirely different appearance of this white marble from the typical Jutogh carbonaceous limestone at first raised a doubt in our minds as to whether it might not represent a different horizon. It has, however, been found that the two rocks contain the same accessory minerals. Further every gradation can be found between them, the white marble occasionally passing along the strike into a dark grey variety. Certain outcrops of the white marble contain thin black bands identical in appearance to the ordinary black limestone (36/959), while outcrops of the black limestone in their turn sometimes contain white bands. Associated with the marbles are thin beds which are slightly carbonaceous, and would seem to correspond to the much more carbonaceous slates associated with the black limestone. On the whole we can hardly doubt that the white marbles represent a special facies of the more usual black limestone, and accordingly on the map the two white marble bands and the two bands of carbonaceous slate and limestone are represented by the same colour. On page 81 below, a tentative suggestion is offered to account for the absence of the carbonaceous ingredient.

Closing of a fold in the white marble at Jarag.

It has been shown that the carbonaceous zone of the Jutoghs occurs in two main bands parallel in outcrop and separated by the Boileaugunge quartzites, forming part of a long recumbent fold. It is natural to suppose that the two bands of white marble represent another recumbent fold which lies over the former one. In fact the second author has traced this fold to a point near Jarag, where it can actually be seen to close. This most interesting exposure occurs a little south-west of Didag. Here, a little above the village of Jarag, on the Khanotyo road, there is a fine outcrop of the white marbles. The band can be traced from the west side of Didag village, around the head of the main *nala* following closely the line of the road. Just south-west of Didag, however, the outcrop broadens out, and instead of continuing southwards bends sharply to the north-east, running beneath the south-east side of Jarag village.

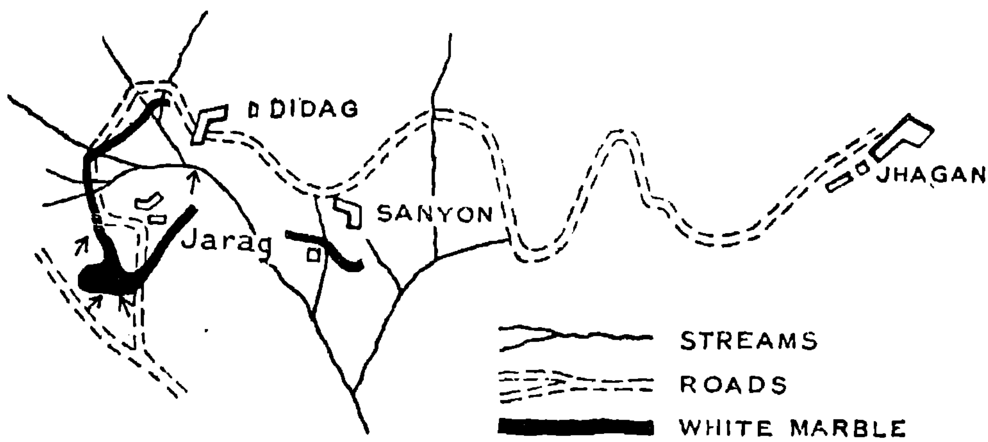

FIG. 14.—Plan of the neighbourhood of Didag showing the outcrop of the white marble. (Scale 2 inches = 1 mile.)

A sketch map of this locality is given in figure 14, as the ½″ map is too small to show the outcrop properly. The actual bend over of the fold can be seen very well in section on the road on the south-west side of the top of the spur, where the rocks associated with the marble can be seen in the form of a sharp overturned syncline, pitching to the E.N.E. Since the fold is proved to close at this point, the reason of the non-appearance of the marble further west is plain. An endeavour was made to join up the upper limb with the band by Nauraghat, but there appears to be no continuous outcrop. It may be that the thin band has been sheared out locally, or is naturally lenticular in character. A small outcrop was, however, seen by the village of Sotani, while boulders were found above the road, half a mile E.N.E. of Sanyon (see figure 14).

Possible explanation of the absence of the carbonaceous element in the white marble.

Now the roots of this fold are obviously far distant, that is to say it has travelled a long way from the north-east to its present position; thus it may conceivably have come from an area where for some reason the conditions that produced the carbonaceous character did not prevail. This explanation will equally apply to the rocks associated with the limestones, so that, if correct, there is no reason to wonder at the fact that the carbonaceous slates and pitted ash beds which occur so characteristically with the black limestone are missing or almost so from the vicinity of the white marble. The intermediate banded varieties would appear to represent deposition in an area in which the factors, whatever their nature may have been, which gave rise to the carbonaceous phenomena, acted intermittently.

Probability of two superimposed folds in the same beds.

We may thus reasonably assume that there are two superposed folds of the same beds, the one characterized by the predominance of white marble which has been proved to close to the south-west, the other characterized by the predominance of black limestone, which so far as our observations extend has not been seen to close, although the small thickness of quartzite between the two carbonaceous bands below Haripur as compared with its much greater thickness between Dum-ke-Bagh and hill 8332 might point to a closure towards the north-east. Reasons will be given below, however, for supposing that in the Simla area, at any rate, the lowest fold closes to the south-west, and it may be that the same applies to the Chor area, especially as the next fold but one above has actually been seen to close to the south-west. The point, however, will have to be left open until the mapping to the north-east of Haripur has been completed. In section, figure 1 on Plate I, the latter interpretation has been assumed.

VIII.—THE OVERTHRUSTS TRACED WESTWARD INTO THE SIMLA AREA.

(i) The Jaunsar thrust.

We now return to the country west of the Giri which leads us on to Simla. It was seen on page 19 that along the boundary of the Jaunsar thrust the Blaini disappears before reaching the Ashni river and the Jaunsars rest directly on the Simla slates. The trace of the thrust is less easily mapped now that the Blaini is gone, at any rate near the motor road between Kandaghat and Chail, since it is not always easy to distinguish between the basal Jaunsar slates and those of the Simla series. Higher up, however, to the north-west, when the Jaunsar slates give place to quartzite, the boundary is clear. It probably crosses the Hirti ridge about a mile to the south-east of hill 6474 and then descends gradually to the Simla motor road, which it crosses at $15\frac{3}{8}$ miles from Simla.

The Jaunsar overthrust.

Section on the Hirti ridge.

It has been stated above (page 21) that the Jaunsar outcrop on and above the Ashni is a synclinal overturned to the south-west, of which the highest beds seen are conglomerates. No horizon much higher than this is seen as far as the railway station of Kanoh, but between this and hill 6169 a series of cream and buff coloured splintery slates occupy the whole area between here and the Hirti ridge. These may possibly be correlated with somewhat similar splintery slates which are found in the outcrop of the Simla series for a long way north-west of Simla. As we descend to the north to the Simla motor road these are replaced by typical Simla slates, which dip under the Chail puckered phyllites at milestone $14\frac{1}{2}$ from Simla, where we draw the trace of the Chail thrust. The only bed here which might conceivably be Jaunsar is a variegated schistose bed between the Chail phyllites and the Simla slates. Our observations farther to the north-west however lead us to believe that this bed is probably a fault rock (page 99). Thus the whole north-eastern limb of the Jaunsar syncline has been cut out. The south-western limb diminishes until at $15\frac{3}{8}$ miles from Simla its outcrop is reduced to no more than 50 yards. Between this point and hill 5605 a cross fault runs, which brings in the Jaunsars again in great force including all its typical members from the conglomerates downward. It also shifts the

Simla slates probably form the core of a syncline in the Jaunsars.

Great diminution in width of the Jaunsar outcrop on both limbs of the syncline.

Jaunsars brought in again by a cross fault.

trace of the Jaunsar thrust a quarter of a mile or more to the south-west.

Outcrop of the Simla and Blaini series at Wakna.

The Simla series occur at the village of Wakna. A thin string of limestone occurs in the slates here, noteworthy as possibly corresponding to the important outcrops of the Naldera limestone to be mentioned later (page 113) which we believe to occur at the bottom of the Simla series. Near the northern end of the village the Blaini again comes in, consisting of two well marked boulder beds with limestone between as well as the bleached slates. This outcrop has been referred to by McMahon (1877, p. 206). It has been traced a considerable way up the hill to the N.N.W. and though not recognized on the ridge itself is seen below it on the same strike at the village of Chiama. The boulder bed was not recognized here, and the limestone itself is patchy and soon dies out, not being seen in the bed of the river below Kashmari. At Chiama the Blaini no longer rests on the Simla slates as at Wakna but on the Jaunsar conglomerate, clear evidence of a great unconformity between the Simla and Blaini series. Above the Blaini, horizons of the Jaunsar much lower than the conglomerate are exposed, which are thus thrust over the conglomerate (Jaunsar thrust).

At Chiama.

Blaini unconformable on the Jaunsar conglomerate.

The Jaunsar thrust at Ghund overlapped by the Chail thrust.

The Jaunsar thrust now rapidly approaches the Chail thrust, until at the village of Ghund it vanishes entirely, being overlapped by the Chail thrust. From here for a long distance to the north-west the Chails are in contact with the Jaunsar conglomerate in direct continuation of the outcrop of that rock at Chiama. Whether the Jaunsar thrust ever reappears cannot be stated with certainty. The possibility that a thin outcrop of quartzite close to the Chails north of the Kuni river marks the trace of it is discussed on page 100.

The Jaunsar thrust N.W. of the Giri.

Let us now return to the Giri valley and trace the Jaunsar thrust towards the north-west. We shall also describe here the underlying beds. It has been seen above (p. 19) that to the north-east of Karganu the Blaini crosses the Giri, dipping north-east under the Jaunsar beds; and that owing to the dip changing to the south-west the Blaini and Simla slates reappear further up the river. It is this outcrop of the Blaini which we will now show to be continuous with the Blaini at Simla. On the Giri it is overlain by the Jaunsar beds, from which it is separated by the Jaunsar overthrust. We have already described (page 23) the way in which the Jaunsar beds die out rapidly when followed north-east from the Giri, so that they are entirely missing at Rana Ghat. The same phenomenon is seen in the opposite direction.

Synclinal fold of Blaini in the Giri river near Karganu, overthrust by Jaunsars.

Dying out of the Jaunsars on both sides of the Giri.

The Jaunsar beds occur in great force in the valley of the Baget above Lakhoti, and on the Naog-Nohan spur they must be quite 1,500 feet thick, consisting mainly of massive white and purplish-green quartzites and purple phyllites (37/620), the highest beds being the soft white and red beds which are so typical of this horizon. No conglomerates are seen in this section.

Lakhoti and the Naog-Nohan spur.

Traced to the north-west the beds die out fairly rapidly, or perhaps one should say are cut out by the Chail thrust. Owing to the very variable nature of the Jaunsar beds, it is not easy to say exactly how the beds die out. But it seems that the greater part of the quartzites are the first beds to vanish, *i.e.*, the uppermost part of the Jaunsar.

On the Balog spur, near Panhoti, the Jaunsars cannot be more than 300 feet thick, and they are last seen just E.N.E. of Nahera, where there are about 40-50 feet of much crushed dark, and in places purplish, slates. At Dhar they are quite missing, so that it is clear that the Jaunsar thrust has from this point been overlapped by the overlying Chail thrust.

Balog spur.

All the way from the Giri river by Lakhoti up to Simla the Blaini beds can be followed continuously. From the Giri up to the Chail-Kufri road they are seen in their full development; but beyond this point they become somewhat attenuated until within the immediate vicinity of Simla. The rocks are everywhere nearly horizontal, though from their outcrop as a whole it is clear that a very gentle south to south-westerly dip prevails.

The Blaini fully developed from the Giri to the Chail-Kufri road.

We will confine ourselves in the first instance to that part of the outcrop south of the Chail-Kufri road. Throughout this first half of the outcrop we find the usual succession of beds within the Blaini, the limestone overlying the two boulder beds with the bleach

Kiar to south of Panhoti.

slates in between the latter. For a short distance, from Kiar to south of Panhoti, the lower boulder bed is missing, and it is then not always easy to fix the boundary between the Blaini and the underlying Simla slates. Typical of the whole outcrop is the way in which the bleach slates are always seen to be very contorted, while the beds above and below seem to be unaffected. A very good section is to be seen in the perpendicular cliffs just under Dhar.

At Dhar.

Here all the beds are well developed, and total a thickness of some 380 feet.

Further north-east, owing to the configuration of the ground, the Blaini outcrop is very irregular. It forms the greater part of

Spur S.S.E. of Koti.

the spur that runs S.S.E. from Koti on the Chail-Kufri road, though the highest parts of this spur are capped by Chail beds. All about here the Blaini limestone is conspicuously developed. An outlier of Blaini occurs on hill 7058, but the upper boulder bed and limestone have been denuded.

Two cross-faults affect this area, both having a downthrow to the S.S.E. The more southerly one is easily detected from the

Cross-faulting.

way the small outlier of Chail beds, forming hill 7191, is repeated further down the spur; and also by the repetition of the lower boulder bed east of Nin. The more northerly one is revealed by the sudden displacement of the Blaini limestone.

Continuing north and west, before the outcrop reaches the

Attenuation of the Blaini.

Reappearance of the Lower Blaini boulder bed at Shalhodi.

Chail-Kufri road it has lost both the limestone and the two boulder beds, and along the main road only the bleach slates are seen. This poor development continues for a long way, until at Shalhodi the lower boulder bed reappears and continues now all the way to Simla.

In the Ashni river a good section is seen on the right bank. Here we find the lower boulder bed overlain by the bleach slates, the latter being about 70 feet thick.

Down the Ashni the Blaini beds are succeeded down stream by the Chails, puckered and sometimes carbonaceous phyllites.

Inlier of Blaini among the overthrust Chail series.

About a mile below the bridge, however, a change of dip to the north-east brings up the underlying Blaini again for a short distance. This inlier extends for some way up the tributary from the east, south of Chaunri and here both the lower boulder bed and the underlying Simla slates are seen.

Bifurcation of the Blaini outcrop due to an anticlinal fold.

Beyond the Ashni the outcrop of the Blaini is not so simple; for, owing to the development of an anticlinal fold in these beds, the outcrop bifurcates, one branch running up to the north-east to join up with the Simla outcrop, and the other running north-west up the Sunal valley.

The N.W. branch of the Blaini ends at Kuwara.

In the Ashni the Blaini beds dip at about 30° to the south-west beneath the Chail series. On the Junga-Kasumpti road not only do they dip at a gentle angle beneath the Chail rocks to the north, but they also dip very steeply beneath them to the south-west. This sharp anticlinal fold opens out to the north-west, bringing up an outcrop of the Simla slates from below. In this direction the upper boulder bed and the limestone reappear, and it was this outcrop of the Blaini limestone to which McMahon drew attention (1887, p. 205). Owing to the fold having a north-westerly pitch this outcrop of the Blaini ceases just below Kuwara, a fine development of the limestone being seen in the river bed here. In addition, a fault on the south-west side of the outcrop cuts off the Blaini and Simla slates against the Chail phyllites. Nearly horizontal Simla slates and Chail phyllites can be seen abutting against one another where the fault crosses the left bank of the stream.

The N.E. branch continuous to Simla.

Following now the north-east branch, the limestone and upper boulder bed reappear once more by Jharech, and from here up to Sanjauli the full development of the Blaini is seen. The mapping of this part of the outcrop is due to Dr. Pascoe.

A double boulder-bed not invariably present in the Blaini.

In the descriptions which we have given of the Blaini beds, it will have become apparent that there are two different developments of these rocks. In the Solon area we find that beneath the Infra-Krol the Blaini consists of a band of pink limestone overlying a boulder bed. In the Simla-Chor area, however, while there is the usual band of limestone, beneath it there are two boulder beds, which are separated by what Oldham termed the 'bleach' slates. These two developments overlie typical Simla slates in both areas.

When the double boulder bed was first seen at Dudham, the authors were disposed to regard it as evidence for a synclinal fold, induced beneath the Jaunsar overthrust; and they thought that a similar interpretation might be applied to the same development of the Blaini at Simla. Since then, however, the intervening and adjacent areas have been mapped, and there now appear to be serious difficulties in the way of accepting this view of the structure.

Alternative explanations of the duplication of the boulder bed.

In the first place the limestone is never seen repeated beneath the lower boulder bed. If the repetition of the boulder bed had been due to folding, then one would have expected a similar repetition of the limestone. It might be suggested that its non-appearance is due to its having been sheared out in the lower limb, or that it has died out locally. But it is remarkable that it should have done so in every section. We have now mapped the Blaini beds continuously from Simla south-eastwards to Badgala above the Giri; and throughout this area, a direct distance of 22 miles, there is never a repetition of the limestone, while the lower boulder bed is seen the whole way except for about a mile just west of Balog (p. 85). Moreover, throughout this 22 miles the Blaini beds do not vary greatly in thickness; so that unless the fold is one of most remarkable flatness, with no sign of ever closing, it seems likely that we are dealing with a normal succession.

We are thus driven to conclude that the two boulder beds are different beds, due to a repetition of the same morainic conditions or whatever it was which gave rise to their formation; though why there is only a single bed in the Solon area is not at present clear. As previously remarked, however, there is still a lot of work to be done around Solon before a complete understanding of the structure there is obtained.

Conclusions.

We may now consider for a moment the beds which underlie the Blaini. Throughout more than half this area from the Giri river to Simla, the Blaini rests directly on the Simla slates. But for about a third of the way we find an outcrop of the Jaunsar series intervening between the Blaini and Simla series. There can be little doubt that these beds are the

Puzzling occurrence of the Jaunsars between the Simla slates and the Blaini.

Jaunsar series, for they include massive white and sometimes purple quartzites, conglomerates both massive and crushed, and purplish phyllites. To the south-east these beds first appear above Piran, and they are well seen on the sides of hill 7058, beneath the capping of Blaini. Near Pajal, on the spur running to the south, are grey and purple slates; while further south along this spur there are several beds of conglomerate (37/624), one of them rather crushed. On the south-west side of the hill purple sandstones and slates predominate, and they often show the peculiar green slickensiding which is so characteristic of the Jaunsar beds elsewhere. The slaty members commonly show a cleavage oblique to the original bedding. On the whole there can be little doubt that we are dealing with an outcrop of the Jaunsar series. Their peculiar position, however, needs explaining, and the point will be discussed further on (page 119).

At Piran and Pajal.

These Jaunsar beds are not seen beneath the Blaini above Tarhai, and they evidently die out somewhere north-east of Thund. But on the north-east side of the Blaini outcrop they are seen for a long way in the same position, in fact to beyond the Chail-Kufri road. Throughout their extent they are much the same, though to the north-west conglomerates are not common.

N.E. of Thund and Tarhai.

Chail-Kufri road.

On the Chail-Kufri road the wall of the road by the 10th milestone is made of these rocks, and they are also well seen on the Koti-Simla road, above Khader (37/631). In this direction also, however, they die out, and by Shalhodi the Blaini is resting on the usual Simla slates.

Khader.

Shalhodi.

Besides this outcrop, a capping of these rocks is found on hill 7225, including a bed of crushed conglomerate (37/626). In the Chakhred *khad* the Simla slates are in full force. But higher up to the north-east these rocks are overlain by the Jaunsar beds again, the beginning of an extensive outcrop, the significance of which will be discussed further on (page 119).

Chakhred Khad.

(ii) The Chail thrust.

We will now describe briefly the Chail rocks as they occur between the Giri valley and Simla.

The Chail series between the Giri river and Simla.

In the country that occurs between the Giri and Ashni rivers the Chail beds are very well developed, though the lowest beds are generally missing. Above the Giri, the talc-schist band is very typically developed on both the south and north sides of the Chail-Naog spur (37/619), varying from 30-50 feet in thickness. Further north-west, however, where it crosses the Panhoti spur by the road from Juned, it is scarcely recognisable, though the associated blue silvery quartz-schists are typically developed. Nor is it again properly seen until one reaches the Chail-Kufri road, between 7 and 8 miles from Chail.

The talc-schist band.

Panhoti spurs.

Chail-Kufri road.

As we have previously noted, the Chail thrust cuts out the Jaunsar thrust in the neighbourhood of Dhar, and from that point northwards the Chail beds rest directly on the Blaini.

Chail series directly thrust over the Blaini.

Beyond the Chail-Kufri road the talc-schist band can be traced continuously to near Junga. All along here to the south-east of Junga it is typically developed. Beyond here, however, it quite dies out, though the junction which it marks between the Chail phyllites and the overlying blue quartz-schists is always quite clear.

Talc-schist band near Junga.

Dies out.

Now the Chail thrust crosses the Ashni about half a mile above the bridge on the Junga-Kasumpti road, in accordance with the prevailing low south-westerly dip. The horizon of the talc-schist band, however, never crosses; for south-west from Junga the rocks become horizontal, and further on, west of Chail, a gentle north-easterly dip sets in. Instead, therefore, of crossing the Ashni, this horizon is found at nearly the same level for a long way on both sides of the river. On the south-east side of the Ashni it runs first south-west and then south-east, so as eventually to join up with the point where we started on the south side of the Chail-Naog spur. Along this line the talc-schist band itself comes in near Donu, and continues in force from there to the south-east.

Talc-schist band does not reach down to the bed of the Ashni river.

Donu.

On the north-west side of the Ashni the Chail rocks, including the talc-schist band, are well developed along the Junga-Kasumpti road. The talc-schists are seen just below Beola, and from here they can be traced to the north-west as far as Nahera, beyond

Junga-Kasumpti road.

which point they are not well seen, though the horizon they represent can be followed. Occasionally the talc-schists themselves are seen, as *e.g.* about a quarter of a mile north of Yan, at about 4,600 feet. The band eventually reaches the Kalka-Simla motor road near the 14th milestone, though it is still not typically developed.

Kalka-Simla motor road.

This band can also be followed along the east side of the Kasumpti-Beola spur to as far as below the east side of Chhota Simla. It was last seen just above Chhachru. It is possible that it continues further; but around the headwaters of this *nala*, below Barnes Court, nothing can be seen *in situ*, the ground being covered with slipped masses of the Jakko carbonaceous slates.

Kasumpti-Beola spur.

In describing the distribution of the Chail beds, emphasis has all along been laid on the course of the talc-schist band. For not only is it easily recognised, but being a thin band it marks a very definite horizon which often helps to explain the structure. At the same time, we should point out that throughout the whole of this area it is underlain by the usual puckered grey phyllites (36/929 and 37/647), and overlain by the usual silvery blue quartz-schists and higher beds of the Chail series. To the north of Beola, however, the uppermost beds thin or die out against the Jutogh thrust, and one is probably correct in supposing that the talc-schist band itself dies out against the thrust somewhere above Mabhana, although, as noted above, nothing can be seen *in situ* just here. Anyway, further north, by Shapahan, where there are better exposures, the talc-schist bed is quite missing, and only the lower Chail phyllites separate the Blaini from the Jutogh beds.

Gradual disappearance of the upper beds of the Chail series going towards Simla.

The Chail series evidently never quite dies out, and a thin band seems to run right round Jakko to Chadwick spur.

We will now return to the Ashni river and trace the Chail thrust to the north-west, at the same time noting the characters of the Chail series as they have been observed in this area.

The Chail series north-westward from the Ashni river.

In the Ashni river close to where the mule track to Chail crosses it the Chail puckered phyllites rest on some soft mottled slates intensely carbonaceous in places. The latter are referred to the Jaunsars, and above them we draw the trace of the Chail thrust.

In the Ashni river.

Lowest horizon of the Chail series; slates and limestone.

On the Ashni for the first time we are introduced to a horizon of the Chails which is older than the puckered phyllites. They do not appear from beneath the puckered phyllites until at least a quarter of a mile north of the bridge where they seem to occur as a shallow dome dipping under the phyllites on all sides. The beds in question are dark-grey carbonaceous slates and perhaps are hardly more than 100 feet thick. Their appearance is quite different from that of the Chail beds which have been previously described, and in addition they show a feature which is to become of considerable importance further north-west. This is the occurrence of one or more lenticles of cream-coloured limestone, clearly interbedded with the slates. It resembles the Blaini in appearance, and were it not for its being so clearly interbedded with the Chails, as well as on account of the occurrence of limestone in a similar position farther north-west which is certainly not Blaini, a doubt might have been entertained as to its true correlation. McMahon (1877, p. 205) mentions the occurrence of 60 feet of limestone in the bed of the Tandalail stream near Badun and again between Badun and Basna. The authors, unfortunately, failed to find McMahon's outcrop, though they saw a boulder of limestone in the locality and in the same beds as those containing limestone in the Ashni. This boulder was banded and resembled exactly limestone found in a similar position at the base of the Chails from Gandrori almost to Halog.

At Badun.

Chail limestone on the Kalka-Simla motor road.

We were no more successful in finding *in situ* the limestone on the Simla motor road referred both by Medlicott (1864, pp. 36, 37) and McMahon (1877, p. 206) to the Blaini. There are, however, boulders of a blue limestone 14¼ miles from Simla both above and below the road, close to the trace of the Chail thrust, which we have no doubt is the limestone in question. McMahon, it is true, stated that it was 13¾ miles from Simla, but it is probable that the road has been made to follow an easier and more circuitous course since McMahon's day. The outcrop has very likely been covered up by debris produced in the course of road construction. Oldham (unpublished report) did not consider that it was Blaini, and we entirely agree with him.

Variegated fault rock (?).

Between the puckered phyllites and the Blaini a peculiar variegated schistose rock occurs containing fragments of a grey slate.

This has been found in several localities in the same position, and we are unable to decide whether it is a fault rock, or a thin remnant of Jaunsar (see pages 97-99).

In this locality the boundary of the Chails is uncertain to the north-west of the motor road, since we did not follow it very far, and cannot be sure that it has been shifted by the cross fault mentioned on page 82, but it is likely that such is the case.

At Gandrori.

A limestone was found at Gandrori in a precisely similar position, associated with the variegated schist, and interbedded with slates, which leave us in no doubt that it belongs to the basal beds of the Chails. This limestone is finely banded, like the boulder seen at Badun and this is the most characteristic type met with in the Chails; at the same time the Chail limestone as seen in its many outcrops presents a very varied character, being sometimes coarsely banded and sometimes not at all. It is also of various degrees of purity, and its colour is equally variable, being either blue, brown, or cream.

Chail limestone from the Gambhar to the Kuni river, mapped by McMahon as Blaini.

It seems to be invariably lenticular but the lenticles range in thickness from an inch or two interbedded with grey slates up to 50 feet or more. It is this limestone which McMahon has mapped as Blaini (1877) from the Gambhar to the Kuni river associating with it the Jaunsar conglomerate which he identifies with the Blaini boulder bed. It has been stated above that from Ghund onward the two are found in contact or nearly so, only separated by the Chail thrust. Medlicott also (1864, p. 38) has identified the Chail limestone and the Jaunsar conglomerate on a portion of this outcrop below Sairi Hill, 5206, with the Blaini series.

An intensely carbonaceous schist has been seen in many places just above the limestone, notably in the Gambhar at Sharer, and in the Kuni.

At Bakesu and Mamlig.

The maximum development of the limestone in this area is between Bakesu and Mamlig. North of Sharer it becomes insignificant in amount though its associated beds are present, and its last occurrence is on the Halog ridge $\frac{3}{4}$ mile N.E. of the post office.

Dying out of the Chail limestone between Halog and Simla.

From here on to Simla there is no limestone in the Chails, nor are the slates present. The variegated schist is often present but it is in contact with the puckered phyllites, from which we conclude that it is not a bed in the Chails but either a fault rock or a remnant of Jaunsar. A strongly carbonaceous bed was seen near Doche almost at the thrust plane, which is reminiscent of the one mentioned above associated with limestone.

Mottled schistose slates above the limestone at Bakesu, Sairi and Sharer.

Between the limestone with its associated slates and the puckered phyllites there often occur some thickness of mottled lavender, red and cream soft schistose slates. These were particularly noticeable at Bakesu, west of Sairi and between Kariauri and Sharer.

The Chail outcrop an isosyncline.

Regarding the structure of the Chail outcrop as a whole in this area, there seems little doubt that it is a syncline overturned to the west or south-west, of which the north-eastern limb is missing to a greater or less extent. The highest beds seen are quartz-schists and massive quartzites. The latter are only seen on the highest ground. They were particularly well seen on hill 5064 nearly a mile N.E. of Sairi. Here they pass on either side into quartz-schists and then into the puckered phyllites, but between these two sets of beds there is no sign of the talc-quartz-schist; but in this area this bed is much more inconstant and less characteristic than is the case in the Chor area. Feeble exposures of the massive quartzite were seen on the Simla motor road at milestone 12⅞ just south of Kathlighat railway station. Quartz-schists occur on either side of it and on the north-east side of these is what the senior author took to be an uncharacteristic exposure of the talc schist; a more characteristic one was seen on the south-west side by the 14th milestone. Along the motor road we now pass up the south-west into typical puckered phyllites which continue on to the Chail thrust at 14½ miles from Simla. North of Kathlighat station the puckered phyllites are not at all typical. Thrust over them is an uncharacteristic exposure of the carbonaceous zone of the Jutogh series.

Uppermost Chail quartzites.

Repetition of the talc-schist band and the puckered phyllites north of the Pateri-ka-Deo.

Another feeble exposure of massive quartzite in the midst of quartz schists was seen at Manjat, about ¾ mile north of the Pateri-ka-Deo, a tributary of the Kuni river. On either side of these beds are a zone of characteristic silvery talcose quartz schists; and both on the western as well as on the eastern side of these are typical puckered phyllites, in the former case at Batol, in the latter between the Pateri-ka-Deo and Kaflead. The evidence for repetition of the beds seems to be perfectly clear. It is just possible that somewhere against the Jutogh thrust the Chail limestone and slate zone may be reached. Nothing definite can be stated as to this since the junction between the Chails and the Jutoghs was not actually seen here, and the boundary has only approximately been mapped in.

Thinning out of the Chails between Halog and Simla.

North of the Kuni the Chails begin to thin out and become rather less typical. The basal limestone and slates are overlain by puckered phyllites, but these are often paler in colour than is the case in the Chor area, and there is no sign of the talc-schist, though below Halog some grey quartz-schists are seen. To the south-east of Halog, when the strike has entirely bent round, the Chails thin out rapidly, until at Gharog there are only about 150 feet left, consisting wholly of the grey or lavender puckered phyllites. On the Chadwick spur about 1¼ mile almost due north of Viceregal Lodge, Simla, some 50 feet of the Chail phyllites are clearly exposed. Oldham mapped these here, as he has done in every other case, with the Jutogh carbonaceous beds. On the north side of Jakko Hill, Chail phyllites are seen in contact with the Blaini on the Snowdon road and are found for a distance of 30 feet above it. It is probable that a remnant of them exists everywhere between the Jutoghs and the Blaini.

A slight remnant present everywhere in Simla.

IX.—OUTCROPS TO THE WEST OF THE CHAIL THRUST TOWARDS ARKI AND SABATHU.

Outcrops west of the Chail thrust.

We shall now consider the outcrops which lie to the west of the Chail thrust in the area between Halog and the Simla motor road. Only partial traverses have been made here and there in this direction, and the boundaries on the map are therefore almost entirely approximate; but the general structure seems clear. Some of the outcrops of Blaini put in on the western margin of the map are in accordance with what can be deduced from Medlicott's and McMahon's observations.

Splintery slates correlated with the Simla slates.

It has been stated (page 83) that from the point where the Jaunsar thrust vanishes from sight near Ghund, Jaunsar conglomerates and quartzites are in contact with the basal Chails as far as Sharer. Underlying these are a series of splintery slates, generally grey, occasionally purple or cream. These bear an extraordinarily close resemblance, on the one hand to the beds described on the Hirti ridge above Kiarighat, separating the Simla motor road from the railway, (page 82), and on the other hand to the beds underlying the Blaini series between Simla and Halog, which have been accepted as the Simla slates; we, therefore, have little hesitation in regarding the beds in question in all these areas as such. The outcrop we are now considering shows signs of being intensely folded, but the average dip is to the east or north-east.

Subathu beds at Dochi on the Sairi-Sabathu road.

During a traverse made along the road from Sairi to Sabathu, where the most complete examination of these beds was made, a small outcrop of Sabathu limestone and shales was seen in the splintery slates immediately to the east of hill 4060. This is undoubtedly the outcrop mentioned by McMahon (1877, p. 206) near Dochi and doubtfully referred by him to the Blaini. Not only, however, is the limestone of a blue colour, but it contains poor sections of shells and is in contact with typical Sabathu shales.

Jaunsar conglomerate thrust over a folded outcrop of Blaini and Infra-Krol: (?) the Giri thrust.

Nearly the whole of hill 4060 and the higher ground to the north and south of it is composed of the typical Jaunsar conglomerate which dips under the Simla splintery grey slates. In contact with the Jaunsar conglomerate in several places, though often with a discordant dip, is the typical Blaini boulder bed and immediately below it is the Blaini cream limestone. The Blaini limestone followed by the boulder bed crops out again on the road about ¼ mile S.S.E. of hill 4060, and between the two outcrops of Blaini the typical Infra-Krol beds are exposed, pale white or cream slates with gritty bands, considerably contorted. Beyond the second band of Blaini are again Infra-Krols. Medlicott (1864, p. 55) states that the Blaini is several times repeated both between Haut (Kunihar) and the Sairi hills, about Bil and on the spur north of Haripur. McMahon's observations (1874, pp. 207, 208) also enable us to put in approximately a third band of Blaini to the west of the two described above. The junction between the Blaini and the Jaunsar is undoubtedly a faulted one, and we suspect, if followed to the south-east, would prove to be the Giri thrust plane. Both the fall of altitude as well as the south-easterly pitch of the folds have contributed to the disappearance of the Krol limestone of the Krol hill by denudation.

The outcrop west of the Chails an iso-synclinal of Jaunsars and Simla slates.

With regard to the broad outcrop to the west of the Chail thrust the repetition of the Jaunsar conglomerate on either margin and the intermediate folded splintery grey slates leave us in no doubt that, like the Chail outcrop, it is a syncline overturned to the west.

It is doubtful where the Simla slate outcrop ends in a south-easterly direction, as the boundary has not been closely followed, and on the map (Plate I) must be regarded as approximate only. It would seem that in the neighbourhood of Chiama and Wakna an anticlinal fold must succeed the syncline on its eastern side, in order to bring in the narrow bands of Blaini. The great thickness of the Jaunsar conglomerate at Chiama also suggests that it is a double band.

The double band of Blaini mapped by McMahon between Sharer and Banjan not confirmed.

Before leaving this portion we may make a comment on McMahon's map and remark as to the occurrence of the Blaini between Sharer and Banjan. The limestone at Sharer has already been stated (page 92) to belong to the Chail series. There is no sign of a second band of limestone anywhere near Sharer nor was any other formation seen to the west of the Jaunsar conglomerates and quartzites except the grey splintery slates of the Simla series. We gather from his omission of village names between Sharer and Banjan that McMahon equally saw no limestone between these two places, so that the mistake arose from a too rash interpolation.

Outcrops west of the Chail thrust between Sharer and Halog and onward to Simla.

To the north of Sharer the interpretation of the outcrops between the Chail thrust and the Simla series is difficult. It will be simplest to give the details of a series of sections in different localities, and then state the deductions which we draw from them.

The Jaunsar conglomerate, at any rate in its typical form as seen at Sharer, has disappeared when the Kuni river is reached.

A small outcrop of quartzite and dark grey slate here occurs below the Chail limestone and slate. This is assumed to be Jaunsar. At Ghech less than ½ mile north-north-west of the Kuni the following succession is seen below the Chail phyllites.

Chail phyllites.

....

Pale-coloured slates 20 ft. (? Blaini bleach slates).
Cream-coloured limestone 6 ft. (? Blaini limestone).
Grey non-fissile slate without boulders (? = Blaini boulder bed).
Purple and grey slates 30 ft.
Massive quartzite 10 ft.
Grey splintery slates (Simla series).

At Pau ka Ghat little more than ¼ mile north of this we find in descending sequence

Chail slates with interbedded limestone.

....

Variegated schistose bed with quartz and slate fragments 10 ft.
Quartzite with tiny pebbles 5 ft.
Ferruginous laterite 10 ft. (Subathu).
Mottled slates 30 ft.
Brown and purple micaceous sandstone (Simla series).

At Bandla nearly ½ mile north-north-west of Pau ka Ghat we have

Chail dark slates with limestone bands.

....

Quartzite with small pebbles 15 ft.
Blue limestone (Subathu) 5 ft.
Red pisolitic laterite (Subathu) 10 ft.
Purple micaceous sandstone (Simla series).

At Jamlog nearly ¾ mile north of Bandla

Chail puckered phyllites.

....

White quartzite 5 ft.
Pisolitic laterite 10 ft. (Subathu).
Purple slates (Simla series).

At Dharel 1¼ miles N.N.W. of Jamlog

Chail dark bluish grey slates with interbedded limestone.

....

White quartzite 20 ft.
Variegated schist.
Pink limestone (Blaini) 30 ft.
Purple and grey slates (Simla series).

At Pallaini Ghat ½ mile N.N.W. of Dharel

Chail slates with interbedded limestone.

. . . .

Variegated schist 20 ft.
Brown ferruginous rock 10 ft.
Grey non-fissile slates without boulders 10 ft. (? Blaini).
Cream and reddish splintery slates (? Blaini).
Purple and grey slates (Simla series).

¾ mile N.N.E. of Pallaini Ghat below Piroi

Chail beds (exposures bad).

. . . .

Dark blue limestone (Subathu).
Brownish sandy limestone (? Blaini).

On the Piroi col ¼ mile north of the last locality

Chail phyllites

. . . .

Variegated schist.
White quartzite.
Ferruginous bed with pellets 1 ft. (? Subathu).
Pink limestone 5 ft. (Blaini).
Grey non-fissible slates without boulders (? Blaini).
Red and cream splintery slates.
Purple and grey splintery slates (Simla series).

Kufri, on the Ghorap spur ¾ mile W. of Halog.

Chail phyllites with occasional brown ferruginous impure limestone.

. . . .

Variegated schist 20 ft.
White quartzite 20 ft.
Grey non-fissile slates without boulders (? Blaini).
Grey splintery slates with concretionary structures (Simla series).

Jubar 3¾ miles S.E. of Halog.

Chail phyllites.
Chail carbonaceous schist.

. . . .

Variegated schist.
White quartzite.
Cream limestone (Blaini).
Dark brown clay.
Grey non-fissile slates without boulders (? Blaini).
Red and cream slates.
Grey splintery slates (Simla series).

Panti about 1½ miles S.E. of Jubar.

Chail phyllites (not well exposed).

. . . .

Grey jointed slates.
White quartzite 10 ft.
Cream limestone 5 ft. not seen on the ridge (Blaini).
Whitish slates 50 ft. (Blaini).
Grey slate with boulders 15 ft. (Blaini).
Purple and grey splintery slates (Simla series).

Chadwick spur, 1¼ miles north of Viceregal Lodge, Simla.

Chail phyllites.

. . . .

Variegated schist and shale 5 ft.
Limestone ? 3 ft. (Blaini).
Grey micaceous sandstone ? 4 ft.
Grey splintery slates 10 ft.
Red slates ? 3 ft.
Limestone 10 ft. (Blaini).
Whitish slates 100 ft. (Blaini).
Grey slate with boulders (Blaini).
Grey and purple splintery slates (Simla series).

Conclusions.

The variegated schist probably a fault rock.

Thin band of white quartzite probably Jaunsar.

From the above sections, and from observations which have been recorded elsewhere, we may come to certain conclusions :—(1) that the variegated schist is not a bed belonging to the Chail series since it is not associated invariably with the same beds ; (2) that it was not originally stratified with the white quartzite although it often occurs with it, because it often is found in sections where the white quartzite is absent ; (3) since it is invariably found close to a thrust plane and since it contains fragments of slate and other rock it probably represents a fault conglomerate, (4) the white quartzite is probably Jaunsar since no similar rock is known from either the Chails or the Simla series ; moreover it appears to be occasionally pebbly, inviting a comparison with the Jaunsar conglomerate.

Stratigraphical relations of the white quartzite.

Since the white quartzite occurs in approximately the same position and on the same strike as the Jaunsar conglomerate, where the latter was seen at Sharer we are tempted to regard it as the same bed on the eastern limb of the syncline. There is a difference, however :—outcrops of Blaini and Subathu frequently separate the white quartzite from the Simla slates. We already have evidence from the Subathu outcrop between Haripur and Sairi and from the continuous junctions between the Blaini and the Simla slates both at Simla and to the south-east of it, that both these beds rest unconformably on the Simla slates and, in the former case, have probably been pinched in by it in folding. It seems to the authors more likely that the white quartzite is a remnant of the overthrusting portion of the Jaunsar, which was overlapped by the Chail thrust at Ghund and has now appeared from beneath it. The Blaini at Ghech will be an unconformable deposit on the Jaunsar, although it is not certain that the purple slates underlying it are not really Simla slates. We are forced to admit, however that our evidence is not conclusive, and that the Jaunsar thrust may possibly not again reappear on this side of Simla.

X.—THE JUTOGH SERIES OF SIMLA.

The isolation of the Simla outcrop from that of the Chor due to denudation.

We next pass to the Simla and Jutogh outcrops. The Chail and Jaunsar thrust planes, whose existence has been demonstrated in the Chor area, have been traced into Simla both from the north-west and from the south-east. Although the Jutogh series is isolated from the outcrop of the same rocks in the Chor area, yet it seems certain that this isolation is due merely to denudation later than the overthrusting postulated. Two isolated outcrops of the Jutogh series capping the high hills at Chail and Bhalawag, half way between Simla and the Chor area, already referred to on pages 23-24, support this view. In both cases only the lowest beds are seen, the overlying Boileaugunge quartzites having been removed by denudation. The hypothesis which we have found to fit the observed facts so well in the Chor area may, therefore, be fearlessly applied at Simla.

Recumbent fold structure applicable to Simla.

In interpreting the structure of the Simla rocks on this hypothesis, the existence of a series of long recumbent folds is only what might be expected, and in regarding the various alternations of carbonaceous limestones, schists and quartzites as repetitions of the same beds rather than a continuous stratigraphical succession, we are not only adopting an interpretation of the structure which would naturally be expected with thrusts of the alpine type, but also what we have good cause to think is also the structure of similar outcrops of this series on the Nauraghat—Shamra spur and between Chabdhar and Haripur.

We have gone over most of the area both at Simla and Jutogh with the help of Oldham's excellent map on the scale of 3 inches to 1 mile and Hayden's more detailed map of Jutogh on a scale of 16 inches to 1 mile, which has never been published, and we find that the outcrops lend themselves perfectly to such an interpretation. The folding which we have concluded to exist at Simla and Jutogh is represented in the section, Plate I, figure 2.

Oldham's views on the structure.

Oldham states that there are three distinct bands of limestone on Jutogh Hill, separated by schists and quartzites, of which only the lowest band is left on Prospect Hill. All of this he assumes to be stratigraphically higher than the Boileaugunge quartzites and the Jakko carbonaceous slates. A fourth band is mentioned at the base of the Jakko slates, exposed on the spur east of Annandale. These occurrences we have verified, but we differ from Oldham, in that we regard them as one and the same band folded on itself as shown in the section (Plate I, figure 2).

Reasons for disagreement.

In the first place the Annandale limestone and the associated black, slaty beds bear too close a resemblance both to the other outcrops on Prospect Hill and Jutogh as well as to the outcrops of black limestone and slate seen at Rajgarh, Olong, Chabdhar, and other places, to make it reasonable to suppose that a bed of such a characteristic and wide-spread type should at Simla be repeated at two horizons separated by 1000 feet of quartzites and schists. In addition, we find that similar types of associated limestone and black slates occur in at any rate one of Oldham's upper limestone bands, which crops out below the top of peak 6778 in Jutogh. Moreover, since the exact succession of limestone, slaty schists, quartz-schists and quartzite are maintained, even though the thickness of each band may vary in the individual outcrops, we feel it to be unreasonable to suppose that such a succession of beds was deposited at successive geological horizons. The varying thickness of the individual beds and especially of the quartzite band on Jutogh Hill and near the top of Jakko may be explained without unduly straining the facts if we suppose that it has been squeezed out by the pressure of the two sides of the fold, which have been brought nearly into contact.

On the Ridge and on Jakko only the lower carbonaceous band and the Boileaugunge quartzites and schists are seen; but to the west, in the direction of the dip, on Prospect Hill and on Jutogh, another overlying fold of the Jutogh series is found, and it is with the rocks seen here that we will now concern ourselves.

A glance at the rock sequence as given on the legend of Hayden's Jutogh sheet (unpublished) shows at once some interesting points. The following sequence is given:—

Sections at Jutogh.

(*d*) Upper quartzite
(*c*) Upper carbonaceous schist.
(*b*) Upper limestone.
(*a*) Upper mica-schist.
(*b*) Quarry limestone.
(*c*) Lower limestone and schists.
(*d*) Boileaugunge quartzite.

Below the Boileaugunge quartzite come of course the Jakko carbonaceous slates, though they are not actually seen on this sheet.

Now if we examine the sequence given above, paying attention to the rock types, it will be seen that there is a repetition of the beds about the 'upper mica-schist,' as shewn by the lettering which has here been attached. The only discrepancy is that in the upper (*c*) there is no limestone mentioned. To be correct, however, the two groups (*b*) and (*c*) should be put into one group, consisting of carbonaceous schist and limestone. We then have the requisites for a fold about the middle group (*a*).

Repetition of the beds.

A copy of Hayden's map is given in figure 15, reduced in scale and with (*b*) and (*c*) grouped together under one character. Now a careful examination of the rocks on the ground shows that the strata above and below the 'upper mica-schist' are obviously the same. They are, in fact, the carbonaceous band, and that the one is the inverted representative of the other is indicated by the fact that the main band of limestone in both occurs nearest the 'upper mica-schist.' Further examination shows that the 'upper quartzite' is exactly the same as the Boileaugunge quartzites; and so we have the fold complete.

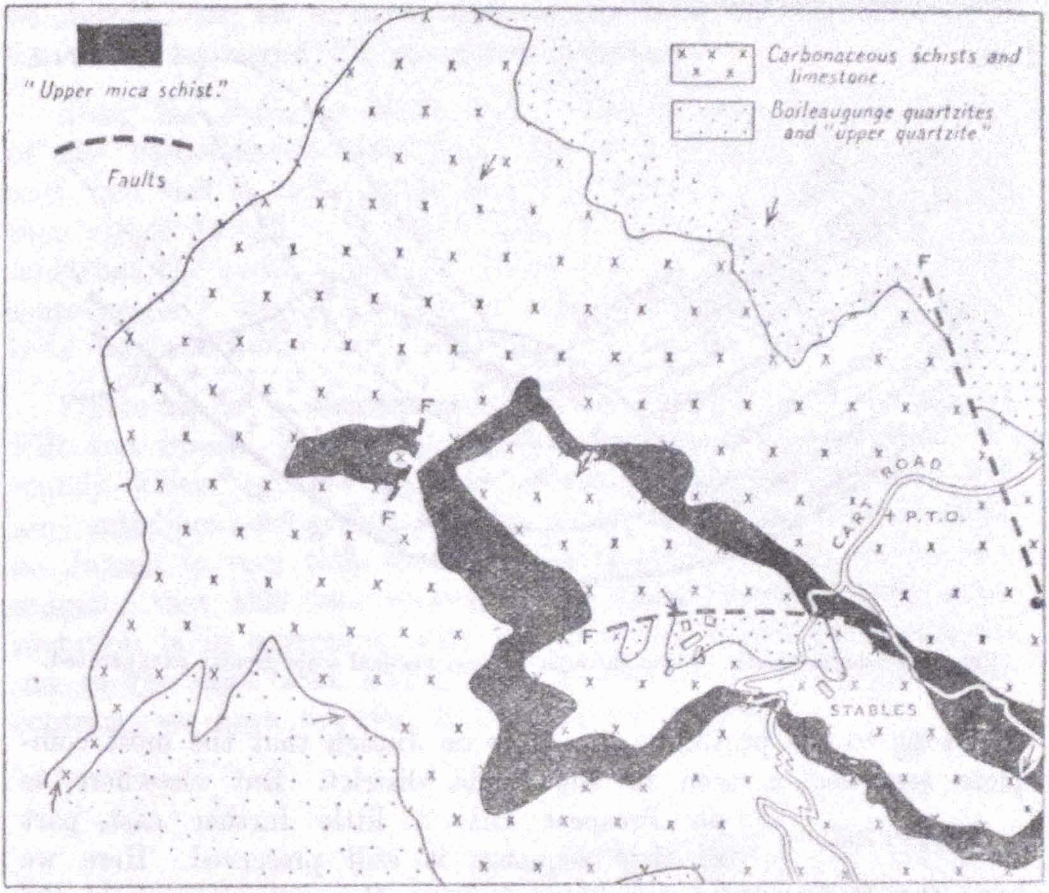

FIG. 15.—Geological map of Jutogh, after H. H. Hayden.
Scale 4 inches = 1 mile.

We really have here two recumbent folds lying on top of each other; for the carbonaceous rocks are repeated three times, though the lowest one is outside the limits of this map.

Going down the road southwards from the Post Office, and continuing on down the zig-zag path west of the stables, one passes over the whole sequence. The beds are folded into a very shallow syncline. The dip is to the south until the middle of the 'upper quartzite,' south of which point it becomes northerly. Down the zig-zag path the various members of the Jutogh beds are well displayed, and we have no doubt as to the correctness of the correlation which has been given above. Figure 16 is diagrammatic section through Jutogh, in which the vertical scale is greatly exaggerated. The folds have been made to close in accordance with evidence obtained elsewhere.

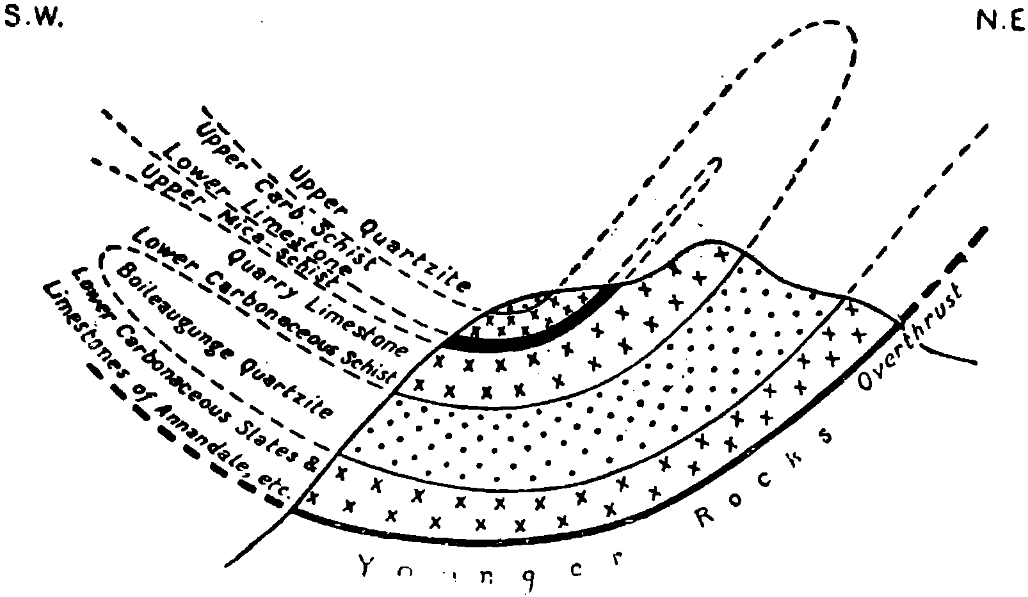

FIG. 16.—Diagrammatic section through Jutogh, vertical scale greatly exaggerated.

Prospect Hill.

Owing to the prevailing dip, it is on Jutogh that the most complete sequence is seen in the Simla district. But elsewhere, as on Prospect Hill, a little further east, part of that sequence is still preserved. Here we have the Boileaugunge quartzites forming the greater part of the hill. They are overlain by a band of the carbonaceous rocks, comprising about 50 feet of limestone much contorted in places, in which is a lenticular band of white marble, and other bands of black limestone containing numerous crystals of amphibole. Overlying it are black slates including the pitted ash beds, here retaining some of the contained mineral. This therefore, represents the upper carbonaceous band seen in the hills above Halog, and also presumably the quarry limestone of Jutogh.

Prospect Hill garnet-amphibolite.

The garnet-amphibolite, which forms the top of the hill, is very similar to many other rocks of this type that are seen in the Chor district. Like them it is probably an intrusive basic igneous rock, which has suffered the same metamorphism as the neighbouring sediments into which it is intruded. If it is intrusive, then there is no need to expect it to occur in the same position on Jutogh; for, as we have seen in the Chor district, these rocks can never be traced for any great distance.

Along the Ridge at Simla, and on Jakko, only the lowest band of the carbonaceous slates and the Boileaugunge quartzites are seen, and this in spite of the fact that Jakko is considerably higher than either Jutogh or Prospect Hill. However, it has already been said that the rocks along the Ridge and on Jakko have a general south-westerly dip, so that it is easily understandable that higher beds (*i.e.*, additional folds) are seen towards the west.

Figure 17 is a diagrammatic section through Jutogh, Prospect Hill and Simla. From the evidence available we cannot tell definitely which way the folds are going to close, nor whether they are anticlines or synclines. But, while the 'upper mica-schist' on Jutogh is very thin, further west it is quite thick, which rather suggests that this fold is opening in that direction. This interpretation is in agreement with the structure which we have made out in the Chor area, and in the absence of any evidence to the contrary we have adopted it for the Simla area.

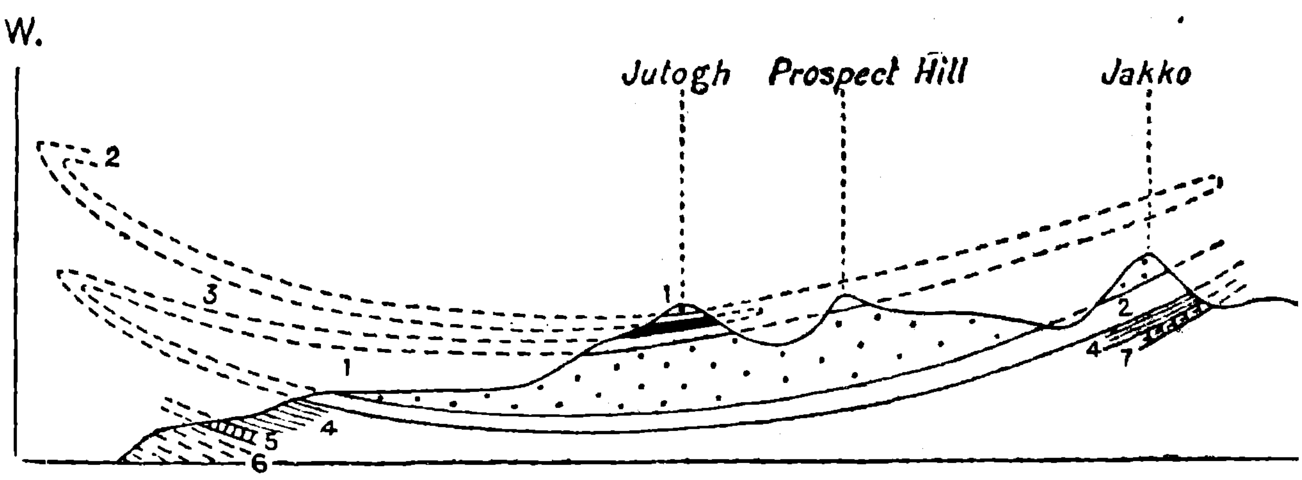

FIG. 17.—Diagrammatic Section through Jutogh and Simla.

(Horizontal scale, 1″ = 2 miles; vertical scale, 1″ = 1 mile).

1. Boileaugunge quartzites and "upper quartzite." } Jutogh series.
2. Carbonaceous schists and limestone } Jutogh series.
3. "Upper mica-schist." } Jutogh series.
4. Chail series.
5. Jaunsar series.
6. Simla series.
7. Blaini beds.

To Oldham's account of the Jutogh rocks of Simla itself we need not add much in this place. There are two points, however, which call for comment. The one is that a small part of Oldham's Jakko carbonaceous slate we now include in our Chail series. This has only become apparent as the result of mapping over a larger area, and has already been referred to above (page 94).

The presence of Chail beds in Simla.

The other point to which we should like to call attention is the use of the name Boileaugunge quartzite. Under this name Oldham included all the beds above his Jakko carbonaceous slates which are found on Jakko and on the Ridge at Simla, and on Jutogh up to his Upper or Jutogh carbonaceous slates and limestone. Now, while quartzites are certainly prominently developed at Boileaugunge, they are not the only type of rock met with. Thus on the whole of Jakko there is scarcely a bed of rock which could be called a quartzite, the rocks being mica-schists and quartz-schists. The same remarks apply to the development of these rocks away from Simla. To call the whole set of rocks quartzites is certainly misleading. It would probably be best to alter the name to Boileaugunge beds, in the same way that we suggest altering the name Simla slates to Simla series, many of these rocks being not slates but sandstones.

The Boileaugunge quartzite.

At Simla the boundary of these Boileaugunge beds has been adapted from Oldham's 3″ map. Our own work on the rocks has been confined to continuing the mapping outside Simla, and we may now proceed to follow the Jutogh series to the south-west from Kasumpti, where Oldham left off.

The course of the carbonaceous band is clear from the map. One of the characteristics of these rocks at Simla is the nearly complete absence of limestone, which is such a feature of these rocks both on Jutogh and in the Chor area. Oldham only mentions two localities, at Annandale and below the first waterfall in the Combermere ravine (1887, p. 147). The former is, of course, well known, but we failed to find any limestone in the Combermere ravine anywhere from above the 1st waterfall to below the 2nd waterfall. As one follows these rocks from Kasumpti, limestone becomes rather more frequent. Thus it has been found *in situ* in this band by Nahera, above Chadoli and east

The Jutogh thrust traced round Simla.

Carbonaceous limestone.

of Badhog; and as boulders on the Mundlu spur above Kanhechi, and at Shadhal, near the motor road, though where it crosses the road and the railway no limestone is to be seen.

The pitted carbonaceous bed.

Very little was seen here of the 'pitted' rock, which is so characteristic of this band on Prospect Hill and Jutogh, and in the Chor area.

From Kasumpti to the motor road the band is rarely more than 200 feet thick, and generally less. This is in marked contrast to the thickness of the same rocks in the Chor district. Between Kasumpti and Kanhechi the rocks are nearly horizontal. But between Kanhechi and the railway there is a very definite northeasterly dip of about 40°. This is a very characteristic feature of the topography along the railway between Kanoh and Shogi, and can be seen from a long way off.

The Boileaugunge quartzites.

Above this carbonaceous band we get everywhere the rocks which have been designated the Boileaugunge quartzites, but which, as remarked above, include other rock types also. The quartzites and quartz-schists are generally very massive, and are largely responsible for the very precipitous southern face of Tara Devi.

Microscopically the quartzites are seen to be true metamorphic quartzites (37/653). The quartz crystals occur in a fine mosaic, while any argillaceous impurities have crystallised out as sericite. The latter is almost universely developed, and is often in sufficient abundance to give the rock a slightly schistose structure.

With an increase in the argillaceous content there is a gradual transition to rocks which may be termed mica-schists. These occur both as very thin seams in the quartzites and as much thicker separate beds. They are not infrequently garnetiferous, while green porphyroblasts of penninite are sometimes seen, as on the spur above Nahera (37/651) near Kahla, and elsewhere. In only one place was this mineral seen in the carbonaceous band, and that was on the top of the spur just west of Basha (37/652).

Tara Devi.

One more outcrop must now be referred to, before we cross the motor road. In the various writings of Medlicott, McMahon and Oldham, no mention is made of a very typical outcrop of the carbonaceous band that occurs on the top of Tara Devi. No doubt the greater part of Tara Devi

Hill is composed of quartzites and schists. But along the crest of the hill are some very good exposures of the carbonaceous rocks, which form the small peaks that diversify the topography of this hill. Not only do we find the usual richly carbonaceous slates and schists, but the carbonaceous limestone is seen and also the 'pitted' rock. The former appears in several places along the top, and was quarried and burnt there 12 or 15 years ago.

The structure of the hill is by no means easy to determine. The rocks are very much folded, though the dips, when not vertical, are almost invariably in a N. to N.N.E. direction, so that the folds are all isoclinal. Although these rocks have a broad outcrop on the top of the hill, at lower levels the outcrop rapidly diminishes. Thus along the railway to the east of the hill, these carbonaceous rocks are only seen for a very short way.

On the west side of the hill carbonaceous rocks are seen for some way along the road, but they do not extend very far to the west, where the ground sinks rapidly, though we have not followed the boundary very closely here. Their best development is along the south side of the spur that runs out west at about 6½ miles from Simla, by some brick fields. Along here the rocks have a northerly dip of about 30°, and the limestone is well developed.

Just as these beds appeared to die out to the east, so they die out to the west, being last seen some way above Shangin. At this point there is an intrusion of massive hornblende-gneiss. From the evidence available it seems, therefore, that we must be dealing with a synclinorium of these rocks overturned to the south, though the exact structure is by no means clear. The band dies out to the east and west because the ground falls away rapidly in those directions, and the fold therefore closes.

Tara Devi carbonaceous band corresponds to the Prospect Hill and Jutogh band.

This outcrop is evidently part of the upper carbonaceous band, the same which is developed on the top of Prospect Hill, but which has here become involved in a subsidiary fold.

Kalka-Simla motor road.

To the north-west of the motor road, the carbonaceous stage of the Jutoghs, which already, even where seen on the road, has become untypical and from which the limestone has disappeared, is altogether cut out. Not only has this happened in the case of the carbonaceous band, but gradually the overlying Boileaugunge quartzites are also cut out at the boundary of the Jutogh thrust until just south of the Kuni river at Kharuta, the upper carbonaceous band is found against the Chails. This contains here about 10 feet of black limestone with carbonaceous slates above. That this is the upper band is proved by tracing it to the north-west. In the Kuni river about 50 feet of limestone are exposed, and almost as much at the village of Tarail $\frac{1}{4}$ mile south of the Simla-Arki road.

Disappearance of the lower carbonaceous band and of the overlying Boileaugunge quartzites.

Upper carbonaceous band thrust over the Chails at Kharuta and in the Kuni.

Jutogh limestone at Tarail.

From here the Boileaugunge quartzite gradually begins to come in again between the Chail phyllites and the Jutogh limestone, to be followed by the lower carbonaceous band, which can then be traced continuously to Simla. Limestone seems to be almost absent from this band; in fact the only proof of its presence at all was afforded by some fragments found near the road just before reaching Shekoh.

The upper Tarail band is presumably the equivalent of the carbonaceous band of Prospect Hill, differing only by the absence from the Tarail limestone of the secondary minerals found in that of Prospect Hill, and also of any lenticles of white marble, which also occur in the Prospect Hill limestone. This carbonaceous band has been traced from the Simla-Arki road along the top of the prominent scarped ridge to a little below and to the north of the highest peak which overlooks the town of Halog. The long dip slopes to the east of this ridge consist entirely of the carbonaceous beds, while the almost perpendicular cliffs on the west consist mainly of the Boileaugunge quartzite which overlies the lower carbonaceous band. After leaving the Arki road, no more limestone was seen in this band, though it is possible that patches of it may occur on inaccessible portions of the cliffs. It begins to bend round to follow the general strike of the rocks, at the northern end of the ridge, but is cut off by a cross fault, which brings up the Boileaugunge quartzites again; above these, on the summits of the amphitheatre of hills of which Gahainda Hill (5846) is the highest, the carbonaceous band is repeated, here also without any limestone.

The upper carbonaceous band traced.

Repetition of the beds by cross-faulting.

It will be seen that the outcrop of this upper carbonaceous band has not been followed completely. From Kharuta it probably follows the high ground to the west of the Paterika Deo and so joins up with the northern outcrop by way of hill 6407, its outcrop on the Simla-Arki road, having possibly escaped notice amidst the shops and numerous other buildings of the village of Banoti.

Two horizons of quartz-schists.

Regarding these two carbonaceous bands as the respective limbs of a long recumbent fold, in accordance with our observations in the Chor area, then the beds within the closed outcrop will belong to a different horizon from the massive quartzites which occur between the two carbonaceous bands, the latter corresponding to the Boileaugunge quartzites and the former to the 'upper mica-schists' which Hayden has mapped in Jutogh and which have been referred to above (page 102).

Differences between them.

In the country with which we are now dealing, the differences between the two sets of beds are striking. The beds between the carbonaceous bands are hard massive quartzites, and quartz-schists are of secondary importance. On the other hand the beds within the closed outcrop of the upper carbonaceous band contain no massive quartzites at all, but are invariably quartz-schists or quartz-mica-schists.

Contrast between the Jutogh series of Simla and Halog.

Another striking difference between the Jutogh beds of this area and those of Simla are that the former are much less metamorphosed; garnets are rarely found in them and when present are small. The absence of secondary minerals in the limestone has already been mentioned. This points to a proportionate decrease in metamorphism radiating from some centre not far removed from Simla, comparable to the Chor granite in the Chor area. Possibly Medlicott's and Oldham's theory as to the former existence of such an intrusive mass in the neighbourhood of Simla may have had a foundation in fact.

The section given in figure 2 on Plate 1 includes the Simla area. One or two points may be referred to. Thus although the Chail beds never actually die out around Simla, it is possible that they very soon did so further north, prior to the denudation. Consequently, on the section the Jutogh thrust has been made to overlap the Chail thrust in that direction above the present topography.

Other points which may be noted in this section are the cutting-out of the Jaunsar series by the Chail thrust, and the cutting out of the Blaini by the Jaunsar thrust. This part of the section is deduced from the evidence obtained further south-east along the Giri valley, which has already been described on pages 19 and 84.

XI.—GEOLOGY OF THE AREA E. AND N.E. OF SIMLA, NALDERA-NARKANDA RIDGE.

We propose to conclude the descriptive portion of this paper with a few remarks on the geology of the country to the east and north-east of Simla. Our examination of this was but cursory, but seeing that our interpretation of its geological structure is almost entirely at variance with the views which have so far been published, we consider that we are not justified in postponing mention of it until a detailed geological survey can be accomplished. More especially is this preliminary report desirable since several features in its geology bear directly on problems which have arisen in the course of our investigation of the other areas dealt with in this paper.

The area referred to includes the Naldera, Mashobra, Mahasu, Fagu, Mattiana ridge and the country which lies between that and the Shali chain of hills. Medlicott's observations on it are to be found on pages 38 and 48-49 of his 1864 memoir. McMahon devotes a section to it (1877 pp. 211-14), and on the map which accompanies his paper has mapped several outcrops of Blaini round Theog. Hayden during one or two casual trips from Mattiana in 1918 found Nummulitic beds on the lower slopes of the Shali range near Barhana. His finds were recorded in *Rec. Geol. Surv. Ind.*, Vol. L, pp. 8–9, and Vol. LI, p. 9. R. W. Palmer worked during May and June 1920 in the country stretching down from the Shali range to the Nauti river and somewhat to the south and east of it. He submitted a report and a geological map which were not published, although a summary of his results is contained in the Director's Annual Report published in 1921 (Palmer, 1921). That portion of the map to the north-east of Mashobra is based on Palmer's map, though it has been considerably modified. We accept no respon-

Previous work in the area.

Medlicott.

McMahon.

Hayden.

R. W. Palmer.

sibility for those parts of Palmer's original map which we have left unchanged through inability to visit the localities.

Broad outcrop of the Simla series between Simla and the Mashobra-Naldera ridge.

The rocks between Simla and the Mashobra-Naldera ridge have been accepted by Medlicott, Oldham and all who have succeeded them as the Simla series. They underlie the Blaini continuously or almost so from Simla to Halog and form an outcrop which, as we have delimited it varies from 3 to 5 miles in width. Their dip is almost invariably in a south-westerly direction. These rocks would repay a careful and detailed examination in the field with the object of detecting repetitions. As it is the authors can only state their firm belief that the outcrop represents an overturned syncline, or more probably a synclinorium of isoclines.

Probably an isosynclinorium.

Purple micaceous sandstone.

On hill 6820 about 5 miles N.W. of Simla is a thick bed of grey and purple micaceous sandstone. Dr. E. H. Pascoe has traced this bed along the Elysium spur to a large outcrop on the Simla-Mashobra road about [illegible] a mile from Sanjauli bazaar, where it is extensively quarried. Overlying this bed at the S.W. base of hill 6820 are grey slates, amongst which are beds containing certain peculiar structures presumably of a concretionary nature, which simulate coprolites or large coiled snail-shells. These pseudo-coprolite beds have been seen in several places near the south-western margin of the Simla series outcrop. Purple micaceous sandstones occasionally occur in the same position, and thin bands of similar sandstone have been seen in various places throughout the series. Whether these represent repetitions of the large purple sandstone band or distinct horizons we are unaware. Between hill 6820 and the Blaini outcrop the beds are mostly grey, occasionally purple, splintery slates, which exactly resemble the beds to the south-west of Sairi between the two outcrops of Jaunsar conglomerate. Occasional thin bands of grey quartzitic sandstone are seen here and there. On the Simla-Mashobra road the splintery character of the corresponding beds has largely disappeared and the slates are more massive with fewer joints. Grey jointed slates of a similar character seem to continue on the other side of the purple sandstone towards Mashobra. On the precipitous cliffs which rise above the road south of Mashobra immense contortions in the rocks are plainly visible.

Concretions.

About here another extremely characteristic set of beds come in. These are grey slates showing a finely banded structure. The main cleavage planes are however parallel to these bands, so that they are not true slates. These have been seen along the road to Kufri and Mahasu and have been traced across the Chail-Kufri road right down to the Giri below Piran (see page 119).

Banded slates, a low horizon in the Simla series.

It seems certain that these represent a lower horizon of the Simla series than any that has been seen to the south-west. Along the road to Naldera these appear to be replaced or to pass down into unbanded slates of the more usual Simla type. Amongst these are soft cream-coloured slaty shales.

In the village of Baldia about 9½ miles from Simla reckoned by the milestones a blue limestone occurs in lenticular outcrops either in the jointed slates or in the soft cream-coloured slaty shales which we have just mentioned. The limestone strikes round the hill north of Baldia and then from mile 10 as far as Naldera it crops out on the crest of the ridge forming long dip slopes on the southern side of the ridge above and below the newly constructed road to Naldera. Now for a distance of about a mile it is interrupted by two cross faults which bring up a series of pale coloured schists and dark blue banded slates showing slaty cleavage, which are identified with the Chail series, as we shall show later (page 114). About 13¼ miles from Simla, this limestone again crops out on the road and appears to continue for a long distance along the ridge which runs westward in continuation of the Naldera ridge, forming long characteristic dip slopes.

Naldera limestone.

Chail series brought up by cross-faulting.

This limestone is mentioned by Medlicott (1864, p. 48) who does not describe it more than as "a thin band of limestone on the crest of the ridge over Basantpur". Dr. E. H. Pascoe drew our attention to it in the first instance. It is hardly ever more than 100 feet thick and is moderately soft, weathering out into irregular crests and hollows. It contains no chert bands and so differs markedly from the Shali limestone. Constantly small black circular discs, which suggest organic remains, occur in it, just as is the case with the so called Kakarhatti limestone north of Subathu.

This limestone is clearly interbedded with what must be regarded as the Simla series and everything points to its being at the very base of that series.

Descending the hill to Basantpur the Naldera limestone and its associated cream slaty shales and jointed slates are succeeded by hard, dark grey, often carbonaceous slates, much more finely banded than the banded slates of the Simla series and showing a marked slaty cleavage, oblique to the bands. Between the Naldera limestone and the hill to the north of Basantpur which overlooks the Nauti river there occur no less than six bands of limestone, in no case more than 50 feet thick and sometimes less. Interbedded with these are the banded dark grey or dark blue slates with slaty cleavage, and grey schists which in their harder varieties also show cleavage oblique to the stratification. The limestones vary somewhat in character even in the same outcrop, but are almost always banded and sometimes finely banded. In their most typical form the resemblance to the limestone which has been described (pages 91-92) at the base of the Chails, and the dark blue slates which are frequently associated with them—most prominently at Dharel, 2¼ miles S.S.W. of Halog—leave us in no doubt that they are to be correlated with that horizon in the Chail series. It is true that even allowing for repeated folding in the Basantpur section, the slates are more developed here than between Halog and the Ashni river, but that cannot be regarded as a serious objection. That there is isoclinal folding in the Basantpur section, in spite of the general south-westerly dip, is suggested by the frequent contortion as well as by the close correspondence of many of the limestone bands.

Chail cleaved slates and limestone unconformable beneath the Naldera limestone at Basantpur.

This series can be traced eastward to Fagu and thence north of Theog. It is undoubtedly the same as the broad outcrop of slates and schists with interbedded limestones which Palmer has mentioned and the western boundary of which with his Madhan slates he has mapped apparently in great detail.

Chail limestones and slates traced eastward to Fagu and Theog.

The whole sequence of these rocks is well displayed between Fagu and Theog and below the road to the east. Looking E.N.E. from Fagu a massive outcrop of limestone can be seen in the side of the spur that runs out south from the 19th mile (37/643). This band, a blue-grey finely banded limestone, can be traced northwards by the village of Janog, where it is very well developed, to the main road by mile 18. Here, however, it has rapidly thinned out, and only a few feet are seen. Another band occurs a little further east passing close to Theog fort; while a third band, an almost white limestone, is seen where the road makes a sharp bend west of peak 8219. These limestone bands are obviously lenticular since they thin out and disappear.

Palmer's correlation of the limestone series with the Krol not acceptable to the authors.

The authors cannot agree with Palmer that the limestone resembles the Krol limestone either in its typical or any other area in which they have seen it. Nor can they agree with McMahon (1877, pp. 212-13) who has referred outcrops of it at Theog and elsewhere to the Blaini. No resemblance can be traced between it and the Shali limestone nor yet to the Naldera limestone. The Deoban limestone is far distant, but it is equally unlike that.

McMahon's mistaken identification of the Chail limestone east of Fagu with the Blaini.

We may refer here to McMahon's observations in this area. In his 1877 paper (pp. 211-13) he refers to several outcrops of the Blaini to the east of Fagu, marking them on the accompanying ¼" map, and particular care was taken to examine them. Unfortunately we are unable to accept his correlation. He refers to a band of limestone about 2 miles due east of Fagu, near the village of Padrog. This rock, however, is not the Blaini but a band of the dark blue limestone which we have described above, and a like remark applies to some of his other Blaini outcrops near by. The rocks associated with this limestone are the same bluish-grey slates that are seen by Fagu, with a good cleavage very oblique to the bedding. The rocks are here nearly horizontal, and this band of limestone can be followed a long way at nearly the same height, though in places it dies out temporarily. Three or four hundred feet below it is a second band, a white or cream limestone, underlain by soft light-coloured schistose slates. The association of the latter rocks with the cream variety of limestone is very characteristic, and is seen in a number of places, *e.g.*, in the Giri valley opposite Darog, the outcrop mentioned above on the main road by peak 8219, and on the spur running north-east from Chharabra, just east of peak 6651.

Another erroneous identification by McMahon as Blaini in the Giri below Parala.

In addition to these outcrops of limestone which McMahon thought to be Blaini, he also describes the occurrence of the Blaini boulder beds, mentioning in particular an outcrop in the Giri below Parala. Here again, however, we cannot accept his conclusions. We have already mentioned that he mistook the

Jaunsar conglomerate where it crosses the Ashni for the Blaini boulder bed. In the Giri below Parala are some thick coarse gravels, which contain large boulders of the Jaunsar quartzite conglomerate, and it is evidently these which he has mistaken for the Blaini boulder bed. There is, however, a continuous section in one bank or the other up the river here, and it shows nothing but dark grey slates with an E.S.E. dip of 30°. These are all part of this big Chail outcrop, as is evidenced by the occurrence of the cream limestone a little further down opposite Darog.

McMahon on his ¼" map makes this same supposed band of Blaini cut the main road near the 21st milestone. But here also we failed to find any trace of Blaini.

Outcrops on the Simla-Narkanda road north of Theog.

Repetition of carbonaceous and ferruginous schists.

Grey phyllites and schists often talcose.

Interbedded quartzite probably referable to the Jaunsar.

On the Simla-Narkanda road, these dark slates associated with limestone continue up to about 21 miles from Simla. Practically horizontal between Fagu and Theog, they then develop an E.N.E. dip. Between miles 21· and 23 one can hardly doubt that there is frequent repetition of slates deeply stained with iron and containing both pyrites and sulphur and one thin band of highly carbonaceous schist. From here up to about ½ mile from Narkanda, one finds nothing but grey phyllites and sericite schists, often puckered and sometimes talcose and silvery, with abundant vein quartz, and quartz schists (37/640 to 642). One exception to the continuous succession of these is an outcrop of massive quartzite near mile 34, where there is a bungalow and a market garden, and another between miles 23 and 24. These are, it is suggested, Jaunsar. A carbonaceous band occurs between miles 36 and 37 and some intrusive dolerite at mile 38.

Jutogh mica and quartz schists at Narkanda.

A thick carbonaceous band occurs at 39½ miles from Simla, and against it on the north-east are highly metamorphosed muscovite-schists and quartz-sericite-schists which can only be correlated with the Jutogh series. It is possible that the carbonaceous band should also be included with them.

The other rocks bear a decided resemblance to the puckered phyllites and talc-schists of the Chail series. The resemblance is not exact, but united with the close parallelism between the underlying slates and limestones and the basal Chail beds it bears strong testimony to the correlation of the whole set of metamorphosed beds between Fagu and ½ mile distance from Narkanda with the Chails which we propose to adopt.

Correlation of the phyllites and talc-schists with the Chail series.

The evidence of isoclinal folding between miles 21 and 23, apart from the presumption that the limestone bands are repeated, makes it reasonably certain that all the beds are intensely folded, the folds between Fagu and Theog being almost horizontal. Although along the Himalayan-Tibet road the beds strike constantly N.N.W. to S.S.E., yet from observations made elsewhere it is plain that the strike pursues in reality an extremely winding course. This is well seen near the fault on the Seuj river, S.S.E. of the Shali peak, where the beds strike round a complete semicircle.

Isoclinal folding in the Chails.

Palmer has observed that this series overlies his Madhan slates and the associated Nummulitic limestones and shales. He seems to incline to the theory that despite its appearance of age it is, therefore, itself Eocene. He suggests however the alternative interpretation that it has been thrust over the Madhan slates. In the published summary it has been assumed that the limestone-slate series coincides with the Simla slates, which was Medlicott's idea; in this case the adoption of Palmer's first theory would imply a Tertiary age for all the Simla rocks; consequently Palmer's second suggestion is favoured. In this the authors entirely concur, though, as stated above, they regard the series not as the Simla slates but as Chail.

Palmer's alternative hypotheses as to the limestone series:—
(i) that it conformably overlies the Madhan slates.
(ii) that it is thrust over them.

The second suggestion favoured by the authors.

While to the north-east of Fagu the rocks are more or less horizontal, to the south, towards Cheog and beyond, a southerly dip sets in; and the rocks around Fagu, which we correlate with the Chail series, pass down under rocks which are almost certainly representatives of the Jaunsar series. They are in fact the northern part of the big outcrop of Jaunsar rocks that stretches nearly to the

The Chail series dips under Jaunsars south of Fagu, and at Cheog.

Giri, and a continuation to the east of the band which we have already described as occurring between the Simla slates and Blaini (p. 87).

In this big outcrop are unmistakeable representatives of the Jaunsar series. Purple conglomerates full of quartz pebbles are seen high up above Dwan, very like the conglomerate exposed in the Ashni; massive white quartzites and purple phyllites form hill 7809 (37/637) and the peak just south of it; while a very characteristic rock is a green and purple schistose slate, extensively used as a roofing slate in the villages hereabouts (37/636).

Over the greater part of this outcrop the rocks are nearly horizontal. Unfortunately time did not allow of a proper investigation of the boundaries of this outcrop, and it has had to be left as an isolated patch on the map. Nevertheless it is possible to suggest an interpretation of the structure, which is not without some foundation in fact.

White quartzite of Mahasu and Mashobra.

The peak known as Mahasu, a little W.N.W. of Fagu, is formed of massive white quartzite; and, though the point has not been absolutely determined, it would seem that these quartzites are the continuation of a band which passes near Kufri, and crosses the spur running north-east from Chharabra near the village of Nehari. This band continues to the north-west and forms the steep north-easterly face of the Mashobra ridge (37/654), where it has a very pronounced south-westerly dip, the Chail rocks on its N.E. side dipping beneath it.

Probably joins up with the Jaunsars of Cheog.

Now further on (p. 123) we suggest that this band of quartzite is a much attenuated representative of the Jaunsars. We have not, however, seen the country immediately south of Mahasu. But in view of what we have said above it would seem highly probable that this band of quartzite will be found to join up to the south-east with the Jaunsar rocks by Cheog. In both areas the Chail rocks dip beneath them, and the outcrop at Cheog is in a direct line with the Mashobra-Mahasu band.

Puzzling position of the Jaunsars both above and below the Simla series.

On this assumption we may proceed to consider the possibilities opened up. Summarily we have two areas, not far separated, in one of which the Jaunsar rocks occur below the Blaini and above the Simla slates, and in the other they occur beneath the Simla slates. Moreover the outcrop of Simla slates is the same in both cases. To this problem there would seem to be only two possible solutions. Either we are dealing with an overthrust fault, by which a Blaini-Jaunsar succession has been thrust over a Simla slates-Jaunsar succession; or else with a fold, the core of which is formed of Simla slates.

Suggested explanation.

For several reasons the latter interpretation is favoured by us, as being supported by a number of facts. Thus the two outcrops of Jaunsar are really continuous, if one neglects the effects of denudation, which has separated them along the line of the Chakhred *khad*. If it is a fold, then the outcrop of Jaunsar which occurs above the Simla slates must be the upper limb, nearly horizontal; the other outcrop, the Mashobra-Mahasu band, must be the lower limb dipping south-west; while the broad outcrop of Jaunsars south and south-west of Cheog is where the two limbs join and the fold closes, thus accounting for the extent of the outcrop.

Further support for this interpretation seems to be forthcoming from the distribution of the Simla slates. Beneath the main outcrop of Blaini beds, from the Giri up to Simla, the Simla slates are all very similar, dark grey to brown slaty shales. As one ascends the Giri from Nohan, however, this type of rock is seen to be underlain by a finely banded slaty grit, consisting of thin black bands alternating with much wider brown gritty bands. As we have already noted, the same change can be observed along the Sanjauli-Kufri road, as one descends in the sequence, and the banded rock evidently represents a low horizon in the Simla slates.

Supposed inversion of the Simla series supports the suggestion offered.

Now it is this variety of Simla slate which comes next to the Jaunsar beds which we are here considering. At Satlabi the Jaunsars are underlain by these banded rocks, while these in their turn are underlain in the Parari-ki-khad by the more usual type of Simla slate, which we have reason to regard as of a higher horizon. If this is so, then we have evidence for regarding the Simla slates just here as inverted, which is in accord with our suggestion of a flat fold. By reason of the very variable nature of the Jaunsar beds it is not possible to say whether one limb of our supposed fold is inverted with respect to the other.

We saw further back (p. 88) that the Jaunsar band which comes between the Simla slates and the Blaini dies out both to the north-west and to the south-west. This must evidently be interpreted as evidence of the Blaini beds having been deposited unconformably on this Jaunsar—Simla slate fold, in one place resting on the Jaunsars and elsewhere on the Simla slates.

The above interpretation is only put forward tentatively. The solution of the problem will no doubt be found further south-east, in the valley of the Giri and beyond it.

XII.—GEOLOGY OF THE SHALI AREA.

The Shali limestone.

To pass on to the Shali range. The Shali limestone is a blue intensely hard dolomitic limestone, weathering to a dirty white colour, characterized throughout almost its entire thickness by bands of black chert of which the majority are from $\frac{1}{8}$ inch to 2 inches in thickness, though bands of 3 to 4 inches are not infrequent and occasionally even thicker ones. Its uppermost beds do not seem to contain chert bands; where it was seen above the bridge over the Nauti, the highest beds are thin-bedded cream-coloured limestone, free from chert, associated with a few bands of thin-bedded quartzitic sandstone. Assuming that the section over the Nauti is not folded and that the dip is fairly constant, the thickness of the limestone cannot be less than 1200 feet. It forms the summit of the Shali peak and of the range for at any rate two or three miles on either side of it, reaching down to an unknown distance on the northern side of the range. Its dip slopes extend for about $\frac{3}{4}$ mile south of the Shali peak, but the Madhan slates and a massive quartzitic sandstone almost reach the summit of Nag Tikar, 9232, while the peaks to the S.S.W. of Nag Tikar are of Madhan slate. Palmer has stated that a white quartzitic sandstone, which he has called the Shali sandstone, overlies the Shali limestone, and this in its turn underlies the Madhan slates.

The Madhan slates.

The Madhan slates consist of beds of various types. The most frequent are grey, jointed slates, showing occasional smooth planes in which a green mineral has been developed. Interbedded with these are greyish or white quartzitic sandstones which often pass into a massive white quartzitic sandstone which cannot be distinguished from the quartzitic sandstone which is often in contact with the Shali limestone. In the midst of these in more than one place are beds of blue clay which are dug out by the villagers for making plaster. Vein quartz is frequently found in all these beds. Beds of purple gritty quartzite and purple shales occur in many places as well as cream and lavender slaty shales.

Subathu beds unconformable on the Madhan slates.

These beds are obviously intensely folded; even against the boundary of the Shali limestone, both quartzite and slates seem to dip variously. It is, therefore, not surprising that the Nummulitic beds, which present a typical Subathu appearance both as regards their limestone as well as their olive shales, should crop out in what looks like a sporadic fashion. It is not at all easy to draw tho boundaries between the two, especially as it is possible that limestone lenticles occur in the Madhan slates.

The quartzitic sandstone of the Shali area.

Palmer who first saw the quartzitic sandstone on Nag Tikar and there commenced to map it as Shali sandstone, was subsequently considerably embarassed when he tried to distinguish it from the exactly similar rock in the Madhan slates. In one instance he was actually led to suggest that an outcrop of this rock which he had formerly mapped as Shali sandstone might in reality be Madhan sandstone. Consequently during the remaining portion of his survey, although he continued to regard the quartzitic sandstone as Shali sandstone where he found it in contact with the Shali limestone, he refrained from mapping it separately.

Belongs to the Madhan slates and not to the Shali limestone series.

We have no doubt that the sandstone in question belongs to the Madhan slates and not to the Shali limestone. Apart from its occurrence amid the Madhan slate outcrops, there is at least one portion of the boundary between the Shali limestone and the Madhan slates, south of the Shali peak, where the quartzitic sandstone does not occur, although it exists in a presumably faulted outcrop lower down the hill.

The Madhan slates probably much older than the Subathu beds.

Palmer considered that the Nummulitic beds were conformable to the Madhan slates and therefore regarded the latter as Eocene. We cannot concur in this opinion: in the first place the Nummulitic beds stand in no fixed relation to the Madhan slates. We have found them in contact with every type of rock in the Madhan slates, so that one must infer that they were deposited on a much denuded surface of the latter; in the second place the Madhan slates represent a type of rock which is entirely foreign to the Eocene not only in this part of India but also in the deposits of the western portions of the Himalayas, the Salt Range, Baluchistan and other localities. By hypothesis they must be older than the oldest beds of the Subathu; yet in none of the various outcrops of the latter have any older or different beds been found than the typical red or olive shales, the limestone and the pisolitic laterite. In conclusion, the Madhan slates are altogether older looking than any Tertiary rock, and we have to look as far back as the Simla slates, if not farther, to find a parallel.

Correlated with the Jaunsars.

The only beds, so far as we are aware, which show any resemblance to them are the very variable Jaunsar series. The jointed grey slates with slickensided surfaces, the purple sandstones and slates afford the nearest parallel to the typical Jaunsars. A closer resemblance than this can be found to certain other beds which we have some reason to regard as Jaunsar. The quartzitic sandstone is very like the bands of a similar rock which have been described on page 118 as occurring on the Mashobra and Mahasu ridge between the Chails and the Simla slates. This, as we have seen, probably passes along the strike to the south-east into undoubted Jaunsar beds, containing the typical conglomerates, although the two outcrops have not actually been traced into continuity. West of Mashobra the Jaunsars thin out and little is left except this quartzite, and before reaching Naldera this also dies out.

The Madhan quartzitic sandstone perhaps to be correlated with the Mahasu and Mashobra white quartzite.

And with the white quartzite below the Chails between Simla and Halog.

An equally close resemblance exists between the Madhan quartzitic sandstone and the band of white quartzite, which is found between the Chails and the Blaini or Simla slates between Simla and Halog and south of Halog. This band has been fully discussed on pages 97-100 and there is little reason to doubt that it is Jaunsar, although its structural relations may be obscure. In more than one place associated with the quartzite, for example at Khanoi, is the blue clay which has been noticed above in the Madhan slates.

Before discussing the general structure of what we may call the Shali area, we shall first describe the rocks on either side of the Nauti river below the fault marked on the map as far down as the bridge. It is here that we obtain practically the only evidence available to us, such as it is, as to the age of the Shali limestone.

Rocks in the Nauti *khad* below Mashobra.

West of the point at which the Nauti after flowing south through a narrow, rocky gorge in the Shali limestone turns sharply at a right angle to the west, Palmer has doubtfully identified the rocks along the river with the Madhan slates. With this identification we cannot agree. The rocks in question are altogether newer looking than the Madhan slates; they are grey slates some bands in which are strongly carbonaceous while others are soft cream-coloured shales; there are no bands of sandstone nor purple shales and quartzites. They clearly dip under the Shali limestone which forms the steeply ascending, often precipitous northern side of the river. It can hardly be doubted that there is a gradual transition from the grey slates through slates which contain thin bands or lenticles of limestone often impure up into the typical Shali limestone with black chert bands. The dips in the river are generally very steep, often vertical, but diminish rapidly as the distance from the river increases. Apparently they form an anticlinal fold, of which the northern limb dips under the Shali limestone while the southern limb dips under the Chail slate and limestone series, which shows precisely the same characters as in its other outcrops and extends from the village of Thail up to the outcrop of massive quartzite some 1,500 feet below the Mashobra ridge. Its junction with the Chails is a continuation of the same outcrop which we have concluded to be the trace of a thrust plane (page 117), probably shifted slightly by a fault as shown in the map.

Not Madhan slates as Palmer suggested.

But conformable beneath the Shali limestone.

Overthrust by the Chail limestone-slate series.

At the southern end of the gorge mentioned above the outcrop of the Shali limestone ends suddenly and is continued again much further to the north-east, so that there is obviously a fault. On the south-eastern side of this fault is a narrow outcrop of typical Madhan slates comprising grey, jointed slates with vein quartz; purple quartzites and slates and massive white quartzite. On the

Cross-faulting below the gorge in the Nauti river.

northern side these beds rest on the Shali limestone, while on the south the Chail series, here containing several thick bands of banded blue or brown limestone, is, presumably, thrust over them. This outcrop of the Madhan slates dies out before reaching the large *nala* which runs into the Nauti from the south, but in this nala about 150 yards from its junction with the Nauti a narrow outcrop of the typical Shali limestone with the underlying strongly carbonaceous slate is seen.

Arguments bearing on the age of the Shali limestone.

Regarding the age of the Shali limestone, we have obviously little to go on. Palmer, on the assumption that the Madhan slates underlay the Nummulitic limestone conformably, considered that the Shali limestone was Lower Eocene or Cretaceous. Now, with the strong probability that the Madhan slates are Jaunsar, this judgment must be revised. The Shali limestone undoubtedly underlies the Madhan slates. Therefore, we have the choice of two alternatives :—(1) that it is really older than the Madhan slates, or (2) that the Madhan slates have been thrust over it. Against the former supposition we have :—(1) the unmistakeably newer appearance of the carbonaceous and other slates that lie at the base of the Shali limestone; (2) the fact that it is by no means always the same bed in the Madhan slates that rests on the Shali limestone; (3) if the Subathus were deposited on a denuded surface of Madhan slates (Jaunsars by hypothesis) combined with underlying Shali, one would have expected that some of the Subathu outliers would have occurred on the Shali, but such is not the case. On the other hand an overthrust of the Madhan slates (Jaunsars by hypothesis) with their pinched-in outcrops of Subathu is quite in accordance with the general geological structures which it is the object of this paper to demonstrate, and that is the view that we shall adopt.

Correlation with a part of the Simla series considered.

That the Shali limestone and its underlying slates may represent an entirely different facies or horizon of the Simla series from that with which we are already acquainted is, of course, possible. In that case their position must be at the very top of the Simla series; for if they lay unconformably below the Naldera limestone, it is impossible that they should be missing between the Chails and the Naldera limestone in what has all the appearance of being a normal unfaulted section. It is of course conceivable that they should have been entirely removed by denudation before the deposition of the Naldera limestone on the Chails, but in that case we should have to regard them as a distinct series altogether from the Simla slates.

Oldham correlated the Shali limestone with the Deoban, but on what grounds we are unaware. It certainly bears no lithological resemblance to it, but the temptation to correlate two such thick limeftone series is strong, and since the distance that separates them is great, there is a likelihood of the character having altered in the intervening area. A correlation of the Shali with the Krol limestone might perhaps be regarded as equally tenable; at the same time the smaller distance that separates the Shali from the Krol outcrops as compared with the Deoban militates against the entirely different character of the Krol and Shali limestones being merely due to deposition in a different area.

Is a correlation with the Deoban limestone possible?

With these remarks we must leave the age of the Shali limestone unsettled. The solution of the problem will doubtless come when the Shali and Naldera outcrops are traced round into the neighbourhood of Arki and Subathu, or perhaps will be found in the country to the north of the Sutlej.

One or two points remain before we leave the Shali area. Palmer seems to have considered that the dip of the Shali limestone would be such as to bring it under the Madhan slates in the Nauti and its tributary *nalas* as he has mapped it round Dharmpur and elsewhere. We are rather disposed to doubt whether the prevailing dips between the Shali range and the Nauti lend themselves to this interpretation, and consider it more probable that all the lower outcrops of the Shali limestone and the overlying Madhan slates and associated Nummulitic strata have been let down by faulting later than the overthrusting or other phenomenon which superimposed the Madhan slates on the Shali.

Step-faulting in the Shali area.

In certain localities the authors have seen undoubted evidence that this has taken place. Thus a prominent hill which overshadows the village of Barhana consists of Shali limestone capped by Madhan quartzitic sandstone. Either the Nummulitic beds or the Madhan slates dip towards and right up against the Shali limestone on every side, and to reconcile this with the fact that normally these formations rest on the Shali seems to be impossible without faulting.

Faulted inlier of Shali limestone at Barhana.

Prolonged in a south-easterly direction the north and south bounding faults of the Barhana inlier cause to end abruptly in either direction a well marked outcrop of Shali limestone which Palmer seems to have missed, just south of the Nauti river. Nummulitic limestone exposed in the river bed dips under towards the Shali, which is overlain by typical Chail limestones and slates. On the downthrow side of the southernmost of the two bounding faults a prominent band of quartzitic sandstone is found on approximately the same strike as the Shali limestone outcrop for as far in a south-easterly direction as the senior author went.

Chail series directly overthrust on the Shali limestone.

The trace of the Chail thrust plane does not appear to have been appreciably shifted by the step fault. This circumstance when considered together with the absence of the Madhan slates between the Shali limestone and the overthrusting Chails would seem to indicate that the Chail thrust advanced over this area not only later than the Jaunsar thrust but also later than the step faulting. Subsequently to the latter event a considerable time must be allowed for the denudation of the Madhan slates and the associated Nummulitics which must at some time have overlain the Shali.

Suggested movement of the Chails along the thrust plane at a later date than the step faulting.

Precisely similar step faulting has occurred in the case of the two inliers of Shali limestone mapped by the senior author south of the Shali peak.

Figure 3, Plate I, is a section through this Shali area.

One more word as to certain intrusions of dolerite which have been found in the Madhan slates, the Shali limestone, and the Chail limestone.

Doleritic intrusions of the Shali area.

All these rocks are moderately coarse grained and generally of a greenish tint as a result of alteration. In the hand specimen plates of white felspar are fairly prominent. As a typical specimen we may select a dyke intrusive into the Chail limestone about 400 feet above Basantpur on the Simla-Bhajji road, about 17½ miles from Simla.

Under the microscope the rock is seen to be composed mainly of felspar, augite and iron ore, with interstitial chloritic material. The *felspars* are of two kinds: relatively large plates, altered to a sericitic aggregate, and not easy to determine; and smaller but more

Microscopic characters of the rock.

abundant water-clear crystals which seem to be albite. The latter show no twinning, but have a refractive index the same as or slightly less than the balsam, and are optically positive. The *augite* is a pale purplish-brown colour, with just a faint trace of pleochroism. It occurs in idiomorphic prisms, and is sometimes closely intergrown with the clear felspar. There is a good deal of *iron-ore*, some of which is almost certainly ilmenite. Interstitial *chloritic material*, evidently of late formation, is responsible for the greenish colour of the rock. There seems also to be a little quartz.

We may term the rock an albite-dolerite.

Another specimen from about 300 feet below and to the southwest of peak 8929 on the Shali ridge differs in having colourless augite, all the felspars altered, and a fine interstitial groundmass of quartz, felspar, and a kind of myrmekite.

It is of interest to note that precisely similar rocks have been seen in the Chakrata district, *e.g.*, near Nimga, intruded into what are probably Jaunsar quartzites.

XIII.—GENERAL CONCLUSIONS ON THE SEQUENCE OF THE ROCKS OF THE AREA AND OF THE ASSOCIATED PHENOMENA.

Having described the rocks of the area and the structural phenomena which they display we are now in a position to discuss their relative ages and those of the different movements which affected them, as well as of the various igneous intrusions with which they have been from time to time associated.

In considering the probable order in which the various events took place, there are certain outstanding facts which seem clear.

In the first place, it is indicated that the rocks above the uppermost overthrust are older than all those below, otherwise the latter would have shared in the high grade metamorphism which those rocks display. For it is unlikely that the place of origin of the upper rocks was so far removed from the Chail and Jaunsar series that the metamorphism which they suffered was not felt by these rocks also. As we have already seen, the metamorphism of these upper rocks is of regional extension, extending probably for many mile to the N.W. and S.E., and must have been felt by the others if they had been in existence. The same remarks, of course, apply to the recumbent folding.[1]

In the second place the overthrusting is clearly younger than all the rocks which are affected by it, that is to say it is at least post-Krol, since from the nature of the structures seen at Sangrah (p. 32) and elsewhere, it is fairly evident that the Krol was involved in folding which was directly induced by the overthrusting.

We can get even nearer to its age than this. We know that in the country to the west of Simla, as well as in the Shali area to the north-east of Simla, rocks of Subathu age, that is to say Middle Eocene or Lutetian, have been folded in with Jaunsars or Simla slates over which the Chail series has been thrust. It is inconceivable that the Subathu rocks should have been deposited so close to the present trace of the thrust plane if their deposition had been subsequent to that phenomenon. Since the Chail thrust must undoubtedly have extended farther than is now the case, it is probable that these older rocks were actually thrust over the Subathus themselves.

From a consideration of these points, we are forced to conclude that the crust movements which were responsible for the recumbent folding and high grade metamorphism of the upper rocks (the Jutogh series), and for the intrusion of the Chor granite, were quite unconnected with the much later movements which were the cause of the overthrusting. While the latter are almost certainly of the same age as the great Tertiary earth movements which helped to produce the Himalayas as a great mountain range, the former cannot possibly be; for in between the two events there has to be time for the deposition of both the Chail and Jaunsar series and the Simla slates to Krol set of rocks.

That the uppermost rocks are characterised as a separate unit, is shown not only by their high grade metamorphism and by the recumbent folding which they alone display, but also by the fact that both the hornblende-schists and the olivine-dolerites are wholly confined to this set of rocks.

Again, it is fairly clear that the regional metamorphism and the recumbent folding must have been more or less contempora-

[1] It is of course conceivable that the Chail and Jaunsar rocks were outside the region of high grade metamorphism. But a consideration of all the evidence leads the authors to conclude that the Jutogh series must be the oldest. The point could only be proved one way or the other by finding the two sets of rocks unmoved from the position in which they were laid down.

neous; for it seems unlikely that a large body of rock could undergo folding of this type had it not already been at a high temperature. And it was no doubt this high temperature, together with the stresses set up by the folding, which was the cause of the regional metamorphism. If the folding had taken place at a low temperature, the rocks would have yielded by fracture and overthrusting, as was subsequently the case with the much later movements.

Another point which has been clearly revealed by the mapping, is that the increased metamorphism around the Chor granite must have been produced after the recumbent folding; for the zones, in so far as they can be made out, run parallel to the boundary of the granite, quite irrespective of the folding. If the increased metamorphism had been of prefolding date, then there would have been no such orderly arrangement.

We have already seen reason to believe that the intrusion of the Chor granite was closely connected with the folding. From what has been said above, then, it must evidently have closely followed on the folding, but before the close of the movements, for it is itself highly foliated. This is a common characteristic of great plutonic intrusions, that in general they seem to take place during the waning stages of the earth movements, after the main movements have subsided.

It may here be noted that the hornblende-schists, which have suffered in the regional metamorphism, are never seen cutting the granite; whereas the later fresh olivine-dolerites do cut the granite.

When the later overthrusting took place, the rocks must have been quite cold. For they have been fractured and have suffered crushing and shearing, with the production of low temperature minerals. Instead of the rocks having yielded by folding, great blocks of the country broke up and were thrust one over the other, each block behaving as a separate unit. One of these units was the set of rocks which had already been folded into great recumbent folds. Whether all this overthrusting took place at the same time, it is not at present possible to say. But it seems likely that the three overthrusts were roughly contemporaneous. It is possible that the uppermost overthrust was the main one, and that its oncoming induced the two thrusts below it, in the same way that these were the cause of the smaller thrusts in the Blaini beds. This, however, is purely speculative.

As regards the age of the hornblende-schists, we have certain facts to go upon. They have suffered in the regional metamorphism, and were anterior to the intrusion of the Chor granite. Hence they are younger than the Jutogh series, into which they are intruded, but older than its metamorphism, and were quite an early episode in the history of our area.

The hornblende-schists.

The olivine-dolerites were evidently much later, for they are quite unaltered, and must have been intruded long after the folding and metamorphism were over. Moreover, they are later than the intrusion of the Chor granite, for they are seen cutting it in quite a number of places. But the fact that their distribution is confined to these older rocks, and that they are never seen intruded into the rocks below, while by no means conclusive, is at least suggestive of their having been intruded prior to the overthrusting, by which they have been carried along into their present position together with the associated rocks.

The olivine-dolerites.

As regards the various cross and step faults recognized in several localities, it is obvious that they must be of later date than the greater portion of the overthrusting, since the boundaries of the thrust trace are in many cases shifted by them. At the same time it seems probable that movement along the thrust plane continued until long after its commencement, and further that the different thrusts did not start or move simultaneously, so that there may have been considerable movement not only after the cross faulting but also after erosive agencies had levelled the unevennesses or excavated the surface. A section near the Senj river, just east of Barhana in the Shali area, seems to afford some evidence of this having happened. It is described on page 126, where it is suggested that the Chail mass has moved subsequently to cross faulting which has brought up a block of Shali limestone right against the present Chail thrust trace without shifting it, and also subsequent to the denuding agencies which have removed the Madhan slates (probably Jaunsar) previously thrust over the Shali limestone.

The cross-faulting.

From the description and sections given above it is evident that the thrust planes no longer have their original horizontality. It follows, therefore, that these planes must have been warped to a greater or less extent since the overthrusting.

Table of the sequence of events.

We may therefore represent the sequence of events in tabular form as follows:—

(*a*) Deposition of the Jutogh series.
(*b*) Intrusion of basic sills and dykes (now hornblende-schists).
(*c*) Recumbent folding and regional metamorphism.
(*d*) Intrusion of the Chor granite towards end of (*c*).
(*e*) Intrusion of the olivine-dolerites, probably soon after (*d*).
(*f*) Deposition of the Chail and Jaunsar series.
(*g*) Deposition of the Simla to Krol series.
(*h*) Deposition of the Subathu series.
(*i*) Folding in of the Subathu with the Jaunsar, Simla, and Blaini series.
(*j*) Main overthrusting with low grade metamorphism.
(*k*) Cross faulting, and warping of the overthrust planes.

XIV.—SUGGESTIONS AS TO THE ACTUAL AGE AND CORRELATION OF THE ROCKS OF THE AREA.

We have endeavoured in the preceding pages to state the evidence upon which we rely for settling the relations of the different series of rocks to each other, and for adopting the general stratigraphical succession and the sequence of events presented in the table on page 3. We still have to face the far more difficult problem of determining the actual age of each rock group and its correlation with the standard horizons of India or elsewhere. In the entire absence of fossils, this is well nigh insolvable, and at the best we can but hope to arrive at a provisional result for some of them.

Amongst the various identities which have met with most general acceptance, at all events until 1908, was that of the correlation of the Blaini boulder-bed with the Talchir conglomerate at the base of the Peninsular Gondwanas, now regarded as Upper Carboniferous, and with a boulder bed at the base of the Productus Limestone of the Salt Range. The glacial nature of the Blaini boulder bed was established by Oldham in 1887 (pp. 144-145); and the existence of scratched boulders, found by Middlemiss in the Blaini conglomerate in the Neweli valley in East Sirmur, and by himself in Simla, was quoted in support of the theory. Other scratched boulders

Oldham's correlation of the Blaini with the Talchir boulder bed.

from the Blaini beds of Simla were photographed by Holland in 1908. Oldham in 1888 brought forward evidence for correlating the Blaini with the Talchir and Salt Range boulder beds; the overlying groups of the Infra-Krol and Krol fell into their place as later Palæozoic or Mesozoic and with them the Jutogh series, which was regarded as a variant facies of the same.

Questioned by Holland, who regarded all the Simla rocks as of Purana age.

This was accepted without question until 1905, when Holland suggested that all these rocks were the parallel of the great Purana systems of the Peninsula, and Cambrian or pre-Cambrian. In 1908 he discussed the question in greater detail and suggested that the Blaini boulder bed was more likely to be the equivalent of the Cambrian glacial boulder bed, which has been recognized in South China, South Australia, South Africa and Northern Europe. The question was very fairly summarized by Hayden (1907-08, pp. 225-227), who has shown that the Spiti beds identified by Oldham with the Blaini are not only not glacial, but are proved by fossil evidence to be considerably younger than the Talchir.

Holland's arguments.

Holland's conclusions were based on two main arguments:—

(1) That the absence of fossils throughout these systems in the outer Himalaya was incompatible with a correlation with the remarkable succession of fossiliferous beds on the Tibetan side of the central Himalayan peaks.

(2) That it is remarkable that in the outer Himalayas, strata older than the assumed Palæozoic rocks and corresponding to the great pre-Cambrian unfossiliferous systems of the Peninsula should not have been caught up in the folding and be occasionally exposed. Hayden further comments on the fact that the Daling and Baxa metamorphic series of the Eastern Himalayas have been actually caught up in the folding of the younger Gondwana rocks, in the way in which we should expect.

The present and other investigations destroy the force of Holland's arguments.

A good deal of work has been done since Holland wrote his paper, which bears directly or indirectly on this question, and however great the justification for a doubt seemed 20 years ago, we now hesitate to reject Oldham's general correlation without considerably more evidence. Holland, himself, if one may judge from a comparison between the 1st (1913 edition and the 2nd (1926) edition of his Indian Geological Terminology (compare especially 1st edition, p. 60 with 2nd edition, p. 92) holds very much less pronounced views on the correlation of the Blaini than he did formerly. Our own results serve to strengthen Oldham's position considerably.

If the conclusions of the present paper are accepted, we now have two great series represented in the Simla region—the Chail and the Jaunsar series, both of which are somewhat metamorphosed, whose existence Holland did not suspect. These entirely fill the demand for a representative of the pre-Cambrian group of the Peninsula in the outer Himalayas. Further, if we were to consider the Simla slates, the Blaini, the Infra-Krol and the Krol as also pre-Cambrian, we should have a far greater thickness of strata than would naturally be expected, to fill the place of the Cuddapah and Bijawar systems of the Peninsula,[1] even if we do not include the Jutogh series with the other two. This, in any case, we consider unlikely, since the high degree of its metamorphism inclines us to regard it as Archæan and equivalent to the Dharwars.

With regard to the first of Holland's arguments, it might equally be contended that it is just as extraordinary that the whole fossiliferous sequence from the Cambrian to the end of the Cretaceous should be unrepresented south of the snowy ranges, with the exception of the Tal series of Kumaon, while a complete sequence exists to the north of the central peaks. We do not consider that the absence of fossils or the failure to find them in any one particular series of rocks is any real proof that life did not exist at that period. Examples might be quoted for similar anomalies, but we might recall that Pilgrim[2] has shown that the great 'Oman series of Persia and Arabia, which probably contains in its complex rocks extending from the Cambrian to the Cretaceous, has only yielded fossils in one or two localities of extremely limited area. These fossils, poorly preserved as they are, have afforded proof of the existence of Carboniferous, Triassic, Jurassic and Cretaceous horizons. Further the Hormuz series, representing no doubt a terres-

[1] It will be seen that the Vindhyan series is not included with the other pre-Cambrian groups, since the latest evidence from fossils proves apparently that in great part, if not entirely, it is of Cambrian age (*Rec. Geol. Surv. Ind.*, Vol. IX, p. 18, 1927).

[2] Pilgrim, The geology of the Persian Gulf and the adjoining portions of Persia and Arabia, *Mem. Geol. Surv. Ind.*, Vol. XXXIV, pt. 4, p. 92 (1908) ; The geology of parts of the Persian provinces of Fars, Kirman and Laristan, *Mem. Geol. Surv. Ind.*, Vol. XLVIII, pt. 3, p. 13.

trial part of the 'Oman complex, has been searched repeatedly for fossils without avail until 1925, when a party of the Anglo-Persian Oil Company were fortunate enough to discover in one small spot traces of undoubted Cambrian Trilobites.

Gondwana correlation of the Blaini and Infra-Krol receives support from Wadia's Pir Panjal work.

D. N. Wadia has described a series of slates and quartzites with a conglomerate at their base in the Pir Panjal range of Poonch, resting on the Panjal Agglomeratic-Slate and Traps.[1] On the Kashmir side of the Pir Panjal Middlemiss and Bion have shown that a similar series of beds containing in one place Lower Gondwana plant fossils rest on the Agglomeratic-Slate, which also contains Carboniferous fossils occasionally. D. N. Wadia has, therefore, correlated the series in Poonch, almost with certainty, with the Gondwanas. Whether the boulder bed at their base is glacial or not is still an open question; but in any case on the southern slopes of the Pir Panjal the most careful search has failed to reveal any undoubted trace of a fossil. We consider that the succession of strata in the Simla Hills, which extend from the Blaini conglomerate up to and including the Krol sandstone do not afford a bad parallel to the unfossiliferous Gondwanas of the Pir Panjal. The undoubted existence of Gondwanas in the outer Himalayas to the east of Sikkim, renders it all the more remarkable that in the intervening area they should be missing.

Oldham's reference of the "Krol sandstone" of Medlicott to the Infra-Krol series.

Oldham (1888, p. 138) came to the conclusion that the sandstone, named by Medlicott the "Krol sandstone" is unconformable to the Krol limestone and belong to the same series as the Infra-Krol. The authors' observations quite confirm this; 4 miles S.E. of Solon on the northern foot of peak 5236, in what seems to be a continuous section from the Infra-Krol up into the Krol limestone, the thickness of the "Krol sandstone" is reduced to a foot from the 100 feet or so which we find on the Krol hill. On the other hand we have found no evidence of unconformity between the Blaini and the Infra-Krol. We, therefore, incline to regard these three members as a single group, which we would provisionally correlate with the Gondwanas.

[1] General Report of the Geological Survey of India for 1924. *Rec. Geol. Surv. Ind.*, Vol. LVIII, pp. 61, 62 (1925).

The Simla series possibly the equivalent of the Dogra slates.

Whether the underlying Dogra slates of the Pir Panjal area (Wadia, 1928) are the same as the Simla slates can only be a conjecture. Lithologically they are very similar and are equally devoid of fossils, if we except a single Gastropod cast which Wadia (1927, p. 233) suggested might belong to a later formation than the Dogra slates.

Correlation of the Krol quite uncertain.

Still more hazardous is it to attempt any correlation of the Krol with one of the numerous post-Carboniferous limestones which have been recognized elsewhere. It may, however, be worth recalling the existence of the curious limestone inlier between Dandli and Riasi, in Poonch and Kashmir states. This has been mentioned by Medlicott,[1] and has since been reported on by D. N. Wadia. This is entirely surrounded by Eocene and Upper-Tertiary rocks, and bears no resemblance to the Palæozoic formations which are exposed in the Pir Panjal range. No observer has been successful in finding any undoubted trace of a fossil in it, any more than in the Krol limestone. The early observers regarded it as Mesozoic, and it is not impossible that both it and the Krol may find a place in the system.

The Riasi Jurassic inlier of Poonch.

Geological work is now sadly needed to link up the two areas of the Pir Panjal and the Simla Hills. Possibly this can never be done completely, as a gap exists throughout the whole of Kangra, where Tertiary rocks conceal everything else from view except for a narrow strip on the inner edge of the valley flanking the crystalline rocks: but we may yet hope that representatives of the Palæozoic and Mesozoic systems of the Pir Panjal will be proved by fossil evidence to exist in the Simla area.

XV.—GENERAL SUMMARY.

Hitherto certain highly metamorphosed beds exposed at Simla and elsewhere in the hilly country to the east, which rest on the unaltered Blaini beds and the Simla slates, have been correlated with the Infra-Krol and Krol series. The authors consider (pp. 8-9) that none of the theories advanced to account for their meta-

[1] Medlicott, Note upon the Sub-Himalayan series in the Jamu Hills. *Rec. Geol. Surv. Ind.*, Vol. IX. p. 53 (1876).

morphism are tenable, because they involve a selective metamorphism, which is inconceivable on such a scale. In view of the constancy in character of the Krol limestone over large areas and the fact that typical exposures of it occur at no great distance from the metamorphosed beds, they think that the Simla rocks, even were they unaltered, are too different from the Infra-Krol and Krol to render the correlation plausible. In addition the simple structure displayed by these rocks on the hypothesis that they represent a straight-forward stratigraphical sequence is incompatible with the alpine type of folding such as the Himalayas undoubtedly display.

It is now suggested that these metamorphosed rocks belong to a much older series, disposed in several (pp. 74-81; 100-104) flat recumbent folds and thrust over the Blaini and Simla slates along a nearly horizontal plane. Subsequent denudation has left the overthrust older beds as outliers on younger rocks. Evidence of this is adduced by the existence of a section (pp. 14-18) in which two distinct bands of Blaini are overlain by two series of quite different lithological composition both of them metamorphosed and neither bearing any resemblance to the Krol. One of these two series is correlated with the middle part of Oldham's Jaunsar series; the other, to which the name of the Chail series has been given, has been recognized on the Simla motor road and in many other places between Simla and Chakrata. Neither of these is sufficiently metamorphosed to be Archæan, so that it is suggested that they are both Purana. In the same section, resting on the Chail series, is a series of carbonaceous slates, limestones and quartzites which are identical with the metamorphosed beds of Simla itself. The name of Jutogh series is proposed for them, and on account of the high grade of metamorphism which they exhibit they are regarded as Archæan. The only explanation of the section is that three overthrusts pass through the area. Geological mapping affords additional evidence of this, by demonstrating that each assumed overthrust is also a marked unconformity (pp. 19-25). The three overthrusts have been traced with occasional gaps of observation from the Simla region to the hills west of the Tons river.

The connection which the metamorphic rocks of the Jutogh series bear to the Chor granite mass, and the zonary arrangement of secondary minerals around the granite, irrespective of the recumbent folding (pp. 60-74), lead the authors to infer that the ntrusion of the granite was contemporaneous both with the recumbent folding and with the metamorphism, though it may have played only a subsidiary part in producing the latter phenomena. It follows that these are all of Archæan age and prior to the deposition of the Chail series. The granite is, therefore, not Tertiary, as has often been suggested (pp. 127-131).

In the Chakrata area the authors confirm Oldham's attribution of the Deoban limestone to a series intermediate in age between the Jaunsars and the Blaini, and suggest that it may be the equivalent either of the Kakarhatti limestone north of Subathu (identical with the Naldera limestone north of Simla), or of the Shali limestone, and of approximately the same age as the Simla series (pp. 44-45).

The Jaunsar series is considered to be intermediate in age between the Simla series and the Chail series. The limestones provisionally placed by Oldham at the base of the Jaunsar series the authors regard as belonging in part to the older Chail series, in part to the Krol (pp. 37, 47, 49-50).

It is suggested that it may prove necessary to restrict the term Jaunsar to the middle division of that series, as defined by Oldham, since there is evidence that its lower division is a part of the Chails unconformable to the Jaunsar, while the upper division proves in some, if not in all cases, to be another part of the Chails presumably thrust over the Jaunsar (pp. 41-43).

A cursory examination of the area E. and N.E. of Simla including the Shali range has not confirmed many of R. W. Palmer's suggestions. The Subathu outcrops appear to be unconformable to the Madhan slates; we consider the latter as probably much older than the Eocene and provisionally correlate them with the Jaunsar series. The extensive outcrop of cleavage slates and lenticular bands of limestone is identified by us with the Chail series, which seems to be thrust over the mingled Subathu and Madhan slates. The latter formations seem to be thrust over the Shali limestone. Conclusive evidence as to the age of the latter is lacking, but there are some indications that it either coincides with or succeeded the upper portion of the Simla series (pp. 120-125).

Evidence is available to show that there are stratigraphical unconformities between the Chail and Jaunsar series (pp. 47-48); between the Jaunsar and the Simla series; between the Simla series and the Blaini-Krol sandstone series (pp. 15, 18, 32, 37, etc.), between the Krol sandstone and the Krol limestone (p. 135);

and between the Krol limestone and the Subathu (pp. 95, 97-98, 122).

In view of the existence postulated by the authors of three thick series of rocks, all older than the Simla slates (previously to this regarded as the most ancient rocks of the area), it is suggested that the thickness of Purana would be unreasonably great if Holland's theory be accepted that the Simla slates, Blaini, Infra-Krol and Krol are also Purana. Holland argued that since the Cambrian to Mesozoic systems were fossiliferous north of the Central Himalayan peaks, rocks of this period, if they existed south of the snowy range should also be fossiliferous; but it is at least equally inconceivable that whereas representatives of the Palæozoic and Mesozoic systems occur in the Pir Panjal range and also in the Eastern Himalayas, they should be altogether missing in the Simla region. The authors, therefore, wish to revert to Oldham's correlation of the Blaini with the Talchir, at all events until more satisfactory evidence to the contrary has been adduced; and would consider the Blaini, Infra-Krol and Krol sandstone as Gondwana. Lithologically they may be compared generally with a series of boulder beds, quartzites and slates which Wadia (1928) has shown to exist in the Pir Panjal range of Poonch and to be almost certainly Gondwanas, although these also are unfossiliferous. The Simla slates closely resemble the Attock and Dogra slates (Wadia, 1928), also apparently unfossiliferous, and both series may be older Palæozoic.

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SUBJECT INDEX.

GEOGRAPHICAL INDEX.

Name.	Latitude.		Longitude.		Pages.
	°	′	°	′	
Juin (hill)	30	42	77	35	35—37, 49.
Juned	30	59½	77	13	89.
Junga	30	1½	77	12	89.
Jutogh	31	6	77	7	9, 25, 65, 101—108, 110.
Kaflead	31	5½	77	3	94.
Kailana	30	41	77	53	46.
Kalana	30	55	77	14	19.
Kalka	30	50	76	56	
Kalsi	30	32	77	51	50.
Kandaghat	30	58	77	6	11, 20, 82.
Kanhar	30	47	77	21½	
Kanhech	30	49½	77	16	26, 27, 28.
Kanhechi	31	1	77	9	107.
Kanoh	30	59½	77	7	82, 107.
Karanji	30	56	77	11	19.
Karganu	30	54	77	13	12, 19, 20, 22, 83.
Kariauri	31	6½	77	2½	93.
Karog	30	56	77	12	19.
Kashmari	31	1½	77	4	83.
Kasumpti	31	5	77	11	89, 90, 106, 107.
Kathlighat	31	1	77	6	9, 10, 93.
Kawal (river)	30	52	77	12	11—13, 30, 33.

Name.	Latitude.		Longitude.		Pages.
	°	′	°	′	
Kurgal	30	55	77	12	
Kuwara	31	3½	77	10	86.
Kwanu	30	41½	77	45	38, 44.
Ladib	30	44	77	20½	29.
Lagnu	30	41½	77	24	32.
Lakhoti	30	56	77	16	23, 84.
Ludihana	30	43	77	27	32.
Mabhana	31	5	77	11½	90.
Madoli	30	42	77	27	33, 34.
Mahasu	31	6	77	17	111, 113, 118, 119, 122.
Mamlig	31	3	77	2	92.
Manal	30	46	77	22	58, 72.
Mandhali	30	50	77	57	
Mangan	30	45½	77	20	29.
Manjat	31	6	77	3	93.
Mareog	30	52½	77	13	12.
Mashobra	31	8	77	14	6, 111, 112, 118, 119, 122, 123.
Matiari	30	49	77	24	70, 71.
Mattiana	31	12½	77	24	111.
Minas	30	46	77	42	39.
Nagtikar (peak)	31	13½	77	20	120, 121.
Nahera	30	59½	77	13½	84.

Name.	Latitude.		Longitude.		Pages.
	°	′	°	′	
Panhoti	30	59	77	14	84, 85, 89.
Panti	31	8	77	7	99.
Parala	31	6	77	24	115, 116.
Parari-ki-khad (river) . . .	31	1	77	17	119.
Pateri ka Deo (river) . . .	31	6	77	2	93, 94, 110.
Pateuri	30	51	77	53	44.
Pau ka Ghat	31	8	77	2	97.
Paura	30	41½	77	25	82.
Pervi (river)	30	52	77	18	15, 16.
Piran	30	58½	77	17	88, 113.
Piriya Ghat	30	44	77	22	25, 28, 29.
Piroi	31	10½	77	1½	98.
Prospect Hill	31	6	77	8	16, 59, 101, 104, 107—109.
Pulilani Ghat	30	42	77	32	36.
Punnar	30	45½	77	25½	68, 71, 78, 79.
Rajgarh	30	51	77	18	16—20, 71, 74, 75, 101.
Rana Ghat	30	56	77	18	22, 23, 84.
Ranyat	30	46½	77	39	
Rerli	30	41	77	25	32.
Riwari	30	52	77	11½	11, 12.
Sahiya	30	37	77	53	50.
Sain Dhar	30	50	77	18	16, 25, 74, 75.

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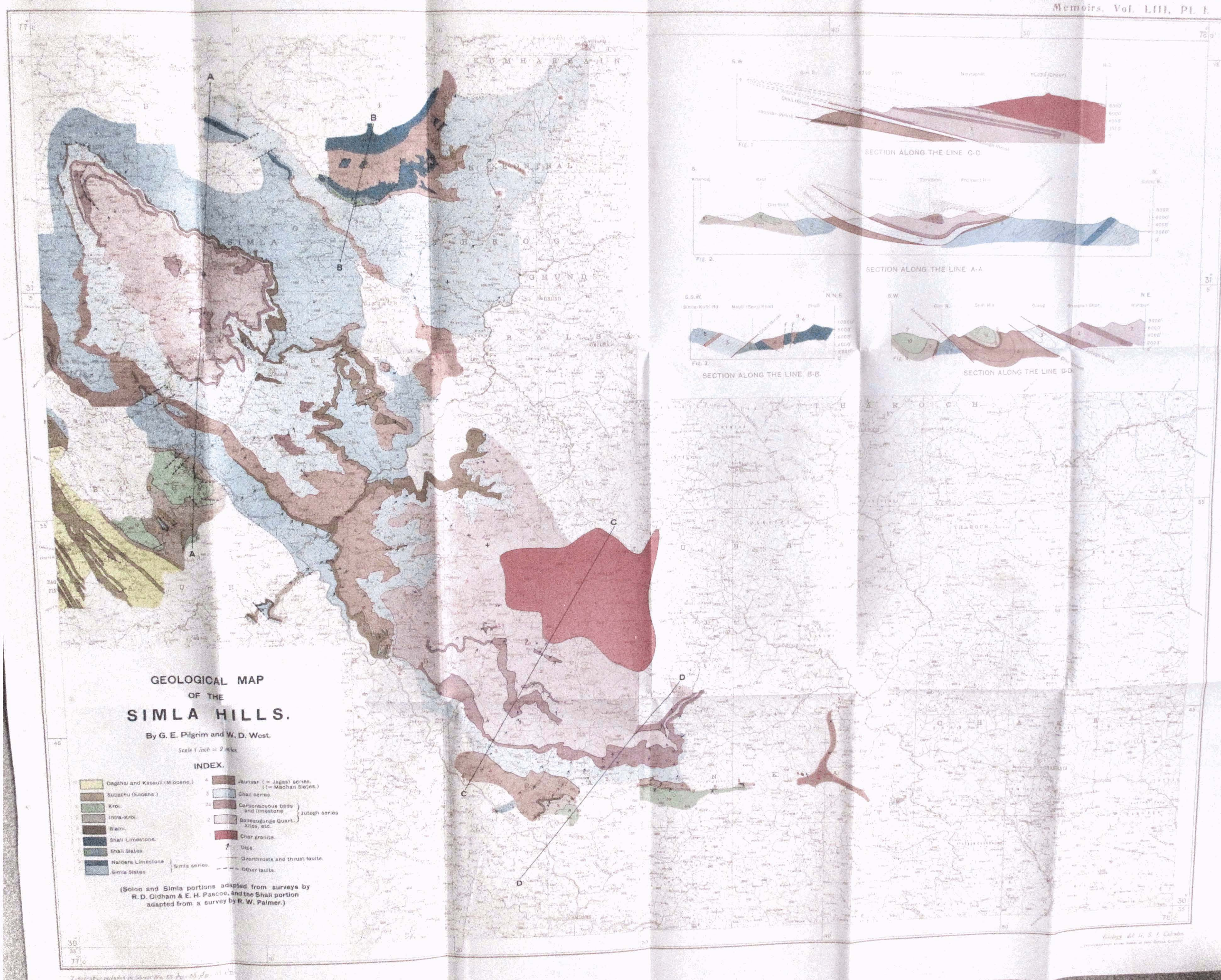
GEOLOGICAL MAP
OF THE
SIMLA HILLS.
By G. E. Pilgrim and W. D. West.
Scale 1 inch = 2 miles.
INDEX.
Dagshai and Kasauli (Miocene.)
Subathu (Eocene.)
Krol.
Infra-Krol.
Blaini.
Shali Limestone.
Shali Slates.
Naldera Limestone
Simla Slates
Simla series.
Jaunsar (= Jagas) series. (!= Madhan Slates.)
Chail series.
Carbonaceous beds and limestone
Boileaugunge Quartzites, etc.
Jutogh series
Chor granite.
Dips.
Overthrusts and thrust faults.
Other faults.
(Solon and Simla portions adapted from surveys by R. D. Oldham & E. H. Pascoe, and the Shali portion adapted from a survey by R. W. Palmer.)
SECTION ALONG THE LINE C-C
SECTION ALONG THE LINE A-A
SECTION ALONG THE LINE B-B
SECTION ALONG THE LINE D-D
SIMLA
CHOR