

These experiments were supervised by a Committee consisting of two representatives of the Department, two representatives of the British Bergius Syndicate and Dr. Bergius and in them trials were made with coals from various parts of the country in small converters while "Orgreave Washed Slack" obtained from South Yorkshire was selected as a suitable coal for tests in a continuously operated plant. The results were again promising and a plant embodying the latest improvements resulting from the work in Germany was supplied to the Fuel Research Station. This plant was installed towards the end of 1926 and in 1927, the small-scale experiments carried out at Rheinau were terminated by agreement and the work continued at the Fuel Research Station.

#### DESCRIPTION OF THE EARLY EXPERIMENTS.

The *Report* in describing the process as evolved originally by Bergius states that his converters were at first glass lined, and then made of plain steel. They were rotated about a horizontal axis, with pebbles within to assist stirring; about 100 atms. was the working pressure, and they were heated externally, either by gas or electricity, for about one hour. After removal, the products were distilled and treated by benzene extraction, the material so recovered being known as "oil". At a later stage in the evolution of his process, Bergius added oil to the charge, at first to avoid local overheating, and later to help in the working of a continuous plant into which a mixture of coal and oil could be pumped in the form of a paste. A further modification was the addition of a proportion of luxmasse, which consists largely of iron oxide with some alumina and titanium, to the charge in order to fix the sulphur in the form of iron sulphide. From subsequent researches at the Fuel Research Station, it was established that the luxmasse had also a definite catalytic effect in hastening the hydrogenation of the coal, contrary to the statements of Bergius.

Other British coals from the Nottingham and Derby, South Yorkshire and Durham coalfields were then tried, generally with satisfactory results. In the course of the work at the Fuel Research Station, the early stages of the reaction were studied and it was discovered that below the temperature of 450° C. normally employed by Bergius, the coal underwent marked changes. Thus, at about 370° C. in the case of a bituminous coal, reaction between the coal and hydrogen took place rapidly and resulted in the formation of a plastic material. If the products were allowed to cool immediately after reaching this temperature a solid product was obtained which had every appearance of having been through a fluid condition. This solid product, which was almost equal in weight to the original coal, had higher coking properties than the coal used in the experiment.

The continuously operated plant at Mannheim-Rheinau consisted of two horizontal reaction vessels in series, contained in baths of molten lead, heated by gas, and fitted with simple mechanical stirrers. A paste consisting of tar, coal and luxmasse was forced through these vessels, with hydrogen, at 150 atms. pressure. Various modifications were tried and numerous tests carried out with varying success, details of which are given in the *Report*.

The equipment which was installed at the Fuel Research Station as a result of the work is also fully described. It provided a continuously operating plant capable of dealing with a ton of coal a day, embodying all features of the latest practice, at the time of erection, of the Bergius Research Institute, together with an adequate plant for making hydrogen.

This plant was used originally for studying Parkgate coal from South Yorkshire and later coals containing less ash, namely, coal from the virgin Seam, Lanark, and finally Beamshaw coal from Wakefield.

## The Classification of the Archæan Rocks in India.

A SYMPOSIUM on the Classification of the Archæan Rocks in India was held at a meeting of the Geology and Geography Section of the Indian Science Congress (Indore, 1936) under the Chairmanship of Mr. B. Rama Rao, M.A., D.I.C., F.G.S., the President of the Section.

The President in his introductory remarks pointed out that there was no general agreement among the several workers in the Archæan tracts of India regarding the classification and correlation of these ancient rocks. He stated this disagreement was in no small measure due to the fact of the scattered occurrences of the Archæan rocks in widely separated areas with the intervening distances between them being so large as to make it almost impossible for any single field geologist to get a personal acquaintance with the typical characteristics of each of such separate regions. He requested Sir Lewis Fermor who had devoted more than 30 years of his life for an intimate study of many of the

Archæan tracts of India, to lead the discussion by giving an account of his views on the subject.

SIR LEWIS FERMORE opened his observations by a reference to his *Memoir* on the Archæans of India, which he said was in the Press and would be issued soon. He stated that he had divided therein the Archæans of the Peninsular India into two main provinces: the Charnockitic and the non-Charnockitic and had brought together the various formations of the different regions under that grouping. These major provinces were further sub-divided into minor provinces on the strength of lithological characters and associated ore deposits. Thus, in the non-Charnockitic Province, 10 sub-divisions, *viz.*, 3 iron ore Provinces of Singhbhum, Mysore, etc., 3 marble Provinces of Nagpur, Balaghat, Narbada and Son Valleys, etc., and 4 Igneous Provinces of Hyderabad, Bundelkhand, Shillong, etc., were grouped. In the Charnockitic Provinces, 18 sub-divisions were grouped under the Garnet, Iron ore and Manganese Provinces.

Speaking on the correlation of the Archæans Sir Lewis referred to some of the general features which had been dealt with in his Presidential Address to the National Institute of Sciences of India and also in the Introductory chapter of his *Memoir* which was in the Press. Referring to certain details of correlation, he stated that the recent work of Dr. Krishnan had shown that the Gangapur series of the Bihar and Orissa were the equivalents of the Sausar series of the C.P. He regarded the Kodurite series as hybrid igneous rocks with the Gondite series and pointed out the possibility of establishing an acceptable correlation by using the Gondite datum-line. The Dharwars of Mysore appeared to him to be more or less akin to the Sakoli series of the C.P. and the Sakarsanhalli series suggested a relationship to the Gondite series. However, the authors of a recent Bulletin on the subject of origin and correlation of the Sakarsanhalli series had not accepted the correlation with the Gondites and they had only shown them to belong to the Dharwars.

The Khondalites represented a higher grade of metamorphism and in the eastern ghat region, Sir Lewis considered the Khondalites to have been once formed in a deeper zone and subsequently uplifted. Portions of Malabar and Travancore had also the Khondalites and Charnockites.

In concluding his remarks, Sir Lewis pointed out the uncertainty of correlations in the Archæans of the Extra Peninsular India.

MR. D. N. WADIA spoke about the Archæans of the North-Western Himalayas. He stated that the Archæan rocks there occupied tracts of northern Hazara, Indus-Kohistan, Gilgit, Ladakh and the Zaskar range. The granites and gneisses of those areas were considered by Stoliczka and Lydekker to be Archæan (Central Gneiss), while the phyllites and schists were regarded as metamorphosed older Palæozoics. McMahon had established the intrusive nature of much of the Central Gneiss and he believed they were of considerably later age ranging from Palæozoic to Tertiary. Since 1928, the speaker had been working in the crystalline area of the Hazara-Kashmir syntaxis and the results of his field-work tended to prove that the Archæans (Dharwars) of that part of the Himalayas were largely of sedimentary origin. These rocks which had been named the Salkhalas series closely resembled the Jutoghs of Simla Hills. The unconformable relations of the Salkhalas to the *puranas* and the fossiliferous Cambrians were observed in some sections. The gneissification of the Salkhalas at many places and the wide prevalence of later intrusive granite gneiss in the Central axial ranges made it difficult to separate any remnants of the Archæan gneisses in the Complex. The Great Himalaya Range west of Ladakh was found to be largely constituted of the Salkhalas converted into paragneiss and the Nanga Parbat (26,620') massif was almost wholly built of those rocks with intrusive biotite-granite of Palæo-Mesozoic age and hornblende-granite injections of post-Eocene period. South of that Range, the Salkhalas showed a steadily decreasing grade of metamorphism and some of the rock elements showed remarkable resemblance with the Dharwar rocks of Rajputana and Singhbhum. Mr. Wadia thought it probable that the Great Hima-

laya Range represented the basement of the ancient Peninsular Archæans on which the Tethyan sediments were laid down. It thus denoted the Himalayan protaxis.

The speaker said that there were no Archæan outcrops between the Aravalli and the Kashmir Himalayas, except the few straggling hillocks of Kirana and Sangha, which probably represented the unburied peaks of a suspected ridge buried under the Punjab alluvium.

MR. W. D. WEST spoke on the difficulty of bringing the Archæans of the Rajputana into the "picture". Dr. Heron's work had shown that the Bundelkhand gneiss was older than the Aravalli series which represented the lowest division corresponding to the Dharwars. Elsewhere, in the Peninsular India, none of the gneisses were definitely established to be older than the Dharwars. There was also some difficulty in fitting up the Archæans of the Peninsular India with Dr. Heron's classification in Rajputana. If the Sausar series of the C.P. were to be correlated with one of the three metamorphosed sedimentary systems in Rajputana on lithological grounds, it was clear that they bore most resemblance to the Delhi system. But the fact that nianganese occurred in the Champaner series—which was the same as the Aravalli system—equally well suggested the correlation of the latter with the Sausars though the two were not alike lithologically. Whether the classifications fitted up properly or not, the probability of the Aravalli strike in S.-E. Rajputana curving round so as to join up with the E.W. strike of the C.P. remained clear.

Referring to Sir Lewis' remarks on the tectonic position of the Eastern Ghat Charnockitic province, Mr. West enquired whether there was any progressive change in the metamorphic grade within the non-Charnockitic province proceeding away from the eastern area and if such a change could be shown to exist, he thought it probable that tilting rather than faulting had occurred.

Mr. West also alluded to Auden's work in the Himalayas, which had shown the existence of the Archæans there with the Aravalli strike.

MR. D. S. BHATTACHARJEE spoke on his recent work in the East Bhandara, C.P., which disclosed certain interesting features and which were very suggestive to him in solving the problem of the classification of the Archæans of India. Mr. Bhattacharjee stated that the tract was bounded by rocks with the three regional strikes, *viz.*, the Satpura, Eastern Ghat and Godavari strikes and itself showed numerous evidences of balancing of the directed pressures responsible for these strikes. In the deeper vertical zones of metamorphism, granite-like rocks with what could be described as "Triangular foliation" were developed; while in the higher zones, foliated rocks closely resembling the Sausars, Sakolis, Cuddapahs, etc., were found. According to him, those rocks were mere metamorphic variants of one and the same group of rocks involved in different proportions and altered under different conditions at different periods of time.

The speaker thought that the studies in the Archæans of India had so far been almost wholly confined to Belts characterized by effects of singularly dominant directed pressures and that was probably the reason for the general disagreement of the various investigators on the method

of classification of these rocks. It appeared to him very likely that when the large tracts outside those belts would be examined, many zones of balanced directed pressure might be found and that the study of such areas might throw more light on that highly controversial subject.

MR. M. B. RAMACHANDRA RAO spoke on the metamorphic rocks of the Sakarsanhalli area (in Mysore) which had figured rather prominently in the correlation of the Archæans. The results of detailed mapping and examination of this belt had already been published in a *Bulletin of the Mysore Geological Department*. The rocks occurred as small included patches and lenticular bands along with the hornblende schists in the intrusive granitic gneisses and the speaker was indebted to the President of the meeting for having suggested a possible stratigraphic sequence which could be deduced from the geological section given in the *Bulletin* referred to. According to that view, the metamorphic rocks of Sakarsanhalli appeared to dip underneath the hornblende schists but whether the stratigraphic relation could be actually established or not was left entirely to future work.

Regarding the correlation of the rocks with the Gondites, the speaker said that nothing further could be definitely stated. The manganese garnet of Sakarsanhalli had raised some discussion and had been commented upon by Sir Lewis Fermor who showed its relationship in composition to the garnets from the Gondite-Kodurite series. Originally, the analysis of the Sakarsanhalli garnet had been interpreted rather differently since it was neither so highly manganiferous as the Gondite garnets nor so highly calcic as the Kodurite garnets. The CaO in the particular specimen had been treated as rather exceptional but the comparison instituted then had no implication of correlation. However, subsequent to Sir Lewis' paper on the Manganese-Lime series of garnets, the speaker was engaged in studying some of the published analyses of many garnets from various parts of the world and the inspection of these analyses had shown him that a few of the garnets from extra-Indian localities could easily be shown to lie within the Gondite-Kodurite garnet field plotted in Sir Lewis' diagram, though the typical Manganese-Lime series appeared to be rather rare outside India. The subject was under further investigation and he hoped that Sir Lewis' view regarding the importance of the peculiar metamorphic associations in correlation problems would ultimately prove possible to be established.

DR. S. K. ROY remarked that Sir Lewis' suggested classification of the Archæans into two main provinces and their further sub-divisions was most interesting and hoped that further investigation by Indian petrologists would prove the validity of Sir Lewis' classification. The speaker, with his staff and students of the Indian School of Mines, had carried out some detailed mapping and petrological investigations of the Dharwars round the Jharia Coal Field and the Mica Mines of Kodarma during the past eight years. Those areas were, however, "little" in comparison with those with which Sir Lewis or Messrs. Wadia, West or Rama Rao were acquainted with and on the experience of which they had based their classification. But, so far as the work carried out by the speaker and

his associates was concerned, they had found Grubenmann's system of classification and general nomenclature of metamorphic rocks quite satisfactory. Grubenmann had proposed to group the Kristallemmenscheifer into twelve groups, while Sir Lewis grouped the Indian metamorphics into 18 provinces. Grubenmann's classification was followed now-a-days in many parts of the world and the speaker believed that although the 18 groups of Sir Lewis showed individual provincial characters—which were, of course, somewhat different from what was usually understood by the provincial characteristics of igneous rocks—ultimately many of the rocks of those provinces might be fitted up with Grubenmann's classification. The speaker thought, for that purpose, careful chemical analyses, calculation of the Niggli values of those analyses and the projection of their various ratios on the Niggli-tetrahedrons, were necessary. Those data would not only determine the original igneous or sedimentary nature of the rocks but also the positions of the latter in Grubenmann's scheme would be made clear.

As suggested by Sir Lewis himself in his Presidential Address to the National Institute of Sciences, Dr. Roy thought it would be better to follow as far as possible Grubenmann's classification of the metamorphic rocks to classify the Archæan rocks of India with, however, occasional modifications to meet the local needs.

SIR LEWIS FERMOR then replied to some of the questions which had been put to him. In reply to Dr. Roy's remarks, he stated that his classification of the Archæans into the Charnockitic and non-Charnockitic Provinces and their further sub-divisions were based on a different conception altogether and had no specific relation to Grubenmann's scheme.

The President thanked the several speakers for their valuable contributions to the discussion and concluded the proceedings with the following remarks:—

"The problem no doubt presents considerable difficulties. A good deal of intensive field work in the several regions of Archæan rocks and a careful co-ordination of the results of such work are still necessary before any final solution could be reached. The classification of the Archæan tracts into provinces and sub-provinces based on mineralogical constitution and the association of epigenetic ores will undoubtedly help to split up the complex formations into convenient sections, but for purposes of correlation of the different isolated formations, it will have to be verified and supplemented by intensive petrogenetic studies of many of the apparently allied types. The correlation of disconnected formations of Archæan rocks of widely separated areas on the basis of the occurrence of any particular lithological type as a recognisable datum-line is not always reliable. But still, in the case of the Archæan rocks several clues will have to be followed and the publication of Sir Lewis' *Memoir* will be eagerly awaited by all students of Archæan Geology to see the lead Sir Lewis gives for amplified application of his line of study.

"Mr. Bhattacharjee's startling inference that the granitic rocks with 'triangular foliation' and the rock groups described as the Sausars, Sakolis and Cudappahs in the Central Provinces, are the resultants of directed pressure of one

and the same mass of granitic material along different zones in a vertical column is not likely to find favour with other geologists acquainted with the region. It is not unknown that in the Archæan Complex, rocks of different modes of origin, involved in various processes of alterations have been rendered almost alike to outward appearance, and the task of the field geologist is, if possible, to sort them out from such confused jumble. In the Archæan complex of Mysore, which had been believed till now to have consisted almost entirely of igneous material, rocks of clearly recognisable sedimentary features are being traced and therefore considerable caution will be necessary before any extreme views could be formulated regarding the genesis of these complex formations. Attempts have been frequently made to classify the Archæan rocks into different groups based on lithological characters, but the question as to how far the crystalline schists as exposed in the several parts of India could be constituted into separate stratigraphic divisions in each of such regions, on the recognition of reliable evidences of break, seems to me to merit further detailed investigation. This involves a more intensive field study of the several exposures of conglomerates which might be found in the different regions of the Dharwar schists. I have already stated in my address that in Mysore from amidst the confusing types of 'conglomeratic rocks' of diverse modes of origin, two clearly marked horizons of what could be regarded as *basal* conglomerates are recognisable in the belts of Dharwar schists. The older set is characterized by the occurrence of pebbles of only quartzites whereas the younger contains in addition pebbles of granitic rocks, suggesting thereby the probability of some of the granites being really older than a section of the crystalline schists which are all at present grouped as one unit.

"This fact of the probable existence of a granitic series older than a section of the crystalline schists included under the Dharwars, leads me to offer a few remarks on the still controversial stratigraphic position of the Aravalli and the Delhi systems in the Archæan rocks of India. I am personally unacquainted with much of these formations and if I venture to offer any remarks they may be regarded more as suggestions than as positive statements. The Aravallis of Rajputana and the Champaner series of Gujerat seem to be now regarded as of one and the same formation. When I had an opportunity of making a hurried study of the latter as exposed in the southern parts of the Bariya State, I got the impression that portions of the Champaner series resembled very much in appearance the rocks of the 'upper division' of the Dharwar schists of Mysore, and also that the quartzites and shales exposed further north forming a major portion of the State bore a striking resemblance to the recorded descriptions of the Idar Quartzites and Phyllites of Mr. Middle-

miss, and parts of the Delhi Quartzites of Dr. Heron. Between the typical Champaner beds and those quartzites there is a zone of conglomerate which at the time when I examined struck me to be autoclastic, but whether it is so or not needs verification by closer investigation and detailed mapping. At any rate, in that region, the typical Champaner beds come in contact with the series of quartzites and shales or phyllites, comparable in character to the types described as forming parts of the Delhi Quartzites. All these formations bear a close resemblance in their lithological character to corresponding types of the middle and the upper divisions of the Dharwar schists of Mysore in accordance with the classification I have tentatively proposed in my address. On the strength of the occurrence of a series of granites older than a portion of these crystalline schists, it would be a point for consideration, if parts of the formations now classified as Aravallis, Champaners and the Delhi Quartzites, may not correspond to the "upper division" of my classification of the Dharwar schists of Mysore.

"Let me also say a few words regarding the Sakarsanhalli series of Mysore. This series seems to have attained more prominence for purposes of correlation than what the actual facts warrant. The Sakarsanhalli rocks form a series of a few insignificant outcrops scattered about in the granitic gneiss, and however interesting they may be from a petrographic point of view, they furnish very little data for purposes of reliable correlation. The question of their origin, whether they are merely the metamorphosed facies of the Kolar hornblendic schists of igneous origin, or whether they constitute thermally altered representatives of an assemblage of a mixed series of sediments may be taken as still unsettled. The occurrence of manganese marbles in the series has suggested the alliance of the rocks with the gondite series of C.P. Manganiferous dolomites and limestones are found further west in the "middle division" of the Dharwar schists, and in some parts where the rocks are thermally metamorphosed, manganese silicates are also found developed in such limestones. The Sakarsanhalli limestone shreds with their manganiferous silicates may perhaps represent the remnants of a once continuous folded series of limestones, but reliable evidences are still lacking to prove this conclusively.

"For a successful solution of the problem of the correlation of our Archæan rocks I think it is necessary for each large area where they are typically exposed, to record how far it is clearly possible to classify the schists into different divisions on provable stratigraphic breaks, and when this has been done, to arrange for a joint investigation of such typical areas by a small body of experienced field geologists consisting of individuals representing the regions on which they have unquestionable knowledge."