VICTORIA TERMINUS, BOMBAY.

B. B. & C. I. RAILWAY STATION, BOMBAY.

The

Growth of Railways in India.

THE growth of Railways in India forms a history illustrating most vividly the difficulty of developing what are, in the main, commercial undertakings, independently of the capital held by the Natives of the country. Had the moneyed classes in India realized from the first the importance and ultimate immense advantage of improved communications, these difficulties would have been slight. As practically no such contributions have been received, the necessary funds had to be found by the Government, and the history naturally divides itself into the policies carried out by each Viceroy in his turn; policies in which his own individual opinion had, generally, a preponderating influence. It will be seen that these conditions did not lead to a continuity of policy either in construction, maintenance, or in due provision for meeting the extraordinary expansion, both in traffic on open lines and the imperative demands for new railways, and for developing or increasing the capacity of existing systems.

LORD ELLENBOROUGH.
1842—44.

In 1843, just before the railway mania in England, a company, of which Mr. (afterwards Sir R.) Macdonald Stephenson was Chairman, proposed to construct railways in India, and Sir Macdonald may, therefore, be considered to have been the pioneer of these enterprises. The deadly famine in 1837 over the North-West Provinces and Rajputana provides an object-lesson of what used to happen in India before it was possible to throw food-grains into the stricken districts.

LORD HARDINGE.
1844—48.

In 1845, the East Indian Railway Company submitted a prospectus to the Court of Directors, East India Company, proposing to raise a capital of one million sterling for an experimental line, 140 miles long, from Calcutta to Allahabad. At that time the Grand Trunk Road was being constructed towards Peshawar, and the only intercourse with England was by sailing vessels round the Cape. The governing bodies were the Court of Directors of the Honorable East India Company, the Board of Control, and the Government of India. The first suggestion was for a three per cent. guarantee, or its equivalent in an annual bonus. Mr. Macdonald went out to India in July of the same year, also a Civil Engineer, Mr. Simms, accompanied by two Indian Royal Engineers, and such good work was done that by April 1846 the survey of the line from Calcutta *viâ* Mirzapur to Delhi was completed; important statistical information was obtained and an elaborate report was transmitted to the Directors. Mr. Simms submitted a memo. on February 2nd, 1846, suggesting terms which have become, in a major part, the basis on which railways have since been constructed by companies.

Meanwhile, the Court of Directors sent out a despatch to the Governor-General, in which they expressed an opinion that there were special dangers attending railway construction in India, such as floods, cyclones, white ants, and luxuriant vegetation, besides the absence of competent engineers acquainted with the peculiarities of the country, which did not encourage them to recommend any operations on a large scale. In consequence, the only contracts made were for 192 miles in all, *viz.*, Howrah to Raniganj; Bombay to Kalyan, and Madras to Arconam. At this time the Government of India may be considered to have been lukewarm, although the Governor-General was strongly in favour of assisting private enterprise; as to the Board of Control it was "narrow and obstructive," and it was not until 1847 that the terms of the above contracts were settled. The Bombay project was submitted to Robert Stephenson, who disapproved of the Government proposals.

MARQUIS OF DALHOUSIE.
1848—1856.

On the 19th March 1849, the Secretary of the Board of Control, James Wilson, sent a despatch to the Court of Directors and agreements were eventually signed on 17th August 1849. It was proposed to start from Calcutta towards Mirzapore or Rajmehal and to put down the English narrow guage, *viz.*, 4 ft. 8½ in. Mr. Simms, in a despatch, dated August 2, 1850, recommending a wider gauge, stated that thereby the centre of gravity of all rolling-stock would be lowered, the lateral oscillation lessened, motion rendered easier, and wear and tear diminished. Lord Dalhousie sent a despatch from Chini in July 1850, advising a Burdwan alignment so as to tap the coal-fields. He also advocated a single line of a 6 ft. gauge. Meanwhile, the Court of Directors were beginning to realize the enormous advantage, both moral and material, attending the development of railways and roads, and expressed a wish to possess a regular system of railways, and that without unnecessary delay. Work was commenced on the East Indian Railway in January 1851. The

Court of Directors having settled on the present standard gauge of 5 ft. 6 in.; Mr. (now Sir Alexander) Rendel being the Consulting Engineer. The Madras Railway in 1852 made an unsuccessful attempt to obtain sanction for constructing railways by direct State work.

The year before any railway was opened, the gross trade of the country amounted to Rs. 32 crores, and had stood at that figure for some time. Lord Dalhousie's celebrated minute was signed on April 20, 1853, and was one of the most statesmanlike documents that has ever been penned. The Governor-General considered that railways are National Works, and that they should therefore be controlled by Government under regulations settled by law, which should not be needlessly or vexatiously exacting. He advocated the immediate construction of trunk lines from Calcutta to Lahore, from Bombay to tap this one; from Bombay to Madras, and from Madras to the Malabar Coast on the West. He foresaw the great social, political, and commercial advantages of such lines, which were to form the main arteries of a complete network of railways.

The system of Government Consulting Engineers was first introduced in 1849, one being allotted to each local Government. These were subsequently reduced to four, *viz.*, the State, Madras, Bombay and Burma. Although the Court of Directors had approved a large scheme and had ordered surveys on August 17, 1853, during the three years from 1853 to 1855, only 169 miles were opened, being an average of 56 miles a year. The capital outlay during that period was Rs. 5,50,00,000 or Rs. 1,83,33,000 a year. The average gross earnings per mile per week were Rs. 81; the average percentage of working expenses to gross earnings was 54,33; and the percentage of net earnings to capital outlay 0·72. The first sanction to the construction of the North-East lines of the Great Indian Peninsula was given in 1850; the South-East line was sanctioned in 1854. The first opening of any portion of the following lines for traffic occurred in this period, *viz.*, the East Indian and the Great Indian Peninsular.

ASSAM-BENGAL RAILWAY.—Cut and Cover at Tunnel No. 8a.

LORD CANNING.
1856—1862.

By the end of 1855 Lord Dalhousie's projected railways were being actively carried out; but progress was checked by the Mutiny of 1857, although it was due to the guaranteed system that the work was not stopped altogether, for funds were available which, under State control, would have been required elsewhere. The invaluable service rendered to the military by the short length of line then opened was again an object-lesson to the authorities. After the Mutiny in 1857, which was estimated to have cost the railways some three millions sterling, the friction that had arisen between the civil engineers and the consulting Royal Engineers in India became so acute that the matter was brought before the House of Commons; the result being that a compromise was effected, though it would have been much better had the matter been fought out. India passed directly under the Crown in 1858 and the reign of the Hon. East India Company came to an end.

On March 13, 1860, the late Sir Juland Danvers, then Secretary to the Railway and Telegraph Department of the India Office, presented his first report on Railways to Sir Charles Wood, Secretary of State for India. This was prepared from information received. In it he stated that the 5 ft. 6 in. gauge had been finally adopted, and that the rate of exchange had been fixed at 22*d*. per rupee. The 99 years' guarantee, which it had been finally decided to grant to Indian Railway Companies, applied to all monies paid into the Government Treasury and expended with the sanction and approval of the Government; on the closing of the capital account the surplus subscribed was to be returned to the Companies. Whenever the profits were less than the guarantee of 5 per cent., the Government had to make it up; any surplus was to be equally divided between the Companies and the Government, and when the amount so received covered all that the Government had disbursed (*plus* simple interest), the whole of the profits were to go to the Companies; the railways might be surrendered for actual cost at 6 months' notice; the Government having the option to purchase after 25 or 50 years at the mean value of the shares during the previous three years, taking over the rolling-stock at a valuation or, as an alternative, they could pay a corresponding annuity; land was given free. Sir Juland stated that the experiment of direct Government construction had been sanctioned for a line from the Iron Works recently established at Naini Tal, to join the East Indian or Oudh and Rohilkhand. The Superintendent, Mr. Sowerby, was of opinion that the cast-iron rails which he was able to turn out might be advantageously used, at a saving of Rs. 13,900 per mile. Allusion is also made in the report to Light Railway and Tramway lines, and it is stated that Col. H. Barr, of the Bombay Army, had received permission to spend £300 in conducting experiments to prove the value of a danger fog-signal which he had invented. On the map attached to the report the following lines are shown as "suspended," *viz.*,—Amritsar to Delhi, Jubbulpore to Allahabad, Kooshtea to Dacca, Sholapore to Bellary, and Salem to Ramnad.

In the next year's report (1860-61), Sir Juland states that the Oudh Railways were stopped, the Secretary of State having decided not to guarantee the capital for any new undertaking, the rupee having risen to 24*d*. The Governor-General consequently reported that construction should go on by all means on the lines already sanctioned, but that no more works would be commenced till those in hand were completed. The urgent need for feeder roads was beginning to be realized, and the Madras Government had determined to build 1,083 miles of them. A letter is noted from Mr. W. B. Wright, the Locomotive Superintendent of the Madras Railway, in which he says:—"I have one native, by name Gunnagee Row, whom I think competent to drive a locomotive, but his own want of self-reliance precludes him from being intrusted with the charge of one." He further states that, the apprentice system has now on the whole been attended with marked success, and that India must become the nursery for further requirements. Sir Charles Wood, then Secretary of State, wrote to the Government of India that he awaited with interest the result of the trial it was proposed to make of a cheap description of tram-road on some short feeder of considerable traffic.

The first portion of the following important lines were first opened for traffic in Lord Canning's time, *viz.*, the Bombay-Baroda and Central India proper, the Madras proper, and what is now the North-Western (State) proper, all on the 5 ft. 6 in. gauge. The metre gauge appeared for the first time on the South Indian. The average earnings of all the lines during the six years was Rs. 149 only per mile per week; the average percentage of working expenses to gross earnings was 48·75; of the net earnings to capital expended 1·19; of miles opened per annum 236 (or 1,418 in all), giving a total of 1,587 miles open for traffic. The yearly average of capital outlay was Rs. 475 lakhs (or 28½ crores in all) giving a total expenditure of Rs. 34 crores.

Lord Elgin.
1862—1863.

Sir Juland Danvers was now designated Government Director of the Indian Railway Companies and attended all their Board Meetings. His reports contained a synopsis of those received from India. In these years a good many schemes for Light Railways were launched, but did not float long. The shortage of rolling-stock, which has been perennial, was beginning to be felt, especially on the Sind line. Lord Elgin travelled by rail to Benares, and Sir Bartle Frere opened the Bhore Ghaut on April 24, 1863; 42,000 coolies had been employed on this work at one time. The Government Director reported that the number of passengers and tonnage of goods using the rail was in proportion to the inducements offered by low rates and sufficient accommodation, but that, at the same time, low rates and remunerative rates were not synonymous and that, for instance, it was doubtful, whether it was possible to carry passengers with a profit at less than ⅛*d*. per mile. Iron sleepers were first introduced and 755 miles of them were ordered. They were "Greave's" circular cast-iron bowls, and were laid down on the Punjab line, on the Eastern Bengal, and on the Madras Railway, where they did good service in all kinds of ballast, and even without any ballast at all.

The Eastern Bengal Railway, on the 5 ft. 6 in. gauge, was the only one of which any portion was first opened in Lord Elgin's time. The average mileage completed being 460 (or 920 in all), making a total of 2,507. The average earnings per mile per week dropped to Rs. 140, while the percentage of working expenses to gross earnings rose to Rs. 60·04, and of net earnings to capital 1·30. The average capital outlay was Rs. 950 lakhs (Rs. 19 crores in all), making a total of Rs. 53 crores up to date. The Tapti Bridge, 1,875 ft., the old Nerbudda, 4,688 ft., and the Soane Bridge, 4,726 ft. long were opened during this period.

Lord Lawrence.
1864—1869.

Soon after taking up the reins of office, Lord Lawrence decided that further application of the agency of Companies was undesirable; moreover, there happened to be a plethora of Government Engineers, for whom work had to be found, and although they had no experience on railways, they were put in charge of the construction then—and have been transferred on promotion ever since—from road and town surveyor's work and from the Irrigation Department, to the Railway branch. As one of them naively confessed some 20 years later, at the Society of Arts, they "had to learn a good deal, and necessarily at the expense of the State." The Governor-General sent home a despatch embodying his views, but Sir Stafford Northcote did not adopt them entirely, for he considered that "commercial" lines should be built as heretofore leaving "political" lines to be constructed by the State, for which purpose a fixed annual charge would be made. Lord Lawrence dissented and before he left India he submitted a minute virtually stopping any new guarantee, recommending State construction, and the withdrawal of all initiation and practical direction of measures from the India Office. In his opinion 3¾ millions sterling could be invested in railway extension every year, and in twenty years the yearly charge would be reduced to one million. He estimated that the gross average earnings would reach £30 per mile per week by 1889 (this they have never done), and considered it would be a mistake to reject the narrow gauge. In the same year the Secretary of State entered into new agreements with the Great Indian Peninsular, and the Bombay-Baroda and Central India, without consulting the Government of India, who protested—but too late. The first unguaranteed railway, 23 miles long, from Nalhati to Azimgunge, was opened by the East Indian Branch Company in 1863. In 1864, the big cyclone occurred in India and caused great damage to railways, and in 1866 the terrible Orissa famine diverted funds from Public Works. In March, 1864, Sir Charles Wood issued his famous despatch, giving rules as to what should be charged to Capital and Revenue respectively. This was a bone of contention between the Government Consulting Engineers and the Agents of the Companies for years. So long as there was no chance of a surplus over the guaranteed interest, the Agents tried to charge everything to Revenue, but whenever the receipts gave signs of a possible surplus they fought tooth and nail to save Revenue as much as possible. Especially acute became these struggles as the time approached when the lines might be taken over by Government.

With the extension of railways, the want of feeder roads was felt more and more. It was during this period that the Calcutta and South Eastern was started to serve a new Port Canning on the Mutla, whereby the dangers of the Hooghly were to be avoided, and steamers were to ply to the Straits, Chittagong and Akyab. Messrs. Brassey, Wythes, and Henfrey held two important railway contracts, one from Calcutta to Kooshtea, and the other from Amritsar to Ghaziabad, but they did not make much money over them, owing to causes which affected all public works: floods, famines, the Mutiny, and the subsequent rise in the price of labour. Sir Juland Danvers again reported rolling-stock to be inadequate; that the cast-iron bowl-sleepers were answering well; that steel rails were being introduced; that feeder-roads were delayed for want of funds; that natives of India only held one per cent. of the railway stock; that the form of debenture contract had been settled; that coal cost from 58*s*. to 72*s*. a ton; that Karachi harbour should be improved; that mails only took 5 days between Calcutta and Bombay; that the Provident Fund had been established; that the Madras Railway had carried 23,000 tons of food to the famine districts, at ⅛ pie per maund per mile; that 40 inches of rain fell in two days on the Sind Railway, nearly wiping it out; that he advised the formation of a Reserve Fund for renewals; that it would cost £1,300,000 to make good flood and other damage on the Great Indian Peninsula.

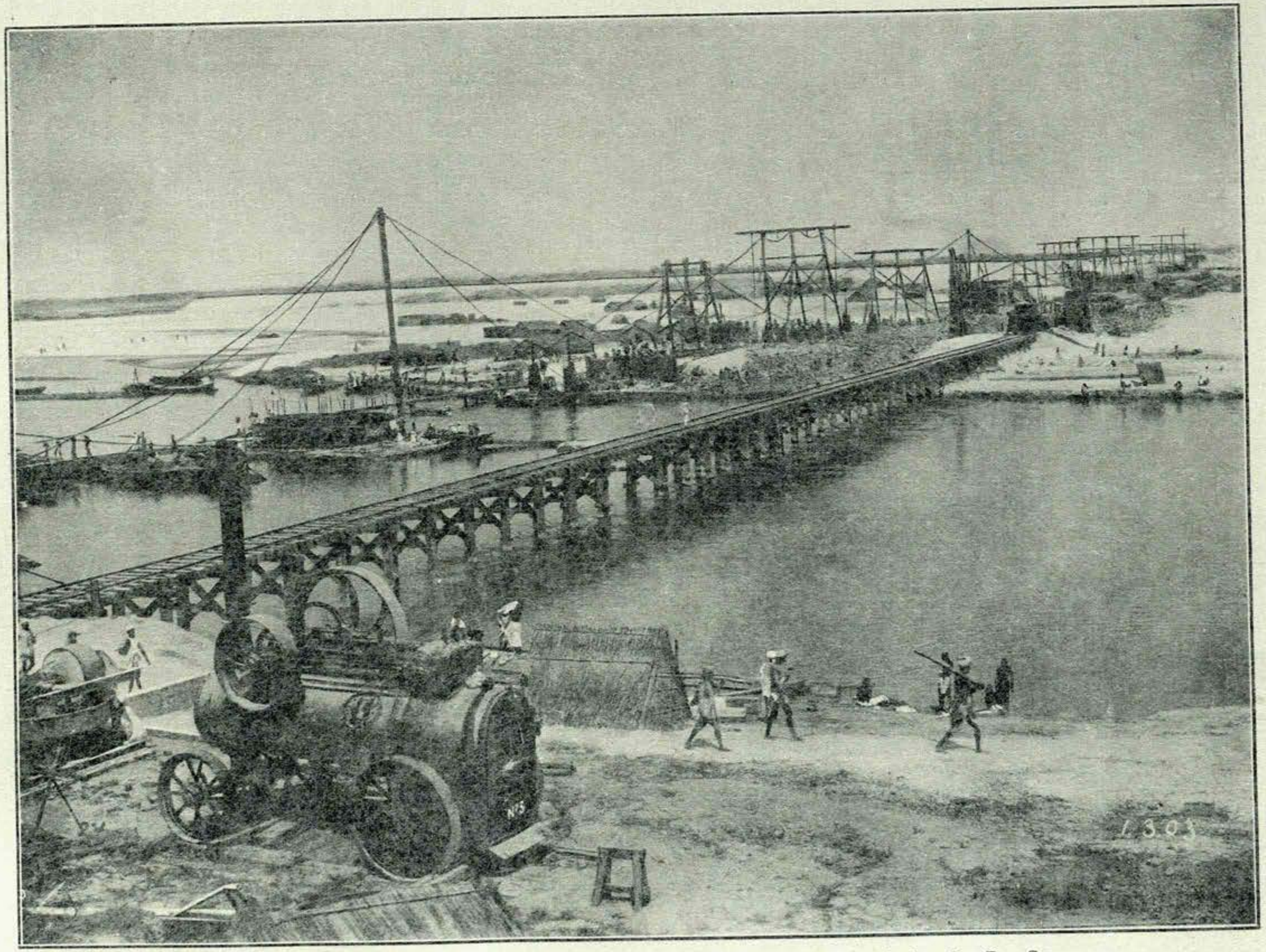
The deficit in 1868-1869 stood at Rs. 166½ lakhs; but meanwhile the total trade of the country had risen from Rs. 32 to 89 crores, and more than compensated the financial loss on guarantees.

During Lord Lawrence's Viceroyalty the only railway of which a portion was first opened was the Oudh and Rohilkhand, a 5 ft. 6 in. line. The average gross earnings per mile per week were Rs. 207, a sensible advance; the average percentage of working expenses to gross capital was 54·62, also a great improvement, while the average percentage of net earnings to capital rose to 2·93; the average mileage opened during the five years was 300 (total 1,501), giving a grand total of 4,008 miles; the average capital outlay was Rs. 620 lakhs (total Rs. 31 crores), bringing the grand total up to Rs. 84 crores, or, at the present rate of exchange, 56,000,000 pounds sterling. The following bridges were opened during this period:—The Tonse, 1,194 ft.; the Jumna (Allahabad), 3,150 ft.; the old Cheyer, 3,500 ft.; the old Papagni, 1,410 ft.; the Jumna (Delhi), 2,697 ft.; the old Chitravati, 2,670 ft.; the old Penner, 1,830 ft.; the Beas, 3,828 ft.; and the Jumna (Saharanpur), 2,675 ft. long.

Lord Mayo.
1869—1872.

Under Lord Mayo the State construction of railways, mostly on the metre gauge, was encouraged in every way; the guaranteed system practically came to an end for a time, and special engineers were engaged both in England and from America to teach the Government Engineers their new duties. The authorities had been so charmed with the capabilities of the Festiniog narrow gauge line, handling mineral traffic in a mountainous country, with the load nearly all down hill, that they applied the same system on a grand scale in the plains of India, for the conveyance mostly of light and bulky produce in every direction. To facilitate this, the maximum running dimensions were enormously enlarged; a comparison of these in the proportion of the gauges shows this plainly. Whereas on the metre gauge rolling-stock 8 ft. 6 in. wide and 11 ft. in height was allowed, on the 5 ft. 6 in. gauge only 10 ft. 6 in. and 13 ft. 6 in. respectively were allowed. In proportion to the gauges, these latter wagons would have been 14 ft. wide and 17 ft. 8 in. high, whereby their capacity per foot run of train would be increased by 75 per cent. Or to put it the other way, had the metre gauge stock been restricted to the comparative size of the 5 ft. 6 in., the wagons would have been only 5 ft. 1 in. wide and 6 ft. 7 in. high and their present capacity would have been diminished by 64 per cent.

The Indian Engineering College at Coopers Hill was established in 1871, to give Civil Engineers a special training. The North-West Provinces and Oudh were again ravaged by famine in 1869; and a cyclone occurred in the same year which was almost as disastrous as the one five years previously. The most remarkable damage was that done at the Gorai Bridge, on the Goalundo Extension of the Eastern Bengal Rail-



CURZON GANGES BRIDGE.—Allahabad-Fyzabad Railway. Sinking Brick Piers during the Dry Season.

way, where one of the iron piers in course of erection (14 ft. in diameter, 45 ft. long, weighing 120 tons) was overturned and never found again, although a new pier was sunk on the same spot.

The railways, owing mainly to an absurdly high standard of construction, had cost £17,000 a mile, and the financial equilibrium having been upset by all the disasters of recent years, the guarantee system fell into disrepute, and the Government thought they could do better themselves, as money could be borrowed on easier terms by the State. Lord Mayo, though he duly appreciated the great services which the Guaranteed Companies had rendered to India, hoped to profit by their experience for the benefit of the future lines, in economy at least, if not in efficiency. Sir Juland Danvers reported that modified terms of contract with Companies had been formulated, and that the rules guiding the State were exceedingly complex. The Scinde, Punjab and Delhi Railway settled a contractor's claim of £213,598 for £45,000, at a cost of £34,000, spread over 10 years arbitration. Major Taylor, who was killed in the Naini Tal landslip shortly afterwards, introduced the American train-despatcher system on the Port Canning line, where it answered very well, as the traffic was exiguous and not tied to time particularly. It was decided to build the Punjab Northern line as cheaply as possible, on the metre gauge, and for a speed of 15 miles an hour; the Indus Valley was to be on the same gauge, although connecting two 5 ft. 6 in. lines; the Volunteer force was started; the seer was made equivalent to a kilogramme, and the Suez Canal and the Mont Cenis Tunnel were opened. Lord Mayo strongly recommended the metre gauge on the ground of economy. A Gauge Committee was appointed; Sir R. Strachey, Colonel Dickens, Sir John Fowler, and Sir Alex. M. Rendel recommended the narrow gauge; Sir John Hawkshaw estimated the cost of a light broad gauge as £800 a mile more than the narrow gauge, by choosing which Sir Douglas Fox considered that £17,000 a mile would be saved. But the military authorities, whose views were represented by Lord Napier, were dead against its adoption. In the end the idea of confining the metre gauge to feeder lines was entirely dropped.

During Lord Mayo's Viceroyalty, which came to a sudden end in such a tragic manner, the average earnings per mile per week rose further to Rs. 265; the percentage of working expenses to gross earnings also rose slightly to 55·34, while the average percentage of net earnings increased to 3·22. The average number of miles opened was 359 (total 1,066), making 5,074 in all, the average capital outlay having been Rs. 2,00,23,000 (total Rs. 6 crores and 70,000), making Rs. 90 crores and 70,000 in all. The rate of exchange had dropped to 22½*d*.

The Sutlej (Ludhiana), 5,733 ft.; the Nerbudda, 1,052 ft.; the Tungabadra, 4,060 ft., and the Gorai, 1,759 ft. long, were the bridges opened during this period.

The Secretary of State permitted the reading of a paper by Mr. W. B. Thornton, C.B., Public Works Secretary, India Office, at the Institution of Civil Engineers, on February 2, 1873, which gave rise to an animated discussion lasting over several evenings and called the "battle of the gauges," from which, however, it was impossible to come to any definite conclusion.

Lord Northbrook.

1872—1876.

In Sir Juland Danvers' reports for this period, we find chronicled extensive floods and more famines, and that 842,696 tons of food grains were poured into the distressed districts. Sir Juland complained of the large amount of capital locked up in stores; he pointed out that Karachi harbour was of great importance, and again urged the construction of feeder roads. Out of 61,940 proprietors of Indian Railway securities only 388 were Natives; showing that the savings were either spent on jewellery, and otherwise squandered in wedding or other festivities, or that they were hoarded; while the class of money-lenders charged, and obtained with ease, one anna in the rupee per month, or 75 per cent. with very little risk.

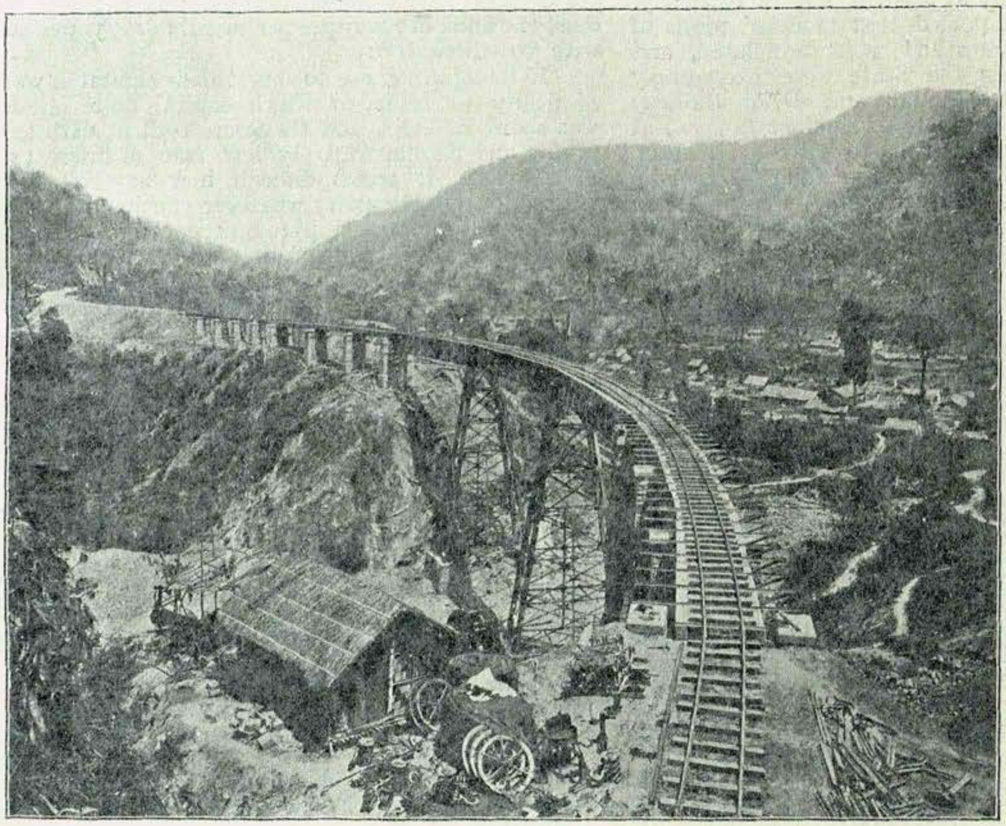
If foreigners chose to invest their capital in works of utility to India, of which capital quite one-half was spent in India, and they were content with small profits and a comparatively low rate of interest for many years, it seems difficult how any intelligent person of any nationality whatever can justly describe these small profits as a drain on the country's wealth. Indeed it has been averred that the material gain to India in one year, due to these works of utility, is more than sufficient to cover their whole capital cost; or, in other words, that the ultimate gain to India represents cent. per cent. per annum on the capital, which gain goes mainly into the pockets of the Natives themselves.

One million sterling was advanced, under certain conditions, for the Holkar State Railway; it was finally decided to build the Punjab Northern on the standard gauge as a light 5 feet 6 inches railway, and to convert the Indus Valley to the same gauge. In Rajputana a station-to-station rate was tried for a short time.

In 1875, Rs. 4 crores were allotted, mostly for railways, but war and famine intervened as usual, and reduced the funds available, and nearly all the money was spent in the above conversion.

Quite a crop of reports appeared: Sir Alexander Rendel reported that the high cost of working Indian railways was due to insufficient loading of wagons. This is partly explained by the amount of empty running which, of course, brings down the average load very considerably. If the small upward traffic were encouraged by minimum transport charges, not only would the average loads be raised, but also the receipts per wagon mile; and, moreover, in cases, where ships have to call in ballast for homeward cargoes they would be encouraged to bring more imports. This would have a tendency to lower freights all round and further encourage traffic. These points have not received much attention.

Sir Bradford Leslie reported in favour of the system adopted at the Punjab bridges, of protecting them with stone deposited in the river, which as it subsides is kept up to a certain height until, in course of time, it forms a continuous submerged weir across the river with a long down stream apron. The piers being single cylinders it matters not what course the water takes in flowing under the bridge. These Punjab structures have very shallow foundations and Sir Bradford's advice was not followed by the Government engineers, who built piers of every shape, except the cylindrical, and depended on the enormous depth to which they were sunk as a protection against scour. The practice was also adopted of confining the river within very narrow bounds and of forming very long protecting banks. All this was costly in the extreme in the first instance and, as the protecting banks are maintained out of revenue, no statistics are available showing what they have cost since they were put down. As the large bridges are very long and very numerous in India, their maintenance must be a very serious drain on the revenue.



ASSAM-BENGAL RAILWAY.—Dyung Bridge No. 134, showing Trestle.

Col. F. S. Taylor, R.E., reported on the so-called "Goalundo Spur." The Eastern Bengal Railway had been extended to the junction of the Ganges and the Brahmaputra, and arrangements had been made at great expense for dealing with the traffic coming down both rivers. At the junction of the rivers the Ganges took a sweep to the North and ran right round a promontory, before falling into the larger river. On this promontory, which showed indications of being composed entirely of hard clay, the railway station, bungalows, river sidings, etc., had been laid down, as the shape of the land had not altered for many years. However, with the Ganges in flood and the bigger river low, a tremendous current swept by the right bank and began to erode the nose of the promontory. Stone was thrown in, which at once aggravated the erosion and the scour, and eventually two deep bays were formed, one by the direct current above, the other by the back water below, until the promontory assumed the form of a spur or pier 800 feet long, in 80 feet of water, made up of stone and brick blocks. The rivers were kept at bay for two years, at a cost of nearly 20 lakhs of rupees and when the fight ceased, by command, the rivers cut through the root of the spur and in 24 hours what had been the right bank of the river became its left shore. These cases illustrate some of the extraordinary difficulties which have enhanced the cost of Indian Railways.

Sir Guildford Molesworth wrote a report on Indian Railways.

At the Society of Arts in London Col. A. Romain Wragge advocated the use of condensed peat fuel.

A Director-General of State Railways was appointed in 1874.

During Lord Northbrook's rule, parts of the following lines were opened for traffic for the first time, *viz.*: 5 feet 6 inches or "Standard" gauge, the Nizam's; metre gauge, the Rajputana-Malwa and the Tirhoot; 2 feet 6 inches gauge, the Gaekwar's Dabhoi. The average gross earnings per mile per week fell to Rs. 51·41, while the percentage of net earnings to capital outlay rose to 3·90. The average miles opened increased considerably, to 489 (total 1,467) bringing the grand total to 6,541, while the average capital outlay was Rs. 2,73,90,000 (total Rs. 10,95,58,000), making a grand total of nearly 101 crores of rupees. The Tapti, 2,556 feet; the Kistna, 3,855 feet; the Gumti (Jaunpur), 1,472 feet; the Ramgunga (Bareilly), 2,277 feet; the Ganges (Rajghat), 3,040 feet; the Ravi (original), 3,217 feet; and the Ganges (Cawnpur), 2,850 feet long, were the bridges opened during this period.

LORD LYTTON.

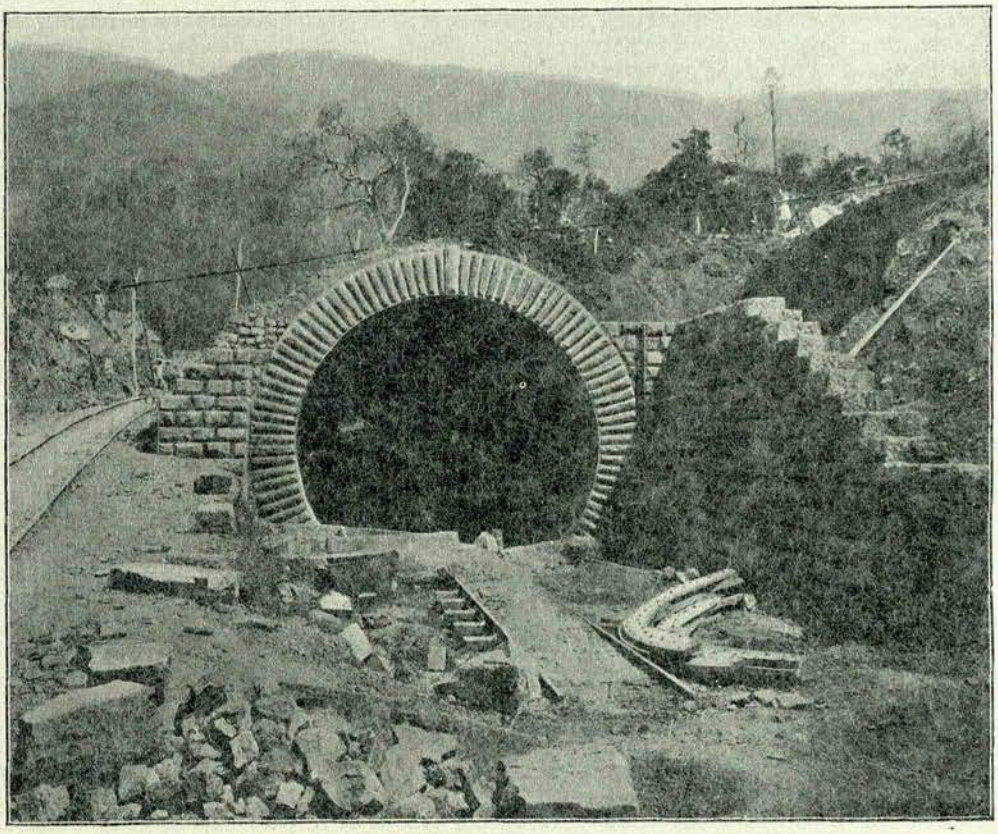
1876—1880.

Major-General J. S. Trevor, Director-General of State Railways, issued his first Report on the lines under his charge, from the beginning to the year 1879-80. This work was printed in Calcutta, covered 345 pages of foolscap size and contained 7 maps.

He stated that in the 10 preceding years 2,500 miles of State Railway lines had been opened, and that 1,500 were under construction, the total cost having been Rs. 2,633 lakhs; 1,351 miles were required to connect the Punjab and Sind, to reach Peshawar, and for Frontier lines, all on the standard gauge. At the site of the Attock Bridge over the Indus there had been a flood 150 feet deep and the traffic at Sukkur over the same river was being taken across by a wagon ferry, by which even locomotives had been crossed with very few accidents indeed, although the current was very rapid and the great whirlpools and eddies very dangerous. To facilitate the lowering of a locomotive on the pontoon a young assistant engineer greased the rails of the incline, in the temporary absence of the ferry master and proceeded to lower the engine, which took charge, crossed the pontoon and plunged into the water. General Trevor also gave full particulars of all the other State lines, mostly of the metre gauge and constructed departmentally, except in the case of the Rajputana and Scindia lines, on which contract work had been very successful; the former was expected to cheapen Sambur Lake salt in the Ganges valley. The Director-General reported that an arrangement had been made for a steam-tramway from Siliguri to Darjeeling by private enterprise. This was the present Darjeeling-Himalayan 2 feet gauge railway, for which the late Sir Franklin Prestage obtained such favourable terms, and which was a great success from the beginning, the work done by the little locomotive engines having never been beaten anywhere.

Ton mile and passenger mile statistics are given in the Report; they were first started on the Dhond-Manmad line in the year 1878-79, and have been found most useful and instructive ever since.

The Famine Commission of 1880 insisted on the importance of railways and wanted 5,000 miles urgently, while 20,000 miles would make India safe; but the Afghan war had diverted all the available funds. A Parliamentary Committee on Indian Public Works which sat in the previous year recommended that the funds to be borrowed by the Imperial Government for "Productive" Irrigation and Railway Works should be limited to 2½ millions sterling, and Lord Lytton on June 8th, 1880, proposed that light cheap lines should be sanctioned on the separate financial responsibility of Provincial Governments. In the same year Col. J. G. Medley, R.E., proposed a Clearing House, but this was considered premature, and it has never yet been established, the distances being considered too great for the working of such an establishment.



ASSAM-BENGAL RAILWAY.—Cut and Cover to Slip at No. 25 Cutting, Tunnel 1a.

The Railway Conference first met and the Provident Fund and Hill Schools were first started in 1880. This year was also remarkable for a great development of State lines and for the introduction of private enterprise in their construction. The Nizam's State Railway was also started at the suggestion of Government.

Col. W. S. Trevor in his report for 1881-1882 remarked that "on the opening of new (State) lines the staff has practically to be taught the duties required." In Chapter VI he gave a *précis* of correspondence on the subject of gauges—which began in 1841.

As illustrating some of the vicissitudes of railway making in India a summary of a portion of this *précis* will be useful. It should be premised that the Government of India decided to make its own trunk lines on the standard, and branch lines on the metre gauge. In spite of all this, it was considered by some of their advisers that the line from Karachi to Peshawar through Lahore would be amply served by a metre gauge, and strange to say, the Secretary of State assented; so the existing Lahore to Multan standard gauge line was to have a third rail or be converted to metre gauge. Lord Napier demurred to this, and only consented to the metre gauge from Lahore to Peshawar as preferable to having no railway at all. This was settled in 1871 against much opposition at home. The Duke of Argyll re-opened the question in 1873, Lord Northbrook recommending standard gauge (though with 60 lb. rails) for military and political reasons. Early in 1874 the Duke of Argyll assented reluctantly, but wanted 45 lb. rails, which was not accepted by the Government of India, and finally, Lord Salisbury in June 1875 gave way, and the standard gauge with 60 lb. rails was laid down. The railways through Central India and Rajputana (except the Agra-Gwalior) were all metre gauge. The Government and the inhabitants of Bombay had throughout strongly advocated the standard gauge from Ahmedabad northwards towards Ajmir—as Delhi is nearer to Bombay than Calcutta, and is therefore the natural outlet for that market—but metre gauge was put down. The Agra-Gwalior line was considered a military branch of the East Indian Railway, and Sindhia, who largely provided the money, was very desirous of having the standard gauge—so standard gauge it was made. It was calmly said that the opening of the Rajputana line would "give valuable experience as to the sufficiency of a metre gauge railway as a *trunk line of communication*."

The output of coal in India in 1880 was a little over a million tons, while 683,768 tons of English coal were imported. The natives were being trained in railway shops and schools all over the country, and after six years' trial on the East Indian Railway, drivers and shunters were favourably reported on, Rs. 16 lakhs having been saved through their employment during that period.

The line from Ruk to Sibi—133½ miles—was laid in 101 days, with material drawn from all parts, in spite of cholera and want of water; it was found most useful after the Maiwand disaster, for one single train did in one day what would have taken 2,500 camels to do in 14 days.

The East Indian Railway was purchased from January 1, 1880, the State accepting each £100 share as equivalent to £125 in terminable annuities or East Indian 4 per cent. paper, which was the most popular; the Company to work the line on agreed terms.

While Lord Lytton was Viceroy, the average gross earnings per mile per week reached Rs. 281. The average percentage of working expenses to gross earnings again fell to 48·89, and the average net earnings reached 5·06 of the capital outlay—topping the 5 per cent. for the first time, and since then it has never dropped below this. The average length of miles opened rose to 524 (total 2,621), making 8,996 in all; while the average capital outlay amounted to Rs. 5,52,13,000 (total Rs. 27,60,63,000), or a grand total of Rs. 128,56,90,000. Portions of the following lines were opened for the first time during this period, *viz.*, standard gauge, Bengal-Nagpur, Indian Midland; metre gauge, Behar line of the Eastern Bengal (State), Bhavnagar-Gondal-Junagad-Porebunder, Burma proper, Pondicherry; 2 feet gauge, Darjeeling-Himalayan.

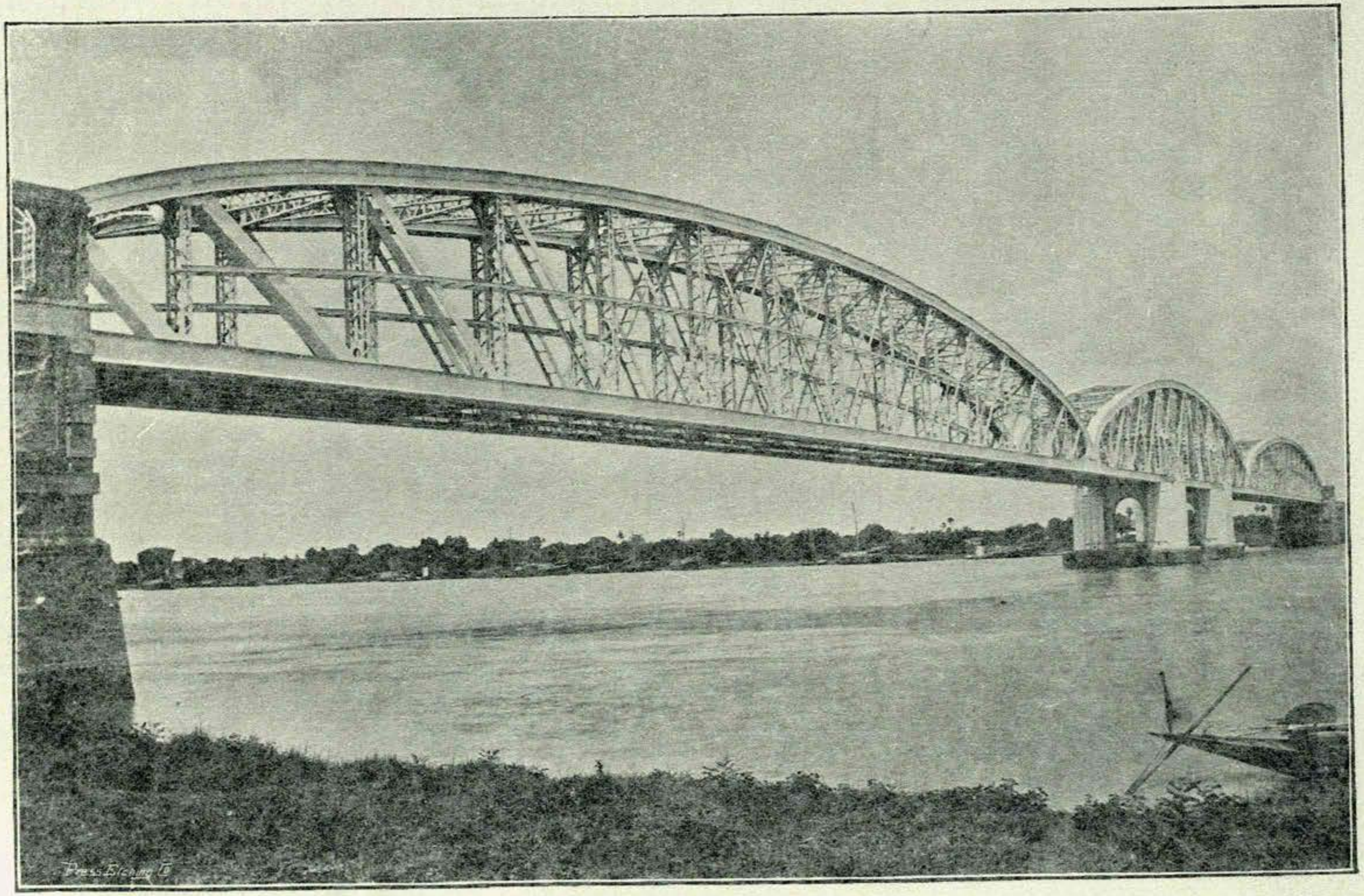
The Alexandra (original), 9,088 feet; the Jhelum (original), 1,880 feet; the Jumna (Agra), 2,272 feet; the Nerbudda, 2,836 feet; the Hagari, 2,396 feet; the Empress, 4,210 feet; and the new Cheyer, 3,500 feet long, were the bridges opened during this period.

Lord Ripon.
1881—1884.

In September 1880 and January 1881, the Duke of Devonshire (then Lord Hartington) recorded his opinion that the time had come for reverting to private enterprise. The new Governor-General went in strongly for famine protection lines, and was well supported by his Financial adviser, Lord Cromer (then Sir Evelyn Baring), who, in March 1881, stated that 2½ millions were quite inadequate and that he looked to English and perhaps Native capital to supplement that amount. "Partly aided" lines were proposed by India, but did not meet with favour at the India Office, and so the subject was bandied to and fro. From March to July 1884 another select committee sat and made certain recommendations which the Secretary of State adopted, generally, in November; 350 lakhs were to be borrowed annually, the Indian Government having made a forecast for the next six years. They strongly condemned the Secretary of State's persistent efforts to force the metre gauge on trunk lines, and were supported in this view by the State and the Committee. Meanwhile, the Eastern Bengal had been taken over by the State and the Rajputana-Malwa had been made over to the Bombay-Baroda and Central India on a lease; the Southern Mahratta was to belong to the State, while a company worked it and furnished the funds, under a 4 per cent. guarantee for 7 years, and 3½ per cent. after that, with a quarter share of profits. The Bengal and North-Western was to have no guarantee and the Government were to share any profits over 6 per cent. The question of competitive rates was raised in 1881 and is not settled yet.

Sir Juland Danvers submitted his last report in 1882, and for two years previous an Indian Administration Report was also issued in two parts, the second containing statistics only. The first part with all the maps and diagrams was reprinted in England and issued as a Parliamentary Paper, for many years.

After the Tay Bridge disaster, a Railway Structure Commission on Wind Pressure was appointed, consisting of Sir William Armstrong, W. H. Barlow, Sir John Hawkshaw, Prof. G. G. Stokes, and Col. Yolland. They reported on May 20, 1881, that a wind pressure of



THE "JUBILEE" RAILWAY BRIDGE OVER THE HOOGHLY RIVER.—Built by Sir Bradford Leslie, K.C.I.E.

from 30 to 40 lbs. per square inch would be sufficient to overturn railway carriages; and that if a pressure of 56 lbs. were provided for with a factor of safety of 26 or 28 lbs., all danger would be avoided.

In Lord Ripon's time the average gross earnings per mile per week reached their maximum up to that time, *viz.*, Rs. 289. The average percentage of working expenses to gross earnings also rose a little to 40·68, a figure it has never reached since then; while that of the net earnings to capital outlay showed a considerable rise to 5·32. The average number of miles opened per annum was 617 (total 2,469), a considerable rise, the grand total reaching 11,527 miles. The average capital outlay was a little over Rs. 672 lakhs (total nearly Rs. 27 crores), while the grand total was nearly Rs. 155½ crores.

Portions of a great number of lines were first opened during this period, *viz.*, standard gauge, Bhopal-Itarsi, Rajpura-Bhatinda; metre gauge, Bengal and North-Western proper, Deoghur, Dibru-Sadiya, Ledo and Tikar-Margherita colliery, Jodhpur-Bikaner, Rohilkhand and Kumaon proper, Lucknow-Bareilly, Southern Mahratta proper, and Mysore Section; 2 ft. 6 in. gauge, Eastern Bengal (State) branches, and 2 ft. gauge, Jorhat State.

The Nerbudda (new), 4,688 feet; the Attock; 1,522 feet; another Nerbudda, 2,306 feet; the Jumna (Muttra), 1,146 feet; the Kistna (Bijapur Branch), 3,392 feet; and the Bhima, 2,342 feet long, were the bridges opened during this period.

Lord Dufferin.
1885—1888.

The Bengal-Nagpur in 1883 and the Indian Midland in 1887 were started with a permanent (Sterling) guarantee of 4 per cent. and a subsequent quarter share of profits.

During 1885 the trouble on the frontier diverted funds from the commercial and protective railways to costly military lines, which were never expected to earn any direct profits.

In 1886, the Scinde, Punjab and Delhi was taken over by the Government and merged in the North-Western; the whole of the company's officers were retained, except those of the Engineering Department, only one Assistant Engineer being kept on.

It was in this year that 14,500 miles of railway track in America were converted to the 4 ft. 8½ in. gauge in two days. A great deal of the rolling-stock had previously been made interchangeable and the preparations for the conversion had taken a long time and caused some inconvenience. Including all gauges the total mileage opened in India at that time was under 12,000. Sir Theodore Hope, the Public Works Minister at this time, pointed out the evils of the London Stores Department, and that the uncertain supplies of funds and material were most wasteful and unbusinesslike. As to funds, the Government were embarrassed by famines, by a possible war with Russia, and by the continuing fall in exchange; as to the London Stores Department, it has gone on to this day on the old lines, discouraging the Indian firms, who were quite ready to supply materials direct and to submit to any inspection considered necessary. But no inspecting officers were appointed in India, and the old sickening delay and uncertainty of delivery continued to hamper the engineers and to add enormously to the cost of works. The Secretary of State in July 1886 warned the Government of India not to increase the taxation for railway construction. In spite of all these difficulties the average number of miles opened during Lord Dufferin's Viceroyalty increased to the highest up to that date, *viz.*, 736 per annum (total 2,945), making a grand total of 14,525 miles open; earnings per mile per week dropped to Rs. 273, nevertheless, the average percentage of working expenses to gross earnings also dropped to 49·07, and that of the net profits to capital outlay rose to 5·40, a record up to then. The average capital outlay per annum was nearly Rs. 940 lakhs (total over 3,759 lakhs); the total outlay rising to Rs. 19,304⅓ lakhs. Portions of the following lines were first opened during this period, *viz.*, standard gauge, Tarkessur; metre gauge, Gaekwar's Mehsana, Eastern Bengal (State), Dacca Section; West of India Portuguese, Morvi and Thaton-Duyinzaik (Light). The Oudh and Rohilkhand was taken over in 1889.

The Solani, 1,750 feet; the Rapti, 1,445 feet; the Jubilee, 4,932 feet; the Ganges (Balaweti), 7,886 feet; the Kanhan, 1,237 feet; the Kaiser-i-Hind, 4,293 feet; the Victoria, 2,720 feet; the Dufferin, 3,507 feet; the Gandak, 2,176 feet; the Jumna (Kalpi), 2,626 feet; and the Kistna (Poona Branch), 2,340 feet long, were the bridges opened during this period.

Lord Lansdowne.
1889—1894.

In October 1889, the Government of India submitted a programme of extensions to the Secretary of State. In November, Lord Cross advised that private enterprise should be encouraged in the construction and working of railways, and he endorsed the opinion expressed in 1884 on the subject of gauge; trunk lines should be of standard gauge (by this time this had become impossible); metre gauge should be confined to extensions and branches of the present metre gauge lines or to cases where the traffic would be so light that the broader gauge would be too expensive, although such traffic as offered would have to suffer the "undoubted disadvantage" of a break of gauge. The Governor-General, however, disapproved of the Secretary of State's financial proposals and considered it would be better to increase his borrowing powers—he proposed another Railway Commission. In 1889 a second battle of the gauges was fought at the Institution of Civil Engineers, with the result that the various advocates of standard, of metre, and of other gauges, alone or mixed, remained unconverted, so that the Government was left without any guidance. It was, however, clearly shown that a really light railway had never been constructed in India. Until 1890 the area served by the metre gauge lines was fairly well defined, but after that the gauge which was fixed upon for use on feeders was used for lines competing with the standard gauge. In 1890 the whole available balance of the Famine Insurance Fund was devoted to railways.

When the South Indian was taken over by the Government, the Secretary of State made a 20 years' contract with the Company, in November 1890, to work, manage and maintain the lines; a million sterling was to be raised (reckoned to be equivalent to Rs. 140 lakhs). The first charge on the receipts was to be 3 per cent. for three years; after that 3½ per cent.; the second charge was to be 3 per cent. on the Government's capital outlay; the surplus to be divided in proportion to the capital found. At the end of the contract the capital was to be repaid in sterling in London, at par. Lord Cross in February 1890 again praised the "Company" system, and the Government of India replied in October, repudiating any leaning either way.

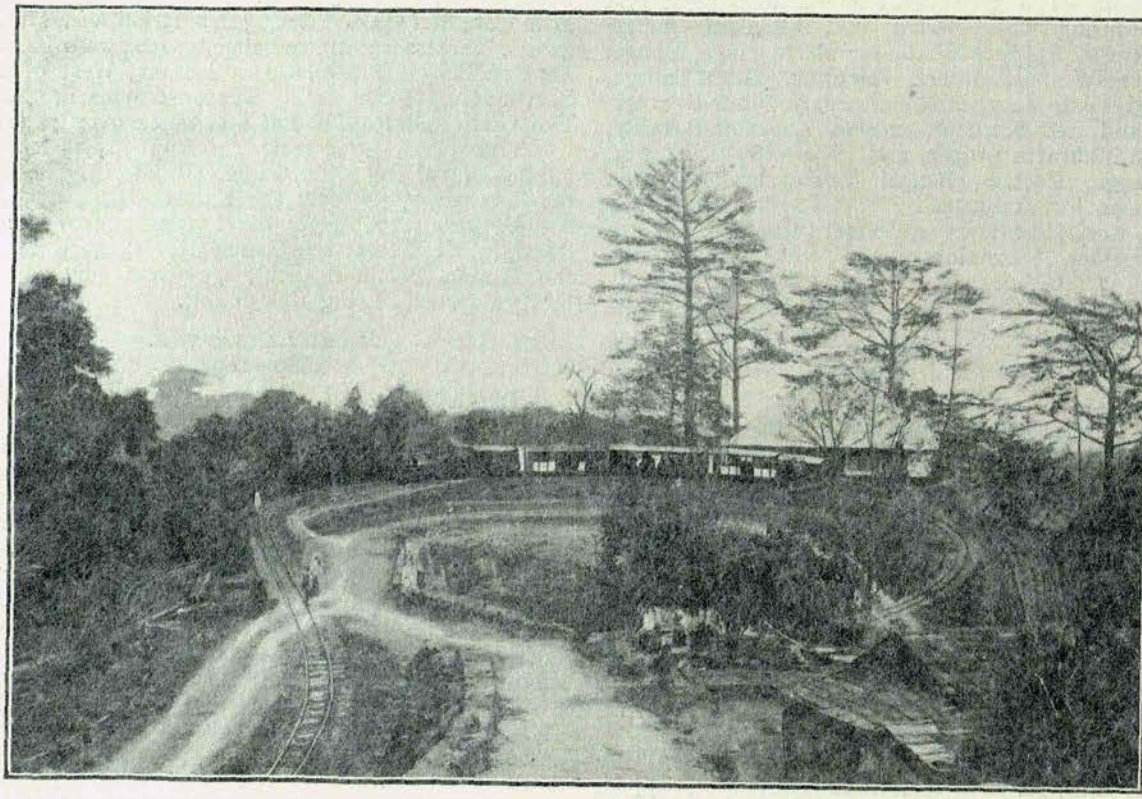
In 1892, rupees half a crore were lent to the Companies for extensions. In 1893 a subsidy was offered, a rebate on 10 per cent. of the interchange traffic; this was estimated to yield 4 per cent., but these terms were strictly adhered to in the case of the Ahmedabad-Parantij only.

In these years the average receipts per mile per week fell considerably, to Rs. 256, and yet the average percentage of working expenses to gross earnings diminished also, being 48·32 per annum, while that of the net earnings to capital outlay receded to 5·28. The average capital outlay per annum was well over Rs. 8 crores (total Rs. 40 crores, 13½ lakhs), the grand total being Rs. 233,17,87,000; or at 16*d*. to the rupee, well over 1,554½ millions sterling.

Portions of a great number of lines were opened, *viz.*, standard gauge, Godra-Rutlam-Nagda, Petlad-Cambay (Anand-Tarapur Section), Delhi-Umballa-Kalka, Madras (North-East line), Bezwada Extension, Jammu and Kashmir (Native State Section); metre gauge, Palanpur-Deesa, Bengal-Dooars proper, Jetalsar-Rajkot, Jodhpur-Bikaner (Bikaner Section), Jodhpur-Hyderabad (British Section), Guntakal-Mysore Frontier, Hindupur (Yesvantpur-Mysore Frontier), Kolhapur, Mysore-Nanjangud; 2 ft. 6 in. gauge, Cooch Behar, Powayan (Light); 2 ft. gauge, Dandot (Light).

The Weinganga, 450 feet; the Sheonath (No. II), 2,250 feet; the Betwa, 2,166 feet; the Ken (Banda), 1,558 feet; the Betwa (Lalitpur), 1,446 feet; the Lansdowne, 1,520 feet; the Penner (new), 1,830 feet; the Eeb, 1,461 feet; the Damoodar, 2,664 feet; the Shersvat, 3,650 feet; the Chitravati (new), 2,670 feet; the Barakur, 1,850 feet; another Penner, 1,740 feet; the Chumbal, 2,714 feet; the Alexandra (reconstructed), 3,976 feet; the Papagni (new), 110 feet; and the reconstructed Ravi, 1,465 feet long, were the bridges opened during this period.

The Lansdowne Bridge at Sukkur, over the Indus rapids, was constructed by the Resident Engineer, Mr. F. E. Robertson, C.I.E., without any staging or false work, and with only one assistant, an Eurasian.



THE LIEUTENANT-GOVERNOR'S TRAIN ON CHINBATTI LOOP OF THE DARJEELING-HIMALAYAN RAILWAY.

Lord Elgin.

1894—1898.

In April 1898 the late Mr. Horace Bell read a paper, at the Society of Arts, London, in which he mentioned the fact that, as 6,000,000 people were being relieved, there were no funds available for Railways, and that of late years private enterprise had practically been discouraged, although no other field for investment was as safe and certain as that of Indian Railways. The discussion that followed showed in a remarkable manner the divergent opinions held by high officials, past and present. The word "assisted," said Mr. Bell, seemed to have been invented to screen the fact of guarantees, to which Colonel Marryat added that while Government 3 and 3½ per cent. rupee-paper was at par and while money in the bazar fetched 15 per cent., an offer of 3 per cent. guarantee was absurd.

Mr. Bell pointed out that Japan had done four times better than India in Railways, in proportion to their respective populations. Although he had been Consulting Engineer to the Government of India, or, perhaps, because of that fact, Mr. Bell advocated the abandonment of the State Administration. He urged that the Government should only control and inspect railways, and that large systems were a mistake, in India at any rate, with their hordes of more or less inefficient and unreliable employees and in the trying climate. Sir Richard Strachey, on the other hand, considered big systems beneficial, but agreed that Government control should not extend to petty matters. On this, Sir J. A. Baines observed that, with these enormous interests and these enormous armies of employees under State Agency, either political or pecuniary corruption was certain to arise. The Chairman, the late Mr. J. M. McLean, M.P., alluded to the large number of Royal Engineers in the Railway Department and said that it was not likely they would willingly let go their hold. It has very justly been pointed out that a Royal Engineer in the Public Works Department, as a rule, received more pay than the officers of the Corps who stuck to their military duties, and more than the Civil Engineers in similar offices. So that the R. E. was rewarded for becoming less efficient as a military man and for learning work at the public expense, for which civilians had undergone a life long training at their own expense. The Chairman also considered the metre gauge a "colossal blunder," while Sir Owen T. Burne asserted that Lord Mayo only intended metre lines as feeders, and Mr. W. Martin Wood had recorded an opinion that they were lighter, more compact, and more economically worked than the broad gauge. According to Sir Juland Danvers, railways, being commercial concerns, were better in the hands of those who could manage them on commercial principles.

In this year, Government, finding that previous terms did not attract capital, revised them and offered those which Colonel Marryat characterized as "absurd," *viz.*, a 3 per cent. guarantee or a rebate limited to 3½ per cent. These proved no more attractive than the previous ones, and it was found that the method could not be relied upon for a steady supply of funds. The attempt to finance through the District Boards having also failed (only 158 miles having been constructed in Bengal), Government had to find funds out of their own resources. Meanwhile but little money had been available for expenditure on open lines, which were consequently starved. So in 1895, the East Indian Railway was allowed to get an Act of Parliament authorizing the raising of capital for construction and equipment. Sanction was given to spend Rs. 29 crores in 3 years—but famine, frontier wars, and falling exchange again intervened and prevented this; the East Indian Railway Act becoming inoperative.

Since 1896 all expenditure on Guaranteed and State lines has been included in the Railway Programme. In 1897 the Railway Branch of the Public Works Department was reorganized, it having been found that the subordination of the Department to a Civilian Member of Council did not adequately provide for a final expert authority. So a Secretary was appointed, with three expert Deputies as Directors of Traffic and of Construction, and an Accountant-General.

During the five years of Lord Elgin's reign, the average gross earnings per mile per week were Rs. 249, a slight fall. Although the average percentage of working expenses to gross earnings per annum was improved to 47·43, that of net earnings to capital outlay did not respond and fell a little to 5·20. The average number of miles opened also fell to 707 (total 3,536), giving a grand total of 22,024 miles. The average capital outlay per annum increased greatly, to Rs. 11,78,29,000 (total Rs. 58,91,43,000), making a grand total of considerably over Rs. 292 crores.

Portions of a great number of lines were opened for the first time, in spite of all difficulties; they were:—standard gauge, Nagda-Ujjain, Tapti Valley, Bhopal-Ujjain, Bina-Goona-Baran, Kolar Gold Fields, Southern Punjab; metre gauge, Ahmedabad-Parantij, Mymensingh-Jamalpur (Jagannathganj Branch), Cawnpore-Burhwal, Assam-Bengal proper, Dhrangadra, Jamnagar, Karaikkal-Peralam, Tanjore District Board, Udaipur-Chitor; 2 ft. 6 in. gauge, Rajpipla, Barsi Light (it had taken 14 years' hard work to get this well-paying line sanctioned, although the only concession was free land), Tarakeshwar-Magra (Light), Tezpore-Balipara (Light); 2 ft. gauge, Howrah-Amta (Light), Howrah-Sheakhala (Light).

The Ramgunga (Moradabad), 2,126 feet; the Kistna, 3,684 feet; the Jhelum (reconstructed), 4,899 feet; the Rushu Kuliya, 1,598 feet; the Penner, 1,990 feet; and the Elgin, 3,695 feet long, were the bridges opened during this period.

Lord Curzon.

1899—1905.

The closing of the Mints enabled allotments to be increased, but the Gujerat and Deccan famines in 1899-1900 again caused curtailment, so that the position became unbearable—for either the construction of much needed new lines, or the ordinary development of old lines, had to be stopped, and the traffic baulked in every way. So, as usual, a middle course, sufficient for neither needs, had, perforce, to be taken. The needs of open lines, which have never been fully satisfied, were considered a first charge—but it is evident that these needs increase with the increase of mileage open, as well as by the constant development of the traffic and by increasing wear and tear of permanent-way and rolling-stock. So that, were the yearly sum allotted a fixed one, new lines would, in time, cease to be constructed long before the total of 60,000 miles even now considered necessary would be completed. However, during the last five years of Lord Curzon's viceroyalty, the financial condition of the country improved yearly, so that for 1906-7 a record allotment of Rs. 15 crores (10 millions sterling) was reached. A three-years' programme, including 13,000 miles of new lines, is now being worked out, and the sensible course has at last been taken of allowing lapses of one year, up to a limit of Rs. 50 lakhs, to be re-allotted to the next.

After 1899 the Administration Reports were all printed in India, and in that year the first "History of Railway Projects in India" appeared. The next year the two parts were merged into one, and the report was very much abridged.

The late Mr. T. Robertson passed two cold seasons in India and reported in 1903 on the Indian Railways at Lord Curzon's request. He recommended the formation of a Railway Board, and in March 1905 this was constituted: Mr. Robertson also made many other recommendations, some of which are being carried out.

There was a large amount of work done in Lord Curzon's time. An average of 1,043 miles of line per annum were opened and 6,255 in the six years, bringing the grand total up to 28,295 miles. In spite of this great accession of new lines the average gross earnings per mile per week rose to Rs. 295, while in 1905 they were Rs. 283, or nearly £20. This, of course, compares very unfavourably with the earnings of the home railways and yet, in spite of all these drawbacks, the average percentage of working expenses to gross earnings was but 47·72 per annum, and that of the net earnings to capital outlay as much as 5·36 per annum, while in 1905 it rose to 5·92 per cent, a result at which most railway undertakings in the world would only be too delighted if they could arrive. The average yearly capital outlay was Rs. 1,069¼ lakhs, or Rs. 7,484¾ lakhs in all, of which no less than Rs. 14,07,99,000, or close upon ten millions sterling, were spent in 1905. This brought the grand total of the capital outlay to Rs. 3,66,93,94,000, or £244,626,267, yielding 6 per cent. per annum. The North-Western Railway which for many years was a very poor-paying line, has now become one of the chief contributors to this splendid result, since the opening of canals along the Upper Indus.

The lines of which portions were opened during Lord Curzon's reign, were as follows, *viz.*:—standard gauge: Petlad-Cambay (Tarapur-Cambay Section), South Behar, Agra-Delhi Chord, Ludhiana-Dhuri-Jakhal, Southern Punjab (Ludhiana Extension), Hurdwar-Dehra (this exceedingly useful line was discussed for ten years); metre gauge, Ahmedabad-Dholka, Jaipur (Siwai-Madhopur), Vijapur-Kalol-Kadi, Nilgiri, Shoranur-Cochin, Hyderabad-Godavari, Noakhali (Bengal), Bengal Dooars (Extension), Tinnevelly-Quilon (Travancore, British Section), Tinnevelly-Quilon (Travancore, Native State Section), Bellary-Rayadrug, Birhur-Shimoga, Hospet-Kotlur; 2 ft. 6 in. gauge, Jubbulpore-Gondia (Extension, Bengal-Nagpur Railway), Mourbhanj, and Parlakimedi (Light), Raipur-Damtari (branch Bengal-Nagpur Railway), Tirupattur-Krishnagiri, Kushalgarh-Kohat, Nowshera-Durgai, Baraset-Basirhat (Light), Buktiarpore-Behar (Light), Cutch State, Kalka-Simla; 2 ft. gauge, Gwalior (Light). The Great Indian Peninsula was taken over in 1900.

The Phulgee, 2,064 feet; the Subanrika, 1,908 feet; the Byturney, 2,400 feet; the Brahmini, 4,640 feet; the Berupa, 1,728 feet; the Sohan, 1,204 feet; the Barah, 1,368 feet; the Sone (Dehri), 10,052 feet; Mahanadi, 6,912 feet; Kuakhai, 3,212 feet; Kathjori, 2,890 feet; Godaveri, 9,096 feet; Roopnarain, 2,632 feet; Indus (Kotri), 1,948 feet; Girna, 1,417 feet; Ganges (Gurmukhtesar), 2,332 feet; Teesta, 2,116 feet; Girna, 1,572 feet; Gokteik, 2,260 feet; Dharka, 1,620 feet; Sankosh, 1,458 feet; the Cossye, 1,736 feet; the Dehing, 1,118 feet; the Turtipur, 3,912 feet; and the Kosi, 3,173 feet long, were the bridges opened during this period.

The total trade of India in 1904-1905 had risen to over Rs. 318 crores with a balance in favour of the country of Rs. 30,21,75,000. The aggregate tonnage of goods lifted in 1905 was 54,940,000; the average rate per ton per mile for all descriptions of goods being 5¼ pie or just under ½*d*. The total number of passengers was 248,160,000. The average rate charged them for all classes being 2·47 pie per mile, just over ¼*d*., the average distance travelled being about 40 miles. In the employ of railways there were no less than 436,348 natives, only 9,175 Eurasians and 6,535 Europeans; 6,907 children, apprentices, and workmen attended the railway schools, and facilities are given for children to attend other schools. The numbers of skilled workmen who have passed through and are still in the locomotive and carriage shops is very great indeed, and the spread of technical education by these means has been most beneficial. The total output of the Indian collieries was 8,430,000 tons and only 197,750 tons of English and foreign coal were imported—of these amounts 2,760,000 and 18,230 tons respectively were consumed by the railways.

Lord Minto.
1906.

The Bombay, Baroda and Central India Railway was taken over by the State on the 1st January 1906. In 1907, the Madras Railway, the only guaranteed line remaining, was taken over by the State, and it has been decided by the Secretary of State that the junction of the reorganized railway with the Great Indian Peninsular system will be at Raichur, and that the Bengalore-Madras Section shall be worked by the Southern Mahratta line, the South Indian Railway being accorded running powers to Madras over this section. The following State lines are leased to Companies, *viz.*:—Bengal-Nagpur, Indian Midland, Assam-Bengal, Burma, Southern Mahratta and the Lucknow-Bareilly Section of the Oudh and Rohilkhand. There are six lines worked on the so-called Branch lines system; besides these there are Companies' lines guaranteed under new contracts; District Board lines; Assisted and unassisted Companies' lines, and Native and Foreign State lines; the balance being State lines worked by the State or by Companies.

DEVONIAN AND LOWER CARBONIFEROUS SYSTEMS.

THE strata intervening between the Silurian and the unconformity-conglomerate which, almost everywhere in India as also in many other parts of the world, indicates the commencement of the Upper Carboniferous, that is, therefore, the Devonian and Lower Carboniferous, are even more scantily represented in India than the Cambrian and Silurian. The scantiness of outcrops of those particular horizons is a characteristic feature of the region included within the limits of the Indian Empire. These horizons are entirely absent from the Peninsular region, unless it be shown eventually that the Vindhyans are partly of that age. Fossils of undoubted Devonian age have only been found in Chitrál and in the Northern Shan States, but in neither case has their stratigraphy been completely worked out. The presence of the trilobite *Phacops latifrons* and of the curious coral *Calceola sandalina* amongst the fossils of the Northern Shan States indicates that the Middle Devonian horizon is represented.

Devonian of Chitrál and of Burma.

In the Spiti region of the Himalaya, the Muth quartzite, an unfossiliferous band some 500 feet thick, and a group of limestones between 300 and 400 feet in thickness with poorly preserved fossils, overlying the Muth quartzite, may possibly represent the whole or a part of the Devonian. These beds are succeeded by the only undoubted Lower Carboniferous strata that have yet been observed in the Indian Empire.

Lower Carboniferous of Spiti.

In the region adjoining the lower part of the Spiti Valley, the aggregate thickness of the strata extending from the presumed Devonian to the Upper Carboniferous conglomerate amounts to over 4,000 feet. In this particular case, there seems to be a gradual passage upwards into the conglomerate, and it seems that the usual unconformity is locally bridged over, the whole of the Carboniferous System being present in this particular section. Where the maximum thickness is exhibited, the Carboniferous beds underlying the conglomerate have been divided into two sections, each of which is about 2,000 feet thick. The lower division named the Lipak Series is mainly calcareous and shaly, and contains numerous fossil brachiopods, amongst which may be mentioned several species of *Productus*, and the typically Lower Carboniferous *Syringothyris cuspidata*, numerous mollusca, and trilobites of the genus *Phillipsia*. The upper division known as the Po Series consists of quartzites and shales. It contains two sub-divisions, a lower one with a few fossil plants that seem identical with certain plants of the Culm of Europe and Australia (Lower Carboniferous), and an upper sub-division with marine fossils, amongst which one notices numerous Bryozoa. These beds have been named the "Fenestella shales" from the leading genus of Bryozoa. They are closely connected with the overlying conglomerate, and belong probably to the Upper Carboniferous.

GEOLOGICAL HISTORY OF INDIA DURING THE UPPER CARBONIFEROUS, PERMIAN, AND MESOZOIC PERIODS.

TOWARDS the end of the Middle Carboniferous, there occurred an extensive orogenic upheaval in many parts of the globe. Mountains, which denudation has now removed, were upheaved to an altitude comparable with that of the highest ranges of the present day, and there are even indications of the existence of glaciers. Except where sedimentation continued uninterrupted in places that remained unaffected by these movements of the earth's crust, we find, therefore, a well-marked stratigraphical break at the base of the Upper Carboniferous, which usually rests unconformably on the underlying rocks. The junction is usually indicated by an unconformity-conglomerate, which often exhibits peculiar characters that have been regarded as glacial. This break is particularly conspicuous in India where the Lower Carboniferous is unknown except in the very local Himalayan exposures just mentioned. With this exception the Carboniferous System, almost everywhere in India, commences with a peculiar boulder bed which cannot be older than Middle Carboniferous, and which supports a vast series of Upper Carboniferous and Permian strata.

Orogenic phenomena in Carboniferous times.

After the great upheaval of the Middle Carboniferous, the crust of the globe remained comparatively quiescent until the middle of the Tertiary era. Throughout the intervening periods we cannot, therefore, avail ourselves of any marked stratigraphical unconformities to establish divisions through that long series of ages. There are, however, indications of certain universal or widespread alterations in the relative level of the ocean that have left their mark in the stratified record, and that greatly assist in demarcating lines of division. Whenever the level of the ocean was comparatively high, its sediments invaded certain areas that had previously been continental. This was particularly the case at the time of the Upper Cretaceous (the period of the Chalk). Whenever the surface of the ocean subsided to an unusually low level, the previously formed sediments were left dry, and sedimentation was interrupted above them until the next return of the ocean. Owing to the wide areas over which they can be recognized, it is these interruptions which have principally been made use of as lines of demarcation between the various systems. Some of the most conspicuous of these interruptions, for instance, the one between the Permian and Trias that separates the Primary from the Secondary, or the one between the Cretaceous and Eocene that separates the Secondary from the Tertiary, are as distinct in India as in Europe. It must be noticed, however, that owing to the quiescence of the earth's crust during these periods, the breaks are unaccompanied by any stratigraphical unconformity. The occurrence of ferruginous beds representing a peculiar alteration product of rocks exposed to the air, known as "laterite," often assists in locating these stratigraphical breaks, in the absence of a stratigraphical unconformity. These ferruginous layers represent the altered surface of the sediment which was exposed to atmospheric agencies during the interval between two marine invasions.

Stratigraphical breaks indicated by lateritic bands.

The corrugation of the earth's crust that produced the great upheaval of mountain ridges in Middle Carboniferous times also accentuated a deep furrow almost encircling the world, and constituting an ocean, of which the present Mediterranean is the last remnant. This extinct ocean, known in geological nomenclature as the Tethys, completely separated the continents of the Northern and Southern hemispheres when it thus became deepened in Upper Carboniferous times. During the Lower and Middle Carboniferous, the separation was not so complete, and the lands of both hemispheres supported similar plants and animals. But during the Upper Carboniferous and Permian, all connection was severed, and the southern continent including the Indian Peninsula, parts of South America and South Africa, and Australia, joined together by lands that have now subsided beneath the Atlantic and Indian Oceans, was inhabited by a flora and fauna quite different from that of the northern lands. Something of the same sort is observed at the present day in Australia and New Zealand which, being separated from the rest of the world by a broad expanse of ocean, are tenanted by different plants and animals. Marine strata of Upper Carboniferous to Eocene age, largely consisting of shales and limestones are developed on an enormous scale in many parts of the extra-peninsular regions of the Indian Empire, and can readily be correlated with those of other parts of the world by means of their abundant fossils. The extra-peninsular regions were then submerged beneath the Tethys, while the peninsula remained as to-day a continental area. Consequently the marine beds of the extra-peninsular region are represented in the peninsula by great masses of fluviatile sandstones associated with coal-seams and containing no other fossils but fragmentary remains of plants and terrestrial animals. Owing to the differences between them and the corresponding flora and fauna of more northern lands, and owing to the scarcity of sections combining the marine and fluviatile facies, and in consequence also of the unfossiliferous nature of many of the fluviatile sandstones, it has not yet been possible to correlate exactly all the peninsular sandstones with the corresponding marine strata of the extra-peninsular regions. In the following pages it will be convenient, therefore, to mention separately the great sandstone formations of the peninsula and the calcareous and shaly marine beds of the extra-peninsular regions. The name of Gondwana series, originally applied to these fluviatile formations in India, has been extended to beds containing a similar fossil flora in South America, South Africa, and Australia; the southern continent, of which these lands are the remnants, is spoken of as Gondwana-Land. For the Palæozoic (Primary) formations that still remain to be noticed, and for the succeeding Mesozoic (Secondary) ones, it will, therefore, be necessary to examine separately two facies: the Gondwana facies with terrestrial fossils, and the marine facies.

Northern and Southern continents separated by the Tethys.

Gondwana-Land.

UPPER CARBONIFEROUS AND PERMIAN SYSTEMS.

(a) *Gondwana Facies.*

The Gondwana Series consists principally of sandstones of fluviatile origin, with some subordinate shales and ironstones, the latter probably of lateritic nature. Certain horizons are rich in coal-seams. These strata occupy basins bounded by faults in the midst of the older rocks of the Indian Peninsula. These basins are arranged in linear series along the valleys of the Damúda and Barákar, the Mahánadi and the Godávari Rivers. The Damúda and Mahánadi series of exposures converge in a westerly direction and coalesce in southern Baghelkhand from where they continue westwards on the southern side of the Narbada Valley, concealed at times by the basaltic lavas of the Deccan trap until they culminate in the lofty peaks of the Sátpura Range. The Rajmahál hills of Bengal also include Gondwana rocks. In the Himalayan region, typical Gondwanas are found in the neighbourhood of Dárjíling and in Bhotán.

The Gondwana rocks are divided into two principal groups, the Lower Gondwanas of Palæozoic age, and the Upper Gondwanas of Mesozoic age. The Lower Gondwanas themselves have been divided into three principal series, known under the names of Tálchir, Damúda and Pánchet.

The base of the Tálchir, whenever it is not removed out of view by faulting, is characterized by a peculiar boulder-bed, regarded as glacial on account of its silt-like matrix and of the striations observed on some of the pebbles. It is known as the Tálchir conglomerate from the name of a coal-field in the Mahánadi region. The upper beds of the Tálchir constituting the Karharbári division contain some valuable coal-seams. The leading fossils of the Tálchirs are impressions of detached leaves known as *Gangamopteris*, which differ by the absence of a mid rib from the leaves of *Glossopteris* characterizing the overlying Damúda beds.

Tálchir boulder-beds.

The Damúda beds are the chief coal measures of India. The lower portion known as the Barákar division is the one most widely spread, and contains the most valuable coal-seams. The upper coal-bearing horizon is known in Bengal as the Rániganj division.

The uppermost division of the Lower Gondwanas, the Pánchet, is destitute of coal. It contains fossil remains of plants, some of which are identical with those of the underlying Damúdas, and remains of extinct reptiles and amphibians.

The geological horizon of the Tálchir conglomerate corresponds approximately with the base of the Upper Carboniferous (Uralian or Stephanian); at any rate, these beds are not older than Middle Carboniferous (Moscovian). The Karharbári coal-seams belong to the base of the Upper Carboniferous. The Barákar coals belong to a higher horizon of the Upper Carboniferous. The Ranigánj coals may be Lower Permian (Permo-Carboniferous or Artinskian). The Pánchet probably corresponds with the Upper or true Permian or Zechstein.

It will be seen, therefore, that the age of the coal measures of India differs considerably from that of the coal measures of Great Britain and the Franco-Belgian

When the Nagda-Muttra line has been completed, it is considered that there will be only three trunk lines left for construction, *viz.* :—The Bombay-Sind connection; the joining of the Assam and Bengal railways, and the so-called North to South Standard Gauge railway. Another important line will be the Kundwa-Akola-Basim Railway which will similarly link up the North and South metre gauge systems. The Marwar-Kotah link will greatly benefit Karachi, where also it is proposed to form a Company for the purpose of building various light railways in the province.

At the last Railway Conference allusion was made to the simplification of the Goods Tariff—this is in hand at last and will be of inestimable advantage to trade in general. The lowering of the minimum tariff has also encouraged traders, and if railways were only allowed to take full advantage of their geographical and geological positions, and the Government could only be induced to share more of its profits with investors, railways and their consequent benefits would increase amazingly.

Coopers Hill College has been closed after a life of 35 years. It was built to accommodate 125 students and the average number has been 46. Of these 35 per cent. dropped out; 24 per cent. failed to pass the final examination, and about 40 per cent. obtained appointments. The course was very costly, as the number of professors was out of all proportion to the number of students.

The third "Battle of the Gauges" took place at the Institution of Civil Engineers in London after another interval of 16 years, when a paper by Sir Frederick R. Upcott, K.C.V.O., C.S.I., was discussed on the 30th January, 1906. Sir Frederick invited the criticism of the members on the two questions (1) whether the cost and confusion which will necessarily accompany gradual conversion outweigh the advantages of uniformity, and (2) whether the growing needs of the traffic may not be met by continuation and extension of different gauges, treating each case on its merits without attempting to define any definite scheme. The majority acquiesced in the view that a compromise rather than any drastic remedy appeared to be preferable, and Sir Frederick, as President of the Railway Board, stated that this compromise agreed substantially with the policy now being carried out by the present Government. He did not, of course, commit any future Government to the same policy.

The sum of Rs. 15 crores was provided for 1906-7, of which 891 lakhs was for open lines (Rs. 382 lakhs of this being for rolling-stock) and the balance for construction. Of this amount, Rs. 14,61,16,000 (£9,741,100), were actually expended, being nearly a crore of rupees in excess of the expenditure for the year 1905-6. At the end of April, 1906, there were 28,607 miles open and 3,297 under construction and sanctioned, total 31,914; or only a little over half the mileage considered necessary by many authorities. The amount of work done, though creditable under all the circumstances of the case, still compares unfavourably with many other countries, both as regards miles per inhabitant and per square mile of territory. On the other hand, the total trade of India had further risen in the financial year 1905-6 to Rs. 321 crores, or a ten-fold increase in less than 60 years, and showed a balance in favour of India of over 33½ crores of rupees; the enormous increase over the figures quoted before the introduction of railways being almost entirely due to their growth.

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The estimate for 1907-8 provides for the expenditure of Rs. 13½ crores (£9, 000,000), a reduction of 10 per cent. on the provision of the previous year. The programme for this year, as originally framed, contemplated an outlay of Rs. 15 crores. Financial considerations, however, necessitated its reduction to Rs. 12 crores, for which figure it received the Secretary of State's sanction. It was subsequently increased by Rs. 1½ crores, thus bringing it up to its total of Rs. 13½ crores. Of this amount, Rs. 1,013¼ lakhs (£6,755,000), has been divided between general open line requirements and additional rolling-stock requirements in the following proportions:—Open lines, 445¼ lakhs; rolling-stock, 568 lakhs. The balance of the grant goes to lines under construction, for owing to the reduction in the programme, the heavy demands on account of open lines, and the large mileage of lines at present under construction, no expenditure on new lines was proposed for the year.

In their memorandum on the Budget in 1906, the Railway Board definitely stated that the then standard of equipment of Indian Railways in the matter of rolling-stock was below the requirements, and acting on this opinion they made the very large provision of 382 lakhs, as noted above, to be spent for rolling-stock during the year 1906-7, and this grant was all expended. For 1907-8, the provision of 568 lakhs which they made, met in full the demands of all railways for grants for rolling-stock for that year.

On the 1st April, 1907, there were 29,571 miles of line open, while the mileage under construction or sanctioned for construction was 2,873, making a grand total of railways completed and in hand at the commencement of 1907-8 of 32,444 miles. Compared with the results of the previous year, the revenue account for 1906-7 shows an improvement of Rs. 23,35,000 (£155,900).

The bridging of the Lower Ganges is a matter that has been before the Government of India for the past seven years, in some shape or form. The question came into being in 1890, and discussion has been going on ever since. Up to the end of 1906, the main point at issue was as to whether the bridge should be built at Sara or at Godagiri. If it were located at the first named place, it would connect the broad gauge and the narrow gauge sections of the Eastern Bengal State Railway. If, on the other hand, Godagiri were selected as the site, the bridge would connect the new broad gauge line from Ranaghat to the Ganges, with the new narrow gauge line from the river to Katihar. A third proposal was imported into the discussion by the Railway Board towards the end of 1906. It was in the nature of a compromise, and the Board held that the provision of a bridge at Sara or at Godagiri would not meet satisfactorily the full requirements of trade as a permanent arrangement. They felt confident that the building of a bridge on one site would be followed eventually by the building of a bridge on the other; and to avoid this, and to enable the metre gauge system to enter Calcutta, they proposed to bridge the river at Rampur Boalia. A Committee, styled "The Ganges Bridge Committee," was appointed by Government at the end of 1906, to consider the various schemes, and to report on the project they recommended as offering the best settlement of the complex question of location. Their report was submitted to Government in April, 1907, and in it the Committee, for reasons set forth in full detail, came to the following conclusions:—(1) That the metre gauge ought not to be extended south of the Ganges; and (2) that the bridge should be built at Sara. The Committee further emphasised the fact that they considered the construction of a bridge over the Lower Ganges a matter of extreme urgency, and that it was the universal hope and expectation of the commercial community and of the general public that the investigation and report of the Committee would result in immediate and practical action. The report was forwarded to the Secretary of State in July, 1907, with a recommendation from the Government of India that the proposals of the Committee be accepted; and here the matter rests at present.

Among the important proposals made in 1903 by the late Mr. T. Robertson, Special Commissioner for Railways, was one for the relaxation of the stringency of the control exercised by Government over the affairs of Railway Companies. In 1904 the Secretary of State called for the recommendations of the Government of India in regard to the matter: but the formation of the Railway Board had first to be effected, and the importance and intricacy of the proposals necessitated much discussion before the case could be laid before the Secretary of State. Under arrangements hitherto existing, the control of Government has been exercised through the medium of Consulting Engineers, who in Madras, Bombay and Burma worked under the local Governments; and in the other provinces were directly subordinate to the Railway Board. Railway Companies have hitherto had no original powers of sanctions, and have had to obtain such authority from or through the Consulting Engineers. With the sanction of the Secretary of State, the Government of India have now decided that certain powers of sanction and administration should be delegated to the Companies' Boards, and that they should be requested to entrust their agents with a considerable portion of their own powers, Government reserving the right to reimpose more detailed control should the circumstances of any line require it. It has also been decided that the appointment and duties of Consulting Engineers should be abolished, and that Government Inspectors should be appointed to carry out the duties prescribed in Chapter 4 of the Railway Act. The change in organization will be brought into force from the 1st June, 1908.

A Committee has been appointed by the Secretary of State to examine into the details of railway administration and finance in India, and the members of the Committee, Sir Walter Lawrence and Sir James Mackay, accompanied by Mr. A. Brereton as a railway expert from the India Office, will arrive in this country some time in December, 1907. Their inquiry will include a report on the constitution and working of the new Railway Board.

presence of the mineral enstatite (essentially silicate of magnesia). They also frequently contain garnet. Some varieties contain quartz, others do not, but even when there is a high proportion of quartz, this mineral assumes a dark bluish colour, which does not affect the general dark tinge of the rock, producing a very different appearance from that of the more familiar types of quartz-bearing rocks, such as ordinary granites and diorites. The heavier and less siliceous types of the Nilgiri or Mountain gneiss belong to the class of rocks known as "norites," while the more siliceous ones come nearer to the composition of diorites and granites, from which they differ nevertheless owing to an unusually high percentage of magnesia and ferrous oxide, and by the presence of enstatite, a mineral characteristic of rocks that have a low percentage of silica, but generally absent from the usual types of highly siliceous rocks, such as normal granites or diorites. Amongst these enstatite-bearing rocks, the types that most nearly approach a granite in composition have been called by Mr. T. H. Holland "charnockites," because the tombstone of Job Charnock, the founder of Calcutta, consists of a slab of that rock. The material is much appreciated as an ornamental stone, owing to its handsome granular appearance and dark colour.

Charnockite.

Somewhat related in composition to the Nilgiri gneiss, and perhaps belonging to the same geological system, are the anorthosites of Bengal, so called on account of their being largely made up of lime-bearing felspars related to the mineral anorthite.

Anorthosites of Bengal.

In Southern India, where the Hosur gneiss, the local representative of the Bundelkhand gneiss, comes into contact with the Nilgiri gneiss, there is some evidence pointing to their being both of about the same age, while we have the direct evidence of stratigraphical superposition to prove that the Dhárwárs, the local representatives of the oldest sedimentary system, are newer than the Hosur gneiss.

Thus, although the investigation is not yet complete, there is every reason to regard the Nilgiri gneiss as a member of the Archæan System, either of the same age as the Bundelkhand gneiss, or somewhat newer.

OLDEST SEDIMENTARY SYSTEMS.

After the consolidation of the original crust of the globe now constituting the Archæan rocks, a time must have come when the temperature was sufficiently lowered for the vapours contained in the primordial atmosphere to condense and form the ocean. Subsequently to this event, the temperature of the earth's crust could no longer vary except within narrow limits, while the temperature of the inner core of the globe continued slowly to decrease, and is still decreasing at the present day. In order to adjust itself to the contraction in volume which results from this gradual cooling of the earth's interior, the outer crust became corrugated into ridges and furrows. The inequalities thus arising in the earth's figure became gradually more pronounced, and at last some of the troughs absorbed so much of the bulk of the waters, that the general level of the ocean surface sank below that of the highest ridges or bulges. In this manner the first continents appeared, and as their surface became at once degraded by atmospheric agencies, true sediments began to accumulate in the neighbouring parts of the ocean. The gradual deepening of the ocean, and the consequent expansion of the continents, by raising these earliest sediments above the sea-level, accounts for their rapid removal by denuding agencies. Consequently they have now almost everywhere disappeared, except where portions of them have been caught up amidst the folds of subsequent corrugations, such as those which accompany the formation of mountain ranges. The increased depth and thickness resulting from this compression has saved some of these folded portions from being completely removed by denudation. This is why the oldest sediments of the globe are almost entirely restricted to narrow highly compressed synclines. Consequently their outcrops assume the appearance of more or less parallel narrow elongated strips, such as is particularly well shown in the Dhárwár region of Southern India. It is the deepest parts of the original synclines that are thus preserved, precisely those parts where the combined effects of compression and heat have produced the most intense degree of metamorphism, and as this is often enhanced by the contact effects of igneous intrusions, a crystalline facies may be produced which it is sometimes very difficult to distinguish from that of certain forms of Archæan gneisses.

Amongst the most characteristic rocks of the oldest sedimentary system of India may be mentioned: hæmatite-schists, magnetite-bearing schists and massive beds of hæmatite and magnetite; massive beds of manganese ore; a great variety of more or less altered volcanic beds, largely basic; hornblendic schists, which probably represent metamorphosed volcanic flows or intrusive sills, various kinds of highly magnesian rocks, such as talc-schists, serpentinous limestones, potstones; highly crystalline limestones and dolomites, passing into scapolite-gneisses and pyroxene granulites, which appear to be the result of metamorphism from associated granitic intrusions.

Single outcrops of this ancient sedimentary series, as a rule, do not contain every one of these forms of rocks, but they always combine a sufficient variety of them to lend to the formation its characteristic facies. The bulk of the formation usually consists of a considerable thickness of slates showing every passage through chiastolite-bearing slates and semi-crystalline phyllites to typical mica schists, often with the development of andalusite and garnets. When the slates are but slightly altered, they are not readily distinguishable from those of some less ancient series of the Peninsula, the Kadapah system for instance; but they frequently exhibit the altered schistose facies over large areas with a degree of metamorphism which is only observed quite locally, if at all, amongst the rocks of Kadapah age.

Granitic intrusions, varying in size from large bosses to narrow veins, are a frequent feature amongst the outcrops of the oldest sediments. Some of the finely foliated mica schists are, as it were, impregnated with narrow strings of intrusive granitic material, the combination thus produced giving readily the impression of a gneiss.

Amongst the various rocks of the system, the massive beds of manganese ore and the still more massive iron ores are the most characteristic. Similar rocks occur in some of the divisions of the succeeding Kadapah, but never in such bulky masses. The brilliantly coloured banded jaspers are amongst the most conspicuous rocks of the oldest sediments, but they are equally well developed in the succeeding Kadapah. The crystalline limestones, which constitute ornamental stones of unrivalled excellence, are very characteristic of the older system.

Banded Jasper.

With the exception of the rather broadly spread-out exposure in Singhbhúm, all the occurrences of the oldest system exhibit, as already mentioned, the structure of groups of narrow synclines, indicating the position of old mountain ranges, most of which have been so thoroughly effaced by ages of continuous denudation, that they have lost all topographical individuality. It is only in the case of the Arávalli that they still form a very distinct geographical feature, probably because the upheaval of this range was partly renewed in later times.

It is the Arávalli range that exhibits these rocks in their greatest variety. They have been grouped into several divisions (Raialo, Ajabgarh, etc.). The continuation of the Arávalli outcrop in Gujrát is known as the Champáner series. Another outcrop, probably of the same series, occurs further east, near the town of Bágh, north of the Narbada. Still further east, further up the course of the Narbada, there are some very typical outcrops of the same system in the neighbourhood of Narsinghpur and Jabalpur. The well-known "Marble Rocks" near the latter town belong to it. Various names have been applied to different parts of this outcrop, such as Chanderdip, Majauli, Lora, but just as in the case of the names given to portions of the Arávalli range, they are also merely of local value. A further extension of this outcrop is found south of the Son in Rewa. The same rocks also constitute the Karakpur hills of Behár, where the slate beds which they contain are extensively quarried. The outcrop extending from Midnapore to Nágpur has already been noticed. In the Bálághát district, they have been described under the name of Chilpi Ghát Series. Another outcrop of the same rocks occurs in Bastar territory. In Southern India, a large number of outcrops have been described under the name of Dhárwár Series, the most famous being the synclinal exposure situated in Mysore, that contains the Kolár gold-field.

The same rocks are found in the Assam plateau where they have been described as the Shillong Series. In the Himalayan region, the same rocks are known as the Daling Series in the Eastern Himalaya, Jaunsar Series in the Chakráta region, Infra-Krol (in part) in the Simla region, Vaikrita in Spiti, Panjál (in part) in the Western Himalaya.

The same system constitutes the Miju ranges at the head of the Assam Valley, and is largely developed in Burma, where the crystalline limestones, containing the rubies and other gems, perhaps belong to this period.

Of the numerous names that have been used by Indian geologists for designating this series, the earliest in date is Champáner (Blanford, 1869); the latest and most popular is Dhárwár (Foote, 1886); the most suitable is Arávalli (Hackett, 1877), as it is derived from one of the most remarkable and one of the oldest physical features of the globe. There is super-abundant evidence that these rocks correspond with the system known in other parts of the globe as the Huronian.

Intrusive Granites and Pegmatites.

Amongst the rocks that are intrusive in these ancient Arávalli or Dhárwár beds, yet undoubtedly older than the overlying Kadapahs, may be mentioned granites, which are of medium grain when the intrusion assumes the shape of a compact boss, as in the case of the rock known as dome-gneiss in Hazáribágh, but which become extremely coarse-grained pegmatites when the shape of the intrusion becomes that of a comparatively narrow dyke. When the pegmatites traverse mica schists, they usually contain marketable mica, as in the pegmatite veins of Rajputana, Hazáribágh and Nellore.

Elæolite-Syenites.

Another group of intrusions, probably of the same age, consists of some very interesting rocks containing minerals of the group of the felspathoids, such as the elæolite-syenites discovered by Mr. T. H. Holland at the Sivamalai hill in Coimbatore, and by Mr. Middlemiss in the Vizagapatam hill tracts, and the elæolite-sodalite-syenites discovered by Mr. Vredenburg in the Arávalli range. This is perhaps also the age of the "dunites" (rocks rich in chrome and magnesia) of the Salem district.

Auriferous Veins.

At a period that is not exactly known, numerous fissures were formed in these ancient rocks, which became subsequently filled by quartz impregnated with metallic minerals, producing mineral veins, the richest amongst which are those containing gold and copper.

THE KADAPAH SYSTEM.

THE orogenic effort that folded the Arávallis, Dhárwárs, and other ancient rocks, has powerfully affected the Indian Peninsula. Later efforts of the same kind have been comparatively feeble, the latest of these not being later than the Older Palæozoic era. Since Older Palæozoic times, the Indian Peninsula has no longer yielded to distinct corrugation, and has behaved as a rigid portion of the earth's crust. The main periods of orogenic effort have been practically synchronous all over the world, and are of great assistance in identifying rocks with one another in distant parts of the world, especially when the rocks are unfossiliferous or nearly so.

Two main periods of orogenic effort have affected many parts of the world during the Palæozoic, one in Silurian times, and the other in the Middle Carboniferous. The Peninsula has been affected by one or perhaps both of them, though in a much slighter degree than by the great post-Huronian upheaval. But the total absence of any fossils, so far as has been observed in beds older than Upper Carboniferous in the Peninsula, introduces an element of doubt in their correlation.

The bulk of the Kadapah System consists of shales and limestones. Slaty cleavage, varying in degree, is often observed in the shales, but the limestones never acquire the crystalline texture that is so common in

The Geology of India.

FROM a geological point of view India is divided into three regions: (1) the Peninsular area, in which there are no mountains in the true sense newer than palæozoic, (2) the region of relatively recent mountains (tertiary in age), constituting the ranges of the Himalaya, Balúchistán and Burma, and (3) the great Indo-Gangetic alluvial plain. These divisions are intimately connected with the physiographical history of the countries that now constitute the Indian Empire. In the Peninsula all the rocks of Upper Palæozoic age, or newer, are either horizontal, or dipping at comparatively low angles. The principal type of disturbance that has affected the peninsular area during the Upper Palæozoic and later times is the formation of elongated, almost rectilinear, trough faults which are of paramount importance in the mineral resources of India, as they account for the formation and preservation of the Indian coal-basins. The central and western portion of the peninsular area is occupied by an enormous outcrop of heavy, black, volcanic rocks known as the Deccan trap. It constitutes flat-topped hills, built of piled-up flows of basaltic lava, which have remained almost undisturbed since they were erupted in cretaceous times. The faulted troughs constituting the coal-basins occupy relatively small areas, principally in the eastern and north-eastern part of the peninsular region. Outside these coal-basins the rocks constituting the peninsular area, wherever they are not concealed by the Deccan trap, are mostly of palæozoic or older age, with the exception of a fringe of cretaceous and tertiary strata at some points along the sea-coast. These later beds, found in the neighbourhood of the present sea-coast, are the only fossiliferous marine sediments of the peninsular area. The absence of such beds from the remainder of the peninsula indicates that this portion of India has been a continental area ever since the earliest geological times, and is one of the oldest land areas of the globe.

Peninsular, extra-peninsular, and Indo-Gangetic regions.

The rocks constituting the extra-peninsular area, that is the mountain ranges of the Himalaya, of Balúchistán and of Burma, contain, in addition to a substratum of rocks identical with some of the older ones of the Peninsula, numerous representatives of marine fossiliferous strata of almost every geological age, from Cambrian to Tertiary. The area remained occupied by the ocean until late in Tertiary times, when the upheaval of the Himalaya was completed.

The great Indo-Gangetic plain, which now joins together the essentially different peninsular and extra-peninsular areas, consists of alluvial soil mostly derived from the disintegration of the Himalaya, whose rapid accumulation has finally obliterated all remnants of the arm of the sea which might still have subsisted between the two areas.

The geological formations of India may be classified into the following divisions:

- Recent formations.
- Pleistocene.
- Siwalik System (Pliocene and Upper Miocene).
- Pegu or Mekran System (Lower Miocene and Oligocene).
- Eocene.
- Mesozoic or Secondary.
- Permian and Upper Carboniferous.
- Lower Carboniferous and Devonian.
- Silurian, Cambrian, and Pre-Cambrian.
- Oldest Sediments.
- Fundamental Gneiss or Archæan.

THE ARCHÆAN.

THE Archæan, if one restricts this name to the rocks underlying the oldest undoubted sediments, consists essentially of crystalline gneissose rocks that must have solidified under conditions quite different from those that attended the formation of later rocks. These gneisses represent, in part at least, the original crust of the globe, when the surface of the originally molten mass first began to solidify.

As in other parts of the world, the Archæan system in India is largely made up of rocks whose composition and structure resemble those of the intrusive rocks of the family of the granites or diorites—granular aggregates of quartz, felspar (silicate of alumina and of alkali or lime), and various ferro-magnesian silicates, such as amphibole, mica of certain kinds, or, less frequently, pyroxene. These rocks differ from many of the true intrusive granites and diorites of later ages owing to the pronounced parallel arrangement of their constituting minerals, producing the structure known as gneissose. In addition to the parallel arrangement of the minerals within the rocks, the whole mass is often arranged in parallel layers of rapidly varying composition. In some of these rocks felspar is scarce or absent, and thus they pass from the condition of gneisses to that of crystalline schists. Amongst the most peculiar types of this class are the sillimanite schists of Orissa discovered by Dr. Walker, and named by him "khondalites" (Memoirs of the Geological Survey of India, Vol. XXXIII); also the corundum bed of South Rewa, in Central India; the manganiferous garnet-bearing schists and gneisses discovered by Mr. L. L. Fermor, and called by him the "kodurites." There are many outcrops of garnetiferous mica schists.

It is sometimes uncertain whether these schists are true members of the Archæan system, or metamorphosed representatives of some of the subsequent normal sedimentary series.

Three well-marked types have been recognized by the Geological Survey of India amongst the rocks of the Archæan. These are: the BENGAL GNEISS (Oldham, Memoirs of the Geological Survey of India, Volume I, 1859), the BUNDELKHAND GNEISS (Mallet, Manual of the Geology of India, p. 10, 1879), and the NILGIRI or MOUNTAIN GNEISS (King, Mem. G. S. I., Vol. XVI, p. 125, 1880).

Bengal Gneiss.

The Bengal gneiss is characterized by its varied composition and conspicuously banded structure. It often exhibits rapidly alternating layers of sharply contrasted composition, some of which exhibit the characters of gneissose granites and diorites, while others are more of the nature of schists. The schistose types are very numerous, including quartzose, micaceous and hornblendic schists, garnet-bearing, magnetite-bearing, sillimanite-bearing, and manganiferous gneisses and schists, such as the khondalites and kodurites already mentioned, and many other varieties.

Bundelkhand Gneiss.

The Bundelkhand gneiss, which, in its type-area, usually has the appearance and composition of a coarse typical pink granite, was once regarded as the oldest rock in India. At a time when gneisses were regarded as metamorphosed sediments, the coarseness of crystallization was thought to be related to the degree of metamorphism, and consequently to the antiquity, of the rocks. As the oldest rocks of the earth's crust must include representatives of its first definitive consolidation from its original molten condition, it is evident that the Archæan must consist largely of rocks formed under conditions different from any with which we are acquainted in the present stage of the globe's history. The Bundelkhand gneiss, when the nature and composition of the rock are considered, closely resembles an intrusive granite, but differs from undoubtedly genuine granitic intrusions owing to the enormous area which it occupies. When the Archæan rocks first consolidated, the primordial atmosphere contained in the state of vapour the totality of the water that now forms the ocean, the volatile chlorides, as well as a large proportion of the carbonic acid and oxygen that have now been absorbed by various solid rocks. It is quite conceivable that under the enormous pressure of this primordial atmosphere, molten masses may have spread out over large areas, and on solidifying assumed the granitic form which at later periods could only have been developed under similar conditions of pressure and temperature in the depths of the earth's crust. Instead of being older than the Bengal gneiss, it is quite possible therefore that the Bundelkhand gneiss may be resting on a substratum of previously solidified rocks. Much of the banded structure of the Bengal gneiss is due to the injection of molten rocks in the midst of previously solidified gneisses or schists. Some of these intrusions may be contemporaneous in age with the outflow of the Bundelkhand gneiss. Thus, the Bundelkhand gneiss, instead of being the oldest rock of the peninsula, may be newer than some parts at least of the Bengal gneiss.

Where granitoid bands of appreciable width constitute part of the Bengal gneiss, they weather into the characteristic groups of piled up blocks of huge dimensions known as "tors." The same mode of weathering affects the Bundelkhand gneiss. In its type-area, the Bundelkhand gneiss constitutes principally a plain, surrounded by cliffs of the much harder Vindhyan sandstones. This plain is traversed by great rectilinear, wall-like ribs of quartz, constituted by huge veins of that substance many miles in length. They give rise to rugged hills, imparting quite a special character to the scenery of Bundelkhand, and affording great facilities for the creation of artificial lakes.

Quartz-veins of Bundelkhand.

Distribution of Bengal Gneiss and Bundelkhand Gneiss.

Lower Bundelkhand is the principal area of this form of gneiss in Northern India. The Bengal gneiss occupies large surfaces in Behár, Manbhúm, Orissa, Rewa, the Dhár Forest, and Gujrát. As regards Southern India, so far as can be made out from published accounts, the schistose gneisses that have been described as Karnatic gneiss or Salem gneiss, seem to correspond with the facies of the Bengal gneiss, while the facies of the Bundelkhand gneiss recalls that of the massive granitoid red gneiss which prevails in the upland of Southern India and has been distinguished under various names such as Bálághát or Hosur gneiss. Its eastern confines from the Palár to the Kistna are almost continuous with the edge of the ghâts, and it is typically developed in North Arcot, in the Kadapah sub-division, in the eastern part of the Bellary district, where it is traversed by gigantic quartz veins similar to those of Bundelkhand, in the Karnúl district, and thence all over the eastern portion of the Hyderabad territory up to the higher reaches of the Godávari river. It has been largely used as a building material throughout Southern India. The magnificent buildings of Vijayánagar, in particular, are constructed of Hosur gneiss.

Central Gneiss of Himalaya.

The Central gneiss of the Himalaya is, in part at least, of Archæan age, but in the present state of the survey cannot always with certainty be distinguished from intrusive granites of Tertiary age; neither are the available descriptions sufficient to tell whether the Bundelkhand gneiss or Bengal gneiss facies is more particularly represented. Still more scanty is our knowledge regarding the Fundamental gneiss in the Burmese and Malay region, though the system is there also represented.

Nilgiri Gneiss.

The gneisses constituting some of the principal hill masses of the Deccan, such as the Nilgiris, the Palnis and the Shevaroys, also closely resemble intrusive rocks except for the great dimensions of their outcrops. They are granitoid rocks of a peculiar dark-grey to black colour, and their distinctness from the other rocks of the Peninsula was first recognized by the late Dr. King, who proposed for this series, the appropriate name of "Nilgiri" or "Mountain Gneiss."

The same rock is also observed near Madras and in the tributary mahals of Orissa, and in the districts of Ganjam and Vizagapatam. The leading features of these rocks are their dark colour and the constant the Arávalli System. As might be expected, the Kadapahs are intermediate between the older Arávallis or Dhárwárs and the newer Vindhyans, not only in point of the degree of alteration, but also in the nature of the rocks constituting the two groups. The shales which are often calcareous, and the somewhat thin-bedded limestones are essentially similar to those of the Vindhyan formation, but the Kadapahs also contain some of the characteristic Huronian rocks, such as the manganese and iron ores, and the banded jaspers. It is only the latter, however, that are equally well represented in both formations. These bright-red jaspers have been extensively used in the inlaid decoration of the buildings of Delhi and Agra.

There are two main divisions of the Kadapah, each consisting of several series separated from one another by unconformities. The rocks resembling some of the Huronian beds, such as the banded jaspers, are especially abundant in the Lower Kadapahs, while the Upper Kadapahs are more like the Vindhyans. Amongst the Upper Kadapahs, one sometimes notices some remarkable conglomerates, or rather boulder-beds consisting of pebbles of various sizes, some of them very large, scattered through a fine-grained slaty or shaly matrix. These peculiar boulder-beds are regarded as glacial in origin.

Boulder-beds.

Of the two sub-divisions of the Lower Kadapah, the lowermost known as the Pápaghni Series has been observed only in the type area of the Kadapah System in Southern India. The upper member of the Lower Kadapah, known as the Bijáwar Series, is widely distributed throughout India, and is easily recognized on account of its association with a grand volcanic outburst, the products of which consist of basic lavas, sills and ash-beds intercalated amidst the Bijáwar sediments, and intrusive dykes and bosses of the same composition penetrating through rocks of greater age than the Bijáwars. These dykes are interesting as being probably the original home of the Indian diamonds, now found as derived pebbles in the later Vindhyan conglomerates.

Volcanic rocks of Bijáwar Series.

The Bijáwars were first described in the State of that name in Bundelkhand (Medlicott, 1860), and were subsequently identified south of the Son River in Rewa, and north of the Narbada River in the Dhár Forest. In the type-area of the Kadapahs, where their identity with the Bijáwar Series was not at first recognized, they were described under the name of Cheyair, and near Gwálior they were called the Gwálior Series. The Penganga beds of the Pránhitá Valley also appear to belong to this same horizon.

The Upper Kadapahs are represented in the type-area of the Kadapahs by the Nallamalai and Kistna Series, by the Kaladgi beds between Belgaum and Kaladgi, and by the Pakhals of the Lower Godávari. They are represented in Rewa State south of the Son River, and round the Chhatisgarh basin.

In the Himalayan region, the representatives of the Upper Kadapahs are the Baxa beds in the Eastern Himalaya, and the Blaini beds in the Simla region. The Haimantas of Spiti are very similar, lithologically, to the Upper Kadapahs. Their uppermost beds are of Upper Cambrian age.

Throughout the greater part of their outcrops, the Kadapahs dip at moderate or very low angles, and show very little sign of disturbance. Almost horizontal beds may be observed resting on the denuded edges of closely compressed synclines of Dhárwár strata, showing that a period of denudation intervened between the Huronian upheaval and the deposition of the Kadapahs. Nevertheless, along the Eastern Ghâts, along the eastern edge of the Chhatisgarh basin, and south of the Son River, the Kadapahs themselves are intensely compressed and folded in such a manner as to indicate that they have evidently formed part of mountain ranges, giving undoubted evidence that in addition to the older period of mountain formation, another set of orogenic phenomena has affected the peninsula after the Kadapah period.

THE VINDHYAN SYSTEM.

THE Vindhyan System named after the Central Indian highland that extends north of the Narbada, Son, and Damúda, and south of the Jumna and Ganges, is a vast formation presenting two principal facies, one mainly characterized by limestones and calcareous shales, the other by enormously massive sandstones. As a rule, the Vindhyan strata dip at low or very low angles, and are even less disturbed than the Kadapahs. Yet, along the south-eastern border of the Arávalli range, and in those places where the Kadapahs themselves have been conspicuously disturbed, the Vindhyans have also been affected by folding and overthrust, indicating that they too have shared in the mountain-forming disturbance. Even in such localities they are not affected to the same degree as the Kadapahs, and it is evident that the main phase in the disturbance of the Kadapah had been completed before the deposition of the Vindhyans, and that the Kadapahs had been greatly denuded in the interval.

In their type-area, which covers an immense territory from Dehri-on-Son to Hoshangabád and to Gwálior, and from there to Agra and to Neemuch, the Vindhyans consist of four main divisions : a lower division exhibiting the calcareous facies, which is known as the Lower Vindhyans; an overlying division consisting of two enormously massive sandstones known under the names of Kaimur and Rewa, separated by some subordinate shales; another division, mainly calcareous and similar to the Lower Vindhyans, which is known as the Lower Bhanders, and lastly, an uppermost division of massive sandstones, known as the Upper Bhander. The calcareous divisions average some 1,500 feet in thickness each, the sandstone ones about 500.

A remarkable group of highly silicious volcanic rocks, varying from rhyolites to quartz-andesites, occurs in the Lower Vindhyans. Amidst the pebbles of certain Vindhyan conglomerates in Bundelkhand and in Southern India, there occur diamonds (the Panna and the Golconda diamonds), probably derived from the denudation of the basic volcanic dykes of Bijáwar age.

There are several other outcrops besides that of the type-area of Central India, though none of them are so extensive. It is only in the type-area that the Bhanders are represented. The Lower Vindhyans together with the Kaimur-Rewa sandstones are well represented in the Dhár forest, north of the Narbada, and in Western Rajputana, the latter exposure exhibiting a particularly fine development of the volcanic beds of the Lower Vindhyans, locally known as the Maláni beds, from the State of that name. All the other Vindhyan outcrops consist mostly or entirely of Lower Vindhyans. They occupy the greatest part of the Chhatisgarh basin, and constitute the Karnúl Series of the district of that name, and of the Bhíma Valley. The Sullavai sandstones of the Godávari Valley perhaps belong also to the same formation, unless they represent the sandstone and shale formation known collectively as the Red Shale Series in Rewa, where it underlies the Lower Vindhyans, and yet seems newer than any of the Kadapahs. It might be regarded as an oldest member of the Vindhyan system. Amongst the mountains of Northern India, the Vindhyans are represented by the Deoban Series near Chakráta, the Krol Series of the Simla area, and the Attock Series of the Punjab.

Building-materials.

The Vindhyan limestones constitute a valuable source of lime, while the sandstones have yielded the material for the masterpieces of Indian art from the time of Asoka to the present day. Amongst the buildings of Vindhyan sandstone may be mentioned the Buddhist stupas of Barhut, Sánchi, and Sarnáth, the exquisite temples of Kajráha, the palaces of Gwálior, Delhi, Agra, Fatehpur-Sikri, Amber, Díg, and the magnificent Jumma Masjids of Delhi, Agra, and Lahore. According to which beds are selected, it is possible to obtain monoliths of Egyptian magnitude, or flags of the thinness of slates. Such a variety of excellent material is obtainable that, in certain parts of India, public buildings and private dwellings, from the flooring to the walls and to the rafters and ceilings are built entirely of stone. Large quantities of railing posts are manufactured out of Vindhyan sandstone, and, until a few years ago, it was the usual material for telegraph posts.

FOSSILIFEROUS REPRESENTATIVES OF THE CAMBRIAN AND SILURIAN SYSTEMS.

Throughout the rock systems that remain to be mentioned, the presence of fossils removes the element of doubt that affects the attempts at correlating the rocks hitherto dealt with. The outcrops that can be unhesitatingly referred, in India, to the oldest fossiliferous formations of the globe, the Cambrian and Silurian, are relatively of small extent when compared with the vast areas occupied by the formations hitherto mentioned. The oldest of all, the Cambrian, has hitherto been met with only in two localities, the Salt Range of the Punjab and Spiti. The system is well developed in the eastern portion of the Salt Range, where its principal members are a purple sandstone, an arenaceous dolomite, and a group of bright-coloured shales with casts of salt crystals. The lower member, the purple sandstone, and the uppermost shales are quite unfossiliferous, but numerous fossils have been found in a band of shales intervening between the purple sandstone and the arenaceous dolomite. The fossils are of Middle Cambrian age, and include representatives of the most characteristic of the Palæozoic fossils, the curious crustacea known as trilobites. They were discovered by Dr. Warth in the year 1888. They belong to the genus *Redlichia* which characterizes the Lower and Middle Cambrian. The unfossiliferous purple sandstone is not unlike the Vindhyans. In the sections of the Eastern Salt Range it is seen resting on a great mass of unstratified clay, in the midst of which are situated the layers of salt from which the mountain range derives its name. But the structure of the range is one of extensive overthrust faulting, and it is probable that the salt marl is not in its normal situation with reference to the Cambrian strata, but is really much newer, and Tertiary in age.

Cambrian of the Salt Range.

Cambrian of Spiti.

Upper Cambrian fossils were discovered by Mr. Hayden in the upper portion of the Haimanta System of Spiti during the year 1898. These fossiliferous beds, whose aggregate thickness is about 1,000 feet, consist of slates with some quartzites and dolomites. They overlie with apparent conformity some 3,000 or 4,000 feet of unfossiliferous strata recalling the Upper Kadapah, and consisting of slates, some of which are ferruginous and carbonaceous, and of quartzites. These unfossiliferous beds may perhaps represent the Middle and Lower Cambrian. Amongst the fossils discovered by Mr. Hayden, there are trilobites belonging to the genera *Ptychoparia*, *Dikelocephalus* and *Olenus*.

Silurian of Spiti.

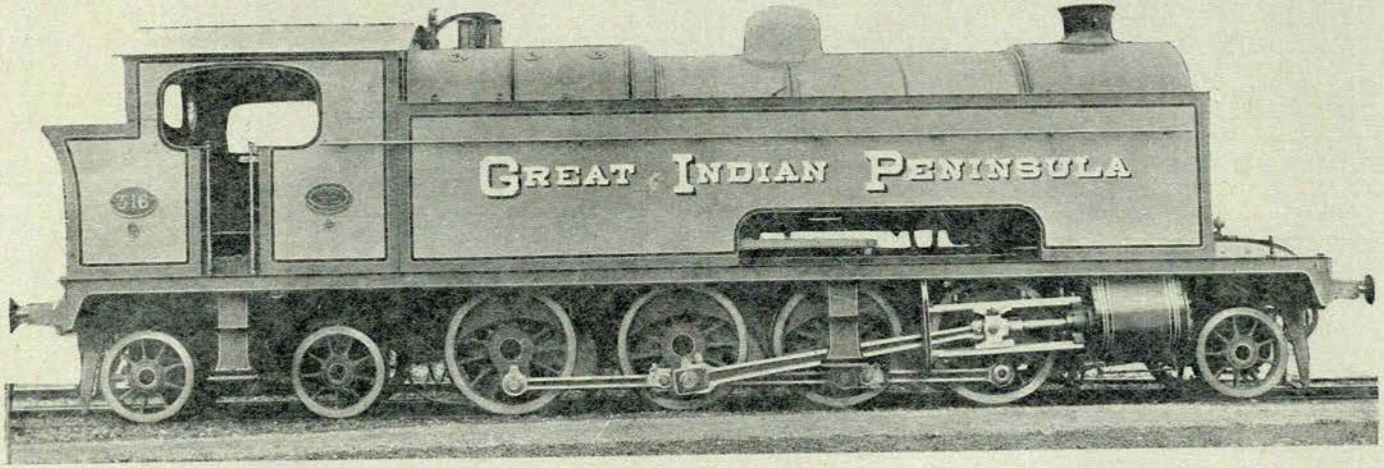
The Silurian is not developed in the Salt Range, where the Cambrian is immediately succeeded by Upper Carboniferous beds. In Spiti, the Upper Cambrian is unconformably succeeded by an unfossiliferous quartzite, about 1,500 feet thick, succeeded by highly fossiliferous limestones and calcareous shales of a total thickness of some 500 or 600 feet. Amongst the leading fossils are a number of trilobites belonging to the genera *Cheirurus*, *Illænus*, *Asaphus*, *Calymene*, and numerous corals, cystoids, brachiopods and gastropods. The fossiliferous beds include both Lower and Upper Silurian horizons (Caradoc to Wenlock).

Silurian of Burma.

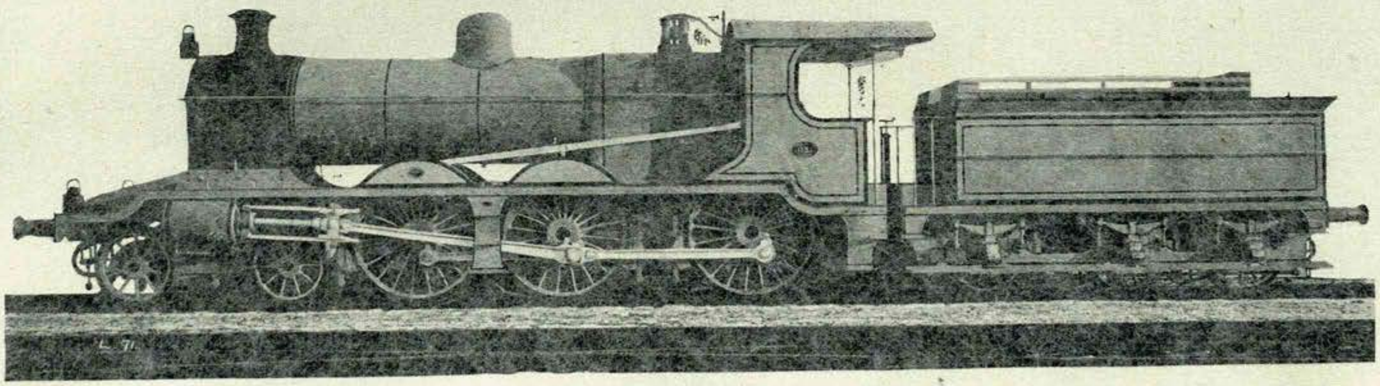
In the Northern Shan States of Burma the Lower Silurian is represented by shales of various colours with thick bands of limestones, containing numerous cystideans, bryozoa, brachiopods and trilobites belonging to the genera *Remnopleurides*, *Calymene*, *Pliomera*, *Sphærocoryphe;* and the Upper Silurian consists of strata exhibiting two different facies: an arenaceous facies (Namhsim Sandstone) containing numerous brachiopods, and some trilobites of the genera *Illænus*, *Encrinurus*, *Calymene*, *Cheirurus*, *Phacops* (*Dalmanites*); and a calcareous facies (Zebingyi Beds), with graptolites, brachiopods, cephalopods, and trilobites of the genera *Phacops* and *Dalmanites*. The Namhsim Sandstones are principally of Wenlock age; the Zebingyi Beds, slightly newer.

Between the Lower Silurian and the Huronian or Archæan of the Shan States, there intervenes a thick series of quartzites and slaty shales that have been regarded as Cambrian, but containing no fossils.

TYPES OF INDIAN LOCOMOTIVES.



G. I. P. LOCOMOTIVE.



E. I. R. LOCOMOTIVE.

basin, all of which are Lower or Middle Carboniferous in age. The Lower Gondwana coal corresponds with the Upper Productive coal measures of North America, and with the coal measures of central France, which recall the Damúdas on account of the enormous thickness of some of their seams.

The constitution of the Lower Gondwanas, where most typically developed in Bengal, may be tabulated as follows:—

		Approximate age.
PÁNCHET	.. ..	ZECHSTEIN.
DAMÚDA	RÁNIGANJ	ARTINSKIAN.
	IRONSTONE SHALES	
	BARÁKAR	
TÁLCHIR	KARHARBÁRI	URALIAN.
	BOULDER-BEDS	MOSCOVIAN.

In the coal-fields situated outside of Bengal, some of these divisions have received different names. Detailed monographs of all the coal-fields have been published in the Memoirs and Records of the Geological Survey of India.*

(b) *Marine Facies.*

Productus-beds.

THE marine representatives of the Ural and Artinsk stages are very widely developed throughout the extra-peninsular regions of the Indian Empire, where they are usually known as the Productus-beds, from the great abundance of fossil brachiopods belonging to that genus which they contain. It is in the Salt-Range that these beds have been most completely studied. In that range they are mostly calcareous and are collectively known as the Productus limestones. They have been classified as Lower, Middle and Upper Productus limestones, each of which is further sub-divided. The base of the Lower Productus limestones is a boulder-bed apparently glacial, identical with the Tálchir boulder-bed and of the same age. It contains a variety of fossils and most of the overlying beds are highly fossiliferous. The successive faunas have been studied in great detail by Waagen, whose descriptions have been published in the Palæontologica Indica. The fauna of the Lower Productus limestones and that of the lower divisions of the Middle Productus limestones indicates that these beds belong to the Upper Carboniferous Period. The remainder of the Productus limestones, owing to the presence of fossil ammonites with complex sutures, such as the genera *Cyclolobus* and *Medlicottia*, is correlated with the Lower Permian (Permo-Carboniferous or Artinskian). The uppermost beds of the Upper Productus limestones are immediately succeeded by a conglomerate of Triassic age, the representatives of the Zechstein or Upper Permian being absent from that region, as from all the exposures of marine Permian in India.

Boulder-bed of the Salt-Range.

The same rocks, either calcareous or shaly, are extensively developed all along the central ranges of the Himalaya. (The outer ranges are largely occupied by rocks corresponding with the ancient unfossiliferous series of the peninsula). The most constant member of the group is the one known as the Productus shales which corresponds with the Upper Productus limestones of the Salt-Range, and is of Lower Permian age.

In Garhwál, the Productus shales overlie unconformably beds of Lower Palæozoic age. In Spiti, they pass inferiorly into a calcareous sandstone of Upper Carboniferous age, the base of which is conglomeratic. This conglomerate usually rests unconformably on various horizons ranging from Silurian to Lower Carboniferous, except where the Po Series, mentioned in a previous paragraph, attains its maximum development: there the conglomerate passes conformably downwards into the uppermost member of the Po Series, the Fenestella shales, themselves of Upper Carboniferous age.

Permian and Upper Carboniferous of Spiti.

It is important to notice, therefore, that the Spiti conglomerate is not the equivalent of the Talchir conglomerate or the boulder-bed of the Salt-Range, but belongs to a higher horizon corresponding probably with some zone of the Barákar.

The Fenestella shales themselves appear to correspond with some of the Barákar and Karharbári horizons, and are represented in Kashmir by the Zewan beds which underlie the Productus shales (Lower Permian), and overlie shales and sandstones containing fossil fishes and impressions of *Gangamopteris*, which belong to one of the zones of the Tálchir and rest on volcanic rocks, probably of Lower Carboniferous age.

Zewan beds of Kashmir.

Beds corresponding with the Productus limestones of the Salt-Range are known in the Eastern Himalaya. In Burma and in Tenasserim, they are largely represented by limestones crowded with foraminifera of the genera *Fusulina* and *Schwagerina*. The Fusulina limestones have also been observed in Balúchistán in the Pishín and Zhob districts. The respective limits of Upper Carboniferous and Lower Permian in all these exposures has not yet been ascertained. One of the curious "exotic blocks" of Johar on the Tibetan frontier, scattered through a gigantic volcanic breccia of Cretaceous age, that forming the peak known as Chitichun I, is a huge mass of limestone containing fossils of the same age as the Kálabágh zone of the Salt-Range at the base of the Lower Permian.

Fusulina and Schwagerina limestones.

Chitichun I.

The uppermost beds of the Lower Permian of Garhwál contain the remarkable genus of ammonites discovered in 1879 by Mr. Griesbach, and described by him as *Otoceras*. The layer containing this fossil is immediately succeeded by Lower Triassic beds without any indication of unconformity, and was, therefore, taken to represent a passage zone between the Permian and Trias. But there is a complete change of fauna between this layer and the succeeding beds, indicating a break quite as pronounced as in the Salt-Range. The Otoceras layer is ferruginous which indicates that it probably remained exposed to the atmosphere, and that there was an interruption of sedimentation after the period during which it was formed. The newest age that can be assigned to it is the top of the Lower Permian.

Otoceras beds.

* Most of these monographs are out of print. They can be consulted, however, in most public libraries.

TRIASSIC, JURASSIC, AND LOWER CRETACEOUS SYSTEMS.

(*a*) *Gondwana Facies.*

THE Upper Gondwanas are for the greatest part barren of useful minerals and have, therefore, received very little attention from the Geological Survey of India. Their age is often doubtful and their nomenclature confused.

The unfossiliferous red sandstones of the Mahádeva group, which attain a thickness of some 8,000 feet in the Mahádeva hills of the Sátpura Range, are perhaps of Triassic age. Similar beds, perhaps of the same age, overlie the coal measures in South Rewa and in some of the Damúda and Mahánadi valleys series of coalfields.

The remaining divisions of the Upper Gondwana are usually of small thickness and are closely related to one another. Their age, ranging from Upper Jurassic to Lower Cretaceous, is sometimes approximately and sometimes accurately defined by means of their fossil contents. In ascending order, there are four divisions: firstly, the Rajmahál; secondly, an intermediate group for which no general name has yet been selected; thirdly, the Jabalpur; and fourthly, the Umia. The three first, and sometimes the last, are represented all along the East coast of the peninsula from the neighbourhood of Vizagapatam to that of Tanjore.

The type of the Rajmahál division is observed in the hills of that name in Bengal, where the fossil plant-bearing beds are associated with basaltic rocks. Basic dykes connected with this volcanic outburst are common in some of the coal-fields of Bengal, and include some interesting petrological types, such as the mica-peridotites discovered in 1894 by Mr. T. H. Holland.

Mica-peridotites.

The type of the Jabalpur beds is near the town of that name. Instead of consisting chiefly of sandstones, like the groups hitherto mentioned, they are largely made up of clays and contain beds of lignite.

In Kachh the Umia beds, chiefly sandstones and shales, attain a vast thickness (3,000 feet), and contain strata with fossil plants closely related to the Jabalpur flora, intercalated between beds with marine fossils respectively of Wealden and Lower Greensand age. This fixes the age of the newest Gondwanas as Lower Cretaceous. Beds apparently of the same age in Káthiáwár and Gujrát contain seams of lignite.

(*b*) *Marine Facies.*

THE marine representatives of the Trias and Jura are enormously developed in the extra-peninsular regions of the Indian Empire, the Upper Jurassic being also well developed along the borders of the peninsular area in Kachh and Rajputana. The different beds of the marine Mesozoic formations in India can be readily correlated with their equivalents in other parts of the world by means of the numerous fossil ammonites which they contain. Each horizon of the Mesozoic is characterized by a particular species of ammonite, and the zones thus defined can be recognized in all parts of the world. It is in the Mesozoic zones of the Central Himalaya and the North-Western Frontier, that a number of able scientists, amongst whom special mention should be made of Stoliczka, Griesbach, Middlemiss, Diener, von Krafft, and Hayden, have accomplished the most brilliant geological work as yet achieved in India.

The Trias, consisting principally of limestones, calcareous shales and massive dolomites, is characterized in the Salt-Range and the Central Himalaya by a richness in fossils unequalled in any other part of the world.

Trias of the Himalaya.

It is especially in the Central Himalaya that the system is most complete, the Upper Trias, in particular, being developed on a truly gigantic scale. In Spiti, for instance, the respective thicknesses of the three divisions are roughly 50, 500 and 3,000 feet. The lower division corresponds with the "ceratite-beds" of the Salt-Range.

Amongst the fossils characterizing various horizons of the Lower Trias, may be mentioned, *Ceratites normalis*, the genera *Danubites*, *Tirolites*, and *Meekoceras*, and, in the upper zones, *Rhynchonella Griesbachi.*

The Middle Trias is characterized by the great abundance of species belonging to the genera *Ceratites* and *Ptychites*, by *Spiriferina Stracheyi* in the lower beds, and, in the upper beds, by *Daonella Lommeli.*

Amongst the enormous succession of strata constituting the Upper Trias may be noticed, towards the base, the beds with *Halobia;* higher up those known as Tropites beds from the abundance of ammonites belonging to that genus; still higher the Juvavites beds of Spiti and Halorites beds of Kumaon, containing innumerable ammonites, amongst which the remarkable genus *Pinacoceras;* lastly, the *Monotis salinaria* shales, and strata with *Spiriferina Griesbachi* and *Megalodon.* The Monotis shales are also largely developed in the Pishín and Zhob districts of Balúchistán, while shales and limestones with *Halobia* constitute a considerable proportion of the Arakan Yoma.

The great thickness of Jurassic limestones, which overlies the Trias in the Central Himalaya, has yielded very few fossils, and therefore cannot be readily subdivided into zones. These limestones are overlaid by the "Spiti shales" of uppermost Jurassic age, whose well-known ammonites are current as an article of trade, being used all over India for certain religious rites.

Jurassic of Balúchistán.

In Balúchistán, the Lias (Lower Jurassic) consists of 3,000 or 4,000 feet of black limestones, some of them oolitic, and calcareous shales, with some highly fossiliferous bands, in which the principal sub-divisions of the European series have been identified. They are succeeded by an equal thickness of massive limestones of Middle Jurassic age, which constitute the lofty peaks that surround Quetta. This massive limestone is unconformably overlaid by the Lower Cretaceous, the Supra-Jurassic series being absent from Balúchistán.

Jurassic of Kachh.

The Upper Jurassic zones, missing in Balúchistán, are represented in Kachh by a thickness of about 3,000 feet of oolitic limestones and shales, passing upwards into sandstones; all the principal ammonite-zones of the Upper Jurassic of Europe have been identified in this sequence. The same horizons are represented in the Salt-Range and in Western Rajputana. The Jurassic is largely represented in Burma, where, however, it has not been studied in detail.

The Upper Jurassic of Kachh is succeeded by an equal thickness of Lower Cretaceous sandstones, often glauconitic, extending up to the horizon of the Lower Greensand, and constituting the Umia beds, already mentioned with reference to the Gondwana facies.

Lower Cretaceous.

In Balúchistán, the Lower Cretaceous is represented by the black "belemnite shales," containing belemnites of the genus *Duvalia*, and by the overlying brilliantly striped white and red limestones known as the "Parh limestones." The Himalayan equivalent of these rocks is the Giumal sandstones. The equivalents of the Parh limestones have been observed in the Arakan Yoma and the Andaman Islands.

THE UPPER CRETACEOUS SYSTEM.

Absence of Middle Cretaceous.

THE middle stages of the Cretaceous, especially those just preceding the Gault, are not known in India, this horizon coinciding with one of the most pronounced breaks in the Indian Geological sequence.

Upper Cretaceous of Southern India.

It is near the East Coast of Southern India, from Pondicherri to Trichinopoli, that the most complete sequence of Upper Cretaceous beds is observed. The beds are principally shales and sandstones with some calcareous bands full of well preserved fossils that have been described in great detail by Forbes, Stoliczka and Kossmat. There are three principal divisions, the Utatúr, Trichinopoli and Ariyalúr. The Utatúr, mostly shales with some coral limestones, contains over 100 species of ammonites distributed in three zones: the Schloenbachia beds with *Schloenbachia inflata, Turrilites Bergeri, Hamites armatus;* the Acanthoceras beds with numerous species of *Acanthoceras,* and with *Turrilites costatus;* and an upper zone with *Acanthoceras conciliatum,* and *Nautilus Huxleyanus.* These three divisions correspond respectively with the Gault, Cenomanian, and Turonian.

The Trichinopoli beds of Lower Senonian age (with 27 species of ammonites), consisting of sands, clays and shingle beds intercalated with shell-limestones, largely used for ornamental purposes, include a lower division characterized by *Pachydiscus peramplus, Protocardium Hillanum,* etc., and an upper division with *Placenticeras Tamulicum, Heterocera-indicum,* etc.

The Ariyalúr, mostly Upper Senonian, is chiefly arenaceous, and contains at its base a highly fossiliferous band with more than 50 species of ammonites belonging to the genera *Pachydiscus, Baculites, Sphenodiscus, Desmoceras,* etc., and numerous lamellibranchiata and gastropods amongst which the Cypreidæ and Volutidæ are particularly well represented. The uppermost strata of the Ariyalúr are known as the Niniyur beds, and contain the characteristic Danian species *Nautilus Danicus.*

Upper Cretaceous of Balúchistán.

Cenomanian beds containing *Acanthoceras* are known in Hazara and in the Samana range. The Upper Cretaceous is largely developed in Balúchistán and in the Laki range of Sind. Its lower members are limestones constituting the Hemipneustes beds, of Campanian or Lower Maestrichtian age. They are followed by a great thickness of sandstones often interbedded with volcanic material, known as the Pab sandstones. Highly fossiliferous bands are sometimes associated with the Pab sandstones, especially in their upper zones, the commonest fossil being *Cardita Beaumonti.* It is possible that some of the uppermost *Cardita Beaumonti* beds are of Danian age.

Bágh and Lameta beds.

The great volcanic group of the Deccan trap in the peninsula is underlaid by a formation of slight thickness, but of considerable horizontal extent, constituting the Lameta series where it exhibits the fluviatile facies, and the Bágh beds, where it is marine. The Bágh and Lameta correspond with the Utatúr of Southern India.

Deccan Trap.

The eruptions of the Deccan trap continued up to the end of the Cretaceous, the uppermost layer of the *Cardita Beaumonti* beds in Sind being still overlaid by a basalt flow. These eruptions have covered an enormous portion of the peninsula with basaltic flows, the western portion in particular, north of latitude 16°, being entirely occupied by this formation. In the Zhob Valley of Balúchistán, the series is represented by huge intrusions of gabbro associated with serpentines locally rich in chrome. Similar rock are extensively developed in the Arakan Yoma and the Andaman Islands.

Chrome-bearing serpentines.

The Deccan trap eruptions appear to have coincided with the final breaking up of Gondwana-Land.

THE EOCENE SYSTEM.

With the end of the Cretaceous, the Mesozoic or secondary era came to a close.

The Eocene in India, as in other countries, includes the bulk of the nummulitic limestones. It includes three principal divisions: the Ranikot, the Laki, and the Khirthar. The uppermost beds of the Upper Ranikot contain the earliest abundant nummulites belonging principally to the species *N. planulatus.*

Laki series with coal-seams.

The Laki division exhibits either a shaly arenaceous or a calcareous facies according to various localities. Its characteristic nummulites are *N. atacicus,* and *N. (Assilina) granulosa.* The Laki limestones abound also in foraminifera of the genus *Alveolina.* The Laki division is economically of great importance containing as it does an important coal-bearing horizon in Balúchistán and the Punjab.

Khirthar series.

The Khirthar consists largely of limestones which, in the range of that name along the Sind-Balúchistán frontier, are as much as 3,000 feet thick. It contains the zones richest in nummulites, amongst which may be mentioned *N. lævigatus, N. perforatus, N. gizehensis, Assilina spira.*

Both the Laki and Khirthar are well developed in Kachh, and in the Salt-Range in the Arakan Yoma and in the Andaman Islands. The Laki is largely developed in Western Rajputana. The nummulitics of Surat and of Assam and the Subáthu group of the Simla region correspond with the Khirthar.

THE PEGU OR MEKRAN (FLYSCH) SYSTEM.

(Oligocene and Lower Miocene).

THE end of the Eocene coincides with the opening of the last and most important chapter of the geological history of India. The quiescent conditions that had lasted ever since the Upper Carboniferous now came to an end, and the earth's crust entered into a renewed phase of disturbance. The enormous mass of sediments that had so quietly accumulated upon the gradually sinking floor of the Tethys was now powerfully compressed in a horizontal (tangential) direction, and was thrown into a succession of ridges, which became the great mountain ranges of the present day: the Alps, the Pyrenees, the Himalaya.

Upheaval of the Himalaya.

Three phases can be distinguished in this grand upheaval, one at the end of the Eocene, one in the Middle Miocene, and the last in the Middle or Upper Pliocene. The first upheaval, although it extensively folded the Eocene and underlying older strata, uplifting them in many regions into ranges of considerable altitude, was not nevertheless sufficient to obliterate the Tethys. This ocean still preserved its continuity; the gradual subsidence of its floor, of which we have evidence from Upper Carboniferous to Eocene, still continued, or even became accentuated, judging by the enormous thickness of sandstones and gritty shales all bearing evidence of deposition in rather shallow water that accumulated throughout the Oligocene. These dark grey or greenish shales and often calcareous sandstones are singularly uniform and monotonous in appearance, constituting the bulk of the great formation known as the "flysch." Beds of similar appearance had already been deposited in the same area during Eocene and even Cretaceous times, but it is during the Oligocene that most of the flysch was deposited.

The flysch.

Towards the end of the Middle Miocene, a second orogenic phase still more powerful than the Upper Eocene one upheaved the flysch strata, folding them into innumerable corrugations, and the Tethys was cut up into a series of disconnected lagoons or inland seas which finally disappeared in the last great upheaval of Pliocene times.

A homogeneous series of strata was thus formed, resting unconformably upon the Eocene, and unconformably overlaid by the Upper Miocene and Pliocene. It constitutes the Pegu system of Burma, and the Mekran system of Balúchistán.

Kojak shales.

The flysch facies of this system in Balúchistán is known as the Kojak shales, an almost unfossiliferous formation, occasionally containing, however, fossiliferous bands with *Nummulites intermedius*, *N. vascus*, and other fossils of Oligocene age.

Calcareous zones of Sind and Balúchistán.

In the neighbourhood of what was once the shore of the ocean in which the flysch was deposited, the sediments acquire a calcareous facies and become highly fossiliferous. In Sind and in Balúchistán the fossiliferous facies is divided into three principal divisions, the Nari, Gáj, and Hingláj. The Nari includes the Middle and part of the Upper Oligocene. Its lower division frequently consists of massive nummulitic limestones resting with varying amounts of unconformity on the nummulitic limestones of Eocene age. It is the last horizon rich in large nummulites, principally *N. intermedius* and *N. vascus*, accompanied by lepidocyclines of the group of *L. dilatata*. The Gáj, consisting of shales and coral limestones, is of uppermost Oligocene age.

Nari series.

Gáj series.

Hingláj series.

The Hingláj Series, well developed along the Mekran Coast, in the Persian Gulf Islands, in the Irawaddi Valley and Andaman Islands, consists principally of clays and sandstones, and conglomerates with a few calcareous bands. The Hingláj Series is mainly of Burdigalian age (Lower Miocene), the uppermost beds being perhaps Helvetian (Middle Miocene).

Granitic intrusions.

Corresponding in age with a portion of the Pegu System are the great intrusions of granite, of diorite, of augite-syenite, and of porphyries, that cut through the Eocene rocks of Balúchistán forming some of the highest hill ranges, such as the Ras Koh, the Khwaja Amran. Of the same age are the Tertiary granites of the Himalaya.

Petroleum, salt, and sulphur.

Other products of this igneous activity are the petroleum of Burma, Assam and the Punjab, and in all probability the salt-marl and salt deposits of the Salt-Range, as well as many deposits of sulphur. The petroleum, owing to its inferior density as compared with water, has collected along the axes of anticlines in the Pegu System, wherever a layer of argillaceous rock has provided an impermeable roof. Gases have also collected along these anticlinal crests, and are apt to find their way to the surface through fissures, producing the mud-volcanoes that often rise along the outcrops of these anticlinal arches. There are four principal groups of mud-volcanoes, situated respectively along the Eastern and Western borders of the Arakan Yoma, in the Gomal Valley along the Afghán-Balúch Frontier, and along the Mekran Coast.

Mud-volcanoes.

In the Punjab, the equivalents of the Pegu System are known as the Murree beds; in the Himalaya as the Kasauli and Dagshai beds.

The coal-seams of Assam and Burma occur in the Pegu System and are of Oligocene age.

In the Mari hills of Balúchistán, some beds, containing *Mastodon angustidens* and other Middle Miocene fossils, probably belong to the upper part of this system.

THE SIWALIK SYSTEM.

THERE are no typical marine deposits in India newer than the uppermost beds of the Pegu System. The main upheaval of the Himalaya and of the mountains of Balúchistán and Burma took place during the Middle Miocene, after which nothing remained of the ocean that formerly occupied their site but a number of basins isolated from one another in which the strata known as Siwaliks, principally clays, sandstones and conglomerate were deposited. Like all inland seas, these basins were subjected to variations in their degree of saltness that were prejudicial to the development of aquatic organisms. Hence the remains of animals of this class are scanty. Some of the conglomerate beds, especially in the Upper Siwaliks, are of fluviatile origin, and may be regarded as alluvial fans.

In Pliocene times, these beds were upheaved during the final phase of mountain-growth of the Himalaya, after which the only earth-movement that has taken place is a comparatively gentle warping that has affected certain regions of Peninsular and extra-Peninsular India and of the Indo-Gangetic plain in Post-Pliocene times.

The chief interest of the Siwalik formation resides in the remains of extinct animals that have been made known to the scientific world through the researches of Cautley, Falconer, and Lydekker. The bones and teeth of these animals are found principally in the conglomeratic layers at the base and at the top of the series. Those found at the base are of Upper Miocene (Pontian) age, and contain a fauna contemporaneous with that of Pikermi in Greece. Amongst the numerous extinct genera of this fauna may be mentioned *Dinotherium*, *Mastodon*, *Hipparion*, *Helladotherium*, *Hyænarctos*. The upper conglomerates are of Pliocene age and contain the living genera *Elephas*, *Equus*, *Ursus* and many others, all of them represented, however, by extinct species.

Siwalik fauna.

THE QUATERNARY ERA.

It is not certain whether at the end of the Pliocene upheaval an arm of the sea still separated the Himalaya from the Indian Peninsula, but if this were so, it soon became filled by the products of the disintegration of the Himalaya, and in this manner originated the great alluvial plain of the Ganges, which now links the Peninsula together with the Asiatic continent. The great depth of the Ganges alluvium, as revealed by borings, indicates that in its case also subsidence must have proceeded simultaneously with deposition.

Formation of the Ganges alluvium.

Except in the neighbourhood of the delta, the greater portion of the alluvial plain is above the level of the highest floods of the Ganges and its tributaries, indicating that this area has been upheaved, or that the delta region has been depressed within relatively recent times. The presence of a mass of ancient alluvium, known as the Madhupur jungle north of Dacca in the midst of the delta region, further indicates that a certain amount of disturbance must have occurred. The existence of ancient alluvial areas enclosed within rock basins along the course of some of the Peninsular rivers, such as the Narbada, Tápti and Godávári, points to the same conclusion, and it is evident that a certain amount of irregular warping has affected India in Pleistocene times. In consequence of these physical changes, the ancient alluvium and the one still in process of formation can be readily distinguished from one another. They are known in the vernacular as "bhángar" and "khádar." In geological age, they correspond with the two main divisions of the Quaternary era, the Pleistocene and Recent. The Pleistocene age of the bhángar or older alluvium is clearly shown by the remains of numerous extinct animals amongst which may be mentioned *Elephas antiquus*, a characteristic species of the Pleistocene of Europe, and various extinct species of horse, ox, rhinoceros, hippopotamus. Contemporaneous with these are the earliest remains of prehistoric man in the shape of stone implements belonging to the "Chellean" or amygdaloid type, the earliest type of the earlier stone age.

Older and Newer alluvium.

Prehistoric man.

Implements of the amygdaloid type have been found embedded in "laterite," a ferruginous material, which is formed as a superficial alteration of rocks in warm regions subjected to "monsoon" conditions, that is, to alternately wet and dry seasons. The effect of lateritic weathering is to remove the silica of rocks, leaving a concretionary mass consisting of hydrates of iron, aluminium or manganese.

Laterite.

When the laterite is very free from silica and contains locally a large excess of the hydrates either of iron, aluminium or manganese, it constitutes valuable ores of these metals.

The laterite is largely of Pleistocene age, but some of it may still be forming at the present day, while there are important masses of the same material that were formed in Eocene or even earlier times.

Some of the "raised beaches" observed all round the coasts of India at altitudes of as much as 100 feet are probably Pleistocene. The consolidated wind-blown calcareous sand largely made up of foraminiferal tests, which occurs along the coasts of the Arabian sea and is largely used as a building material under the name of Porbandar stone, is also probably Pleistocene.

Raised beaches.

Porbandar stone.

There are two regions of Pleistocene and Recent volcanic activity situated along lines of dislocation in the curved systems of ranges on either side of the great Himalayan "arc." The eastern one situated in the "Malay arc" follows the inner or eastern side of the Arakan Yoma, and its continuation the Andaman Islands, the best known volcanoes being Pupa, Narcondam Island, and Barren Island.

Recent volcanoes.

Along the western or "Iranian arc," the largest volcano within the Indian Empire is the extinct Koh-i-Sultán in the Nushki Desert.

Oscillations of the relative sea level during the Recent Period are indicated by such features as low-level raised beaches, the oyster-bed lately discovered in Calcutta, the submerged forests of Bombay and the East Coast.

The Geological Survey of India.

The Geological Survey of India was organized along its presents lines in 1850, under the superintendence of the late Dr. Thomas Oldham, LL.D., F.R.S., and was designed in the first instance for a survey of the coalfields of the country. The work has, however, been extended over other areas, with a view to the preparation of a geological map, and the investigation of other minerals of economic value.

Coincident with the issue of the geological maps descriptive *Memoirs* and shorter papers in the *Records* have been published, dealing with the scientific and economic aspects of the work of the Department. The published memoirs now exceed 90 volumes, and the main results have been summarized in Manuals, separately treating the scientific and the economic results of the survey.

Since the retirement of the late Dr. T. Oldham, the Department has been under the direction successively of—

H. B. Medlicott, M.A., F.R.S.; W. King, B.A., D.SC.; C. L. Griesbach, C.I.E.; and T. H. Holland, A.R.C.S., F.R.S.

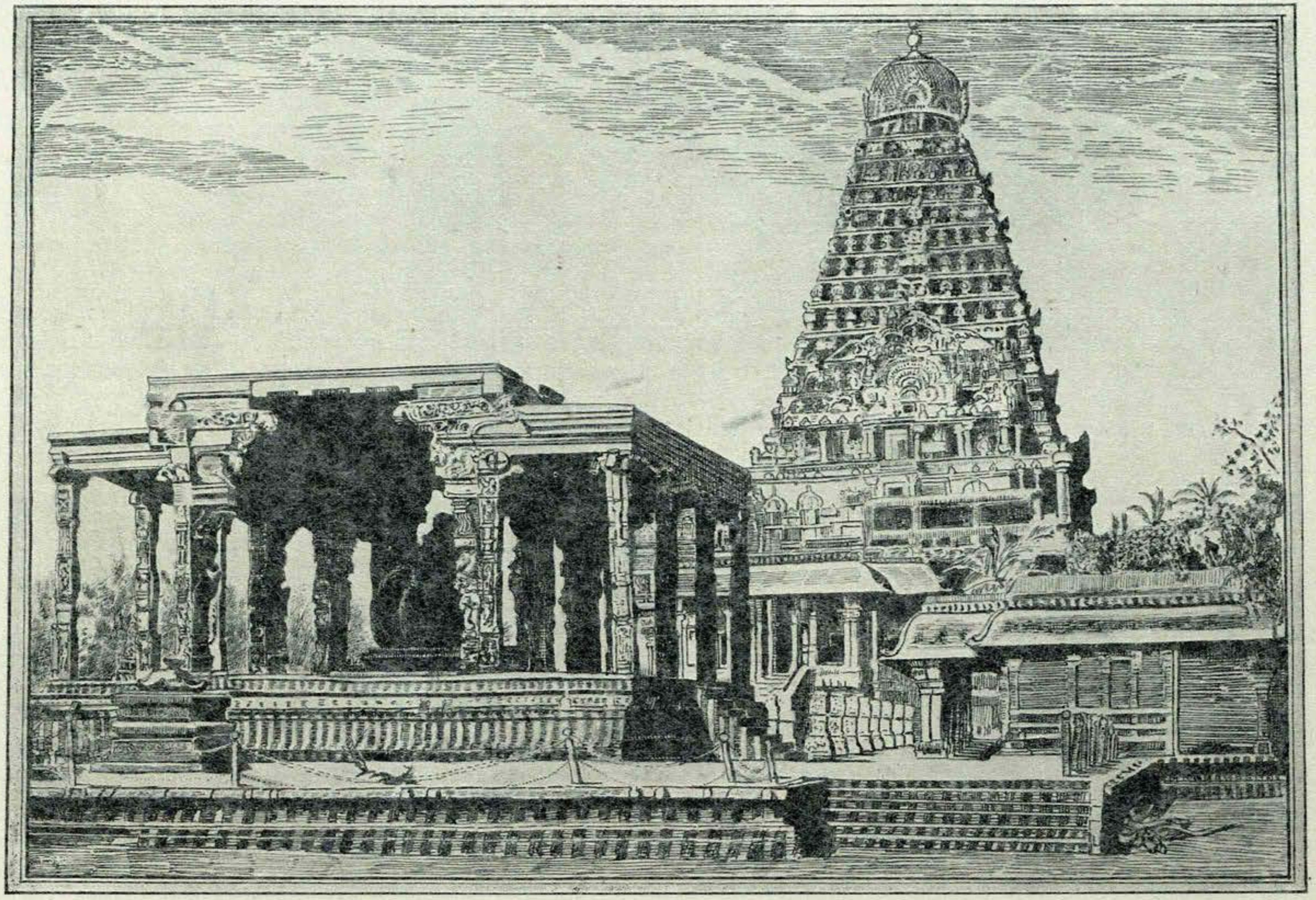
Table of Geological Formations in the Indian Empire.

		Geological age.
Newer alluvium (khâdar), delta formations, etc.	Volcanoes of Burma, the Bay of Bengal, Balúchistán.	RECENT.
Karnúl caves. Older alluvium (bhángar) of Ganges, Narbada, Godávari, etc., with *Elephas antiquus*, *Hippopotamus*, etc., and Chellean implements ; "karewa" deposits ; older raised beaches, Porbander stone, etc., etc.		PLEISTOCENE.
FINAL PHASE OF HIMALAYAN UPHEAVAL.		
(Cuddalore sandstone). **SIWALIK.** Upper beds with *Equus*, *Elephas*, *Ursus*, *Sivatherium*, etc.		PLIOCENE.
SIWALIK. Middle series.		
SIWALIK. Lower beds with *Hipparion*, *Mastodon*, *Dinotherium*, *Helladotherium*, etc.		PONTIAN.
SECOND PHASE OF HIMALAYAN UPHEAVAL.		

Peninsular Area.	Kachh.	Salt-Range.	Himalayan Region and N.-W. Frontier.	Baluchistan and Sind.	Burma and Malay Region.	Geological age.
PEGU or MEKRAN SYSTEM. Gáj beds of Kathiawar.	PEGU or MEKRAN SYSTEM. Hingláj or Dwárka series. Gáj series.	Murree beds, intrusive salt and petroleum.	Kasauli, Dagshai, and Murree beds. Intrusive granites.	Flysch System. Intrusive Granites Syenites, etc. Beds with *Mastodon angustidens*.	PEGU SYSTEM. Intrusive petroleum.	HELVETIAN.
				Hingláj series.		BURDIGALIAN.
				Gáj series.		AQUITANIAN.
				NARI Upper.		STAMPIAN.
				NARI Lower.		SANNOISIAN.
FIRST PHASE OF HIMALAYAN UPHEAVAL.						BARTONIAN.
KHIRTHAR. Nummulitics of Broach, Surat, etc.	Khirthar series.	Khirthar series.	Nummulitics of Subâthu.	Khirthar series.	Khirthar series.	LUTETIAN.
LAKI. Nummulitics of Western Rajputana.	Laki series.	Laki series.	Laki series.	Laki series.	Laki series.	
				RANIKOT (Sind only). Zone of *N. Planulatus*.		CUISIAN.
				RANIKOT (Sind only). Lower marine beds.		LONDON CLAY.
				RANIKOT (Sind only). Fluviatile beds.		WOOLWICH AND READING.

PENINSULAR AREA.	KACHH.	SALT-RANGE.	HIMALAYAN REGION.	BALUCHISTAN AND SIND.	BURMA.	
DECCAN TRAP.	DECCAN TRAP.			Deccan Trap, intrusive gabbros and serpentines. Pab sandstones.	Intrusive serpentines.	DANIAN.
NINIYUR. Rájámahendri beds.			Breccia of Johar, volcanics of Upper Indus.	*Indoceras* beds. *Hemipneustes* beds.		MAESTRICHTIAN.
ARIYALUR.						CAMPANIAN.
TRICHINOPOLI. Upper						LOWER SENONIAN.
TRICHINOPOLI. Lower.						TURONIAN.
UTATUR. Upper Utatúr. *Acanthoceras* beds of Southern India, Tharia beds of Assam, Bágh and Lameta beds.			Chikkim series of Central Himalaya, *Acanthoceras* beds of Hazara and Samana.			CENOMANIAN.
UTATUR. *Schloenbachia* beds of Southern India.						GAULT.
STRATIGRAPHICAL BREAK.						
					CORRESPONDING BEDS NOT CLASSIFIED.	LOWER GREENSAND.
	UMIA beds.		Giumal sandstone.	Parh limestone.		WEALD.
Gondwana facies. JABALPUR, RAGAVAPURAM, RAJMAHAL. Fossiliferous beds of Western Rajputana.	KATROL	Fossiliferous limestones.	Spiti shales.	Belemnite shales.		UPPER JURASSIC.
	CHARI			Massive limestone.		BATHONIAN.
						BAJOCIAN.
	PATCHAM.			Black limestones.		LIAS.
MAHADEVA (Pachmari).		Limestones with bivalves.	Monotis shales. Juvavites and Halorites beds.	Monotis shales.		NORIAN.
			Tropites beds. Halobia beds.			CARNIAN.
			Daonella beds. Muschelkalk.			MUSCHELKALK.
		Ceratite beds.	Hedenstrœmia, Meekoceras, Ophiceras beds.			BUNTER.

Peninsular Area.	Kachh.	Salt-Range.	Himalayan Region and N.-W. Frontier.	Baluchistan and Sind.	Burma and Malay Region.	
PANCHET.						**ZECHSTEIN.**
DAMUDA. Ráníganj. Ironstone shales. Barákar.		Upper Productus beds. Kálabágh beds. Virgal and Katta beds.	Productus shales. Fenestella shales, Zewan beds.	Fusulina limestones.	Fusulina and Schwagerina limestones.	**ARTINSKIAN.**
TALCHIR. Karharbári. Boulder bed.		Lower Productus beds. Speckled sandstone. Boulder bed.				**URALIAN.**
						MOSCOVIAN.
			Culm beds.			**LOWER CARBONIFEROUS.**
			Lipak series. Fossiliferous beds of Chitrál. Muth quartzite.		Middle Devonian beds.	**DEVONIAN.**
			Upper and Lower Silurian fossiliferous beds.		Zebingyi beds, Namhsin sandstones.	**UPPER SILURIAN.**
					Fossiliferous beds.	**LOWER SILURIAN.**
		Magnesian sandstone.	Upper Haimanta.			**UPPER CAMBRIAN.**
VINDHYAN. LOWER & UPPER BHANDER.		Neobolus beds. Purple sandstone.	Lower Haimanta.			**MIDDLE CAMBRIAN.**
VINDHYAN. KAIMUR & REWA. LOWER VINDHYANS including Karnúl and Málani beds.			Deoban, Krol, and Attock series.		Pre-Silurian Sandstones, etc.	**? SILURIAN or ? CAMBRIAN.**
KADAPAH. **UPPER**, including Nállamalai, Kistna, Kaládgi series.			Baxa and Blaini series.			**? CAMBRIAN.**
KADAPAH. **LOWER.** **BIJAWAR**, with Cheyair and Gwálior series, and basic volcanic rocks. **PAPAGHNI.**						**PRE-CAMBRIAN.**
ARAVALLI, Champáner, Chilpi, Dhárwár, Karakpur series, etc. Dome-gneiss, mica-pegmatites, etc.			Daling, Jaunsar, Vaikrita series, etc.		Crystalline limestones, etc.	**HURONIAN.**
NILGIRI OR MOUNTAIN GNEISS, granitic or granulitic in structure and rich in enstatite, also Anorthosites. **BUNDELKHAND GNEISS**, including granitoid gneisses such as the Bala Ghat or Hosur Gneiss. **BENGAL GNEISS**, including the schistose and banded gneisses.			Central Gneiss.		Fundamental Gneiss.	**ARCHÆAN.**



The Vimana of the Temple at Tanjore.

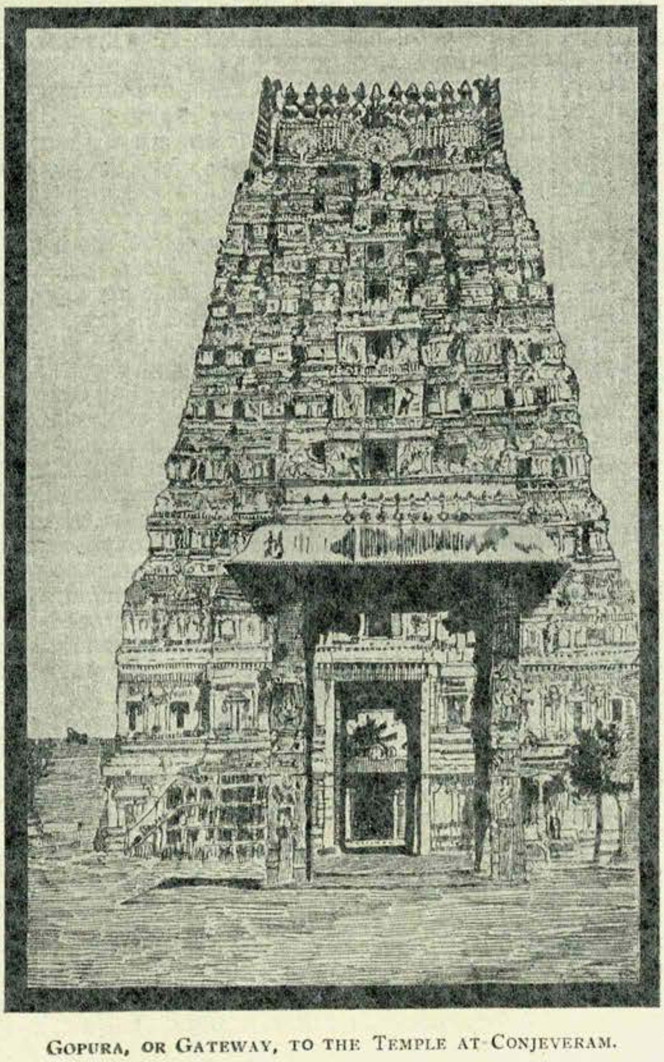
Indian Art and Architecture.

(Continued.)

DRAVIDIAN ART.

The Dravidians have inhabited the southern portion of the peninsula from time immemorial. No record, or even tradition, exists regarding the birthplace of the race, which in language and character differs from that of their neighbours, from whom they have, during the course of their history, kept apart and separate. The theory that they are of Turanian origin is chiefly based upon the numerous Assyrianisms that exist in their institutions and mythology; but when the close commercial connection between the Persian Gulf and the Malabar Coast from the earliest times is taken into account, it must be admitted that conclusions, supported by such evidence alone, are not entirely convincing. They presented a solid barrier to the conquest of the whole peninsula by the Aryans, although showing little power of expansion themselves; but between the 4th and the 7th centuries, one branch of the Dravidian race overflowed its northern boundaries, and conquering the Chalukyan kingdom, penetrated as far north as the Nerbudda river. They were subsequently driven back, but not before they had left behind them, as a magnificent record of their artistic genius, the Kylas Monolithic Temple at Ellora, an illustration of which appears in Volume I.

This outburst appears to have exhausted the fighting capabilities of the race, for they thenceforth sunk into the partial, or total, dependence which has been their lot to the present day. None of the other races of India, however, succeeded in absorbing them, nor did they even obtain an appreciable or permanent settlement in the country. The Dravidians always remained wealthy and powerful, and from about the year A.D. 1,000, buildings were erected which proved them capable of embarking in the most splendid architectural undertakings. These are exemplified in the Stone Temples erected at Madura Tanjore, Chillumbrum, Tinnevelly, and other places in the Madras Presidency.



GOPURA, OR GATEWAY, TO THE TEMPLE AT CONJEVERAM.

Nearly all the existing buildings, however, are of comparatively modern date, the great building age in Southern India having been the 16th and 17th centuries. Some structural buildings, it is true, can be traced back to the 10th or 13th century with certainty, but beyond that, the dates are purely conjectural.

It is generally accepted, however, that the Kylas at Ellora and the temples at Purud Kal are anterior to the 12th century and that probably the "raths" at Mahavellipur belong to the 5th or 6th century.

These latter, however, being cut from single blocks of granite, show no signs of wear or decay, and therefore afford no outward evidence of their age. They are five in number, and stand on the seashore, each being carved from a single block of granite. Externally they are all more or less finished, but in only one has an attempt been made to hollow out the interior. It is completely cracked through, and is unfinished, the work having been probably abandoned when it was found that the support left for the solid granite roof was insufficient. Comparison between them and the later constructed temples, leave no doubt but that they gave the type to all the Dravidian religious edifices, although the grouping of the various buildings had not then been developed. In the Kylas at Ellora this step has been made, and the whole arrangement is as complete as at any future period.

Apart from its historical interest, the Kylas is one of the most singular and interesting monuments of the architectural arts in India. Unlike the Buddhist excavations, it is not a mere interior chamber cut into the rock of a hillside, but is as complete a temple as could be erected on the plain. Its sole drawback, from the point of view of its effect, being that in cutting the rock around it to provide an exterior, the whole has necessarily been placed in a pit. A trench was cut into the sloping side of a hill, in the form of an oblong, to the depth of about 100 feet at its innermost side, leaving the outermost wall of rock intact. From the central mass, the earth was removed and a complete temple has been fashioned; the exterior and interior being most elaborately carved. The outermost wall has been pierced and wrought into the form of a gateway, through which entrance is obtained into the temple and the court which surrounds it. Cut out of the surrounding cliff is a peristylar cloister with cells and halls in two, and sometimes three, storeys. Outwardly the "Vimana" resembles the "raths" at Mahavellipur, but is more refined in form, while the interior has been hollowed out, and is supported by massive piers. What strikes the beholder with astonishment is, that the whole is carried out in accordance with a perfectly thought-out design. On either side of the porch are two square pillars called "deepdans" or lamp-posts, and two elephants about life size, all cut out of the native rock.

Despite the calculations of Fergusson, that the actual labour involved in excavating such a monument, is less than that required to build one of similar dimensions, the impression produced by the Kylas is that of admiration for the mind, or minds, that could conceive such a work, and respect for the industry and tenacity of purpose that brought it to so perfect a completion.

We will now proceed to the temples of a later date, chiefly constructed of stone and brick, found only in the Southern portion of the peninsula.

They resemble in some respects, and yet differ in others, from those of the Hindus of Central and Northern India. They form more imposing groups; for beside the Temple proper, or "Vimana," they comprise a "Mantapa" or porch, and sometimes a considerable number of "Gopuras" or gateways, as well as a "Choultrie" or pillared hall.

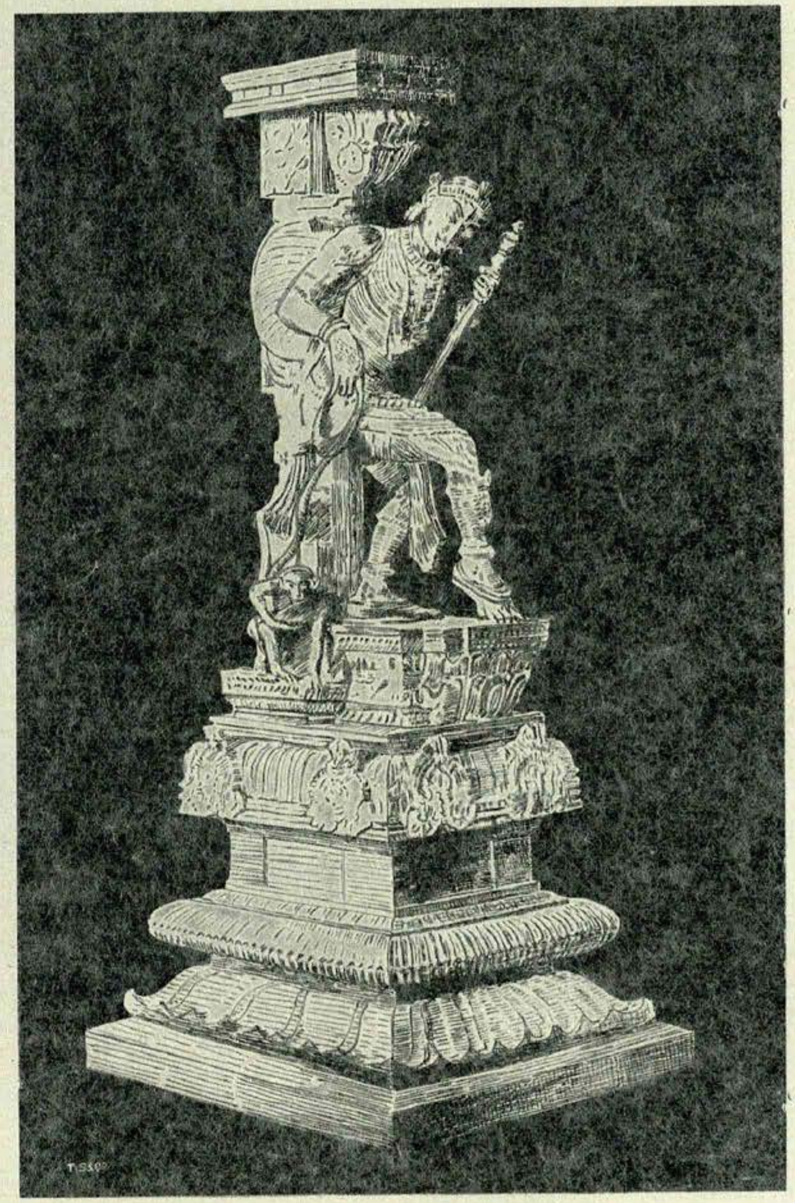
The Vimanas are invariably square in plan, and rise in storeys gradually decreasing in size until the dome-shaped apex is reached. The Temple at Tanjore has as many as fourteen of these storeys, and rises to a height of nearly 200 feet. It is almost the only one in which the "Vimana" is the prinicpal object, round which the subordinate ones are grouped in such a manner as to make a consistent whole. In most instances the buildings have been aggregated together, as if by accident, and the temple which is the principal object is so utterly overpowered by the secondary ones as to destroy all appearance of design. The "Vimana" stands in a court surrounded by a high wall, externally quite plain, but ornamented internally by colonnades, and cloisters or buildings devoted to the service of the Temple. Entrance to this court is obtained through one or more gateways or "Gopuras," that at Seringham having as many as seventeen. The form of the "Gopuras" differs from that of the "Vimanas" only in being oblong instead of square in plan. This necessitates the abandonment of the circular crowning ornament, its place being taken by one cylindrical in shape. Some of the Gopuras are imposing structures; that at Kumbaconum, for instance, rising to twelve storeys. Both "Vimanas" and "Gopuras" are elaborately ornamented with carving, consisting of horizontal bands of niches, covering the walls of each storey. These horizontal bands are cut, in the centre of each of the four walls, by a vertical line of larger cells, supported by projections to right and left, which, decreasing in size as they ascend, are crowned by a winged ornament. Seen in the blaze of an Indian day, these buildings are not lacking in richness of effect, though the eye wearied by the innumerable shadows, cast from the multitude of carved details, looks in vain for the relief a plain undecorated surface would afford.

The most extraordinary structures connected with these Temples are the pillared halls, or "Choultries," which occupy positions within the enclosures or courts. Their uses are various; but the Nuptial Halls, in which the mystic union of the male and female divinities is celebrated once a year, are the most elaborate and extensive.

They sometimes consist of nearly 1,000 columns composed of close-grained granite, covered with sculpture from base to capital, with scarcely two pillars exactly alike. They lack, however, the sense of design and arrangement of the Jaina porches, the pillars being placed too close together, and at absolutely regular intervals. What impression of grandeur can be obtained from a forest of granite pillars, each formed from a single stone, and all more or less carved, they possess; but their want of design detracts painfully from the effect they might have produced. A certain number of pillars in the centre are sometimes omitted, but this is the only attempt on the part of their builders to break the monotonous lines of columns. Allied to these halls are the corridors, which sometimes occupy a large portion of the ground within the walled enclosure. That at Ramisseram is nearly 4,000 feet in length, the breadth varying from 20 feet to 30 feet, and the height being 30 feet. Their pillars are about 10 feet apart, and are most elaborately carved.

The most artistic features of the Dravidian style are the compound pillars, employed to support the stone roofs of the temple porches. They consist of a main shaft, upon which the great beams supporting the flat roofs rest. In order to lessen the width of the roof span, brackets are employed, and these are supported by pillars of lighter construction, attached at their bases to the main shaft. The effect is extremely graceful and original, giving an appearance of lightness and strength to the whole column.

Before proceeding to consider the Dravidian sculpture, a point of great archæological, and in a lesser



Carved Figure at Madura.