Relatively large quantities of nitrogenous and of potassic manures are found necessary, phosphates being less needed; to meet this demand, potash salts and nitrate of soda are now imported in quantity. Ten years ago there was practically no importation of these manures.

A certain amount of the land has to be irrigated, especially that occurring on the leeward side of the high land forming the interior of the island. On the windward side, however, the rainfall is higher and irrigation is not necessary. On the island of Hawaii itself most of the plantations are unirrigated, but on the other islands irrigation is very general. Here, also, useful help has been given by expert engineers in ascertaining the cheapest effective way of obtaining the necessary water.

## NATURAL SCIENCE IN BENGAL.

THE annual report of the Asiatic Society of Bengal for the year 1909 has now been published. We notice that the society celebrated its 125th anniversary on January 15, 1909. The celebration took the form of an evening reception held in the Indian Museum. Many scientific, archæological, philological, and historical exhibits were shown, illustrating the progress and activities of the society. The council awarded the Barclay memorial medal for 1909 to Lieut.-Colonel David Prain, F.R.S., I.M.S. (retired), in recognition of his biological researches.

The total number of contributions to the society under the heading mathematics and the natural sciences was seventeen. Commenting on these, the report points out that Mr. Hooper's paper on *Tamarisk manna* shows that the chief sugar in it is not mannite, but a saccharose. Babu Bidhu Bhusan Dutta, in a contribution on the constituents of the roots of *Arisaema concinnum*, Schott, and *A. speciosum*, Mart., shows that these two famine foods contain much nutriment, chiefly starch. Mr. B. L. Chaudhuri directed the attention of the society to the mosquito-larvæ eating propensity of fish of the genus Haplochilus, and asked for cooperation in making further observations. Several species of this genus of small fishes are voracious feeders on the larvæ.

Babu Nibaran Chandra Bhattacharjee directed attention to the way in which *Marsilia quadrifolia* fruits only when the water in which it has been growing recedes from it and leaves it dry. Mr. H. Martin Leake's paper on Indian cottons is of importance. His object is to breed early cotton suitable for cultivation at Cawnpur, with the good lint of the slow-maturing cottons; he has observed the characters in bud development which lead to early or late maturity in order to recognise such as combine with the desirable quantities in the lint. Mr. E. P. Stebbing, in a paper on the Loranthus parasite of the Moru and Ban oaks (*Quercus dilatata*, Lindl., and *Quercus incana*, Roxb.), shows how destructive the parasite is to these oaks in the neighbourhood of Naini Tal and in Kumaon. Sir George King's "Materials for a Flora of the Malayan Peninsula" has been continued. Accounts of the orders Gesneraceæ, by Mr. H. N. Ridley, and Verbenaceæ, by Mr. J. Sykes Gamble, have been received. Mr. Burkill has diagnosed two varieties of the lemon oil grass, *Cymbopogon Martini*. Prof. P. Brühl has contributed a paper on recent plant immigrants into Bengal; 234 species are named by him; their origin is discussed and the causes of their introduction. America supplied 54·7 per cent. of these immigrants.

## THE DEVELOPMENT OF ELECTRICAL POWER AT NIAGARA FALLS.[1]

THE development of electrical power at Niagara Falls has long attracted widespread attention and interest. Since the first installation upon the American side, descriptions and discussions of its works and methods have been granted a conspicuous place in technical records and the scientific Press, but the fact is apparently less known that there now exist at Niagara four more installations, each larger than the pioneer plant, and one at least differing from it to a very marked degree in the method in which the turbines are employed and coupled to the electrical generators.

The author, having paid a visit to Niagara in December, 1907, when exceptional opportunities were afforded him of inspecting the whole plant of the Ontario Power Company, takes the present opportunity of recording the following notes, which may supplement the knowledge of the subject hitherto available, especially so as, after the completion of these notes, correspondence took place with the Ontario Power Company with the object of eliciting further information, and photographs were received illustrating the operations of the company.

*Scheme.*—Briefly outlined, this company's development comprises the taking of water from the Upper Niagara River above the Horseshoe Fall, leading it through pipes and penstocks to turbines in a station below the Fall, and there utilising its energy for the generation of electricity, which is transmitted to a second station on the hill above, and thence distributed. There is a fall in level of 55 feet in the rapids above the Horseshoe Fall, and to take advantage of this the headgates are placed just above the rapids. From the headgates three great steel and concrete tunnels or conduits, laid below the surface of the Victoria Park, will convey nearly 12,000 cubic feet of water per second to the top of the cliff above the power-house, and just beyond the Fall. Thence it will pass through twenty-two steel penstocks in shafts and tunnels down and out through the cliff to an equal number of horizontal shaft turbines in the power-house below, which is situate on the water edge immediately at the foot of the Horseshoe Fall. From the generators, the electrical cables will pass through tunnels to the twenty-two banks of switches, transformers, and instruments in the distribution station on the hill above, and thence to the transmission lines beyond, the whole installation, when complete, being capable of an output of more than 200,000 horse-power.

The intake works for the entire 200,000 horse-power are now finished. One of the three main conduits is completed and in use, while the portals and headworks for the second and third tunnels are completed, and a portion of the excavations made. Six of the twenty-two penstocks are completed, and with their turbine-sets are at work, and at the time of the author's visit the seventh was practically completed. The distribution-station building is complete for the switchboard of the entire twenty-two units, for the transformers of eight, and the other apparatus of fourteen units, and is well ahead of the developments in the power-house.

The most important engineering features wherein this latest company differs from its predecessors are the arrangement of intake works, the design of main conduit and spillway, the horizontal shaft turbine units, the symmetry of arrangement of the whole, the centralisation of control, and the protective isolation of the various apparatus.

*Particulars of Niagara River and the Falls.*—The total drop in the Niagara River in its course of thirty-six miles between Lake Erie and Lake Ontario is 326 feet, of which 216 feet is in the Falls and the rapids immediately above them.

The American Fall is 167 feet high and 1000 feet in width, while the Horseshoe Fall is 159 feet high and 2600 feet in width. The greatest depth of the river immediately below the Falls is about 192 feet. It is estimated that an average of 222,400 cubic feet of water pass over the Falls each second. This is 25,000,000 tons per hour, or about one cubic mile a week, and represents a kinetic energy of nearly 5,000,000 horse-power. At the headworks of the Power Co. the river is 3400 feet wide, and flowing at an average velocity of about 8 feet per second.

*Intake.*—These works have been placed and designed, not only to take advantage of the additional height of the rapids as mentioned above, but also with special reference to the ice difficulties, which have been the limiting factor in the success of Niagara power. Cake-ice in enormous quantities floats down for weeks at a time from the Great Lakes, and mush-ice is also formed in the rapids, primarily by the freezing of spray and foam, and secondarily by the disintegration of cake-ice. The latter trouble is avoided, since the intake is in the smooth water just above the

[1] From a paper entitled "An Account of a Visit to the Power Plant of the Ontario Power Co. at Niagara Falls," read before the Institution of Mechanical Engineers on January 7, by Mr. C. W. Jordan.

rapids at a place where the current is very swift. To exclude the former trouble, the following precautions have been taken:—a long and tapering forebay, protected at the entrance by the main intake, terminates at its narrow down-stream end in a deep spillway. Upon the river side it is enclosed by a submerged wall, while the other side, near the spillway, is occupied by the main screen building leading to the inner bay and to the portals and headgates of the three conduits.

The intake, which is nearly 600 feet long, stretches across the inlet at Dufferin Island almost parallel with the current in the river. Throughout its whole length, a concrete curtain wall extends down 9 feet into the water, which is 15 feet deep at this spot, so that the gate openings beneath admit only deep water, and this at right angles to the swift exterior surface flow, which, sweeping the full length of the curtain wall, carries the floating ice past to the rapids beyond.

The intake is divided into twenty-five bays, through which the water is admitted at a velocity of 5 feet per second. Provision is made for inserting stop-logs into each of the twenty-five openings in order to regulate the flow of water.

The outer forebay has an area of 8 acres, and a depth ranging from 15 to 20 feet, and is bounded on its down-stream side by a submerged wall or dam 725 feet long, terminating at the down-stream end of the screen-house, which is 320 feet long, built of reinforced concrete faced with Roman stone.

The inner forebay is 2 acres in area with a depth of 20 to 30 feet, whilst the gate-house, similar in construction to the screen-house, is 120 feet long and divided into six bays, two for each of the main conduits. The 18-foot "Stoney" gates which guard the entrances to the conduits weigh 18 tons each, or 36 tons including the counter-balance. They were built by Ransomes and Rapier, and are operated by electric motors of 5 horse-power capacity.

At the main screen the same precautions for the exclusion of ice are repeated. This structure, which is 320 feet in length, in 20 feet depth of water, lies across the entrance to the inner bay, and parallel with the direction of flow in the outer bay. Here again a curtain wall formed by the front wall of the superstructure admits only deep water to the screens at right angles to the main current, while it also excludes ice with the surface currents maintained through the forebay by a huge spill of surplus water. At the gate structure, where the water is 30 feet deep, the tapering portals leading to the electrically operated Stoney headgates are protected with wide-meshed screens, which are also enclosed and safeguarded by a curtain carried by the front wall of the gate-house. There is an ample ice-run from the bay in front of the curtain to the river, and both at the headgates and screens an open canal spills into a gravity ice-run emptying into the river. Both buildings are supplied with steam for heating and thawing from an underground boiler plant, and the author can testify to the entire success of the heating. It was a bitterly cold day, snowing and freezing hard, with a nasty wind, but inside these houses it was almost unpleasantly hot, in spite of the large masses of ice-cold water coming in continuously from the river. The water before entering the conduits must pass through three automatically selective steps, each excluding ice, and, in addition, through two screens, each behind ice-runs, in heated buildings containing live steam for emergencies, and the experience of three winters has proved the above plan of excluding and preventing the formation of ice to be an entire success—a record which is unprecedented for power plants in a climate like that of Niagara.

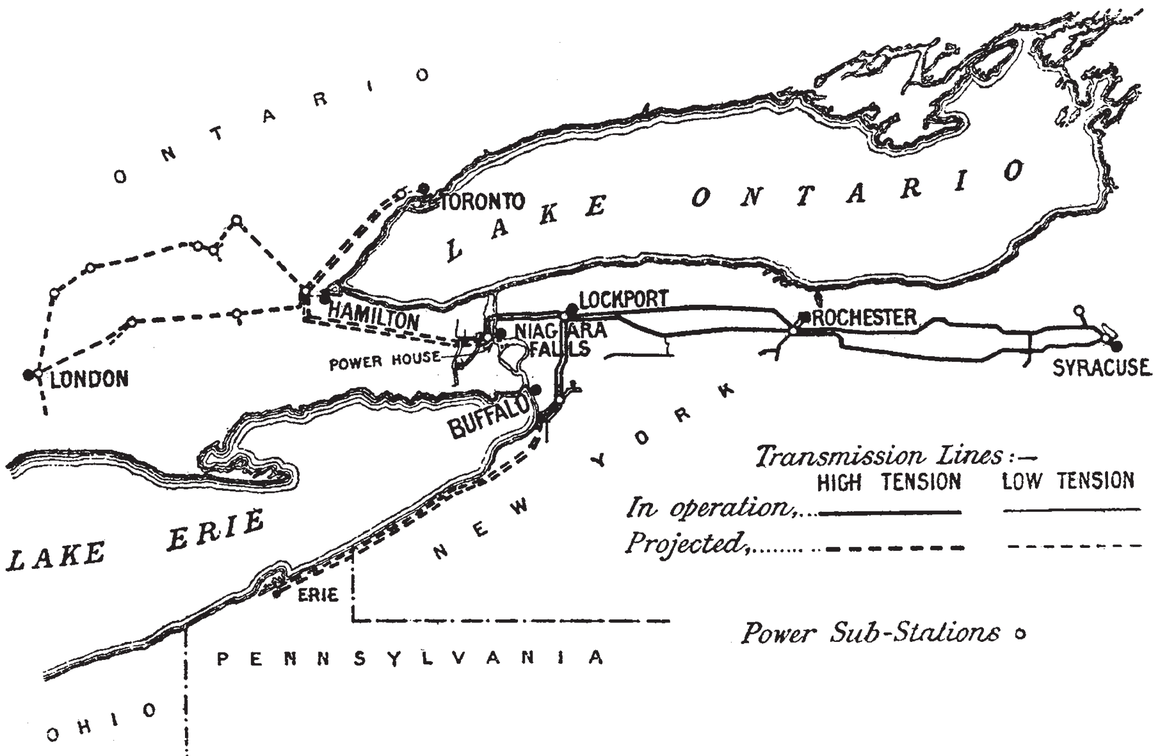


FIG. 1.—Power District of Niagara Falls.

An electric overhead travelling-crane runs along the screen-house for removing the screen-frames for cleaning and changing when necessary, and as this building is situate in the park the roof is flat and finished off as a promenade, access being obtained from the outside by broad steps at either end of the building, and from this point a magnificent view of the upper rapids is obtained.

*Main Conduits.*—These are of 0·5-inch rivetted and reinforced steel embedded in concrete 18 feet and 20 feet in diameter and 6500 feet long, sunk beneath the surface of the park. The water flows through them at an approximate velocity of 15 feet per second. The only conduit at present in service has a sectional area of 254 square feet, and is capable of supplying sufficient water for the operation of six generators at full load. The second and third conduits have not as yet been installed. Just beneath the top of the cliff, behind the power-house, is a long underground chamber 274 feet long, 10 feet high, and 16 feet wide, with an arched concrete roof to support the conduit above. Rivetted to the bottom of the main conduit are seven large tapered steel castings leading to the 9-foot valves and penstocks below, each supplying water at 10 feet per second to a single horizontal shaft turbine in the power-house below.

*Spillway and Weir.*—The spillway at the end of the conduit, which is intended to prevent water-hammer in the case of sudden loss of load, is little more than the enlarged end of the main conduit, raised and fitted with an enclosed weir and underground discharge. The weir is adjustable as to height, and the discharge tunnel, after a steep initial pitch in the taper from the weir, follows a uniform grade and symmetrical curve while circling about to reach the river in a helix, thus preserving a water column which is smooth and unbroken, of highest velocity and least expenditure of energy. This has the effect of preventing erosion, restricted flow, and excessive air-suction, the latter on account of the danger of ice forming from the spray under forced circulation of air.

*Location of Power-house.*—The power-house is situated on the river bank nearly at water-level and close under the Horseshoe Fall, and it is an interesting and important point that the full head of water between the upper and lower rivers has been acquired so far as was possible from an economic standpoint, while the huge and costly excavations rendered necessary in the previous schemes have also been dispensed with, resulting in a greatly reduced capital expenditure.

Owing to limited space, the generating station is only 76 feet wide, but when completed it will be nearly 1000 feet long; the generating units stand side by side in a single row right down the centre of the building, the turbines being on the land side and nearest their source of supply. The space between them and the rear wall is occupied by a gallery, upon which are mounted the oil-pressure governors, each almost over the end bearing of the turbine it controls.

The mean water-level at the generating station is 343 feet above tide, though it varies from 338 to 365 feet. The walls of the generating station are of concrete, the rear wall being 12 feet thick at the bottom and the river wall 9 feet.

*Generating Units.*—Each generating unit consists of a horizontal double turbine direct coupled to a generator. The completion of the station and its equipment will be but an extension of the present form until, according to present plans, there will be an installation under the one roof, capable of continuously delivering 200,000 horse-power of electrical energy. Three of the generators, which are all of the conventional horizontal shaft pattern and exactly alike in appearance, have a capacity of 10,000 horse-power each, while the others have each a capacity of 12,000 horse-power. These machines are wound for three-phase current at 12,000 volts and 25 cycles, and have revolving fields, the revolutions being 187·5 per minute. The total weight of each generator is 231 tons, and each was entirely assembled on the spot, including the building up of the laminated iron rotor and the winding and insulating of the armature.

*Turbines.*—The turbines were made by J. M. Voith, Heidenheim, a. d. Brenz, Germany, and are of the Francis or inward-flow type, double, central discharge or balanced twin turbines, and are designed to deliver 12,000 horse-power at 175 feet head. Their shafts are 24 inches maximum diameter, and each carries two 78-inch cast-steel runners of "normal" reaction. The housings are of reinforced steel plates 16 feet in diameter, spiral in elevation, and rectangular in plan. Gates are of the wicket or paddle type, and the rotating guides forming them are carried by shafts which project through stuffing-boxes to an external controlling mechanism worked by the governors, thus freeing the casings from the objectionable internal-gate rigging, and leaving the approaches to the guides uniform and open. Whilst the velocities in housings and draft-tubes are high, corresponding losses are avoided by easy changes of velocity and direction, and large curves free from acute angles or obstructing projections.

*Leads.*—The leads from the generators are single conductors, insulated with treated cambric. These lead each in a separate compartment, are mounted on porcelain insulators, ample clearance to earth being allowed everywhere; the compartments are built up of thin shelves of reinforced concrete fastened to the concrete substructure of the power-house, and are closed by asbestos doors readily removable for inspection. At no place are the leads of more than three generators brought near one another, and the leads of each set of three generators, where they approach their respective oil-switches on the gallery, are so protected and isolated from each other that earths or short circuits are impossible. Field circuits, exciter leads, and control wires are carried in iron conduits, and are either in separate passages or at a proper distance from the main wires.

*Distributing Stations.*—The generating and distributing stations are parallel, and nearly 600 feet apart, with a difference of 260 feet in elevation. The distributing station is wider and shorter than the power station, and is divided into three longitudinal bays or five main sections. The narrow front bay contains the switches, bus-bars, &c., at generator pressure; the wider rear bay contains those at transmission pressure. Between these bays is the main middle bay, divided transversely by a three-floor switchboard section into two long transformer-rooms. The projecting central bay is utilised as offices. The transformers stand along the centre of the two rooms in groups of three, corresponding in position and capacity to their respective generators. Similar apparatus is arranged in rows parallel with each other and with the generating units. Unit values corresponding to the generators in capacity and position are maintained throughout. Thus each generating unit has its individual cables, switches, and switchboard, section of bus-bars, transformers, interrupters, and high-pressure switches complete to the transmission lines, enabling independent operation as an independent power plant, or, through the selector switches, and duplicate sectional bus-bars, the operation of all units in any combination of groups, as readily and perfectly as their operation in parallel.

*Transformers.*—The low-pressure bay contains on the main floor the 12,000-volt automatic oil circuit breakers in double column, and in the chamber beneath only the sectional duplicate bus-bars and their immediate connections. In the transformer-rooms the transformers stand in pits 6 feet below floor-level, and parallel with them, adjacent to the high-pressure bay, are corresponding pits for choke-coils or other protective apparatus. Beneath, and between the foundations, are laid the various systems of piping for water, oil, and drainage, and the main cableways to the transformer above. Each transformer is fitted with a recording thermometer, and is of the oil-insulated, water-cooled type, three to a unit, connected in delta on the low voltage, and in star with centre grounded on the high-voltage side. The secondary potential of each transformer is 36,000 volts, and, as connected, the resultant line voltage is approximately 62,000 volts. Each transformer has a normal capacity of 3000 k.v.a., and weighs, complete with oil and case, approximately 50 tons. They are cylindrical in form, and the three constituting a unit are arranged in a triangular group in the pit.

*Recording Instruments.*—The graphic recording instruments are of a new type, and comprise voltmeters, ammeters, wattmeters, and frequency and power-factor indicators. They are so connected in the low-voltage circuits that there is a continuous record of each generator as well as of the demands of any set of feeders. In the control-room, the chief operator's position is in the centre, where at his desk he may observe, by means of his instruments, every electrical occurrence, and direct his assistants as required. He has his own private telephone system running to all the rooms in the building, and also has direct connection with telephones along the transmission wires. The telautograph is invariably used for communicating with the generating station, because of its unmistakable records. The chief operator is thus able, without moving from his chair, to control every electrical circuit and situation of the system, and to stop, start, regulate, or synchronise each unit. He can throw the output of each unit through its transformer to the transmission as if from a single isolated plant, or he can throw the current upon either bus-bar while supplying its transformers from the same or another bus-bar. The experience obtained up to the present in the practical working of the plant has been so successful that it is to be anticipated that other large plants in the future will adopt the same system.

*Distribution of Power by the Ontario Power Co.*

Two 60,000-volt lines run from the distributing station for six miles to a point on the Niagara River near the town of Queenstown, where they cross the gorge, and connect with the lines of the Niagara, Lockport, and Ontario Power Company delivering power for use in the United States. These lines consist of aluminium conductors 1⅛ inches in diameter, carried on steel towers 55 feet high to the top wire, with an average span of 500 feet. The insulators for this line are of porcelain, and weigh 35 lb. each.

The first of the transmission lines was put into operation on July 7, 1906, and the plans realised at present, and contemplated for the immediate future, in the plant of the Niagara, Lockport, and Ontario Power Co., involve a maximum transmission distance of 160 miles. This distance puts the plant amongst the longest transmissions of the world.

*Size of Cables.*—There are only three sizes of cables used on the main transmission lines, designated by the company as 3/3, 2/3, and 1/3 respectively. The 3/3 cable is aluminium cable, consisting of nineteen strands, and having a total area of 642,800 cir mils, being equivalent to 400,000 cir mils copper. The areas of cross-section of the other cables are respectively two-thirds and one-third that of the large one.

It is impossible to enumerate the manifold purposes for which the power is used, but some of the more important are the following:—

*Light.*—The power generated at this station and sent out over the above-described transmission lines furnishes part or all of the public and private lighting in Niagara Falls, Welland, Stamford, and St. Catherines, Ontario; and Lockport, Depew, West Seneca, Hamburg, Batavia, Rochester, Canandaigua, Auburn, Baldwinsville, Phœnix, Fulton, and Syracuse, New York.

*Heat.*—The same power operates electric furnaces for the reduction of iron, copper, and other ores, and the manufacture of cement, calcium carbide, and lime nitrates in Port Colborne, Welland, Niagara Falls, and Thorold, Ontario, and Lewiston, Lockport, and Caledonia, New York.

*Power.*—The same power operates wholly or in part the trolley systems in Syracuse, Rochester, Canandaigua, Geneva, West Seneca, and Hamburg; and the interurban lines Syracuse, Lake Shore and Northern Syracuse and South Bay, Rochester and Geneva, Rochester and Mount Morris (Erie Railroad), Buffalo, Lockport and Rochester, Buffalo and Hamburg, and Buffalo and Dunkirk (partly constructed). It operates the steel works of the Ontario Iron and Steel Company at Welland, Lackawanna Steel Company (7000 employees), Shenandoah Steel Wire Company, plate-rolling mills of Seneca Iron and Steel Company, and pumping works of Depew and Lake Erie Water Company at West Seneca; repair shops of the New York Central and Hudson River Railway Company, and Delaware, Lackawanna and Western Railroad Company, and the works of the Gold Coupler Company at Depew, stone-crushing establishment of the Kelley Island Lime and Transport Company at Akron; works of the United States Gypsum Company at Oakfield, and various smaller industries located on main transmission lines.

The utilisation of a portion of the vast energy of Niagara without in any way detracting from the splendour or beauty of the Falls is destined to create in the Ontario peninsula and in western New York a vast manufacturing district.

## SCIENTIFIC WORK OF THE SMITHSONIAN INSTITUTION.

THE report of Dr. Charles D. Walcott, secretary of the Smithsonian Institution, for the year ending June 30, 1909, has just been issued. All the numerous departments of the institution's activity receive attention, but it is possible here to deal only with the more direct scientific work accomplished during the year under review. Subjoined is a summary of the parts of the report dealing with matters of scientific interest.

*Smithsonian African Expedition.*

Through the generosity of friends of the institution, there was provided during the year a special fund to pay for the outfitting and to meet the expenses of the naturalists on a hunting and collecting expedition to Africa under the direction of Colonel Theodore Roosevelt. No part of the fund was derived from any Government appropriation or from the income of the institution. The special interest of the institution in the expedition is the collection of biological material for the United States National Museum.

The party sailed on March 23, 1909, from New York, whence steamer was taken to Mombasa, British East Africa. The expedition arrived in Africa on April 21. A letter, dated at Nairobi, May 31, announced the shipment of twenty barrels of large mammal skins in brine, comprising Colonel Roosevelt's first month's collection. While no new species, so far as is known, is included in this first shipment, the collection will supplement materially the specimens already in the National Museum. Together with this shipment are expected a large number of specimens of small mammals, and also of birds. Through the Smithsonian African expedition the National Zoological Park has been presented with an exceptional collection of live African animals.

*Cambrian Geology and Palaeontology.*

Dr. Walcott's studies of the older sedimentary rocks of the North American continent, which he has been carrying on as opportunity offered for more than twenty years, were continued in Montana and the Canadian Rockies during the field season of 1908. The scientific results of the 950-mile trip through the forests and on mountain trails will aid materially in the solution of several problems connected with the stratigraphy and structure of the main ranges of the eastern Rocky Mountains and of the geological position and age of many thousands of feet of the sandstones, shales, and limestones forming the mountains in northern Montana, British Columbia, and Alberta. On the return an examination was made of the geological formations in the vicinity of Helena, Mont., and of the Wasatch Range, south-east of Salt Lake City, Utah. Three additional papers giving a summary of the results of these studies in Cambrian geology and palæontology were published during the year.

*Researches on Atmospheric Air.*

A Hodgkins grant was approved in October, 1908, for the erection of a small stone shelter on the summit of Mount Whitney, California, for the use of investigators during the prosecution of researches on atmospheric air, or on subjects closely related thereto. The pioneer trip to the summit of Mount Whitney in the summer of 1881 by the late secretary, Dr. Langley, at that time director of the Allegheny Observatory, will be recalled in this connection, as well as his conviction that in no country is there a finer site for meteorological and atmospheric observations than Mount Whitney and its neighbouring peaks.

Mr. C. G. Abbot, who succeeded Secretary Langley as director of the astrophysical observatory of the Smithsonian Institution, and to whose immediate suggestion and earnest personal efforts the preparation for and the establishment of this important post on Mount Whitney are largely due, began his observations there in the summer of 1909, and obtained important data in the determination of the solar constant. The cooperation of Prof. W. W. Campbell, the