this is especially true on shipboard or in places where there is much noise and where a much louder signal or a visual signal is required. To meet these requirements a much less expensive set of apparatus has been designed. The transmitter is precisely the same as in the preceding case, but the polarized receiving relay, R, is much smaller and is not provided with as sensitive adjustments, it having been found that for bell signals they are not necessary. The sounder is entirely dispensed with, and is replaced by a high class vibrating bell, shown at P in the diagram of receiving station C. This bell is so arranged that it can be adjusted to work in unison with the vibrations of the decohering apparatus. The Clarke coherer relay in this case is mounted on top of a mahogany box which contains the decohering magnets, resistance coils for bridging the terminals and also condenser for suppressing the spark at the vibrating contact, as fully shown in the diagram at station C. The plugs in the cohering tube, G, are provided with the same adjustment as in the more elaborate set. The working of the apparatus is perfect in every respect. When required, the vibrating bell, P, can be replaced by an incandescent lamp which can be readily turned on and off from the distant station. It is certainly extremely interesting to place the transmitter of this set in one room and the receiver in another and then listen to the vibrating bell ring out loudly in response to every impulse of the waves. No ground connection, however, or air plate is required for either set of apparatus when the distance between the transmitter and the receiver is comparatively short. For the benefit of those who wish to experiment, and perhaps endeavor to build their own apparatus, a simple coherer is provided which is shown in perspective in one of our half tone illustrations and in detail in the lower engraving. The outer binding posts of this coherer are intended to hold two light rods of metal of equal length projecting out on either side. These rods or wings are necessary when it is desired to transmit to any considerable distance without using the earth connection or air plate.

LIQUID AIR AND ITS PHENOMENA.

PROF. W. C. PECKHAM, ADELPHI COLLEGE.

Renewed interest has recently been awakened in the liquefaction of air by the announcement that it can be produced in practically unlimited quantities. This result has been brought about by the development of the method of expansion, and its use in a new and ingeniously devised apparatus. Credit for this is due to Mr. C. E. Tripler, of New York, who has for many years been engaged in the study of this problem.

Our first page illustration shows the appearance and arrangement of his plant. It consists of a triple air compresser, a cooler and a liquefier. The compresser is of the ordinary form, having three pumps upon one piston shaft working in a line. The first gives 60 pounds pressure; the second raises this to 750 pounds, while the third brings the air under a compression of 2,000 pounds per square inch.

After each compression the air flows through jacketed pipes, where it is cooled by city water. For this work about 40 horse power is employed. After the third compression the air flows through an apparatus which disposes of some of its impurities, and it passes on to the liquefier. It is this part of the apparatus which constitutes Mr. Tripler's special invention. By means of the peculiarly constructed valve, whose details are not made public, a portion of the compressed air is allowed to expand into a tube surrounding the tube through which the remaining air is flowing. This expanded air absorbs a large amount of heat from the air still under compression in the inner tube. The contents of the inner tube are thus cooled. In this way the air is brought below the temperature of liquefaction and its pressure is very much reduced, so that, upon opening the valve at the bottom of the apparatus, a stream of liquid air is received, flowing out with scarcely more force than the water from our ordinary city service pipes. Thus the liquefaction of the air is accomplished by the "self-intensification of cold" produced by the expansion of a portion of the compressed and cooled air, without employing any other substance to bring about this result.

In this lies the difference between the process employed by Wroblewski and Olzewski many years ago, in the liquefaction of various gases, and finally, in the liquefaction of air by Olzewski and Dewar.

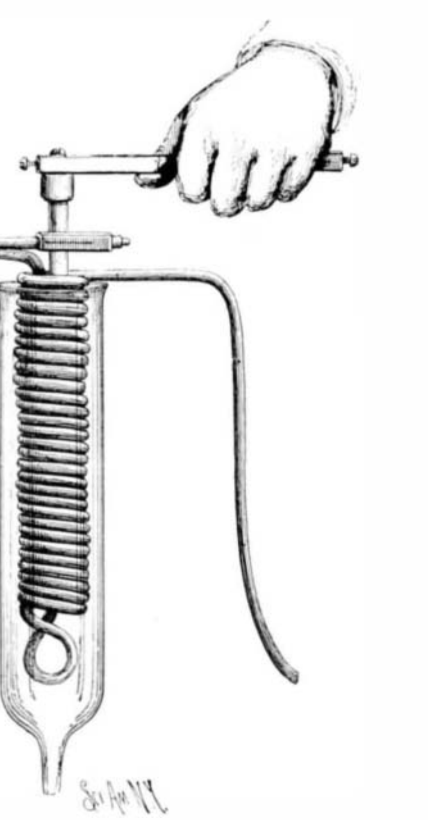
Through the courtesy of Mr. Tripler, we are able to present a cut of the original apparatus by means of which, in January, 1890, the first liquid air was made in America, and probably in the world, by this means. It is known that the method by expansion of air under pressure has been employed both in England and Germany, but the earliest published date connected with any of these experiments is 1895, and previous to that time, as Mr. Tripler states, his application for an English patent was on file in the English Patent Office.

Our cut of this original apparatus shows the tube through which the air under compression flowed into the spiral coil. Having traversed this coil, it rose through a tube (not seen) in the middle of the coil and passed the valve shown at the top. The whole was surrounded by a glass tube open at the bottom. By the expansion of the escaping air the coil and the inner tube were so cooled that liquid air trickled down the pipes and dropped out at the bottom of the tube.

This most interesting piece of historical apparatus is only 12 inches long and 1$\frac{3}{8}$ inches in diameter. Its capacity was of course extremely small as compared with the great plant which will deliver from 30 to 40 gallons of liquid air per day of 10 hours, with an expenditure of from 40 to 50 horse power, and its operation must have been extremely slow, as compared with the operation of the modern plant, which will give liquid air in less than 15 minutes after the pump is started.

As fast as the liquid air is drawn from the liquefier it is placed in tin cans, packed in felt, in which it can be kept for a very long time. Cans have been sent as far as Lynn, Mass., in one direction, and Washington, D. C., in the other, and the contents were not seriously diminished by evaporation in transit. Such a can holding 3 gallons would not wholly evaporate in less than 8 to 10 hours.

Prof. Dewar invented a double walled glass bulb, in which between the walls a high vacuum is formed (see Fig. 8). In this the air will last five to six times as long as in an ordinary packed dish. Indeed, it lies practically quiet without boiling, while in an open dish (see Fig. 9) the boiling is quite violent, and very soon the walls are covered with ice frozen from the moisture of the air. This is doubtless the coldest free liquid that has ever been produced. Its boiling point at the ordinary pressure of the atmosphere is —191° C.



TRIPLER'S ORIGINAL APPARATUS—USED IN 1890.

An extended table of the physical constants of the "so-called" permanent gases is embodied in this article and will doubtless interest our readers. A glance at this will show that the boiling point of the air is the lowest temperature thus far attained at atmospheric pressure. Only hydrogen and helium having lower boiling points, and neither of these has been liquefied up to this time in a free state, that is, at atmospheric pressure. The same statement can be made with regard to air boiling in a vacuum. This has the lowest temperature yet attained.

The possession of a large quantity of a liquid at so low a temperature makes it possible to perform many experiments of a very startling and marvelous character. When a dishful of the liquid air is dipped from the can, it boils so violently that drops of it are projected to quite a distance. This continues until the dish is cooled to the temperature of the liquid, when it becomes quiet, simmering gently. In this condition it is turbid, containing solid particles of carbonic acid and possibly ice. These may be filtered out through filter paper, and the liquid is seen to be of a delicate shade of blue, clear as water.

Since the boiling point of nitrogen is 13° C. below that of oxygen, it follows that, in the first boiling, nitrogen is distilled from the oxygen as alcohol may be distilled from a mixture of alcohol and water through the difference between their boiling points. By this means the liquid air becomes very much richer in oxygen. The liquid air would at first contain only 20 per cent of oxygen, but after boiling for a while the proportion of oxygen increases to 75 per cent. If the liquid be poured upon a block of ice, it bounds off like water from a hot stove. The ice at the freezing point is 344° F. hotter than the liquid air—a distance of 132° greater than separates boiling water from ice. We cannot comprehend it any better than we can comprehend the space which separates us from the sun. Although so cold, the hand may be dipped into the liquid or the liquid may be poured into the hand without producing much sensation, since the heat of the hand evaporates the liquid so quickly that a layer of vapor is formed around the hand; in other words, the liquid is thrown into a spheroidal state with reference to the hand. If, however, contact does take place between the skin and the liquid air, a most serious burn results. One day, when Pictet had a burn upon his hand from fire, he also produced one accidentally by liquid air; the ordinary burn healed in ten or twelve days, but the other was open for six months.

Fig. 4 shows a copper tube 2 inches in diameter, with walls one-eighth of an inch thick. On pouring a couple of fluid ounces of liquid air into the tube, and driving a wooden plug firmly in with a hammer, it is driven out almost immediately, and with such violence that boards overhead are indented by it. About 100 cubic feet of air are compressed into one gallon of the liquid, occupying 231 cubic inches. The liquid therefore occupies but $\frac{1}{748}$ of the space filled by the gas at first, and on returning to its gaseous form at atmospheric pressure, it must expand to 748 times its volume. The enormous pressure produced in this transformation is thus apparent. It would scarcely seem to be possible to construct apparatus in which it could safely be stored and allowed to come to atmospheric temperatures.

Fig. 3 shows the effect produced upon iron by reducing its temperature to that of liquid air. An ordinary tin dipper placed in the liquid and allowed to cool till boiling ceases becomes brittle and breaks like glass upon being struck against a table or thrown upon the floor. Copper and platinum, on the other hand, remain tough at the lowest temperatures. The tensile strength of iron would be increased very greatly by cooling.

Fig. 7 shows a dish of liquid air in which a rubber ball is floating. It will be noticed that the vapor flows over the edge of the dish, not rising in a cloud from it, as does steam, since it is much heavier than gaseous air at ordinary pressures. This vapor presents the appearance of a cloud of steam and would be easily mistaken for it. The chill which the hand receives on being exposed to it would, however, quickly convince one of the difference. When the rubber ball has been cooled to the temperature of the liquid, it becomes exceedingly brittle, and on being thrown against a wall flies into many pieces. A very curious effect produced upon a billiard ball or other article of ivory by cooling it to the temperature of liquid air has not been explained. On exposing it to the arc light for a few seconds and viewing it immediately in a darkened room, it shines with a brilliant green phosphorescence. It is possible that many other substances, such as eggs and bone, may be found to possess the same property. Whisky and alcohol are frozen with little difficulty by means of this liquid. It is a curious experiment (see Fig. 12) to hold

PHYSICAL CONSTANTS OF (SO-CALLED) PERMANENT GASES.

	Critical Temperature. Centigrade.	Critical Pressure. Atmospheres.	Boiling Point at Ordinary Pressure. Centigrade.	Freezing Point. Centigrade.	Freezing Pressure. Mm.	Density of Gas.	Density of Liquid at Boiling Point.	Color of Liquid.
Carbon dioxide, CO_2	31° [1]	77·0	—78·2° [3]	—79° [2]	760 [2]	22	0·83 @ 0° [4]	Colorless.
Ethylene, C_2H_4	95·0	44·0 58·0	—110 [5]			14		
Hydrogen, H_2	—234·5 [6] (Theor.)	20·0	—243·5 [6] (Theor.)			1		Colorless.
Nitrogen, N_2	—146	35·0	—194·4	203 —214 Mean 208	60	14	0·885	Colorless.
Carbonic oxide, CO	—139·5	35·5	—190·0	—207·0	100	14		Colorless.
Argon, A	—121·0	50·6	—187·0	—189·6		19·9	About 1·5	Colorless.
Air	—140·0	39·0	—191·0	—207 [9]			0·933	Bluish.
Oxygen, O_2	—118·8	50·8	—182·7			16	1·124	Bluish.
Nitric oxide, NO	—93·5	71·2	—153·6	—167·0	138	15		Colorless.
Marsh gas, CH_4	—81·8	54·9	—164·0	—185·8	80	8	0·415	Colorless.
Helium, He			Below —264 [7] (Theor.)			2·02 [8]		
Fluorine			—187					

[1] Andrews. Deschanel Nat. Phil., II., 352.
[2] Villard & Jarry. Comptes Rendus, 1895, 120, 1413.
[3] Regnault. Muspratt's Chemie, IV., 1626.
[4] Thilorier. Muspratt's Chemie, IV., 1626.
[5] Fownes. Elem. Chem., 12th ed., p. 534.
[6] Olzewski. Phil. Mag., 1895 (5), 40; 202.
[7] Olzewski. Ann. Phys. Chem., 1896 (2), 59, 184.
[8] Clève. Compt. Rend., 1895, 120, 1212.
Dewar.

a tube in which is liquid air in a glass of whisky, which in a few minutes becomes frozen solid. On warming the outside of the glass the solid whisky may be removed, and we have a whisky tumbler composed of whisky itself, but the whisky is in a condition suitable only for consumption in the Klondike.

A jet of carbonic acid directed into a dish floating in a glass of liquid air (see Fig. 13) is immediately frozen and forms carbonic acid snow, in the open air, which, on being placed upon a table, passes into the gaseous state without melting. A jet of steam directed into a glass of the liquid air causes a violent evaporation of the air and condensation of the steam, so that a cloud of particles rolls away from the dish, but in a remarkably short time round hailstones of the size of peas will be found floating quietly in the liquid air. They have cooled from +212° to —312° Fah. in the short space of a few seconds. Consider how much heat they have given up. The heat of evaporation of water is 967° Fah.; 212° more to zero; 144° given off in freezing and 312° more in falling to the temperature of liquid air; 1,636° is the grand total. Eighty degrees per second would be a moderate estimate of the rate of loss. More remarkable still is it to see the air of a room condense upon the sides of a tube in which liquid air is boiling in a vacuum. Fig. 15 shows this experiment. When the pressure gage registers about half an atmosphere, the liquid air is seen to be boiling in the tube with violence. Ice crystals from the moisture of the outside air coat the exterior of the tube; but trickling down through these crystals, and falling off to the floor, are the drops of the atmosphere of the room condensed directly at ordinary pressure into the liquid form. They disappear almost instantaneously in a cloud of vapor upon the floor, not wetting it at all—a most singular sight to see a liquid which does not wet the surface upon which it strikes.

A most striking experiment has been designed by Mr. Tripler, as were many of the experiments which have been already described, to show the tensile strength of frozen mercury. Fig. 10 illustrates this. Into a paper dish is poured a quantity of mercury. Into the ends of the dish have been inserted a pair of heavy screw eyes. If this dish is placed in a basin of liquid air, the mercury is quickly converted into a solid, since its freezing point is relatively high; 30° below zero. Now this, suspended in the manner shown, will support a heavy weight for a long time. A block an inch square in cross section will not melt under 20 to 30 minutes. Of course, anything else could be done with the frozen mercury which might be done with any other similar piece of metal; as, for example, it might be used to drive a nail.

Possibly the most striking experiment is this: A quantity of liquid air is poured into a tea kettle, and the kettle is set over a hot fire of coals; the liquid air evaporates and shoots in streams from the spout of the kettle in a straight column to the height of 3 to 4 feet—a sight which Watt never dreamed of. While this is going on, if a glass of water is poured into the kettle, it will be found to be frozen in a very short time; and if the kettle is removed from the fire, its under surface is found to be covered with the carbon dioxide of the fire frozen solid within a couple of inches of the red hot coals.

All the experiments usually performed in illustrating combustion in oxygen may be performed with heightened effect by means of liquid oxygen, separated from the nitrogen in the manner already described. A piece of sponge, saturated with the liquid oxygen, when touched by a taper from a safe distance, explodes with violence and is blown into fine shreds (see Fig. 6).

A most beautiful experiment is shown in Fig. 5, in which a newspaper crumpled into a roll has been saturated with liquid air, and is set on fire at one end. It burns with violence, but not so rapidly as in the liquid oxygen.

An electric light carbon may be heated to a red heat at its tip, and then plunged vertically into a deep glass of liquid oxygen, as in Fig. 14. A most singular combustion takes place. The heat of the carbon evaporates the oxygen in its immediate vicinity, and the carbon burns with great brilliancy and violence, forming carbon dioxide, which is largely frozen in the liquid air before it reaches the surface and falls back to the bottom of the dish, so that the combustion is maintained and its products retained within the dish.

Of course matches will be relighted, a piece of paper take fire or a cigarette burn if a spark remains in any of these, upon exposing them to the oxygen in the glass of liquid oxygen. Fig. 2 shows the mode of igniting a steel pen or watch spring in the liquid oxygen. It is only necessary to stick the point of the steel into a match and light it, to furnish a sufficient heat to communicate the fire to the steel, when it burns with the same brilliancy as in the ordinary experiment.

Fig. 11 shows a very brilliant experiment. A large flask, 10 or 12 inches in diameter, is filled to the neck with water. Into the top of the flask liquid air is poured. This at first floats, since the specific gravity of liquid nitrogen is 0·885; but as the nitrogen boils away, leaving the oxygen behind, the drops of oxygen begin to sink into the water, since its specific gravity is 1·124. As these drops sink, they are partially turned into vapor, which of course tends to rise through the water. This action communicates a rapid whirling motion to the oxygen, and drives it back again. This may be many times repeated, giving a very beautiful exhibition, since the drops of oxygen may be as large as an inch in diameter.

The magnetic character of liquid oxygen can be exhibited on a large scale in the manner shown in Fig. 1. A test tube with a side tube is filled with liquid oxygen, and a cork inserted. The side tube allows free evaporation to take place. This is then suspended, as shown, by a sling. If an electromagnet be brought near the end of the tube, the tube swings toward and adheres to the pole of the magnet just as if it were a piece of iron. This is, perhaps, the first adaptation of this experiment for exhibition on a large scale.

The enormous force of liquid oxygen is illustrated in Figs. 16 and 17—an experiment which was tried at the request of the inventor of one of our best known guns. A heavy steel tube 18 inches long and of about an inch bore, open at both ends, was securely fastened in a vise. Into the middle of the tube a plug of cotton saturated with liquid oxygen was placed. This was touched off by a taper from a safe distance. The effect of the explosion is shown in Fig. 17, which is a careful drawing from the tube itself.

The practical uses and applications of liquid air have not yet been made, but doubtless the inventive world will find a place and a use for this new power. Already inquiries in this direction are somewhat numerous. The scientific aspects of the matter are of the highest interest. By boiling liquid air in a vacuum, the lowest degree hitherto attained has been reached, and men are brought the nearest they have ever been to the absolute zero. It would appear that, at the point reached, chemical action has well nigh ceased. Even that most active element fluorine, whose chemical affinities at ordinary temperatures are uncontrollable, becomes comparatively inert. It has recently been cooled in oxygen boiling in a vacuum to —210° C. without solidifying. It became a liquid at —187° C. In its liquid form it had apparently no desire to attack anything excepting only substances containing hydrogen, such as turpentine and benzine. Its well known action upon glass entirely ceased. It would seem probable that men have reached in liquid air boiling in a vacuum a temperature quite comparable with that of the spaces between the stars, and that we may realize in a faint degree something of the time when stars and sun have ceased to shine and grown cold.

The Current Supplement.

The current SUPPLEMENT, No. 1161, contains many articles which will interest our readers. As promised in our issue of last week, the present number contains the full biographical notice of the late Sir Henry Bessemer, taking up in detail his various discoveries and inventions. "Tests of Bicycle Wheels" forms the subject of an article on a new departure in the testing of bicycles. The continuation of Judge Greeley's "Report of the Commissioner of Patents for 1897" is specially important, as it takes up the development of industries through patented inventions, including electrical railway, the telephone, the bicycle industry, the typewriter, amateur photography, cash registers, cash carriers, basic steel, aluminum, and other industries. "The Annealing of Copper" is a timely and practical article. The "Photographic Investigation of 150,000 Volt Power Discharge" is illustrated with engravings made from photographs taken during a disruptive discharge at a very high voltage. "The Solution of the Flight Problem" is an interesting study in aviation, treating of the scientific flight of birds. Among the articles of popular interest are "Bernard Palissy and his Art," "Perrault's Colonnade of the Louvre," "German New Guinea," "The Egg of the Dung Beetle," and "The Manufacture of Compressed Oxygen" on a Commercial Scale.

The Warships of the United States Navy.

Two full page illustrations, showing the comparative dimensions of the vessels of the United States Navy, with descriptive text giving full particulars as to size and armament, will be found in the SCIENTIFIC AMERICAN SUPPLEMENT, No. 1046. Mailed on receipt of 10 cents by the publishers, or it may be ordered through booksellers and newsdealers.

PYROGRAPHY ON VELVET AND PLUSH.—The design must be bold in its outlines, and the pile inside of the pattern is singed off with the platinum needle. Care should be taken not to hold the needle vertically, so as not to burn the ground of the material. It should be held more horizontally, but not too much, else the points of the bordering fibers will be scorched. A little practice is necessary before starting at a larger work. When the above is done, brush off the hairs and lay in the colors as desired in the ground thus deepened. Bronze or gold may also be employed for this purpose, and looks still better.—Die Mappe.

Science Notes.

Prof. Alexander Graham Bell has been elected president of the National Geographic Society, Washington.

London's big fire has led the County Council to authorize an increase in expenditures of nearly a million dollars right away, and to add $125,000 a year to the estimates.

The Physikalische Verein, of Frankfort on the Main, proposes to erect a memorial to the late Philipp Reis, the inventor of the telephone. The society, of which Dr. Petersen is the president, has appointed a committee to further the scheme, the carrying out of which is estimated to cost about $7,500.

Prof. David P. Todd, Director of Amherst College Observatory, Amherst, Mass., U. S. A., has nearly completed a bibliography of eclipse research to join on with Ranyard's classic work published many years ago in the Memoirs of the Royal Astronomical Society. He would be glad to receive copies of papers and titles of works and articles published since 1875.

Father Kneipp left 850,000 marks for the continuance of the various Kneipp institutions at Wörishofen.

Dr. Thomas Egleston, emeritus professor of mineralogy and metallurgy at Columbia University, has presented the government of France with the sum of $5,000, in aid of the mineralogical collection of the School of Mines at Paris, from which he graduated in 1860.

Russia is beginning to honor her Siberian explorers. A statue is to be erected at Chabarowsk, on the Amur, of Deshnew, the Cossack who went by sea, in 1648, from the river Kolyma to the river Anadyr, thus sailing through Bering Strait for the first time, and proving that Asia was separated from America. It is proposed, moreover, to change the name of the East Cape into Cape Deshnew, which will probably be objected to by geographers.

Snow statues are the latest fad among artists; invented by Pierre Roche, a French sculptor of good reputation. The statue is made of copper, and in its lowest part a vessel with liquid carbonic acid is placed, whose slow evaporation generates great cold. On the metallic surface a snow or hoar frost-like covering is produced in a short time from the moisture of the air, which is prevented from thawing by the freezing solution in the interior.

The coldest inhabited country appears to be the province of Werchojansk, in Oriental Siberia, says The National Druggist. The mean altitude of the terrain is about 107 meters (about 390 feet) above the sea. A Russian savant passed one entire year in this inhospitable region and kept a daily record of the temperature, which he has recently published, and from which it appears that the daily mean of the entire year is 19·3° C., or 2·74° F., below zero! The daily mean for January, 1896, was 53° C., or 63·4° F., below zero.

Dr. Colajanni, an Italian sociologist, living in Naples, has just completed a little monograph descriptive of the quarters in European cities having the largest number of inhabitants to the 1,000 square meters. In London the average to every 1,000 square meters is 196, in Paris it is 265, in Rome 280. In Naples there are 939, and in the Pendino quarter of that city 1,254. Dr. Colajanni makes an appeal to his government to remedy the terrible conditions of life in his native city. Living pellmell in buildings that cannot be called human habitations, lacking air, light and proper food, these Neapolitans show a harvest of death that exceeds from a quarter to a third the average mortality of the rest of Italy. Dr. Colajanni adds: "The ancient legend, 'Vide Napoli e poi morire,' is a sad truth today. For, in the magic horizons and under the azure heavens are the most active laboratories of death existing on the face of the globe."

According to Dr. Bell, in The Scottish Geographical Magazine, the forest fires of Canada are generally caused by lightning. In the great forest between Alaska and the Straits of Belleisle the portions recently burned are easily recognized by the tenderer green of their foliage from the parts which have been longer spared. The fire rushes along with the speed of a galloping horse. The branches and dead leaves on the ground burn like tinder and the flames rise to nearly 200 feet. Resinous pinewoods burn fastest. One of them extended 160 miles in ten hours. The traces of a fire remain for nearly a century. Birds and beasts are stifled or burned. Beavers and muskrats, which are amphibious, have a chance of saving their lives. After the fire a few trunks of the largest trees are left. Next spring roots begin to sprout and seeds to grow. In fifteen or twenty years the soil is covered with poplars, willows, etc., which shelter young firs and other trees. In fifty years the conifers are uppermost, and in one hundred the others are dying out beneath the pinewood. A third of the forest region of Alaska has trees of fifty years old, another third trees of fifty to one hundred years, and the rest trees over one hundred years old. The fire seems to suit the Banksian pine, as it opens the pines and sets free the grains. Without fires this species would hardly reproduce itself. Such fires took place even in the Pleistocene epoch of geology.