called by Reuleaux 'Kapsel räderwerke,' or 'chamber-crank trains,' according to Kennedy.

List of other papers.

The following additional papers were read in this section, some of them by title only: — A method of testing long plane surfaces, applicable to the alignment of planer-beds, lathe-beds, heavy shafting, etc., by *W. A. Rogers*. The commercial and dynamic efficiencies of the steam-engine; Centrifugal action in turbines, by *R. H. Thurston*. Velocity of the piston of a crank engine, by *C. M. Woodward*.

PROCEEDINGS OF SECTION E. — GEOLOGY AND GEOGRAPHY.

ADDRESS OF C. H. HITCHCOCK OF HANOVER, N.H., VICE-PRESIDENT OF SECTION E, AUG. 15, 1883.

THE EARLY HISTORY OF THE NORTH-AMERICAN CONTINENT.

There is a special appropriateness in the association of geography with geology, as indicated in the assignment of sciences to section E; for the latter gives us an account of the origin of every topographical feature of the earth's surface, whether island, continent, mountain, plateau, valley, or oceanic depression. If we would properly understand the significance of the earth's contours, we must unravel the mysteries of geology: so a knowledge of topography is essential to the complete comprehension of the geological features of any country. If a geologist were taken by a balloon to an unexplored part of the earth, he would instantly recognize, from their topographical outlines, volcanic and granitic cones, limestone hills, elevated plateaus of basalt or horizontal sandstones, and special types of orographic structure. Hence the modern geologist first draws the contours of his district before applying the colors of geological age. The existing relief features of the earth have been produced one by one in successive periods; and it is the task of the geologist to discover what were the characteristic physical developments of the several ages. He can delineate a connected historical sketch of the beginning, growth, and completion of a continent. Such histories are rare, because attention has but recently been turned into this direction. One of the first American geologists to frame such an outline is Prof. J. D. Dana, to whom we owe the enunciation of this fundamental truth, — that the first formed land has always remained above water, and has been a nucleus about which zones of sediment have accumulated. We can now recognize this primitive continent, with all its successive stages of growth, upon every geological map.

Time would fail us to present the entire physical history of our continent; and we will therefore confine our attention chiefly to its earlier chapters, noting those points which are under discussion. As we are endeavoring to *advance* science, we must touch upon debatable topics, and hope by friendly discussions to become wiser.

We must assume the correctness of the commonly received opinions concerning the earliest history of our planet, — that it passed through the condition of a nebula, and then of a burning sun, the period of igneous fluidity. By subsequent refrigeration it has become either partially or wholly solid. Not until a crust had formed, and the earth had cooled enough to allow water to remain permanently, was it possible to talk of dry land and ocean. With these premises allowed, it seems to us evident that the material of the earth must be disposed in concentric zones, arranged according to density, the heaviest being at the centre. If the various elements were free to move, as is the case in all natural or artificial igneous fluids, we must expect to find the heavier metals situated beneath the others; and, following the analogy of extra-terrestrial bodies, the central nucleus may be principally iron, like the heavier meteors. Zones corresponding to stony meteors, lavas, the trap family, and granites would naturally succeed in order, the last named being at the surface. This outer zone is also characterized by the presence of much silica and oxygen. The primeval ocean came from the vapors surrounding the igneous sphere, condensed to liquidity as soon as water could remain upon the solid crust without immediate vaporization.

This original crust may have been essentially a plain, and consequently entirely covered by water; for if the land were now levelled off, the ocean would submerge every acre of the continents. As refrigeration progressed, ridges and valleys would form in accordance with that fundamental principle that the outer envelope must conform to the shrunken nucleus; and this contraction gives rise to that tangential force or lateral pressure which has acted through all time. Whether these earliest ridges rose above the ocean would depend upon the amount of elevation. Some authors argue that these ridges follow the course of great circles. If there are causes adequate to produce such results, — or any other world-wide arrangement, — they must have commenced to operate at the very beginning of contraction. Most authors maintain that the very thick strata of the older rocks have been formed just like modern sediments, having been broken off the ledges, and transported into oceanic basins in horizontal attitude. If so, there must have been great mountainous elevations, deep oceanic depressions, and extensive aqueous action; since the thickness of the crystalline schists is greater than that of the strata in the fossiliferous ages. The amount of distortion, crumpling, and faulting of the crystalline rocks is also greater. These same authors hold that the original strata were in all respects like modern sands, gravels, and clays, and that their present crystalline structure is due to metamorphism. No one has yet discovered any uncrystalline pre-Cambrian beds; nor have the original foundation rocks been pointed out, since the oldest known layers are stratified, and cannot therefore have constituted part of the original unstratified crust.

Professor Dana thinks the primitive land originated because of a difference in the rate of conduction of heat during the process of refrigeration. Cooling would be fastest where the heat was conducted most rapidly. The first areas to cool would be the first to solidify. The first solidified crust was heavier than the adjacent liquid: so it sank until it found a fluid as dense as itself. Then the liquid above this crust would in turn become solid, and sink; and this process is supposed to have continued until a permanent shell had become fixed in the earth's circumference, which constantly increased in breadth and thickness, becoming continents. Meanwhile the other portions remained liquid; and their surfaces must have stood at the same level with the first-formed crust till that congealed, and became depressed because of the diminution of volume in solidification. These depressions became the ocean's beds. From this beginning down to the present time the processes of growth have consisted in the thickening of the continents and the settling-down of the oceanic depressions, while the chief force employed has been the lateral pressure derived from contraction. LeConte and Pratt express the process thus far described by the term 'unequal radial contraction.' The total gravity of the particles of matter along each radius is supposed to be the same; and hence, if the heat is conducted most rapidly over the shorter radii composed of denser minerals, the ocean-basins would cool first. These two views thus demand a different arrangement of the lighter and denser materials; the one necessitating that the continents, and the other the depressions, were first to congeal. Both, however, make the gratuitous and unproved assumption, that the surface was not uniform in composition; the differences being probably like that between granite and trap. The principle stated above — that, where all the particles are free to move in a liquid, the lighter elements must rise to the surface, and the heavier minerals sink down in proportion to their specific gravity — is at variance with this assumption. Fortunately it is not essential to a right theory of continental growth. There is no reason, therefore, to doubt that the original crust had essentially a uniform thickness over the whole earth. Contraction would originate ridges and valleys in the normal way, most likely of similar dimensions. There must soon burst forth ejections of igneous matter, owing to tidal attraction; and these would show themselves along the weakest lines. At the outset it is difficult to assign reasons why either the elevations or depressions would be the weaker; and hence we should look for a multitude of locations of igneous overflow, both over the future continents and oceans. There may be no better reason for the eventual enlargement of certain of these volcanoes than that circumstances only very slightly favored them; but, this favor being continued, they would exist and enlarge at the expense of the others, affording us another illustration of the 'survival of the fittest.'

It seems to us there is now afforded an opportunity for reviving in a modified form the view of Poulett Scrope in regard to the origination of the earlier crystalline deposits. Suppose we say, that, besides the original unstratified igneous granitic material, the oldest stratified crystalline rocks are derived from volcanic ejections; being the continued enlargement in size, and reduction in number, of the early indeterminate vents. The several ejections would increase in size till they became islands, either gneissic or granitic; and, if an archipelago is allowed us, we can easily show how continents would accumulate, using only the universally acting forces of lateral pressure and sedimentary accumulation.

Of other theories relating to the origin of the earlier crystalline beds I may mention two. The first is that advocated by Lyell, who termed these rocks *hypogene*. After the solid granitic crust had been formed by refrigeration, "the hot waters of the ocean held in solution the ingredients of gneiss, mica-schist, hornblende-schist, clay slate, and marble, — rocks which were precipitated one after the other in a crystalline form" (Lyell's Principles of geology, 10th ed., i. 142). In such a menstruum, life could not have existed. A very similiar view was advocated by Dr. T. Sterry Hunt in his presidential address before this association in 1871.

The second is the view more commonly entertained, — that, after the solidification of the crust, sedimentation accumulated stratified systems from the granitic foundations, as ordinary sand, gravel, and clay, which were subsequently acted upon by thermal and aqueous influences termed *metamorphic*, and thus converted into crystalline schists. The widespread and powerful action of metamorphism is conceded; but it is a more appropriate adjunct to volcanic than sedimentary accumulation.

A few of the considerations favoring our theory will now be presented.

1. Considering the igneous origin of the earth, volcanic energies would naturally continue their action as soon as there was a crust to be broken through, and immense piles of melted rock would ooze from the numerous fissures. Up to Laurentian times all admit the universality of igneous outflow, while but few have ventured to speak of any thing like volcanic action, except as it has been manifested in the formation of dikes in these early periods. There has been a tendency to class the ancient granites and porphyries with rocks of sedimentary origin, and consequently to restrict the action of igneous agencies to phenomena of slight importance. Several English writers, and, in our country, Dr. Selwyn of Canada, have been calling our attention to the existence of a volcanic group in later Huronian or early Cambrian times. These are the rocks so largely developed about Lake Superior, New England, and the Province of Quebec, consisting of stratified schists, diorites, diabases, amygdaloids, and felsites, identical in composition with true eruptive masses of the same name. Investigation shows that

oftentimes these schists are disposed like the lavas ejected from one series of volcanic vents. Suppose, for example, that Etna or Vesuvius should become extinct. In the course of ages the rains would obliterate the craters, and reduce the lavas to a rounded dome of greater or less regularity. We should recognize the volcanic origin of the mountain in the absence of craters from the lithological similarity of the rocks to those known to have been melted and ejected from vents, while the disposal of the material in a conical attitude shows us that it might once have been covered by craters. So we find in our eastern country many domes of diabasic or protogenic schists, whose volcanic origin may be predicated, both from their lithological character and physical aspect.

Now, this volcanic group of Huronian times indicates the existence of a greater degree of igneous activity than has been described for the paleozoic ages, even those of Great Britain ; and consequently this is an indication pointing significantly towards the predominance of thermal influences in the still earlier periods. In the Laurentian age the fires should have been yet more vigorous, because the time of universal igneous fluidity was less remote.

2. A careful study of the crystalline rocks of the Atlantic slope indicates the presence of scattered ovoidal areas of Laurentian gneisses. Those best known have been described in the Geology of New Hampshire. Instead of a few large synclinal troughs filled to great depths with sediments, the oldest group is disposed in no less than twenty-two areas of small size, scattered like the islands in an archipelago. In a chapter upon the physical history of the state, I have proposed the theory that the earliest land within its limits consisted of this series of islands, not packed as closely together as now, in an area of perhaps three thousand five hundred square miles, but as much more widely separated as would be determined by smoothing out the various anticlinals and synclinals that were formed later. By reference to our maps in Maine, Massachusetts, New Jersey, Pennsylvania, Virginia, North Carolina, and Georgia, many similar ovoidal Laurentian areas may be specified, usually larger than those of New Hampshire. This may be due partly to a less thorough knowledge of the exact areas occupied by this older gneiss, and partly to the existence of a greater number of volcanic vents, giving rise to a more widely spread and thicker mass of ejected material. Over the Atlantic slope and Canadian highlands these primeval islands have, in later periods, been cemented together by a subsequent deposition of material; but in Missouri, Arkansas, and Texas, we recognize, even now, these early islands.

3. The lithology of the Laurentian and other crystalline rocks is very like that of igneous ejections. It is proper at this point to recall the proper restriction of the term Laurentian. As originally defined by Logan, it included every formation that antedated the Huronian. In the Report upon the geology of Canada for 1877–78, Selwyn proposes to restrict the Laurentian outcrops to "all those clearly lower, unconformable, granitoid, or syenitic gneisses in which we never find interstratified bands of calcareous, argillaceous, arenaceous, and conglomeratic rocks." The Hastings and Grenville series, and all the schists containing the eozoon, are excluded from the Laurentian by this definition, as well as the Bethlehem, Lake Winnipiseogee, and Montalban groups of the Atlantic slope. The Laurentian is azoic, the other groups eozoic; and, unless newer distinctions are to be made hereafter, it looks as if we might claim these various azoic Laurentian islands as the first-formed dry land, as they certainly are the nuclei of the existing continents.

There are no minerals in these Laurentian islands that do not occur in eruptive granite; and the schistose structure is often so faint that the field geologist need not be blamed if he acknowledges his inability to detect it. Likewise we discover the same fluidal inclusions and the vacuoles that pertain to granite. If we follow Sorby and Clifton Ward in saying that granite has been formed beneath a pressure equivalent to a weight of forty thousand feet of strata, the same must be said of the early gneisses. With this general assertion of the identity of gneiss and eruptive granite, we must be satisfied at present, without entering into detail.

4. The analogy of the origin of oceanic islands at the present day suggests the igneous derivation of the Laurentian areas. Most of the high islands of the Pacific are composed of lava, with the volcanoes frequently in action. Hawaii, of the Hawaiian group, may illustrate their position and shape. Its area above the water-line is 4,210 □ miles, and its cubical contents above the sea-level are about the same with those of New Hampshire. It rises from a plateau over 16,000 feet deep, thus forming a cone 30,000 feet high, whose cubical contents must be twenty times greater than the portion making dry land. The length of the entire series of islands, all of similar character, is 350 miles, and the area of the base of the lava must be about 100,000 □ miles. These cones have been built up by the accumulation of lava ejected from the interior of the earth, and they are entirely isolated, the nearest land being 1,000 miles distant. The ground-plan of this volcanic mass is that of two elliptical areas, either of which is like some of our Laurentian islands, and is certainly as large as any of these ancient lands south of the St. Lawrence. The land area of the Hawaiian Islands is less than that of Massachusetts, but their base must be equal to the whole of New England and New York combined. Surely it cannot be avowed that volcanic areas are too small to be compared with the space occupied by our oldest formation.

The so-called lowlands are likewise of volcanic origin; since coral polyps have built up reefs upon the igneous area after the disappearance of the fire, and the Hawaiian areas are encircled by reefs. After the volcanoes have become cold, loose material would be worked in between them, coral reefs would grow, and, in various ways, the land area would be enlarged, and finally an archipelago may become a large island. It needs only time and a repetition of these constructive agencies to make a continent out of a series of archipelagos.

There are two points requiring explanation in this connection, — first, the supposed deeply seated localities where granite is produced; and, second, the origin of foliation in the schists.

We should naturally expect that the earlier igneous rocks would have been derived from reservoirs quite near the surface, because of the thinness of the crust. With this notion agrees the presence of cavities containing liquid, and of hydrated minerals, which are more common in the older eruptive rocks, and have led to the aqueo-igneous theories of the origin of granite. Water would be scarce at great depths, and hence these rocks ought to originate near the surface where moisture was abundant. It seems to us that this consideration should more than balance the arguments usually cited in favor of the origin of granite at enormous depths, as it is difficult to see how both can be true.

Mr. H. C. Sorby has led the way in studies of the mineral constituents of eruptive rocks. He measures the included cavities in the component minerals, and calculates how much the contained substances must have contracted in cooling, allowing for an increase in the temperature of the point of vaporization under pressure. By assuming the temperature to be correctly determined, he ascertains the amount of pressure indicated by mathematical formulae, and finds it to be the equivalent of a thickness of 40,000 feet of overlying rock in Cornish granites, and of 60,000 feet in Scotch granites. Later writers seem to have regarded this pressure as certainly produced in the way thus suggested, and that its appearance at the surface has been due to an enormous erosion which has denuded the overlying blanket. This conclusion is not necessary; for, 1°, an enormous pressure would result from the tangential force of contraction, which would be entirely adequate to have produced the cavities. 2°. The necessity of an erosion of 40,000 feet over all the granites in every part of the world cannot be maintained. In North America, for example, it would necessitate the supposition that nearly eight miles' thickness of rock had been removed from one-fourth of the surface since the Laurentian, for the blanket removed would have equalled in dimensions the crystalline areas. The mere statement of the amount of denudation required refutes the theory. 3°. By reference to existing volcanoes, it is plain that a column of lava will often be adequate to exert the needed pressure. Teneriffe rises 12,000 feet above the ocean, and its cone descends 18,000 feet more to the submarine plateau. When the crater is full of melted lava, there must be a pressure of 30,000 feet at the base of the cone: hence the lava from the reservoir supplying Teneriffe might exhibit the vacuities produced by a pressure of 30,000 feet without any weight above the peak.

When molten lava pours down the side of a crater, the included vapors and liquids must disappear because of the removal of the pressure; but, after a substantial crust has formed, the peculiar markings imprinted at the great depth would remain: hence we can understand how it is that the vacuities are to be seen both in granites and lavas that have been subjected to great pressure. At the Boston meeting of this association I endeavored to show that there are mountain masses of granite in New England possessing all the physical characteristics of volcanic cones. The material must have been liquid, hot, ejected from a vent, and flowed over a plateau, building up a cone, and indurating the underlying floor. It was claimed that such phenomena could be explained only by supposing the granite to have been erupted just like lava. This granite contained the usual vacuities indicative of great pressure just as they are also found in the lava of Monte Somma or the trachyte of Ponza.

When one examines the interior structure of modern lava-flows, he is surprised to find beds nearly as well defined as the foliation of schists. Around vents like Vesuvius or Etna the lava accumulates naturally in quaquaversal sheets, no one eruption being very extensive. When steam and hot water are copiously supplied from the caldron, there may be flows of hot mud and tufa. The closing phases of eruptions are usually showers of ashes falling upon the cone or beyond. If the vent is beneath the ocean-level, the lava is minutely subdivided, and the deposit will be like sand or gravel. Between the igneous flows the ordinary aqueous agencies will wear off excrescences, and scatter the fragments down the slope. These various agencies will produce a concentric stratiform arrangement in the whole mass. Where the eruption is massive, a similar set of layers will be formed.

This mass of volcanic material will be very susceptible to metamorphic influences when placed under the proper conditions of heat and pressure. As the result, new minerals will be formed, arranged in foliated beds or schists. Thus briefly stated may be the origin of foliation. So long ago as 1825, Poulett Scrope advocated essentially this doctrine for the arrangement of the crystalline particles in the crystalline schists, having found an analogous structure in certain volcanic accumulations.

Sufficient has now been said in advocacy of our doctrine that the first land consisted of volcanic islands. This was the Laurentian or azoic accumulation. Cartographers have not yet distinguished the several crystalline deposits, so that it will not be practicable at present to point out the supposed volcanic areas of the Hastings, Grenville, Montalban, Huronian, and other eozoic periods. Sedimentation would also act so that in this age many beds must be referred to an aqueous derivation. By the close of the eozoic the continent was outlined; or at least the framework of the future superstructure was put into position. The broader patches about to be mentioned had their origin in the earlier numerous islands cemented by detrital accumulations.

The more important areas developed in the eozoic must have been Greenland, Canada east of Lake Winnipeg, the Atlantic district, the Rocky Mountains, the Sierra Nevadas, and numerous buttes over the Cordilleras. The three great depressions of Hudson's Bay, the Mississippi valley, and the Salt-Lake and Nevada basins commenced to sink very early, and the future growth of the continent consisted largely in filling them up with marine sediments. An inspection of a map drawn upon a correct scale will dissipate the fancied resemblance to the letter V, in the Canadian dominion, so often insisted upon. Neither has the development of the land been in bands parallel to the north-west and south-east arms of this supposed angle. A better conception would find three great basins, excluding the unknown regions of Mexico and Alaska, in each of which operations were conducted independently. The best known is that of the interior of the United States, or the Mississippi hydrographic basin. This depression was nearly encircled by a crystalline border of high land. Beginning at Alabama, we follow it to New England, thence by a slight gap to the Adirondack promontory, thence across the Lakes to the Dakota promontory. In Minnesota and Dakota the schists are more or less covered by cretaceous clays and tertiary sands; but they evidently constitute the floor for the surface strata occasionally piercing through the later deposit, as in the Black Hills. Thus we may connect the Dakota and Rocky Mountain crystallines. From Wyoming southerly the granites are again conspicuous into New Mexico. Thus the circuit is not complete: it is like a horseshoe, with the lower Mississippi valley in the gap; yet this may have been filled in the Cambrian age, since Laurentian islands are found in Texas, Arkansas, and Missouri. We might give reasons for believing in the recent origin of the depression between New Mexico and Alabama.

The map will show, around the borders of this Mediterranean Sea, the primordial sea-beach, whether examined in Virginia, New York, Michigan, Colorado, or Texas. Could we dissect the land, we should find an immense platter of Cambrian sediments coextensive with the crystalline highlands surrounding and underlying it. In Cambro-Silurian times the story is repeated. Marine limestones formed other dishes, each limited in size by the upturned edges of the platter underneath. The rest of the history is given in our text-books. Our Mediterranean Sea was not closed till the end of the cretaceous, when the salt-water was expelled, never to return.

In the west a similar ovoidal, crystalline border can be traced, holding paleozoic sediments. Beginning at the Rocky Mountain chain in Wyoming, we follow it southerly to Mexico. Across Arizona are many gneissic outlines, but not sufficiently numerous to close the gap. In California we reach a country entirely gneissic beneath the sands of the desert, which connects with the Sierra Nevadas, and is traceable along the Nevada line nearly to Oregon. There the course is changed, the rocks trend north-easterly, show themselves conspicuously in the Blue Mountains of eastern Oregon, the Salmon River Mountains of Idaho, and western spurs of the Rockies again in Montana, which are continuous to our starting-point in Wyoming. Our crystallines do not pass north of the parallel of 49° into Columbia. We have therefore found a complete crystalline border for the depressions of our western territories, and, within this ovoidal line, all the members of the paleozoic, mesozoic, and cenozoic groups, but not arranged with the simplicity of their distribution in the east.

Less is known of the arctic basin than of the others; but the scattered sketches afforded by voyagers indicate the presence of the more important members of the geological column. Where these basins adjoin, there is a much wider area of ancient land.

In conclusion, I will simply recapitulate the more important phases of the growth of our continent.

We start with the earth in the condition of igneous fluidity.

It cools so as to become incrusted and covered by an ocean.

Numerous volcanoes discharge melted rock, building up ovoidal piles of granite, which change gradually into crystalline schists. When these hills are high enough to overlook the water, they constitute the beginnings of dry land.

At the commencement of paleozoic time the continent is composed of three immense basins, located near Hudson's Bay, the Mississippi hydrographic area, and the great Nevada series of land-locked valleys.

The later history of the development of the continent presents the details of the filling-up of these depressions, the expulsion of the Mediterranean seas, and the description of the varied forms of life that successively peopled the land and water.

The history opens with igneous agency in the ascendant. Aqueous and organic forces became conspicuous later on, and ice has put on the finishing touches to the terrestrial contours. The completed structure we must acknowledge to be 'very good.'

NOTES AND NEWS.

Our leading article of June 29 was based in part upon a mistake, which we desire to correct. Foreign periodicals received by mail in single numbers have not been dutiable within the last five years. Nevertheless, the writer of the article, who subscribes to three foreign scientific journals, and receives them by mail, had been forced to pay duty on each number for the past nine or ten months; and the same has been the case with others of our acquaintance. Our post-office regulations are so frequently changed that one can rarely tell whether he is the victim of a blunder or a whim.

—M. Pasteur, who has just obtained a grant of fifty thousand francs from the French Chambers to send a scientific mission to Egypt to investigate whether the cholera be not due to the development of a microscopic animal in the human body, states, in a letter to *Voltaire*, the reasons which induced him to recommend the board of health to send out the mission in question. He says, "I urged the sending-out of this mission on account of the great progress that science has made since the last cholera epidemic respecting transmissible diseases. Every one of those