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THE

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Vol. IX OCTOBER, 1898 No. 10

LAKE CHELAN

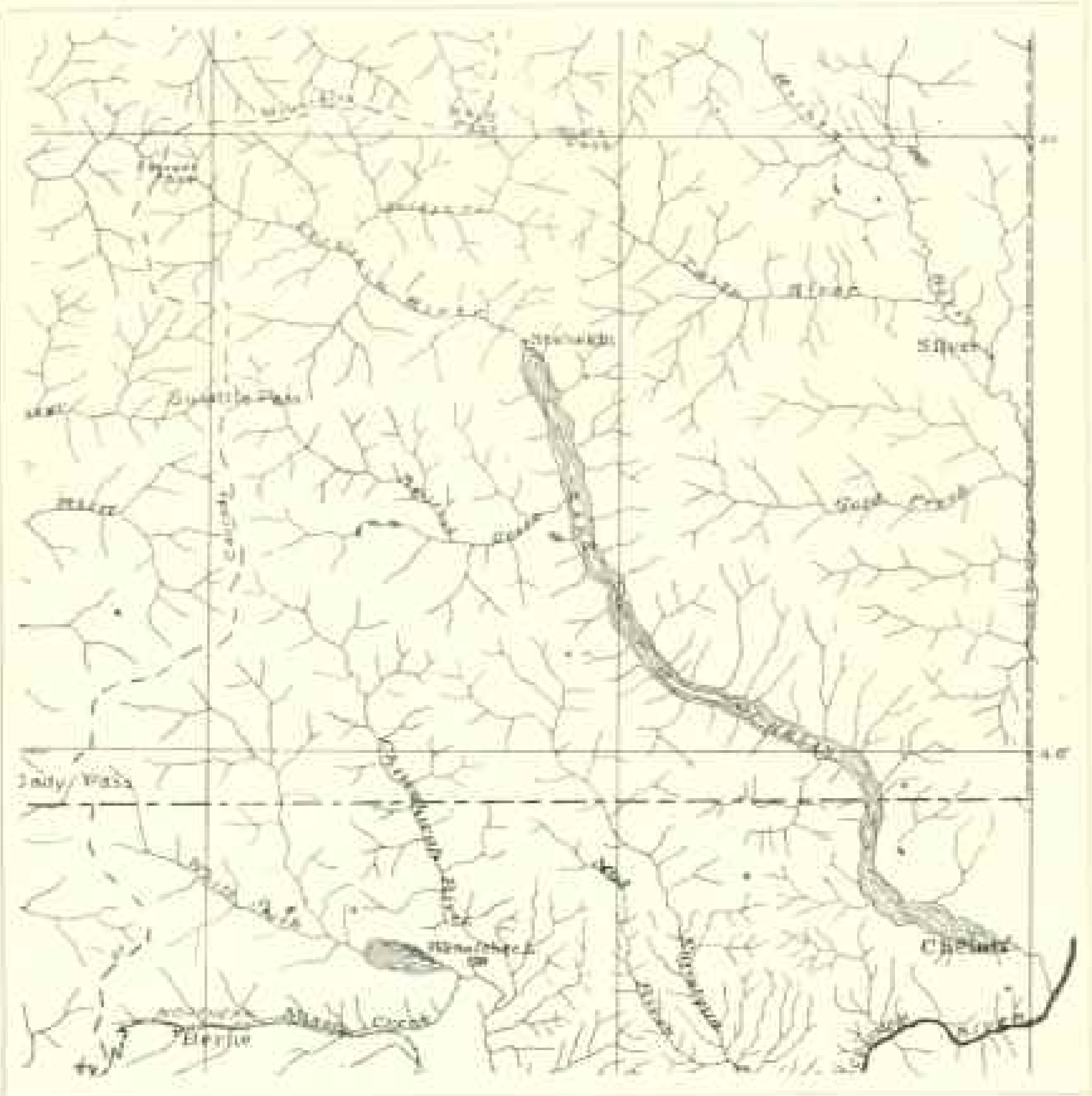
By Henry Gannett,

Chief Geographer, U. S. Geological Survey

To most readers, especially those of the East, this title conveys little information, for it is an almost unknown lake, in an almost unknown region. It lies in the northwestern part of the state of Washington, upon the eastern slope of the Cascade range, its lower end being near Columbia river, into which it is drained; thence it stretches northwestward in a long, winding ribbon, far up toward the heart of the range. Into the head of the lake flows Stehekin river, whose sources are in Cascade pass, at the summit of Cascade range. The river has numerous branches, all of which head in high, snowy mountains, among small glaciers, and it consequently brings a considerable volume of water to the lake.

In the northern part of Washington the Cascade range consists of a broad and extremely rugged mass of granite mountains, whose highest summits are between 10,000 and 11,000 feet in altitude. High up in the heads of the gorges and at the foot of the peaks are many small glaciers, the remains of others, much larger, which in times past extended far down the present stream valleys, filling them to great depths with streams of ice. Evidences of these are present in all the valleys and gorges of this part of the Cascade range. The occupation of these gorges by glaciers is so recent that in many of them the subsequent work of the streams by which they are now occupied has produced but trifling results. Only in a few places are evidences of extensive stream erosion seen.

The bed of Lake Chelan and its principal tributary, Stehekin river, together with the branches of that river, were at one time filled by a vast glacial system, extending from the crest of the Cascades southeastward nearly to Columbia river. The glacier was nearly 100 miles long, and when it was in its prime the ice must have been several thousand feet in thickness.



MAP OF LAKE CHELAN AND VICINITY, IN THE STATE OF WASHINGTON, [illegible]

A glacier is a river of ice, and it behaves almost precisely as a river of water does. Its effects upon its channel are almost precisely similar to those of a river upon its channel, excepting in the fact that all its operations are on a vastly greater scale. The channel of a river may be measured by yards or hundreds of yards, while that of a glacier is measured in miles. The depth of a river may be a few feet only or a few scores of feet; that of a glacier may be thousands of feet. It is this greater size, volume, and weight which makes glacial ice behave like water. In such large masses ice is plastic, accommodating itself to inequalities of its bed, flowing with some freedom, spreading out and contracting, much as water does.

A word of caution must here be interpolated. The channel of a river, in which its water flows, must not be confused with its valley, which it drains. The above comparison refers to the *channel* of a river, not to its valley.

Glaciers in mountain regions commonly head in amphitheaters or cirques—basins lying directly at the heads of cañons, under the shadow of the summit cliffs. An amphitheater is surrounded on three sides by vertical walls or steep slopes, down which the ice and snow slide in avalanches, accumulating in the bottom. The effect is precisely like that of a waterfall. The falling snow and ice dig a hollow or depression at the foot of the steep descent just as water does. Such amphitheaters are found at the heads of all glacial gorges in high mountains, and today are found to contain small alpine lakes in place of the ice which once occupied them. From its head in the amphitheater the glacier moves down the gorge, scouring and cutting the bottom and sides as it travels. The ends of the mountain spurs are planed off instead of being trimmed to sharp, angular points, as is done by streams in gorges cut by them. If the bottom of the cañon be uneven, if it contain abrupt elevations and depressions, the glacier flows over them as water would flow over similar obstacles in its channel, gradually cutting them away. Where the descent becomes abruptly steeper the ice, in bending to follow the surface, is commonly cracked, forming a network of crevasses, making travel over its surface very difficult and dangerous.

Where the main glacier is joined by a branch, the bed of the branch is commonly found to be at a higher level than the bed of the main glacier, because being larger and heavier the main glacier has greater cutting power; indeed, in many cases the beds of small branches are hundreds, or even thousands, of feet higher than that of the main glacier to which they are tributary. The parallelism between the glacier and the river in their channels is further illustrated by this fact. The surface of the ice in the main glacier and in the branch must have been at the same level, although the bottoms, as stated above, differ greatly in elevation. So it is with a river at the point of junction of branches. The surface of the water must be practically at the same level in all cases, but the bottoms of the channels differ by the difference in depth of the streams at their point of junction. This fact affords us a measure of the minimum thickness of the ice at any place. It cannot have been less than the vertical distance between the bed of the main glacier and that of the tributary, and, indeed, must in all cases have been greater, owing to the thickness of the tributary.

LAKE CHELAN, AT THE NARROWS

To extend the comparison between a river and a glacier, it may be added that the central portion of the glacier flows faster than the bottom and sides, as they are retarded by friction, just as in the case of a stream. This is demonstrated by the gradually increasing curvature of the lines crossing the glacier, such as transverse lines of dirt or crevasses. In the upper portion of the glacier these may be straight, or nearly so, but lower down become more and more curved, with the convexity downward.

A glacier is constantly receiving upon its surface rock, gravel, etc., which fall upon it from its walls. In its long journey from its source to its melting point, a journey which may occupy many years, large quantities of such material accumulate, and it naturally falls mainly upon the edges of the glacier, forming lateral moraines. Where two branches join, the two lateral moraines on the inside join and form a medial moraine, and thus in a complicated glacier system the main glacier below the junction of a number of branches may bear upon its surface many

WEST SIDE OF HORSESHOE BASIN

moraines lying lengthwise with the glacier. At the melting point all these moraines are dropped in a confused heap, forming the terminal moraine. This may extend for a considerable distance up and down the valley, because the foot of the glacier moves backward and forward according to the season. In a wet, cold season the foot advances down the gorge, while in a warm, dry season it retreats toward its source.

Herein we may see another point of similarity between the glacier and a certain type of river. In the arid regions of the West the streams which have their sources in the mountains flow down into the valleys and disappear, being absorbed by the dry soil and the thirsty atmosphere. These streams, like glaciers, bear detritus down from the mountains, and upon their disappearance in the valley they drop this detritus as the glacier does.

There are, therefore, certain characteristics by which the gorge produced by glacial erosion may be distinguished from that produced by aqueous erosion. The glacial gorge has the shape of

CASCADE PASS AND AMPHITHEATER

the capital letter U, while the waterworn gorge is a V-shaped notch. In a glacial gorge the spurs separating the tributaries have their ends blunted or planed off, while in a waterworn gorge they are sharp and angular. In a glacial gorge the tributaries enter the valley above its level, while in a waterworn gorge they commonly grade down to its level. A glacial gorge has an amphitheater at its head; a waterworn gorge has not. A glacial gorge is commonly lined near its lower end with lateral moraines and across its foot stretches a terminal moraine, and often this terminal moraine has formed a lake.

GERMAN FALLS

With the exception of lateral moraines, Lake Chelan and its tributaries present all these features peculiar to glacial erosion, and owing to the fact that the ice has but recently abandoned the gorge, aqueous erosion has made but little progress, the glacial forms are but little masked and are still the most prominent features in the landscape.

Crossing Cascade pass from the west, one descends immedi-diately into an amphitheater, enclosed on the west and south by a mountain wall surrounded by high peaks. On the north is the pass and on the east the land rises slightly, forming the lower rim of the amphitheater. The hollow of this amphitheater contains, all the year around, a great snow-field a mile or more in length, which gives rise to Stehekin river. The accompanying illustration is taken from the rim of the amphitheater, looking toward the pass, which appears in the background, with the snow-field below it.

From the summit of the lower rim of the amphitheater there is a steep descent of several hundred feet, down which the Stehekin plunges in a series of cascades. The valley, at first narrow, broadens as it becomes deeper and the U-shaped form of a glacial valley becomes more pronounced. On either side at short intervals small branches join the stream. These head among the high mountains and flow with gentle courses through ancient glacial valleys to the edge of the glacial gorge of Stehekin river, over whose walls they leap in great falls. One such stream heads in Horseshoe basin, on the left-hand side of Stehekin river, where its waters are derived from a small glacier. The waterfall known as Gorman falls is the leap of the stream over the edge of the glacial wall, which here is practically vertical.

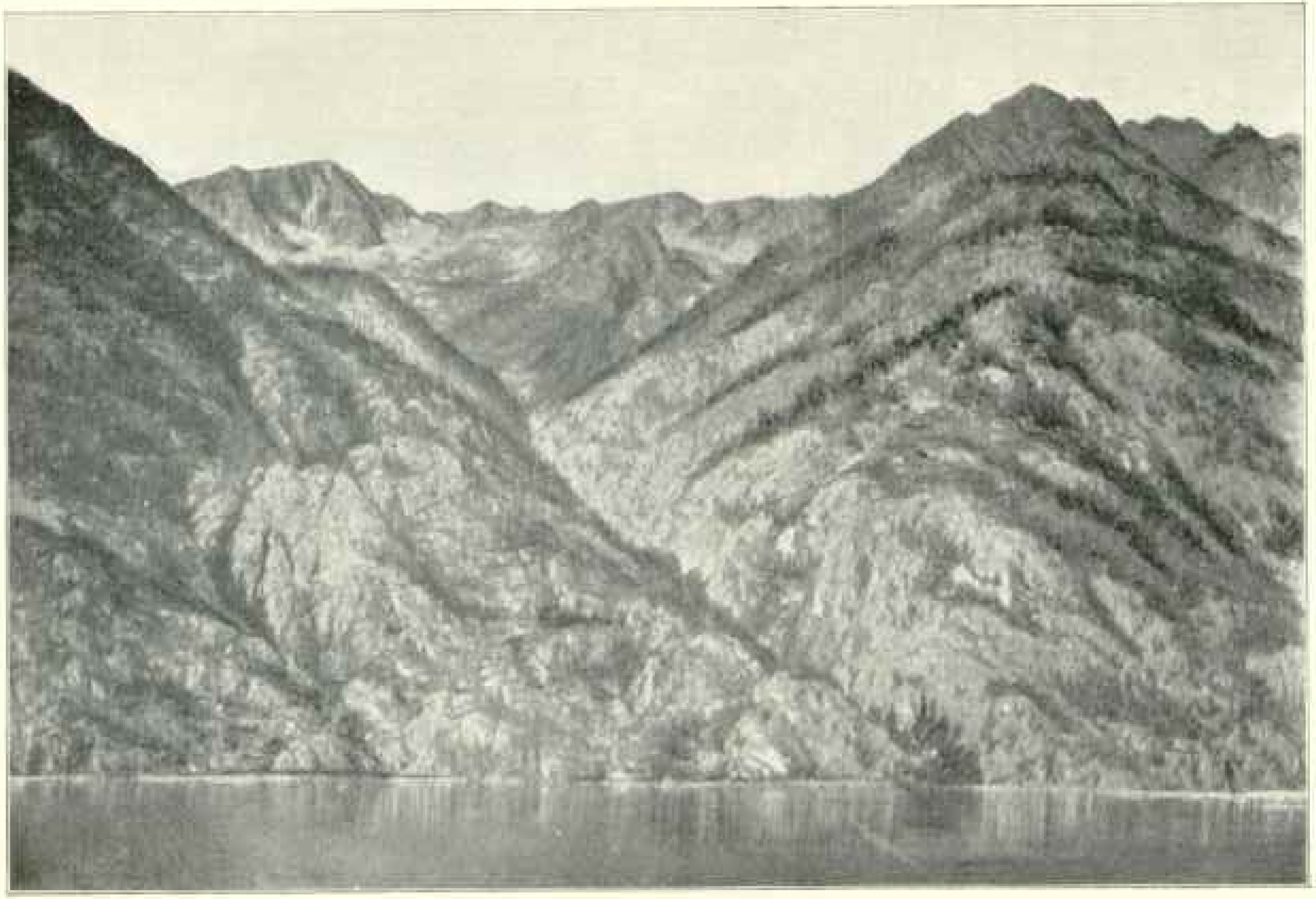
The walls of the gorge along Stehekin river range from 4,000 to 5,000 feet in altitude above the bottom of the valley, and the angle ranges from near verticality at the top to 40° or 45°. Near the mouth of Company creek, some 15 miles above the head of the lake, the wall is fully 5,000 feet in height, descending in one great sweep from the summit of the mountains down to the bottom. Company creek, coming in on the right, though a large stream, flows on a level several hundred feet above the bed of Stehekin. Bridge creek, which joins the Stehekin three or four miles farther down, coming in from the right, also a large branch, flows in a valley several hundred feet above that of the Stehekin, descending to it by a series of cascades and waterfalls in a waterworn gorge 200 or 300 feet deep, which it

STEHEKIN VALLEY, AT THE MOUTH OF COMPANY CREEK has cut since the retreat of the glacier. Bridge creek has numerous branches, and at the junction of each of these branches similar phenomena are observed, although in case the branches are nearly equal in size the bench or rise in the glacial valley is not as marked as in the case of smaller branches. From all indications it appears that the ice must have been at least 3,000 feet deep in this gorge of the Stehekin, since several of the smaller branches join the main glacier at that height above its bed.

Lake Chelan is between 50 and 60 miles in length and from half a mile to a mile or more in breadth. Except near its lower end, it is enclosed throughout its course between high steep walls, rising at angles of 40° to 45° directly from the water's edge to an altitude of 5,000 or 6,000 feet above the sea. The elevation of the lake above the sea is 1,100 feet, and its cañon walls rise 4,000 or 5,000 feet above its surface. Nearly all the streams which flow into it are small, and tumble over its walls in a series of cascades. There is but one stream of magnitude, Railroad creek, which is tributary to it. This, which is upon the west side, heads in the divide of the Cascade range, among the high peaks, where its sources are fed from living glaciers and its valley is a glacial gorge.

Near its upper end the lake is narrow and its depth increases gradually, but about midway of its length it reaches a depth of fully 1,400 feet, its bottom being, therefore, 300 feet below sea-level. Thence its depth diminishes gradually to its lower end, but not as regularly as it increases. The rock walls which enclose the lake are strikingly parallel to one another. The high mountains which border it at its head extend down nearly to its foot, and then suddenly break away to the lower country, first upon the east side and then upon the west.

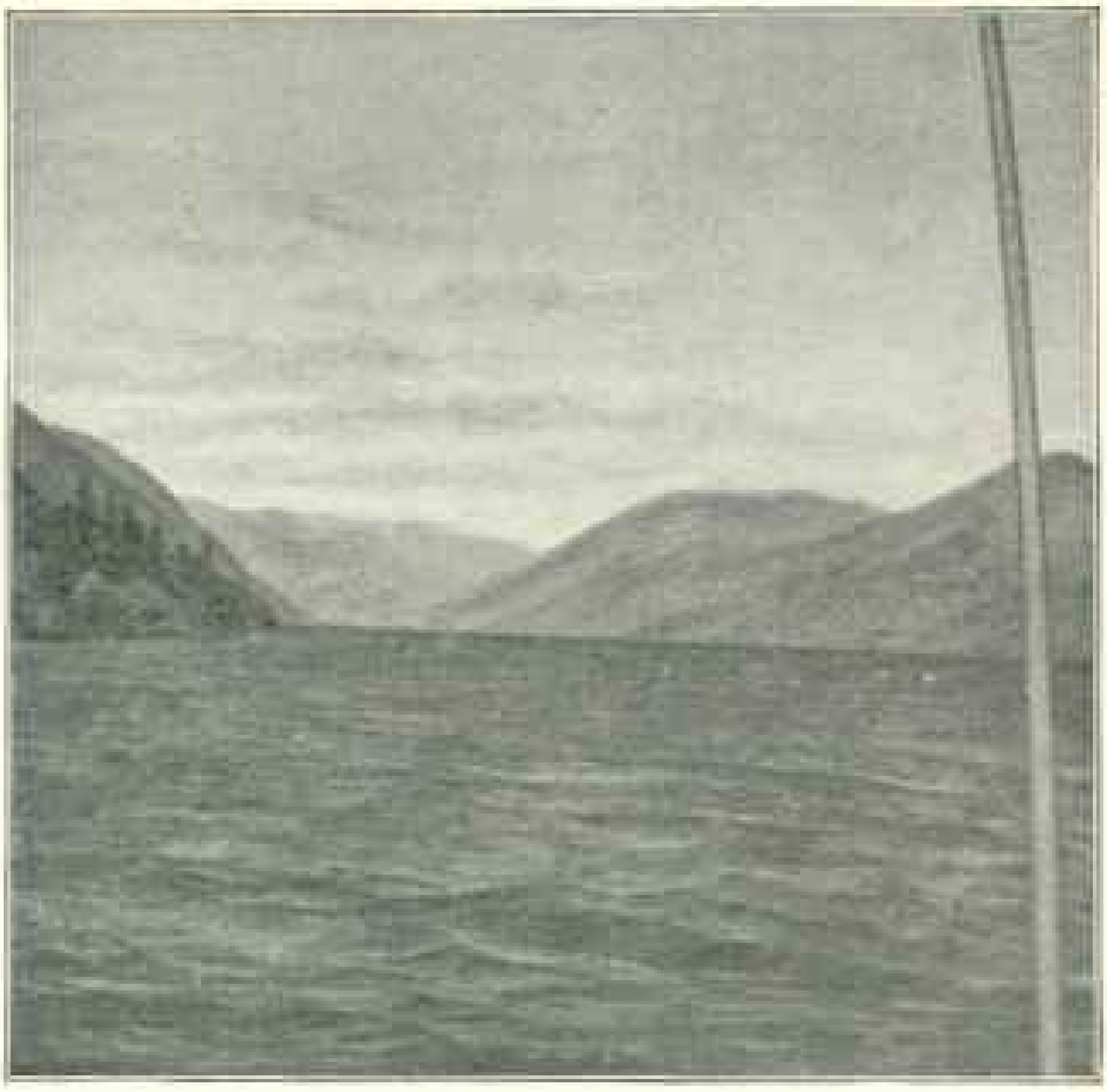
The dam by which the lake is formed is the terminal moraine of the glacier. The lake is now drained by a stream which has cut through this terminal moraine, and after a short course of three miles and a descent of 400 feet joins the Columbia. Above the present outlet are indications of former outlets of the lake in the shape of coulées, cut through from the west, or rather south, side of the lake to Columbia river. The lower of these, Knapps coulée, which leaves the lake at about three miles above its present outlet, has an elevation, at its summit, of about 300 feet above the present level of the lake, with a sharp descent to Columbia river at its lower end. The other leaves the lake at a point about 10 miles above its present outlet, and is much



MOUNTAINS BORDERING ON LAKE CHELAN

lower, its summit being only about 100 feet above the present lake level.

Lake Chelan is not difficult of access. The traveler leaves the Great Northern railway at Wenatchee, on Columbia river; thence twice a week a little steamer stems the swift current of the Columbia for forty miles, to the mouth of Chelan river, and a stage covers the remaining three or four miles to the outlet of the lake, where is situated the little town of Lakeside. On the days when the steamer does not run on the Columbia the journey from Wenatchee to Lakeside may be made by stage. The lake is traversed by a small steamer which, leaving Lakeside in the morning, reaches Stehekin, at the head of the lake, where there is a hotel, late in the afternoon, returning the next day. On the shores of the lower part of the lake there are numerous ranches, but within the mountain portion the only signs of habitation are a few landings, and above Stehekin there are no settlements, and travel in this region must be upon horseback, with pack train.



TYPICAL VIEW FROM A BOAT ON LAKE CHELAN

FREDERIC W. PUTNAM,

President of the American Association for the Advancement of Science;

Fiftieth Anniversary Meeting, Boston, 1898

The presidency of the American Association passed last month from a chemist to an anthropologist, and that of the British Association from an anthropologist to a chemist, and there are no more illustrious rolls in the scientific annals of the world than those upon which the names of Gibbs and Putnam, Evans and Crookes are now inscribed. The election of Professor Frederic Ward Putnam as President of the American Association was an event of more than ordinary interest and satisfaction to American scientists, Professor Putnam having not only established his claim to such recognition by forty years' scientific work of the highest character, but also won the admiration and regard of scientific men everywhere by the signal ability, the marvelous tact, the untiring zeal, and the unfailing courtesy with which he has served the cause of science for the long period of twenty-five years as permanent Secretary of the American Association.

Frederic Ward Putnam was born in Salem, Massachusetts, April 16, 1839. His immediate ancestors were the Putnams, Fiskes, Wards, and Appletons, who came from England during the first half of the seventeenth century. Young Putnam received private instruction until 1856; and as he displayed unusual aptness for the study of natural history his parents afforded him every facility for the pursuit of his favorite study. When he was but sixteen years of age he had compiled a "Catalogue of the Birds of Essex County, Massachusetts," and about the same time he was made curator of ornithology in the museum of the institute.

At this time the attention of Louis Agassiz was drawn to the young man's devotion to natural history, and through his influence Putnam went to Cambridge, where he entered the Lawrence Scientific School, intending to devote himself to medicine. This intention was not carried out from the fact that he was soon made assistant in the Zoölogical Museum and afterward appointed curator of the Peabody Museum. His natural aptitude for scientific pursuits, aided by the excellent methods imparted to him by his friend and master, Agassiz, prepared young Putnam in a most admirable manner for his life work in science, and from the day of his acceptance of the position in the Essex Institute he has always been in demand for places of honor and trust in scientific work. In 1859 he was made curator of ichthyology in the museum of the Boston Society of Natural History. In 1864 he became director of the museum of the Essex Institute, and three years later was made superintendent of the East Indian Marine Society's museum, and when the Peabody Academy of Science was established he was made director of the academy. In 1873 he was elected permanent secretary of the American Association for the Advancement of Science. In 1874 he was appointed member of the Kentucky geological survey for the special investigation of the caves of that state. In the summer of the same year he was for a time instructor in the school for natural history at Penikese, and in the fall, on the death of Professor Jeffries Wyman, he was called to the charge of the Peabody Museum. In January, 1875, he was formally appointed curator of the museum. The next summer found him again in charge of the department of fishes in the Museum of Comparative Zoölogy, and for two years he divided his time between this institution and the Peabody Museum.

In 1876 he was appointed by the government to report on the collections made by the survey west of the one hundredth meridian, which report was finished in 1879. In 1887 he was elected president of the Boston Society of Natural History, retaining the office two years. In 1882 he was appointed state commissioner on inland fisheries by Governor Long, in which office he remained for seven years. In 1886 he was appointed to the new chair of American Archaeology and Ethnology in Harvard University. Since 1890 he has been president of the Boston branch of the American Folk-Lore Society, and in 1891 was president of the parent society. In 1891 he was made chief of the Department of Ethnology at the Chicago exposition, retaining this office until the fair closed. In April, 1894, he was appointed curator of the Ethnological Department of the American Museum of Natural History in New York, and his time is now divided between the institution and the Peabody Museum in Cambridge.

Until 1876 Professor Putnam was an ardent worker and an authority in zoölogy, making for himself an enviable name by his constant and conscientious work; but since that date his efforts have been in the department of ethnology. His interest in these studies was aroused as early as 1857, when during a visit to Montreal he dsicovered a shell-heap and on investigation determined it to be the site of an ancient habitation. He was one of the first in this country to attribute these relics to man, and since that time he has personally explored shell-heaps, burial mounds, village sites, and caves in various parts of North America, and has directed extensive explorations in the United States and Mexico and in Central and South America. He has been the director of large bodies of assistants in ethnological and somatological investigations, the results of which are evidenced in the collections in the Peabody Museum, the American Museum of Natural History in New York, and the Field Columbian Museum in Chicago. In connection with these researches he has published more than three hundred papers. He was the originator of the *Naturalist's Directory;* he was one of the founders of the *American Naturalist* and an editor of it till 1874. He has edited the reports and proceedings of at least a dozen societies and institutions, and has contributed not a little to the more popular magazine literature of the day. J. H.

MESA VERDE

By F. H. Newell,

Chief Hydrographer, U. S. Geological Survey

The Mesa Verde, situated in the extreme southwestern corner of Colorado, has been made known through the beautifully illustrated book of Nordenskiold, entitled "The Cliff Dwellers of the Mesa Verde." Besides ethnologic interest, it has many attractions for the geographer or geologist. It is a remnant of an ancient plain which formerly stretched southerly and westerly from the country where now are situated the high La Plata mountains. During the course of geologic time the same force presumably which uplifted the La Platas tilted this plain and, erosion being facilitated, it was deeply trenched, until now the Mesa Verde stands as a great table-land slightly tilted toward the south, presenting to view from all sides sharp precipitous edges. On the north is the bold promontory known as Point Lookout, facing toward the La Plata mountains; on the west is the broad Montezuma valley, drained by tributaries of McElmo creek; on the east is the valley of Mancos river, and on the south the narrow canyon through which Mancos river discharges on its way from the La Plata mountains to San Juan river.

Standing on the southern edge of the Mesa Verde and looking across the deep canyons of the tributaries of the Mancos, it is seen that the same plain extended originally far to the south into New Mexico; but what appears to be a level surface is found upon traversing the country to be a land deeply dissected and almost impassable except along the flat-topped ridges or valley bottoms.

The Mesa Verde derives its name from the fact that its top is densely covered with a growth of cedar and piñon trees, contrasting with the arid and almost desolate lowlands. In viewing the mesa from a distance and in going around it the impression is derived that its surface must be a plain, but upon laboriously climbing to the top of it it is found that it is in reality more like a hollow shell. The whole interior has been dug out, not in one great valley, but in almost innumerable small narrow canyons, which converge toward the south and enter the Mancos. The plan of the surface of the mesa would give the appearance of a number of fingers stretching up from the south and spreading out toward the northern end. In other words, the fingers of time have, as though drawn from north to south, dug out the long narrow valleys, leaving only thin parallel ridges rising almost to the original height. Traveling along the top of these ridges is easy, as the surface is smooth. Numerous cattle trails wind in and out among the trees, and on horseback the ground can be covered as rapidly as the rider can dodge the stiff-pointed, dead, lower branches of the trees; but in attempting to go from side to side it is found to be almost impossible to make progress. Reaching the edge of a precipice, the explorer wanders up or down until by chance he finds a place where the rock has been broken down, and on reaching the bottom of the valley he must again search perhaps for miles for an opportunity to climb out.

About the only sure and practicable way of visiting various parts of the mesa is to ascend near its upper edge, at Point Lookout, and then keep on this narrow rim, in this way passing around the head of the different finger-like gorges. There is here a trail traveled by pack animals. At places the ridge is so narrow that the rider looks down almost vertically on one side into the Montezuma valley and on the other into the head of the small canyons that lead to Mancos river. A misstep would throw a pack animal far down either slope.

The peculiar form of the mesa is due largely to the existence of a heavy bed of sandstone which forms the top-capping and protects the softer underlying rock. This weathers and cracks in almost vertical cliffs all around the outer edges. In the interior of the mesa, however, at the head of the numerous small canyons, erosion has proceeded in a peculiar manner, and one which was found by the aborigines to be highly favorable to their purposes. Along the edges near the top of the canyon certain portions of the sandstone have weathered, leaving great shelves, protected above by the overhanging masses. These shelves can be reached often with great difficulty, as the cliffs below them may be 100 feet or more vertically, and access from the top is almost impossible. The roof of these openings gradually slopes down to the floor, so that these great horizontal crevices or caves, as they are sometimes called, may extend back 50 or 100 feet, and in length may stretch for several hundred feet.

Around and on the mesa are found numerous fragments of pottery or of chipped stone, and here and there mounds of refuse, showing the location of ruined houses or towns. The innumerable objects testify to the former presence of a large population. Ruins of stone towers on prominent points show that the arts of defense were an important feature of their life. It is, however, under the shelter of the great overhanging rocks that we find the ruins almost in perfection. Here, in the dry climate, protected from the occasional fierce storms, the dust of centuries has accumulated, and even organic matter has hardly undergone any change. The great stone houses and towers rise story upon story, and behind, in the piles of refuse thrown in the part of the cave where the roof approaches the floor, are the worn-out sandals, the broken pottery, and all the rubbish of a town. Here, evidently, were kept great flocks of turkeys, and in the rubbish sometimes graves were made, the bodies now being dried to the condition of tough leather, being perfectly preserved mummies. The clothing on these, such as the feather robes, has retained its texture and even in places its color. No fragments of metal have been found, but all the implements are of bone, wood, or stone.

The buildings are constructed of carefully squared rock, each of which must have been brought some considerable distance up steep ladders or along the narrow trails which lead to the towns. Water was had in some cases by small springs or seeps within the rock; in others it was brought in earthen jars, carried, presumably on the heads of the women, from the springs far down in the valley. The foot and hand holes cut in the rock still show the path by which the dwellings were reached, but in places these terminate on overhanging cliffs, where it is obvious that ladders must have been employed.

These ruins have been an object of superstitious dread by the Utes and other Indians living in the neighborhood and have not been disturbed by them through centuries; but with the advent of the white men destruction has come, and many of the finest have been wantonly pulled to pieces or injured in the search for relics. In particular an estufa or council chamber situated below the surface of the ground and the only one remaining in perfect condition was partially pulled to pieces in order to take some of the logs of the roof to exhibit at the World's Fair at Chicago. Various individuals have made a business of collecting the pottery from these ruins, rifling the graves and selling the material thus obtained to tourists or to collectors of curiosities. Several museums have sent exploring parties into the vicinity and have obtained material for exhibition. Although these ruins are presumably the property of the National Government, little, if anything, has been done to preserve them, and the National Museum possesses comparatively few objects from this locality. It is a matter of regret that these interesting ruins are not being preserved, as even from a commercial aspect they would have an ever-increasing value to that part of the State in attracting tourists from all over the world. In spite of the difficulties of access, it is estimated that at present 75 parties a year visit the more important of these cliff-houses. The trip is made from Mancos, a town on the Rio Grande Southern railway, a day being spent in reaching the ruins on horseback, another day or more in visiting the ruins, and the greater part of one day in returning to the railroad. It might be practicable to construct a wagon road, but no steps of this kind should be taken to facilitate travel until ample protection is provided to prevent the defacing and injury of the buildings by careless visitors.

THE GEOSPHERES *

By W J McGee,

Vice-President of the National Geographic Society

Perhaps it is my first duty, as it is a privilege, to offer you a word of welcome on behalf of the Society which I have the honor to represent—one of the institutions of the National Capital engaged in its own way in educational work. Speaking for that Society, Mr President and ladies and gentlemen of the National Educational Association, I bid you cordial welcome to Washington, and place at your disposal all the facilities which are ours.

Before leading you away from the earth's surface, which has been so admirably described by the last speaker, I wish to confess that I labor under a certain embarrassment. In the first place, I am attempting to speak for another man, and on his subject. The subject was chosen by Major J. W. Powell; first an educator like most of you; then a soldier who left an arm at Shiloh; next the explorer of Colorado canyon, the boldest piece of exploratory work in the history of our country; then a geologist and long Director of the U. S. Geological Survey; at the same time an ethnologist and founder of the Bureau of American Ethnology; and from first to last a philosopher, one of the most vigorous thinkers America has produced. It is but natural that I should shrink from discussion of a subject developed by so original a thinker and selected by him for presentation before you in his own inimitable way.

Again, I belong to the class of knowledge makers who most feel their own limitations in appearing before those who assimilate and apply knowledge, placing it within reach of the people and thereby performing the real work of raising humanity from plane to plane as time goes on. I apprehend that my ideas may seem vague and my expressions obscure, but I confidently appeal to your intelligence to aid in making the ideas clear and useful to the multitude of American youth for whom you stand sponsors.

* An address delivered before the National Educational Association, Washington, July 9, 1898.

First as to definitions—definitions rendered the more necessary for the reason that the essential ideas which I wish to express have not yet found their way into the dictionaries. Since early in the history of knowledge, men have recognized the *atmosphere*—*i. e.*, the body of air above the earth. At first the recognition was vague; it became more and more definite as time went on; and now educated men and women and children know the atmosphere as a gaseous envelope surrounding the solid earth, an envelope composed of a complex mixture of substances, chiefly of oxygen and nitrogen. This atmosphere is one of the geospheres, the outermost of four.

Since the beginning of knowledge, too, men have perceived the waters of the earth; and, as time has gone on, they have recognized more and more clearly the substantial unity of the standing waters of ocean and bay and lake, the running waters of springs and rivers, and the solid waters of Arctic and Antarctic snows and the glaciers of mountain and pole; and they are coming to extend the unity to include the aqueous vapor of the air, one of the constituent gases of the atmosphere. Water is a definite mineral substance existing in three forms, as solid, liquid, and gas, though chiefly in the second form; it constitutes a *hydrosphere*—the second of the four geospheres—covering the greater part of the solid earth and covered by the greater part of the atmosphere.

Human knowledge began with the recognition of the solid earth; as time passed the knowledge became definite through the endless interactions between human mind and human environment; and today most intelligent people recognize a terrestrial sphere beginning with the soils and rocks beneath their feet, passing beneath river and lake and ocean to the antipodes, and extending from equator to pole in a spheroidal mass forming the visible solid part of our planet. Now it is only the superficial portion of this spheroidal mass which lies within reach of observation; this is the rocky crust of the earth, the object-matter of the science of geology; it consists of a wide variety of mineral substances, mainly combined in rocks of a specific gravity averaging about 2.70. This earth-crust forms the lands of the earth and the basins of the oceans; all of the geographic and topographic features so well described by Dr Redway are built up or carved out of it; the continents, the islands, the valleys, the mountains of the world represent this vast mass of rock-matter, which it is convenient to call the *lithosphere*—the third of the four geospheres.

While observation of terrestrial things ends with the atmosphere and hydrosphere and lithosphere, definite thinkers find it necessary to form some idea of the constitution of the interior portions of the planetary mass at depths below the reach of direct vision. Now knowledge of the earth's interior is gained not through geology but through the sister science, astronomy. You are aware that within recent years astronomers have reduced to system our sun, the planets and asteroids which circle about it, the satellites which follow the planets, and the long-mysterious rings of Saturn—the various constituents of our solar system; and the paths of the planets and satellites have been surveyed, while each of the bodies has been measured and weighed, so that their volumes and densities are known with considerable accuracy. Let me indicate the accuracy with which this astronomical work has been done by saying that sun, planet, and satellite have been weighed with an accuracy no less than that of the grocer in dealing out sugar and tea, and that the orbits of planets, satellites, and asteroids have been surveyed as accurately as the roadways and even the railways of the earth's surface. The earth itself has been weighed, with somewhat less accuracy than the other planets, it is true, yet with sufficient accuracy to indicate that its mean density is nearly six times that of water (5.6 ±), or more than twice that of the known lithosphere. Accordingly it is known beyond peradventure that the earth has an interior portion much denser than the known exterior; and this somewhat vaguely defined part of the earth may conveniently be called a *centrosphere*—the innermost of the four geospheres.

In the light of these definitions, you will understand that my object in coming before you is not so much to say new things as to try to establish a new point of view. Knowledge progresses in two ways which are interrelated yet fairly distinct; the first is analysis and the second is synthesis; the sum of knowledge is increased by analysis, while its quality is improved by synthesis. I am now attempting, not to bring new facts before you, but to put old facts together in a new way, and thus to carry you to a higher plane in the synthesis or generalization of a wide range of observations; and I am seeking to do this in such manner as to reflect the workings of another man's mind—the mind of the real author of this address.

Let us now consider the relations between the geospheres.

In the first place, the matter of the geospheres is unlike in state or physical condition. The atmosphere is almost wholly gaseous; the hydrosphere is for the most part liquid, though in part solid and in small part gaseous; the lithosphere is almost wholly solid, though a minute part is gaseous (chiefly as impurities in the air), while a small part may be liquid under temporary and local circumstances; for the present the centrosphere may be considered a transolid. Thus the four geospheres represent the three well-known states of matter, together with a fourth state which is not certainly known from direct observation. It is the marvelously delicate interrelation between the three exterior geospheres that gives character to the earth as the theater of life and the home of humanity; for plant and beast and man are alike dependent on the lithosphere for the solid part of their bodily substance, on the hydrosphere for the greater part of their sustenance, and on the atmosphere for the breath of life.

In the second place, the exterior geospheres at least are, despite the differences in physical condition, in some degree intermixed. The greater part of the atmosphere floats over the waters and lands of the earth as a thin mantle growing more and more tenuous outward; an early estimate of its thickness was forty-five miles, but the American physicist Woodward has recently shown that the outer portion is much less dense than at first supposed, and that the total thickness of the mantle exceeds the radius of the solid earth. A small part of the atmosphere is intermixed with the waters of the hydrosphere, especially the running waters of rivers and brooks; another part pushes down into the lithosphere, filling interstices in the rocks and playing an important role in the chemical and physical changes ever proceeding in the earth-crust. In like manner, while the greater part of the hydrosphere exists in the oceans, lakes, rivers, snow-fields and glaciers, a considerable volume rises far into the atmosphere in the form of aqueous vapor, and a much greater volume permeates the lithosphere as ground water or in still more intimate combination with the solid earth-substance. So, too, the material of the lithosphere is in small part dissolved or suspended in the waters or afloat in the air; at the same time there is an obscure interrelation between the lithosphere proper and the centrosphere, manifested in volcanic and other phenomena and perhaps in the presence of metals among the rocks, for there are certain reasons (which cannot now be set forth) for regarding the centrosphere as an aggregation of metalloid substances, much as the lithosphere is an aggregation of lithoid substances. The blending of the exterior geospheres is especially intimate where the three are in normal contact, *i. e.*, about the terrestrial surface on which men live and with which geographers deal; and the soils, the plants which subsist on the soils, the animals which consume the plants, and the crowning human organism which dominates all the others are products of the commingling.

Just as the geospheres are intermingled in material, so they are, in some measure, interrelated in normal movements. The atmosphere is an aerial ocean, ever astir with currents due primarily to the rotation and revolution of the sphere, *i. e.*, to movements depending on the density and volume of centrosphere and lithosphere; the waters of the ocean are evaporated into the atmosphere, carried far in its currents as aqueous vapor, and then precipitated to flow back again as fresh water, while the body of the ocean is enlivened by currents set in motion by the ever-moving atmosphere as well as by tides produced by rotation and revolution; the lithosphere is constantly destroyed and reconstructed by the moving waters of the hydrosphere, while the earth-crust is warped and continents are lifted and sea-bottoms depressed by the obscure but potent movements of the centrosphere. So the normal movements of the geospheres are interrelated; and most of them, from the rhythmic rise and fall of the earth-crust through which continents are lifted and submerged to the trade-winds and oceanic currents, may be traced to the motions of the centrosphere.

Let us now consider for a moment how the conditions and motions of the exterior geospheres would be affected by circumstances which, at first sight, might seem trivial; for thereby we may see more clearly how delicate are the interrelations on which terrestrial life and human activity depend. Suppose the temperature of the earth were raised, say, 200° F., what would follow? Your common sense, born of experience, tells you that much or all of the hydrosphere would cease to exist as such and become a part of the atmosphere; that the atmosphere would thereby be multiplied in volume and density, changed in substance, and modified in movements, yet that the lithosphere would remain substantially unchanged save that some of its substance would be dissolved in the densified atmosphere. Probably the centrosphere would not be greatly affected; yet even so slight a change in circumstance as an increase of temperature by only 200° would remove the hydrosphere from the earth and greatly modify the atmosphere.

Let us next consider the effect which would follow the reduction of the temperature of the earth by, say, 400° F., something we should have been unable to do a generation ago, but which we can now do easily by reason of recent experiments and discoveries in physics. You will remember that about a score of years ago Cailletet of France and Pictet of Switzerland began to liquefy different gases by the application of pressure at low temperature; many of you know that this line of experimentation was continued by the distinguished chemist and physicist of London, Dewar, who liquefied one gas after another until every gaseous substance known to man, including hydrogen, has been reduced to the liquid state; and I am sure many of you know that an American, Tripler, has recently improved on the work of our European cousins and has learned to liquefy air in large quantities, at low cost, by the skillful application of pressure and artificially reduced temperature. Tripler's work, by the way, is worthy of more than passing note, for his advance has given mankind a new hold on the powers of nature, with a promise of practical applications yielding benefits much greater than were promised by electrical control when inventors first began to utilize electricity for mechanical and other purposes; but this is a digression. Now, liquid air is a little lighter than water and boils or evaporates at about 312° below zero, F. So we know that if the temperature of our planet were to be reduced by 400° the atmosphere would cease to exist as such and would shrink to one eight-hundredth of its present bulk and be converted into a hydrosphere; we know, too, that long before the reduction was completed the hydrosphere would cease to exist as such and would become a part of the lithosphere, for the waters of ocean and lake would be congealed (as we know from Tripler's experiments) into a dry powdery mass of crystals, crumbling under blows or pressure just as granite and limestone and other rocks crumble at our present temperature; the waters would become rock added to the rock which now exists. By this transformation the volume of the lithosphere would be augmented by that of the present oceans, the present sea-level would become sea-bottom, and a lighter sea of liquid air (only a dozen or a score of yards in depth) would wash the frozen globe, leaving continents and islands rising above its surface in a geographic configuration differing not greatly from that of the present. Over this globe no air would float, save possibly a light vapor scantier than the aqueous vapor now borne in our atmosphere; and no man or beast or plant, no trace of life could exist.

Consideration of the profound modification in the exterior geospheres necessarily following changes in temperature which can only be considered as slight in comparison with the wide temperature range even of our solar system aids us in understanding something of the conditions which attended the early stages in the development of our planet. The earth as a whole is apparently a cooling body, though the rate of cooling may be—indeed must be—almost infinitesimally slow. So the planet primeval must have been warmer, a greater part of its water must have been afloat as vapor in the atmosphere, which must have been heavy with vapors and the fumes of solids soluble in hot water. In like manner the changes necessarily produced in the geospheres by diminished temperature enable us to take a long look into the future and foresee the fate which awaits the aging planet—unless, indeed, this fate may be averted by aid of human ingenuity. There are many indications that the mechanism of the solar system, and, indeed, of the stellar system, is running down. We know that the water of the earth is going into new combinations from time to time as a constituent of the rocks of the lithosphere; we know that the water area of the globe is diminishing from age to age as the eons run, for the clastic deposits with which geologists are most concerned were laid down in water, while those now forming are largely if not mainly accumulated on land; there are deserts on every continent today, while the record of geology indicates that during the Carboniferous and earlier ages all the lands of the earth were fertile and humid. And just as the hydrosphere is going into the lithosphere by chemic absorption as well as by interpenetration, so the commingled oxygen and nitrogen of the atmosphere are slowly seperating and combining with the substances of the lithosphere, and probably also with the substance of the hydrosphere. The changes yield a glimpse of planetary history; they suggest a time when the now deep-buried centrosphere was enveloped only by heavy atmosphere, with no lithosphere save possibly its own scums and slags, and no hydrosphere save possibly viscid lakes of its own substance half liquefied by relief from pressure like the lavas of later time; they raise visions of slowly segregating waters and accumulating rocks formed through interaction between the condensing atmosphere and the cooling centrosphere; they indicate the differentiation of the geospheres in nice adjustment to temperature and other conditions. The changes indeed give a threat of ultimate absorption of air and water into the rocks, leaving a dead planet of centrosphere and lithosphere only, swinging helpless through space like our frozen moon; yet there is a faint promise in a fifth geosphere produced through delicate interaction among the three exterior spheres of the earth, lying about the common boundary of the three, dependent on all, yet able (at least in some measure) to control their relations—a *psychosphere*, comprehending the scanty but potent and ever-growing mantle of thought which today envelops the world.

Just a few words more, if you please, concerning the general relations among the geospheres: The atmosphere is a body of gas conditioned primarily by temperature; the hydrosphere is a volume of liquid conditioned by temperature and gravity; the lithosphere is a shell of rock conditioned by temperature, gravity, and a more complex chemic affinity than is found in the mixture air or the compound water; the centrosphere is a transolid and probably metalloid body, conditioned in ways that are not well known; the several geospheres combine to form a planet conditioned by temperature, gravity, chemic affinity, and perhaps other agencies, which extend to other planets and satellites and suns of the cosmos. So the features of the geospheres, *i. e.*, the characteristics of our planet, are largely determined from within; yet it is not to be forgotten that each geosphere contributes to the making of the others, and thus to the molding of the planet and in some measure to the shaping of the cosmos. This has already been indicated incidentally.

Let us now proceed to consider a few of the special relations among the geospheres which affect cosmic economy: We have good reason for supposing that the earth is a cooling body, that some of its primeval heat is constantly passing into space to affect (howsoever infinitesimally) other bodies; but do we know why the temperature of the earth is not lowered more rapidly—why the lowering is so slow as not to be detectable by the observations of history? We know that if the earth were simply a ball swinging through interstellar space and cooling by the radiation of its heat into space it would soon be refrigerated; we know too that in this case the temperature of its surface would be determined solely by two factors, viz: (1) the temperature of the ball itself, and (2) the temperature of interstellar space. Now, on examining our planet as an actual thing and not as a figment of the imagination, we do not find that the temperature of its surface is determined, or even perceptibly affected, by its own proper heat; we do find that the temperature of the external earth is determined by the heat received from the sun. It follows, of course, that the earth is not merely a cooling ball suspended in cold space. On examining more critically the conditions determining our temperature we find there are two, viz: (1) insolation or accession of solar heat, and (2) conservation of a considerable part of this heat for a time by a terrestrial mechanism. This mechanism resides chiefly in interrelations among the exterior geospheres. The most important conservative agency is the aqueous vapor of the air, which not only stores quantities of heat to be given off on condensation, but serves to check radiation from the earth into space. When the sun shines on the ocean, a film of water is evaporated to be borne high in the clouds and carried far over the mainland; when it is condensed a part of its heat is employed in raising the temperature of surrounding air, water, and rock; so that water, chiefly in the form of vapor, stores heat more effectively than any other substance with which we are acquainted. Still more efficient is aqueous vapor as a blanket checking evaporation; dry air is diathermous, but vapor-laden air checks radiation from the earth as a garment checks radiation from the body. Since there is no part of the earth, even on the deserts and polar ice-fields, in which there is not an appreciable quantity of aqueous vapor in the air, this substance forms a clothing for the earth, determining its temperature, rendering it habitable, and making it what it is today, the stage of human activity.

There is another class of special relations between the geospheres which I should like to bring before you, partly as a new discovery. As before pointed out, the rocks of the earthcrust or lithosphere are permeated by water in the form known technically as ground water or phreatic water. Now one of our most distinguished geologists, Professor Van Hise of the University of Wisconsin, has recently shown that this ground water plays an important role in changing the texture and structure of rocks, especially at depths where the pressure is great and the temperature higher than at the surface. It is a well-known property of water to dissolve certain substances, and its efficiency in dissolving many rock-substances is greatly increased when the substances are subjected to pressure and heat; and, under these conditions, it also ionizes complex substances—*i. e.*, separates them into their simple components or ions. Accordingly when moist rocks are subjected to strong pressure at high temperature, as is frequently the case deep in the earthcrust, the rock-matter is dissolved at the points and planes of greatest pressure and precipitated or redeposited at neighboring points and planes of less pressure; so that, for example, a crystalline cube of wet and hot rock-matter may be permanently distorted by long-continued pressure on opposite faces, the crystals gradually yielding to the stress in the direction of pressure and elongating themselves in the orthogonal directions. Through its property as a dissolving and ionizing agent, that portion of the hydrosphere which penetrates and suffuses the lithosphere has determined the texture and structure of most of our rocks; it has transformed the muds and sands and slimes of original deposition into shales, sandstones, and limestones; in some instances it has reconverted or metamorphosed these rocks into schists, quartzites, and marbles; still more significantly it has aided in remetamorphosing deep-seated rocks into lavas and other crystallines. This extreme effect of water is peculiarly instructive in that it reveals something of the character of the centrosphere, whose dense materials are brought within reach of observation only by water as a solvent and sublimant in the form of lavas, vein-stones, and other rocks of hypogean origin. There is reason for regarding the atmosphere as a differentiating and dissipating factor, and the hydrosphere as a unifying and conserving factor, both interacting with the centrosphere in such manner as to develop the lithosphere and convert it into the terrestrial home of humanity; but this relation need not be pursued for the present. Yet it is worth while to note a curious relation between lithosphere and centrosphere which is apparently controlled by the waters both of the surface and the depths: The two inner geospheres are in unstable equilibrium; this is shown by the occasional escape of the deep-seated materials from the foundation of the lithosphere (if not from the centrosphere itself) in the form of extruded lavas and sublimated vein-stones; it is shown also by the interminable heaving of the centrosphere manifested in continental oscillation and, to some extent, in the uplifting of mountains; it is indicated further, in still more interesting though obscure fashion, by the apparent reduction of loose-textured solids to the denser transolid condition in provinces subject to loading through deposition of exceptional volumes of sediment—*e. g.*, the Gulf of Mexico, the world's most notable province of loading, whose configuration suggests a hypogean "slump" which may be imitated experimentally by pouring a few drops of heavier and cooler liquid into a viscid liquid at the critical (or boiling) point; but this most interesting relation may also be passed over for the present with the simple suggestion—made by many phenomena—that the solid lithosphere and transolid centrosphere appear to be interconvertible at a critical point of temperature and pressure, much as the atmosphere and hydrosphere may be considered interconvertible in state and in substance on passing a critical point conditioned by the same factors, and that the hypothesis of interconvertibility explains some of the most puzzling facts in geology.

There are other interrelations between the geospheres, interrelations innumerable; time will not permit me to mention a tithe or even a hundredth part of them; yet there is one more relation which appeals strongly to those geographers who, like myself, always see the lands and the waters from the human standpoint, and I beg your indulgence for the three minutes required to set it forth briefly. My predecessor, Dr Redway, has admirably defined for you the natural provinces of America, and shown you that the features of the land, formed during the ages by the work of running waters, shape the character of our people. I trust he will permit me to add a word to his theme, as well as to that of the thinker for whom I am speaking: In what we call the western hemisphere the land and the waters are so related as to form a broad continent, the North American continent, mainly in the North Temperate zone; during the ages the centrosphere has heaved and sunk according to its wont, and has interacted with the atmosphere and hydrosphere in such manner as to produce a lithosphere of far-reaching formations, crumpled here into mountains, stretching there in broad plains, modified everywhere at the surface into fertile soils, charged often at the depths with mineral treasures—the whole a rich patrimony wasted on unintelligent aborigines until men of thought and action came to claim it. Then, since the lands were broad and fertile, agriculture spread more rapidly than ever before, more rapidly than would be possible under other conditions; next the magnificent distances and rich produce compelled improved transportation facilities, and steam was harnessed more effectively than would be possible under other conditions. Meantime the broad problems presented by a broad land widened the views of men already inspired by political freedom, and America became a nation of inventors, a people of applied science; geography was studied more broadly than would be possible in a petty province; it grew into a science of geology, inspired by the breadth of the formations and their wealth in resources, guided by intelligence broad as the land, and today the geologists of this country lead the world in their science. The sister sciences were invigorated by the association. I have said that the solar system has been weighed and measured with unparalleled accuracy during recent years, and may now add that the work was done by American genius, and that today the shipping of the civilized world is guided by nautical almanacs based on this American work. Another science, regenerated in America by reason of favorable conditions, is anthropology. We have had better opportunities than the students of other countries for research concerning mankind; we have in Washington and in other cities representatives from every important country on the face of the earth, representatives of every living race, of every blood in human veins; then we have a wider range of culture constantly before us than any other nation, a range running from savage aborigines through barbaric tribes up to the representatives of the kingdoms and empires from other countries, and finally to our own enlightened people, standing on the highest plane which mankind has ever attained—the plane on which social organization is based on intellectual freedom. We have every stage in human culture before us, and hence have been able to develop a broader and profounder science of anthropology than the world has seen before. Especially during the last half century our country has sprung forward in the race for intellectual attainment, surpassing all other nations; and our application of scientific principles has kept pace with our development of knowledge. Today if English promoters in Egypt want locomotives furnished on short notice, they send to America, knowing that, despite the doubling in distance, the order can be filled more quickly than at home; today if a bridge is to be built more rapidly than the engineers of other countries can do it, American engineers are called to the task. Our progress in application has combined with our progress in knowledge to strengthen individual character, to produce a free and forceful individuality greater than other countries know—an individuality splendidly expressed in the faces before me. This exalted individuality is displayed in more perfect coördination of thought, in more complete union of hand and brain than the world has ever seen before; it is revealed in moral uprightness and strength of character, in personal courage, even in that splendid marksmanship—the highest expression of coördination between mind and muscle—which is America's latest revelation to the world. The individual character of Americans gives national character to America; our patriotism, the spontaneous product of free minds, is broader and deeper than any sentiment brought out by royal edict; no other country could match the recent impulse which prompted the millionaire clubman of New York and the roving cowboy of Arizona to stand shoulder to shoulder in a war for humanity's sake. It is the unequaled individuality of the free citizen, united and controlled by a dominant idea, that forms the basis of our indomitable social organization, a social organization faintly expressed by that coördination in army and navy which overwhelms opposition. Complete as is our coördination in military matters, it is much more perfect in civil life, in that unceasing conquest over nature toward which our deepest thoughts are bent; and our 70,000,000 individuals, each a tower of individual strength, are kept in touch by telegraph and telephone and press, united in thought and purpose, knit into the strongest social and political fabric the world has seen. It is this social fabric, the expression of thought and purpose, which I have in mind in referring to the psychosphere, most delicate yet noblest of the geospheres, which seems to be enveloping our planet and commencing the control of the rock-sphere, the water-sphere, and even the air-sphere for the good of humanity. And it is this conquest of the powers and resources of the exterior spheres, inspired by intellectual freedom and guided by liberal education like that which you dispense, that has placed America in the foremost rank among the nations of the earth.

PROPOSED COLLECTION OF FORESTRY STATISTICS

At a special meeting of the National Geographic Society, held in the Lecture Hall of the Boston Society of Natural History, Boston, Massachusetts, August 25, 1898, Vice-President W J McGee in the chair, the following resolutions were adopted:

Whereas, through the increasing consumption of forest products, the destruction of forests, and the vast extension of means of transportation, questions hitherto of restricted bearing are rapidly assuming grave international importance; and

Whereas the National Forest Association of Germany has undertaken to collect throughout the world forest information and statistics of commercial importance:

Resolved, That the National Geographic Society express its deep sense of the value to mankind of the work thus begun, and pledge its countenance and support to the investigation; and

Resolved, That a committee of three be appointed by the chair to communicate these resolutions to the National Forest Association of Germany, and to take such other steps as may be necessary to carry them into effect.

In conformity with the resolution, the chair appointed Mr Gifford Pinchot, of Washington, chairman, and Messrs William H. Brewer, of New Haven, and Arnold Hague, of Washington, as a committee to take requisite action on behalf of the National Geographic Society.

MISCELLANEA

It has recently been ascertained that the British consumption of sugar (1,568,000 tons per annum) is almost equal to that of France, Germany, Austria, Holland, and Belgium combined.

The import trade of Canada during the fiscal year 1897–1898 amounted to $140,305,950, an increase over the preceding year of $21,000,000. The exports had an aggregate value of $159,485,770, an increase of $25,482,000.

A Danish expedition to explore the east coast of Greenland between the 66th and 70th degrees north latitude sailed from Copenhagen on August 16, under Lieut. Amdrup. The ship, the *Godthaab*, has a complete scientific equipment and is provisioned for two years.

The Duke of the Abruzzi (Prince Luigi of Savoy) has added to his achievements in mountaineering by a successful ascent of the Aiguille Sans Nom, an Alpine peak that has hitherto defied the efforts of the most intrepid and determined explorers. The daring feat was accomplished on August 16.

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