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in the immature stage, and that the new wing was produced from internal growth, and ready to take the place of the injured one on the emerging of the insect from the pupa, thus analogous with the reproduction of lost limbs of spiders and crustaceans.

If this be the case, which appears most likely, we may draw the following conclusion: *All the arthropods, including true insects, are capable of reproducing lost or much mutilated limbs, if the same takes place previous to a moult or while yet in the immature stage.* From the difference in habit of true insects from the lower arthropods, we might also infer that the reproduction of a lost limb would more readily and often take place among the latter, while not absent in the former, as facts also show.

March 2, 1886.

[*Paper U.*]

SOME NOTES UPON THE MORE RECENT FOSSIL FLORA OF NORTH DAKOTA AND AN INQUIRY INTO THE CAUSES THAT HAVE LED TO THE DEVELOPMENT OF THE TREELESS AREAS OF THE NORTHWEST.—*John B. Leiberg.*

A most noticeable feature of the prairies of North Dakota, west of the Missouri river, is the immense amount of silicified wood scattered everywhere over the surface.

This, in a region now almost devoid of arboreal vegetation, naturally leads one to speculate on the causes that have operated to destroy this ancient forest growth and prevent any other from taking its place in modern times.

We find that the land is covered by a rich and fruitful soil, producing various kinds of herbaceous plants in great abundance, and the average rainfall is sufficiently large to warrant us in not classing the climate as arid.

Various theories have been advanced to account for this absence of forest covered areas in the Northwest: one of the most commonly accepted being that which ascribes the cause to the annually occurring prairie fires, consuming with the dry grass such seedlings as during the summer had found a lodgment.

For some portions of the western prairie region this theory is doubtless, in the main, the true one; but in the extreme Northwest, from the Rocky Mountains eastward, other causes have been

and are yet at work to prevent any extensive forest growth, either wild or cultivated; and if the views hereafter set forth prove to be the true ones, the same causes will be constantly tending to enlarge the timberless areas towards the east.

As before remarked, the portion of North Dakota lying west of the Missouri river possesses no timbered areas aside from the forest growth on the Missouri river bottoms.

Scattered groves of stunted trees are found here and there lining the banks of the small streams on the northern and eastern slopes of the buttes, and in the deep ravines that occasionally radiate from these hills. The number of species of trees that compose these groves are not many; boxelders and cottonwoods occupying the chief place. With them occur Prunus Americana, wild plum, confined to the region of the Little Missouri river; Prunus pumila, dwarf cherry, Shepherdia Canadensis and argentea and Eleægnus argentens, the buffalo berries; various species of gooseberries and currants, while the Coniferæ are represented by a trailing Juniper, that usually covers the driest portions of the hills with its widely creeping branches.

The forest growth now so scanty was not always so. On every hand we see abundant remains which testify to the fact that in a not so very distant geologic epoch, vast forests flourished, where now only their fossil or carbonaceous remains are met with.

On crossing the Missouri river at Bismarck one notices within a distance of 20 or 25 miles to the westward, the drift sheet that covers eastern Dakota and so much of Minnesota gradually thinning out, and the underlying rocks coming to the surface. At the same time numerous seams of lignite or brown coal, some of considerable thickness, begin to crop out in the banks of streams, deep ravines, and wherever the surface has suffered any extensive denudation. Large slabs, or pieces of fossil-wood likewise become abundant. These features increase constantly the farther westward we go. The pebbles in the beds of the streams are all fossil-wood in every variety of silicification, often very beautiful, the grain of the wood, the ducts, the annual layers, the knotty and gnarled branches are all faithfully preserved. Not only is the wood of the limbs and trunks of these ancient trees preserved, but even their stumps still remain in the ground apparently in the identical place where they once grew. In numerous places

not an acre of ground can be found for long distances, but has dozens of these fossil tree stumps protruding from the ground. These stumps are transformed into the hardest kind of silica, and the actions of the winds and the driving dust and sand have put an unapproachable polish on them.

It may be remarked in passing that it is a rather novel and strange arrangement, that the settler upon these prairies should, in order to clear his farm, be obliged to pull the stumps of trees that flourished perhaps 50,000 years ago. Yet such, in many localities, is the fact.

Occasionally, a huge trunk is found silicified as it fell.

The rocks and clayey subsoil abound with leaf impressions, and at times remains referable to the fruit or seeds are found.

The leaves enclosed in the rocks have usually been transformed into a black carbonaceous substance, which crumbles quickly upon exposure to the air, but the outline of the leaf, as well as the minutest features, are found perfectly preserved when first exposed. In the clay, nothing but the impressions of the leaf commonly remain, but every detail is plainly marked.

Where the rocks or the clays have been subjected to heat by the burning of the underlying lignite beds, the fossil stumps have melted into huge fantastic humps, and the contained leaf impressions have baked into the clay, leaving almost indestructible imprints.

Upon investigation, it has been found that the species of trees that made up these ancient forests were in a great measure composed of species that yet have living representatives in our own country.

Among genera to which these fossil trees have been referred may be mentioned the oak, birch, poplar, willow, beech, sycamore, sassafras, magnolia, sumach, tulip tree and many others, showing how closely the then existing sylva was related to our own. The abundance and size of the fossil remains indicate a luxuriance and vigor of growth not found now except on the western slope of the continent. Many of the trees must have been of immense size. On the bluffs bordering the valley of the Green river in Stark county, Dak., I have measured stumps that showed a diameter of fully twelve feet. The heavy beds of lignite, occurring everywhere, and of which the upper beds, at least, are composed almost

wholly of semi-carbonized wood, betoken a long continued growth.

Without attempting to fix the exact geological epoch in which these forests flourished, it can be safely said that the character of the fossil remains indicates very clearly, climatic conditions similar to those existing at the present day in portions of our territory 5 degrees or 6 degrees farther south.

It has been supposed that the country in which we find these fossils, at this time was low and marshy, only here and there rising into low hillocks. Be this as it may, we know that forest growth is closely related to, and dependent upon the amount of the annual rainfall, and the evidence we have proves conclusively the existence in the past of a much more humid climate than the same region now enjoys.

To the cutting off of this supply of atmospheric humidity, I attribute, more than to any other cause, the extinction of these forests, and the prevention of others from taking their place.

If we travel westward, we find as we progress, the timbered areas increasing in extent, the forests become denser and evincing a more vigorous growth, until on the Pacific slope they reach their maximum in the heaviest and densest forests on the North American continent. This exuberance of growth is closely graduated according to the amount of the annual precipitation.

The rain and snowfall on the Pacific slope is usually accompanied by winds from the southwest or west. These winds coming from the ocean bring up an immense quantity of moisture. Much of it is deposited on the Coast and Cascade ranges, but the broken character of these ranges, and many low passes furnish an avenue of escape for a not inconsiderable portion of the rain clouds to the plains beyond. Comparatively little precipitation takes place here, and the clouds travel almost without interruption eastward, until intercepted by the Bitter Root range. This range, for a distance of 250 miles north and south, stands in the way like a gigantic wall. Its mean altitude is higher than the elevation of the heavy rain clouds; it has but few passes and they not low. In consequence the clouds are banked up against this rocky wall in immense masses, filling the canons and ravines with a thick, heavy vapor. Condensation takes place, and great quantities of rain or snow fall on the western slope and summit of this ridge, while but little is deposited on the eastern

slope. A portion of the packed-up cloud masses is deflected towards the north, and rounding the Bitter Root range is spread out over northern Montana. For this reason the heavy forest-covered area extends near the 49th parallel much farther towards the east than is the case two degrees or three degrees southward.

One cannot help noticing the sharply drawn line of demarcation between the western slope of the above mentioned mountain range and the eastern. The Pacific side being exposed to the moist winds from the ocean, the forests are very similar in character to those that cover the Coast and Cascade ranges, but on gaining the summit and descending on the eastern slope, a change is seen at once. Although the timber is principally composed of the same species that are found on the western slope, yet it is far from retaining the same size and vigorous growth that characterizes that. From this point eastward, the timbered areas dwindle very rapidly in extent and frequency, until the western declivity of the main range of the Rockies is reached. Here, whatever moisture escaped over the Bitter Root range and the evaporation from the country lying between the two ranges is condensed, and in consequence we see here and there stretches of fairly well developed timber areas.

Over the range to the eastward, the arboreal vegetation thins out rapidly, finally ceasing altogether a few hundred miles from the mountains.

If we now conceive the altitude of the ranges to the west lowered 2,000 to 3,000 feet, a great change would take place. Much of the moisture now deposited on the western slopes would be carried over the Bitter Root range to the eastward, causing a large increase in the annual rain fall, and elevating the mean annual temperature very considerably.

This was doubtless the existing condition at the time these now petrified forests of the northwest flourished. The Coast, Cascade and Rocky Mountain ranges had but recently emerged from the ocean; the Bitter Root, though elevated long anterior, had not yet reached a height sufficient to offer any obstructions to the uninterrupted flow of atmospheric humidity from the Pacific; besides there certainly existed large bodies of water in the basins between the ranges. Gradually the country was elevated, the marshes, ponds and basins were drained, and the ranges to the westward deflected and cut off the air currents from the Pacific. This led to

a great decrease in the annual rainfall and temperature, and a gradual dying out of the forests.

I have before noticed that the mean annual rainfall is probably yet sufficient to maintain a fair amount of forest growth, were it only more evenly distributed. As it is now, much the greater portion falls as snow or as very early or late rains, leaving nothing for the growing season. Again the extremes of temperature in the summer months is rather inimical to the successful growth of a forest. The writer remembers well how a few years ago, in the latter part of June, the thermometer registered in the shade 114 degrees for days in succession. The wind was blowing briskly from the south, and was like a rush of hot air from an oven. All kinds of native herbaceous plants dried up—cured on the stalk—and the foliage of the trees partly wilted and fell off. A few days later the mercury descended to the freezing point.

Did this ancient Tertiary (?) forest extend east of the Missouri river? This we do not know with certainty as the greater portion of the country here is so deeply covered with the drift deposit, but from the occurance of beds of lignite in place, at various localities, it is reasonable to infer that it did, though perhaps only in more or less scattered groves. Possibly the ridges now called the *coteaus* are granitic in origin, and at this time presented a bare rocky surface upon which a forest could not exist.

The present timbered areas in the northwest are due in a large measure to the vast quantity of water left behind by the melting ice of the glacial period, in the form of numerous marshes, ponds and lakes. The evaporation from these sources tends to maintain a tolerably constant degree of atmospheric humidity. This condition does not exist west of the Missouri. There are no ponds or lakes to retain the moisture, which drains off as rapidly as it falls.

A question now suggests itself: Is this portion of the continent still rising, and if so what will the ultimate result be?

We know that the earth's crust is constantly changing, elevating certain portions and depressing others. The Sierra Nevada which may be considered the continuation of the Cascades, is said to be rising at the rate of six feet in a century. There is nothing to disprove the supposition that the ranges to the north and northeast are not also rising in a more or less rapid ratio.

The smoking volcanic peaks among the Cascades and the

thermal springs of the interior basins, show that the underground forces of the globe, so largely instrumental in elevating and shaping the continents, are by no means wanting here. If it is the case that the western side of the continent is continually rising then the climate of the plains to the east will continue to grow drier until it becomes too arid to support any form of vegetable life. Our records do not cover sufficient time to say if the mean annual rainfall is diminished. It is a noticeable fact, however, that there is a gradual drying up of many marshes and small streams throughout Minnesota and North Dakota. It is usually supposed to be due to the breaking up of the sod, causing the rain and melting snows to sink into the ground instead of collecting in ponds. But it is plainly to be seen that there has been a gradual loss of water long before any ground was broken. The river channels are more contracted, the lakes show that they formerly stood at a much higher level, and narrow arms or inlets of lakes, together with numerous small ponds, have become shallow marshes and peat bogs. These results should in the main, I think, be ascribed to a continuous slow elevation of the country, causing more or less disarrangement of the subterranean water courses, as shown in the drying up of springs, in furnishing a more rapid drainage and in decreasing the mean annual rainfall and temperature.

May 4, 1886.

[*Paper V.*]

DESCRIPTION OF MAPS SHOWING THE CLIMATE, GEOGRAPHY AND GEOLOGY OF MINNESOTA.—*By Warren Upham.*

The exhibit in the New Orleans exposition, 1884–'85, by the geological and natural history survey of Minnesota, included twenty maps showing the climate, geography and geology of the state, prepared by the writer under the direction of Prof. N. H. Winchell, the state geologist.

Four of these maps show the climatology.

1. Mean annual rainfall: 34 inches in the southeast corner of the state; 28 to 32 about lake Superior and Rainy lake; thence diminishing westward to 22 at Moorhead and Fargo and at lakes Traverse and Big Stone on the west boundary of the state. It is