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TIMBERLINES AS INDICATORS OF CLIMATIC TRENDS[1]

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EVEN though Hutton and Lyell more than a century ago established the principle that the face of the earth has been shaped by forces still in operation, there has remained a great gulf between the geological past and the historical past. Almost ironically, the geologists denominated as "recent" formations of an antiquity far beyond the reach of history. The attempt to bridge the gulf and to connect the past with the present, actually as Lyell did theoretically, is a recent development. The progress toward the construction of a continuous chronology back into the geological past is one of the most significant scientific developments of the last decade. The problem has been attacked from a number of different angles: The excavations of archeologists and their correlation with geological terrains, the records of the annual varves in water-laid deposits collected by DeGeer and in America by Antevs[2]; the interpretation of variant thickness of tree rings in ancient logs by Douglass[2]; the identification of subfossil pollens under the leadership of Erdtmann[3]—each in its own way has helped to carry the chronicle back.

But with all that may be learned by these and other methods, our knowledge of the past must remain very fragmentary. And, what is far more important from my point of view, our appreciation of the long-time climatic trends, which in the end must mould our civilization, is as yet hardly dawning.

[1] Address to the Geological Society of Washington, October 28, 1936.

[2] For a general account see Smithsonian Inst. Publ. No. 3152, pp. 304–312, 1931.

[3] G. Erdtmann, *Archiv. f. Bot.*, 77: 1–173, 1922.

Only recently have we become aware of the fact that in some countries there have been vast changes in climate within the period of civilization, or even within the last thousand years. On the contrary, mankind has generally assumed that such climatic changes as obviously must have occurred in periods of glaciation came on too slowly to have any human importance. More recently, however, our eyes have been opened to the significance of many signs of great climatic changes within historic times. To illustrate my point I need only to cite the extensive evidences of civilization left by former agricultural peoples in parts of Syria now quite too arid for agriculture,[4] or the Old Norse colonies in Greenland whose prosperity was sustained by dairy farming for several hundred years in a region where to-day it is impossible to grow winter feed for cattle. The colonists were buried in ground now perpetually frozen, but their coffins and even the marrow of their bones were permeated by masses of tree roots, which is indubitable evidence of mild temperatures at that time, for roots can not grow into frozen soil.[5]

One of the most significant contributions of geology to biological theory is the revelation of vast migrations of plants and animals over the face of the earth in past times. Knowledge of the movements of the past should surely lead us to suppose that similar migrations are in progress to-day with as great activity as they ever were in past ages. But it is one of the curiosities of scientific thinking that neither botanists nor zoologists have made any serious effort to detect such movements in progress. Indeed, the science of ecology has been built on the contrary assumption that organisms are in stable equilibrium with their environment, which is the same as saying that species have spread as far as is permitted by physical barriers. It ought to be no very difficult matter to put this assumption to the test and to ascertain in the case of any given plant whether its range is fixed or changing; whether it is just holding its own, advancing into new ground, or giving way before adverse factors which are pressing it toward extinction. Once we obtain a considerable body of data we should be able to form reliable judgments of the climatic trends that are factors in any movements brought to light.

The place to study plants or animals in migration is at the limits of their ranges. Just as it is difficult to observe the ebb and flow of the tides in mid-ocean, so it is difficult to discover biotic shifts in the middle of specific areas. But exactly as one can readily observe small changes in tide level on a sloping beach, so can one detect very slow advances or retreats of species at the edges of their ranges where they stop short and drop out.

My interest was first drawn to the problem when I was working in the Sugar Grove region in Ohio more than twenty-five years ago.[6] But my real opportunity to pursue the matter came with the Katmai expeditions of the National Geographic Society, which took me to the arctic timberline in Alaska.

The town of Kodiak stands almost exactly at the edge of the great forest of Sitka spruce which stretches up the Pacific coast from Oregon and Washington. On the mainland the interior forest of Canadian white spruce likewise reaches its terminus within a few miles of the Valley of Ten Thousand Smokes.

These timberlines naturally invited research into the factors which fixed their position. I say fixed their position, for at the beginning I had no idea other than that they must have extended as far as the climate would permit. So I began the study with the belief that further spread of the trees must be prevented by a failure somewhere of their mechanism for dissemination. Was the climate too severe for them to grow a crop of cones? Did such cones as might occur bear viable seed? Was there heavy mortality among seedlings? Were the trees so stunted that their growth could not keep ahead of death from adverse factors? How did their rate of growth compare with that of the same species several hundred miles back from the edge of the forest?

In none of these particulars were the spruces at Kodiak deficient. They bore cones profusely in each of the six seasons that we observed them. The volcanic ash was in places covered with seedlings as thick as they could stand—a growth much denser than could possibly survive. Other seedlings better spaced continued to thrive and grow vigorously. Neither the form of the trees nor their annual increment suggested stunting. There was none of the dead wood characteristic of timberlines generally. The average width of the growth rings measured at Kodiak was close to one tenth of an inch. Occasionally a tree increased more than an inch in a single year. The growth in thickness is not less but actually somewhat greater than in the same species, as measured by the Forest Service in southeastern Alaska.

Nothing that could be observed about the trees at Kodiak, therefore, gave any indication that they had reached their limit and were held in check by climatic factors. On the contrary, it was found that while all the trees at the very edge of the forest were small, they were also young, seldom more than half a century old. Again, there are no dead trees nor fallen logs at the edge of the forest. But three miles back within

[4] Ellsworth Huntington and Stephen S. Visher, "Climatic Changes, Their Nature and Causes." New Haven, Yale University Press, 1922.

[5] W. Hovgaard, *Geog. Rev.*, 15: 605–615, 1925.

[6] R. F. Griggs, *Bull. Torr. Bot. Club*, 41: 25–41, 1914; *Ecology*, 15: 80–96, 1934; *Ecology*, 17: 580–417, 1936.

the forest were many trees three hundred years old or more, while fallen logs abounded, as in normal forests. Everything that could be observed on the ground, therefore, suggested that instead of being held to a stationary line the forest was advancing.

The conclusion that the forest is advancing in Alaska is by no means original with me. The conditions have been noted by many of the observers who have described the region beginning with Petrof in 1884.[7] The explorers sent out by the Alaska division of the Geological Survey report substantially similar conditions throughout western and northern Alaska.[8] The most easterly point at which an advancing timberline has been definitely reported is at Wiseman (Long. 150°, Lat. 67°30′) by Robert Marshall. Historical accounts of the country in early days confirm conclusions drawn from the forest itself. A century ago the people of Kodiak had to go many miles to find wood such as now grows nearby. There are two islands near Kodiak which in the coast pilot of 1875 are called Woody Island and Bare Island. Woody Island still retains its name, but Bare Island is now covered with heavy forest, and its name has been replaced by another more appropriate. There can be no doubt, therefore, that the forest is actively migrating out into the tundra at Kodiak. One further question for a long time undermined confidence in the conclusions reached. Evidence drawn from the trees on the ground can at best go back only a few hundred years. We might be dealing with nothing more than an episodic oscillation of timberline swinging about a mean which after a few centuries of advance would retreat again, leaving things as they were. To assure ourselves in this matter my colleague, Dr. Paul W. Bowman, made a study of the fossil pollens from the bogs at Kodiak.[9] There was no spruce pollen except an occasional grain such as would be blown from a great distance. The present forest is therefore the first that has occupied this country since the beginning of the bogs.

Turning now to climatic correlations, we find a general belief among botanists, not very well supported by evidence, to be sure, but conforming fairly well with many facts, that tree growth is limited by the isotherm of 10° C. (50° F.) for the warmest month. It is interesting to observe that in southwestern Alaska the isotherm stands 250 miles beyond the edge of the forest.

The facts indicate, I think, that there is occurring in Alaska a plant migration of exactly the same character as the paleontologist finds evidence of in past geological ages. Apparently the climate of Alaska has become mild so recently that the trees have not been able to keep up with the change and occupy all the territory suitable for them.

It should be noted that no certain indication is given as to whether the improvement has stopped or is still going on. But the presumption would be that before dying out the change would slow down, giving the trees opportunity to catch up. Study of this migration front at Kodiak yields information which is probably valuable in reaching an understanding of other migrations past and present. It gives a clue, perhaps, to the failure of botanists generally to recognize migrations in progress. We all know that the winged seed of a spruce tree may be carried many miles by the wind, so that the country beyond the forest border must be liberally sown with tree seed every year. It might be expected therefore that the forest would spread with great rapidity, in the same way that pioneer plants come in on ground laid bare by the retreat of a glacier or as foreign weeds spread like wildfire through cultivated ground.

But the advance of one plant association against another is quite different from the invasion of bare ground where the newcomers meet no competition. The country beyond the forest in Alaska is thickly covered with other vegetation, tall grass or vigorous health which chokes intruders. Very few of them succeed in establishing themselves. The abundant seedlings observed at Kodiak were coming up on the new surface provided by the ash from Katmai. Instead of advancing many miles per annum, therefore, the forest creeps into the grassland very slowly. At Kodiak the advance is of the order of one mile per century.

This will seem a very slow migration, yet to a person on the ground the progress of the trees appears rapid—so conspicuous that it has been noticed and commented on by many non-botanical observers. The advance in northwestern Alaska reported by the geologists is much slower, probably not one tenth as fast. This may seem excessively slow, but I suspect that as such migrations go it is rapid. I have no doubt but that with proper technique advances or retreats of vegetation lines as slow as a mile in a hundred thousand years would be readily observable. But it would probably not be possible to assign quantitative rates to slow migrations.

If the testimony of the varves is to be relied on as evidence of the rate of climatic change responsible for the glacial retreat, movements of species on the edges of their ranges slower than changes in Pleistocene climate can be detected. There is little doubt that a comprehensive study of the many species which reach their limits in the vicinity of Washington, for instance, would give us a good picture of current trends in plant

[7] Ivan Petrof, Alaska, U. S. Tenth Census, Pt. 8, p. 75, 1884.

[8] Philip S. Smith and J. B. Mertie, U. S. Geol. Survey Bull. 815, p. 72, 1930.

[9] Paul W. Bowman, *Ecology*, 15: 97–100, 1934.

migration and probably of climatic change also, in this vicinity.

Returning now to the more immediate problem revealed by conditions in Alaska, we must inquire as to the extent of the migration and climatic change indicated. In our southwestern States the flora gives much evidence of having been in a static condition over a long period. There is no time here to go into the details of this evidence. I will merely cite Pearson's[10] careful study on the San Francisco Mountains of Arizona, where his instruments at timberline gave exactly the theoretical temperature limit, showing during the years of observation an isotherm of precisely 50° for July.

In northeastern America, on the other hand, the starvation of the Norse colonies in Greenland, already alluded to, indicates deterioration of climate perhaps compensating the amelioration demonstrated in Alaska. This suggestion is supported by the opinion of Canadian explorers, who think that the forest is retreating in that quarter. But the forest border has never been carefully studied there, and conditions certainly should be looked into.

Meanwhile, the more immediate question seemed to be to find out how far east and south the forest advance might extend. Accordingly, I spent the field season of 1935 studying timberlines in the mountains lying between the apparently static condition of the Southwest and the unstable forest border of Alaska, working north from southern Wyoming to Jasper and back again in the Cascades.

There are in this region many places where young trees are advancing into grassland areas, giving appearances very similar to the migrating forest front at Kodiak. Such a place, which is well known to many of you, is Paradise Park on Mount Rainier. But almost without exception when such places were studied there was clear evidence of an earlier forest in the shape of old stumps or charcoal. Though no evidence of fire was detected in Paradise Park, charred logs abound not many miles away in Indian Henry's Hunting Ground, where new growth is also coming in, as in Paradise Park. Thus it seems likely that all the manifest upward extension of the forest about Mount Rainier is merely in the nature of recovery from fire rather than real advance. Such parks, moreover, lie below the limit of trees. Higher up on Mt. Rainier as elsewhere the last trees are prostrate mats which give evidence of having ascended as high as climate will permit.

A climatic timberline, representing as it does a delicate balance between opposing forces in nature, is modified by very slight disturbances and recovers its original condition very slowly. When a Douglas fir or yellow pine forest in the Rocky Mountains burns, it is replaced by lodgepole pine, and no man knows how many centuries elapse before the original climax forest returns—this at low altitudes. At timberline recovery is much slower. But though on Mount Rainier the original timberline forest was in places, at least, destroyed by fire, fires are in general less frequent near the peaks than at the foot of the mountains.

A more common source of timberline modification is grazing. It is astonishing to one who has not studied the matter to find how little grazing it takes to disturb conditions at timberline. Around Lake O'Hara in the Canadian Rockies, for example, sheep or cattle have never been grazed, as they have on almost all the mountain meadows in our national forests. The only live stock which has been pastured there is a small number of pack horses used by tourists going in and out to the lake. But one familiar with primeval timberlines at once recognizes that the foraging of these animals has upset natural conditions. Wherever undisturbed timberlines were found in the Rocky Mountains, they appeared to be stabilized. No evidence of advance was detected.

In a few places, as around Lake Louise and on Mount Hood, there was, locally, clear evidence that timberline was in retreat. Such isolated withdrawals are presumably due to locally unfavorable conditions. Dr. W. W. Rubey informs me, for example, that the white-bark pines in the southern part of the Wyoming Range have recently died in large numbers. Local irregularities of this sort are to be expected. They serve to emphasize the necessity of an extensive view if conclusions as to climatic change are to be drawn.

The stability of timberlines in the Rocky Mountains, coupled with rapid advance in western Alaska and evidence of increasing cold in northeastern Canada, affords, I think, an important insight into the character of climatic changes in general. In common with most others, I used to suppose that the great climatic changes indicated in geologic times were world-wide in scope. Conditions here in North America make it clear that shifts in climate of sufficient magnitude to become of geological significance are not necessarily even continental in extent, but may occur in much smaller areas. It will be recognized that this greatly simplifies the problem of accounting for such things as ice "ages," since it may involve merely a redistribution of the heat and rain received by the earth rather than variations in the total amount. It is clear, for example, that an interchange of the climate now prevailing in southern Norway with that of Greenland at the same latitude would have a profound effect on the floras of those regions and would, indeed, make the

[10] G. A. Pearson, U. S. Dept. Agric. Tech. Bull. 247, 1931.

name Greenland again appropriate, as it was when the country was originally discovered, permitting again its enthusiastic colonization by people familiar with Norway.

Like the archeologists who unearthed the evidence that the climate in Greenland had changed so radically, the botanist is unable to bring forth the data from meteorology, geology and oceanography which might enable us to understand the change demonstrated. But if we are convinced that we are witnessing just such a climatic change as has characterized the Pleistocene throughout, researchers in these sciences ought to be able to discover the causes at work and thus to find the answer to what is perhaps the greatest riddle of geology.

Meanwhile, there is an immense amount of work to be done in examining plants on the edges of their ranges everywhere. This I expect to push actively myself, and it is my earnest hope that others also may be persuaded to take up the work and push it along until a mass of data and a technique adequate for broad general conclusions may become available.

OBITUARY

RICHARD CRITTENDEN McGREGOR

THE death at Manila, on December 30, 1936, in his sixty-sixth year, of Richard Crittenden McGregor, chief of the division of publications, Department of Agriculture and Commerce, and managing editor of the *Philippine Journal of Science,* brought to a close the career of one of the rapidly dwindling number of early American pioneers in scientific work in the Philippines. Born in Sydney, Australia, on February 24, 1871, he was educated in Stanford University, where he obtained his A.B. in 1898. After five years of varied field experiences in Panama, in Lower California and in the U. S. S. *Pathfinder,* he came to the Philippines in 1901 to join the staff, as ornithologist, of the Bureau of Science, which at that time was just being organized. The enthusiasm he put into the then almost virgin field of Philippine ornithology is attested by the fact that our present coordinated knowledge on over 750 species, in about 300 genera, a good number of them being unknown to science before he had taken a hand, is largely due to his efforts. McGregor's basic work on the features of distribution of bird genera and species in the Philippines has furnished one of the most convincing lines of evidence in the faunistic alliances of the various islands in the Archipelago.

But it is not in birds alone that science in the Philippines is indebted to him. He was an inveterate collector of natural history objects. Many species of insects and other animals, as well as of plants, have been described or recorded from many parts of the Philippines that are difficult of access, on the basis of material brought back by McGregor from his numerous field trips.

Although formally designated managing editor of the *Philippine Journal of Science* in 1919, his editorial connection with that paper had long antedated that year. He was largely responsible for making it a worthy exponent of scientific progress in this part of the world. McGregor had, prior to his death, been waging a two-year losing battle with polyneuritis, which rendered him almost a cripple. But, so devoted was he to the task that, a few weeks before the end, when he must have been suffering intense physical pain, he wrote the undersigned from his sick bed (August 2, 1936): "I do nothing but work on copy and proof, and even so am never out of work. I don't mind working Sundays, but I miss wandering around the fields and forests."

Posterity is prone to give all the honor to the United States army and navy forces for the successful implantation of American sovereignty in the Philippines. In the rapid pacification of the Philippines and the progress the country attained under American direction along educational and material lines, their due share of the credit is quite frequently denied the early American civilian workers—educators and scientists of the type of Richard Crittenden McGregor. Careless of his own well-being, absorbed as he was in the stronger call of scientific pursuits, but meticulous to a fault, even to the extent of going out of his way, where it involved the welfare of his coworkers, contagious in his zeal for work, patient, thoroughly human—his were the attributes that would attain the effective conquest of any people.

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HARRY NELSON VINALL

HARRY NELSON VINALL, senior agronomist of the Bureau of Plant Industry, U. S. Department of Agriculture, died suddenly on February 22 at his home in Washington, D. C., as the result of a heart attack. He had been connected with the department since 1906, devoting his time to research with forage crops, especially sorghums and grasses. During the last ten years he had been particularly active in pasture research. Born on a farm in Story County, Iowa, the son of George W. and Delina Neal Vinall, he was graduated a bachelor of science from Kansas State Agricultural College in 1903 and a master of science from Cornell