condition produced by the action of the oil.

An attempt to measure directly the difference of potential between the two ends of an isolated unequally heated bar of metal would, apparently, encounter obstacles quite as great as those which have thus far proven unsurmountable in the case of attempts to measure directly the contact difference of potential between metals. The outlook is, therefore, not bright for any immediate and final answer, on experimental grounds, to this question of the direction and magnitude of the local electromotive forces with which we have been dealing.

I wish to add one afterthought. If electricity flows like a perfect gas through a homogeneous solid conductor of uniform cross-section, its velocity at any given cross-section of the conductor must be, approximately at least, proportional to the absolute temperature of this cross-section. Now the ordinary law of resistance in the case of a fluid moving through small passages is this: Resistance is proportional to the velocity. Accordingly, we are led to the conclusion that the resistance encountered by our electric stream should be proportional to its velocity, that is, other things being equal, proportional to the absolute temperature at the part of the conductor considered. Now we know that in pure metals this is the general law of resistance, and the fact that this law finds an explanation in a conception of the electric current formed without any reference to electrical resistance adds considerable weight to the argument in favor of that conception.

Edwin H. Hall.

Harvard University.

THE ALAMOGORDO DESERT.*

The Alamogordo desert of southern New Mexico lies immediately west of the 106th meridian, west, and approximately between thirty-two and thirty-four, north. It is bounded on the north by the Oscuro range of mountains, on the east by the Sacramentos, on the south by the Jarillas and the Organ mountains, on the west by the San Andreas. As here defined, therefore, the desert is of comparatively limited area, one hundred or one hundred and twenty-five miles from north to south, and perhaps thirty-five to fifty from east to west; a very convenient little desert, easily manageable, one might suppose, for any naturalist, who, with inborn love of adventure, starts out in search of the wilderness to find scenes and pastures new.

A year ago in this presence, it may be recalled, the present speaker, by aid of photographic illustrations, attempted to sketch the relations obtaining, as would appear, between the geology of the desert and its flora; in the present paper it is intended briefly to resume the earlier argument with such added reflections as may be suggested by present conditions and by recent renewed acquaintance with the problem.

The desert of Alamogordo or Tularosa is a great plain, not unmarked, however, by singular topographic inequalities later on to be described. Only the most casual geologic examination is sufficient to show that the plain floor corresponds stratigraphically with the beds in some places exposed at or near the tops of the surrounding mountains, in any case far up their flanks. On the east especially limestones of carboniferous age rise sheer some 1,000 feet or more straight up from the desert floor, and are again capped by other strata only at length, perhaps 1,000 feet higher, surmounted by materials correspondent with those in the level of the plain.

On the west the same thing is true; but more emphasized still is the difference in

* Address by the vice-president and chairman of Section G for 1904. Philadelphia, Pa.

level between segments of corresponding strata. Here the weird Organ mountains break the horizon by upthrust spires and pinnacles of granite which to some early voyageur crossing these dusty plains suggested the pipes and architecture of some far-off organ, and the mountains were so named; but upturned granite means that the sedimentary rocks are here further uplifted still than on the eastern side, so that we quickly find ourselves in presence of vast parallel faults and our desert lies thus between their giant walls. It is as if half the region between this city and New York should suddenly sink two or three thousand feet, or what is the same thing, it is as if the several thousand feet of difference in level were brought about by the depression of the included area, and the simultaneous elevation of the sides. At any rate, the desert plain of the Alamogordo or Tularosa sands is simply the upper surface of a gigantic block of the earth's crust that sank some time subsequent to the deposition of the Jura-Trias and the earlier cretaceous strata of this western world. These strata include, as we know, the famous 'red beds' which tinge the mountains of half the continent, the red beds with all their gypsums, marls and salts of every description. Accordingly, as a result of this faulting, our desert has for its foundation everywhere great fields of gypsum, often for long distances wide-exposed, sometimes thinly veiled by loosened sand, sometimes deep buried by vast deposits of wine-red marls and clays, or covered anon by the products of erosion, whether by water or by wind. The waters from the mountain snows have brought their débris; the winds of the desert have come with their burden, but nowhere has such transportation traversed the desert borders, at least in recent times; there are to-day no excurrent nor percurrent streams; the winds die along the mountain walls and the waters sink in the desiccated sands.

But this is not all. This great sunken block of earth's crust seems itself to have been cracked again and again; there are secondary faults, and along the line of one of these thinner or weaker places the subterranean energies of the world have some time found emergence. Floods of lava welled up in the midst of the desert, and fountains of fire streamed along the ground, following existent topography for miles and miles, now narrowing to dimensions measured by rods between low ranges of hills, now widening for miles across the broader valleys, only to lie at last a vast field of blackened cinder, slowly disintegrated by the desert storms. This is one of the most peculiar topographic features of the whole desert. As things terrestrial go, this is a recent phenomenon. The age of the lava may be measured by centuries, a few thousand years, it would seem, at most. The surface over which it poured was a friable, marly soil. As the floods cooled, the mass cracked and gaped in every direction. Rains descending upon the surface sank to the ground below and shaped for themselves channels. The lava so undermined has fallen into a tumbled ruin of weirdness and confusion, indescribable, impassable.

The lava constitutes one of the features of this remarkable desert; there is yet another. Along the western border, partly uncovered by erosion, partly by the western winds, great bodies of gypsum lie exposed. As this slowly disintegrates the wind gathers the particles set free and bears them eastward, the famous white sands, covering township after township with drifted mineral white as snow. Vast windrows shifting slowly with every storm, and forever reinforced by the unceasing contributions of the west, mark the landscape over several hundred square miles, unique, intact, forever changing, yet the same forever.

Added to these peculiar and special topographic details of this surprising desert we have, of course, those less noteworthy, the common every-day features of desert make-up: we have mountain slope, rocky fields and hillsides, eroded valleys, marshy sinks, where lose themselves the vanishing torrential streams; wide plains of marly clay, belts of sand-dunes, red sands, yellow sands, also shifting and moving, but, better subservient to the vegetation of the region, these present simply vast fields of low hills or hummocks ten to twenty feet in height, separated on every side by tortuous valleys, winding in labyrinthine fashion, wind-swept, hard and bare.

One other topographic feature must yet be added to complete our picture. The forces of erosion even along the mountain walls have kept pace fairly well, at least, with the changes in level. Great cañons break back even through the hard, encrinitic limestones, dividing again and again where the waters have carved the rugged pathway by which the explorer may reach the mountain summit. The result of this erosion forms a wide talus around the desert, spreading great fan-shaped deposits at the mouth of the cañon, where immense blocks and boulders choke the exit, succeeded by ever smaller rocks and pebbles farther out, until at length only the finest silt is swept along from the widened margin far across the almost perfectly level plain.

Now it is evidently needless to say to every wisest man in an ecologically minded audience such as this, that every one of these peculiar topographic features, whether special or not, will display its own peculiar flora. True, this is not always the case; this desert must be studied in its entirety, and it will require months of patient research to even sketch its far-reaching problems. As a whole the flora may be said to be that of our western arid regions generally, and yet, after all, it is not just like that of any other region, north, south, east or west; not that it has peculiar species, perhaps, but that it has its own particular groups of species.

Two factors, and two alone, as it seems to me, determine the phytology of this desert; the one, difference in the constitution of the soil, referable to its geologic history; the other difference in level, referable to the same initiative. Thus there is a peculiar flora on the sands whether white or red; another on the silted plains less liable to transportation by the wind; another where the salts emerge, whether in briny springs and fountains or as crystals whitening the surface of the ground; another for the mountain shelves; and still another for their far-off summits.

The El Paso Northeastern Railway passes the desert on its eastern side. There are two stations on the line where for several miles in every direction the surface is a red-brown sand. One of these stations has been by the railroad people appropriately named Desert, the other is Escondida. The level of the two stations is the same, 4,000 feet, and the flora is identical, although the points are thirty miles apart. Each, however, is by itself unique and entirely separate from the other. The dominant species is *Yucca radiosa,* so much so that these points are called the yucca desert. Of course, the almost ubiquitous mesquite is there and *Atriplex canescens* and *Artemisia —— sp.?* There are other species, to be sure, such as forms of *Chrysothamnus* and *Ephedra,* but the plants first named give to the plain its character as far as vegetation goes, and in topography as well; they not only thrive here and come to abundant flower and fruit, but they hold these peculiar sands otherwise driven about the world by desert winds.

Now it is a remarkable fact that the white sands, thirty or forty miles off to the northeast, exhibit an almost identical flora. The student hastens across the intervening desert to meet that shining wall, expecting to find all things new; but, behold, the white sands are *sands* first of all rather than anything else. Whatever their chemistry, and they have their peculiar problem for the chemist, only a vegetation that can endure a moving, shifting terrene can flourish here. The white sands form, accordingly, part of the yucca desert. Their relation to vegetation is almost purely physical, but they exhibit some peculiarities. They are gypsum, as everybody knows,* but while they move as other sands, they must be compared with wet sands; the vast drifts, thirty to fifty feet in height, are *moist* often to within a few inches of the surface, and are so compactly driven that one may walk upon the solid surface with comparative ease. A white wall like to the appearance of marble is moving slowly eastward, whelming all vegetation as it goes, some of which, able to grow through the encroaching mass, persists, so that all the plants now appearing on the surface, so far as examined, are anchored by lengthened stems or roots to the underlying older soil. The same yucca that appears at Escondida here emerges sometimes by green tips from a snow-white drift twenty feet in height, or anon, seems to crown triumphantly some lower mound. The mesquite holds on, in some places a desperate fight, and certain species of *Rhus* —*R. aromatica* and *R. trilobata,* perhaps—maintain a perilous existence out over the whole region, sometimes even on the summits of the highest knolls. These sumacs are the characteristic species of the white sands.

But let us turn north. A journey of fifteen or twenty miles brings us to the black wall of the lava flow. This is a fearful region. The Mexicans call it *mal pais,* 'bad country'; giant floods whose waves are stone, fields and fissures, caverns, holes, pits and wells, alternating with tilted slopes, knife-edge culms and ridges, make a topography weird, impassable, fascinating because so unapproachable. Yet the *mal pais* is covered with vegetation. Of course, the vegetation changes, but by no means as one might easily suppose. Here is no new species, no variety of a species when the desert is studied as a whole. The change is correspondent to a change in level. The lava beds are high, and they are crowned with the flora of their own altitude. We shall meet it on the foothills of all the mountains we presently ascend. Here is no alteration of soil, for the only soil is that deposited by the wind, the lava itself being perfectly intractable. Here are the familiar mountain cedar, *Juniperus occidentalis; cholla,* sometimes twelve or fifteen feet high, where, springing in some ragged well-hole, it seems to peer out above the sooty walls that hem it in; here is the mountain barberry. Even the nut pine, *Pinus edulis,* has mistaken these pitchy steeps for the clayey flanks of its usual mountain fastness, and now and then rivals the cedar in its hold upon the jagged upturned edges of these flinty sheets. Even the lava beds have not apparently affected the general character of the desert flora.

At the south end of these black fields, however, emerge great springs. Here all the plain is saturated with salt and alkali, and here is a peculiar flora conditioned by this fact. The waters emerge almost from the edge of the lava sheets, and tufts of

* The following analysis of this material has been kindly furnished me by Dr. L. W. Andrews of the Mallinckrodt Chemical Works, St. Louis:

Calcium sulphate, $CaSO_4$........	77.64	per cent.
Water, H_2O	20.55	"
Calcium carbonate, $CaCO_3$.......	0.95	"
Silica and undetermined, SiO_2, etc.	0.86	"
	100.00	

Suæda and *Allenrolfia* are set close against the lava wall. This is ideal; this we should expect and here it is.

The sands and the lava lie in the middle of our desert. If we take these as a starting-point and move toward the summit of the mountains, the successive belts of vegetation gradually shape themselves so that we learn presently to identify them by their color. A plain below the general level is gray, grass-covered, with here and there a bunch of *Ephedra* or nopal, no yuccas, no *Atriplex,* no other forms of cactus. As the terrene rises to the silt plain, thickets of cholla alternate with mesquite and the crucifixion thorn; not that other species do not occur, but these are dominant, give to the belt its character and color. A little further mountainward and we reach the *Covillea tridentata,* ever in bloom, which lies as a girdle of green and gold around the whole base of the mountain range, visible for miles and marking for us the limits of the talus with an exactness that is remarkable. Beyond the *Covillea* belt come the cacti as the terrene becomes more rocky; *Mamillaria,* with its species numerous and varied, the unique but widely distributed ocatillo, the prickly pear, often in giant form—all these cover the rocky slopes that lead up to the steeper walls of paleozoic rocks. Sometimes, where a shelf occurs, and the bare limestone forms a flat, mesa-like field, the yuccas come back, but not the Escondida form, with *Agave parryi,* and abundant ocatillo, while in the rocky defile below, locked amid gigantic boulders, now on their tardy journey to the talus plain, the creamy flowers and fruit of *Dasylirion* lift their glorious spikes, the envy and vexation of the photographer.

The strata of the lower carboniferous limestones now confront us; crystalline, encrinitic and exceedingly hard, rising often hundreds of feet sheer up and down. But these dry walls likewise have their flora. *Mamillaria micromeris* matches with its hoary spheres the weathered stone or lights it up betimes with scarlet bloom, and *Notholæna innata* fills with somber tufts every shattered crevice.

But the upper members of the carboniferous are much softer and, amenable to erosion, present a gentler, flowing topography. These slopes are everywhere clothed with oak, not trees indeed; far from it; low dense shrubs, the so-called shin-oak, *Quercus gambellii* and *Quercus gunnisoni.* These two species form pale green belts around the mountains, and are recognized easily, distinguishable for miles. These species indeed form a sort of phytographic border land; all below is desert; all above is forest; for above stands, or lately stood, one of the fairest bits of woodland in the United States, and that means in the world. But this forest is again in large measure conformable to geologic structure, its distribution determined by the history of what lies beneath.

As we ascend the mountain, passing all the carboniferous limestones, sands, chalk-beds and shales, we presently encounter the 'red beds' already mentioned, the most remarkable geological horizon in the country, familiar to every student of our central mountains, noted even by the ordinary tourist, the same wherever found—in Utah, Colorado, the Black Hills of South Dakota, and here again in these far-off mountains of the Mexican border, the same vast gypsum-burdened deposits of clay and shale and sand. The red beds yield easily to erosion. The washings from their wasted flanks have tinged the desert far below, and reddened the walls of every rocky cañon on the way. Sloping terraces and flat-topped hills afford a soil rocky but not infertile, supporting once more its own peculiar vegetation. Here are still the shin-oaks, it is true, but all overshadowed by other nobler trees; here is *Berberis trifolio-*

lata, the Texan barberry; here is *Pinus edulis,* Engelmann's nut pine, and most characteristic and perfect of all, here stands *Juniperus pachyphlœum,* the mountain juniper, great forests of it, ancient trees betimes, all comparatively low, but with giant trunks six or eight feet in diameter; these time-defying cedars are the trees of the red beds. With the junipers, especially as we pass their upper limits and come out upon the calcareous cretaceous swells and plains, occurs another oak or two. The soils are now remarkably rich in lime. The waters that fall on the higher mountain levels escape above the red-bed shales, but so impregnated with lime that they actually form a new stony deposit often for a distance of many rods about the point of exit. On these calcareous soils stands now the forest, along the very summit of the mountain, nine thousand feet above sea level, a magnificent forest of spruce and pine and fir: *Pseudotsuga douglasii,* the Douglas spruce, five or six feet in thickness; *Abies concolor; Pinus ponderosa* in beautiful perfection of its immortal youth; *Pinus flexilis* at its very best; a typical Oregon forest six or eight miles wide and some twenty long, crowning the summit of this isolated mountain peak in the midst of the deserts of southern New Mexico, for, as everybody knows, these are in general species of the forest of the far Pacific coast. As one stands now at last thus at the very summit of his problem, and from some promontory rock of vantage looks out upon the vast plain thus mountain-girt, the indescribable beauty of the scene must first impress him. Far to the west lie the San Andreas, the Organ and the Oscuro ranges, a long low wall, gray and solid, its serrate summits indentured in the azure sky; below, the plain, brilliantly lighted, soft and brown and lucid, save as the *mal pais* stretches its blackness as a bar sinister across the northern end, while away to the south the gypsum desert seems a cloud of snow beneath our feet, more brilliant than that evanescent whiteness that floats in the deep blue far above—the one the strange counterpart of the other; all is so silent, so changeless and so fair!

But just now we heed not the beauty of the landscape; other thoughts come crowding upon the observer, all equally insistent and impressive. Evidence of enormous physical change thrusts itself upon our astonished attention; not the sunken desert itself alone, that great block already described, but the denuded and sundered mountain walls, the great cañons that stretch back for miles, cut down through even the solid limestones at the mountain base—a process vast and old. Once the cretaceous sea rolled here, and when it retreated here were beds of limestones hundreds of feet thick. Where are they now? Only here and there a remnant on the mountain summit; the desert is covered with their débris almost to distant sea.

No less is one impressed by the slowness of all this topographic change. There is evidence of violence, suddenness, nowhere, save in the *mal pais,* which is local, recent, and does not affect the general problem. The moving currents of the air, the soft ministrations of the summer shower, the melting winter snows, have carved these mountains, are sculpturing them to-day. Those columnar whirlwinds that even now like dancing dervishes chase each other across the plain, are shaping anew the desert; that thin cloud that hangs yonder like a banner from the mountain top is a rainstorm, changing even now the general altitude of the range.

But once again; as we look out thus from the summit of our problem we are impressed with still another fact more far-reaching, more splendid still. The whole living covering of the world, the vegetative garment of the desert and the mountain, conforms exactly to the surface, to soil and level, no doubt with an exactness that we have only begun to guess or understand. There is a mathematical line that limits the distribution of every plant, but the area forever shifts and varies. The topography varies, except the *mal pais,* by changes so slight, so delicate, as to be imperceptible to eyes unskilled, and with the topography varies its covering of life. Let us say first that these topographic changes will change the limits of distribution. Once the sands cover the silt plains, and the grasses will vanish while yucca and artemisia succeed. Widen the talus and covillea will stretch farther its golden scepter. But the problem runs far deeper than this. As the face of the world undergoes these delicate, subtle changes, the plant responds in something far more than shifting distribution. A plant, as every student of botany well knows, is the most plastic sort of an organism in the world, responding in every sort of way to its environment. We who study the microscopic structure of the humblest plants understand the limitless possibilities here. When we reflect that the suppression of a single cell at the critical moment may change the direction of the axis or alter the contour of a leaf, it is hard to set too high an estimate upon the possible response made by a simple plant to environmental variations, however delicate. We who study the physiology of the plant, peer into its changing cells and strive in imagination to reproduce the marvelously intricate reactions, physical, chemical, that forever shift and play within those narrow limits—we need not be told that every vegetable cell has in it opportunities a thousandfold to match and meet all the subtle changes suggested by the slow-creeping but implacable forces that work out the physiognomy of this time-worn earth. A little more calcium here, a little more phosphorus there, sulphates, nitrates and the rest, and the thing is done. Nay, when we even think of the form in which all energy comes from yon distant sun, and the delicate machinery on which it plays, we need seek no further occasion for the intervention of every sort of outer cosmic force. Not a tree on all the Iowa prairies but shows in its every lineament, in its very expression, a response to the Iowa environment; and so, we may be sure, every desert plant records in its present form and stature all the affirmations, all the responses it has made in all the centuries to the bidding, the silent bidding, the most gentle coaxing, of the world external. For, note you, the call for change at any given instant has not been great; the slow upheaval of these mountains, their peaceful, gentle removal by the winds and rain; that is all; but that has changed and is changing the living world. Where the terrestrial call is rude or sudden, response there is none. The lava beds show no single characteristic species. Their flora is simply that of their own rocky level. Nor could here any sudden initiative on the part of the plant avail. The adaptation is absolute now, and to vary save as the environment varies would simply invite disaster. As well the tadpole suddenly assume lungs or the lizard put on feathers.

Nor is this all—our desert as it lies shining here before us is but a fraction of that wider, vaster desert that covers all the south and west. Across the Organ and San Andreas yonder is another desert exactly comparable to that we study; all Arizona, southern California, Sonora, Chihuahua, much the same; here and there a mountain summit tufted with forest, western in type, high slopes thinly clad with stunted juniper, benches of covillea, wide low plains covered with mesquite, with yucca and cactus and all the less noble plants that stand between; and our problem widens, becomes vast as the continent, and any answer that we make must be far-reaching as the flora of a world.

Our desert lies shining here before us; but not one of these plants except the cactus is in broader sense unique; each has its kin rising in happier fields to fairer fortune. The yuccas are lilies, but lilies bloom in Bermuda and in Teneriffe, and in every most fertile garden of the world. The mesquite is a *Prosopis*, but the *Prosopis* genus shows many a handsome forest tree, and even the mesquite in the Arizona valleys, where conditions are less hard, rises a forest with trees fifty feet in height. The cactus, as I read it, with undifferentiated floral leaves and abundant sporophylls, is an ancient adaptation to an ancient desert, possibly pre-cretaceous, and takes possession of the world just so fast as the world becomes desert; unstable in cultivation, not because new, but because reversionary.

I do not mean to say necessarily that the Alamogordo desert flora has had its origin where it stands, although such a contingency is not impossible of thought. Had this been the only desert on the continent its flora is as might have been expected. But there are a hundred similar intra-montane regions whose geologic history is the same. These have in similar fashion originally shaped a flora each for itself. No doubt once similar conditions are set up in regions at first unlike, an exchange of species may take place. American cacti are at home in the deserts of Europe and the Russian thistle flourishes on Dakota plains.

The desert lies shining here before us, changing forever, but all its changes are of imperceptible delicacy and slowness. Its methods would seem not different from those by which nature has from the first essayed the education of the vegetable world. Between salt water and fresh all conditions offer by infinitesimal shadings where the rivers meet the sea, thus green plants first emerged from ocean; all conditions from shore-line low-water mark to dry land, thus the plants at length sat on the shore, wet only by tides or by the gentle rain; all conditions of level by which the plants occupy the kingdom of the upper air: all conditions of spore-union by which they meet at length the problem of aerial fertilization: so that while sports there may be among plants outside the pale of cultivation, nevertheless, they must always be within limits set as result of more gentle changes effected by the slow, and for the most part exquisitely delicate, transformations which make up the history of the planet. Given a desert flora, a cactus flora, for instance, and there may be endless species-making, by sport, if you will, or otherwise, but in every case a cactus; but the cactus itself is the child of continental movements which brought about some old-time, perhaps cretaceous desert.

Our desert lies shining before us; it is old and silent: would you know its secret, read the rocky records that lie behind, around, beneath, and be assured that once the story of yesterday were understood, the facts of to-day would ask no wider explanation. The physical forces of this world still drive the loom that weaves the web of life. Before the loom the unseen weaver sits, guiding her web that passes to an endless roll, changing withal the width, the pattern, as conditions rise. Changes her arabesque, it is for cause, changes it not, it is alike for cause; and if at intervals, as we watch, anon new figures rise, may it not be but the return of some earlier triumphant cycle that here begins anew, evident enough in cause and feature were once that giant scroll unrolled, or were her watchers more patient, more enduring. Alas! in presence of this mighty loom what fleeting, evanescent interpreters are we!

THOMAS H. MACBRIDE.