

VOLCANO STUDIES.

On the line of the projected railroad from Guayaquil to Quito there is a little mountain village which is destined to become the Chamouni of the American continent. Guanarete, or Santa Rita, as the Spaniards call it, forms the summit station of the Cerro de las Playas. For more than ninety miles the Cerro runs parallel to the range of the Central Andes, and opposite Quito, at an elevation of nine thousand feet above the level of the Pacific, the heights of the eastern slope afford a view of the grandest mountain panorama of the western hemisphere. In the east the main chain of the Andes is broken by two gaps that reveal the highlands of the Paramos, the central plateau of the South American Sierras; and the nineteen snow-capped peaks in the north, south, and southwest include the five highest active volcanoes on earth.

A life-insurance bureau might repudiate the policy of an Andes explorer. He may lose his way, and starve to death; he may reach his goal, and freeze to death: but among the volcanoes of Ecuador he will not die of *ennui*. A first-class man-hunter, like Suwaroff, may get expert enough to undertake a battle or a siege as a butcher would take a beef contract, and repeated attacks would case-harden even the garrison of a much-besieged town, but not the defenseless burghers. To passive participants danger can never become a routine business, and against the resistless power of a volcano experience has but rarely forearmed the forewarned.

Nor can scientists ever exhaust the problems of volcano study. The *primum mobile* of plutonic agencies is still a mystery, and the fluctuating theories hardly rival the fitfulness of the phenomena. Besides, every volcano has a system of its own. The Sangay, forty

leagues due east from Guayaquil, has never indulged in vehement eruptions, but has nevertheless afflicted the surrounding country with a greater amount of cinerous deposits than any active or extinct volcano of this continent; excepting, perhaps, that prehistoric monster crater that inundated Southern Oregon with twenty thousand square miles of lava streams. The Sangay works day and night, and with the steadiness of a self-regulating steam-mill. I ascended the peak in 1881, with a party of American engineers, and whenever we rested the dark gray ash-cloud which the north wind drifted toward Cuença preserved the uniformity of its outline like the ridge of a sharply defined mountain range. As seen from the edge of the main crater, the eruptions seem to come by fits and starts, but the aggregate of the matter ejected in any given minute remains about the same from morning till night. Pauses there are none; a soughing draft, with a heavier puff at intervals of fifteen to twenty seconds. The furnace of the Sangay has three larger and about fifty smaller vents, that discharge an aggregate of at least forty pounds of ashes per second, or fifteen hundred tons on each day of the year.

With two short intermissions this drain upon the resources of Vulcan has continued year after year since the winter of 1728, before which time the mountain was supposed to be an extinct volcano. With two intermissions, I say, for the ash-rain almost ceased in 1812, on the day when the volcano of St. Vincent turned a fertile island into a cinder heap; and in 1842 ceased entirely for two weeks, distinguished only by the *bramidos de vera paz*, the subterranean thunders, which frightened rather than injured the natives of Northern Guatemala. But what changes in the inter-

nal economy of our Mother Earth can have increased her daily expenditure of fuel to the amount represented by those fifteen hundred tons of ashes? If the fuel is burned in a perpetual furnace, how did it dispose of its ashes before it opened the present vent? — for no other mountain ceased smoking when Sangay began. It is the only incessantly active volcano of South America, and perhaps of the whole western hemisphere, since Steller's arctic Stromboli has never been rediscovered. On the western slope of the mountain a few orange-gardeners eke out a living, for winds from the opposite direction are rare; but on the north, east, and south, drift-ashes about the consistency and color of coarse bran flour have covered an area of four hundred square miles; and if the restless mill should continue to grind, the whole valley of Cuença will ultimately be ruined. In a high wind the ash-cloud above the crater flutters like a banner in a storm, often terminating in curious, ribbon-like shreds, that extend for miles along the horizon, like the smoke-trails in the wake of a Cunard steamer. Vultures sometimes hover at the edge of the cloud, or float along with it in a sort of lazy drift before the wind. "*Se quieren calentar*" (they want to warm themselves), said my Indian guide; but it is more probable that they utilize the ashes for disinfecting purposes, as our barn-yard chickens often bespatter themselves with dust.

The Sangay is our Stromboli, and an indispensable complement to the wonders of the New World, though it is a pity that it should display its pyrotechnics in a fertile valley, instead of on a rocky island.

The peak of Pinchincha in the coast range is an intermittent volcano. Ten or twelve times in the course of this century huge fissures in the flank of the cone have opened and discharged torrents of lava; but the main crater emits only a thin smoke-cloud, and now and

then, after weeks of dire birth-throes, a shower of pumice-stones, mingled with a few larger rocks and jets of superheated steam. The crater is subject to chronic obstructions, and serves as an earthquake signal, for almost every seismic tremor is preceded by disturbances in the coast range, the opening of new fissures, and subterranean detonations; the volcano seems to form the top of a kettle that has to vent its steam by an occasional explosion. The vapor eruptions occur about once in five weeks, and when the oven is in full blast its hot breath can be distinctly felt on the Alturas of San Rafael, upon the ridge of the Eastern Andes. The flue must connect with a very deep-seated furnace. The snow on the slope of the peak often melts without any visible increase of the volcanic emanations, and the theory is that air currents of a truly infernal temperature force their way through clefts where the scoriæ cannot follow. The thermal springs at the foot of the mountain are too scalding hot for medical purposes, and evaporate almost on the spot where they exude from the rocks. But heat and force are convertible terms, and if the scientists of the future should devise means to tap that source of caloric, and store the dynamic elements, the Pinchincha could furnish motive power enough for all the railroads of South America. On the west side of the mountain one lava stream has run for a distance of fourteen English miles, and, judging from its naked surface, seems to be of rather recent origin, though since the arrival of the Spaniards violent eruptions have occurred only (once in eight or nine years) in the form of stone-showers.

The Cotopaxi (El Gran Cerro, "the great mountain," as the natives call it with a sort of devil-worshiping reverence) indulges in even larger pauses, but has the gift of making up for lost time. On the second and third day of June, 1803, the volcano ejected more

than a cubic mile of cinders and burning stones, and the roar accompanying the eruption was perhaps the loudest voice heard on earth since the "dreadful shouting of the gods," during the conflagration of Troy. The rumbling of an earthquake moves along with the cause of the disturbance, like the rush of a storm or the boom of a tidal wave; but the thunder of a volcano reverberates from a fixed centre, and has to transmit its peals by sound-waves, like the report of a cannon-shot. In that way the roars of Cotopaxi were carried to Guayaquil on the sea-coast, and the echo as far as San Juan de Llanos in New Grenada, a distance of *five hundred and sixty English miles*, — the distance from Boston to Petersburg, Va., or from Paris to Copenhagen! A Spanish officer who survived those two days at Paso del Toro, six miles east of the peak, describes the effect of the detonations as *stupefying*, mentally as well as physically. The Indians crouched in their cabins like cowed beasts, and the Creoles ran to and fro in a dazed way, or huddled together in the churches and shops. About four hundred yards below the top of the peak there is an ugly crevice, which in the course of the last century had been almost filled with cinders from the upper vent, though occasional smoke explosions still proved its connection with the subterranean furnace. But in 1803 that hell-gate burst, and the two craters poured forth a volume of flaming scoriæ, which must have amounted to an average of about eighty tons per minute; for on the plateau of Loreto, thirty miles west of the mountain, the ground was covered with a five-inch layer of volcanic ashes, and at the foot of the volcano that stratum varied from fourteen to twenty-eight inches. The lateral crevice has closed again, but the top crater cannot be trusted. It has a way of bursting forth at the most unexpected times, and on any a cloudless night the peasants

of the Quito valley have been awakened by the thunders of the Gran Cerro, or a sudden shower of bituminous stones.

The view from the ridge of Santa Rita comprises two other active volcanoes, the Tunguragua and the Imbabura, the latter (not the Cotopaxi, as some of our geologists have it) being the one that vomited the strange *mélange* that deluged the Val de Quito with mud-water and dead fish.

But besides these conspicuous volcanoes the Central Andes contain a large number of hidden craters, which now and then become vicarious to the obstructed vents of the regular chimneys. All Northern Ecuador seems, in fact, to rise from the workshops of Tartarus, and scarcely a day passes that the Titans do not assert their activity in some way or other. Every now and then the stillness of the upper Paramos is broken by the crash of a rock avalanche. The concussions, which, like fever tremors, vibrate through the bones of the mountains, shake down all loose rocks and loosen others, and the highland streams have to force their way through such mountainous heaps of gravel that the rain-floods scarcely suffice to keep their channels open, and many of them, like the Rio Esmeraldas, run for miles below piles of boulders that defy the dislodging ability of the current. These avalanches make the Paramos rather unsafe. The crash of their descent often startles the explorer of the highlands on slopes where neither trees nor cliffs afford a shelter, and where life or death may depend upon a single step. In such moments a herd of Andes cows would be a study for a painter. Swiss cattle would be sure to stampede, but in Ecuador experience has taught them a trick or two. Instead of running away, they stand stock still, and watch the slope with straining eyes. If the cannonade comes down a little to the left or right, they move slowly in the opposite direction; but if it comes

right towards them, they know better than to risk a broadside, and generally manage to save their lives by facing the volley, and trying to dodge the individual bombs. The herder looks out for a tree, and that failing flings himself flat upon the ground; as the larger rocks come down in wide bounds, the odds are that they will not touch him. It is the safest plan; but temerity is as capricious as the code of honor: there are men who would charge a battery rather than touch a snake, while others surround themselves with a whole menagerie of venomous pets, but blanch at the sight of a pocket pistol. Between Loxa and Quito I once followed the example of my traveling companions, two furloughed United States midshipmen, who had got off the stage-coach to help the mules across a steep bluff. We had hardly alighted when the driver had to ply his whip to dodge a stone volley that came crashing through the brambles of the upper slope. It was curious how, even in full trot, the mules pricked up their ears and watched the advent of the volley; but still more amusing was the behavior of the two cadets. They stood bolt upright, and cheered each bomb as if they were standing on the target-beach of Annapolis, while our equatorial fellow travelers were crouching down in the most deferential attitudes. Bodily prostration somehow suggests the idea of self-abasement, but it is all custom.

By the special mercy of Providence the perennial ash-rains of Mount Sangay are cold; but the northern volcanoes often heat the atmosphere with burning cinders, and if a strong wind blows those fire-flies against the plateau of the neighboring highlands the effect is apt to burn itself into the memory of the surprised traveler. It is like passing through the spray of a flaming coal-oil tank, or through a cloud of those tsé-tsé gnats that pierce shirt and jacket; for, like the steel chips of a Bessemer hammer-work, the sparks from the

smithy of Vulcan preserve their caloric for minutes together.

It is probable that volcanoes do not emit *flames*, in the ordinary sense of the word, but the larger specimens of their solid contents often emerge in a state of incandescence that would serve all the purposes of an orthodox Hades. During the eruption of Pinchincha in the winter of 1879, I saw a volcanic bowlder go down the eastern slope in wide bounds, but in spite of its velocity setting the brush afire along the whole track of its descent; that is, not only where it struck the ground, but also wherever it dashed through, or over, a tuft of dry grass. A week after the last great outbreak of Imbabura, several fragments of volcanic rocks dug out of a vineyard near Rio Payra were still too hot to be handled with impunity. By a direct contact of a few seconds, a bomb of that sort would fire a Monitor through all its coats of iron.

The two most generally accepted theories about the origin of volcanic agencies are the infiltration and compression explanations. According to the former, sea-water or deep rock springs filter down to the furnace of the central fire, and thus generate rock-rending steam clouds; according to the latter, the gradual contraction of the earth's crust compresses the air of subterranean caves, and forces it up through craters and crevices. But the steam hypothesis is, on the whole, the more plausible one, for the propulsive force of volcanic eruption seems to imply the agency of an actual explosion, or a sudden rupture of a solid obstacle. In deep mines, the collapse of the roof rocks forces out the air in an irresistible, but still gradual, current, while a gas explosion shoots up bodies and truck-wheels, as if from the mouth of a cannon, and motors of that sort alone can account for the artillery feats of the active volcanoes. In 1868 the crater of Arequipa, in Peru, hurled one of its missiles as far as Cañadas,

twelve miles from the *foot* of the mountain; and four miles nearer, the proprietor of a grain plantation found in his fields a volcanic block, eighteen feet in diameter, whose weight was estimated at eight hundred and fifty tons.

In the coast range, many springs have a way of becoming thermal at short notice, and the simultaneous calefaction of its affluents sometimes heats a whole creek to the steaming point. Eels manage to survive such decoctions, perhaps by the same trick that enables them to defy the droughts of the summer weeks; but fishes that cannot burrow in the sand have to live above hot-water mark, and are rarely found below the mouth of the treacherous tributaries. Nearly all the creeks of the Rio Bamba district are more or less impregnated with bituminous solutions, besides being heated by intermittent thermæ, but the hot-spring region *par excellence*, both in degree and permanence of temperature, is the upper valley of the Rio Esmeraldas, a tropical Yellowstone River in a frame of cyclopean mountain walls, with a fringe of perennial verdure. The emerald mines have been abandoned, but the Val de Esmeraldas continues to deserve its name. It is one of the very few *unspoiled* parks of nature. The cloud-capped ridge of Antisana at once shelters it against the north wind and the cinder showers of the northern volcanoes, and supplies its springs with the drainage of its perpetual snow-fields. And though the crater of Antisana has ceased to excrete volcanic matter, the activity of its furnace asserts itself along the base of the mountain in a long series of geysers and *fumaroles*, or smoke fissures. With this permanent supply of heat and moisture the vegetation of the volcanic hot-house could defy climatic vicissitudes, and does defy the diurnal changes of its elevated habitat. At an altitude of eleven thousand feet, where the night-frosts limit the flora of other valleys to grasses and a few hardy va-

rieties of rhododendron, the soil of the Val de Esmeraldas produces oaks, myrtles, mountain cedars, vines, holly, tiger-lilies, rose bay and buckthorn, as well as a large number of deciduous flowers. All along the dolomite cliffs of the upper valley there are *temblorones*, or tremble rocks, that vibrate under each hammer-stroke of the volcanic Titans; steam forces its way through the fissures of the cliffs, like a mystery struggling for expression; the smoke crevices, the hollow sound of each footfall, everything, suggests the idea of a soil where a little digging would reveal strange secrets of the nether world. Between the mouth of the Rio Palomas and the upper limit of arboreal vegetation, the valley is intersected by fourteen or fifteen fumaroles, of which the least would make a New England village the goal of a perennial pilgrimage. The genesis of these clefts resembles the formation of crevices in the ice-bridge of a rising river. In ninety-nine cases out of a hundred, an earthquake exhibits the phenomena of a lateral concussion; but whenever it is accompanied by a direct *upheaval*, the result is a rent through the mass of the superincumbent rocks, the permanence of such clefts depending upon the nature of the surface strata. In Lisbon, the gulf that swallowed the Cayo Real, with its six thousand refugees, closed in the next minute by the collapse of its gravelly edges; while at Messina and in the Val de Esmeraldas, the solid rock testifies to the achievements of a force which, according to Professor McKinney's estimate, has in one instance done the work of three million tons of gunpowder. Miners know that an insufficient charge of blasting-powder often consolidates the surface rocks by wedging them closer together, and that in other cases the explosion expels the tenuous gases through a hardly visible fissure. But in the *barranca* of Peder-nà, at the foot of Antisana, a chasm sixty-five feet wide and four thousand

feet long has been torn through at least three miles of massive rocks, to which depth the walls of the barranca have been fathomed and have sounded solid. Clouds of dun smoke rise in whirls from that hatchway of Tartarus, and the actual depth of the chasm has been estimated at from ten to fifteen miles. Rocks which five men had to move with the aid of leverage have been tumbled over the brink of the abyss, but no human ear has ever heard the termination of their descent. For the upper fifty feet the walls of the gorge are clothed with a mantle of dingy vegetation, a matted tangle of vines, brambles, and pendent mosses. Further down, the naked rocks project in rough cliffs, and in the fissures of these cliffs cluster the only inhabitants of the barranca, drowsy bats, awaiting the fading of their luminous sky-light, and squeaking their protest against untimely interruptions of their slumber. If a stone or a pistol ball dislodges them from their hiding-place, they plunge out of sight, or flutter to and fro along the twilight edge of the nether darkness, while their screams echo up like the cries of the Stymphalides from the shores of Orcus. Their dismal dormitory is at least well warmed; besides the smoke clouds, occasional jets of steaming water squirt through the fissures of the barranca, with a hissing noise, as if the safety-valves of the subterranean furnace had opened, or the old Midgard Serpent were tightening her coils. At the head of the gorge, on the north side of the valley, a little mountain brook trickles down over a terrace of moderate steepness, which in the hot season becomes a sort of dry stairway, though Theseus and Pirithous might have declined to enter the nether world by that gate. The river road bridges the successive barrancas at their upper ends, where their width varies from five to fifteen feet. Some of the smaller ones are almost hidden by a cover of tangle-vines, though they all

emit smoke, and most of them a pungent smell of hydrochloric acid. It is a curious fact that people can become habituated to this smell — that is, not only inured to its influence, but fond of it — and use it as a medium of stimulation. In the Rio Bamba district there are caves where the Indians get gas-tipsy, like children in the fumes of a wine-cellar. To non-habitués this smell is as uninviting as coal-gas. Its physiological action resembles that of nitrous oxide in its immediate effect upon the brain and the nerves and the fitful acceleration of the pulse. The after-effect of the wretched tippie is a two days' headache, although its devotees claim that it makes them *previsionado*, "fore-sighted," as my landlord in Las Payras termed it. After a gas spree, one of his Indians dreamed that he saw a boy in the *serape*, or traveling-shawl, of a neighbor's son, but as thin as a shadow. The next week the neighbor's boy failed to return from a hunting-trip, and two months after they found his body, wrapped up in an old shawl, on the Plateau of Dos Peñas, where he had lost his way and starved to death.

The mining hamlet eight miles above the mouth of the Palomas was abandoned during the war of independence, but a trip to the head of the valley is well worth the risk of a night's camp in the ruined *casuchas*. Visitors may try their luck at the old placer diggings, where here and there emeralds are still found in paying quantities, together with agates and obsidian pebbles, ground dingy by friction, but breaking into glass-like pieces of marvelous dark blue, sky-blue, and iridescent hues. Gold, too, was formerly dug from the river-sand; but the mines of Western Brazil have sapped that industry, as the Eldorado of Northern Georgia was blighted by the Californian treasure-troves. Two miles above the ruins the valley narrows into a cañon, where one of the intermittent geysers hisses and bubbles

in the rocks above, and now and then, overboiling its cauldron, splashes down into the river with a peculiar jingling noise, that rings through the basalt cliffs like peals of merry laughter.

Naturalists may study the vegetation of the upper valley and the curious modifications of a tropical flora in the rarefied air of this volcanic conservatory; for instance, the bright colors but diminished size of the bromelia flowers and ground orchids. The cold winds that stunt the vegetation of the eastern slope do not affect the river thickets of the Esmeraldas, though a protracted drought now and then blotches the verdure of the foliage. Under the equator the warm season lasts from March to July, and, *à priori*, the weather should be expected to be as uniform as the length of the days and nights; but after the summer solstice the rain-clouds of the northern woodlands prevail against the siroccos of the southern pampas, and during the following three months often mingle their thunder-showers with the ash-rains of the volcanoes.

Sportsmen may devote a day to the feræ of the higher ridges, where ocelots, hill-foxes, and wild dogs find a safe retreat in the rock-chaos of the Paramo. Vicunas, too, can be stalked on their highland pastures, though they take an amazing deal of killing. Near Salto Yegua the Quito sportsmen once bagged an old buck that bore the marks of five rifle-balls, besides a patchwork of fighting and scraping scars about his neck. The Creoles hunt them the year round, but some of their haunts in the summit of the Andes are so inaccessible that they will never be wholly exterminated.

In a lateral valley of the Esmeraldas is a famous cavern, the *cueva de rugidos*, or murmuring cave, an open grotto with a crevice, where the approach of an earthquake can be heard, or rather felt, like the rumbling of a distant explosion, and, as the natives assert, for hours in advance of the catastrophe. But the

frequency of these murmurings makes their predictive values somewhat doubtful, and for actual eruptions there is a far surer augurium, — the rule of alternation of the different craters. The volcanoes hardly ever work together, but explode by turns; and if the smoke clouds in the west presage wrath to the coast range, the neighbors of Cotopaxi know that their own monster can be relied upon to keep the peace. The two mountain ranges seem, in fact, to form the double roof of an interconnected system of subterranean cauldrons, which can use only one flue at a time; and only during the most violent volcanic paroxysms is the shock of the eruption transmitted across the central valley. At such moments, indeed, the idolaters of elemental force cannot worship their deity at a grander shrine than on the summit ridges in the snow world of the Eastern Andes, where now and then the highlanders have seen the explosions of distant Pinchincha hurling their fire-storm against the western sky, while at the same moment an earth wave shook the solid rocks under their feet.

During the last week of August, 1842, the Rumbling Valley of Northern Guatemala depopulated several villages by its continuous uproars. The noise was frightful and incessant, but, strange to say, the phenomenon seems to have limited itself to an acoustic demonstration. There was no earthquake, nor even an earth tremor, and when the villagers found that the cause of their panic was a *vox, et preterea nihil*, they ventured to return to their homes. The "roars" lasted till September 6th, and ceased as abruptly as they had begun.

Above the head-waters of the Esmeraldas lovers of the sublime may ascend the Paramos by the old Antisana Farmhouse road, and visit the Cerro del Padre, where a sheer precipice of eighty-five hundred feet overhangs the valley of Aguas Negras. Or he may visit the farmhouse itself, the highest human hab-

itation on the globe, eighteen hundred feet above the source of the Esmeraldas, and *thirteen thousand* feet above the level of the Pacific. *Jamotes* (a kind of sweet potatoes), onions, cabbages, apple-trees and currants are cultivated in the stone-walled garden behind the hacienda. The pastures, further up, abound with whortleberries, and in March with a species of larkspur, with buck beans and crocus. Wild-growing bushes of various kinds furnish fuel for culinary purposes, for white frosts are limited to the five hours from one to six A. M. The neighborhood of the equator alone cannot account for this combination of creature comforts with an enormous altitude: it must be the influence of the ever-burning fire underneath, the volcanic furnace radiating its heat through every vein of the great mountain system; for even up here there are several hot springs and one fumarole — a hot-air flue rather than a smoke-vent — in a ravine where the shepherds often pass the night in the open air.

The peak of the volcano rises still six thousand feet higher, and can be ascended when the abnormal freshness of the air is tempered by the rays of the noontide sun; but even from the farmhouse the view transcends the grandest panoramas of the European Alps. That from the top of Mont Blanc, for instance, is but a flat map of the dwarfed surrounding mountain systems, while the bird's-eye view from Antisana is com-

bined with *excelsior* prospects of the still higher summits of the Eastern Andes, — besides the smoke-wreathed dome of Cotopaxi and the apex of the equatorial highlands, the unscaled and unscalable snow-peak of Chimborazo.

From the tavern of Santa Rita the Val de Esmeraldas can be reached in a single day; Sangay and Antisana in two days; in four days the Ophir of the Rio Napo mines, and with a good guide in about the same time the summit of Cotopaxi and the Paramos of the Central Andes. Due west, it is only forty miles to the sea, from where the coast plain stretches in an unbroken line to the north end of the continent, and around to the foot of the isthmus.

That line will be the route of the predicted intercontinental railroad, and if General Eads's broad gauges should prove a success, the tourists of the next century (and, for all we know, of the next decade) will leave Boston on the morning after Christmas, and eat their New Year's dinner where the tree shade shelters them from the rays of a vertical sun, or on the piazza of an international hotel. Even now our winter tourists visit the Eden of the equator in numbers that task the resources of the old Spanish mountain taverns.

The Savoyards, too, may have improved their hotels by that time, but the landlords of Chamouni must spice their pastry well if they would compete with the caterers of Santa Rita.

Horace D. Warner.

KNOWLEDGE.

KNOWLEDGE — who hath it? Nay, not thou,
 Pale student, pondering thy futile lore!
 A little space it shall be thine, as now
 'Tis his whose funeral passes at thy door:
 Last night a clown that scarcely knew to spell —
 Now he knows all. O wondrous miracle!