On the effects of volcanic action in the production of epidemic diseases in the animal and in the vegetable creation, and in the production of hurricanes and abnormal atmospheric vicissitudes / by H.J. Johnston-Lavis.

EFFECTS OF VOLCANIC ACTION IN THE PRODUCTION OF DISEASES AND ATMOSPHERIC VICISSITUDES

JOHNSTON-LAVIS

On the Effects of Volcanic Action in the Production of Epidemic Diseases in the Animal and in the Vegetable Creation, and in the Production of Hurricanes and Abnormal Atmospherical Vicissitudes

BY

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WITH GRATITUDE I DEDICATE THIS WORK

To My Beloved Wife,

ANTONIA FRANÇOISE JOHNSTON-LAVIS,

WHO THROUGH A LONG MARRIED LIFE ENCOURAGED ME IN MY MEDICAL AND SCIENTIFIC WORK, AFFORDING ME VALUABLE HELP AND APPRECIATION AND AIDING ME TO OVERCOME ALMOST INSURMOUNTABLE DIFFICULTIES.

THE AUTHOR.

PREFACE.

SOME two years since several friends drew my attention to the triennial Parkin prize of £100 of the Royal College of Physicians of Edinburgh, and strongly advised me to compete for it. As the subject set, the title of which heads this essay, was one requiring an intimate knowledge both of vulcanology and of medicine they urged me, as one of the few persons combining an acquaintance with both these branches, to enter for it. The subject seemed such a vast and unmanageable one for an essay that I hesitated till the allotted three years were nearly up. Still urged by my friends I at last decided to make the attempt to tackle it, especially as I had ready at hand much of the material required. When completed I submitted the manuscript to some outspoken, critical friends, and with their encouragement sent it in as a competing essay, with the result that it gained the prize.

As the subject is an important one, especially to volcanic countries like Iceland, Italy, New Zealand and many other of our colonies, I think it may be of interest to the public, to whom, therefore, I have now the pleasure of presenting it in book form.

H. J. JOHNSTON-LAVIS.

Villa Lavis,
Beaulieu-sur-Mer.
May, 1914.

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INTRODUCTION.

THE history of mankind teems with attempts to associate his ailments and his diseases with natural phenomena. The more imposing these latter are the deeper is the impression that they are causative of man's sufferings. As we recede into the historic past, and therefore as we find accumulated human knowledge and experience more limited, the more and more do we find the *natural* interpreted as the *supernatural*.

Of the many displays of Nature's workings there are none that can compare, in the marked impression they leave upon the mind, with volcanic outbursts and eruptions. It is but an obvious sequence that these will hold the first place as an explanation of any widespread ailment or disease, which, as a matter of pure coincidence, may appear at, or soon after, such a volcanic display. Certainly extraordinary astronomical phenomena, such as comets, eclipses, &c., have a far greater area of influence, but I think all will admit that volcanic eruptions produce a greater impression in the

immediate neighbourhood of their occurrence. Earthquakes, which are beyond the scope of this essay, are likewise a cause of much speculation on the relationship of earth movements with storms and disease.

As human knowledge extends itself and different natural phenomena become understood and are docketed in their right places, imaginary connections between them and epidemics are, in most cases, broken down; in some, however, new associations are found. The enormous acquisitions to our knowledge concerning the causes of diseases by ever-increasing researches in chemistry and, to a far greater extent, by the very modern science of bacteriology, have been able to clear up many false mental associations of disease with terrestrial phenomena.

On the other hand, many astronomical, meteorological and terrestrial phenomena have likewise reached comprehension by scientific investigation, and volcanic researches have equally progressed. Chemistry and physics have combined in the hand of the geologist or vulcanologist to afford us fairly complete information upon the principal chemical composition of volcanic materials and the physical manifestations associated with their expulsion from the earth's crust.

Strangely enough not only in olden days were many ills of humanity accredited to

volcanic eruptions, but, notwithstanding our advanced knowledge, the less thinking public are still much inclined to find imaginary connections between these and disease. After the great Krakatao eruption numbers of people in different parts of the world credited their ailments to some pernicious effect of that great outbreak—yet no such relationship could be shown by any logical line of thought. Many epidemics were contemporaneous with this great eruption as would be the case with any other, and many people, *post hoc propter hoc*, attributed disease to the volcanic emanations which filled the world's atmosphere. Had this generalized agent been the cause, then the different regions of the earth should have been sensibly affected by the same ailments. No evidence of any such generalized epidemiological influence has, however, been brought forward—in point of fact the Royal Society's Report makes practically no reference to the subject. Neither do the French reports of the St. Pierre catastrophe point to any special relationship between the eruption and any epidemic disease or special meteorological conditions other than magnetic disturbances. Heilprin ("The Eruption of Pelée," &c., Philadelphia, 1908) records the magnetic storm observed over almost the whole world, but especially the U.S. Coast and the Geodetic Survey stations at Cheltenham, Maryland,

Baldwin and Kansas, as well as at Toronto, Stoneyhurst, Greenwich, Val Joyeux, Hamburg, Paris, Potsdam, Pola, Pulkowa, Athens, Honolulu, &c. Nothing special upon this subject is recorded by T. Anderson and Flett in their report of the almost simultaneous eruption of the Soufrière of St. Vincent.

"SCIENCE IS THE ART OF USING COMMON SENSE."

CHAPTER I.

Physics of Eruption.

By eruption we mean the conveyance of volcanic matters to the surface of the earth and the dispersion of part into the atmosphere and deposition of the remainder on the terrestrial surface.

All volcanic matter consists of a mixture of solids, liquids and gases in different and varying proportions. Primary volcanic matter consists of a mixture of oxides and silicates in a state of glassy fusion in which gases are dissolved and in and from which certain chemical compounds have to a greater or less extent separated as crystals and floated into the pasty magma as cooling progresses. Several of these volatile constituents are liquids or solids at ordinary atmospheric temperatures, but are evolved into a gaseous condition by the great heat of the volcanic magma. Their evolution is dependent upon the three factors—temperature, pressure and relative quantity.

The solution of H_2O, SO_2, HCl, HFl, NaCl, KCl, in the magma at 1,000° to 2,000° C. is, in most cases, analogous and

comparable to the solution of CO_2 in water or wine at ordinary atmospheric temperatures. The liquid solvent can hold, for a given temperature, more or less of the volatile constituents according as the pressure rises or falls, just as occurs with champagne or seltzer water.

When a volcanic outburst takes place this magma, in which the volatile constituents are in true solution, undergoes a marked and speedy diminution of pressure with the rapid evolution or conversion of these bodies to a gaseous form—a process analogous to the effervescence of champagne on removing the cork. Part of the magma is converted into froth, which issues as scoria or pumice in ratio to the temperature, the amount of contained volatile constituents and the amount of diminution of pressure. If the vesiculation or frothing reaches an extreme limit, the cooling by the loss of latent heat is such that the evolution is extremely rapid, with a coincident breaking up of the vesicular walls into consolidated spray, which constitutes pumice dust, commonly called ashes. It has been calculated that fragments of bubbles of glass (pumice) are so small that in the eruption of Cotopaxi 4,000 to 25,000 were required to weigh one grain. If the amount of volatile elements is small or the temperature of the magma low or the change of pressure relatively small, the magma will well

out in a more or less frothy or scoriaceous condition from the volcano and flow as a *lava stream.* The liberation of the volatile elements will be a relatively quiet process.

All these products, lava, scoria, pumice or pumiceous dust, constitute the *essential ejecta.* In addition to them, and often mixed with them even in larger proportions than themselves, come the *accessory ejecta.*[1] These consist of the ruins of the crater walls broken up, abraded and ejected by the violent rush of new volcanic matter. Such materials range from large masses, many tons in weight, down to the most impalpable powder.

Finally a third group is constituted by the *accidental ejecta*, which, like the second group, owe their origin to the excavating and abrading effect of the exit of the new *essential* volcanic materials through the sub-volcanic platform. Their composition may therefore be very variable—limestones, sandstones, clays, sands, old igneous or plutonic rocks, &c., their fragments being mixed with the *essential and accessory* ejecta.

The heavier pieces of the broken up or pulverized masses and fragments of volcanic ejecta fall nearer and nearer the vent in ratio to their increase in size, while the finer the

[1] Johnston-Lavis, "On the Fragmentary Ejactamenta of Volcanoes," *Proceed. Geol. Assoc.*, vol. ix, pp. 421-432, figs. 3.

material is, the greater will be the distance it is conveyed by prevailing winds. Thus, of grains of a given diameter, the heavier, such as those composed of magnetite, olivine, augite, will fall sooner, and therefore nearer the eruptive centre than those of felspars, leucite, &c., and these, in their turn, will not be carried so far as the glassy residue. Consequently the composition of a volcanic dust will vary according to the distance from the eruptive focus. In the Krakatoa eruption the finer particles were actually detected as Krakatoa dust and reached as far as the Seychelles, the East and West Coast of Africa, Paramaribo, Trinidad, Panama and the Sandwich Islands, Ceylon and British India, while a shower of dust fell on the S.S. "British Empire" when this was 1,600 miles distant.

Where the *essential ejecta* of a volcano are light and pumiceous, the enormous loss of heat energy in the expansion of the process of vesiculation reduces temperature so rapidly and completely that, by the time they reach the ground, they can hardly scorch woodwork, and people who protect themselves from mechanical injury by wearing pillows or light tables on their head can move about with comparative safety. I need only quote the frequently cited letters of Pliny the Younger or the stories of the inhabitants of Ottajano and S. Giuseppe in the late eruption of Vesuvius in 1906.

In certain eruptions, such as that of St. Pierre de Martinique, the initial explosion blew out and away the top of the volcano, composed of a vast mass of lapilli at a very high temperature, the rise and fall of which avalanche was accompanied by and held with accumulated gases and vapours, also at an intensely high temperature. This wiped out St. Pierre and its inhabitants in a few minutes, but here the materials, though highly heated, were *accessory ejecta* and not in a state of fusion and therefore possible expansion, so that they fell upon the burning town and destroyed everything by heat and fire, as shown by the melting of metals and glass. Those on board ships in the harbour who escaped, although severely burnt, found the heat the principal trouble to their breathing. Messrs. T. Anderson and J. S. Flett[2] give an account of the hot blast, to which I shall refer later.

The spread of the lava streams is relatively limited, and rarely are human beings or animals overwhelmed by the molten rock, except in cases of gross laziness or stupidity. The longest lava streams recorded are the two branches of the Skaptar Jokul outburst of 1783, one of which was about fifty and the other about thirty miles long.

[2] "Report on the Eruption of the Soufrière in St. Vincent" in 1902, &c., London, 1903.

On the other hand, the distribution of fragmentary materials may be even world-wide, as in the case of the great eruption of Krakatoa, the evidence pointing to the whole world's atmosphere having been pervaded by the finer dust. Even in the last great Vesuvian eruption of 1906 a vast fan-shaped cloud of falling sand and dust spread eastwards right across the Italian peninsula and the Adriatic, and fell heavily in Montenegro. As I write I have before me a large test-tube full of the heavy, blackish dust, collected on the roof of the Royal Palace at Cettinje by H.R.H. the Princess Xenia. In the eruption of Vesuvius in A.D. 472, the dust (ashes) fell in Constantinople and Tripoli, and Vesuvian dust has been recorded at various times as falling in Belgrade, Syria, Egypt, Dalmatia, Rome, &c.[3] Innumerable other examples might be quoted, one of which, hitherto not remarked, I believe, is that throughout the greater part of central and southern Italy, in the depressions and pockets of the limestone, the soil shows a large proportion of tufaceous elements, representing innumerable showers of volcanic dust fallen in late tertiary and quaternary times. In fact, much of the fertility of this region is owing to this source of fertile, vegetable soil. Any observer may remark how the bare

[3] Galiani, "Dei Vulcani Ignovomi e del Vesuvio." Livorno, 1779, p. 137.

limestone mountains become fertile and wooded as we approach the neighbourhood of recent or quaternary volcanoes.

Mud, or a mixture of the loose ejecta of a volcano with water, is another destructive agent to life. The eruption of mud is still an unsolved problem, though I think that a careful study in each locality where mud was ejected would easily clear up any doubts. In most cases it is produced by an eruption taking place through shallow water of the sea or of a lake. Frequently the lake occupies the crateral excavation made by an earlier eruption. Condensation of the enormous clouds of vapour produced in the eruption, or the precipitating effect of dust and acid vapours on rain clouds affords the necessary water.

The rapid melting of snows in the old crater on the slopes of a volcano is one of the most disastrous origins of volcanic mud. I have ridden twenty miles at a stretch transversely across deserts of boulder pebbles and sand which had been swept down by the sudden melting of the snow-mantle of the Kotlugià volcano in Iceland.

To give a few examples of mud eruptions: Tit-Singh records that Asamayama and some other volcanoes of Nipon expel enormous quantities of mud. In 1793 Mount Miyi-Yama in the Island of Kisussion erupted firstly a gigantic mass of rocks, then a torrent

of liquid mud, so overwhelming that 50,000 people were destroyed by it.

Humboldt says that, not only does the mud issue from the crater and flanks of the mountain, but also from crevasses in the neighbouring plains. This I attribute to the settling of the particles in the water-logged earth as the result of the concomitant earthquakes and tremors. A catastrophe of this kind occurred in Java in 1822. Humboldt also gives many examples from South America.

The lacustrine origin of some of these muds is proved by the enormous number of fish met with in the mud from Cotopaxi, Sangay and Tunguragua. These fish (*Pimelodes cyclopium*) live in the lake streams and water-filled crevasses of these volcanoes.

Towards the end of the 18th century the Imbabura in Ecuador (4582 m.), after a state of inactivity for a century, burst forth, covering the surrounding country with mud and fish. Thereupon immediately followed a "Pernicious Fever," which decimated the population and was attributed to the miasma arising from the putrefying fish mixed with the mud.

CHAPTER II.

Chemistry of Eruption.

I USE the above heading as referring to those products that may influence the health or life of man, animals or plants. It would be *ultra vires* to treat of volcanic chemistry in general.

The classical researches of Breislak, Ste. Claire Deville, Fouqué and a whole galaxy of vulcanologists have made us fairly well acquainted with the composition of the gaseous emanations of volcanoes. Of late years the remarkable investigations of M. Albert Brun have filled in the minor details of this subject. Though we may not agree with his conclusions, we can but admire his careful and elaborate work. The following table is modified from M. Brun's list of gases obtained by *re-heating* different lavas, and these correspond with the "*smoke*" of the volcano—though probably the proportions are different. I have given it as being the most recent, but it varies little from that of most observers anterior to his investigations.

Nitrogen and its hydrogen compound ... $N—NH_3$.
Chlorine and its hydrogen compound ... Cl—HCl.
Carbon and its hydrogen compounds and oxygen ... ... C—Hm Cn—CO—CO_2.
Sulphur and its oxygen compounds ... ... SO_2. (H_2S is only met with when there is an abundance of hydrocarbons.)
H_2SO_4, only met with in certain fumaroles and solfataras.
Fluorine combined with hydrogen and silicon as ... ... HFl—$SiFl_4$.
Free or combined hydrogen.
Ammonia and its salts ... ... NH_4Cl—NH_4Fl.
Chlorides and fluorides of metals, the principal of which are ... ... Na—K—Mg—Ca.
Of the iron group the most important are ... ... $FeCl_3$ and Al_2Cl_6.
Salts of copper, manganese, lead, titanium and arsenic are always present in the crater salts, but in small quantities.
Boron is rare, and iodine and bromine doubtful.
Soluble phosphates are sometimes met with in the dusts (ashes).

Personally I contend that the error into which M. Brun has fallen is in not considering water as the principal exhalation of active volcanoes and in even almost ignoring its existence. I hold his view as being a misinterpretation of his own results of reheating of rocks. In my opinion the main part of the H_2O gas (not to call it steam or water and so tie us to a statement of the *physical* state of this compound) is evaporated early in the eruptive phase. What remain still enclosed in the cooled rock are the less volatile

elements, which M. Brun has obtained by secondary distillation. In other words he has collected and studied the final volatile residues of a fractional distillation in which Nature has done all the first part.

Unquestionably a good part of these terminal distillates had escaped with the main clouds of smoke, and in fact, formed important constituents thereof.

The experience of all constant students of active volcanoes and the writer's own observation agree in placing H_2O first. The next most common component of the *smoke* is HCl, when the volcano is in a state of chronic or Strombolian activity. As soon as a slight paroxysm occurs sulphurous acid dominates, though, so far as evidence is obtainable, the HCl is given off very abundantly. Carbonic acid, nitrogen, hydrogen and hydrocarbons have been detected. Then come alkaline chlorides, ammonium chloride, ferric chloride, calcium and magnesium chlorides and, to a less extent, sulphates of the same bases.

During the latter part of an eruption and immediately subsequent to it there is a large evolution of carbonic acid, principally through cracks and fissures of the surrounding slopes and district. Wells, cellars and depressions in the soil get filled with this heavy gas and frequently men, animals, birds, insects, &c.,

become overwhelmed and pay their life for carelessly venturing into such precincts. Analyses of such *temporary mofetti*,[1] as they are called, usually reveal almost pure CO_2. The following are two well-known analyses of temporary mofetti :—

Monticelli.		*Sainte-Claire Deville.*	
Carbonic acid ...	87	Carbonic acid ...	54·70
Air	13	Nitrogen	45·30
	100		100·00

Analysis of the Permanent Mofetta of Grotta del Cane.

Carbonic acid	97·47
Oxygen	0·52
Nitrogen	2·01
	100·00

In some volcanic regions the persistent evolution of this gas goes on for centuries,

[1] *Mofetta* is a word having a very wide distribution. In the island of Réunion there is a place called *Mafate*, which is renowned for its sulphur springs and their malodorous emanations. *Mafate* is a Malgache name and means "that which kills." *Maveth*, the Hebrew word, means "pestilence" or "death." *Moffat*, in Scotland, is known, amongst other things, for its sulphur springs. So important was the question of mofetti considered, especially as a supposed relationship between terrestrial emanations and epidemic diseases, that a monograph was written by Leonardo di Capoa in 1683 upon the subject. "Lezioni intorno alla Natura delle Mofete." Napoli, 1683, in 8vo fol. 8 + pp. 179 and index.

which usually indicates the decline and decay of volcanic activity at that locality, and such emanations are known as *permanent mofetti.*

Volcanoes in a solfataric condition evolve much carbonic acid, sulphuretted hydrogen and some ammonia sulphate, though probably these two latter are due to the presence of a reaction of SO_2 with organic matter in the neighbourhood of the heated mass evolving the gas.

Some of the sulphur is deposited in crystalline form and another portion is oxidized to H_2SO_4, which attacks the felspars and forms a series of alums. The ammonia is often deposited as a chloride or sulphate. Arsenical vapours are also frequently deposited on cool surfaces as sulphides of arsenic in the form of realgar and orpiment.

M. A. Brun lays much stress upon the large percentage of acids and salts found in the dust, but he does not appreciate that every grain has served as a nucleus of condensation, as both the vapour and the dust with which it is mixed lose their temperature in rising from the mouth of the volcano. This will be especially the case with the chlorides and sulphates of the metallic and alkaline bases. M. Brun found that the dust ejected at the height of the eruption of Vesuvius (April 7-8), 1906, was twenty times more acid than that which fell at the decline (April 13), obviously

due to the fact that the dust which fell at the climax of the eruption had a larger supply of vapours to condense.

This, however, is a purely academic question. What does interest us is the caustic and astringent action of these acids and salts added to the mechanical effect of the dust itself.

The dusts often contain up to 2 per cent. or more of these soluble substances which, after rain, become partly dissolved and, upon drying, recrystallize out as a white, yellow or green saline crust. If one walks far over such crusts one finds, upon examining one's boots, that the nails are thickly plated with copper. I here give the analyses of the different dusts, which were made after the last great eruption of Vesuvius in 1906 by the late Professor Casoria, one of the most expert vulcanological chemists.[2]

[2] Casoria, E., "Sulla composizione chimica delle Cenere vesuviane cadute a Portici nei giorni 9 e 10 Aprile, 1906." Prima memoria. *Ann. R. Scuola Sup. d'Agricol. di Portici*, 1906, vol. vi., and *Chemiker-Zeitung*, 1906, 30, No. 61. Also Casoria, E., "Le sabbie e le ceneri vesuviane cadute a Portici nel mese d'Aprile dell'anno 1906." Seconda memoria. *Ann. R. Scuola Sup. d'Agricol. di Portici*, 1909, vol. ix, pp. 26 (posthumous). See also Johnston-Lavis, H. J., "The Eruption of Vesuvius in April, 1906," *Scientif. Proceed. R. Dublin Soc.*, vol. ix, p. 8, January, 1906, pp. 63, 16 pl., 2 plans, 2 figs., and 2 col. maps. Reprints. Dublin, 1909, in 4to.

	HCl	H_2SO_4
100 grm. of grey dust contain...	0·00219	0·00294
100 grm. of cocoa-coloured dust contain	0·00109	0·00145

Only the faintest traces of sulphurous acid were found.

Hypothetical salt grouping	In red dust	In grey dust
NaCl	49·158 ...	44·300
$MgCl_2$	5·110 ...	6·964
$MnCl_2$	1·494 ...	1·559
$CaSO_4$	27·198 ...	31·731
K_2SO_4	8·399 ...	13·488
Na_2SO_4	8·557 ...	1·927
SiO_2	0·079 ...	0·026
Total ...	99·995 ...	99·995

	Red dust	Grey dust	Sol. salts in lava of Boscotrecase
Ca ...	8·399	9·334	0·945
Mg ...	1·292	1·759	—
K ...	3·768	6·048	12·758
Na ...	22·116	18·047	30·395
Mn ...	0·657	0·681	—
Cl ...	34·520	32·977	20·136
SO_4 ...	29·520	31·150	4·723
SiO_2 ...	0·079	0·026	—
CO_3 ...	—	—	30·749
Total	100·351	100·022	99·995

Dried at 180° C., the red dust contained 3·240 % of salts.
" " the grey " 2·651 "
" " the lava of Boscotrecase contained ... 0·395 "

CHAPTER III.

Physical Effects of Eruptions on Human Beings and Animals.

In the first place, however unimportant an eruption may be, fear and panic seize upon a certain number of the neighbours. The effect of this may produce death or injuries in an indirect way, such as accidents in the attempt to escape. We are all well aware how the lowered vital functions resulting from fear weaken the resisting power of man or animals against microbic infection, or set up a metabolic disequilibrium. A striking example of the effect of panic and religious credulity was that of the several hundreds of people who flocked into the two churches of Ottajano and S. Giuseppe on April 7, 1906, when the great eruption of Vesuvius was in full blast, and where they remained praying instead of clearing the roof, upon the low slopes of which was rapidly heaped up nearly one ton of lapilli per square metre! The rafters soon gave way and all those beneath were crushed by the falling roof and its burden of volcanic material.

No doubt many epidemics, attributed in history to eruptions, were the depressing effect favouring the extension of some epidemic already in the neighbourhood.

Other results, such as the disturbance of putrid peat bogs and drainage, the putrefaction of fish from crater lakes or a shallow sea, or the decomposing bodies of flocks, may be cited as indirect causes of epidemic or other diseases attributable to volcanic eruptions.

As a source of direct destruction of life to man and animals we may take the case (1) of lava streams.

Where death of man takes place through being overwhelmed by lava streams, it is in almost all cases due to his own stupidity or carelessness, for, even with great outflows of very fluid, basic lava, unless the slope be very steep and the outflow very broad, most people with a fair amount of agility and common sense can get out of the way. In the case of the students who lost their lives at Vesuvius in 1872, when standing at a spot where a new opening was formed, their death was really due to scalding from the jet of steam and vapours.

Animals more easily fall victims, as often they hide in holes or retreat to eminences and allow themselves to be surrounded and overwhelmed.

(2) The fragmentary ejecta act in very different ways.

Essential pumice we have already referred to — the effects thereof were illustrated at Pompeii. Pliny the Elder and his suite were able to walk about with pillows on their heads. Certainly, he died, but we glean from the writings of his nephew that he was a stout plethoric old admiral, in whom, probably, bronchial, arterial and cardiac degeneration was far advanced, so that the excitement, heat, and dust constituted very likely the last straw to an apoplectic attack or heart failure. That the conditions during the eruption were fairly bearable is proved by the fact that his companions not only did not die, but were also able to add to their burdens by carrying his body to Stabiæ.

The casts of bodies which constitute striking objects in the museum of Pompeii were all moulds and skeletons, found in the upper stratum of dust, which represents the final efforts of the volcanic outburst. These were people who returned either to rescue their property or to steal that of others, and who were, no doubt, suffocated through the blocking of their respiratory passages by a hot, caustic, irritating dust. The temperature of this dust could not have been high, as the clothes and other combustible materials, though they have rotted, show no traces of roasting or carbonization.

Geologists, after years of careful searching

amongst the volcanic materials of Vesuvius, the Phlegraean Fields, the Alban Hills, the Eifel, Central France and other districts in full activity in populated countries, have found that they afford human remains only on extremely rare occasions.

Catastrophes entailing a large loss of human life, caused by ejections, chiefly of accessory materials, such as were the agents of those of St. Pierre, St. Vincent, &c., are relatively rare. The same may be said with regard to animal remains. In fact the only examples of which I know in the Naples district are a skeleton of *Cervus elaphus*, which I found near Pianura, and a deer bone, found at Fajano, near Nocera,[1] and I spent many years in examining all the volcanic deposits of this region for the construction of the great geological map of Vesuvius and Monte Somma. In fact the Pianura skeleton points to the death of the animal having been caused by his getting bogged on the shores of a volcanic lake.

[1] Johnston-Lavis, H. J., "Notizie sui depositi degli antichi laghi di Pianura e di Melfi," *Boll. Soc. Geol. Ital.*, vol. xiv, pp. 111-118, pl. 1; also "On the Formation at Low Temperatures of certain Fluorides, Silicates, Oxides, &c., in the Pipernoid Tuff of the Campania," *Geol. Mag.*, dec. iv, vol. ii, No. 373, July, 1895, pp. 309-313. Also Scacchi, A., "Sulle ossa fossili trovate nel tufo dei vulcani fluoriferi della Campania," *Atti. R. Accad. Sc. fis. e mat.*, Napoli, 2a. ser., vol. iii, 1888.

The results on human beings of the sudden ejection of large quantities of highly heated solid stones, lapilli and dust by a tremendous blast of hot gases is similar to those destructive effects already mentioned at St. Pierre. Here no expansion and vesiculation of an actual fluid magma could take place, hence the store of heat energy could not be used up as in true pumice eruptions by the expansion and vesiculation. The hot blast phenomenon was also a marked feature in the St. Vincent eruption.[2] This hot blast travelled at the rate of 30 miles an hour and killed everybody it reached. The peculiar condition of the trees afterwards seems to show that the blast swept down the mountain a mixture of hot stones, sand and dust with hot gases. Those who recovered describe their first sensation as having been a sudden pain in their mouths and throats and intense pain in the eyes, due to the fine, hot dust; the more exposed parts of the face and hands were scorched; those who had beards collected the dust in them, which burnt the underlying skin; then followed pain in the chest and abdomen as the dust reached the bronchi, or was swallowed in the effort of moistening the mouth.

[2] Messrs. T. Anderson and J. S. Flett, "Report on the Eruption of the Soufrière in St. Vincent in 1902, and on a visit to Montaigne Pelée in Martinique," London, 1903.

These survivors say that there was a strong smell of burning sulphur. I have, however, known hydrochloric acid, chlorine and other chemical odours to be likened by the ignorant to a sulphurous smell. Many of those who did not die immediately collapsed some days after from their burns or the scorching of their mouths, throats and respiratory passages, or from general shock.

Here we have the result of four elements: heated air, vapours of irritant and caustic chemical compounds, caustic and irritant salts in the dust, and finally the mechanical effect of the dust itself.

Animals, naturally, are affected in the same way, and of course all ground-hiding animals, reptiles and insects are killed by suffocation from the choking of their burrows, if not by the direct action of the ejecta. Gases and mofetti are deleterious especially to animal life. The acid caustic vapours evolved during big eruptions are usually carried up so far above the earth's surface that they have little chance of being destructive to life, except in the cases of the hot blast, such as that of St. Pierre or of the Soufrière of St. Vincent. With volcanoes in a state of chronic activity, such as Etna, Vesuvius, or Stromboli, a strong wind will often force the "smoke" issuing from the summit as a long tail down the leeward side of the mountain and away over

the plain for miles. The effect is extremely irritating to the air passages and often has a caustic action on the leaves and flowers. On two occasions, after being compelled to work in this vapour in the crater, the author has had bronchitis, lasting, however, but a few days and of a character such as is produced by HCl, or other chemical vapours.

In the latter stages of an eruption, as before referred to, the principal phenomenon is the evolution of the *mofetti*. Where death is produced in man or animals, all the symptoms are those of ordinary carbonic acid suffocation. Even in pre-chemical days the similarity between deaths from naturally produced gas and the combustion of carbon was recognized, and in the latter half of the eighteenth century the Académie des Sciences de Paris ordered a report to be made upon the subject.[3]

Mud or *Moya* or *lava d'acqua* eruptions are likely to be destructive to life under special circumstances where an outburst is sudden near steeply inclined ravines in which a great

[3] M. Portal, "Rapport fait par ordre de l'Académie Royale des Sciences au sujet des Sieur et Dame le Maire, étouffés par la vapeur du Charbon." This attained five editions and was translated into Italian: "Rapporto fatto per ordine dell'Accademia delle Scienze sopra gli effetti di Vapori Mofettici nel corpo dell'uomo e specialmente dei vapori di Carbone." Paris 1776 in 12°.

agglomerated population may be located. Although Herculaneum was deeply buried under 20 metres of such mud, hardly any human remains have been met with, as the population had, no doubt, a large margin of time to escape. Here the mud was, I take it, the mixing of heavy rains with the loose ejecta in the annulus or circular depression between the new crater ring and the outer enceinte of Somma, from where it swept through the lowest notch in the Somma ring and down the ravine above Herculaneum.

In examining tuffs of mud origin such, for instance, as the Peperinos around Albano, or those of the Campi Phlegraeae, of Monte Vultura, of Central France, of those near Andernach in the Eifel or in Iceland, human or animal remains are almost unknown. The peperino on the outer slopes of Albano are marked on their under surface by the moulds of the grass blades on the grass-covered slopes over which the mud slithered, and the casts of tree trunks and branches are common near the bottom of the deposit, but animal remains practically do not occur.

CHAPTER IV.

A Small Selection of Citations of Different Authors of the Supposed Relationship of Eruptions to Epidemic Diseases of Man, Animals and Plants.

One of the earliest books devoted to the relationship of terrestrial dynamics to diseases is by P. Beroaldus.[1] Although more attention is paid to earthquakes than to volcanoes, there are references to the latter. Beroaldus quotes the many ancient writers from Thales and Homer onwards as to the possible relations between seismic phenomena and diseases such as plague, gonorrhœa, hydrophobia, ozœna, dyspnœa, orthopnœa, satyriasis, siriasis, &c.; but as this hardly comes within the scope of this essay, and as little is to be learnt from the book except the generalized superstitions as to cause and effect, I do not propose to enter further into the subject.

I. Sorrentino, who wrote one of the most pondered and unbiassed histories of Vesuvius,[2]

[1] "De Terremotu et Pestilentia," Bononiæ, 1505.
[2] "Istoria del Monte Vesuvio," Napoli, 1734 in 8°.

records the death of a few people, which he mostly attributes to lightnings or electric discharges from the falling dust, and refers from time to time to damage to plant life. He, however, devotes a whole chapter to the great fertility of the soil and the best quality of wines grown thereon due to the ejecta of Vesuvius. (See chapter xxvi, p. 97.)

P. Castelli[3], in describing the great eruption of Vesuvius in 1631, spends several pages in discussing the effects of the dust. He attributes its innocuity to its being completely and not partially burnt.

Some two hundred books and pamphlets were published concerning this eruption, many of them grossly exaggerated accounts of human suffering, and of a religious character intended to excite the piety of the people.

G. Paragallo[4] says that Dion Cassius, Platina, Ambrogio Leone and S. Porzio mention morbific pestilences following upon eruptions and discusses what they say, but adds but few examples himself.

[3] "Incendio del Monte Vesuvio, Nel quale si stratta di tutti gli Luoghi ardenti, delle Differenze delle Fuoghi; loro Segni; Cagioni; Prognostici; e Rimedii con Metodo distinto, Historico, e Filosofico," Roma, 1632, fol. iv, pp. 92 and index pp. 63 *et seq.*

[4] "Istoria naturale del Vesuvio," Napoli, 1705, p. 409 *et seq.*

D. F. Serao, writing anonymously,[5] describes the deaths of animals, birds and reptiles, &c., which he attributes to being the result of the eruption, but these seem to have been killed by mofetti. He gives details of the effect of the fine dust on the leaves and fruits of plants and of the relative damage to each kind. These observations were confirmed by P. G. d'Amato.[6]

G. M. Mecatti[7] says that physicians noticed that at the epoch of the eruption of 1754 there were many diseases, and some of them mortal. They declared that they were occasioned by the salts and particles of arsenic which were spread through the air, poisoning it, as it were. The diseases attributed to the eruption were anginas, apoplexies, inflammations and engorgement of the glands—rather a heterogeneous mixture. He gives the case of two friends who had bad throats after accompanying him in his excursions to Vesuvius, one of whom died from an inflamed throat

[5] "Istoria del Incendio del Vesuvio accaduto nel mese di Maggio dell Anno mdccxxxvii, scritta per l'Accademia delle Scienze," Napoli, 1738. There were, up to 1778, five editions in Italian beside Latin, English and French translations.

[6] "Divisamento critico sulle corrento opinioni intorno ai fenomeni del Vesuvio e degli altri Vulcani," Napoli, 1756 in 8°.

[7] "Racconto Storico filosofico del Vesuvio, &c.," Napoli, 1752 *et seq.*

and chest. He himself does not seem to have been affected!

Padre G. M. de la Torre[8] gives a much more substantial account, which I think worthy of quoting in full (translation) :—

(Letter from Dr. Jean Vivinzio to Padre de la Torre.)

"I have received, Reverend Father, your letter of the month of January, in which you informed me that the Abbé Péton was going to have printed at Paris a French translation of your learned *Histoire du Vésuve*, and that you were sending him the continuation of your observations in order to make them complete up to the year 1760. You persuade me to add to it a detailed account of the unfortunate epidemic disease about which I have often spoken to you, and which I attributed to the eruption of Vesuvius which began in the year 1754, and lasted till the month of February, 1755. . . .

"The malady in question showed itself especially at Nola, my native town, and in the neighbouring places, S. Paolo, S. Eramo, Sirico and Saviano. For the sake of clearness I will begin by explaining the situation of these places relative to Mount Vesuvius, putting Nola as their centre. The town of Nola is,

[8] "Storia e fenomeni del Vesuvio," Napoli, 1755. Also German and French editions.

as you know, to the north of Vesuvius; it is 10 Italian miles distant from it. With respect to Nola, S. Paolo is to the east, S. Eramo and Saviano are to the south, and Sirico to the south-east. All these places are 1 or 1½ miles from Nola, and in consequence 9, 10, or 11 miles from Vesuvius. They are all situated in the midst of beautiful plains, excepting S. Paolo, which lies partly on the slope of very fertile and agreeable hills. From none of these places can one see Vesuvius, as it is masked on the right by Monte Somma, and on the left by Monte Ottajano. Enough for the situation of these places! I now come to the point. On December 2, 1754, Vesuvius opened up on the side of Boscotrecase and of Ottajano, without being preceded by any earthquake shock. . . . On January 20 one began to see a thick smoke coming out of the side of the mountain, together with a large quantity of red-hot material.

"On the 31st of the same month two new mouths opened on the side of Ottajano, and the summit of the mountain now threw out nothing but smoke. Five days had scarcely passed since the volcano had ceased to vomit flames and stones, when the wind blew from the south, and the terrible malady which I am going to describe to you made its appearance at Nola and in the villages of which I have

spoken. It was a peripneumonia, which announced itself by great weakness and difficulty in breathing and by a little troublesome cough. The first day the pulse was normal, as also the urine and the tongue. On the second day the breathing became more difficult and hurried, and, if one put one's hand to the mouth of the patient one felt a great heat. The cough became more violent, without there being any expectoration ; the cheeks, eyes and lips seemed on fire and the tongue dry ; the urine had become watery, the pulse feeble and small ; all the patients complained of great headache and felt as though there were a great weight on the chest. In the night following upon the second day the cough and the difficulty in breathing increased so much that the patients were obliged to sit up. With some, delirium appeared constantly on the morning of the third day, and with others towards the end of that day ; the pulse became intermittent, the breathing hoarse (*sic*), although the patients had their heads raised ; but, in this position, the cough ceased. The tongue was black, the face and lips cyanotic. The surface of the body, which had preserved a natural heat during the whole course of the malady, became fresh ; the urine was small in quantity. When the patients had remained five or six hours in this state, they fell into a lethargy ; the surface of the body became cold,

the pulse stopped and they died in the night of the third day, or the morning of the fourth, or, at the latest, towards evening. None died under 18 years of age, but in twenty days thirty-two succumbed between the ages of 18 and 30; twenty-eight between 30 and 50; twenty-seven between 50 and 65. They were thus divided: Eight at Nola, thirty-five at S. Paolo, seventeen at S. Eramo, seventeen at Sirico and ten at Saviano. Neither the leeches, more or less abundant, which I made a practice of employing from the very commencement of the malady, nor the large blisters which I had applied immediately to the side or towards the scapula, nor the exhibition by the mouth of simple oximel with nitre or sal prunelloe, or with fixed, unwashed antimony, mixed by Boerhave's method and accompanied by decoctions of barley, were of any avail. . .

"Such was the state of affairs when, reflecting upon what it could be which rendered the ailment so rebellious to all the most natural, and usually the most efficacious remedies, it occurred to me that a very active, very powerful principle must be the cause. Although within the memory of man, or at least for the forty years that my father has practised medicine, we had no knowledge of a Vesuvian eruption having produced such disastrous effects, I judged, nevertheless, that this extraordinary malady must be attributable to the

smoke which issued then in abundance from the summit of the volcano and from the lava streams. I easily understood that this smoke, impregnated with sulphurous and ammoniacal constituents, which had been brought by a southerly wind to Nola and the environs and which one breathed in with the air, was the cause and reason of persistence of the malady, in that it contracted and irritated the interior membrane of the lungs; a property which these maladies have, according to the latest observations of Haller. It was not at all a mere conjecture, but a certainty, as the observations which I am about to describe will show.

"(1) The malady only attacked those who worked in the fields and who remained there the whole day, and never those who remained at home or who went out for a walk, or on a journey.

"(2) The malady began by a south wind and made progress the whole time that it (the wind) lasted: if the north or east wind began to blow the ailment ceased, although the latter winds were colder than the former; but if the south wind began again to blow, the disease also recommenced its ravages.

"(3) Those who worked in the fields of S. Paolo were the worst affected.

"(4) Finally all the remedies, whether interior or exterior, that one usually applies with

good results, only aggravated the disease and hastened death.

"Let me now be allowed to draw up the consequences of these observations. The country folk, who worked in the open, breathed an air charged with those particles of ammonia, sulphur, nitre, vitriol, which, as you remarked in your *Histoire*, rose from the already cooled lava in the form of mofetti, and took away the breath. It was these irritating particles which, brought to us by the southerly winds, were the cause of all the evil. For, if it is not yet certain that exhalations and vapours can be carried to a distance of thirty miles by the wind, at least none will deny that they can be spread as far as eleven miles (Italian). Also the southerly winds gave birth to and maintained the malady, and the other winds caused it to cease. Add to this that all those who worked in the fields of S. Paolo were the most affected, because this place being situated under the hills, the smoke could not be carried farther by the wind, which was charged with heavy particles, which rise with difficulty. These particles then, were more massed together there; consequently their action must produce more marked, more severe effects. Finally, the strongest proof is that every active remedy increased the evil because it had in itself an active principle. Moreover it was produced by a south wind, which, in our

country never causes such maladies, and it ceased when there was a wind from the north or east, which are the only ones which occasion them. Such are the strong reasons which support my opinion.

"I remember, Reverend Father, what the celebrated Doctor San Severino said to me upon this subject some months ago in your presence at the Baron de Schellendorf's, the chamberlain of the King of Prussia; that he could not believe that the epidemic of Nola had been caused by the eruption of Vesuvius, although all appearances seemed to prove it; because, he said, it had never been seen, even in the environs of Vesuvius, that the material vomited by it had produced such effects. However sensible his reflections may be, I can answer them in a few words. A heterogeneous, irritating matter, which is carried to a certain distance by the force of the wind, makes its effects felt there, where the force which pushes it begins to fail in some way, that is to say, where the wind begins to diminish, because there it can collect together. Vesuvius has its base at the edge of the sea; the southerly winds, which for us are the sea winds, therefore push with great force the smoke of Vesuvius and all the other exhalations from this volcano; therefore, in the neighbouring places the action of the wind, which is very strong, does not allow the

irritating particles, with which this smoke is filled, to act. But at Nola and in the surrounding places one scarcely feels the south winds; accordingly, all these particles can gather together there the more easily. Doubtless I shall be told that although the south wind blew in the last eruption the smoke of Vesuvius did not cause any malady. My answer is that the rain which fell then, as is known, in great abundance, killed the irritating particles—and none will deny that it has this property. Without these rains I believe that we should have experienced a disaster similar to that of 1755; for at the time of the last eruption, I mean that of 1759, I was called for many chest troubles, which I most happily cured because the exciting cause was without doubt a slighter one. I could make many more observations upon this subject, Reverend Father, especially upon the objection that may be made me that all the authors before you who have given a description of the eruptions of Vesuvius have never spoken of like things. But to that I will answer that there were then no careful observers, or that they attributed this sort of malady to other causes, as has happened to me myself; for I will own that it was only after that time, and especially in recalling what you had told me before about the effects of Vesuvian matter, that I began to believe that the disease of which I have spoken drew its origin from it.

"Let us pass now to the observations which I made upon the corpses which were opened during the course of this malady. They were all, immediately after death, covered with purple markings, which is to say that in every direction the blood made its way into the cellular tissues, the purple forming in no other way, according to the last observations of Haller. In the same way may be explained the cyanotic colour of the face and lips and that blackness of the tongue which were observable in the patients on the third day. I found nothing in particular in the abdomen, excepting that all the blood vessels which extend over this region were distended with blood. . . . The volume of the lungs was so increased that they occupied the whole capacity of the chest; they were like a mass of black-coloured skin; if one put them into water they fell to the bottom. If they were opened and cut one saw that the blood had penetrated into the pulmonary vesicles. The right ventricle of the heart and its auricle and the pulmonary artery were distended with blood; but the left ventricle and the adjacent vessels contained less than the right, although they were still fairly full. I only opened the head of three corpses, and I observed that in all three the vessels of the dura mater and the pia mater were filled with blood. I went no further with these discoveries, and afterwards

I reproached myself for not having continued my researches.

"I limit myself to these observations in order to pass on to the method which I employed at the end and to the means with which I happily cured my patients, and that in a short time. All the symptoms showing that the evil was caused by the contraction of the interior membrane of the lungs, one had to direct the treatment to anything that could simply expand it. Thus, from the beginning of the illness, without having recourse to the leech, I started by having applied exteriorally to the patients compresses of linen dipped in luke-warm decoctions of marsh mallow, althea, &c. I took care to let them imbibe continually by means of a funnel the steam of these decoctions, and I had some put in various parts of the patients' room to let them breathe the vapour. Interiorally I employed emulsions of mallow seeds, sweet almonds, and white poppy seeds, sweetened with sirop of violets. . . .

". . . The patients treated in this manner had, from the end of the first day, freer respiration and the cheeks less red; all the symptoms changed for the better. Then I proved that it was a good thing to have 10 or 12 oz. of blood drawn from the arm. Always continuing the exterior remedies of which I have spoken, I then began to add to each pound of emul-

sion half a drachm of nitre, which I continued to do also on the second day. On the third day the patients were cured, without the survival of the least expectoration or any other crisis. One had to employ the remedies of which I have spoken from the very beginning of the malady; for they were useless if the illness had made any progress. . . .

". . . Such, Reverend Father, are the details which you have demanded of me. I should, perhaps, have better fulfilled your expectations if I had had more time. At least I have tried to omit nothing essential. . . ."

"Signed JEAN VIVINZIO."

This is certainly one of the most carefully recorded examples in the eighteenth century of the supposed connection between the eruption and an epidemic.

Mecatti, again, refers in a casual way, when speaking of the eruption of 1759, to acute and inflammatory diseases and sudden deaths. Further on he refers to eye diseases, whooping-cough and peripneumonias, due to the same cause.

A common phenomenon in the immediate neighbourhood of a volcano is the disturbance of the level in the wells and the sudden turbidity and unpleasant taste and smell of the water, which often renders it undrinkable. Earthquakes are known to produce the same effect and no doubt the change in both cases

is due to the vibrations disturbing the water channels. The simple emanation of true mofetti, chiefly composed, as we know, of CO_2, would make the water more pleasant. What really takes place is the settling down of the fragments constituting the soil and the expulsion of gases and juices arising from the decomposition of organic matter therein.[9]

M. Torcia[10] remarks that, in the year 1779, all round the Bay of Naples they had second crops, which people attributed to the eruption. He wisely remarks that the same occurred at Capri and, in fact, from one end of Italy to the other, where the ashes did not fall. This well illustrates the unfounded character of popular, hasty deductions.

M. Attumonelli[11] discusses at great length the mechanism of death by volcanic exhalations, and attributes much to electricity, but admits he is not a naturalist. At that time our knowledge of electricity was embryonic.

Sir Wm. Hamilton[12] says that in the erup-

[9] See as an example G. de Bottis, "Ragionamento Istorico dell' Incendio del Vesuvio accaduto nel mese di Ottobre del 1767."

[10] "Relazione dell'ultimi eruzione del Vesuvio accaduto nel mese di Agosto di questo anno 1779," Napoli, 1779.

[11] "Dell'eruzione del Vesuvio accaduta nel mese d'Agosto, 1779," &c., Napoli, 1779.

[12] "Oeuvres complètes, traduites et commentées par l'abbé Giraud-Soulavie," Paris, 1781, pp. 260-266.

tion of 1779 the leaves of trees in the neighbourhood of Somma and Ottajano were covered by very caustic white salts, and that a royal keeper was much surprised by feeling his hands and face burnt by drops of rain.

R. Mead, who was physician to George II, wrote an article which was published in Italian in Galiani's book.[13] This article constitutes the chapter entitled "Venefiche Esalazione ed Effluvii che manda fuori la Terra." He there discusses, as well as the knowledge of his time allowed, the nature of mofetti. He attributes malarial and other malignant fevers to terrestrial emanations, especially in volcanic regions.

T. Monticelli, in his account of the eruptions of Vesuvius in 1822,[14] mentions that all small quadrupeds, land testacea, insects, birds, &c., were killed within an area of five miles around Vesuvius.

A. Scacchi[15] makes no mention of any epidemic disease, though several imprudent people were suffocated by the mofetti, and as this writer was a well-trained scientific man and a

[13] "Dei Vulcani e Monti Ignovomi," Livorno, 1779. See pp. 195, vol. ii, *et seq.*

[14] "Opere," Napoli, 1841, in three vols.

[15] "Relazione dell'incendio accaduto nel Vesuvio nel mese di febbraio del 1850, seguita dai giornalieri cambiamenti osservati in questo vulcano dal 1840, sinora," *Rend. R. Accad. Sc. Napoli*, vol. ix, 1850, and Ann. d. Mines, 4me. ser., vol. xvii, Paris, 1850.

careful observer, such negative evidence is of considerable value.

The same author, in collaboration with L. Palmieri, prepared the report on the eruption of 1855. They mention the death of all the silk-worms, which they think may have been due to the volcanic exhalations or the poisonous state of the mulberry leaves from the volcanic dust. Later, in May, an epidemic fell upon the horses, nearly every one falling ill, and a great number dying. This they attribute to the volcanic exhalations of Vesuvius "*the eruptions of which often bring epidemics amongst mankind.*"

For further details as to the composition of volcanic mofetti and the physiological action of carbonic acid poisoning see Collard de Martigny,[16] and Snow,[17] and the opinions of Claude Bernard.[18]

The lake of Avernus was credited by Virgil as possessing an atmosphere that was irrespirable by birds—yet no record is given of its maleficent action upon man, or of its producing epidemics. In fact the large number of build-

[16] "Action du Gaz Acide Carbonique sur l'économie animale," *Archives Générales de Médecine*, t. xiv, p. 203.

[17] "On the Pathological Effects of the Atmosphere vitiated by Carbonic Acid Gas and by a diminution of Oxygen," *Edinb. Med. and Surg. Journ.*, vol. lxv.

[18] "Leçons sur les effets des substances toxiques et médicmenteuses," p. 106.

ings on its shores, including the Temple of Apollo, distinctly negative any such conclusion.

Turning our attention to the literature of Etna, we see that frequent mention is made by earlier writers as to the injurious influence of its eruptions on human beings. Maravigna [19] speaks of the eruption of 1669 as producing diseases amongst the inhabitants, but makes no mention of such ailments.

G. Recupero [20] reports that different diseases such as anginas, catarrhs and dysentery were prevalent, especially on the south side of Etna, in the eruption of 1763, which caused a high mortality. He, himself, had erysipelas of the face, from which he says he recovered by a miracle.[21] The observations were confirmed by F. Ferrara,[22] who declares that the chief affections were those of the organs of respiration and of the eyes.

Iceland offers many examples of the destructive character of volcanic eruptions to human, animal and vegetable life on a scale hardly surpassed in other parts of the world, and

[19] "Storia Generale dell'Etna."

[20] "Storia naturale e generale dell'Etna," Catania, 1815, 2 vols. in fol.

[21] *Ibid.*, t. ii, p. 132.

[22] "Storia generale dell'Etna che comprende la descrizione di questa montagna: la storia delle sue eruzione, e dei suoi fenomeni," Catania, 1793, p. 93.

recorded by a cool-headed, matter-of-fact people.

Hecla, in one of its nineteen recorded eruptions, that of 1636, ejected "masses of sulphur, cinders and pumice," in consequence of which the health of the country suffered very much, the inhabitants were ravaged by an epidemic, and large numbers of cattle perished. In 1693, thousands of birds died and the rivers were filled with dead fish.[23]

The same author, in describing the eruption of Hecla of 1666, mentions the dust being carried 240 km., completely darkening the sky with ejections of red hot stones to several kilometres distant, and followed by an immense column of hot water. The result was that the inhabitants were decimated by "a disease" and the animals by an "epizootic." The following quotation is from Mr. J. C. Scythe, concerning the Hecla eruptions of 1845. "Disease spread amongst both men and animals. The exhalations of acid vapours and the dust which stuck to the grass seemed to be the principal cause. The wool of the sheep fell off, their bones and their teeth were the most injured. Tumours developed in their jaws and caries attacked the bones of the head. Cows suffered more than the sheep. The hair fell off and many perished. Horses resisted

[23] J. C. Scythe, "Description des Phénomènes de l'Hecla."

the best. The birds flew away and the wood-fowl (gelinotte) disappeared entirely from the country to the south of the volcano."

The great Kötlugjà (or Kettle Rift), according to Messrs. Olafsen and Povelsen,[24] produced in the eruption of 1755 much the same effects.

In 1783 the tremendous outburst of the Skaptár Jökull district took place in the south country. Two radiating fissures or *gjas* rent the ground and, from a great number of mouths, gave forth two lava streams, one roughly fifty miles and another some thirty miles in length. The fragmentary ejecta filled the atmosphere with dust and is said to have dulled the whole atmosphere of Europe. Twenty villages were destroyed and 9,000 people killed, besides an enormous amount of cattle. Speaking of the same eruption Dr. Ebenezer Henderson[25] remarks "What was more terrible was the volcanic materials shot up to such an altitude that they spread over the whole surface of the island, impregnating the atmosphere with a nauseous vapour, intercepting the sun's rays and poisoning all that could satisfy hunger or quench the thirst of man and animals. Fish abandoned the coast; the elements

[24] "Voyage en Islande. Trad. par Gauthier de Lapeyronie," t. iv, 271.

[25] "Voyage en Islande."

seemed to compete amongst themselves which would do the most damage. Famine and disease spread their ravages on all sides."

This eruption commenced on June 8. On June 17 the fine ejecta reached the nearest lands of Norway, Denmark and parts of Germany, forming the north-west coast of Europe. This continued till July 22. M. Morgue de Montredon mentions[26] in letters from Copenhagen "that this thick vapour dried up the grass of the fields, changing its colour, and that most of the leaves of trees fell off." "This vapour had," it is said, "a strong and disagreeable odour of sulphur."

From America we can choose similar examples, such as that of the eruption of the Coseguina in Nicaragua in 1835[27] or in 1791 the eruption of Imbaburu, South America.[28]

Similar accidents of the effect of mephitic vapours on man and animals have frequently been recorded, such for instance as at the Pic de Teneriffe in 1704.[29] Lancerote in 1730.[30]

[26] "Recherches sur l'Origine et sur la Nature des Vapeurs qui ont regné dans l'atmosphère pendant l'été de 1783," *Mem. Acad. Sc. Paris*, 1784.

[27] Coldclough, *Phil. Trans.*, 1836, p. 27.

[28] C. Lyell, "Principles of Geology."

[29] "Bory de Saint-Vincent, Les Iles Fortunées," p. 290.

[30] Leopold von Buch, "Description Physique des Iles Canaries."

"The eruption of Fuen-Coliente," Palma, in 1678.[31] N. P. Wassilieff records a similar striking example from a volcano of the Ouyüne-Kholdongue in Manchuria.[32]

Perhaps the best account we have of the whole question is the interesting little work of D. L. de Corogna,[33] from which I have quoted several of his examples. He says that nearly all eruptions in the neighbourhood of Santorin intelligent people do not hesitate to credit as producing certain morbid states. In the 1650 eruption the air was filled with sulphurous vapours, so that precious metals were tarnished, and on September 30, nearly all the inhabitants suffered from sharp pain in the eyes with great secretion of tears, and most remained blinded for a couple of days, some dying from these ophthalmias, whilst others were suffocated by the pestilential vapours, so that about fifty human beings and a thousand animals perished. P. Richard, who recounts this,[34] says, "The sulphur reached the brain so quickly and so violently that it paralysed all sensations of the dying." When those who had been

[31] L. von Buch, op. cit.

[32] *Bull. Soc. Geol. France*, 2 ser., t. xiii, 1856.

[33] "De l'Influence des Emanations Volcaniques sur les Etres Organisés, particulièrement étudiée à Santorin pendant l'éruption de 1866."

[34] "Relation de ce qui s'est passé de plus remarquable dans l'île de Santorin," Paris, 1656. See p. 421.

temporarily blinded regained their sight, they were unwise enough to approach nearer the eruptive focus, but were suffocated and died on the spot. Those less near escaped with attacks of fainting only. A ship that passed too near the volcano had all its crew suffocated on October 2. On November 4, a shower of black dust fell over the neighbouring country and killed about twenty labourers.

In the Santorin eruption of 1707, the exhalations, even with "the strongest men, impeded their breathing and they had frequent faints or violent headaches, and with many of them it produced repeated vomiting." The air was described as "like that in a tempest at sea when a general discharge is made and the odour of the powder, mixed with that of the hold and the tar, makes the strongest sailors vomit." We must remember that the eruption was intra-marine and therefore no doubt disturbed a lot of old putrefying mud and other organic deposits.[35]

L. da Corogna remarks[36] that the "usual maladies of the island are fevers, rheumatisms, dysenteries, affections of the chest and some chronic ailments." At the commencement of the 1866 eruption there was a marked improvement in the health of the islanders

[35] L. da Corogna, op. cit. pp. 132-133.

[36] Op. cit., p. 134.

from all these maladies, which some attributed to more ozone and electricity, but which idea he did not accept, and rather attributed to "sulphurous and ferruginous emanations."

Later the local physicians remarked the invasion of the population by diseases of the eyes, anginas, cephalalgias, bronchial, and digestive troubles, though they kept no records. Corogna, on his arrival, examined eight cases, which I here resume :—

Observation No. I.—Mademoiselle B., aged 21, tonsillitis, pharyngitis and laryngitis, coming and going as the wind blew the smoke and vapours over Phira, her place of residence.

Observation No. II.—Madame B., aged 51, usually liable to migraines. Now gets gastric upset with foul tongue, nausea or bilious vomitings, loss of appetite, reddish urine and violent headaches when the vapours are blown in the direction of her residence.

Observation No. III.—Mr. M. D., aged 40, very strong and healthy, developed simple conjunctivitis with sharp pain and photophobia, cured in a few days by a solution of zinc sulphate.

Observation No. IV.—M.G., aged 45, subject to dysentery, but not to eye troubles. Had a conjunctivitis lasting thirteen days cured by argentic nit. sol. and leeches.

Observation No. V.—X., young man, aged 24, up to the time of eruption was quite well in

his lungs. He developed a bronchitis with violent cough, slight hæmoptysis and sore throat, especially when the volcanic vapours reached him, followed, after three or four days, by a free expectoration and "febrile pulse"; the first few days he had hoarseness and occasional pains in chest. On auscultation mucous and sibilant râles. Under treatment, recovered in a fortnight.

Observation No. VI.—Madame D., aged 50, nervous temperament. Intense headaches since commencement of the eruption, which came and disappeared with the vapours. She migrated out of reach of these and henceforth was free.

Observation No. VII.—Madame F., aged 30, healthy, was attacked by a severe angina, limited to the tonsils and superior part of the pharynx, after two days' exposure to the volcanic fumes. There was marked redness, pain and dryness of the throat with difficulty of deglutition, which was cured in a few days.

Observation No. VIII.—Mademoiselle S., healthy. Each time the volcanic fumes reached her she was attacked by nausea, followed by vomiting, anorexia, foul mouth and coated tongue.

Da Corogna says that other islands, twenty or thirty miles away, markedly suffered from the volcanic vapours when blown in their direction.

The fumes of the Santorin eruption were analysed by M. Fouqué and were not found different in composition from those in other eruptions and localities, though H_2S. seems to have been more than usually prevalent. Corogna found that, on introducing some of the acid and saline dust into the eye of a guinea-pig, the animal developed conjunctivitis in twenty-four hours.

CHAPTER V.

Physical Effects of Eruptions on Plant Life.

Of course, all plant life is destroyed by a lava stream, and the destructive effect of the radiant heat often extends some distance on each side of the flow, especially on the lee-side. Trees, when surrounded by a lava stream, stand for some time, until all the green wood of the stem is scorched. A wreath of flame surrounds the tree at the margin of the lava from the distilled gases from the wood. Eventually, when all the trunk is carbonized, a gust of wind topples the tree over which has only a fragile charcoal stem to support it.

When a thick layer of dust or lapilli falls, all plants of herbaceous character are completely killed, whereas bushes and trees may be singed or completely burnt, as the intensity of the action varies. If the ejecta are not very hot, but consist of big blocks, the branches are broken off. Anderson aud Flett found the trees blasted, especially on the side towards the volcano. In the last great Vesuvian eruption all the woods on the north slope of

Monte Somma showed the smaller twigs broken, and the bark stripped from off the upper surfaces of the spreading branches. The woody stems of small herbaceous plants were frayed into rags before they were buried. Lower down the mountain the vines were in the same condition, and were buried at Ottajano and S. Giuseppe under a layer of from 50 cm. to 1 metre of stones and lapilli.

The worst moment of destruction was April 7 and 8, yet all these vines soon sprouted, and the same autumn actually bore some fruit.

Mr. Narlian's plantations of vines on the Isle of Vulcano were, to a large extent, destroyed by the eruption of Vulcano in 1889, but here the ejections went on for weeks. Notwithstanding this, many of the vines eventually sprouted. Vines and other deep-rooted plants naturally resist, where those which draw their nourishment from near the surface must obviously perish.

In cases where the fall of ashes is slight, the leaves of all plants are damaged by the blocking of the respiration pores, as are plants kept in a dusty house without being washed, though in the former case the leaves are more seriously damaged by the caustic action of the acids and salts associated with the dust. If a slight rain occurs at the same time, the volcanic dust is converted into a caustic mud which smears and cauterizes everything.

Torrential rains, on the contrary, have obviously a beneficial effect.

The following are a few examples of the damage wrought to vegetation by volcanic eruption, quoted from other writers :—

J. A. Borelli[1] states that the injury to vegetation produced by the 1669 eruption was enormous. There were 25,000 salmi of wine less in that year. The same occurred in 1694, according to Maravigna.[2] In 1763 the harvest was almost entirely destroyed, and the olives and vines also suffered much damage.[3]

Ferrara insists that the caustic action of the dust of the eruption of Etna in 1787 burnt the young plants and the buds and sprouts of the trees. According to him the Piano di Mascali and much of the country to the south of Etna were devastated. The showers of dust and lapilli destroyed all the vineyards and trees of the middle zone, so that in some places nothing but the trunk was preserved.

In 1852, G. Gemmellaro[4] says of the damage done to vegetation that the smoke of the volcano, spread over the surface by the wind and

[1] "Historia et Meteorologia incendii Aetnaei anno 1669 ac responsio," &c., Regio Calab. 1670; see cap. iv.

[2] Op. cit.

[3] Recupero, op. cit.

[4] "Sunto del giornale dell'eruzione dell'Etna nel, 1852." *Atti. d. Accad. Gioenia,* Ser. 2a, vol. ix, Catania, 1854, pp. 113-141.

"saturated with HCl, and the showers of ashes (dust) attacked the plants in all the neighbourhood. Thus Zaffarana, Santa Venerina, Bongiardo, Dagala, and all the fields near Mascali and Giarre were burnt by the volcanic vapours.

L. Spallanzani[5] mentions the fact that the smoke of Stromboli, when laid down the slopes of the mountain by the wind for more than a few hours, damages the vines and prevents the grapes from ripening.

D. de Dolomieu[6] recounts that the vapours of the Isle of Vulcano were destructive to vegetation, and in consequence the Bishop launched an anathema on those who dug for sulphur and liberated more vapours.

In Iceland, Hecla is said to have been once surrounded by fertile plains, but J. C. Scythe says that all the pasturage was destroyed for a great distance around by the eruptions of 1636 and 1693, which again occurred in 1766. A similar repetition of plant destruction followed in 1845. In 1890, when the writer visited the district, the areas of lava streams were of course quite barren, but the birch bush forests around the toe of the mountain,

[5] "Viaggi alle due Sicilie e in alcune parti dell' Appenino," Pavia, 1792-97. Also French, German and English editions.

[6] "Voyage aux Iles de Lipari fait en 1781," Paris, 1783, in 8.

growing on loose sand and lapilli, seemed very prosperous.

In the eruption of Coseguina in 1835 the ejecta fell as far as eight leagues to the south of the crater, and, in great part, destroyed the forests along their path.[7]

Gonzalès F. de Oviédo says that in the Masaya, Central America, eruption all vegetation was dried up for two leagues around.

In an earlier eruption of the Morne Garon, St. Vincent, in 1812, all the plantations of the island were destroyed. The accounts of the hot blast in the more recent eruption, given by Messrs. T. Anderson and Flett, were that the destruction was but partial and limited to the neighbouring parts of the Soufrière.

G. Hartung gives a long description of the damage done to the harvest on St. George's Isle in 1580,[8] and a red dust, ejected in 1672, likewise did great damage to harvest and pasture.

In 1800 the Japanese volcano, Guntur, ejected "a white mud, acid, with a sulphurous odour," completely devastating a fertile valley. In 1822 the volcano Galung-Gung, south of Talaga Bodas (Oceania) wrought much destruction to vegetation.[9]

[7] *Phil. Trans.*, 1836.

[8] "Les Açores," p. 103 *et seq.*

[9] L. von Buch, op. cit., p. 424.

It is almost incredible that, as late as 1857, G. Gigli [10] expresses an opinion that volcanic dust may generate insects that attack the vines and, though he does not say so, he leads one to infer that cholera could be produced likewise. Compare this with P. Castelli,[11] who describes the *absence of all sorts of vermin* after the 1631 eruption and recognizes the improved crops due to this cause and especially to the dust, washed by the rain, acting as a fertilizer. Another queer hypothesis is put forward by M. Carusi, [12] who refers the sprouting of new plants after a big eruption to "electrical attraction."

In Da Corogna's mission to the Santorin district affected by the eruption of 1866 [13] he noticed that plants belonging to the Liliaceæ were those most affected, and especially the *Aspodelus ramosus*. He carried out a series of experiments, and found that by washing the damaged leaves in distilled water he obtained HCl with chlorides of ammonium and sodium.

He exposed a series of plants to fumes of H_2S, HCl, NH_4S_2, and found that HCl was more rapid in its action but did not penetrate

[10] "Discorso sulla Zona Vulcanica-Mediterranea," Napoli, 1857.

[11] Op. cit., p. 71. [12] Op. cit., p. 62.

[13] Op. cit., p. 148 *et seq.*

far, being more of the nature of a caustic. The sulphide acted slower but more completely, producing effects more allied to a toxic poison to plant life.

The results harmonize with those of Messrs. Turner and Christison[14] and those of De Candolle.[15]

I have noticed the same effects near the "Calcaroni" in Sicily (the kilns in which sulphur is melted out of the ore by the burning of some of itself with the liberation of sulphurous acid). The country all around a soda factory, where some of the HCl fumes escape, soon becomes a barren waste.

[14] "On the Effects of Poisonous Gases on Vegetables," *Brewster's Edinb. Journ.*, 1828, p. 140.

[15] "*Pysiologie végétate*," pp. 1345-1363.

CHAPTER VI.

Influence of Eruptions in the Production of Hurricanes and Abnormal Atmospheric Vicissitudes.

WHAT was said with regard to the imaginary relationships of eruptions and epidemic diseases applies with equal force to this meteorological question.

Certainly the idea goes back into mythological times, for the Lipari, or, as they were earlier called, the Æolian Islands, gained their reputation from this popular superstition. The ancient mariners had noticed the apparent increase of smoke from Stromboli with the warm, supersaturated Sirocco wind, usually associated with a cloud cap to the mountain, and followed by warm rain. Similarly they had remarked that, when the air was dry and a Greco or Tramontano was blowing a streak of smoke down the side of the cone, dry, fine, but windy weather was to be expected. When the air was calm and the smoke plume small and rising straight up, warm, fine, dry weather would follow.

The fishermen of all this neighbourhood still

use Stromboli as a weather glass, and the writer has often followed their example with satisfactory results.

The ancients therefore installed their god Æolus in these islands, and no doubt this superstition was the root of all subsequent ones. The actual relationship of Vesuvian activity to varying meteorological and astronomical conditions has been carefully studied by myself.[1]

Amongst ancient writers we may quote Strabo.[2] As the result of observation it has become a belief that here (Æolian Islands), as well as at Etna, these exhalations of fire are fomented by the wind, and, as this falls, so do they (the exhalations).

As an example of this class of false deduction even so late as the latter half of the nineteenth century, we can cull the following: Taking the case of G. M. Carusi, who tried to show some association of hurricanes and abnormal atmospheric vicissitudes with eruptions,[3] and

[1] "The Relationship of the Activity of Vesuvius to certain Meteorological and Astronomical Phenomena," *Proceed. R. Soc. Lond.*, No. 243, 1886; also "De la Relation existant entre l'Activité du Vésuve et certains Phénomènes Météorologiques et Astronomiques," *Bull. Soc. Belge Geol. Palêontol. et Hydrol.*, t. xxi, 1907, pp. 303-324, pl. 1.

[2] *Lib.* 6, p. 423.

[3] "Tre Passeggiate al Vesuvio ne' di' 3 e 21 Giugno e 27 Settembre, 1858," Napoli, 1858, in 8, pp. 65; see p. 25 *et seq.*

gives a series of reports of storms from different parts of Italy at dates ranging from June 7 to 23, but really one cannot see the relationship of these to increased activity of Vesuvius.

Compare this with the clear-headed judgment of one of his contemporaries, F. del Guidice.[4] I cannot put the subject before you in better words than his :—

"There is no want of true historians who, accurate in collecting facts coincident, in their opinion, with eruptions, have recorded windstorms, hurricanes, a furious state of the sea, and many other such things. But, penetrating in the full light of reason, and without bias, in this twilight of human knowledge, with more expeditious and certain steps, anyone can correlate the incidents related with the season in which they occurred and with their history, over a long period of years.

"Is there anything astonishing that, during an eruption in January and February, the sea became squally, ships were in danger, winds were violent and tempestuous? How frequently such incidents are repeated in the winter without the slightest sign of any volcanic agitation."

[4] "Breve Considerazioni intorno ad alcune piu constanti fenomeni Vesuviani," *Atti R. Ist. d'Incoraggiamento di Napoli*, vol. ix, 1855, p. 57 *et seq.*

We all know, experimentally, that fine dust and acid gases produce the precipitation of moisture. The drizzle of London, Glasgow, or other smoky towns is, unfortunately, a big illustration of it. Those who visit the Solfatara or the fumaroles on Vesuvius, know the common experiment of burning a little paper or straw, and the enormous apparent increase of vapours that occur as the result. I have often illustrated the same by breathing across the stopper of an HCl bottle.

The torrential rains that often accompany an eruption owe their origin to this process, whether the water be derived from a supersaturated atmosphere or from condensation of the volcanic vapours as they are cooled in the upper atmosphere.

The lightnings that accompany an eruption and that not infrequently kill people who approach too near, probably owe their existence to frictional origin in the rising and falling ejecta, or are of hydro-electric origin, as in Armstrong's steam-jet generator. The late Professor L. Palmieri made many long and detailed observations, records of which are scattered through his numerous writings.[5] These electrical conditions, were, from a practical climatic point of view, of little importance.

[5] *Ann. R. Osserv. Meteorolog., Vesuviano*, Napoli, 1859, *et seq.*, &c.

No doubt, when the volcano has approached so near its critical point of tension, the sudden barometric fall that precedes a storm is sufficient to turn the scale in favour of the volcanic outburst. In fact this has often been noticed, not only in volcanic eruption but especially with earthquakes.

The light phenomena produced by the fine dust in the atmosphere were first seriously discussed by the Hon. F. A. Rollo Russell,[6] who wrote upon afterglows, blue, green, and coloured appearances of the sun and moon, sky-haze and coronas to sun and moon. He also cites the earlier observations of the association of these light phenomena to volcanic outbursts from 1510 to 1886. A. Heilprin[7] discusses and summarizes these twilight glows, bishop's rings, anthelia after the Mont Pelée disaster, but a fuller analysis is given by E. Marchand.[8]

Barographic disturbances are occasionally noted after very violent eruptions, but these do not appear, so far as they have been studied, to be more than purely academical in interest.

[6] Krakatoa Report of the Royal Society, 1883-86.

[7] "The Eruption of Pelée," a summary and discussion of the Phenomena and their Sequels, *Philadelphia Geograph. Soc.*, 1908, in 4°.

[8] *Annuaire de la Société Météorologique de France*, 1905.

CHAPTER VII.

General Conclusions.

It would be no difficult matter to increase the number of quotations and records of eruptions with their supposed effects on man, animals, plants and atmosphere, but I doubt whether any good would accrue.

In the light of modern knowledge we are certain of some fundamental facts that were not, nor could be, appreciated a few years ago. In the first place it is obvious that all volcanic materials, with the exception of mud from the sea bottom, from crater lakes or from the organic, contaminated slope of the mountain, are *aseptic*, having been exposed, or even originated, at a very high temperature. In the next place, not only are they *aseptic*, but they are, furthermore, *antiseptic* from the nature of the volatile acids and salts which are mixed with them. On the other hand, it is an indisputable fact that many diseases and epidemics accredited to volcanic eruption are known to be due to a definite microbe. It is evident, therefore, that the one precludes any definite relationship to the other. In fact we are forced

to conclude that, not only are volcanic ejecta incapable of *directly* producing epidemics, but rather the atmosphere and the earth's surface are actually, more or less completely, antiseptic ized by their agency. I do not hesitate to say, therefore, that there is no *direct* relationship between volcanic eruptions and disease in man or animals.

There are, however, several *indirect* ways in which epidemic diseases may be brought into existence, or, at any rate, accelerated by volcanic outbursts—which I will take seriatim :—

(1) The irritant and depressing effects of poisonous fumes may be so erosive as to lower the resisting power of the mucous membranes of ocular, respiratory, and, to some extent, upper digestive tracks to microbic invasion.

(2) Water-courses may be disturbed, landslips contaminating them with organic impurities ; proper drainage of sewage may be impeded, wells infected from surrounding contaminated soil, ventilation of houses prevented —all of these being malignant influences, favouring diseases, epidemic or otherwise.

(3) Moral depression from fear—a condition well recognized as rendering living beings less immune to infection. Imperfect nourishment from destruction of food stuffs, agricultural land, the cutting off of food supply communications and suspension of bread-winning work.

The evidence of a relationship between

earthquakes and epidemic diseases in man and animals, although outside the scope of this essay, is far more definite than that of eruptions, yet there is no doubt that the effect of earthquakes is *indirect.* In fact, sections (2) and (3) apply equally well to both classes of terrestrial dynamics.

Out of all the evidence brought forward there are really only those of Dr. Vivinzio and M. da Corogna, which are sufficiently detailed as to be submitted to satisfactory analysis. Dr. Vivinzio's observations are, no doubt, correct, but his conclusions are untenable. In the first place, Vesuvius and the neighbouring Campania is an admirable locality of observation. Its enormous population, its varied rocks, soil and levels, the great number of its extensively recorded eruptions, make it an unrivalled spot for such investigations. What we really do find is that it is a comparative rarity for any describer of Vesuvian eruptions to even mention the subsequent prevalence of any epidemic. Surely, after the great eruption of 1906[1] some definite epidemic would have

[1] Johnston-Lavis, H. J., "The Eruption of Vesuvius in April, 1906." *Scientif. Proceed. Roy. Dublin Soc.*, vol. ix, pt. 8., January, 1909, p. 63, 16 pl., 2 plans, 2 figs., and 2 col. maps. Also Mercalli, G., "La Grande Eruzione Vesuviana cominciata il 4 Aprile, 1906," *Mem. Pontif. Accad. Rom di Nuov. Lincei.*, vol. xxiv, 1906, pp. 34, pl. v.

occurred in the numerous towns and villages that were, more or less, damaged or destroyed by the ejecta or that received the showers of dust?

The epidemic of pneumonia, described by Vivinzio, I have seen occur in the neighbourhood of Naples in several localities at different times, and quite independent of any increased activity of Vesuvius.

The ailments of the people of Santorin, described by Da Corogna, were, unquestionably, either mechanical or chemical, and, although such wide-spread ailments do occur after eruptions, they can hardly be called epidemiological in the usually accepted sense of that word.

The destructive, mechanical, physical or chemical effect on plant life is very marked in some eruptions, amounting, in certain cases, to very great damage. On the other hand, I have already referred to the great fertilizing effect of igneous ejecta when spread over barren limestones. Furthermore the last (1906) eruption of Vesuvius, notwithstanding much damage done at the moment of the outburst, has added much valuable agricultural land to the slopes of the mountain. For a good many years the constant large and small outpourings of Vesuvius covered much valuable land with lava streams, the jagged surfaces of which require centuries to decompose sufficiently

to support plant life of any importance. In a few hours much of this was buried under thick layers of volcanic dust and lapilli. The following November I saw that, after being washed by the autumn rains, this new soil was already, in many spots, planted with flourishing cabbages, cauliflowers, lettuces, &c., and, a year or two after, was supporting plantations of prosperous-looking young vines.

A soil that contains from 4·22 per cent. to 7·05 per cent. of potash, and from 0·12 per cent. to 0·852 per cent. of phosphates is obviously one of the most ideal ones. The potash is tied up in an insoluble form to ordinary water percolation, and, therefore, devoid of caustic action, but E. Casoria[2] demonstrates that, by the solvent effect of humic acid and other root secretions, sufficient leucite is *digested* for the complete requirements of potassic and phosphatic nourishment of each plant. Large potash consumers, like the Solenaceæ (tomatoes, tobacco, potatoes, &c.), may be grown consecutively, without rotation of crops, for many years on the slopes of Vesuvius. Vines, large potash consumers, here reach a point of development almost unrivalled in the world.

[2] "Mutamenti chimici nelle lave vesuviane per effetto degli agenti esterni e delle vegetazione," *Boll. Soc. Naturalisti in Napoli, ser.* 1a., vol. ii, an. 2, 1888, p. 18.

Although damage may be done to vegetation by the fall of dust and lapilli, the complete destruction of worms, snails, insects and parasitic fungi must be eventually a great asset to the revived plant-life of the region. The great absence of, especially, worms and land snails around an active volcano is worthy of remark.

If we audit the accounts for good or evil to plant life, I think we shall be safe in saying that there is much on the credit side.

Of the production of hurricanes and abnormal atmospheric vicissitudes, little further can be added to the remarks in Chapter VI.

Beyond the condensation effects from the dust and gases, the rendering of the atmosphere a little more opaque to the sun's rays, and coincident sun and moon appearances with some magnetic disturbances, no great meteorological commotion can be laid to the account of volcanic eruption.

The subject of this essay is a far-reaching one, involving an extensive knowledge of several branches of human learning, and this, or any other debate can but mark time in our efforts to clear away ignorance and superstition, and replace them by a common-sense view of natural phenomena.