Graduating Thesis.

Origin of the Soil.

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Reference books:

Rocks and Soils by Stockbridge.
Weathering of Rocks by Merrill.
Introduction to Geology by Scott.

Origin of the Soil.

I Origin of our Planet.

Our common views as to the origin of this earth upon which we live, move, and have our being are based upon a theory known as the "nebular hypotheses." It is supposed that ages ago all space extending far out beyond the extreme limits of the most distant planet now known, was filled with mist and nebula with a central nucleus which is now the sun. This mass of nebula gradually radiating heat contracted and of necessity caused a rotary motion from west to east. As some portions were denser than others on contracting there was a greater attraction towards the denser centers gradually forming a number of rings each of which was destined to form a planet.

As the radiation of heat increased the contraction also increased and in turn accelerated the rotary motion until it reached the velocity which by the laws of centrifugal force was capable of throwing off these outside

rings from the central mass. These masses thrown off continued to contract and rotate until each one formed a planet of itself. Thus originated our own present earth.

In this vaporous condition it still radiated heat until finally ages later it condensed to the liquid state- a mass of molten rock. But the liquid gradually became denser and denser until it solidified, and now we find that what was originally a mass of nebula is on the outer surface of the sphere a crust of hot material known as rock. The cooling process continued until the surface would allow the vapor, as it condensed into water and fell, to remain. Thus we have the outer crust of rock, the material from which the soil originated, and the water, the most active natural agent in disintegration.

II. Descriptions and Classifications of Rocks.

Before taking up the processes of decomposition, I will give a description

and classification of the rocks.

A rock is defined as any material of the earth's crust, which may contain but a single mineral but usually is a mechanical mixture of several minerals. All rocks fall into one of three classes on the bases of a genetic classification, namely, igneous, sedimentary and metamorphic rocks.

The igneous rocks were the first to be formed from the cooling of the surface of the globe. Hence, they are the ones from which all others have had their origin. In later ages the igneous rocks have a deeper seated origin and fall into two divisions, namely, the plutonic, those that have solidified deep within the earth and been brought to the surface by the removal of overlying mass, and second, the volcanic, those cooled near the surface.

The igneous rocks fall into five distinct families as follows:

Granite Family

The granite family contains from 65 to 75 % of silica and 10 to 15 % alumina.

It is comparatively rich in the alkalies, (Sodium and Potassium) it also contains iron oxide, magnesia, and lime. On consolidating the principal minerals found are quartz, orthoclase, oligoclase, and hornblende. The family further divides itself into obsidian, pitchstone, pumice, and rhyolite all of a glassy texture; and quartz porphyry and granite. The last two named being of the greatest importance. The quartz porphyry contains orthoclase and quartz. Orthoclase is one of the varieties of felspar containing potash; the final product of its decomposition is kaolin.

Quartz forms the principal mass of rock formation and crystallizes in hexagonal forms.

The granites are thoroughly crystalline rocks. The principal minerals are quartz, orthoclase, and mica. The color is dark or light depending upon the amount of silicates in it. Texture from fine to very coarse.

Syenite Family

The syenite family is similar to the granite family except the proportion

of silica is less being from 55 to 65 %. The principal mineral is orthoclase. The syenite obsidian is indistinguishable from the glasses of the granite family except by analyses. Trachyte and phonolite are similar; the phonolite differing in having a higher percentage of sodium. It separates into thin plates and when hit gives a peculiar ringing sound.

Syenite is a crystalline rock resembling granite in appearance but having no quartz. It consists of orthoclase, oligoclase, and hornblende.

Diorite Family.

The diorite family contains about the same amount of silica as the preceding family but less alkalies and more lime and magnesia. The principal mineral is soda-felspar.

Basalt Family.

The basalt family has a small amount of silica and alkalies but a large percent of lime, iron and magnesia. The principal minerals are plagioclase felspar and magnetite and are uncommon glass tachytyte. The

different varieties are basalt, trap, dolerite, diabase and gabbro.

Ultrabasic Family.

The ultrabasic family has no felspar. The quantity of silica is below 45 %. It is composed almost entirely of ferro-magnesian minerals

III. Processes of disintegration.

The disintegration of rocks is constantly going on. The decomposition consists of two processes. The first is the destroying of the form or pulverization affected by the change in temperature, chemical action of water and air, and organic life. The second is the transformation process resulting from running waters, movements of glaciers and icebergs, and the action of the ocean.

1. By External Forces.

The four distinct factors carrying on the process of transforming rock into soil are: 1. Change of Temperature; 2. Action of water both mechanical and chemical; 3. Action of the Atmosphere; 4. Action of Organic Life; Each of these will be taken up and

treated separately.

Change of Temperature.

It is a well known fact that heat expands and cold contracts. At first thought it seems hardly probable that the change of temperature from time to time would be enough to make any material difference in rocks bringing about decomposition but such is the fact. As the temperature is constantly changing and every degree causes a corresponding expansion or contraction of the molecules in the rock materials there is a tendency to weaken the power of cohesion and set up an oscillating movement. This action opens the way for other physical and chemical forces ready to step in and carry the process a stage further.

*"The actual movement of expansion and contraction of stone under ordinary temperatures has been a matter of experiment. W. H. Bartlett has shown the the average rate of expansion for granite amounts to

* Merrill, page 120-1

.000004825 inch per foot for each degree F.; for marble .000005668 inch, and for sandstone .000009532 inch."

Shaler states that rock surfaces in the eastern United States may be subjected to temperatures varying from 150° F. at midday in summer to 0° and below in winter. This change of 150° in a sheet of granite 100 feet in diameter would produce a lateral expansion of about one inch of surface. That this expansion must tend to lessen the cohesion and tear the upper from the deeper layers is self-evident.

Rocks being poor conductors of heat will not be affected below the surface or at the surface for any great length of time unless it is on a slope where all loose material will be removed by some physical agent.

Action of Water.

The most active agent in nature in the disintegration of rocks is water, acting both in the liquid and solid state. Water, vaporizing from the seas and lakes, carried by the winds

over hills and valleys, then condensing and falling in the form of rain, dissolving the gases of the atmosphere, produces marvelous geological changes upon the surface of the earth by both its mechanical and chemical actions.

Mechanical Action of Water.

The transformation resulting from the physical action of water must be considered from two different modes; first, abrasion or erosion caused by a mass of moving water; second, it acts as a destroyer of cohesion penetrating the rocks, separating the particles, thus making them more susceptible to subsequent agents.

Running waters are chief among the direct means by which erosive results of mechanical influences are produced. The vapor of the atmosphere, coming in contact with cooler air, condenses and falls in rain upon the hills and mountains. By the action of gravity it forms little rivulets which unite to form streams hurrying down the hillsides with great rapidity, cutting

away the earth in some places, building it up in others, never tiring but moving on thru endless ages. Is it any wonder that valleys are formed, canons and gorges cut out of solid rock and thousands of tons of sediment transported annually?

The material held in suspension flowing down stream tends to detach more particles from the banks and the beds of the river. The material carried down stream in one year is enormous. The Mississiffi Riper detaches and carries mechanically to the ocean annually 3,702,758,400 cubic feet of solid material; the Ganges 6,368,000,000 cubic feet. These rivers are not exceptions but many others are as active. What becomes of this material? The answer is simple. When rocks become thoroughly surrounded by water they loose about one-half of their specific gravity so they are hurled down stream comparatively easy. Some are transformed into smooth water-worn pebbles and depasited as sediment. During an overflow the

material is deposited in the valleys making them valuable for production. The formation of deltas results from a deposit of suspended materials. The coarse particles are deposited at the mouth of the river while the smaller ones are carried out further into the sea.

Glaciers are frozen streams moving slowly but irresistibly down valleys and mountains, grinding and pulverizing rock masses over which it moves and carrying fine particles of rock frozen in with ice.

Chemical Action of Water.

No water precipitated either in the form of rain, hail, or snow is chemically pure hydrogen oxide. While falling it absorbs small amounts of carbon dioxide, (CO_2) oxygen, and organic constituents. The carbon dioxide giving it an acid reaction, the oxygen making it an oxidizing agent, and the ammonia a reducing agent. These impurities are increased as soon as the water gains access to the vegetable matter accumulated upon the rocks and soils.

To the chemist a substance is said to be insoluble, if on filtering, after the action of water on it under given conditions no residue is found; but to the geologist, where water has been acting for thousands of years no mineral is insoluble.

All rocks are to some degree undergoing disintegration. Silicate of alumina is the most difficult to dissolve but it is affected to some extent; for all rocks have numerous microscopic pores which are filled with water. The water extracts all the soluble matter, gradually reduces it in size and makes it more porous.

Solution by water alone is applicable to but comparatively few minerals; gypsum, rock-salt, lime-stone and dolomite being the best examples. One part of gypsum is soluble in 400 parts of water. This is quite important in agriculture as lime is an essential ingredient to vegetation. To the solution of rock-salt is due the origin of saline springs. Calcium carbonate is

difficulty soluble in water, the solubility being increased with the increase of carbon dioxide. The solution of this substance has produced great changes in the physical features of nature. The caverns in which the earliest human remains are discovered resulted from this removal of calcium carbonate while the enormous caves of Kentucky, Tennessee, and Virginia are of similar origin.

The conversion of the anhydrous into the hydrous minerals results by direct simple combination with the elements of water. An example is the frequent change of iron oxide, hematite, into oxyhydrate, limonite.

$$2\,Fe_2O_3 + 3H_2O = Fe_4H_6O_9$$

As natural waters also contains free oxygen, all substances which unite easily with it are oxidized if brought into contact with it. Thus the ferrous compounds are converted into the ferric. $2\,Fe_3O_4 + O = 3\,Fe_2O_3$

Other actions are the oxidizing of the sulphides into the sulphates.

Pure water is never found in

nature. The power of solution is greatly aided by the carbon dioxide in it. Water acidulated with this gas is very active on the carbonates of lime and magnesia. Silicious minerals are readily attacked and dissolved by carbonic acid waters; certain silicates being converted into soluble carbonates.

"Agriculturally considered, this dissolving power of water acidulated by carbonic acid is of vast importance, not only by reason of the conversion of insoluble silicates into the soluble compounds of elements of plant nutrition, but this solvent property is exerted on a class of indispensable compounds, namely the phosphates of different bases. Especially phosphates of lime, magnesia and iron, and the salts containing the essential ingredients of vegetation, phosphoric acid, but existing in an insoluble and comparatively worthless condition, are by the dissolving powers of the carbonic acid, however, rendered soluble and available as plant-food."

Action of Air.

The action of air upon rock is similar to that of water, being due chiefly to the presence of carbonic acid and oxygen. Oxygen is an oxidizing agent converting the protoxides into the higher oxides; iron and magnesia minerals being most easily affected. Iron sulphides and the sulphates of protoxides of iron, $FeSO_4$, are also affected. These products are easily soluble in water, and by their presence further combination results.

Action of Organic Life.

The action of living organisms upon rocks is constantly and quietly taking place and is almost if not quite as resistless as the action of water. The action is either that of a chemical or physical nature or a combination of the two.

The disintegrating power of animals is exerted chiefly thru chemical means. The geological activity of animals may be both formative and destructive but largely destructive. Coral reefs, chalk, flint deposits, the infusorial earth, and most of the lime formations are composed chiefly of calcareous lower organisms.

The products of the decay of these organisms furnishes a hydro-carbon which acts as a natural reducing agent to several mineral forms. These products not only act at the surface but being dissolved in the water they permeate into the earth and exert their reducing influences in every region. The higher oxides are reduced to the lower ones; the oxygen extracted goes to form carbonic acid which unites with these lower oxides and forms carbonates. These in turn are acted upon by the atmosphere and form hydrous oxides.

The decomposition resulting from the action of plants is probably accomplished as often thru physical as chemical means. The roots are the chief factors in the process. The chemical action of the plant consists in the secretion and excretion of an organic acid through the pores of the root which has the property of decomposing and dissolving some of the rock mass with which it comes in contact.

The physical action of roots is allied to the action of frost in disintegration. They permeate the minute crevices and on growing expand and rend the rocks asunder. The roots possess a distinctly acid reaction and it being dissolved

in water makes it capable of dissolving salts not soluble in pure water.

All roots die wholly or in part each year; and are incorporated into the soil, thus giving back all they took out and the 95% which originally came from the atmosphere. In places where this is not consumed again by subsequent vegetation as in forest or under water, it accumulates and forms vast stores of "muck" and "humus." The transformations of the plant-living tissues into these products of decomposition is due to chemical action.

Decomposition is oxidation; here the decaying mass consists chiefly of carbon and hydrogen, which becomes by union with atmospheric oxygen, oxidized into carbon dioxide and water, with marsh gas (CH_4) and carbon-monoxide; while the albuminoids, nitrogenous constituents of vegetation, became transformed into ammonia (NH_3) and nitric acid (HNO_3). This decomposition further results in the formation of gic, ulmic, and humic acids.

2. Disintegration through Internal Forces.

Having considered the external forces at work in transforming rocks into soils we will now treat of the internal forces.

Volcanoes.

One of the results of volcanic action is the transformation and decomposition of rocks. Water-gas is not the ~~only~~ gas emitted but the elements of sodium chloride and other gases as hydrogen, oxygen, nitrogen, with sulphur and carbon in the presence of all the mineral ingredients of rocks. When these are forced out the hydrogen sulphide and sulphurous acid become oxidized into sulphuric acid, the most powerful of mineral acids, and attacks the silicic acid compounds and unites with the bases and forms numerous new compounds. These eruptive rocks thus acted upon loose their density, tenacity, and hardness become porous and at last transformed into clay-like compounds. The most common products are alum, sulphate of iron, and calcium sulphate.

Thermal Waters

The rock decomposition resulting from thermal waters is almost the same as that from volcanoes. The abundant mineral constituents of these hot springs are compounds of carbonic and silicic acid and chlorine, with calcium, magnesium, and sodium,

Contraction of Earth's Surface

Earthquakes: Earthquakes are not of very much importance in the formation of soil. The wave-like motion of the ground is sometimes violent enough to bring about landslips in mountain regions and shake down masses of earth and rocks from the cliffs into the valleys beneath. Very often when this takes place a stream is dammed up and converted into a lake or new channels have been cut and the course of the stream changed.

Sometimes an earthquake produces great fissures in the ground. They may close up or leave great chasms. Sometimes the level on both sides of the chasm is the same or one side may be elevated and the other depressed or both in which case causing a fault and exposing more surface to the action of external forces.

Changes of Level: The surface of the earth is constantly changing either by elevation or depression. Examples of the former may be seen in the temple of Jupiter Serapis on the Bay of Naples. In this building there are three marble columns still stand-

ing; on each of them is a belt about ten feet above ground and nine feet wide, honey-combed by the working mollusca. It is evident that there was a time when the water was around these pillars but by a gradual elevation of the earth's surface at that place they have been raised above the water but are now sinking again.

Well defined sea marks are common in high altitudes. Places which were once used as harbors are now far inland. Marine animals, shells, corals, etc. have been found on land. All these go to show that these parts were once covered with water.

Ancient buildings which were constructed on land but now beneath the sea, buried forest found below the sea-level, and submerged river channels are all evidences of depression. All the great continents are composed of rocks laid down in the sea and still contain fossils of marine animals which goes to show that these continents have been under the sea. Probably all of the continents were not submerged at the same time or even

that all parts of any one, but now one part then another until finally all have been covered.

The principal function of the subterranean agencies first, bring up from below and form at the surface, and at all depths beneath it, certain kinds of rock; and second, they tend to increase the inequalities of the earth's surface, thus counteracting the external agencies.

IV. Products of disintegration.

Granite decomposes into its constituents minerals, felspar, quartz and mica. Felspar may be transformed into various products forming kaolin, clay or marl. Quartz is unaffected except it becomes separated into crystals and mixed with the products of other forms. Trachyte becomes transformed into an impure kaolin. Phonolyte results in the formation of a marly product. Diorite forms many and varied decomposition products. Hornblende diorite, contains little lime but much magnesia, with oligoclase it weathers with difficulty, producing a fertile loam free from quartz-grains. Basalt weathers with greatest difficulty

for the formation of a marly product. Diabase weathers with products more or less resembling diorite.

V. Sources of Organic Constituents of the Soil.

Plants consists of both organic and inorganic matter. And as they derive the most of their food from the soil, the organic material must be incorporated with the mineral constituents of the rocks.

1. Plants

It has been practically illustrated that the lava from recent volcanic eruptions is in a short time covered with microscopic vegetable organisms. These obtain their food from the atmosphere and finally die, leaving vegetable material for higher forms of plant life to follow. They die others follow and so the process goes on until there is quite an accumulation of organic matter. Only about 5% of the entire weight of organic products is of mineral origin; the remaining 95% is from the atmosphere; all of which goes to the soil after the plant dies. The proportion of organic matter necessary for the production of crops is com-

paratively small though in some soils it may be found in large quantities. Peat may contain as high as 70% of organic matter, while some rich garden soils have 26%. The average for good productive lands is not above 6%.

The conditions essential to organic decomposition are those most favorable to combustion or oxidation - access of air, presence of moisture, and application of heat.

Air is necessary in oxidation. The presence of moisture and heat aids the humus forming process inasmuch as chemical action is increased by these agencies.

If decaying material contains albuminoids then the process is putrefaction, the products being compounds of hydrogen with carbon, nitrogen, phosphorous or sulphur. Putrefaction also evolves a gas, "ammonia" (NH_3). This combines with acids and forms ammonia salts. The ammonia undergoes further alteration or oxidation known as "nitrification" in which the ammonia becomes transformed into nitric acid.

The conditions favorable to this change

air, moisture, and temperatures between 12° and 55° C.; 37° is the temperature at which the maximum nitrification takes place.

2. Animals

All that has been said about plants in contributing to the organic material of the soil might be said in regard to animals, only that animals do not obtain their food from the atmosphere directly but through the vegetable world.

One difference in degree is that plants are carbonaceous in composition and animals more nitrogenous; therefore they consequently have a greater yield of the products of ammonia and nitric acid. The plants procuring their organic matter from the atmosphere as well as from the soil return it to the soil through death while the same being true of animals they also return organic matter as a result of life functions.

Animals return to the soil the food not assimilated, as effete matter (or excreta) both solid and liquid, which, after decomposition contributes to the soil the same products as decayed vegetable matter.

Not only do animals aid in soil for-

mation by excrements etc. but by burrowing and ploughing of certain animals which is analogous to the labor of the human ploughman. Such animals as ants, moles, and prairie dogs have brought to the surface thousands of cubic yards of earth where it is more readily acted upon by the atmospheric agencies.

The action both physical and chemical, of earth worms, has been marvelous. Darwin describes the secretions of organic acids in the digestive organs of worms as follows: "From the contents of intestines of worms and from their castings being acid, it seems probable that the process of digestion induces an analogous chemical change in the swallowed triturated and half-decayed leaves. The large quantity of carbonate of lime secreted by the calciferous glands apparently serves to neutralize the acids thus generated; for the digestive fluids of worms will not act unless it be alkaline. As the contents of the upper part are acid, the acidity can hardly be due to the presence of uric acid. We may therefore conclude that the acids in the alimentary canal of worms are

formed during the digestive process, and that probably they are nearly of the same nature as those in ordinary humus".

Darwin also estimates that the material brought to the surface by worms is .2 of an inch deep over every acre. It appears that the ammonia contents added to the soil by the action of worms is 321 ℔ or 96,963 pounds of ammonia per acre. This is for ammonia only and we can only surmise that other materials are proportionally added.

VI. Classification of Soils.

The varieties of soil so far as composition and properties are concerned are innumerable. But two systems of classifications have been devised. The first based on the method of formation, the second on physical characteristics.

Genetic Classification: Two varieties are found, namely, Sedimentary and Transported Soils.

The sedimentary soils are those that remain in the place where formed or close to it; and are of the character of the underlying rock from which they were

produced.

The Transported soils are those that have been moved from their place of formation by geological agencies, and fall into two classes, namely, drift and alluvial soils.

Drift soils consists of small stones mixed with finer material from the disintegration and erosion. They are unstratified and usually composed of diversified material.

Alluvial soils are those formed by water deposits and are very fertile; usually stratified. They embrace river bottoms.

Physical Classification:- Soils classified upon a bases of physical characteristics are gravel, sandy soils, clay, loam, marl, lime soil, salt soil, and humus.

Gravel consists of pebble of rock and stone mixed with fine earth. It is difficult to work and lacks nutriment. Sandy soils contain 80% or over of fine sand. It is a light arable soil, easy to work and may contain the proper elements to make it very productive. Clay soils are those that contain at least 60% of clay. They are impermeable to water, dry slowly, are liable to be wet and cold. They are heavy to work but very fertile

Loam soils are those ranging between the sandy and clayey soils. The properties partake of the characteristics of the sand or clay in them. Marl is a term applied to calcareous clays. Usually implies a soil containing much shell lime and greensand then it is used as a fertilizer. In lime soils the calcium carbonates predominate. Salt soils are those that contain considerable of soluble salts usually of lime or soda and are not fertile. Humus soils are rich and fertile and are the products of vegetable decomposition.

VII. Conclusion.

Thus we see that this earth has been transformed from its original misty and nebular state or even its original solid state deprived of all vegetable and animal life to fertile valleys and verdant mountains producing and supporting the most diversified forms of vegetation and innumerable species of the animal kingdom.