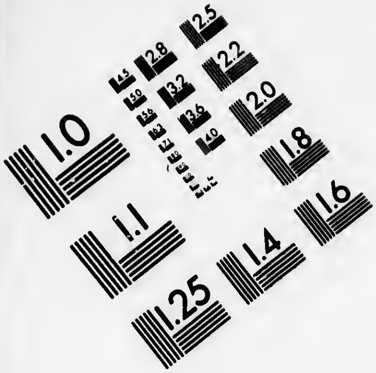

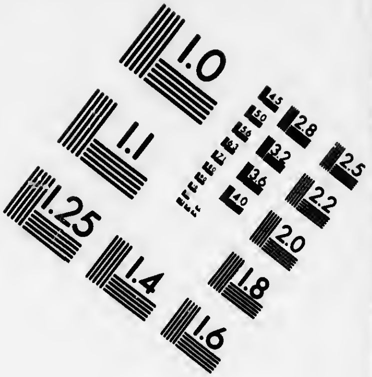

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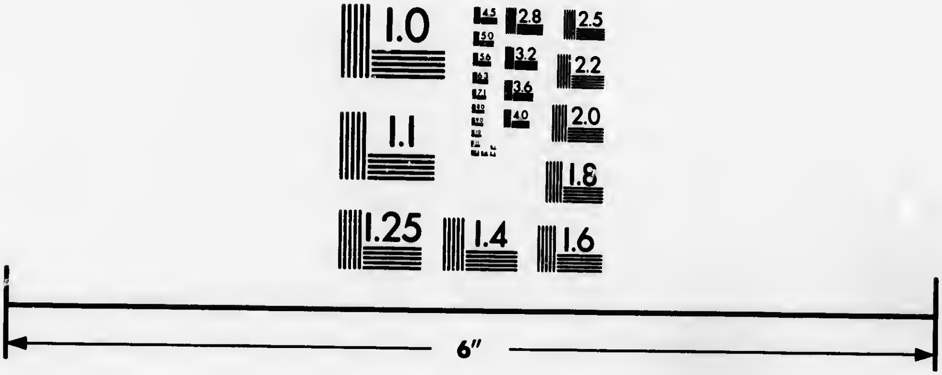

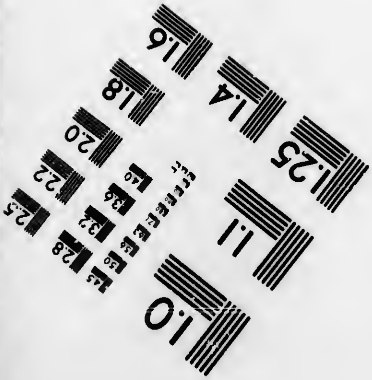

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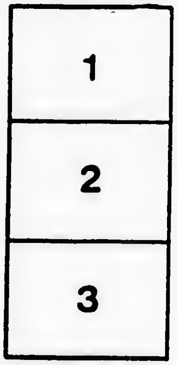
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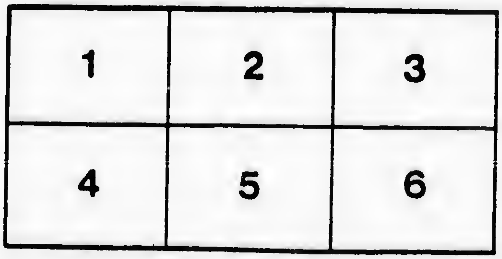
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What the Rocks Reveal

-- OR --

Geology Simplified

-- BY --

J. HOYES PANTON, M.A., F.G.S.

Professor of Biology and Geology, in the Ontario Agricultural College, Guelph.

SECOND EDITION, REVISED AND ENLARGED.

Guelph, Ont.
J. J. Kelso, Book and Job Printer.
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PREFACE.

SECOND EDITION.

This booklet has been written with the view of simplifying the teachings of nature, as they are revealed upon the fragmentary pages of the geological records.

Especial attention has been given to the *composition*, *origin* and *formation* of soil, and also to the economic *products* of the rock systems of Ontario. Teachers in rural schools could make good use of the information in this book by giving a series of talks on Geology Friday afternoons, 3 to 4 o'clock, during the Fall term. Few subjects are better suited to develop observation, induction and method than Geology, and none can be made more interesting and instructive to a pupil. Teachers attempting this attractive way of imparting a knowledge of this science, should encourage pupils to collect specimens and bring them to school, so as to form a museum that will represent the Geology of the district. Every fact should be illustrated, as far as possible, with diagram or specimen, and thus an appeal made to the *eye* and *hand*, as well as to the *ear*, so as to make an impression upon the young mind. Other subjects relating to Agricultural Science might also be taught by a series of talks on Friday afternoons, and the pupils of rural schools soon obtain such a knowledge of science as would make farm life attractive and instructive.

J. HOYES PANTON.

Guelph, April 7, 1897.

CHAPTER I.

ROCKS AND WHAT CONSTITUENTS THEY ADD TO THE SOIL.

Geology may be defined, as that science which has for its object a knowledge of the earth. In the study of it we have much to do with rocks. A rock, in geological language, is any portion of the earth's crust, and hence the term is as applicable to a bed of sand, clay or gravel, as to a mass of so called rock.

All rocks belong to one or other of three classes :

1. **Igneous.**—They embrace such as those whose origin is associated with the presence of heat, e. g. the product of volcanoes.

2. **Aqueous.**—Rocks that have been deposited in water as sediment and afterwards hardened, belong to this class, e. g., limestone, sandstone.

3. **Metamorphic.**—These include such as have undergone a marked change, likely through the influence of heat and pressure in the presence of moisture, e. g., slate, marble.

Take any stone in the field or by the wayside and it can readily be classed in one of these three groups; most in Ontario belong to the second and third groups.

The rocks of these divisions are usually represented by masses, such as *sandstone*, *limestone*, *coal*, *dolomite*, *granite*, *chalk*, *gneiss*, *trap*, *quartzite*. These contain certain minerals, among which some of the most important in connection with the formation of soil are:—Quartz, Feldspar, Mica, Hornblende, Calcite, Gypsum, Apatite, Iron and Serpentine.

It is considered that 48 per cent. of the earth's crust is Feldspar, 35 per cent. Quartz, and much of the balance limestone.

These minerals are composed of certain chemical elements, 14 of which enter largely into the composition of soil, viz. :—Oxygen, Silicon, Sulphur, Carbon, Hydrogen, Chlorine, Phosphorous, Nitrogen, *non-metallic;* Iron, Aluminum, Calcium, Magnesium, Sodium, Potassium, *metallic*. One-half of the earth's crust is Oxygen and about one-quarter Silicon. We have thus reached the ultimate elements which enter into the composition of the rocks from which soil is derived.

These unite and form *acids*, as Nitric, Sulphuric, Carbonic, Phosphoric, Silicic, and also combine to produce *bases*, as Soda, Potash, Magnesia, Lime and Alumina. A union of bases with acids gives rise to Salts, the most common form of compound in rocks and the soil which they form, e. g., Carbonates, Nitrates, Sulphates, Phosphates and Silicates.

Let us repeat the various steps by which we arrived at our conclusion.

1. Rocks divided into three great divisions :—Igneous, Aqueous, Metamorphic.

2. The rocks of these exist in masses, such as Limestone, Coal, Sandstone, etc.

3. The constituents of the rock masses are such minerals as : Quartz, Gypsum, Feldspar.

4. Elements which compose the minerals : Oxygen, Potassium, Carbon, etc.

We shall now consider more definitely the composition of the minerals referred to.

1. Quartz consists of *silica*, a substance containing Silicon and Oxygen. Quartz occurs in a variety of forms, such as : Rock Crystal, Amethyst, Chalcedony, Cornelian, Agate, Jasper

and Flint. Sand is simply ground up Quartz, but it often contains particles of other minerals.

2. Feldspar is one of the most important minerals in rocks. It is composed of *silica, alumina, potash, soda* and *lime*. These are combined as double Silicates, e. g., Silicate of Alumina (clay) and Silicate of Potash form Potash Feldspar—Orthoclase; Silicate of Alumina and Silicate of Soda—Albite; Silicate of Alumina and Silicate of Lime—Anorthite. We have, therefore, three leading varieties of Feldspar: Orthoclase, composed of *clay* and *potash*; Albite, *clay* and *soda*; Anorthite, *clay* and *lime*.

From this it will be seen how important this mineral becomes in soil formation, by supplying clay, potash, soda and lime, when it is decomposed or broken up by the action of the weather.

Orthoclase is most common and occurs in many of our hard boulders in the field as a salmon-colored rock.

3. Mica consists of *silica, alumina, potash, magnesia, lime* and some *iron*.

4. Hornblende supplies *silica, iron, magnesia*.

5. Calcite, Chalk, Marble and Limestone

have much the same composition, i. e., *carbonic acid* and *lime.*

6. Gypsum contains *sulphuric acid* and *lime.*

Selenite, a translucent mineral like mica, and alabaster resembling marble, are varieties.

7. Dolomite is composed of *carbonic acid*, *lime* and *magnesia.*

8. Serpentine consists of *silica*, *magnesia* and *water.*

9. Apatite is a source of *phosphoric acid* and *lime.*

10. Iron is a combination of *iron* and *oxygen.*

11. Chlorite contains *alumina*, *magnesia*, *iron* and *silica.*

12. Rock Salt is composed of *sodium* and *chlorine.*

In the preceeding list we give nearly all the elements that enter into the composition of plants. How the rocks containing these are broken up and decomposed, we shall consider in a subsequent chapter.

A tabulated statement showing the percentage composition of the most common rocks and minerals from which the ingredients of the soil are derived.

	Silica.	Phos. Acid.	Carb. Acid.	Sulph. Acid.	Alumina.	Potash.	Lime.	Soda.	Magnesia.	Iron.
1. Quartz,	100									
2. Feldspar (Orth.),	65				18	17				
3. Mica,	47				40	10				3
4. Iron,										100
5. Hornblende,	50				10		12	2	18	8
6. Apatite,		42					55			
7. Serpentine, *	44								43	3
8. Chlorite, †	27				23				14	24
9. Gypsum, ‡				46			33			
10. Limestone,			44				56			
11. Dolomite,			46				32		22	

* Water (10). † Water (12). ‡ Water (21).

Varieties of Feldspar.

	Silica.	Alumina.	Potash.	Soda.	Lime.
Orthoclase,	65	18	17	..	..
Albite,	68	20	..	12	..
Anorthite,	43	37	..	..	20
Oligoclase,	62	24	..	9	5
Labradorite,	53	30	..	4	13
Andesive,	64	24	2	5	5

13. Gneiss is a combination of Quartz, Feldspar and Mica, in layers.

14. Granite is the same, but the minerals are more in a confused mass.

15. Trap varies in composition, but usually contains much Feldspar.

16. Sandstone is chiefly composed of Quartz.

CHAPTER II.

IGNEOUS AND ERUPTIVE ROCKS.

Let us now consider more fully the great divisions into which rocks are divided.

IGNEOUS rocks are sometimes referred to as Eruptive and Unstratified rocks; the former term is applied from their mode of formation, the latter from their appearance, while igneous refers to their origin.

Character :—Usually hard, more or less crystalline, not in layers and without fossils (the traces of animal or plant life)

Occurrence :—*a*. In irregular masses of all ages. *b*. Beds overflowing other deposits. *c*. In the form of tortuous veins (*granite*). *d*. Broad veins as *dikes*, which are sometimes over-topped with step-like masses described as *trap*.

Constituents:—*a*. Granite consists of *quartz*, *mica*, *feldspar*, mingled together. Syenite is a variety with *quartz*, *feldspar* and *hornblende*. It often occurs as *dikes* or wall-like masses of originally melted rock; *b*. Serpentine; *c*. Trap contains much *feldspar* and some *iron*; when it presents a rough form of crystallization it is termed Basalt. *d.* Trachyte is more or less porous, rough and usually light gray and rich in *feldspar.* Pumice is a variety. *e.* Obsidian is a glass-like form of usually dark colored lava.

Localities:—Lake Superior, Highlands of Scotland, Palisades of the Hudson, Fingal's Cave, (Basalt), Montreal Mountain, (Trap), and all deposits from Volcanoes in present and past time. The "Devil's Slide," at the entrance to Yellowstone Park, affords an excellent example of two dikes.

Here two walls 200 feet high, 50 feet thick, with a space of 150 feet between them, slope up the side of Cinnabar Mountain 2,000 feet.

The "Devil's Tower," in the table-lands of Wyoming is 800 feet high. The longest diameter of the base being 326 feet. It consists of a mass of huge crystals of *basalt*, some three feet in diameter and these continue unbroken from the bottom to the top.

This huge obelisk of stone is visible for forty miles.

The walls are almost vertical, showing only a slight slope, and presents a front that no human being can ever hope to climb.

The study of the Igneous rocks gives us a clue to the origin of the earth and the condition of the earth's interior at the present time. The story of the earth, as gathered from an examination of these rocks, is outlined as follows:—

1. A period when the earth was represented by a glowing mass of incandescent vapor. 2. A time when it existed as a chaos of melted rock. 3. A thin crust formed. 4. A period when the water could descend and remain upon the gradually cooling surface. Many upheavals and fissures would be made in the newly formed crust at this time. 5. When the continents began to emerge and became a source of material for redistribution through the agency of water. 6. Final arrangement of the great land divisions of the globe. Each of these stages in the history of the earth would, no doubt, extend over a vast period of time.

That the earth has been and is now in a heated condition, is proved by the following facts:—

1. The presence of *boiling springs* and *geysers* in various parts of the world: Iceland, New Zealand and Yellowstone Stone Park in Wyom-

ing. In this wonderland are 3500 boiling springs and 84 geysers.

2. *Volcanoes*, of which 407 are known.

3. The *temperature* in deep mines increases 1° for every 60 feet of descent.

4. *Water* from deep Artesian Wells is warm.

5. Presence of Eruptive Rocks far from present Volcanoes, such as in some parts of Lake Superior district, Quebec, Wales and among the Rocky Mountains.

At the rate of increase of 1° in temperature for every 60 feet descent, metals would fuse at a depth of 30 miles. This is allowing the increase to be uniform, but such may not be the case. However, the crust of the earth must be comparatively thin compared with the rest of the material of which it is composed. There can be no question, but vast masses of molten material exist in the interior, ready to escape when communication is made with it. With this eruption of molten material Volcanoes and Earthquakes are associated. The origin of Volcanoes is accounted for as follows :—

1. A union of chemical elements in the interior of the earth which causes rupturing of

the earth's crust, and the ejection of lava from the fissures.

2. Settling of portions of the earth's crust, which causes fissures and the generation of intense heat.

3. Accession of water to the heated interior; this is changed to steam and rupturing of the crust results.

The last explanation has much in its favor; when we consider that Volcanoes are usually near the sea and great volumes of steam are emitted during an eruption. Earthquakes are usually associated with Volcanoes. The result of Volcanic eruption is the formation of mountains of *Eruption*. These are simply deposits from the crater or mouth of the Volcano. During an eruption, lava, gas, vapor, ashes, cinders and rock fragments issue from the crater. Stony lava (Trachyte) cools slowly; glassy (Obsidian) rapidly, while spongy (Pumice) is full of vapor bubbles. Great internal force is followed by upheavals, sometimes extending long distances, and giving rise to mountains of *Elevation*. Most mountain chains have been developed in this way; in other words, they have resulted from a crumpling and elevation of the earth's crust, and afterwards become worn by the action of the atmosphere into the variety of forms we see them assume. We may mention here another kind of mountain, that of *circumdenudation*. This results from material once around it being all removed, so as to leave the mountain only. We have, therefore, three forms of mountains : a. *Eruptive*, chiefly Volcanoes; b. *Elevation*, mountain chains; c. *Circumdenudation*, single and isolated forms.

CHAPTER III.

AQUEOUS ROCKS AND HOW FORMED.

AQUEOUS rocks, also known as Sedimentary and Stratified, from their form and appearance. These rocks have been deposited in water as sediment, and afterwards solidified by agencies to be referred to subsequently.

Character :—They are not so hard as Igneous rocks, less crystalline, arranged in layers, show a sedimentary structure, and usually contain fossils. Lake Winnipeg affords a good illustration of how this sediment may collect. Red River, which empties into the lake, contains very muddy water by the time it reaches the lake, so muddy that the water is not clear for two hundred miles; beyond this the water is quite clear. What has become of this sediment? It has settled in the lower end of the lake, and thus vast deposits are collecting there, which, in time, will, no doubt, become solidified and add something to the earth's crust for future geologists to examine. Lake Geneva, in Switzerland, also furnishes an example of a lake into which muddy water is emptied and clear issues from the other side, leaving the deposits in the lake bottom. Most of our great lakes illustrate how Aqueous or Sedimentary rocks may be formed.

Occurrence.—These rocks occur over wide areas in thick masses, and usually are very little disturbed from their original position.

Examples :—Limestone, sandstone and clay beds are in this group. Some have estimated that the earth's crust is made up of fifty miles of Igneous and Crystalline rocks and thirteen miles of Aqueous.

We also place among Aqueous rocks : Chalk, largely formed from the decomposition of shells and corals ; Marl, a lime deposit in places once covered with water ; Stalactites, icicle-like structures on the roofs of caves ; Stalagmites, the deposits on the floors of caves ; Gypsum, Coal and Salt.

Localities :—Very common throughout Ontario and all places where limestone, etc., are found.

CHAPTER IV.

METAMORPHIC ROCKS.

METAMORPHIC rocks include such as seem to have undergone great changes since they were deposited like Aqueous rocks.

Character:—They have a close resemblance to Igneous, being hard and crystalline, occur in layers, usually have no fossils, and sometimes indicate a more or less disturbed condition from that in which they were originally placed.

Occurrence:—They appear in thick masses extending over wide areas, and as hard *boulders* scattered over our fields.

Examples:—Slate, Mica, Talc, Marble, Graphite, Apatite, Quartzite, Gneiss and Iron. Gneiss is a very common rock in this division, most of the hard boulders in our fields being fragments of it.

Localities:—Muskoka, Quebec, and the east side of Lake Winnipeg.

It has been observed that where a stream of lava flows over beds of clay, coal, chalk, they have a tendency to change into slate, graphite and marble. Hence the conclusion regarding the origin of Metamorphic rocks is, that, after their deposition as Aqueous rocks, they were submitted to the action of *heat* in conjunction with *moisture* under great *pressure.* Their hardness and stratified structure seem to indicate this. Their composition closely resembles that of Igneous rocks and leads us to infer that they were likely derived from the first rocks that came into existence. Inasmuch as Aqueous rocks are at first deposited in a soft condition, a question naturally arises how have they become hardened, as we find them to-day in our limestone deposits, and beds of sandstone? Some one or more of the following reasons will be found sufficient to explain the results in each case:

1. The cementing action of such compounds as lime, iron, silica, in the deposits. We see this illustrated in the action of mortar, a mixture of lime and sand; the "setting" of Plaster of Paris, used by plasterers in molding, and other ornaments upon ceilings, and very forcibly in the construction of pavements on our city streets, by the use of sand and some other compound like lime. This, though as soft as mud, will, in two days, become as hard as the hardest rock.

2. Heat, as shown in making bricks.

3. Pressure, to some degree, may aid in the consolidation of deposits.

4. Drying exerts a very hardening influence upon clay.

5. Springs, containing lime, iron and silica in solution, might be in deposits, and produce a cementing effect.

6. The decomposition of shells, corals, etc., would supply compounds likely to give rise to hardening of deposits.

CHAPTER V.

FOSSILS, HOW FORMED, AND WHAT THEY REVEAL REGARDING THE PAST.

We have already used the word fossils and simply referred to their presence in some rocks; but these remains are of such importance that we shall now consider them more fully, and for that purpose we shall endeavor to *define* what a fossil is, how it is *formed*, and what *inferences* can be drawn from its presence in a rock.

Fossils are the relics or remains of animals or plants imbedded in rocks. A footprint is as much a fossil as the remains of the animal which made it.

I. **How Formed**:—*Partial change.* The animal or plant becomes imbedded in the deposits and undergoes only a partial change, so that there is no difficulty in identifying the object as that of some animal or plant, in part or whole. Such is seen, when a bone or piece of wood still retains much of its appearance and structure, and yet, to some extent, is petrified. This is what may be termed the simplest form of fossil.

2. *Moulds*:—In this case the object has been buried in the deposits, afterwards entirely decayed, so as to leave a mould of its form. Long years after, when the soft deposits harden and come under the examination of man, as hardened rock, he finds an empty space, the form of the object long decayed.

3. *Casts*:—These result from some infiltrating material, such as lime or silica in solution finding its way into the mould and filling it up, so that when the rock is broken up, casts of shells, etc., drop out. This form of fossil is very common in the rocks at Galt, Elora and Guelph.

4. *Replacement*:—Here the infiltrating material, lime, silica, or iron compound in solution, is present the moment decay of the object begins, and as particle by particle of the substance decays they are replaced by the infiltrating substance. This results in a complete replacement of the whole object and produces a perfect representation of the entombed body. So complete is this that sometimes the very structure of the eyes of an imbedded animal is preserved in stone. These fossils are by far the most unique and interesting.

5. *Impressions:*—To understand how these may have been formed, let us imagine a seashore, where the tide leaves a portion of it exposed nearly twelve hours. During this interval birds and other animals, in search of food, may wade over the soft deposits and leave well marked footprints. The deposits, exposed to the sun, harden, and when the returning tide overlays them with a new layer of clay or sand, the whole is imbedded. If these soft rocks become hardened in time, there is no doubt but such rocks will, on splitting, show many well preserved traces of footprints. Ripple marks and even rain drop impressions may be preserved in the same manner.

1. **Inferences from Fossils**:—*The age of rock.* Some fossils are the remains of animals that existed only for a short period in geological time. The trilobite, a crab-like creature, became extinct about the time of the coal deposits, and, therefore, its presence will indicate rocks before that time. The mastodon did not appear until many systems of rock had been formed. From its remains we infer that the rocks in which they occur are high in the geological scale.

2. *Nature of the Deposits:* — Animals and

plants live under certain conditions, such as in deep or shallow, salt or fresh water, consequently their presence as fossils indicate the condition under which they flourished. Hence we speak of lake, sea or river deposits, according to the fossils they contain.

3. *Climate*:—No fossils are of more interest in giving us a clue to the climate of the past than corals. They flourish only in well aired, salt water that never is lower than 68° *F.* Remembering this, we can understand how their presence in rock makes a great revelation concerning the climate of the past. Along the shores of Lake Erie there are some 50-75 species of coral. How changed the climate is now to those days, when Ontario was beneath a sea whose temperature never sank below 68°. The remains of luxuriant plants, found in our coal beds recall a time of forest and jungle, such as is only seen in tropical regions.

Thus we see how from fossils we can glean something about the climate of our country in the years long receded into the past, and how they reveal to us much of an interesting character anterior to the advent of man. The Aqueous rocks, containing fossils, become of great import-

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ance in geological evidence regarding changes which the earth has undergone since life appeared upon it; while the Igneous rocks help us to solve some of the marvellous conditions prior to the introduction of life.

CHAPTER VI.

THE MODIFYING INFLUENCES TO WHICH ROCKS ARE SUBJECTED.

Constant change is taking place on the earth's crust. Nature knows no rest—one ceaseless round pervades her endless operations. No sooner are rocks formed than agencies are at work to destroy them. Some of these changes we shall now consider.

1. **Elevation.**—Rocks have been raised, and are still, by some subterranean force. This may be effected suddenly, or slowly. At the present time the west coast of South America and of Norway are rising.

2. **Submergence.** — Some places are now sinking, as is seen at Cape Breton, parts of Nova Scotia and Greenland.

3. **Denudation.** — This change, the great agency by which soil is formed, takes place when any portion of the earth's crust is removed, so as to leave a fresh surface exposed, and acted upon by agents which, in time, disintegrate and decompose the rock. Among the chief agents of

denudation are: the *atmosphere*, embracing the effect of oxygen, carbonic acid, wind and vapor; *water*, as rain, river, lake, sea and ice; *life*, as animals and plants. The result of one or more of these agents during long periods of time is very effective in breaking up rock, and producing material for the formation of soil. We shall now consider how these forces act upon the earth's crust.

OXYGEN.—The air contains 21 per cent. of oxygen, an element that has a very strong affinity for nearly all other elements, and especially for iron, a very common substance in rocks, notably Igneous and Metamorphic. Oxygen changes ferrous oxide ($Fe O$) into ferric oxide ($Fe_2 O_3$) which, in the presence of water, has a tendency to become hydrate ferric oxide (Yellow Ochre). Ferrous carbonate ($Feco_3$), in the presence of oxygen, oxidizes and also forms Yellow Ochre ($Fe_2 O_3 + H_2o$). Ferrous oxide ($Fe O$) is common in many rocks containing pyroxene, hornblende and mica. Iron sulphide ($Fe s_2$) is also readily acted upon by oxygen to form Yellow Ochre. The sulphur forms sulphuric acid, which combines and forms sulphates. We find $Fe s_2$

sometimes in granite, syenite, gneiss, mica, slate, trap and limestone. Its presence is injurious to stone. The above changes are brought about by the addition of Oxygen (*Oxidation*) to compounds. Changes that lead to the disintegration of rock are also brought about by the withdrawal of oxygen (*deoxidation*).

This takes place through the agency of organic matter which, when decaying, has a great affinity for oxygen. This change may occur even in the soil. Ferric oxide (Fe_2O_3) in soils and rocks is insoluble; but decaying organic matter withdraws some oxygen and forms Ferrous oxide (FeO). This, in the presence of carbonic dioxide, becomes ferrous carbonate ($Feco_3$), soluble and washes out of the rock which becomes decolorized; the water passes into springs and gives rise to chalybeate (iron) springs. The ferrous carbonate oxidizes on exposure to the air and becomes ferric oxide (Fe_2O_3), which is deposited at the side of the spring, but if carbonic dioxide is present, it will again become a soluble iron carbonate. Thus iron accumulates in two forms:—

a. Ferrous carbonate (Feco_3), where organic matter is plenty, e. g., in vicinity of coal beds.

b. Ferric oxide (Fe_2O_3), where organic matter is scarce, e. g., beds of iron ore.

Boulders by the wayside often illustrate some of these changes, by the rusty streaks upon their surface. Where rocks show this presence of oxygen combining with iron, it is only a matter of time when they will be a heap of loose material, forming a contribution to the soil beneath. Iron is one of the most susceptible elements in bringing about the disintegration of rocks; whether it be combined with oxygen, as an oxide, or with sulphur, as a sulphide. Oxygen exists in the air mixed with nitrogen and not chemically combined; consequently it readily separates from it to unite with other elements.

CARBONIC ACID.—This is always in the air, and it, too, is a powerful disintegrating agent in the presence of moisture, especially upon rocks containing carbonate of lime, magnesia or iron. With these, insoluble in water, it combines and forms bi-carbonates, soluble in water; and thus while breaking up the rocks, it at the same time supplies food in solution for plants.

This process is well illustrated by taking some clear lime water and passing carbonic acid into it (simply breathing into it through a tube will show it); the water becomes milk-like, and if allowed to stand a short time, a chalky sediment will form; this is carbonate of lime, insoluble in water. Now if more gas is added, in a short time the sediment vanishes and the water clears up, because the insoluble carbonate of lime has changed to bi-carbonate of lime, soluble in water. There is just as much lime in the water as before, but it is now invisible. This change is going on constantly where carbonates are in the soil.

We observe how rapidly the inscriptions on marble tombstones become obscure; no doubt largely due to this solvent action of carbonic acid associated with rain.

It also has the power to remove from Feldspars, and other hard rocks, some of the compounds of lime, soda and potash, forming carbonates and leaving clay as a result from the rock disintegrated.

Hard as granite is, in time it falls to pieces, before the decomposing power of carbonic acid, and supplies sand, clay, oxide of iron, and the alkaline matters washed out. Illustrations of these changes in granite are seen at the base of Pike's Peak and other mountains around Colorado Springs where great heaps of disintegrated granite lie. Even slate in some cases undergoes dissolution in a somewhat similar manner. In this compound we have not only a powerful agent in the destruction of rock, but also a great provider of soluble material suitable for plant food.

WIND.—The effect of wind is seen more especially in districts where sand is common, or along the seashore, where particles of sand blowing constantly against rock, in time beat holes into it, which enlarge and bring about results in rock destruction almost incredible, were they not borne out by actual facts. The shifting of the "sandhills" in Manitoba, near Brandon, and those of Prince Edward County, Ontario, are also illustrations of what wind may do as a denudating force.

RAIN.—It is not difficult to understand how rain may be a powerful factor in grinding down rock, both as a mechanical and chemical force. Every rain storm lays bare much surface, by simply washing away fine material from hillsides to lower parts, and thus exposing fresh surfaces for further wear; then by its solvent action, both as pure water and as water containing carbonic acid, its effects upon rock are very great. All rain contains more or less of this acid, derived some from the air and some from the soil, through which it passes.

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CHAPTER VII.

THE WORK OF RIVERS, ETC.

Rivers.—The influence of rivers, as denudating agents, depends upon their length, volume, slope and the nature of their bed and banks. They also act mechanically and chemically. In their course they form "Valleys of Denudation"; these have strata of the same character on opposite sides. A few rivers may be given here to illustrate what important agents they become in denudation.

Niagara River has cut its way through a bed of rock over 150 feet thick, a distance of 7 miles. It is estimated that the Falls recede 3 feet annually, and were at Lewiston 15,000 years ago.

The Mississippi deposits at its mouth annually 7,471,400,200 cubic feet, and cuts down its whole drainage basin one foot in 5,000 years. This is sometimes represented as equivalent to 50,000 acres of sediment, three feet deep. The Delta at its mouth contains 13,600 square miles, 528 feet deep. The Ganges has deposited a Delta equivalent to 20,000 square miles. Egypt is the gift of the Nile, and Holland the contribution of the Rhine to Europe. The Yellowstone River, of Wyoming, has cut out a gorge 12 miles long, 1200-1500 feet deep, the walls of which are adorned with all the colors of autumn leaves. The Colorado River, in a course of 1,000 miles, has cut out 14 Canyons; the last two, Marble Canyon, 65 miles long, has walls 3,500 feet high, and the Grand Canyon, 207 miles in length, shows in some places walls 6,200 feet high, composed of 2,600 feet of limestone, 2,000 of sandstone, 800 of quartzite and 800 of dark colored gneiss. The greatest and grandest gorge in the world. The Mammoth Cave in Kentucky, with its 223 avenues, averaging 21 feet in height and width, representing 150 miles of underground passages, is largely the work of a subterranean river since Miocene days. To-day, after threading your way for nearly three miles, you come to the Echo River, upon which you can sail for a mile and landing continue your journey for six miles farther along these strange avenues, shrouded in eternal darkness and gloom.

By the action of this extinct river five galleries have been worked out, equivalent to the removal of 12,000,000 cubic yards of limestone. Such examples at once impress us with the striking results effected by rivers in transporting sediment and disintegrating rock.

From observations made as to the rate at which rivers *deposit* sediment and *cut out* gorges, the rate at which stalactites *form* in caves, and mountains *wear away* by denudation, Geologists are able to calculate the relative time that has been required to bring about changes that have occurred in the ages long receded into the past. Such agents of change—sedimentation, erosion, construction and denudation—may be termed *geological clocks.*

Lakes and *Seas.*—The effect of large bodies of water upon a rocky shore is seen by the formation of "Outliers" and Caves. The former result, where the waves succeed in separating a portion of the main rock, by cutting around it and causing it to appear like a detached rock in the water.

Caves may be formed in four ways: a. by the elevation of rock, as in many parts of the Blue Ridge Mountains of Virginia; b. along the shore, where a place is exposed to the action of the waves, as Fingal's Cave, Isle of Staffa; c. by subterranean rivers, as the Mammoth Cave, Kentucky, or the Wyandot of Indiana; d. sometimes beneath lava beds.

Ice.—The action of this as a disintegrating agent upon rocks is best seen in countries where a perpetual snow line exists. The snow keeps increasing until so much accumulates on the mountain tops, that it finally moves down into the valley. If the mountain slope be steep, the body of snow and ice will move downward with terrific rapidity and force, sweeping everything before it. This is an *Avalanche;* they often occur in the Rocky Mountains. The avenues, apparently cut through forests, up the mountain side, indicate to an observer the pathway of an avalanche. If the slope is very gradual the body of ice will move slowly and form a *glacier*, or river of ice. The movement of this may be very slow, not exceeding 3–15 inches per day, but it will move on grinding and wearing the rocks beneath it and bordering its sides, until it reaches either the sea, or a place in the valley where the temperature is sufficient to melt it; there it melts and becomes the source of a river, and scatters at its terminus boulders, gravel, sand and clay, which it has formed and gathered in its course through mountain ravines. The Muir Glacier, of Alaska, has a frontage three miles wide where it enters the water and three hundred feet high. If you could see the whole face it would represent a wall of ice 1000 feet high. Every ten minutes a new iceberg is formed at its front, and as it falls into the water the sound is heard three miles away.

This glacier moves eight feet per day and has 200 tributaries. Its greatest length is 50 miles, and it is 20 miles wide where the tributaries meet, but narrows as it reaches the sea. It is almost as large as all the glaciers of Switzerland put together.

Some of the glaciers in the Alps are 20 miles long, 1–3 miles wide, 300–600 feet deep. The Humboldt, of Greenland, is 45 miles wide and 300 feet thick.

Where the glacier reaches the sea it pushes out for a distance, the end breaks off and gives rise to an *iceberg*. Such are seen floating from northern places to the Gulf of St. Lawrence. Some are 300 feet high, and sometimes only a seventh is above water. There is always from 4–7 times as much below as above the water.

It can be readily understood how ice in all these forms will exert a powerful influence in disintegrating the rocks in mountainous districts. Frost, as it occurs in the small cracks of rocks along the banks of a river and on mountains, denudates, by bursting off pieces of rock.

Sometimes the fragments may be very large. In such cracks you usually observe small stones, which serve as wedges, by sinking deeper as the frost causes the opening to expand; until they finally burst the portion off. This accounts for much of the debris *(talus)* seen at the base of mountains or along a river bank.

Life.—All animals that burrow, form passages into which air and water get, and act upon the material near, so as to disintegrate it. Worms are a great benefit in this work. It has been estimated by able investigators that they increase the surface soil at the rate of one-fifth of an inch yearly, by the deposition of their castings, or, expressed in other words, add 16 tons of finely divided rock to an acre each year.

The holes they form also afford passages for rain and air, in fact, they are "nature's ploughmen."

Plants, while living, act upon rocks with acids formed in the minute root cells. This has been shown by growing plants on marble, when its surface becomes quite corroded and eaten into from the solvent action of the liquids in these cells. When dead, the plant in decaying gives rise to carbonic acid, itself a great solvent, and as decay of the roots proceeds leaves passages suitable for the access of air and water. From the facts referred to on denudation, the reader will readily see what an enormous change must be constantly going on where these agencies are at work, and that their combined action tends to the preparation of material important in the formation of soil.

CHAPTER VIII.

ACTION OF SUBTERRANEAN FORCES UPON ROCKS.

Tilting and Fracturing.—The effect of subterranean forces upon rocks often elevates them, so as to raise one side higher than another, and cause them to show a slope ("dip").

The direction of the ridge which is at right angles to this is called the "strike". If the rock fracture, a "fault" will likely result and the strata of one side will not correspond with the other. By this means rocks are often raised and brought into view as an "Exposure," and if quite marked may be styled an "Outcrop." By this change three forms of Valleys may be produced. a. A Valley Dislocation, where the strata on opposite sides do not correspond; b. Valley of Undulation rèsulting from a folding of the rocks, so that the strata dip towards the valley; c. Valley of Elevation is formed on the ridge resulting from the folding of strata. Though a valley of elevation, yet it may occupy a depression, by the ridge having sunk after it was formed and a river flowing upon it so as to cut out a channel. The strata on both sides in this case dip from the valley.

Where the strata of rocks are parallel to one another the term *comformable* is used, and where they are not, *unconformable.* The latter indicates a great lapse of time between the two periods at which the deposits were laid down.

5. **Metamorphism.**—This change is produced by pressure, heat and moisture acting together. It changes clay to slate, chalk to marble and causes "Cleavage" a tendency of rocks to split into an indefinite number of thin layers independent of the layers of stratification, e. g., mica and slate.

It may be confined to a limited portion (local) or extend over a wide area (regional) as is represented in the northern parts of Canada, where these rocks are common, e. g., Muskoka, etc.

An examination of the earth's crust, in all parts of the world, shows that it consists of regular layers, that these layers always occupy the same relative position to one another, that is to say, that if the layers are numbered 1, 2, 3, 4, 5, etc., you will never find 4 above 5, 6 above 8.

This fact is of great importance, for it enables us at once, to arrange the layers represented at any place in regular order, some may be absent, in fact no district has all, for we have learned that a place is usually beneath water, before it can receive a deposit and it is not likely all *places* are submerged at the same time. The layers have characteristic fossils, so that by knowing some of the most important, we at once know the position of the geological records before us. Remembering these four things:—the earth's crust is composed of layers; no place has all the layers; these layers are in regular order; each layer has its characteristic fossils; we can understand how it is possible to make a systematic arrangement of the various rock formations represented in the earth's crust.

The absence of certain layers is accounted for, by the fact, that the locality either has been above the sea, when the deposits were laid down; or that they were made but have been washed away. A third explanation is sometimes given, that the place was so far out in the sea, that it was beyond the influence of deposition which is usually confined to portions of the sea bottom, nearer the shore.

The layers of rock which compose the earth's crust are usually grouped into Ages, Systems and Formations. The Ages being the most comprehensive.

Comparing the stony records of geology to a book on history, we may call the Ages, volumes; the Systems, periods; and the Formations, chapters.

CHAPTER IX.

THE STONY RECORDS.

Below is a tabulated statement, showing the different Ages and Systems, and some of the striking characters in each System. The Formations into which these Systems are divided in Ontario, are given at the close of chapter XI.

AGES.	SYSTEMS.	LEADING FEATURES.
Acrozoic, The summit of life. Gr. *akros*, extreme; *zoe*, life.	16 Modern,	Man.
	15 Pleistocene,	"Ice Age" and modern species of animals.
Kainozoic, Recent life. Gr. *kainos*, new; *zoe*. life.	14 Pliocene,	Great Mammals, Mammoth, etc.
	13 Miocene,	First Ruminants, Mastodon.
	12 Eocene,	Many Mountains appear, Alps, etc.
Mesozoic, Middle life. Gr. *mesos*, middle; *zoe*, life.	11 Cretaceous,	Chalk in England, Coal in Northwest.
	10 Jurassic,	Immense reptiles and the first bird.
	9 Triassic,	Many bird-like tracks, Salt in England
Palaeozoic, Ancient life. Gr. *palaios*, ancient; *zoe*, life.	8 Permian,	First true reptiles.
	7 Carboniferous,	Coal, trilobites disappear. [Petroleum
	6 Devonian,	Fish and Corals, many land plants,
	5 Silurian,	Salt and Gypsum in Ontario, first fish.
	4 Cambro-Silurian,	Gas and Limestone.
	3 Cambrian,	Life represented by but few forms.
Archaean, Ancient. Gr. *archaios*, ancient.	2 Huronian,	Minerals, ores of Copper and Silver.
	1 Laurentian,	Minerals, ores of Iron, Graphite, etc.

1, 2, 3, 4, 5, 6, 7, 8, sometimes termed Primary. 9, 10, 11, Secondary.
12, 13, 14, Tertiary. 15, 16, Quaternary.

The Ages are named according to the condition of life at the time. The Systems are called in some cases (Huronian, Devonian, etc.,) from places where they are well represented; in others (Carboniferous, Cretaceous,) from the nature of the deposits in the rocks; and in some (Eocene, Miocene, etc.,) from the resemblance of life to that of the present day.

In giving examples of localities where certain rocks are found, we shall refer more particularly to Ontario, when they are represented, but if not, to other parts of Canada, the United States and Europe.

CHAPTER X.

THE VOLUME ABOUT MINERALS.

ARCHAEAN AGE.—This is distinguished for vast areas of hard crystalline rocks, rich in minerals. The term Archaean (ancient) has been given because they are the oldest rocks we know of. Once the term Azoic (without life) was used, but the discovery of some supposed fossils led to a change, and Eozoic (dawn of life) was substituted. As many did not believe they were fossils, the term Archaean (ancient) was applied, as being a correct one, under the circumstances. This Age, including 50,000 feet of rock, is represented in Ontario by two systems, Laurentian and Huronian.

Laurentian System.—This *name* has been applied to the period on account of the rocks being well represented along the shores of the Lower St. Lawrence. It is largely a mineral area.

Nature.—The rocks are hard, crystalline, more or less disturbed, usually in layers and often present the appearance of granite. Though we find Quartz, Mica and Feldspar here, yet it is not in a confused mass, as in granite, but in layers. The rocks often show veins containing mineral ores.

Localities.—These rocks are found along the north bank of the river St. Lawrence, in parts of Quebec, throughout Muskoka, east side of Lake Winnipeg, and extending north to the Arctic Ocean. Between Morrisburg and Kingston, on the G. T. R., is an area of this rock. Many of the boulders scattered throughout fields in Ontario belong to this system; how they came here will be answered in a chapter on the Ice Age.

Life.—Many geologists are sceptical about any life existing, when these rocks were formed; but of late years specimens have been discovered in Ontario which seem to indicate that life existed in Laurentian times.

The representatives of life, if any, were confined to the sea. The fossil said to be found in these rocks is called Eozoon Canadense and is recognized by some eminent authoritities, (notably Sir J. Wm. Dawson) as a true fossil.

The reasons usually set forward in support of the view, that the Laurentian rocks were deposited as Aqueous and afterwards underwent a great change, so as to completely modify their general structure and appearance, are:

1. The presence of limestone which was likely a product of life.

2. Beds of Graphite, a form of carbon likely derived from plants.

3. Deposits of Iron Ore, the accumulation of which is largely dependent upon the presence of decaying organic matter, as referred to in chapter VI. Iron thus becomes a sign of life and a measure of its amount.

4. The presence of fossil Eozoon Canadense.

5. The beds are often in layers, indicating a sedimentary structure.

Economic Products.—Limestone, serpentine, iron ore, asbestos, apatite, graphite, mica, galena and some gold.

Huronian System.—This name is given on account of large areas of it along the northern shores of Lake Huron.

Nature.—The rocks are hard but not so crystalline as the preceding; considerable conglomerate (pebbles and fragments of rock cemented together in a solid mass) is found among them. Many of the rocks indicate a shore deposit, that has become hardened and consolidated. Great masses of Quartzite occur here, some slate and in some places areas of trap.

Locality.—The district around the northern shores of Lake Huron, Georgian Bay and the islands in that vicinity.

Life.—It is claimed by some that fossil worm tracks and some obscure forms of sponges have been discovered. A doubtful fossil resembling Eozoon has been reported in the Lower Huronian of Europe.

Economic Products.—Copper and Silver ores, Gold, Iron and Nickel.

CHAPTER XI.

THE SOURCE OF GAS, SALT, GYPSUM AND PETROLEUM.

Palaeozoic Age.—This age is represented by 70,000 feet of rock and includes six systems. During it many animals appear, but they are largely confined to the sea, and do not number many species; the plants are flowerless and the fish have cartilaginous skeletons instead of bone. The seas were thronged with mollusks before the volume closed.

Cambrian System.—The *name* Cambrian refers to Cambria in Wales, where the rocks of this system are well represented.

Nature.—Considerable sandstone is found among the rocks of this period, some quartzite, slate and some limestone.

Localities.—A somewhat triangular area containing much of this system is found extending from about Morrisburgh on the G. T. R. to the junction of the Ottawa and St. Lawrence Rivers; also in some parts of New Brunswick.

Life.—There is no doubt but that traces of animal and plant life occur in these deposits. Seventy-two species of trilobites, (crab-like creatures), some corals, crinoids, (sea lilies), cuttle fish, worm tracks and some brachiopods, (allied to lamp shells), have been found in these rocks. The peculiar tree-like fossils near Kingston are located in these deposits.

Economic Products.—These are gold, copper, iron, manganese, asbestos, soapstone, and sandstone suitable for building, (see Parliament Buildings, Ottawa), glassmaking, and some hard enough for whetstones.

Cambro - Silurian.—The name implies a transition between the Cambrian below and the Silurian above.

Nature.—The deposits of this period consist chiefly of limestones. In some of the earlier rocks evidences of metamorphism are present and the rocks show a disturbed condition.

Locality.—The area lying between Kingston and Weston on the G. T. R., and extending northward, embraces rocks of this system. Whitby, Toronto, Peterboro and Bowmanville are upon it.

Life.—The remains of animals and plants are now quite plentiful. Corals are very common. Graptolites (some not unlike a minute saw) are very numerous in Quebec. Trilobites are very numerous. Many large fossils, of forms allied to the cuttle fish, are obtained. The writer found one six inches in diameter in rocks at Oshawa. The shells consisted of a series of chambers, the last being occupied by the animal.

The straight forms are known as Orthoceratites. Plant life was still confined to the sea.

Economic Products.—Limestone, largely used for building purposes and the manufacture of lime; Sandstone, used in making glass; Bituminous Shale, once used for the production of coal oil, (Utica Slate formation at Collingwood), the source of Gas, (Trenton formation), some Marble and also Hydraulic Limestone (Quebec formation), and Lithographic Stone.

Silurian System.—This *name* is derived from the word Silures, the name of an ancient tribe of Britons, who lived in the West of England, where the rocks of this period have been studied.

Nature.—These rocks are chiefly dolomitic limestone, (a combination of lime and magnesia with carbonic acid) but in some places a soft red sandstone appears.

Locality.—In Ontario the area over which the G. T. R. passes from Weston to Baden, embraces rocks of this system.

Life.—Fossils are innumerable in deposits of this system. So common have shells become, that it is known as the "Age of Mollusks." Many remains of seaweed occur; a very characteristic one (Arthrophycus) is found in rocks near Grimsby. A fossil land plant has been found. Corals also abound. In Europe remains of fish have been found at the summit of Silurian rocks. In 1888 some remains of fish were found in these rocks in New Brunswick.

The Silurian species has been estimated as 718 corals, 1,579 trilobites, 1,567 brachiopods, 1,086 bivalve shells, 1,306 univalves, 40 fishes.

Economic Products.—Salt (Goderich), gypsum (Paris), building stone (Forks of the Credit), Dolomite for building purposes and the manufacture of lime (Guelph), lithographic stone (near Walkerton).

The deposits containing gypsum and salt are supposed to have originated partly in salt lakes or inlets of the sea, while rapid evaporation was taking place; some account for them by a simple chemical union of the elements of which they are composed.

It was likely a time of elevation and dry climate with deserts and salt lakes.

The Silurian period seems to have been a time of shallow seas, warm climate and life largely in the sea.

Silence was a leading feature of those days; for there were no animals capable of making a sound. As yet no forests, plant life being confined to the sea.

The only sound would be the moaning of nameless seas and the noise of the wind rushing over the bare rocks.

The Green Mountains made their appearance at the close of the period.

Devonian Period.—The name Devonian is derived from Devon in England. Some have applied the name *Erian* to this system on account of the great area of these deposits found about Lake Erie. This is the Old Red Sandstone of Scotland.

Nature.—In Scotland sandstone is common among the deposits; but in Ontario they are largely limestone, clay beds and some sandstone.

Locality.—The area included between Baden, on the G. T. R., and Sarnia lies within this system. With this period the geology of Ontario ended, until the 15th (Pleistocene) was reached, when the Province received another donation. During the vast period of time including seven systems, Ontario was at a geological standstill, as far as receiving further deposits. It is likely the rocks were above the sea, and thus not in a position to receive additions to the beds already formed.

Life.—The advance of life, both plant and animal, is very marked. Land plants are common in the form of ferns, and trees similar to pines; they indicate the presence of forests. Fish are so plentiful, that this has been termed the "Age of Fishes"; these were of a peculiar type, known as *ganoids*.

The skeleton was cartilaginous, and hence boneless; the body was covered with plates, or firm scales, and the tail was unequally lobed. They were wonderful in variety, size and number, and were prepared either to attack or defend themselves against their enemies.

The Dinichthys was a huge form, whose remains have been found in Ohio; its head was 3 feet in length and the body as great in diameter; while the length of the creature was fully 30 feet. Supplied with tusks 1 foot long, it became a terrible engine of destruction in the nameless seas of Devonian times.

Coccosteus, *Cephalaspis*, *Pterichthys* are fossil forms referred to in nearly every geology, as types of these peculiar forms of animal life. It was among the fossils of the Old Red Sandstone Hugh Miller labored with such distinguished success, and in describing them, became famous for his descriptive powers. Corals were very abundant; 75 species are reported in the rocks along the shores of Lake Erie, and insects' remains have been discovered.

Economic Products.—While a certain amount of limestone is obtained from these rocks, the great product is petroleum, its source being in the Corniferous formation of this system.

Regarding the origin of this valuable product, two explanations have been set forward. a. The distillation of bituminous coal. b. The decomposition of organic matter, chiefly vegetable. The oil is generally found in a porous dolomite limestone, a few feet in thickness and comparatively soft. Two well known fields exist in Ontario :—Petrolia and Oil Springs, with about 2,500 wells, from which petroleum is being obtained.

All petroleum is not derived from Devonian rocks. Canadian is derived from lower Devonian (Corniferous); Kentucky and Pennsylvania wells are from upper Devonian; Virginia's are from sub-carboniferous; and Ohio's are from the lower coal measures.

The following are the Formations into which the Systems we have considered are further divided, in the Province of Ontario :—

1, Lower, 2, Middle and 3, Upper Laurentian.

1, Lower and 2, Upper Huronian.

1, Animikie, 2, Nipigon and 3, Potsdam, of the Cambrian.

1, Quebec series, 2, Trenton (source of gas), 3, Hudson River, of the Cambro-Silurian.

1, Medina, 2, Clinton, 3, Niagara, 4, Guelph, 5, Onondaga (source of salt and gypsum), 6, lower Helderberg, of the Silurian.

1, Oriskany, 2, Corniferous (source of petroleum), 3, Hamilton, 4, Portage-chemung, of the Devonian.

CHAPTER XII.

COAL, ITS ORIGIN AND FORMATION.

Carboniferous System.—This *name* has been given on account of the nature of the products in this system, there being much carbon present. This is a term likely to be misleading; for we may conclude that wherever much coal occurs the rocks must belong to the Carboniferous. This is not the case, as is seen in the coal deposits of our Northwest, which belong to the Cretaceous system. However, Carboniferous has been applied to the system by early geologists and must be accepted now.

Nature.—The rocks of the system include 15,000 feet of deposits containing immense quantities of coal, which is found in seams varying from a few inches to 30 feet in thickness; between these are layers of shale, sandstone and clay, and often deposits of iron ore. Limestone is also found in rocks of this period.

Locality.—As we learned in the last chapter, the geological records of Ontario closed, and we must therefore seek elsewhere for coal deposits. Such occur in Nova Scotia and New Brunswick, and to some extent in British Columbia.

Life.—The plant life of this time was of a most luxuriant type, and very uniform ; it is the same in all beds of the coal of this time, which leads us to infer that there was a uniform climate for that period in all parts, where this system occurs. We find representatives of it in the United States, Canada, Greenland, the Arctic Regions and Australia. The plants were large, very numerous, but the species were limited and all were flowerless types like the ferns, mosses and club-mosses of to day. They bore no flowers and matured no seeds, but produced spores, from which plants of low types grow. So abundant was this simple form of plant life, that it has been termed the "Age of Flowerless Plants."

The typical plants of the time were Ferns, Calamites (allied to our Horsetails), Lepidodendron, Sigillaria and Stigmaria ; some of great size, though the types of our plants allied to them are seldom a foot or so high ; these had stems 3-5 feet in diameter and grew proportionately high. The accumulated remains of these luxuriant forms of plant life are what contributed the material for the production of our coal. Animal life is not so characteristic and striking as that of plants. Some amphibians make their appearance, a few spiders and some snails have been found. The trilobites are nearly all extinct; consequently where we find trilobites on rocks near the surface we need not expect to find coal below, as they disappeared before coal was formed.

Economic Products.—The great product of this system is coal; but iron ore is sometimes associated with it, and limestone and sandstone are also obtained. Regarding the origin of coal, two theories are set forward; both agree in considering, that coal is derived from the accumulated remains of plants, but differ as to how the formation of the deposits took place.

1. *Raft Theory.*—This theory accounts for coal by an accumulation of vegetable matter that shifted from its original position, became submerged, and changed into coal. This might occur in large rivers, and is only applicable to comparatively limited areas of deposits.

2. *Swamp Theory.*—According to this view the accumulated remains did not change their position, but simply became submerged and

gradually changed to coal, beneath whatever may have covered the beds, such as sand or silt. This is well suited to account for extensive deposits in different parts of the world. A forest, located at the mouth of a river not much above the level of the sea, would meet the requirements of this view. Every seam of coal represents an ancient land surface; consequently where several seams occur we are led te believe that there were several periods of elevation and submergence.

The luxuriant vegetation of the time seems to indicate warmth, humidity, uniformity, and very little movement in the atmosphere. Some argue from the rank vegetation an excess of carbonic acid in the air.

The abscence of mountains would, no doubt, cause less precipitation and more moisture. It was in reality a time of forest and jungle and the sea covered with numerous islands. At the close of the system the rocks were considerably disturbed and subjected to change. All coal, as already stated, is not confined to the carboniferous system. It is found in the Jurassic (Yorkshire), Triassic (Virginia), Cretaceous (Northwest), Miocene (Oregon), Carboniferous (England, Nova Scotia and Pennsylvania).

Permian System.—This name is derived from Perm, in Russia. It represents a transition period between the closing and opening of two periods. Some of the gigantic types of plant life have passed away, and never appear in the rocks again. This is seen in the Sigillaria and Stigmaria. Some of the red sandstones of Prince Edward Island belong to this period. It also appears in Nova Scotia and some parts of Virginia.

At the close of the Palaeozoic age the Appalachian Monntains appeared. During this age about 70,000 feet of rock were formed, and throughout this vast period of time igneous ejections seemed to have occasionally occurred, as is seen in some Cambrian deposits in the Rocky Mouutains; Cambro-Silurian of Nova Scotia; Silurian of New Brunswick; Devonian of Quebec, and Lower Carboniferous of New Brunswick.

CHAPTER XIII.

MARVELLOUS FORMS OF LIFE.

Mesozoic Age.—This volume of the records has but a small amount of deposits as compared with the preceding; something about 11,000 feet, yet among them are found some of the largest creatures that have ever existed upon the face of the earth. The outburst of reptilian life was something marvellous, and its decline was equally remarkable. One of the smallest volumes and, yet, in it the developement of life, rapid, and the size attained almost incredible. We find three well marked systems here.

Triassic.—A *name* given because the rocks are represented in some places by three layers.

Nature.—Much sandstone is found here; it has been called the New Red Sandstone.

Locality.—This layer is found on Prince Edward Island, around the Bay of Fundy, and along the Connecticut River in the United States.

Life.—The unique plants of the Carboniferous days are all gone; ferns still continue to flourish, and a strange plant (Cycad) comes upon the scene; it was a sort of pine and palm, resembling the former in structure, the latter in appearance; pines also occur. In the deposits of Connecticut, (U. S.) the rocks abound with many varieties of three-toed markings, which were, for a long time, considered the footprints of birds. Some impressions are 22 inches in length by 12 in width and indicating a stride of 6 feet. Whatever animal made such footprints must have been immense. Latterly it is believed that most, if not all, of these three-toed markings were caused by reptiles.

In Europe some five-toed markings are found upon Triassic rocks. The first mammal (allied to the Kangaroo) occurs in these deposits.

Cuttlefish, in coiled shells are becoming much more common and show more complicated partitions in the shells. The straight form of cuttlefish (Orthoceras) so common in silurian rocks, die out here.

Economic Products:—Salt-beds occur in these rocks in Cheshire, England, and coal in Virginia.

The Palisades of the Hudson River, N. Y., were formed at the close of the Triassic days.

Jurassic System.—This name is derived from Jura mountains.

Nature.—Considerable limestone and shale are in some parts, while in some places the rock resembles the fossil roe of fish; on this account the term Oolitic has been applied to it.

Locality.—British Columbia shows some deposits. They are also found in England.

Life.—The Cycads reach the summit of their developement here, and so numerous are they in the deposits that the term "Age of Cycads" has been used. But the surprising feature of the Jurassic is the innumerable remains of gigantic reptiles (Dinosaurs) it has yielded.

The Ichthyosaurus (fish lizard), 30 feet in length, with jaws 3 feet long filled with teeth, and eyes, a foot in diameter, is a common form, often illustrated in books. The Plesiosaurus, with long graceful neck, glided over the waters, like a huge swan, and seems often to have waged war with its enemy the preceding reptile, for the remains of the one have been found within the body of the other. The Pterodactyle was a huge reptile able to fly through the air; and several forms evidently moved like the Kangaroo by bounds from place to place. The Atlantosaurus had a thigh bone 8 feet in length. From this we can imagine the size of the gigantic reptile of which it was a part. One has been estimated to have been 70 feet long and 10 feet high. Such were the monsters of Jurassic days, and the period might well be styled "The Age of Reptiles."

The first fossil bird was found (1862) among these rocks, and styled the Archaeopteryx. It was very incomplete, but enough was discovered to show that it was a bird that had many things in common with reptiles, much more so than the birds of our time.

Economic Products—Some coal in Yorkshire is located in these deposits and also some in parts of Virginia.

The Rocky Mountains began to rise out of the sea towards the close of this period.

CHAPTER XIV.

THE TIMES OF CHALK AND COAL.

Cretaceous System.—This *name* is given on account of the nature of the deposits in some parts, especially in England, where vast beds of chalk are found in rocks of this period. The same deposits in the North-west have no chalk, but abound in coal.

Nature.—A large amount of chalk is in some, and coal, as already noticed, in others, while great beds of clay also are common.

Locality.—Immense deposits of this system occur on the continent of America from a little west of Brandon, on the C. P. R., to Calgary, near the Rocky Mountains, (800 miles.) It is also well represented in the United States and England.

Life.—A great advance is made in both plant and animal life. Plants with netted leaves are common. From this onward flowering plants increase, and the Flora of the time becomes more attractive. Fishes have advanced and possess bony skeletons. Their tails had become equally-lobed before this, but cartilage represented the skeleton. Types more or less allied to our modern perch and salmon appear. Reptiles, though still represented by some large forms, have begun to wane. Cuttlefish, represented by Baculites and Ammonites,the former with straight, the latter with curved shells, are very common; both possessing shells with very complicated partitions.

Several birds have been found in American deposits, some of which have teeth and show well marked reptilian characters.

Economic Products.—Vast deposits of Coal in the Canadian North-west. This is chiefly lignite, and exists in unlimited quantities over an immense area. It is harder the nearer the moutains it is found, and in some places it is anthracite. Chalk occurs to a considerable extent in England. Salt has been obtained from these deposits in Louisiana. At the end of this period the Continent of America, which hitherto was represented by two great bodies of land, became one by the gradual upheaval of the submerged region. The Colorado mountains, which had been a line of islands in the Cretaceous sea, were pushed up and the strata along the flanks much tilted.

CHAPTER XV.

GREAT MAMMALS AND THE ELEVATION OF MOUNTAINS.

KAINOZOIC AGE.—We now have an approach to recent things and many of the shells are the same species as are found in present waters. The names of the different systems are applied according to the percentage of shells found in them resembling modern types. Three systems are embraced in this volume of the records.

Eocene System.—This *name* (Gr. *eos*, dawn; *kainos*, new,) signifies the dawn of recent things, and contains from 3-10 per cent. of shells like those of our own time.

Nature.—The deposits are chiefly clay and limestone.

Locality.—Extensive areas occur around Paris, (France), some in England and in the United States.

Life.—Nummulite, a coin shaped fossil, is very characteristic of these rocks. Tapirs are very common in the deposits of the Eocene basin of

Paris, where 40 species have been found. Extensive deposits, containing the remains of whales, are found in Alabama. Vertebrae, measuring one foot and a half in length and one foot in diameter, have been discovered. At Florissant, Colorado, a remarkable deposit of Upper Eocene has been found, one layer of which is black with the remains of insects of all kinds; 1000 species have been identified. On the island of Sheppy, England, the remains of 13 species of palms have been discovered. The Flora of England resembled that of Australia now. This system is not represented in Canada, unless it be in some of the Upper Cretaceous of the North-west. The close of the period is marked by great elevation of land in some parts, and several mountain chains came into existence about this time, viz:—Alps, Pyrenees, Carpathian and Himmalaya.

Miocene System.—The *name*, (Gr. *meion*, less; *kainos*, new,) given because we find in this that 19·30 per cent. of the shells are modern. This word means less recent, but refers to the succeeding period.

Locality.—This is wanting in Canada, but well represented in India and several places in Europe and the United States.

Life.—Some immense forms of the mammalia appear here, such as the mastodon, much larger than the largest elephant. Teeth of this have been found weighing 17 pounds, and tusks a foot in diameter.

The Dinotherium, another gigantic mammal, existed at this time. It had huge tusks resembling, in position, those of the walrus. A tortoise has been found 13 feet long, and the remains of some gigantic antelopes. Plants are numerous, but less tropical than formerly. The Flora of Europe was like that of the Southern States now. It is supposed that the Atlantic was dry land at this time; this may account for the resemblance the plants of Europe bear to those on the coast side of the United States. At the close of the Miocene the Coast Range of Mountains of California and Oregon came into existence, and likely at the same time occurred the great lava-flood, covering to a great extent portions of Nevada, Oregon, Washington and Idaho, and extending into Montana and British Columbia. It is estimated that these deposits cover an area of 150,000 square miles, 3,000-4,000 feet thick. The Columbia River has cut a channel for 100 miles through beds 1,000-3,000 feet thick, showing in some places 30 sheets of lava. The source of this lava seems to have been in the Cascade Mountains.

Pliocene System.—The *name*, (Gr. *pleion*, more ; *kainos*, new,) signifies more recent, there being 30-90 per cent. of the shells recent.

Locality.—These deposits occur in England, Italy and Carolina.

Life.—The shells are nearly all recent, but the mammals are still extinct. The Mammoth appears here. The Flora of Europe resembled that of America now. In the latter part of the period the land, both in Europe and America, was more elevated and extensive than at present. This corresponds to the first Continental Period of Lyell.

The climate was now getting colder, and changes taking place which showed that the former warm climate was at an end.

CHAPTER XVI.

THE ICE AGE.

ACROZOIC AGE.—This Age forms the last volume in the geological records, and in it we find some of the most interesting pages in the story of the earth. It embraces two system, Pleistocene and Modern.

Pleistocene System.—Pleistocene or Glacial, (Gr. *pleistos*, most; *kainos*, new,) in which all the shells belong to existing species.

The deposits occur as extensive beds of clay, sand, gravel and loose boulders, well represented in the northern parts of America and Europe. Ontario now received additional deposits. These constitute what is known as "Glacial Drift." It is widely distributed in the Northern Hemisphere, and extends from the Arctic regions to 50° north latitude in Europe, and about 39° in North America. It generally occurs as sand, clays and gravels, spread in widely extended sheets, representing three distinct layers.

1. Unstratified clays with angular fragments

of stone, more or less polished and striated. These beds form the so-called Boulder Clay or Till, resting on rock which is abraded and striated.

2. Stratified sands, gravels and clays, also with boulders.

3. Sands and gravels, also stratified, but the stones in them are more rounded and water worn than in the preceding.

It is considered that when the Boulder Clay was formed in America the northern part was higher than now and the climate Arctic, so that the mountain tops became the starting points of glaciers.

Then followed a time of subsidence, reaching 4,000 feet in North America, during the deposit of stratified clays, and thus making it favorable to floating ice and glaciers to act conjointly. After this, re-elevation began and reached its maximum in the earlier part of the next system, (Modern.). These glacial deposits have always afforded interesting facts for study, and are credited to the result of ice action during the Ice Age, a term applied to the Pleistocene. In order to understand fully the importance of conditions that existed during this Period, it is necessary to examine the work of ice in the forms of avalanche, glacier and iceberg. This is possible by visiting some places where such are at the present time.

Our lessons upon the effects of ice are usually gathered from phenomena witnessed in Alaska, Greenland, Switzerland and Norway, where there is a line of perpetual snow. The snow cannot remain always on top of the mountains, but eventually comes down rapidly, as an *avalanche*, or slowly as a *glacier*. The latter threads its way down the mountain side and through ravines, continuing its course until it either reaches a place where the temperature is sufficient to melt it or pushes out in the sea, when a portion breaks off and floats away as an *icsberg*. Its course valleyward is, usully, very slow, sometimes only ten inches per day. As it moves along at this rate it receives contributions of rock material, falling upon its surface. This arranges itself in regular rows, called *lateral moraines*. If two glaciers from different valleys unite a *medial moraine* is formed. It is not unusual for great cracks (*crevasses*) to appear in the glacier and into these many of the huge stones on the ice drop, even reaching the bottom. From this it is easily understood that the glacier will have a tremendous grinding influence, both on the rocks on which it is gliding and those embedded in it.

At last the body of ice is overcome by heat and melts, giving rise to a *terminal moraine*, and the source of a river. This water will have a tendency to distribute the material carried down in the following order: course boulders, pebbles, gravel, sand, and the clay carried far into the valley. It sometimes happens during a very warm season, a glacier shortens, and thus an opportunity is afforded to observe how it has affected the rock over which it moved. The result is, the hard rock has been abraded, polished and scratched, the scratches or *striae* are in the direction from which the stream of ice has come. Glaciers are often many miles long, miles wide and hundreds of feet thick. With such forces at work, we can readily believe an immense amount of rock material must be ground up, adding a contribution to the soil of the valley, and that many of the rocks in the mass and beneath it, will have a more or less rounded form, from the constant rubbing during miles of transport.

In the case of an iceberg, which is a portion of a glacier that has reached the sea before the temperature is sufficient to melt it, much of the material is transported and finally finds a resting place wherever the "berg" melts, depositing its load in a place far from where the rocks are located from which the fragments were derived. We observe this every year in the deposits of Greenland rocks dropped into the Gulf of St. Lawrence, and along its shores, by melting icebergs, and witness the work in Switzerland, much as already described. It is now generally accepted that both in Europe and North America, during Pleistocene days, phenomena occurred much as we see in the countries referred to. Immense glaciers were common, and, likely, for a portion of time at least, icebergs played an important part in the work. Some hold that the Ice Age lasted 160,000 years, but later geologists bring it within a period of 25,000 years. As already observed, the climate in those days had become arctic and the land, for a time, more elevated to the north; the south, also, may have been much submerged and conditions were present suitable to the formation of glaciers and and icebergs, both of which were factors in what resulted. The question may arise here, what proofs have we in Ontario of the Ice Age? The following may be given:

1. The presence of rounded boulders, fragments of northern rock, entirely different from Ontario limestone.

2. The boulders have a southern limit: the south shore of Lake Erie about 39° N. Lat. In Europe the limit is 50° N. Lat.

3. The rock surface of our province in many places is abraded, polished and scratched, the *striae* showing a N. E. direction.

4. Our clays are to the south, north of these is gravel, and farther north are boulders.

5. The action of glaciers to-day produce similar results.

It has always been a question of much interest to account for the change in the climate that led to the Ice Age. There are two leading views concerning the cause; one explaining it on physical grounds (Lyell's); the other on astronomical (Croll's); of these the former seems the more reasonable. By this it is claimed that a different distribution of land and water currents could produce the changes that took place; for instance, if the Gulf Stream broke through the Isthmus of Panama, England would no longer enjoy the influence of that current, but experience an arctic winter. The second view maintains that there is an eccentricity in the earth's orbit around the sun, which at intervals of many thousand years produces winter, when the earth is in aphelion (farthest from the sun) while to-day winter takes place in perihelion (nearest the sun.) It is claimed that under such conditions, we might reasonably expect a glacial period. To those desiring a full explanation of this view, we would recommend a reference to some large work upon Geology.

CHAPTER XVII.

THE APPEARANCE OF MAN.

Modern System.—This period includes from the Close of the Ice Age up to the present time. By some described under the divisions Post-glacial and recent periods. In the earlier part of it the land of the Northern Hemisphere was more extensive than it is now, and is described as the "second continental period" (Lyell), the first being in the Pliocene. It closed by a submergence (the flood of biblical history), after which there followed a gradual elevation, which has given the continent of America its present appearance.

The climate became temperate after the long years it had been held within the icy grasp of the former period. In these earlier deposits (Post-glacial) are located the cave deposits and river gravels of Europe, from which so much light has been gathered concerning man's antiquity, which by many is not referred to an earlier date than that immediately following the close of the Ice Age (Pleistocene), viz.: the Post-glacial. However, some claim that man existed before the Ice Age.

The following are the chief sources from which proofs bearing upon man's early appearance are derived:—

1. Cave deposits, e. g. Kent's (Devon), Kirkdale (York), and Aurignac (France). These are referred to Palæolithic times, a division of the so-called "Stone Age."

Man's remains are associated with those of the cave bear, hyena, lion and tiger with which he fought for the caves. There is little doubt but that he hunted the mammoth. This race of men likely perished in the flood.

2. Kitchen Middens, in Denmark; masses of refuse, indicating the presence of man. These are located in Neolithic times, a more recent division of the "Stone Age," a better race of men than in the preceding period.

3. Lake Dwellings in Switzerland, built by a still later race of men, belonging to the "Bronze Age," about the time of the "Mound Builders" in America. The present is known as the "Iron Age."

The noted fossil man of Mentone (France), belongs to the Palæolithic period. The animals of post-glacial days were characteristic. Many of them were gigantic forms, such as the mastodon and mammoth; woolly rhinoceros, Irish elk and megatherium, an immense sloth found in the deposits of South America, and several other mammalian types. Many of these became extinct at the close of the Post-glacial period. The remains of the mastodon and mammoth found in America are usually referred to Pleistocene times, but there are those who locate them in Miocene deposits.

By some this last age is divided as follows:—1, Glacial; 2, Champlain; 3, Terrace; 4, Recent.

1. Glacial. A time of elevation of the earth's crust in high latitudes, probably from 1-2,000 feet above the sea, accompanied by an arctic climate and the formation of glaciers, producing results much the same as we see where glaciers are now.

2. Champlain. A subsidence of land until the sea stood 500-1000 feet above its present level, and therefore covered much of the land of to day. This was a period of inland seas, a

milder climate and melting of the ice, giving rise to great lakes and rivers. Some glaciers would continue. Icebergs and field ice would be common, resembling the icebergs of Greenland in their results.

3. Terrace. This marks a gradual emergence of land approaching to the continent and climate of the present.

It was during the Champlain period that our fresh water lakes formed one body of water, which emptied out by the Mississippi instead of the St. Lawrence, as now. Some discuss this last volume (Acrozoic) under the divisions:—Glacial, Post-glacial and Recent.

In that portion of the volume which reveals traces of man, we sometimes find the following divisions made:—Stone Age, *palæolithic* the earlier part, *neolithic* the later; Bronze Age and the Iron Age, now in progress. During the Acrozoic Age Mammals reached their highest development.

Many were huge forms, such as the mammoth, mastodon, the Irish elk with antlers ten feet across, the cave bear larger than the grizzly of the Rocky Mountains, some huge oxen, and the megatherium (a huge sloth found in deposits of South America).

Economic products from the Rock Systems of Ontario, as reported in the annual report of the Bureau of Mines :—

	1892.	1895.	
Building Stone,	$880,000	$438,000.	Chiefly from Silurian
Cement	85,997	159,477.	"
Lime	350,000	280,000.	"
Tile and Brick.	1,339,335	1,173,429.	"
Pottery	80,000	108,000.	"
Gypsum deposits	25,900	20,500.	"
Phosphate	23,810	———	Laurentian.
Salt	162,700	188,000.	Silurian.
Mica..........	1,500	2,900.	Laurentian.
Nickel	590,902	404,861.	Huronian.
Copper	232,135	160,913.	"
Gold..........	36,900	50,281.	"
Petroleum and products	1,400,435	1,173,429.	Devonian.
Gas	160,000	282,986.	Cambro-Silurian [and Devonian.
Total	$5,369,694	$5,170,138	

CHAPTER XVIII.

ORIGIN AND FORMATION OF ONTARIO SOIL.

The following is a popular exposition regarding the Origin and Formation of Soil, with special reference to the Province of Ontario, and represents in a summarized form much of the preceding teachings of geology.

I. A Vertical Section of Ontario Soil.

If we examine a vertical section of soil in any part of the Province, it will present the following characters:—

1. Certain large stones, hard and more or less crystalline, some of a salmon color, some greenish, others a mixture of black and white, and in many cases the material will be arranged in layers.

If quarries are near, the rock is not at all of the same nature as the large, hard, round stones already referred to, and which for convenience we will call *foreign boulders*.

These we shall show have been brought here in ages long past, and lie by our roadsides, and in our fence corners, silent monuments of thrilling scenes that happened in the Ice Age.

2. Other large, loose stones of a much softer nature appear, but they resemble the rocks of the quarries, if such are in the vicinity. These are not so much rounded, we shall call them *local boulders;* for they have not been transported so far as the preceding.

3. Scattered throughout the loose earth, we observe the remains of decomposed plants that have flourished from time to time upon the soil in which they are now found. These form the *humus* of the soil.

4. Our ideal section will also show ground-up rock, usually called soil.

5. Beneath all is a floor of rock. Our section thus shows five constituents, *foreign boulders, local boulders, humus* (organic matter) *soil* (pulverized rock) and a *solid floor* of rock. From this it is readily seen that the composition of soil largely depends upon the nature of the rock below it, and upon those at a distance (in Ontario those lying to the north), because, as we shall see later on, much material was transported

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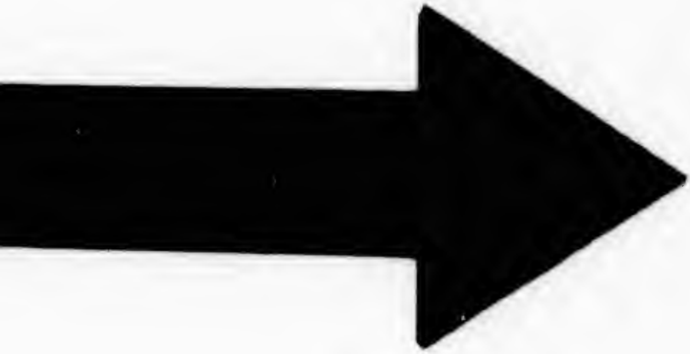

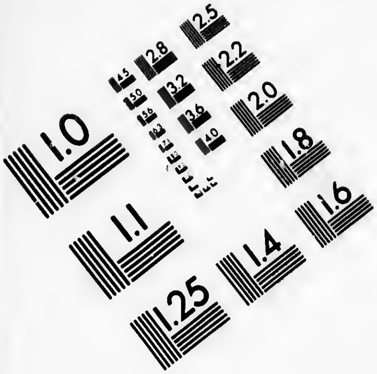

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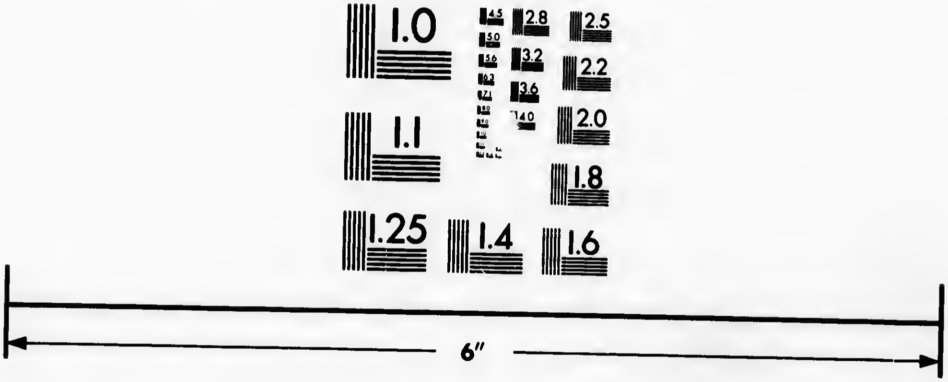

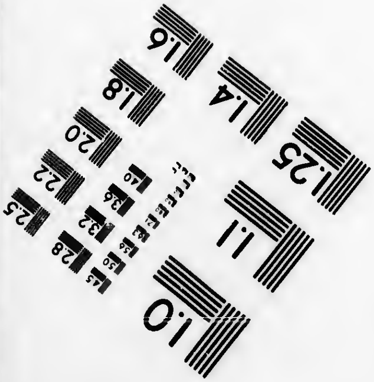

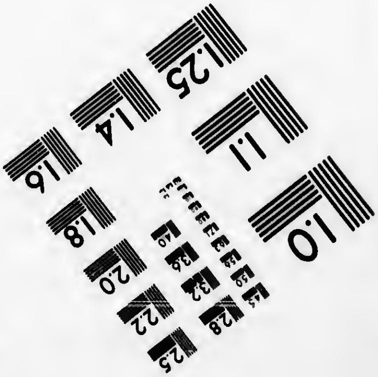

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from the north during the "Ice Age." We shall now consider the nature of the rock that underlies our Province and the regions north of it.

II. The Rocky Floor of Ontario.

1. A district embracing that portion of the Province extending from near the junction of the Ottawa and St. Lawrence Rivers to Morrisburg and north to the Ottawa. This is largely underlaid by rocks of the Cambrian System (No. 3) in which there is much sandstone, some limestone and slate.

2. This area extends from Morrisburg to Kingston and continues in a north-westerly direction beyond the limits of the Province, widening as it passes north. This is the Laurentian System (No. 1), the great mineral area of Canada.

In many places the rock is bare, yet this district possesses rocks, which, when decomposed, supply some of the most valuable constituents in soil. Here we find much Feldspar, consisting of clay, silica and potash which it contributes to the soil on disintegration; Apatite, the source of Phosphoric Acid; Iron, and other deposits of great importance in soil formation.

Thus in this apparently barren area we have rocks which, in time, break up and supply valuable constituents to the soil, such as phosphoric acid, potash, soda, iron, lime, magnesia, sulphur, clay and sand.

3. The area extending from Kingston to a little west of Toronto, known as the Cambro-Silurian system (No. 4), contains vast beds of limestone.

4. A district from near Toronto to Baden, on the G. T. R., consists of Silurian Rocks (No. 5), largely made up of dolomite (containing both magnesia and lime).

5. From Baden to the western boundary of the Province includes Devonian Rocks (No. 6), composed of limestone and clay deposits. We have thus six systems represented in Ontario:—1, Laurentian; 2, Huronian (around lake Huron and much the same as No. 1); 3, Cambrian; 4, Cambro-Silurian; 5, Silurian; 6, Devonian. At No. 6 the geological records closed, as far as Ontario was concerned, until they re-opened at No. 15 (Pleistocene). It is remarkable that, as far as deposits are concerned, we received none from No. 6 to No. 15.

Other places received great additions, such as coal beds, chalk and other deposits of great thickness, while Ontario received none. Since nearly all rocks are formed under water, it is likely our country was, during that vast period of time, high and dry and thus beyond the influence of the sea.

However, great changes were going on, and the surface of the Province was considerably modified from the action of agents which we shall now consider :

III. Disintegrating Agents.

Disintegrating agents, i. e., agents breaking up rocks. These acted upon the solid floor of Ontario during vast periods of time.

1. Air, in the presence of moisture, has a great influence upon rocks, especially if iron is in them, and this is a common ingredient among the oldest rocks. You often notice by the wayside, boulders with rusty stains upon them. These result from the action of the air upon the iron in the stone. It will only be a matter of time before it is dissolved and the stone crumbles to pieces. The element, oxygen, a constituent of air, has a great tendency to unite with

other elements, and, hence, its destructive effects upon many rocks. Consequently, the simple action of the air in the long ages between the Devonian and Pleistocene periods would no doubt do much in breaking up the rocks upon which it acted.

2. Water, especially in the form of rain, beating upon the rocks during this long period would exert a wonderful influence upon the rock surface in two ways, viz. : mechanical and chemical. The former needs no explanation, for it is readily seen how rain would act, as we see it today, by distributing the ground-up rock and wearing away, by mechanical action, the surface over which it flowed. But there is another way in which it can act very forcibly, especially when it contains carbonic acid which is present in the atmosphere. When this carbonic acid and rain water come in contact with rocks, especially such as contain lime, magnesia and iron, they form with them compounds soluble in water, and thus break up the rock in which they are found. This solvent action of water explains why it is always more or less charged with mineral substances, producing hard water. Many caves, especially those found in limestone, have been

formed by the solvent action of water, and the beautiful icicle-like structures in them have been deposited from water, drop by drop. The Mammoth Cave of Kentucky has 223 avenues, representing 150 miles. The average height and width of these passages is 21 feet. The amount of limestone removed is said to be equivalent to 12,000,000 cubic yards. This to a great extent is the result of the solvent action of water. Rain charged with carbonic acid during long ages would certainly act so as to disintegrate the limestone floor of Ontario. See its effects upon the marble tombstones in a graveyard, and observe how it corrodes the limestones of the field so that we readily distinguish them by their *weathered* appearance.

3. Plants, as soon as they appeared, would exert an influence upon the surface. While living, the tender roots penetrating the soil would feed upon the minute particles and dissolve those near them, and when they decayed, channels would be left for rain to pass into the soil, and the decomposing plants supply carbonic acid, which would aid in the work of disintegration.

4. Animals, especially such as burrowed,

would open up the way for air and rain to enter the soil. Few animals are credited with more influence in the breaking up of the soil, than the common earthworm. From extensive experiments by Darwin, it has been discovered that in some places worms add one-fifth of an inch of mould yearly to the soil, or at the rate of 16 tons to the acre derived from the deposits they leave upon the surface. Besides this, their burrows form passages for air and rain to act upon the rock material exposed.

5. Frost, while it existed, would be a powerful agent. We see how it breaks down the rocky banks of rivers and sculptures the mountains. Much of the rock lying at the base of mountains, cliffs and steep banks is the result of frost.

Now, the more we consider these five agents, *air*, *rain*, *plants*, *animals* and *frost*, the more we will be convinced of their disintegrating effect, especially when we think of the vast period of time elapsing from the close of the geological record (Devonian No. 6) in Ontario, until they were re-opened for deposits in the Pleistocene days (No. 15). This gap, as already noticed, embraced eight periods, each of which may have been thousands of years in duration; yet in that time the rock surface was undergoing changes, that must have prepared great deposits of finely divided rock. However, this soil would be largely localized, being much of the same nature as the rock below it; but when the Pleistocene period arrived, the Ice Age appeared, and was destined to mingle this pulverized rock in a most marvellous manner. In order to understand this more fully, let us examine some things going on now in countries where mountains are found with snow capped summits throughout the whole year, and from these phonomena form some conclusions regarding the state of affairs in Ontario during the Ice Age, claimed by some writers to have lasted 160,000 years.

IV. Ice Age.

Ice Age, the period during which enormous quantities of rock material were ground up and mixed with soil formed previous to its appearance.

In countries where the mountains are high above the level of the sea, a line of perpetual snow is formed, and ice keeps accumulating throughout the year. In time the mass becomes so great that it can no longer remain upon the mountain top, but begins to descend. If the slope is steep, the descent is rapid, and the mass of ice is known as an *avalanche*, which moves with tremendous force into the valley below.

But if the descent is gradual, then the ice moves slowly towards the lower country, and forms an ice river (a *glacier*), sometimes miles long and hundreds of feet thick. It glides onward, sometimes at a slow rate—only a few inches each day—yet it moves, and what seems very remarkable, moves more rapidly in the centre than on the sides. This has been shown by putting stakes in the glacier and along the sides. In the course of time they assume a V shape, indicating that those in the centre have made more progress than those at the side. In course of its journey, fragments of rock are constantly falling upon the glacier. If cracks (*crevasses*) occur in the rock, which is quite a common thing, the rock drops into them and becomes imbedded in the ice. In cases where some reach the bottom, one can readily understand what a grinding effect these imbedded rocks will have upon the rocks below. Thus a glacier becomes a tremendous agent in grinding up rock. This river of ice will continue gliding on until it reaches a point at which the temperature is sufficient to melt it, and then it becomes the source of a river. If it is a very warm season, the glacier is not so long, and an opportunity is offered to see how things appear where the glacier was the season before. The solid rock is smoothed, polished and covered with markings running in the direction from which the glacier came, and the boulders lying about are rounded. Now if the glacier reaches the sea before it melts, a portion of it breaks off and moves away as an *iceberg*. This will carry away all the rock material in it, and will be deposited where it finally melts. This is what occurs yearly along the coast of Labrador and Newfoundland, where so many *bergs* strand at certain seasons. Now, if an elevation of the sea-bottom took place here, we would find it covered with great boulders, not the same as the rocks along the shore, but like those in Greenland, whence the icebergs came.

The question naturally arises now, Is it possible that such conditions have ever been in this part of the world? We are forced to admit such is the case, to some extent, when we consider the following facts :—

1. Boulders are found all over our province. These are not at all the same kind of rock as the stones of quarries near by, but strongly resemble the rocks lying to the north and northeast of us.

2. These boulders are not found much south of the 39° north latitude, that is, a little south of Lake Erie. They extend in an irregular manner, as far as Cincinnati. Foreign boulders can be seen almost anywhere north of this limit, which strongly resembles in their distribution the boulders in districts now undergoing the grinding influence of glaciers.

3. In many parts of Ontario, where a rock surface is exposed, the rock is abraded and polished, and entirely covered sometimes by peculiar markings (striæ of geologists). These have a more or less uniform direction (northerly), which indicates the glacier came chiefly from the north.

It is difficult to account for these foreign boulders and the smooth, polished, scratched rocks below, extending only so far south, unless we imagine the same condition that we see now in other parts of the world where glaciers and icebergs are found.

Then, too, we find the arrangement of our clay, gravel and boulders is similar to that where glaciers are to-day. In Western Ontario our clay beds lie to the south. In Artemesia, north of these, are great stretches of gravel; and still further north are extensive areas covered with boulders. No better explanation to account for this state of affairs can be given than the presence of a glacial period in Ontario—a time when the northern part of our continent was more elevated and became the starting point of glaciers that made their way southward until regions were reached where they melted, leaving the boulders of our wayside as silent monuments of that period in geological history. It is an open question to what extent these phenomena are due to the action of glaciers and icebergs. Some attribute them entirely to glaciers, while others consider them partly due to iceberg action.

In regard to the duration of the glacial period, there is great diversity of opinion. No doubt it lasted for thousands of years. During this time immense quantities of rock were ground up and transported to the south of the starting point of the glaciers. At the close of this wonderful period it is supposed that all of our fresh water lakes were united, and formed a vast body of water which covered the entire province. This would have a great influence in mixing up the soil that had been formed before the glaciers existed and that which had been prepared during that period. During this time the waters of this great lake found an exit by the Mississippi River. In time the waters began to subside, and Queenston Heights formed a shore line. The Niagara River existed before the glacial period; part of its course extended from the present whirlpool to St. David's, this in course of time was filled up with glacial clays. When it began to flow again, instead of keeping in its old bed it flowed down to Lewiston and poured its water into the subsiding lake. As this lake diminished, the falls increased, and receded gradually until they reached the place we find them to-day.

The time required for this gradual change in their position was once put at 35,000 years. More thorough investigation has led geologists to believe that it probably took only 10,000 to 15,000 years. It is doubtful at what period the waters found an outlet into the Atlantic Ocean. But shortly after this took place, the physical features of Ontario began to assume their present outline, and the province became fitted for man's abode. From what has been set forth in this lecture, we conclude that the soil of Ontario has been obtained from the disintegration of rock during the vast period of time extending from the 6th to the 15th system of the geological records; the grinding action of ice, both as glaciers and icebergs, during the Ice Age, and what has resulted from a modification of the earth's crust since that time, together with the decomposed remains of plants and animals that have from time to time been added to it.

If the writer has awakened a desire in his readers to seek further information in the attractive field of geological science, he feels assured that they will consult larger works and satisfy the taste developed by reading this elementary treatise. In this connection the following books on geology will be found interesting and instructive:—"A Compend of Geology," by Joseph Le Conte; Handbook of Canadian Geology, by Sir J. W. Dawson; and the Manual of Geology, by Dana, latest edition.

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