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John Warkentin

Geological Lectures by Dr. John Richardson, 1825-26

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GEOLOGICAL LECTURES BY DR. JOHN RICHARDSON, 1825-26

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October 7th 1825 — Lecture 1st by Dr Richardson

Geology — Is a Science that treats on the Structure and formation of Rocks — and Earths — and the studying of it convinces one, of the regularity of those are most stupendous works and leads the mind to a higher veneration of the omnipotent and Divine Being —

The Ancients had erroneous opinions of Geology — but in more recent Times, acute observers have assigned good reasons for the apparent confused irregularity of the Nucleus or Surface of the World — they have found effects from causes and proved the beautiful Order of this part of the Almighty's Works. —

Geology is useful — particularly to the Traveller, whom it instructs in the knowledge of the Country through which he may pass — It teaches him where to look for Springs — Minerals — and valuable Earths —

In civilized Countries — the different formations are often shown in the Houses or large Buildings — which are generally constructed of the Material found in the vicinity of the Neighbourhood — or as built in the locality —

To be a Geologist — a Person ought to be acquainted with Mineralogy

The first page of Back's lecture notebook

INTRODUCTION

In the late fall and early winter months of 1825-26 a series of geology lectures was delivered in a log fort on the western shore of Great Bear Lake, about 450 kilometres south of the Arctic Ocean. This was 17 years before the establishment of the Geological Survey of Canada, five years before the founding of the Natural History Society of Halifax, and four before that of the Literary and Historical Society of Québec. Almost certainly this was the first course on geology given in today's western Canada, and perhaps in all British North America. It is true that observations on the geology of different parts of British North America were being made in the early 19th century, such as David Thompson's (Warkentin, 1967) geological summation in about 1800 of the western interior of Canada, W.E. Cormack's (1928) mineralogical descriptions recorded on his walk across Newfoundland in 1823, Captain Bayfield's (1829) remarks on the Lake Superior area in the 1820's, Dr. J.J. Bigsby's (1822, 1824, 1825a, 1825b, 1828, 1829a, 1829b) reports on the geology of the St. Lawrence-Great Lakes in that same decade, and W.H. Keating's (1959) account of the rocks observed on Stephen H. Long's expedition to Minnesota and Lake Winnipeg in 1823. But the lectures at Great Bear Lake differed from such descriptive geological field observations; they were an attempt to instruct a small group of men in selected fundamentals of geology, and so comprise what may have been the first "extension course" in science in what is now Canada. Dr. John Richardson, surgeon and naturalist on the two Franklin land expeditions to the Arctic of 1819-22 and 1825-27, gave the lectures.

The first Franklin expedition had been a disaster, with many men lost and the mapping of the Arctic coast not completed. On the second Franklin expedition a base called Fort Franklin was established in 1825 on Great Bear Lake, about 112 kilometres east of the Mackenzie river (Fig. 1). The fort was small. The main structure 7.3 x 12.2 metres, comprised a hall and quarters for the officers. Other buildings sheltering men and stores were arranged so that with the hall they enclosed a court. Thirty persons wintered here in 1825-26, four naval officers from Great Britain, Captain John Franklin,

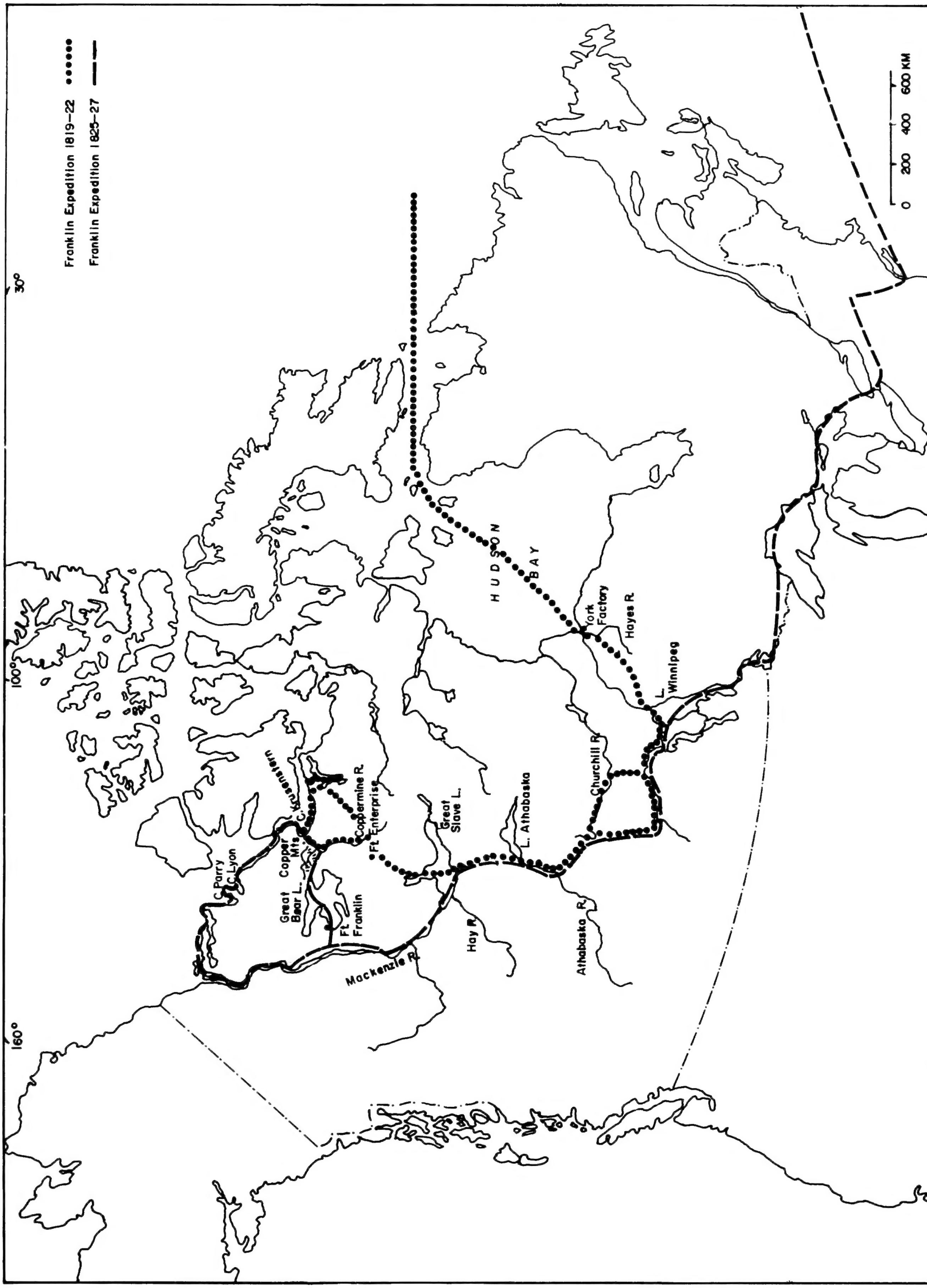

Figure 1: location map showing the routes of the 1819-22 and 1825-27 (Franklin) expeditions

Dr. John Richardson, Lieutenant George Back, and Admiralty Mate Mr. E.N. Kendall, a Hudson's Bay Company Chief Trader named Peter Warren Dease, and 25 men. The explorers intended to reach the Arctic coast early in the exploring season of 1826. For officers and men this meant a winter of marking time, isolated in a post in the High Arctic.

Even though there was work for the men, such as bringing in food and fuel, and the officers made scientific observations, special efforts still had to be made to maintain morale. The situation was not unlike that experienced by sea-borne Arctic explorers when their ships were frozen in ice over winter. Although the Franklin party wintered on land, they were many days' travel from the nearest Hudson's Bay Company post, and furthermore did not possess the facilities for entertainment which ships could carry.

As the evenings lengthened and the grip of winter restricted activities the officers endeavoured to keep everyone usefully occupied. On his Arctic expedition of 1819-20 Captain William E. Parry (1821) had demonstrated the value of printing a newspaper, putting on amateur theatricals, and organizing other entertainment to keep up the spirits of his men during the winter. Franklin attempted a similar approach. To keep the men employed over some of the long evenings and at the same time provide them with new skills a school was established, meeting every other evening in the week from 7 to 9 o'clock. Each of the officers took a certain number of pupils and taught reading, writing and arithmetic. The men responded well and Franklin (1828b, p. 54-5) stated that a number did learn to read and write.

The officers also attempted to improve themselves, especially in science. Officers who volunteered for exploring expeditions in the 19th century were normally trained in navigation, surveying and topographical drawing, and were often genuinely interested in the scientific work of the day, especially natural history. Franklin, for example, was a Fellow of the Royal Society, had been made a member of the Wernerian Society of Edinburgh after the 1819-22

Expedition and knew Roderick Murchison, William Hooker, Robert Jameson, and other leading scientists. He corresponded with them and assisted them in securing collections of rocks and plants from foreign lands. Amongst the educated classes of Britain investigation into many aspects of science, especially the study of plants, animals, minerals and rocks in the field, was fairly widespread. Useful scientific contributions were made by men and women who devoted time and money to pursue such activities. Many naval officers were part of the same cultural tradition. Conversant with the science of the time, they hoped to contribute to it when on special assignments such as exploring the northern part of North America.

Consequently it comes as no surprise that the officers were interested in attending a series of lectures on geology when this was proposed by Dr. Richardson (Back, 1825). These lectures reinforced some earlier instruction they had received. Before the expedition left Britain Dr. W.H. Fitton, President of the Geological Society of London, instructed Richardson and the other officers in geology to prepare them for their explorations, much as astronauts are taught some geology nowadays to enable them to explore the surface of the moon more intelligibly. They had studied the collections of rocks in the museum of the Geological Society, and Dr. Fitton provided a portable collection for further study which was carried to Great Bear Lake. The explorers also took a small library with them which included (Franklin, 1825, 1828a) the following books: Robert Jameson's (1821), *Mineralogy*; William Phillips' (1823), *Mineralogy*; Alexander Humboldt's (1823), *Superposition of Rocks*; Conybeare and Phillips' (1822), *Geology of England and Wales*; DeCandolle's (1821), *Philosophy of Plants*; and Wahlenberg's (1820), *Flora Upsaliensis*. The full titles and the editions likely used are given in the references.

It was thought (Back, 1825, Oct. 1; Franklin, 1823/27, Oct. 6, 1825) that the lectures by Richardson would help the officers in their study of the rock collections assembled by Dr. Fitton and in their reading of geology. Franklin (1825, Nov. 6, 1825) expressed this well in a letter to Roderick Murchison:

> We have brought up the collection he (Dr. Fitton) had the goodness to give us for reference--and our excellent friend Dr. Richardson's affords all the information he has, or which he can gather from the books we have brought respecting them--so that through him we endeavour to keep up the information which Dr. Fitton first imparted--We have got Conybeare & Phillips--Phillips & Jameson on Mineralogy and Humboldt on the Superposition of Rocks--but to the inexperienced--one lecture from a person conversant with the Science is more profitable than many hours reading on Subjects naturally difficult to be comprehended--.

The officers probably had the immediate object in mind of learning how to identify rocks and minerals while exploring, but the broad ranging nature of Richardson's discourses makes it apparent that the lectures were an introduction to the whole field of geology, especially to the classes and formations of rocks as they were known at that time.

We would have no further evidence of Richardson's lectures than the brief reference to them by Franklin (1828b, p. 56) in the published narrative of the expedition, and the comments by Franklin (1825) and Back (1825) in their letters and journals, if Back had not kept a complete set of notes on the lectures which happily have been preserved, and are now deposited in the archives of the Scott Polar Research Institute, Cambridge, England.

Dr. John Richardson, a native of Dumfries, Scotland had his 38th birthday during the time he was giving these lectures. He was apprenticed as a surgeon in Dumfries and took medical classes at the University of Edinburgh. In 1807 he was appointed an assistant surgeon in the Royal Navy. Richardson had a profound interest in natural history and eventually established a fine reputation as a marine zoologist. In 1819 he was appointed to Franklin's first expedition as surgeon and naturalist, and while living in Edinburgh for a short time before the expedition sailed for British North America, studied mineralogy and attended lectures by Robert Jameson, Professor of Natural History at the University of Edinburgh. As was common in this period, a great deal of Richardson's knowledge must have been acquired from his own background reading. On the second Franklin expedition he once more served as surgeon and naturalist, and also was in effect Franklin's second in command. From 1828-38

Richardson was the chief medical officer at the Melville Naval Hospital at Chatham, England, and from 1838-55 the senior physician to the Royal Naval Hospital at Haslar, England. In 1848-49 he journeyed to the Arctic once more to assist in the search for Franklin, lost on his third Arctic exploring expedition. Richardson never lost his interest in natural history and extablished a fine reputation as an ichthyologist and was recognized as an authority on the physical geography of northern British North America. Knighted in 1846, he retired from the navy in 1855, and died ten years later. Johnson (1976) has prepared a full biography of Richardson as explorer, naval medical administrator and natural historian.

George Back was born in 1796. He joined the Royal Navy in 1808, and first journeyed to the Arctic in 1818 on a ship commanded by John Franklin. He was engaged as midshipman on Franklin's 1819-22 exploring expedition, and was a member, of course, of Franklin's 1825-27 expedition. He remained associated with the Navy until the end of his life, moving in and out of retirement a number of times, and often advising the Admiralty on Arctic matters. In 1833-35 he led an expedition to the Arctic in search of Captain John Ross, and in 1836-37 he was the leader of an exploring voyage to the eastern Arctic. Back was knighted in 1839, promoted to Rear Admiral (Reserve) in 1857, Admiral in 1876, and died in 1878. Holland (1972) has written a short incisive account of his career.

DESCRIPTION OF THE NOTEBOOK

Lieutenant Back kept his notes carefully, as if he were attending a university course of lectures, in a separate notebook 26.7 x 16.5 cm. There are 27 pages of notes, written in ink, followed by 5 pages of coloured geological cross sections. Richardson delivered a total of 11 lectures; each is numbered and dated in the notebook. The first was given October 7, 1825, and the last January 13, 1826. Back's handwriting is usually legible, although sometimes it deteriorates as if Richardson was lecturing fast and Back was forced to write too quickly making it impossible to decipher a few words. That these are notes taken down from lectures is further indicated by the fact that Back wrote in point form, used dashes to separate sub-topics, abbreviated words, used the symbol for ditto, and left blank spaces in some listings when he could apparently not keep up with Richardson. The staccato nature of some sections, where Back listed main points only as Richardson proceeded, further substantiates this view. Misspellings are numerous, as one might expect, and there are examples of phonetic spelling, likely based on the way Richardson pronounced certain unfamiliar words. The most obvious example is "oophytile" for Euphotide, later corrected in Back's handwriting very lightly in pencil.

There are no maps in the notebook, and we have no way of telling whether Richardson referred to maps while describing geological formations. Back is well known for his topographic sketches, and in the text there are a few drawings of strata and other features but these are no better than the illustrative material inserted by any careful student in his lecture notes. Indeed, the lack of diagrams is rather disappointing, and is possibly related to inadequate means for illustrating the lectures. However, the coloured geological cross sections at the end of the lectures (Fig. 3 is an example) illustrate effectively the sequence of rocks described by Richardson. No direct references are made in the notes to these sections, so they may have been copied by Back from other sources.

METHODOLOGICAL BACKGROUND

Richardson's own notes are not available for analyzing his geological ideas. His ideas can only be approached indirectly through what was recorded by Back. In all likelihood Richardson's exposition was much more complete than is apparent from Back's notes, and the reservation must be made that these notes are not necessarily a full or even an entirely true reflection of Richardson's thoughts on geology. There is no fully satisfactory way of verifying this, although it is possible to compare the notes made by Back with Richardson's own geological descriptions included in the official reports of the two

Franklin expeditions. This is done at the end of this introduction. For the present it is assumed that Back's notes constitute a true record of Richardson's geological ideas at the time the lectures were given.

Richardson delivered his lectures on geology during a critical period in the development of the subject. In the years 1790-1810 William Smith (1815, 1817) demonstrated the utility of fossils in identifying and tracing sedimentary strata and established a chronological sequence of sedimentary rocks for the Secondary (Mesozoic) rocks of eastern England. However, Richardson lectured to his fellow officers just before Charles Lyell started to write his *Principles of Geology* (1830, 1831, 1833) which brought a great measure of order and consistency in approach to the study of geology, at least in Great Britain. In the 1820s there was little understanding of how the earth had been formed, and still some lingering argument over the fundamental question of how rocks such as basalt, granite, gneiss and syenite had originated. This was one of the fierce controversies in the history of geology and since Richardson transferred some hints of this great debate to the remote Arctic it merits consideration.

One school of thought held that a considerable proportion of the earth's rocks, including the oldest, had been deposited as precipitates in a great universal fluid or ocean which once covered the entire globe. Supporters of this aqueous theory of the origin of the earth's crust were called Neptunists. A famous German mineralogist, A.G. Werner, 1749-1847, was the main proponent of this view, and it became identified with his name. Werner (1809) classified the succession of rocks in the earth's crust into what he thought were four universal categories, the Primitive, Transition, Floetz (Secondary) and Alluvial classes. The Primitive Class refers to the oldest and highest rocks in the world, formed as chemical precipitates when the global ocean was deepest. Organic remains are absent and mechanical rocks rare. When Werner first worked out his system he thought (Adams, 1954, p. 218-9) that sedimentary beds directly overlay the Primitive. They consisted of mechanical deposits derived from already existing Primitive rocks together with organic remains and associated precipitates. These beds had been deposited in horizontal layers at lower elevations than the Primitive as the universal fluid declined in volume and fell in level, and comprised the Secondary Class, or Floetz, from the German word for flat. Later, Werner introduced (Adams, 1954, p. 218-9) another major category of rocks between the Primitive and the Secondary. These rocks were similar to the Primitive but not quite as crystalline and contained a few organic remains. It was believed that by the time these rocks were formed the processes of precipitation, erosion and sedimentation working concurrently were producing both crystalline and sedimentary rocks. Werner called (Adams, 1954, p. 219) this the Transition class. The Alluvial deposits were much younger than the Transition and Secondary. Formed from previously existing rocks, they were only loosely consolidated and were still being laid down. Robert Jameson, 1774-1854, who had studied under Werner, was the German scholar's leading and most active supporter in Great Britain.

The opposing school of thought held that the oldest rocks were not precipitates in a universal ocean but were of igneous origin, formed by the cooling of hot molten material originating in the interior of the earth. Hence supporters of this concept, calling upon subterranean heat, were called Vulcanists.

Basalt and granite were key pieces of evidence in the debate on the origin of rocks, with both Neptunists and Vulcanists claiming them for their own. Two Scots, Sir James Hall, 1761-1839, an amateur chemist, and James Hutton, 1726-97, an amateur geologist, had fairly well proven by the turn of the 18th century that rocks such as basalt and granite were of igneous origin, Hall through laboratory experiments and Hutton through field studies (Geikie, 1962, p. 305-11, 317-26).

Hutton (1795) worked out a comprehensive system explaining amongst other things the origin of rocks and the surface features of the earth. He postulated the igneous nature of many rocks, and this became known as the Huttonian theory. Hutton also argued that landforms were produced by normal processes of erosion working uniformly over long periods of time. Since no sudden catastrophies were called upon in this explanation of the origin of landforms it came to be known as the doctrine of uniformitarianism.

By the 1820s the Huttonians had carried the field against the Wernerians on the issue of the igneous vs. chemical origin of those rocks which we regard today as igneous, but there were lingering pockets of resistance. Robert Jameson was a stubborn man and held his ground as a staunch Wernerian or Neptunist against the Huttonians or Vulcanists for many years. And he influenced Dr. John Richardson who had attended his lectures just before embarking for North America on Franklin's first expedition. The men became good friends, and later Jameson identified and described rock specimens collected by the Expedition. In 1808 in his compedium on mineralogy Jameson (1808) strongly advocated the Wernerian doctrine on the origin of rocks and vigorously challenged the Huttonian position. In 1821 he said little about the controversy (Jameson, 1821), yet as late as 1834 he still maintained that granite could be formed both as a precipitate from a liquid, probably water, and also from a state of igneous fusion (Jameson, 1834, p. 220).

Richardson made considerable use of Jameson's ideas in his lectures, but he was influenced by other authorities as well. After all, in the mid-1820s options were still open on which geological interpretations and which classifications of rocks to use because Lyell's great consolidating work, which very well might have channelled Richardson's presentation, had not yet appeared. In his lectures Richardson named some authorities even if he did not provide exact references, and this is helpful in determining where he got his ideas. Further, nearly all of his sources can be established by comparing Back's notes with the contents of the books the Expedition brought to the Arctic. The quotations from these sources are never exact. They scarcely could be, filtered as they were through Back's notes. But there are sufficient similarities in organizations, and in the use of terms and specific phrases, between the notes and particular early mineralogical and geological treatises to leave little doubt where Richardson got his information.

The following excerpts indicate the sorts of relationships which can be established between points made in the lectures and the sources on which they appear to be based:

(a) Richardson, Lecture 6: "*Greywacke* consists of fragments of Quartz Felspar - Lydian Stone and Clay Slate, connected by Basis of Clay Slate"

Jameson (1821, p. 377): (Greywacke) "It is composed of angular or other shaped portions of quartz, felspar Lydian-stone and clay-slate, connected together by means of a basis or ground of the nature of clay-slate...."

(b) Richardson Lecture 10: (London Clay) "It chokes the Plough and rolls before it unlike other Clay. —The Beach or bank when dried is cracked resembling the Giant's Causeway."

Conybeare and Phillips (1822, p. 33): (London Clay) "This clay chokes the plough and rolls before it in a broken and muddy state; after rain it is not slippery, but adheres to the shoes; after drought it presents cracks nearly a yard in depth and several inches in breadth. On the Nore, south of Walton it forms a sort of pavement in many places, and divides by desiccation into small columns resembling, on a small scale, the Giant's causeway."

(c) Richardson, Lecture 6: (Transition Greywacke) "According to Humboldt it may be determined in Schistos-Porphyry-Sienite-Granular and compact Limestone—4th Euphitide and 5th Aggregated Rocks.—"

Humboldt (1823, p. 130-31) "If we examine the transition formations according to their structure and their oryctognostic composition, we distinguish five very strongly marked associations; the schistose rocks; the porphyritic rocks (feldspathic or syenitic); granular and compact limestone, with anhydrous gypsum and rock-salt; euphotides and aggregated rocks (grauwacke, and calcareous breccias)."

Turning now to the lectures as a whole it is evident that Richardson based much of his material on Jameson (1821) and Conybeare and Phillips (1822). Jameson's *Mineralogy* (1821) basically is a description of rocks and minerals organized according to the Wernerian classification of rocks by age into the Primitive, Transition, Secondary and Alluvial groups (see Figure 2 for modern equivalent formations). The great innovative approach of William Smith (1815, 1817) to investigating the Secondary (Mesozoic) rocks of England, firmly based on the fossil record, did not illuminate Jameson's book, although Jameson did describe in his mineralogical way an essentially correct succession of Secondary strata in England. However, the principles established by Smith (1817) were followed by Conybeare and Phillips (1822) in describing the sedimentary formations of England and Wales. Thus the two books used by Richardson complement one another to some extent. Jameson (1821, p. 345-82) considered the Primitive and Transition rocks in considerable detail, and although he discussed (*ibid*, p. 382-424) the Secondary and Alluvial at even greater length he did not have nearly the clarity of interpretation which Conybeare and Phillips (1822, p. 3-470) provided on those formations. On the other hand, the latter did not consider formations earlier than the Secondary, nor volcanic rocks, intending to leave that to a second volume which was never published. It becomes apparent halfway through Richardson's lectures on the Secondary that he switched from Jameson to Conybeare and Phillips as his main source, although he still drew on Jameson for some facts and seemed to base his discussion of volcanic rocks largely on the Scottish mineralogist.

Other books were used. Humboldt's (1823) *Superposition of Rocks*, can be detected as a source on at least six occasions, and it is likely that Phillips' (1823) *Mineralogy* was also employed. It has not been possible to identify sources for all the material in Richardson's lectures. This is to be expected because Richardson likely would have drawn on other reading, discussions with geologists such as Fitton, and observations of his own on British North American rocks.

CONTENTS OF THE LECTURES

Richardson's lectures are organized as indicated in the list of topics below. The first three lectures concern general introductory geological matters; the other eight lectures describe a chronological sequence of rocks and geological formations, largely using British examples.

Topics	Lecture No.
What is Geology?	1
Important Rock Forming Minerals	1
Composition of Rocks	2
Texture and Structure of Rocks	2
Classification of Rocks Into Formations or Classes	2
Comments on Erosion	3
Distribution of Fossils	3
Theories of Geological Change	3
Description of the Geological Classes	3
Primitive	3,4,5
Transition	6
Secondary	7,8,9,10
Tertiary	10
Alluvial	10
Volcanic	11

Lecture 1. Richardson takes us directly into the world of early 19th century European geological thought. His belief that geology leads to the recognition of the regularity of nature's stupendous works and to higher respect for the divine being is characteristic of the geological writings of the time. So was the quick switch to the practical applications of the subject and possible wider relationships. Associating particular rocks with building stones, mining activities, fertility of the land, shape of mountains, scenery, and so on, was characteristic of both Jameson (1821) and of Conybeare and Phillips (1822). Richardson's suggestion that a geologist should have a knowledge of mineralogy and botany reflected the relatively recent recognition by geologists that botanical knowledge was valuable in classifying strata. The importance of zoology should rightfully have been mentioned as well. The discussion of minerals, composition of rocks, and rock texture and structure was a very mixed up version of Jameson's (1821) treatment, with some additional material from Conybeare and Phillips(1822).

Lecture 2. In discussing the composition of rocks Richardson used the term "Mountain Rock" which Jameson (1821, p. 337) defined as

> those mineral masses of which the greater portion of the crust of the Earth is composed. Minerals, or mineral aggregates, to have the true characters of mountain rocks, must occur not only in great masses, but frequently, and present in their structure and composition such characters as shall serve to distinguish them, and make them known in whatever situation they may be found.

Richardson followed Jameson (1821, p. 337-45) throughout this section, but not very clearly. Jameson's main points were: "Simple Mountain Rocks" are formed of one mineral, "Compound Mountain Rocks" are aggregations of various minerals. "Indeterminately aggregated" rocks are rocks in which there is no dominant matrix, so they are confusedly joined together as in some marbles, and "Determinately aggregated" are rocks where one mineral is dominant and clearly encloses another mineral or a number of other minerals. The contemporary term for matrix was "Basis" or "Ground" and was often used by Richardson. "Determinately aggregated" rocks were subdivided further by Jameson, and his introductory passage (Jameson, 1821, p. 338) on these rocks is reproduced below. Richardson used it as a source for this section.

> The *determinately aggregated structure* presents a number of subordinate differences. It is either *simple* or *double* aggregated. The *Simple Aggregated* contains two subordinate kinds. In the *first*, the minerals are connected together in such a manner that one serves as a basis for the other, which is included in it; and it also contains two subordinate kinds. These are denominated the *porphyritic* and *amygdaloidal*. In the second, all of the parts are immediately connected, or joined together; and here we have also two subordinate kinds, the *granular* and *slaty*.
>
> The *Double Aggregated* includes five subordinate kinds: These are, 1. *Granular slaty*. 2. *Slaty granular*. 3. *Granular porphyritic*. 4. *Slaty porphyritic*; and 5. *Porphyritic and amygdaloidal*. The first four kinds of double aggregated structure comprehend one structure in another, so that, as the denominations intimate, a smaller structure is contained in a greater. In the fifth or last

kind, one does not include the other; but, as the denomination expresses it, they are placed near or beside each other.

In his comments on structure Richardson introduced only the simplest terms and concepts, such as inclination of strata. And he was not much more advanced in his remarks on surface features. Granite boulders at Great Bear Lake appear to be attributed to "Cap and Ball" erosion. More likely, of course, the boulders were erratics. This is the first recorded reference to a Canadian example in these lectures.

In the short section on classifying rocks into formations or classes, Richardson introduced what he will cover in the remaining lectures. Richardson was content to list the classification scheme he would use, name some of the formations, and make a few remarks on the nature of the rocks to be found in each. Figure 2 shows the classification used by Richardson and tabulates the major rocks described in the lectures to follow. This division of rocks originated with Werner (1809), as indicated above, and was subsequently adopted by Jameson (1804, 1805, 1808, 1821) and Humboldt (1823). Richardson demonstrated that he would get away from the model of Werner and Jameson when he did separate a young series of sedimentary rocks, the Tertiary, from the Secondary, basing this on Conybeare and Phillips (1822, p. 3-57), although Conybeare and Phillips did not use the term Tertiary.

In the brief preliminary description of the classification scheme he adopted Richardson stated that no fossils are found in the Primitive but are present in the Transition, and that recent shells exist in the Tertiary and appear in mineralized form in the Secondary. These ideas were not discussed as criteria for classifying rocks as they should have been. Nor did Richardson consider what is meant by a "formation", how beds can be grouped into formations, how fossils may be used to identify strata, and how stratigraphic sequences can be recognized. The phrase "Superposition of formations" was used, but not defined. In subsequent lectures there are only occasional fleeting allusions

Figure 2. Rocks, Formations and Geologic Time - Units Described by Richardson and Comparable Modern Geologic Time - Units.

TERTIARY		Alluvial Diluvial	CENOZOIC	Quaternary: Recent Pleistocene
TERTIARY		Upper Fresh Water Upper Marine Gypsum Lower Fresh Water London Clay Plastic Clay	CENOZOIC	Tertiary
SECONDARY		Chalk Chalk Marl Green Sand Weald Clay Iron Sand	MESOZOIC	Cretaceous
SECONDARY	OOLITIC LIMESTONES – UPPER	Purbeck Beds Portland Oolite Kimmeridge Clay	MESOZOIC	Jurassic
SECONDARY	OOLITIC LIMESTONES – MIDDLE	Coral Rag Oxford Clay	MESOZOIC	Jurassic
SECONDARY	OOLITIC LIMESTONES – LOWER DIVISION – UPPER BEDS	Combrash Forest Marble Stonesfield Slate Bradford Clay Great Oolite Fullers Earth	MESOZOIC	Jurassic
SECONDARY	OOLITIC LIMESTONES – LOWER DIVISION – LOWER BEDS	Sandy Oolite Green Sandy Marl	MESOZOIC	Jurassic
SECONDARY	OOLITIC LIMESTONES – LOWER DIVISION	Lias	MESOZOIC	Jurassic
SECONDARY		M – Calcstone (Muschelkalk) New Red Sandstone	MESOZOIC	Triassic
SECONDARY		Magnesian Limestone (Zechstein)	PALEOZOIC	Permian
SECONDARY		Coal Measures Mountain Limestone	PALEOZOIC	Carboniferous
SECONDARY		Old Red Sandstone	PALEOZOIC	Devonian
SECONDARY		(Not separated out as yet. Many of the rocks below are of this age.)	PALEOZOIC	Silurian Ordovician Cambrian
TRANSITION		Transition Euphotide Basalt Gneiss and Mica Slate Transition Limestone Clay Slate Glance Coal Alum Slate Pudding Stone Greywacke		
PRIMITIVE		Quartz Rock Euphotide Serpentine Green Stone Trap Porphyry Sienite Primitive Limestone Clay Slate Mica Slate Gneiss Granite		

to some of these matters. Only in Lecture 10 did Richardson make a reference to the fact that particular genera are characteristic of particular beds, and even there it was only a remark in passing. Fossils were not central to Richardson's analysis and were not used as diagnostic keys for identifying and correlating strata. In these lectures they were merely another descriptive characteristic along with minerals. In this way Richardson reflected the dead hand of Werner and Jameson and did not follow the lead of the great geologist William Smith. Smith is not even mentioned by name. In fact, Richardson did not explicitly make it clear that crystalline rocks do not necessarily occur in the strict chronological order in which they appear in the lectures. This can, of course, be inferred because granite, for instance, was mentioned in both the Primitive and the Transition classes.

Richardson used the terms Diluvial and Alluvial but did not define them. They are now called Pleistocene and Recent respectively. Conybeare and Phillips (1822, p. xxviii) drew a clear distinction between Diluvial and Alluvial as they were used at that time:

> To this general covering of water-worn debris derived from all the strata, the name of *Diluvium* has been given from the consideration of that great and universal catastrophe to which it seems most properly assignable. By this name it is intended to distinguish it from the partial debris occasioned by causes still in operation; such as the slight wear produced by the present rivers, the more violent action of torrents, &c. &c.; to the latter the name *Alluvium* has lately been appropriated; but many authors confound the two classes of phenomena together, describing them generally as alluvial.

Lecture 3. While discussing diluvium Richardson commented on detached rocks found on hills. Today these are considered to be glacial boulders. Richardson related these detached rocks to the eroding action of currents during the deluge, and noted the different views held by William Buckland (1823), Professor of Geology at Oxford, and Conybeare and Phillips (1822, p. xxix-xxx) on how the erosion was accomplished. There are no comments on processes of erosion, and none on the doctrine of uniformitarianism which was a pressing issue in geological thought at this time. Indeed, Richardson gave little attention to geo morphology in these lectures.

A problem which perplexed geologists was how to explain fossil remains of tropical plants and animals found in latitudes where present temperatures were obviously much too cold for those species. Richardson's explanation, that the required increase in temperature had been brought about by the heat of active volcanoes, was also suggested by Conybeare and Phillips (1822, p. xix).

Richardson did not consider the causes and origins of major physical changes in the earth, except to mention James Hutton's theory of subterranean fire. Hutton (in Playfair, 1956, p. 55) suggested that the energy of the earth's internal heat caused strata to be raised "up to the heights at which they are now placed". The forces of erosion then carried material back to the ocean, comprising what in effect was a vast ever-on-going cycle of erosion and regeneration. Back's notes are obscure here. Richardson appears to have cast some doubt upon the theory of subterranean fire, but his reasoning, involving the occurrence of northeast trending strata in the world and the implication that this required a process which acted simultaneously everywhere over the earth, appears not to have been recorded clearly. It seems fair to infer from these scattered statements that, whether or not Richardson adopted Hutton's views on the continuing regeneration of the earth, he did not believe in catastrophism on a world scale, apart from the deluge.

The remarks on subterranean heat served to introduce, rather abruptly towards the end of this lecture, the more detailed discussion of the various classes of rocks, beginning with the Primitive. Figure 2 indicates the order in which Richardson described the classes and major rock formations. He began with granite. Immediately there was a hint of the controversies over the origin of granite which prevailed at that time. Richardson laconically stated that Werner considered granite to be the oldest rock, that Hutton thought that it was the newest, and that Humboldt believed that granite containing the most quartz was the oldest. Having said this, Richardson presumably just kept on lecturing without stating his own preferences, which is typical of the way he handled controversial scientific matters in most of the lectures. The various classes of rocks described by Richardson are considered below.

Lectures 4-5. Richardson followed Jameson (1821) fairly closely in his discussion of the Primitive rocks, adding occasional additional facts from Humboldt (1823). The rocks, granite, gneiss, mica slate and so on, were arranged, quite mistakenly, in what was thought to represent a chronological record of the geological history of the crust. Hutton (in Playfair, 1956, p. 12-15, 168-71) had already argued that the rocks usually described in the Primitive had no regular position in a sequential succession of formations.

Richardson indicated that there might be gradations from one kind of Primitive rock to another depending upon mineralogical composition, and that certain rocks held intermediary positions in such a sequence. Further, he suggested that there was a linkage between Primitive clay slate (argillaceous schist) and Transition slate, but noted some differences. Nowhere did he directly state that there were any difficulties in trying to find a proper place for igneous rock in the Wernerian time scale.

Primitive limestone was crystalline limestone, and included marble used for statuary purposes. "Oophytile" was likely what Back made out of Richardson's pronunciation of euphotide, an early term for gabbro.

Most of the descriptive examples were of British rocks, but a few North American illustrations were included. Richardson stated that gneiss was the predominate rock in North America, occurring on the Hill (Hayes) and English (Churchill) rivers, and on the Barren Grounds. These areas had been visited by Richardson, Franklin, and Back on Franklin's first expedition. In describing the gneiss of North America Richardson provided the only remotely-light descriptive touch recorded anywhere in the lectures, "naked rounded Rocks peeping through the Trees".

Some of the problems inherent in the Wernerian classification and the Wernerian way of looking at geology are revealed in these lectures. The rocks classified as Primitive were considered to be the oldest in the world, and, as it happens, the North American gneiss mentioned by Richardson is a worthy candidate for this honour, yet, most of the intrusive igneous and metamorphic rocks which Richardson described under the Primitive could have been formed at almost any time in geological history. James Hutton (in Playfair, 1956, p. 12-15, 168-71) had already demonstrated this, yet strangely Richardson did not examine this question. He could have alluded to this quite appropriately because he did state that Hutton and Werner disagreed on the age of granite. Conybeare and Phillips (1822, p. xvii) specifically used the term igneous in referring to trap, a general term for dark fine-grained rock, including basalt, but admitted that there still was some conjecture on its origin. Richardson did not enlighten his own discussion with similar qualifications.

Lecture 6. Jameson (1821, p. 376) treated the Transition as a separate class but admitted that some mineralogists had assigned these rocks to the Primitive or Secondary, and that many of the rocks might in fact be considered part of the Primitive series. Richardson followed Jameson in still considering them a separate class and stated that the Transition was distinguished from other classes by the rocks "being conglomerate". Back's notes contain flurries of unrelated statements so that parts of this lecture lack clarity. After starting a description of greywacke (an inclusive term for dark cemented argillaceous sedimentary rocks considered to be the base of the Transition) Richardson made some general comments, based on Humboldt (1823, p. 130-1, 138-9) on what associations of rocks could be found in the Transition, and then he referred to greywacke again. Richardson seems to have based his comments on the following passage in Humboldt (1823, p. 138-9), which helps to clarify Back's notes:

> I consider as terms of the series of transition rocks six groups, which appear to me to be well characterized by the predominating rocks, by their position, and by the extent of their masses. These groups or great formations are, I. Steatitic, granular limestone, transition mica-slate and grauwacke with primitive fragments. II. Porphyry (not

> metalliferous) anterior to orthoceratite limestone, to transition clay-slate, and mica-slate. III. Clay-slate containing grauwacke, limestone, porphyry, and greenstone. IV. Porphyry and syenite (metalliferous) posterior to transition clay-slate anterior to limestones containing organic remains. V. Porphyry, syenite and zircon-granites (not metalliferous) posterior to clay-slate and limestone with orthoceratites. VI. Transition euphotide with jasper and serpentine.

Richardson stated that "Greywacke and Clay Slate are in a greater proportion throughout the World than the Primitive Rocks", but a thorough search in Richardson's usual sources has not uncovered the authority for this statement. Lydian stone, often mentioned by Richardson, is a quartz or flint of a greyish-black colour. According to Richardson organic remains are not numerous in the Transition limestone, but at least two fossils are named. Near the end of this lecture, in connection with a comment that the Red Sandstone of the Secondary class immediately succeeds the Transition, Richardson stated that all granular rocks pass into each other, but he did not use that concept to make his discussion more explanatory.

Richardson was caught in an impossible bind in this lecture. The rocks described as part of the Transition series and arranged in a time sequence possessed closely related lithological characteristics but there were no consistent and systematic chronological relationships.

The classification of rocks used by Richardson in describing the Primitive and Transition series has very little resemblance to the classifications of today. This is not surprising. The study of geology was only beginning and the rocks of Britain older than the Secondary were folded and complex making it very difficult to unravel the correct stratigraphic sequences. However, in 1831, only six years after Richardson had delivered his lectures, Roderick Murchison and Adam Sedgwick (Geikie, 1962, p. 414, 424), working independently, started their researches into the sequence of the older rocks of England and Wales with splendid results. Within a decade the Silurian and Cambrian geological systems were established (Geikie, 1962, p. 414-20, 424-7; Murchison, 1839), bringing a new stratigraphic order to the classification of the older rocks, although an unfortunate controversy raged for years over where the dividing line between the Silurian and the Cambrian should be established.

It has proved much more difficult to interpret the geological history of the rocks older than the Cambrian. Beginning in the 1840s, classic work on these ancient rocks was begun by William Logan (1863, p. v-vii, 22-86), supported by other members of the Geological Survey of Canada. Logan and his associates investigated the crystalline rocks of southern Canada, sometimes working in areas adjacent to Lakes Huron and Superior which the Franklin exploring expedition had passed on its way to the Arctic.

A diagram follows the lectures on the Transition class and shows the relationships of granite to various other rocks. This demonstrates graphically that Richardson recognized mineralogical linkages between rocks and the close relationships of the Transition rocks to the Primitive series, since the granite at the base of the diagram may be taken as a part of the Primitive class. Along the left-hand column the granite passes via intermediate rocks into a conglomerate and greywacke of the Transition class, along the vertical column the granite passes from gneiss and clay slate to Transition clay slate, and along the three right-hand columns it passes into various other Transition rocks.

Lectures 7-10. By the 1820s geologists had attained considerable success in bringing some order into classifying Secondary and Tertiary strata, that is rocks ranging from the Old Red Sandstone, which is Devonian in age, to the present, and the geological history described here has largely stood the test of time. Through Conybeare and Phillips (1822), Richardson benefited both from William Smith's (1815, 1817) work on the Secondary strata of England and from the investigations of Thomas Webster (1814, 1816) on the Tertiary. In these lectures there is a roll call of formations made famous in geological literature by the classic work of such men. Figure 2 lists many of these formations. Although Jemeson (1821, p. 382-401) described these beds, Conybeare and Phillips (1822, p. 58-470) was the main source of information, and enabled Richardson to go into considerable detail in describing many strata.

Problems in nomenclature arise if rock-stratigraphic units and time-stratigraphic units are confused. For instance, the Old Red Sandstone is a rock-stratigraphic unit which geologists of the early 19th century found difficult to date and classify because of the scarcity of fossils. Working together, Murchison and Sedgwick (Geikie, 1962, p. 430-3) studied these strata in detail and used the rocks of the Old Red Sandstone to define the Devonian System, a time-stratigraphic unit. Mountain Limestone, so called because it often formed the tops of mountains, is now identified as of Lower Carboniferous age. The Coal Measures is now considered to be of Upper Carboniferous age, and the New Red Sandstone is recognized as of Triassic age, the base of the Mesozoic. The M-Calcstone, the Muschelkalk of continental geologists, is considered today to be of Triassic age, and the Lias as of Jurassic age. Figure 2 shows these correlations. The names of formations do not necessarily describe the rock types they contain. The Old Red Sandstone and the New Red Sandstone as one notes from Richardson's descriptions contain some rock types that are neither red nor sandstone.

Richardson suggested that the limestone on the west shore of Lake Winnipeg, and the bitumen of Pierre au Calumet together with some sedimentary rocks along the Mackenzie river were of Lower Carboniferous age. Today they are recognized (Camsell and Malcolm, 1821, Map 1585; Douglas, 1970, Map 1250A) as of Ordovician, and of Devonian and Cretaceous ages respectively. Along Slave river the limestone beds are softer and Richardson considered that they, together with the strata of the Salt Plains visited on the 1823 expedition, passed into Magnesian Limestone; rocks that are thought to be of Silurian age today.

Professor Buckland (1821, p. 450-68; 1823, p. xlvii-xlviii), as Richardson suggested, had attempted to correlate the rock formations of Britain and continental Europe. Such comparisons were still very difficult to make because palaeontological work had barely begun, so that Richardson's comparisons across the Atlantic were very sketchy and audacious. There are many comments on organic remains and the names of a few characteristic fossils are given, but Richardson did not discuss in detail how fossils could be used to define geological horizons.

Richardson provided considerable detail on the Oolitic Formation, identified today as Jurassic in age, which William Smith had investigated so thoroughly. Smith (1815, 1817) identified and mapped the strata using such names as Cornbrash, Coral Rag, and Kimmeridge Clay. Back's notes are not clear here; there is some confusion between strata of the Upper, Middle and Lower Divisions of the Oolitic limestones, and also between strata of the Upper and Lower Beds within the Lower Division. Conybeare and Phillips (1822, p. 59) listed the beds as follows: (i) Upper Division: Purbeck beds, Portland Oolite, and Kimmeridge Clay; (ii) Middle Division: Coral Rag, Oxford Clay; (iii) Lower Division: (a) Upper Beds, Cornbrash, Stonesfield slate, Forest Marble, Great Oolite; (b) Lower Beds: Fullers' Earth, Inferior Oolite, Sand and Marlestone; with the Lias beds underlying all this.

The Iron Sand, Weald Clay, Green Sand, Chalk Marl, and Chalk are today considered as being Cretaceous in age. The famous "Chalks with Flints" was mentioned, and Richardson stated that chalk was unknown in America, although it is now known to be present. His only general remark on the use of fossils for correlation occurs in Lecture 10, and it was very tentative: "Genera the same Species characteristic of Beds.--Suites above Chalk different."

Lecture 10. The first classification of the Tertiary rocks into an organized sequence of beds was accomplished by French geologists (Geikie, 1962, p. 341-5) working in the Paris Basin in the late 18th and early 19th centuries. Thomas Webster (1814, 1816) described similar beds on the Isle of Wight, establishing the sequence of Tertiary rocks in Britain. Conybeare and Phillips (1822, p. 6-57) made full use of Webster's work, on which Richardson in turn based his lectures. Webster had described (1814) the alternation of rocks deposited in marine and fresh water which is characterisitic of the

Tertiary rocks in Britain. Richardson noted this in his introductory lecture, but he did not discuss this further in the more detailed exposition in Lecture 10. The alternation of beds has to be inferred from the sequence of formations described. The London Clay and the various marine and fresh water formations mentioned are considered to be of Eocene age today.

Despite the fact that Richardson included the Diluvial and Alluvial as major classes of rocks in his introductory lecture, he did not describe any formations younger than the Tertiary in these last lectures. The Diluvial and Alluvial beds only received incidental comments in a few places.

Lecture 11. Richardson ended the lecture series with a few brief remarks on volcanic rocks based on Jameson (1821, p. 424-32). Richardson obviously was aware that the volcanics did not fit into the stratigraphic sequence he had been following when he said that the volcanics were classified "more by the Chemical than the Geological Character". The lectures ended abruptly with no effort made to pull together the many and diverse geological topics considered over many weeks in the fall and early winter of 1825-26.

CROSS SECTIONS

Three cross sections follow the written notes. They provide a valuable summary of Richardson's classification and a clearer picture of the sequence of rocks in the various classes than can be obtained from some of the lectures. The first cross section, on two pages, includes the entire sequence of rocks from granite to alluvium (Fig. 3); the second, also on two pages, shows the Secondary beds in greater detail; and the third, on one page, the Tertiary. No locations are given for the cross sections, but it is evident that the two more comprehensive cross sections cut across much of England, and that the one of the Tertiary is of the London basin.

It is necessary only to comment on the first, most comprehensive, cross section. The main formations of the Primitive series are shown as vertical beds. They are higher in altitude than the other series and are eroded into peaks and valleys, with narrow bands of porphyry and quartz rock deliberately drawn so as to indicate that they are resistant to erosion. Transition rocks are hardly present in the diagram; only one bed of greywacke is shown. The Secondary strata do not dip quite as steeply as the Primitive, and they are distinctly lower in elevation. Coal seams are shown in the Carboniferous Limestone. Tertiary beds dip quite gently. Thin diluvial deposits are shown in the low spots of the Primitive series, and thicker deposits overlie the Secondary and Tertiary in horizontal layers. Scattered patches of alluvium cover the diluvium. Under the diagram are summary annotations of characteristic fossil assemblages for the different beds. These are more clearly presented than the lists of organic remains provided in the lectures.

There is no way of telling whether Back copied the cross sections from Richardson or from one of the books on geology available to him. Perhaps they are a combination of both.

RICHARDSON'S PUBLISHED GEOLOGICAL REPORTS OF 1823 AND 1828

Richardson's geology can be placed in wider perspective by examining his published geological reports on the areas traversed by the two Franklin land expeditions (Fig. 1). The first report, "Geognostical Observations", is 41 pages long and was published in 1823 (in Franklin, 1823, p. 497-538); the second, "Topographical and Geological Notices", first read before the Geological Society of London, comprises 58 pages and was published in 1828 (in Franklin, 1828b, p. i-lviii, Appendix No. 1).

The "Geognostical Observations" of 1823 was organized simply, according to the expedition's itinerary. Richardson recorded in succession the different kinds of rocks observed in travelling from York Factory to the Arctic Ocean. By this route, Richardson, of course, crossed the Precambrian Canadian Shield after leaving the Hudson Bay Lowland, and then for many miles followed approximately the boundary between the Shield and the Paleozoic rocks. Occasionally he digressed from the seriatim description of rocks seen en route, and discussed the wider distribution of a particular formation, for instance the exposure of limestone in various places from Lake Winnipeg to the Mackenzie river (in Franklin, 1823, p. 505-7).

Richardson used (*ibid.* p. 534-8) the terms Primitive, Transition, Secondary and Alluvial in discussing the rocks of British North America. Many specimens of rocks were brought back to Great Britain, and the assistance of Robert Jameson was secured in identifying them. Very little use seems to have been made of fossils in classifying strata.

Richardson (*ibid.* p. 501-5, 509-11, 511-34) noted occurrences of Primitive rock right through the Far North to the shores of the Arctic Ocean. He suggested (*ibid.* p. 535) that gneiss appeared to be the most extensively distributed rock, and gave (*ibid.* p. 520) a special name to the gneissic region east of the Coppermine river, calling it the "*Barren Ground* formation". He implied (*ibid.* p. 520, 535) that gneiss was inimical to vegetation, and that it might have been a factor in restricting the growth of trees, as he also suggested in his lectures. Richardson wrote (*ibid.* p. 527, 528, 536) that there were Old and New Red Sandstone rocks on the Coppermine river, and that the Copper Mountains were principally composed of trap, related to the Secondary class (*ibid.* p. 528, 537). Jameson had identified these rocks from hand specimens brought back to Britain, and the Edinburgh scholar's annotations are (in Richardson, 1819-22) repeated almost word for word in Richardson's printed report. It is now known that all the rocks are of Precambrian age, indicating how difficult it was for Jameson to classify them.

A summary description of the distribution of the Primitive, Transition, and Secondary rocks noted in the field was provided (in Franklin, 1823, p. 534-8) in conclusion. In the course of describing the trap, Secondary trap and porphyry rocks of the Arctic Coast, Richardson (*ibid.* p. 537) expressed the most definite views he was to make at this time on the debate concerning the Neptunist or Vulcanist origin of rocks:

> Many of these trap and porphyry rocks presented the columnar structure which has been considered as indicative of a volcanic origin, but their other characters and the horizontal strata upon which they reposed seemed to give them a still greater claim to Neptunian origin. Our opportunities of observation, however, were much too limited to permit us to offer a decided opinion upon this disputed point.

These sentences demonstrate how Richardson was inclined to be cautious, and that he had not yet jettisoned the Neptunist ideas of Werner and Jameson.

In the summary Richardson, (in Franklin, 1823, p. 537-8) referred to extensive alluvial deposits, and mentioned that many boulders were observed. He stated that large rolled blocks of stone had been attributed to the Flood, but he did not use the term diluvial. Richardson (*ibid.* p. 538) reported that the blocks he saw on the Barren Grounds were angular in form and closely related to the underlying bed rock and probably represented the remains of durable rock after erosion.

The geognosy is very dull reading, seeming to be an endless description of rocks with very few generalizations. It becomes interesting when one bears in mind the geological concepts underlying Richardson's descriptions and makes an attempt, using a modern geological map, to ascertain which formations were described.

The "Topographical and Geological Notices" of 1828 had some welcome differences. Richardson once more described the kinds of rocks observed en route, but he made a greater effort to provide regional generalizations. The account is still organized according to the sequence of exploration, this time beginning with the expedition's arrival at Great Bear Lake. Richardson, however, had much more information available to him, including data from the earlier expedition. He also made use (in Franklin, 1828b, p. xxvii-xxiv) of secondary accounts, such as those of Sir Alexander Mackenzie (1801) on the northern Rockies and Edwin James (1823) on the southern Rockies, and incorporated information (*ibid.* p. lvii) supplied by fur traders. However, on this expedition, most of Richardson's own field observations were made and the rocks and fossils collected in the exploring season of 1826, after the lectures considered here were delivered. Much greater use was made of fossils in identifying strata than in the 1823 "Geognostical Observations". This is a much more interpretative report; generalizations came much easier to Richardson and he made some apt regional comparisons. There was even a sense of wonder introduced, as when he confessed (in Franklin, 1828b, p. xlviii, xl) to being perplexed by surface features which we now know to be caused by permafrost. On the whole this was a fuller and considerably more interesting geological essay than the earlier report.

Richardson (*ibid.* p. ii-li) discussed the rocks observed at Great Bear Lake, Bear Lake River, and those of the Mackenzie River and the Arctic Coast, organizing each into a regional description of the types of rocks observed.

Major differences in kinds of rocks were usually recognized by Richardson, but he did not have the detailed knowledge of fossils, nor the time to study many stratigraphic sections, to date formations definitively. He recognized (*ibid.* p. xvii-xviii, xxxi-xxxviii) that the rocks on the west side of Great Bear Lake and along the Mackenzie River were sedimentary, including a lignite formation and bituminous shales; they are now known to be of Cretaceous and Devonian age. Fossils from Bear Lake River were brought back to England, and William Sowerby (*ibid.* p. xiii) tentatively identified them as "probably referrible to some of the Oolites near the Oxford clay." This is a good approximation of their age, because the rocks today are recognized as of Jurassic age. Lignite and bituminous strata on the Mackenzie River were described (*ibid.* p. xvii-xix) and Potters Clay on that river was mentioned (*ibid.* p. xix) but Richardson did not establish their stratigraphic relationships. Richardson's tour from the mouth of the Mackenzie to Cape Krusenstern along the Arctic Coast is of great geological interest, because as he proceeded on his journey he correctly recognized a succession of major geological formations. The following sequence was described (*ibid.* p. xli-xlviii): bituminous alum shale east of the mouth of the Mackenzie, limestone at Cape Parry, trap east of Cape Lyon, followed by the limestone once more at Cape Krusenstern. These rock types are recognized today to be respectively of Cretaceous, Silurian, Precambrian, and Silurian age.

Richardson mentioned (in Franklin, 1828b, p. viii-ix, p. xiv) boulders whenever he encountered them, and in contradiction to his 1823 report (in Franklin, 1823, p. 538) he recognized that they had been transported from elsewhere. In 1825-26 on Great Bear Lake, he identified (in Franklin, 1828b, p. vii-ix) granite boulders which he thought must have come from the Fort Enterprise area, 275 kilometres to the southeast (Fig. 1). He based this interpretation partly on information obtained in his travels of 1820-21. This likely was the first published evidence of the northward transportation of boulders in Canada. Richardson proposed no mechanism to explain the movement, and nowhere in his report did he mention striations on bed rock. In the 1890s, J.B. Tyrrell (1896, p. 177-84) made observations of a similar nature on the direction of the movements of boulders which he then used as part of this evidence to hypothesize the former existence of a source region of continental ice somewhere west of Hudson Bay. Tyrrell (*ibid.* p. 175F-7F) called this area, from where he suggested the ice had radiated outward, the Keewatin centre of continental glaciation.

Most of the 1828 report concerned the rocks north of Great Slave Lake covering the new areas explored by the expedition, but in the concluding sections Richardson (in Franklin, 1828b, p. li-lviii) described in just eight pages the geological formations extending southwards to Lake Winnipeg. In this fine summary he presented the gross areal distribution of the different kinds of rocks more clearly than it was described in the conclusion of the 1823 report (in Franklin, 1823, p. 534-8). He had more data to work with, including Dr. J.J. Bigsby's (1824) account of the geology of the Lake Huron region. Richardson attempted to trace the boundary between the Primitive and the Secondary strata across British North America, that is, the boundary between the Precambrian Canadian Shield and the younger Paleozoic rocks. Sir Alexander Mackenzie was credited by Richardson (in Franklin, 1828b, p. lii) as making an original and important remark in noting that fundamental boundary in the geological formations of North America. Some of the main scenic features of the Shield were described (*ibid.* p. liii) very effectively. The limestone on the Athabaska, Slave and Mackenzie Rivers was identified (*ibid.* p. liv-lviii) as Magnesian limestone and some of the fossils were listed. Richardson believed (*ibid.* p. lvi-lvii) that the Athabaska limestone belonged to the Magnesian formation, included in the Permian of today, because of the bitumen and associated salt springs it contained, but pointed out (*ibid.* p. lvii) that on the basis of the fossils he had brought back to England geologists identified the formation as Mountain Limestone, that is of Lower Carboniferous age. Actually it is neither; the rocks are Devonian in age.

Richardson already had a good command of mineralogy when he wrote his 1823 report, and there is no indication from the lectures of 1825/26 or the 1828 report that his knowledge of rocks had substantially increased or that his concepts had altered significantly during those few additional years. Describing and identifying the rocks of the Precambrian Canadian Shield was a special problem. When Richardson's published geological reports of the early part of the 19th century are compared to the reconnaissance geological descriptions of the Barren Grounds written by J.B. Tyrrell (1896) near the end of the 19th century the reader is struck by the fact that in one particular aspect they are not all that different. Tyrrell, it is true, included much more physical geology, and the concept of continental glaciation was available to him to help identify and interpret physical features such as till plains, moraines, eskers, boulders and striae which are inevitably encountered in most parts of Canada, but there is considerable similarity in the broad general way Richardson and Tyrrell described and identified rocks in the field. This is not so strange. When it comes to the rocks of the Precambrian Canadian Shield, all that a reconnaissance geologist could do, whether he was writing near the opening or the closing of the 19th century, was to identify the rocks as best he could and leave interpretations and age correlations to a more advanced era.

A great deficiency in both of Richardson's reports is the absence of geological maps. Locations of a few major classes of rocks, such as Primitive, Floetz Limestone, and Mountain Limestone, and the names of some rocks are printed on general maps (Franklin, 1823, 1828b) included in the published reports on the expeditions depicting routes and areas explored. But they are inadequate. Richardson's presentation of geological data would have been greatly enhanced and his interpretations clarified if he had mapped the formations he described. Since this was not done, many of the short descriptions of the distribution of geological formations remain unrelated verbal fragments within the text and tend to become lost.

CONCLUSION

In his two printed geological reports Richardson gave good evidence that he was a precise and exact field observer. His lectures too exemplified this. Geology was presented by Richardson as an observational science, not a body of speculative theory. Nor did he spend time dreaming about the economic possibilities of the rock formations he had examined in British North America. The austerity in approach is further substantiated by the limited mixing of religion, teleology and geology, in contrast to the works of other contemporary writers. The sentiments on the "regularity of Natures most stupendous works" leading "the Mind to a higher Veneration of Omnipotence and Divine Being" at the beginning of the lectures, or Richardson's (in Franklin, 1823, p. 538) concluding sentence in the "Geognostical Observations",

> We may conclude with observing, that the preceding details shew that in the regions we traversed, the rocks of the primitive, transition, secondary, and alluvial classes have the same general composition, structure, position and distribution, as in other parts of America which been examined; and as these agree in all respects with the rock formations in Europe and Asia, they may with propriety be considered as universal formations, parts of a grand and harmonious whole, the production of infinite wisdom.

are just normal for the time, and don't affect the general tone of his lectures or published reports. Richardson's main aim in the lectures was to give his fellow officers some knowledge of how strata were classified, i.e., a knowledge of basic geology, rather than to describe the regional geology of the area they were exploring. Local examples were occasionally mentioned, but Richardson had considerably more information on the geology of British North America at his command, gained on the 1819-22 expedition and the journeys of the summer of 1825, which he could have imparted to the officers in his lectures.

The lectures very clearly date from the geological world of the 1820s. Werner's ideas were on the way out, but his Primitive and Transition classes were still bedevilling geological work. Very shortly after Richardson's geological lectures were delivered, a new intellectual arsenal for classifying strata was ready for field geologists who were to continue the task of exploring the geology of British North America. Richardson's geological observations and lectures of the 1820s still show the intellectual lineage of an earlier era in geological thought, so that there in the High Arctic we are carried back to the heroic period of geology (Zittel, 1901, p. 46) when great debates on fundamental geological matters raged as the discipline was being founded as an empirical science.

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Notes made by Lieutenant George Back during a series of lectures on geology given at Fort Franklin on Great Bear Lake by Dr. John Richardson from October 7th, 1825 to January 13th, 1826.

Lieutenant Back's Notebook is on permanent loan by J. Pares, Esq., to the Scott Polar Research Institute, where it is catalogued as MS.395/1 in the Institute's Archives.

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October 7th 1825 - Lecture 1st by Dr. Richardson

Geology - Is a Science that treats on the structure and formation of Rocks - and Earths - and the studying of it convinces one, of the regularity of Natures most stupendous works and leads the Mind to a higher Veneration of the omnipotence and Divine Being-

The Ancients had erroneous opinions of Geology - but in more recent Times acute observers have assigned good reasons for the apparent confused irregularity of the Nucleus or Surface of the World- they have found effects from causes and proved the beautiful Order of this part of the Almighty's Works.-

Geology is useful - particularly to the Traveller, whom it instructs in the knowledge of the Country through which he may pass- It teaches him where to look for Springs - Minerals - and valuable Earths-

In civilized Countries - the different formations are often shewn in the Houses or larger Buildings - which are generally constructed of the Material found in the vicinity of the Neighbourhood - or at least in the Country-

To be a Geologist - a Person ought to be acquainted with Mineralogy [2] and Botany - in order to know how to Class and arrange-

But an acquaintance with five different Kinds of Rock, appears to be sufficient for common purposes.-

These are

Quartz - which is vitrious & translucent-
Feldspar - foliated - even & tabular-
Mica - smooth - in layers - & pliable-
Hornblende - irregular - streaked-
Limestone - greyish white - easily scratched by a Knife.-

Quartz forms about ½ the surface of the World- it has a glassy appearance and is too hard to be scratched by the Knife - this circumstance will always detect it from Limestone- it is of different Colours-

Feldspar -- may be scratched with a knife, though but faintly- it is of different colours- and may be known from quartz from its fracture, &c.-

Mica - is soft - and easily separated into leaves- it is transparent and has a Metallic appearance-

Hornblende - is black - glittering - and splintered- when breathed on - it becomes dull - and emits a strong [3] bitter odour-

Limestone - varies in Colour - but is often greyish yellow- it is sometimes mixed with quartz-

Lecture 2nd - Friday 14 October

In decomposition - Sand - Limestone and Clay-

Simple Rocks - as Limestone- Compound d^{o} - as Granite - Aggregated and Conglomerated. Mountain Rocks-

Mechanical Debris - of old Rocks - where loose Sand or Gravel is found and the pieces appear rounded or loosely cemented - as Sandstone - Pudding d^{o}-

Aggregated - as Granite-

Porphyritic - having dissociated Crystals embedded.-

Amygdaloidal - with Cavities either empty of filled (not certain of the Cause) either Air or Water[?]

indeterminately Aggregated in opposition to Simply Aggregated-

Granular Structure- by cohesion as in Granite-

Sandstone - Tabular as in Mica Slate - owing to the flatness of the Mica-

Double Granular Structure - as Gneiss - Gran-Slaty - and Slaty-Gran-Graphic Granite or Porphyritic Granite with Crystals-

Slaty Phorphyry with Crystals-

Prophyritic Amygdaloid- and Basalt-

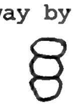
Strata - when inclined emerge from beneath each other and what in Geology would be termed the lowest often forms the highest part of the Mountain or Hill-

Chain of Mountains - Central Ridge-

Tabular Strata - Clevage of a Bed as in Slate Containing Mag^{m} Iron Ore - as 

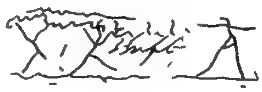
[4] Fissures in Trap Rocks- do not determine the Strata-

Observe in Strata the Angle of inclination - or Pitch of inclination and dip = as $\angle$ of $\overline{45}$ dip S-

Columnar Structure - (Giants Causeway) - are worn away by the Action of Air and Water and leave the Cap and Ball as = 

Boulders of Granite - Great Bear Lake -

Veins - are irregular - broken and branch off in various directions - as



not parallel.-

Primitive Formation - Transition For^{n} - Secondary - Tertiary - Diluvial - and Alluvial

Primitive is the lowest - and has a more crystalized - aspect - forms the highest Hills and is destitute of Organic Remains.-

Granitic Gneiss - Mica Slate - Quartz Rock

Clay Slate and primitive Limestone-

Granite alternates with other Rocks.-

<u>Gneiss Formation</u> - in more alternate <u>layers</u> or Beds uniting with Clay Slate Formation - or one may be wanting -- Superposition of formations-

Transition Formation - Conglom^{r} Structure as Greywacke - (if portions are small (Slate) - Pudding Stone - Prim - Limestone Slate Transition Limestone- Black - containing Organic remains-

- Trap - Earthy aspect corresp^{d} to Primitive [5] Crystal - highly inclined Strata - or Vertical

<u>Secondary Class</u> - Old Red SandStone - Magnesiun Limestone containing Salt - Clay - <u>Lias</u> Limestone - Marbeck Marble - (as old Statues in Churches-) Chalk Marl - Bituminous <u>Shale</u> or Coal Formation-

<u>Tertiary Formation</u> - appearance of <u>recent Shells</u> (Second^{y} appears mineralized) layers of Marine Shells alternating with layers of fresh water Shells- (Crag of Suffolk)

Note - Organic Remains are of unknown kinds with some few exceptions - to those of the present type - (London Clay)

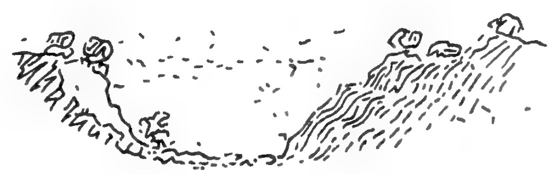
November 18th - Lect^{re} 3^{d}-

Tertiary Formation - are found Land Animals alternate with Sea Animals -

Flint debris of Chalk - The intervening space

of the Chalk will be found in the Valley, from the separation which the Action of Water has produced-

Large pieces of detached



Rocks are often found on the summits of Hills - or in places remote from where any exist- Professor Buckland maintains that they were carried there (in a horizontal direction) by the impulse of the Deluge-

Connebeare on the other hand asserts that the waters of the Deluge have separated and washed away the softer parts - and thus formed deep Vallies and left the masses of Rocks &c. on the tops of Hills

[6] Tropical Animals are found in parts of the World - where they have not been known to inhabit - which is accounted for - as having taken place in very remote Ages - where the effect of Volcanoes (which are now extinct - was so great as to render the Temperature of those climates favorable to their existence-

The Huttonian Theory supposes the action of subterranian Fire to be the principal cause of the great Geological changes.- but - the general appearance of NE Strata through out great portions of the World - would lead to the conclusion - that such changes must have occurred at the same moment - which perhaps may admit of doubt.-

Werner says that Granite is the oldest Rock

Hutton - affirms it to be the newest.-

Humboldt - describes - Granite with the most Quartz - (of a white hue) as the oldest-

Granite - fine granular - resembling Sand stone- Granite component parts of which are very large - as Labrador Felspar.-

(Lofty Mountains) - the summits are often composed of a fine stratified or slaty Granite like Gneiss-

It is the Colour of Felspar that gives the name to Granite - as "Flesh coloured &c"-

All other parts of Granite except quartz alter - and decay-

The Columnar Structure in Granite is not uncommon-

[7] Felspar decomposed forms Clay, Quartz - Sand

wherever the Mountains are rounded (if of Granite) they are soft or loosely cemented - with steep acclivities and small Vallies-

Where they are peaked - the Granite is compact and hard.-

Sienite is composed of Horneblende and Felspar, or it is the presence of Horneblende in Granite.-

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November 25th Lecture 4th

- Old Granite - has least Mica.-

Gneiss - Is a granular Slaty Rock - in which Felspar predominates - the Mica being arranged into Slates and mixed with Quartz in the Centre- It is stratified - and the Mica is distributed in parallel ranges.- It is of a Greyish-Yellowish brown - and whitish black

Colour. - where there is a diminution of Felspar it becomes Mica Slate.-
- of Felspar - is formed the fine China Clay.-
Gneiss contains - Garnets (which are of a reddish brown colour) Horneblende, whence it becomes Horneblendic Gneiss - Limestone or statuary Marble, in large Crystals and the purer the white - the older it is considered to be.-

Trap-beds and Gneiss are mixed at the junction.

In Gneiss - Granite is the lowest and Mica Slate the uppermost - in it is found - Porphry - beds of Green Stone - and Mica Slate-
Veins traversing Gneiss are filled with its component parts - but they are not Slaty-
Gneiss contains every Mettle except Mercury

[8] Staniferous Granite next to the Old d^{o} of Humboldt-

Serpentine - a green soft Rock that yields to the Knife

Gneiss contains - embedded - fine - Gneiss -

Granite alternate - Gneiss - Stanif-d^{o} and white Stone-

The Rocks of America are principally of the Gneiss formation.-

Granular Limestone, in Gneiss.- also Serpentine - Horneblende Slate - Green Stone Clay Slate and Quartz which contains Sulphur

Gneiss district - in the English River- they are naked rounded Rocks peeping through the Trees.-

Hill River - and Barren Grounds are composed of Gneiss

The Alps and Pyrennes are formed of it - so are the Andes to the same height - above which are Volcanic Rocks.-

In New Formations - Felspar decreases and Mica increases-

Mica Slate - is formed of Quartz and Mica with little or no Felspar.-

Fine Slaty passes into Clay Slate

Mica Slate contains Garnets - and when plentiful determine it.- Emeralds are also found in it-

Mica Slate - rests on Gneiss and is covered with Clay Slate-

Mural Precipices seldom high.

[9] Lecture 5th - December 2nd

Granite above Mica Slate.- Compound R.-

Crystaline Limestone - white primitive-

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*Clay Slate (Simple Mountain Rock - containing neither Quartz Felspar or Mica but is homogeneous.- it is Grey-Green - Black or Red-

Slates are of a glimmer & lustry Pearly Colour-

They may be smooth or streaked - are greasy to the touch - and yield easily to the knife-

Clay Slate - is opaque and has a greyish dull Streak - it does not adhere to the Tongue like Slaty Clay-

[one word is indecipherable] in Clay Slate.-

Cliffs of Clay Slate are not so rugged as

1 Mica Slate - they are of a Yellowish grey colour (reposing on Mica Slate) and deep lustre.-

2 Clay Slate - dark grey - as roofing Slate.-

3 Greenish grey Colour

4 Bluish grey and reddish.-

To link Clay Slate to Transition-

Primitive Clay Slate has larger Scales of Mica than Transition Slate - when it has Nodules of Limestone it is Transition in which latter Carbon is abundant.-

Organic Remains are found in the Transition - or in the newer (one word is indecipherable).-

Whet Slate - found in Clay Slate-

Chlorite - a bright green.-

Talc Slate - micaceous (but not like it clastic) it is of a Tallowish nature, and when bent remains in that position

Allum Slate - like bituminous Shale.-

Pot Stone - occurs also in Clay Slate-

Flinty Slate - also - and it is rich in Metals

Beds of Marble, &c occur in it.-

Primitive Limestone (Simple Mo^tn Rock)
Structure - granular, large and distinct sometimes small - it is seldom spotted- the fracture is foliated and [10] splits always in one way - its fragments are more or less translucent - and it yields to the knife-
Limestone attains its Maximum in Clay Slate
in it is found quartz - Scales of Mica - and the Veins are sometimes filled with Manganese-

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Foliated Green Gypsum.- Alabaster - coarser kind - Plaster of Paris-

Primitive Sienite - contains Felspar Quartz and Horneblende Porphyry (or red) Compound Rock- It is the Basis which give the Name - and not the Crystals. the embedded parts are generally Felspar and quartz. it is seldom stratified and contains Chalcedony and Agates

where there is a Peak as  the rest of the Rock is generally of a different kind.-

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Primitive Trap (Stairs) In which Horneblende forms the principal constituent part-

Seam Structure.-  are very hard (Gallery) [?]

Green Horneblende Rock, when scratched it has a Mountain Green Streak-

Brittle - when scraped the dust flies away-

Frangible - as Clay Slate where the dust remains

Green Stone - of Horneblende and Felspar but Horneblende predominates - or (two words are indecipherable) when greyish Green with Crystals it becomes Porphyritic Green Stone-

Green Stone Slate - Horneblende and Felspar.- Horn & Mica-.

Serpentine - is translucent at the edges it has a greasy feel and can be cut with a knife - but not scratched like Talc-

[11] Minerals with Magnesia are found in it- It occurs in Gneiss - Mica Slate and Clay Slate
is inimical to Vegetation - and has an Ochry Surface.-

Oophytile [Euphotide is pencilled in above Oophytile] is related to Serpentine and is of a deep green Colour and feels uncteous to

the touch-
It is a Transition Rock - it assumes a whitish Crust-

Quartz Rock - white - reddish or Bluish - it contains Mica and some Felspar - frequently abounds with Sulphur and Chlorite--

Granite - Gneiss - Mica Slate - and Clay Slate connected by Oophytile [corrected in pencil to Euphotide]

Lecture 6th December 9th

Transition Formation

Plants (in Organic Remains) found in the Northern Region are similar to those found in Tropical Regions.-
Ferns and Mosses &c are embedded in those Rocks which are principally composed of Carbon - whilst those containing Animals - Corals &c have a greater proportion of Lime-
Brexia (or fragments of other Rocks)
Transition, is distinguished from others - by the Rocks being conglomerate
Humboldt - considers Euphitide - as the newest in this Series-

Greywacke - is fine grained - allied to Sandstone and Porphyries with glassy Felspar, connected with the Volcanic Species.-
Greywacke or brexia of Pudding Stone - in which are mixed - Granite - Lime Stone - Gneiss - Mica Slate - Clay Slate - Sienite - (Anchitite) - Trap and Gypsum.-
According to Humboldt it may be determined in Schistos - Porphyry - Sienite - Granular and [12] compact Limestone - 4th Euphitide and 5th Aggregated Rocks.-
Greywacke occurs in different parts of the Transition Series -
Groups of Rocks of two or more Kind - are found to preserve the Same Characters in opposite points of the Globe.-
- Stactitic Granular LimeStone-

2 - Transit$^{\underline{n}}$ Porphyry with Sienite and Crystals of Horneblende - and with Horneblende - also black LimeStone.-

3 -

4 -

5 Porphyries

6 Serpentine Rock-

Greywacke consists of fragments of Quartz Felspar - Lydian Stone and Clay Slate, connected by Basis of Clay Slate.

Greywacke Slate - when the Parts are nearly invisible - it is Transition Clay Slate - and is liable to a change of Aspect - it passes from Slaty Rocks to Sienitic Rocks.

Pudding Stone - connected to Greywacke consists of Granite Gneiss Clay Slate and newer transition Rocks. Basis highly Silisified - when approaching to Quartz or Sand Stone there are no Organic remains.

Alum Slate - formed of Carbon and Sulphur is of a bluish Black Colour - retains its Colour when scratched with a knife and has a Glistering appearance - is determined from Bituminous Shale from the latter having a Brownish Streak-

Glassy Alum Slate-

Glance Coal - no bituminous Smell - Shines like Jet and has a Slaty Fracture- it is allied to Graphite (or Carbon and Iron - (Blacklead)

[13] Graphite in Gneiss.-

Carbon attains its maximum in the great Coal Measures-

Glance Coal in Transition Rock contains Organic Remains-

Fish are found in Transition Clay Slate.-

Greywacke and Clay Slate are in a greater proportion throughout the World than the Primitive Rocks- Many Mountains in Switzerland - America - Europe - are formed of this Formation.- (Pyrennees)

Cornwall - Tin Mines.

It contains compact Quartz-

Transition LimeStone - compact - fracture splintry - translucent at the Edges - it varies much in Colour - sometimes Black traversed by Veins of Felspar.- so black sometimes as to mark the Fingers-

Foetid LimeStone - smell of Sulphur - is compact and fine Granular- Most of the fine and ornamental Marbles belong to the Transition Formation - whilst that of Statues &c is primitive.-

Lydian Stone found in Beds or Masses in Limestone- Mica also occurs.- Organic Remains not numerous Entrochite - Mediapore &c - are found in the oldest Rocks.

Transition LimeStone is less cavernous than Secondary

Porphyritic Rock or Brexia - Tables of the Law supposed to be written on Sienite.-

Gneiss and Mica Slate are found in the Transition Series-

Quartz Rock - Granular with Scales of Mica-

[14] Red Sand Stone - immediately succeeds Transition Series- all Granular Rocks pass into each other-

Trap Rocks &c

Basalt - Volcanic Origin, allied to Green Stone - the latter passes into Sienite-

Amygdoloid - basis gen^{ly} Horneblende - when Reddish is Porphyritic-

Transition Euphitide or Serpentine - beds of reddish Jasper-.

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[15] Lecture 7th December 16th

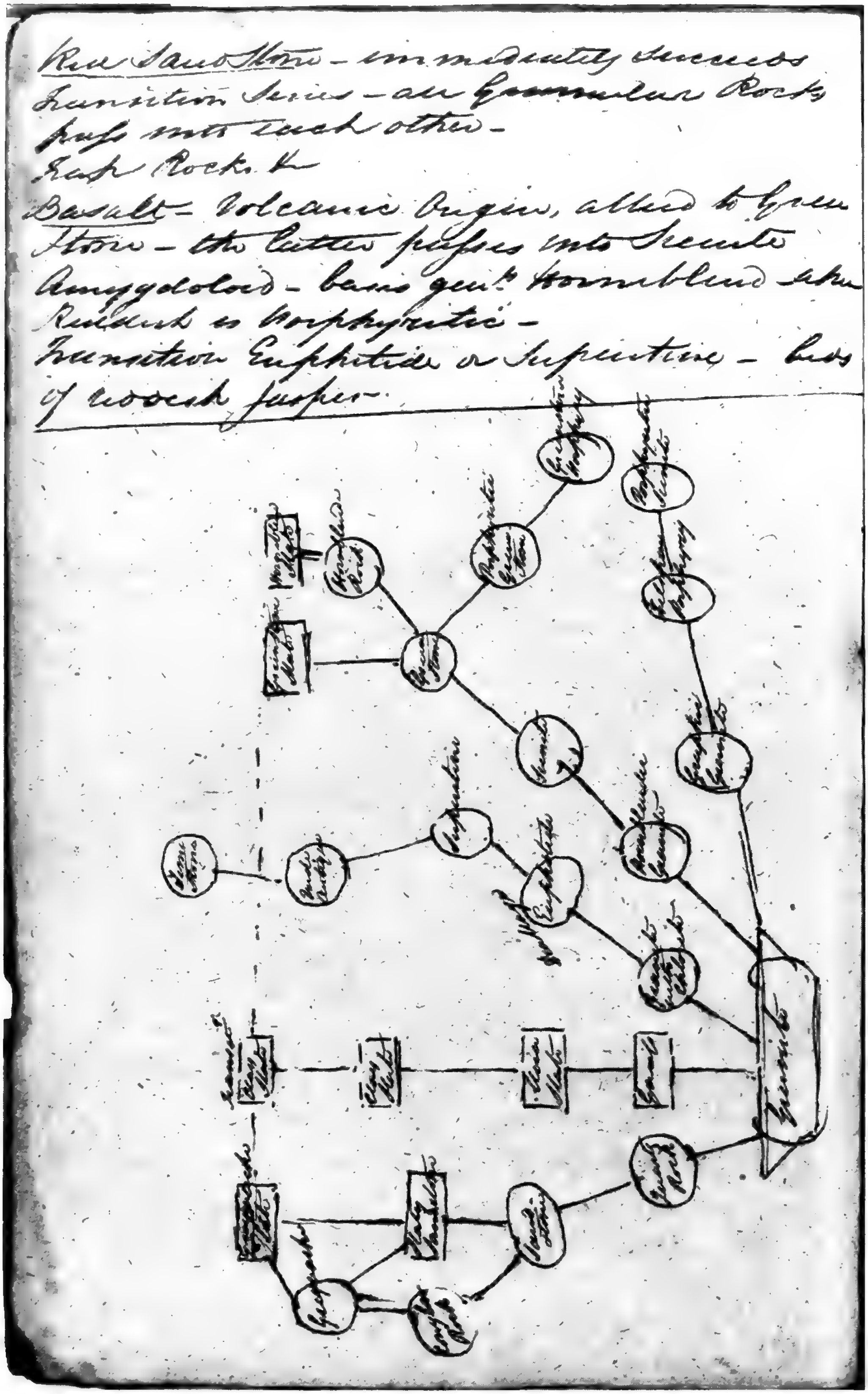
Floetz, in horizontal Strata.-

Secondary Series-. Old Red Sandstone - New d^{o} - Magnesian Limestone - Lias - Oolite Series Purbeck Clay - Argillacious Marl - Chalk - Marl and Chalk.

- Secondary Formation, unequally developped-

Old Red Sandstone - Coarse grained - of a Brownish red Color- composed of a greater part of Quartz - Felspar and Mica- Basis hard.

Slaty Structure - sometimes grey- with Scales of Mica - its purplish Color distinguishing it from newer Red Sandstone.



Red Sandstone – immediately succeeds
Transition Series – all Granular Rocks
pass into each other –
Trap Rocks &
Basalt – Volcanic Origin, allied to Green
Stone – the latter passes into Sienite
Amygdaloid – basis genl. Hornblend when
Reddish is Porphyritic –
Transition Euphotide or Serpentine – beds
of wood jasper –

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Corn Stone - as calcareous concretions found in it-

Trap Tuff - Basis Amygdaloidal.-

Peat Stone of different Colors - Porphyritic- few Organic remains found in old Red Sand Stone - Mountains of it are frequently 2 or 3000 feet - with highly inclined Strata.- it is connected with the Coal Measures.

Mountain LimeStone - prevalent Colour is Yellowish Grey- but it passes into Greyish White - and Greyish Blue- it has a red - a Yellow Tint - as in Lake Winnipeg a bluish Grey as in McKenzie's River- some of its Beds are granular and foliated some softer as in Slave River - passing into Magnesian Limestone.- Nodules of Chert or Flinty Slate - with Iron Pyrites occur in it - and it is very Cavernous

Beds of Trap &c

It is rich in Metalliferous Ores & Lead Mines

Bitumen is found in it as at Pierre au Calumet

Zoophytes exist - and Verterbrae of Fish-

Trilobites allied to Crabs.

Encynee - Shells &c - Coralines - occur.

[16] the Tops of Mountains are often formed of Mill Stone Grit - but it becomes more [word omitted?] when it approaches Primitive Rocks - as McKenzies River-

the thickness of Stratum is at right Angles to the Beds.-

Springs are found at the Bases but not on the sides of Mountain Limestone as St. Winnifreds Well - Flintshire-

Coal Measure - succeeds to Mountain Limestone- Mill Stone Grit - contains more Silex than the Sandstones-

Shale (or thin Slate) Nodules of Clay Iron Stone- It forms Table Lands - and is most important series (-Coal Measure)

Sandstone Slate - Iron Stone and Shale-

Slate becomes coarser and passes into Sand Stone-

Black bituminous Coal (Glance Coal without bitumen)

Slate Clay or Shale affords a dull Streak of a grey bluish Colour-

Clay Slate by accrease of Bituminous Matter it passes into Coal-

Bituminous Shale contains impressions of Ferns &c-
Sand Stone - with Carbonaceous Matter with Mica-
Clay Iron Stone occurs laying in rows-
Potters Clay - beds of Graphite-
Iron Pyrites - abundant - it burns with a sulphureous Smell-
Trunks - Stems &c found in it.
It forms a round and soft Outline-
The Strata often follow the inequalities of the surface - sometimes highly inclined-

[17] Lecture 8th December 23d

Coal Measure - separated by Lime Stone with layers of Clay.-
Magnesian Limestone - by Humboldt Alpine Limestone- there is another Sandstone between the Old and New Red Sandstone on the Continent.-
Mag-Limestone lies between the Coal Measure and Sandstone- the existence of Gypsum determines it to belong to the New Red Sandstone-
Mag-Limestone is of a light fawn or Salmon Colour - is traversed by Veins of Calcspar (which is the shining substance) it is sometimes found Slaty - and in Slabs - and dissolves slowly in Acids.- It contains - Gypsum and Rock Salt - as those on the Salt Plains on Slave River.- the Soil near it is poor in Herbage - the Yellow Rose flourishes.- it contains foetid Limestone - it is called Dolomite or Mag-Limestone-

It is two Beds - separated by Marl in Yorkshire.- is Cavernous - Organic Remains very common - impressions of Fish &c - Gryphites Entrochites - Trlobites [sic] - &c - Bones of Crocodiles have been found.-
It forms low Hills - about 500 Feet at most- the Beds are sometimes arched - & sometimes horizontal-
New Red Sandstone - or variegated Sandstone - small Granular - - grains of Quartz Mica - cemented by Clay. is from Chocolate to Salmon Colour- disposed in Zones and often spotted-
Red Marl - remarkable for Fissures - [18] - crumbles easily - and affords large Sandy Tracks- it is argillaceous with grains of

Felspar - sometimes Amygdoloidal and sometimes passes into Trap Rock. when Slaty - it shews that it contains plates of Mica-

New Red Sandstone may always be distinguished by its containing Gypsum and Rock Salt. is destitute of Petrifactions - and its Hills are Seldom higher than 800 feet- Beds nearly horizontal.- Salt and Mineral Springs occur- Gypsum - granular- or foliated - fibrous &c - is compact - white or Grey-

Muritiferous Clay - Colours veriegated.- Contains disseminated Pyrites-

Alabaster - Gypsum or Spar (of which are made Vases - Necklaces &c- No organic Remains found- is compact - in parallel Lines.- The Towns whose names end in which - are celebrated for having Salt in their Vicinity - 216 Salt works were worked at or near Nantwich in Cheshire in Elizabeths Reign.-

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Lecture 9th December 29th

Covering the New Red Sandstone or Red Marl are the Oolitic Limestones- Sands and Clays which form small Hills separated by Clay Vallies - in which Organic Remains are generally found-

M - Calcstone - a Shelly Limestone or Humboldts Limestone of Gottingen- it is of a white-palish Color - Granular &c - [19] containing Horn Stone passing into Flint Gypsum and Coals- Shells abundant but Corals are rare- Bones of Animals also are said to be found- Buckland supposes it to be the same as the Lias-

- Sandstone or Sandy Marl - fine white - granular - containing Lias - Shells &c Jura Limestone - containing Gypsum and a little Sandstone

Lias - with thick Argillaceous deposits- it lies over the red Marl in England and appears striped- having beds of Stones with Clay between- also Blue Lias.-

-large Stones - called Girdles.- Lias Clay bituminous near Axminster - Galena occurs in it but Chert is rare- Iron Pyrites or Sulphuret of Iron - abundant- also Organic Remains &c Animals with Verterba numberable.- Two Genera - like Crocodile or Lizards found in it. as well as Turtle and Crabs.

Fossils in Clay Iron Stone at Whitby - and Wood mineralized by Iron.- Lias forms broad and level Plains and produces a cold Soil - but is good for Woods.

Lower division of Oolites.- Above the Lias is a green Sandy Marl- over which is the Sandy Oolite - mixture of Iron gives it a bluish Cast- the hardest portions are blue in the interior-

Upper division - 9 beds. lower resting on Fullers Earth or Blue Yellow Clay [20] Stonesfield and Oxford Clay separate the middle from each other.

Great Oolite - calcareous- a fine Free Stone procured- Henry the 7th Chapel built of Bath Oolite. the Colour is generally of a Yellow cast- beds of a laminated structure above the Oolite is the Bradford Clay containing Organic Remains.
Stonesfield Slate is more remarkable for them than any other - Animals of the Lizard kind 40 feet long and 5 feet high have been found.
Forest Marble - with layers of Sand - beds thin and Slaty of a grey colour composed of Shells cemented by Clay but externally brown
Cornbrash - is of a greyish blue Colour but brown externally - from the red Soil- it is the bed of Mineral Springs- fragments of Fossil Wood are found in it.-
The great Oolite forms a flat Table Land succeeded by a gentle Slope formed by Fullers Earth- the inferior oolite forms a second Terrace.-

Middle Division. Oxford of Fen Clay beds of great thickness and of a dark Colour- Argillaceous Species mixed with Calcareous and bituminous matter- Iron Pyrites occur and Gypsum which is a Sulphate of Lime

[21] Coral Rag and Pisolite - beds of 1 to 200 feet thick of Calcareous or free Stone Beds- it is of a light Colour but is not equal to Portland Stone for durability - it moulders quick away. Sandy beds lie under Oxford Clay. Iron abundant - Shells numerous-

Upper division of Oolite - Kimmeridge Clay blue slaty or highly bituminous- dark brown Colour- contains no Pyrites - its smell is bituminous - but not Sulphureous.
Portland Oolite - Limestone beds containing Chert- Remains of Fish and Madrepores found-
Purbeck bed - Argillaceous Limestone consisting chiefly of Shells of calcareous Cement- Turtle have been found in it- the Soil is a Marly Clay.

Lecture 10th January 6th 1826

Lying above the Oolite is the Iron Sand and Weald Clay &c- Iron Sand - in which Sand and Sand Stone prevail - is Siliceous - contains Oxide of Iron - fossil Wood - Wood Coal - Shells &c- the Soil is of a Brownish Red.-
thickness of the Beds is about 500 feet- Hills of no great Elevation produces Hops in Kent.-
Weald Clay or Weald of Kent. a dark tenacious Clay - contains Shells- sometimes called Petworth Marble. Specks of Mica and Selenite are found-
in is frequently washed away - as in the Isle of Wight - where it is Said to run out. (cold Soil)

[22] Green Sand so called from the colour - resembles Iron Sand. consists of Sand and Sandstones cemented by a calcareous Matter- it contains green Earth which is also found in different Sandstones- also beds of Chert - Calchedony - Conglomd Rock with green Rocks - Iron Pyrites and Crystals of Quartz- in the Quarries of Blackdown 150 Species of Organic Remains were found.

Chalk Marl - Contains Argillaceous Matter and Sand- distinguished from Chalk in being more laminated - also more gritty.- has regular Nodules of Iron Pyrites &c Fragments of Bones were found in it at Folkstone- thickness 3 or 400 feet.-

Chalk uppermost of the Secondary Strata is nearly white- earthy - meagre and adheres to the Tongue, and Soils the Fingers - dull &c.- Yellowish Colour sometimes hard.-
The lower bed is in green Grains- middle Coarse that contains Horn Stone.
Upper is White having Flint Nodules (which is a remarkable feature) - Veins of Flint are rare. Organic Remains are numerous - and important - Fish and Univalves &c Sea Eggs - Star Fish - only one of Madrepores
The Hills are [two words are indecipherable] one Side and Steep on the other - highest Elevation 1000 feet.
Rivers seldom rise in Chalk.-
Chalk rendered red with Iron - when not much covered with Soil it is very unproductive
Chalk is unknown in America but common in England.-
[23] All the Fossil Remains are filled with the Matter envelloping them- Genera the same Species characteristic of Beds.- Suites above Chalk different.
Plastic Clay covers the bed of Chalk.-

Tertiary Formation -

Sand Clay and Marl consolidated with Limestone- Remains not mineralized - but appear recent - are sometimes confounded with Alluvial deposits- (Paris formations London and Isle of Wight-) deposits in Basins of Chalk. Plastic Clay over the debris of the Chalk beds- Sand Clay and Pebble Beds.- lowest Beds unctuous and tenaceous Sands of different Colours - called variegated Sand.- Clays laminated sometimes argillaceous Rocks &c- Coal of Vegetable Origin- Pyrites and Tabular Iron Stone found at Isle of Wight- Amber found on the Coast of Yorkshire- Organic Remains in Plastic Clay- has a flat surface.

London Clay Argillaceous deposit bluish or blackish Clay- Some Strata effervesse- Septaria washed out of it which is Characteristic of the London Clay- Fossils Copal and Amber found- Organic Remains numerous - Crocadiles - Fish and Coals few of the Genera of recent Shells wanting some resemble those found in the Indian Seas and Warm Climates.- Contains portions of Fossil Wood (Isle of Sheppy) quantity of Seeds and Fruit found - upwards of 700 Specimens (not known) thickness [24] 700 feet - (Richmond Hill London Clay) It chokes the Plough and rolls before it unlike other Clay.-
The Beach or bank when dried is cracked resembling the Giants Causeway. the Beds above the London Clay contain Shells such as are found in the neighbouring Waters

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Lower fresh Water Formation (Isle of White)
2 Coase Limestone with Sandstone - Siliceous
1 Limestone with Gypsum and Bones
Lower Bed very Sandy - containing Shells Petrifactions - Siliceous Matter - Amber - Chalcedony and quartz.-
Gypsum Formation - Gypsum and Marl with a multitude of Bones &c- it is white or Yellowish Limestone - and is separated from the Marine Formation by the Green Marl-

Upper Marine Formation - is a Series of thick Beds of Sand and Sandstone- the Sand with Angular particles of quartz &c Sandstone contains few Organic Remains.-

The Upper or great fresh Water Formation

the newest (Paris Basin) layers of Sand Clay and Mill Stone in thick Beds- above is layer of Limestone impregnated with quartz- it is of a Yellowish White Colour contains Flint and Horn Stone with cylindrical Cavities.- it is covered by alluvial and contains fresh water Shells [25] which are thin and friable (Hedon Hill Isle of Wight)-

Remarks - great proportion of Arenaceous Beds - Silica forms the greater part of Flint - it is found pure in Rock Crystal

Granites owe their construction to crystallization- quartz Rock resembling Gneiss- difficult to find where the Crystalline process ends and where the Fragmatic begins
Sandstones are less aggregated as we ascend from the lower to the newer formations.

Lecture 11th January 13th 1826

Volcanic Rocks - determined by the absence of Quartz - or more by the Chemical than the Geological Character.-
(of a Black Colour - shining - with Cells-
Cordilleras 2500 Leagues. (Humboldt)
Augites found in Limestones-
Great Masses of Basalt found in primitive and Transition Formations - some are Volcanic-
Trachite (signifying rough) like Felspar Colour Grey - approaching to black - fracture earthy - friable - disintegrates easily-
Pumice - shining Horneblend and Mica-
Iron Glance Specula of Iron occurs in Cavities and Veins-
It constitutes all the loftiest Summits [26] of the Cordilleras-
Obsidian - like black Glass- translucent at the Edges- it occurs in Beds and Streams in Volcanic Tracts.
Pitch Stone - like broken Resin - is feebly translucent at the Edges.-
Pearl Stone - resembles Pearl- Is of a black grey and red Colour-
Pumice - Grey and white - vessicular - vitrious feels sharp and Meagre - floats on Water-
Pumice - porous & used for polishing Wood &c - like froth of the Glass Pots - cellular-
Trachite - Granite altered by Fire - Pumice may be it.-
Clink Stones are common in Basalt.- Slaty with a cross fracture - (Lake Huron la cloche)

Tuffa - having a Base with Fragments containing Opal and Shells. (Jameson)

Conglomerates cover immense Surfaces - friable like Tuffa - or hard like SandStone

Pumice - Rocks of Various kinds altered by Fire.-

Basalt contains Augite which is a lighter colour than Horneblende - Greyish or greenish Black - fracture even - pale Streak. Two kinds - Felspar and Horneblende and Felspar and Augite - Giants Causeway - and Staffa.-

[27] It traverses Limestone and Sandstone of the Coal Measures-

Basalt is Amygdaloidal-

Basalt and Green Stone Lava - nearly the same softened by Heat - Scoria vesicular

Wherever Trachites are abundant - Lava is rare.-

Modern Volcanic &c- Lava - Volcanic ashes &c-

Compact Lava - grey lustre - Scratches with the knife.-

Vessicular Lava - upper part of the Stream-

Spumy Lava - Volcanic Glass-

Rocks formed by Hot Springs - in Italy they actually put the Mould into the Springs and so obtain a perfect Stone of which a great part of Rome is built-

Torrents of Mud - form Stones - resembling Trachite- Water thrown up by Gass-

Crystals &c - thrown up with it-

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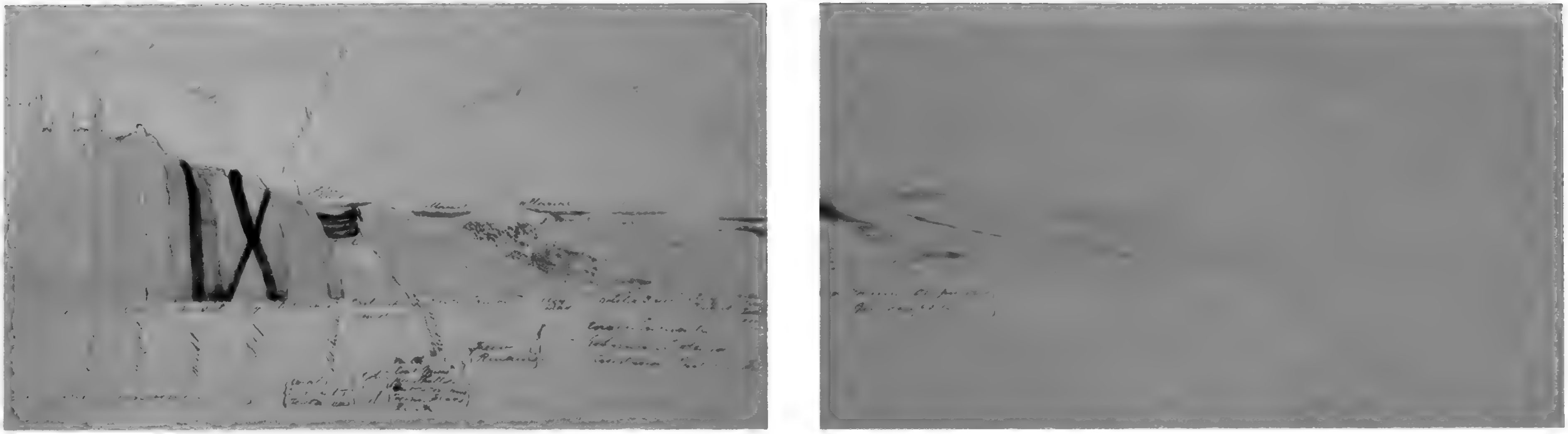

Figure 3: Back's geological section of Primitive to Alluvium strata

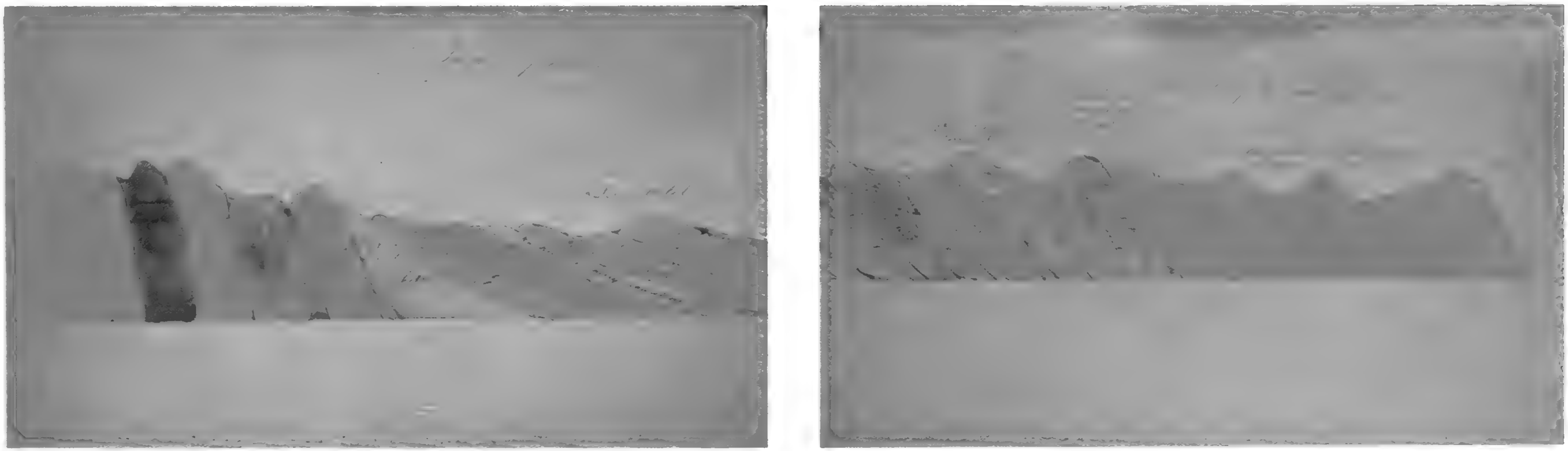

Figure 4: Back's geological section of Secondary strata

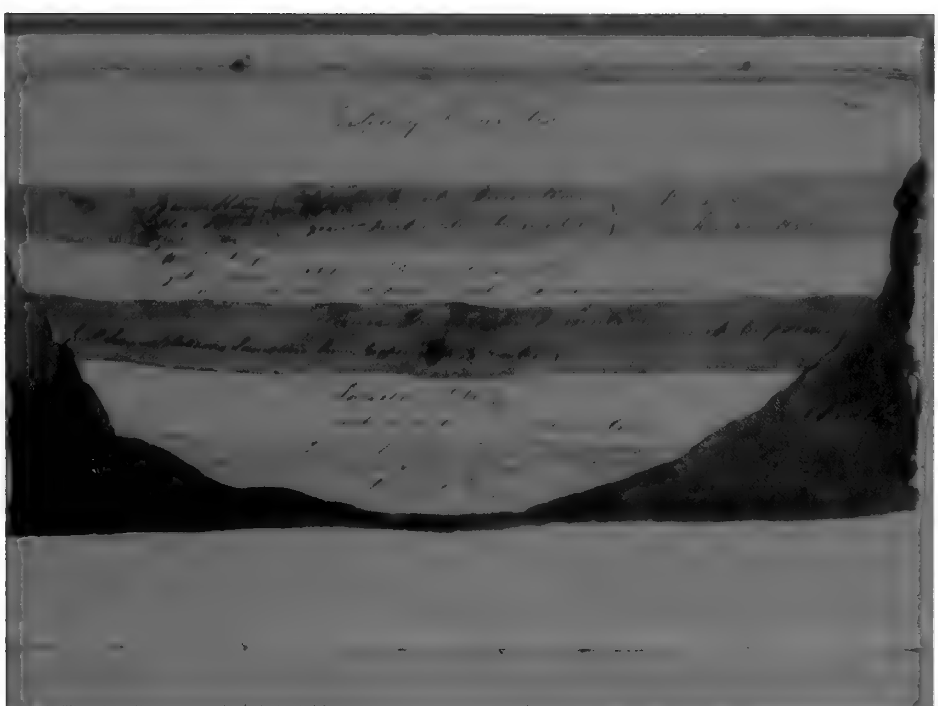

Figure 5: Back's geological section of Tertiary strata

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