ART. XXIII.—*Proofs of the Rising of the Land around Hudson Bay;* by ROBERT BELL, of the Geological Survey of Canada.

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IN the provinces of Ontario and Quebec, it has been found from actual levellings by Gilbert, Spencer and Upham, that the old shore-lines are not perfectly horizontal, but that they slope upward in a northeasterly direction at rates varying in different regions from a few inches to a foot and even two feet per mile. If this upward slope were continued in the same direction to the northeastern extremity of Labrador, 1300 miles from Lake Huron, the increase in the elevation might there amount to 1000 or 2000 feet. It is scarcely probable that the differential elevation is constant and regular for such a great distance. Still, it is a fact that well preserved shore-lines are to be seen at great heights in the northern parts of Labrador. In my Geological Survey Report for 1884, I have mentioned ancient beaches at Nachvak, 140 miles south of Hudson Strait, which have an estimated altitude of 1500 feet above the sea.

The two sides of Hudson Bay present very different physical characters. The eastern is formed mostly of crystalline rocks and, as a rule, is more or less elevated, with a broken surface sloping somewhat rapidly westward or towards the bay; while the western side is mostly very low and much of it is underlaid by nearly horizontal Silurian and Devonian strata. These low shores are accompanied by shallow water extending far to seaward. The head of James Bay, which forms the southern prolongation of Hudson Bay, is extremely shallow, but the various rivers which flow into it have cut channels through the soft shallows, and by means of these the land may be approached with sea-going vessels. The whole of Hudson Bay may be said to be shallow in proportion to its great area, as the soundings show that it does not average more than 70 fathoms in depth.

The shores of the bay everywhere afford abundant evidence that there has been a comparatively rapid rise in the land and that the elevation is still going on. I have mentioned numerous proofs of this in my various official reports on the geology of these regions from 1875 to 1886, and I shall now recall a few of those and give fresh ones in addition, some of which came to my knowledge on a journey to the bay during the past summer. It is well known to those who have paid any attention to the subject that since the establishment of the posts of the Hudson's Bay Company in the mouths of the rivers around the bay, 200 years ago, there has been an ever-increasing difficulty in reaching these establishments from the sea.

On the eastern side the most striking evidence of the rising of the land is afforded by the numerous well-preserved and conspicuous terraces cut in the till and other deposits. Near the sea these may be seen at various heights, up to about 300 feet, but above this elevation the scarcity of soft material out of which terraces might be excavated, renders this kind of evidence less apparent than it might otherwise be, at higher levels.

On this side of the bay, one of the best evidences that the elevation of the land is still going on is furnished by the long lines of driftwood which one sees in many places far above the reach of the highest tides. The old beaches, on which this wood is plainly seen, occur at various levels up to about thirty feet above high tide, but the remains of rotten wood may be detected in some localities up to nearly fifty feet, above which it has disappeared from the ancient shores by long exposure to the weather. This driftwood consists principally of spruce, but a little white cedar and other kinds, which have been brought down by the rivers, are also mixed with it. The bark having been worn off by the action of the waves while the trunks were still fresh, has tended to their preservation. Owing principally to the salt water and the cold climate, wood endures for an incredibly long time in exposed situations in this region wherever it has an opportunity of drying quickly after rain. Some of the wood which may still be seen upon the higher levels may be upwards of 600 years old.

It has been suggested that all this driftwood along hundreds of miles of coast may have been thrown up by some extraordinarily high tide. But there are many reasons why this is quite unlikely. It seems impossible that any modern tide could rise to such a great height and deposit so much wood at different levels all at once and in such even lines, following all the sinuosities of more than one of the raised beaches. The supposititious extraordinary tide would necessarily be of brief duration and would be accompanied by a tremendous gale blowing upon the coast. This would have the effect of throwing the wood in confused heaps and only into situations favorable for catching it, such as angles of the shore. But instead of this, we find it at different levels laid longitudinally all along, as if accumulated by slow degrees with moderate winds from every quarter. The fact that the wood is freshest along the lower lines and becomes progressively more and more decayed as we ascend, and that finally only traces remain on the higher levels, shows that it must have been stranded from time to time as the land was rising above the sea, and we are forced to adopt this obvious view of the case.

In support of the paroxysmal tide theory, it is related that once during a northern gale the tide was forced as high as the front gate in the palisaded enclosure at Rupert House near the head of James Bay, and it is added that this would be equivalent to a height of about thirty feet. When at Rupert House last summer, I could hear no authentic account of such an extraordinary rise in the water and besides the gate referred to did not appear to be more than fifteen feet above the sea-level. But even if such a great rise in the water had once occurred at this place, it would prove nothing in regard to the raised beaches on the long straight shore out on the open sea. Hudson Bay is about 1000 miles long and its outline is funnel-shaped, with James Bay representing the contracted extremity. Rupert House is situated near the end of this narrow continuation, so that just here we should expect very high water with a spring tide and northern gales driving the sea in from the broad expanse outside and heaping it up at the extremity of the constantly narrowing termination.

The gravel terraces seen at various elevations around the coves and upon the thousands of small islands along the east coast of James Bay are remarkably sharp and well-preserved and almost as fresh-looking as if they had been formed but yesterday. They are generally bare of trees or bushes and the yet smooth surface-pebbles are only partially covered by lichens. Similar terraces may be seen farther north on this coast and in Hudson Strait, wherever material exists out of which they may be formed. On Marble Island the raised beaches are very plainly visible on account of the whiteness of their smooth, quartzite shingle.

On the west side of Hudson Bay the land is generally too low to admit of the relatively higher sea-levels of former times having been recorded in the shape of terraces near the present shore line, but if we go back into the woods we shall find unmistakable evidence of the existence of such higher levels at comparatively recent periods. These consist of long, low ridges of drifted materials, such as we see in a fresher state at the present high tide mark. They are made up of driftwood and other vegetable debris in a completely decayed condition, covered by moss and having trees and shrubs growing upon them. In some places we may still trace the forms of the larger trunks which had been cast ashore by the waves at high tide. Between these ridges and the present shore there is a thick growth of the coniferous forest and the ground is carpeted with moss, over which the tide has never passed. Examples of these low ridges may be seen near the head of tide-water at the mouth of Nelson River, at Attawapishkat River and in places between the latter and Albany River.

To the west and southwest of James Bay the till, covering the nearly flat Silurian and Devonian rocks, is generally overspread by stratified clays. Marine shells are found in these up to an elevation of 400 to 500 feet, but on the eastern side of the bay no fossils have yet been detected at such high levels, owing perhaps to the scarcity there of marine deposits and to the fact that but little search has yet been made for them. In the sandy deposits among the hills about twenty miles south of Cape Wolstenholme, I saw abundance of *Saxicava rugosa* and *Tellina Grœnlandica* with smaller numbers of a few other species, at heights varying from the sea level up to about 200 feet; and last summer I found brackish water varieties of a number of the commoner species of our northern marine shells up to 70 feet above the sea in the clay banks along the lower portion of the Noddawai River.

Around the head of James Bay and up its western side the encroachment of the outer lines of the forest upon the wide alluvial flats which extend all along these shores and are constantly broadening towards the sea is good evidence that a rising of the land is now going on. The existing condition in this part of the bay is well described by Mr. A. P. Low in speaking of Agoomski Island. On page 24 J. Geol. Survey Report for 1887, he says:

"The island closely resembles the adjoining mainland in physical character, being very low and swampy. The shore-line above high-water mark is made up of muddy flats covered in part with grasses and sedges, followed further inland by thick growths of small willows, these in turn giving place to small black spruce and tamarac as slightly higher ground is reached. The line of these trees is often over two miles inland from high-water mark, itself a long distance from the sea at low water."

No living mollusks are to be found in James Bay except perhaps in the northern part, owing probably to the muddy and brackish nature of the water, but abundance of the dead shells of a considerable number of kinds are washed out of the clays forming the present shores. Some of these belong to moderately deep-water species and are well-preserved, retaining the epidermis. This, of course, shows a recent elevation of the sea bottom.

Richmond Gulf on the eastern side is separated from the main bay by a high bar of stratified rocks, which strike with its length and dip westward or towards the open sea. This bar is cut through by several gaps, all resembling one another, except in their heights above the sea, and all bearing evidence of their having been well worn channels of communication at more or less remote times according to the greater or less elevation of their beds above the sea. Only one narrow passage now remains open or low enough to admit the water, but two others are as yet only slightly raised above the tides.

Some of the aboriginal geographical names around the head of James Bay are significant of considerable changes in the topography since these shores became inhabited by the natives who still occupy them. The large peninsula between Hannah and Rupert bays is called Ministik-oo-watum, which means wooded island with a cove or hole in it, ministik being the Cree for a wooded island and watum for a cove or hole. The heads of the channels, which now run in behind the present peninsula from the opposite sides, are separated by a strip of low ground some ten miles long covered by bushes. Midway across this strip, the elevation is estimated to be about fifteen feet above high tide. The most prominent point on the coast between Moose Factory and Fort Albany is now called "Cockispenny" by the whites, but the Cree name is Ka-ka-ki-sip-pin-a-wayo Minis, or Island where the Crow-duck (Cormorant) lays eggs. Since this island became connected with the mainland, bushes have taken the place of the grasses and sedges which first grew upon the low ground between them, and the former are constantly acquiring a stronger growth. Many years ago the winter trail of the coast passed over the neck of this peninsula, but now it has become necessary to go outside of it, because the bushes have grown so large that they catch the snow which, in such situations, remains too soft for dog teams and snow-shoers.

The salt marshes along the west coast of James Bay and also in the vicinity of York Factory, which used to attract vast numbers of wild geese and ducks, have been gradually drying up, much to the inconvenience of the Hudson's Bay Company's people, who depended largely upon them for food.

The character of the lower portions of such rivers as the Moose, Albany and Attawapishkat shows a recession of the sea. This is particularly observable in the lower thirty miles of the Moose, where very long and narrow or ribbon-like islands run parallel to one another for many miles. The process of their formation appears to have been a constant drawing out of their lower extremities as the sea receded from them, just as the lowest islands of the present day are growing.

On the east-main coast, where the land is comparatively high, the grade of the rivers is rapid as they approach the bay, and in some of them, as the Nastapoka and the Langlands, there are perpendicular falls of about 100 feet almost directly into the sea. This condition indicates recent elevation.

One of the best evidences of the modern rising of the land is to be found in the beach-dwellings of the Eskimos, which may be seen at all elevations up to about 70 feet. In summer these people generally camp on the shore, and their favorite locations are at the mouths of small streams into which the sea trout run at high tide. Here they construct weirs of stones, which impound the fish when the tide retires. On Outer Digges Island, I have found these fish traps and the rings of stones and other structures marking their old camping places, up to a height estimated at 70 feet.

Among the historical evidences bearing upon this question since the advent of the white man, may be mentioned the fact that in 1610, Henry Hudson, the navigator, wintered in a bay full of islands on the east coast south of latitude 53°. None of the bays in this region would now be possible for this purpose, showing that a considerable change in the level of the sea has taken place in less than 300 years.

In 1674, Charles Bayley, then local governor for the Hudson's Bay Company, sailed through in a sloop between Agoomski Island and the main west shore of James Bay. It would now be impossible to pass here in a sea-going vessel of any kind. In 1886 I found it difficult to get through in bark canoes, drawing only a few inches of water. The shoaling is not due to a silting up, since the almost dry bottom consists of a level surface of till with bowlders scattered thickly over it.

From 1675 to 1685 the Hudson's Bay Company's establishment in the mouth of Moose River was upon Hayes' Island, which, it is to be presumed, was selected for convenience of landing goods from their vessels and shipping out their returns. This island is now unapproachable except by canoes and small boats. For more than 200 years the factory* has stood upon Moose Island, the next below Hayes' Island. The annual ship from England anchors in the channel cut through the sands off the mouth of Moose River. On account of the risk of rough water, it is necessary to discharge the cargo by schooners. Within the memory of living men, these schooners could ascend to a wharf built opposite the large storehouse of the factory. But for many years, the same schooners have been unable to ascend all the way, and the cargo requires to be transferred into scows, which complete the trip to the wharf; and the distance to which the schooners can ascend is constantly diminishing. In the beginning of the present century Princess Island, a narrow bushy strip immediately in front of the factory, was separated by a channel with a good depth of water at the lowest tides. Last autumn I saw it quite dry on several occasions during ebb tide. It is well known to every one who has lived at this post in the present generation that every now and then a new "lump" will appear in the bed of the river

* Factory, a residence of a factor or agent.

and become permanent, growing higher and higher, eventually escaping submergence at most tides and at length becoming covered with grass and then with bushes. Some islands which were covered only with bushes forty or fifty years ago, now support a growth of young trees. The small one on the west side of Middleboro', below Moose Island, is an example of this and the appearance of the trees upon it is within the memory of Mr. Broughton, the gentleman now in charge of Moose Factory. Middleton Island, between the mouths of Rupert and Noddawai rivers, lies close to the east shore of Rupert Bay. Up to a few years ago, canoes and boats could pass at high tide through the long narrow grassy channel behind this island, but last autumn I found it impossible to do so with my canoes and we were obliged, at great inconvenience, to go round outside.

Two hundred years ago, the ships of the Hudson's Bay Company appear to have had no difficulty in entering the mouths of various rivers on the Eastmain coast which cannot now be used as harbors. In old times the principal post of the company on that coast was in the mouth of Eastmain River, which had no doubt been chosen because it afforded a good harbor. It is only a few years since the mouth of Little Whale River, several hundred miles farther north, had to be abandoned as a harbor on account of the increasing shallowness of the water.

At York Factory there is a "ship hole" in the channel of Hayes' River, directly in front of the storehouse. The sea-going vessels of light draft employed in the Hudson's Bay Company's trade have been accustomed to anchor in this hole and formerly they remained afloat at all stages of the tide, but of late years, vessels drawing even less than those of former times have begun to "take the ground" at low water. In objection to the belief that the land is rising it may be said this may be due to a silting up of the hole, but on examining the material brought up on the flukes of the anchors, I found it to consist of light colored stiff bowlder clay or till.

In 1782, after the French Admiral Lepeyrouse had destroyed Fort Prince of Wales at the mouth of Churchill River, he landed with cannons on the southeast side of Nelson River and hauling them across the point between it and Hayes' River, captured York Factory. Two ships belonging to the Hudson's Bay Company which were then lying in Hayes' River, laden with valuable cargoes, escaped under cover of the darkness of the following night and got safely to England. At the present time, it is only possible for a sea-going vessel to get out from this river at the top of high water with favorable wind and careful piloting in daylight. To say nothing of the difficulty caused by the darkness, it is unlikely that all the other conditions now necessary to enable a vessel to leave the river, conspired to aid the escape of these ships. It is much more reasonable to believe that the water was deeper then than it is now. The landing of Lepeyrouse with his guns on the shore of Nelson River abreast of York Factory was a feat the like of which could not be accomplished at the present day, owing to the extreme shallowness of the water.

The present Fort Churchill or "New-Fort," as it is still called, was built in 1782 on the west side of the river about four miles and a half above Fort Prince of Wales as soon as the French had retired after destroying the latter establishment. The residents now suffer much inconvenience on account of the continued shoaling of the water and they have been obliged to lengthen out their "launch" or long landing tressel from time to time in order to be able to reach the outer end of it with their coast boats.

Off the western side of the lagoon within the mouth of Churchill River is Sloop's Cove, a small elliptical pond connecting with the lagoon by a very narrow entrance, through which the water barely passes at high tide. On the arkose rocks beside this little cove many inscriptions have been cut and some ring-bolts have been fastened, for mooring vessels, all of which indicate that the cove was used for wintering ships in old times. Indeed it is known that the "Furnace" and the "Discovery," two small ships commanded by Captain Middleton, passed the winter of 1741–42 in this cove. I have examined the place on various occasions and have copied most of the sketches and inscriptions on the rocks, and it always appeared to me that the conditions which we observe indicate a rise in the land since the last ship wintered there. At the present time, the tide does not rise high enough to allow of the passage into it of crafts larger than ordinary row-boats. No sea-going vessel could now enter it, which would indicate an elevation nearly equal to the draft of the ships formerly frequenting it. It would be a boon to the agents of the Hudson's Bay Company at Churchill if they could now winter their small schooner in this cove instead of being obliged to send her every autumn to winter at York Factory. The captain who commands her happens to be the person now in charge of the company's post at Churchill, and both he and his crew are obliged to walk back 150 miles through the mud from York Factory after leaving their vessel there in the autumn and to walk the same distance again to bring her back in the spring. Mr. J. B. Tyrrell visited Sloop's Cove in the autumn of 1893, and in a paper published in the Geological Magazine for August, 1894, says he thinks the land is here in a state of equilibrium. Two inscriptions which he saw on the rocks, namely, "May 25th and May 27th, 1753," were about seven feet above the present high tide and he thinks these were cut by men standing on the ice. This, however, does not prove much, for the men were quite as likely to have sat as stood while engraving these inscriptions. As the tide still enters the cove and keeps it full of water, the average relative level of its ice to the rocks surrounding it may not have differed much from what it is now. When I visited Fort Prince of Wales in 1879, oak planks brought from England while the fort was still occupied as well as timbers of native wood, all charred by Lepeyrouse's fire, were found stranded far out of reach of the present tides and still in perfect preservation. On the occasion referred to, I met at the "New Fort" children of some of the people who were living at the "Old Fort" when it was captured by the French, and from them some information could be obtained as to the conditions at that time. We have, besides, the description and illustrations in the book by Samuel Hearne, who was then in charge of the place. Any light which these accounts may throw on the state of matters then as compared with the present time, points in the direction of some elevation having taken place.

Among the photographs which I took around Fort Prince of Wales in 1879 is one which shows strips of dry land grasses alternating with little parallel ridges of gravel thrown up by the waves and now above the highest tide-mark, but *below* the level of the spot which was pointed out to me as the landing place of Lepeyrouse. The ground on which the fort stands was an island during high tide at the time the place was occupied and a bridge was thrown across the narrowest part of the little separating channel to connect the island with the main land. This channel is now entirely dry.

If anything further were wanting to show that an elevation of the land is now going on in this region we have some direct personal evidence in the lifetime of the witness himself in support of the facts already cited. About twenty years ago, a very aged Indian, who was said to have "seen more than a hundred winters," and who was quietly passing the last years of his extraordinarily long life at Norway House, told me in presence of the factor, Mr. Roderick Ross, and the other gentlemen of that establishment that he had, when a boy, witnessed the landing of Lepeyrouse and the destruction of Fort Prince of Wales. He gave graphic details of every circumstance, which agreed perfectly with Lepeyrouse's own account, and he answered all my questions on other points entirely satisfactorily and without a moment's hesitation. Among other things, he mentioned that the spot where the Frenchmen's boats landed was quite close to that portion of the western wall which they undermined and blew up with gunpowder. He said that when all was ready, they laid "a rope" (train) of gunpowder across the beach and setting fire to the end of it, ran off to a safe distance to witness the effect. It is now a considerable distance from this spot to the nearest point of water at high tide.

The proofs of the rising of the land around Hudson Bay in post-glacial times would be admitted by any geologist, and the question of the continuance of the movement at the present time is, I think, answered in the affirmative by the actual general shoaling of the water which is going on and the encroachment of the land on all sides, some proofs of which have been given in the foregoing pages. All the facts which have been mentioned (and many more might be added) point in the same direction, while there appears to be no evidence of a contrary character. The officers of the Hudson's Bay Company are an intelligent set of men, and their universal opinion, based upon lifetimes of observation, is that the land all around the bay is rising. The following is part of a letter recently received from Mr. Joseph Fortescue, lately a chief factor in the Hudson's Bay Company, in answer to my request for his opinion on this subject:

"Regarding the rising of the shores of Hudson Bay, I have no doubt whatever. When I was at York Factory, I heard several Indians say that the sea or tide had retired two miles from places they remembered when they were young, and my own observations during twenty years there would lead me to entertain the same opinion. When I revisited Moose Factory, after nearly forty years absence, I found a great change in the appearance of the coast and river. Channels which were navigable at all times of the tide formerly, could now only be used at high water."

ART. XXIV.—*On the Occurrence of Thaumasite at West Paterson, New Jersey;* by S. L. PENFIELD and J. H. PRATT.

IN 1878 Baron von Nordenskiöld* described a mineral from the copper mines of Åreskuta, Jemtland, Sweden, which, according to the analyses of Lindström,† had the composition $CaSiO_3$, $CaCO_3$, $CaSO_4$, $14H_2O$ and to which the name thaumasite was given, from *θαυμάζειν, to be surprised.* The mineral was not found in distinct crystals but was crystalline and on a fracture showed a fine fibrous structure. Its homogeneous character and its right to be considered a distinct mineral species rested upon the following: The material seemed to be homogeneous when examined with the microscope, and the three analyses of Lindström, made upon material collected in the early part of this century by Polheimer, in 1859 by Nordenskiöld, and in 1878 by Engberg, agreed not only very closely with one another but also with the theory demanded by the formula.

That a mineral with such a remarkable composition was capable of existence was not accepted by all mineralogists, and Bertrand,‡ on examining thin sections of it with the microscope was led to believe that it was a mixture, composed of a uniaxial mineral with negative double refraction supposed to be calcite, of a biaxial mineral gypsum, and of a third mineral, the optical properties of which could not be made out, probably calcium silicate or wollastonite.

The idea of Bertrand's that thaumasite was a mixture was not accepted by Nordenskiöld, and the latter to sustain his position presented the following arguments,§ which were very convincing: First, if it were possibly a mixture it certainly would be very remarkable that three independent samples, collected at such widely separated periods, should agree so closely in percentage composition. Second, there is no known hydrated calcium silicate which, when mixed with calcite and gypsum, could yield a product containing over 42 per cent of water. Third, it would not be possible for a mixture of calcite, gypsum and wollastonite, with specific gravities of 2·72, 2·31 and 2·90 respectively, to yield a product with such a low specific gravity as thaumasite, 1·877.

Specimens were moreover sent to Lacroix for renewed

* Comptes Rendus, vol. lxxxvii, p. 313, 1878.
† Öfv. Ak. Stockholm, vol. xxxv, No. 9, p. 43, 1878.
‡ Bull. Soc. Min. de France, vol. iii, p. 159, 1880, and vol. iv, p. 8, 1881.
§ Geol. För. Förhandl., Stockholm, vol. v, p. 270, 1880.

optical examination, and in a letter to Nordenskiöld he states* that the material was found to be practically homogeneous, uniaxial and with negative double refraction, but whether hexagonal or tetragonal could not be determined. The uniaxial material which Bertrand had taken for calcite was in reality thaumasite, and Bertrand in a letter to Nordenskiöld† withdrew his objection. He gives also the approximate indices of refraction $\omega=1{\cdot}503$, $\varepsilon=1{\cdot}467$, which differ from those of calcite.

In 1890 Widman‡ described specimens of thaumasite belonging to the mineral collection of the University of Upsala, which are reported to have been found at Kjölland, about thirteen miles from the original locality Åreskuta, and two analyses by Hedström quoted by him agree very closely with the ones made by Lindström. From Hedström's analyses the formula $CaSiO_3$, $CaCO_3$, $CaSO_4$, $15H_2O$ was derived, and as pointed out by Widman this slight change in the formula agrees satisfactorily with the analytical results of Lindström, who really had found over fourteen and one-half molecules of water.

It is with pleasure that the authors are able to announce the discovery of this unusually interesting mineral at Burger's quarry, West Paterson, New Jersey, the material having been first brought to our notice by Mr. Geo. L. English, of New York, who sent a specimen of it to the mineralogical laboratory of the Sheffield Scientific School for identification. The mineral occurs as an aggregate of prismatic crystals, sometimes so loosely held together that the individuals can be separated by crushing between the fingers, while more often the masses are firm and have somewhat the appearance of white alabaster. Occasionally distinct prismatic crystals were observed, averaging $0{\cdot}5^{mm}$ in diameter and 2 to 4^{mm} in length, but they were poorly formed and without distinct terminations. Some of the masses showing fine prismatic crystals have a decidedly silky luster. There is a distinct prismatic cleavage. Measurements were only possible in the prismatic zone and approximated to 60°, which determine the crystallization as hexagonal. On examining fragments imbedded in Canada balsam ones can readily be found which show a uniaxial interference figure with negative double refraction. Using a polished plate, the index of refraction for the ordinary ray was determined by means of total reflection in α–mono-bromnaphthalene and found to be 1·5125 for yellow Na. By means of a prism of 32° 58′ the following values were also obtained for yellow, $\omega=1{\cdot}519$

* Geol. För. Förhandl., Stockholm, vol. ix, p. 35, 1887.
† Ibid., vol. ix, p. 131, 1887.
‡ Ibid., vol. xii, p. 20, 1890.

and $\varepsilon=1{\cdot}476$. It must be stated, however, that a prism cut from a crystalline aggregate cannot yield wholly satisfactory results, as the light does not traverse a single individual, and that for example which yielded the extraordinary value above was vibrating in crystals whose vertical axes were approximately and not perfectly parallel to the edge of the prism. Levy and Lacroix* give $\omega=1{\cdot}507$ and $\varepsilon=1{\cdot}468$.

In order to be absolutely sure of the uniform character of the material for analysis, selected pieces of the mineral were crushed and sifted to a uniform grain and separated by means of methyl iodide CH_3I, which was diluted with ether. That every particle of the mineral in the separator floated at a specific gravity of 1·887 and sank at 1·875, a difference of only 0·012, is sufficient proof of the homogeneous character and great purity of the material. Lindström gives as the specific gravity of the Swedish mineral 1·877 and Widman gives 1·83.

The results of the analysis are as follows:

	I.	II.	III.	Average.		Ratio.
SiO_2	9·23	9·33	9·23	9·26	·155	·97
CO_2	6·87	6·77		6·82	·155	·97
SO_3	13·56	13·32		13·44	·168	1·05
CaO		27·08	27·19	27·13	·484	3·04
H_2O	42·81	42·72		42·77	2·377	15·00
Na_2O	·39			·39		
K_2O	·18			·18		
				99·99		

The ratio of $SiO_2 : CO_2 : SO_3 : CaO : H_2O$ is very nearly 1 : 1 : 1 : 3 : 15, demanded by the formula $CaSiO_3$, $CaCO_3$, $CaSO_4$, $15H_2O$. The analytical results are, moreover, very close to those obtained upon the Swedish mineral by Lindström and Hedström. A slight amount of alkali sulphate is probably present as impurity, therefore the alkalies have been neglected in making the above calculation. That Na_2O and K_2O are not isomorphous with CaO is shown by the following experiment: 1·1765 gram of the powdered mineral were treated in a platinum dish for over two days with cold water, the insoluble mineral was then filtered off and the soluble portion analyzed, with the following results: SiO_2, 0·39 per cent; SO_3, 0·56; CaO, 0·56; Na_2O+K_4O, 0·25. These indicate that thaumasite is slightly soluble and that the alkalies have an independent existence, for a quantity of Na_2O+K_2O equal to about one-half of that found in the original analysis was

* Les Minéraux des Roches, p. 286, 1888.

extracted, while relatively only a very small proportion of the calcium was dissolved, a result which would not have taken place if the alkalies had belonged with the thaumasite. A small quantity of alkali sulphate may, therefore, be regarded as impurity, and deducting from the analysis the alkalies and sufficient SO_3 (0·64 per cent) to convert them into sulphates, and recalculating to one hundred per cent, the following results are obtained, which agree satisfactorily with the values required by theory:

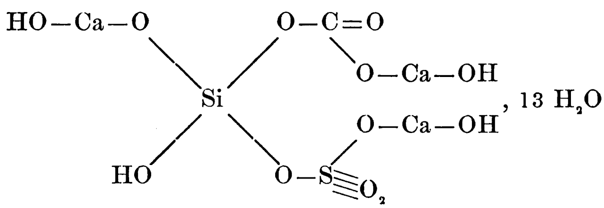
	By recalculation.	Theory.
SiO_2	9·38	9·64
CO_2	6·90	7·08
SO_3	12·95	12·86
CaO	27·47	27·01
H_2O	43·30	43·41
	100·00	100·00

Hoping to obtain data concerning the constitution of the mineral, experiments were made to determine the temperature at which the water was driven off. As determined by Lindström, the mineral slowly loses water at 100° C., and in our experiment, after heating for over ninety hours, a loss of 29·35 per cent was obtained, but the weight had not become constant. At 150° the weight soon became constant and then at 200°, 250° and 300° respectively constant weights were obtained, and in each case the heating was continued until the loss of weight during several hours did not amount to more than a few tenths of a milligram. Between 300° and 360° no loss of weight was obtained, but the material still contained water which, as seen by a closed tube experiment, was expelled at much below a red heat.

The results obtained from ·6663 grams of the air-dry mineral are as follows:

	Loss.	Proportional parts using $\frac{1}{15}$ of total H_2O as unity.
Two days in dessicator	Nothing	
Nine hours at 150°	37·41	13·13
Seven hours at 200°	1·82	0·64
Eight hours at 250°	1·41	0·50
Five hours at 300°	1·05	0·37
Below redness	1·08	0·38
Total	42·77	

It is evident from the above that 13 molecules are to be regarded as water of crystallization and two molecules, sufficient to form four hydroxyls, as constitutional. The last two molecules are, moreover, expelled at four separate temperatures, indicating the existence of four hydroxyls which play different parts or have different positions in the molecular structure. It is evident also that the $CaSiO_3$, $CaCO_3$ and $CaSO_4$, together with the water, are united in some way into a complex molecule, and probably as suggested by Groth* in some way analogous to the combination of silicate and sulphate in the haüyne-nosean group of minerals or of silicate and carbonate in cancrinite. Regarding silica as the linking non-metallic element, the following constitution may be suggested as a probable one:



The above may also be expressed as $[(CaOH)CO_2]$ $[(CaOH)SO_3]$ $[CaOH]$ $HSiO_4$, 13 H_2O. The formula agrees in a very satisfactory manner with the results obtained in driving out the water, for it demands four independent and different hydroxyl molecules.

Formulæ may be written with four hydroxyls and with either carbon or sulphur as the linking element, but they do not seem to the authors so probable as the one given above.

The occurrence of thaumasite at Paterson is in the trap which has been quarried for road material. It is associated with heulandite, apophyllite, laumontite, pectolite, chabazite, scolecite and natrolite, all of which are found at the locality in beautiful crystals. Widman mentions the occurrence of apophyllite with the thaumasite at Kjölland. The thaumasite has crystallized later than the zeolites and occurs upon or surrounding them. A considerable quantity of it was found.

In closing the authors express their thanks to Messrs. Geo. L. English & Co. of New York for generously furnishing them with material for the investigation.

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Sheffield Scientific School, February, 1896.

* Tabellarische Uebersicht der Mineralien, p. 149, 1889.