II.—*A Chemical Examination of Greenland Telluric Iron.*

By Joh. Lorenzen.*

(Translated from Meddelelser fra Grónland. Heft 4. 1883.)

WHEN in 1870 Nordenskjöld had made the discovery at Blaafjeld (Ovifak) on the Isle of Disco of the remarkable large iron blocks, there soon, as will be remembered, arose a whole literature on the occurrence and origin of this iron. Although the Danish naturalists had, from the first raised a series of objections against the theory of the meteoric origin of these iron-blocks, the problem of their existence could not be satisfactorily solved without careful geological investigations having been first made into the nature of the whole of the Greenland basalt-formation. Such investigations having been made by Mr. K. J. V. Steenstrup, I was directed by the Danish Commission for the Geological and Geographical Survey of Greenland to make a chemical examination of the materials collected. The following is a report of the examination thus undertaken, which, however, was not confined to the rich collection brought home by Mr. Steenstrup, but has been extended to a number of specimens of iron preserved in the Museum of the Copenhagen University. These have been found in Greenland at different times since the beginning of this century, but only a few of them have been hitherto accurately described, although they may, most of them, have been mentioned, incidentally at least, in some work or another. With the specimens in question so many problems are connected, that I have thought it proper to confine —previously at least—the object of my examination to the two most interesting ones. The first question which arises is that of the native iron itself, and also to a certain extent that of the basaltic rock. The second question concerns the graphitic felspar, the "Anorthitfels" of Dr. Törnebohm,† which constantly occurs with the iron. I have not examined the pyrrhotite and the chlorophæite, these being of less interest. As long as the point of issue was the possibility of the iron being meteoric, the occurrence of the pyrrhotite was more important than it is now, especially because it was taken for Troilite, owing to an incomplete analysis made by

* Dr. Lorenzen died on the way to Greenland, the 5th May, 1884.

† Bihang t. Svenska Vet. Akad. Handl., Vol. 5, 1878, No. 10, p. 14.

Dr. Nauckhoff.* Now, however, as Mr. Steenstrup† and later on Prof. Lawrence Smith‡ have proved the accordance between the pyrrhotite of Blaafjeld and that of Igdlokunguak, and as the telluric origin of the iron has been indisputably established, this matter is placed more in the background.

Before proceeding to the detailed description of the iron, I shall make some remarks with regard to the manner in which the analyses have been made.

As a rule the iron was dissolved in hydrochloric acid, in some few cases in *aqua regia*. The solution evaporated, the dry residue was dissolved as usual by means of a little diluted hydrochloric acid. In the solution the copper was first determined; then the iron was separated from nickel and cobalt by ammonium carbonate after the method of Lippert, as given both in Rose's and in Fresenius's works on quantitative analysis. If only so much ammonium carbonate be added, that a little iron is still in the solution after precipitation, this method is very excellent. The small amount of iron remaining was precipitated by ammonia in excess and added to the first precipitate. This operation was repeated several times in order to extract all the nickel and cobalt, but experience shows that in most cases two precipitations, if well made, would have been sufficient. In the two first analyses the nickel and cobalt were weighed in the form of metals, in the others in the form of sulphates. When dissolved, the iron always left a residue, which naturally was a little attacked by the acid, and it must therefore be expected that a little alumina, iron-oxide, lime, magnesia and silica, perhaps also alkalies, would be found in the solution. As none of these substances has anything to do with the composition of the iron, I have not determined any of them but the silica and alumina. It also ought to be remembered, that the quantity in which they are present in the solution depends upon quite casual circumstances, such as this, whether a more or less diluted acid be used, &c. Moreover, it would have been very troublesome to determine the lime and the magnesia on account of the large amount of salts of ammonia which by applying the above method had been accumulated in the solution.

Phosphorus was searched for in all the analyses, by applying the method described in Fresenius's Quantitative Analysis, 6th edition, II. p. 434. As Dr. Törnebohm by means of a combined microscopical and chemical investigation has found Schreibersite in the Blaafjeld iron, I was rather as-

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* Bihang t. Svenska Vet. Akad. Handl. Vol. I. 1872, No. 6.

† Videnskabelige Meddelelser fra naturhistorisk Forening i Kjöbenhavn 1875, 284.

‡ Ann. de Chimie et de Physique, 5te série, t.XVI. 1879, pp. 452-505.

tonished at not being able to detect any trace of phosphorus in any one of the specimens analysed, except in the Niakornak iron, where its presence had already been stated by Forchhammer and Lawrence Smith. It ought, however, to be remembered, that the amount of the other constituents of the iron-pieces is somewhat varying. In searching for the phosphorus, as a rule, I used 5 to 6 grs. of the iron.

Sulphur was determined by dissolving the iron in *aqua regia*, and evaporating to dryness, whereupon the residue was dissolved in a little hydrochloric acid, and the sulphuric acid precipitated by barium-chloride.*

Carbon was determined by the method of Ullgren (described both in Fresenius and in Rose); the iron was dissolved in sulphate of copper, and the remaining carbon was oxidised by chromic and sulphuric acid, and weighed as carbonic acid.

Chlorine was not determined, although present in small quantities in all the iron specimens, as appears from the iron chloride oozing out on almost every piece of iron. But this examination would form a part of an investigation of all the soluble salts contained in the iron, which my time has not yet permitted me to undertake.

I have not examined iron from all the new localities, but only from those that are somewhat abundantly represented in the Copenhagen museum. The following account first describes the iron from the chief locality, Blaafjeld (Ovifak, or more correctly Uifak); then that found in three other localities on Disco island, viz. at two different places in the Mellemfjord on the west side—and at Asuk in the northern part of the island, which latter place has obtained a peculiar interest, as it was the first place after Blaafjeld where Mr. Steenstrup succeeded in finding iron *in situ*. Then follows the description of the loose blocks, all of which have, with perhaps one exception, been imbedded in the basalt; and of the remarkable iron taken from the Greenland grave at Ekaluit. To the examination of the last is added an analysis of Greenland wrought iron, viz. two knives, the material for which must have been taken from the basalt.

Lastly follows an examination of the *graphitic felspar*, taken from two of the many localities.

I. IRON IN SITU.

A. Blaafjeld. (Ovifak=Uifak.)

Under this heading I also include the loose blocks which have been found on the shore at "the iron locality," because they also have once been

* Rose. Handbuch d. Anal. Chemie. II. p. 563.

imbedded in the basalt. It is well known that investigations have been made with regard to this iron by many chemists, as Nordenskjöld, Nordström, Nauckhoff, Wöhler, Daubrée, and Lawrence Smith, all of whom have given their opinions on the now settled question of its telluric or cosmical origin.*

Several of these investigators have attempted to make out different types of iron, which at the first sight seems very natural, but further examination shows that nearly every new piece of iron may be taken for a new type. If the types which the different investigators have set up be compared, the identification of them also will be found a very troublesome work. Really all transitions may be found. As an instance of this, may be mentioned that metallic iron is found in the form of small grains imbedded in common dolerite, and that grains similar to these are also found imbedded in a soft green mass, which latter is found in some of the blocks lying on the shore. A fresh fracture of this rock affords an exceedingly beautiful aspect, when the silver-white shining iron grains are seen disseminated in the fine green ground-mass. This aspect, however, lasts only a short time; after a few minutes the grains become already somewhat dim, and after some days we see only a spotted grey-brown mass with a few metallic points. These latter are more durable; some fragments of the rock in question were kept in a closed glass for more than half a year, together with a small cup filled with concentrated sulphuric acid, and at the end of this time the metallic points still retained their original appearance. While in the cases just mentioned, the dolerite or the green ground-mass was absolutely predominant, we, on the other hand, find other specimens in which the iron and the basalt are almost equally developed, or where the iron is beginning to prevail. The analyses given under No. 8 were made on fragments taken from such a block. Before the block was broken to pieces, it looked very firm and strong, but nevertheless it was very easily crushed with the hammer. It appeared that the interior was composed of a soft mass, which when pulverised and sifted, might be separated tolerably well into grains of iron and a brown powder, which latter evidently owed its origin to decomposition. The grains of iron could not be further powdered, and were a little malleable. On the outside, the loose mass was encompassed by a firm crust, intermixed with basalt. I think that

* Since the above lines were written in Danish, a new paper by Nordenskjöld has appeared, wherein this matter is discussed from quite a new point of view, the correctness of which, however, the author cannot admit; but it would take too much space to enter on a further discussion of it here.

some of the bigger blocks are of this kind, as both Daubrée and Lawrence Smith state that the blocks examined by them when sawn through were found to consist of a firm crust around a loose interior. Further, a whole series of transitions are found between these blocks, and those specimens which consist almost entirely of metallic nickel-iron. Of these last No. 1 and partially No. 2 below are examples. It is true that such hard, firm and tough masses of iron present an appearance quite different from that of the grains that are found in the manner above described, disseminated in the basalt, or in the remarkable green ground-mass. But in fact a difference between the two is to be found only in the amount of the iron present. It appears as if the iron had originally been deposited at many points, and being still in a fluid state had in some places accumulated to form greater masses. It is an interesting fact that both malleable and cast iron has been produced; at Blaafjeld both forms occur, while at the other localities only the malleable iron is found. I have not analysed the Blaafjeld malleable iron, but Mr. L. Smith has made an analysis of the same,* the result of which agrees very well with one of the varieties examined below. No. 1 again, as well as several specimens that have on former occasions been examined by others, belongs to the form which may be considered as natural cast iron.

As is well known, there is still a peculiarity on which a distinction might be founded, I mean the aptitude so characteristic of many specimens of this iron to crumble when preserved in a museum, while it stands the open air much better. As a contrast to these might be set up some other specimens, for instance No. 1, and some parts of No. 2 below, which consist almost entirely of metallic iron, and may be preserved in a museum without the interior of the same being damaged. Further also, the grains mentioned above that are found imbedded in the basalt do not seem to lose any of their original fresh lustre.

No. 1.—A piece of iron of the size of a large fist, oblong, flat on one side, and round on the other side. Fracture granular, silver-white when quite fresh. The iron very hard and tough; cannot be crushed with a common hammer, but only with a steam hammer. Very difficult to bore even with the hardest tools. On the whole very pure, only in a few places enclosing some of the rock. No difference between the exterior and interior parts; the boring was done in the interior. The iron excellently durable. It had been lying for a long time on a flat roof exposed to rain and sunshine, and after having been broken to pieces, it has been

* l. c. p. 465.

kept in the dry air of the museum, without suffering any damage under these very different conditions.

The specific gravity of a small piece weighing 2·6185 grs. was 6·87 at 20° C. The chief analysis was made on 2·471 grs.

Results of the analysis :

Cu	0·16
Fe	91·71
Ni	1·74
Co	0·53
S	0·10
C	1·37
SiO_2	0·31
Al_2O_3	1·21
Insol. in HCl	2·39
	99·52

Phosphorus could not be traced in 6½ grs. of iron. The determination of carbon is the mean of two analyses, which gave 1·35 and 1·38 respectively.

No. 2.—A flat slab, which when broken to pieces showed in some parts a similar green mass to that mentioned above, but in other places pure, silver-white iron, with foliated fracture, and fine cleavage faces. This piece had formerly resisted the influence of the weather in the open air very well, but is now partially altered on account of its being preserved in the museum. The parts consisting of pure iron are those best able to resist, and these show on fresh fractures the fine silver-white lustre.

Composition of the iron :

Cu	0·16
Fe	91·17
Ni	1·82
Co	0·51
S	0·78
C	1·70
SiO_2	0·46
Al_2O_3	2·12
Insol. in HCl	0·77
	99·49

The chief analysis was made on 2·716 grs. Phosphorus not traced in 5½ grs. The determination of carbon is the mean of two, giving 1·62 and 1·78 $_{0}/^{0}$ respectively. The great percentage of sulphur is striking as well as the large amount of dissolved alumina, while the undissolved residue is insignificant. This shows that the rock had been easily decomposed by the acids used.

No. 3.—The worn specimen mentioned above. One analysis was made on the altered interior (I.), another on the fresh exterior parts (II.). In both cases the metallic parts were tolerably well separated from the non-metallic ones. This was best effected by pulverising and sifting, on the altered interior parts. It was not possible to undertake a further separation by a magnet. To separate oxide of iron from metallic iron in the analysis seemed of no use, as the alteration had only reached a certain point, and an analysis made to-day might have given quite another result than one made a year afterwards. Because of the method also by which the iron grains had been isolated, the proportion found would have been quite arbitrary. Thus part of the metallic iron stated in the analysis must be taken to have been in reality in the state of oxide.

Composition of the iron:

	I.	II.
Cu	0·19	0·28
Fe	82·02	59·77
Ni	1·39	1·60
Co	0·76	0.39
S	0·08	?
C	1·27	1·20
SiO_2	0·59	0·39
Al_2O_3	1·08	3·79
Insol. in HCl	8·03	22·23

The chief analysis was made on 2·539 grs. (I.), and 2·5705 grs. (II.). The determination of carbon is the mean of two, giving 1·24 and 1·31 respectively. In the same analysis phosphorus was not traced in 5½ grs. In the second analysis made, phosphorus and sulphur were not searched for. As I obtained a much larger residue than I had expected in II., I determined the amount of silica therein, which was found to be 59·61 per cent. When the purity of the silica was tested, it appeared that it contained a small quantity of other elements. When it is taken into consideration that part of the alumina had been dissolved, it appears that the rock itself must have been considerably attacked by the acid, and the high percentage of silica cannot then be cited as an objection to the conjecture that the rock is a common basalt.

B. The Mellemfjord.

A. The Interior Parts of the Fjord.

I have examined the iron as well as the basalt from this new locality. This Iron like that next to be described is malleable, and all these specimens of iron present great similarity to each other. It is found in round and oblong grains usually of the size of a pea or a little larger. The larger grains often consist of smaller ones, which are welded together, as is very easily detected by hammering the grains flat. When the basalt is hammered, two or more pieces may often be kept together by the tough flexible iron. The iron is silver-white, very soft, and may in consequence of its extraordinary malleability be hammered into very thin plates, which very easily preserve impressions of the hammer and anvil. When hammering the grains I always saw small pieces of basalt falling out, which had been imbedded between the grains or in their cavities. The specific gravity therefore ought only to be determined on a flat and well-hammered plate; the grain before being hammered will always, even if the surface be filed quite shining, give too low a specific gravity. Mr. Steenstrup and I made the following experiments: a grain weighing 1·0045 showed a specific gravity 5·84, another one weighing 0·8885 gave 7·80. The first when hammered lost a considerable quantity of basalt, and this explained the low specific gravity. When the other grain was hammered, its specific gravity rose to 7·92. A third specimen equally hammered weighing 1·4955 grs. showed a specific gravity of 7·48. The high specific gravity depends upon the small quantity of the carbon contained therein, which circumstance also accounts for the iron being so malleable; and upon the small contents of nickel and cobalt.

I searched for phosphorus and sulphur in the same analysis in 4 grs. by the method given in Rose's Handbuch and Anal. Chemie. II. p. 503, but I was not able to detect any phosphorus. The chief analysis was made on 2·164 grs. Results of the analysis:

Cu	0·33
Fe	93·89
Ni	2·55
Co	0·54
S	0·20
C	0·28
SiO_2	0·46
Insol. in HCl.	1·48
	99·73

The Basalt.—From this place Mr. Steenstrup brought home iron that had been taken partly *in situ*, partly from loose blocks. The basalt found *in situ* is compact, and reminds one very much of the basalt of Asuk or that of the Jernpynt in the Mellemfjord. The loose blocks consist of medium grained dolerite. It is very interesting, that although we may find iron-grains of the size of a pea in the compact basalt, we also find much smaller grains, but in the dolerite large iron-grains only are found.* As the latter afforded more facility *for separating the iron from the basalt*, I chose the dolerite for the analysis, the results of which follow :—

SiO_2	53·01
Al_2O_3	15·85
FeO	11·53
CaO	8·72
MgO	7·51
Na_2O	4·49
	101·11

Some traces of manganous oxide and potash. The iron is given only as ferrous oxide, the two oxides not having been separated. Thus we have here a basalt with a percentage of silica a little higher than usual; but, apart from this, it does not present any difference from common basalt.

B. The Jernpynt in the Mellemfjord.

This occurrence shows a great resemblance with that at Asuk, as did also that last mentioned from the interior parts of the fjord. The basalt here is sometimes spotted in a similar way to that of Asuk, but it may also occur in the form of a fine-grained dolerite. What has been said on the manner in which the iron-grains are imbedded in the basalt found in the interior parts of the fjord, holds good here also. Still the iron is not so white and not quite so soft and malleable, on account of the larger amount of carbon contained therein. For the same reason, perhaps, the specific gravity also is a little lower. In one specimen of hammered iron weighing 0·9625 grs. I found the specific gravity 6·90 at 14°C., in another, weighing 1 gr., 7·57 at 14° C.

Results of the analysis :

Cu	0·48
Fe	92·41
Carried forward ...	92·89

* For this observation I am indebted to Mr. Steenstrup.

Brought forward	92·89
Ni	0·45
Co	0·18
S	Trace.
C	0·87
SiO_2	0·90
Al_2O_3	0·60
Insol. in HCl.	4·57
	100·46

Phosphorus and sulphur were searched for in the same manner as in the case of the iron from the interior parts of the fjord. The chief analysis was made on 1·674 grs. The determination of carbon is the mean of two giving 1·03 and 0·72 per cent. respectively. The materials were here separately selected for each determination of carbon. It is interesting to see how, with regard to the percentage of nickel, this iron makes a transition to the Asuk iron.

C. Asuk.

This was the first place after Blaafjeld where Mr. Steenstrup found iron *in situ*, and the locality has a peculiar interest, as it appears herefrom to be the most probable theory that all the "basaltic" iron had a telluric origin.* The iron found there was disseminated throughout the basalt in the shape of very fine specks, which could only be isolated by means of a magnet, after a very careful pulverisation. In the specimens, brought home later on, there are bigger grains, some of which attain the size of a hazel-nut. Yet most of them are rather small, smaller than those from the other localities, and if a biggish one is hammered one feels somewhat disappointed, seeing that a large part of it is the basalt, lying between iron grains, while the latter look as if they were welded together. The iron is silver-white, very soft and malleable; some hammered grains weighing 1·056 grs. afforded the specific gravity 7·26 at 12° C.

When crushing the basalt I collected some bigger and smaller grains, which were used for the analysis. As it was difficult to get much material, I did not determine the sulphur. The iron was dissolved in *aqua regia*, and phosphorus was searched for in this solution, but none was found.

* l. c., 1875, p. 296.

Results of the analysis:

Cu	0·14
Fe	95·15
Ni	0·84
Co	0·06
C	0·96
SiO_2	0·68
Al_2O_3...	0·51
Insol.	1·90
	99·74

Of all the iron found *in situ* or in loose blocks, this shows the lowest percentage of nickel and cobalt. Yet one of the Greenland knives mentioned below contains a still less amount than this. And at any rate we see that we ought to be very cautious in using the percentage of nickel and cobalt for determining whether loose blocks or Greenland iron tools are of "basaltic" origin or not; for if the proportion can be so low as we have here, we fail to see why it might not be still lower, or why nickel and cobalt might not perhaps be quite absent.

I have not examined the iron taken *in situ* from other localities, the material being so scanty that nothing could be spared for analyses.

II. LOOSE BLOCKS.

A. Arveprindsens Eiland.*

While the pieces of iron brought home in the beginning of this century by Ross and Sabine have been often mentioned, it has been less generally known that Giesecké also about the same time found a piece of iron much farther to the south, in Greenland proper. As he does not mention it in his Diary, we only have a slight evidence of this fact in the Catalogue of his collection; where this specimen, which is now in the Copenhagen museum, is said to have been found in a bog on Arveprindsens Eiland. The specimen has a peculiar appearance, showing on its surface impressions such as might be made with fingers in a soft mass. The weight is 410 grs. From this piece two small pieces were sawn off, one for the chemical analysis, and another for polishing and etching. The latter did not give the usual Widmanstätten figures, but only indistinct, shining, silver-white figures in the greyish-white ground-mass.

* Means, Heir Apparent Island.

The iron was very tough and hard. An exterior crust of malleable iron was distinguished from the interior part, which latter the hammer only crushed without beating it flat. On account of the failure of one analysis, the carbon was determined from the interior, while the other elements were determined on small hammered plates.

The chief analysis was made on 2·850 grs.

Results :

Cu	0·06
Fe	95·67
Co	trace?
S	0·09
C	1·94
SiO_2	1·40
Insol.	1·09
	100·25

I obtained a very small precipitate in the filtrate from the iron when sulphuretted hydrogen had been added and the solution had been neutralised. As the quantity was too small to be weighed, it was only examined before the blow-pipe with salt of phosphorus. The bead was blue as well in the interior as in the exterior part of the flame, and thus cobalt ought to be present. Whence has this come? It has been proved that extraordinary small quantities of cobalt and nickel may be present in many sorts of iron used for practical purposes,* and a European origin might therefore be suspected in the case of this iron. But the considerations set forth above in mentioning the Asuk iron, show that a Greenland and basaltic origin is also possible.

If a piece of rock had been adhering to the iron the question would easily have been solved, but I have not been able to find any.

B. Niakornak.

Of all loose blocks consisting of so-called "meteoric iron," a block from this place which is now in the Copenhagen museum is the best known, as it has been examined both by Forchhammer† and by Lawrence Smith.‡ The Copenhagen museum received it from Dr. Rink, who on his travels in North Greenland, 1848-50, got it from a Greenlander in an Esquimaux

* Weiske. Ueber den Kobalt u. Nickelgehalt des Eisens. (Journ. f. praktische Chemie. 1866, p. 479.

† Oversigt over det kgl. danske Videnskabernes Selskabs Forhandlinger, 1854, p. 1.

‡ l. c. p. 489.

hut between Jakobshavn and Ritenbenk. This man had found it near the shore on a plain covered with pebbles, through which the Anontok river discharges itself into the sea. Climatic difficulties, viz. snow in winter and floods in summer, prevented Dr. Rink from more closely exploring this plain.

Dr. Rink found the specific gravity of the whole piece=7·00, and that of some small fragments=7·02. Forchhammer found also for some small fragments, Sp. gr.=7·073 at 15° C. Lawrence Smith found for the pulverised iron 7·60, and an experiment made on a fragment weighing 2·7875 grs. afforded me 7·29.

The iron is very hard, shows granular fracture and sometimes small cleavage faces. When etched it shows small irregular Widmanstätten figures. Original weight 10½ kilogram. The analyses of Forchhammer (II.) and Lawrence Smith (III.) are given for use of comparison with mine (I.).

	I.	II.	III.
Cu	0·16	0·45	0·18
Fe	92·46	93·39	92·45
Ni	1·92	1·56	2·88
Co	0·93	0.25	0·43
P*	0·07	0·18	0·24
S	0·59	0 67	1·25
C	3·11	1·69	1·74
SiO_2	0·24	0·38	1·31
Insol.	1·09	—	—
	100·57	98·57	100·48

It will be seen that the analyses do not fully agree with each other, the reason of which is, I presume, that the iron is not quite homogeneous in all its parts. The same thing may be said for the residue; it is also shown by the varying specific gravity. The determination of carbon is a mean of two, giving 3·02 and 3·20 per cent. respectively. The result of two other experiments, when the carbon was burnt in oxygen, was a little lower, viz, 2·64 and 2·83 per cent. Among the specimens from Blaafjeld similar hard varieties rich in carbon are found, and as it cannot be doubted that the iron has been once imbedded in basalt, it is very possible that it may have been taken by the Greenlanders from Blaafjeld and have been brought by them to this spot. We notice here also on fresh fractures the usual exudations of chloride of iron.

* I am indebted to the kindness of Mr. O. Christensen for the determination of phosphorus in my analysis of this specimen.

Forchhammer mentions "that in one place traces were seen of an earthy mineral, but it could not be determined whether it originated from the trap-pebbles of the plain and had been cemented to the iron by rust, or whether it ought to be considered as the remains of a stony mass which had once surrounded the iron." Perhaps there was not enough for an analysis, and microscopical investigation was not at that time sufficiently advanced to decide such a question. Even now I found a trace of a crystalline mass, but on an attempt to grind it, the whole was crushed to dust. Probably it was a bit of basalt.

C. Fortune Bay.

In 1852 a block weighing 11844 grs. was found at Fortune Bay on Disco by the physician Rudolph, and sent to the Copenhagen Museum. Forchhammer has only given two small communications about it, without giving an analysis. He promised a further communication, but must have been hindered from fulfilling this promise, as no such account has ever appeared.

Originally it was very difficult to sever a piece from the whole block, but the smaller pieces themselves are now easily crushed under the hammer; by crushing them we get partly a coarser powder, consisting of small angular fragments of a colour like that of pyrrhotine, and partly of a finer and more brittle powder. Still the iron has nothing to do with pyrrhotine; it contains only a very insignificant amount of sulphur, and gives, when dissolved in hydrochloric acid, only a very slight odour of sulphuretted hydrogen. Polishing and etching afford some indistinct figures.

The chief analysis was made on 2·4005 grs. Phosphorus not traced in 6½ grs. Specific gravity determined on a fragment weighing 5·6054 grs. and found to be 7·19 at 16½° C. The determination of carbon is a mean of two giving 2·38 and 2·41 per cent. respectively. On fresh fractures the usual exudation of iron chloride was remarked.

Results of the analysis:

Cu	0·20
Fe	92·68
Ni	2·54
Co	0.58
S	0·01
C	2·40
SiO_2	0·31
Insol.	0·08
	98·80

The analyses show a perfect conformity between the Niakornak and the Fortune Bay iron. As to the latter, the locality itself on the Disco coast, not far from Blaafjeld, makes it highly probable that the iron originated from this locality.

No fragments of adhering basalt could be detected.

D. FISKERNÆS.

While the Niakornak, Fortune Bay and Jakobshavn* iron, perhaps also Giesecké's iron from Arveprindsens Eiland, are very naturally grouped around the basalt formation of North Greenland, this occurrence at first sight seems somewhat more inexplicable, the locality being more than 700 miles distant from the basalt. Our museum received it in 1859 from Dr. Rink, who had obtained it from Mr. Matzfeldt. It has been mentioned, but not closely examined by Forchhammer; and yet this iron, which is very similar to that found at Ekaluit, is undoubtedly the most interesting of all the loose blocks. Forchhammer himself makes the remark, that several circumstances make its meteoric origin very uncertain. The iron in question now consists of two small fragments, weighing 153 grs. Really it is a dolerite, through which the metallic iron ramifies in such a manner, that if we grind a plate of it we see the dolerite and the iron alternating with each other. I therefore give an analysis of both below.

The iron is very malleable, whereby it is distinguished from the other loose blocks, except the outer parts of Giesecké's iron. The specific gravity of some small hammered plates, weighing together 0·960 gr., was 7·06. In the chief analysis, which was undertaken upon 1·962 grs., the iron was dissolved in *aqua regia*, and phosphorus could not be detected in this solution. I did not search for sulphur, in order that I might not use too much of the iron. Results of the analysis:

Cu	0·36
Fe	92·23
Ni	2·73
Co	0·84
C	0·20
SiO_2	0·64
Al_2O_3	0·64
Insol.	1·99
	99·63

* On Nordenskjöld's Greenland expedition 1870, Dr. Oberg received this specimen from Dr. Pfaff in Jakobshavn. (Svenska Vetenskaps Akademiens Förhandlingar, 1870, p. 1069.)

The Dolerite.—Mr. Steenstrup has kindly communicated to me the following results of a microscopical examination : "In a section of eighteen square millimetres of the rock accompanying the Fiskernæs iron, I saw a fine grained ground-mass nearly without 'basis,' consisting of small crystals of a triclinic felspar, surrounded by rounded grains of pyroxene, olivine, and ramified particles of magnetite and titanic iron. The mean size of these small crystals is up to 0·3 mm. Seven larger crystals of a triclinic felspar up to 1·5 mm. in length, are disseminated in the ground-mass, the small crystals of which have been arranged around the larger ones. The whole section as well as the single small crystals appear very fresh, and the rock is not to be distinguished from a common coarse-grained basalt from North Greenland, whence it probably originates."

The analysis agrees with the microscopical examination. This was made only by decomposition with carbonate of soda, so that the alkalies were not determined :—

SiO_2	50·64
Al_2O_3	15·98
FeO	14·92
CaO	9·39
MgO	5·14

It will be seen that the composition is also that of a common basalt, and after all there can be no doubt as to the original locality of the iron. It is easy to understand why it should be carried so far off when we remember that it is malleable. Now that Steenstrup has found iron in a grave in Greenland, we know how much the Greenlanders value this metal, and can understand how such a piece might be carried so far by the hand of man.

E. Ekaluit.

It has long been known by the discoveries of Ross and Sabine that the Greenlanders possessed tools, especially knives, of hammered iron, but it is only by the recent investigations of Steenstrup that it has been ascertained where the natives have obtained this iron, for in a Greenland grave at Ekaluit in the Umanakfjord, he found nine pieces of basalt, wherein were contained grains of metallic iron. Really no difference could be detected between the manner in which the iron is imbedded in the basalt and the way in which the iron is found *in situ* in other places.

The analysis was made on 1·562 grs. On account of the small quantity of material, phosphorus, sulphur, and carbon, were not searched for. A small amount of the latter element must be present, as I remarked a faint evolution of carburetted hydrogen, when dissolving the iron in hydrochloric acid.

Results of the analysis :

Cu	0·23
Fe	94·11
Ni	2·85
Co	1·07
Insol.	0·61
	98·87

The iron is malleable, and the grains may easily be hammered out to small plates about half an inch in diameter. Prof. Japetus Steenstrup some years ago described some Greenland knives,* the edge of which consisted of a row of such small iron plates. They were placed in a groove in a piece of bone, the one end of the latter being used as a handle. Prof. Johnstrup found in one of the small plates as much as three per cent. of nickel. We now plainly perceive the succession; first the iron *in situ*; then in smaller detached pieces of basalt, which the Greenlanders put in the graves with the dead,—a distinct proof of the value attributed by them to these small pieces of iron;—and finally, we see the tool itself with the wrought-iron: and the way of working it was simply by hammering it flat.

F. Greenland Knives.

The knives here examined are of another type than those above mentioned, and far more similar to knives of European workmanship. A largish piece of iron is hammered out to a common knife blade, and fitted into a bone handle. Evidently the Greenlanders must have had larger grains in this case than in the case of the knife of the first type; and as it presented a great deal of interest to know whether Greenland malleable iron of such a size might really be procured, I gladly complied with a request of Prof. Japetus Steenstrup, to make these knives also the object of a chemical examination, the more so as I obtained thereby a very interesting addition to my materials.

The first knife had been found on "Hundeeiland" (Dog Island), between Disco and Egedesminde; the other one at Sermermiut, close to Jakobshavn. Only copper, nickel and cobalt were determined.

* Japetus Steenstrup, Sur l'emploi du fer météorique par les Esquimaux de Greenland. (Compte-rendu du congrès international d'anthropol. et d'archiol. préhist. Bruxelles, 1872.)

Results:

	I.	II.
Cu	0.18	Trace.
Ni	0·23 (Ni and Co together)	7·76
Co		0·56

Both knives were a little more than two inches in length, and consisted of silver-white iron, upon which an etching had been made before I received them, and had produced fine, winding, elevated lines. The second knife (II.) was in some places covered by a wax-like, greenish mass, the colour of which undoubtedly was due to oxidised nickel. For the analysis 1·139 grs. were used in I., in II. 2·949 grs. The whole knife I. weighed 3·1 grs., and the whole knife II. 6·1 grs. In I. was found a distinct trace of cobalt together with a predominant amount of nickel.

It was the more interesting to examine these two pieces of iron, as I thereby had the limits for the percentages of nickel extended. In I. we find the whole percentage of nickel and cobalt 0·23—less than in the iron from Asuk, where it reached 0·40 per cent. This is thus the smallest amount found, if Giesecké's iron is excepted. In II. the joint amount of nickel and cobalt was 8·32, a figure that surpasses by one per cent. the highest percentage hitherto found, viz. 6·50 per cent. Ni and 0·79 per cent. Co, the amount found by L. Smith in a piece of iron from Blaafjeld.

I first examined the knife I., and the small percentage of nickel found therein naturally raised the question whether this iron might really originate from the basalt, although the amount of nickel found in artificially produced iron is exceedingly insignificant, even as compared herewith.* It was very fortunate that in the knife II. such a large amount of nickel was found, as the question of the origin of the iron of this knife is thereby indisputably decided.

SUMMARY OF ANALYSES OF THE GREENLAND TELLURIC IRON.

	Blaafjeld (Ovifak), Disco.				Mellemfjord, Disco.		Asuk, Disco.
Cu	0·16	0·16	0·19	0·23	0·33	0·48	0·14
Fe	91·71	91·17	82·02	59·77	93·89	92·41	95·15
Ni	1·74	1·82	1·39	1·60	2·55	0·45	0·34
Co	0·53	0·51	0·76	0·39	0·54	0·18	0·06
S	0·10	0·78	0·08	?	0·20	trace	?
C	1·37	1·70	1·27	1·20	0·28	0·87	0·96
SiO_2	0·31	0·46	0·59	0·39	0·46	0·90	0·68
Al_2O_3	1·21	2·12	1·08	3·79	—	0·60	0·51
Insol.	2·39	0·77	8·03	22·23	1·48	4·57	1·90

* Weiske, l. c.

	Arvepr. Eiland.	Niakornak.* Jakobsh. D.	Fortune Bay, Disco.	Fiskernæs Godthaab, D.	Ekaluit, Nugssuak.	Greenland Knives.	
Cu	0·06	0·16	0·20	0·36	0·23	0·18	trace
Fe	95·67	92·46	92·68	92·23	94·11	?	?
Ni	—	1·92	2·54	2·73	2·85	0·23 }	7·76
Co	trace?	0·93	0·58	0·84	1·07		0·56
S	0·09	0·59	0·01	—	?	?	?
C	1·94	3·11	2·40	0·20	?	?	?
SiO_2 ..	1·40	0·24	0·31	0·64	—	?	?
Al_2O_3..	—	—	—	0·64	—	?	?
Insol.	1·09	1·09	0·08	1·99	0·61	?	?

* Contains also 0·07 per cent. of phosphorus. D means district.

It is remarkable that the amount of copper in the second analysis was very small, scarcely to be perceived, but still more astonishing is it that the percentage of cobalt does not increase in the same proportion as the nickel. Somewhat similar is the case in the analysis of L. Smith mentioned above.

III. GRAPHITIC FELSPAR.

When some years ago Dr. Nauckhoff made his careful analyses of the iron and rocks from Blaafjeld, he unfortunately chose a series of specimens which were *so faintly distinguished from each other*, that it is nearly impossible to get a clear view of the subject from them. If we compare the analyses, we find between several of them, for instance between Nos. 7, 8, 9, and 10, some resemblance as well in the mass-analysis as in the mineralogical composition. A low percentage of silica, and a high one of alumina, is characteristic in these four specimens; as also the presence of a red mineral, which Nauckhoff believes is spinel and partially also graphite. Nauckhoff has not taken much notice of the graphite, but L. Smith specially examined "la dolérite graphitique," as he calls it.* One point at that time was whether the rock at Blaafjeld did or did not contain anorthite, which was denied both by Steenstrup and L. Smith. Dr. Törnebohm, however, who made his examination nearly at the same time as L. Smith, subjected the specimens formerly analysed by Nauckhoff to a microscopic examination, and singled out from the rest, under the name of "anorthitfels," some parts of the rock which appear to belong to the very same variety that L. Smith examined chemically as well as optically without finding any anorthite. It is the merit of Dr. Törnebohm to have first called our attention to this point, but, as the results of these investigations are so different, I thought that the examination ought to be taken up again.

* l. c pp. 481, &c.

Another motive for doing this was that this peculiar rock, which is imbedded as smaller inclusions in the basalt and dolerite proper, is by no means found at Blaafjeld alone, but accompanies the iron in other places, it must necessarily be inferred that there is some connection between them. In this rock are also found some reddish grains—the red mineral mentioned above—which have also given rise to different interpretations; while Nauckhoff correctly regards them as spinel, Smith, after examining them chemically and optically, believes them to be corundum. In the specimens examined by me, the felspar always exhibited excellently reflecting cleavage-faces, even when very much graphite was disseminated in it. The latter may be intermingled in smaller or larger quantities; sometimes it forms so large a proportion of the rock, that the same is more like an impure graphite than a graphitic felspar. I have made a closer examination of specimens of this rock from Blaafjeld as well as from Nuk in the Waigat. The reasons that I have examined the felspar from Nuk and not that taken from the other localities whence the iron also was examined will be explained below.

Steenstrup and L. Smith, who have denied the presence of anorthite at Blaafjeld, have described the felspar as labradorite. Both of them have treated sections of the rock with hydrochloric acid without any effect; L. Smith has further treated the pulverised rock with hydrochloric acid, without being able to detect lime in the solution; which undoubtedly would have been the case if he had had to do with anorthite. The explanation may be that these experiments have been made on the basalt proper, not on the graphitic felspar (anorthitfels), the question then being whether the rock around the iron blocks was eucrite or basalt.

I therefore tried to treat a little more than three grains of the graphitic felspar with cold hydrochloric acid of twenty-four per cent. for forty-eight hours, the solution being occasionally stirred up. Hereby 4·2 per cent. of lime and a little magnesia were dissolved, besides iron oxides and alumina. I therefore agree with Dr. Törnebohm that this triclinic felspar, which is so easily decomposed by hydr hloric acid, is really anorthite. Mr. Steenstrup has ground a section of the same specimen that was used for the analysis. This section was put in hydrochloric acid in a test-tube, one end of which had been drawn out flat in such a manner that the glass might be laid under the microscope, and the progress of the decomposition of the felspar be observed. The section was broken by degrees into smaller pieces, but it might be observed in every piece how veins of an isotropic matter were formed, and how these veins were gradually widened, the unaffected parts getting smaller. That this isotropic matter should only be amorphous silica seemed rather doubtful, as the section must, if this be the case, have been broken at each of the veins.

I am now coming to the red grains, the spinels of Nauckhoff and Törnebohm, the corundum of L. Smith; although the latter investigator, on account of "chemical criterions," also deems the presence of spinel to be possible. Really the chemical as well as the optical criterions speak in favour of spinel being present, and it seems strange that it has escaped the attention of the renowned American chemist, that under the microscope the reddish grains appear dark in all positions between crossed Nicols. This seemed to make it certain that the mineral was crystallising in the tesseral system, not hexagonally. I ought yet to add, that Prof. L. Smith himself remarks that the mineral probably is corundum, "quoique les observations optiques ne soient pas certains."

For isolating the spinel he used two different methods. On the first occasion the graphite was burnt in a current of oxygen, and the heated residue was fused with alkaline carbonates to which a little caustic soda was added. The fused mass was treated with water and hydrochloric acid; on the undissolved residue the fusing and treating with acid was repeated. A small portion still remained, which was only decomposed by bisulphate of potash. It had the following composition:

SiO_2	0·95
Al_2O_3	92·02
Fe_2O_3	3·25
MgO	2·68
	98·90

The second time, the rock was first treated with hydrofluoric acid, then the graphite was burnt in oxygen—a very long process—then the residue was fused with carbonate of soda, and in the residue after all these operations 98 per cent. of alumina were found. Already the difference in the percentage of alumina is striking. I think that the amount of magnesia found in the first analysis are the chemical indications, from which L. Smith has drawn his conclusion as to the presence of spinel.

It at once appeared rather doubtful to me whether the spinel, if we really had to do with spinel, might pass uninjured through these violent processes, and therefore I tried to isolate it in another manner, in doing which I succeeded very well.

If the rock in a coarsely pulverised state is put gradually in small quantities into a mixture of saltpetre and carbonate of soda, the latter being kept fused at a very high temperature, the graphite will be oxidised and the silicates will be decomposed in a very short time. After cooling the mass is thoroughly well elutriated. After elutriation with hot water, the residue was treated several times with concentrated hydrochloric acid, and after that the spinel was found quite isolated. 12 grs. of the rock afforded when treated in this way 1 gr. spinel in the form of hard dark grains, which when seen by transmitted light appear red. When laid in Canada balsam and viewed under the microscope, they also here appear red and quite fresh, and there is on the whole no difference whatever to be found between these and other grains still imbedded in the rock. The hardness surpasses that of quartz and the specific gravity is 3·45.

For the analysis the mineral was pulverised in a steel mortar. The metallic iron, which by this process had been mixed up with the mineral, was dissolved by hydrochloric acid. 0·2995 gr. then afforded the following composition :—

SiO_2	0·20
Al_2O_3 (Fe_2O_3)	80·60
Cr_2O_3	1·24
MgO	19·11
	101·15

Unfortunately I lost part of the solution in which the iron was to be determined volumetrically, but that some amount was present might safely be assumed. In the analysis the iron is given in the form of sesquioxide together with alumina, but part of it must be protoxide, which would explain the excess. In a previous analysis, made on 0·4805 gr., I found 19·57 per cent. magnesia. If then 19 per cent. MgO be added to some amount of iron oxides, we have between 20 and 30 per cent. of strong bases combined with 70 per cent. alumina, and 1 per cent. chromium oxide, wherefore I do not hesitate to pronounce the mineral to be a real *chrome-coloured spinel.*

I have further analysed *the rock itself*, the graphite being burnt in a current of oxygen and determined as carbonic acid. Results :

Graphite	6·78
Residue	93·22
	100·00

The residue was really smaller, and the loss by heat considerably larger, viz. 10·28 per cent., thus something must have been lost besides the carbon. The residue was decomposed by carbonate of soda, and showed the following composition :

SiO_2	39.75
Al_2O_3...	26·08
Cr_2O_3	1·23
Fe_2O_3	12·33
CaO	12·01
MgO	4·51

I did not succeed here in isolating the spinel, which must have been more easily decomposable, in consequence of its having been kept for 20 hours heated in oxygen, a proceeding which was necessary to have the graphite burnt. The amount of magnesia and chromium-oxide may be derived partially from the spinel. Considering that neither the graphite nor any of the other constituents of this rock perhaps ever occur in the same relative proportion (L. Smith for instance found 17·50 per cent. graphite), it is not to be expected that analyses of different, nay even of the same specimens, will give the same results. It may then be of some interest to compare the analyses which have been made wholly or partially on this rock, and therefore I communicate below an abstract of the analyses of Nauckhoff, nos. 7 (I.), 10 (II.), 9 (III.), 8 (IV.) placed together with that of L. Smith and my own. Only it ought to be remembered that the graphite in the two latter analyses had been removed beforehand.

	Nauckhoff.				Smith.	Lorenzen.
	I.	II.	III.	IV.		
SiO_2	34·72	37·92	44·94	36·59	34·16	39·75
Al_2O_3	31·83	32·36	22·20	19·18	33·85	26·08
Cr_2O_3	—	0·08	—	—	—	1·23
Fe_2O_3	4·88	—	—	—	—	12·33
FeO	5·53	4·02	9·45	14·85	17·00	—
CaO	10·19	11·57	11·01	8·73	8·80	12·01
MgO	9·35	2·86	4·98	7·24	4·23	4·51
C	0·53	6·90	3·35	2·55		

Between the results, inconsistent as they are in other respects, there are yet some accordances, as in the low amount of silica and the high percentage of alumina and partially also of lime.

With a view to ascertaining whether the results here found agreed with what might be observed at the other iron localities, I also examined the felspar from Nuk in the Waigat. Mr. Steenstrup had observed that in some places the red spinels occurred along with a wine-yellow mineral, most abundant at Nuk, although it seemed doubtful whether even from this locality sufficient material for an analysis might be obtained. This was an inducement to examine this felspar, although I had not analysed the iron from this place. For isolating the minerals, I used the method described above. 80 gr. were employed, but the two minerals occurring only in very small quantities the difficulties of the operation were very much augmented, and I obtained so small an amount, that it did not suffice for an analysis. When put in Canada balsam and tried in polarised light, the yellow grains proved to be anisotropic, and therefore could not be spinel. They appeared fully fresh, but whether they be quartz or another mineral I am not able to decide.

In order to ascertain whether the felspar in this rock, which did not contain as much graphite as the Blaafjeld specimens, was also anorthite, I treated 3·044 grs. with cold hydrochloric acid of 24 per cent. during 48 hours. A large amount of iron oxides, a little magnesia, and 0·043 gr. or 1·41 per cent. lime were dissolved. Though not so much lime by far is dissolved here as in the Blaafjeld specimens, yet I think it is sufficient to warrant the belief that this felspar is also anorthite, considering the likeness existing throughout between the felspar in question and that of Blaafjeld.

It has been necessary to enter into these details respecting the composition of this graphitic felspar, on account of the close connection existing between this peculiar and interesting rock and the iron. It seems certain that it is not possible to account for the origin of the iron without also explaining whence the rock therewith connected has come. I do not think that, after the recent discoveries of Mr. Steenstrup, the meteoric origin of the iron will be seriously asserted. Thus two alternatives are left, viz. that the iron may have either been carried up with the basalt, when in a fluid state it broke forth from the interior of the earth, or, that it may have been originated, during or after the eruption, through a reduction of the ferruginous minerals contained in the basalt, especially the magnetite and olivine. If we accept the theory put forth by Dr. Törnebohm, which seems a very plausible one, that the graphitic felspar has originated from a marl or slate rich in lime, alumina, and carbon, and if we remember that the Greenland basalt has in many places broken forth through coal-beds, the conjecture is probable that pieces of such beds of coal and slate were broken off, and as far as the inorganic constituents were concerned, were remelted, whereby oxides of iron were reduced to metal. On account of some very interesting microscopical examinations, Dr. Törnebohm holds it rather probable that the iron may have been reduced after the congealing of the basalt by means of bituminous matter accumulated in vesicles or cavities. To me it seems more natural to assume that the iron has been produced by the dry way, in a manner similar to that by which we make iron technically. Perhaps we may expect important contributions towards a solution of the problem from a closer microscopical examination of the way in which the iron occurs in the other localities.

As I had thought it possible that the basalt of Blaafjeld, where such large blocks of iron had been formed, might contain somewhat less of combined iron, I made a series of experiments with the view to ascertain whether this might be the case. I took fragments of basalt adhering to the blocks themselves, examined them by the lens to see if they were partly of pyrrhotite and iron; decomposed them with hydrofluoric acid, reduced with zinc and determined the iron volumetrically. Although these experiments do not supply any evidence bearing upon the above view, yet I think it right to give an account of them. It appears that all the specimens tested contained the same quantity of iron as is usually found in basalt. Although there is a little difference i- a few of them, it is too slight to decide anything. The whole quantity is given as protoxide. The results were:

I.	... ...	12·95 per cent. FeO.
II.	... ...	12·34 ,,
III.	... ...	13·63 ,,
IV.	... ...	14·65 ,,
V.	... ...	14·86 ,,
VI.	... ...	11·23 ,,
VII.	... ...	14·90 ,,

I. is compact basalt. The specimen had been surrounded with iron on all sides.

II., III., IV. and V. are all taken from basalt adhering to different pieces of iron.

VI. was taken from a large piece of fine-grained dolerite, which had been in immediate contact with the iron.

VII. finally was taken *in situ* on the shore 50 feet west of the iron.

It may be added that, although it would have been a strong evidence in favour of the reduction theory if it had been proved that the amount of iron oxide had diminished in the basalt around the metallic iron, yet, of course, the above experiments by no means prove that the theory is wrong, but only that we do not get further on this way.

If we assume with Daubrée that the metallic iron has been carried up from the interior of the earth, we meet with a difficulty in explaining whence the graphitic felspar originates, as it does not seem easy to understand that the like origin could be attributed to the latter; and the latest investigations of Mr. Steenstrup distinctly show that the iron and the felspar are so closely connected that their origin must be supposed to be attributed to the same causes.