TITANIUM IN BLAST FURNACES.

By Auguste J. Rossi.

The influence of titanium or titanic acid on the fusibility of the slags and upon the regular working of the blast furnace is a question upon which we have had but very few direct investigations in this country and in which, to the enlightened practice of Europe, has been opposed a kind of prejudice, possibly justified in certain circumstances but not based on well defined or precise grounds, and frequently in contradiction with the facts.

Phosphorus has certainly an injurious effect on iron and cast iron, but for many purposes to which the latter is applied phosphorus pig is much in demand for fine castings not requiring great strength, and, although in general it is an element to be avoided in an iron ore, the question is one of relative quantities admissible for certain purposes. But while as to phosphorus the subject has been exhausted, so that we know with certainty between what limits we can use phosphorus ores with advantage, the same cannot be said of titanium.

The question may be stated as follows : Is titanium an element so obnoxious that ores, otherwise excellent, easily and cheaply obtained, should be rejected on account of its presence, even in small or limited quantities? Is it the excess of this element which has caused this general prejudice, and is the latter justifiable in all cases? Are there any limits within which the presence of titanium would pass unobserved and would not influence the working of the furnace?

We have endeavored in this paper to throw some light on these points by presenting the facts collected upon the subject in the course of certain researches that we have been called upon to make. We shall give, in a condensed form, the literature of titanium, satisfied if we can contribute in some measure the elements of a conscientious investigation, independent of any personal or preconceived opinion.

That a prejudice may have existed for a long time without any apparent reason is strikingly illustrated in the practice of the blast furnace. For many years lime alone has been considered as the only real fluxing element in a limestone. Calcites, often more difficult or more expensive to obtain, have been exclusively used as fluxes, while dolomites, near at hand and cheaper, have been rejected under the impression that magnesia had no fluxing properties. If such an impression arose from the fact that magnesium silicate is infusible, the same could have been said with equal truth of aluminium silicate, and still aluminous ores have been always considered as very advantageous in the blast furnace. But the same objection would apply to lime, for of all the compounds that silica can form with lime *alone*, only one is practically fusible in the blast furnace. Lime in excess in a slag will render it so infusible and so pasty as to be the cause of grave disorders, "filling up the hearth with infusible blocks, which, in some cases, have been found to weigh as much as *30 tons*. Will it be said that lime has no fluxing properties? The fact is that the double silicates of lime and magnesia or of alumina and magnesia are enormously more fusible than the simple silicates of these bases and *as fusible* or even more so than the corresponding silicates of lime and alumina which for years have constituted the slags of many furnaces exclusively. The introduction of a third base into a double silicate will considerably increase its fusibility, triple silicates fusing much more readily than double silicates. Beside, as far as saturation of silica is concerned, one pound of magnesia, to form a silicate of a certain character, a neutral silicate, for instance, will take up 1½ pounds of silica, while lime will take up only 1.07 lbs. Hence with a dolomite as a flux, with ores containing a certain quantity of alumina, as they almost invariably do, there will be not only a saving on the first cost, but the quantity of limestone necessary will be decreased, the amount of foreign matters to be fused diminished and the fusibility of the slag increased. It is only at a comparatively recent date, however, that iron masters have recognized these facts, and such an authority in metallurgy as Dr. Percy stated in 1864 that "*The use of dolomite as flux instead of calcite must be avoided; it tends to produce infusibility of the slag*" (Percy's Metallurgy, p. 506).

Titanic acid is a substance very tedious and difficult to determine in iron ores and pig irons, as every chemist knows. Sometimes, according to the state in which it is present in the ores, it may be precipitated with the insoluble residue of silica obtained from the fluxing of the ores with alkaline carbonates and nitrates and subsequent treatment, and it may then be mistaken for silica. Although it imparts to the latter a yellowish coloration when ignited, this coloration disappears by cooling and it may be overlooked, or, when titanic acid is present in small quantities, the coloration may not be noticed. It may and will generally pass into the acid solution obtained from the filtration of the insoluble residue and there, occasionally, may show its presence by causing the filtrate to run milky when the precipitate on the filter is washed with water. Frequently these indications are lacking and, if not specially determined by approved methods, titanic acid will be overlooked and mistaken for iron, to which it "sticks," as Mr. Riley says (Journal of British Iron and Steel Institute). It will vitiate the determination of phosphorus, in many cases absolutely preventing the precipitation of phosphoric acid.

(See for determination of titanium in iron ores, pigs and steel, the excellent papers of Messrs. Shirmer, Drown and others, American Institute of Mining Engineers; A. A. Blair's Analysis of Iron, Tenth Census of the U. S., Vol. XV., 1880.)

Literature of Titanium.

Titanium is an element found almost everywhere. It is present in variable quantities in many rocks, ores and minerals. Magnetic ores frequently contain titanic acid, and thus titanium finds its way into many blast furnace slags and into pig irons. It is met with in trap, basalt, mica, gneiss, garnet, amphibole, hornblende, etc., hence in many clays and certain mineral waters. It has been detected in meteorites and is an important constituent of the solar atmosphere (Roscoe & Schorlemmer's Chemistry, p. 255), its presence being indicated by certain dark bands in the ultra violet spectrum (Watts' Dictionary of Chemistry, 1872, p. 1976) ; it is found in nearly all crystalline rocks, hematites and magnetites (Bauerman's Metallurgy, p. 53, etc.).

Titanic acid is found in comparatively large quantities in the ash of coal. Very many samples of coal from widely separated districts gave it in every instance (Chemical News, 1883, p. 157), in some cases as much as 0.16% of the ash. It is also found in limestones in small quantities, and in fact in all the materials that enter a blast furnace. It is found in many iron ores and clays, and generally in silicates, consequently also in blast furnace slags (Fresenius Quantitative Analysis, p. 127). Chemically, titanium is closely related to tin ; it used to be described as a rare element, but it has been found lately to exist in considerable quantities in iron ores and clays (Bloxham's Chemistry, Titanium), and may be regarded as one of the usual constituents, having been very generally found associated with iron ores (A. A. Blair, Chemical Analysis of Iron, 1888, p. 193).

All of the rocks and minerals from Berks, Montgomery and Philadelphia counties (Pa.), syenite, dolerite, gneiss, pyroxene, schist, hornblende, the rock formation of the famous Cornwall mines (Pa.), contain titanic acid in quantities from 0.50% to 5% and more (Geological Survey of Pennsylvania Cb., p. 61). It exists in the clays and slate clays of York, Adams and Lancaster counties (Pa.), in which it is to be regarded as an essential component, its amount being remarkably constant (Am. Inst. of Min. Eng., 6, p. 190).

From rocks it finds its way into ores. In *New Jersey* the very general presence of this element in the clays and some of the gneiss rocks has led to the belief that it is rarely absent from iron ores and nearly all of the later analyses of ores of this State since 1870 show its presence from traces to 11.60% and more of TiO_2 (Geological Survey of New Jersey, 1879, p. 152), and still some of these ores, considered amongst the finest of the country, have been and are daily smelted in blast furnaces in Pennsylvania and New Jersey in admixture with other ores. The Dickerson mine, one of the very best, contains 0.79% TiO_2, the Mount

Pleasant 0.58%, the Teebo 0.59%, the Hibernia mine 0.55% (Am Inst. Min. Eng., Vol. XIV.). The Ringwood mines (Passaic Co.), worked since the last century, and belonging now to Messrs. Cooper & Hewitt, have supplied for years the ores used in the Durham and Ringwood furnaces (Am. Inst. Min. Eng., Vol. XIV.). They contain from 0.30% to 2.72% TiO_2 (Geological Survey of New Jersey, 1873, p. 53). Other ores containing 11.60% TiO_2 have been smelted in the same furnaces or in others in admixture (Ib., 1873, p. 55, *et seq.*). Ores from New Jersey containing 6.23%, 8.21%, 11.60% TiO_2 have been smelted alone in a blast furnace for several months, or nearly one year (personal information from the manager of the furnace).

Iron ores of many districts of *Norway* and *Sweden,* forming enormous, almost unlimited deposits, and containing in some cases 25 to 45% of TiO_2 are waiting for the development of an industry which only the lack of combustibles other than charcoal impedes (Journal of British Iron and Steel Institute, 1880, p. 132) ; many of them have been smelted in these countries and some have been imported to England for treatment. It is present in the ores of the district of Ivenkœping (Sweden), to the extent of 6.37% TiO_2, yet these ores are smelted alone in the blast furnaces of this region furnishing one of the well known brands of Swedish iron (Jordan, Revue de l'Exposition Universelle, 1867, p. 155, II.); in the ores of Newbottom district 9.10% TiO_2, of the Norland province, Ulfo, 9.50% TiO_2, of Kronaberg district 8.50% TiO_2 (Report of the U. S. Commissioner to the Vienna Exhibition, 1873, p. 182), and in many other ores of that country and Norway 7.10% to 15.10% and 40.80% TiO_2 (Prof. Forbes, Jour. of Br. Ir. and St. Inst., 1880).

It is found in *Russian ores* smelted in blast furnaces in the Ural district (4.06% to 4.86% TiO_2) ; this district manufactures 18,000 tons of pig metal per year (Revue de l'Exposition Universelle de 1867, p. 548, III., Jordan) ; in ores smelted in *Bavaria* in the blast furnaces of Hochstein and Eisenberg (Munzerheim ores) 1.396% TiO_2 (Ib., p. 594, III.). A slag of the Concordia Iron Works (Coblenz), contained 6.70% TiO_2 (Percy's Metallurgy, p. 515) ; that of a Styrian charcoal furnace 6.71% TiO_2

(Osborn's Metallurgy, p. 128); that of a Swedish furnace, Ezerholn, 9.20% TiO_2 (Ib.) (Vathaire les Hauts Fourneaux). It is found in Antrim and other *Irish bog ores,* aluminous ores, in quantities varying from 3.51% to 5% TiO_2 (Percy's Metallurgy, p. 207, 225), ores extensively imported into the United States by furnaces in Pennsylvania, and elsewhere here and in England smelted in admixture with other ores (Kimball, Am. Inst. Min. Eng., Vol. IX., p. 14). The Irish Hill Mining Co. ores contain 5.80 to 6.20% TiO_2 (Chemical News, 1881, p. 294), (Encyclopedia Britannica, p. 81).

It is found in bauxites (*France* and elsewhere), mixed as a flux with other ores, 3.20% TiO_2 (Ib.). In *Algeria,* Oran province ores 1.25% TiO_2, in *Sardinia,* Iglesias ores 1.25% TiO_2 (Vathaire les Hauts Fourneaux). In many iron sands of *Sicily* 8.90% TiO_2 (Revue de l'Exposition Universelle, 1867), (Bauerman's Metallurgy), and in *New Zealand* (Ibidem).

It is found in *Pennsylvania ores* in quantities of 0.30% TiO_2, in McIlvee ores, York Co. (Geological Survey of Penn. MM., p. 227), in Chestnut Hill ore bank, mined by the Berks Co. Mining Company, 3.93% TiO_2 (Ib., MM., p. 229), in Brandywine ores 10.44% TiO , smelted in blast furnace without any trouble in admixture with others in the proportion of 12% in the charge, about 1.25% TiO_2, average; in the magnetic sands of Adams Co. 7.37% TiO_2 (Geolog. Sur. of Penn., M. 3, p. 101, MM., p. 227 *et seq.*).

It is found in *New York* State ores almost constantly (10th Census of the United States, Vol. XV., p. 555, 556, etc.), in Chateaugay ores 0.47% TiO^2 smelted in blast furnaces (Am. Inst. of Min. Eng., p. 81, Vol. IX.), in ores of the northern part of the State 0.733% TiO_2 (Ib., Vol. XIV.), in Lake Champlain ores, Westport, TiO_2 4.58% (Ib., Vol. XI., p. 159), split rock 14.70% TiO_2 (Ib., Vol. II., 1873, p. 13), used in blast furnaces in admixture. In ores from Oneida Co., Kirkland ores, 10 to 40% TiO_2, smelted in admixture in the Coleraine furnaces. In Westchester Co. aluminous ores 2.41% to 4.41% TiO_2, recommended in admixture with others (Kemball Ib., Vol. IX., p. 14), in limonites of Staten Island (10th Census of the U. S., p. 124)

In *North Carolina ores* in proportions varying from 12.08% to 13.71% TiO_2 (10th Census U. S., p. 311), and up to 38.61% (Ib.,

p. 562), in Cranberry ore banks 0.95 titanic acid, in Chatham Co. ores 1.04% TiO_2, in Mitchell Co. ores 0.95% TiO_2, up to 5.33%, metallic iron 65.44%, Roan Mountain ores (Am. Inst. Min. Eng., Vol. XI., p. 159), in Centre Co. ores 8.65% TiO_2, metallic iron 60.88% (10th Census), (Am. Inst. Min. Eng., Vol. XI.).

In Colorado ores, in quantities of 11.99%, 11.61%, 12.92%, 12.73%, 13.84%, 14.86%, 13.06% TiO_2 in different districts (10th Census U. S., p. 476).

In *Oregon* ores. Putnam Co., Oswego Furnace smelts ores containing 0.54% TiO_2. In ores of Clackamas Co. and of other districts in which its presence was ascertained but quantities not determined (10th Census, p. 566).

In *Rhode Island* ores, Iron Hill Mine, Providence Co., 9.35% TiO_2.

In *Virginia* ores, in which it is "present" in almost all the ores in quantities not determined, in some TiO_2, 0.16% (10th Census, p. 267–576) and up to 6.53% TiO_2, metallic iron 52.20% in North Garden ores (Am. Inst. of Min. Eng., **6**, p. 159).

In *South Carolina* ores, Silver Mountain bank, York Co., TiO_2 39.67% (10th Census U. S., p. 267–576, etc.). In many other ores of different States its "presence" is "quoted" but without any amount being given (10th Census U. S.). In some analyses it may figure in the "*Insoluble Residue and Silicious matters,*" but no analysis of the latter is given (Geological Survey of Pennsylvania and of other States).

It has been found in the *Canadian* ores, 11.27% TiO_2. (Revue de l'Exposition Universelle de 1867, p. 685), in the Bay St. Paul ores, 48.60% TiO_2 smelted in two blast furnaces in 1873 furnishing an excellent iron (Mr. Riley, Jour. Br. Ir. & St. Inst., 1874, p. 132), they constitute the mineral ilmenite (Am. Inst. Min. Eng., II., p. 13), in Moisie River sands, 4.15% to 28.95% TiO_2 (Bauerman's Metallurgy, p. 53, *et seq.*) (Chemical News).

It is *a constant element* in the *English ores* smelted in the Cleveland district in the furnaces of Sir Lothian Bell and others. The Cleveland ores contain a good deal of titanium (Mr. Riley, Jour. Br. Ir. & St. Inst., 1874, p. 132), while in the Northampshire it is found most readily, even in the cinders. In fact, titanic acid occurs in all clays. It is a *very common material,* very difficult to find; it has a great tendency to *stick to the iron, and has been very often estimated as oxide of iron and mistaken for it* (Mr. Riley, Ib., p. 132, *et seq.*).

It has been found frequently in the U. S., in the Lehigh furnaces, in the crevices of the hearth after the furnace had been blown out. As for instance at the Crane Iron Works, and pig iron from the same works was *colored purple by the presence of titanium;* the ores containing titanium were from Morris Co., New Jersey (Osborn's Metallurgy, p. 485).

It would appear from the preceding quotations that titanium is not a rare element, nor one confined to special localities or countries; in fact, it is met with in a number of iron ores here and in Europe and Africa, etc., in quantities from traces to 50% of TiO_2. That some of these ores, at least, have been smelted in blast furnaces sufficiently appears from the above, and from the fact that many pig irons both here and in Europe contain it as a constant element in very notable quantities, and have contained it for years without any mention being made of troubles resulting from the use of such ores in a blast furnace or from the slags run with these pigs, which slags did also contain titanium, as we will see further.

When a proportion of titaniferous ore is added to the charge, it increases the strength of the metal, at the same time giving it a peculiar mottled character (Bauerman's Metallurgy, 1874, p. 53). Titanium may be present in pig iron to the extent of about 1% (1.64% TiO_2); its presence was considered as a very favorable factor (Ib.).

Pig irons containing 0.47%, 0.71%, 1.15% titanium, corresponding to 0.77%, 1.16%, 1.88% TiO_2, have been regularly produced in English furnaces from a mixture of 7½% ilmenite, containing 38.84% TiO_2 with red hematites and local ores, which supposes in the mixture an average of about 2.913% TiO_2, admitting that the *local* ores did not contain any (Percy's Metallurgy, p. 551). Sir Lothian Bell has obtained from regular mixture of ***English local ores*** used daily in the furnaces of the Cleveland district, ⅓ Cornish ore, ⅓ red hematite, ⅓ Irish bog ore, pig irons containing respectively, 0.79%, 1.15%, 1.629% titanium, corresponding to 1.29%, 1.88%, 2.87% TiO_2 (Percy's Metallurgy, p. 552), (Memoir of Lothian Bell to the British Association, 1863), and the slag run with these pigs contained 0.75% TiO_2 (Percy's Metallurgy, French translation under the auspices of the author, 1865), (Memoir of Lothian Bell, 1863), (Phenomena of Iron Smelting, L. Bell, 1873).

Cleveland pigs contain titanium in a regular and constant manner as a *normal constituent,* as analyses show, in quantities of 0.09%, 0.13%, 0.14%, 0.20%, 0.22%, 0.26%, 0.51%, 0.56%, corresponding to 0.15%, 0.21%, 0.23%, 0.33%, 0.36%, 0.42%, 0.84%, 0.92% TiO_2, and up to 1% titanium (1.64 TiO_2), and *above* (Percy's Metallurgy, French Translation), (Memoir Lothian Bell, 1863), (J. of B. Ir. & St. Inst.). Mr. Riley says (J. of Br. Ir. & St. Inst., 1880, p. 190), titanium is *always present* in fair amounts up to 1% (1.64 TiO_2), but rarely above that in Bessemer or *Cleveland* pig; it is *always* found in Bessemer pig. In the discussion of the paper which has given rise to these observations, not the slightest mention is made of troubles resulting for the furnace from the normal and daily use of ores capable of supplying the above percentages of TiO_2 to the pig, and the English furnaces, as is well known, have longer runs than the American, a run of eight years or more not being a rare case with the former.

Pig irons *smelted in this country* have shown titanium also as a pretty constant element, and the examples quoted below could be multiplied. The analyses were made by Messrs. Drown and Shirmer (Am. Inst. Min. Eng., **17**, p. 346).

Pig Irons.	*Titanium.*	*Titanic Acid.*
Richmond,	0.018	0.030
Greenwood,	0.052	0.084
Hecla,	0.048	0.080
Dutchess,	0.055	0.090
Glendon,	0.099	0.160
Silver Gray,	0.114	0.190
Leesport,	0.115	0.191
Bushong,	0.225	0.370
Unknown,	0.318	0.520
* Perryville,	0.040	0.066

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* **This latter pig was analyzed by the writer.**

Ores containing less than 3½% of titanic acid are not recognized any more as titaniferous ores (Dana's Mineralogy). Ore containing 39.20% TiO_2, ilmenite, have been successfully worked for several years at Norton (England) by the Norwegian Titanic Iron Co. The slag run from the furnace contained 36.18% TiO_2, and 27.83% silica. The uncertainty of importation, the leanness of the ores, which contained only 32 to 36.31% iron, the amount of coal necessary to run in slag such an enormous amount of silica and titanic acid (64.01%) prevented the scheme from being financially profitable after a few years. But the metallurgy of the treatment was a success, and showed that, with proper management, a furnace can carry such a percentage of titanic acid in the charges without clogging (Wm. H. Bowren, Am. Inst. Min. Eng., **11**, p. 159). (Osborn Metallurgy, p. 474). The Canadian Titanic Ore Co. smelted in two blast furnaces ores from Bay St. Paul quoted above, containing 49.60% TiO_2, without any trouble in the furnaces. The ores were very lean (Mr. Riley, Journal of Br. Ir. & St. Inst., 1874, p. 132; 1876, p. 190).

A good liquid slag can be obtained *without any difficulty* with ores containing 3.55% TiO_2 (Prof. Forbes Am. Inst. of Min. Eng., Vol. XI., p. 159). With proper charges and fluxes, with an amount of titanic acid not above 8%, it is not difficult to work an ore *cleanly* and *profitably* (Ib.). With an acid cinder and a slack blast, ores containing from 8 to 13% TiO_2 can be readily treated without any trouble (Ibidem). (Chemical News, Dec. 11, 1888.) These are the statements and practice of an eminent chemist and metallurgist who has been for years consulting engineer for blast furnace managers in Sweden, Norway and England, who has supervised the running of many furnaces in Sweden and Norway, smelting titaniferous ores, and the furnace at Norton (England), treating the ilmenite from Norway mentioned above.

Although troublesome when present in large quantities and having a tendency to render the slags pasty, in working the furnace to a certain kind of pig and not at a too high temperature, the *fluxes* of the furnace require but *very little foreign matters* in working with titaniferous ores (Osborn Metallurgy, p. 431).

Scandinavian iron masters have often expressed to Prof. Forbes their surprise at the want of information possessed by English metallurgists in general upon the subject of highly titaniferous ores, containing such percentages as 25% to 40% titanic acid. Their experience has shown that the only objection to the use of such ores is that they are found to be more or less refractory, as they con tain a greater percentage of titanic acid, and if much titanium is present they require a quantity of coal so much larger to smelt them as to render their employment alone not profitable when ores free from titanium can be obtained cheaply in the district. After considerable experience in smelting these ores, the Norwegian ilmenite and others which yield a very good iron, it was not found profitable to smelt them alone for the preceding reasons, but their use was found beneficial when employed in about equal proportions with the other ores of the district free from titanium (Prof. Forbes, J. Br. Ir. & St. Inst., 1877, Vol. XI.).

Titanium iron is essentially a forge iron. A furnace that can make iron under an acid cinder and a slack blast and keep the silica out will *not be troubled with titanium deposits;* the details of furnaces for smelting these ores are like those suitable for ordinary hematites or magnetites (Am. Inst. Min. Eng., 1877, **2.**) Titanic acid is also found in slags. Slags containing 0.75% TiO_2 have been run in the Cleveland district from the smelting of local ores (Percy's French Translation) (*Revue de l'Exposition Universelle, p. 37*). The Concordia iron works slag, quoted by Percy (see above), contained 6.70% TiO_2 ; one quoted by Osborn as run from a styrian charcoal furnace the same; a slag from Ekersholm, Smoland district (Sweden), contained 9.00% TiO_2 (Osborn), (Vathaire, Les Hauts Fourneaux, p. 41). Blast furnace slags contain titanic acid when treating titanic ores. It is combined with the bases and silica. It does not notably change the appearance of the slag and nothing but an analysis can discover its presence. It gives a violet coloration to the cinder, the shade of which is more blue than that due to oxide of manganese, but this blue coloration can be imparted to the silicates by so many different causes, that it cannot be considered as a proof of the presence of titanic acid (Rivot's Docimacy, p. 157), (Revue de l'Exposition Universelle, 1867, Swedish ores).

When smelting titaniferous ores with white iron *most of the titanic acid enters the slag*, the pig iron is said to yield an excellent wrought iron and steel, and as little titanium is found in these products, it must be due to the indirect beneficial effect of smelting ores containing titanic acid (Wm. Crooke's Adaptation from the German Edition of Prof. Kerhl's Metallurgy, London, 1869, p. 316). About 1% titanium (1.64 TiO_2) may be present in the pig, it increases the strength of the metal (Ib., p. 317).

The iron obtained at Norton (England) from Norwegian ilmenite was found to be extremely strong and was used in Europe for armor plates commanding three times the price of ordinary iron (Osborn's Metallurgy, p. 474).

This Norton iron obtained from ilmenite containing 40.95% titanic acid, 39.20% as average of cargo, went to the armor plates of Sheffield on account of the toughness which this iron not only possessed but imparts to other iron in admixture in the puddling furnaces. When rolled into plates and merchant bars it possesses such a *clean, soft, tough nature* as should render it invaluable for boiler plates, sheets of cold stamping and kindred uses . . . and ores now useless could be made of vast service to the iron trade and to the industries (Mr. Deby, Secretary Br. Ir. & St. Association, **2**, p. 19, 1877).

Titanium is found in very variable proportions in certain pig iron, to which it appears to communicate a great tenacity (Rivot's Docimacie, p. 156). It increases the strength of the metal (Bauerman, p. 53). Ores containing titanium may be considered very favorable for the manufacture of pig metal; in many respects they are preferable to the spathic ores, for, with very little attention they will produce white iron rich in carbon, the very material required for German steel (Osborn Metallurgy, p. 431).

In Sweden it is a common practice to add 10% of titaniferous ores to the charges to remove sulphur. Whatever may be the reason of this effect, what is known with certainty is that titanic ores in the U. S., Canada, New Zealand, Sweden and Norway, are such that the metal produced from them is wonderfully good (Dr. Forbes, J. of Br. Ir. & St. Inst., 1874, p. 131). Titaniferous ores containing 48% TiO_2 smelted in Canada have furnished an *excellent pig* (Mr. Riley, Ib., p. 132).

In Norway and Sweden the ores of Krager and Eger, containing 15% and 7.10% TiO_2 respectively, are worked in blast furnaces. If ores do not contain more than 8% TiO_2 their reduction is not difficult and the product is of good quality. An examination of the ores analyzed in this report (Report 1879 Geological Survey of New Jersey) shows the presence of titanic acid in these New Jersey ores from traces to 5% TiO_2. These are *all* used successfully and are said to *make good iron* (Prof. Cook, Geology of New Jersey, 1879, p. 152).

The New Jersey ores, containing 11.60%, 6.23%, 8.21% TiO_2, and averaging about 8.50% TiO_2 in the charges, have been smelted alone in a blast furnace for nearly one year and have yielded a pig iron of a *"remarkable strength,"* "which could almost be bent in two without breaking." The cast iron was graphitic and considered an exceptionally good No. 1 gray foundry iron. It commanded, it is claimed, one dollar more per ton (personal information).

Putting aside the questions of the *improvement and good qualities claimed* for the iron obtained from titaniferous ores, the practice in Europe and even in this country, within certain limits, seems to establish the fact that titanium cannot be considered as being *always* and *necessarily* a cause of trouble in the blast furnace if properly dealt with, even when present in very large quantities, since ores containing as much as 40%, and even 48%, of titanic acid have been smelted, in known cases, for several years in the same furnace as *successfully,* if not as profitably, as others richer in iron and free from titanium or containing lesser proportions of it. On the other hand, certain blast furnace managers in this country go as far as to maintain that *inappreciable quantities,* mere traces of titanic acid, are sufficient to interfere with the good working of a furnace—clogging and stopping it. Others, a little more liberal, will not even admit a limit of 0.25% of titanic acid in an iron ore, nor will they consider it practicable to use it in a blast furnace. For them the smaller percentage is as deleterious as the larger, the only difference being that the action is smaller and that it requires a longer time to fill up the furnace. To these extremists it might be answered that, unconsciously, then, many iron masters have produced in this country, daily and normally, pig irons in which the quantity of titanium has reached as much as 0.318%, corresponding to 0.52% TiO_2 (from 0.03% to 0.52%, considering *only* the analysis given above). All of these proportions, according to their view, the smallest as well as the largest, were sufficient to have ultimately clogged the furnaces, and still the latter have had years of excellent running as regards economy and quality of product, at least some of them did have, since one of these pig irons, the "Bushong," containing 0.37% TiO_2, has commanded one dollar more per ton on the market.

Admitting that the ores smelted contained 50% of iron, that is, that two tons of ore were fluxed per ton of pig metal, a quantity of 0.52% TiO_2 in the pig would correspond to 0.26% in the ores, and this supposes that there was none left to pass into the slag; how then could the latter be rendered *pasty* or *infusible?* Furthermore, if *all* the titanic acid is thus accounted for in the pig, none has been left in the furnace to clog it and we are in this dilemma: either some titanic acid *did* pass into the slag and the ores contained more than 0.26% TiO_2 or *all of the titanic acid can be made to pass into the pig and thus leave the furnace.* That none was left in these furnaces, not even *traces*, if we adopt the views of these extremists, appears to be sufficiently proved by the fact that the pig irons analyzed were not special specimens, but the regular product of the iron works from which they came.

We find in England, in the Cleveland district, in Staffordshire and Northampshire, smelted daily from the regular local ores, normal pigs which, as Mr. Riley says, contain titanium in good quantity, up to one per cent. or more and occasionally as much as 1.6%, corresponding to 1.64% or even as much as 2.87% TiO_2, and the same authority adds, "Titanic acid is also found *most readily* even in the slags" of these districts. We have every reason then to suppose that the slags run with the American pigs quoted did *also* contain titanic acid. With materials 50% rich in iron the preceding figures would correspond to at least 0.82% to 1.43% TiO_2 in the English ores; with materials only 40% rich to, at least, 0.67% to 1.18% in the charges, and these English furnaces have much longer runs than the American. We know from analysis given by Percy and others that at least the "Irish bog ores" used about in proportion of one-third with the other local ores, contain (Antrim) 3.51% to 5% TiO_2. This would bring the proportion of titanic acid in the mixture to from 1.17 to 1.66%, or 0.70% to 1.00% titanium, figures which correspond very nearly with those found for titanium in the normal pigs of the district.

Even in this country certain iron masters more enterprising and more experienced than others have successfully disposed of several thousands of tons of ores containing from 9% to 15% titanic acid, average 12%, by smelting them in a mixture with other ores in such proportion that the average proportion of titanic acid was 0.38%, and with as much as 0.75% titanic acid in the mixture with proper care they did not experience any trouble.

They have gone so far as to state that, after many experiments with titanium, the result of their experience has been that a mixture containing a *greater percentage* of titanic acid *than 1.25%* could not be successfully used. This admits clearly a possible maximum limit, and is in complete contradiction with the assertions of the extremists. The following is another illustration of American practice. It covers a lapse of ten years' running of two blast furnaces. These furnaces used five different kinds of magnetites, all containing titanic acid in quantities varying from 0.33 to as much as 1.34%, as analyses made at the time and subsequent ones have proved. The ores averaged in admixture about 0.70% titanic acid. They were exclusively smelted for that period without any trouble whatever from deposits, sluggish slags or clogging. The furnaces had runs of three and three and a half years—a very good run in the United States—and they produced all grades of iron from white to gray No. 1, and even to graphitic iron. Titanic acid was detected in the slags. These two examples corroborate the results of the English practice. They are given here because we are particularly acquainted with the circumstances of each case and can substantiate these assertions.

If we pass to Sweden and Norway we find there ores containing 5% to 10% TiO_2 smelted alone clearly and profitably in charcoal furnaces, others containing 15% to 20% TiO_2 or more, smelted in admixture or even alone with a beneficial effect; and, lastly, Norway ores containing as much as 40% TiO_2 and only only 36% of iron smelted by a company in England for a few years with a perfect success as far, at least, as the *metallurgy* of the treatment was concerned. No clogging or stoppage of the furnace, no pasty slags interfering with its working are mentioned. In Canada we notice results exactly similar with ores of nearly the same composition as the preceding Norway ore. We find slags in England and slags run from normal local ores containing 0.75% $Ti O_2$, others quoted above containing 6.70% and 9% $Ti O_2$, slags run from local ores containing enough titanic acid to supply to them these percentages. We find pig irons in England and in this country containing this element as a constant factor in quantities from 0.08 to 1.64% titanium and more. There seems to be a contradiction somewhere. Without pretending to settle the question by our own authority, we believe that enough facts have been presented to justify, at least, the following remarks:

Titanic acid, though present it may be said in almost all magnetites and hematites of certain districts, in various quantities, generally small, has been mostly *ignored* until a comparatively recent date. In the analyses given in the geological survey of New Jersey it does not figure until 1870, from which date it was *looked* for and found regularly in different quantities, from 0.30% to 1%, in ores in which its presence had not been previously suspected, and so constantly, from traces to 15%, in different ores from widely separated regions, that this fact has called for the statement of the late Prof. Cook, that it seems to be almost a normal element of the New Jersey ores (Geol. Sur. of N. J., 1879). As Mr. Riley has observed, its determination is very difficult, and it has been very often mistaken for *oxide of iron.* In the reports of the geological surveys of Pennsylvania, up to 1886–87 at least, most of the analyses are tabulated "Silica and insoluble residue," no composition of this residue is given. Titanic acid might and could have been present there and entirely overlooked. (See Analyses of Geological Survey of Pennsylvania.)

Such a supposition is not a gratuitous one. In the analyses of iron ore given in the 10th Census of the U. S., we find, amongst other examples, p. 311, under the denomination of North Carolina ores, "Silica and insoluble residue, 28%," and in the subsequent analysis of these 28% of "residue," titanic acid appears for 11.82%, nearly half ! Such a proportion would have been completely ignored except for special analysis. In many other ores titanic acid figures only as "present."

Consequently, iron masters in Pennsylvania, New Jersey, and elsewhere must have been smelting for years, and are even smelting to the present day, in admixture with other ores or alone, local ores or magnetites and hematites from New Jersey, for which they have been satisfied to pay the best prices on account of their richness in iron, and in which titanic acid had not been suspected or its proportion determined up to 1870, and for others much later still. Yet, there has not been any complaint made of these ores on this score ; on the contrary, they have commanded a better market ; trouble has been taken to have them shipped to distant furnaces. We could quote many such ores, but limit ourselves to the Dickerson mine, 0.79% $Ti O_2$; Mt. Pleasant Mine, 0.58% $Ti O_2$; Teebo Mine, 0.59% $Ti O_2$, all in Morris Co.; the Ringwood Mines (Passaic Co.), 0.30 to 2.72% $Ti O_2$; the Hibernia Mine, 0.55% $Ti O_2$. (See Geolog. Survey of N. J.) (Am. Inst. M. Eng.) In the analyses of the Dickerson Mine, Mt. Pleasant, Teebo, Hibernia, given *in 1868* in the Geological Survey of New Jersey, titanic acid *does not appear, not having been sought for.*

The following analyses will give an idea of the value of these ores, those of Mt. Pleasant and Hibernia have been made by us, those of Ringwood Mines are taken from the Geol. Survey of N. J.:

	MT. PLEASANT.		RINGWOOD.		HIBERNIA.	
FOUND.	Rich ore.	Av. cargo.	I.	II.	I.	Av. Ore
Silica	1.60	8.17	3.00	5.80	5.90	8.87
Sulphur	0.07	0.09	3.00	5.80	0.05	8.87
Phosphoric acid	0.50	0.81	0.45	traces	1.05	1.15
Alumina	1.40	0.68	2.59	1.91	1.23	3.13
Oxide of iron	95.65	85.84	94.06	90.47	87.99	80.59
Oxide of manganese	0.07	0.06	0.25	90.47	0.06	80.59
Lime	0.50	2.21	1.57	90.47	2.57	3.44
Magnesia	0.40	1.53	0.22	0.72	1.23	1.50
Titanic acid	0.58	0.58	0.30	2.72	0.55	0.55
Metallic iron	69.27%	62.10%	65.84%	63.29%	63.72%	58.36%
Observations	Iron is in the ore as Magnetic oxide.		Iron as Ferric oxide.		Magnetic oxide.	Analysis by L.L. Bierewith.

Is titanic acid, then, *always* and *in all quantities* an objectionable element in an iron ore? Is it not more correct to say that, within certain limits, which we may perhaps fix at 1.00% or more, it has proved little objectionable; on the contrary, that it has passed for years unnoticed? No disturbances have occurred in the running of the furnaces unknowingly smelting such titaniferous ores to call attention to a detrimental element. So much seems to be assured, and confirmed by the English practice. Above these quantities what is the limit at which its presence in an iron ore would begin to be felt by its effect upon the running of the furnace in respect to economy or at which the judicious treatment, such as a change in the routine of the charges and fluxes adopted for non-titaniferous ores, might become necessary to insure both economy and success? American furnaces may have unconsciously worked ores containing much more titanic acid than 1 or 1.25%, and some have done so to our positive knowledge (8% to 10% titanic acid in the charges, as derived, at least, from verbal assurances of certain iron masters), without experiencing any particular troubles, but in the absence of direct and well authenticated practice, and especially of *regular analyses of the charges* in the case alluded to, it may not be fair to draw a conclusion.

If, as stated by Dana, an ore ceases to be recognized as titaniferous when it contains less than 3½% TiO_2, this figure might be called the limit, and the personal observations of Prof. Forbes affords a corroboration of this statement. Beyond that, if we take to guide us the European practice in Norway and Sweden, the examples quoted above would prove that, with proper fluxes, even regular titanic acid minerals, such as Ilmenite, containing from 40 to 48% of this substance, can be and have been cleanly and successfully smelted in furnaces without any disorders resulting in the latter from their use. The question of economy in the particular case mentioned depended on many factors and, at any rate, has nothing to do with the metallurgy of the treatment.

If dealt with as corresponding proportions of silica would be when present in ores in very notable quantities, titanium has certainly a tendency to produce "deposits" and to render the slags less fusible. All depends on the judicious and rational choice and proportion of the fluxes to obtain a desired result. "Nothing economical or skillful can be accomplished when the charges are badly engineered (Osborn's Metallurgy, p. 478); the skill of a blast furnace manager as a metallurgist consists mainly in forming a fluid slag with the materials at his command (J. of Br. Ir. and St. Inst., 1874, p. 75). Certain natural compounds of titanium, such as sphene, calcium silico-titanate and keilhauite, are perfectly fusible in a blast furnace. (Ib., p. 43.) Their composition is as follows:

	Sphene.				Keilhauite.
	I.	II.	III.	Average.	
Silica	32.26	31.90	31.20	31.78	31.33
Titanic acid	38.57	40.60	40.92	40.00	28.04
Lime	27.65	25.89	22.25	24.59	19.56
Oxide of iron	0.76	1.61	5.06	2.00	6.57
Alumina	0.76	1.61	5.06	2.00	8.03
	(Piedmont) Rivot.	Dana. Rivot.	(Arendal) Rivot.	Average of these 3 analyses.	Dana.

So eminent a chemist and metallurgist as Prof. Forbes has certainly cleared this question from all possible doubts by his practice. He has smelted, without admixture, ores containing 40% titanic acid without any trouble in the furnace. We refer to the excellent papers of Mr. W. M. Bowren (Am. Inst. Min. Eng., **9**, 159), and to that of Mr. Deby (J. of Br. Ir. and St. Inst., **2**, 1877, p. 13) for the details of the operation. The ores treated were the Norway ilmenite, of which an average analysis of a cargo gave (see papers quoted):

Titanic acid	39.20
Ferric oxide	18.59
Ferrous oxide	30.00
Alumina	2.89
Manganous oxide	0.60
Silica	5.70
Loss	0.22

Iron=36.3%.

The composition of the slag actually run from the furnace, as given in the paper alluded to, approximated, as closely as can be obtained in practice, the composition *of sphene, a natural mineral of titanium,* fusible in the blast furnace. This is what good management can do.

Composition of Slag.		Average Sphène.
Silica - - - -	27.83	31.78
Titanic acid - -	36.18	40.00
Lime - - -	24.36	24.59
Oxide of iron - -	1.86	2.00
Alumina - - -	9.18	“
Magnesia - - ·	0.60	“

As it can be calculated from the preceding analyses and from the charges of the furnace as given in Mr. Bowren's paper, *all the titanic acid* of the ore is accounted for and has mostly been made to pass into the slag, excepting the small percentage left in the pig metal, perhaps 1 to 2%, and, of course, titanium having left the furnace it could not in any manner be the cause of obstruction by hangings or deposits.

If these results were not as economically obtained as with other ores free from titanium, it may be a question if the higher prices realized for the products were not a compensation for the extra expense of combustible, or would not be if the ore, though containing as much titanic acid, had been richer in iron; but it is useless to discuss this side of the question; the *possibility* of smelting successfully and cleanly such highly titaniferous ores is all that we intended to establish beyond dispute. The objections to the presence of titanic acid in an iron ore would thus be entirely modified if we adopt the conclusions of Prof. Forbes and the results of his practice and of that of the Swedish metallurgists. *It would be no longer a question of "clogging of the furnace" but simply one of economy in each case.*

Reduced to this it would seem that such small quantities as 1 to 1.25%, or even more, of titanic acid could not be objectionable on this score, especially if these titaniferous ores present, as they do, such characters as render them very valuable otherwise.

Prof. Forbes (J. of Br. Ir. and St. Inst., 1877, p. 132) has called attention to the fact that ores of this kind, in Norway, Sweden, Canada and New Zealand, are remarkably *free from phosphorus* and very frequently also from sulphur; though not absolutely and invariably so, still, as a rule, real titanic ores are extremely free from these elements, and when they are not, the question may be raised, does not the phosphoric acid come from adhering barren gangue of apatite and not from the *ore itself?* Mr. Riley (Ib.) commenting on these remarks of Dr. Forbes has fully confirmed his assertions. It is quite exceptional (says he) to find titanic ores containing any phosphorus. The same observations have been made independently, in 1875, by Prof. Cook for the titaniferous ores of New Jersey (Geol. Survey of N. J., 1875, p. 35). Analyses (he says) indicate this curious relation between titanium and phosphorus, that a considerable percentage of the former always corresponds to a very *small* amount of the latter. The behavior of such ores in the blast furnace and the character of the product might be an interesting point in the metallurgy of iron, and the chemical examination of iron ores to test this hypothesis further or substantiate these facts ought to be continued.

It was true with the ores smelted in the two furnaces we have spoken of as having run for ten years, that those containing *least* phosphorus contained most titanic acid, as analyses showed:

	I.	II.	III.	IV.
Average Phosphorus - -	0.064	0.160	0.270	0.730
Do. Titanic acid - -	0.98	0.90	0.58	0.33

We have collected a number of analyses of ores coming from mines separated by the Atlantic or by distances on land still greater, which we give below. Any idea of fortuitous coincidence has to be excluded, and still the results seem to corroborate, in a remarkable manner, the above observations.

UNITED STATES.

Pennsylvania.

1. McElvee ore - - -	TiO_2	0.33%	P. 0.013	Met. Iron	68.50%
2. Chestnut Hill ore -	"	3.93%	traces	"	63.75
3. Cornwall ore - - -	"	7.37	traces	—	—

(Geolog. Survey of Pa., M3.)

North Carolina.

1.	Rockingham Co.	TiO_2	13.71%	P. .052	J. of Iron & St. Inst., 2, p. 13.
2.	—	"	38.61	traces	10th Census U. S., p. 311-326-561.
3.	—	"	0.95	0.007	

New York.

1.	TiO_2	2.41%	P. 0.095	Weschester Co. Ores. Vol. **9**, Am. Inst. M. Eng.
2.	"	3.88	" 0.07	
3.	"	3.52	" 0.04	
4.	"	3.90	" none	
5.	"	3.51	" traces	
6.	"	4.41	" 0.07	
7.	"	10 to 40%	" traces	10th Census, p. 311, etc.
8.	"	0.733	" 0.021	Am. Inst. M. Eng., **14**.
9.	"	0.470	" 0.02	Chateaugay, Ib., **9**. Iron, 60.46%.

Colorado.

1.	TiO_2	11.99%	P. 0.025	10th Census, p. 476.
2.	"	12.92	" 0.026	
3.	"	11.61	" 0.037	
4.	"	12.73	" 0.011	
5.	"	13.84	" 0.040	
6.	"	14.86	" 0.039	
7.	"	13.04	" 0.039	

Oregon.

1.	TiO_2	0.54%	P. 0.006	10th Census, p. 566. Oswego Furnace.

South Carolina.

1.	TiO_2	39.67%	P. traces	10th Census. York Co.

New Jersey.

1.	TiO_2	7.70%	P. 0.04%	Iron 64.46	Geological Survey of N. Jersey.—Ores from diferent counties.
2.	"	1.00	" traces	do. 64.90	
3.	"	7.50	" 0.07	do. 65.52	
4.	"	9.80	" 0.04	do. 62.23	
5.	"	3.60	" traces	do. 67.10	
6.	"	11.60	" traces		
7.	"	4.70	" traces		
8.	"	5.90	" traces	do. 52.00	
9.	"	2.72	" traces	do. 63.33	
10.	"	1.95	" 0.06		
11.	"	1.95	" traces	do. 67.20	
12.	"	4.40	" 0.09	do. 53.00	
13.	"	1.00	" traces	do. 64.95	
14.	"	4.95	" 0.08		
15.	"	1.45	" traces		
16.	"	5.00	" 0.08		
17.	"	1.30	" 0.06		

SWEDEN.

1.	- TiO_2 6.37%	P. 0.023%	Ivenkoeping. (Revue de l'Exp. Univ., p. 155, II.)
2.	- " 15.10	" traces	J. of Br. Ir. & St. Institute, 1880, p. 132.
3.	- " 40.90	" traces	

And many others.

NORWAY.

1. Ilmenite, TiO_2 39.20 (average); P., none, and many other ores containing it in various proportions are remarkably free from P. (Journal of Iron and Steel Institute, 1879-1880.)

BAVARIA.

1. TiO_2 1.396% P. 0.12 Revue Exposition, p. 594, III.

RUSSIA.

1. TiO_2 4.86% P. none Iron 63.00. Ib., p. 548. Ural District.

SICILY.

1. Iron sands, TiO_2 8.90% P. none. Ib.

FRANCE.

1. Bauxite, TiO_2 3.20% and above. P. none. Encycl. Brit.

CANADA ORES.

1.	TiO_2 48.50	P. none		Bay St. Paul (Am. I. M. E.). (J. of Br. Ir. & S. Inst.)
2.	" 4.83	" traces		Moiste River (Bauerman). (Revue Exposition.)
3.	" 16.00	" none		
4.	" 2.34	" traces	Iron 68.34%	Ontario Ores, p.214-321. (J.of Br. Ir. & St. In.'81)
5.	" 3.17	" 0.07	do. 66.98	
6.	" 2.12	" 0.052	do. 63.88	Ilay Cook Mine, Ottawa. (Am.-I. Min. Eng., **12.**)
7.	" 0.73	" 0.07		Snowden, township near Toronto. (Ib.)

(7) Ores carried to Cleveland, Ohio, and smelted there.

IRISH ORES.

1. Antrim (Percy), TiO_2 3.51 P. traces.

NEW ZEALAND.

1.	- - - - - -	TiO_2 6.17%	P. traces	
2.	- - - - - -	" 11.43	do. none.	Iron 61%

(Chemical News.)

Unfortunately in many analyses of ores published in the 10th Census titanium is given as "present;" but as the amount has not been determined, it is impossible to conclude as to the coincidence between absence of P. and presence of titanium. In many others the "insoluble residue" is only given and all deductions are presented. At any rate, many ores remarkably free from phosphorus (and very often from sulphur also), as it appears from the above analyses, and also very rich in iron, now piled up on the banks of the mines or not mined to any extent, could be advantageously smelted and made available for Bessemer pigs, if, as the European practice tends to show, and as the American practice corroborates within certain limited amounts, perhaps, the objections to the use of titaniferous ores in a blast furnace were as much of a prejudice, in a general manner, as those which have been raised against the use of magnesia as a flux. "Titanium does not melt in any heat of a blast furnace" (Robert Hunt, Dict. of A. M. & Mines, 1878).

Possibly the prejudices of the extremists against the use of ores containing *any quantity* of this element did originally arise from a knowledge of this fact; but this does not prevent certain titanium compounds from being perfectly fusible, as we have had occasion to observe in respect to magnesia, lime or alumina. If furnaces working ores or materials containing titanic acid in limited quantities have experienced serious troubles the question may be asked: May it not be "*post hoc,*" although not "*propter hoc.*"

Resuming the above, we submit the following conclusions:

1°. Titanic acid is not *necessarily* and *always* a cause of trouble in the blast furnace, even if present in large quantities.

2°. In small quantities its presence appears to have been ignored for many years, and furnaces have run and do run to-day with ores rich in iron, containing as much as from 0.30% to about 1% titanic acid in the charges without apparent trouble of any kind, these ores being smelted alone or in admixture with others more or less free from titanium.

3°. When present in very notable quantities it has a tendency to render the slag pasty and clog a furnace with titanium deposits if it is not made by a judicious treatment to *pass into the slag.*

4°. With proper care and with fluxes very little different from those ordinarily used, ores more highly titaniferous have been smelted cleanly and profitably, but perhaps less economically than others.

5°. With a judicious adaptation of the fluxes to the composition of the ores, with a view to obtaining a slag of a certain character and to the production of special grades of pig metal adapted to the given circumstances, lean ores containing 40 and 48% of titanic acid have been successfully smelted in a regular manner for years, but at a much greater expenditure of combustibles.

6°. To decide *what* are the limits at which an ore containing titanic acid would require a modification in the ordinary charges used with similar ores free from it, would demand direct experiments, continued for a length of time, experiments which have only been made exceptionally in this country, so far as we know. How much would the extra expenditure of combustible, if any, be compensated by the special qualities claimed for the pig metal obtained, and we may say, certain to be obtained (independently *of any particular beneficial action of titanium*) by the possibility of using cheap and rich ores comparatively free from phosphorus, and, to a great extent, from sulphur: these are questions of practice on which we may have an opinion, but which cannot be discussed in this present paper, our aim having been especially to present facts upon both sides and not merely a personal theory.

7°. It cannot be maintained, at any rate, in presence of the European practice, and even of the limited American practice with such ores, that *inappreciable quantities, mere traces, or very small proportions* of titanium in ores are objectionable and sure to cause trouble in the furnace.

8°. If we rely entirely upon European practice the *metallurgy of all kinds* of titaniferous ores has been a complete success.

9°. The titaniferous ores appear to be "*par excellence*" Bessemer ores, containing little or no phosphorus, and they form, both in Europe and in many States of the Union and Canada, enormous deposits now useless.

10°. The development of the steel industry is now taxing to their limit of production the best ores of this country; at least those available in the Eastern and Middle States. Many furnaces import hematites from Lake Superior, which cost them at the furnace from $6 to $7 per ton, because these ores are comparatively free from phosphorus, while nearer at hand they have titaniferous ores as rich in iron or richer and yet more free from phosphorus, but which they do not dare to work.

Even in Colorado, ores free from titanic acid are shipped, at a great cost, to certain works which do not care to treat the immense banks of titaniferous ores near by.

The question of the use or of the exclusion of such ores is one which ought to attract the serious attention of metallurgists in this country. Enough has been done elsewhere to encourage efforts in this direction ; the metallurgy of titaniferous ores is no secret. The results, if favorable, and there are all reasons to believe that they would be if we trust to what has been done in Europe, would richly pay for the expense incurred.

New York, March, 1890.

ABSTRACTS.

ANALYTICAL CHEMISTRY.

Analysis of Chrome Iron. R. FRESENIUS and E. HINTZ.

The authors effect the solution of chrome iron by subjecting it, while heated, to a current of dry chlorine gas. About 5 grms. of the chrome iron are placed in a small porcelain boat and then inserted into a refractory glass tube of about 60 cm. length. Suitable safety tubes containing water are attached to collect the volatilized chlorides. The porcelain boat must be heated very gradually, and the heat, finally, is so regulated that but little of the ferric chloride reaches the first safety tube. The operation requires about 3 to 4 hours. For details as to the method for the complete analysis of chrome iron, see the original article. (*Ztschr. anal. Chem.*, **29**, *28–35.*) J. F. G.