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THE IRON-ORE RESOURCES OF EUROPE

BY

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By Joseph B. Umpleby.

Most of the commercially available iron-ore deposits of the world occur on one or the other side of the North Atlantic. The location, extent, and character of our own deposits are well known to those who are interested in the American iron industry, but comparable information in English concerning the deposits of Europe is not available. We hold undisputed first place in the production of iron and steel, and our furnaces and mills are capable of sustaining a large export trade, but it is not enough to have intimate knowledge of our domestic deposits alone: we must know also the extent and the possible development of those foreign deposits with which our own must compete in international trade. A wealth of literature has been published on the iron-ore deposits of Europe, but it is the product of many writers, each occupying his individual viewpoint, it is printed in many languages, and much of it appears in publications that are not found in most libraries. The author of this report has undertaken to reduce this large and diverse record to nearly common scale or proportions and to present its content as briefly as possible to the American reader.

The work of determining the location and extent of foreign mineral deposits was originally undertaken as part of a comprehensive survey of the world's mineral wealth for the guidance of the American Commission to Negotiate Peace, but now that this purpose has been served the work is being continued as an aid to our foreign trade and a guide in the most rational development of our domestic resources.

The results of the work of the Geological Survey on foreign mineral deposits will be published in the form of an atlas of commercial geology, containing maps showing the distribution of the economic minerals, accompanied by brief texts, and in bulletins, such as this one, giving more detailed information on a single mineral, together with a working bibliography. As iron resources are of paramount importance to industrial nations another bulletin,[1] focused on the industrial aspects of the deposits of iron ore in central Europe, has also been issued by the Geological Survey. That bulletin may serve as a companion volume to this one, which deals primarily with the deposits themselves.

[1] Brooks, A. H., and La Croix, M. F., The iron and associated industries of Lorraine, the Sarre district, Luxemburg, and Belgium: U. S. Geol. Survey Bull. 703, 1921.

THE IRON-ORE RESOURCES OF EUROPE.

By Max Roesler.

INTRODUCTION.

OBJECT AND SCOPE OF REPORT.

This bulletin gives a summary of the facts concerning the deposits of iron ore in Europe and estimates of the quantities of ore and of iron they contain. It reports no original research work; it is simply the result of a study of the work of many writers and is an attempt to reduce the variant products of that work to common values. The geographic review of the deposits is preceded by a brief sketch of the nature and geology of iron-ore deposits in general and a few notes on the methods of utilizing the ores. The geologic distribution of the deposits is considered, and the more extensive deposits are described. The economic value of the iron ore in the several countries of Europe is shown by the statistics of production and consumption.

Unfortunately, the political boundaries of many European States are still uncertain, and some valuable ore deposits are not yet definitely allocated to a particular political unit. Perhaps undue emphasis is given to the deposits of Germany and France, but the political conditions from which this study arose make this emphasis natural, and it is probably in accord with the present popular interest.

LIMITATIONS OF THE WORK.

The value of the results of any study depends directly on the accuracy of the information on which the study is based. The authors of numerous articles consulted were men who occupied different viewpoints, and perhaps most of them were geologists, who had little interest in the economic value or development of the deposits. On the other hand, some of the articles were written by engineers, whose work was impaired by lack of geologic knowledge.

A notable limitation on the work was that imposed by the languages in which the articles were written. Originals written in French, German, or Spanish were consulted directly, but those written in the Slavonic languages were available only in translations or abstracts.

A further limitation is inherent in the subject. The quantity of ore already mined from the average deposit can be easily calculated, and the quantity of ore that is probably minable can be estimated with fair assurance as to accuracy, for it is dependent on definite limitations; but the quantity that is possibly available is in only a few deposits susceptible of rigid definition, and personal judgment must enter largely into any estimate of it.

DEFINITIONS.

The term "ore" as here used means an aggregate of iron-bearing minerals that is now commercially valuable or that may reasonably be expected to be valuable in time of need. The experience of the last few years with so-called "war" minerals has shown that material which in normal times would not be considered ore can be utilized in time of stress.

In classifying material as ore the means and cost of transportation have been ignored. On the other hand, technologic difficulties or values, such as the inherent difficulty of mining thin seams or of mining at great depth and, so far as possible, the metallurgic value of the product, have been considered.

In order that the estimates given might be made reasonably uniform in value certain limits were fixed to the definitions of "known," "probable," and "possible" ore—terms that are used throughout this bulletin.

"Known" ore is developed material that is or can be profitably mined now.

"Probable" ore is material that may probably be mined hereafter, the probability being based on present standards in mining and metallurgy and on geologic indications as to the continuity of the deposit.

"Possible" ore includes ore of present commercial grade which lies so deep that it is not now available but which a slight improvement in mining methods or an increase in price would render available; ore which is of lower grade than that now used but so near to that of present grade that it will probably be used in a not very distant future; ore which is used chiefly as flux; and ore which is chemically not fit for use in present metallurgic practice but that may be used in the future, such as titaniferous ore or ore containing a large quantity of silica. The figures showing "possible" ore must be used with caution, because even though they are the result of careful consideration they involve many assumptions and are subject to many errors in judgment. It is hoped, however, that they have comparative value; at least they have all been evaluated with equal rating.

In this grouping consideration has been given to industrial changes, such as the constant decrease in the production of ore from the English coal measures and the increase in the production of ore from the Bavarian and Swabian Alps.

Except where otherwise stated the unit employed is the metric ton.

GEOLOGY OF IRON-ORE DEPOSITS.

As the valuation of iron-ore deposits depends largely on the interpretation of geologic data a brief statement of the salient features of the geology of the deposits is necessary to enable the reader to understand the descriptions and to put him in a position to criticize the conclusions presented.

Iron occurs in almost all the rocks that are exposed at the earth's surface. According to F. W. Clarke[2] the lithosphere contains 4.5 per cent of iron. This iron is scattered through the rocks in innumerable complex minerals—silicates, carbonates, sulphides, oxides, etc.—but in order to form an ore body the iron in these minerals must be concentrated so that their iron content is from 4 to 14 times as great as that in the earth's crust in general.

The minerals of which the great bulk of the world's iron-ore deposits is composed are comparatively simple. They are:

Oxides	$Fe_2O_3.FeO$	Magnetite.
	Fe_2O_3	Hematite.
	$Fe_2O_3.H_2O$	Goethite (crystalline), limonite (amorphous).
Carbonate	$FeO.CO_2$	Siderite.
Complex silicates		Chamosite, thuringite, and glauconite.

The field work of many geologists and the laboratory work of R. B. Sosman and J. C. Hostetter,[3] E. Posnjak and H. E. Merwin,[4] and others have shown that the iron oxides rarely occur in pure form in nature. They form series containing varying amounts of Fe_2O_3, FeO, and H_2O and may be grouped as follows:

Magnetite-hematite	$Fe_2O_3.FeO–Fe_2O_3$
Hematite-goethite	$Fe_2O_3–Fe_2O_3H_2O$
Brown ores	$Fe_2O_3.H_2O–Fe_2O_3 \pm H_2O$

Siderite is also frequently found as an impure carbonate in which iron is replaced by calcium, magnesium, or manganese.

Chamosite, thuringite, and glauconite have aided in the formation of some of the sedimentary deposits of iron ore but in themselves form relatively few commercially valuable deposits.

If arranged according to mode of formation deposits of iron ore can be grouped in two major classes—(1) concentrations formed by deep-seated agencies and (2) concentrations formed by surficial agencies. The mineralogy and to some extent the form of the deposits of these two classes are essentially different.

1. The agencies that form deposits of the first class are igneous, but the temperatures and pressures involved in their formation may

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[2] Clarke, F. W., The data of geochemistry, 4th ed.: U. S. Geol. Survey Bull. 695, p. 35, 1920.

[3] Sosman, R. B., and Hostetter, J. C., The ferrous iron content and magnetic susceptibility of some artificial and natural oxides of iron: Am. Inst. Min. Eng. Trans., vol. 58, pp. 409–433, 1917; Zonal growth in hematite and its bearing on the origin of certain iron ores: Idem, pp. 433–444.

[4] Posnjak, E., and Merwin, H. E., The hydrated ferric oxides: Am. Jour. Sci., 4th ser., vol. 47, pp. 311-348, May, 1919.

range from those of molten magmas to those found at the earth's surface. Two types of deposits of this class are of common occurrence—(*a*) deposits associated with gabbros and (*b*) deposits associated with granitic rocks.

(*a*) The ores associated with gabbros carry iron mainly as magnetite, and most of them contain considerable titanium, which occurs as ilmenite. The ore bodies generally form integral parts of the intrusive masses in which they occur and are regarded as segregations within the igneous magma.

(*b*) The ores associated with granitic rocks contain magnetite as their only essential iron mineral if they were formed at great depth, but they may contain any mineral of the magnetite-hematite series if they were formed at moderate depth. If they include titanium it occurs as titanite, not as ilmenite. In deposits formed at great depth the relations between the ore bodies and the parent granite or allied rock are commonly very like those of the ore masses associated with the gabbros, but in deposits formed at moderate depth the relations are generally very different. In ores formed at great depth the iron minerals are apparently segregated as a result of magmatic differentiation in place, whereas in those formed at less depth, under pressure permitting tenuous or mobile constituents to escape from the magma, the iron is collected by and carried with these constituents to be later segregated in veins or in deposits that replace limestones or other rocks. Most iron ores thus formed by replacement occur close to the borders of the invading igneous masses. Throughout the western part of the United States limestones that were invaded by the magmas of monzonites appear to have been particularly susceptible to replacement by minerals carried by metalliferous solutions that obviously originated within the monzonitic igneous masses, and here there are many "contact" deposits of magnetite. Elsewhere, as along the south coast of the Province of Santiago, in Cuba, igneous rocks have been replaced by iron ore through the agency of solutions connected in origin with rocks related to granite.

2. The iron-ore deposits of the second major class—the concentrations formed by surficial agencies—are of several different types:

(*a*) Residual deposits formed by the alteration and concentration of iron minerals very nearly in place; including lateritic deposits formed by the removal of material other than iron, and by the alteration of the iron minerals to amorphous or crystalline ferric hydrate, with more or less adsorbed water; also gossans of sulphide ore bodies formed by oxidation of the sulphides.

(*b*) Bog ores formed by the deposition of ferric hydrate and ferrous carbonate from surface solutions. The iron in these deposits is precipitated from solutions by organic matter or by the evaporation of its solvent.

Where oxidizing iron-bearing solutions come into contact with rocks rich in iron sulphide some of the iron-ore material may obviously be formed practically in place, so that deposits of types *a* and *b* may grade into each other.

(*c*) Sedimentary ores formed by weathering and subaqueous deposition. Some of these deposits, such as magnetite beach sands, may be of purely mechanical origin, but more frequently chemical agencies form subaqueous deposits of iron silicates or carbonates, or precipitate iron from solutions as ferric hydrate.

(*d*) Replacement and vein deposits formed by iron-bearing waters of surficial origin in the course of artesian circulation. Deposits of this type are so similar to the deposits of siderite formed by the cooler solutions of igneous origin that the two can be discriminated only with difficulty. The ore minerals are carbonates and more or less ferric hydrate.

The following classification, based on the above distinctions, will be used in describing the deposits here considered:

- 1. Deep-seated deposits
  - (*a*) Gabbroic.
  - (*b*) Granitic
    - Deposits within the igneous rocks.
    - Contact-metamorphic deposits.
    - Replacement deposits and veins.
- 2. Surficial deposits
  - (*a*) Residual deposits.
  - (*b*) Bog ores.
  - (*c*) Sedimentary deposits.
  - (*d*) Replacement deposits and veins.

This classification takes no account of the complex metamorphic agencies that alter many deposits and conceal evidence of genesis. In many places dynamic metamorphism has brought about changes that have made ore bodies from leaner aggregates of iron minerals. Replacement, solution, and redeposition act upon ore bodies to enrich or to impoverish them. The result of these processes may be an ore body whose history is exceedingly complex. Such ore bodies will be classified so far as possible according to their original mode of deposition.

THE UTILIZATION OF IRON ORES.

In considering statistics of the consumption of the iron ore it must be remembered that the industry involves other factors than the possession of iron ore. Minor factors are the availability of metals used for making alloy steel and of flux for smelting. The dominant factor in the present state of the industry, however, is possession of coal suitable for making coke of metallurgic grade. The importance of this factor is shown by the fact that in order to smelt 42,000,000 metric tons of Lorraine ore and to convert the resultant pig iron to products of finished steel, coal and coke would be required equivalent to at least 55,000,000 metric tons of coal.[5]

According to statistics published by the American Iron and Steel Institute, 44,431,905 short tons of coke was used in the United States in 1916 to produce 39,434,797 long tons of pig iron. The weight of fuel needed to convert iron ore to pig iron is not greatly in excess of the weight of ore utilized, so that if the making of pig iron were the ultimate end sought it might be almost as economical and efficient to ship coal to an ore-mining district as to ship ore to a coal-mining district. But the making of pig iron is only the first step in the industry. Steel and manufactured products must be made from the pig iron, and each step requires fuel. For that reason the centers of the iron and steel industries are in or near coal-mining districts, the three largest iron and steel centers of the world being connected with the Appalachian, the British, and the Rhenish coal fields.

The use of charcoal in the iron industry is steadily decreasing and the use of electro-metallurgy is as steadily increasing. The employment of processes that permit the utilization of coals of lower grade than those heretofore used for the manufacture of metallurgic coke will greatly enlarge the territory suitable for the development of the iron industry.

The principal raw materials required for producing pig iron are ore as a source of metal, coke as fuel, and limestone as furnace flux; but as limestone is, in general, much more widely distributed than iron ore and coking coal the ordinary prime necessities for the maintenance of an iron industry consist of ore of commercial grade and of coal suitable for making coke. Nearly all the world's iron smelting is done in or near districts where coking coal is mined.

The coal equivalent of the coke employed in smelting weighs less than the ore that goes into the furnace, but the operations involved in the production and fabrication of finished steel require considerably more coal than ore. The economics of the iron industry, epitomized in the well-known saying "ore goes to coal," are illustrated by Sweden and Spain, which, though possessing great reserves of rich iron ore, have iron industries that are almost negligible and send millions of tons of ore to countries that are better supplied with fuel.

ACKNOWLEDGMENTS.

The present paper is the outgrowth of a report compiled by the United States Geological Survey for use at the Peace Conference and not originally intended for publication. As it is believed, however, that the information is of general interest it has been brought together here in compact form. The discussions concerning the

[5] Spencer, A. C., in Smith, G. O., and others, The strategy of minerals, p. 133, 1919.

individual deposits are too brief for the student who desires great detail, but footnote references to the publications examined and the bibliography will, it is hoped, lead readily to the sources of the information. By far the greater part of the material consulted consists of the more readily available publications of governmental surveys and scientific societies and of articles in the technical press. The results of the study of the world's iron-ore resources compiled for the International Geological Congress in 1910 were of the highest value and offered a firm and comprehensive base for the present study. Next in value was the excellent and complete annotated bibliography published in the Journal of the Iron and Steel Institute of Great Britain, which pointed the way to many sources of information that would otherwise have been overlooked.

The work was done under the direction of J. B. Umpleby, who was at all times ready with helpful suggestions. The notes of Eleanora F. Bliss on consumption and production were freely used. The author feels particularly grateful to A. C. Spencer for helpful criticisms and suggestions and for the readiness with which he made available his vast store of unpublished information.

SUMMARY.

GEOGRAPHIC DISTRIBUTION OF IRON-ORE DEPOSITS WITHIN THE COUNTRIES OF NEW EUROPE.

Though the Peace Conference rearranged the political divisions of Europe, racial antagonisms, class struggles, and divergent economic demands or needs promise to make still further rearrangement necessary. Enough information is available, however, to show the new political relations of the larger deposits of iron ore in Europe. The political divisions used in this study are shown on Plate I (in pocket). The principal changes in the ownership of iron-ore resources can be summarized very briefly.

The part of the minette ore basin that lies in Lorraine Annexée has been returned to France. Of the German bog ores, the part estimated for Posen has been allotted to Poland, as has also the small deposit of Triassic ores in the part of Silesia whose ultimate possession remains to be determined by a plebiscite. The small deposits near Krakow, in Galicia, also fall to Poland.

The iron ores of Bohemia and Moravia, as well as those of the Szepes-Gömör district, which lies in the Ruthenian country, on the southern slopes of the Karpathians, have been allotted to Czecho-Slovakia. The deposit in the Vares district, in Bosnia, has been allotted to Jugo-Slavia. The deposits in eastern and southeastern Hungary (those of Banat and of Hunyad being the only extensive ones) are regarded as belonging to a greater Rumania.

Poland and Finland, parts of old Russia, are regarded as independent. The uncertainty in regard to Poland's eastern frontier and the rearrangement of the Baltic States does not affect the allocation of the iron reserves in that region, because the unallotted territory contains no ores valuable enough to be reported. The rest of old Russia has been divided geographically into the Ural Mountain region, central Russia, southern Russia (which includes the Crimea and is largely Ukrainian), and the Caucasus.

The following table shows, in quantities and percentages, the geographic distribution of the iron in the iron-ore deposits of Europe, and the accompanying chart (fig. 1) shows in graphic form the distribution by percentages.

Iron reserves of Europe.

[Millions of metric tons.]

	Known.	Probable.	Possible.	Total.	Per cent.
France	1,790.0	1,053.6	1,526.0	4,369.6	35.2
United Kingdom	317.5	464.3	1,472.3	2,254.1	18.2
Sweden	442.9	376.1	729.6	1,548.6	12.5
German Republic	255.6	207.4	911.7	1,374.7	11.1
Spain	353.1	116.3	148.9	618.3	5.0
Central Russia	140.0	180.0	204.1	524.1	4.2
Norway	85.8	56.4	330.1	472.3	3.8
Southern Russia (Ukraine)	71.0	131.0	142.0	344.0	2.8
Czecho-Slovakia	22.3	84.8	58.6	165.7	1.3
Ural region	52.3	60.8	47.8	160.9	1.3
Poland	11.2	50.6	69.2	131.0	1.1
Austrian Republic	76.7	9.5	30.0	116.2	.9
Luxemburg	60.0	21.0	....	81.0	.7
Greece	18.0	18.0	22.5	58.5	.5
Belgium	2.5	14.1	23.2	39.8	.3
Portugal	8.2	16.2	12.5	36.9	.3
Jugo-Slavia	9.5	8.0	16.0	33.5	
Caucasus	6.2	6.2	18.6	31.0	
Finland	3.6	11.4	1.9	16.9	
Rumania	2.5	8.5	4.0	15.0	.8
Italy	5.5	3.3	....	8.8	
Switzerland	1.2	....	2.2	3.4	
Bulgaria	....	.7	....	.7	
	3,735.6	2,898.2	5,771.2	12,405.0	100.0

Figure 2, which is drawn to scale to facilitate visual comparison, shows the iron content of the ore in the reserves of the principal countries of Europe. The figure is based on statistics that are not of equal accuracy throughout and requires some explanation.

France has the largest reserves. She stands so clearly above the other countries of Europe that there is no question of her holding first place.

The United Kingdom is ahead of Sweden in the iron content of her total reserves. Very good information is available in regard to the iron-ore deposits of both countries. The Swedish reserve is preponderantly magnetite of high grade; the British reserve is carbonate and hematite of much lower grade. The "known" and "probable" ore can be estimated for both countries with considerable assurance as to the accuracy of the figures. The estimation of the "possible" reserves involves decisions on matters that are open to

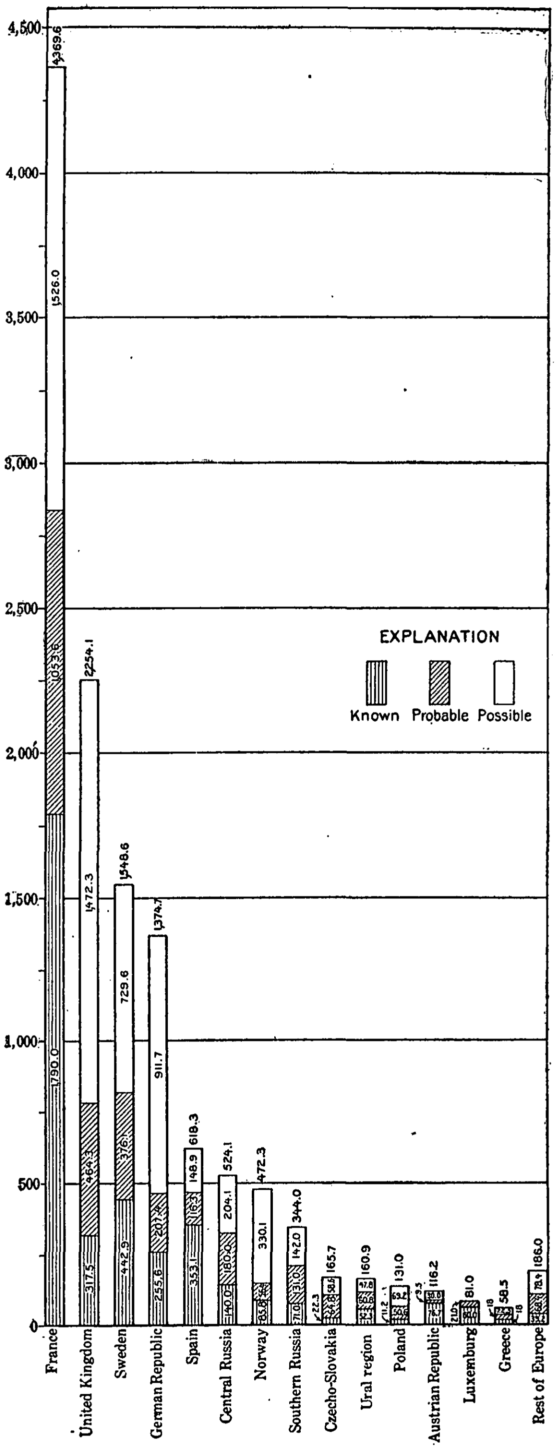

FIGURE 1.—Comparative chart showing the estimated known, probable, possible, and total amounts of iron in the iron-ore deposits of several countries of Europe.

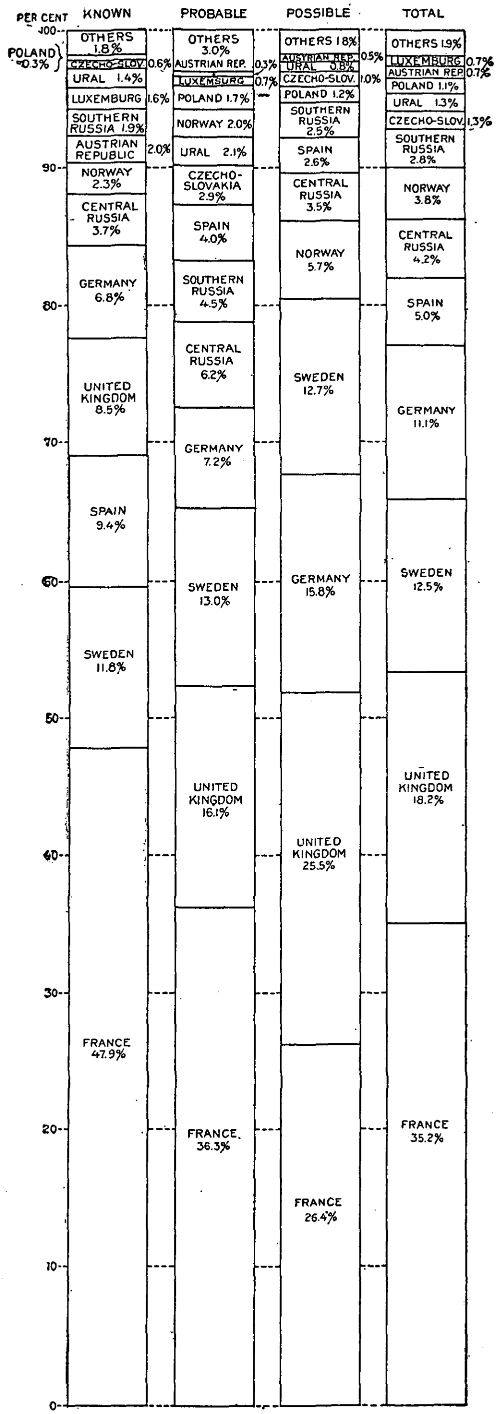

FIGURE 2.—Chart exhibiting estimated proportions of Europe's iron inventories contained in the ore deposits of the several countries.

controversy and must depend on the attitude of the person making the estimate. The quantity of ore in Sweden that can be put in this class depends on the depth to which mining can be carried in ores that, under normal conditions, are bound to have a ready market. The estimate for Great Britain is complicated by the fact that much of the ore there can not compete with foreign ores, even if it may be readily minable, so that in spite of the enormous British reserves the use of imported ores in England is increasing and the production of domestic ores is decreasing. The enormous reserves of iron that English geologists have estimated as in the ground in Great Britain are undoubtedly there, but they will probably not be used in a quantity greater than that shown by the figure given under "possible" reserves, and even that figure may be too large.

The fourth rank should go to Germany. The estimates of her ore reserves have been carefully worked out and are acceptable for "known" and "probable" ore. The accuracy of the large figure for the "possible" reserve depends on the future of the Salzgitter-Iselde and Württemberg-Bavarian fields. Production in both these districts was steadily increasing before 1914. Germany has shown her capacity to use her resources thoroughly enough to justify the conclusion that she will continue to use them in spite of the native pessimists who can foresee her future as only that of an agrarian State.

Spain stands fifth. Her measured and available reserve is next to that of Sweden, but difficulties and expenses of transportation, which have been left out of consideration in calculating her reserve, make it questionable whether her entire reserve will be mined.

Central Russia is sixth in quantity of iron ore. The present outlook is that political conditions will delay the normal development of this field.

Norway has a large quantity of concentrating ore that has not been so useful in the past as it may be in the future.

Southern Russia, in its ore in Krivoi Rog and Kerch, has a valuable reserve, and future development may give her a higher place than the eighth, her present rank.

Czecho-Slovakia, the Ural Mountain region, the Austrian Republic, and Luxemburg have nearly equal amounts of known ore, and Poland has a reserve of unknown value. All these may be put in the same class so far as reserves of iron ore are concerned. The principal reserves in Czecho-Slovakia are the oolitic silicate and brown ores of central Bohemia and the spathic ores of the Szepes-Gömör district. The possession of these reserves and of those in that part of the Dombrova coal basin that lies in former Austrian Silesia places Czecho-Slovakia in a strong position to establish and maintain an iron industry.

The Ural Mountain region contains ore deposits of many different types, and further investigation may discover deposits that have not been included in the present estimate.

The Austrian Republic has an excellent reserve in the spathic ores of Styria and Carinthia, but its utilization is more or less dependent on foreign coal.

The Luxemburg part of the minette basin constitutes a fully explored and valuable reserve, but it is a problem how completely it will be exhausted. Only about a third of the reserve has been assigned to the "probable" class.

The reserves of Poland are composed largely of brown ores that in a critical scheme of classification lie close to the line that separates available from unavailable ores. Slight changes in technology may increase their value; or a slight decrease in the cost of competing ores may make them valueless.

The chromiferous ores of Greece will be a desirable addition to the European supply of iron ore for some time to come.

Belgium, Portugal, Jugo-Slavia, the Caucasus, Finland, Rumania, Italy, Switzerland, and Bulgaria all have small reserves. Turkey in Europe contains some ore; Holland, Denmark, and the Baltic States contain practically none.

GEOLOGIC DISTRIBUTION.

Eckel[6] classifies the iron ores of Europe in regard to type as follows:

Types of iron ore in Europe.

	Millions of metric tons.	Per cent.
Sedimentary basin deposits	8,407	70
Normal replacements	1,441	12
Contact deposits and doubtful magnetites	1,912	16
Residual deposits	272	2

By using the classification already outlined and giving total iron content in "known," "probable," and "possible" ore, as shown by a detailed study of the reports on the deposits, the author obtained, independently, figures that are very close to those given by Eckel. They are shown in figure 3, which indicates also the distribution of the sedimentary ores in geologic time.

Europe contains only small deposits of pre-Cambrian sedimentary ores like those of the Lake Superior region and Minas Geraes. Krivoi Rog, in southern Russia, is the only definitely sedimentary deposit which is believed to be pre-Cambrian. Some of the concentrating

6 Eckel, E. C., Iron ores, p. 41, McGraw-Hill Book Co., 1914.

magnetite ores of Scandinavia may belong to the same class, but the evidence as to their origin is not complete.

Later sediments cover so large a part of Europe that the exposures of Ordovician rocks there are very small. The only valuable sedimentary ores of that horizon are found in the folded rocks of the Armorican Peninsula, in Normandy.

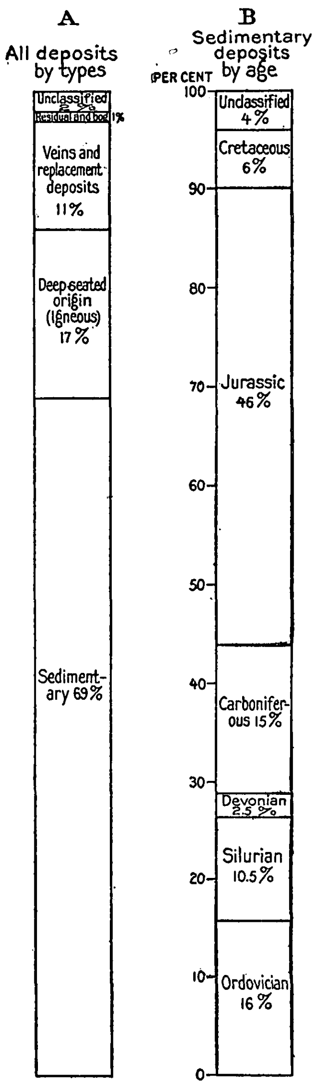

FIGURE 3.—Diagrams showing proportions of Europe's estimated iron reserves contained in ore deposits of different types (A) and different geologic ages (B).

Silurian oolitic ores are found in Brittany-Anjou, in the Thuringian Forest, and in central Bohemia, and there are other Silurian sedimentary ores in Spain in the ranges west of the Ebro. The famous Clinton ores o f the eastern United States of America are of this age.

Devonian rocks are also of slight extent in Europe, and the sedimentary ores of that age are widely scattered in small bodies. The largest bodies are those of the Lahn-Dill syncline, the Kellerwald-Sauerland region, and the Harz Mountains, in Germany; of the Liége-Namur district, in Belgium; and of the March Valley, in Moravia. The ores of Belgium and Moravia are no doubt bedded ores, but the genesis of the Devonian ores in Germany is uncertain.

Carboniferous sedimentary ores are mined only in Great Britain, but those in the Campine coal field of Belgium may have a possible future.

To the Jurassic belong 46 per cent of the sedimentary ores in Europe, which are almost entirely oolitic ores. Oolitic Jurassic ores are found in the Lorraine Basin, in Haute-Marne, and in the Jurassic remnants of northwestern Germany. Sedimentary brown ores occur in the Jurassic of Poland. Oolitic silicate ores are found in the Jurassic at Chamoson and in the Erzegg-Planplatten district of Switzerland. Carbonate ores that are in part oolitic are found in the Jurassic series in England from Cleveland to Gloucester.

According to De Lapparent[7] early and middle Jurassic time, during which these ores were formed, was a period of gradual marine transgression under uniform rather high temperature in eastern Europe. The sediments deposited during the earliest part of the Jurassic were apparently sandy and included much coarse material and were therefore not very favorable to the deposition of iron ore. During the later part of early Jurassic and during middle Jurassic time the land areas were being eroded more slowly and the littoral deposits were rich in iron precipitates. Late Jurassic time was a period in which calcareous sediments were laid down, and in which large iron deposits were not formed, though some of the English ironstones belong in the lower horizon of the upper Jurassic.

Cretaceous sedimentary ores do not form a very large part of the sedimentary ores of Europe. They are found in the Salzgitter-Iselde field of Germany and in the district west of the Rhine. Cretaceous ores are found also in Wilts and Kent, England.

The only important ores of recognized sedimentary type later than Cretaceous are the Pliocene ores of Kerch, on the Crimean Peninsula.

Next to the sedimentary ores in value are those of deep-seated origin. The ores of the Scandinavian massif and the big magnetite masses of Gora Blagodat and Magnitnaia, in the Ural Mountains, comprise the larger part of the European reserves of this type. Smaller deposits of magnetite in the Ural Mountain region and in the mountains between Bohemia and Germany make up the remainder. The amount of undesirable titaniferous ores in Europe is small compared with the deposits of titaniferous magnetites in the Adirondacks and in the Bushveld complex in South Africa. Deposits at Taberg in Sweden, at Val d'Aosta in Italy, on the Lofoter Islands, and in the Ural Mountain region are their only representatives.

Vein and replacement deposits are scattered through Europe and occur in rocks of all ages. All the deposits in Spain except those in the ranges west of the Ebro, all those in the Pyrenees, the deposits of Siegerland and Spessart in Germany, of Styria and Carinthia in Austria, all those in central Russia, and many of those in the Ural Mountain region, and in Cumberland and Lancaster in England belong to this class. These deposits supply a large part of the low-phosphorus ore mined in Europe—the type of ore required for making Bessemer steel.

Residual and bog ores are also widely distributed, but the only large deposits of these types are the chromiferous ores of Greece.

An unclassified group contains the pyritic ores from which the "purple ore" is derived, minor deposits that have been grouped together, and deposits on whose genesis evidence is lacking or too conflicting for decision.

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[7] Lapparent, A. de, Traité de géologie, 4th ed., vol. 2, pp. 1045–1056, Paris, 1900.

PRODUCTION AND CONSUMPTION.

The production and the consumption of iron ore in Europe in 1913 are summarized in the following table and in figures 4 and 5, which are based on official statistics of production, export, and import. Consumption represents production plus imports minus exports—that is, ore available for consumption. The figures showing consumption are not so accurate as those showing production, for no account is taken of changes in stocks.

Iron ore produced and consumed in Europe in 1913.

Country or district.	Production. Quantity (metric tons).		Production. Per cent of total.	Consumption. Quantity (metric tons).	Consumption. Per cent of total.
Austria-Hungary:					
Austria	3,039,324				
Hungary	2,059,076				
Bosnia	220,131				
		5,318,531	4.9	6,155,000	5.6
Belgium		149,450	.1	7,100,000	6.5
France:					
Lorraine	19,978,937				
Normandy	812,984				
Brittany-Anjou	269,703				
Pyrenees	393,844				
Other departments	462,402				
		21,917,870	20.4	13,000,000	11.9
German Empire:					
Alsace-Lorraine	21,136,265				
Prussia	5,669,786				
Silesia	[165,545]				
Hesse	887,486				
Bavaria	485,254				
Brunswick	256,879				
Saxony	2,725				
Other German States	169,508				
		28,607,903	26.5	37,995,000	34.8
Greece		309,956	.3		
Italy:					
Grossetto	27,698				
Livorno (Elba)	548,672				
Bergamo-Brescia	11,762				
Luca	3,302				
Cagliari (Sardinia)	11,682				
		603,116	.55	601,000	.6
Luxemburg		7,333,372	6.8	9,005,000	8.3
Norway		544,443	.5		
Portugal		49,162	.05		
Russia:					
South Russia	6,880,931				
Krivoi Rog	[6,347,600]				
Kerch	[479,500]				
Ural region	1,800,206				
Poland	311,228				
Central Russia	526,548				
Siberia and Caucasus	3,604				
Northern Russia	3,292				
		9,525,809	8.8	9,100,000	8.4
Spain:					
Vizcaya	3,864,593				
Almería	1,350,247				
Santander	1,278,087				
Guadalajara-Teruel	940,835				
Other provinces	2,427,906				
		9,861,668	9.1	954,000	.9
Sweden:					
Norbotten	4,913,603				
Central Sweden	2,428,659				
Other districts	133,309				
		7,475,571	7.0	1,120,000	1.0
United Kingdom:					
Scotland	601,055				
Ireland	60,977				
Cleveland	6,136,595				
Northampton	2,963,521				
Lincoln	2,683,117				
Stafford	904,976				
Other districts	2,904,842				
Coal-mine ore	[1,286,739]				
		16,254,085	15.0	24,000,000	22.0
		107,950,703	100.0	109,030,000	100.0

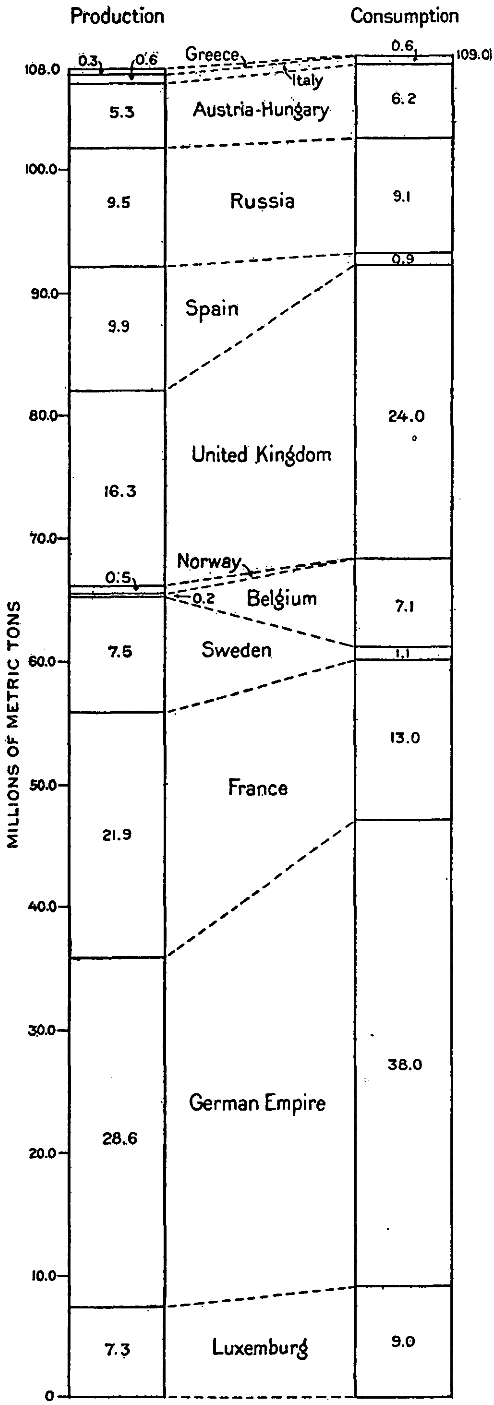


FIGURE 4.—Chart showing amounts of iron ore produced and consumed in Europe as a whole and in the several European countries in 1913.

The excess of 1,000,000 tons of ore available for consumption over the quantity of ore produced represents the imports from countries outside of Europe, including a part of the 1,350,000 tons produced in Algeria.

Figure 4 shows that Europe is practically self-supporting so far as its iron-ore industry is concerned. Italy, Austria, Hungary, and Russia are nearly self-supporting. Spain as exporter and the United Kingdom as consumer form a group, and France, Germany, Luxemburg, and Belgium consumed the excess of Scandinavian as well as their domestic production.

Figure 5 shows the position of the individual countries in 1913 as producers or consumers. Norway, Sweden, and France had large oversupplies to export. Belgium, the United Kingdom, and the German Customs Union (Germany and Luxemburg) were forced to import a large part of the ore they used.

Figure 6, which is based on statistics for 1913, shows the changes in producing capacity brought about by the war. The striking feature shown is the reduction of the output of Germany from 26.5

per cent to only 7.5 per cent of the output of Europe. The diagram also indicates the splitting up of Austria-Hungary and of Russia.

The iron industry in Europe labors under several disadvantages as compared with the industry in the United States. Perhaps the greatest of these disadvantages is the low output of iron per man employed in mining ore. The following table gives some figures for comparison:

Iron in ore mined per man per year.

	Tons.
Sweden	395
Lorraine Annexée	378
French Lorraine	375
Luxemburg	355
France outside of Lorraine	300
Germany outside of Lorraine Annexée	92
United Kingdom	230
Spain	140
United States	590

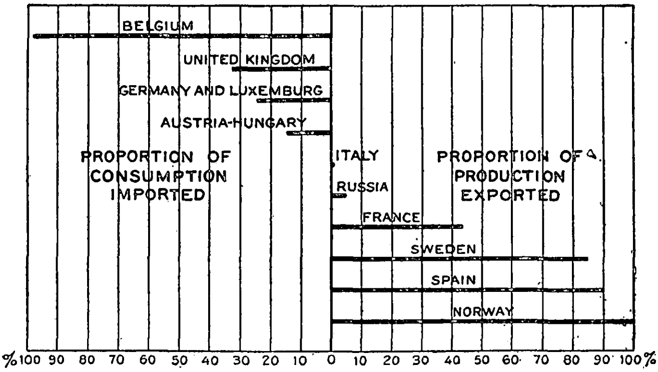


FIGURE 5.—Chart showing proportion of total iron ore consumed supplied by net imports of proportion of total iron ore produced going to net exports in 1913 for several countries in Europe.

The figures representing the annual output per man in the other important branch of the iron industry, coal mining, show a similar difference between the product of labor in Europe and in the United States.

A further disadvantage in Europe appears to be the comparatively low blast-furnace output. In the United States the tendency to develop or improve the unit and to decrease the number of units employed has resulted in an annual output of 120,000 tons per blast furnace. In Europe, where the tendency is to keep old equipment in service as long as possible without improvement, the annual output per furnace is much less. In Germany it is 55,500 tons and in England it is 28,000 tons.

If greater output per unit is a measure of efficiency Europe falls far below the United States in the three elements of output in the iron industry—iron in ore mined per man, coal mined per man, and pig iron produced per furnace; but as Europe has heretofore been able to compete with the United States in cost of product she must have had some counterbalancing means of economy in production. One of these may have been cheaper transportation. In the United States the great ore-producing center is the Lake Superior district, and the great coal-producing center of the Appalachians is on an average 725 miles away from the iron and is 125 miles from tidewater. In England coal and iron are close together and are so near tidewater that they can be cheaply shipped for export. On the Continent the Lorraine Basin is separated from the Westphalian coal field by only 200 miles, and the coal field is connected with tidewater by an excellent canal and river system.

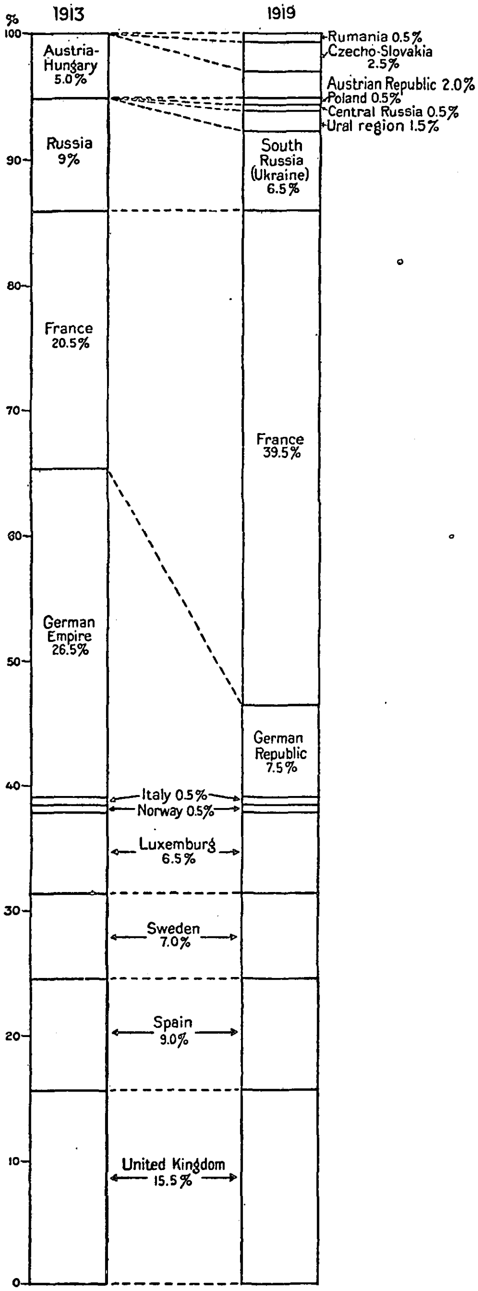


FIGURE 6.—Chart showing proportional contributions of the several countries to the total quantity of iron ore produced in Europe in 1913 and proportions of potential output under the political subdivisions of 1919.

Another means of economy in production in Europe has been an abundant supply of cheap labor, which has enabled the European producers to turn out cheap products from comparatively poor natural material without employing labor-saving devices to the extent that they have been employed in the United States. This advantage, however, has had the evil effect of producing a surplus of finished products for the domestic market. Cheap labor, more or less discontented, can not supply the ultimate market supplied by high-priced labor, with its higher standard of "necessities." The fact that the domestic markets in Europe could not take their proper share of the finished products no doubt added to the need for foreign markets, and that need had its due share in precipitating the World War.

Europe's supply of labor is bound to be great, but it does not now seem to be willing to continue cheap. It is difficult to forecast the future of Europe's iron industry, but a rather chaotic period of reconstruction seems inevitable. Better-paid labor will enforce more efficient mining and smelting, greater mass production, and the further use of labor-saving devices; and deposits that are not well adapted to the altered conditions will be abandoned and foreign deposits that can supply cheaper raw materials will be drawn upon. Among such foreign deposits would be those of Cuba and Brazil.

In countries where nearly all the ore mined is exported, such as Sweden, Norway, and Spain, the future will probably bring only slight changes. The United Kingdom, with her large mining and smelting industry, will feel the new conditions keenly; indeed, her industrial future will doubtless depend on the speed with which she adapts herself to those conditions. The future of the iron industry of France and Germany will depend on their cooperation. The extent to which Westphalian coal and Lorraine iron ore are utilized together will measure the extent of their success or failure. Luxemburg also is dependent on Westphalian coal but has not sufficient iron ore to export it to Germany in exchange for coal. Belgium is almost entirely dependent on foreign deposits for the iron ore to supply her blast furnaces, and she has in the past drawn on Westphalia for coal to augment her own supplies. Czecho-Slovakia and Russia are almost entirely independent as to raw materials. Italy lacks coal and does not make much pig iron, but she has developed a very good steel industry from imported material. Austria is dependent on foreign sources for coal. If she is to use English coal, as she has in the past, she must import it through territory that has been hostile to her. Poland has not the resources to develop more than a small iron industry. Switzerland, Holland, Denmark, and the new Baltic States have no resources of their own on which to base any extensive iron industry.

COMPARISON OF CONTINENTS.

The world's iron-ore resources are not sufficiently explored to permit an exact comparison of the resources of the several continents, but an approximate comparison may be allowable.

The reserves of North America are well known but have never been calculated to the same exactness nor to the same lower limit of grade as those of Europe. If so estimated they could probably be counted on for three times as much iron as those of Europe.

The resources of South America are not so well known. Extensive deposits of deep-seated origin lie along the western slopes of the Andes, and immense pre-Cambrian reserves are found in Minas Geraes and Urucu in Brazil. The ore in the Minas Geraes district that contains over 45 per cent of iron, according to an estimate made by the author from information supplied by E. C. Harder and B. L. Miller, carries more iron than that in all Europe, and the inclusion of ores of lower grade would greatly increase the estimate. If its reserves are estimated as closely as those of Europe have been South America would undoubtedly prove to have at least twice as much iron as Europe.

The information concerning Africa is very indefinite. Except the writers of some French and German reports on the iron-ore deposits of northern Africa, the men reporting on the deposits of that continent have regarded them as abstract geologic phenomena, whose economic value was of no interest. It is this lack of records of practical value that has compelled the writer to estimate the iron ores of Africa at about one-sixth of those of Europe.

The iron-ore reserves of Asia are not well known. Mines are working in China and Chosen, India has considerable reserves and a small industry, and Siberia has extensive reserves. Large deposits of laterites are found in the Philippines. Probably Asia can be counted on for at least three-fourths as much iron as Europe.

Oceania has enough iron ore to support a local industry, but her reserves do not amount to an appreciable part of the world's total.

A summary of the iron-ore reserves of the world, in which those of Europe are reckoned as unity, shows the following comparative figures, which, however, because of a lack of complete knowledge, are admittedly not precise:

Iron-ore resources of the world.

Europe	1
North America	3
South America	2
Africa	$\frac{1}{6}$
Asia	$\frac{3}{4}$

These figures indicate that the world's available supply of iron would last more than 1,000 years at the rate of production of 1913. On the other hand, if production continues to increase at the pre-war rate, which was 25 per cent in every five years, the supply would be exhausted in about 130 years. Use at this rate would involve the consumption of 6,000,000,000 tons of pig iron in the year 2043, as compared with about 80,000,000 in 1913. A growth of industry so great as this output would imply does not seem to be probable. A considerable reduction in the rate of increase in production and a correspondingly longer life of the world's iron-ore reserves seem far more likely.

SPAIN.[8]

DISTRIBUTION, CHARACTER, AND EXTENT OF THE DEPOSITS.

Deposits of iron ore are scattered all through Spain. (See Pl. II, in pocket.) Fortunately the larger deposits are not far from tidewater. Some of these deposits have been for many years the sources of considerable iron ore and they have therefore been carefully studied, so that the information about them is unusually complete. The deposits are here grouped geographically according to the mountain ranges in which they are found and by provinces. The greater part of the data on the available reserves is taken from a report made by Vidal.

CANTABRIAN CORDILLERA.

The mountain range along the northern coast of the Iberian Peninsula furnishes more than half the iron ore produced in Spain. The deposits are found in the Provinces of Lugo, León, Oviedo, Santander, Vizcaya, and Álava.

Lugo Province.[9]—The ore bodies in the Province of Lugo are brown ore and spathic ore, which occur in crystalline Paleozoic schists. The greater part of the ore in Lugo contains a medium amount of phosphorus. The ores of Incio and Brollón are of Bessemer grade. Ore is found also at Vivero, Villamea, Muras, Villaodrid, and Basmonde. Except the ore at Villamea, which contains an average of 35 per cent of iron, these ores contain more than 48 per cent of iron. According to Vidal[10] there are 122,000,000 metric tons of ore in the province. In the estimate below a little has been added in the "possible" class to this total.

Iron resources of the Province of Lugo, Spain.

[Millions of metric tons.]

	Ore.	Iron.
Known	70	35.0
Probable	30	13.5
Possible	40	16.0

[8] Vidal, L. M., Résumé des gisements de fer de l'Espagne: The iron-ore resources of the world; an inquiry made upon the initiative of the Executive Committee of the 11th International Geological Congress, vol. 1, pp. 47-85, Stockholm, 1910. Ahlburg, J., Die nutzbaren Mineralien Spaniens und Portugals: Zeitschr. prakt. Geologie, vol. 15, pp. 183-210, 1907. McBride, H. A., Production of iron ore in Spain: Mines and Minerals, vol. 31, pp. 577-580, 1911.

[9] Teichgräber, —, Eisenerzvorkommen in Galicien, Spanien: Stahl und Eisen, vol. 24, pp. 332-334, 1904.

[10] Op. cit., pp. 54-57.

León Province.[11]—The deposits in the Province of León are of two very different types and value. At the Wagner group of mines, between Ponferrada and Astorga, the ore occurs as bedded lodes of siderite superficially altered to brown ore. The ore contains from 49 to 52 per cent of iron and 1.6 per cent of phosphorus. The deposit is estimated to contain 25,000,000 tons. Besides this there is in the province 100,000,000 tons of low-grade ore containing 32 to 44 per cent of iron, 0.13 to 0.5 per cent of phosphorus, and high silica, deposited in ferruginous sandstone. In estimating the reserve in this province the deposit at the Wagner mines has been considered "known," for the only factor militating against its exploitation is the difficulty of transportation. The deposits in sandstone have been classed as a "possible" reserve.

Iron resources of the Province of León, Spain.

[Millions of metric tons.]

	Ore.	Iron.
Known	25	12.5
Possible	100	35.0

Oviedo Province.[12]—In Oviedo, as in León, there are two kinds of deposits. Near the Picos d'Europa there are beds of brown ore and hematite in Carboniferous limestone. They contain 57 to 64 per cent of iron, 0.005 to 0.15 per cent of sulphur, and 0.011 to 0.123 per cent of phosphorus. Of ore of this class it is estimated that there is 62,000,000 tons. In central Oviedo, at Proaza, Teverga, Careno, and other places, there are deposits of ferruginous sandstone which has been mined for use as flux in the smelters at Bilbao.

Iron resources of the Province of Oviedo, Spain.

[Millions of metric tons.]

	Ore.	Iron.
Known	60	36.0
Probable	50	20.0
Possible	50	17.5

Santander Province.—About 12 per cent of the iron ore produced in Spain comes from the Province of Santander. It is Bessemer ore of good grade, of the sort that has given high repute to Spanish ore.

[11] Jones, J. A., Development and working of minerals in the Province of León, Spain: Inst. Min. Eng. Trans., vol. 20, p. 420, 1901.

[12] Grosch, P., Roteisensteinlager in Asturien: Zeitschr. prakt. Geologie, vol. 20, pp. 201-205, 1912. Jones, J. A., The Devonian iron ores of Asturias: Inst. Min. Eng. (London) Trans., vol. 18, pp. 279-292, 1899-1900. Adaro, L. de, and Junquera, G., Criaderos de hierro de Asturias: Inst. geol. España Mem., vol. 2, 1916. Nicou, P., and Schlumberger, C., L'industrie minière et métallurgique dans les Asturies: Annales des mines, 10th ser., vol. 7, pp. 203-260, 1905.

The deposits are brown ores in clay, which occur on a footwall of Cretaceous limestone and are said to be the result of the "decalcification" of the limestone. The deposits range in thickness from 10 centimeters to 70 meters and are not covered. The larger deposits are at Cabarga and Camargo and are mined by open cut. About 5,000,000 tons has been mined since an estimate of 22,950,000 tons was made by Vidal.[13] Allowing for developments and mining, it is estimated that the known ore in the province amounts to 20,000,000 metric tons, containing 9,000,000 metric tons of iron.

Vizcaya Province.[14]—The location of the deposits in the vicinity of Bilbao is shown in Plate III. These deposits have been the mainstay of iron-ore production in Spain, but they have probably passed their period of maximum productivity, though there remains a very considerable reserve.

According to De Launay [15] the deposits were formed by the replacement of limestone by ores derived from ascending solutions. Where the solutions passed through sandstone or shale, formations which are less easily attacked, they formed veins. The bodies have undergone metamorphism since their deposition. The ore minerals are siderite, hematite, and brown ore. Commercially four types of ore are recognized:

Vena: Very pure earthy hematite.

Campanil: Crystalline hematite with large crystals of calcite. ("Campanil" means bell metal, a name suggested by the resonance of the ore when struck with a hammer.)

Rubio: Red concretionary hematite.

Siderite: Found at depths.

Analyses of iron ore from the Province of Vizcaya, Spain.[a]

Type of ore.	Fe.	Mn.	CaO.	SiO_2.	P.
Vena	49 to 60	0.5 to 1.5	0.1 to 9	1 to 7	Trace.
Campanil	48 to 58	1 to 4	.5 to 5	3 to 6	Trace to 0.2
Rubio	48 to 58	.5 to 2	.5 to 2	2.5 to 14	Trace to 0.9
Siderite (calcined)	54 to 62				

[a] Vidal, L. M., Résumé des gisements de fer de l'Espagne: The iron-ore resources of the world (11th Internat. Geol. Cong.), vol. 1, p. 51, 1910.

The main masses of ore are found southwest of Bilbao along the flanks of an anticline striking northwestward for 30 kilometers and are 2 to 8 kilometers wide.

[13] Vidal, L. M., op. cit., p. 61.

[14] Brough, B. H., The iron-ore mines of Biscay: Cassier's Mag., vol. 23, pp. 697-709, 1903. Dann, E., Die Eisenerzlager und die Eisenindustrie von Bilbao: Stahl und Eisen, vol .33, pp. 1181-1185, 1232-1236, 1913. John, ——, Die Eisenerzlagerstätten von Bilbao und ihre Bedeutung für die zukünftige Eisenerzversorgung Grossbritanniens und Deutschlands: Glückauf, vol. 46, pp. 2002-2013, 2045-2052, 1910. Adams, F. D., Notes on the iron-ore deposits of Bilbao: Canadian Min. Inst. Jour., vol. 4, pp. 196-204, 1901.

[15] Launay, L. de, Traité de métallogénie: Gîtes minéraux et metallifères, vol. 2, pp. 380-381, Paris et Liége, 1913.

At the time the estimates given by Vidal were made the value of the siderite was not well recognized, and the extension of work to greater depths than those then figured now seems probable. Vidal's estimate of the ore near Bilbao [16] minus the ore mined since is accepted, and a considerable addition is made for "possible" ore from greater depth and further development.

Iron resources of the Province of Vizcaya, Spain.

[Millions of metric tons.]

	Ore.	Iron.
Known	35	17.5
Possible	30	13.5

Álava Province.—Near Villambrosa, in the Province of Álava, there is a vein of hematite ore, which, however, is of no economic value.

Summary for the Cantabrian Cordillera.—The table below summarizes the quantities of metallic iron in deposits in the Cantabrian Cordillera.

Iron in ores in the Cantabrian Cordillera, Spain.

[Millions of metric tons.]

Province.	Known.	Probable.	Possible.
Lugo	35.0	13.5	16.0
León	12.5		35.0
Oviedo	36.0	20.0	17.5
Santander	9.0		
Vizcaya	17.5		13.5
	110.0	33.5	82.0

THE PYRENEES.

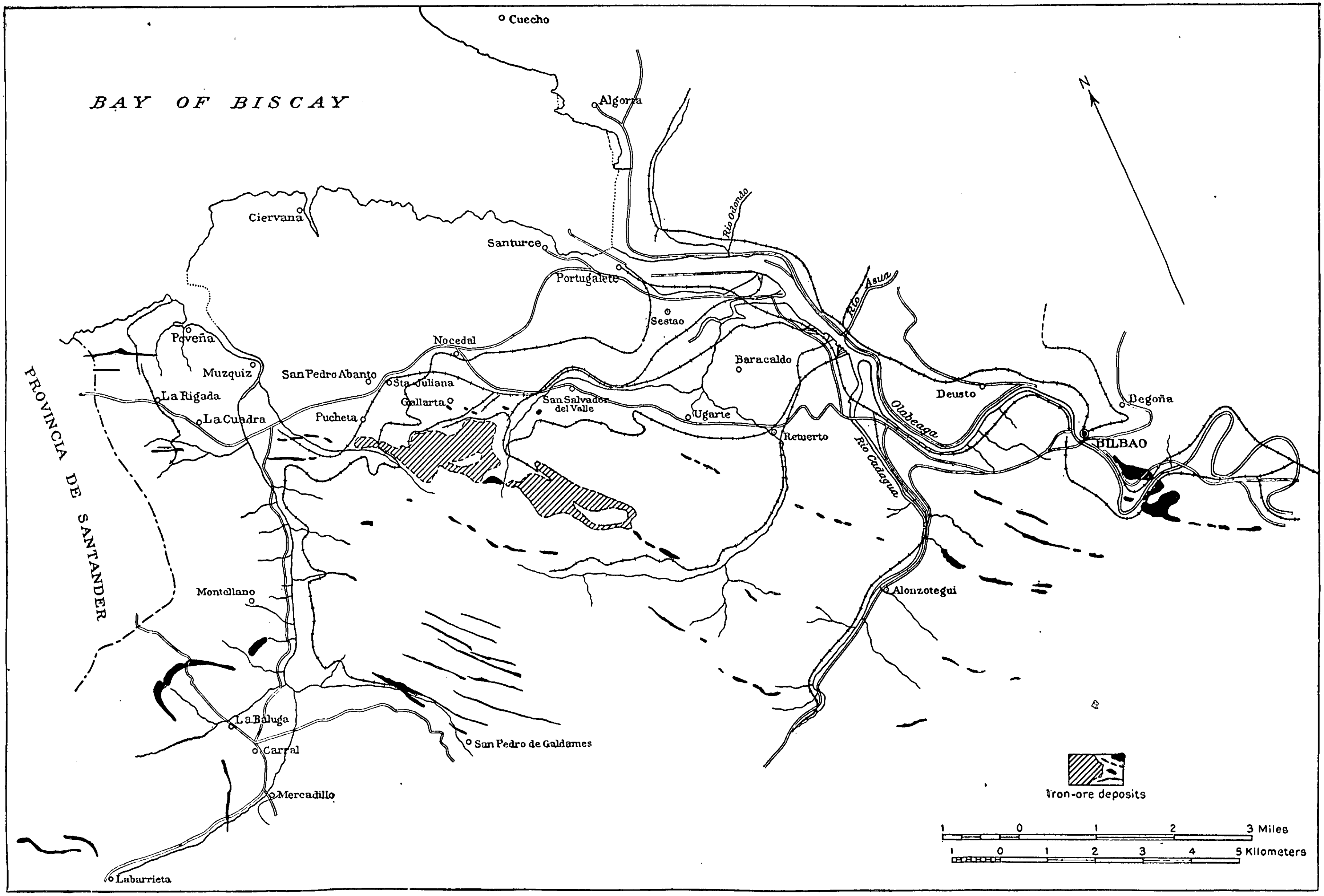
The deposits along the southern flanks of the Pyrenees are of far less extent than those of the range along the north coast. They occur in the Provinces of Guipuzcoa, Navarra, Huesca, Lerida, and Gerona.

Guipuzcoa and Navarra provinces.[17]—In the eastern part of Guipuzcoa, at Ardituri and Berastegui, and in Navarra, at Irun and Lesaca, there are bedded lodes of hematite and siderite. They appear to be of the same type as the ores of the eastern Pyrenees, in France. The hematite contains 40 per cent of iron; the calcined siderite 55 to 58 per cent of iron and low phosphorus.

At Cerain and Multiloa, in Guipuzcoa, there are brown ores that fill cavities in Cretaceous limestone.

[16] Vidal, L. M., op. cit., p. 53.

[17] Mallada, L., Datos geológico-mineros de varios criaderos de hierro de España: Com. mapa geol. Bol., vol. 26, pp. 152–203, 1899.



MAP SHOWING THE DISTRIBUTION OF IRON-ORE DEPOSITS IN VIZCAYA PROVINCE, SPAIN.

Iron resources of the Provinces of Guipuzcoa and Navarra, Spain.

[Millions of metric tons.]

	Ore.	Iron.
Known	8	3.6
Probable	4	1.8
Possible	4	1.6

Huesca Province.—From Huesca are reported deposits of magnetite at Queto, a vein of siderite near Bielsa, and brown ores in Triassic limestone at Calasanz. Nothing is recorded as to their extent or character.

Lerida Province.—In Lerida there is a vein of brown ore at Aynet de Besan, siliceous brown ore at Arseguel, very pure hematite in limestone at Ager, and brown ores that are said to be valuable at Bausen.

Gerona Province.—Near Celra, in the range between Celra and Gerona, there are some beds of brown ore interstratified with Silurian schists. They were formerly exploited for the furnaces at Le Creuzot. They appear to be extensive, but no data are given as to the extent to which they have been exhausted.

Summary for the Pyrenees.—The only ores in the Pyrenees on which quantities can be calculated are those of Guipuzcoa-Navarra, which, estimated in metric tons of iron, may be reckoned as—known, 3,600,000; probable, 1,800,000; possible, 1,600,000.

RANGES WEST OF EBRO RIVER.

In the ranges west of the Ebro there are several deposits of bedded brown ores and some hematite, which are associated with sediments of Silurian age. They are found in the Provinces of Logroño, Soria, and Saragossa.

Logroño Province.—In the Province of Logroño iron ores are found near Ezcaray, in the Sierra de la Demanda. They are of low grade, containing only 32 per cent of iron, and can be considered only as a "possible" reserve, comprising 20,000,000 metric tons of ore containing 6,400,000 metric tons of iron.

Soria Province.—Near Olvega there are reported to be small deposits of ores of low grade.

Saragossa Province.—The ore found near Tierga, in the Sierra de la Virgen, is of better grade, as it is nearly all hematite containing over 60 per cent of iron and low phosphorus. The known reserve amounts to 34,000,000 metric tons of ore containing 18,700,000 metric tons of iron.

Summary for ranges west of Ebro River.—The deposits in the Province of Logroño contain 6,400,000 metric tons of "possible" iron;

those in the Province of Saragossa contain 18,700,000 metric tons of "known" iron.

SIERRA MENERA.[18]

The iron ores of the Sierra Menera, a range that passes from the Province of Guadalajara into the Province of Teruel, lie near the boundary between these Provinces, as shown in figure 7. The deposits have been looked upon as a promising substitute for the declining deposits on the north coast. The detailed studies of these

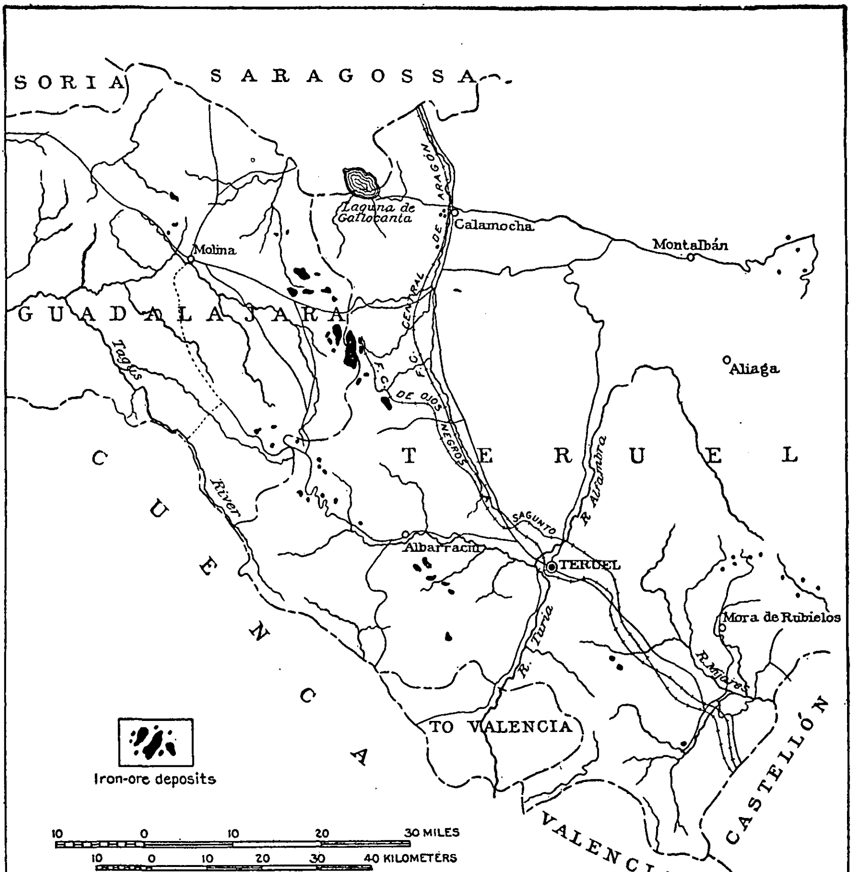


FIGURE 7.—Map showing deposits of iron ore in the Sierra Menera, Spain. (From Inst. geol. España Mem., 1918.)

deposits by Kindelan[19] rank among the most careful and thorough yet made.

The deposits are brown ores, very light in weight, associated with metamorphosed Silurian sediments. They contain over 50 per cent

[18] Kindelan, V., and Ranz, Manuel, Los criaderos de hierro de Guadalajara y Teruel: Inst. geol. Mem., vol. 3, 1918. Ysassi, V. de (edited by A. S. Callen), The iron mines of the Sierra Menera district of Spain: Am. Inst. Min. Eng. Trans., vol. 53, pp. 84-89, 1915.

[19] Kindelan, V., op. cit., pp. 1-121.

of iron, about 5.5 per cent of silica, from 2 to 11 per cent of manganese, and 0.012 to 0.169 per cent of phosphorus.

The estimate below is based on data furnished by Kindelan.

Iron resources of the Sierra Menera, Spain.

[Millions of metric tons.]

	Ore.	Iron.
Known	130	65
Possible	60	24

SIERRA GUADALUPE.

In the hills between the Tagus and the Guadiana, in the Province of Cáceres, there are lenses of ore in early Paleozoic metamorphic rocks. The ore is siderite, hematite, and brown ore, some of it manganiferous. It is variable in composition, containing 31 to 58 per cent of iron, 0.02 to 12 per cent of manganese, and 0.00 to 0.85 per cent of phosphorus. The deposit does not appear to be of great extent.

SIERRA FREGENAL.[20]

In the Province of Badajoz, at Fregenal and Burguillos, there are veins of hematite and magnetite associated with granite and metamorphic sediments. The ore is of very good grade, consisting of 55 to 66 per cent of iron, 0 to 4 per cent of manganese, 3 per cent of silica, and 0.00 to 0.01 per cent of phosphorus. The vein system covers about 713 hectares and has been estimated to contain 150,000 tons per meter of depth.

Iron resources of the Sierra Fregenal, Spain.

[Millions of metric tons.]

	Ore.	Iron.
Known	7	3.9
Possible	7	3.9

SIERRA MORENA.[21]

The Sierra Morena lies north of Guadalquivir River, in the Provinces of Huelva and Seville, and extends to the Province of Jaén.

[20] Mallada, L., Datos geológico-mineros de varios criaderos de hierro de España: Com. mapa geol. Bol., vol. 26, pp. 152-203, 1899. Yarza, De R., Additional data on iron-ore reserves of southern Spain: Cong. géol. internat., 11e sess., Compt. rend., pp. 297-306, 1910.

[21] Schmidt, C., and Preiswerk, H., Die Erzlagerstätten von Cala, Castillo de las Guardas, und Aznalcollar, in der Sierra Morena: Zeitschr. prakt. Geologie, vol. 12, pp. 225-238, 1904. Mallada, L., Datos geológico-mineros de varios criaderos de hierro de España: Com. mapa geol. Bol., vol. 26, pp. 152-203, 1899.

Huelva Province.—At Cala there are veins of magnetite and brown ore in diabase. They contain 51 to 58 per cent of iron, 12 to 20 per cent of silica, and less than 0.02 per cent of phosphorus. Their content of sulphur becomes higher with increase of depth. They have been estimated to contain from 6,000,000 tons (J. Crum) to 16,000,000 tons (E. Klockmann).

At Tueler, near Cala, ore of the same type occurs in the same way, but it contains more phosphorus (0.05 per cent). The deposit is said to contain 15,000,000 tons.

The pyritic deposits of Rio Tinto, which furnish iron ore as a by-product after roasting, must be counted as a reserve, for the ore is shipped to the blast furnace. The deposits contain by estimate 150,000,000 tons "known" and an equal quantity of "probable" ore.

Iron resources of the Province of Huelva, Spain.

[Millions of metric tons.]

	Ore.	Iron.
Known	174	93.2
Probable	150	60.0

Seville Province.[22]—Bodies of magnetite and of brown ore are reported to occur in Cambrian schists at Almaden de la Plata and Pedrozo, veins of carbonate are reported to occur in Cambrian rocks in the Sierra de Jayona, and an extensive area of float ore is said to be found on the Cerro de Hierro. The ore bodies have been but slightly developed and the available estimates, which place the resources at 18 to 35 million metric tons of known ore, seem to be inadequate.

Iron resources of the Province of Seville, Spain.

[Millions of metric tons.]

	Ore.	Iron.
Known	18	9
Probable	18	9
Possible	18	9

Jaén Province.—At the east end of the Sierra Morena, in the Province of Jaén, there are ferruginous sandstones, which are probably of no commercial value. South of the Guadalquivir there are lenses of hematite containing little silica and phosphorus, which are now being exploited. Their extent is not known.

Summary of Sierra Morena.—The resources of the Sierra Morena are tabulated on page 39.

[22] Yarza, De R., Additional data on iron-ore reserves of southern Spain: Cong. géol. internat., 11e sess., Compt. rend., pp. 297-306, 1910.

Iron resources of the Sierra Morena.

[Millions of metric tons of iron.]

Province.	Known.	Probable.	Possible.
Huelva	93.2	60	....
Seville	9.0	9	9
	102.2	69	9

RANGES OF THE SOUTH COAST.[23]

The ore bodies along the south coast occur in Triassic sediments. They consist of brown ore, hematite, and some magnetite. They occur in the provinces of Malaga, Granada, Almería, and Murcia.

Malaga Province.[24]—In the Marbella and Oja district there are deposits of high-grade magnetite.

In the Archidona, Antequera, and Campillos districts the ore is largely brown ore and hematite, which contains about 55 per cent of iron and little phosphorus.

The known reserve in the Province of Malaga is estimated at 10,000,000 metric tons of ore containing 5,500,000 metric tons of iron.

Granada Province.[25]—The ore in the Province of Granada occurs near Alquife and in the Cerro del Conjuro. It contains about 50 to 59 per cent of iron and only traces of phosphorus. Some of the ore is so friable that it has to be briquetted.

Iron resources of the Province of Granada, Spain.

[Millions of metric tons.]

	Ore.	Iron.
Known	17	8.5
Possible	10	5.0

Almería Province.[26]—Almería is the largest producer of iron in the provinces on the south coast. Deposits are found at Bedar and Chive, in the Sierra Cobrera and Sierra Alhamilla, and at Bacares, Menas, Macael, Alcudia, Cantas, Olula, and Gergal. Undeveloped bodies occur in the Sierra de Filabres and at Beires.

[23] Bulmer, G. H., The Alquife iron-ore mines, in the south of Spain: Inst. Civil Eng. Proc., vol. 159, pp. 312–314, 1904–05. Mallada, L., Datos geológico-mineros de varios criaderos de hierro de España: Com. mapa geol. Bol., vol. 26, pp. 152–203, 1899.

[24] Gillman, F., Malaga magnetites: Inst. Min. Met. Trans. No. 20, p. 447, 1910–11.

[25] Yarza, De R., Additional data on iron-ore reserves of southern Spain: Cong. geól. internat., 11e sess., Compt. rend., pp. 297–306, 1910.

[26] Fabrega, P., A study of the iron-ore deposits of Almería; translated by C. V. Haines from Rev. minera, vol. 58, pp. 266–269, 284–288: Min. Jour., vol. 82, pp. 44–45, 78–79, 114–115, 1907. Fircks, F., Über einige Lagerstätten der Provinz Almería in Spanien: Zeitschr. prakt. Geologie, vol. 14, pp. 142–150, 233–236, 1906. Yarza, De R., Additional data on iron-ore reserves of southern Spain: Cong. geól. internat., 11e sess., Compt. rend., pp. 297–306, 1910.

Reports covering the developed districts show that they contain ore carrying from 50 to 57 per cent of iron and little phosphorus.

Iron resources of the Province of Almería, Spain.

[Millions of metric tons.]

	Ore.	Iron.
Known	45	24
Probable	24	12
Possible	24	12

Murcia Province.[27]—Ore is reported to occur in Triassic rocks near Cartagena, some of it carrying 22 to 26 per cent manganese, and at Lorca, Morata, and Cehegin.

Iron resources of the Province of Murcia, Spain.

[Millions of metric tons.]

	Ore.	Iron.
Known	25.5	11.7
Possible	10.0	5.0

Summary for south coast ranges.—The resources of the ranges on the south coast are summarized below.

Iron resources of the ranges on the south coast of Spain.

[Millions of metric tons of iron.]

Province.	Known.	Probable.	Possible.
Malaga	5.5	....	....
Granada	8.5	....	5
Almería	24.0	12	12
Murcia	11.7	....	5
	49.7	....	22

SUMMARY OF THE IRON RESOURCES OF SPAIN.

The quantities of iron in the deposits of Spain are summarized below.

Iron resources of Spain.

[Millions of metric tons of iron. Compare Pl. II, in pocket.]

	Known.	Probable.	Possible.
Cantabrian Cordillera	110.0	33.5	82.0
Pyrenees	3.6	1.8	1.6
Ranges west of Ebro River	18.7	....	6.4
Sierra Menera	65.0	....	24.0
Sierra Fregenal	3.9	....	3.9
Sierra Morena	102.2	69.0	9.0
Ranges of the south coast	49.7	12.0	22.0
	353.1	116.3	148.9

[27] Yarza, De R., Additional data on iron-ore reserves of southern Spain: Cong. geól. internat., 11e sess., Compt. rend., pp. 303-306, 1910.

PRODUCTION AND CONSUMPTION.

The iron ores of Spain are of a quality so high that they have found a large and easy market, and they have therefore been exploited heavily, so that, as the accompanying chart (fig. 8) suggests, their production may have reached its maximum rate, but on the other hand, the reserves are so large that the present production of

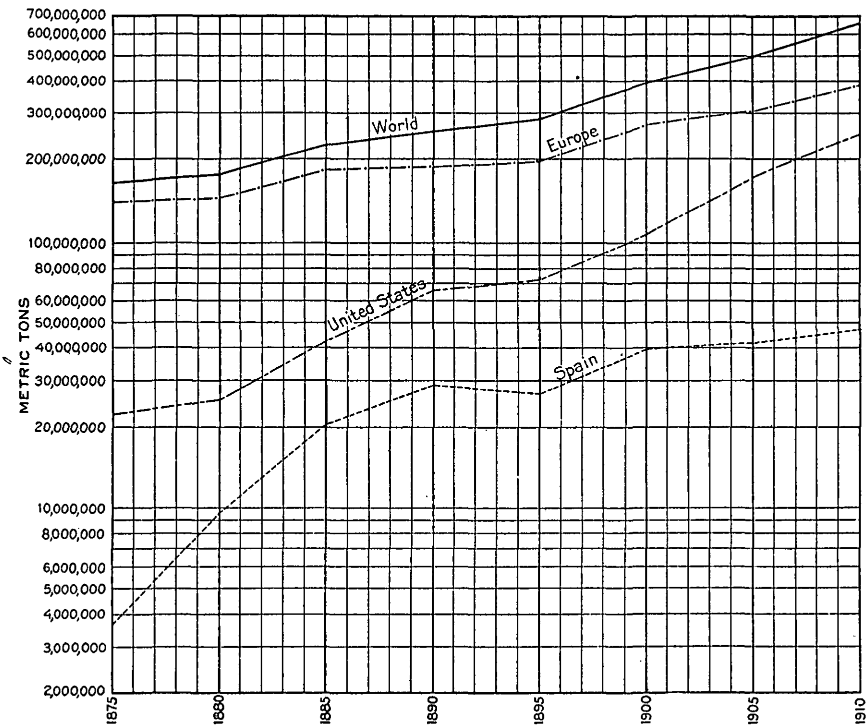


FIGURE 8.—Ratio chart showing iron ore produced during five-year periods ending 1875 to 1910 in Spain, Europe, the United States, and the world. This chart and similar ones showing the production of iron ore in other countries affords a ready comparison of the rates at which iron mining has increased in the several countries. The figures are so plotted that in all parts of the chart guide lines of like slope indicate like rates of increase or decrease, and steeper slopes correspond with higher rates of change.

8,000,000 to 10,000,000 metric tons a year will be continued for at least a few decades. In 1913 the production of iron ore in Spain was 9 per cent of the total production of Europe.

Most of the ore produced has heretofore been taken from deposits near tidewater, but a very considerable part of it has been taken from scattered deposits, as the following table shows.

Iron ore produced in Spain, 1912–1915.

[Metric tons.]

Province.	1912	1913	1914	1915
Lugo	272,600	290,300	211,650	24,690
Oviedo	184,467	186,192	126,585	121,383
Santander	1,272,835	1,278,087	1,076,613	678,085
Vizcaya	3,514,368	3,864,593	2,618,149	2,674,638
León	1,149	....	....	....
Guipuzcoa	82,837	96,718	49,304	25,856
Navarra	6,002	8,246	4,419	7,923
Lerida	1,814	19,500	11,000	6,500
Saragossa	....	20,460	32,438	8,533
Guadalajara	256,292	278,528	163,710	54,786
Teruel	676,840	662,307	375,360	379,907
Cáceres	....	4,825	872	....
Badajoz	90,675	94,308	52,581	16,052
Huelva	156,831	211,942	120,292	38,092
Seville	318,805	368,894	293,232	268,832
Jaén	43,830	47,052	16,407	11,080
Malaga	55,620	56,850	44,280	14,694
Granada	212,242	234,719	185,812	136,672
Almería	1,133,568	1,350,247	1,003,314	915,679
Murcia	801,435	770,540	422,179	234,437
Barcelona	34,695	17,360	11,768	....
Córdova	120	....	....	....

The production from Vizcaya and Santander will probably decrease; that of the other Provinces will probably increase.

Very little pig iron was produced in Spain in 1913, a fact shown by her small ore consumption, which was only 1 per cent of the total consumption in Europe although there is considerable coal in Spain.

PORTUGAL.[28]

DISTRIBUTION, CHARACTER, AND EXTENT OF THE DEPOSITS.

The general distribution of the deposits of iron ore in Portugal is shown on Plate II (in pocket) and on the sketch map (fig. 9). The available descriptions of the deposits are lamentably lacking in mineralogic detail, and the data at hand are insufficient to enable any one to form a judgment as to the correctness of the classification adopted.

Moncorvo.—The most extensive deposits are those of Moncorvo, in the Trazos Montes district, in northwestern Portugal. They are described as concordant lenses in schists and are classed by J. P. Gomes [29] as metamorphosed sedimentary deposits. The ore contains 40 to 60 per cent of iron, 4 to 7 per cent of silica, and little phosphorus and sulphur.

[28] Gomes, J. P., Die Eisenerzvorräte von Portugal: The iron-ore resources of the world (11th Internat. Geol. Congress), vol. 1, pp. 85–93, Stockholm, 1910. Ahlburg, J., Die nutzbaren Mineralien Spaniens und Portugals: Zeitschr. prakt. Geologie, vol. 15, pp. 196 et seq., 1907.

[29] Op. cit., pp. 88–89.

Iron resources of Moncorvo, Portugal.

[Millions of metric tons.]

	Ore.	Iron.
Known	10	5.0
Probable	10	5.0
Possible	25	12.5

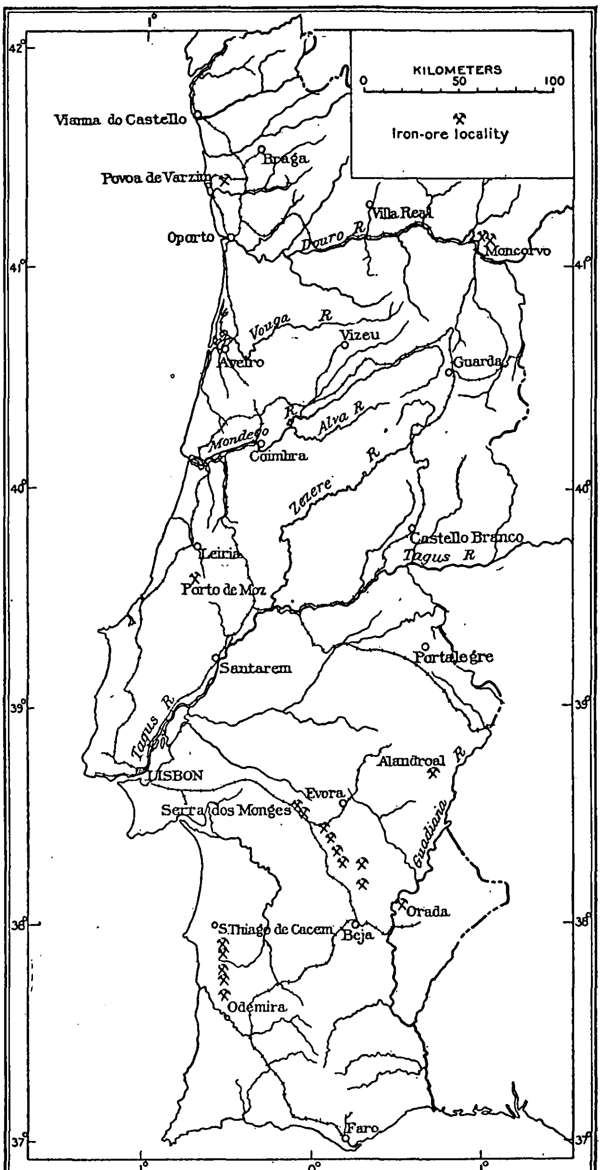


FIGURE 9.—Map showing deposits of iron ore in Portugal. (From "The iron-ore resources of the world.")

Porto de Moz.—In west-central Portugal, at Porto de Moz, there are veins of iron ore in Jurassic limestone. The sorted ore contains 55 to 60 per cent of iron. The reserves are small.

Iron resources at Porto de Moz, Portugal.

[Millions of metric tons.]

	Ore.	Iron.
Known	1	0.6
Probable	2	1.1

Serra dos Monges.—In central Alemtejo, in the Serra dos Monges, there are lenses of brown ore in crystalline schists near diorites. J. P. Gomes interprets them as metamorphosed sediments. The ore contains 55 to 63 per cent of iron, 0.01 to 0.02 per cent of phosphorus, 0.3 to 0.5 per cent of sulphur, and 3 to 7 per cent of silica.

Iron resources of central Alemtejo, Portugal.

[Millions of metric tons.]

	Ore.	Iron.
Known	3	1.6
Probable	14	7.7

São Thiago de Cacem and Odemira.—Shallow deposits of superficial manganiferous iron ore are found in southwestern Portugal. They are peculiar in that their greatest extent lies across the strike of the metamorphic rocks on which they rest. They contain 30 to 40 per cent of iron and 20 to 30 per cent of manganese and are rather siliceous.

Iron resources of southwestern Portugal.

[Millions of metric tons.]

	Ore.	Iron.
Known	3	1.0
Probable	7	2.4

Summary.—The quantities of iron in the deposits of Portugal are summarized below.

Iron resources of Portugal.

[Millions of metric tons of iron.]

	Known.	Probable.	Possible.
Moncorvo	5.0	5.0	12.5
Serra dos Monges	1.6	7.7	....
Porto de Moz	.6	1.1	....
São Thiago de Cacem and Odemira	1.0	2.4	....
	8.2	16.2	12.5

PRODUCTION AND CONSUMPTION.

Portugal has no iron industry. Her production of iron ore in 1913 amounted to about 50,000 tons, all of which was exported.

UNITED KINGDOM.

The iron ores of the United Kingdom (Pl. IV, in pocket) have been studied thoroughly by geologists whose reports appear in publications of the Geological Survey of Great Britain issued during the nineteenth century. These reports establish the existence of an enormous amount of iron-bearing material in the United Kingdom, but they leave considerable doubt as to the amount of it that should now be classified as ore. In compiling the information on the United Kingdom for this report reliance was placed chiefly on the summaries worked out under the direction of Henry Louis[30] and on the summary of reserves published in 1917.[31]

Eckel[32] has discussed the British ore reserves, and De Launay[33] has prepared summaries of their geology.

DISTRIBUTION, CHARACTER, AND EXTENT OF THE DEPOSITS.

The distribution of the British ores is best shown on a geologic map. In fact a map showing the Jurassic and the Carboniferous formations in Great Britain would include all the valuable deposits. The deposits will therefore be described in groups according to the geologic horizon in which they occur.

MESOZOIC ORES.

Jurassic sediments that contain iron ores are exposed in a belt whose north end is marked by a line extending from Scarborough to Whitby, on the east coast, and which runs almost due south to Northampton and swings westward to the Bristol Channel.

Cleveland.[34]—At the north end of the Jurassic belt are the deposits of the Cleveland district, shown in figure 10, which are the largest producers of iron ore in Great Britain. The ore is an oolitic siderite[35] containing some glauconite. It is intercalated between beds of shale and sandstone in six well-defined beds, which range in thickness from 1 to 12 feet. The only bed exploited is the "main" seam, which is from 6 to 12 feet thick.

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[30] Louis, Henry, The iron-ore resources of the United Kingdom of Great Britain and Ireland: The iron-ore resources of the world (11th Internat. Geol. Cong.), vol. 2, pp. 623-641, Stockholm, 1910. Department of Scientific and Industrial Research, Advisory Council, Report on the sources and production of iron and other metalliferous ores used in the iron and steel industry, London, 1918.

[31] Strahan, A. (Director), Summary of progress of the Geological Survey of Great Britain, pp. 6–7, London, 1917.

[32] Eckel, E. C., Iron ores, pp. 315–322, McGraw-Hill Book Co., 1914.

[33] Launay, L. de, Gîtes minéraux et metallifères, 3 vols., Paris, Ch. Beranger, 1913.

[34] Louis, Henry, op. cit., vol. 2, pp. 630–633.

[35] Launay, L. de, op. cit., vol. 2, p. 484.

The ore carries a little over 30 per cent of iron, 8 to 10 per cent of silica, and 1 to 1.5 per cent of phosphoric acid, and the calcined ore has an iron content of about 43 per cent.

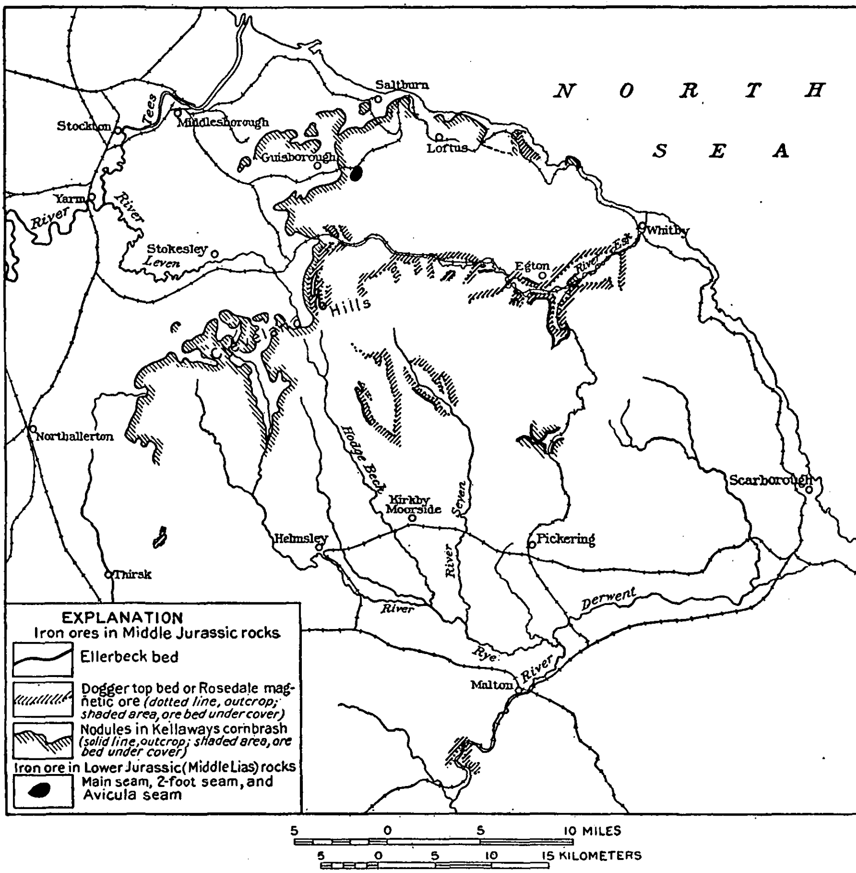


FIGURE 10.—Map of the Cleveland iron-ore district, England. (From "The iron-ore resources of the world.")

Iron resources of the Cleveland district, England.

[Millions of metric tons.]

	Ore.	Iron.
Known	190	57
Probable	190	57
Possible	400	120

Lincoln.[36]—In Lincoln (see Pl. V) there are several beds of carbonate ores, from which brown ores that lie near the surface, in the Mesozoic strata, have been derived. The most valuable are the Frodingham beds, which average 12 feet in thickness and are found in an area covering 12 square miles. Another deposit in Lincoln, the

[36] Louis, Henry, op. cit., vol. 2, pp. 634–635.

Marlstone bed, is of minor importance. It is extensively developed in Leicester.

The ore contains only 23 per cent of iron but is easy to mine and is being drawn upon more and more. The ore in the smaller seams is of higher grade.

Iron resources of Lincoln, England.

[Millions of metric tons.]

	Ore.	Iron.
Known	250	67
Probable	250	75
Possible	450	135

The apparent higher grade of the "probable" and "possible" reserves is due to the fact that a greater proportion of the thinner, higher-grade seams has been put in those classes.

Leicester.[37]—The Marlstone bed is better developed in Lincoln than in Leicester. It is known for a distance of 12 miles and probably extends 20 miles. The ore is of the same type as that in Lincoln but contains more iron.

Iron resources of Leicester, England.

[Millions of metric tons.[

	Ore.	Iron.
Known	62	18.6
Probable	38	11.4

No "possible" ore has been estimated, because there is not sufficient information on which to base a figure.

Rutland and Oxford.[38]—A deposit known as the Northampton bed, which is of large extent and value, in Northampton, occurs also in Oxford, where it is from 4 to 13 feet thick and furnishes considerable ore similar to that of Lincoln and Leicester. The reserve is very considerable and lies mostly in Oxford.

Iron resources of Rutland and Oxford, England.

[Millions of metric tons.]

	Ore.	Iron.
Known	123	35.0
Probable	86	21.5
Possible	300	75.0

[37] Louis, Henry, op. cit., vol. 2, pp. 635–636.
[38] Idem, p. 636.

Northampton.[39]—The beds of carbonate ore in the Mesozoic rocks of Northampton (Pl. V) are of great extent and of good grade. They are known over an area 100 miles long and as much as 20 miles wide. The estimates made run up to 1,000,000,000 metric tons, but the figures below are believed to be more reasonable.

Iron resources of Northampton, England.

[Millions of metric tons.]

	Ore.	Iron.
Known	100	32
Probable	100	32
Possible	300	96

Inverness.[40]—Recent developments on the island of Raasay, east of northern Scotland, have disclosed deposits of oolitic siderite similar to the deposits of the Cleveland district in age, type, and mode of occurrence.

Iron resources of Inverness, Scotland.

[Millions of metric tons.]

	Ore.	Iron.
Known	10.0	2.5
Probable	11.9	3.0

Summary of iron in Mesozoic ores.

[Millions of metric tons of iron.]

	Known.	Probable.	Possible.
Cleveland	57.0	57.0	120
Lincoln	67.0	75.0	135
Leicester	18.6	11.4	....
Rutland and Oxford	35.0	21.5	75
Northampton	32.0	32.0	96
Inverness	2.5	3.0	....
	212.1	199.9	426

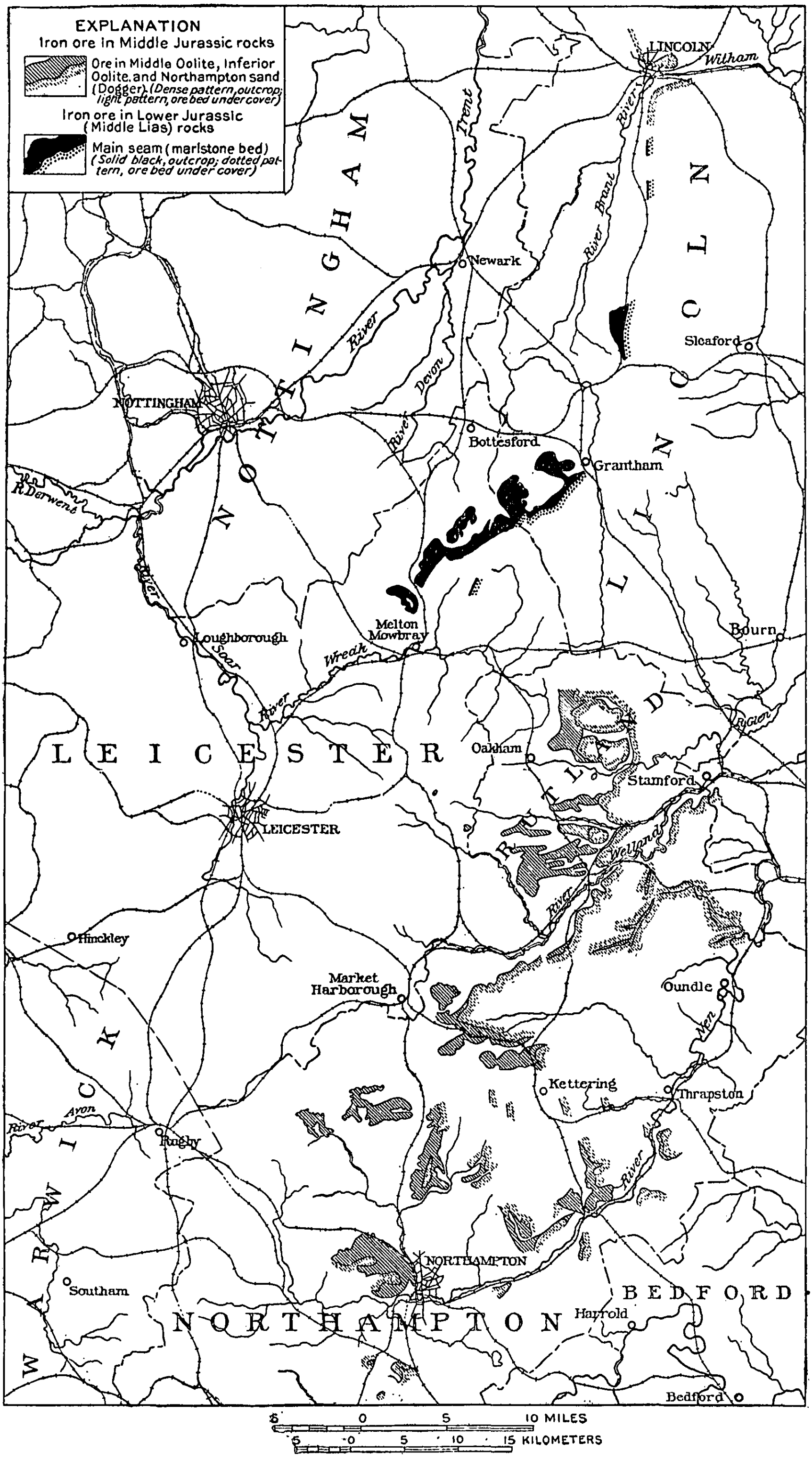
CARBONIFEROUS ORES.[41]

Immense quantities of clay ironstone ores are associated with the coal measures that crop out from Newcastle almost to Gloucester and that appear in outliers in Scotland and South Wales, and some of these ores, such as those of Northumberland, are in the Carboniferous but not in the coal measures. In 1910 Louis estimated that there was a potential reserve of 34,000,000,000 tons of this ore, 15,000,000,000 tons of it in South Wales alone.

[39] Louis, Henry, op. cit., vol. 2, pp. 633–634.

[40] Department of Scientific and Industrial Research, Advisory Council, Report on the sources and production of iron and other metalliferous ores used in the iron and steel industry, p. 32, London, 1918.

[41] Louis, Henry, op. cit., vol. 2, pp. 637–641.



MAP OF THE IRONSTONE DISTRICTS OF NORTHAMPTON AND LINCOLN, ENGLAND.

From 1880 to 1915 the production of ores of this type fell from 5,244,000 long tons to 1,235,000 long tons. In 1880 it formed 29 per cent of that of the United Kingdom; in 1915 it had dropped to 9 per cent. If there were no future reduction in the mining of this ore the reserve of 34,000,000,000 tons which Louis assigns to the Carboniferous beds would last 25,000 years.

Apparently the economic trend has been to use these ores in continually decreasing quantities, and the possibility that they will be utilized to a point nearing exhaustion is growing less. In this study, therefore, the estimates of Louis have been greatly reduced.

Carboniferous iron ores in Great Britain.

[Millions of metric tons.]

	Known.		Probable.		Possible.	
	Ore.	Iron.	Ore.	Iron.	Ore.	Iron.
Northumberland and Durham	35.0	10.5	65.0	19.5	200	60
York and Derby	....	....	....	....	200	60
Stafford, Salop, Warwick, and Worcester	200.0	74.0	400.0	148.0	800	296
South Wales	....	....	....	....	1,500	450
Glasgow and Edinburgh	7.7	2.5	76.6	24.5	400	128
	242.7	87.0	541.6	182.0	3,100	994

HEMATITE AND MAGNETITE ORES.

England still has a small supply of high-grade Bessemer ores, from which she produced about 1,500,000 tons in 1915.

The reserves of high-grade hematite and magnetite ores are tabulated below, in millions of metric tons of metallic iron:

Known	17.5
Probable	25.3
Possible	50.3

Cumberland and Lancaster.[42]—In Cumberland and Lancaster, at the localities shown in figure 11, hematite ores occur as a replacement of Carboniferous limestone. They average more than 50 per cent of iron and contain very little phosphorus, so that for metallurgic use they are very desirable.

Iron resources of Cumberland and Lancaster, England.

[Millions of metric tons.]

	Ore.	Iron.
Known	35	17.5
Probable	50	25.0
Possible	100	50.0

[42] Louis, Henry, op. cit., vol. 2, pp. 625-626.

Cornwall and Devon.—The lodes of red hematite of Cornwall and the deposits of Devon, which are apparently magnetite that replaced limestone, are of excellent grade. The reserve is very small,

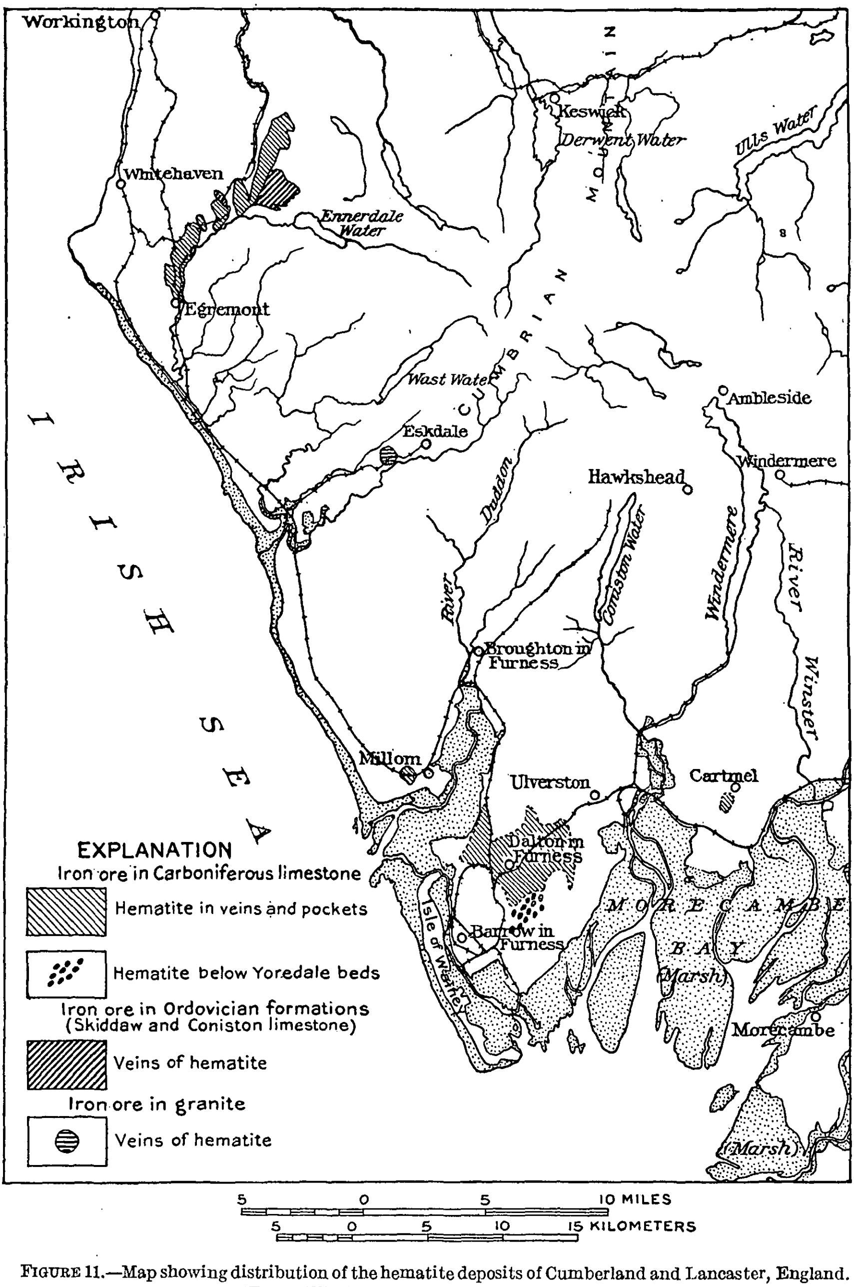


FIGURE 11.—Map showing distribution of the hematite deposits of Cumberland and Lancaster, England. (From "The iron-ore resources of the world.")

the "probable" and "possible" class including only about 250,000 tons of iron.

MISCELLANEOUS DEPOSITS.

Gloucester.[43]—Pockets of brown ore averaging 36 per cent of iron are found in Carboniferous limestones in Gloucester.

Iron resources of Gloucester, England.

[Millions of metric tons.]

	Ore.	Iron.
Known	2.5	0.9
Probable	3.0	1.1

Somerset.[44]—In Somerset, at Brandon Hills and Withyford, there are veins of spathic ore that were mined up to 1914. The production has stopped and no estimate is made of the reserves.

North Wales (Carnarvon).[45]—Pisolitic ores in the Cambrian rocks of North Wales supply about 20,000 tons of ore a year. The reserves have not been considered worth estimating.

Wilts and Kent.[46]—In the Cretaceous rocks of Kent and Wilts there are bedded oolitic ores. They furnished about 20,000 tons in 1915.

Iron resources of Wilts and Kent.

[Millions of metric tons.]

	Ore.	Iron.
Probable	148.5	46
Possible	5.5	2

Ireland.[47]—Ireland produced 39,000 tons of iron ore in 1915, most of it from pisolitic residual ores of County Antrim. Clay ironstones are found near Lough Allen and in Kilkenny County. Magnetite is found at Ballycog. The reserves of ore are not large and have not been estimated.

Summary of the miscellaneous deposits.—The iron content of the miscellaneous deposits is summarized below.

Iron resources of Gloucester, Wilts, and Kent.

[Millions of metric tons of iron.]

	Known.	Probable.	Possible.
Gloucester	0.9	1.1	....
Wilts and Kent	....	46.0	2
	.9	47.1	2

[43] Department of Scientific and Industrial Research, Advisory Council, Report on the sources and production of iron and other metalliferous ores used in the iron and steel industry, p. 24, London, 1918.

[44] Idem, p. 25.

[45] Idem, p. 30.

[46] Idem, p. 23.

[47] Idem, pp. 32–33.

SUMMARY OF IRON RESOURCES OF THE UNITED KINGDOM.

The iron resources of the United Kingdom, classified as they have been considered here, are summarized below.

Iron resources of the United Kingdom.

[Millions of metric tons of iron. Compare Pl. IV, in pocket.]

	Known.	Probable.	Possible.
Mesozoic ores	212.1	199.9	426.0
Carboniferous ores	87.0	192.0	994.0
High-grade ores	17.5	25.3	50.3
Miscellaneous	.9	47.1	2.0
	317.5	464.3	1,472.3

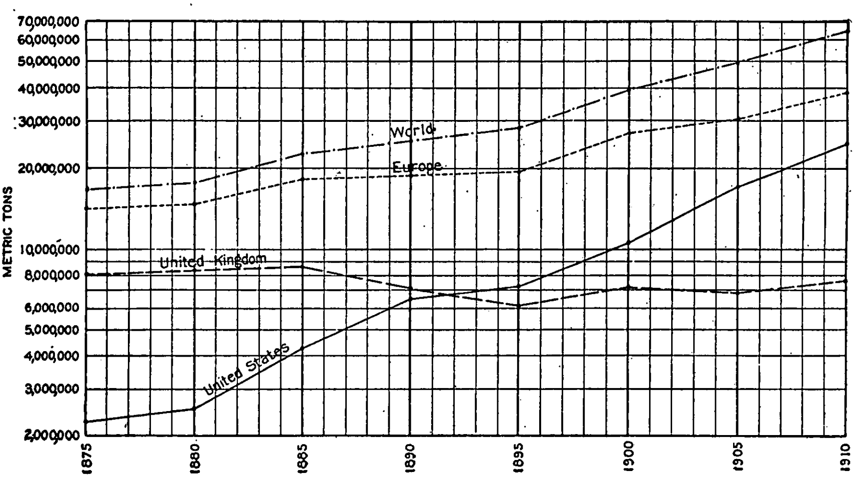


FIGURE 12.—Ratio chart showing iron ore produced during five-year periods ending 1875 to 1910 in the United Kingdom, Europe, the United States, and the world. (See explanation of fig. 8, p. 41.)

PRODUCTION AND CONSUMPTION.

In 1913 the United Kingdom stood fourth in the list of producers of iron ore and third among the producers of pig iron. Until 1890 she held first place, but in that year the United States passed her in the output of both iron ore and pig iron. In 1896 the production of ore and in 1903 the production of pig iron of the German Customs Union passed that of the United Kingdom, and in 1911 France took third place in the production of ore.

As figure 12 shows, the production of iron ore in the United Kingdom since 1870, though almost constant, has declined slightly. Of all European countries producing over 1,000,000 tons of ore in 1913 the United Kingdom is the only one that shows a decline in that year.

Figure 13 is a more comprehensive tabulation of the history of the iron industry in the United Kingdom. It shows that though her production of iron ore has fallen off her imports have risen at a rate so high that her consumption has increased rather steadily though very gradually. To show how Great Britain compares with the two other countries having a large iron industry, the production of pig iron in the United Kingdom, Germany, and the United States was plotted on one diagram (fig. 14), which shows that her chief rivals were rapidly leaving Great Britain behind when the war broke out.

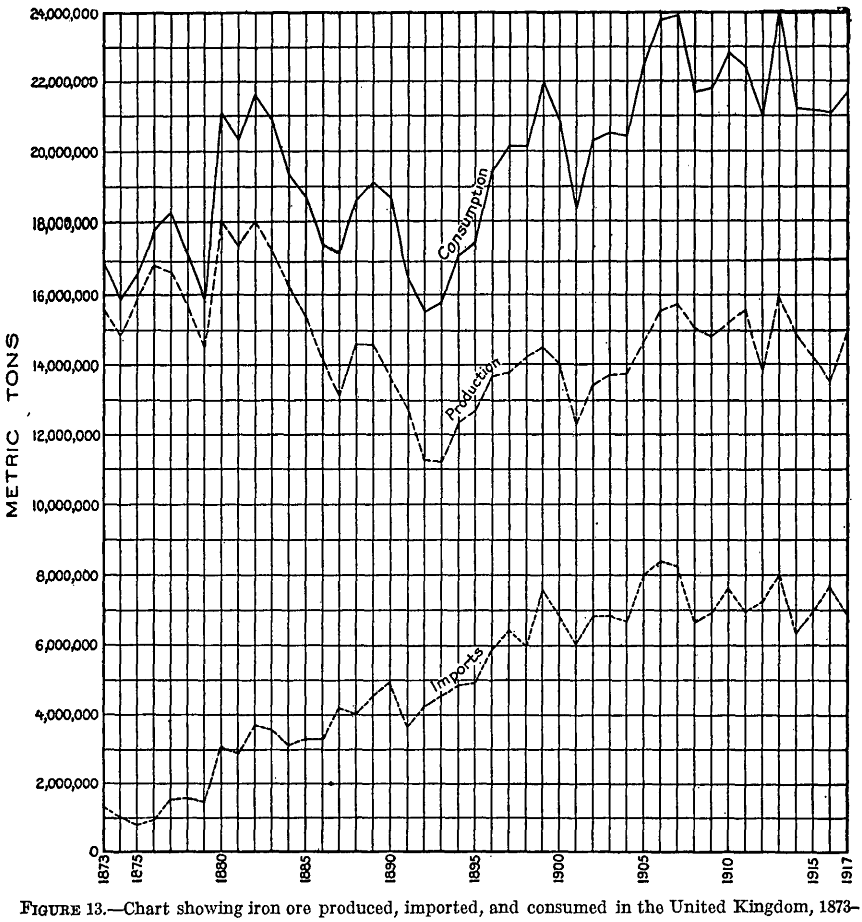


FIGURE 13.—Chart showing iron ore produced, imported, and consumed in the United Kingdom, 1873–1917. The average annual exports amount to 10,000 tons.

The war severed the bond between Lorraine iron ore and German coal, a bond which had caused the rise in the French and German production of iron and iron ore and which is so patently to the advantage of both France and Germany that it will almost inevitably be repaired. But for some time both Great Britain and the United States probably will be free to increase their iron industry without fear of a serious rival.

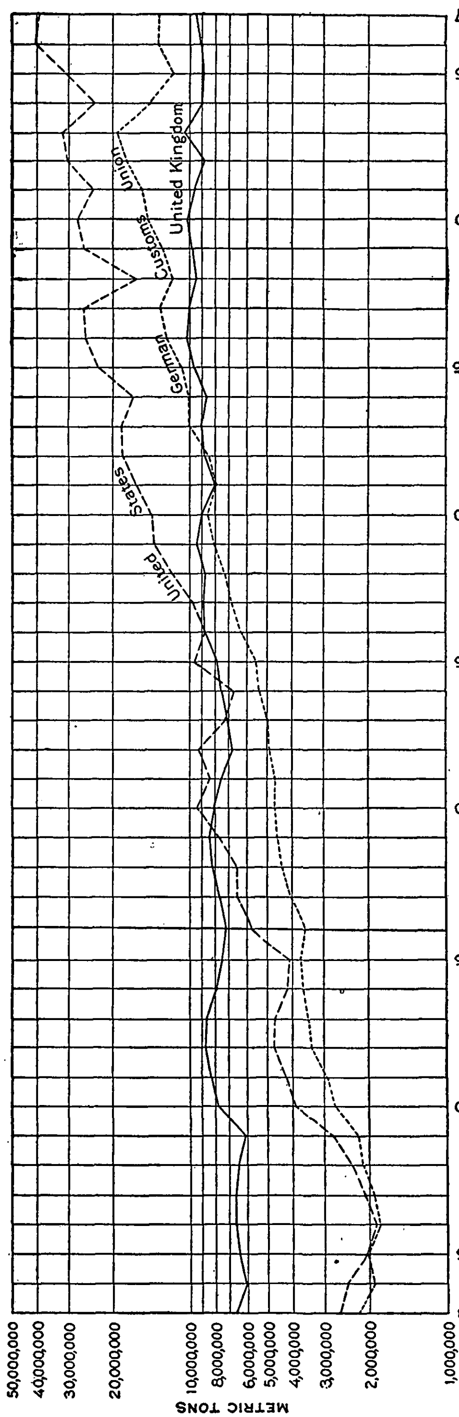


FIGURE 14.—Ratio chart showing iron ore produced annually in the United Kingdom, the German Customs Union, and the United States, 1873–1917. (See explanation of fig. 8, p. 41.)

In 1913 the United Kingdom produced 15.5 per cent of the European production of iron ore and consumed 21.5 per cent of the European consumption. (See fig. 4, p. 26.) She is a heavy importer of ore, especially of Spanish ore, and the leaders of her iron industries have safeguarded the future by gaining large holdings of ore in Brazil. As her coal resources are very large her position in the iron industry is assured for many generations.

An ore reserve that may have some influence on the British iron industry is found in Spitzbergen, where there are said to be huge workable deposits, though it has not yet been proved that they are workable. The ownership of the island is also in doubt, a fact indicated by Sir Martin Conway [48] in a paper read at a meeting of the London Geographical Society, and in the subsequent discussion.

FRANCE.

DISTRIBUTION, CHARACTER, AND EXTENT OF THE DEPOSITS.

Before the war there was some question as to whether France or Newfoundland ranked next to the United States in resources of available iron ore, but since the lost provinces have been restored to France that question is settled beyond doubt. France now stands second in the world and is preeminent in Europe with more than four times the resources of any other European nation. (See Pl. VI, in pocket.) She controls politically all the ore in the Lorraine Basin except the small part of it that lies in Luxemburg and has large deposits in Normandy, in Brittany, in Anjou, and in the eastern Pyrenees, as well as smaller deposits in 20 other departments. The most important of these deposits, historically, politically, and economically, are the minette ores of the Lorraine Basin, and because of their importance they will be described in much greater detail than the rest of the European deposits.

LORRAINE BASIN.[49]

HISTORY.

As the ores of Lorraine contain much phosphorus they were used only to a small extent prior to 1878, when a new metallurgic process gave them larger value. Nevertheless, after the Franco-Prussian

[48] Conway, Martin, The political status of Spitzbergen: Geog. Jour. (London), vol. 53, No. 2, p. 83.

[49] Ansel, H., Die oolitische Eisenerzformation deutsches Lothringen: Zeitschr. prakt. Geologie, pp. 81-94, 1901. Bailly, L., Exploitation du minerai de fer oolithique de la Lorraine: Annales des mines, 10th ser., vol. 7, pp. 5-55, 1905. Cayeux, L., Le minerai de Lorraine, Paris, 1918. Kohlmann, W., Die neuere Entwicklung des lothringischen Eisenerzbergbaues: Stahl und Eisen, vol. 31, pt. 1, pp. 413-424, 469-479, 544-556, 1911. Kohlmann, W., Die Minnetteablagerung des lothringischen Jura: Stahl und Eisen, vol. 22, pt. 1, p. 493, 1902. Krecke, F., Eisenerz und Kohle in Französisch-Lothringen: Glückauf, vol. 46, pt. 1, pp. 4-9, 1910. Lynch, M. C., Why France needs the Briey Basin: Iron Trade Rev., vol. 60, p. 924, 1917. Villain, M., Le gisement de minerai de fer oolithique de la Lorraine: Annales des mines, 10th ser., vol. 1, pp. 113-322, 1902. Nicou, P., Les ressources de la France en minerais de fer: The iron ore resources of the world (11th Internat. Geol. Cong.), vol. 1, pp. 4-14, Stockholm, 1910. Einecke, G., and Köhler, W., Die Eisenvorräte des deutschen Reiches: Idem, vol. 2, pp. 711-715.

war the Germans were very careful to take away from France all the ore bodies in Lorraine that appeared to have any value. In fact, the boundary set for Lorraine was decided upon by strategists after consultation with the metallurgist Stumm and the mining engineer Hauchecorne.

After 1878, when Thomas and Gilchrist discovered a method of converting high-phosphorus pig iron into steel, the value of the minette ores was greatly enhanced. French geologists urged prospecting for deeper ores east of the areas where mines were being worked and found that the greater and richer part of the ores of the Lorraine Basin actually remained to France.

Minette iron ore produced from 1871 to 1913.

[Metric tons.]

Year.	Lorraine Annexée.	Luxemburg.	French Lorraine.	Total minette ore.
1871	364,000	990,000	505,000	1,860,000
1872	678,000	1,174,000	1,009,000	2,861,000
1873	860,000	1,332,000	1,289,000	3,480,000
1874	821,000	1,443,000	920,000	3,183,000
1875	744,000	1,091,000	976,000	2,810,000
1876	661,000	1,197,000	1,060,000	2,917,000
1877	678,000	1,263,000	1,126,000	3,067,000
1878	822,000	1,408,000	1,287,000	3,517,000
1879	830,000	1,613,000	1,343,000	3,787,000
1880	996,000	2,173,000	1,658,000	4,828,000
1881	1,096,000	2,162,000	1,796,000	5,054,000
1882	1,359,000	2,539,000	2,160,000	6,058,000
1883	1,644,000	2,551,000	2,140,000	6,336,000
1884	1,909,000	2,448,000	1,980,000	6,338,000
1885	2,153,000	2,648,000	1,612,000	6,412,000
1886	2,102,000	2,361,000	1,714,000	6,177,000
1887	2,471,000	2,650,000	1,953,000	7,074,000
1888	2,805,000	3,262,000	2,261,000	8,329,000
1889	2,959,000	3,103,000	2,413,000	8,475,000
1890	3,256,000	3,359,000	2,630,000	9,246,000
1891	3,126,000	3,102,000	2,735,000	8,963,000
1892	3,571,000	3,370,000	2,928,000	9,870,000
1893	3,607,000	3,352,000	2,810,000	9,769,000
1894	3,922,000	3,958,000	3,062,000	10,942,000
1895	4,222,000	3,913,000	3,084,000	11,219,000
1896	4,842,000	4,759,000	3,441,000	13,041,000
1897	5,361,000	5,349,000	3,804,000	14,514,000
1898	5,955,000	5,349,000	3,884,000	15,188,000
1899	6,973,000	6,014,000	4,106,000	17,093,000
1900	7,742,000	6,171,000	4,446,000	18,360,000
1901	7,595,000	4,455,000	3,842,000	15,892,000
1902	8,793,000	5,130,000	4,129,000	18,053,000
1903	10,683,000	6,010,000	5,282,000	21,975,000
1904	11,135,000	6,348,000	5,954,000	23,437,000
1905	11,968,000	6,596,000	6,400,000	24,963,000
1906	13,834,000	7,229,000	7,399,000	28,463,000
1907	14,102,000	7,493,000	8,738,000	30,333,000
1908	13,282,000	5,801,000	8,446,000	27,529,000
1909	14,443,000	5,794,000	10,684,000	30,921,000
1910	16,652,000	6,263,000	13,137,000	36,052,000
1911	17,743,000	6,060,000	14,858,000	38,661,000
1912	20,083,000	6,511,000	17,235,000	43,829,000
1913	21,136,000	7,333,000	19,629,000	48,098,000

Figures for 1871-1910 are those given by W. Kohlmann in Die neuere Entwicklung des lothringischen Eisenerzbergbaues: Stahl und Eisen, vol. 31, pt. 1, p. 547, 1911. Figures for 1911, 1912, and 1913 from official statistics.

The table shows that the output of French Lorraine had far surpassed that of Luxemburg and was rapidly reaching that of German Lorraine (Lorraine Annexée) before the war began, in 1914. The comparative rates of increase in mining in these three regions is clearly shown in the accompanying diagram (fig. 15), which indicates that the progress of mining iron ore has been steadier in German

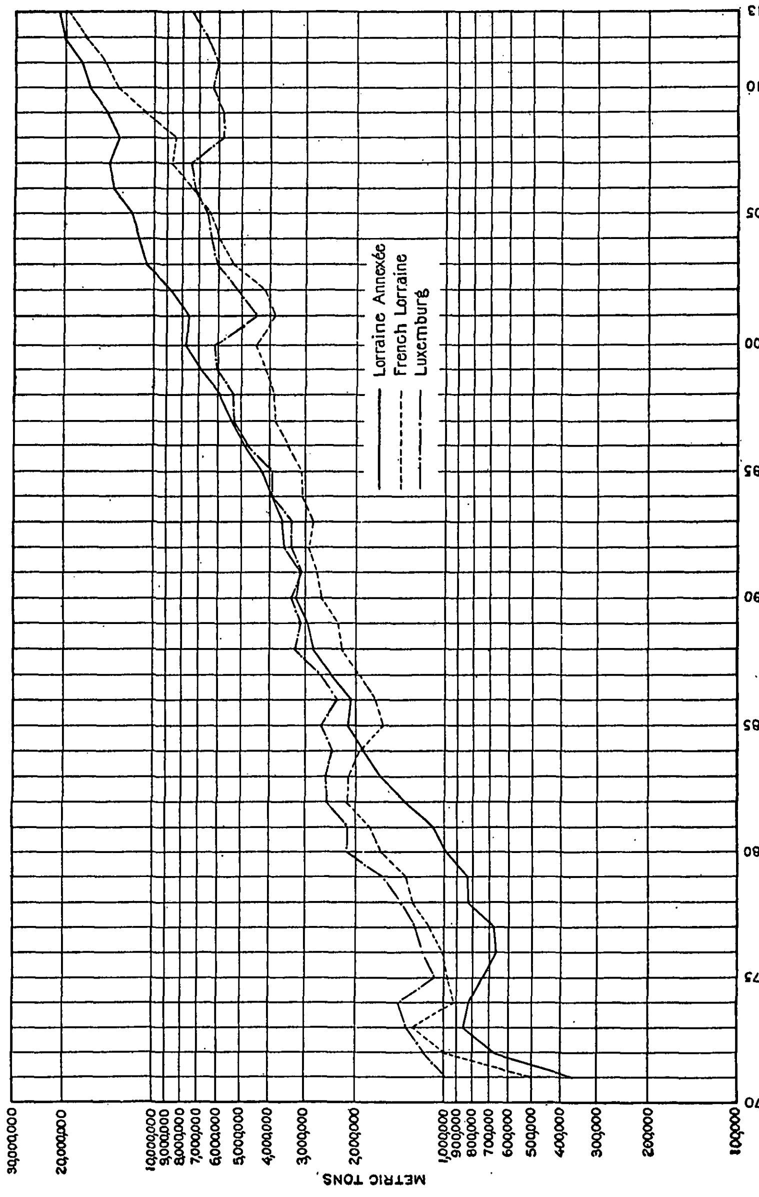


FIGURE 15.—Ratio chart showing iron ore produced annually in Lorraine Annexée, French Lorraine, and Luxemburg, 1871-1913. (See explanation of fig. 8, p. 41.)

Lorraine than in either French Lorraine or Luxemburg. Indeed, Luxemburg appears to have lost more in recent bad years, such as 1900 and 1901 and 1907 and 1908, than either of the other regions.

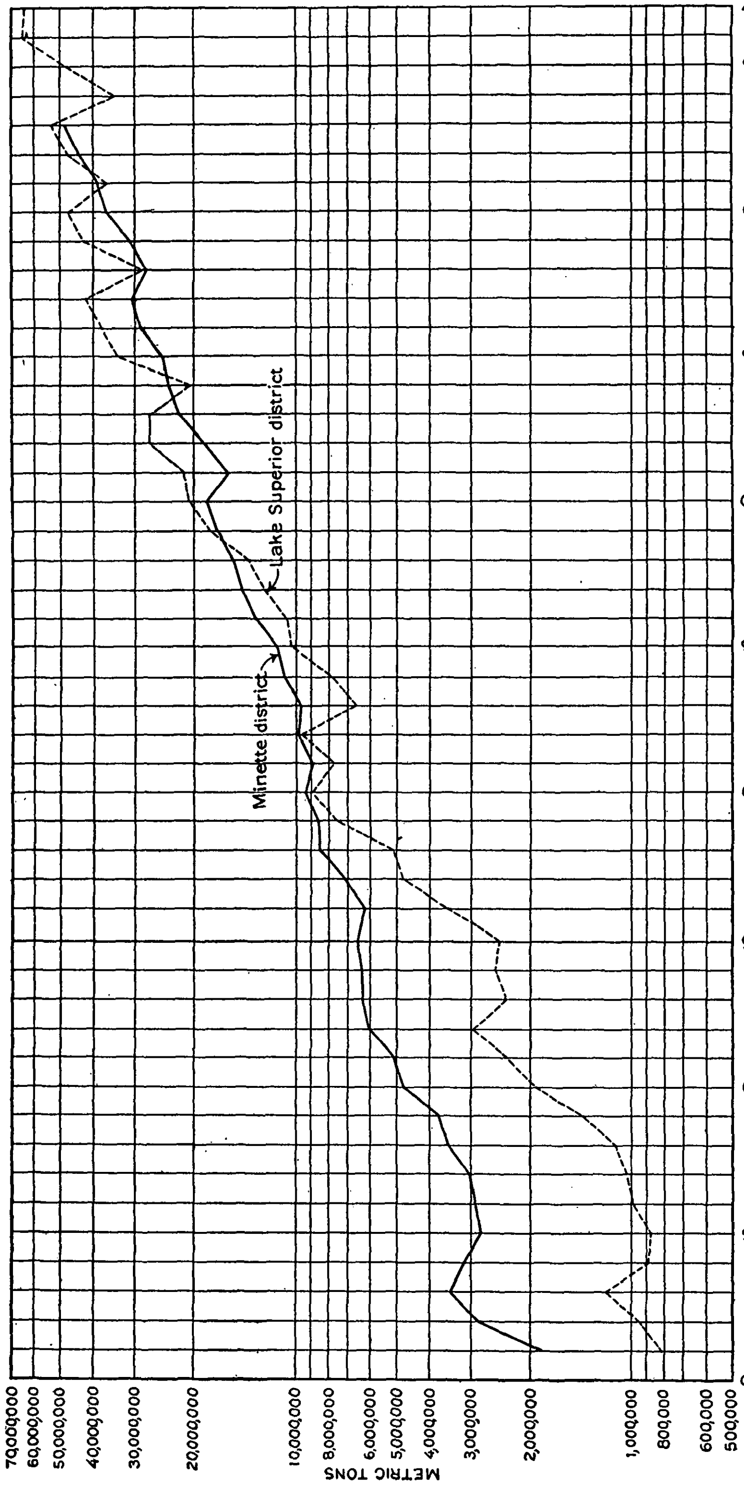


FIGURE 16.—Ratio chart showing iron ore produced annually in the minette basin of Lorraine, 1871–1913, and in the Lake Superior district, 1871–1917. (See explanation of fig. 8, p. 41.)

From 1908 to 1913 French Lorraine was rapidly gaining on German Lorraine, whereas Luxemburg, since her bad years 1907 and 1908, had only in 1913 regained her production of 1907.

In figure 16 the rate of increase of production in the Lorraine Basin is compared with that in the Lake Superior district. The curve for the Lorraine Basin is derived from the table given above. That for the Lake Superior district is derived from a table given by E. F. Burchard.[50] The figure shows that the average rate of increase in the Lake Superior district has been greater than that in the Lorraine Basin; also that the output of the Lake Superior district is subject to much wider fluctuations than that of the Lorraine Basin. The causes of these fluctuations are worthy of consideration by American economists.

In 1913 French Lorraine was producing much more ore than she needed for domestic consumption and was exporting the surplus to Belgium, Luxemburg, and Germany. The output of German Lorraine was handled almost entirely in furnaces within the German Customs Union. France had a surplus to export; Germany was an importer, and an increasingly heavy one, a fact that was undoubtedly recognized by the Germans before they started the war and that may even have increased their readiness to start it. It certainly affected their strategy, for their desperate assaults on the Verdun salient, which was a continual menace to their iron-mining regions, were probably due in part to their desire to safeguard their hold on those regions. Their plans and desires for the future are fully shown by the memoranda drawn up by the German Association of Metallurgists and Steel Makers and by P. Krusch's article in "Das neue Deutschland" of March 15, 1918. They all insist on the overwhelming value of the minette ore in the prosecution of the war and on the need of so "rectifying the frontier" as to include the Briey district, because of its importance for the "next" war.

How the French regard the iron ores of Lorraine is well shown in a recent paper by L. Cayeux,[51] whose temperamental aversion to accepting the really excellent estimates of the earlier German writers [52] and whose shrewd, practical conclusion that it will be best for France to export some Lorraine ore to Germany [53] reveal the typical French psychology.[54]

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[50] Burchard, E. F., Iron ore, pig iron, and steel: U. S. Geol. Survey Mineral Resources 1917, pt. 1, p. 572, 1919.

[51] Cayeux, L., Le mineral de Lorraine, Paris, 1918.

[52] Idem, p. 25.

[53] Idem, p. 36.

[54] The iron and related industries of the Lorraine Basin are considered in detail by Brooks and La Croix in Bulletin 703 of the U. S. Geological Survey.

EXTENT AND CHARACTER OF THE DEPOSITS.

The minette ore fields lie in eastern France, in the Departments of Meurthe-et-Moselle and Lorraine, and extend into Luxemburg and

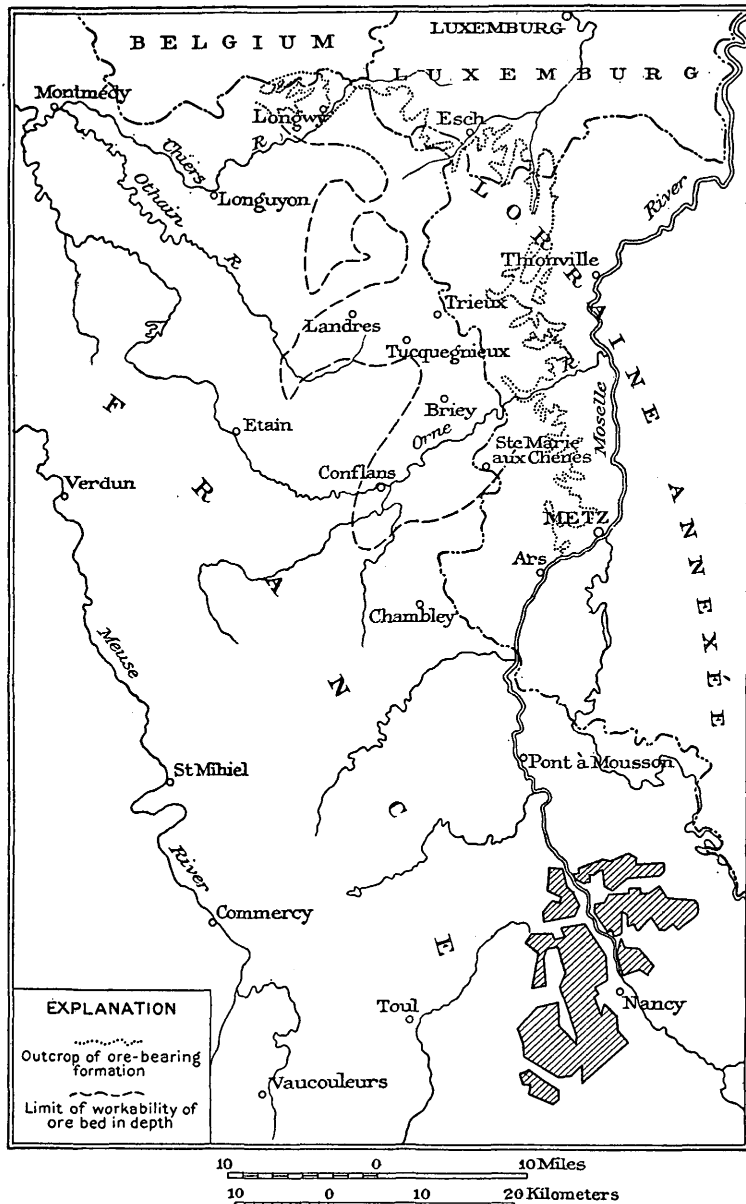


FIGURE 17.—Sketch map of the minette iron-ore basin, showing the position of the deposits, the Franco-German boundary of 1870, and iron-mining concessions in the vicinity of Nancy.

the Belgian province of Luxemburg. (See fig. 17.) The main deposit extends southward from Belgium to a point 5 miles below Orne River, where the ores become too lean to be worth mining. The iron formation continues to the south and near Nancy is again workable. The sinuous line indicating the western limit of ore on the sketch map is not the limit of the ore formation but represents the extent of the ore that is regarded as workable under present conditions. It may be extended considerably in the future. The eastern limit is the outcrop of the ore-bearing formation.

Of the recognized deposits an area of 3,600 hectares lies in Luxemburg and an area of 71,600 hectares in France. The Belgian part of the basin has been exhausted.

The deposits are sedimentary, lie in synclinal basins that pitch to the southwest, and are cut into blocks by faults that extend from northeast to southwest and from northwest to southeast. Most of the faults are of slight displacement and do not greatly affect the deposits, but the Crusnes fault has a throw of as much as 120 meters. These minor structural basins are themselves a part of the great Paris Basin, of which they form the eastern rim.

Mineralogically the ores are mainly oolitic brown ores, cemented by lime, clay, or sandy clay, but some siderite is present. The grains of oolite average about 0.25 millimeter in diameter and are composed predominantly of ferric hydrate but contain some hematite, iron silicate, and iron carbonate.

That they are sedimentary deposits seems to be fairly well established, though some geologists believe that they were formed by metasomatic replacement of calcareous oolites.

The ore is classed as calcareous or siliceous, according to the cement. The following analyses [55] show the range in composition of the two types:

Chemical composition of minette ores.

	Calcareous.	Siliceous.
Fe	26 to 40	30 to 40
CaO	8 to 20	4 to 10
SiO_2	4 to 8	8 to 15
Al_2O_3	2 to 6	2 to 8
P_2O_5	1.5 to 2	1.5 to 2

The ore occurs as bedded masses that are almost entirely free from inclusions of barren material. The deposits are interbedded with clays, limestones, and sandstones of Jurassic age. The French place them at the top of the series, below the Lower Dogger, but the Germans regard them as the bottom member of the Lower Dogger.

The seven recognized ore beds vary considerably in thickness and in composition. At some places the beds include masses of ferruginous limestone, which are sorted out and used as a flux with siliceous

[55] Kohlmann, W., Die neuere Entwicklung des lothringischen Eisenerzbergbaues: Stahl und Eisen, vol. 31, pt. 1, p. 415, 1911.

ores. Between the ore beds lie beds of limestone, marl, and sandy marl. The following is a generalized section:

Section of minette ore beds.

Hanging wall:
- Dense, impervious marl.
- Red siliceous ore.

Middle calcareous ore series:
- Red calcareous ore.
- Yellow ore.
- Gray ore.

Lower siliceous ore series:
- Brown ore.
- Black ore.
- Green ore.

Footwall of sandy marl.

This section is at few places seen in its entirety, and even where a large part of it is present the mining is commonly limited to one of the beds because the others are not of exploitable thickness.

The following analyses [56] shows the average composition of the more valuable beds:

Chemical composition of minette beds.

	Fe.	CaO.	MgO.	P.	SiO_2.	Al_2O_3.	CO_2, H_2O.
Red bed	40.4	8.2	0.5	0.7	9.6	5.5	14
Yellow bed	38.0	9.8	1.5	.3	7.0	4.2	....
Gray bed	31.8	19.0	.5	.7	7.0	2.3	22
Brown bed	24.0	8.6	2.0	.6	16.6	6.5	....
Black bed	39.7	5.9	.5	.7	15.1	5.2	14

The most valuable of these is the gray bed, which covers almost the entire district and reaches a maximum thickness of 7 meters.

The ore is mined by open cuts, adits, and shafts, the means chosen depending, in general, upon the depth of the ore below the surface of the ground. As most of the outcrops are in the eastern part of the area, formerly German, Germany had the advantage of working the more easily mined material. Lower costs of labor and a slightly higher average grade of ore made it possible for French ore to compete with German in spite of more costly methods of mining.

The minette ores owe their value to their proximity to the coal of Westphalia, the Saar, and Belgium; to the fact that they afford self-fluxing mixtures, and to the commercial value of the phosphatic slag formed in converting Lorraine pig iron to steel. The iron content of the ore smelted has been decreasing gradually, though this is not to be taken as indicating that the more recently developed and deeper-lying ore masses are of inferior grade, but rather

[56] Einecke, C., and Köhler, W., Die Eisenerzvorräte des deutschen Reiches: The iron-ore resources of the world (11th Internat. Geol. Cong.), vol. 2, p. 714.

that now the fractions of the developed masses that are mined out are larger than formerly.

RESERVES.

The reserves of ore in the Lorraine Basin were very carefully estimated in 1911, as well as before and since that time. The estimates used here are taken from Kohlmann.[57] The estimate he gives for the French part of the basin is a modification of that given by Villain.[58]

Iron ores in the Lorraine Basin in 1911.

[Millions of metric tons.]

	Calcareous ore.	Siliceous ore.	Total.
France:			
Bassin de Nancy	....	200	200
Bassin de Briey	2,000	....	2,000
Bassin de Crusnes	....	600	600
Bassin de Longwy	....	300	300
Total in France	2,000	1,100	3,300
Germany:			
North of Fentsch	863	263	1,126
Between Fentsch and Orne	385	....	385
South of Fentsch	180	150	330
Total in Germany	1,428	413	1,841
Luxemburg	125	125	250
Total in Lorraine Basin	3,553	1,638	5,191

The above estimates show evidence of careful consideration and conservative calculation. Only ore that met the metallurgic requirements of that time and that could profitably be extracted with the mining methods then in use was taken into consideration. Since that time there have been improvements in the methods of handling the ore and advances in metallurgic practice. The French estimates can also be increased, because the ore may, perhaps, be followed west of the area in which concessions have been granted.

After considering all the factors enumerated and studying all information available the estimates given on page 64 were adopted.

[57] Kohlmann, W., Die neuere Entwicklung des lothringischen Eisenerzbergbaues: Stahl und Eisen, vol. 31, pt. 1, pl. 419, 1911.

[58] Villain, M., Le gisement de minerai de fer oolithique de la Lorraine: Annales des mines, 10th ser., vol. 1, pp. 113-322, 1902.

Iron resources of the Lorraine Basin.

[Millions of metric tons.]

	Known.		Probable.		Possible.	
	Ore.	Iron.	Ore.	Iron.	Ore.	Iron.
France:						
Former German Lorraine	1,800	558	500	150	500	150
French Lorraine	3,000	990	750	225	1,000	300
	4,800	1,548	1,250	375	1,500	450
Luxemburg	200	60	70	21	....	....
	5,000	1,608	1,325	396	1,500	450

NORMANDY.[59]

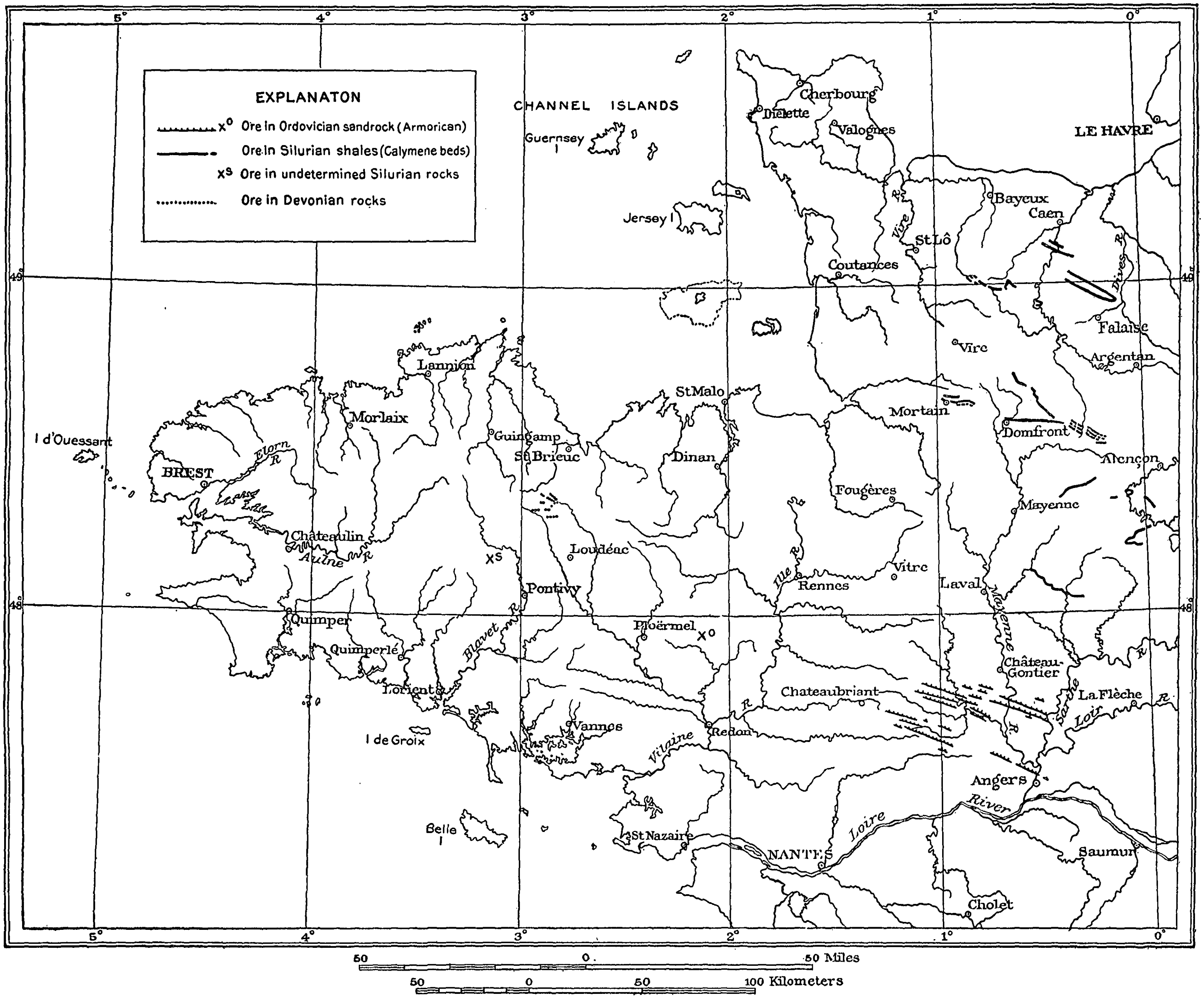
In northern France, in the old Province of Normandy, in the Departments of Orne, Calvados, and Manche (see Pl. VII), lie the ore deposits which rank second in importance to France. The history of iron making in Normandy is like that in other countries that have long been inhabited. Steel from ore mined in Normandy helped William the Conqueror to win the battle of Hastings. But gradually the forests used in making charcoal for smelting the ore approached exhaustion and laws were passed to conserve the remaining forests, so that the iron industry died and Norman ores were forgotten for many years. Then came the modern need of iron and the use of coal. But Normandy lacks coal, so the future value of its iron ores lies in their ability to compete with other ores in foreign markets. That they can so compete is shown by the fact that before the war the Germans had become heavily interested in the ore deposits of the district.

According to Cayeux the ores are all oolitic. The original oolite, which was composed of calcium carbonate, was replaced by siderite, and siderite is still the primary mineral, but where it lies near the surface it has been altered to oxides, and near Dielette[60] it has been metamorphosed to form beds of hematite and magnetite.

The deposits, though of secondary origin, are intercalated in sedimentary beds, and their distribution is due to complex folds that have an east-west trend. Plate VII shows the location of

[59] Bigot, A., L'exploitation des mines de fer de la Basse-Normandie: Rev. gén. sci. pures et appl., vol. 24, pp. 346-352, 1913. Bigot, A., Le bassin minière de la Basse-Normandie: Idem, pp. 258-263. Cayeux, L., Structure et origine probable du minerai de fer magnétique de Dielette: Compt. Rend., vol. 142, pp. 716-718, 1906. Cayeux, L., Coup d'œil sur les minerais de fer de la presqu'île armoricaine: Soc. française de minéralogie Bull., vol. 41, p. 134, Nos. 7, 8, July-December, 1918. Cayeux, L., Les minerais de fer oolithiques de France, Paris, 1909. Heurteau, C. E., Note sur le minerai de fer silurien de Basse-Normandie: Annales des mines, 10th ser., vol. 11, pp. 613-668, 1907. Maulde, J. de, Les mines de fer et l'industrie métallurgique dans le Département du Calvados, Caen, 1916. Nicou, P., Les ressources de la France en minerais de fer: The iron-ore resources of the world (11th Internat. Geol. Cong.), vol. 1, pp. 15-20, Stockholm, 1910.

[60] Cayeux, L., Structure et origine probable du minerai de fer magnétique de Dielette: Compt. Rend., vol. 142, pp. 716-718, 1906.



MAP OF THE ARMORICAN PENINSULA, FRANCE, SHOWING THE DISTRIBUTION OF OOLITIC IRON ORES IN NORMANDY, BRITTANY, AND ANJOU.

some of the deposits. The outcrops occur from Caen on the north to Domfront on the south and from Falaise on the east to the coast at Dielette on the west. The ore beds occur in stratified formations of Ordovician age, except at Dielette, where the age of the rocks is Darwin, and these formations belong to the folded early Paleozoic and ancient group of rocks that constitute the old land mass known as the Armorican Peninsula. This peninsula of northwestern France, the massif of south-central France, the western part of the Iberian Peninsula, and the Scandinavian massif are the four land masses in Europe that have stood above the level of marine invasions since early Paleozoic time.

According to P. Nicou[61] the reserve of the entire Armorican Peninsula amounts to about 220,000,000 tons. Their estimates amount to 4,700,000,000 tons. An estimate by L. Cayeux[62] increases the estimate of available ore in the peninsula to 1,825,000,000 tons. During years immediately preceding the war the Germans became much interested in these deposits, and German geologists made some studies of them that were published during the war.[63]

The average analysis of the ores of Normandy shows that they contain 47 per cent of iron, 12 per cent of silica, 3 per cent of alumina, and 0.6 to 0.7 per cent of phosphorus.

As the ores of Dielette are superior in grade to the ores of the rest of Normandy they were considered separately. They contain on an average 57 per cent of iron, 12 per cent of silica, and 0.25 per cent of phosphorus.

Iron resources of Normandy.

[Millions of metric tons.]

	Known.		Probable.		Possible.	
	Ore.	Iron.	Ore.	Iron.	Ore.	Iron.
Dielette	50	28	50	25	50	25
Rest of Normandy	175	77	1,000	400	2,000	800

In this table the estimates made by Germans are purposely discounted, possibly without doing justice to Krusch and Beyschlag, because it seemed to be to their advantage to overestimate rather than to underestimate.

[61] Op. cit., p. 27.

[62] Cayeux, L., Coup d'œil sur les minerais de fer de la presqu'île armoricaine: Soc. franç. minéralogie Bull., vol. 41, p. 134, 1918.

[63] Krusch, P., Das neue Deutschland, Mar. 15, 1918.

BRITTANY AND ANJOU.[64]

Ore deposits similar to those of Normandy are found in somewhat younger rocks in Brittany and Anjou. This country forms the southern part of the Armorican Peninsula, and its geologic history is similar to that of Normandy. The location of this deposit is shown in Plate VII (in pocket).

The ores occur with sedimentary rocks of Silurian age, in part as intercalations and in part as surface deposits. They extend through the Departments of Maine-et-Loire, Loire-Inférieure, Morbihan, Vendée, Ille-et-Vilaine, and Mayenne. They are mostly brown ores and siderite, but locally ores of better than average grade contain hematite or magnetite.

The ores of Brittany and Anjou contain about 50 per cent of iron, 16 per cent of silica, 3 per cent of alumina, and from 0.3 to 0.75 per cent of phosphorus. Their composition varies greatly from place to place, and some of the ore contains sulphur.

An estimate made by Bellanger,[65] though it is admittedly incomplete, was used as a basis for that given below.

Iron resources of Brittany and Anjou, France.

[Millions of metric tons.]

	Ore.	Iron.
Known	250	115
Probable	500	230
Possible	500	230

PYRÉNÉES-ORIENTALES.[66]

In the eastern Pyrenees, Province of Pyrénées-Orientales, near Canigou, as shown in figure 18, lie the ore deposits from which come most of the low-phosphorus iron ore produced in France. The deposits consist of lenses and veins of spathic ore or derived oxidation products in Silurian sediments. De Launay's description [67] shows that the ore was deposited from solutions that were probably of hydrothermal origin. There is evidence of considerable replacement.

As marketed the ore contains about 54 per cent of iron, 3 to 4 per cent of manganese, 4 per cent of silica, and very little phosphorus.

[64] Bellanger, E., Note sur l'importance probable du gisement ferrifère de l'Anjou: Annales des mines, 10th ser., vol. 20, pp. 452–456, 1911; Les minerais de fer de l'Anjou: La Nature, 1911. Cayeux, L., Coup d'œil sur les minerais de fer de la presqu'île armoricaine: Soc. franç. minéralogie Bull., vol. 41, p. 134, 1918. Nicou, P., Les ressources de la France en minerais de fer: The iron-ore resources of the world (11th Internat. Geol. Cong.), vol. 1, pp. 20–22, Stockholm, 1910.

[65] Op. cit., p. 456.

[66] Nicou, P., Les ressources de la France en minerais de fer: The iron-ore resources of the world (11th Internat. Geol. Cong.), vol. 1, pp. 22-27, Stockholm, 1910.

[67] Launay, L. de, Traité de métallogénie, gîtes minéraux et métallifères, vol. 2, pp. 386-392, Paris and Liége, 1913.

The following estimate of the reserves is based on Nicou's estimate:

Iron resources of Pyrénées-Orientales, France.

[Millions of metric tons.]

	Ore.	Iron.
Known	30	16.5
Probable	30	16.5
Possible	30	16.5

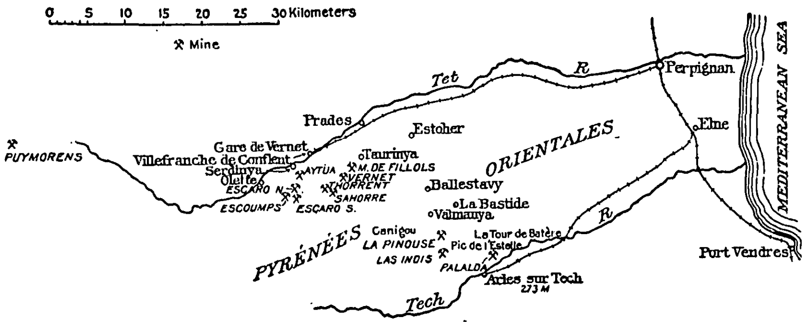


FIGURE 18.—Sketch map showing distribution of iron mines in the Province of Pyrénées-Orientales, France. (From "The iron-ore resources of the world.")

HAUTE-MARNE.[68]

The brown ores of the Department of Haute-Marne are intercalated at six horizons in lower Jurassic sediments. Some of this ore fills cavities, some is geoidal, and the top bed is oolitic. The medium-phosphorus ore now mined is taken from the oolitic bed. The analyses show approximate averages of 43 per cent of iron, 14 per cent of silica, 7 per cent of alumina, 2.5 per cent of manganese, and 0.4 per cent of phosphorus.

Figures given by Nicou indicate the resources tabulated below.

Iron resources of Haute-Marne.

[Millions of metric tons.]

	Ore.	Iron.
Known	13.5	5.5
Possible	10.0	4.5

In this estimate the bed now being mined is included in the "known" and the other beds in the "possible" reserve.

[68] Rigaud, F., Notice sur les minières de la Haute-Marne: Annales des mines, 7th ser., vol. 14, pp. 9-62, 1878. Nicou, P., Les ressources de la France en minerais de fer: The Iron-ore resources of the world (11th Internat. Geol. Cong.), vol. 1, pp. 29-30, Stockholm, 1910.

OTHER DEPOSITS.

According to official statistics 19 departments other than those mentioned furnished 335,000 metric tons of iron ore in 1913, and deposits are recorded in still other departments.

In Ariège and Basses-Pyrénées deposits similar to those of Pyrénées-Orientales produced about 61,000 tons of ore in 1913. No definite estimate can be made of the quantity of ore left. These deposits can be credited with a reserve of probably 250,000 tons of metallic iron. The gossan deposits in the Department of Aude do not appear to be worth considering.

The Bordeaux Basin furnished 26,000 tons of ore from Lot, Lot-et-Garonne, and Dordogne, and deposits are known in Charente and Haute-Garonne. The deposits in these Departments are brown ores, most of them carrying little phosphorus. They are of residual type and are probably not very extensive. They can be credited with probably 100,000 tons of iron.

Some deposits of iron ore are scattered along the edges of the massif in south-central France. Sedimentary deposits in the Department of Aveyron, at the southwest end of the massif, have produced 50,500 tons of high-phosphorus ore; other like deposits in Saône-et-Loire, at the northeast end, produced 32,000 tons of high-phosphorus ore, and similar ore is found at Alliers. It is probably safe to count on 2,500,000 tons of iron from these deposits. In Ardèche and Hérault, on the southern edge of the massif, 27,000 tons of medium phosphatic iron ore were mined in 1913. The deposits are approaching exhaustion and probably all that is left is about 250,000 tons of iron. In Indre, Vienne, Lozère, Tarn, and Gard about 80,300 tons of low-phosphorus ores have been mined, and because of their metallurgic desirability these ores will probably be mined to exhaustion. Gard, Tarn, and Indre appear to have considerable reserves and can be counted on for 2,500,000 tons of iron. Altogether probably 5,250,000 tons of metallic iron may be extracted from the south-central massif.

In southeastern France, in the Alpine districts of the Department of Isère, there are some gossan ores which have produced about 10,000 tons of low-phosphorus ores. In the mountains in the Department of Var there are brown ores, high in iron and medium phosphatic, which have a future. Nicou credits these deposits with a reserve of 3,000,000 tons, which can be considered equivalent to 1,500,000 tons of metallic iron. They produced 10,300 tons of ore in 1913.

The Departments of Jura and Haute-Saône, in the Jura Mountains, have produced 7,500 tons of ore. The ore is low in phosphorus but is also very low in iron.

There is some iron ore in the Paris Basin, in Cher, Nord, and Pas de Calais, but it is not of any importance as a reserve.

The Departments that are of minor rank as compared with Lorraine, Normandy, Brittany and Anjou, and Pyrénées-Orientales show a combined probable reserve of 7,100,000 tons of iron.

SUMMARY OF RESERVES.

France's total reserve of iron is estimated in the following table:

Iron resources of France.

[Millions of metric tons of iron. Compare Pl. VI, in pocket.]

	Known.	Probable.	Possible.
Lorraine	1,548.0	375.0	450.0
Normandy	105.0	425.0	825.0
Brittany and Anjou	115.0	230.0	230.0
Pyrénées-Orientales	16.5	16.5	16.5
Haute-Marne	5.5	....	4.5
Other deposits	....	7.1	....
	1,790.0	1,053.6	1,526.0

PRODUCTION AND CONSUMPTION.

Figure 19 shows the rapidly accelerating growth of the production of iron ore in France prior to 1910. Details of the production in 1913, by Departments, from French official statistics, follow:

Iron ore produced in France in 1913, by Departments.

	Metric tons.		Metric tons.
Ardèche	26,783	Lot-et-Garonne	33,479
Ariège	36,569	Lozère	200
Aveyron	50,414	Maine-et-Loire	130,193
Basses-Pyrénées	23,507	Manche	61,388
Calvados	388,923	Mayenne	3,000
Dordogne	2,600	Meurthe-et-Moselle	19,978,937
Gard	31,998	Orne	362,673
Haute-Marne	57,714	Pas de Calais	150
Haute-Saône	1,500	Pyrénées-Orientales	333,778
Hérault	543	Saône	29,186
Ille-et-Vilaine	132,040	Tarn	11,253
Indre	27,690	Var	10,313
Isère	9,968	Vienne	9,140
Jura	5,946		
Loire-Inférieure	134,663		21,917,870
Lot	23,352		

The production according to the major districts is shown below.

	Metric tons.
Lorraine Basin	19,978,937
Normandy	812,984
Pyrenees	393,844
Brittany and Anjou	269,703
19 departments not included above	462,402

The production of iron ore in France in 1913 was 20.5 per cent and her consumption was 12 per cent of the European total. (See fig. 6, p. 28.)

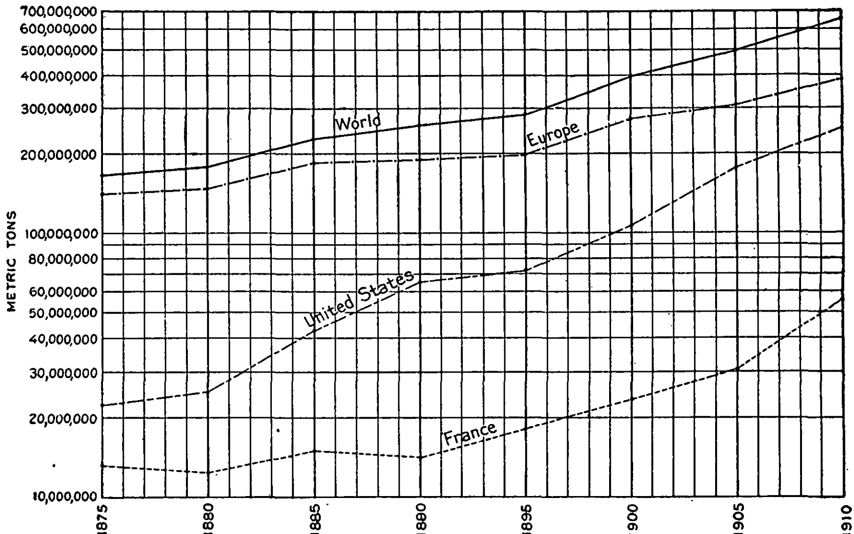


FIGURE 19.—Ratio chart showing iron ore produced during five-year periods ending 1875 to 1910 in France, Europe, the United States, and the world. (See explanation of fig. 8, p. 41.)

The progress of iron mining from 1894 to 1913 for France as a whole and for the Department of Meurthe-et-Moselle is shown in figure 20. Essentially all the product of Meurthe-et-Moselle has been minette ore from the Longwy, Briey, and Nancy basins. The future significance to France of controlling essentially all of the iron ore of

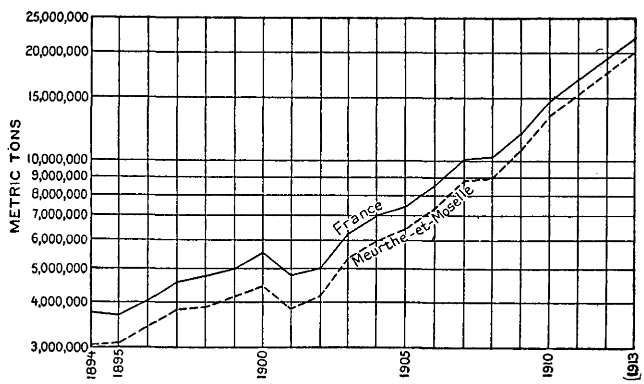


FIGURE 20.—Ratio chart showing iron ore produced annually in France and in the Department of Meurthe-et-Moselle, 1894–1913. (See explanation of fig. 8, p. 41.)

old Lorraine is indicated by the capacity of producing over 40,000,000 tons of ore as demonstrated by the performance of 1913. What could France do with iron ore in such an amount as this? The extent to which the country has become an exporter of iron ore is shown in figures 5 (p. 27) and 21. Full control of the Saar Basin, the development of the Pont-à-Mousson field, the expansion of the production of Pas de Calais, and the increased use of friendly Belgian coal may take care of the greater part of the ore, but as none of this coal produces as good and as cheap coke as the coal of Westphalia, unless that coke is used the iron and steel produced will be proportionately more expensive than in the past—not a hopeful outlook for the ultimate consumer.

The shipment of ore to England and the return of coal has been suggested,[69] but as this involves an added freight burden and a

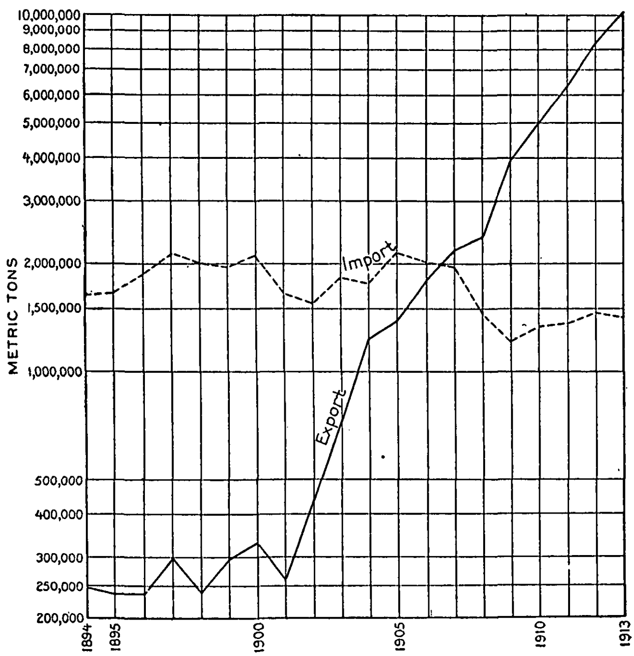


FIGURE 21.—Ratio chart showing iron ore exported and imported annually by France, 1894–1913.

change in English smelting practice it does not appear to promise steel at a cost as low as could be attained by the use of Westphalian coal.

It may be possible for a time to compel the shipment of Westphalian coal to France without commensurate return of ore to Germany, assuming the rebuilding of destroyed steel plants and blast furnaces in France and Belgium and an expansion sufficient to take care of the iron ore formerly handled in Westphalia, but the enforced shipments without adequate exchange could last only during the term of Germany's punishment, and the assumption of the develop-

[69] Ferasson, L., La question du fer, Paris, Payot et Cie., 1918.

ment of plants vastly beyond past performance may not be well founded. Assumptions of this sort are based on the development in France of a "flaire" for industrial expansion that seems contrary to the accepted genius of the French people. The logical though perhaps unpleasant course to follow is to resume as soon as possible an equitable interchange between Lorraine iron ore and Westphalian coal, and the fact that France realizes this is shown by a recent study made by Cayeux.[70]

The ore of Normandy was used to a greater extent during the war than ever before. If the French Government should follow a more liberal course in regard to mining concessions in this district it might be possible to build up a considerable export trade in ore with Great Britain, but the high-grade Brazilian ores probably offer a more economic source of supply for British furnaces. The low-phosphorus ores of the Pyrenees will continue to be sought in the future as in the past by makers of Bessemer steel.

The French iron industry seems assured of expansion in the near future, but it is not probable that France will develop a fuel-producing capacity comparable to her ore-producing capacity in spite of her control of the Saar Basin. She should continue to be an exporter of iron ore. The policy of avoiding export by curtailing production would be somewhat in accord with French conservation tendencies, but in practice this policy would prevent France from taking the position in the iron-ore industry that her resources warrant.

BELGIUM.

DISTRIBUTION, CHARACTER, AND EXTENT OF THE DEPOSITS.

Although Belgium is able to attract much iron ore from abroad and ranked sixth in the list of producers of pig-iron in 1913, she ranked about twentieth among producers of iron ore in that year, with a production of approximately 150,000 tons.

The Belgium iron-ore deposits are of three types—bedded oolitic ores in Devonian rocks in Liége, Namur, and in Jurassic rocks in Luxemburg; vein deposits in Namur and Liége; and surficial brown ores in the Campine country of Antwerp and Limburg. The Belgian end of the Lorraine ore field is so nearly exhausted that it need not be considered.

Campine region.—Most of the iron ore produced in Belgium in recent years has been the high-phosphorus brown ores mined in the Campine region. The greater part of this ore was used for special purposes in Germany. The quantity still available has been estimated by Lespineux [71] and the data given by him indicate that it

[70] Cayeux, L., Le minerai de Lorraine, Paris, 1918.

[71] Lespineux, Georges, Note retrospective sur les mines de fer en Belgique: The iron-ore resources of the world (11th Internat. Geol. Cong.), vol. 2, p. 659, Stockholm, 1910.

contains "known" resources of metallic iron amounting to 2,500,000 metric tons and "probable" resources amounting to 2,500,000 metric tons.

Extensive deposits of iron ore are associated with the coal measures of the Campine field. They have been prospected by drilling, and Lambert [72] discusses the possibility of utilizing them, but this possibility seems so remote that these ores have not been considered in calculating the reserves.

Namur-Liége district.—The bedded ores of Luxemburg have been practically exhausted, and those of the Namur-Liége district have been exhausted to a depth below which the underground water makes them so expensive to mine that they can not compete with the ores of the Lorraine Basin, which are imported from France. The vein deposits of the Namur-Liége district are not of much importance.

Several estimates of the amount of ore left in the Namur-Liége district have been made. A. Delmer [73] estimated that some 351,000,000 metric tons of ore are still unmined. The geologist can accept this estimate, but the miner will probably never be able to work as far below water level as the geologist can estimate the iron content of a regular bedded deposit.

As very little of the ore can compete with other ores, because of the high cost of mining none of it is placed in the category of "known" ore as here defined. On the other hand it seems fair to take the 33,000,000 metric tons which Delmer assumed to be workable as "probable" ore and to add double that amount for "possible" ore to allow for future developments in mining technology.

Iron resources of the Namur-Liége district.

[Millions of metric tons.]

	Ore.	Iron.
Probable	33.0	11.6
Possible	66.0	23.2

The ore is an oolitic hematite in an argillaceous or calcareous cement. It averages 35 to 40 per cent of iron and contains only a medium amount of phosphorus.

[72] Lambert, Guillaume, Découverte d'un puissant gisement de minerais de fer, etc., Brussels, 1904; critical review by B. Schulz-Briesen in Glückauf, vol. 41, pt. 1, pp. 37–42, 1905.

[73] Delmer, A., La question du minerai de fer en Belgique: Annales des mines de Belgique, vol. 17, pp. 853–940; vol. 18, pp. 325–448, 1912–13.

Iron resources of Belgium.

[Millions of metric tons of iron.]

	Known.	Probable.	Possible.
Antwerp-Limburg (superficial brown ore)	2.5	2.5	....
Liége-Namur (oolitic hematite)	....	11.6	23.2
	2.5	14.1	23.2

PRODUCTION AND CONSUMPTION.

As a producer of iron ore Belgium is nearly negligible. In 1913 she produced 150,000 tons of ore, and in the same year her blast furnaces consumed 7,100,000 tons, equal to about 6.5 per cent of the total consumption in Europe. Of this ore over 6,500,000 tons came from the minette ore fields and the remainder from Spain and Sweden.

The iron industry of Belgium was originally based on the firm foundation of resources of domestic coal, but in recent years it has been cheaper to import from Germany much of the coal used rather than to depend entirely on domestic production. It will be to the advantage of Europe in general that Belgium should continue to draw on German coal, because it is the best and cheapest coal, but if political considerations should stop this normal trade, coal mining may be developed in Belgium to an extent sufficient to take care of her iron industry. The development of the Campine coal fields would have the additional advantage of making accessible the iron ores that are associated with the coal measures there.

NETHERLANDS.

The only iron ores in Holland are small superficial deposits of bog ore, which were once mined but are now entirely valueless. Holland has no iron industry but has some coal in the province of Limburg. It is reported that she is trying to start a factory to supply iron and steel for home consumption.

LUXEMBURG.

DISTRIBUTION, CHARACTER, AND EXTENT OF THE DEPOSITS.

The reserves of Luxemburg consist of a part of the ore of the Lorraine Basin described under the heading "France" (pp. 55–64). As only the edge of the basin lies in Luxemburg most of the ore is found near the surface and is mined open cast. As it is mined cheaply and can be used in self-fluxing mixtures, the ore is valuable in spite of its low grade.

Iron resources of Luxemburg.

[Millions of metric tons.]

	Ore.	Iron.
Known	200	60
Probable	70	21

PRODUCTION AND CONSUMPTION.

The iron industry of Luxemburg has heretofore been bound up with that of the German Customs Union. Its gradual growth is shown by figure 15 (p. 57). With her furnaces undamaged by war and aside from possible restrictions on imports of ore from France and of coal from Germany, there seems to be no reason why Luxemburg should not regain her former position as a producer of iron ore.

GERMANY.

DISTRIBUTION, CHARACTER, AND EXTENT OF THE DEPOSITS.

The inventory of the iron-ore deposits in Germany is probably more nearly adequate than that for any other country, the reports on which the estimates are based being both thorough and numerous. (See Pl. VIII, in pocket.) Those who made the estimates may differ in opinion as to the genesis of the ore—in fact, much of the German literature on the subject is devoted to more or less amicable disagreements—but the facts observed are so carefully recorded that the reader can safely draw his own conclusions.

The territorial rearrangements that affect the allocation of ore deposits are definitely outlined by the peace treaty. The uncertainties in regard to the boundary between West Prussia and Poland and the rearrangements that may be caused by a plebiscite in Silesia or the East Prussian districts can affect only amounts that are negligible in the sum total.

SAAR VALLEY.[74]

There is no large quantity of valuable iron ore in the district that has been taken from Germany to replace the destroyed coal fields of Pas de Calais. Some clay ironstone is associated with the coal, but it has no economic value, though it was used in the early days of the industry.[75]

[74] Einecke, G., and Köhler, W., Die Eisenerzvorräte des deutschen Reiches: K.-preuss. geol. Landesanstalt Archiv für Lagerstättenforschungen, Heft 1, pp. 240-242, Berlin, 1910.

[75] Hasslacher, A., Beiträge zur älteren Geschichte des Eisenhüttenwesens im Saargebiete: Zeitschr. Berg-, Hütten- u. Salinenwesen preuss. St., vol. 44, pp. 75-97, 1896.

WEST RHINE.

The territory west of the Rhine also contains little iron ore. Some brown ores are found in cavities in limestone near Aachen (Aix-la-Chapelle), and ore of the same sort in the Eifel district was the basis of an iron industry that can be traced back to ancient times. A little of this ore occurs also on the southern slope of the Soonwald. The production from the Aachener Kohlenkalkbezirk in 1913 was 3,722 tons.

Estimates made by Einecke and Köhler[76] are tabulated below.

Iron resources of the region west of the Rhine.

[Millions of metric tons.]

	Known.		Probable.		Possible.	
	Ore.	Iron.	Ore.	Iron.	Ore.	Iron.
Soonwald	1.0	0.2	0.30	0.1		
Aachen	3.0	1.1			0.5	0.2
Eifel			5.00	1.9		
	4.0	1.3	5.30	2.0	.5	.2

EAST RHINE.

The most valuable reserves remaining in German possession lie in the East Rhine region. The production in 1913 was 4,897,000 tons. The region is covered by the clause in the peace treaty forbidding fortifications. It will be taken up in detail by districts, from north to south.

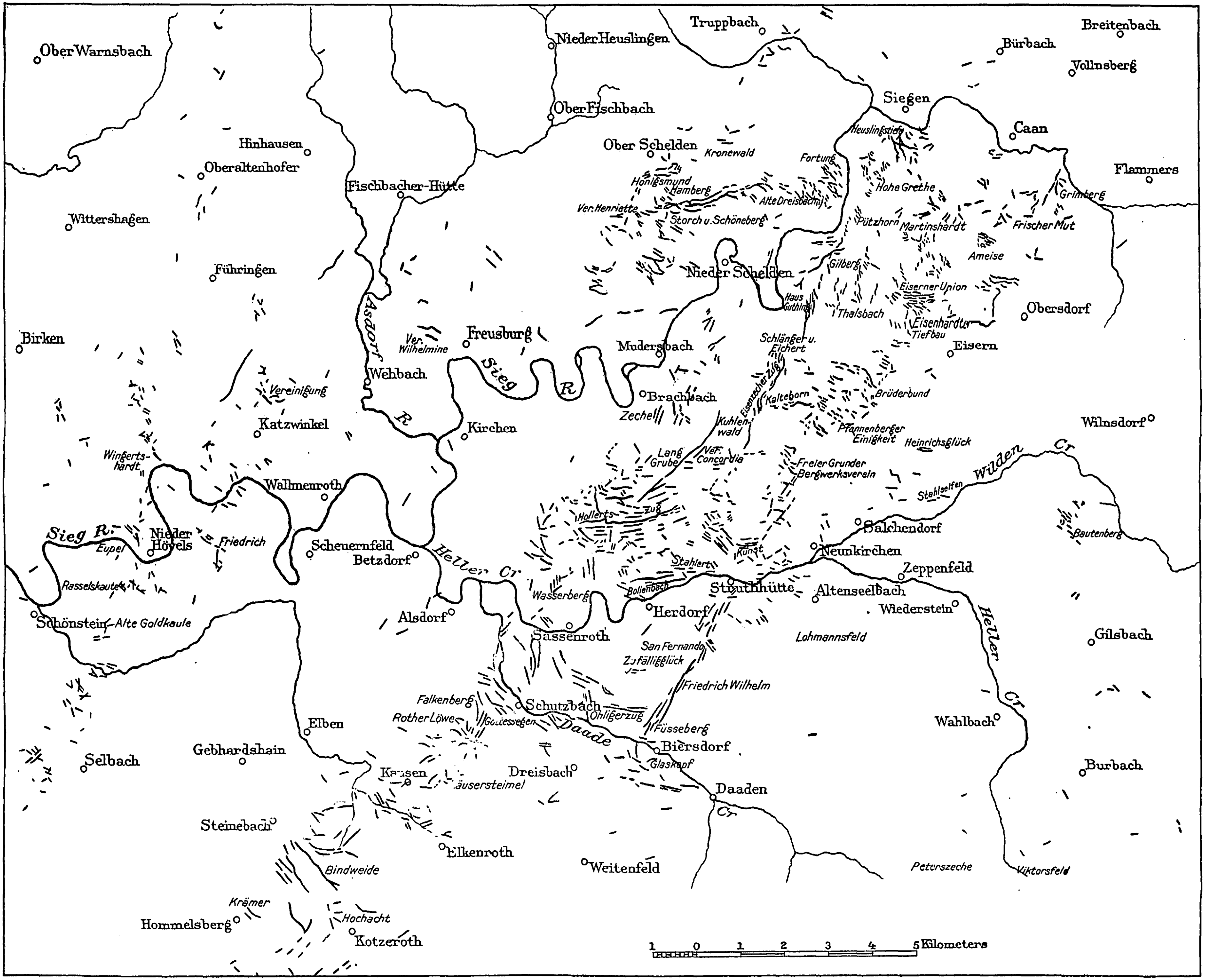
Bergischer-Kalkberg district.[77]—The iron resources of the districts east of the Rhine consist of brown ores that were deposited in cavities in limestone. The Bergischer-Kalkberg district produced about 1,500,000 metric tons of ore in the 50 years prior to 1913, and its resources are not great. Einecke and Köhler's estimate shows that it can be credited with the reserve indicated below.

Iron resources of the Bergischer-Kalkberg district.

[Millions of metric tons.]

Known.		Probable.		Possible.	
Ore.	Iron.	Ore.	Iron.	Ore.	Iron.
3.5	1.4	5.5	2.2	4	1.6

[76] Op. cit., pp. 244-271.
[77] Einecke, G., and Köhler, W., op. cit., pp. 200-212.



MAP SHOWING DISTRIBUTION OF THE SIDERITE DEPOSITS OF SIEGERLAND, GERMANY.

Siegerland district.[78]—The ore of the Siegerland district is probably the most valuable in Germany. It is a very excellent grade of carbonate ore occurring in veins in Lower Devonian rocks. The distribution of the vein system is shown in Plate IX. The ore contains 38 to 40 per cent of iron, 6 to 9 per cent of manganese, and on roasting yields metal averaging 60 per cent and an earthy residue of 12 per cent.

The reserves have been very carefully estimated in considerable detail by Einecke and Köhler.[79]

Iron resources of the Siegerland district.

[Millions of metric tons.]

	Ore.	Iron.
Known	116	42.92
Probable	50	18.5
Possible	50	18.5

Lahn-Dill district.[80]—South of the Siegerland district lie the valuable deposits of the Lahn and Dill synclines. The ore is predominantly sedimentary hematite, which is supposed to have been deposited from iron-bearing vapors and solutions of volcanic origin beneath the sea.[81] The ores in the Dill syncline are siliceous; those in the Lahn syncline are somewhat calcareous. Their content of iron is variable, averaging 48 per cent, according to Einecke and Köhler, though German official statistics show that as mined it is about 42 per cent.

Besides the hematite there are brown ores derived from it. The location of the deposits of both types is shown in Plate X. The estimate of reserves given by Einecke and Köhler [82] is tabulated on page 78.

[78] Einecke, G., and Köhler, W., op. cit., pp. 159-200. Bornhardt, W., Über die Gangverhältnisse des Siegerlandes und seine Umgebung: K.-preuss. geol. Landesanstalt Archiv für Lagerstättenforschungen, Heft 2, 1910. Lotz, H., Beitrag zur Kenntnis vom Alter der Siegerländer Erzgänge: Zeitschr. prakt. Geologie, vol. 15, pp. 251-253, 1907. Resow, W., Das Ganggebietes des der "Eisenzecher Zuges": Zeitschr. prakt. Geologie, vol. 16, pp. 305-328, 1908.

[79] Op. cit., p. 182.

[80] Beyschlag, F., Krusch, P., and Vogt, J. H. L., Die Lagerstätten der nutzbaren Mineralien und Gesteine, 2 vols., p. 1072, Stuttgart, F. Enke, 1913. Einecke, G., and Köhler, W., op. cit., pp. 92-149.

[81] Hatzfeld, C., Die Roteisensteinlager bei Fachingen an der Lahn: Zeitschr. prakt. Geologie, vol. 14, pp. 361-365, 1906. Krecke, F., Sind die Roteisensteinlager des nassauischen Devons primäre oder sekundäre Bildungen? Zeitschr. prakt. Geologie, vol. 12, pp. 348-355, 1904. Lotz, H., Die Dillenburger Rot- und Magneteisenerze: Deutsche geol. Gesell. Zeitschr., vol. 54, pp. 139-141, 1902. Rose, ——, Zur Frage der Entstehung der nassauischen Roteisensteinlager: Zeitschr. prakt. Geologie, vol. 16, pp. 497-501, 1908. Harbort, E., Zur Frage nach der Entstehung gewisser devonischer Roteisenerzlagerstätten: Neues Jahrb., 1903, Band 1, pp. 179-192.

[82] Op. cit., pp. 114-126.

Iron resources of the Lahn and Dill synclines.

[Millions of metric tons.]

	Ore.	Iron.
Known	166.0	68.7
Probable	92.25	36.9
Possible	100.00	40 0

Westerwald-Taunus-Vogelsberg district.[83]—Tertiary brown iron ores fill cavities in limestones in the Taunus and Vogelsberg hills and in the Westerwald region. Although not comparable in amount to larger deposits, they are a source of considerable ore of fair grade.

Iron reserves of the Taunus, Vogelsberg, and Westerwald regions.

[Millions of metric tons.]

	Ore.	Iron.
Known	15.7	4.7
Probable	1.2	0.4
Possible	15.3	3.8

Spessart.[84]—There is one other valuable group of deposits of iron ore in the East Rhine district—the metasomatic carbonate ores in the "Zechstein" formation of northwestern Spessart. The ores are easily mined and beneficiated, so that they are a cheap source of iron, although they contain only about 33 per cent of iron. A content of manganese amounting to 8 to 16 per cent adds to their value.

The estimate given by Einecke and Köhler [85] covers only the ore that is immediately available, so that in the estimate below an arbitrary figure has been added for "possible" ore.

Iron resources of Spessart.

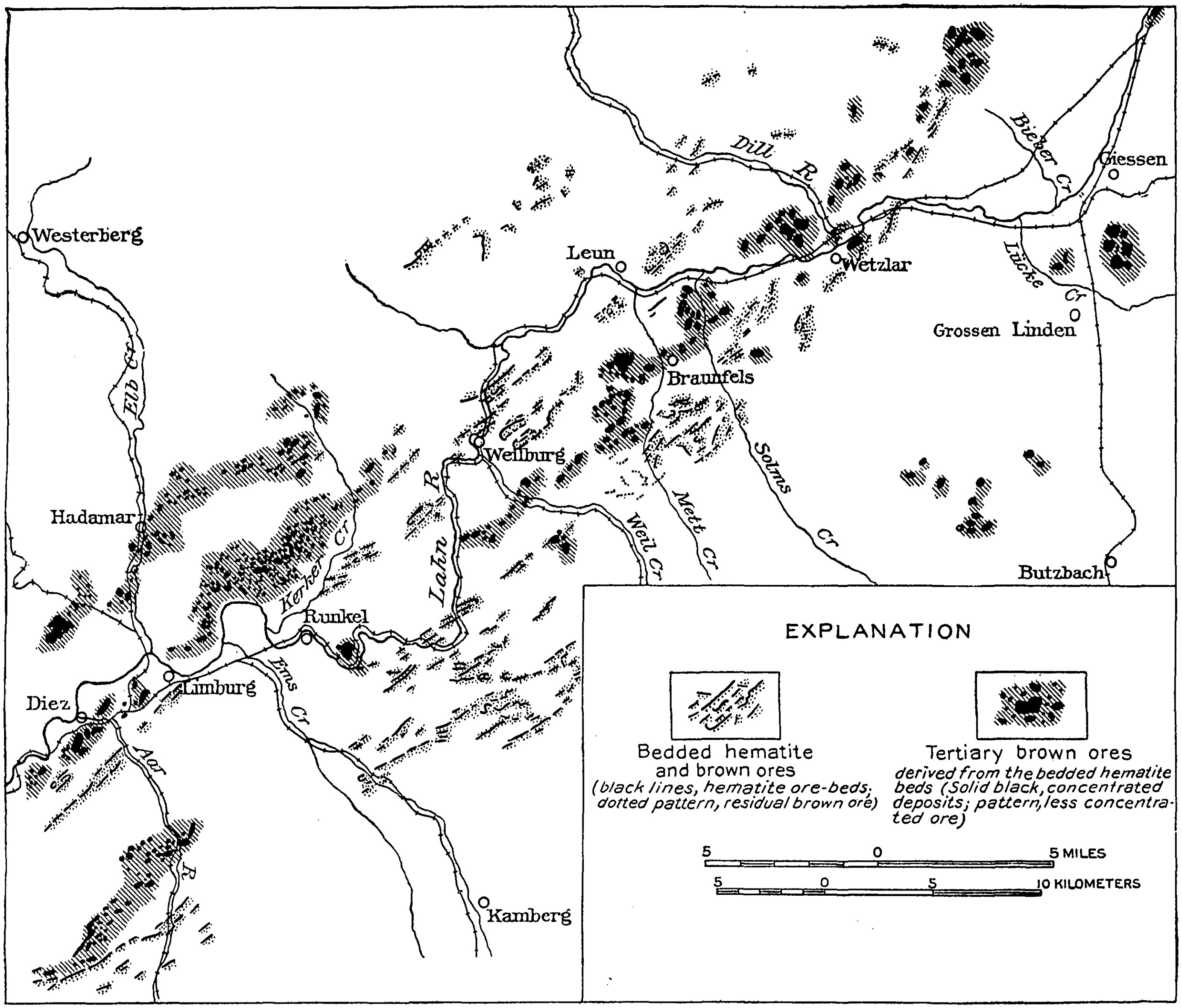
[Millions of metric tons.]

	Ore.	Iron.
Known	3.5	1.2
Possible	3.5	1.2

[83] Einecke, G., and Köhler, W., op. cit., pp. 216–232, 270–278, 636–666. Beyschlag, F., Die Eisenerze des Vogelberges: Zeitschr. prakt. Geologie, 1897, pp. 337–338. Bodifee, ——, Über die Genesis der Eisen- und Manganerzvorkommen im Taunus: Zeitschr. prakt. Geologie, vol. 15, pp. 309–316, 1907. Chelius, C. R. L., Eisen und Mangan im Grossherzogtum Hessen, etc.: Zeitschr. prakt. Geologie, vol. 12. pp. 356–362, 1904. Delkeskampf, R., Die technisch nutzbaren Mineralien und Gesteine des Taunus: Zeitschr. prakt. Geologie, vol. 11, pp. 265–276, 1903. Münster, H., Die Brauneisenerzlagerstätten des Seen- und Ohmtals am Nordrand des Vogelgebirges: Zeitschr. prakt. Geologie, vol. 13, pp. 242–258, 413, 1905. Vierschilling, A., Die Eisen- und Manganerzlagerstätten im Hunsrück und Soonwald: Zeitschr. prakt. Geologie, vol. 18, pp. 393–431, 1910.

[84] Einecke, G., and Köhler, W., op. cit., pp. 480–590. Bücking, H., Der nordwestliche Spessart: K.-preuss. geol. Landesanstalt Abh., neue Folge, Heft 12, p. 148, 1892.

[85] Op. cit., p. 489.



MAP SHOWING DISTRIBUTION OF IRON-ORE DEPOSITS IN THE LAHN-DILL DISTRICT, GERMANY.

Summary.—The following figures sum up the reserves of metallic iron in the entire East Rhine district.

Iron resources of the East Rhine district.

[Millions of metric tons of iron.]

	Known.	Probable.	Possible.
Bergischer-Kalkberg	1.4	2.2	1.6
Siegerland	42.9	18.5	18.5
Lahn-Dill	68.7	36.9	40.0
Westerwald-Taunus-Vogelsberg	4.7	0.4	3.8
Spessart	1.2	....	1.2
	118.9	58.0	65.1

WESER DISTRICT.

Throughout the hills that form the middle part of the drainage basins of the Weser and the Ruhr, extending from Duisburg on the west eastward nearly to Magdeburg and southward to a point below Cassel, there are deposits of iron ore.

Salzgitter-Iselde region.[86]—The most valuable of the deposits of ore in the Weser district lie in the northern foothills of the Harz Mountains, in the Salzgitter-Iselde region in two synclines in Cretaceous rocks.

The deposits, which are of sedimentary origin, consist of brown iron-ore conglomerate cemented in places by oolitic material, and form sedimentary beds 20 to 30 meters thick. Their outcrop has been traced for 21 kilometers.

The ore is high in phosphorus and contains about 30 per cent of iron, as mined, and 12 per cent of moisture. Roasting gives a product whose iron content is about 40 per cent.

Einecke and Köhler,[87] in calculating the reserves, considered only the ores immediately available and contented themselves with saying that the possibilities were "very considerable." Their figures were used for the "known" and "probable" ore, but the estimate of "possible" ore is based on the dimensions of the deposits given in their account.

Iron resources of the Salzgitter-Iselde region.

[Millions of metric tons.]

	Ore.	Iron.
Known	248	74.4
Probable	30	9.0
Possible	1,000	300.0

[86] Einecke, G., and Köhler, W., op. cit., pp. 350-390.
[87] Idem., p. 387.

Harz Mountains.[88]—In the Harz Mountains there are many deposits of iron ore. The most extensive are the deposits of hematite and those of brown ores derived from it near Elbingerode and Hüttenrode. They are sedimentary deposits and are similar to the Lahn-Dill ores in occurrence. There are also sedimentary hematite ores in the Devonian rocks of the Upper Harz and carbonate veins in the southern Harz.

Iron resources of the Harz Mountains

[Millions of metric tons.]

	Ore.	Iron.
Known	20.5	9.2
Probable	22.1	8.9
Possible	55.0	21.8

Kellerwald-Sauerland region.—In the southern part of the Weser district there is a continuation of the ore deposits of the Lahn-Dill district. The ores are hematite and brown ores derived from hematite in Devonian sediments.[89]

Iron resources of the Kellerwald-Sauerland region.

[Millions of metric tons.]

	Ore.	Iron.
Known	4	1.1
Possible	8	2.2

Lower Hesse.[90]—Ore of a different type is found at Mardorf Zwesten and Schieffelborn, in Lower Hesse. It is residual pisolitic brown ore called "bohnerz."

	Ore.	Iron.
Known	1.5	0.6
Probable	1.0	.3
Possible	2.0	.7

Bentheim-Ochtrup-Ottenstein region.[91]—In the northwest corner of the Weser district some clay ironstone ores lie in thin seams in Cretaceous clays. They are not worked at present, but slight changes

[88] Ermisch, K., Die Knollengrube bei Lauterberg am Harz: Zeitschr. prakt. Geologie, vol. 12, pp. 160–172, 1904. Einecke, G., and Köhler, W., op. cit., pp. 390–431.

[89] Einecke, G., and Köhler, W., op. cit., p. 428.

[90] Idem, pp. 472–480.

[91] Krusch, P., Die Eisenerzvorkommen der untern Kreide im Westen des Beckers von Münster, etc.: Glückauf, vol. 54, pp. 261–268, Apr. 27, 1918. Willert, —, Das Toneisensteinvorkommen von Ahaus und Koesfeld [Bentheim-Ochtrup-Ottenstein]: Glückauf, vol. 44, pt. 1, pp. 304–309, 1908. Einecke, G., and Köhler, W., op. cit., pp. 278–301.

in practice might make them available, so they can not be neglected as a reserve. In fact, German experts have lately been giving these ores renewed attention in the hope of finding a way to use them. The reserve figures given below are based on the estimate made by Einecke and Köhler.[92]

Iron resources of the Bentheim-Ochtrup-Ottenstein region.

[Millions of metric tons.]

	Ore.	Iron.
Probable	15	4.5
Possible	200	60.0

Teutoburger Wald and Wesergebirge areas.—There are many iron-ore deposits in the Teutoburger forest, but only a few of them are worth noting. The brown ores of Hüggel and the carbonate ores of Schafberg and the brown ores derived from them are now mined. Besides these some clay ironstones occur in the Wittekind formation, and a ferruginous limestone, which contains 18 per cent of iron and is used as a flux, occurs in the Wesergebirge district.

The estimates of Einecke and Köhler[93] indicate the reserves tabulated below.

Iron resources of the Teutoburger Wald and Wesergebirge areas.

[Millions of metric tons.]

	Ore.	Iron.
Known	20.5	7.2
Probable	23.5	7.8
Possible	100.0	18.0

Oolitic ores.—Besides the deposits specially mentioned, there occur through the Weser district small islands of oolitic ore similar to the minette ores of Lorraine.[94] These ores occur in islands of the same Jurassic horizon as the Lorraine ores. Although the individual occurrences are small the aggregate reserve is considerable.

Iron resources in oolitic ores in the Weser district.

[Millions of metric tons.]

	Ore.	Iron.
Known	20	6.4
Probable	25	8.0
Possible	100	32.0

[92] Op. cit., p. 298.
[93] Idem, p. 347.
[94] Idem, pp. 492-527.

Summary of the Weser district.—The quantity of iron in the Weser district is summarized below.

Iron resources of the Weser district.

[Millions of metric tons of iron.]

	Known.	Probable.	Possible.
Salzgitter-Iselde	74.4	9.0	300.0
Harz Mountains	9.2	8.9	21.8
Kellerwald-Sauerland	1.1	....	2.2
Lower Hesse	0.6	0.3	0.7
Bentheim-Ochtrup-Ottenstein	....	4.5	60.0
Teutoburger Wald-Wesergebirge	7.2	7.8	18.0
Oolitic ores	6.4	8.0	32.0
	98.9	38.5	434.7

NORTH AND CENTRAL GERMANY.[95]

Throughout the plains of north and central Germany there are deposits of bog iron which in 1913 yielded 36,350 tons of ore. Many of those in the northwestern part are exhausted, as are also those in Upper Silesia. Some of them have gone to Poland with the territory in Posen and West Prussia. An estimate of what remains to Germany is given below.

Iron resources of north and central Germany.

[Millions of metric tons.]

	Ore.	Iron.
Known	8	2.4
Probable	8	2.4
Possible	8	2.4

THURINGIA.[96]

In the older formations of the Thuringian forest there are several kinds of iron deposits. In the Cambrian rocks at Schmiedefeld[97] there are contact-metamorphic deposits of magnetite in limestone next to granite. In the Silurian of the eastern part of the forest there are large beds of oolitic chamosite.[98] Einecke and Köhler describe the ore as a somewhat argillaceous and siliceous carbonate.

[95] Einecke, G., and Köhler, W., op. cit., pp. 527–530. Eisenerze in Schlesien und Posen: Zeitschr. prakt. Geologie, vol. 14, p. 62, 1906.

[96] Einecke, G., and Köhler, W., op. cit., pp. 431–472. Beyschlag, F., Die Erzlagerstätten der Umgebung von Kamsdorf in Thüringen: K. preuss. geol. Landesanstalt Jahrb., 1888, pp. 329–377. Loretz, H., Der Zechstein in der Gegend von Blankenburg und Königsee (Thüringerwald): K.-preuss. geol. Landesanstalt Jahrb., 1889, pp. 221–245. Lowag, J., Mangan und Eisenerzvorkommen im Thüringerwalde: Oesterr. Zeitschr. Berg- u. Hüttenwesen, vol. 50, pp. 608–611, 623–625, 635–636, 1902. Russwurm, ——, Neue Aufschlüsse von Magneteisenerz im Thüringerwalde: Glückauf, vol. 43, pt. 1, pp. 163–164, 1907.

[97] Schlegel, Karl, Das Magneteisenerzlager vom Schwarzen Krux bei Schmiedefeld: Deutsch. geol. Gesell. Zeitschr., vol 54, pp. 24–55, 1902.

[98] Zalinski, E. R., Untersuchungen über Thuringit und Chamosit aus Thuringen: Neues Jahrb., Beilage Band, vol. 19, pp. 40–84, 1904.

De Launay (after Loretz)[99] says that it is composed of oolitic grains of chamosite, with some thuringite, cemented by iron carbonate and lime carbonate. After it is roasted the ore is of about 45 per cent grade and high in phosphorus. Unlike other German ores it contains a little titanium dioxide (1.4 to 1.8 per cent).

The production of iron ore in the Thüringerwald in 1913 was 280,200 tons.

Iron resources of the Thuringian forest.

[Millions of metric tons.]

	Ore.	Iron.
Known	52.0	15.9
Probable	52.3	13.5
Possible	105.0	27.3

BAVARIA AND WÜRTTEMBERG.[1]

In the Jurassic sediments of the Swabian and Bavarian Alps there are brown ores of several types. The location of some of the deposits is shown in figure 22. They are partly intercalated oolites, partly

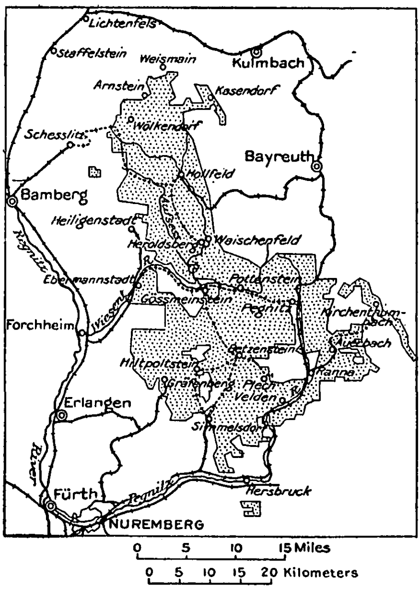


FIGURE 22.—Sketch map showing areas of developed iron ore in the Franconian Alps, Bavaria. (From Einecke, G., and Köhler, W., op. cit.)

[99] Loretz, H., Der Zechstein in der Gegend von Blankenburg und Königsee (Thüringerwald): K.-preuss. geol. Anstalt Jahrb., 1889, pp. 221-245.

[1] Einecke, G., and Köhler, W., op. cit., pp. 590-631. Fluhr, R., Die Eisenerzlagerstätten Württembergs: Zeitschr. prakt. Geologie, vol. 16, pp. 1-23, 1908. Holzapfel, E., Die Eisenerzvorkommen in der Fränkischen Alb: Glückauf, vol. 46, pt. 1, pp. 341-350, 1910. Rothpletz, A., Über die Amberger Erzformation: Zeitschr. prakt. Geologie, vol. 21, pp. 249-260, 1913. Schmidt, A., Württemberg's Erzbergbau in der Vergangenheit: Glückauf, vol. 43, pt. 2, pp. 1034-1042, 1907.

replacement deposits, and to some extent are of residual origin. These ores have been receiving considerable attention in recent years and bid fair to become one of the most important of Germany's reserves. They are of immense extent and their possible value seems very large in spite of the fact that they contain too much silica for general use. The production in 1913 was 498,900 tons.

Iron resources of Bavaria and Württemberg.

[Millions of metric tons.]

	Ore.	Iron.
Known	42	17.9
Probable	250	92.0
Possible	1,100	382.0

SCHMIEDEBERG.[2]

At Schmiedeberg, in the part of Silesia left to Germany, lies a high-grade deposit of magnetite ore of igneous origin.

Iron resources of Schmiedeberg, Germany.

[Millions of metric tons.]

	Ore.	Iron.
Known	0.6	0.3
Probable	2.0	1.0

SUMMARY OF GERMAN IRON RESERVES.

The iron resources of Germany are summarized by districts below.

Iron resources of Germany.

[Millions of metric tons of iron. Compare Pl. VIII, in pocket.]

	Known.	Probable.	Possible.
West Rhine	1.3	2.0	0.2
East Rhine	118.9	58.0	65.1
Weser	98.9	38.5	434.7
Bog ores (north and central Germany)	2.4	2.4	2.4
Thuringia	15.9	13.5	27.3
Württemberg and Bavaria	17.9	92.0	382.0
Schmiedeberg	.3	1.0	....
	255.6	207.4	911.7

PRODUCTION AND CONSUMPTION.

The steady increase in the production of iron ore in the German Customs Union, which advances at a somewhat slower rate than that of the United States but faster than Europe as a whole, is shown in figure 23.

[2] Berg, G., Die Magneteisenerzlager von Schmiedeberg: K.-preuss. geol. Landesanstalt Jahrb., 1902, pp. 201-266. Einecke, G., and Köhler, W., op. cit., pp. 572-576.

The slowly increasing relative importance as well as the predominant position of the minette ores of Lorraine Annexée is shown in figure 24.

In 1913 the production of iron ore in Germany and Luxemburg together amounted to 33 per cent and the consumption to 43.5 per cent of the total in Europe. Of the ore produced in the German Customs Union Luxemburg produced 20.5 per cent, Lorraine Annexée 59 per cent, and the rest of Germany 20.5 per cent.

The latest available statistics (those for 1912) show that of the total ore consumed Luxemburg used 19.1 per cent, German Lorraine 24.5 per cent, Prussia 53.7 per cent, Bavaria 0.9 per cent, and the rest of Germany 1.8 per cent. The last three items, representing the consumption of new Germany, aggregate 66.4 per cent.

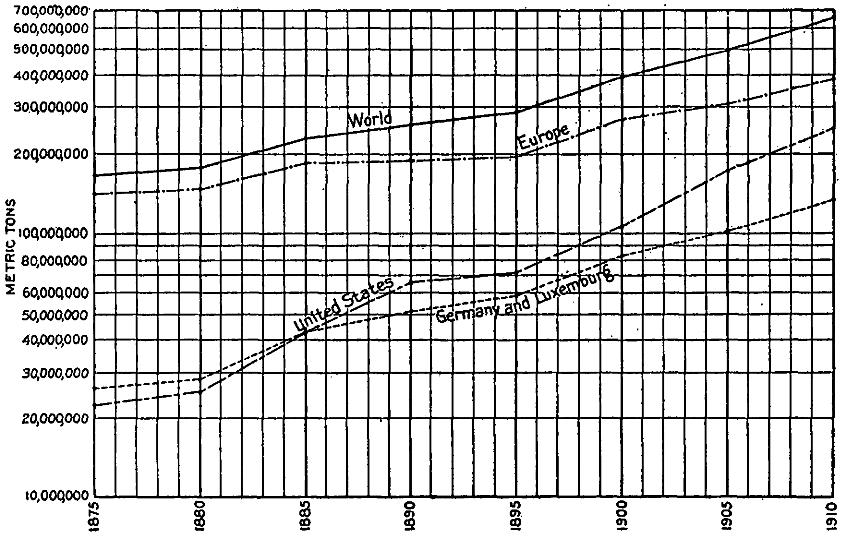


FIGURE 23.—Ratio chart showing iron ore produced during five-year periods ending 1875 to 1910 in the German Customs Union, Europe, the United States, and the world. (See explanation of fig. 8, p. 41.)

The indicated capacity of the German Republic to produce iron ore is only 20.5 per cent of the capacity of the former German Customs Union, whereas its indicated capacity of consumption is 56.4 per cent of the capacity of the former German Customs Union. Thus, in order to continue the iron and steel industry of the territory now remaining at the same rate as before the war, Germany must import a much larger proportion of the ore required than in the past. If artificial barriers are erected against this importation the iron industry of Germany will decline and ultimate consumers in other countries will lose a source of cheap iron and steel.

Germany's reserves of ore still appear to be fairly extensive, but she has no iron-ore producing districts that rank with those that have been lost. The following table, based on official statistics,[3]

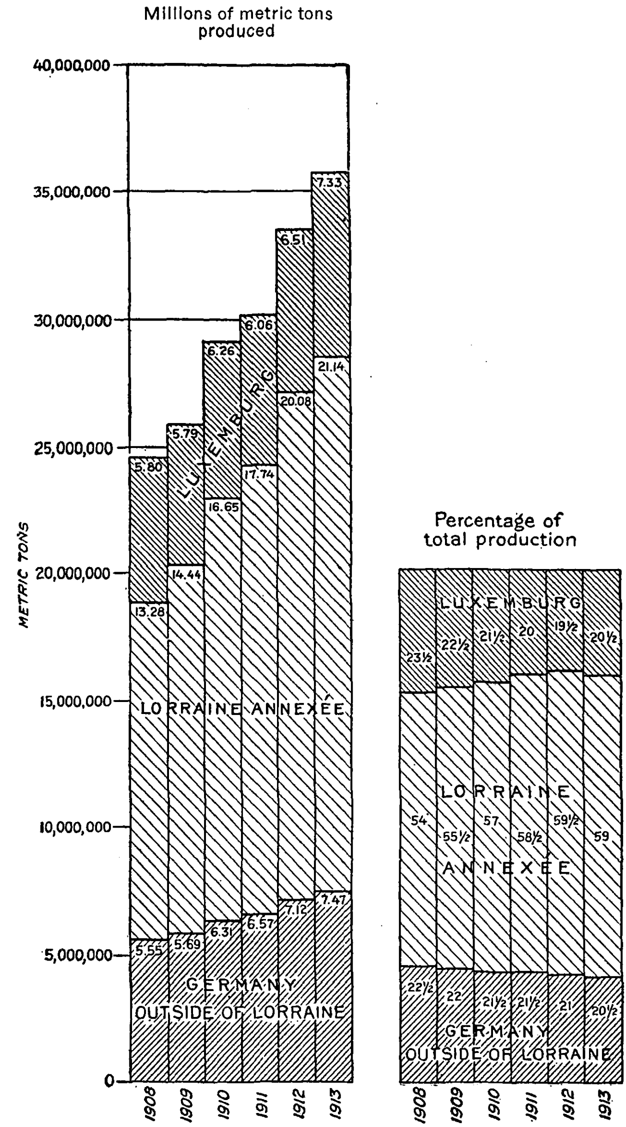


FIGURE 24.—Diagrams showing iron ore produced annually in the German Customs Union, 1908–1913, and the quantities and proportions contributed by Luxemburg, Lorraine Annexée, and German mines outside of Lorraine.

shows the quantity of iron in the ore mined per man per year in the remaining districts of Germany:

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[3] Vierteljahrshefte zur Statistik des deutschen Reichs.

Metric tons of iron in iron ore mined per man per year in certain districts in Germany.

Mining district.	1908	1912	1913
Aachener Kohlenkalk	110	101	78
Bergischer Kalk	42	....	....
Siegerland Spateisenstein	63	72	75
Lahn-Dill	66	80	86
Taunus and Lindener Mork	53	55	50
Vogelsberger Basalteisen	154	135	158
Waldeck-Sauerland	45	52	52
Schafberg-Hüggel	82	71	48
Wesergebirge	125	159	168
Peine-Salzgitter	212	209	260
Harz	163	271	244
Bog ore	118	44	36
Thuringia-Sachsen	139	149	131
Bavaria-Württemberg-Baden	146	167	143
Average for new Germany	80	97	95
Silesia	40	41	27
Lorraine	335	388	378
Average for former German Empire	159	207	201

In spite of all that Germany has lost and the poor sort of ore that remains she has, in the coking coal of Westphalia, in her undamaged furnaces, and in her known genius for work, resources that assure her a strong position in the world's iron and steel industry. The near future, with formidable economic barriers and with markets dulled by social unrest and domestic disturbance, may be very dark, but enmity and social unrest can not prevail forever against Europe's need of iron.

SWITZERLAND.[4]

DISTRIBUTION, CHARACTER, AND EXTENT OF THE DEPOSITS.

The iron ores of Switzerland are of more interest to the historian than to the economist, for most of the deposits are so situated that they can not be exploited economically. (See Pl. VIII, in pocket.)

Jura Mountains.[5]—In the Jura Mountains of western Switzerland are found the so-called "Bohnerze"—pisolitic ores derived from Mesozoic iron-bearing limestones by superficial disintegration during the Eocene epoch. They are low-grade, slightly titaniferous ores which contain 42 per cent of iron after washing. In 1910 this ore was being mined near Delsberg at the rate of about 6,500 tons a year.

It is difficult to estimate the reserves of ore of this type, because its occurrence is extremely irregular. C. Schmidt[6] says that about 1,000,000 tons are known. As transportation is not considered another million may be estimated as "possible."

[4] Schmidt, C., Bericht über die Eisenerzvorräte der Schweiz: The iron-ore resources of the world (11th Internat. Geol. Cong.), vol. 1, pp. 105–141, Stockholm, 1910. Hotz, W., Die Lagerstätten der nutzbaren Mineralien in der Schweiz: Zeitschr. prakt. Geologie, vol. 17, pp. 29–42, map, 1909.

[5] Fleury, E., Le fer et le terrain sidérolithique dans le Jura bernois: Soc. fribourgeoise sci. nat. Bull., vol. 12, pp. 29–33, 1904; abstract in Inst. Min. Eng. Trans., vol. 29, pp. 690–691, 1904–1905.

[6] Schmidt, C. [Mining in Canton Wallis], reviewed in Zeitschr. prakt. Geologie, vol. 11, pp. 205–208, 1903.

Iron resources of the Jura Mountains, Switzerland.

[Millions of metric tons.]

	Ore.	Iron.
Known	1	0.4
Possible	1	.4

Mont Chemin.[7]—In the metamorphic rocks of Mont Chemin, a part of the mass of Mont Blanc, particularly in the marble, there are lenses of magnetite and hornblende. The material is of rather good grade but is negligible as a reserve.

Avers.[8]—In the Triassic limestone and associated porphyry of the valley of Avers there are intercalated beds of siderite and hematite. They are of only historical importance.

Gonzen.[9]—Jurassic sedimentary ores, which, singularly, lack oolitic structure, are found near Gonzen. They are of good grade, are more or less manganiferous, but are insignificant in quantity.

Chamoson and Erzegg-Planplatten.[10]—Jurassic ores also occur at Chamoson and in the Erzegg-Planplatten area. They are oolitic and siliceous. The ore minerals are chamosite and siderite. Their average iron content is 30 per cent.

Iron resources of Chamoson and of the Erzegg-Planplatten area.

[Millions of metric tons.]

	Ore.	Iron.
Known	2.5	0.8
Possible	2.5	.8

Other deposits.—There are many small and inaccessible deposits in Switzerland that together can be considered as affording a possible reserve of a million tons of iron.

Summary for Switzerland.—The quantities of iron in the ore deposits of the region indicated are summarized below:

Iron resources of Switzerland.

[Millions of metric tons of iron.]

	Known.	Possible.
Jura Mountains	0.4	0.4
Chamoson-Erzegg-Planplatten	.8	.8
Others	....	1.0
	1.2	2.2

[7] Schmidt, C. [Mining in Canton Wallis], reviewed in Zeitschr. prakt. Geologie, vol. 11, pp. 205–208, 1903.

[8] Heim, A., Über die Erze des Avers und Oberhalbsteintal in Graubünden (abstract): Geol. Centralbl., vol. 1, p. 740, 1901.

[9] Wencélius, A., Eisen und Manganerzgruben der Schweiz: Berg- u. Hüttenm. Zeitung, vol. 62, pp. 541–545, 1903.

[10] Idem.

PRODUCTION AND CONSUMPTION.

Switzerland mines no iron ores, and her deposits are so inaccessible that she is not likely to develop an iron-mining industry.

ITALY.[11]

DISTRIBUTION, CHARACTER, AND EXTENT OF THE DEPOSITS.

Italy is nearly self-supporting as to iron ore. She obtains most of her ore from the island of Elba. (See Pl. XI, in pocket.)

Elba.[12]—The famous high-grade, low-phosphorus ores of Elba occur in metamorphic rocks of pre-Silurian to Eocene age. According to De Launay[13] the ores are vein and metasomatic deposits associated with granitic intrusives. Later metamorphism has tended to make them appear more complex. The ore minerals are oxides (magnetite, hematite, and ferric hydrates) near the surface and contain increasing amounts of sulphides with increase in depth.

The reserves were estimated at 7,500,000 tons in 1904. From 1904 until January 1, 1909, 1,240,000 tons were mined. Since then about 500,000 tons a year has been mined, or about 6,250,000 tons from 1904 to 1919, so that about 1,250,000 tons are left in the deposits. Allowing for development work there are probably about 2,500,000 tons of ore containing 1,100,000 tons of iron on the island that fall into the class of "known" ores.

Sardinia.[14]—According to recent information, examinations stimulated by war needs have proved that 6,000,000 tons of ore occur in Sardinia, in the Nurra district, at the north end of the island. These ores are sedimentary and oolitic. Their average content of iron is about 45 per cent, so that it seems fair to credit the deposits with probable reserves amounting to 6,000,000 metric tons of ore containing 2,700,000 tons of iron.

At Ogliastra, between the Bay of Orosei and the Gulf of Cagliari, there are bedded deposits of brown ore. Their value is doubtful.

At San Leone there are veins of magnetite which are supposed to contain 875,000 tons of good ore, and near Iglesias there is a bed of brown ore and magnetite which contains about 60,000 tons.

Altogether the deposits in Sardinia can be credited with a "probable" reserve of about 3,333,000 tons of iron.

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[11] Aichino, Giovanni, Note sur les ressources en minerai de fer de l'Italie: The iron-ore resources of the world (11th Internat. Geol. Cong.), vol. 1, pp. 93–105, Stockholm, 1910.

[12] Capacci, C., The iron mines of the island of Elba: Iron and Steel Inst. Jour., 1911, No. 2, pp. 412–450, with map. Poech, F., Die Eisenindustrie auf der Insel Elba: Oesterr. Zeitschr. Berg- u. Hüttenwesen, vol. 51, pp. 365–371. 1903. Sevieri, V., Analyses of Elba ore: Rassegna mineraria, vol. 14, pp. 101–102.

[13] Launay, L. de, Gîtes mineraux et metallifères, vol. 2, pp. 400–408, Paris, Ch. Béranger, 1913.

[14] Duenkel, ——, Berichte über eine im Jahre 1900 ausgeführte Bereisung der Insel Sardinien und einiger anderer Bergreviere Italiens: Zeitschr. Berg-, Hütten- u. Salinenwesen preuss. St., vol. 50, pp. 622–668, 1902. Testa, L., The iron-ore deposits of Sardinia: Iron and Steel Inst. Jour., 1911, No. 2, pp. 364–379

Val d'Aosta.[15]—In the Val d'Aosta, in the Piedmont country near the French border, there are lenses of magnetite in serpentine, which very clearly seem to have been formed by magmatic segregation. The ore is of extremely high grade and is low in phosphorus.

Recent estimates place the reserves of ore at 1,000,000 tons for the deposits of Traversella and 5,000,000 tons for those at Cogne. The total for Val d'Aosta can be taken as 3,600,000 metric tons of metallic iron.

Bergamo-Brescia.[16]—In the Brembana Valley there are replacement veins in beds of siderite. They have furnished low-phosphorus ore for many years, but as the Italian Metallurgical Association estimates the reserve at only 20,000 tons they may be dismissed as unimportant.

Central Italy.[17]—Brown ores are found in Central Italy, in the Versilia district, at Campiglia Maritimma, at Massa Maritimma Orbetello, and at Tolfa.

They are credited with a reserve of 2,000,000 tons of ore, or about 800,000 tons of metal.

Miscellaneous.—Iron ore is reported to occur at Stilo,[18] in southern Italy, and at Monte Peloritani, in Sicily.[19] Its quantity does not seem to be large.

Summary for Italy.—The quantities of metallic iron in the deposits of Italy are summarized below.

Iron resources of Italy.

[Millions of metric tons of iron. Compare Pl. XI, in pocket.]

	Known.	Probable.
Elba	1.1	....
Sardinia	....	3.3
Val d'Aosta	3.6	....
Central Italy	.8	....
	5.5	3.3

[15] Catani, R., The iron-ore deposits of Piedmont: Iron and Steel Inst. Jour., 1911, No. 2, pp. 353–363. Bonney, T. G., The magnetite mines near Cogne: Geol. Soc. London Quart. Jour., vol. 59, pp. 55–63, 1903. Müller, F. C., Die Erzlagerstätten von Traversella im Piemont: Zeitschr. prakt. Geologie, vol. 20, pp. 209–240 (with geologic map), 1912. Peters, F., La Valée d'Aoste et ses principaux gîtes métallifères: Rev. univ. mines, vol. 39–40, pp. 97–116, 1912.

[16] Calvi, G., The production of iron ores in the Brembana Valley: Iron and Steel Inst. Jour., 1911, No. 2, pp. 380–389.

[17] Ciampi, A., The iron-ore deposits of central Italy: Iron and Steel Inst. Jour., 1911, No. 2, pp. 390–408. Ristori, G., I giacimenti limonitici (Campiglia Marittima): Soc. toscana sci. nat. Atti, vol. 20, pp. 60–75, 1904.

[18] La Valle, G., On the iron-ore deposits of southern Italy and Sicily: Iron and Steel Inst. Jour., 1911, No. 2, pp. 409–411.

[19] Lotti, B., Die geologischen und tektonischen Verhältnisse der Erzlagerstätten Nordost-Siziliens: Zeitschr. prakt. Geologie, vol. 15, pp. 62–66, 1907.

PRODUCTION AND CONSUMPTION.

Since the beginning of the twentieth century Italy's production of iron ore has been increasing at a rate consonant with that of the United States and has been ahead of the European rate. Both her production and her consumption of iron ore amount to about 0.5 per cent of the total European consumption and production. In addition she utilizes large quantities of scrap iron and imported pig iron, so that she produces about twice as much steel as pig iron. By the use of electro-metallurgy she is building up the iron industry in her mountain Provinces to an extraordinary degree.

Italy shows what can be done by energetic industry without large domestic reserves. The fuel she uses for her metallurgic work is of foreign origin except as she uses heat generated by electricity, and as she has not enough ore she imports pig iron to supply her needs.

Statistics of the iron industry in Italy in 1913.[20]

	Metric tons.
Iron ore produced	603, 116
Pig iron produced	385, 340
Steel produced	846, 085
Coal (anthracite and lignite) produced	701, 081
Coal imported	10, 834, 008
Coke produced	1, 336, 382
Pig iron imported	221, 688
Iron and steel scrap imported	326, 231
Iron ore imported	8, 026
Iron ore exported	9, 660
Pig iron exported	555
Scrap exported	6, 895

Recent changes in the map of Europe do not affect Italy's supply of ore, but unless there is a change in the present ominous state of the coal industry in Great Britain she must look to Germany or to the United States to supply her deficiency of coal.

NORWAY.[21]

DISTRIBUTION, CHARACTER, AND EXTENT OF THE DEPOSITS.

The iron-ore deposits of Norway (see Pl. XII, in pocket) are difficult to classify. Whatever may have been their origin they are composed of minerals that are formed deep in the earth's crust—magnetite, or magnetite and hematite. Those in which ilmenite is found with

[20] Mineral Industry, 1915.

[21] Vogt, J. H. L., Die Eisenerzvorräte Norwegens: The iron-ore resources of the world (11th Internat. Geol. Cong.), vol. 2, pp. 603–621, Stockholm, 1910. Launay, L. de, L'origine et les caractères des gisements de fer scandinaves: Annales des mines, vol. 4, pp. 49–106, 109–211, 1903. Nicou, P., Étude sur les minerais de fer scandinaves: Annales des mines, vol. 19, pp. 85–174, 177–240, 249–378, 1911. Sjögren, H., The geological relations of the Scandinavian iron ores: Am. Inst. Min. Eng. Trans., vol. 38, pp. 766–836, 1907. Vogt, J. H. L., Norges Jernnalinforekomster: Norges geol. Undersökelse, No. 51, pp. 1–225, 1910.

magnetite are associated with gabbros, diabases, and nepheline syenites. They are clearly of igneous origin. The small deposits of southern Norway are of contact-metamorphic origin.

Most of the Norwegian ores occur in a complex of metamorphosed early Paleozoic rocks. The ore minerals are magnetite and hematite and the gangue contains garnet and vesuvianite. Deep-seated metamorphism has in part determined the form and the mineral composition of the deposits and has obscured or concealed their mode of origin. They are probably sedimentary deposits like the Clinton iron ores, as Sjögren [22] suggests, but the evidence submitted is not sufficient to eliminate the possibility that they were formed by replacement. Whatever may have been their origin they have passed through the deep-seated zone.

The ores are classified commercially according to their content of iron. Those that contain less than 48 per cent (average about 35 per cent) are classed as "concentrating" ores; those that contain more than 48 per cent are classed as direct smelting ores.

The larger deposits are found throughout northern Norway, and a group of smaller deposits in the Christiania district produces ore that is used in local smelters.

Concentrating ores of northern Norway.[23]—The concentrating ores are magnetite and hematite disseminated in metamorphic rocks.

In estimating the reserves the large bodies of concentrating ore that can be mined by open cut were classed as "known," and the smaller bodies or the deeper parts of larger bodies were classed as "probable" and "possible" reserves, according to the time at which they might be mined, whether in the near or the more distant future. The figures given are based on estimates made by Vogt [24] or on more recent private reports.

Iron in concentrating ores of northern Norway.

[Millions of metric tons of iron.]

	Known.	Probable.	Possible.
Sydvaranger	36.0	....	135.0
Dunderland (including Fuglestrand)	31.5	35	105.0
Salangen	7.5	....	12.0
Sörreisen	....	....	15.0
Sjaafjeld-Melkedal	....	....	6.0
Eiteraadal	....	....	4.5
Other deposits	....	....	10.0
	75	35	287.5

The "other deposits" include those at Tromsösund, Öksfjord on Hindö, Bogen-i-Ofoten, and Näverhaugen.

[22] Sjögren, H., The geological relations of the Scandinavian iron ores: Am. Inst. Min. Eng. Trans., vol. 38, pp. 766–836, 1907.

[23] Vogt, J. H. L., Die regional-metamorphosierten Eisenerzlager im nördlichen Norwegen: Zeitschr. prakt. Geologie, vol. 11, pp. 24–28, 59–65, 1903.

[24] Op. cit. (The iron-ore resources of the world, vol. 2), pp. 603–621.

Direct smelting ores of northern Norway.—Mineralogically and genetically the direct smelting ores are similar to the concentrating ores but can be smelted without previous beneficiation.

Iron in direct smelting ores of northern Norway.

[Millions of metric tons of iron.]

	Known.	Probable.	Possible.
Sydvaranger	2.1	3.1	4.2
Beitstaden-Aafjorden	4.1	8.3	11.0
Other deposits	.1	.2	.4
	6.3	11.6	15.6

The location of the important Sydvaranger deposits is shown in figure 25. Among the "other deposits" are those of Melövar and Bjarkö, Kaljord, Lunkenfjord, and smaller deposits on the Lofoten-Vesteraalen islands.

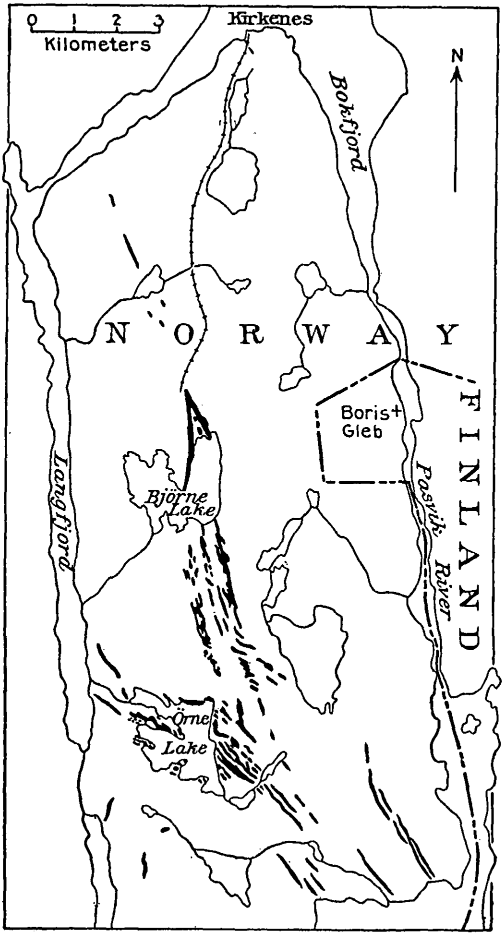


FIGURE 25.—Map of iron-ore fields of Sydvaranger, Norway. (After Beyschlag, Krusch, and Vogt, 1910.)

Titaniferous ore.—There are in Norway many small deposits of workable ore that are at present unavailable because they contain from 3 to 40 per cent of titanium dioxide. The largest deposit is at Selvaag, in the Lofoten Islands. The total "possible" reserve of ore of this class amounts to 17,500,000 metric tons of metallic iron.

"Purple ore."—The deposits of iron and copper sulphides at Sulitjelma produce on roasting, as a by-product, an iron ore which contains 62 per cent of iron and is used in the blast furnace. The iron in these deposits, estimated in metric tons, may be classified as known, 3,100,000; probable, 7,400,000; possible, 6,200,000.

Southern Norway.—In southern Norway, in the Christiania district at Fehn, Kragerö, Nissedal, and Arendal, there are several small deposits of direct smelting ores. The ore contains about 50 per cent of iron and some phosphorus. The ore minerals are magnetite and hematite. They are contact deposits or replacement lodes and are of igneous origin.

Vogt's figures, which have been used here, show resources in metric tons of metallic iron as follows: Known, 1,400,000; probable, 2,400,000; possible, 3,300,000.

Summary for Norway.—Estimates of the quantities of metallic iron in the deposits of iron ore in Norway are given below.

Iron resources of Norway.

[Millions of metric tons of iron. Compare Pl. XII, in pocket.]

	Known.	Probable.	Possible.
Concentrating ores of northern Norway	75.0	35.0	287.5
Direct smelting ores of northern Norway	6.3	11.6	15.6
Titaniferous ores of northern Norway	....	....	17.5
Purple ore of Sulitjelma	3.1	7.4	6.2
Direct smelting ores of southern Norway	1.4	2.4	3.3
	85.8	56.4	330.1

PRODUCTION AND CONSUMPTION.

Norway exports practically all the iron ore she produces, which amounts to about 0.5 per cent of the total European output. As she lacks coal she can establish an iron industry only by electrometallurgy. Her ores have not been mined to the extent that they appear to warrant, and their future development will probably be rapid.

SWEDEN.[25]

DISTRIBUTION, CHARACTER, AND EXTENT OF THE DEPOSITS.

The iron-ore deposits of Sweden lie in three geographic regions—in Swedish Lapland, or northern Sweden; in central Sweden; and at Taberg, in southern Sweden. (See Pl. XII, in pocket.)

[25] Lundbohm, Hjalmar, Petersson, Walfr., and Tegengren, F. R., The iron-ore resources of Sweden: The iron-ore resources of the world (11th Internat. Geol. Cong.), vol. 2, pp. 551–603, Stockholm, 1910. Launay, L. de, L'origine et les caractères des gisements de fer scandinaves: Annales des mines, vol. 4, pp. 49–106, 109–211, 1903. Sjögren, H., The geological relations of the Scandinavian iron ores: Am. Inst. Min. Eng. Trans., vol. 38, pp. 766–836, 1907. Guinchard, J., Sweden, 2d ed., 1914. Nordenström, G., The most prominent and characteristic features of Swedish iron mining: Iron and Steel Inst. Jour., 1898, No. 2, pp. 35–76. Spackeler, ——, Schwedens Eisensteinbergbau: Glückauf, vol. 45, pp. 473–481, 509–515, 545–550, 594–603, 632–638, 669–672, 1909. Winchell, H. V., Swedish mines and mining: Min. and Sci. Press, vol. 102, pp. 35–38, 1911.

NORTHERN SWEDEN.[26]

The iron ores of Swedish Lapland (see fig. 26) form the largest reserve of magnetite in Europe, probably in the world. They are found in igneous rocks and in metamorphic rocks of igneous origin. The ores occur in lenticular masses, in dikelike forms, and in bands that alternate with bands of apatite rocks from which they may be easily separated. They are associated with syenitic rocks.

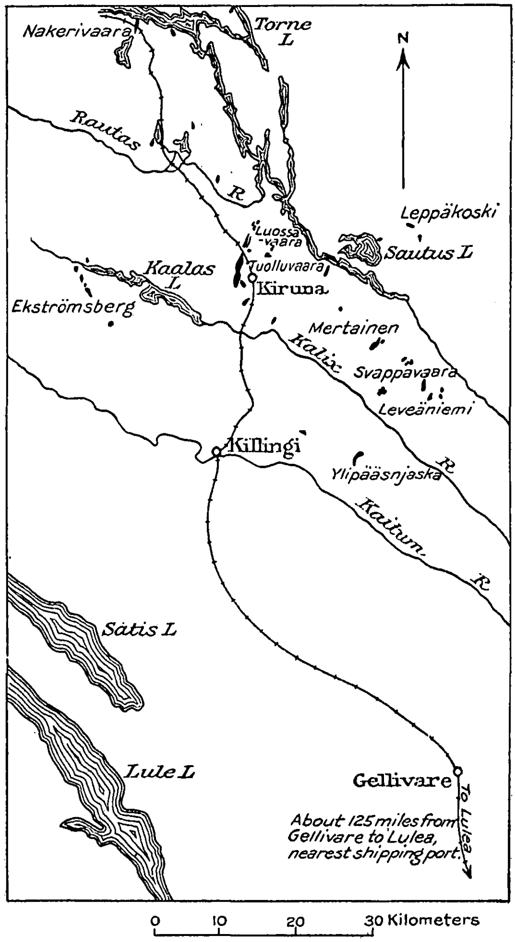


FIGURE 26.—Sketch map showing distribution of iron-ore deposits of northern Sweden. (After E. C. Eckel, 1914.)

The genesis of the ores has been a subject of discussion among geologists for many years. It has been described as sedimentary metamorphic by Herdsman,[27] as pneumatolytic hydrothermal by Bäckström,[28] and as magmatic by Högbom,[29] whose view has been supported and enlarged upon by many others. The bulk of the evidence points clearly to their magmatic origin. The presence of some tourmaline, of specularite, and of apatite indicates that the ore is a segregation of the pegmatitic rather than of the basic type.

[26] Daly, R. A., Origin of the iron ores at Kiruna, Stockholm, 1915. Fermor, L. L., On the origin of the iron ores of Swedish Lapland: Iron and Steel Inst. Jour., 1911, No. 2, pp. 113-122. Geijer, P., Igneous rocks and iron ores of Kirunavaara, Luossavaara, and Tuollavaara, Stockholm, 1910. Geijer, P., Studies on the geology of the iron ores of Lapland: Geol. Fören. Stockholm Förh., 1912.

[27] Herdsman, W. H., On the organic origin of the sedimentary ores of iron and of their metamorphosed forms, the phosphoric magnetites: Iron and Steel Inst. Jour., 1911, No. 1, p. 476.

[28] Lundbohm, H., Sketch of the geology of the Kiruna district: Cong. géol. internat., 11e sess., Guide des excursions, No. 5, 1910.

[29] Högbom, quoted by Stutzer, O., The geology and origin of the Lapland ores: Iron and Steel Inst. Jour., 1907, No. 2, p. 141.

O. Stutzer,[30] in a very able thesis, maintains that the ore and apatite and the associated syenitic rocks are intrusive. Geijer[31] maintained until recently that they are extrusive, but in his latest article[32] on the subject he records more recent observations that have caused him to alter his opinion and to agree that the ores are intrusive.

Metamorphism has been an agent in the formation of most of the deposits, especially at Gellivare, where its effects are more clearly evident.

The ore is of high grade, containing 62 per cent of iron, and the greater part of it contains from 1 to 2 per cent of phosphorus. The ore at Luossavaara, Leveäniemi, and Mertainen contains less phosphorus. That at Ruoutevare contains so much titanium that it is considered as only a "possible" reserve.

Iron resources of northern Sweden.

[Millions of metric tons.]

	Known.		Probable.		Possible.	
	Ore.	Iron.	Ore.	Iron.	Ore.	Iron.
Kirunavaara, Luossavaara, and Tuollavaara	365	226.3	420.0	260.4	840.0	520.8
Svappavaara, Leveäniemi, and Mertainen	50	31.1	35.8	21.3	61.7	35.8
Gellivare and Koskulls-Kulle	129	82.7	127.5	81.6	115.7	74.0
Ekströmsberg	20	12.8	20.0	12.8	40.0	25.2
Ruoutevare					12.0	4.8
	564	352.9	603.3	376.1	1,069.4	660.6

CENTRAL SWEDEN.[33]

The ores of central Sweden occur as lenses and stocks of magnetite in schists and gneisses. Their geology is complex. They are probably ores of magmatic derivation, like those of northern Sweden, but have migrated farther from the parent magma and have undergone greater metamorphism.

A map in the atlas of "The iron-ore resources of the world"[34] shows 66 deposits in Sweden, of which that at Grängesberg, the largest, is shown in detail in the accompanying map (fig. 27). Swedish statistics include still others that are not shown on the map.

[30] Stutzer, O., Die Eisenerzlagerstätten "Gellivare" in Nordschweden: Zeitschr. prakt. Geologie, vol. 14, pp. 137–140, 1906. Stutzer, O., Die Eisenerzlagerstätten bei Kiruna: Zeitschr. prakt. Geologie, vol. 14, pp. 65–71, 140–142, 1906. Stutzer, O., The geology and origin of the Lapland iron ores: Iron and Steel Inst. Jour., 1907, No. 2, pp. 106–207.

[31] Geijer, P., Igneous rocks and iron ores of Kirunavaara, Luossavaara, and Tuollavaara, Stockholm, 1910.

[32] Geiger, P., Recent developments at Kiruna: Sveriges geol. Undersökning Årsbok 12, pt. 5, 1918.

[33] Johansson, H. E., The Grängesberg iron ores: Cong. géol. internat., 11e sess., Guide des excursions, No. 32, 1910. Kukuk, ——, Die mittelschwedischen Erzlagerstätten; Glückauf, vol. 47, pt. 1, pp. 820–827, 861–870, 905–914, 1911. Petersson, W., Die Erzfelder von Norberg: Cong. géol. internat., 11e sess., Guide des excursions, No. 29, 1910. Sjögren, H., The Persberg mining field: Idem, No. 34. Sjögren, H., The Längban mining field: Idem, No. 33.

[34] Tegengren, F. R., [The iron-ore resources of] central and southern Sweden: The iron-ore resources of the world (11th Internat. Geol. Cong.), pp. 586–597, Stockholm, 1910.

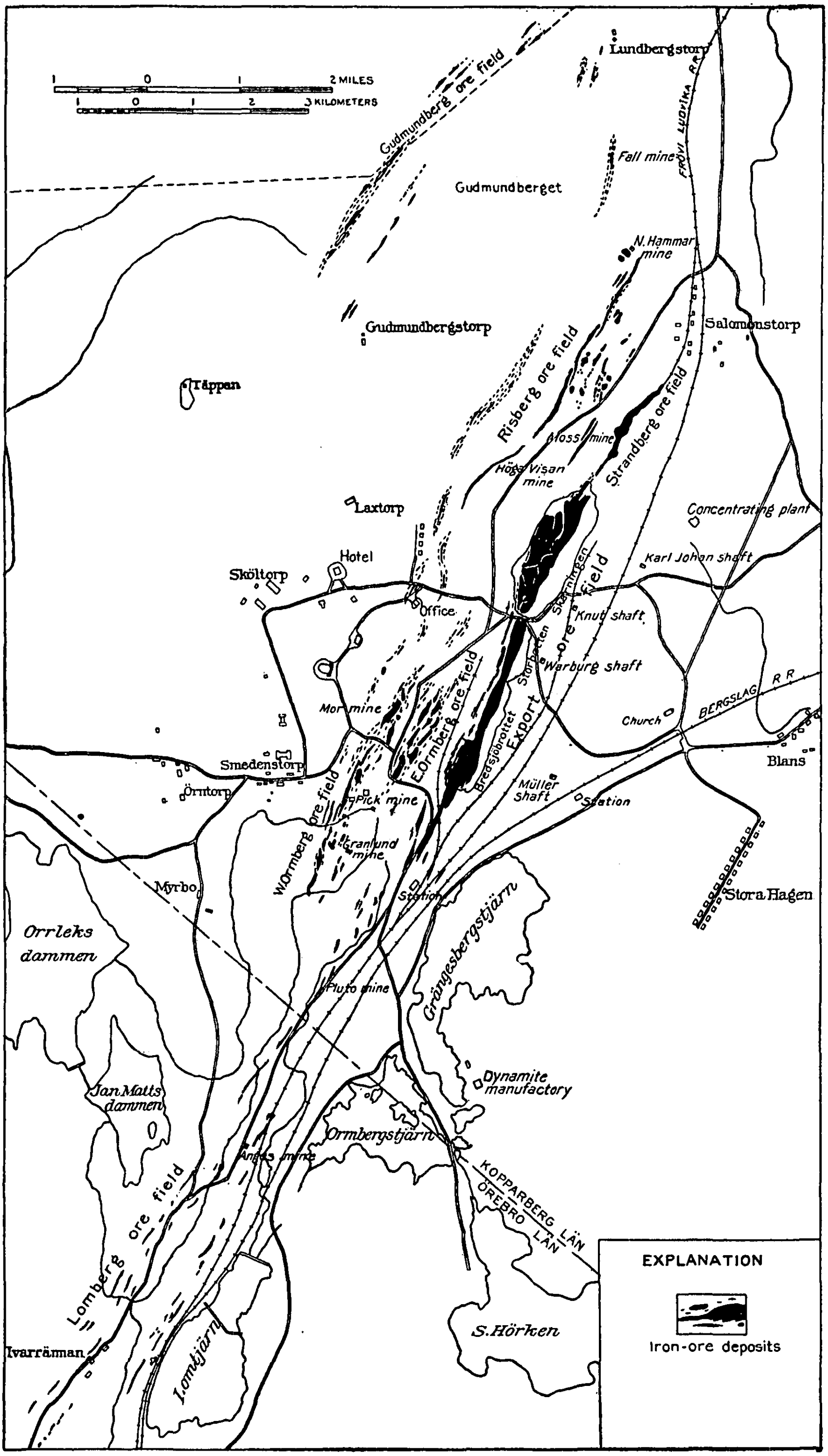


FIGURE 27.—Map of the iron-ore field at Grängesberg, central Sweden. (From "The iron-ore resources of the world.")

The ore in the largest deposits contains much phosphorus, but that in many of the smaller deposits contains less. About one-third of the ore is concentrating ore and about two-thirds is direct smelting ore.

From figures given by Tegengren (185,000,000 tons) and from the official statistics of the production in 1916 the iron content of these deposits has been figured as 90,000,000 tons "known." As there are many undeveloped bodies, and as certain producing areas were not considered by Tegengren, 60,000,000 tons more may be classed as "possible."

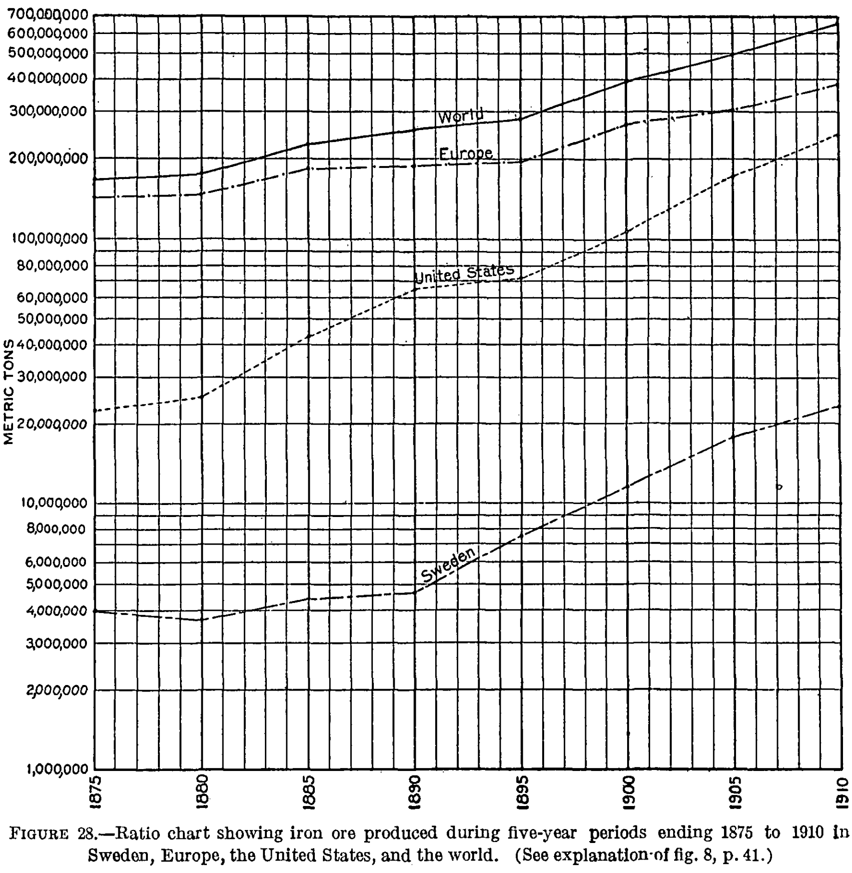


FIGURE 28.—Ratio chart showing iron ore produced during five-year periods ending 1875 to 1910 in Sweden, Europe, the United States, and the world. (See explanation of fig. 8, p. 41.)

SOUTHERN SWEDEN.

In southern Sweden, at Taberg, there is a deposit of concentrating ore of titaniferous magnetite, which is made up of segregated masses of the basic type. Owing to its content of titanium it is not now available, so it is put down as a "possible" reserve containing 50,000,000 metric tons of ore carrying 9,000,000 metric tons of iron.

SUMMARY FOR SWEDEN.

The metallic iron in the iron-ore deposits of Sweden is estimated in the table below.

Iron resources of Sweden.

[Millions of metric tons of iron. Compare Pl. XII, in pocket.]

	Known.	Probable.	Possible.
Northern Sweden	352.9	376.1	660.6
Central Sweden	90.0	....	60.0
Southern Sweden	....	....	9.0
	442.9	376.1	729.6

PRODUCTION AND CONSUMPTION.

As shown in the accompanying ratio chart (fig. 28), Sweden has had a steadily increasing production of iron ore. Her production of pig iron also has been increasing, but at a slower rate, though in recent years the introduction of electrometallurgy has accelerated the rate considerably. In 1913 Sweden produced 7 per cent of the iron ore mined in Europe and consumed only 1 per cent of it. With her very great reserves she should be an exporter, for she has much more ore than she needs for domestic use. Through her control of the railroads Sweden has strictly regulated the exportation of iron ores. She has set a definite schedule of the amount of ore which may be exported each year and will doubtless make the mining companies abide by it. This control is designed to conserve a natural resource that can be used in exchange for coal she requires from Great Britain and Germany.

FINLAND.

DISTRIBUTION, CHARACTER, AND EXTENT OF THE DEPOSITS.

The greater part of Finland is a massif of ancient crystalline rocks covered with glacial débris. At the extreme north end of the country and on its southwestern fringes there are some early Paleozoic formations. The Finnish territory is physiographically a part of the Scandinavian massif, and the history of the primary iron ores of Finland is the same as the history of those of Norway and Sweden.[35] (See Pl. XIII, in pocket.)

In northern Finland, near Kittilä,[36] there are large deposits of concentrating iron ore in metamorphic rocks. The mineral is magnetite. The ore generally contains little iron, but in some of the deposits, such as those at Sydvaranger, there are pockets of ore of

[35] [Finland's economic ore deposits, as taken from consular reports]: Zeitschr. prakt. Geologie, vol. 15, pp. 294–302, 1907. Trustedt, O., Die Eisenerzvorräte Finnlands: The iron-ore resources of the world (11th Internat. Geol. Cong.), vol. 1, pp. 547–551, Stockholm, 1910.

[36] Keene, A. F., unpublished information.

better grade. Two bands, 300 to 500 meters wide, have been traced for 12 kilometers. Though they are 180 kilometers from the nearest railroad the properties at Kittilä are said to have been sold for 15,000,000 kroner (about $4,000,000).

The only statement available [37] as to the extent of the deposits says there are "exhaustless quantities" of ore, a statement which obviously affords no ground for an estimate.

In central Finland, in the "lake country," are the so-called "lake ores," which are brown bog ores containing 35 per cent of iron and generally considerable phosphorus.

Here also reliable estimates are lacking, though the deposits appear to be extensive.

In southern Finland, at Jussarö,[38] on the Gulf of Finland, and at Pitkäranta,[39] near Lake Ladoga, there are ore bodies of the igneous type. Those at Jussarö are lenses of magnetite, which pitch under the Gulf of Finland and have been explored by magnetic surveys. At Pitkäranta the ore is probably of contact-metamorphic type and consists of magnetite of concentrating grade. The ore contains 1.3 per cent of sulphur.

Iron resources of Finland.

[Millions of metric tons.]

	Known.		Probable.		Possible.	
	Ore.	Iron.	Ore.	Iron.	Ore.	Iron.
Jussarö			30	11.4		
Pitkäranta	13.5	3.6			7	1.9
	13.5	3.6	30	11.4	7	1.9

Because of lack of information probably only a very small part of Finland's iron ore has been estimated. More ore bodies of the Kittilä type may perhaps be discovered in northern Finland by further prospecting, for the country is similar to that of northern Norway, in which such ores are so generally distributed.

PRODUCTION AND CONSUMPTION.

The lake ores have heretofore been utilized for a local industry and the primary ores of the north may be exploited hereafter, but as Finland lacks coal there is no reason to suppose that she will ever develop an extensive iron industry.

[37] Min. Jour. (London), vol. 87, pp. 375-376, 1909.
[38] Tiegerstedt, A. F., Fennia [Finnish Geog. Soc. Bull.], vol. 14, No. 8, 19 pp., 1898.
[39] Trustedt, O., Die Erzlagerstätten von Pitkäranta am Ladoga-See: Comm. Geol. de Finlande Bull. 19, 1907.

THE BALTIC STATES.

Esthonia, Latvia, and Lithuania are composed of low, flat-lying ground, which lies within an area that was once covered by glaciers. No deposits of iron ores have been reported from them, and it seems as if the only deposits they are likely to contain would be surficial bog ores of small extent.

POLAND.[40]

DISTRIBUTION, CHARACTER, AND EXTENT OF THE DEPOSITS.

Location of mineral lands.—New Poland (see Pl. XIII, in pocket) covers territory whose geologic structure ranges from that of the flat-lying young formations of the northern plains and marshes through that of the gently folded Mesozoic and Paleozoic rocks of central and southern Russian Poland to the mountain structure of the Karpathians. Poland's most valuable mineral resources lie in the Dombrova coal basin and the Triassic lead and zinc basin in its southwestern part. Next in value are the iron ores in the Mesozoic and Paleozoic rocks of Russian Poland. The mountainous regions of the northern slopes of the Karpathians are singularly lacking in mineral wealth, probably because the Tertiary rocks of which these slopes are composed were deposited under conditions that were adverse to the formation of sedimentary mineral deposits and because no later intrusions have introduced metalliferous solutions.

The eastern limits of new Poland have not been definitely fixed, but as no important iron ores are reported from the doubtful areas their determination does not affect the total reserve.

Triassic ores.[41]—In southwestern Poland lies the Triassic (Muschelkalk) basin, which is mostly in Silesia and partly in Russian Poland and Galicia. The iron ores are gossans that overlie the zinc and lead ores, to which this area owes much of its value.

Jurassic and bog ores.[42]—Directly northwest of the Triassic area, in Jurassic sediments, there are sedimentary spathic ores with brown ore, derived from them. These ores average between 30 and 35 per cent of iron and have furnished a considerable supply to local furnaces. Toward the northeast, in the Kielce district,[43] ores of the same sort at the same and lower horizons are found.

[40] Iron-ore resources of the world (11th Internat. Geol. Cong.), vol. 1, pp. 173–174, 494–501, Stockholm, 1910.

[41] Bartonec, F., Über die erzführenden Triasschichten Westgaliziens: Oesterr. Zeitschr. Berg- u. Hüttenwesen, vol. 50, pp. 645–650, 664–669, 1906. Tietze, E., Die geognostischen Verhältnisse der Gegend von Krakau: K.-k. geol. Reichsanstalt Jahrb., vol. 37, p. 423, 1887.

[42] Bartonec, F., Über die geologisch-montanistischen Verhältnisse des südöstlichen Teiles von Polen: Oesterr. Zeitschr. Berg- u. Hüttenwesen, vol. 62, pp. 726–729, 1914.

[43] Doborzynski, S., [Iron ore in the Kielce district]: Geol. Centralblatt, vol. 2, pp. 262, 686, 1902.

In the estimates given below the gossan ores have been left out of account.

Jurassic iron ores of Poland.

[Millions of metric tons.]

	Ore.	Iron.
Known	32.5	10.6
Probable	150.0	50.0
Possible	210.0	68.6

Besides the Jurassic ores Poland will be able to count on some of the bog ores that formerly belonged to Germany. The amount has been taken arbitrarily as one-fifth of the former German supply.

Bog iron ores of Poland.

[Millions of metric tons.]

	Ore.	Iron.
Known	2	0.6
Probable	2	.6
Possible	2	.6

Iron resources of Poland.

[Millions of metric tons of iron.]

	Known.	Probable.	Possible.
Jurassic	10.6	50.0	68.6
Bog ores	.6	.6	.6
	11.2	50.6	69.2

PRODUCTION AND CONSUMPTION.

In 1913 Russian Poland produced a little over 300,000 tons of iron ore. The territory added to it from Germany and Austria to form new Poland has added a little to the productive capacity of new Poland, but none of the iron deposits are far from the line that lies between economic availability and worthlessness. Slight economic changes might easily make it wiser for Poland to draw her iron ore from foreign sources rather than to mine her own ore.

AUSTRIA.

DISTRIBUTION, CHARACTER, AND EXTENT OF THE DEPOSITS.

The new Austria (see Pl. XIV, in pocket) lies in the eastern Alpine ranges and except a small northern part is entirely mountainous. As might be expected in such an area there are numerous small deposits of iron ore, but the only large deposits are the Erzberg of Styria and the Hüttenberg of Carinthia.

The Styrian Erzberg is world famous for the excellent quality of the iron ore mined there and has supplied iron since the earliest historical times. The location of the main deposits is shown in figure 29. The ores in both the Styrian district and in the Hüttenberg district of Carinthia appear to be siderite and brown ores resulting from its decomposition. According to most recent reports,[44] the carbonate has been formed as metasomatic replacement of Devonian and older limestones. The older reports regard the deposits as syngenetic—that is, as formed by sedimentation at the time the inclosing rocks were formed.

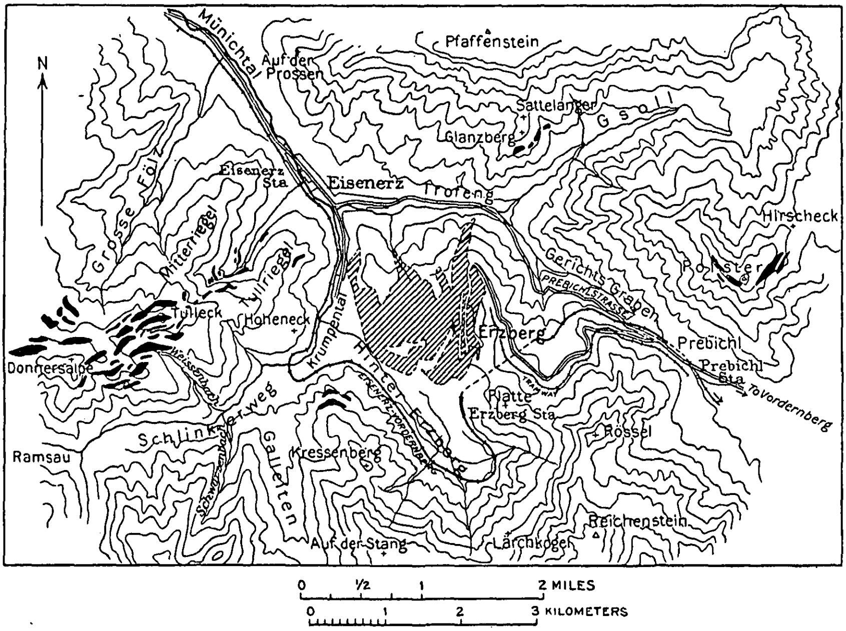


FIGURE 29.—Map showing deposits of iron ore in the vicinity of Erzberg, Styria, Austria. (From "The iron-ore resources of the world.")

The ores are of rather low grade, but simple roasting gives a product containing 50 per cent of iron. They are very desirable because of their freedom from sulphur and phosphorus.

In the estimate of reserves given below about half of the low-grade, "rohwand" ores, as they are called, were classified as "possible."

Iron resources of Austria.

[Millions of metric tons.]

	Known.		Probable.		Possible.	
	Ore.	Iron.	Ore.	Iron.	Ore.	Iron.
Carinthia	7.0	3.2	7.0	3.2		
Styria	210.0	73.5	18.0	6.3	150.0	30.0
	217.0	76.7	25.0	9.5	150.0	30.0

44 Launay, L. de, Gîtes minéraux et métallifères, vol. 2, pp. 396-399, Paris, Ch. Béranger, 1913.

PRODUCTION AND CONSUMPTION.

In 1913 the production of iron ore in what is now the Austrian Republic amounted to about 2,000,000 tons. Most of the ore was utilized in domestic furnaces. Hereafter Austria will be largely dependent on foreign sources for fuel. Formerly she shipped much of her ore to Trieste and imported coal from England for smelting it. Now that she has access to the sea only through foreign territory she may find it better to import coal from Silesia. The Austrian iron ores are so desirable that there will always be a demand for them and some way will be found to utilize them.

CZECHO-SLOVAKIA.

DISTRIBUTION, CHARACTER, AND EXTENT OF THE DEPOSITS.

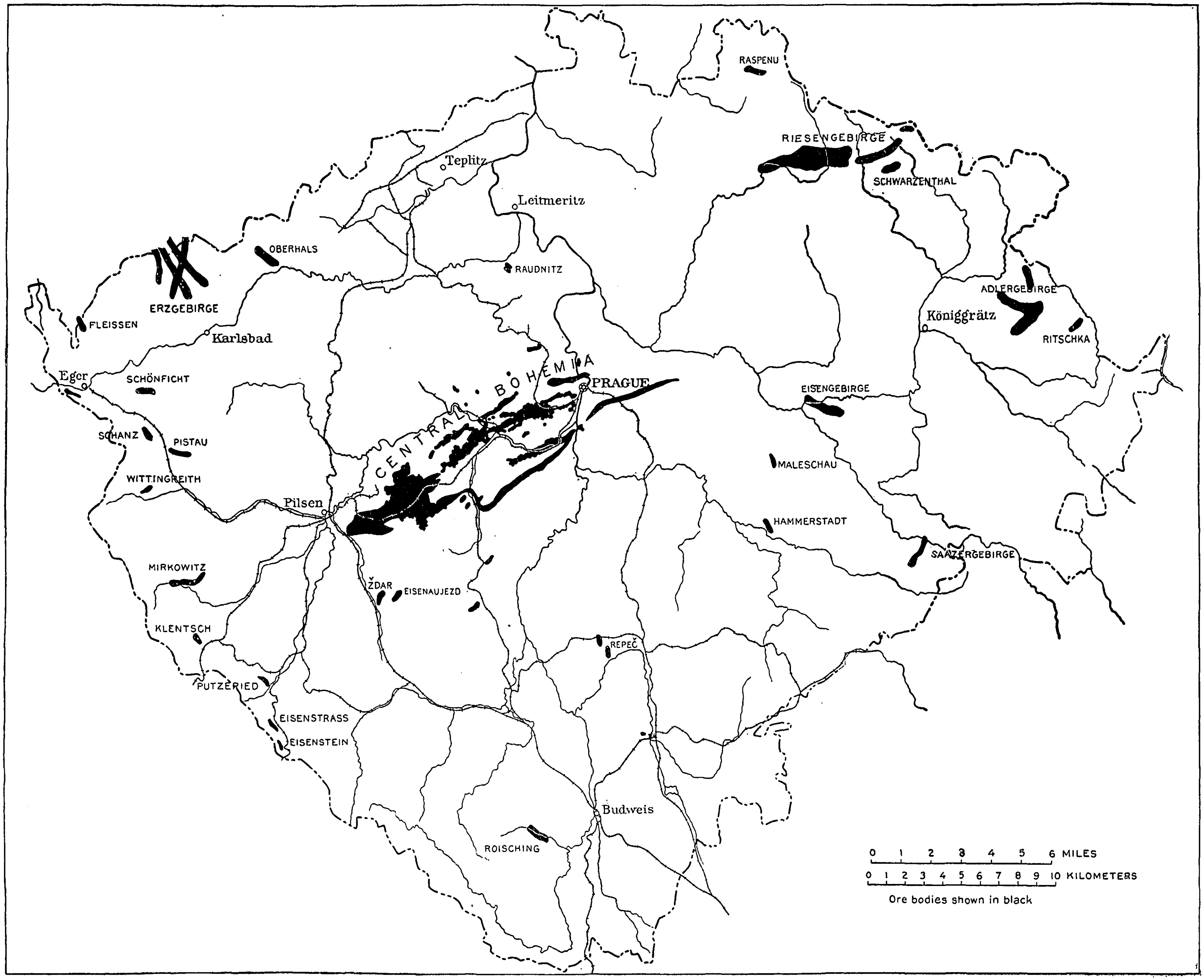
Czecho-Slovakia is fortunate in containing within her borders all the essentials for a successful iron industry. It is a large, level, interior country, fit for agriculture, bordered by mountains, and cut by northeastward-trending ranges that contain an abundance of iron and coal. (See Pl. XIV, in pocket.)

BOHEMIA.

The location of the numerous Bohemian iron-ore deposits is shown in Plate XV, which is a generalized reproduction of map 12 of the atlas accompanying the volume on the iron resources of the world issued by the Eleventh International Geological Congress. The most extensive and productive area of iron-ore deposits lies in central Bohemia, in the Brda Mountains, where beds of oolitic hematite and of the iron silicate chamosite are intercalated in Silurian sediments. The ores are of low grade, containing an average of about 35 per cent of iron, 13 per cent of silica, and 1.5 to 2 per cent of phosphorus.

The estimate of these ores given by Uhlig [45] is very comprehensive. The known ore, 35,000,000 tons, can be considered as averaging 35 per cent of iron and so credited with 12,400,000 metric tons of metallic iron. The "probable" ore, which is estimated on geologic data, amounts to 222,000,000 tons. In order to allow for a possible decrease in the grade of ores with increase in depth this can be taken as containing 30 per cent of iron and credited with 66,600,000 metric tons of iron. There remain about 70,000,000 metric tons of undeveloped ores in the possession of companies other than the one making the report. In consideration of the large area occupied by outcrops of these ores the estimate seems low, and for that reason the "pos-

[45] Uhlig, V., Die Eisenerzvorräte Oesterreichs: The iron-ore resources of the world (11th Internat. Geol. Cong.), vol. 1, pp. 151-153, Stockholm, 1910.



MAP OF BOHEMIA SHOWING DISTRIBUTION OF THE PRINCIPAL IRON-ORE DEPOSITS.

sible" ore is given as 100,000,000 metric tons containing 30,000,000 metric tons of iron.

The numerous small deposits of iron ore in Bohemia, consisting of brown ores, hematite, and magnetite, have been described in concise tabular form by Uhlig.[46] None of these deposits have produced ore recently and no statement as to their content of ore or of iron is available, but they form a possible reserve that can not be entirely neglected. They are credited in the "possible" class with 25,000,000 metric tons of iron.

Iron resources of Bohemia.

[Millions of metric tons of iron.]

Known	12.4
Probable	66.6
Possible	55.0

MORAVIA.

The iron ores of Moravia have been described and estimated by Kretschmer.[47] The larger deposits lie in the March Valley and in the foothills of the Sudetic Mountains. Those in the valley consist of bedded ores in Devonian rocks; those in the foothills are mostly pre-Cambrian magnetites and brown ores derived from them and from amphibolite rocks that accompany them.

The entire Moravian reserve of iron amounts to less than 5 per cent of the world's production of pig iron in 1913. As Moravia has become a part of Czecho-Slovakia its iron reserve will be merely a small addition to the Bohemian reserves. But Moravia contains some of the richest coking coal of the Dombrova Basin, and though its production of iron ore in 1912 amounted to only 6,268 tons, it produced in that year 507,653 tons of pig iron.

RUTHENIA.

The iron-ore deposits in Ruthenia were of considerable importance before the war, as they contributed a large supply to the Moravian and Silesian furnaces. The most productive district is that of Szepes-Gömör,[48] on the southern slope of the Karpathians, whose location is shown in figure 30. The ore consists of veins and masses

[46] Uhlig, V., Die Eisenerzvorräte Oesterreichs, Eisenerzvorkommen Böhmens: The iron-ore resources of the world (11th Internat. Geol. Cong.), vol. 1, pp. 145–149, Stockholm, 1910.

[47] Kretschmer, Franz, Die Erzvorräte der wichtigsten Eisenerzlagerstätten Mährens: The iron-ore resources of the world (11th Internat. Geol. Cong.), vol. 1, pp. 161–171, Stockholm, 1910. Kretschmer, F., Die Sinterbildung vom Eisenerzbergbau Quittein nächst Müglitz (Mähren): K.-k. geol. Reichsanstalt. Jahrb., vol. 52, pp. 353–494, 1902.

[48] Loczy, Ludwig von, and Papp, Karl von, Die im ungarischen Staatsgebiete vorhandenen Eisenerzvorräte: The iron-ore resources of the world (11th Internat. Geol. Cong.), vol. 1, pp. 178–223, Stockholm, 1910.

of spathic iron ore in a complex series of metamorphic rocks. A small part of the ore mined comes from brown ores derived from the primary carbonates. The ores are genetically connected with intrusions of quartz porphyry.

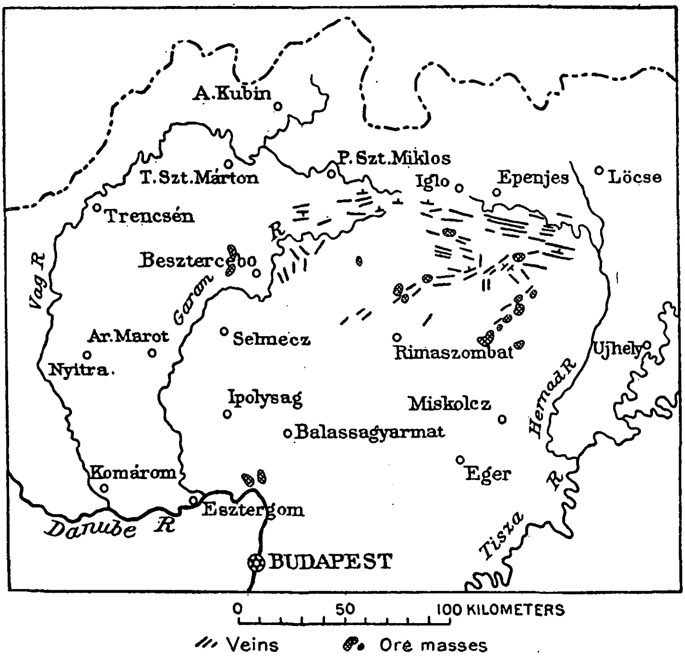


FIGURE 30.—Map showing deposits of iron ore in the Szepes-Gömör district, Ruthenia, Czecho-Slovakia. (From "The iron-ore resources of the world.")

According to an estimate made by Von Papp[49] the ores can be tabulated as indicated below.

Iron resources of Ruthenia.

[Millions of metric tons of ore.]

Known	26.1
Probable	47.7
Possible	18.0

Of this ore the "known" and "probable" averages about 38 per cent and the "possible" is ore of lower grade, which for safety can be reckoned as containing 20 per cent of iron. In terms of metallic iron the "known" reserves are 9,900,000 metric tons, and the "probable" reserves are 18,200,000 metric tons.

The ore contains little phosphorus, and roasting increases its iron content to about 53 per cent and makes it commercially desirable.

[49] Papp, Karl von, op. cit., p. 223.

SUMMARY OF CZECHO-SLOVAK RESERVES.

The metallic content of the iron ores in Czecho-Slovakia is shown in the table below.

Iron resources of Czecho-Slovakia.

[Millions of metric tons of iron.]

	Known.	Probable.	Possible.
Bohemia	12.4	66.6	55.0
Ruthenia	9.9	18.2	3.6
	22.3	84.8	58.6

PRODUCTION AND CONSUMPTION.

In 1913 Czecho-Slovak territory produced about 2,500,000 metric tons of iron ore. With her large coal resources, of which the best coking coals of the Dombrova Basin are a part, she should be able to utilize her own resources to the fullest extent, together with so much of the Swedish magnetite ores as are necessary for making a good smelting mixture with the central Bohemian ores. The future of the iron industry in Czecho-Slovakia is very promising.

HUNGARY.

The old Hungary was rich in iron ores. The loss of the Szepes-Gömör, Banat, and Hunyad districts leaves the new Hungary without any deposits except a few small scattered ones on the Karpathian slopes. Coal is also lacking within the new State, so that there is no reason to expect a Hungarian iron industry.

PRODUCTION AND CONSUMPTION IN THE AUSTRO-HUNGARIAN EMPIRE.

Though Austria-Hungary has ceased to exist, a brief résumé of her position in 1913 is necessary in the study of Europe as a whole. The resources over which the old empire had control are shown in the following table:

Iron resources of the Austro-Hungarian Empire.

[Millions of metric tons of iron. Compare Pl. XIV, in pocket.]

	Known.	Probable.	Possible.	Type of ore predominating.
German Austria	76.7	9.5	30.0	Siderite.
Bohemia	12.4	66.6	55.0	Chamosite and hematite.
Hungary	12.4	26.7	7.6	Spathic and brown ores.
Bosnia	9.5	8.0	16.0	Siderite and hematite.
	111.0	110.8	108.6	

The accompanying ratio chart (fig. 31) shows the progress of iron mining in Austria and Hungary and in the Austro-Hungarian Empire as compared with the United States, Europe, and the world. It shows that the increase since 1880 has been consonant with the normal world increase.

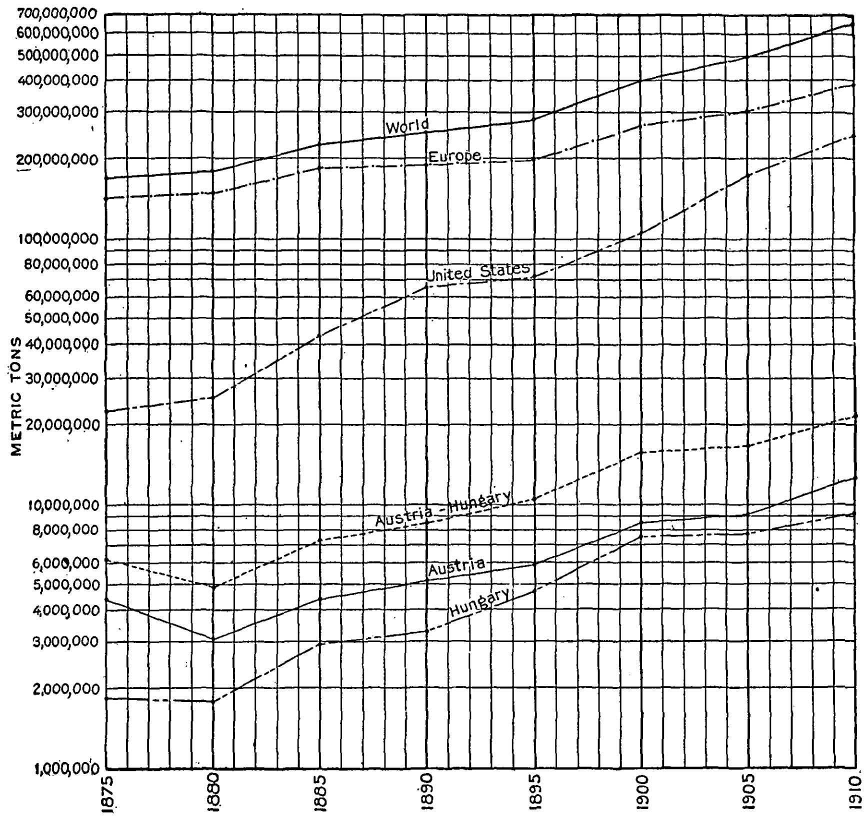


FIGURE 31.—Ratio chart showing iron ore produced during five-year periods ending 1875 to 1910 in the Austro-Hungarian Empire, Austria, Hungary, Europe, the United States, and the world. (See explanation of fig. 8, p. 41.)

In 1913 Austria-Hungary produced 5,318,531 metric tons of iron ore, divided as follows:

	Metric tons.
Austria	3, 039, 324
Hungary	2, 059, 076
Bosnia	220, 131

Allocation of the output of the Empire for 1913 to the political divisions of 1919 affords the result shown in the following table:

Iron ore produced in countries that formed the Austro-Hungarian Empire, 1913.

	Per cent.	Metric tons.
Czecho-Slovakia	47	2,500,000
Austrian Republic	37	1,960,000
Rumania	12	640,000
Jugo-Slavia	4	220,000

In 1913 Austria-Hungary imported 14 per cent of the iron ore she consumed in her blast furnaces. Her production amounted to 5 per cent of the European total and her consumption to 5.5 per cent. (See figs. 5 and 6, pp. 27, 28.)

As a result of the reconstruction Czecho-Slovakia will be in the best position to establish an iron and steel industry. She has more than enough coal within her borders to make her independent, and she has the iron ores of central Bohemia, the March Valley, and Szepes-Gömör—sufficient to supply her needs for some time to come.

The Austrian Republic, in the Styrian Erzberg and Carinthian Hüttenberg, also has a supply of excellent ore, but she is dependent on other countries for coke.

THE BALKAN STATES.

The only one of the Balkan States that had any but a small unreported local iron-ore industry in 1913 was Greece. Rumania and Jugo-Slavia get some of the deposits that contributed to make up the Austro-Hungarian total in 1913, but neither will have a large iron industry. (See Pl. XVI, in pocket.)

BULGARIA.

DISTRIBUTION, CHARACTER, AND EXTENT OF THE DEPOSITS.

The Bulgarian deposits are so very small that they can never be regarded as of more than local importance. They have been described by Scott,[50] Muset,[51] and Vankov.[52]

Bedded deposits of hematite are reported at Breznik and Kremikovci and lenses of magnetite at Krumovo and Rudin-Kamak. Also some slag that contains 50 per cent of iron is left from ancient workings at Samakov.

According to Vankov,[53] the Bulgarian reserve amounts to 1,450,000 metric tons, of which 950,000 metric tons is slag. The reserve has been estimated as containing probably 700,000 metric tons of iron.

[50] Scott, H. K., Notes on some Bulgarian mineral deposits: Inst. Min. and Met. Trans., vol. 22, pp. 597-615, 1913.

[51] Muzet, A., L'industrie minérale dans les Balkans: Soc. ind. min. Bull., vols. 14-15, pp. 113-151, 1911.

[52] Vankov, Lazar, Die Eisenerzlagerstätten im Königreich Bulgarien: The iron-ore resources of the world (11th Internat. Geol. Cong.), vol. 1, pp. 331-339, Stockholm, 1910.

[53] Idem, p. 339.

PRODUCTION AND CONSUMPTION.

There are no figures to show the production of iron ore in Bulgaria and nothing on which to base an expectation of a future iron industry there.

GREECE.[54]

DISTRIBUTION, CHARACTER, AND EXTENT OF THE DEPOSITS.

The principal deposits of iron ore in Greece are the chromiferous ores in the Laurium Peninsula near Lake Kopais and on the islands of Euboea and Skyro. They are closely associated with Cretaceous serpentines, and the one point on which most geologists who have studied the deposits are agreed is that the ores were derived from the serpentine.

According to Nottmeyer[55] these ores were deposited in a shallow sea on the serpentine from hydrothermal solutions. Scott[56] regards the ores as segregations in the serpentine, fissure deposits in limestone, or contact deposits between limestone and serpentine. Habets[57] regards them as original segregations from peridotite magma which were enriched by metasomatism during serpentinization of the peridotite.

The ore is described as consisting of nodules or shotlike grains of "brown hematite" cemented by a binder of more hydrated, softer amorphous ore. In places the ore shows a thinly banded structure. It usually occurs on top of serpentine and is covered by later limestone.

The ore is so very similar to Cuban lateritic and New Caledonian residual ores in occurrence and type that it is thought by the writer to be of the same origin—that is, the ores are regarded as due to weathering, essentially in place.

Deprat's studies in Euboea[58] and Lepsius's work in Attica[59] show that the serpentines are derived from basic igneous rocks intruded into Cretaceous limestones. These igneous rocks suffered dynamic metamorphism, which in places caused a rearrangement of their minerals and produced some schistosity. This schistosity might be preserved after serpentinization and lateritization and might give some of the ore a banded structure, whereas the ore formed from

[54] Vallindas, K., Geol. Centralbl. vol. 9, pp. 425–426 (abstract), 1917. Scott, H. K., Iron and Steel Inst. Jour., 1913, No. 1, pp. 447 et seq. Cottrell, — (U. S. consul), Mining industry of Cyclades: Min. Jour., vol. 75, p. 661, 1903. Habets, A., and Bonanos, N., Rev. univ. des mines, vol. 21, pp. 129–148, 1908. Reports on iron deposits in foreign countries, Board of Trade, London, 1905. Nottmeyer, Max, Die Eisenerzvorräte Griechenlands: The iron-ore resources of the world (11th Internat. Geol. Cong.), vol. 1, pp. 341–349, Stockholm, 1910.

[55] Op. cit., p. 345.

[56] Scott, H. K., Iron and Steel Inst. Jour., 1913, No. 1, pp. 447 et seq.

[57] Habets, A., and Bonanos, N., Rev. univ. mines, vol. 21, pp. 129–148, 1908.

[58] Deprat, J., Étude géologique de l'île d'Eubée, 217 pp., maps and photographs, Besançon, 1904.

[59] Lepsius, R., Geologie von Attika, Berlin, 1893.

massive serpentine by lateritization—that is, by weathering in place—would be granular, an explanation that is borne out by the sharp contacts between the ore and the limestone and the more indefinite contacts between the ore and the serpentine, noted by Scott. The occurrence of the ore in fissures in limestone could be accounted for by assuming migrating solutions during or after lateritization. A careful physiographic and paleogeographic study would be necessary to test the hypothesis advanced.

The estimates of the reserves are not very definite. Nottmeyer says there are 75,000,000 to 100,000,000 metric tons in the Laurium district. The ore contains about 45 per cent of iron, 2 per cent of chrome, and from 0.01 to 2.20 per cent of phosphorus.

Iron resources of Greece.

[Millions of metric tons.]

	Ore.	Iron.
Known	40	18.0
Probable	40	18.0
Possible	50	22.5

Besides the deposits described there are small deposits of iron ore on some of the islands south of Greece.

On Zea there are some highly manganiferous ores near Spathi. They contain 49 per cent of iron and 22 per cent of manganese. On Syra there are some slightly manganiferous ores, and on Cerigo, Thermia, and Serpho there are deposits of hematite. Though some of these small deposits have been mined no estimates of their content of ore are available and they are not included in the reserves.

PRODUCTION AND CONSUMPTION.

Greece produces about 300,000 tons of chromiferous iron ore, which is used in European furnaces. As she lacks coal she has not and probably will not have an important iron industry.

RUMANIA.[60]

DISTRIBUTION, CHARACTER, AND EXTENT OF THE DEPOSITS.

The information concerning deposits of iron ore in Rumania is very scanty. The greater part of Rumania is plains country of a type in which one would scarcely expect to find any kind of ore, but in the hilly region of Dobrudja ore has been reported, and in the foothills of the Transylvanian Alps magnetite lenses in schist are said to occur between Podeni and Obirsa. Brown ores in limestone

[60] Poni, P., Études sur les minéraux de la Roumanie: Univ. Jassy Annales sci., vol. 1, pp. 15-148, 1901.

are found on Mount Dirmoxa. So far as known there are no estimates of the reserves.

The most extensive ore deposits that Rumania gains by the accession of territory from Hungary are those of the Banat and Hunyad districts, in the Siebenbürgen country, whose location is shown in figure 32. These deposits [61] consist of beds of spathic ore, which is altered to brown ore near the surface. There are some small bodies of magnetite in the district, but they are of very little value.

The carbonate and brown ores of the Hunyad district have been carefully studied by Von Papp,[62] and according to his estimate the district can be credited with "known" resources of 3,700,000 metric

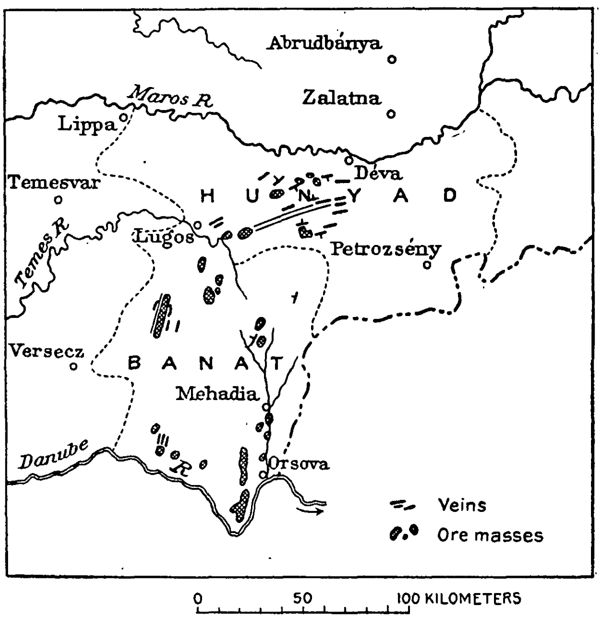


FIGURE 32.—Map showing deposits of iron ore in the Banat and Hunyad districts, Rumania.

tons of ore and "probable" resources of 13,300,000 metric tons. The ore averages about 44 per cent of iron and from 0.04 to 0.1 per cent of phosphorus. The estimate gives no information on which to base possible reserves, except to say that there are some 3,800,000 metric tons of jasper and flinty ores which are not now available, and as they do not seem likely to become available they are omitted. In terms of metallic iron the district can be credited with "known" resources of 1,500,000 metric tons and with "probable" resources of 5,500,000 metric tons.

[61] Loczy, Ludwig von, and Papp, Karl von, Die im ungarischen Staatsgebiete vorhandenen Eisenvorräte: The iron ore resources of the world (11th Internat. Geol. Cong.), vol. 1, pp. 245–262, Stockholm, 1910.

[62] Idem, p. 262.

Besides the Hunyad district there are smaller deposits of iron ore all along the inner side of the Karpathian arc in the mountains of Siebenbürgen and on the northern and western planes of the Transylvanian Alps. These scattered deposits produced about 175,000 tons of ore a year in pre-war days, most of it from the complex mineral region of the Banat. No one of these districts is sufficiently large to be shown on the map by more than a cross. In the aggregate they can be counted on for "known" resources in metallic iron amounting to 1,000,000 metric tons, "probable" resources amounting to 3,000,000 metric tons, and "possible" resources amounting to 4,000,000 metric tons.

Another part of former Austria-Hungary that is now mapped as a part of Rumania is the Bukowina.[63] Jakubeny, in the southern Bukowina, used to be the seat of a considerable iron industry. There seems to be very little prospect of reviving the industry under present conditions, although there undoubtedly are scattered small deposits in the neighboring parts of the Karpathians.

Iron resources of Rumania.

[Millions of metiic tons of iron.]

	Known.	Probable.	Possible.
Hunyad district	1.5	5.5	....
Banat and minor districts	1.0	3.0	4
	2.5	8.5	4

PRODUCTION AND CONSUMPTION.

Details of the production of iron ore in Hungary are not available, so that it is not known how much of the production of Hungary should be allocated to deposits that have been given to Rumania, but the figure is probably not very large. However, next to Greece, Rumania, of all the Balkan States, has the best opportunity to develop an iron-ore industry, though she lacks the fuel for smelting on a large scale.

JUGO-SLAVIA.

Until the Adriatic question and the future of Albania have been decided the boundaries of the new Jugo-Slav State can not be definitely fixed. (See Pl. XVI, in pocket.) The only deposit of iron ore that will be affected by the settlement of these questions is that at Rubigo, in Albania (see p. 115), but as it seems to be a small

[63] Paul, C. M., and Walther, B., Grundzüge der Geologie der Bukowina: K.-k. geol. Reichsanstalt Jahrb., vol. 26, p. 261, 1876.

deposit its allocation will not seriously affect the estimate of iron-ore reserves.

SERBIA.

Milojkovitch [64] states that there are many deposits of iron ore in Serbia and foresees a brilliant future for iron-ore mining in that country, but the information he gives is accompanied by no data that make it possible to estimate the reserves.

Vranja.—At Vranja, near the headwaters of Morava River, northeast of Uskup, there are masses of magnetite in crystalline schists. In this area there are also deposits of lead, iron, and copper sulphides, which were formerly mined, but the association throws doubt on the value of the magnetite deposits.

Suvo Rudishte.—In the crystalline schists of western Serbia near Suvo Rudishte there are a number of deposits of magnetite. The ore appears to contain much iron, but it contains also considerable sulphur. These small, scattered deposits can never be more than a source of supply for a small local industry.

Papratishte.—At Papratishte there is a hill on which hematite and brown ore lie between serpentine and Cretaceous limestone. The resemblance of the deposits to those in Greece near Lake Kopais suggests that this deposit may have future value.

Ralja and Guberevaz.—In northern Serbia, south of Belgrade, there are deposits of oolitic sedimentary ores, which contain much iron and considerable chromium. They appear to be valuable, but the information concerning them is so meager that it gives no idea of their extent.

Majdanpek.[65]—The iron gossan of the deposits of pyrite and chalcopyrite at Majdanpek is useful as a flux but is scarcely of much value as an iron ore.

CROATIA AND SLAVONIA.

Croatia and Slavonia, which were once parts of Austria-Hungary but now form parts of Jugo-Slavia, contain few deposits of iron ore. There are some bedded brown ores and deposits of siderite near Tergove,[66] in Croatia, as well as brown ores near the boundary of Carinthia and Bosnia. They form only a small reserve, which has not been calculated.

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[64] Milojkovitch, J. A., Die Eisenerzvorkommen in Serbien: The iron-ore resources of the world (11th Internat. Geol. Cong.), vol. 1, pp. 311-329, Stockholm, 1910.

[65] Wendeborn, B. A., Die Kupfererz und Limonit Lagerstätten von Majdanpek: Zeitschr. prakt. Geologie vol. 20, pp. 266-280, 1912.

[66] Loczy, L. von, and Papp, K. von, Die im ungarischen Staatsgebiete vorhandenen Eisenerzvorräte (11th Internat. Geol. Cong.), vol. 1, pp. 275-278, Stockholm, 1910.

BOSNIA AND HERZEGOVINA.[67]

There are several small deposits of iron ore in Bosnia and Herzegovina, most of them of little value at present, though the vast amount of slag in the dumps indicates that they were once the sources of a large industry.

The ore deposits of the district of Vares, northeast of Serajevo, in Bosnia, are still valuable. They consist of bodies of hematite and siderite, of metasomatic origin, deposited in limestones that now form part of a series of greatly metamorphosed sedimentary rocks.

Iron resources of the district of Vares, Bosnia.

[Millions of metric tons.

	Ore.	Iron.
Known	21	9.5
Probable	20	8.0
Possible	40	16.0

This district is the only one in Jugo-Slavia whose reserves have been estimated, so that the figure for Vares and for Jugo-Slavia as a whole is the same. If applied to Jugo-Slavia this figure is obviously incorrect, but as there is no information on which to estimate the quantity of ore in the other deposits mentioned any additional figure would be an arithmetic expression of a mere guess.

In 1912 Bosnia and Herzegovina produced altogether about 200,000 tons of ore that was utilized in the furnaces of Trieste or in the home production of charcoal iron. There is no reason why this production should not be continued.

Jugo-Slavia lacks the coal that a more extensive domestic iron industry would require.

ALBANIA.

Iron ore is reported to occur near Rubigo, in Albania, but no information as to type or extent has been found.

TURKEY IN EUROPE.[68]

There is little available information regarding the iron ores of European Turkey, and they are believed to be of slight value. An investigation of coal deposits near Rodosto disclosed the occurrence of iron ore, and there is said to be magnetite sand and "schistose magnetite" at Samakov. The reserves are considered negligible.

[67] Katzer, F., Die Eisenerzlagerstätten Bosniens und der Herzegowina: Berg-u. Hüttenm. Jahrb., vols. 57, 58, and 59, 1909–1911.

[68] Nottmeyer, Max, Die Eisenvorräte der Turkei: The iron-ore resources of the world (11th Internat. Geol. Cong.), vol. 1, pp. 352–353, Stockholm, 1910.

RUSSIA.

DISTRIBUTION, CHARACTER, AND EXTENT OF THE DEPOSITS.

AREA CONSIDERED.

The one thing certain about Russia seems to be that it will not have the same boundaries in the future that it had in 1913. Finland can be accepted as a definite state, and in the present connection the boundaries of Poland are sufficiently established to permit its treatment as a definite state, particularly as the uncertainty in regard to its eastern boundary includes an area that lacks iron ore. The old Lett provinces of the Baltic contain no iron ore.

On the other hand, the vast territory that makes up the rest of old Russia also seems liable to subdivision. The differences between central and northern Russia and the Ukraine seem to be too great to permit peaceful fusion. The diverse interests of the Ural region, the Caucasus, and the Crimea may cause the formation of new political entities, but as they have not yet sufficiently risen out of the mists of civil strife to be clearly outlined they can be treated here only as geographic expressions.

In studying Russia reliance was placed chiefly on the work of Bogdanowitsch.[69] Articles in Russian had to be studied through résumés in other languages or through the excellent short abstracts in the Geologisches Centralblatt.

NORTHERN RUSSIA.[70]

Lodes of hematite in diorite, brown sedimentary ores, and bog ores are reported from the Government of Olonetz. (See Pl. XVII, in pocket.) There is little information about them, but they are said to be unimportant.

CENTRAL RUSSIA.[71]

Metasomatic brown ores are reported from the Governments of Kaluga, Tula, Rjasan, Orel, Kursk, Voronezh, and Tambof. (See Pl. XVIII, in pocket.) The ore contains about 40 per cent of iron. About 286,000 tons of it was produced in 1912. The estimates made by Bogdanowitsch form the basis for the figures given below.

[69] Bogdanowitsch, K., Die Eisenerze Russlands: The iron-ore resources of the world (11th Internat. Geol. Cong.), vol. 1, pp. 363–544, Stockholm, 1910.

[70] Schepowalnikoff, A., [Ore deposits of Tulomosersk district, Government of Olonetz]: Geol. Centralbl., vol. 2, p. 547 (abstract), 1902; [The ore deposits of Lake Tulmo, Government of Olonetz]: Geol. Centralbl., vol. 3, p. 327 (abstract), 1903. Bogdanowitsch, K., op. cit., pp. 516–518.

[71] Bogdanowitsch, K., op. cit., pp. 485–494. Ernst, A., Die Kohlen und Eisenerzlagerstätten des centralen Russlands: Berg- u. Hüttenm. Zeitung, No. 50, 1900. Bogdanow, D., [Iron-ore deposits in Effremow district, Government of Tula]: Geol. Centralbl., vol. 3, p. 6 (abstract), 1903. Kobetski, J., [On Iwnian iron ore, Government of Kursk]: Geol. Centralbl., vol. 3, pp. 35–36 (abstract), 1903.

Iron resources of central Russia.

[Millions of metric tons.]

	Known.		Probable.		Possible.	
	Ore.	Iron.	Ore.	Iron.	Ore.	Iron.
Governments of Voronezh and Tamlof (Lipetsk)	300	120	400	160	400	160.0
Moskva Basin	50	20	50	20	75	30.0
Governments of Orel and Kursk	....	....	....	....	37	14.1
	350	140	450	180	512	204.1

SOUTHERN RUSSIA.[72]

Krivoi Rog.—The most famous deposits of iron ore in Russia (see Pl. XIX, in pocket) are those of Krivoi Rog, in southern Russia.[73] They are found in greatly metamorphosed schists and, according to Bogdanowitsch, are of similar origin to the ores of the Lake Superior region—that is, they are metamorphosed sediments. Their age has not been definitely established but is thought to be pre-Cambrian.

The ore mineral is hematite and the gangue is quartz. The ore contains 50 to 70 per cent of iron, but ore containing less than 56 per cent of iron is not mined. The content of phosphoric acid varies from 0.01 to 0.06 per cent.

The estimates available show considerable differences of opinion. An estimate made by Szymanowski[74] in 1903 gives 57.5 million tons. An estimate made by Bogdanowitsch[75] in 1910 gives 86,-700,000 tons, and an estimate made by C. R. King[76] in 1914 gives 206,000,000 tons.

Iron resources of Krivoi Rog, Russia.

[Millions of metric tons.]

	Ore.	Iron.
Known	50	31
Probable	50	31
Possible	100	62

[72] King, C. R., Russia—its future as a coal and iron producer: Eng. Mag., vol. 48, pp. 481–492, 1915. The Russian iron industry and the Ukraine: Stahl u. Eisen, No. 12, 1918 (abstract in Chem. Industry, Feb. 28, 1919). Simmersbach, Bruno, Die südrussischen Eisenerzfelder von Krivoi Rog und Kertsch: Oesterr. Zeitschr. Berg- u. Hüttenwesen, vol. 62, pp. 253–257, 272–275, 288–291, 303–305, 1914. Bogdanowitsch, K., op. cit., pp. 501–516.

[73] Szymanowski, M., Krivoi-Rog: Soc. ind. min. Bull., vol. 14, 3d ser., pp. 1385–1459, 1900.

[74] Szymanowski, M., [Krivoi Rog iron-ore reserves]: Geol. Centralbl., vol. 3, p. 35 (abstract), 1903.

[75] Op. cit., p. 505.

[76] King, C. R., op. cit.

Donetz.—In the Donetz Basin,[77] east of Krivoi Rog, there are pockets of brown ore which at one time gave rise to great hopes and exaggerated estimates, but the hopes were disappointed and the ores are at present of little or no importance.

Kosak Mogila.—North of the Sea of Azof, at Kosak Mogila,[78] there are small deposits of magnetite and hematite in metamorphic schists. Whether development might make them valuable is open to question. They appear to be of a type that is of great value in other countries.

Kerch.—On the east end of the Kerch peninsula [79] there are extensive beds of oolitic ore, which are underlain by limestone of good fluxing quality. They contain 40 to 45 per cent of iron, about 2 per cent of manganese, 15 per cent of silica, and 1.3 per cent of phosphorus.

Iron resources of Kerch, Russia.

[Millions of metric tons.]

	Ore.	Iron.
Known	100	40
Probable	250	100
Possible	200	80

Summary of southern Russia.—The quantities of metallic iron in the iron-ore deposits in southern Russia are summarized below.

Iron resources of southern Russia.

[Millions of metric tons of iron.]

	Known.	Probable.	Possible.
Krivoi Rog	31	31	62
Kerch	40	100	80
	71	131	142

CAUCASUS.[80]

The only deposit in the Caucasus region concerning which reliable information is available is that at Daschkiessan, south of Elizabetopol, in Transcaucasia. (See Pl. XIX, in pocket.) It appears to be a contact-metamorphic deposit of high grade. The iron content of the ore is 62 per cent.

[77] Bogdanowitsch, K., op. cit., pp. 511-513.

[78] Idem, p. 511.

[79] Zeidler, R. [Kerch iron-ore district]: Geol. Centralbl., vol. 3, p. 5, 1903. Bayard, M., Note sur les gisements de minerais de fer des presqu'îles de Kertch et de Taman: Annales des mines, 9th ser., vol. 15, pp. 505-522, 1899.

[80] Besborodko, N., Über eine neue Chromeisenerzlagerstätten am nördlichen Kaukasus und ihre mineralogischen Verhältnisse: Neues Jahrb., Beilage Band, vol. 34, pp. 783-798, 1912. Terpigorew, A. [Magnetite deposit of Daschkiessan, in the Caucasus]: Geol. Centralbl., vol. 3, p. 7 (abstract), 1903.

Iron-ore resources of the Caucasus.

[Millions of metric tons.]

	Ore.	Iron.
Known	10	6.2
Possible	30	18.6

URAL MOUNTAIN REGION.[81]

In the Ural Mountains and their foothills there are deposits of many kinds of iron ore and their descriptions give the impression that there is still much to learn about them. They will be taken up in order from north to south.

Bogoslovski estate.[82]—Most of the ore on the Bogoslovski estate is of igneous origin and appears to consist of contact-metamorphic bodies. The ore minerals are hematite and magnetite, which contain from 40 to 60 per cent of iron and 0.04 to 0.1 per cent of phosphorus.

Although there is plenty of ore for local production the reserve is small. (See Pl. XVII, in pocket.)

Iron resources of the Bogoslovski estate, Russia.

[Millions of metric tons.]

	Ore.	Iron.
Known	2	1.0
Probable	1	.5
Possible	1	.5

Troisk.[83]—At Troisk, on the western slopes of the Ural Mountains, there are contact-metamorphic deposits of iron ore. No data as to grade are at hand. The reserves, which consist of 3,000,000 metric tons of ore, are taken arbitrarily as containing 1,500,000 metric tons of iron. (See Pl. XVIII.)

Perm and Viatka.[84]—In the governments of Perm and Viatka, west of the Ural Mountains, there are argillaceous deposits of siderite of sedimentary origin. They cover large areas and furnish considerable ore to near-by smelters. They are of low grade in the crude state (22 per cent of iron), but they make good ores when roasted. (See Pl. XVIII.)

[81] Bogdanowitsch, K., op. cit., pp. 364–485. Preston, T. H., The Urals and their mineral wealth: Min. Mag., vol. 14, pp. 197–201 (with map), 1916.

[82] Keene, A. F., unpublished information. Fedorow, E., and Nikitin, W., [The Bogoslovski mining district]: Geol. Centralbl., vol. 2, pp. 326–327 (abstract), 1902. Ouspensky, L., [On Bogoslovski]: Geol. Centralbl., vol. 3, p. 36, 1903. Shockley, W., The Bogoslovski mining estate: Am. Inst. Min. Eng. Trans., vol. 39, pp. 274–302, 1908.

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[84] Bogdanowitsch, K., op. cit., pp. 472–477.

Iron resources of Perm and Viatka, Russia.

[Millions of metric tons.]

	Ore.	Iron.
Known	20	4
Probable	20	4
Possible	20	4

Gora Blagodat-Nizhni Tagilsk region.[85]—Concentrating ores occurring in gabbro and containing 27 per cent of iron, oolitic hematite ores containing 37 per cent of iron, and high-grade magnetite ores containing 55 per cent of iron are found in the Gora Blagodat-Nizhni Tagilsk region. Most of the reserve is of the type last named. (See Pl. XVIII.) The estimate given below is based on the details given by Bogdanowitsch.

Iron resources of Gora Blagodat-Nizhni Tagilsk region.

[Millions of metric tons.]

	Ore.	Iron.
Known	10	5.0
Probable	10	5.0
Possible	10	4.5

Versk Isetsk.[86]—There are metasomatic deposits of brown ore and hematite in the central Ural region. (See Pl. XVIII.) The brown ores contain about 50 per cent of iron and 0.11 per cent of phosphorus; the hematite contains 56 to 60 per cent of iron and little phosphorus. The estimate given below is based on private reports.

Iron resources of the central Ural region.

[Millions of metric tons.]

	Ore.	Iron.
Known	6.5	3.3
Probable	11.5	5.8

Alapaievsk district.—East of the Ural region, but still in European Russia, in the Alapaievsk district, there are extensive beds of metasomatic brown ores. (See Pl. XVIII.) Bogdanowitsch's sketches indicate that the ore is of surficial origin. It contains about 44 per cent of iron.

[85] Loewinson-Lessing, F., [On the magnetite deposit of Gora Blagodat]: Geol. Centralbl., vol. 12, p. 170 (abstract), 1909.

[86] Nikitin, V. [On the geology of Versk-Isetzk]: Com. géol. Mém. 22, 1907. Russian with French abstract.

Iron resources of the Alapaievsk district, Russia.

[Millions of metric tons.]

	Ore.	Iron.
Known	30	13.2
Probable	70	28.0
Possible	50	20.0

Bilimbaievsk.—Ores similar to those of Alapaievsk occur in the Ural region in the Bilimbaievsk area. The reserve amounts to 1,000,000 metric tons of ore, containing 500,000 metric tons of iron.

Sissert estate.[87]—There are 38 deposits of iron ore on the Sissert estate. They are magnetite and brown ores. From company reports the "known" reserve is estimated at 1,000,000 metric tons of metallic iron, and the "possible" reserve at 2,500,000 metric tons. This estate includes the famous Kyshtim copper mines. (See Pl. XVIII.)

Ufalievski district.—Reports indicate that the Ufalievski district, in the central Ural region, contains every kind of iron ore known in the Ural Mountains. It is credited with 3,000,000 metric tons of iron, but this estimate is very likely to prove too low.

Bakalsk district.[88]—Scattered deposits of brown ore occur in the Bakalsk district, in the southern part of the Ural region. (See Pl. XVIII.) The ore averages about 50 per cent of iron.

Iron resources of the Bakalsk district.

[Millions of metric tons.]

	Ore.	Iron.
Known	26	13
Probable	26	13
Possible	10	5

Magnitnaia Gora.[89]—Magnitnaia Gora, a famous iron mountain, lies on the east slope of the southern Ural range. (See Pl. XVIII.) The main ore body is a segregation of magnetite and hematite in gabbro. The estimate below includes some highly titaniferous ores and some brown ores in the Kussinskaja district.

87 Keene, A. F., unpublished information.

88 Bauermann, H. [On the iron-ore deposits of the Ural: Iron and Steel Inst. Jour., 1898, No. 1, pp. 134-145. Koniouchevsky, L. [Geologic study in Bakalsk region]: Geol. Centralbl., vol. 4, p. 310 (abstract) 1904.

89 Morozewicz, J., Die Eisenerzlagerstätten des Magnetberges (Magnitnaia Gora) im südlichen Ural und ihre genesis: Min. pet. Mitt., vol. 23, pp. 113-152, 225-262, 1904.

Iron resources of Magnitnaia Gora and the Kussinskaja district

[Millions of metric tons.]

	Ore.	Iron.
Known	25	11.3
Possible	25	11.3

Summary of the Ural Mountain region.—In the subjoined summary of the iron resources of the Ural Mountains the reserves given are probably low. The excellent and complete report of Bogdanowitsch presents a multitude of geologic details, and its estimates of the reserves that could be checked by those in other reports have almost always proved to be moderate. Many deposits are mentioned for which no estimates are made.

Iron resources of the Ural Mountain region.

[Millions of metric tons of iron.]

	Known.	Probable.	Possible.
Bogoslovski estate	1.0	0.5	0.5
Troisk	....	1.5	....
Perm-Viatka	4.0	4.0	4.0
Gora Blagodat-Nizhni Tagilsk	5.0	5.0	4.5
Versk-Isetsk	3.3	5.8	....
Alapaievsk	13.2	28.0	20.0
Bilimbaievsk	.5	....	....
Sissert estate	1.0	....	2.5
Ufalievski	....	3.0	....
Bakalsk	13.0	13.0	5.0
Magnitnaia Gora	11.3	....	11.3
	52.3	60.8	47.8

SUMMARY OF RUSSIA.

The quantities of iron in the deposits in the subdivisions of Russia here considered are tabulated below.

Iron resources of Russia.

[Millions of metric tons of iron.]

	Known.	Probable.	Possible.
Ural region	52.3	60.8	47.8
Caucasus	6.2	6.2	18.6
Southern Russia	71.0	131.0	142.0
Central Russia	140.0	180.0	204.1
	269.5	378.0	412.5

PRODUCTION AND CONSUMPTION.

The development of an iron industry in Russia has been adversely affected by political conditions since 1900. The ratio curve of production for the period preceding 1900 (see fig. 33) shows a steady increase, but since then there has been practically no increase, and for the five-year period ending 1915 there was probably a very large decrease.

The bases of an iron industry—coal, iron, and a population capable of using finished products—undoubtedly exist in Russia. Southern

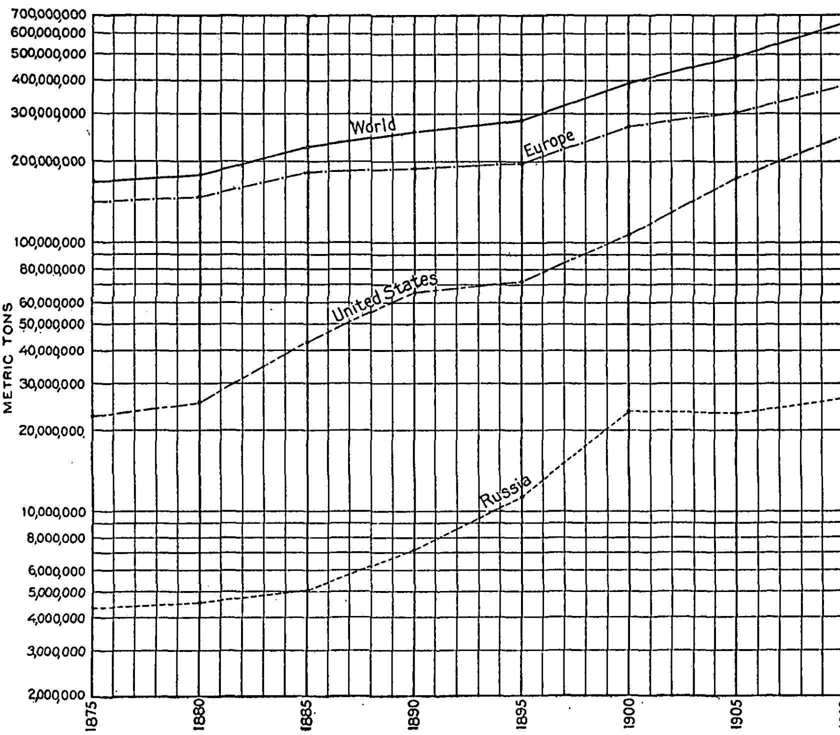

FIGURE 33.—Ratio chart showing iron ore produced during five-year periods ending 1875 to 1910 in Russia, Europe, the United States, and the world. (See explanation of fig. 8, p. 41.)

Russia, including the country of the "Little Russians" (Ukrainians) and the Crimea, is particularly fortunate. The iron ores of Krivoi Rog and Kerch and the Donetz coal basin are in this region, and the independent farm system of its black-earth belt makes the region a less fertile field for political agitation than central Russia, with its communal farming aggregates, and offers a more ready and more intelligent market for finished products. However, for some time to come politics rather than industry will dominate the former Empire of the Czars, and its future is not easy to foretell.

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DOBORZYNSKI, S., [Iron ore in the Kielce district]: Geol. Centralbl., vol. 2, pp. 262, 686, 1902 (abstract).
Brief review of article by Doborzynski on iron ore near Kielce, north of Olkusk. Deals mostly with genesis. Ore carries 40 to 50 per cent of iron. Occurs as "Klüftenfülling" in Jurassic.

TIETZE, E., Die geognostischen Verhältnisse der Gegend von Krakau: K.-k. geol. Reichsanstalt Jahrb., vol. 37, p. 423, 1887.
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PORTUGAL.

[See Spain.]

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SCHÖPPE, W., Über kontaktmetamorphe Eisen-Mangan-Lagerstätten am Aranyos Flusz, Siebenbürgen: Zeitschr. prakt. Geologie, vol. 18, pp. 309–339, 1910.
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General data on mining in Russia. Some statistics of production and much economic information. Place iron-ore reserve of Ural region at 135,000,000 tons. Give much data on ownership. Crimean reserves, 450,000,000 tons, 40 per cent ore; Poland reserves, 300,000,000 tons, 40 per cent ore.

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KING, C. R., Russia—its future as a coal and iron producer: Eng. Mag., vol. 48, pp. 481–492, 1915.
Review of situation in Russia, with a good many figures and an optimistic outlook for the future. Shows greatest familiarity with southern Russia.

NEUMARK, Dr., Die russische Kohlen- und Roheisen Industrie: Stahl und Eisen, vol. 21, pp. 62–68, 110–122, 1901.
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SCHEPOWALNIKOFF, A., [The ore deposits of Lake Tulmo, Government of Olonetz]: Geol. Centralbl., vol. 3, p. 327, 1903 (abstract).

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——— [Ore deposits of Tulomosersk district, Government of Olonetz]: Geol. Centralbl., vol. 2, p. 547, 1902 (abstract).

Very brief review. Hematite between dolomitized and silicified limestone.

CENTRAL RUSSIA.

BOGDANOW, D., [Iron-ore deposits in Effremow district, Government of Tula]: Geol. Centralbl., vol. 3, p. 6, 1903 (abstract).

Brief review. Deposits carry 38 to 55 per cent of iron. Metasomatic ferric hydrates on altered limestone along Tanj River.

BOGDANOWITSCH, K., op. cit., pp. 485–494.

ERNST, A., Die Kohlen und Eisenerzlagerstätten des centralen Russlands: Berg- u. hüttenm. Zeitung, No. 50, 1900.

Description of Moscow coal fields and iron ores of Tula-Jelez and Orel-Kromy.

KARAKASCH, N., [Some iron-ore deposits in the Shisdrink district, Government of Kaluga]: Geol. Centralbl., vol. 2, p. 136, 1902 (abstract).

On a deposit of brown ore and siderite in central Russia. Shows ore to be extensive but gives no idea of grade or thickness.

KOBETZKI, J., [On Iwnian iron ore, Government of Kursk]: Geol. Centralbl., vol. 3, pp. 35–36, 1903 (abstract).

Deposits contain 380,000,000 poods (6,220,000 metric tons) ferric hydrates in 7 to 70 inch bed. Iron, 50 to 55 per cent; phosphorus, 0.4 to 0.68 per cent; sulphur, less than 0.28 per cent; manganese, up to 1.34 per cent.

KRASNOPOLSKY, A., [Iron ore in Jeletsk district, Government of Orel]: Geol. Centralbl., vol. 3, p. 36, 1903 (abstract).

Brown ore in clay. Too low grade for much use.

SAMOJLOW, J., [On the formation and paragenesis of the iron ores of central Russia]: Geol. Centralbl., vol. 1, p. 358, 1901 (abstract).

Review of Russian article.

SOUTHERN RUSSIA.

BAYARD, M., Note sur les gisements de minerais de fer des presqu'îles de Kertch et de Taman: Annales des mines, 9th ser., vol. 15, pp. 505–522, 1899.

Historical and geologic note.

BESBORODKO, N., Über eine neue Chromeisenerzlagerstätten am nördlichen Kaukasus und ihre mineralogischen Verhältnisse: Neues Jahrb., Beilage Band, vol. 34, pp. 783–798, 1912.

A mineralogic study of a serpentine-chromite-nickel deposit in southern Kuban area, 12 kilometers south of Psemjonowka.

KOBETZKI, J., [On iron and coal of Iwanow, Government of Ekaterinoslaw]: Geol. Centralbl., vol. 3, p. 8, 1903.

Limonite interbedded with anthracite. Ore reserve over 1,000,000,000 poods (16,400,000 metric tons). Iron, 46 to 61 per cent; sulphur, 0.08 to 0.3 per cent; lime, 0.2 to 2.2 per cent; insoluble, 5.3 to 32.9 per cent.

MONKOFSKI, C., Krivoi Rog (partial translation by A. Foniakoff): Rev. univ. mines, vol. 12, pp. 72–105, 1905.

Pure geology.

PIOTROWSKI, L., [Iron ore in Don Basin]: Geol. Centralbl., vol. 3, p. 35, 1903 (abstract).

Ore consists of siderite "nests" in green gypsum-bearing clay. Hydrochemical ore formed by action of $FeSO_4$ on limestone. No idea of extent.

POPOV, S., Zeitschr. Kryst. Min., vol. 52, pp. 606–614, 1913.

A study of the minerals of the Kerch Peninsula.

SIMMERSBACH, B., Die südrussischen Eisenerzfelder von Krivoi Rog und Kertsch: Oesterr. Zeitschr. Berg- u. Hüttenwesen, vol. 62, pp. 253–257, 272–275, 288–291, 303–305, 1914.

Covers iron industry of entire country in introductory part. Very thorough study of Krivoi Rog with estimate of 55,160,000 tons (based on Symanowski). Much less information on Kerch.

SOKOLOW, N., Iron ore in Pokrovsk property of Grand Duke Michael: Com. géol. Bull., vol. 19, pp. 407–421, 1900.

Brief résumé in French. Iron deposit at southwestern extremity of Government of Ekaterinoslav, at confluence of Bazalouk and Dnieper.

SZYMANOWSKI, M., [Krivoi Rog iron-ore reserves]: Geol. Centralbl., vol. 3, p. 35, 1903 (abstract).

Figures Krivoi Rog at 3,500,000,000 poods (57,300,000 tons). Rubin gives review of Krivoi Rog literatüre.

——— Krivoi Rog: Soc. ind. min. Bull., 3d ser., vol. 14, pp. 1385–1459, 1900.

A complete detailed study. Contains bibliography. Figures reserves at 57,000,000 tons of ore carrying about 60 per cent of iron.

TERPIGOREW, A., [Magnetite deposit of Daschkiessan, in the Caucasus]: Geol. Centralbl., vol. 3, p. 7, 1903 (abstract); Zeitschr. prakt. Geologie, vol. 13, pp. 116–117, 1905 (longer review, with sketches).

Estimates 5,000,000,000 poods (81,900,000 tons) in Daschkiessan, 900,000,000 poods (14,700,000 tons) in Gez-Dasch. Iron 62 to 68 per cent, silica 5 per cent, with much calcite. At 5 versts from these are unexplored deposits whose reserves probably equal "several milliard poods." The review in Zeitschr. prakt. Geologie ends by saying that these are the only reliable ("zuverlässige") deposits of iron ore in the Caucasus.

THIESS, F., Die Erzgruben von Krivoi Rog: Oesterr. Zeitschr. Berg.- u. Hüttenwesen, vol. 55, pp. 608–609, 1907.

Brief description, principally of industrial features, drawn from Russian sources.

WINDA, ——, [Iron ores of coast of Black Sea]: Geol. Centralbl., vol. 3, p. 36, 1903 (abstract).

Clay ironstone and brown ores. Abstract does not show what part of Black Sea coast is being discussed.

ZEIDLER, R., [Kerch iron ore district]: Geol. Centralbl., vol. 3, p. 5, 1903.

Gives reserve of 7,100,000,000 poods (116,300,000 tons) and does not cover entire area.

The Russian iron industry and the Ukraine: Stahl und Eisen, No. 12, 1918; abstract in Chem. Industry, Feb. 28, 1919.

Krivoi Rog reserve 500,000,000 tons. Kerch reserve 500,000,000 tons. Donetz Basin and Kosak-Mogila of no importance. Other industrial data for 1912.

URAL REGION.

BAUERMANN, H., On the iron-ore deposits of the Ural: Iron and Steel Inst. Jour., 1898, No. 1, pp. 134–145.

Description of mining, with photographs and a plan of Bakal district.

DUPARC, L., and MRAZEC, L., Sur le minerai de fer de Troitsk (Oural du Nord): Compt. Rend., vol. 136, pp. 1409–1411, 1903.

Details of geology at Osamka mine at Troitsk, near Koswa.

FEDOROW, E., and NIKITIN, W., [The Bogoslovski mining district]: Geol. Centralbl., vol. 2, pp. 326–327, 1902 (abstract).

The original is apparently a monograph on the geology and ore deposits of the district.

KONIOUCHEVSKY, L., [Geologic study in Bakalsk region]: Geol. Centralbl., vol. 4, p. 310, 1904 (abstract).

Fixes age of deposits in Devonian. No data on size given in abstract.

——— Geologic study of Zigaza and Komarovo iron deposits: Com. géol. Mém., No. 21, 1906 (Russian and French abstract).

Geologic study. Quotes estimate of 2,000,000 tons for Komaroskov district, 580,000 tons for Zigazinsky, and 180,000 tons for Bachkirsky.

LOEWINSON-LESSING, F., [On the magnetite deposit of Gora Blagodat]: Geol. Centralbl., vol. 12, p. 170, 1909 (abstract).

Geologic description.

——— [On the magnetite deposit of Wyssokaja, in the Ural region]: Geol. Centralbl., vol. 8, p. 411, 1906 (abstract).

A discussion of genesis. Concludes that ore is contact metamorphic.

MOROZEWICZ, J., Die Eisenerzlagerstätten des Magnetberges (Magnitnaia Gora) im südlichen Ural und ihre Genesis: Min. pet. Mitt., vol. 23, pp. 113–152, 225–262, 1904; abstract in English in Inst. Min.-Eng. Trans., vol. 29, pp. 679–681; abstract in German in Zeitschr. prakt. Geologie, vol. 15, p. 90, 1907.

Very complete study, both petrographic and geologic. Interesting presentation of hydrothermal theory.

MRAZEC, L., and DUPARC, L., Über die Brauneisensteinlagerstätten des Bergreviers von Kisel im Ural (Kreis Solikamsk des permschen Gouvernements): Oesterr. Zeitschr. Berg- u. Hüttenwesen, vol. 51, pp. 711–715, 735–740, 1903.

Detailed descriptions of geology and mining.

NIKITIN, V., On the geology of Versk-Isetzk: Com. géol. Mém. 22, 1907 (Russian with French abstract).

Mostly geology and petrography (excellent photomicrographs), with a description of metalliferous deposits.

OUSPENSKY, L., [On Bogoslovski]: Geol. Centralbl., vol. 3, p. 36, 1903 (abstract).

Geologic data. Original article in Jour. des mines (Russian), No. 11, pp. 125–166, 1900.

PRESTON, T. H., The Urals and their mineral wealth: Min. Mag., vol. 14, pp. 197–201, map, 1916.

General and brief review, giving mostly historical and industrial data.

SHOCKLEY, W., The Bogoslovski mining estate: Am. Inst. Min. Eng. Trans., vol. 39, pp. 274–302, 1908.

General article. Estimated iron-ore reserve of 8,000,000 tons hematite and limonite 30 to 66 per cent iron in basin deposits, 13 to 65 feet thick, 200 to 650 feet wide, 500 to 1,600 feet long. About 10,000 tons chrome iron ore mined since 1805. Tables of weights and measures.

SMIRNOW, N., [Magnitnaia Gora of the Schaitanske district]: Geol. Centralbl., vol. 12, p. 171, 1909 (abstract).

Considers Magnitnaia as segregation of titaniferous magnetite from gabbroic magma. This is not the Magnitnaia Gora of the southern Ural region.

TERPIGOREW, A., [Distribution of iron ores of Ssulinsk iron works]: Geol. Centralbl., vol. 3, p. 6, 1903 (abstract); Zeitschr. prakt. Geologie, vol. 13, p. 115, 1905 (better and longer review).

Iron ores are metasomatic ferric hydrates. Can not make estimate because of irregular nature of ore bodies.

ZEMIATSCHENSKY, P., [On the genesis of some of the Ural ore deposits]: Geol. Centralbl., vol. 2, p. 685, 1902 (abstract).

Deals especially with the genesis of the metasomatic deposits in clay slates.

Jour. Chem. Ind., February 15, 1919, p. 47 R; from Zeitschr. Chemie, November 29, 1918.

Gives following estimates on reserves: Alapaievsk district—Sinitschihinske group, 400,000,000,000 poods (6,600,000,000 tons); Syrjanover group, 1,000,000,000,000 poods (16,400,000,000 tons); Alapaievsk group, 1,200,000,000,000 poods (19,700,000,000 tons). Average iron, 45 per cent. Deposits in Governments of Rjasan, Vladimir, and Nizhni Novgorod are extensive and of high metal content. Deposits at Lepesk in Government of Tambov are exceedingly valuable.

SPAIN AND PORTUGAL.

ADAMS, F. D., Notes on the iron-ore deposits of Bilbao: Canadian Min. Inst. Jour., vol. 4, pp. 196–204, 1901.

Good brief description with map and photographs.

ADARO, L. DE, and JUNQUERA, G., Criaderos de hierro de Âsturias: Inst. geol. Mem., vol. 2, 1916.

One volume of text and one of maps. Part of a series of comprehensive and detailed articles on iron-ore deposits of Spain. De Adaro is the author, but owing to his death it was necessary for Junquera to revise the original for publication.

AHLBURG, J., Die nutzbaren Mineralien Spaniens und Portugals: Zeitschr. prakt. Geologie, vol. 15, pp. 183–210, 1907.

Good, fairly comprehensive article.

BROUGH, B. H., The iron-ore mines of Biscay: Cassier's Mag., vol. 23, pp. 697–709, 1902–3.

A well-written, carefully worked out semipopular article. Good photographs.

BULMER, G. H., The Alquife iron-ore mines, in the south of Spain (Granada): Inst. Civil Eng. Proc., vol. 159, pp. 312–314, 1905.

Brief description, mostly of mining.

DANN, E., Die Eisenerzlager und die Eisenindustrie von Bilbao: Stahl und Eisen, vol. 33, pp. 1181–1185, 1232–1236, 1913.

Gives location and geology of the deposits and a review of past history. Forecasts a future of 15 to 20 years. Gives details of ore handling. Very good article.

FABREGA, P., A study of the iron-ore deposits of Almería, translated by C. V. Haines from Rev. minera, vol. 58, pp. 266–269, 284–288: Min. Jour., vol. 82, pp. 5, 44–45, 78–79, 114–115, 1907.

Written by a truly Spanish scholar, therefore it takes us from cosmogenesis to date. The translation is good. The economic and industrial part is clear. Estimates 50,000,000 tons.

FIRCKS, F., Über einige Lagerstätten der Provinz Almería in Spanien: Zeitschr. prakt. Geolgie, vol. 14, pp. 142–150, 233–236, 1906.

Contains short description of some of the iron deposits.

GILLMAN, F., Malaga magnetites: Inst. Min. Met. Trans., vol. 20, p. 447, 1911.

Interesting discussion of origin.

GOUNOT, A., Métallurgie du fer dans les Asturies: Soc. ind. min. Bull., 4th ser., vol. 3, pp. 749–783, 1904.

On Spanish metallurgy. Contains some descriptions of ore.

GROSCH, P., Roteisensteinlager in Asturien: Zeitschr. prakt. Geologie, vol. 20, 201–205, 1912.

An interesting geologic study.

JOHN, ——, Die Eisenerzlagerstätten von Bilbao und ihre Bedeutung für die zukünftige Eisenerzversorgung Grossbritanniens und Deutschlands: Glückauf, vol. 46, pt. 2, pp. 2002–2013, 2045–2052, 1910.

A complete study with many sections and a map. Gives geography, geology, and study of reserves, as well as economic and statistical review and forecast. Reserve, 50,500,000 tons. Says present production rate will last only 10 or 11 years, and suggests need of new source of similar ore for Great Britain and Germany.

JONES, J. A., Development and working of minerals in the Province of León, Spain: Inst. Min. Eng. Trans., vol. 20, pp. 420–441, 1901.

Pages 430–440 contain a brief note on iron deposits.

——— The Devonian iron ores of Asturias: Inst. Min. Eng. Trans., vol. 18, pp. 279–292, 1900.

A study with analyses and descriptions of the formations. Appears to have been written by a stratigrapher rather than a man accustomed to mining geology.

KINDELAN, V., and RANZ, MANUEL, Los criaderos de hierro de Guadalajara y Teruel: Inst. geol. Mem., vol. 3, 1918.

Detailed monograph with excellent maps. Part of series in course of publication, on Spanish iron ores.

LOZANO, R. S., Datos geológico-mineros de la Provincia de Cáceres: Com. mapa geol. Bol., vol. 26, pp. 205–219, 1899.

Description of geology and mining.

MACKAY-HERIOT, E., The Bilbao iron mines: Eng. and Min. Jour., vol. 76, pp. 510–512, 1903.

Description of deposits. Most emphasis on ore and method of occurrence. Some mining. Good general article.

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