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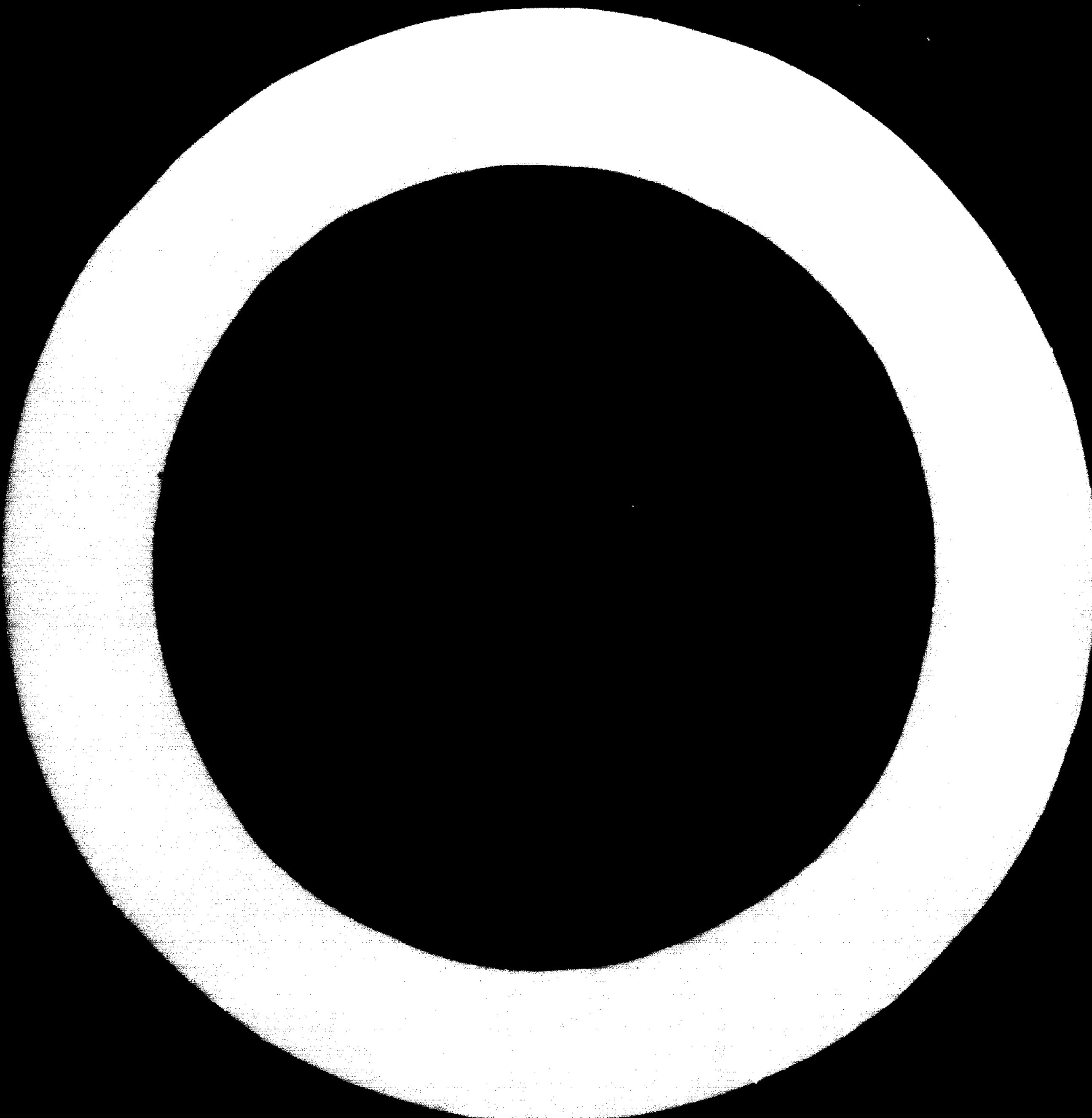

UNITED NATIONS

INTERREGIONAL SYMPOSIUM ON THE APPLICATION OF MODERN TECHNICAL PRACTICES IN THE IRON AND STEEL INDUSTRY TO DEVELOPING COUNTRIES

11-26 NOVEMBER 1963

D03105

STEEL SYM. 1963
Technical Paper A.1.
2 October 1963
ENGLISH
Original: SPANISH

EXPLORATION OF A SMALL IRON ORE DEPOSIT

STUDY OF THE IRON-CONTAINING ZONE OF VALENTINES IN THE EASTERN REPUBLIC OF URUGUAY

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This report describes experience gained in the study and development of an iron ore deposit in the eastern Republic of Uruguay, intended to supply the emerging national iron and steel industry, which is being developed to cover internal requirements and to make products in various stages of manufacture for export.

Uruguay is a country without much experience in the extractive industries, and with almost none in the exploitation of metalliferous ores. All its consumption of metals is supplied by imported products in various stages of manufacture.

The annual production of rolled steel products is about 125 000 tonnes per annum, part of which is imported and part rolled in Uruguay.

The *per capita* consumption is 70 kg annually, a figure which is very low, but which, according to the growth curve, will increase rapidly in the next few years. It has therefore been thought necessary to develop our iron and steel industry by increasing and diversifying its output, which is at present limited to the rolling of steel for reinforced concrete. At the same time, the possibilities of supplying steel made from our own raw materials are being more closely examined.

The existence of iron ore deposits in Uruguay has been known for many years. Mining concessions were applied for as far back as 191[illegible], but the low consumption of steel per head of population in the early decades of the century, together with the lack of economic incentives, made it impossible to consider the possibility of creating an integrated iron and steel industry in Uruguay. By 1956, circumstances had so developed that it was thought possible to produce a large number of steel products in our own country, using our own mineral resources.

With this in mind, all the existing information on iron ore deposits which were capable of commercial exploitation was investigated.

Although the ore was in all cases lean or in thin seams, which accounted for the fact that it had not already been worked, these deposits were re-examined in 1956 by the Geological Institute of Uruguay, as a result of a private request.

The findings of these preliminary investigations have drawn attention to the Cerro Mulero deposits.

After considering the possibilities of making the relevant investigations with the resources of our own country, working through national organizations, or alternatively of consulting foreign experts or firms, it was concluded that the Geological Institute of Uruguay was at the necessary technical level to undertake the task. In order to develop the programme to the best advantage, the collaboration of an expert was requested and obtained from UNO to help in the initial stages of the work.

Having made this decision, the scheme of study was financed jointly. The manufacturers promoting the project financed the necessary direct costs, the State contributing an equal amount through the Geological Institute of Uruguay. These investments totalled 5 000 dollars for the 24 months during which the main work took place.

It will be appropriate at this point to review briefly the organization which has carried out the work, its origin, growth and aims, so as to obtain a better idea of the development of the investigation of the deposit.

The Geological Institute of Uruguay was formed in 1912 under the name of the Institute of Geology and Drilling, with the object of undertaking a geological investigation of the national territory as a basis for the mineral and industrial exploitation for the whole of the country. Its functions were summarized as follows in a government decree in 1925:

a) Overall examination of the sub-soil of the country.
b) Study of the elements and resources of materials with agricultural and industrial applications.
c) A hydro-geological investigation, and the utilization of the abundant supplies of underground water present in the Uruguayan sub-soil.
d) Study, extraction and conservation of the fossil deposits.
e) Preparation of a geological map of the national territory.

f) Scientific and technical advice on any subjects within its frame of reference, as required by all State administrative departments, in relation to public works in general.

g) Advice of a similar nature at the request of corporate bodies and private individuals.

The present organization consists of a general administration which is directly responsible for the museums and specimen stores, and the administrative division, responsible for the finances and staffing of the organization.

The organization also includes a general geological division and a division of geological economics, responsible for the laboratories of mining technology, petrography and mineralogical chemistry.

Finally, there is a drilling service, with workshops, stores and depots, for the use of the technical specialists required for efficient working.

A General Inspectorate of Mines was attached to the Geological Institute by the law passed on 2nd May 1933. This body is charged with the administration of the mineral resources of the country which, under the provisions of the law, are the property of the State. The State concedes the right of corporate bodies and individuals to exploit these resources, provided that such individuals satisfy the conditions laid down in the Mining Code, and are interested in the exploitation of minerals existing within the country.

From this account of the functions of the Geological Institute of Uruguay and of its competence to carry out investigations in the field of mining engineering, it can be clearly seen that it is in a position to carry out successfully a study of an iron ore deposit intended to supply the national iron and steel industry.

A complete plan of study has been devised of the region which includes Cerro Mulero, and to which we will give the name of the iron-containing zone of Valentines, since the deposits found there are part of a very large outcrop zone which includes the region studied.

The plan worked out by technical experts of the Institute was carried through with very few modifications of its original form, and may be described as follows.

In accordance with the organization of the work, the project was carried out under the supervision of a chief engineer, who was in charge of all operations, and who was in direct control of the petrographic and mining laboratory, the drawing office and photographic section, the specimen stores and the camps. The last-named were under the supervision of a resident engineer, responsible to the chief engineer, and assisted by two overseers, one in charge of drilling and the other of the team of surface workers.

The headquarters of the project kept contact with the chemical laboratory and drilling services through the appropriate sections.

The first step was to make a topographical map of the region, which covered an area of 140 km^2. This work was carried out by the Military Geographical Service, which made the general maps to a scale of 1 : 15 000 and detailed maps to a scale of 1 : 2000. These maps, together with the stereoscopic pairs utilized for the survey, were used throughout without difficulty.

The specialized staff of the Institute were responsible for the complementary topographical work of levelling and tachymetry.

The maps and sketches prepared during the preliminary investigations, which w .e also undertaken by the geologists of the Institute, provided a basis for a geological study of the region.

Having obtained these topographical and geological data, it was possible to proceed with the main objective of studying the seams or strata of ore. These tasks could be divided roughly into surface work and drilling. The surface work consisted mainly of trenching in a direction at right angles to the strike of the ore seams and excavating to a depth sufficient to eliminate the surface weathering, and to allow the pitch of the seam to be determined. In general, these trenches were spaced at intervals of 200 m, a distance which was more than sufficient, taking the uniformity of the bands into account, to obtain accurate and complete information at the surface. About twenty trenches were excavated, corresponding to a total volume of material of 2 500 m^3.

The drill holes were made by four type Calix Ingersoll Rand shot drills with steel shot. The holes were made in the same profiles as the trenches with, in general, two for each profile, so as to be able to locate accurately the floor and head of the seams.

The whole of the drill cores were examined, a preliminary classification and microscopic examination being made at the camp.

After this preliminary study, the samples were sent to the laboratory at Montevideo, about 250 km away, where they were treated as follows :

Two series of samples were taken for each metre of drill hole; these were labelled and placed in containers for subsequent control tests. The rest of the sample was coarsely ground, and, when sufficiently homogeneous, was quartered so as to obtain a weight of about 250 g. These samples were then ground a second time to 100 mesh, and about 100 g sent to the laboratory, the rest being stored as control samples.

Small specimens were sent to the petrographic laboratory for microscopic examination.

The chemical laboratory of the Institute analyzed the samples for iron, silica, sulphur, phosphorus and titanium.

In the petrographic laboratory the ore was examined under the microscope by transmitted and reflected light, to determine the transparent and opaque constituents.

All the plans required for the investigation were prepared by the drawing office, which was also used for the cartographic work.

Having obtained all this information, the amount of ore contained in the deposit was measured, and its mean composition - the main object of the investigation - was determined.

It will be appropriate at this point to comment on the work, which was carried out entirely by Uruguayan specialist staff and workers, in the light of the experience gained.

It was only to be expected, having used almost exclusively the material available to the Geological Institute of Uruguay, which was not specifically adapted to the purpose, that difficulties would arise; however, these were surmounted in every case.

The first modification was made to the drilling programme. When the true geological structure was known, the 100 drill holes 20 m deep, provided for in the original plan, were replaced by about 20, 70 to 80 m in depth. Their planimetric location was modified as a result.

In order to reduce the drilling costs, the sites to be drilled were determined with care, without using a rigid locating system, so that it was possible to obtain with a small number of drill holes complete information relating to the deposit in depth, and to reduce substantially the final cost of the project.

Under the conditions existing when the study commenced, the surface work and the drilling operations had to be started at the same time, with the result that the choice of location of some of the first drillings was not altogether satisfactory. To solve this problem the work was arranged as follows:

- First, a topographical survey of the ore-bearing areas was prepared
- Prospecting and trenching was carried out to enable the subterranean structure to be inferred.
- Finally, the drilling sites were located and drilling operations were commenced.

In this way the cost of the programme was reduced considerably and the progress of the work was accelerated.

One of the main drawbacks was the lack of high-performance efficient drilling equipment, which would have speeded up the work. Drills had to be used which were designed specifically for making large-diameter holes for water. Although it was possible to complete all the work which had been planned, this equipment had the drawbacks of low rate penetration, the large amount of drill core obtained, and the need to use steel shot, which complicated the interpretation of the sample in cases where the amount of core recovered was small or non-existent. When the industry is established, it will clearly be necessary to make further investigations using drilling equipment designed specially for the purpose.

The need to convey carefully a large quantity of samples from the camp to Montevideo (250 km away), with a preliminary classification on the site followed by a second one on arrival at the laboratories, increased the cost and delayed the reporting of the analytical data. Although the accuracy of the results is not thereby affected, this disadvantage will have to be avoided in future by setting up laboratories for mechanical preparation and chemical analysis near to the deposit, at any rate for routine testing.

Only the railway is available for the transport of staff and materials, with a frequency of two journeys of five hours per day to cover a distance of 250 km; this represents an obstacle to communication between the camp and the laboratories, the workshops and the administration, situated in Montevideo. It would be necessary to consider the possibility of more rapid and frequent traffic, to enable the work to be speeded up.

RESULTS OBTAINED

The geological study, the drilling operations, and the petrographic and chemical investigations of the surface samples and drill cores, enabled the geological structure of the iron ore strata and the mean concentration and amount of the ore tested, proved, probable and possible, to be established for the iron-containing zone of Valentines.

Only a part of the deposits has so far been investigated, with 24 borings representing a total of 1 500 m drilled and about 2 500 samples collected, classified, analyzed and stored.

The information given below relates to the part of the deposit which was studied but the preliminary results suggest a high degree of uniformity over the whole of the region.

GEOLOGICAL STRUCTURE

The principal mineral-bearing zone in the sector studied consists of strata with a mean thickness of 50 m, which form part of an anticlinical fold with an axis of N 70^{o}W. The dip is constant between 60 and 70°. Various fissures have led to displacements of the blocks with respect to each other. Each of these blocks forms a ridge of the highest parts of the region.

MINERAL

The surface samples of our iron ore have a certain similarity, from a petrographic point of view, to the itabirite of Brazil described by J. van N. Dorr II, and they have been so identified provisionally.

The mineral itself consists of well-stratified beds of quartz and hematite.

Three main petrographic types can be distinguished in the principal mineralized bed, which are all conformable with the exposed geological structure. These are:

Normal itabirite, consisting of quartz, augite and magnetite. In fact, this represents a deep metamorphic facies of the taconite.

The freshly-extracted rock has the following mineralogical composition by volume:

magnetite	38%
augite	30%
quartz	32%

Feldspathized itabirite, resulting from the metasomatic growth of microcline on the rock described above, or from the 'injection' of narrow veins of feldspathic quartz parallel to the secondary foliation and determining the final bed-by-bed structure.

Pyroxenite and magmatized gneiss. From the economic point of view, these can both be considered to be barren rock.

In order to calculate the tonnage present, it was necessary to refer to the exact geological structure and to obtain the volumes of each of the three types of mineral present in the ferriferous deposits, as the iron content varies significantly from one type to another.

1 000 chemical analyses were made of the normal itabirite, giving a mean iron content of 3 %. The feldspathized itabirite is a less frequently occurring material; only 150 analyses have been made, indicating a mean iron content of 32%.

The rock considered to be barren contains less than 10% of iron.

All these analytical results have been obtained by acid attack on the iron oxides, which means that only the reducible constituent of the ore was taken into account.

The volume calculation applies solely to the principal deposits; beds less than 10 m in thickness were neglected.

Under the given economic conditions, it was envisaged in the first instance that open-cast mining would be used exclusively; this method imposes limitations on the thickness of deposit which can be worked. In addition, the utilizable volume extends to a depth of not more than 150 m, even when some borings show that ore exists at a depth of 220 m. (a fact which is confirmed by the geological data, which indicate that iron may be present at much greater depths).

Taking the considerations discussed above as the main criterion, we have arrived at the following total figures, expressed in millions of tonnes of ore, proved and probable, for the part of the deposit investigated:

Apretado	:	19
Aurora	:	9
Isabel	:	13.5
Morochos	:	5

totalling 46.5 million tonnes.

As far as the iron content is concerned, the following comments may be made:

a) the figures correspond to the total deposit, including the 'barren' parts, and represent an overall total of 36% iron;

b) a preliminary beneficiation, probably by magnetic separation, at the quarry exit, would increase the iron content appreciably, to about 3?% in the form of normal itabirite.

As this ore is low in iron, the question arises as to whether it can be utilized directly for reduction, or whether it would be necessary to concentrate and agglomerate the ore before use.

Such an ore, with a simple structure, and a particle size of about 1 mm, appears to lend itself to the preparation of a concentrate, experiments in some laboratories abroad having shown that it is possible to produce without difficulty concentrates with an iron content of almost 70% and a recovery from the oxides of 93%.

Concentration trials have been made on this ore, using gravimetric and magnetic separation techniques; the results, which were satisfactory in each case, give the impression that the product is obtained more rapidly and economically by magnetic separation, and with a better oxide recovery.

The pelletization trials have demonstrated the possibility of obtaining pellets with 71% iron, 0.022% phosphorus, 0.015% sulphur and 1.1[illegible]% silica, and containing no alumina or lime.

As the particle size is sufficient, i.e. about 1 mm, the possibility of sintering as a method of agglomeration could also be considered.

CONCLUSIONS

The following conclusions can be drawn from the results of our study of the iron-containing zone of Valentines:

1. The study of iron ore deposits in other metalliferous zones could be made successfully with the organization and the means at the disposal of the Geological Institute of Uruguay.
2. On the basis of the proved and possible tonnages established in the study, it can be estimated that 46.5 million tons of ore are present in the Valentines zone.
3. The possible reserves of the mineralized region can be estimated at 60 million tonnes.
4. The mean iron content varies between 36 and 3[illegible]% over the whole of the deposit.
5. The ore has a simple structure and contains quartz, augite and iron oxides in the form of magnetite and hematite.
6. The iron is present in simple compounds which will certainly enable a concentrate with 68-70% iron to be produced with an iron recovery of 92-93%.

7. The iron oxide particle size is about 1 mm.

8. These conditions indicate the possibility of applying gravity separation (the Humphrey spiral) or magnetic concentration.

9. After suitable preparation the ore could be pelletized or sintered, to give a final product with a high iron content.

10. The net cost of the study amounted to 0.0025 dollars per tonne of ore, covered by equal contributions from the promoting company and the Geological Institute of Uruguay.

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