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REPORT OF THE ECONOMIC COMMISSION FOR AFRICA MISSION TO THE ISLAMIC REPUBLIC OF MAURITANIA 11 - 25 January 1965

CONTENTS

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I. INTRODUCTION

1. The ECA Mission to the Islamic Republic of Mauritania, of which the following is the report, was sent, following the recommendations of the BAMAKO conference, with the object of placing the Republic on the same footing as other West African Countries in regard to investigations into its comparative advantages as a site for an integrated iron and steel industry serving the whole sub-region and for other industrial possibilities.

The mission was composed of Mr. Shukri (Regional Advisor on Geology) Head of the Mission, Mr. Z. Rupnic (Natural Resources Division, Energy) and Mr. J. Strakos (Industry Division, Mechanical metallurgy) who visited the Republic from 11 to 25 of January 1965. They were joined by Mr. Baba Kasse (Director of the ECA Sub-Regional Office in Niamey) from the 14th to 18th of January and by Mr. A.E. Denis, Director of Steel, Ministry of Industry, France, from the 15th to 19th of January. The mission subsequently left for Guinea.

2. The terms of reference of the mission were as follows:-

i) To investigate the comparative advantages in regard to access to raw materials, markets and other facilities, of sites in Mauritania for the location of an integrated iron and steel works serving the sub-region.

ii) To investigate the raw materials and other resources available for the production of basic chemicals and fertilizers.

iii) To undertake appropriate studies on the possibilities of the utilization of gypsum reserves for the cement industry of the sub-region.

iv) To prepare an inventory of engineering establishments.

v) To investigate the possibility of establishing appropriate facilities for processing and preserving (refrigeration) meat and fish products for export.

vi) To undertake appropriate studies on the possibilities of establishing industrial plants for the production of leather and leather goods.

vii) To advise on general economic development problems

viii) To advise on technical assistance programmes.

Of these, paragraph 5 will be the subject of a report by a separate mission and paragraphs 6 and 7 will be dealt with in reports to be prepared for the West African Conference to be held in Niamey in December.

3 On the way to I.R.N. the three permanent members of the team stopped in Dakar. They had a fruitful briefing with Messrs. Marcel Croisier (Regional Representative in Dakar, for Senegal and Mauritania) and with his Associate Mr. Pierre Bourgois and with other members of the T.A.B staff in Dakar.

4. The team visited the University of Dakar, which is an important centre of learning and includes in the Faculty of Science seven different Departments. 2610 students joined the Faculty of Science of whom about 14 are from Mauritania. It is possible that this centre will be able to cope efficiently with a greater number of students from neighbouring French speaking countries. Discussions were held with the Dean of the Faculty and Professor of Physics, Professor Masson, and with Professor Bougy, Professor of Geology, who worked in Mauritania for many years and is still carrying out research work there with his students.

5. Professor Sougy was very helpful in outlining his work and Professor Masson showed the team the Institute of Physical Meteorology run by the Faculty of Science, which is specially engaged in solar energy and its application. A small pump that works with the use of this energy and producing some 10 L per minute was demonstrated to the team. The work of Professor Masson and his collaborators on the use of the same energy in the production of electric power was also explained and a machine under construction was shown. Mr. Masson is optimistic of the results of his work and raised the question of enlarging the Centre at Dakar, instead of creating a new one at Niamey He plans to submit a request for financial assistance to the Technical Assistance Board or Special Fund for the enlargement of the Dakar Centre.

6. The members of the team had also very interesting discussions with Mr. J. F. Agassiz, the Manager of the Special Fund project for the appraisal of mineral resources of Senegal.

7. In I.R.I. the team was received and had discussions, among others, with the following officials, arranged in alphabetical order

Dr. Ba Bocar Alpha, Minister of Economic Affairs, Posts and Telecommunications.

Mr. Philips Bastid, Mining engineer of the "Société des Mines de Fer de Mauritanie" (MIFERMA)

Mr. Y. Barbier, Geologist, Department of Mines

Mr. Momanaref, Chief, Statistical Department

Mr. Brenier, Director of Plan

Mr. A. Brunelle, Chief, Department of Mines, who was to accompany us during our stay

Mr. Cornu, Techical Adviser to the Ministry of Works

Mr Jean Dépagne, Ingénieur Géologue BRGM.

Mr. Hamouni, Commissaire général du Plan à la Présidence

Mr. Janvier, Ministry of Works

Mr. Mkhaitirat, Director at the Department of Economic Affairs, Ministry of Economic, Industrial & Social Affairs

Mr. Haïbe Moktar, Conseiller économique et financier du Président de la République

Mr. Mouragnes, Relation extérieur, MIFERMA

Mr. Richardson, General Manager of MIFERMA

Mr. Roussel, Ministry of Public Works, - Chief of Akjoujt, and the Chief accountant for the Republic.

His Excellency the Minister, Dr. Alpha invited the team for a farewell party at his home on the eve of our departure.

8. The members of the mission visited the iron-ore deposits at Fort Gouraud, the copper deposits near Akjoujt, the gypsum of Sebkha de Ndrhamcha, N.E. of Nouakchott, the harbour of Port Etienne and the new wharf under construction at Nouakchott. All transportation facilities were arranged by the Government except for the visit to Fort Gouraud, which was arranged by MIFERMA.

9. Unfortunately not all the technical reports were made available to the members of the team in I.R.M. Again, because of inadequacy of transportation facilities, and of shortage of time, the team had no chance to visit many of the interesting exposures such as the newly discovered chromite and beryl deposits in the Precambrian north of Akjoujt or the phosphatic deposits at Civé near the River in the south. Because of all these factors, it was not possible to have a complete first hand picture of the potentialities of the mineral resources of the country.

10. Statistical data concerning the infrastructure of the I.R.M. is given in the Bulletin Statistique et Economique, a quarterly publication, of which the first number appeared early in 1964. This is

published by the Service de la Statistique, B. P. 240, Nouakchott and the project is financed by the French Fonds d'Aide et de Coopération (FAC). The area of the I.R.M. is about 1.1 million square kilometers with a population of some 850,000 inhabitants. The most important industry is the mining of the rich iron ore of Fort Gouraud, which makes a large and increasing contribution to the GNP.

11. The report begins with a concise resumé of the geology of the I.R.M. and the accompanied mineralization, which is important for any future appraisal of the mineral resources of the country. This is followed by an account in some detail of the mineral resources already exploited or about to be exploited and future prospects. Again as underground water is an important resource for the I.R.M., which is an arid desert in its northern part, a summary of these underground water resources is also given. The next section deals with energy resources and with electricity and water supplies which are often closely connected. The question of an integrated iron and steel industry is then discussed followed by a short account of other industrial possibilities.

II. GEOLOGY:

12. The oldest rocks in Mauritania belong to the Middle Precambrian (Birrimian), the so called Amasaga - Ghallaman series and associated migmatites (old granites). These form the greater part of the Precambrian occurrences at Tasiast, Tijirit, Amsaga, Tiris, Ghallaman and Chegga (from west to east) and are shown as P(C) on the International Geological map recently published. The series is represented in its greater part by gneisses: calco-magnesian gneisses, quartzofeldspathic gneisses and hypersthene gneisses, and by mica schists, quartzites and others. All are severely migmatized and old calc-alkaline syntectonic granites are widely spread. Charnockites are also present.

The famous Fort Gouraud iron mineralization is present in these Birrimian quartzites. The early Precambrian (Dahomeyan) seems to be absent. Haughton (1963), however, described both the Amsaga-Ghallaman series and the Simandou and Mount Nimba series under the Dahomeyan. The latter is also considered as Dahomeyan P(D) in the International Geological map, whereas the former, in spite of the fact that it contains analogous banded iron stones, is considered as Birrimian P(C). The attribution of both series to one age is more plausible.

13. The Amsaga-Ghallaman series is followed by the Upper Precambrian, the series of Aguelt Nebkha and of Aioun Abd el Malek, shown as P(B) on the International Geological map. These are formed of arkoses, arkosic sands and various schists. The crystalline rocks of Middle and Upper Precambrian age are cut by more recent post tectonic calco-alkaline granites, considered as migmatized areas by others. They are also rarely cut by alkaline granites, aegyrine and riebeckite bearing, which recall the riebeckite granites of Zinder in Niger.

14. The Amsaga-Ghallaman, the Aguelt Nebkha and Aioun Abdel Malek series and associated granites occur in the Northern part of the I.R.M. They form the core of the Eglab-Hetti structural high elongated in an ENE-WSW direction, separating the structural lows of the Tindouf-Rio de Oro basin in the north from the Taoudenni basin in the south, one of the biggest synclinoriums of the world.

15. According to some authors the Akjoujt series, "séries plissées intermédiaires", belong to the Later Precambrian, shown on the International Geological map as P(A). This series occurs in the western part of the I.R.M. and is elongated roughly, in a N-S direction, towards Bakel and extends farther south into Guinea and Mozambique where it bifurcates. It is strongly folded and is covered in the east by Palaeozoic formations of the Adrar Plateau and disappears to the west under more recent sediments. The Akjoujt series is separated by a discordance and a conglomerate, and in places by a thrust, from the Amsaga series in the north. It forms the greater part of Inchiri and Aftout and has a

total thickness of several thousand metres of various para schists and of quartzites with some greenstones. The copper deposit of Ben Moghrein (Akjoujt) is related to this series. The Akjoujt series is thrust over the Selibaby M'Bout "granite", which forms a tectonic window of basement rocks.

Lately (see Sougy 1964) the validity of a Precambrian age of the Akjoujt series and its formation of a part of the African Precambrian shield has been questioned. An early paleozoic age including the "Infracambrian" of French literature, which is regarded as earliest Paleozoic by some, has been demonstrated for at least the "Falemian", the N-S non metamorphic sediments forming the eastern boundary of the slightly metamorphosed Akjoujt series.

The nearly flat lying or slightly dipping Paleozoic sediments in the east, representing a foreland structure, are folded towards the west into an orogenic N-S belt thrust eastwardly on the basement rocks and forming three zones. These are from east to west: Homoclinal Paleozoic sediments, folded zone; and metamorphic folded zone. The thrusts (Giraudon and Sougy 1963 and Dars & Sougy 1964) are marked by mylonites and the orogenic belt extending north-south is named Mauritanide by Sougy and is considered to belong to a Hercynian movement. Marcelin (1964) recognised three phases in the folding, thrusting and metamorphic history of the Akjoujt region.

In this case granites, which some authors have considered as intrusive in the Birrimian, would be considered as Paleozoic. Syenites intruded into the Akjoujt series in Tamkarkat gave abnormal radiometric figures and fluorspar was recorded in them.

16. In the Amsaga region, Barrere (1961, 62, 63) described important NE-SW faults that extend for over 140 km and gave evidence of the presence of important basic and ultrabasic intrusion, in which appreciable chromite deposits were recorded. Pegmatites carrying beryl and radiometric anomalies were also recorded in the same region. Gold, copper and molybdenum are recorded to be present in minor intrusions in a country of basement crystalline rocks in the NE corner of I.R.M.

It is difficult with our present knowledge to assign these mineralizations to a particular age. It is very possible that these mineralizations, though present in crystalline basement rocks are due to a much later mineralization related to that of the Akjoujt series. On the other hand some of the ore minerals reported in areas covered by the Akjoujt series could possibly be related to the older Amasaga series, which appears as tectonic windows in the Akjoujt series. The exact chronological status of these mineral deposits should be left open for the present.

17. The Paleozoic in I.R.M. extends from the Infra-Cambrian to the Namurian-Westphalian of the Carboniferous. It occurs in the Taoudenni basin forming the cliffs of Hank, the plateaux of Adrar and Tagant, the Aouker, Assaba, Affolé, area NE of Zemmour and at Sequiet el Hamra between the Rio de Oro and Algerian borders. The Paleozoic of Adrar has a maximum thickness of 1000 meters.

18. The Infra-Cambrian bounds the southern edge of the Yetti high and the eastern boundary of the Amsaga series. It also forms the core of Affole. It is formed of basal complex, of the sandstone of Hank, of stromatolithic limestones of Atar and of an upper series of argillaceous and sandy sediments of Affolé. It is limited at its top by the Cambrian transgression and more particularly by a glaciation marked by a tillite. The sediments at Affolé dip gently towards the NE and form a gigantic fault-outlier, (butte témoin, klippe). Mention has already been made of the analogy of the "Falemian series" in the west with the Paleozoic rocks to the east. This suggests a north-south trough, in the Akjoujt-Bakel area, which began developing on a true Precambrian basement during early Paleozoic times, and in which deposition continued into carboniferous time (see later).

19. The Cambrian overlies unconformably the Precambrian in the north near the borders of Algeria and of Rio de Oro in the extreme north-west of I.R.M. in the Zemmour. It also overlies unconformably the Infra-

Cambrian south of Hank. It passes from Hank through Adrar to surround the eastern edge of the Akjoujt series, its probable metamorphic counterpart. It also forms the Aouker and Hodh. It is formed of shales (shales of Hodh), of the dolomites of Assaba and of sandstones, siltstones and conglomerates. It is followed conformably by marine Ordovician.

20. The Ordovician follows in a regular fashion the Cambrian. It extends from Erg checht south of Hank to Ouadane and Chinguetti (Adrar) and bends to form the plateau of Tagant and the tectonic window of Assaba. It is represented by a sandy facies that bears Linguiae (the sandstones of Chinguetti, of Oujeft and of Zli).

21. The Silurian is represented by graptolitic shales south of Adrar and by limestones, besides shales and gypseous and ochrous beds, on the northern flank of the Yetti high at Seguiet el Hamra and the Zemmour. The beds at Zemmour contain Monograptus, Cardiola, Rhynchonella, Orthociratids and Crinoids. There is evidence of a minor disconformity between the Silurian and the Ordovician, related to the Caledonian orogency.

22. The Devonian is well represented on the southern flank of the Tindouf basin at the two last mentioned localities and south of the Adrar at H'el Metlan and at Krat. It is represented by both limestones and sandstones with Spirifers and Brachiopods and belongs to the Lower, Middle and Upper Devonian. The fauna is poor in reef-building forms and the sediments are considered to be formed in shallow waters, in which currents and tides were unfavourable for the construction of reefs.

23. The Carboniferous is present at the far north eastern part of I.R.M. overlying the Devonian. It ranges from Tournaisian to Viséan to Namurian-Westphalian. Carboniferous sediments also form the core of the Taoudenni basin and could very possibly contain coal deposits. The main folds involve the Carboniferous and are therefore not earlier than Hercynian. In post Hercynian time, westward downwarp of the north-south Akjoujt-Bakel area, previously described, resulted in the accumulation of a substantial thickness of Jurassic, Cretaceous and more recent sediments

along the coastal region.

24. The Precambrian and Paleozoic formation of many parts of I.R.Mas those of Mali and Guinea, are invaded by important basic sills and dykes. The exact age of these is not known but they are undoubtedly post Carboniferous as they cut the whole Paleozoic section of the Taoudenni basin and are pre-Continental Intercalaire (Jurassic-Cretaceous), as they never intrude these more recent sediments. It seems that they could be of Triassic age.

25. The Continental Intercalaire, so called In Kerche formation, hereafter referred to as CI, is the continental equivalent of the Cretaceous. It unconformably overlies the Paleozoic formations of the southern flank under the Taoudenni basin. Rocks belonging to the same age are concealed under the Continental Terminal (Tertiary) cover of the coastal basin. No evidence is known of the occurrence of marine Cretaceous beds in the valley of the Senegal River in outcrop. However, Maestrichtian deposits are known in subsurface. These form a basin in the Kaeidi region. The Maestrichtian transgression is followed by a calmer period with the deposition of chemical sediments before the Lutetian transgression.

26. Both Marine Tertiary and the equivalent Continental Terminal, the so called Bacikounou formation, (hereafter referred to as CT) are represented in I.R.M. by marine Middle Eocene (Lower Lutetian) limestones, dolomites, clays and sands, which cover unconformably both the Akjoujt and the Amsage series and are covered by the CT and further east by red sand dunes and Inchirian marine Quaternary deposits. The Mauritania-Senegal Eocene gulf appears to extend up the valley of the Senegal River as far east as the region of Bakel. The Eocene transgression has surpassed that of the Maestrichtian The sediments dip towards the Atlantic increasing in thickness and changing their facies from sands to clays, limestones and dolomites in the same direction. It is with these Lutetian beds that phosphatic deposits occur at Civé near Kaeidi.

Subsequent to Upper Lutetian times the sea retreated and continental argillaceous sandstones were deposited. It is due to this uplift that the CT replaced marine sediments. The Mio-Pliocene and Villafranchian are represented by continental deposits.

27. Later during the Quaternary marine transgression took place along the coast during the Tyrrhenian and Flandrian stages to form important calcareous sandstones in the north and sandy clays in the south.

Recent and ancient salinas (sebkhas) are present in the more recent sediments from which salt is exploited. Gypsum has been also exploited for a short interval from one of them, the sebkha de N'Drahamcha. The beach deposits are formed in places of black sands with ilmenite.

28. It is in the coastal basin and offshore as well as in the Taoudenni basin and in the north eastern extremity of the country (on the southern flank of the Tindouf basin) that oil possibilities exist It is also in these sediments that lie the highest possibilities for underground water It is to be noted that vast areas of the country are completely masked by recent dunes and by other superficial deposits, thus concealing any mineral deposits that could be present. The important magnetic and radiometric anomalies at Aguilal Faye, south of Akjoujt, are completely covered by sand dunes and were only discovered by airborne surveying.

III MINERAL RESOURCES

29. I.R.M. came into the picture of mineral producing countries, occupying a leading place amongst the high-grade iron ore producers of the world, with an annual production from Fort Gouraud amounting to 4.9 million tons during 1964. There is little doubt that minerals will make an increasing contribution to the I.R.M. in the future as the Akjoujt copper deposits are on the threshold of exploitation and as other mineral resources are under appraisal. In the following lines a resumé of the Fort Gouraud iron deposits and of the Akjoujt copper

deposit is given, followed by a summary of what has been achieved with regard to the search for other mineral deposits that need further appraisal.

A. Deposits at present under exploitation or about to be exploited

The Iron ores of Fort Gouraud:

30. The story of the opening of the iron ore deposits near Fort Gouraud illustrates well the time lag that often occurs between discovery and development of an ore deposit. The existence of a "mountain of iron" was noted at the beginning of the century in 1912 and was confirmed by the geologists of the Services des Mines of Dakar in 1935. In 1949 Bethlehem Steel Company made an appraisal of the deposit. This was followed by a new survey in 1951 carried out by a Franco-Anglo-Canadian mission. In February 1952 a company was formed (the Société des Mines de Fer de Mauritanie (Miferma) to proceed with the development of the deposit. A decree No.273 dated 20 October 1958 granted a concession covering 325 Km^2 to the company. Law No.59-061 of 10 January 1959 made the permit valid for 30 years. It was in 1960 that preparations were finally begun. The Miferma shares are owned 60 per cent by French interest (among which are the Bureau de Recherches Géologiques et Minières (BRGM) 22.5 per cent and Société Métallurgique Francaise, (USINOR), 28 per cent , 20 per cent by the British Iron and Steel Corporation, (BISC) Ore, Ltd. 15 per cent by the Italian Finanziaria Sidérurgica ("FINSIDER"), and 5 per cent by German groups, including several steel companies. The Government acquired 5 per cent of the shares from the shareholders in proportion to their invested capital. A U.S.$66 million loan from the World Bank sparked implementation of the preparatory work. Extraction started in 1962, when 785,000 tons were stock piled. The U.S.Bureau of Mines gave the annual production as 295,000 long tons in 1961 and 984,000 in 1962. The first train transportation of the ore to Port-Etienne took place in June 1963 and in that year about 1,300,000 tons were exported. The 4.9 million tons produced in 1964 were above the planned target, and the target of 6 million after 1966 may be reached at an earlier date.

31. The present capital of the company is 13.3 milliard CFA. The capital cost of the operation is estimated to be 45 milliard CFA, some U.S.$200 million. Most of the output of the mine is covered by long-term agreements with the iron and steel industries of France, Britain, Italy and Germany.

The Government receives a 50 per cent share of net profit plus duties on the exported ore amounting to between 6 and 9per cent of the FOB price (6 per cent for annual exportation of up to 4.5 million tons, 7 per cent from 4.5 - 5 millions, 8 per cent from 5-5.5 millions and 9 per cent over 5.5 millions). The Government, on the other hand, paid for many of the development schemes of the industry such as the search for underground water resources for Port-Etienne.

Geology and Reserves:

32. Mention has already been made of the fact that iron ores are present in the oldest rocks of I.R.M. of Middle Precambrian (Birrimian) age and are comparable to other Precambrian iron ore deposits of Africa of the Lake Superior type. The ore occurs at Kédia d'Idjil (Fort Gourraud), 350 Km from the Atlantic coast in a straight line and 675 Km by rail to Port-Etienne. The Kédia d'Idjil forms a conspicuous relief reaching 920 m in height and dominates a plain of an average height of 300 m. It extends in an WW direction for about 26 Km and has a triangular shape with its shortest, 12 Km long base, at the east and its apex in the west forming mount F'Derik. The plain is formed of different gneisses that change into micaschists and quartzites at the border of Kédia. Kédia itself is formed of two main structural units: a ferriferous synclinorium to the north and north east and a syncline of breccias to the south. These two units are separated by a faulted anticline of F'Derik - Achouil (Destombes, map 4). The metamorphic rocks and the itabirites are steeply tilted, striking mainly east and west. Kédia D'Idjil is bounded to the south by the subhorizontal beds of the Infracambrian. At its western margin at F'Derik the flanks of the mountain are covered by alluvial deposits, the pebbles of which are made of nearly pure hematite ready to be mined.

33. About fifty outcrops of the ore cover an area of 900,000 m^2, in which nine groups of important ore bodies of almost pure hematite interbedded with banded hematite quartzites are present. Of these rich ore bodies, three are the most important: Tazadit in the east, F'Derik in the west and Rouessa in the middle. Only two of these are exploited at present. Tazadit is said to contain 90 million tons and F'Derik 45 million tons of high grade ore averaging 64.5 per cent Fe, 0.04 per cent Mn, and 0.03 per cent P, 0.0025 per cent S and 1-5 per cent Si. The ore body was hit at a level below 400 m at Tazadit and at about the 300 m level at F'Derick by inclined drilling. The bottom of the ore was not reached at the two places and the bodies seem to extend downward to appreciably unknown depths. At the time of our visit to Rouessa an extensive test drilling programme, on a grid pattern with lines 20 m apart, was concluded. The thickness of the ore was found to be 100 m at a depth of 300 m. The estimated reserve is given to be over that of Tazadit and the exploitation of the Rouessabody is expected to take place shortly. The estimated 200-250 million tons of high grade ore said to be available within the main ore bodies seem to be a a conservative estimate. Besides these high grade ores, 8,000 million tons of 40 per cent ore are estimated to be included in the poorer ores of banded hematite quartzites.

34. Three types of ore can be distinguished:

a) A hard, compact, fine-grained type, massive or finely banded, steel blue in colour, and with a specific gravity of 4.5. This ore contains more than 66 per cent Fe and less than 2.5 per cent SiO_2. It is a "steel mineral"; F'Derik ore body consists of this type of ore.

b) A soft and friable type which represents the "skeleton" of a banded hematite quartzite in which the silica bands have been leached out and the high grade bands reduced to biscuits, a fraction of an inch thick, of nearly pure hematite. The specific gravity is 3.6. It is suitable for high furnaces.

c) A medium-hard lumpy ore, generally associated with type "b". The grain size is coarser than in type"a" andit is more porous and friable. The specific gravity is around 4. Tazadit ore body consists of these last two types, which contain 64 to 65 per cent Fe and 4 per cent SiO_2.

Mining:

35. The open cast mining at Tazadit is carried out in a series of horizontal cuts 10-12 m high from the high levels downwards. Under-ground mining is expected later. The walls of the formed pit slope at an average angle of 45°. It is estimated that for every 5 tons of ore, 8 tons of waste and 2 tons of mixed ore (i.e. ore with less than60 per cent Fe) has to be disposed of. The mixed ore is at present stocked for future dry treatment. Cutting is carried out by ten Crawl masters which drill blast holes 150 mm in diameter and blasting is carried out by nitrate explosives. Also six Crawl IR and twenty seven Montabert drillers and seven DR 365 and twenty eight DR 600 compressors are used for cutting. Haulage of the products of blasting, for crushing at the mine, is carried out by one diesel driven, two electric (150B)- and three electric driven (190B) - Bucyrus Erie mechanical shovels, (2.5 cy, 6 cy and 8 cy respectively) assisted by 3 diesel Marion 93M - mechanical shovel 2.5 cy and by caterpillar bulldozers. The ore is then transported by eight Kenworth 275, by three Avelling Barfort 8T and by three Koehring 13T trucks.

36. The ore (typeb & c with 30per cent and 20 per cent of fines below 10 mm respectively and the rest is lumpy) passes through an Allis Chambers superior model 54-74, 1800 T/h gyratory crusher, situated at the margin of the pit. The products, crushed to - 200 mm are conveyed at 1200 T/h by a Koch/Sarre belt conveyor 1400 m long and 1.20 m. wide for stacking at the railway station. The belt passes underground through a tunnel

and the operation is remotely controlled at an observation unit installed near the crusher. The stacking is carried out by a Koch/ Sarre 1800 T/h double wing stacker. The difference in elevation between crusher and stacker is 190 m. An automatic sampling equipment permits the supervision of the Fe and Si content of the ore. The ore is reclaimed from the stock pile by a 440 T Lauchhammer 2500 T/h shovel wheeled (8 shovels 660 litres each) at the same rate and conveyed to train wagons. A Koch-Sarre 3000 T/h haulage unit loads simultaneously two wagons each of a 75 T capacity. A new city, Zouérate, was founded on the plain north of Tazadit on an area of 460,000 m^2. Diesel-electric generators are used to supply the town with light and the mine with power.

Transportation from Fort Gouraud to Port Etienne:

37. The railway passes through a tunnel cut through the cliffs of Choum (1890 m long), and on the sand dunes of Azafel and of Akchar. The company possesses fifteen CC diesel 126 T locomotives 2,500 cv, six BB diesel 68 T locomotives 850 cv, twelve 100 T wagons for ballast 51m^3 capacity, five hundred and ninety 100 T wagons for ore, 34 m^3 capacity and thirty three 96 T wagons for water tanks 700 h/l capacity. A train is composed, at one time, of 3 diesel locomotives (2,500 cv each), 135 wagons for ore, several flat wagons for various items and tanks for water and gas-oil. The train has a total length of 1570 m and an empty weight of 4000 T and carries 10,000 tons of ore. It runs at a speed of 40 Km/h when loaded, and at 48 Km/h when empty and thus it takes about 16.5 hours to run from the mine to the port. The company is confronted with the serious problem of the rapid wearing out of the rails, a few kilometers away from the mines.

38. At Port-Etienne an automatic rotary train dumper unloads the ore (about 200 wagons/day) into a 300 T bin to a 4000 T/h belt conveyor, 1.60m wide, with a speed of 3 m/sec. Stacking is carried out by a 340 T stacker with an arm 45 m. long having a speed of 13.50 per mm when loaded. The stock pile is 23 m high, 650 m long and the base of its triangular section is 58 m. The capacity of stock, in two piles, amounts to some

1,600,000 T. The ore is reclaimed by a 410 T shovel wheel LMG, (2,500 T/h) which is 20 m high and possesses a power of 600 cv, and by a shovel 8 cy mounted on a 190 B, long range Caterpillar (1250 T/h). Some 15,000 tons of ore are stacked per day. The ore is then conveyed to the grinding unit by feeding belts. The operation of the grinding plant can be so regulated as to produce the grain sizes required for the market. The whole operation is automatically controlled and registered on a panel.

The -200 mm ore passes through a primary and a secondary milling machine. The ground material is screened to the following grain sizes in mm: 0-10, 10-20, 20-75 and 75-200. Seven different qualities are distributed to the clients: five from Tazadit ore (TVA 0-200, TVB 0-75, TZA 75-200, TZB 10-75 and TZF 0-10) and two from F'Derik ore (FPA 75 - 200 and FPB 10-75). The ore is then transported by a conveyor to a 1000 T regulating hopper. The ore is automatically sampled in a nearby sampling unit that takes 50T/h sample. A 3000 T/h belt (1.40 m wide and a velocity of 3 m /sec) conveys the ore to the vessels, where a 217 T loading tower loads them at the same rate of 3000 T/h. It traverses 145 m along the length of the quay at a speed of 24 m per minute and carries a boom 20.50 m long, adjustable 16 m horizontally and 10.50 m vertically. Ultimately the loading capacity will be increased. The harbour situated some 12 km south of Port-Etienne can receive 65,000 tdw carriers along its 245 m long and 19.50 m wide platform in water 12.50 m deep. Minor dredging will allow 100,000 tdw vessels to be loaded. The quay is connected to the shore by a pier 425 m long. At Port-Etienne there is a well equipped workshop engaged in various maintenance work. The electric power station (with eight Mirrlees of 1000 Kw each with a possible extension to twelve) supplies the monthly consumption of 850,000 Kw for the plants and the newly built city of Cansado.

The copper deposits of Akjoujt:

History:

39. These important copper-gold deposits are located approximately 4 Km west of the village of Akjoujt, near Guelb Moghrein, about 280 Km by road NE of Nouakchott and some 350 Km SW of Port-Etienne. The site is at longitude 14° 25' W and latitude 19° 45' N. It is accessible by road along the excellent Nouakchott-Akjoujt road. Akjoujt is also served by Air Afrique and by postal and telegraphic services. The existence of copper was noted in 1931 and the discovery of copper slag in the neighbourhood indicated ancient exploitation of the ore. It was only in 1946, however, that a geologist at the Service des Mines, took samples, which were analysed and gave interesting results. An exploration permit (B) in the name of the Government of French West Africa was given in 1947 and was renewed in 1949. As the results of investigations carried out were encouraging "Syndicat de l'Inchiri" was formed in 1950 by the Federation of French West Africa, the Territory of Mauritania and the Bureau Minier de la France d'outre-Mer to investigate further the property. Diamond drilling of 2800 m on a grid of 100 m apart, the sinking of a 100 m shaft, studies on the dressing of the ore and on finding water in sufficient quantities were carried out. Later in 1953 the Syndicat was succeeded by the Société des Mines de Cuivre de Mauritanie (Micuma). This latter company carried out a more exhaustive programme of drilling 17,000 m on a 50 m grid, of driving 2000 m of adits, and was actively engaged in developing methods of concentration, from the year it was founded to 1959. Micuma was able to verify the presence of appreciable amounts of copper ore containing gold but was confronted with difficulties of extracting the copper from its oxide ores. In 1963 Mr. Walter Serra, on behalf of Mr. L. Lindsley of Canada went to I.R.M. to explore the mineral possibilities of the country, when the Akjoujt copper deposit was brought to his notice. Later exhaustive feasibility studies were carried out, in the same year, that resulted in a report entitled

"Review and Evaluation of Akjoujt Copper-Gold Deposits for Northfield Mines Inc." by Watts, Griffis & McOuat Ltd., Canadian Bechtel Ltd., G. G. Freeman and G. H. Gibbs. The possibility of exploiting the ore with profit was confirmed, especially as the recovery of copper from oxide or silicate ores has been proved feasible, and the Lindsloy group submitted through the Northfield Mines Inc. the possibility of exploiting the ore to the I.R.M. authorities.

Negotiations went on between the authorities concerned and a new company Socuma (a reconstruction of Micuma) was formed. The American and Canadian group holds 55 per cent of the capital, the Mauritanian Government 25 per cent and French financial interests; including the BRGM 20 per cent. Further on site studies for proving adequate water resources, for process testing and improvement and for project testing, engineering and design were carried out by the Government and by Socuma. Socuma started, while the team was in I.R.M., the prelimnary steps for exploitation.

Geology and Reserves:

40. The ore is present as previously mentioned in the Akjoujt series of the Mauritanide orogenic belt. It occurs in a prominent hill that consists essentially of iron oxide minerals carrying copper and gold and forming a "hat" overlying sulphide ores. The oxide ore is a "zoned" deposit, 500 m. long, 50 m thick, dipping at 35°, and forming a hill which rises 80 m above the surrounding flat desert. It is about 100m in vertical depth with negligible waste capping or cover. The metal content increases with depth and appears to consist of two or three bands paralleling the footwall schist contact, separated by sub-ore. Beneath this oxide capping and at a depth of 30 to 40 m below the surrounding plain irregular lenticular bodies of disseminated sulphides have been proven to have a maximum thickness of 100 m and a lateral extent of 440 by 700m, most of which could be mined by open-pit. The bodies are slightly elongated

in a north-east to south-west direction and dip to the south-west at about 20°. The dip flattens with depth to nearly horizontal at a vertical depth of 200 m below the surface. The down-dip limit has not yet been fully determined.

41. The oxide ore is irregularly porous to compact, friable to hard, and consists chiefly of iron minerals hematite, limonite and magnetite, the latter being residual. Although several copper minerals, including malachite and atacamite are visible, most of the copper values are tied up in the limonite-hematite oxides. The sulphide ore in the surface dumps consists of a dark grey carbonate with associated anthophylits and sulphides in the form of pyrrhotite and chalcopyrite. Magnetite is a prominent gangue mineral and is said to constitute 30 per cent of the sulphide ore.

Reserves are estimated as follows:-

Oxide ores:
7,180,000 metric tons assaying 2.85 per cent Cu with 4 gr of Au/T
Open pit sulphide ores:
16,150,000 metric tons assaying 1.70 per cent Cu with 1 gr of Au/t
Underground sulphide ores:
6,375,000 metric tons assaying 1.67 per cent Cu with 1 gr of Au/t

The ore carries also silver, the amount of which is not known to the mission. The waste-to ore ratio in the oxides is 0.4 to 1, whereas it is 2 to 1 in the sulphides.

Proposed mining:

42. The cap is ideal for low-cost selective open-pit mining. In the sulphide ore open-pit mining is economical to a depth of 160 m below the surface, after which the remaining ore can be extracted underground by means of longwall retreat mining, with a belt of conveyor up the footwall of open-pit excavation.

It is proposed to mill oxide ore at a rate of 3000 tons per day for 350 days per year or 1,050,000 tons per year for seven years. Sulphide ore will be milled at 4000 tons per day or 1,400,000 tons per year for 12 years by open pit and a further four years by underground mining. Additional underground ore may be developed. The total presently indicated operating life on this basis is therefore at least 23 years. A higher rate of sulphide mining may be economically indicated by further study.

Mining operations will be confined to two shifts of eight hours each per day, five days per week, with sufficient stockpiling of crushed ore for continuous milling. Conventional open-pit mining is planned, using 10 m benches, 20° off-vertical percussion blast-holes, 100 mm diameter and 13 m long, with 3.5 m burden, 4 m spacing, and 6.5 m steel charge, 2½ cubic yard diesel shovels and 30-ton diesel trucks. Haul roads will be 8 per cent against the load and 18 per cent with the load. Working wall slopes will be 22° and final pit walls 45°, including a 16 m haul road. Ammonium-nitrate will be used for primary blasting. Hand held pluggers and dynamite are recommended for secondary blasting. Portable compressors and portable flood-lighting plants will be used to eliminate pipe-lines and power lines around the pit.

Ore Treatment:

43. Although the recovery of copper and gold is more difficult from the oxide ores, the latter will be mined before the sulphide ores as they are much higher in grade. The proposed processing plant is designed to treat 3000 metric tons of copper oxide ore per day. The "Salt-Coke Segregation" process, one-stage method, will be used to reduce the copper oxides to metallic copper, which is then recovered by conventional flotation. The segregation process treats an oxidized or mixed oxide - sulphide copper ore with a halide salt and a carbonaceous material, such as coke or coal at 750° C to 850°C, to produce fine metallic copper.

In 1962, a small tonnage of ore from the oxidized zone was shipped to the U.S.Bureau of Mines Experimental Station in Tuscon, Arizona for segregation tests, using the "one stage" indirect-fired furnace technique. The 6 inch furnace was used, followed by flotation in a continuous pilot plant operation. The pilot plant run on the Akjoujt ore gave copper recovery of 91 to 93 per cent and rougher flotation concentrates of 45 to 50 per cent. The cleaned concentrates ran over 60 per cent Cu.

The present treatment plant, owing to exposure to sand blasts, seems to be unusable and each individual item was under inspection when the team was there. It includes crushing, conveying, milling, roasting and flotation facilities to handle two tons of oxide ore per hour.

44. It is proposed that:-

a) Ore is to be delivered by trucks from the pit to a 50 ton surge bin and jaw crusher, where it is reduced to minus 150 mm;

b) crusher product is belt conveyed to a 6,000 ton storage pile for tunnel draw;

c) ore is conveyed from storage pile to a 19 foot Aerofall mill and crushed to minus 2.36 mm;

d) crushed ore is then conveyed to a 3,500 ton fine ore storage bin. An extension of this bin provides storage for 300 tons of salt and 325 tons of coke or coal;

d) crushed ore is then conveyed to a 3,500 ton ore storage bin. An extension of this bin provides storage for 300 tons of salt and 325 tons of coke or coal;

e) the ore, together with 1 per cent salt and 1.5 per cent coke, is conveyed from the bin to a rotating mixing tube and then to furnace surge bins by means of conveyors. From the surge bins, the ore is fed to twelve indirect-fired furnaces. The surge bins ahead of the furnaces act as an atmosphere seal, that is, a column of ore is always maintained above the screw feeders;

f) the hot segregated material is then transferred to "Baker" type water coolers with seals at the discharge end of the furnaces and at the feed end of the coolers to prevent introduction of atmosphere. The ore discharges from the coolers at about 95°C;

g) the ore discharge from the cooler is conveyed to a 500-ton surge bin by means of bucket elevators and a "hot" belt conveyor;

h) the calcined material is then evenly fed to four conical ballmills for fine grinding to minus 0.15 mm. Classification is done by cyclones in closed circuit with the ball mills;

i) the overflow from the cyclones is taken to a conditioner and then to a pulp distributor for even distribution to three banks of flotation cells im parallel;

j) the rougher concentrate is taken to one bank of cleaner cells. Both the cleaner tailings and the scavenger concentrate are returned to the ball mill for regrind;

k) the final concentrate is pumped to the filter with the filter coke being belt conveyed to a stockpile for loader pickup;

l) the tailings are pumped to a thickener and then to a pond at 50 per cent solids.

The operation of the plant results in the generation of over one million tons of tailing per year and requires the construction of a tailing disposal area that will be serviceable for fifteen years. It is planned, owing to high cost of water in the area, that water be reclaimed from the tailings pond and returned to the plant.

45. A 12 inch pipeline will be constructed for a distance of 120 Km to transport the water required(6000 m^3/day) for the plant from Benichab. It is planned that a 0.61 m wide belt conveyor with 15 m boom

conveyor at an average rate of 200 tons per hour delivers ore concentrates from the storage-shed to the ship's holds. A 4,000 ton vessel is to be loaded in twenty four hours.

The total capital investment for development of the mine is estimated at 10,000 million CFA and the Mauritanian Government will derive total benefits amounting to 500 million CFA. The Government has already proved the presence of adequate reserves of water for the installations at Akjoujt.

B. Future Prospects

46. A geological map on a scale of 1:2,000,000 is available (sheet No. 7 of 9 sheets of a Geological map of West Africa revised by BRGM). Another map, on a scale of 1:1,000,000, and financially backed by FAO is in course of publication. The estimates of its cost are given as 23.7 million CFA. Many parts of the country, with special interest for the search for underground water and for mineral resources, were mapped on larger scales such as a 1:200,000 map of the country bounded by latitude 19° and 20° N and longitude 13° and 15° W, and 1:50,000 maps of Barrero in the Amsaga. Systematic airborne geophysical surveys of the Akjoujt series were included in the four-year plan 1963-66. About 45,000 Km^2 in the southern part have been proposed to Fonds Européen de Développement d'Outre-Mer (FEDOM). The total cost of these surveys was estimated at 247.3 million CFA. Both magnetic and radiometric methods were used by CGG during their survey along northeast to southwest lines of flight 2 Km apart, and a spacing of 1 Km was used at interesting localities. The reinterpretation of the previous survey of the Akjoujt area carried out by Cruélius proved the presence of four magnetic anomalies that could be due to the presence of copper, whereas the survey carried out by CGG showed the presence of twenty eight magnetic anomalies of appreciable importance. Eight out of these are attributed to the presence of chromites in a country of anorthosites, serpentines and amphibolites whereas four others could be attributed a priori to the presence of magnetite bearing quartzites. Two anomalies are connected

with the syenite body of Bounga in which "belts" of iron with fluorspar and galena are known to exist. At Aguilal-Faye two anomalies, which are exceptionally important with regard to their extension and intensity, are covered by dunes under which the CT is present. A geochemical survey carried out in February 1964 by the Service des Mines et de la Geologie of I.R.M. gave abnormally high figures for vanadium, copper and chrome at the same locality. The meaning of the remaining abnormalities is not yet known owing to our present meagre knowledge of their geological setting. Some of the anomalies detected are investigated on the ground, but such an investigation does not cover at present all of them.

It is interesting to remark that some of the known deposits were not detected by the aerial survey.

The search for oil entailed geological, photogeological, seismic and aeromagnetic surveys of the concession areas mentioned under petroleum in the present report. Again parts of the country were radiometrically surveyed from the air and electric methods were used during the search for water in some places such as at Bou-Lanouar. In the following lines our knowledge of the status and future prospect of mineral occurrences, not exploited till the present, is given.

Iron:

47. Besides the Fort Gouraud deposits the following occurrences are known:

a) A permit was granted to BRGM in 1961 to search for iron and related substances in a square the side of which is 5 Km long in the Gleitat-El-Khader near Akjoujt. The BRGM spent over 40 million CFA and the work comprised digging pits and test drilling. Some 18 million tons of iron of a tenor of 52-53 per cent, 0.13 per cent P and 0.9 per cent Mn were determined. The mineralized surface layers have thicknesses of 10 to 20 m. These ore bodies are associated with lenses of carbonatite emplaced in precambrian

schists and quartzites. Its exploitation is not contemplated for the present.

b) Iron deposits also occur in the region of Ynk. These were discovered by Renaud about 1953. They are some 150 Km NE of Aleg and are represented on the 1:1,000,000 map by the three hillocks of Gouararate, Nouamis and Ynk. They form 80-100 Km^2 and are differentiated from the surrounding country of quartzites and sands by their reddish brown ferruginous colour. It may turn to be a window of Precambrian age in the Akjoujt series. The ore is formed of a bank of debris of hematitic quartzite with a tenor of 50-55 per cent iron and over 150 million tons are estimated. This is probably the surface expression of a mineralized zone in depth.

If this turns out to be of importance the iron could be transported along a 285 Km road to be built from the deposits to Boghe the nearest fluvial port.

c) The copper deposits of Guelb Moghrein could yield about 10 million tons of magnetite concentrate averaging 67 to 68 per cent as a by-product from the treatment of the oxide and sulphide ores.

Copper:

48. Besides the possibility of the extension of the Guelb Moghrein deposit, Matveief described the area of Akjoujt as a copper province and indeed indications of copper have been found in a zone over 60 Km in length and about 30 Km in width. The iron deposits at El Khader in the neighbourhood of Akjoujt, previously described, could very possibly contain copper in depth. Again copper mineralization is recorded in the iron deposits south of Yank, to the north of Bakel, and further copper possibilities are not exhausted.

Again copper is recorded in some late granite porphyries, of uncertain age, cutting the crystalline basement in the north eastern part of the

country. It is still to be proved if this occurrence is related to the Akjoujt mineralization or belongs to an older one. The "Bureau d'Investissement en Afrique" spent 62 million CFA in 1961-62 searching for copper, tin, wolfram, molybdemum and related substances in a permit of 25 Km^2 in this part of the country. A geophysical survey and a drilling programme was carried out.

Molybdenum :

49. Molybdenum was recorded by the same Bureau in the same permit, associated with pyrite in pegmatites in close contact with granodiorites. It is reported that exploitation of these minor intrusions is not envisaged as the mineral deposits are dispersed in this part of the country.

Radio-active minerals:

50. The Commissariat à l'Energie Atomique (CEA) holds two permits covering the Amsaga-Tiris-Zemmour region which were renewed for five years from 4 May 1964. The prospecting lease includes searching for lithium besides uranium and thorium. The CEA spent 164 million CFA during the period 1958-1963. The reports were not available to the Mission, but it is stated that the indications discovered are small and exploitation is not envisaged. Lately there was a mission searching the Nema region in the south-eastern corner of the Republic where they recorded interesting geological structures but discouraging indications of the minerals.

The geophysical airborne survey of CGG of the northern part of the folded Akjoujt series showed two areas that gave high radiometric figures: the first is situated at Guelb Kella in the Amsaga and the second is recorded in the Tamkarkat region in the syenite of Bou Nagaaraguene, cutting the Akjoujt series, in which fluorspar is reported. It gave 1000 and even 1500 clicks per second.

Gold :

51. A permit with an acreage of 25 Km^2 was granted to the "Bureau

d'Investissement en Afrique" in 1960 for two years in the north-eastern part of I. R. M. in the crystalline basement to search for gold and related substances. Twenty seven million CFA were spent and quartz dykes with visible gold were discovered. Analysis of these showed in places interesting gold content. The age of gold mineralization is not known and although it is present in areas of crystalline basement, the gold bearing dykes could very possibly be formed much later. The gold to be produced as a by-product from the Akjoujt copper deposits will permit I. R. M. to become the leading producer among the French-speaking African countries.

Wolframite and Fluorspar:

52. Interesting amounts of wolframite were found at Tarbrinkout in the Akjoujt area in the Mauritanide belt. This occurrence was investigated by the "Bureau Minière" some years ago. The indications have not been proved to have mine-making possibilities at present. Fluorspar is recorded in the Bou Nagaaraguene syenite, which shows abnormal radiometric figures.

Beryl:

53. As previously mentioned beryl is present in the Amsaga region in pegmatites of the basement complex. Mr. Barrere mapped (1960-62) on a scale of 1 50,000 in this region an area bounded by the Akjoujt series in the south, by the Mauritanian Adrar in the east, by the Akchar in the west, and by latitude 20° 45' in the north. Beryl was discovered at Mount Iguilid, about 40 Km NW of Atar. The hill is arcuate, extending in a north to south direction and is 9 Km long and 1.5 Km wide, rising about 100 m above the surrounding plain. Beryl occurs in pegmatites intruded into a gabbroic body. They are sometimes conspicuously zoned with phenocrysts of quartz, microcline tourmaline and white mica. Two of the twelve pegmatites present are of special interest. One of these two is about 200 m long and varies in thickness from 5-75 m and contains plentiful giant crystals of beryl in essentially quartz gangue. Trenches were

made and these confirmed the high concentration of beryl in them. The second is poorer in beryl but the gangue is principally made of feldspar of great purity. This is of interest as the feldspar could be mined jointly with the beryl. The tonnage is still unknown and is under estimation. The ore is conveniently situated about 60 Km from Choum and the railway. The project was financed by FAC.

Chromite:

54. As previously mentioned this is present in the Amsaga region. Chromite occurs in anorthosites and serpentines that form a thin but extremely long band, extending from the latitude of Guelb el Foulet (to the west of Touerma) southward for 6[illegible] Km and cutting the Akjoujt-Atar road at 100 Km. Along the whole length of the band spots of chromite are present but in places some lenses of greater extension are equally present. It would be considered, as far as our present knowledge goes, as a chromitiferous province, a miniature of the great dyke of Rhodesia as are the Akjoujt deposits a miniature of the Copper Belt. Two of these lenses are of special interest; the first occurs 4 Km NE of Guelb el Foulet and extends for about 100 m and then reappears at several other points in a massive form. Samples of this body assayed 15-25 per cent of chromium metal. The second occurs at about the centre of a triangle formed by the Gloub, Aidgati el Azib, and El Heirich. The lens outcrops for about 50 m. and then disappears under a mantle of superficial deposits. Assaying results of this lens gave about 25 per cent metallic chromium.

Results of digging drives by the Department of Mines, while the Mission was there, proved to be very encouraging and the exploration work should be continued until a real appraisal of the deposits is reached.

Vanadium and Nickel

55. Indications of vanadium and nickel have been discovered in the region of Akjoujt.

Phosphates of Civé:

56. These deposits are situated in the immediate borders of Civé village on the right bank of the Senegal River about 9 Km N of Matam and 40 Km from Kaedi. These have been partially studied by the Senegal River Mission between 1936-1937, and by Baud (1936-38). They have been subject to exploitation for utilization in the agricultural station at Bambey (Senegal) before the last war. The deposits are in four phosphate beds of a total thickness of 1 m intercalated with shales and covered by argillaceous sands. Cherty beds frequently occur. The beds of Eocene age are continuous and deviate but little from the horizontal and could be exploited by open-pit mining. The tenor varies between 50 to 70 per cent of tricalcium phosphate. Four million tons of ore are known at present. Some 57 test shafts and some 100 m of test drilling have been carried out. Further exploratory work is needed to follow up the phosphate horizon in the neighbourhood. Other deposits are known to occur at Koundel, Daoulal, Foundu and Diouldé-Diabé. However, from what is already known, the local use of the deposits in agriculture, on a larger scale, is possible. For this reason, the "Service des Mines" in collaboration with the "Service du Génie Rural" in the I. R. M. have examined the possibility of its exploitation on a cooperative basis. The proximity of the deposit to the Senegal River and the possibility of erecting a superphosphate plant in I.R.M., now that sulphuric acid could be produced from the Akjoujt sulphide ore, make it necessary to make a feasibility study of the exploitation of the phosphatic deposits and to carry out further studies for new prospects.

Limestone :

57. Enormous quantities of various types of limestone are known in the Adrar and in other places. The outcrops near Atar are at present crossed by the Miferma railway and could be used, but nearer suitable sources are probably present in the neighbourhood of Bou-Lanouar Unfortunately no analyses of these limestones were available in Nouakchott, and the writer was told that they do not exist. Analyses

of the different types and an inventory of these should be made available not only for a steel industry but for a construction material and for other industries.

58. Gypsum:

Gypsum occurs not far from the coast, 10 Km. northeast of Nouakchott at the northern and eastern borders of the Sebkha called N'Drahamcha, which extends for over 100 Km in length from Coppolani in north to north-east direction. They are separated from the ocean at the west by a belt of sand dunes. Several exploration works were carried out by digging pits and by drilling. These were made by a military detachment in 1957, by the "Laboratoire du Bâtiment et des Travaux Publics" of Dakar in the same year and by the topographic company "Setophom" for the Direction des Travaux Publics". A reinterpretation of the results was made by Mr. Clariond, an expert of the "Bureau Industriel Africain" (BIA) for the Société Centrale d'Equipement du Territoire (SCET) who estimated the reserves at 17.5 million tons that could be doubled or even tripled. An unsuccessful attempt of exploitation was carried out at Km 102 from Nouakchott on the road to Akjoujt, owing to a bad choice of locality. More recently BRGM carried further work with the ultimate aim of an economic exploitation of the deposits. Five million CFA were estimated to be spent on the operation. The work carried out there by the BRGM delimited an area of 650 m x 500 m, about 73 Km from Nouakchott. The area is the most favourable because (a) it is not flooded by waters; (b) is near the highway; and (c) is the nearest possible to Nouakchott. The work of BRGM included 13 holes 15.5 cm made by handauger to an average depth of 2.50 m, 67 holes by a Mac-Culloch drilling machine to a depth of 8 m and a diameter of 67 cm and, 60 pits 1.50 x 1 m to an average depth of 2.50 m. The final report of BRGM was not available in Nouakchott till the time the team left. Some gypsum has been extracted and used in the construction of the capital.

The gypsum beds in the southern and central parts of the Sebkha itself are over 2 m in thickness and thin out towards the north and east.

The evaporites are intercalated with fine saliferous clay laminae the clays also cut obliquely the beds. They dip southward and rest on an old 0.5 - 1 m marine shelly beach, which itself overlies bluish massive limestones similar to those outcropping to the north-east of the Sebkha on the road to Akjoujt. The evaporites are overlain by a 10-15 cm of fine clay separated from the gypsum by large translucent crystals of gypsum. The fine clay is overlain by a tan admixture of gypsiferous sands and clays that vary between 0-0.20 m. The gypsum in this locality is formed of a porous crystal aggregate and is less dense and more friable than gypsum recorded at Km 90. The available analysis showed that it is of a very good quality with an average of 85.3 per cent hydrated calcium sulphate and contains very little Na Cl rarely exceeding 1 per cent to 1.30 per cent.

In this area alone about 1 million tons have been estimated with but a negligible cover. The deposits could be exploited by open pit quarrying without the use of explosives. Five piezometric wells showed that underground waters will not affect quarrying operations.

Besides these deposits, gypsum occurs in wind-borne deposits, 2 Km N of the bifurcation of the Cappolani - Touela highways. These are formed of well sorted gypsum crystals, about 1 mm in size. These fragmental deposits are ready for mining and could be shoveled directly to the trucks. The amounts are great but an appraisal of these deposits was not made. In view of easy mining, of the proximity of both types of deposits to the highway between Nouakchott and Akjoujt, of the high quality and homogeneity of the ore to suit various purposes, and of the very high price of imported cement (a ton of even hydraulic cement costs 14,000 CFA at Nouakchott, 16,000 CFA at Kaedi and over 45,000 CFA in the eastern regions) the feasibility of constructing an industry for both plaster for the sub-region and cement for internal consumption should be made. A study of the necessary raw material (limestones, clays etc.) both in the Nouakchott and in the Kaedi areas, with the necessary analysis made, should form the basis for construction material industries. The Technical Assistance expert who is expected to assist the I.R.M. (Mines Department) with the analysis of minerals could very well include this item in his work programme.

Rock Salt:

59. I.R.M. used to be an important producer of salt, which was produced from different salinas, the most important of which is that of Trarza (specially that of N'Tereft) and that of Sebkha d'Idjill. Primitive methods are used in the extraction of the salt and some 2000 tons per year and 7-8,000 tons per year are extracted from Idjill and Trarza respectively. The exploitation has declined lately owing to the competition of deposits in Mali (which used to be the principal customer) and of the marine salt of Kholack. Since 1960 the total production amounted to about 600 tons per year only. The demand will be enhanced when the exploitation of the copper of Akjoujt starts, when about 1,000 tons per month will be required in the treatment of the oxide ores.

Black Sands:

60. The "Syndicat de l'Ilmenite" comprising BRGM and the "Société des Etablissements Kuhlmann" on a 50-50 basis was granted twenty one permits for the search of ilmenite, zircon, rutile and garnet in 1959 which were valid to the end of last December. They are located along the whole coastal region; five of which are north of Saint Louis, Sénégal, three at Nouakchott area and fourteen towards Port-Etienne. Each permit is 25 Km^2. Some 200,000 tons of ilmenite disseminated in a sand with 2.7 per cent - 3 per cent of ilmenite are estimated, of which 120,000 tons are present in the area situated between Coppolani (40 Km North of Nouakchott) and Port-Etienne. It is reported that the deposits are unfavourable, but a complete feasibility study was not made and there is a possibility of using the Nouakchott wharf for exporting the ore.

Training & Aid

61. The question of training is an essential question in the future prospect of the mining industry. The country completely lacks indigenous geologists and mining engineers. Besides the fine work being done on the spot by Miferma to train Mauritanians to become assistant technicals (plumbers, carpenters, electricians etc.,) to take over part of the technical work, it is hoped that the time will soon come when some of the

indigenous leadership will get the chance of University education in Earth and related Sciences (geology, geophysics, geochemistry, mining and ore dressing) and so give a hand in the assessment of the mineral potential of their country and its exploitation. Noting that they are accustomed to work under local conditions and less expensively than others, they will be influential implements in fulfilling such a task. It will be very useful, if not essential, that scholarships are granted to promising Mauritanians to continue their studies at, for example, "L'Ecole de Géologie de Nancy", France, at the Faculty of Science, University of Dakar, or at other Universities and higher Institutes in Africa or outside the continent to obtain their first University degree. It takes a comparatively long time for a fresh University graduate in science or engineering to become a skilled expert, and a start should be made in this direction as soon as possible.

62. The project of the wharf at Nouakchott, under construction by the "Enterprise des Travaux Publics de l'ouest" (Etpo) Nancy, France will be an impetus to the exploitation of ilmenite beach deposits near Nouakchott, of the gypsum deposits at Sebkha N'Drahamcha and will be used for the export of copper concentrates from Akjoujt.

The wharf is designed to load 10 tons per m^2 maximum concentrated truck load and 1 ton maximum uniform load. The dock is 320 m long, terminating with a loading platform 88 m long by 21 m wide. This platform will be 5 m above low tide and 3.5 m above high tide level. There will be 8 m of water at the outer end and 6 m at the shore end of the loading platform. Due to open-pile construction, no vessel larger than a lightering barge can tie up to the dock. It is possible that the wharf is to be extended to deeper waters. It is unfortunate that the construction of the wharf planned to be completed in October 1964 has been delayed owing to the tilting of the piles during its construction. It is also regrettable that large vessels could not tie up to the dock.

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63. The French bilateral aid in I.R.M. is said to supply some two hundred experts, of whom eighty one are teachers, administrators, judges etc., thirty two medical doctors, forty four engineers and technologists and seventeen for Post and Telecommunications. The financial aid is said to be over 900 million CFA, a sum which is greater than that contributed by the U. N. Technical Assistance. The remark that the least developed countries are the least helped by Technical Assistance seems to be true for I.R.M. The people there are aware of this. Meanwhile, they were appreciative of the work ECA and Technical Assistance are doing and can do for their country.

64. A programme of work for an appraisal of the mineral resources of the country, including the investigation on the ground of the already discovered anomalies by airborne surveying (to cost about 76 million CFA) and a new airborne survey of the southern part of the folded series (to cost 75 million CFA), was proposed to FAC and to FEDOM, but not wholly approved till the present. It is to be noted here that priority should be given to the completion to a logical end of projects already started, rather than leaving them unfinished and starting completely new projects. The drilling, for example, of the two large anomalies covered by sand dunes at Aguilat-Faye and discovered during the first airborne survey is made or at least the two should be carried out simultaneously. His Excellency the Minister of Economic Affairs, Dr. Alpha, is very much interested in the help of a Special Fund or Technical Assistance in this respect. He asked the Director of Mines to prepare a request but it is understood that they are in need of advice as to its formulation.

IV. WATER RESOURCES

65. The search for underground water resources in I.R.M. is a necessity for the country, specially in its northern desert region, not only for the needs of the people and their livestock but also for the requirements of the expanding mining industry. That is why the I.R.M. is planning, at present, an intensive programme for underground water

resources, with the ultimate aim of assessing the country's resources and the publication of a hydrogeological map on a scale of 1:1,000,000. This interest is apparent from the four-year plan (1963-1966) in which the following sums were alloted for hydrogeological investigations:

a) 182 million CFA were allotted for studies on the south western part of the country south of latitude 18° (including 65 for Trarza, 44 for piezometric work on same, 45 for drilling the Maestrichtian and Trarza, Brakna-Boutilimit and Mederda, and 28 for piezometric work of Trarza-Brakna).

b) 18 million CFA for the south eastern part of the country.

c) 45 million CFA for the country north of latitude 18°, including 7 for the publication of a hydrogeological map, 8 for piezometric studies of the aquifers at Atar, 10 for a special investigation of the Benichab region and 20 for a study of the borders of the Taoudenni basin;

d) 10 million CFA for a general synthesis of present hydrogeological knowledge and the publication of a map on 1:1,000,000 scale.

66. The distribution of underground waters in I.R.M. depends on its geology. The northern Precambrian areas, which attain some 280 m in height are the most desertic of the country. Water occurs mostly in the Yetti yellow granites and is practically absent in Gallaman and in the Zemmour. It is usually very superficial and occurs in the alluvial deposits of the wadies and in sand dunes. The salinity of the waters, at first low, increases rapidly with usage.

Relatively deeper wells are also recognised in the altered and fissured crystalline rocks where the water is from 8-20 m. thick. Some of the wells yield up to 20 m^3/day. The salinity is usually high and exceeds 10g/ litre. From the writer's experience in the Egyptian

deserts, walls should be built in the alluvial deposits of the wadies at suitable places and where the wadies narrow/they could help in the preservation of the rains, which usally come every ten years in this part of I.R.M. At Bir Moghrein (Fort-Trinquet) the permeability varies from 1.2 x 10^{-4} to 3.4 x 10^{-4} and the reserves are estimated to be 200,000 m^3/km^2.

In the middle regions of the crystalline rocks at Tiris hydrological conditions are but slightly different. Highs (such as Kedia d'Idjil, 920 m) dominate the surrounding plains, 300 m. The discovery of the iron ores of Fort Gouraud enhanced the study of the water resources in the area. At El-Aouj, 25Km NW of Fort Gouraud near the Sebkha d'Idjil the water sources are in fissured quartzites that form with the gneisses a synclinal structure. The reserves, however, are very feeble. Two test wells near Wadi Touerga, where four salty wells already existed, were a failure. Four wells were drilled farther SE (at F'Derik) one of which gave 20 m^3/ day of water poor in salts. The conditions are more favourable on the northern and northeastern flanks of the Kedia, though farther away from Fort Gouraud. At wadi Tazadit three sources are known from drilling. The reserves were estimated at 4.5 million m^3 but the amount of recharge is not known Similar successful results were obtained in the Seyala Touil and in Rouissat. A search of the Infracambrian was planned to fulfil the requirements of the city of Idjil, estimated at 1000 m^3/ day. At present, the water requirements of Fort Gouraud are brought from the aquifers at Bou-Lanouar in the coastal basin.

Again in the Tasiast-Tijirit-Amsaga of the middle region of the crystalline rocks, water occurrences are present in superficial deposits, in natural hollows and in/deeper (15-25 m) weathered and joined basement.

67. In the crystalline rocks of the N-S Akjoujt series conditions are much more favourable as rainfall is greater and varies from 100 mm in Akjoujt to 800 mm in the southern parts and alluvial deposits are more important. Again the contemporaneity of these with Paleozoic rocks and the presence of permeable formations, such as greenstones, allow the

presence of deeper aquifers, the so called Akjoujt aquifers. At Inchiri, where water resources had been examined to satisfy the requirements of the copper-ore concentration plant, deeper aquifers in greenstones, in calcareous rocks and in altered and fissured schists were discovered. These are separated from the superficial alluvial waters. At present, these waters are not known to contain reserves that will satisfy the requirements of the copper installations, amounting to 6000 m^3 per day, and water is planned to be brought from Benichab in the coastal basin.

68. In the Taoudenni basin, one of the largest synclinoriums of the world, the sediments range, as previously mentioned, from the Infracambrian to the CT. The water resources of this basin are not well explored.

The Infracambrian at the northern edge of the Taoudenni synclinorium seems to contain several aquifers, specially in sandy beds and in fissured limestones, that supply some surface wells at many places, such as those of Chegga, of El Mzereb, of Hamdoue and of Kasr Torchane. Those of Chegga give some 400 L/h that are apparently constant and those at El Mzereb emerge at two different horizons. Testing of these beds and of their contact with the Precambrian has to be carried out to ascertain their water possibilities.

In the Infracambrian klippe of Afolle, a false bedded sand-stone seems to be the only possible aquifer.

69. The Cambrian sediments at Hodh show water possibilities in the fractured rocks near fault planes. These could be very easily detected on aerial photographs, but their output is precarious. A programme of digging wells in the region is planned and this should include also deeper drilling to test the possibilities of the underlying Infracambrian.

Farther east and north, surface wells are present in the "baten" at the base of the cliffs in the basal complex, from which water flows. Towards the east at the N-S Kiffa plain, the same hydrological characters

as those at Hodh are present. The calcareous beds outcropping at the base of Assaba are of little interest as they dip westward and do not retain water near the surface but could change into an aquifer in depth.

70. The Cambro-Ordovician sediments of the Falemian are favourable for water storage, not only because of the presence of suitable beds but also for the presence of synclines at many places. Renaud (1956) considered the water sources at Moudjeria to be from an aquifer in deep vell fissured Ordovician white quartzitic sandstone. This is based on the fact that during five years no notable changes in the temperature, discharge or chemical composition of the waters were observed. The Moudjeria region seems to be the best location for testing the water possibilities. of the Falemian.

In the cliffs west of Tagant and of Assaba it was observed that wells, which give over 1 m^3/h are situated at the contact of this quartzitic sandstone with an underlying false bedded Cambrian sandstone. Those that give over 2 m^3/h are situated in the Ordovician quartzitic sandstones in synclines formed by faults and those that give over 3 m^3/h are present where both conditions of the two previous types are satisfied. Wells with a discharge of less than 1 m^3/h are present in the false bedded Cambrian sandstone. The fissured Ordovician quartzitic sandstone is a good reservoir. Farther north at Adrar, the Ordovician sediments are not sufficiently prospected to be able to correlate conditions there with those in the south.

In the cliffs of Atar, water sources at Tirjit, at the base of Upper Cambrian sandstones are not related to any apparent structure. One of these sources is warm (31° C) and gives 50 m^3 per day, while another has a normal temperature of 17° C, with a weaker output. Their origin is still incompletely known.

71. The Gothlando-Devonian formations are less extended than those of the older Paleozoic. They are, however, very suitable for water reservation and at many places the amount and constancy of water

discharges indicate the presence of aquifers in Devonian sandstones in depth. Their structural setting is also specially suitable for water storage as synclines of these formations occupy a low lying zone, where the waters of Adrar and of Tagant converge.

72. The presence of sebkhas (salinas) in the Taoudenni basin is of interest. This seems to be due to capturing the waters of deep seated Paleozoic aquifers along doleritic dykes or fault planes. The salinity of the surface waters is probably due to evaporation and does not exclude the possibility of the presence of fresh waters in depth.

The phreatic waters south of the basin, fed by the waters of the Niger could infiltrate the very suitable sandy beds of the TC, of the CI and of the Paleozoic reservoir beds such as the Infracambrian stromatolithic limestones and the Cambrian and Silurian sandstones. The topographic section between the Niger and Taoudenni basin favours this probability. Possibilities of underground waters in this part are immense and deep test drilling should be carried out as soon as possible.

73. The continental Secondary and Tertiary deposits in the Taoudenni basin increase in thickness towards the east andsouth-east,as shown by a geophysical survey and are fed by the important Niger aquifer. The wells known in these formations give waters of good quality (less than 500 mg/l), with excellent discharges. This aquifer of the continental sediments is limited towards the west by a sterile zone owing to the rising of the crystalline basement. The contact lies between a dry well at Arhorat Raye (65 Km to the east of Nema) and the productive well at Kra el Azraq some 40 Km to the east. The northern limit of the aquifer has yet to be determined by drilling.

74. In the coastal sedimentary basin different aquifers are known. These include: a) superficial and lenticular fresh waters in the Quaternary and in the alluvial deposits of the Senegal River; b) the aquifers in the CT of Trarza, of Benichab and of Bou-Lanouar; (c) the aquifer of Amechtile in the fissured Eocene calcareous sediments; (d) that of Brakna or the sandy Eocene aquifer and (e) the deep aquifer in the Maestrichtian.

As previously mentioned, this sedimentary basin is bounded on the east by the Akjoujt and by the Amsaga series. These are unconformably overlain westward by Lutetian sediments, which are themselves concealed towards the west under a cover of the CT and of more recent Quaternary sediments. The basement of the sedimentary basin dips towards the Atlantic and the sediments themselves dip, increase in thickness, and change in facies from sandy into argillaceous and calcareous facies in the same direction towards the ocean.

The underground waters in the basin are delineated by a sterile zone in the sediments immediately overlying the crystalline rocks in the east and are bevelled towards the west by salt waters impregnating from the ocean. This bevelled contact between salt and fresh waters dips eastward at about 1 per cent. The increment of NA CL is gradual between the areas of salty and of fresh waters. Again there is an intermediate zone between the phreatic and sub-phreatic on the one hand and those of deeper levels on the other. The argillaceous sediments increase in the areas of salt waters, whereas sandy sediments are relatively more abundant where fresh waters are present.

75. The aquifers of the CT in the Trarza area are widely extended and are of importance to the people for both their survival and for the raising of their cattle. It is from these waters at Idimi that Nouakchott, the capital, is supplied with its 2000 m^3/ day requirements. This source extends to the calcareous Eocene sediments, the aquifer of Amchtil in the east and by salt waters in the north. The water is generally stored in argillaceous sandstones but sometimes in sandy beds intercalated with argillaceous sandstones. The overlying phreatic waters in the Quaternary are continuous in some places with the CT sources. The yield of the wells is high and is sufficient for agricultural purposes. The wells in Rosso Boutilmit produce from 10-15 m^3/h for a lowering of 1-2 m in wells 1.8 m in diameter. In an 8 inch well at Hassi el Bagra the yield was 28.2 m^3/h for a lowering of 8 m and 44 m^3/h for a lowering of 11.25 m. The permeability amounts to $K-10^{-4}$ m/sec, estimating 100 m for the thickness of the aquifer. The

salinity is low and generally varies between 300 to 400 mg/l except in very old wells and in some areas, e.g. those close to the salty waters. In the centre of the aquifer dissolved salts amount to 300 mg/l and they are even less in the sector between Nimijard, Mederdra and El Metoyen.

76. Two other similar but separate aquifers are known: that of Benichab, which will supply the copper plant of Akjoujt (6000 m^3 per day) and that of Bou-Lanouar, from which Port-Etienne draws its water. The Benichab aquifer is limited by the salty waters of the N'Drhamcha Sebkha to the south-west and by the sterile zone to the north-east and seems to be connected with the aquifer of the CT of the Akchar. The aquifer is about 10-20 m below sea level, and its central part yields 60m^3 per h for a lowering of 7m. The aquifer seems to be recharged yearly though the surface and the salinity is less than 300 mg/l.

The Bou-Lanouar aquifer shows the same geological setting as that of Benichab. It seems to extend northward into Rio de Oro. The water is present in beds of argillaceous sandstones with lenses of sands and clays and is underlain by argillaceous sediments. The yield is 50 m^3/h for a lowering of 12m. The salinity is higher than that of Benichab and is of the order of 450 mg/l but identical ions are present in both. The work of Putallaz on the Bou-Lanouar aquifer showed that it will be ample for supplying Port-Etienne with its water requirements of 3,000 m^3 per day for twenty five years. Unfortunately, an estimate of the total amount of water in the source is not given.

77. The aquifer in the fissured calcareous Eocene sediments, the Amechtil aquifer, lies between the sandy CT to the west and the sandy facies of the eocene to the east. The waters are stored in fissured dolomites, limestones or magnesian limestones. The wells passed through some 40-50 m of argillaceous sandstones of the CT before tapping this eocene aquifer. The waters contain 500-575 mg. of soluble salts per litre.

The water sources in the sandy Eocene, the Brakna aquifer, lie between the calcareous Eocene source and the sterile zone at the eastern border of the sedimentary basin. The salinity of the waters varies between 200 to 300 mg/l.

78. Two comparatively deep wells in the Bou-Lanouar area showed the presence of a deep aquifer below those of the CT previously mentioned. The salinity of its waters is 1,300 mg/l and is present in marine Tertiary and probably pre-tertiary sediments, some 420 m deep and some 600 m above the basement. A depth of 1,000 m is estimated for the basement by seismic survey. The overlying phreatic (at a depth of 28 m and salinity of 280-440 mg/l), sub-phreatic (at a depth of 70-100 m and salinity of 1,168 mg/l), and intermediate (at a depth of 180-186 m and salinity of 1,676 mg/l) water resources in Quaternary and CT seem to contribute to this deep source. The water at a depth of 100-120 m only is surplus to the present requirements of Port-Etienne.

The deepest water source is that present in the Maestrichtian, which is present in subsurface in the centre of the Senegal-Mauritanian basin. It yields over 100 m^3/h. Although this Cretaceous aquifer was not identified with certainty in the northern part of I.R.M., yet there is evidence of its presence in the southern part and a programme for evaluating its potentialities is planned.

79. Water is present in the sand dunes, in the alluvial deposits of wadies and, as previously mentioned, in the fissured and weathered surface of the crystalline rocks and in other superficial deposits.

Mention is given here of the important phreatic waters south of the Taoudenni basin. The recent continental deposits there are fed by the Niger and the aquifer could be followed, as shown by wells, to 250 Km north of Tombouctou. The Niger waters could infiltrate, as previously mentioned, into the TC, and CI and the Paleozoic sediments.

V. ENERGY RESOURCES AND ELECTRICITY AND WATER SUPPLIES:

80. Primary energy resources

The country is extremely poor in conventional primary energy sources.

1. Hydropower:

The only river of any size is the Senegal, which forms the border between Mauritania and Senegal.

The Bakel project on this river has an estimated potential of about 300 GWh per annum. Sharing this output between the two countries, 150 GWh p.a. should be taken as the practically exploitable hydro-potential of Mauritania. The country is extremely poor in precipitation . About 2/3 of the total territory has less than 100 mm precipitation per annum and only the region on the border to Senegal has somewhat larger precipitation., from 400 to 700 mm per annum.

2. Hydrocarbons:

The territory of Mauritania includes part of three sedimentary basins: the Senegal basin on the coast, the Tindouf basin and the Taoudenni basin which lies in the eastern part of the country along the border with Mali.

Three Companies have searched for oil so far without success.

La Société Africaine des Pétroles (S.A.P.), held the "permit of Nouakchott" of 29,535 km^2, of which 3,730 km^2 are off-shore. It was valid for five years (starting April 1960) during which they were to spend 1½ milliard CFA. The company carried out geological, photogeological, aeromagnetic and seismic surveys and not finding a suitable structure terminated its activities on 15 May 1964 after spending about 350 million FCA.

La Société Petropar (Société de Participations Pétroliéres) held a permit in the coastal region north of Nouakchott to Port Etienne

covering 38,447 Km^2, of which 13,852 Km^2 are offshore. The company was to spend 2 milliards .. CFA during five years (starting April 1960) but actually spent 500 million CFA. Western Geophysical and CGG carried out for Petropar photogeological and land & marine seismic work. Results were not encouraging except for two small areas. Because of this and of the negative results obtained by SAP in the south and by the Gulf company in the north in Rio de Oro, it gave up its permits on the 15 May 1965.

La Société des Pétroles de Valence held two permits situated in the north of I.R.M. between the Algerian and Rio de Oro frontiers, also of five years duration. The two covered 4,600 Km^2 and the amount to be spent was 253 millions CFA. A contract for 50 million CFA was given to Société Géografrance which carried out topographic, geological and reflection seismic surveys. But the work was also abandoned on these two permits.

Although a monoclinal structure is reported for the coastal basin, yet the presence of a thick sedimentary section that increases in thickness northward, and that is not completely devoid of other structures together with the fact that the structural rather than sedimentation characteristics of the basin were examined, make it possible that further studies may yield favourable results. From an examination of the available data it would appear that the two sedimentary basins of I.R.M. have not been exhaustively studied and a search for ancient shore lines by sedimentological methods is still to be made. A final condemnation of the oil possibilities is not conclusive and the Government of I.R.M. is advised to invite interested people to explore and perhaps to drill, putting at their disposal all the available results of previous searches.

3. Coal:

No deposits of coal are known in Mauritania. The carboniferous present in the Taoudenni basin is a potential area for the presence of coal deposits and should be further investigated.

4. Wood and charcoal:

In the countries at a less developed level, wood and charcoal are used to a relatively large extent in spite of the fact that the use of wood for energy purposes is far from being economically justified. This is especially true in the case of Mauritania where, with the exception of the river region, on the border of Senegal, every vegetation should be considered as extremely valuable.

5. Radio-active materials:

No economically exploitable deposits of such minerals are known in Mauritania. The geology of much of the country, however, is favourable for the occurrence of such mineral deposits.

6. Solar energy:

Much of the territory of Mauritania is desert with high levels of solar radiation. In view of the lack of any other energy sources in the country, the development of economic solar energy installations would be of great value to Mauritania.

81. Production, trade and consumption of primary energy

1. Production

There is no production of hydropower, hydrocarbons or coal in the country. Wood and charcoal are used for cooking purposes. No statistical information is available on the quantities of wood and charcoal used yearly, but according to the personal estimate of Mr. Ponomareff, Head of Statistical Department in Nouakchott, it is likely to be some 12,000 tons of wood equivalent or about 4,000 tons of coal equivalent (7,000 kcal/kg coal) per annum.

2. Trade - Import:

Primary energy is imported in form of liquid fuels via Port-Etienne by sea and via Rosso from Senegal. In 1963 the breakdown of the imported fuels was (expressed in tons, rounded):

	Via Port Etienne	Via Rosso	Total
Gasoline	5,600	7,000	12,600
Kerosene	350	1,500	1,850
Gas oil	15,100	2,700	17,800
Total	21,050	12,200	32,250

With a conversion factor

1 ton of liquid fuel = 1.3 ton of coal equivalent (= t c e) the imported quantities of liquid fuels are equivalent to about 42,000 tce.

3. Consumption

The total of primary energy consumed in 1963 was

Wood & charcoal		Liquid fuels		
4,000 tce	+	42,000 tce	=	46,000 tce

Per capita consumption:

With a total population of 880,000 in 1960, specific primary energy consumption can be estimated at 52 kgs of coal equivalent.

For comparison, specific consumption in 1962 for some countries and parts of the world is as follows:-

World	1,465 kgs of coal equivalent
Africa	308 " " " "
South Africa	2,437 " " " "
Zambia	850 " " " "
Ethiopia	11.6 " " "
Uganda	46 " " "
Tchad	13 " " "

82. Electric Energy

1. General

Only six localities are elctrified in Mauritania:

	Localities	Electric Power Utility
1.	Nouakchott	Construction électromécaniques Huet
2.	Port Etienne	SAFELEC (Société Africaine d'Electricité Dakar)
3.	Consado	"
4.	Zouerate	MIFERMA
5.	Atar	Military power plant, exploited by Administration
6.	Rosso	Etablissements Lacombe

All electric power plants in the country are equipped with diesel power groups.

2. Installed capacities at the end of 1964.

	Locality	Diesel power groups in KW	Total capacity in KW
1.	Nouakchott	2 x 510 + 2 x 220	1,460
2.	Port-Etienne	8 x 1,000	8,000
3.	Consado	Supplied from Port Etienne by overhead line	15 kv
4.	Zouerate	2 x 1100 + 4 x 2200	11,000
5.	Atar	5 x 50	250
6.	Rosso	1 x 40 + 1 x 120	160
		Total	20,870

At Idini, some 60 Km from Nouakchott, there is a small Diesel power group of unknown capacity, for pumping water to Nouakchott.

3. Production

Information respecting estimates of electric energy production is available only in Nouakchott and Port-Etienne (in MWh:)

	Nouakchott	Port-Etienne
1962	614	680 x/
1963	950 x/	1050 x/
1964	1800 x/	?

In 1964, the peak load at Nouakchott was 560 KW.

There are no statistical data available for production in other localities.

4. Distribution:

a) Medium voltage networks

All medium voltage overhead lines and underground cables are constructed for 15 kV, but with the exception of Nouakchott, they are operated on 5.5 kV. The majority of the lines are overhead, but at Cansado underground cables are used because of climatic conditions. There are two types of supporting poles:

- at Rosso and localities situated near the shore, poles with large crossarms (type HE) are used. This type of crossarms is made resistant against the salted air coming from the sea and requires little maintenance.

- In localities with dry air, like Atar, "telescopic" poles are used.

The insulators are of the pin-insulator type. Originally, porcelain insulators were used, but, successively, they were replaced by glass insulators.

The conductors are all of copper. The neutral of the system is everywhere isolated.

x/ Estimated.

(b) Transformer step-down substations

Prefabricated substations in metallic boxes, from medium to low voltage, were installed in many localities. At Port Etienne, this type of substations did not prove good because of adverse climatic conditions (sandy winds and salted air) and will be successively replaced by substations in brick. This type of substation was also used in Zouerate and Cansado. At Atar and Nouakchott, metallic prefabricated boxes proved good.

(c) Low voltage networks

The low voltage distribution network is operating under 220/380V in all localities except those where it is 127/220.

The majority of supports are made in the form of "telescopic" poles as they are easier and more handy than the poles with the large crossarms. In some places with salted sandy terrain near Atar, the concrete of the telescopic poles corroded at the base in less than four years. In such terrain the bases of the poles have to be protected adequately.

(d) Summary of distribution networks

Lengths of the lines in mid 1962, in km

		Medium voltage		Low voltage	
		15 KV	5.5 KV	220/380V	127/220V
Port Etienne:	Overhead	-	3.7	13.2	-
	undergr.und	-	-	-	-
Rosso:	overhead	-	2.	-	9
	underground	-	0.3	-	-
Atar:	overhead	-	2.5	5	-
	underground	-	0.1	-	-
Noukchott:	overhead	14.5	-	1.5	-
	underground	2	-	-	-
Cansado:	overhead	-	-	-	-
	underground	-	4	6.6	-
Zouérate	overhead	-	3.3	5.2	-
	underground	-	1	2.5	-
Total	overhead	14.5	11.5	38.4	9
	underground	2	5.4	9.1	-
Grand total		16.5	16.9	47.5	9

The total length is 89.9 Km.

5. Consumption

Electric utility development is very recent and therefore there is very little information available on the consumption of electric energy.

With the exception of the MIFERMA installations at Zouérate and Port Etienne there are at present practically no industrial enterprises working in the country.

Consumption at Nouakchott and Port-Etienne is somewhat lower than the production figures given in para.81, but power plant use and distribution losses are not known, so no exact figures can be given on the energy sold to consumers.

6. Production costs and consumers' tariffs

at Nouakchott Fuel prices are:

heavy fuel	7 Fr. CFA/Kg.
diesel oil	20 Fr. CFA/Kg.
gas oil	40 Fr. CFA/Kg.

Taking into account that at full-load 3.20 kWh are produced out of one Kg. diesel oil, the fuel costs of electric energy at full-load can be estimated at 6.20 CFA/kWh.

But, as the power plant and diesel groups are very seldom running at full-load, the practical figure of consumption per kWh produced is rather high. In the Westinghouse study the following breakdown of production costs is given:-

1.	Fuel and lubricants	15.41 Fr. CFA/kWh
2.	Salaries	3.86 Fr. CFA/kWh
3.	Maintenance	3.18 Fr. CFA/kWh
4.	Amortization	5.42 Fr. CFA/kWh
5.	Miscellaneous	10.13 Fr. CFA/kWh
	Total	38.00 Fr. CFA/kWh

The item "Miscellaneous" is evidently only the difference between the average sales prices of electricity 38 Fr. CFA/kWh and the sum of the first four items.

Consumers are paying 38 Fr. CFA/kWh on the average.

At Port Etienne, MIFERMA is supplying energy to SAFELEC at a price of 15 Fr. CFA/kWh. A rebate is given for loads between 500 and 1,000 kW.

SAFELEC's low voltage consumers have to pay the basic tariff P=38.50 Fr. CFA/kWh. For high voltage consumption, the basic tariff is 0.7 x P = 0.7 x 38.50 = 26.95 Fr. CFA/kWh and a fixed annual charge is charged for the maximum load in kW.

7. Future development

No complex development plans on electric energy exist but only some studies made by various commercial firms for dual purpose plants for the simultaneous production of water and electricity. In Westing house study the following estimates are given on the development of electric power at Nouakchott:

	1963	1967	1972	1977
Gross production, GWh	1.8	3.78	10.3	14.6
Maximum load, KW	500	960	2500	3520
Load factor, %	42	45	47	47.5
kWh/capita	149	192	372	440
W/capita	48	55	101	117

In the Four-Year Plan 1963-1966, doc.(3), the following investments are foreseen for electrification of the towns:

Nouakchott	75 million Fr. CFA
Port-Etienne	120 " " "
Other centres	100 " " "
Total	295 million Fr. CFA

These investments were allotted in the four-year period as follows:-

in million Fr. CFA

Total	1963	1964	1965	1966
295	90	75	65	65

83. Water

1. General

One of the largest problems in Mauritania is to meet the water requirements of the population in the towns and smaller agglomerations

and to supply sufficient water for livestock and agriculture. Precipitation is very poor, so there are only three major sources of water:

- the river Senegal
- underground water
- the sea

While there is no water-problem existing in the river region, it becomes heavier further north.

The water-problem is everywhere closely connected with the energy problem, which is especially hard for Mauritania as it has no primary energy resources and water resources are still unsurveyed. A survey of water resources is however absolutely necessary as basic information for all development plans of the country, since only then will it be possible to see if underground water resources are sufficient to cover the long-term water requirements. Should that not be the case, then desalination of sea water by means of nuclear energy would probably be the best long-term solution.

With regard to the acuteness of the water supply problem, Nouakchott and Port Etienne are of especial interest.

84. Nouakchott

To supply Nouakchott with water and electric energy, several projects have been elaborated, starting from different sources of water:

1. The existing water supply is obtained by pumping water at Idini from underground sources and transporting it by pipes to Nouakchott some 60 Km distant. The present price of water at Nouakchott is 120 Fr. CFA/m^3 with the following breakdown of costs :

Fuel and lubricants	9.42 Fr.CFA /m^3
Salaries	19.89 Fr.CFA/m^3
Maintenance	7.91 " "
Amortization	69.55 " "
Miscellaneous	13.23 " "
Total	120.00 Fr.CFA/m^3

(x) The present water supply is 1650 in 3/day.

2. Future requirements

In Westinghouse study, the following estimates of increase in population water requirements and electrical maximum loads for Noukchott are given:

	Population	m^3/day	kW KW
1964	12,500	1,650	600
1974	28,000	4,000	2,910
1977	30,000	5,700	3,520

To cover these requirements, three projects have been elaborated:

a) "Administrative" project:

Water: 3 new drillings, each 60 m^3/h
2 old drillings each 30 m^3/h
Total production 5,760 m^3/ day.
From Idini to Nouakchott a new water pipe 350 or 400 mm should be laid. The old pipeline has a diameter of 200 mm.

Electricity: In the existing power plant, the two diesel groups 2 x 220 kW will be replaced in 1970 by 2 x 510 kW. The total installed capacity will be then 2,040 kW.

b) Gesolerg - project:

- Pumping station Idini and power plant Nouakchott will continue to operate;
- A dual-purpose desalination plant on heavy fuel oil will be erected at Nouakchott with a fresh water production of 2,000 or 3,000 m^3 per day and an electric steam power plant for 1,200 kW.

c) Westinghouse project:

- Pumping station Idini and power plant Nouakchott will stop operating;
- Dual-purpose desalination plant on heavy fuel oil will be erected at Nouakchott for: 3,780 m^3 of fresh water per day and 2 x 2000 kW.

Economic comparison of the projects (in million Fr. CFA)

i) Total value of investments

	Existing plants value			New plants investment			Total value		
	Constr.	Equip.	Total	Constr.	Equip.	Total	Constr.	Equip.	Total
Admin. ø 350	250	150	400	500	100	600	750	250	1000
ø 400	250	150	400	600	100	700	850	250	1100
Cegelerg	250	150	400	75	547	622	325	697	1022
Westinghouse									
1st phase	-	-	-	335	750	1085	335	750	1085
2nd phase	-	-	-	65	120	185	65	120	185

ii) Fixed charges (in million Fr.CFA)

		Project		
		Administrative	Cegelerg	Westinghouse
Amortization	Construction	850 . 0.02 =17	325.0.02=6.50	335. 0.02= 6.7
	Equipment	250 . 0.05 =12.5	697.0.05=34.85	750. 0.05=37.5
Maintenance	Construction	850 . 0.005= 4,25	325.0.005=1.63	335. 0.005=1,67
	Desalination plant	-	547.0.125=6.84	750. 0.125=9.37
	Diesel plant	250 . 0.05 =12.50	150.0.025=3.75	-
Total		16.75	12.21	11.04
Salaries		10.00	16.30	16.10
Miscellaneous		5.75	6.94	7.15
Total		62.00	76.80	78.49
Comparison factors		100	124	126

iii) Production costs

Specific fuel costs (net):

For water: Idini: 0.5 kWh/m^3 = 0.5 x 0.3 $\frac{kg}{kWh}$ x 40 $\frac{Fr}{Kg}$ = 6.0 Fr.CFA/m^3

Cegelerg: 12 kg fuel oil/m^3 x 7 $\frac{Fr}{kg}$ = 84 Fr.CFA/m^3

Westinghouse: 11 kg fuel oil/m^3 x 7 $\frac{Fr}{kg}$ = 77 Fr.CFA/m^3

For electricity: At Nouakchott 6 Fr/kWh

In the projects I.C. cegelerg and Westinghouse, total fuel costs are included in water production so that electric power production has no costs. This method of calculation is not quite correct, although the end total costs for water and electricity are the same. Fuel costs should be divided into water production and electricity production according to the Mollier chart.

The above net specific fuel costs have to be increased by 10 per cent for miscellaneous and for chemical additives:

I.C. cegelerg	4.0 Fr. CFA/m^3
Westinghouse	1.6 Fr. CFA/m^3

Gross specific production costs:

	Admin. project	Cegelerg	Westinghouse
Water Fr. CFA/m^3	6.60	96.4	86.3
Electr.Fr.CFA/kWh	6.60	-	-

With water and electricity production as estimated for 1970, the following yearly production costs (= proportional costs) can be established (in million Fr. CFA):

	Admin. project	Cegelerg	Westinghouse
Water Plant Idini	$1.5.10^6 m^3$. 6.6 = 9.9	0 $5.10^6 m^3$.6.6 = 3.3	-
Desalin.Plant	-	$10^6 m^3$. 96.4 =96.4	$1.4.10^6$.86.3=129.5
Electr. Diesel Plant	4 GWh.6.6 =26.4	1 GWh.6.6 = 6.6	-
Desalin.Plant	-	3 GWh 0 = 0	4 GWh.0 = 0
Total	36.3	106.3	129.5
Comparison factors	100	292	356

Differences in production costs are enormous because the distillation of water requires incomparably more energy per m^3 produced than a simple pumping of water from underground.

iv) Total costs (in million Fr. CFA)

For production targets in 1970

	Admin. project	Cegelerg	Westinghouse
Fixed charges	62.0	76.80	78.40
Production costs	36.3	106.30	129.45
Total	98.3	183.10	207.85

To cover total expenses by sales of water and electricity, the following unit prices giving income a little higher than total expenses have been proposed:

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		Admini. project	Cegelerg	Westinghouse
Unit Prices	Water Fr/m^3	35	80	90
	electr. Fr.kWh	12	16	19
Income	Water	$1.5.10^6 m^3 .35 = 52.6$	$1.5.10^6 m^3 .80 = 120$	$1.5.10^6 m^3 .90 = 135$
	Electricity	4 GWh.12 =48,0	4 GWh.16 =64	4 GW.19 = 76
Million Fr.CFA	Total	100.6	184	211

The above cost analysis shows that the "Administrative" project with the simplest pumping technique is also the cheapest.

There is another project existing to supply water to Nouakchott:

(d) Mannesmann project:

The German firm Mannesmann (Duesseldorf) proposed the following solution:

- Water should be pumped from the river Senegal from Podor and conducted by a pipeline with a diameter of 350 mm to Nouakchott at a length of 180 Km. Capacity of the installations should be 6072 m^3/day.
- Along the pipeline ten water stations should be erected to provide the local population and livestock with water at a capacity of 50 m^3 per day and station.

Total investments would amount to 998 million CFA Fr. In the cost analysis below the following suppositions have been made:

- amortization, replacement and maintenance costs increase with time, taking into account the condition of the material,
- costs of money (interest) are not included,
- operating costs for pumping increase with the amount of water pumped through the pipe-line.

Cost of water supplied to Nouakchott

(in rounded figures)

		1966	1970	1975
Water supplied to Noukchott in $10^6 m^3$/year		1.00	1.46	2.00
Fixed annual charges in million Fr. CFA	Amortization, replacement and maintenance	15	17	30
	Salaries	15	15	15
Unit's costs in Fr. CFA/m^3	Fixed charges	30	22	23
	Pumping	2.35	4.10	7.00
	Water treatment	7	7	7
	Total (rounded)	40	33	37

Remark: Water taken off in the water stations along the pipeline is supposed to be given to the local population gratuitously. It seems that the Mannesmann-project is very competitive with the projects a), b) and c) above.

In the USA, too, some experts have questioned the economics of desalination in the case where fresh water can be obtained more cheaply by pipelines from remote but sufficiently large fresh water resources. Costs of water transport are calculated in the USA at about 10 cents per 1000

gallons over a distance of 1,600 kilometres.

In the Mannesmann project the lowest water transport costs are equivalent to 60 US cents per 1,000 gallons over a distance of 180 km. In comparison with the American figures, the Mannesmann project is therefore very expensive.

85. Port Etienne

Similar water supply studies have been made also for Port Etienne. Water desalination plants have been compared with the conduction of water by pipeline from the wells at Tirersioum, a distance of 84 Km.

Unit cost for the two alternatives in Fr CFA/m^3 are (in rounded figures)

Alternative	Fixed charges		Production costs		Total costs	
	Fr/m^3	%	Fr/m^3	%	Fr/m^3	%
Pipeline conduction	78	60	48	40	126	100
Desalination	41	30	95	70	136	100

Remarks:

- Water requirements: in 1965 - 1100 m^3/day
  in 1975 - 2000 " "
- Water supply capacity estimated at 2000 m^3/day.
- An examination of the investment costs for the desalination plant shows rather a low specific investment in Fr CFA/m^3 per day and gives rise to the assumption that investment costs have been under estimated.

  On the other hand specific investments in 10^6 Fr CFA/Km for the pipeline conduction are higher than e.g. the Mannesmann project for Nouakchott:

At Port-Etienne : diameter 300 mm: $5.2.10^6$ Fr. CFA/km
At Nouakchott " 350 " 4.6 " " "

- Taking into account the foregoing remarks it is very likely that the pipeline alternative is even more favourable than shown in the table above.

86. Other energy sources for water and power supply

The economic survey of water production costs in the previous two paragraphs shows that the desalination alternative is more expensive than the pipeline conducting alternative, mainly because of the incomparably larger energy costs of desalination.

Another factor responsible for the high specific costs of water production in desalination plants is the low capacity of the plants projected for Nouakchott and Port-Etienne.

In connexion with this, two non-conventional energy sources have to be examined: nuclear energy and solar energy.

1. Nuclear energy

Dual purpose nuclear plants designed for electric power production and the desalination of sea water may be economic, provided the capacity of the plant is high enough.

In the paper by Cowa (Ref), a relatively small dual purpose nuclear plant is described. The reactor's thermal output is 110 MWt and multi-flash distillation units can produce 4.27 to 10.25 million US gallons[1/] per day, according to the chosen factor G.O.R.(Gained output Ratio). Maximum net power production varies from 6.6 MWe to 18.MWe, depending on water production.

Taking as an example the 5-1 G.O.R.evaporator with a daily production of 5.10^6 gallons = 19,000 m^3 of water and 158,000 kWh, the total investment amounts to US$ 11,7 million = 2,930 million Fr.CFA.

1/ 264.2 US gallons = $1m^3$.

When using a 10 - 1 G.O.R. evaporator, the capital cost is about $16.6 million. For these plants, operating costs will range from $0.70 to $1.20 per 1000 gallons or 46 to 80 Fr. CFA per m^3, assuming a credit of 7 mills/kWh or 1.8 Fr.CFA/kWh (Op.Cit , figure 9).

To make a comparison between conventional and nuclear plants for water and power supply, the cheapest project for Nouakchott is chosen that is the "Administrative project" and the smaller nuclear plant, type 5-1 G.O.R. with a production (in 330 days a year): 6.5 million m^3 water per year and 52 GWh per year.

The operating cost data shown in figure 9 are based on a calculated reactor fuel cost of 27. 2 US cents per million BTU, but all other cost factors are treated as in "A standardized procedure for estimating costs of Saline Water conversion", prepared by the United States Office of Saline Water.

This procedure assumes operation for 330 days a year and amortization charges of 7.4 per cent per annum. The cost of electrical equipment is amortized with the remainder of the plant.

The total production costs (fixed charges plus operating costs) amount to about US $ 2.2 million or Fr. CFA 550 million per annum.

In the "Administrative project" the price ratio water/electricity is about 3:1. Taking the same price ratio also for the nuclear plant, these costs would be covered by the following tariffs for water and electricity:

Price of water about 23.4 Fr. CFA / m^3

Price of electricity about 7.8 Fr. CFA/kWh.

These prices are about 33 per cent lower than in the "Administrative project" inspite of the fact that water is desalinated and not pumped. The difference comes from the about 5.5 times larger capacity of the nuclear plant as compared with investment costs less than 3 times larger. This means with the proposed nuclear dual purpose plant that specific investment costs are about twice as cheap as with the "Administrative project".

A comparison of the nuclear plant with the conventional desalination dual purpose plant, e.g. Westinghouse project for Nouakchott, shows:

Nuclear plant with water and electricity production capacity	4.6 times larger
has investment costs only	2.3 times larger
and total production costs for water	3.8 times lower
for electricity	2.4 times lower

It is true that the capacity of the dual purpose nuclear plant 5 - 1 G.O.R. is far larger than the requirements of energy and water in Nouakchott calculated for 1970. These requirements are extrapolated however to 1970, on the basis of the present situation where there is so to speak no industry and therefore they are very low. There exists a circulus vitiosus (vicious circle): Industry cannot be located at Nouakchott because the prices of electric energy and water are so high, and these prices are high because water and electricity production is low as a result of the fact that there is no industry.

This vicious circle should be broken: In future development plans some appropriate industrial enterprises have to be included.

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The reactor of the proposed nuclear dual purpose plant has a thermal power of 110 MWt. It is relatively very small. The total production cost is therefore relatively high: expressed in the US terms, it is 35 US cents per 1,000 gallons.

In a Study by Mr. Philip Hammond of the Los Angeles Scientific Laboratory, USA, estimates have been made showing that very large reactors of 2000 to 25000 MWt will be able to produce water at a price of 20 to 10 US cents per 1000 gallons. To get an idea of the productivity of such a large reactor: a 2000 MWt - desalination plant

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with a G. O.R. 5 - 1 would produce 10 million gallons per day and that would be enough for the irrigation of 100 km^2. This amount of water for irrigation would be equal to a precipitation of 1,140 mm per annum.

Besides the water for irrigation, a 2,000 MWt dual purpose nuclear plant would give some 200 gross MWe electric power.

Investment for such a nuclear plant may be estimated at some US $ 120 million.

With the same method of calculation as in the case of the 110 MWt nuclear plant, the 2,000 MWt dual purpose nuclear plant would give the following unit prices:

for water: 19 US cents 1000 gal. or 12.6 Fr. CFA/m^3

for electricity 1.68 US cents per kWh or 4.2 Fr. CFA/kWh

These prices would be three times lower than those in the "Administrative project", but, on the other hand, investment would be of such a size that the economics of the project in total should be checked in all details. One of the main points to be checked is which agricultural products would justify the irrigation costs.

2. Solar energy

Possibilities of utilization of solar energy are manifold and in a country without other resources of primary energy, as e.g. in Mauritania, it seems to be imperative that solar energy be utilized whenever it is economically justified. Import of conventional (or later even nuclear) fuels and burning of wood would be thereby largely reduced.

With regard to technology the problems of solar energy utilization have been solved to a very large degree, but real difficulties exist in the fact that investment costs for almost all applications of solar energy are very high and as result conventional forms of energy, even when imported, are often much cheaper.

(a) Water desalination

Investment costs of distillers vary greatly with construction and types of materials used. Plastic covers, for example, are lower in initial cost but, having less durability, are not necessarily so in production cost. With glass covers, the initial cost is of the order of $ 15 to $ 30 per square metre with a lifetime of twenty years. With a yearly yield of 1.5 to 2 m^3 distilled water per square metre, a realistic production cost estimate is $ 1 to $ 2 per m^3 of fresh water plus operating labour cost .

Large-scale solar distillers face a much more difficult situation at least in the capacity range beyond 50 m^3 per day. They must be usually competitive with fresh water transport from more distant sources or with other demineralization processes. Such plants, yet to be built, may be expected to produce at some $0.30 to $ .65 (= 75 to 162 Fr. CFA) per cubic meter in the near future.

The large solar distillers can incorporate various refinements, such as forced convection and multiple effect distillation , thereby improving efficiency but adding to investment cost if not to product cost. The most optimistic calculation of all in this category is undoubtedly one arriving at a cost of about $ 0.08 or 20 Fr. CFA per m^3 .

Closer investigations on the reality of these estimates, should be carried out by some industrial enterprises, the potential producers of the large-scale distillation plants.

(b) Mechanical and electric power from solar heat engines

Solar heat can be converted to mechanical power - for direct use as in water pumping and for further conversion to electricity - by means of piston and turbine engines according to well-known principles.

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Solar heat can be converted to mechanical power - for direct use as in water pumping and for further conversion to electricity - by means of piston and turbine engines according to well-known principles.

Possibly the most significant development, reported from Israel (12) and demonstrated at a symposium in Rome in 1961, is a small turbine-solar power combination based on a new type of collector and turbine, and operating on a heavy fluid (monochlorbenzene) with a lower boiling point than water. In this power "package", with a capacity of from 2 to 10 kW, the turbine achieves an efficiency of 15 to 20 per cent. The intial cost is estimated at from $513 to $1,435 per kW installed with the collector accounting for more than 2/3 and the product cost at from 34 to 52 mills / kWh or 8.5 to 13 Fr. CFA/kWh.

Should the idea of "solar ponds" be solved accordingly, the collector cost could be reduced from $20 to $1 per m^2 and thus put solar power in an entirely different category for rather large-scale production.

A "solar pond" one square kilometre in size could produce power at ten mills per kWh, with a production of 30 GWh per year at 1.5 per cent over-all conversion efficiency.

(c) Other applications of solar energy

Solar energy may be used also for water heating, cooking, refrigeration for food preservation, drying of agricultural and other products and for telecommunications. The economics of these applications vary very much from case to case and according to the size of the plant. It is not possible to give an opinion on the economic feasibility of solar energy application in general, but in a country like Mauritania it may be rather easy to find many relatively economic ways of using solar energy.

(d) How the solar energy problem should be tackled in Mauritania

In many developed countries of the world big efforts have been made and financial assistance given to increase scientific and technological knowledge about solar energy utilization. The "solar know - how" does exist in the world and therefore it is not necessary for developing countries to spend their limited means on research and

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development work in the domain of solar energy utilization. The existing meteorological stations in the country should, however, extend their activities to measurements of solar energy.

As solar energy is the only sure source of primary energy in the country, it is of very great importance to know for which purposes and to what extent it can be used economically, in the short and in the long terms.

As a result of that knowledge the general line of energy policy could be fixed with regard to the import of the other energy forms necessary for covering all requirements.

To get as quickly as possible a realistic picture on the applicability of solar energy to Mauritania, a UN Special Fund Project should be established for a duration of three months with the following experts:

Two experts on practical solar energy utilization, preferably one from Israel and one from the USA

One expert on the industrial production costs of appliances similar to those which would be used for solar energy utilization.

One expert on irrigation and general water supply problems.

Locally, the following experts should collaborate with the Project: experts on agriculture, on soil and on trade.

VI. INTEGRATED IRON AND STEEL INDUSTRY

87. The following survey of the comparative advantages of Mauritania as a site for a coastal iron and steel works serving the sub-region is similar to those previously made for Gabon, Ghana and Liberia (Iron and steel and first stage of transformation Vol.I, E/CN.14 INR.72 dt.21 July 1964) and for convenience of reference numbering of the paragraphs is the same as in that report.

2.17. The Port-Etienne site in Mauritania

The site was selected because it is located at the terminus of the railway line that transports the iron ore mined by the Miferma Company from Fort Gouraud. The port can already handle exports of more than 6 million tons of ore annually.

The site chosen is south of the Miferma company harbours, on the Cap Blanc Peninsula which is divided in two by the frontier with the Rio de Oro, thus limiting the possible site area to a coastal strip 2 km long and 0.8 km wide. However, an agreement might conceivably be concluded with the Rio de Oro to increase the width of this strip.

2.227 Port-Etienne

The peninsula consists of a sandstone plateau rising about 20 metres above sea level. This fairly resistant type of soil can carry a weight of 5 kg / cm^2 and foundation-laying does not seem to present any problems, but the ground will have to be levelled. A first tentative estimate of $1 million has been made for the cost of the entire operation.

2.326 The Port-Etienne harbour

The proposed harbour is located south of the town of Port-Etienne, where there is only a small fishing harbour, and sea-going vessels unload their cargoes on to lighters, which are the only craft able to reach the harbour.

There is approximately 40 feet of water at low tide at the proposed location. The total range is of the order of 1.50 metres.

Like the Miferma harbour, the plant harbour would be situated in the Baie du Lévrier, well protected from the trade winds and calm practically all the year round, except for one fortnight a year when the east winds blow.

2.46 The Port-Etienne site

The only means of communication with the interior are the mine railway and the service track built alongside it. There are air and sea links with Nouakchott, the capital.

2.5 A fundamental disadvantage of the Port Etienne site, however, is the question of water supply, and an attempt has been made to estimate the additional cost entailed by the necessity of desalinating sea-water. The known supplies of groundwater are insufficient for the requirements of the plant. Furthermore, if these were used reserves would be very rapidly exhausted. One possible solution would be for the plant to provide the electricity and fresh water it needs by a combination of a high-pressure boiler, a back-pressure turbine and a sea-water desalinization plant. The exhaust steam from the back-pressure turbine, with a temperature of 150° - 200° and a pressure of 4 - 15 atmospheres, would supply the necessary heat.

This type of project would be more economic than one designed to produce separately the electricity and the low-pressure thermal energy required for the desalination plant.

Two variants were studied: in the first it was supposed that the plant would meet water and electricity requirements, but the problem of ensuring the continuity of operation necessary for running an iron and steel plant was not taken into account. In the second alternative, however, it was assumed that certain equipment would be duplicated to provide against break downs or the necessity for major repairs.

Calculations of fuel costs and the depreciation of the plant were based on a fuel oil price of $35.30 and on the assumption of depreciation at 8 per cent over twenty years.

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The breakdown of the total annual expenditure of the generating plant between the production of water and electricity was estimated by calculating the average cost price per kWh on an equivalence basis, assuming that a conventional power station would be built at Port-Etienne to supply the iron and steel plant and some other local industries. The prices of water and electricity quoted in the study correspond to the arithmetical mean of the prices of all the sub-variants and are given below:-

Price of Electricity	$22.45 per 1,000 kWh
price of Water	$362.00 per 1,000 m^3

A detailed study would be necessary, however, to calculate the cost prices more exactly.

2.71. The fact that the Miferma installations, with a training organization are not far away provides a good starting point for the training of the plant workers.

Provision would have to be made for housing the labour force at Port-Etienne, but some of the general facilities of the Miferma company could also be used by the iron and steel plant, subject to possible enlargement.

3.7 The Port-Etienne site

3.71 The iron ore

The plant located at Port-Etienne would be supplied with ore from Fort-Gouraud. Mining is carried out in the Tazadit and Fderik areas and will soon be extended to the Rouessa district. Reserves probably exceed 200 million tons.

Only ore with an iron content exceeding 60 per cent is sold at present. Ore with an iron content below 48 per cent is considered sterile, and medium grade ore is kept in stock for subsequent rehandling and concentration.

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HYPOTHESIS A: The composition of commercial ore varies between the following limits:

ANALYSIS OF RICH ORE		
Fe	65.7 %	62.0%
SiO_2	3.2-3.5 %	7.0 %
CaO	0.7 %	0.7 %
Al_2O_3	1.3 - 1.5 %	1.3 - 1.5 %
Heat loss	1.1 - 1 %	1.1 %

It is usually reckoned that Fe + SiO_2 = 69 per cent.

The moisture content due to watering at Port-Etienne varies from 1 to 2 per cent.

It may be assumed that the iron and steel plant will utilize the leanest ores, which have a "dry" iron content of about 60 per cent. It would be pointless to water the ores when they reach the plant.

HYPOTHESIS B: The ore used at the plant would be medium grade ore of which the average composition is given in the following table:

ANALYSIS OF MEDIUM GRADE ORE	
Fe	53.4 %
SiO_2	14.9 %
Al_2O_3	4.2 %
CaO	-
P	0.04 %
Heat Loss	4.15 %

Annual ore requirements, including the additional ore for the LD steel process, would be in the region of 550,000 tons under hypothesis A and 662,000 tons under hypothesis B.

The cost of ore franco plant works out at $9.27 per ton under hypothesis A and at $5.56 per ton under hypothesis B.

3.72 Manganese ore

The Miferma ore contains hardly any manganese but, as its sulphur content is low, it seems unnecessary to provide for additional supplies of manganese ore. Only small quantities would be needed in any case. The slag from LD steel manufacture contains 2 per cent of manganese due to additions of ferro-manganese at the steel plant. This slag thus seems to provide an adequate supply of manganese.

3.73 Coke and coke breeze

Under hypothesis A, estimated coke consumption is 518 kg per ton of pig iron, plus a fuel oil injection of 160 kg.

If requirements in coke breeze for sintering are taken into account, the annual consumption of the plant amounts to 234,000 tons (including coke breeze).

Under hypothesis B, coke requirements show an increase amounting to 568 kg per ton of pig iron, assuming a fuel injection of 160 kg. The utilization of medium grade ore means an annual coke consumption of 271,500 tons (including coke breeze).

3.75 Electricity

Apart from the Miferma generator (8,000 kw - Diesel engine), there is no other electricity supply available in the area. The iron and steel plant would thus be entirely dependent upon its own power station, designed for the simultaneous production of fresh water from sea water (see under paragraph 2.5).

3.76 Limestone

Rather large quantities of limestone are needed for the charges, as the ore from Fort Gouraud is siliceous, which means that approximately 233 kg of flux is required per ton of pig iron under hypothesis A and approximately 563 kg under hypothesis B. Annual consumption of limestone works out at 83,900 tons and 202,700 t respectively, without taking into account the lime requirements of the steel plant (43,000 tons)

There is a limestone deposit in the Atar area, close to the mining company railway and there are probably other deposits nearer at hand. In any case, it would always be possible to import good quality limestone by sea from Senegal. Another solution would be to pick up supplies at a European port, thus providing return freights for the ore-carriers. Under these conditions the price of limestone franco plant, including unloading charges, would be $2.8 per ton.

4.25 Mauritania

The monthly wage of a labourer at Port Etienne on the basis of a forty four hour week is between fr CFA 10,000 and 12,000. Social security contributions vary from 15 to 22 per cent of wages. The average hourly wage of an unskilled worker can thus be estimated at $0.30.

4.4 PORT ETIENNE

ITEMS	CONVERSION COSTS ($ 1,000 per annum)					
	Ovendo	Port Harcourt	Tema	Lower Buchanan	Monrovia	Port Etienne
1.	2	3	4	5	6	7
Labour						
Hyp A	1,174	1,326	1,151	1,381	1,381	1,386
Hyp B	1,174	1,339	1,163	1,381	1,381	1,393
Other						
Hyp A	7,526	7,196	7,196	7,196	7,208	7,282
Hyp B	7,526	7,559	7,223	7,196	7,208	7,282
Total						
Hyp A	8,700	8,522	8,347	8,577	8,589	8,667
Hyp B	8,700	8,898	8,385	8,577	8,589	8,674

5.135 Plant sited at Port-Etienne

Destination of finished products	Distance transported (km)		Cost of transport ($/ton) (terminal costs included)			Method of land transport
	by sea	by land	by sea	by land	total	
1.	2.	3.	4.	5.	6.	7.
Nouakchott/ Port-Etienne	-	-	-	-	-	-
Dakar	650	-	8.0	-	8.0	-
Monrovia	1,800	-	10.4	-	10.4	-
Conakry	1,400	-	9.6	-	9.6	-
Mamcu	1,400	250	9.6	9.2	18.8	Rail
Freetown	1,500	-	10.0	-	10.0	-
Abidjan	2,600	-	12.0	-	12.0	-
Bouake	2,600	300	12.0	9.2	21.2	Rail
Accra	3,000	-	13.0	-	13.0	-
Tamale	3,000	500	13.0	13.2	26.2	Road
Takoradi	2,800	-	12.8	-	12.8	-
Lome	3,150	-	13.2	-	13.2	-
Sokode	3,150	250	13.2	9.2	22.4	Rail
Cotonou	3,250	-	13.4	-	13.4	-
Lagos	3,400	-	13.8	-	13.8	-
Kano	3,400	900	13.8	12.4		Rail
Port Harcourt	3,800		14.4	-	14.4	-
Gombe/Bautchi	3,800	750	14.4	11.6	26.0	Rail
Douala	4,050	-	15.0	-	15.0	-
Yaounde	4,050	300	15.0	8.4	23.4	Road
Libreville	4,100	-	15.2	-	15.2	-
Pointe Noire	4,600	-	16.1	-	16.1	-
Brazzaville	4,600	400	16.1	9.6	25.7	Rail
Bamako	650	1200	8.0	14.0	22.0	Rail
Ouagadougou	2,600	1200	12.0	14.0	36.0	Rail
Niamey	3,250	300	13.4	22.8	36.2	Road
Fort Lamy	3,800	1450	1.4	21.2	35.6	Rail & Road
Bangui	4,600	1600	16.1	18.4	34.5	Rail &Water

5.145 Freight rates ex Port-Etienne ($perton)

Port of destination	% share of shipments	Freight rates given by ECA for the study	Variants	
			Conference rate	Special study rate
1	2	3	4	5.
Douala	3.4	15.00	21.00	13.60
Pointe Noire	3.6	16.10	23.80	14.40
Abidjan	10.8	12.00	16.10	11.70
Cotonou	2.6	13.40	17.70	12.50
Libreville	1.6	15.20	21.63	14.00
Tema	16.2	13.00	16.90	12.20
Takoradi	5.4	12.80	16.50	11.90
Conakry	1.6	9.60	14.10	10.10
Monrovia	6.6	10.40	14.62	11.09
Nouakchott/P.Et.	2.3	-	-	-
Lagos	14.8	13.80	18.10	12.70
Port Harcourt	15.6	14.40	19.42	13.02
Dakar	12.3	8.00	13.50	9.00
Freetown	2.2	10.00	14.30	10.20
Lome	1.0	13.20	17.30	12.40
Average freight weighted in relation to tonnage shipped.	100.0	12.24	16.79	11.67

5.22 SUPPLIES OF SLAG AVAILABLE

Site of plant	Hypothesis A		Hypothesis B	
	Kg/t of iron	tons per annum	Kg/t of iron	tons per annum
1.	2.	3.	4.	5.
OVENDO	0.212	76,320	0.212	76,320
PORT HARCOURT	0.229	82,260	0.659	237,240
TEMA	0.229	82,260	0.350	126,000
LOWER BUCHANAN	0.229	82,260	0.229	82.260
MOKTA	0.313	112,680	0.313	112,680
PORT ETIENNE	0.385	138,600	0.693	249,480

5.236 Port Etienne site

Slag from the plant might possibly be used for road building; Because of the restricted size of the local market, however, the price of slag has been estimated as nil.

6.1 - 6.11 ESTIMATE SCHEDULES COMPARED - PRESENTATION OF RESULTS

Unit = $ 1,000

Schedule items	Hypothesis	OVENDO	PORT HARCOURT	TEMA	LOWER BUCHANAN	MONROVIA	PORT-ETIENNE
1. Capital costs	A	107,000	(103,100)	103,100	107,000	105,850	99,000
Equivalent annual outlay		10,898	(10,501)	10,501	10,898	10,781	10,083
2. Raw materials		13,514	(14,889)	14,446	11,486	12,025	19,567
3. Conversion costs		8,700	(8,522)	8,347	8,577	8,589	8,667
4. End costs		4,673	(4,067)	3,730	4,287	4,206	5,502
Total		37,785	(37,979)	37,024	35,248	35,601	43,819
1. Capital costs	B	107,000	(112,600)	107,600	107,000	105,850	99,000
Equivalent annual outlay		10,898	(11,468)	10,959	10,898	10,781	10,083
2. Raw materials		13,276	(17,075)	17,355	10,615	11,696	19,454
3. Conversion costs		8,700	(8,898)	8,385	8,577	8,589	8,674
4. End costs		4,673	(4,067)	3,678	4,287	4,206	5,502
Total		37,547	(41,508)	40,377	34,377	35,272	43,713

Note:- The figures for Port Harcourt are put in brackets to emphasize the point that it was not possible to survey this site as accurately as for the other sites.

Unit	Hypothesis	OVENDO	PORT HARCOURT	TEMA	LOWER BUCHANAN	MONROVIA	PORT ETIENNE
1	2	3	4	5	6	7	8
$ per ton of	A	107.96	108.51	105.78	100.71	101.72	125.20
iron or steel	B	107.28	118.59	115.34	98.22	100.78	124.89
% of Lower	A	107.2	107.7	105.0	100.0	101.0	124.3
Buchanan under Hypothesis A	B	106.5	117.8	114.5	97.5	100.1	124.0

6.12 Analysis of results

Let us take first the results under hypothesis A,

The Lower Buchanan site takes first place, closely followed by Monrovia. In fact, the 1 per cent difference between the two sites need not be regarded as significant. The trend might be the other way round if surveys were made of foundations or a different hypothesis were adopted regarding the choice of ores at Monrovia. The real conclusion is that the two Liberian sites give the best results and a decision between them could be made only if more detailed surveys were made later on.

Tema comes next but is rather badly handicapped in the matter of raw materials, partially compensated for by its excellent situation for the distribution of finished products.

The difference between the Liberian sites and Tema is much greater than that between Tema and Ovendo or Port Harcourt: Tema rates 5 per cent over Lower Buchanan; Ovendo and Port Harcourt 7.2 per cent and 7.7 per cent respectively.

Ovendo takes third place for raw materials, but in the aggregate falls to fourth on the score of capital costs (difference due to costs of accommodating and training manpower) and its poor situation for the distribution of finished products.

The margin between Port Harcourt and Ovendo is very slight (0.5 per cent, as against 2.2 per cent between Ovendo and Tema). However, the structure of expenditure items at Port Harcourt is closer to Tema's: raw materials constitute the drawback (bigger than at Tema), partially, but to a lesser extent, offset by its favourable location for distributing finished products (Port Harcourt takes second place in this respect).

The Port-Etienne site comes last of all, in spite of the advantage offered by the quality of the soil. In fact, the market price of the ore franco plant, is amongst the highest for the group of sites studied. Furthermore, the price of fuel oil is comparatively higher than in the majority of the other ports included in the study. The drawback affects the price of electricity and intensifies the problem of the water shortage at Port-Etienne. Finally, the out-of-the-way location of the site in relation to the consumer markets serves to increase the difference in the cost price of steel in comparison to the most favourably located site.

Assuming that the price of fuel oil at Port-Etienne were the same as the prices estimated for other locations such as Monrovia, Port Harcourt or Tema, i.e. about $20.65 per ton, the cost price of steel would be reduced by $7.06 per ton (hypothesis A), but the relative position of the sites would remain unchanged.

If we take hypothesis B, we find first that the order of the variant figures is unchanged, except for Tema and Ovendo: the latter site in Gabon replaces the former in third place. The marginal differences widen considerably, however, (17.8 per cent between last and first site as against 7.7 per cent under hypothesis A) with the exception of Port-Etienne, for which the margin remains almost unchanged.

This is because, in the case of the three sites where commercial ore is obtainable (Lower Buchanan, Monrovia and Ovendo), reckoning the "social" cost for West Africa instead of the market price of iron ore reduces the cost of raw materials. The difference in effect is not, however, very great - 0.7 to 2.5 per cent - and is mainly due to the position at Tema and Port Harcourt being worsened by the substitution of local for imported ore, slightly more so at Port Harcourt than at Tema. It affects equally capital costs, raw materials and conversion costs.

With regard to the Ovenda site, it should be remembered that it can be considered only if the Belinga mine is operating and this cannot happen before 1972 at the earliest.

Finally, the use of leaner ore at Port-Etienne means relative stability in the cost price of steel.

Table No.1.6

SCHEDULE OF ESTIMATES FOR A PLANT LOCATED AT PORT ETIENNE

HYPOTHESIS-A, rich ore at market price - B, Local ore at "social" cost

SCHEDULE ITEM No.	Denomination	Hypo-thesis	Unit	Quantity needed annually	Unit price ($ per unit)	Annual cost $ per year
1.	2.	3.	4.	5.	6.	7.
1.	CAPITAL COSTS ($1,000)					
1.1	Foundations	A-B				(1,000)
1.2	Erection of Wharf	A-B				(1,000)
1.3	Water supplies	A-B				-
1.4	Iron & steel plant	A-B				82,500
1.5	Training of labour	A-B				11,000
1.6	Accommodation for labour					3,500
	TOTAL (1)	A-B				99,000
	Equivalent annual costs ($ per year)	A-B				10,083,180
2	RAW MATERIALS ($)					
2.1	Iron ore - blast furnace	A	P.F	33,480,000		
		B	P.F	33,480,000		
		A	t	527,760	9.27	4,892,335
		B	t	640,080	8.54	3,546,043
2.2	Iron ore - steelworks	A	P.F	1,432,080		
		B	P.F	1,432,080		
		A	t	22,500	9,27	208,575
		B	t	22,500	9.27	208,575
2.3	Manganese ore	A	t	-	-	-
		B				
2.4	Coke for blast-furnace	A	t	186,480	24.02	4,479,250
		B	t	204,480	24.02	4,911,670
2.5	Coke breeze	A	t	47,520	24,02	1,141,430
		B	t	66,987	24,02	1,609,028
2.6	Fuel oil for blast furnace	A	t	57,600	35.30	2,033,280
		B	t	57,600	35.30	2,033,280

cont...2

Table 1.6 cont...

1.	2.	3.	4.	5.	6.	7.
2.7	Fuel oil - other purposes		t	17,550	35,30	619,515
2.8	Electricity		100Kw/h kw	101,400 15,600	22.45	2,276,430
2.9	Scrap iron	A B	t	40,000 40,000	- -	- -
2.10	Limestone for blast furnace.	A B	t	83,880 202,700	2.8 2.8	234,864 567,560
2.11	Limestone for steelworks	A B	t	43,000 43,000	2.8 2.8	120,400 120,400
2.12	Fresh water	A-B	1000m^3	7,008	362.0	2,536,896
2.13	Miscellaneous materials	A-B	-	-	-	1,024,240
	TOTAL (2)	A B				19,567,215 19,453,577
3.	CONVERSION COSTS					
3.1	Labour	A B	hour/year	4,604,160 4,627,180	0.301 0.301	1,385,852 1,392,781
3.2	Other	A B				7,281,550 7,281,550
TOTAL (3)		A B				8,667,402 8,674,331

cont...

Table 1.6 cont...

1.	2.	3.	4.	5.	6.	7.
4.	END PRODUCTS					
4.1	Transport of finished products	A-B	t	350,000	15.72	5,502,000
4.2	Sale of slag	A B	t	138,600 249,480	- -	- -
	TOTAL (4)					5,502,000 5,502,000
5.	RECAPITULATION					
5.1	Capital costs	A-B				10,083,150
5.2	Raw materials	A B				19,567,215 19,453,577
5.3	Conversion costs	A B				8,667,402 8,674,331
5.4	End products	A B				5,502,000 5,502,000
	GENERAL TOTAL	A B				43,819,767 43,380,362
	Costs per ton of steel	A B	t	350,000	125.20 124.89	43,819,767 43,713,058

Table No.2

COMPARISON OF THE COASTAL SITES

HYPOTHESIS-A RICH ORE AT MARKET PRICE - B, LOCAL ORE AT "SOCIAL COST"

SCHEDULE ITEM No.	Denomination	Hypothesis	ANNUAL COST OVENDO (Gabon)	PORT-HARCOURT (Nigeria)	TEMA (Ghana)	BUCHANAN (Liberia)	MONROVIA (Liberia)	PORT-ETIENNE (Mauritania)	OBSERVATIONS
1.	2.	3.	4.	5.	6.	7.	8.	9.	10
1.	CAPITAL COSTS ($1,000)								
1.1	Foundations	A-B	(5.000)	(5.000)	(5,000)	(5.000)	(5,000)	(1,000)	Provisional estimate
1.2	Erection of wharf	A-B	(5.000)	(5.000)	(5.000)	(5,000)	(5.000)	(1,000)	.do.
1.3	Water supplies	A-B	p.m.	(p.m.)	p.m.	p.m.	p.m.	p.m.	Technical survey needed
1.4	Iron and Steel plant	A	82,500	(82.500)	82,500	82,500	82,500	82,500	
		B	82,500	(92.000)	87.000	82,500	82,500	82,500	
1.5	Training of labour	A-B	11,000	(8,250)	8,250	11,000	11,000	11.000	
1.6	Accommodation for labour	A-B	3,500	(2,350)	2,350	3,500	2,350	3.500	
	TOTAL	A	107.000	(103.100)	103,100	107.000	105,850	99,000	CAPITAL COSTS X 0.10185
		B	107.000	(112.600)	107,600	107,000	105.850	99.000	
EQUIVALENT ANNUAL COST ($)		A	10,897.950	(10,500.735)	10,500.735	10,897.350	10,780.822	10,083.150	
		B	10,897.950	(11,468.310)	10,959.060	10.897.950	10,780.822	10,083.150	

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
2.	RAW MATERIALS								
2.1	Iron ore for blast-furnace	A	2,313.376	(5,005.953)	4,845.505	3,005.711	3,129.667	4,892.335	
		B	2,084.826	(4,780.766)	6,963.840	2,171.385	2,813.184	3,546.043	
2.2	Iron ore for steel works	A	97.110	(219.024)	212.004	131.508	124.956	208.575	
		B	87.516	(293.670)	259.038	95.004	112.320	208.575	
2.3	Manganese ore	A	132.552	(-)	-	-	148.788	-	
		B	132.552	(203.256)	170.208	-	148.788	-	
2.4	Coke for blast furnace	A	4,530.269	(4,350.146)	4,285.944	4,220.006	4,399.050	4,479.250	
		B	4,530.269	(4,821.120)	4,434.394	4,220.006	4,399.050	4,911.610	
2.5	Coke breeze	A	1,152.335	(1,037.163)	1,056.814	1,040.556	1,138.392	1,141.430	
		B	1,152.335	(1,450.304)	1,454.669	1,040.556	1,138.392	1,609.208	
2.6	Fuel oil for blast furnace	A	2,388.204	(1,136.874)	1,196.874	945.907	907.200	2,033.280	
		B	2,388.204	(1,338.120)	1,296.346	945.907	907.200	2,033.280	
2.7	Fuel oil, other purposes	A-B	718.673	362.408	362.408	286.416	263.250	619.515	
2.8	Electricity	A-B	1,680.924	(1,182.324)	1,014.000	608.400	608.400	2,276.430	
2.9	Scrap iron	A-B	-	(-)	-	-	-	-	From inside plant
2.10	Limestone for blast furnace	A	7.488	(155.812)	154.678	77.112	134.640	234.864	
		B	7.488	(1,167.350)	122.760	77.112	134.640	567.560	
2.11	Limestone for steelworks	A	68.800	(295.410)	293.260	146.200	146.200	120.400	
		B	68.800	(450.947)	293.260	146.200	146.200	120.400	
2.12	Water	A-B	p.m.	(p.m.)	p.m.	p.m.	p.m.	p.m.	Technical survey needed
2.13	Miscellaneous materials	A-B	1,024.240	(1,024.240)	1,024.240	1,024.240	1,024.240	1,024.240	
	TOTAL MATERIALS	A	13,513.971	(14,889.354)	14,445.727	11.486.056	12,024.783	19,567.215	
		B	13,275.827	(17,074.505)	17,355.163	10.615.226	11,695.664	19,453.577	

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
3.	CONVERSION COSTS								
3.1	Labour	A	1,174.061	(1,325,998)	1,151,040	1,381,248	1,381.248	1,385.852	
		B	1,174,061	(1,339,258)	1,162.551	1,381,248	1,381.248	1,392,781	
3.2	Other	A	7,526,075	(7,195,999)	7,195,999	7,195.999	7,208,144	7,281,550	
		B	7,526.075	(7,559,084)	7,222.883	7,195,999	7,208.144	7,281.550	
TOTAL		A	8,700.136	(8,521,997)	8,347,039	8,577.247	8,589.392	8,667.402	
		B	8,700,136	(8,898.342)	8,385.434	8,577.247	8,589.392	8,674,331	
4.	END PRODUCTS								
4.1	Transport of finished products	A-B	4,672.500	(4,067,000)	3,823.000	4,431,000	4,431,000	5,502.000	
4.2	Sale of slag	A	-	(-)	- 38.712	- 143,955	- 225,360	-	
		B	-	(-)	- 151.200	- 143.955	- 225.360	-	
	TOTAL END PRODUCTS	A	4,672.500	(4,067,000)	3,730.288	4,287.045	4,205.640	5,502,000	
		B	4,672.500	(4,067,000)	3,677.800	4,287.045	4,205,640	5,502,000	

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
5.	RECAPITULATION								Equivalent annual costs
5.1	Capital costs	A	10,897.950	(10,500,735)	10,500.735	10,897.950	10,780.822	10,083.150	
		B	10,897,950	(11,468,310)	10,959.060	10,897.950	10,780.822	10,083.150	
5.2	Raw materials	A	13,513.971	(14,889.354)	14,445.727	11,486.056	12,024.783	19,567.215	
		B	13,275,827	(17,074.505)	17,355.163	10,615 226	11,695,664	19,453.577	
5.3	Costs of conversion	A	8,700.136	(8,521.997)	8,347.039	8,577.247	8,589.332	8,667.402	
		B	8,700.136	(8,898.342)	8,385.434	8,577.247	8,589.392	8,674.331	
5.4	End products	A	1,672.500	(4,067.000)	3,730.288	4,287.045	4,205.640	5,502.000	
		B	1,672.500	(4,067.000)	3,677.800	4,287.045	4,205.640	5,502.000	
	GENERAL TOTAL	A	37,784.557	(37,379.086)	37,023.789	35,248.298	35,600.637	43,819.767	
		B	37,846.413	(41,508.157)	40,367.457	34,377.468	35,271.518	43,713.058	
6.	COSTS PER TON OF STEEL $ per unit	A	107.96	(108.51)	105.78	100.71	101.72	125.20	350,000 t of finished products
		B	107.28	(118.59)	115.34	38.22	100.78	124.89	

VII OTHER POSSIBILITIES OF INDUSTRIAL DEVELOPMENT

1. At present only a small proportion of the population of Mauritania are wage earners. Out of a total population of about 850,000 only 14,300 are employed.

The distribution of employment into major working categories is as follows:-

Agriculture and fishing	326
Mines and quarries	3,265
Industry of transformation	191
Building and public work	2,503
Water and electricity	124
Banks and commerce	435
Transport	841
Services	6,599
Total	14,289

The number of employees employed by the private sector is 8,090 and by the public sector 6,194.

With the exception of the group "Services" where most of the people are employed in central and public offices, the majority of employees are engaged in "Mines and quarries". Practically all these employees are concentrated in the work of the mining corporation "Miferma". The same is true of employees in the category "Building and public work", who have been mainly concerned in building the mining facilities of the iron-ore mine at Fort Gouraud.

Besides the mining industry there are at present practically no other industries. The category of "Industry of Transformation" in which about 1 per cent of total employees is concentrated represents in general the bakeries, garages, one printing-office, some tailors and two joineries.

Mauritania has at present very few technically qualified nationals as shown in the following tables:

	Nationals	Foreigners	Total	% of Foreigners
Directors	6	173	179	98
Managers	34	928	962	96
Qualified employees	137	324	461	70
Qualified workers	701	2,003	2,704	74
Others qualified	1,102	500	1,602	31
Workers	4,415	156	4,571	3
Total	6,395	4,084	10,479	39

	Nationals	Foreigners	Total	% of Foreigners
Professionals working on metals	14	71	85	83
of which: mechanics	10	35	45	77
welders	1	16	17	93
tin smiths	-	2	2	100
boiler-makers	-	4	4	100
locksmiths	-	1	1	100
fitters	3	13	16	80
Electricians	5	66	71	92
Professionals work.on building	243	388	631	60
of which: bricklayers	93	142	235	60
armoured concr.	29	32	61	51
joiners	32	91	123	73
pavers	23	4	27	15
painters	25	57	82	70
Plumbers	4	24	28	85
engine-drivers	10	17	27	62
drivers	27	21	48	44

Most of the qualified personnel are concentrated at Fort Gouraud in the iron ore mine and at Port-Etienne where they work in port and mechanical repair shops both owned by Miferma.

89. The decisive factor in increasing the national income of Mauritania is the mining of raw materials and possibly their transformation for export. The expansion of small-scale local industries is strictly limited by the small internal market and the sparse population of the country.

The most valuable raw materials at present and also in the near future are the rich deposits of iron ore at Fort Gouraud and the reserves of copper ores at Akjoujt.

On the other hand account must be taken of the lack of sources of primary energy, the lack of water for direct industrial consumption, the complete lack of Mauretanian technical workers and the very low local consumption.

As far as the copper ore deposit is concerned there is a strong possibility of reviving mining and ore dressing (up to the copper concentrate). The revival of mining activities may encounter considerable difficulty in securing the necessary amount of water (100-150 l/sec which would have to be transported from Benishab to Akjoujt (a distance of 120 km).

3. The question of the further transformation of iron ore is still more complicated, especially from the point of view of the inadequate supply of other necessary raw materials, water and lack of centres and markets. As has already been shown these circumstances put Mauritania at a considerable disadvantage as compared with other locations on the West African Coast as a site for an integrated iron and steel works. There exists however the possibility of installing a blast furnace plant to smelt some of the Société Miferma's iron ore to produce pig iron for export. The production would be based on the import of coking coal and the surplus of energy in the form of blast-furnace gas and coke oven gas might be used partly in the demineralizing process of sea water and partly as a source for the production of electric

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power and refining the by-products of the coke evens.

Under Mauritanian conditions the production of pig iron should be done preferably on the basis of sorted high-grade iron ore, without agglomeration or pelletizing.

Should the production of pig iron attain 1 million tons per year (and this should be considered as the economic limit for this type of production - two blast furnaces at cca 1,000 m^3), approximately 900,000 tons of coking coal would be imported per year. Under these conditions a series of coke ovens would have to be installed to obtain furnace coke, in addition to which it would be necessary to set up all the installations for extracting by-products of coal. The coke ovens should produce about 700,000 tons of coke per year. The greatest part of it (cca 600,000 tons) would be used in the furnaces and the remaining part of fine coke might find other industrial uses.

This would imply the building and equipping of wharves to permit the unloading of products necessary for pig iron processing and the loading of export products, without interfering with the loading of ore carriers. The necessary amount of limestone is possibly available, not too far from the Miferma railroad, in the region of Atar.

This type of production would result in an excess of energy in the form of blast-furnace and coke-oven gas totalling about 1,400,000 gigacalories.[x/] Of this approximately 500-600,000 G.cal would be used for demineralization of sea water (needed in the processing of pig iron) in a combination which would provide at one and the same time abundant and relatively cheap electricity, which might also encourage the establishment of other local industries. The remainder, i.e. approx. 800,000 G.cal would be available either for the production of electric energy or for further industrial use. This would have a favourable influence on the general energy situation in Mauritania.

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x/ 1 Gigacalorie (Gcal) = 10^6 kcal

The by-products of coke production ammoniac gas, phenols, tars, etc. might be used as a basis for the production of fertilizers, (sulphate of ammonium), insecticides or dyes, resins etc., and this might help to increase somewhat the local agricultural production and might contribute to the development of local small scale industry.

These general outlines are based on technical possibilities. Their realization would require, of course, a more detailed study, especially in regard to the import of coal and the possibility of exporting pig iron.

VIII CONCLUSIONS

90. A knowledge of the geology of the I.R.M. and of the mode of origin of the different minerals present (a study of the metallogenic provinces and epochs of the country) forms the basis of any real appraisal of its mineral resources. Although much is known in this respect, yet many important problems are still unsolved and a more complete picture showing the correlation of the geology of the country with its mineral resources should be made. The publication of a geological map on a scale of 1:1,000,000 now being undertaken, will greatly help in this direction.

91 Water for both the domestic use of the people and for industrialization purposes has been available so far and it seems possible that enough water will be found to enable the nomads to settle down and raise their livestock. It is recommended that dams should be built at suitable places in the alluvial deposits down to bed-rock to preserve scarce but valuable rain water. A survey of water resources is essential, however, to see how far they are capable of meeting long term requirements or whether desalination will be necessary to supplement them.

92. The possibility of using solar energy should be examined and it is recommended that a UN Special Fund Project should be initiated for this purpose.

93. The inventory of mineral resources showed the presence of appreciable amounts of different minerals and good prospects for mineral discoveries in both the crystalline rocks and in the more recent sedimentary series is anticipated. Indeed there is little doubt that the minerals output will make an increasing contribution to the national production of I.R.M. in the future.

Iron ore output reached about 5 million tons last year of a very rich ore from Fort Gouraud. The copper-gold deposits of Akjoujt are about to be exploited. Other iron and copper deposits are in sight. Gypsum, beryl, and chromite have been partly explored and are expected to be exploited in the future. Limestones and clays are present in great amounts and are potential assets for future uses, but analyses of these should be made available. Both phosphates and black sands are potential deposits for future exploitation. The erection of a superphosphate factory depending on the phosphate deposits of Civé and a sulphuric acid industry depending on the Akjoujt ore is a possibility for future prospects and calls for a feasibility study. Gold, molybdenum, wolframite, fluorspar, vanadium, nickel and radio-active minerals are known to occur in I.R.M. Future exploration work is needed for their appraisal and for spotting new deposits.

94. There is a strong possibility of finding carbonaceous deposits, which are much needed by I.R.M. in the Taoudenni basin and the oil possibilities of the country are not completely explored. The Government is advised to carry out a programme to search for local coal deposits and to invite interested people to continue exploring its oil possibilities, putting at their disposal all the available data.

95. It is to be noted that a prospection project should be carried out right to a final conclusion. For instance, anomalies discovered by airborne surveys should be followed up until it is certain that they are to be disregarded for the present or are proved to be potential economic deposits. Airborne surveys should be followed by ground geophysical surveys and/or by geochemical surveys and then by drilling, whenever promising anomalies are ascertained. The Government of I.R.M. is advised to find a way to drill the two large magnetic anomalies, which are covered by sand dunes at Aguilat-Fay, as soon as possible. Also to investigate on ground all the exposed anomalies discovered from the air.

96. While a pig iron exporting industry is a technical possibility the detailed cost calculation presented in this report shows that Mauritania is at a considerable disadvantage as a site for integrated iron and steel works.

97. One of the basic problems of I.R.M. is the lack of qualified technicians that can satisfy at a high level the technical requirements of mineral appraisal and of industries based on mineral resources. Efforts should be made to fill this lacuna as soon as possible. This is a necessity for further progress.

98 The French "Fonds d'Alide et de Coopération" (FAC) have contributed greatly in exploring different potentialities of I. R.M. and in executing prospection projects. A greater part of the projects included in the present four-year plan is actually financed by the same organization. Some of these projects are mentioned in previous chapters.

99 The case of I.R.M. is an example of the fact that usually the countries, which are least developed receive the least technical assistance from the United Nations.

ECA, the Technical Assistance Board or Special Fund can help with regard to:

(a) Expanding the present centre in Dakar for the application of solar energy.

(b) The assessment of the mineral potentials of I.R.M.

(c) Assistance with regard to the running of the Geological Survey and Department of Mines, of which a nucleus already exists.

(d) Assistance with regard to problems connected with mining legislation.

His Excellency Dr. Alpha, the Minister of Economic Affairs asked the Director of Mines to prepare a request for assistance concerning a mineral appraisal of the country but it is understood that they are in need of advice as to its formulation.

Some other remarks and more detailed information are given in the previous chapters.

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