CPRM

COMPANHIA DE PESQUISA DE RECURSOS MINERAIS

- CPRM -

MINERAL RESOURCES DEVELOPMENT COMPANY

REPORT ON MINERAL EXPLORATION

OF POTASSIUM SALT - ROCK SALT

IN THE AREA ADJACENT TO THE NATIONAL RESERVE AREA

- STATE OF SERGIPE -

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JULY, 1972

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The present Report on Exploration of Potassium salt and Rock salt deposits, occurring in areas adjacent to the National Reserve Area, in Sergipe, was written by the technical team of CPRM's Directorship of Operations, under the orientation of the Technical Director of Operations.

Valuable contributions from DNPM's Potassium Project and from Petrobrás are acknowledged, permiting CPRM's interpretation and integration of the data, obtained in its own laboratory and field works.

CPRM is grateful for its personnel's comments and collaboration pertaining to this work. It submits to DNPM, under the Brazilian Code of Mining, this Report which embodies the mining elements needed to the rational geoeconomic interpretation of the deposits. It aims to establish the parameters for the greater understanding of the problem concerning the integrated exploitation of the Sergipe evaporites.

JULY, 1972

I - INTRODUCTION

CPRM - Companhia de Pesquisa de Recursos Minerais (Mineral Resources Development Company), raises to the consideration of the Departamento Nacional da Produção Mineral - DNPM (National Department of Mineral Production), in the accomplishment of the Brazilian Code of Mining the qualified Report on Mineral Exploration referring to 29 areas granted to the exploration of potassium salt and rock salt, in the region adjacent to the National Reserve Area, defined by Decree N. 61,157, of August 16, 1967.

Wide comprehension of the technical, economical and commercial problems, encircling regional economic deposit of evaporite salts is based on the appraisal of every geological-stratigraphic parameter and on mineral economics (a conjuncture of national and world markets), fully authorizing the definition of the feasibility limits for economic mining, - a conclusion of the present report.

Requests for mineral exploration addressed to DNPM were set mainly on the revaluation of data obtained from Projeto Potássio - DNPM's (Potassium Project) as well as from surface elements of the neighboring region, furnished by Petrobrás, which, after dully compared, they enabled CPRM to confidently consider the continuity of the Sergipe evaporite beds beyond the area of national reserve thus determining a magnitude for the integrated reserve, a major step the nation's implantation of an industry of potassic fertilizers to meet domestic demand and, perhaps, to interfere in the external market.

Being extremely important to arrive at a precise definition as to the Sergipe evaporite beds extension and being equally relevant to know their possibilities in terms of integrated reserves for they already were object of previous bidding by the Federal Government through CPRM, it is thoroughly necessary to determine and to avaluate the mineral reserve - a task undertaken by CPRM - complementary to the work namely the Potassium Project in the National Reserve Area, developed by DNPM.

There are few remnant aspects to be defined. Those are bound to be properly analysed during the deposit development phasis. It is of common awareness that the volume of data already disposed of for the presents areas, allied to extrapolation of intensive and extensive knowledge of the National Reserve Area will ensure the same geological-stratigraphic condition, not allowing any other technical connotation besides considering sufficient the number of existing elements of definition for the geoeconomic equation of the referred deposits, in terms of mineral exploration.

In view of the above and from what will be further exposed in the present report, CPRM believes that the presented data - a basis for the reserve evaluation - are in agreement with the Brazilian Code of Mining, as far as the acquaintance of the mineral deposits is intended.

Facing the mass of elements of DNPM's Potassium Project, they reflect the accomplishment of Article 30, paragraph a of that code.

II - REVIEW

With the development works carried out by Petrobrás in the fields of Carmópolis, Siririzinho, Riachuelo and Santa Rosa de Lima highly significant facts were revealed concerning the geology of Sergipe Basin.

At first, surface works, and later, geophysic surveys mainly of the seismographic reflexion type plus pioneer drilling for oil, made evident that the search for oil brought up valuable supplementary information concerning local occurrence of a new mineral riches: Potassium.

In 1964/65, when Petrobrás drilled the areas of Carmópolis and Santa Rosa de Lima, in the Ibura Member, Muribeca formation, several potassium salt (carnallite, sylvinite and rock salt) horizons were observed.

Evaluation of achieved knowledge led the government to constitute (Aug. 16, 1967, Decree N. 61,157) a National Reserve Area in Sergipe, with 425 km^2, limited by parallels 10° 35' 12" and 10° 45' south latitude and meridians 36°55' and 37° 15' 15" west longitude.

Such area comprises the oil fields of Carmópolis, Siririzinho, and port of Riachuelo, as well as two distinct areas, with sylvinite deposits called: Santa Rosa de Lima - Siriri and Taquari-Jurema-Vassouras which are separated from each other by the oil field of Siririzinho.

The National Department of Mineral Production (DNPM) was given exclusiveness of exploration in this area, according with paragraph N. 1, article 2 of Decree N. 61,157.

In the beginning of 1968, DNPM created the Potassium Project assembling a high level national team besides a renown foreign technical adviser, and building laboratory facilities to support chemical research, in Aracaju.

For those activities, DNPM received substantial help in the form of financing, from BNDE (Brazilian Development Bank), and carried out work in a rhythm consistent with the national interest, excelling obstacles to fulfill the chronogram previously established for the approved Plan of Exploration.

On May 19, 1970, Potassium Project's presented his final report to the Director General of DNPM. It was basically the result of detailed geologic mapping of the National Reserve Area, geophysical prospecting and drilling program totalling 23,148 m at 25 location in the areas of Vassouras, Taquari, Jurema, Miranda, Santa Rosa de Lima and Siriri.

Decree N. 66,455 of April 15, 1970 granted the Mineral Resources Development Company - CPRM - the results of the exploration works accomplished, and their entering as part of CPRM's capital subscribed by the Federal Government was assured.

These results, after being incorporated by CPRM, are object of a public bidding, according to the conditions settled by CPRM in view of the decree which dealt with the Company's constitution.

Since 1970, CPRM maintains in Aracaju, Sergipe, and at the Company's office in Rio de Janeiro, technical teams conducting laboratory work to broaden previously known aspects of the matter, seeking to dispel doubts emerged during the processes of complementary exploration and bidding, including a circumstancial piece of work on the Potassium Market Analysis - National and International Conjunctures.

Keeping a close approach to the matter, along with new detailed studies of the National Reserve Area, besides underground information given by Petrobrás, allowed the government to consider the national interest there is in the incorporation of bordering areas, in which salt deposits have been observed, to those of the Reserve Area and to guarantee the success of giving to the country a large size industry of potassium fertilizers.

Within the present framework of the subject, contemplating the integration that has occurred, CPRM has totalled 29 requests for exploration of potassium and rock salt, directed to and dully authorized by DNPM now submitting for DNPM's consideration the competent Reports of Exploration.

III - GEOGRAPHICAL SETTING

III.I - Physiography

Soluble salt deposits of the Sergipe Alagoas sedimentary basin underlie an area composed of the following physiographic units:

a) Coastal area;
b) Tidal flats;
c) Alagoas lake area, in which lake developments may be controlled by faults;
d) Central tableland, which occupies central Sergipe and a major part of Alagoas and is formed by flatlying rocks of the Tertiary Barreiras Formation.
e) Southwest highland areas, in which shales, sandstones and limestones crop out, in central and western Sergipe.

Aracaju is the most important city, as far as this report is concerned. Aracaju's main physiographic feature comprises lowlands with ancient coastal lines showing that the areas surrounding the city were covered by epicontinental sea in recent geologic time. There are few saline-works near the city.

In the group of investigated areas, which are the reason for the present report, the land is moderately rolling, showing dominant froms of low hills and plateaus, with average height of approximately 100 - 150 m above sea level.

III.II - Location and Acess Routes

The continental border of the Sergipe-Alagoas sedimentary basin, with a medium width of 20 km, extends from Vaza Barris River (SW of Aracaju) to approximately 50 km northeast of Maceió, in a global extension of 350 km. The eastern limits of the basin which are not yet defined, become united in the interior of the plataform.

The region studied in the present report (45,000 ha) lies totally within the state of Sergipe, comprising three groups of areas extending to the southwestern, e astern and western portions of the National Reserve Area shown in the annex map.

The first group contains 12 areas of 2,000 ha each, named from A to L. It consists of a 24,000 ha strip of land north of the City of Aracaju, distant from it about 40 km, completely laid in the districts of Japaratuba, Siriri and Capela.

The second group, made up of 13 areas of 1,000 ha each, described as areas 1 to 13 consists of a 13,000 ha strip of land located some 30 km northeast of the city of Aracaju, e ast of the Reserve Area, imbedded in the districts of Japaratuba, Carmópolis and Santo Amaro das Brotas.

The third group composed of 4 areas of 2,000 ha each named from M to P is located 30 km northeast of Aracaju, south of the Reserve Area, in between rivers Pomonga and Siriri, laid in the districts of Santo Amaro das Brotas, Rosário do Catete, General Maynard and Pirambu.

Sergipe Alagoas Basin is served by a network of roads, most of which are dirt or gravel. A federal paved road, BR 101, runs along the axis of the basin linking the cities of Aracaju and Maceió, both located in the coast.

The basin is also served by raioroad belonging to the Rede Ferroviária Federal S.A. (Federal Railway System) which connects the towns of Cotinguiba and Carmópolis, both located in the Reserve Area, and Aracaju.

Acess to the three groups of investigated areas may be made through any of the following routes, from Aracaju:

- A to L areas may be reached after 69 km on paved BR-101 or 67 km by railway (RFFSA), which connects Aracaju and Propriá.
- 1 to 13 areas may be approached after 54 km on paved BR-101, and then on unpaved road, after 5 km, to the town of Japaratuba and from it, on unpaved road, after 2.5 km, to Pirambu.
- M to P areas may be reached after 28 km on paved BR-101 to Maruim and 18 km of unpaved road to Planta.

Each of the routes being followed, every area of the three groups may be visited using gravel roads and trails which link the head houses of the various farms in the region.

III.III - Climate, Vegetation and Hydrography

The region is inserted within the climate conditions of the Brazilian Northeast, with definite aspects of vegetation.

The basin, in the littoral region has mean annual temperature of approximately 24°C. With a few exceptions, annual variations around the average are few, rarely exceeding 5°C.

Dominant climate in the region, according to Köppen is of the type As', with a rainy season extending from april to august and reaching maximum rainfall in the month of june.

Mean annual precipitation stays between 1,000 and 1,800 mm. Litoral vegetation is predominantly of coconut trees, presenting characteristics of mangrove swamps in the flat areas, while in the highland areas scrub trees and xerophile bushes grow. In the hill sides of the valleys remnant tropical forests predominate while the low-lying areas are occupied by green sugar cane plantation.

The hydrographic system of the region is mainly represented by the rivers Sergipe, Japaratuba and Poxim. The drainage system bears west-east direction with final course toward the Atlantic Ocean.

With the exception of the Sergipe river which allows continuous navigation in its medium and lower courses,all other rivers are restrictively permissive to small boats. Besides the above mentioned rivers, several lakes and lagoons represent sources for water supply in the region, deserving to be mentioned Tiririca, Grande Jaguaribe and Catu lakes.

III.IV - Port

Aracaju, capital of the State of Sergipe is located some 40 km from the region where salt deposits lie, is has its own port, easily attainable by federal paved road BR-101 and by railroad of RFFSA (Federal Railway System).

Port of Aracaju, with seven warehouses to dock ships is reached by a narrow channel whose depth in tide does not exceed 3 m, allowing operation of just small 4,000 to 5,000 TDW boats. Port facilities are being constructed (a maritime terminal is under way) one mile ahead of the existing dock warehouses, which will permit the operation of freighters up to 30,000 TDW, giving chance to greater flowage facility for the potassic fertilizer, and eventually, for the rock salt to be produced in Sergipe.

The implantation of such maritime terminal will involvea 5 to 8 million dollar investment.

With possible alternatives for the sea outlet of the mentioned production, ports of Maceió and Salvador can be incorporated into a global economic study as their distance from the Sergipe mining region is 280 and 360 km, respectively, by rail and paved road.

Port of Maceió, which is nearer, occupies a jetty 420m, long being connected to another jetty about 120 m in length and 20 m in width.

An internal railway has direct connection with RFFSA. Minimum depths along the jetty vary from 5.2 to 8.2 meters at low syxygy tide. Presently the operation of ships up to 10.000 TDW is possible for that port presents idle operational capacity.

The port of Salvador has an extension of 2,070m and that already includes ore and coal docking facilities with depths of 10 m, as well as dock facilities for flammables in identical conditions. It also has a varied choice of cranes up to 30 tons as well as a steam floating hoist with the hauling capacity of 120 tons being able to dredge up to 12 m depth.*

*Brazilian Navy - D.H.N.
Directorship of Hydrography and Navigation.
Roteiro - Brasil
D.H 1-8
1968

Presently, operation in the port of Salvador is possible for 30,000 TDW ships.

Before a deeper economic feasibility study can be achieved it is impossible to define which of the three port alternatives applicable at medium or long term will best meet the economic interest of the undertaking.

It should be remembered that such appreciation will regard the compulsory implantation in the port of Maceió of an adequate substructure to cope with rock salt production and commercialization made by Euluz-Dupont group.

On the other hand, utilization of the Salvador port, the most distant from Aracaju will allow the interlacing of the petrochemical pole of Aratú and the salt complex, which may result in a more expressive component for the dynamics of the problem.

At any rate, however, it is evident that the economic feasibility of displacement of great masses of fertilizers and rock salt will have to necessarily count on an efficient port system, ensuring loading and transport according to a scale economy level, which occurs in similar cases already solved in other parts of the world.

IV - GEOLOGY OF THE SERGIPE ALAGOAS BASIN

IV.I - Regional Geology and Stratigraphy

Regional geology was raised to reasonable level of comprehension due to detailed geologic mapping, geophysical surveys, drilling and underground geology, etc, realized by Petrobrás, especially after 1957, with special emphasis on sediments of mesozic basins, important for oil.

The stratigraphic sequence of the basin comprises, besides the Precambrian crystalline basement rocks, Paleozoic, Mesozoic and Cenozoic sediments (See chronostratigraphic chart - Annex 3)

1 - Basement Complex

Lithostratigraphy of the Basement Complex was defined by geologic surveys developed in the horst which separates the sedimentary portion of Sergipe/Alagoas from the Basins of Recôncavo, Tucano, Jatobá.

Geology of the referred crystalline area is rather complex, the greater lithologic units were dated Precambrian to Paleozoic in age and are represented by:

1.1 - Gneiss of the Brazilian shield and Paulo Afonso migmatite;
1.2 - Metasediments of the Miaba and Vaza-Barris groups;
1.3 - Intrusives of the Pernambuco/Alagoas batholith;
1.4 - Estância Formation;
1.5 - Extrusive and hipoabyssal rocks.

1.1 - Gneisses are the oldest rocks in the area and their age is attributed to the lower Precambrian. Petrographically, those rocks are composed of a biotite gneiss with pink, dark or light grey edging. It is present in all of the horst being more frequent south of Sergipe, north of Alagoas and Pernambuco.

Paulo Afonso migmatites are mixed type gneiss-granite rocks originated from injections of acid rocks in gneiss. They crop out in the region of Paulo Afonso and close to acid intrusive masses.

1.2 - Miaba group is represented by existing rocks between the gneiss and Macambira reverse fault, located around a circle-like window surrounding Itabaiana town in Sergipe. This group was divided into three formations named according to the sequence of deposition: Itabaiana, Jacarecica and Jococa, representing the deposits at the southern flank of the Sergipe geossyncline, active during the Middle Precambrian.

Vaza-Barris Group is represented by a group of highly folded and foliated rocks, composed of phyllites, metagraywackes, marbles intercalated with chlorite, sericite-schist, metasandstones, metasiltites and some metavolcanic rocks. It is divided into the following formations, ordered according to their relative age: Capitão, Palestina, Olhos d'água, Frei Paulo and Ribeirópolis. Area of occurrence of this group is roughly located, between parallels which cut across Maceió, to the north and Aracaju, to the south. Their age is admittedly the same as that of the Miaba group.

1.3 - Occurrences of intrusive rocks are located north of São

Francisco river and become part of the Pernambuco/Alagoas batholith locally comprising rocks of an intermediate group, predominantly acid. They crop out more extensively than the gneiss, and their age is 500 to 600 million years.

1.4 - Estancia Formation - It consists of fine sandstone and sandy, micaceous siltite, red to purple, greysh green, with intercalation of ardose and thin beds of multi-composed conglomerate. Its age is uncertain, possibly Cambrian or Silurian. It rests on a heterogenous unconformity, over the gneiss and on a non-conformity over the rocks of the Vaza Barris group. Its area of occurrence extends south of the Vaza Barris river.

1.5 - Basic rocks occur in small extensions in various points of the batholith. Diabase occurs in Santa Luzia (Sergipe). Acid rocks are present in more restricted areas and they are represented by andesite, rhyolite and rhyodacite.

2 - Lower São Francisco Group

This group is represented by a pack of non-marine sediments which crop out northeast of Sergipe and southeast of Alagoas, appearing in Japaratuba-Mirim river valley (Sergipe) up to the Coruripe Valley (Alagoas), limited in the base by rocks of the Basement Complex and on top by the euxinic sediments of Muribeca Formation.

It is divisible into two great units which are distinguished by their lithostratigraphic characteristics.

These two units are: Lower - Igreja Nova Subgroup; Upper - Coruripe Subgroup.

2.1 - Igreja Nova Subgroup - This subgroup is best exposed in the neighborhood of Igreja Nova (Alagoas) and it represents a basal unit of the sedimentary column of the basin with approximately 70 m of thickness, located stratigraphically between the basement, in the lower part and the Coruripe sub group in the upper part. This subgroup is divided into five formations named below, according to their order of deposition.

2.1.1 - Batinga; 2.1.2 - Aracaré; 2.1.3 - Candeeiro; - 2.1.4 - Bananeiras; 2.1.5 - Serraria.

2.1.1 - It is characterized, both at surface and underground by the occurrence of rhytmic siltites, paraconglomerates and coarse sandstone. The lithofacies are gradational, the finer material occupies the upper part, the coarser predominates in the inferior portion of the formation.

This formation is subdivided into three members:

a) Atalaia; b) Mulungu; c) Boacica.

a) Atalaia Member includes the coarse clastics section (immature and coarse kaolinized sandstones, white in color) of Batinga Formation which occur south of Sergipe, lying over the basement.

b) Mulungu Member - It is composed of pebbly conglomerate debris, boulders of igneous and metamorphic rocks, with varied form and degrees of roundness, randomly immersed in a sand-siltic matrix, with changing tones from green to light brown. They occur more frequently south of Alagoas.

c) Boacica Member - It is characterized by the occurrence of laminated siltites - either fine and regular, similar to a varvite or with cross stratification and frequent gradations to sandstone and shale. They are best exposed in the Boacica river valley (Alagoas).

2.1.2 - Aracaré Formation - It comprises all of the sedimentary section overlying siltites of Batinga Formation and underlying red shales of Bananeiras formation or sandstones of Candeeiro formation. Generally, presence of silex is diagnostic for the reconaissance of the unit.

Usually, the most important outcrops in the left margin of São Francisco river are located between Aracaré hill and Borges Farm.

At the surface, the basal part of the unit shows, most of the times a predominance of brilliant black shale; in the middle portion there is a zone of radioactive peaks; and on the upper part silex occurrences are predominant. Permian age is attributed to these sediments.

2.1.3 - Candeeiro Formation - The sediments of this unit are not recognized at the surface. The unit is constituted of white, pink to grey and red in color, fine to medium grained sandstone, with coarse intercalations, locally containing granules and subangular pebbles of silex. It occurs at the surface north of Perucaba river up to the vicinities of São Miguel dos Campos, Alagoas. This formation corresponds to a fraction of the upper part of Lower Japoatã formation. The formation is admittedly Neo Jurassic in age.

2.1.4 - Bananeiras Formation - It is constituted of siltic and micromicaceous shale and red, brown to maroon, light green, spotted clay without fissility. Locally, turboglyphs, other basal marks and some possible contraction fissures were observed. The outcrops ot this unit are visible in the western border of the basin, in Muribeca, Sergipe up to the south of Junqueiro, Alagoas. Underground, occurrence is regional, the formation being eroded only in the higher areas of the basin. The greater thicknesses are show in the vicinities of Carmópolis (Sergipe), thining southwards.

The lower contact of the formation corresponds to a prominent erosional unconformity.

2.1.5 - Serraria Formation - This unit is composed of white feldspatic, kaolinic and sometimes conglomeratic sandstone, grey to red in color, medium to coarse grained, poorly to regularly sorted (frequently with subangular grains).

The upper part of the formation presents sandstone with bands of grains and pebbles and numerous occurrences of silicified wood. Inclusions or even layers of carbonaceous matter are found in association with the sandstone of the formation.

Cross stratification may be considered a characteristic of this unit. The outcrops of the formation are distributed along the western border of the basin, from Muribeca, Sergipe to Piauí river. Underground occurrence is common, only being absent in the regional heights which suffered intense erosion at the end of Lower Cretaceous.

Judging from the position of stratigraphic relations, we refer these sediments to Lower Cretaceous, Upper Jurassic in age.

2.2 - Coruripe Subgroup - It is represented by a sedimentary packing composed of coarse clastics with some benches of intercalated non-marine limestone.

The unit comprises all of the sediments located between the base of Muribeca formation and the top of Serraria formation.

The subgroup was divided into six formation, named in order of sedimentation as follows:

2.2.1 - Barra de Itiúba;
2.2.2 - Penedo;
2.2.3 - Rio Pitanga;
2.2.4 - Morro do Chaves;
2.2.5 - Coqueiro Seco;
2.2.6 - Ponta Verde.

2.2.1 - Barra de Itiúba Formation - It is composed of a monotonous sequence of shales, with relatively thin intercalations of sandstone, siltite and limestone. At the surface, due to easy alteration of shale, outcrops are rare unless when preserved by intercalations with beds of sandstone, siltite or limestone.

The percentage of sbale seems to be higher underground are needle-like. The shales and smooth, green to black in color partly calciferous, and containing small limstone nodules. Sandstone of this unit is fine and well sorted, usually clean, light colored, from grey to white. The limestone is very hard, sometimes micro crystalline or made of ostracoidal coquinas.

The formation is exposed along the Japaratuba and Japaratuba Mirim river valleys. The thickness is variable. In Sergipe, the formation seems to be truncated by an Eo-Cretaceous - unconformity.

The unit has a relatively reduced thickness: not usually beyond 500 m. In Alagoas, where a more continuous sedimentation might have occurred, it reaches a thickness of 2000 m.

The age of Barra de Itiúba Formation is referred to as Lower Cretaceous.

2.2.2 - Penedo Formation - It is composed of thick bench sequences of poorly sorted sandstone, with intercalation of shale and siltite. The sandstone is white to grey and yellow in color. Grains of feldspar, altered to kaolin give the sequences them a white dotted characteristic.

The sandstone show, most of the time, cross stratification. The laminated and needle-shaped, partly micaceous shale has varied colors, from light green to dark grey. The siltite usually greyish and micaceous, occur irregularly distributed throughout the section. Locally, presence of impure argillaceous limestone is observed. This formation crops out in discontinous areas, from Japaratuba valley, in Sergipe, to the Coruripe river valley, in Alagoas. Average thickness is around 800 m. Its age is attributed to lower Cretaceous.

2.2.3 - Rio Pitanga Formation - It is characterized by the occurrence of coarse clastics, predominantly formed in talus and alluvial fans. It is usually formed by argillaceous conglomerate and multicomposed breccia, green to red in color and closed, usually hard breccia.

The formation crops out in discontinuous be~~r~~wches in the western border of the Sergipe/Alagoas Basin, from Propriá to Muribeca, in Sergipe.

Underground occurrences of this unit are recognized from the areas of Itaporanga and Riachuelo up to Taquari, in Sergipe.

The thickness is just variable, and according to the greatest beds, around 800 m, observed in the external borders of the Lower Japaratuba, in Sergipe.

In Alagoas no occurrence of this formation is known. Its age is inferred as Lower Cretaceous.

2.2.4 - Morro das Chaves Formation - It is characterized by the occurrence of limestore benches and reefs, beds of shale, limestone and greatly chalky coquinoid marl light grey in color, white to pink.

Beds of smooth micromicaceous shale, green to grey, partly calciferous and siltic, intercalated with fine to medium, generally calciferous sandstone, grey and with occasional coarse and conglomeratic horizons occur through the partly predominant diagnostic lithology.

In Sergipe, outcrops are known in the vicinity of Muribeca, Visgueiro, in the Riacho dos Pilões, near Japoatã and in the Morro do Chaves, near Propriá.

In Alagoas, in the São Miguel river valley and in Pedreira, southeast of Porto Real de Colégio outcrops may be studied. The area of Japaratinga to the north of Alagoas, to the area ofBaixa Grande, in Sergipe.

There, the thickness does not exceed 200 m and it reaches, in Alagoas, approximately, 1,500 m. Its age is believed to be Lower Cretaceous.

2.2.5 - Coqueiro Seco Formation - It is composed of monotonous alternations of sandstones, shale and siltite. The sandstone is fine to medium grained, with coarse and conglomeratic levels.

There are frequent siltic intercalations through these sandstones. The shale is generally light brown in color, betuminous to sub-betuminous, partly siltic and partly laminated, containing fine intercalations of brown dolomitic limestone cryptocrystalline to microcrystalline in form.

Due to strong facies changes observed throughout the unit, different lithologic types are evident, thus allowing the individualism of four members:

a) Arambipe;
b) Francês;
c) Roteio and;
d) Manguaba.

a) Arambipe Member - It is characterized by the predominance of sand and subrounded, medium to coarse grained sandstone. Relative abondance of kaoline, in lenses or disseminated, gives the member a whitish color, which is peculiar to it.

b) Francês Member - It is characterized by the abundance of coarse grained sand horizons, quartz fragments and orange feldspar intercalated with lenses and benches of brown shale, foliated, sub betuminous to betuminous.

c) Roteio Member - It is constituted of thick horizons of brown shale, locally associated to lamminae of light brown limestone.

d) Manguaba Member - It is characterized by light brown, sub betuminous to betuminous shale, with frequent intercalations of brown, cryptocrystalline limestone, laminated and generally dolomitic, grading to dolomite, abundance of which serves to distinguish this unit from all others.

Near the lower and upper limits there are beds of medium to coarse sandstone, kaolinic to feldspatic and poorly sorted.

The sediments of Coqueiro Seco Formation are observed in the area of Jequiá to Maceió, in Alagoas. Greater thickness coincides with regions structurally downwarped of the Alagoas graben. The outcrops of the unit are frequent but denounce strong weathering attack which, in general, left the sediments poorly preserved or transformed into soil. The age of the sediments is considered to be Lower Cretaceous.

2.2.6 - Ponta Verde Formation - It is composed predominantly of gray to green needle-shaped shale.

Fine occasional sand-siltic intercalations occur through the typical and predominant lithology. This formation has not been identified in outcrops up to this date, while it occurs underground, south of the lowest structure of Alagoas, within the area comprised by Pilar, Mal. Deodoro, Maceió and Ferrão Velho. Average thickness varies from 200 m. Its age is attributed to Lower Cretaceous.

3 - Muribeca Formation (Aptian)

The term Muribeca was a designation given to sediments cropping out near Muribeca town in Sergipe. Later, wrong correlations induced to a mistake which included the evaporites and associated rocks, in the Muribeca Formation. The name Muribeca later became well known due to the economic importance of this formation as a main producer of hidrocarbonates.

A poor fauna of ostracods occur in this formation, namely the non-marine Crythexidea. Some fossils have been observed, mainly represented by moulds of fish, mollusks and rests of carbonized plants. From these fossils, Aptian age is inferred to the layers of this unit.

In the Sergipe sedimentary basin, the Muribeca formation is represented by the groups of sediments which occur on top of the units composing the Lower São Francisco River group or even the crystalline complex.

It is a typical underground formation and it has been deposited in an essentially evaporitic environnent.

The members which comprise this formation have conformable contacts, whereas unconformities have been observed in the upper and lower limits of the formation.

We may generally separate each period in which environmental conditions gave chance to deposition of evaporites-anhydrite and soluble salts - in Muribeca formation: Maceió member of Paripueira evaporites the older, and Ibura/Oiteirinhos evaporites the younger.

Occurrences of soluble salts in the Ibura Member, in the Santa Rosa de Lima, Taquari, Vassouras, Aguilhada, Timbó, Ilha das Flores and Mosqueiro domaines contain mineralogic identity and, apparently, configurate one sole saliferous basin.

Muribeca formation is composed of betuminous shale, laminated limestone, evaporites, sandstone and conglomerate. According to major and minor frequency of the lithologic types, this unit may be subdivided into five members, as follows.

a) Maceió Member - It is formed by intercalations of fine to coarse grained, light grey to brown, calciferous and feldspatic sandstone with intercalations of brown dolomitic sandstone. Along the base of the member a good key stratum including laminated limestone occurs with shale, being informally denominated, Mundaú limestone.

   A layer of rock salt occurs through the Maceió member, being called Paripueira evaporites.

b) Tabuleiro dos Martins Member - It is characterized by the predominance of partly betuminous and partly siltic brown shale with intercalations of dark brown limestone. Occasional developments of sandstone and siltites are registered.

c) Carmópolis Member - It is a unit essentially made up of usually coarse to very coarse grained clastics composed of conglomeratic sandstone to multicomposed conglomerates, with an argillaceous calciferous matrix and with intercalations of usually hard, calciferous shale, grey to dark brown in color.

d) Ibura Member - It is characterized by containing the zone of soluble salts which extends troughout the basin. Over this zone the sediments are classified according to intimate and continuous intercalations of grey to brown shale and limestone, permeated by cryptocrystalline anhydrite layers, bluish grey in color, and associated with micaceous, calciferous siltite, grey to dark grey, and some fine to occasionally medium grained, calciferous sandstones, showing apparently very weak porosity. Locally a hard dolomitic limestone is present, grey to dark grey, light ivory and brown in color, grading into dolomite.

Below the saliferous zone, some limestone and dolimite occur associated with anhydrite, with varying thickness of 150 to 600 m.

The anhydrite horizons of this member are formed by nodular anhydrite, cemented with calco-argillaceous material, conferring to the group a brecia-like character which is to common all clastics of the Ibura member.

e) Oiteirinhos Member - In this member fine clastics predominate, represented by grey to brown shale, with interlaminations of light brown limestone and local intercalations of sandstone and siltite. It deserves to be mentioned that the key stratum named Two Peak Anhydrite, composed of radioactive shale, was identified in this member.

As Muribeca Formation is the most important, as far as this Report is concerned, we present further comments about its stratigraphic setting.

Muribeca Formation extends throughout great portion of the Sergipe/Alagoas Basin. In Sergipe, only the sediments which compose the upper part of the formation are present, the opposite being true in Alagoas.

Carmópolis and Ibura member are the only present members in Alagoas and in Sergipe. However, in Alagoas, Ibura member occurs at swall depths, having been almost completely removed by erosion. Oiteirinhos member, on the other hand, appears only in Sergipe. The thickness of the unit is approximately variable, the thickest beds being observed in Alagoas. Average thickness of about 100 m is common.

The lower contact is unconformable in Sergipe and north of Alagoas, and the sediments overlie older strata of the Coruripe subgroup.

In the region of Maceió, Alagoas, Muribeca Formation seems to be conformably overlying the green shale of Ponta Verde Formation.

The upper contact of this unit includes a local unconformity in Sergipe, where the unit is covered by marine shale of Riachuelo Formation and clearly unconformable in Alagoas, where the sediments of this unit tend to crop out and the exposed part is marked with a clastics cover of the Barreiras Formation.

4 - Sergipe Group: it is composed of the following - formations.

4.1 - Riachuelo Formation (Upper Albian/Lower Albian).

It represents an intimate lithologic association formed by carbonate rocks, shale, siltite and sandstone overlying non-marine layers of the Muribeca Formation and underlying the carbonate rocks of the Cotinguiba Formation.

Riachuelo Formation extends from the south flank of the Penedo horst and from the highlands of Muribeca/Japoatã southwards to Vaza Barris River in Sergipe.

It also occurs in the Pontal de Coruripe graben in Alagoas.

The exposed section of this unit is distributed in Sergipe, in a strip of land approximately 20 km in width, between the area of Itaporanga up to the Poxim river valley, north of Pacatuba.

This formation presents a uniform thickness, range of which is around 500 m.

Thickness of its members are, however, variable and irregular. Four members may be distinguished in this unit:

a) Angico Member - It is characterized by medium to coarse clastics, overlying marine sediments of Muribeca Formation and below the carbonate rocks of Cotinguiba Formation. It presents fine to conglomeratic sandstone intercalated with siltite, shale and limestone. Sandstone and siltites may present coquinoidal beds and they have shells similar to Turitella, distributed in fine regular layers.

b) Taquari Member - This member is composed of marine shale, intercalated with limestone which occurs overlying Muribeca Formation and underlying clastics of Angico member and limestone of Maruim member.

The limestone is white to grey, homogeneous, cryptocrystalline and partly marled, presenting, locally, algae horizons. The shale is grey, partly banded, calciferous, micaceous and fissil. Anhydritic inclusions may occur locally. At the surface, these sediments show yellow color.

c) Maruim Member - It is composed of oolitic and pisolitic, coquinoidal and algal limestone reefs, detritic limestone with sandstone horizons, siltite or shale.

Oolitic and pisolitic limestone predominate in this unit. At the surface, algal reefs are observed for they are resistant to erosion.

d) Aguilhada Member - It features a thick section of dolomite underlying the oolitic and pisolitic limestone of Maruim member. This member is essentially made up of saccharoidal dolomite, ivory to light brown with intercalations of fine to conglomeratic sandstone, green, grey or red shale and, occasionally, other non dolomitized limestone.

4.2 - Cotinguiba Formation - Turonian-Santonian

This formation is noticed by the predominance of limestone with local occurrence of clastics.

It overlies the Riachuelo formations recovered by Piaçabuçu sediments.

According to several lithologic variations observed, two members may be defined:

a) Aracaju Member - Formed by intercalations of shale and limestone, located in the basal portion of Cotinguiba Formation.

b) Japucari Member - Framed with massive and stratified limestone.

4.3 - Piaçabuçu Formation

Defined by a group of layers formed by grey to green, clastic to pyritic, medium to coarse grained shale, limestone and dolomite which overlie the limestone section of the Cotinguiba Formation.

Two members may be separated in this unit.

a) Calumbi Member - Composed of shale and green to grey argillite

b) Marituba Member - Formed by coarse clastics and usually pyritic limestone and dolomite.

5 - Barreiras Formation (Tertiary)

It is a continental formation made up of coarse pebbled and quartzose sand, usually fragmented, cemented by argillaceous material of varied color, intercalated with yellow, reddish to red, plastic and non calciferous clay.

This is a surficial formation extending over great part of the basin. Its lower contact is always unconformable with several underlying formations.

6 - Quaternary

The quaternary deposits of continental and coastal origin are informally embodied under the denomination of beach and alluvial sediments.

IV.II - Structural Geology

The main structural characters of the Sergipe-Alagoas -

sedimentary basin may be identified in the Gravimetric Map "Bouguer" (Annex N.4).

These structural aspects may be summarized as follows:

Sergipe - Estância platform, Mosqueiro lowland (graben) Sergipe. Regional highlands, Siririzinho highlands and Divina Pastora, Japaratuba and São Francisco lowlands.

Alagoas - Penedo highlands (horst), Palmeira Alta highlands and Alagoas lowland (graben).

The Bouguer Map show two main systems of faults with roughly ortogonal axis and general directions SW-NE and NW-SE which were checked and dully tested by the works done by Petrobrás. These systems are very important for the definition of the structural geologic configuration of the basin and they are characterized by gravity faults of regional and local orders.

Evidences of older faults (conglomerate associated with fault scarps, unconformity and absence or increase of sections) observed in the Paleozoic and Mesozoic of the Basin, go back to the beginning of deposition of Pitanga Formation (Wealden). Apparently this type of tectonics was active up to the upper Tertiary mainly in the northeastern and western borders of the basin. The main faults occur between Santo Amaro and Alagoas (pre-Ibura-Carmópolis) when the regional configuration of the structure was defined. The tectonic activities of Paleozoic to Jurassic are yet little known.

In Muribeca Formation the units most attained by faults were Maceió and Tabuleiro dos Martins members. Carmópolis, Ibura and Oiteirinhos members were reached only faults in the border of the basin and rare faults that cross transversely (Ex. Betume river fault, NE of Sergipe).

Generally, three main periods of faults my be distinguished in the Sergipe Alagoas Basin: 1/ Middle pre-Alagoas (pre-Muribeca) 2/ Middle Alagoas - Albian (Muribeca -Riachuelo) and 3/ Upper Cretaceous - Tertiary (Cotinguiba-Piaçabuçu).

The sediments of Muribeca Formation in the Sergipe Basin proper are not cut by faults with great thrust. The faults of the west-northwest borders (Iporanga and Betume rivers) are exceptions.

In the Pre-Muribeca faults, on the other hand, significant reactivity is absent not reaching, therefore, the top of Carmópolis member.

The Pre-Muribeca unconformity is made up of one of the most important structural characters of the Sergipe Basin, not being identified however in the Alagoas Basin.

One important contribution to present stratigraphic-structural framing of the basin, mainly the formation of a saliferous sequence may be attributed to halite-kinetic energy.

In the chapter which is specific to the geology of the deposit, considerations are given in more detail about its structural geology.

IV.III - Geologic History

The Lower Cretaceous of the Sergipe-Alagoas basin in Pre-Aptian epoch, after the deposition of sediments aged Poxim, was characterized by tectonic movement. The Brazilian coastal basins, including their submarine extensions, along the adjacent coast, were also affected by tectonic upheaval.

In Sergipe, one of the predominant lines of fractures corresponds roughly to the line of coast whereas the other is located in a general NW-SE direction.

The Estância Platform and the Sergipe highlands or Aracaju highlands, as some geologist of RPNE - Petrobrás prefer to call, it, were organized into positive areas.

At the end of the Pre-Aptian diastrophic area, the Aracaju highland was rapidly invaded by the Aptian sea, formerly with coarse clastic deposition filling its paleovalleys.

The fine clastics of Muribeca Formation deposited over the platform, in an Aptian - marine transgression process, sincronous to the unit equivalent to the overlying shale of the Carmópolis Field, directly over the metamorphic rocks.

In the other parts of the basin, the sedimentation starts again, over an unconformity surface, with short hiatus, which lasted until the end of the Muribeca primeval Aptian time (definition of surface). The denudation of the Estância Platform, another positive area located in the extreme southern limit, continued up to the beginning of the Turonian. Between these two positive Pre-Aptian areas, the Mosqueiro pit developed.

In the Estância Platform, the Turonian sea initially deposited conglomerates and sandstones, changing the lithofacies rapiddy into the Sapucari limestone which underlies them.

In the Mosqueiro pit however, the process of deposition carried on, due to the continuity of subsidence of fine clastic sediments (sandstone and shale) through the marine Maestrichtian and Paleocene, forming a notable event in the geologic history of the basin. In the frontal area - the submarine platform - seismic surveys indicate considerable thickness of Tertiary marine sediments, very rich in hidrocarbonates, as those of the gulf of Mexico.

In the Estância Platform, along the Itaporanga fault which, according to geophysics, corresponds more exactly to a fault zone, similar to a folding joint, oil rich reefs would have been developed during the invasion of the Turonian Sea. In this platform, Turonian sediments overlie the remmant Vaza Barris group, whose lithologic representatives overlie the coarse red sandstones of Estância formation, in a regular unconformity, at least in the largest part of the area.

In the north, separation of the Sergipe Basin, eith marine deposition post Poxim - São Miguel of the Lower Cretaceous from the Alagoas Basin was imposed by the Penedo highland.

It is possible that, in the tectonic pit of Japaratuba, the subsidence has been progressive up to the Aptian, and sedimentation was probably continuous.

São Francisco lowland extends between the Paracatuba horst and the Penedo highland.

It is convenient to call attention to the fact that the pre-Aptian tectonism was marked throught the basin, by traction efforts resulting in normal faults.

There is a structural trend centered in the Sergipe highland, being marked by these faults, that extend up to Carmópolis toward Muribeca town, near the crystalline contact.

Another trend is perceived west of Quiçamã, Riachuelo and Divina Pastora, marking with the other trends already referred to, the geologically favorable areas concerning other oil feelds.

The Evaporitic Basin of Sergipe formed into an epicontinental sea, is represented in the map of location (Annex 1) and in the Paleogeographic map (Annex 2) which show the probable contours of the Aptian saliferous basin. There is an internal basin which extends from Japaratuba to Santa Rosa de Lima. This basin is linked with another which occupies extensive areas parallel to the cost.

The internal basin is possibly joined to the coastal basin at least by one narrow and shallow channel. How the connection of this larger, coastal basin with the ocean was made, is unknown. The existence of the channel may be confirmed by the presence of halite.

The narrow and shallow dimensions of the channel are indicated by the presence of potassium and magnessium salts in the drill holes of ITATIG and IBASA in Cotinguiba, as well as in the AU-I, PU-I wells and several wells of the continental platform of Sergipe, made by Petrobrás.

The sea water, entering the coastal basin in surface currents, headed toward the beach where evaporation occurred.

Close to the border of the basin, already dense brine fell in a vertical current, reaching for the zone of equal density. Afterwards, it moved toward the deeper region. If no obstacle appeared, the concentrated brine would return to the sea, being dilluted in it. In this circulation regime, thick packing of limestone/dolomite and anhydrite could have formed, and the reduction of the vertical section of the channel gave conditions to crystallization of halite in the basin.

The progressive reduction of the channel section or the crust's rearrangement impeached dense brine to return to the sea, in a submarine current and even paralysed it. From this point on if there was equilibrium between the inflow and the evaporation, the brine was concentrating, reaching, the limit of deposition of thick packs of halite.

The brine existent in the internal basin was already substantially concentrated and almost absent in limestone and anhydrite content was deposited near the coastal basin channel.

Bàsal halite, in the Taquari/Vassouras gronted brome contents of 0.0055% the same fact occurring for crystallized halite found in the sea water. It is possible that depositition of basal halite be previous both to the confinement of the coastal basin, and to the channel formation.

As it is shown is the bromine log of halites, a crystallization regime of pre-concentrated brines was predominant, followed by an alternated crystallization regime which was a function of the periodic enrichment of the brine, caused by halite solution and by acess of new brine. The complete evaporite depositional cycle is composed of a sequence, limestone - gypsite halite, magnesium and potassium salts - halite - gypsite - limestone resultant from the evaporation of more and more concentrated brine by evaporation up to the middle of the cycle, following the precipitation of an inverse sequence, with the concentration of brine decreasing until it reaches the initial level.

In summary, the following main events related to the deposition of evaporites may be pointed out:

a) Submergence of Santa Rosa de Lima - Japaratuba basin and deposition of basal layers, after deposition of Carmópolis member.

b) Individualization of Santa Rosa de Lima and Taquari Vassouras by the relative uprising of Siririzinho highland and brine flow toward Santa Rosa de Lima to Taquari-Vassouras.

c) Control of deposition by depth of channel.

d) Crystallization in normal conditions of evaporation.

e) Submergence of evaporites at Ibura time and folding of strata, with progressive transgression; and

f) Absence of geothermal and regressive metamorphism. Presence of metamorphism by secondary, external, down-upward solutions.

V - GEOLOGY OF THE DEPOSITS

A great mass of data obtained by DNPM's Project Potassium and by Petrobrás in the National Reserve Area and vicinity, allowed the definition of the geologic parameters which interested the formations composing the Sedimentary Basin of Sergipe, and particularly Muribeca Formation which contains the evaporite deposits of the region.

In the National Reserve Area basides hundreds of oil wells opened in Carmópolis and Siririzinho,40 holes distributed throughout the area were drilled: 15 of Petrobrás and 25 of the Potassium Project. The latter were specifically realized for the study of soluble salt deposits in Sergipe.

In the requested areas, 25 holes were drilled, being 3 for the Potassium and the remainder for Petrobrás. Of the latter,12 holes revealed presence of soluble salts, which did not happen with the others.

The following chart shows that in the requested areas, besides the holes made for the Potassium Project (PKC-2, PKC-3, PKC-25), nine holes bearing soluble salt were drilled,totalling 12 positive wells and negative wells, excluding wells MRI and MR2 which have not been drilled due to technical difficulties.

We may observe in the studies made that, besides the above referred wells, elements of neighboring wells were used serving for example CPRF-1-SE, PU-3, RCst-1, the CP wells (of Carmópolis) and others.

The positive wells of the Potassium Project and of Petrobrás were cored. The cores were sampled and analysed, composite logs were made, in scale 1:200, with curves of gamma and Neutron rays. Lithologic column, description of drilling cores and samples as well as a schematic column of the structure totalling 26 composite logs were completed (Annex 15).

It should be stated that PKC-3 and PKC-2 wells were made by Potassium Project and the FC-1-SE well was drilled by Petrobrás, all of them positive, out of the National Reserve Area and located within the explored area. The composite logs named above and the electro radioactive logs have been enclosed in this report, in scale 1:1000, taken in the wells mentioned previously, including the logs located in the neighborhood (Annex 16).

The type of logs taken in the drill-hole are: E-Induction, Laterolog, Sonic/Caliper, Gamma/Neutron, Density (Gamma/Gamma) with caliper; Density/gamma caliper and Dipmeter varying from well to well, depending on the conditions of mud at the time in which they were realized and depending on the objective of the hole.

From the economic point of view, Muribeca Formation is considered the most important unit of the Sergipe Alagoas Sedimentary Basin.

Carmópolis and Ibura, two of the members comprising Muribeca Formation, existing in Sergipe, contain great reserves of ore. The Carmópolis member has been notable as a reservoir of hidrocarbonates and the Ibura Member as a container of thick saliferous beds, the principal object of this Report.

As it was briefly mentioned in chapter IV of the present work, Muribeca Formation is lithologically organised into an interlamination of grey and light brown shales which give a varvitic aspect to it.

List of Wells in the Explored Area

WELLS		FD	Depth referred to Muribeca's base	Thickness of soluble salts	Thickness of marine sediments	Depth of Embasement
POSITIVE	FC-1	733	694	103	39	FD-M. Carmópolis
	PKC-3	1328	1328	249	-	"
	PKC-2	1063	1063	138	-	"
	AG-1	1935	1397	39	420	1817 m
	AG-2	1333	1333	288	-	FD-M. Carmópolis
	AG-3	1355	1355	84	-	"
	AG-4	1317	1317	262	-	"
	AGN-1	1473	1389	37	84	FD-F.Barra Itiúba
	JD-1A	1548	1520	127	28	FD-F. Bananeiras
	PL-1	1580	1424	115	156	"
	PU-1	1430	1356	184	74	FD-F. Rio Pitanga
	LM-1	1480	1285	161	195	"
NEGATIVE	PKC-25	704	704	0	-	FD-M. Carmópolis
	EM-1	540	465	0	75	FD-F. Penedo
	SEM-1	797	690	0	107	"
	VV-1	2696	1345	0	1351	FD-F. Bananeiras
	MR-3	1277	N.A.	-	-	FD-M. Angico
	BGst-1	2445	1423	0	1010	2433 m
	JT-1	1820	1337	0	483	FD-F. Serraria
	SJst-1	1984	875	0	1068	1943 m
	BD-1A	1543	1502	0	41	FD-F.Barra Itiúba
	CPU-1	1612	1574	0	38	"
	PU-2+	1452	1309	0	121	1430 m
	AN-1	1178	1159	0	0	1159 m
	AS-1	1255	1212	0	0	1212 m

M - Member

F - formation

FD - final depth (reached unit signalled)

* - Approximate thickness of marine sediments

** - Underlying drilled sediments

H - Faulted

By observations made in similar situations, we may conclude that this lithology is typical of an evaporitic environment (epicontinental sea), suffering however of other environmental influences during its deposition, ensuring its division in 5 members named as follows: Maceió, Tabuleiro dos Martins, Carmópolis, Ibura and Oiteirinhos.

Some evaporitic intercalations, represented by halite horizons, occur in the Maceió member, the only existing in Alagoas.

Tabuleiro dos Martins member, recognized in the basin is composed of dark grey to black and light brown shale interlaminated with light brown dolomitic limestone typical of Muribeca Formation.

These members were possibly eroded, or not deposited in the Sergipe Basin, the remmant being the Carmópolis, Ibura and Oiteirinhos members.

The Carmópolis member is composed of sandstone and conglomerates, deposited in the scarp-faults (pre-Muribeca) and paleoreliefs, partially coincident with the structural lowlands. This member is the oil reservoir of the Carmópolis, Siririzinho and Riachuelo oil fields.

Ibura and Oiteirinhos members, which form the evaporitic section itself, are described according with detailed zoning made by CPRM's Geologist J. C. Fonseca (Annex 5).

Such study tends to detail the stratigraphy of the evaporitic section, this in turn favors future and present identifications and stratigraphic correlations of the members, and helps appropriate evaluation of the salt zone reserves.

The existent data were used for the zoning, including the composite logs of 26 wells (Annex 15) their chemical analysis, electro-radioative logs and cores.

After the stratigraphic zoning was ready, a chart was drawn to show the sampling intervals and the respective results of analysis (Annex 14-1), in which average amounts for the main zone of sylvinite and carnallite with their corresponding thickness were arranged.

A stratigraphic section, illustrated with gamma ray log was also prepared, in which the evaporite zones were identified, considering the elements available (Annex 6).

The soluble salt sections belonging to Ibura and Oiteirinhos members are composed of layers and zones of halite, sylvinite, carnallite, tachyhydrite and some shale. Sylvinite is disposed in layers made up of a mechanical mixture of sylvite and halite. This section occurs in the sub-basins of Santa Rosa de Lima and Taquari Vassouras and it includes parts of the Carmópolis and Siririzinho oil fields and, that of Aguilhada in the considered area, with thickness varying from several tens to hundreds of meters. It reaches a maximum of 466 meters at the PKC-1-SE well, located next to Taquari farm, and considered a center of deposition for the Taquari-Vassouras sub-basin.

Besides these two sub-basins, other deeper basins occur, namely Piranhas/Timbó, Ilha das Flores and Quiçamã/Socorro/Aracaju, all of them containing intercalations of salt zones, besides that of Mosqueiro/Continental Shelf, with a thick section of soluble salts, located at depths of over 2,500 m.

It should be mentioned, however, that these sub-basins remained inter connected at least during the period of deposition of the soluble salts.

The evaporitic section was divided into 10 cycles according to a numerical order, from the base upward. These cycles were then subdivided into zones designated by initials which stand for two predominant and/or principal components, followed by the number of the correspondent cycle.

Athough the cycles generally include shale and/or argillaceous halite with limestone lamminae, sometimes associated with anhydrite at the base, they do not represent depositional cycles, if we consider that the bromine anaylisis made in the halite of several saline zones indicate only successive concentration of brine giving origin to several salts contained in cycles, from 1 to 6.

In reality, we might regard the salt cycle as only one big cycle, in which the stages above referred would be divided.

On the other cycles such as 1,9 and 10 may be subdivided into subcycles in view of the intercalation of shale limestone with rock-salt or anhydrite.

Cycle N. 1, representing the basal section of evaporites, contains a sequence of shale with limestone lamminae, grading to limestone and anhydrite which makes up the N. 1 stratigraphic mark called M1, the stratigraphic basis of the soluble salts. Successive intercalations of rock salt and shale follow them. The apper part of the shale marks 2, 3 and 4 present lamminae and fine layers of limestone, having their own characteristics and being identified in the gamma log. In the upper part of this cycle a carnallite section is observed, whose top and base consist of a fine layer of sylvinite, possibly of secondary origin, from carnallite. Cycle N. 2 begins with shale mark 5, bearing high radioactivity detected in the gamma log, also presenting fine intercalations of limestone in the upper part. Subsequently a rock salt zone is observed along with the first thick zone of carnallite C-2 also designated thick zone of lower carnallite, represented by poorly stratified dark-red carnallite strata, roughly crystallized, with intercalations of laminated rock salt. Usually this carnallite zone features an average content of potassium, higher than that of the other thick zone of carnallite C3-2, of the saline section. The carnallite zone is divided into two subzones C2-1 and C2-2, being the first richer in potassium and identifiable in the gamma log. Locally, as it happens northeast of Siririzinho field, at the base of this carnallite zone, a fine zone of sylvinite S2-1 occurs with a thick one (S2-2) named lower sylvinite zone, with rough crystallizations possibly secondary, from carnallite.

Cycle N. 3 begins with a section of shale and halite, namely FH-3 zone, with fine lamminae of limestone.

A section of rock salt follows locally containing a zone of carnallite C3-1, recognized in wells PKC-8 and CP-17. Rock salt of this section is generally presented with rough crystallization and sith carnallite disseminations sometimes with red spots, possibly resultant from carnallite leaching from zone C3-1. Subsequently we observe a second thick zone of carnallite C3-2 also designated thick zone of upper carnallite, composed of intercalations of red carnallite, roughly crystallized and laminated rock salt.

Close to the base we find a layer of rock salt also designated mark M6A, being frequent the occurrence of a tachyhydrite sub zone T3 associated with carnallite and halite, near the top.

Cycle N. 4 begins with a section composed of halite and layers of clay, with fine lamminae of limestone and some anhydrite. A fine zone of carnallite then occurs with halite intercalations, and in the upper part of the cycle the first thick zone of impure tachyhydrite T4, orange in color, with rough crystallization and intercalations of carnallite and halite associated to lenses of clay.

Cycle N. 5 is represented by a lower section of halite with intercalation of shale, also including a thick layer of shale, mark M8, characterized in the neutron log by a peak of higher absorption, partially associated to tachyhydrite and carnallite. Halite and shale present fine local lamminae of limestone and anhydrite..

In the upper part of the cycle a section of tachyhydrite is found, whose occurrence is limited to the area of Vassouras.

Cycle N. 6 has, at the base, a section of shale, mark M9, rock salt with fine intercalations of carnallite and clay, besides fine local lamminae of anhydrite. Following, there is a section composed of carnallite, intercalated with rock salt and at the base, a rich carnallite zone, mark M10, also designated Rich Carnallite. The upper part of the cycle is represented by the second and thickest section of tachyhydrite T6, reaching 100 m thickness in the PKC-1-SE well. This tachyhydrite is clean, clear, translucent, roughly crystallized, presenting a layer of carnallite, mark M11, at the middle of the section and intercalations of carnallite at the base, called sub zone TC-6.

Cycle N. 7 is represented by main zones of sylvinite, intercalated with rock salt zones. Sylvinite zone S7-1, at the base of the cycle, overlies C7 carnallite/halite zone, lying at the base of the cycle. Carnallite is presented partly limpid and translucid, a kind of occurrence observed only in that zone. Sylvinite S7-1 is possibly secondary and it is originated from leached carnallite, at least at its lower part. This sylvinite extends in the Taquari/Vassouras area, with considerable thickness, reaching a maximum of 9 meters, S7-2 and S7-3 sylvinite zones are considered to be a sole composite in the area of Taquari/Vassouras. S7-3 Sylvinite extends along the Santa Rosa de Lima sub-basin with approximately 6 m thickness. The sylvinite zones, above referred, in their main areas of occurrence present high K_2O contents, above 20%. Cycle N. 7, in its upper part ends with a thinner rock salt zone, characterized by abundant lamminae of halite, finely crystallized, in the Taquari/Vassouras sub-basin.

Cycle N. 8 begins with a rich salt section containing, at the at base of Santa Rosa de Lima sub-basin, a thick layer of anhydrite. This section, mark M12, is characterized by the presence of clay being, identified in the radioactive log. It extends withim the Santa Rosa de Lima and Taquari/Vassouras subbasin.

The cycle ends with a section of clear, sandy rock salt layer which in the Santa Rosa de Lima area presents a thick layer of anhydrite with several twisted lamminae. In this rock salt section a fine, S8 sylvinite zone was observed only at the PKC-18 drill hole.

Cycles 9 and 10 are more extensive in all of the sedimentary basin. In cycle anydrite predominates, generally showing beds with enterolithic folding. Anhydrite of cycle 9 presents displacively grown nodules according to the existing calciferous and clayey matrix.

Intercalations of shale and limestone are also present.

Mark M15 is detected in the gamma log, with intercalations of anhydrite and shale, and Mark M16 by less impure, thick anhydrite, with intercalation of laminated shale.

The upper part of the cycle is represented by a rock salt section occurring only in PKC-6 and CPX-5 drill - holes in the Taquari-Vassouras sub-basin and at the sub-basin located to the southeast, out of the area being object of this Report.

In cycle 10, intercalations of shale and light brown laminated limestone predominate. Two sections with anhydrite and limestone occur, being revealed by the electro-radioactive logs and by the cores.

The top and base of the section of Mark M17 contain anhydrite. It is also designated Two Peak Anhydrite zone. The section of Mark M18 is called limestone of the top of Oiteirinhos member and it presents, at the base, in the Santa Rosa de Lima sub basin an intercalation of anhydrite to end the evaporitic cycle of the top of Muribeca Formation. The upper part of this formation locally presents erosion indicated by the absence of this limestone and of the Two Peak Anhydrite.

Cycles N. 3 and N. 4, comprising thick zones of lower carnallite C3-2 and of lower tachyhydrite T4, have not been identified in the Santa Rosa de Lima sub-basin.

The deposition of these cycles must have been controlled by a barrier resultant from less subsidence of the Siririzinho structural highlands or by the structural lowlands of Divina Pastora and of Treme, of the above referred sub-area, in which the drilled holes PKC-23 penetrated into part of the saline section.

The greatest thickness and, consequently, the largest reserves of the main zones of sylvinite and carnallite are structural lowlands where it presents the largest thicknesses equal to those of packs of marine sediments.

The normal tendency of a soluble salt section confined and plastic, under the pressure of burial is to flow in the vertical direction, forming a dome or even a diapir folding aspect which does not occur in the Santa Rosa de Lima and Taquari Vassouras sub-basins. In the Aguilhada sub-basin, C2 and C3 carnallite zones present anomalous thickness, totalling over 100 meters at the Ag-2 and Ag-4 drill holes (see Annexes 7, 8, 11 and 13).

The salt base at the Ag-1, Ag-2, AG3 and AG4 drill holes is approximately horizontal and located at 1200 m level, whereas the salt top in the same drill holes is at around - 1119 - 918 - 1164 - 973 m respectively.

We verify, therefore, a strutural difference at the salt tops, in the area of thickening (Ag-2, AG-4) of about 146 to 246 meters, a situation which describes a domic aspect probably formed by the flow of the carnallite zones northward.

Negative drill hole PU-2 also located in the Aguilhada sub-basin seems to present a fold with reverse fault with repetition of a 270 meter section, comprising parts of Riachuelo and Muribeca formations, which is a unique circumstance observed in the studied area.

Shale marks M2, M3, M4, M5 of the salt basal section are present in the several sub-basins, also being observed beyond the limit of the soluble salts occurrence, similar to the drill-holes of the Castanhal area, RO-61 of Riachuelo, FC-1 and CPF-1 of Aguilhada (See annex 7). Probably, during the transgressions which originated the cycles, some barriers, presently transformed into areas with no soluble salts, were generally in the Taquari/Vassouras sub-basin located at lower depths. In this sub-basin, a sub-erosion strip of land occurs in the upper part of the salts, possibly associated to erosion of the top of Muribeca Formation.

This strip of land, disposed along north/northeast direction extends from VA-2 drill hole to PKC-2 and PKC-3 drill holes located in the requested areas (see isopach maps, annexes 11, 12, 13).

In this strip of land, the top of the salts is represented by saline stratigraphic zones gradationally inferior in the down dip direction.

Sub-erosion limits the areas of occurrence of the main sylvinites. They are located in the upper part of the salts. Thus, these sylvinites are probably absent in the explored areas to the north, the same being true with the thick zone of carnallite C3-2 occuring in part of the explored areas (see stratigraphic section of Annex 9).

Another geologic aspect occuring in a central area, of the Taquari/Vassouras sub basin, concerning TQ-1, PK-6 and PK-7 drill holy is also economically important.

In this area, the two economically important thick zones of carnallite are leached, remaining only a halite zone roughly crystallized, with carnallite disseminations. In the CPX-2 drill hole located near the limit of the referred area, only the lower C2 zone is leached (See Annex 13).

From the study made, no section or zone repetitions were observed. In general, there is a compatibility between the dips of the section and its structral position.

The saline section dips in the direction of the also inundated. Initially, clastics were deposited throughout the area and, afterwards, salt precipitated in the shallow sites, presently saline sub-basins.

The structural deformations, strong dips and folds observed in certain saline zones of the sub-basins seem to have been the result of dissolution phenonena which developed along with deposition.

Thus in the carnallite zones, layers intercalated with laminated halite are not deformed in the upper part but present folding and dissolution in the lower part, a fact which is more frequent toward the contact with the underlying carnallite layer.

Probably, these small structures as well as the larger are related with dissolution and recrystallization of underlying more soluble salts and consequently, a collapse of overlying less soluble salts.

The rock salt zone overlying Mark 12, at tue salt top is thick in the Santa Rosa de Lima sub-basin, were several lamminae of anhydrite occur, showing folds throughout the area, while the salt zone (ceiling of the sylvinite zone) over the same Mark has normal stratification and, gentle dips.

In the Taquari/Vassouras sub-basin both rock salt zones are thinner, the lower being well stratified and horizontal. The upper zone is poorly stratified. These deformations of the upper zone are also possibly collapsable structures associated to precocious dissolution.

Cycle 9 anhydrites are nodule-like, showing enterolithic folds in fine layers. Possibly these structures are also related with deposition and are resultant from displacive growth of anhydrite crystals in buried, though not yet lithified layers.

VI - ORIGIN OF THE SERGIPE EVAPORITES

Saliferous sequences originated from precipitation of water and subsequently covered by more recent impermeable sediments are known throughout the world. Deposition of salts occur in an area of marine basin, partially separated from the main source of water by physical barriers. In an arid climate, where evaporation exceeds precipitation, there is a continous inflow of salt water into the restricted basin. Due to water density differences developed within the basin, some outflow of bottom water may be established but the restriction of the outflow by a physical barrier, such as a sill, results in the development of a high salt content in the basin.

In a large basin, the salt concentration is greater in areas far from the entrance of salt water. The deposition of evaporites begins in those areas with the precipitation of anhydrite ($Ca\ SO_4$). If the concentration of the solution continues to increase, the anhydrite precipitation zone gradually will move back heading toward the point of primary inflow and halite ($Na\ Cl$) will precipitate in areas where anhydrite had formerly deposited. If the equilibrium between the internal and external flows as well as the salinity gradient inside the basin have become relatively constant, anhydrite will continue to be deposited in a certain area, while halite will have been continuonsly deposited in another area.

Those salts not precipitated will return to the sea on a continuing basis. Storms which may occur in arid climates do not seriously affect the equilibrium of the basin. They would wash mud in the salt deposition areas resulting a common occurrence of clay stringers associated with salt. Given the right conditions, thick sections of pure halite are deposited.

If the salinity of the basin is further increased, the zones of anhydrite and halite deposition will move closer to the point of water entrance and in the areas of highest salinity, farther from the point of inflow, the more soluble potassium and magnesium salts will, precipitate, instead of returning to the sea, in solution. This horizontal migration of zones of deposition may certainly reverse if other conditions reduce the over all salinity of the basin.

In this manner, almost any sequence of evaporites may take place in a given site. Vertical sequence, therefore, is not necessarily correlated directly with the order of increasing solubility of various salts, which is greater from anhydrite to halite, or to magnesium and potassium salts.

In the Sergipe basin, mainly due to lack of the carbonate sequence, anhydrite or gipsite which generally precede the deposition of halite, it cannot be fully organised according to a classic model of an evaporite deposit formation as that of the type explained above.

Prof. N. C. Wardlaw of the University of Calgary, Canada, consulted by the Potassium project and analysing the general conditions for the evaporite formation and detailing specific peculiarities of the local problem, arrived at the following conclusions.

The Sergipe evaporites are conspicuously similar in age, mineralogy and structure to those of the coastal regions of Congo and Gabon in Africa.

The tachyhydrite ($Ca\ Cl_2.MgCl_2.12H_2O$), a rare mineral in other known evaporitic deposits, occurs in units of over 100 m thickness in the Cretaceous evaporitic sequences of Sergipe. At an advanced stage of evaporation, the brines must have been abnormally enriched in $Ca\ Cl_2$ and depleted in SO_4.

Brines with these characteristics exist in the Red Sea and Dead Sea today suggesting an interesting similarity.

The ReadSea is up to 2000 m deep and is flanked by complementary uplifed blocks with relief of up to 3000 m above sea level. This situation provides a significant head tending to drive formation waters in to the Gulf. Some of these waters are thought to be rich in $Ca\ Cl_2$ and providing a mechanism that would change the composition of the marine brines.

The structural setting may be an important clue of the abundance of in Sergipe, and to its rarity in other major evaporite deposits of the world, many of which formed in extensive intracontinental basins which were tectonically stable and where the surrounding ralief was relatively slight.

In this situation, the influence of formation waters in changing the composition of marine brines might be significantly less than in deeper basins in the vicinity of higher relief.

If South America separated from Africa and if the beginnings of this separation were dated as Jurassic, the Lower Cretaceous evaporites of the Coastal strips of eastern Brazil and of West Africa could have formed in a structural setting of which the Red Sea provides a present day model. However in the absence of further structural information it is uncertain whether the Cretaceous sequences of the coastal regions of west Africa and Brazil have been affected by faults on the scale of those bounding the Red Sea.

A different process of calcium enrichment has been suggested for the brines of the Dead Sea where SO_4 appears to be reduced perhaps by bacteria, leaving an excess of calcium in solution. Such a process could account for the missing $Ca\ SO_4$

and also on the $CaCl_2$ enrichment in the Sergipe evaporites.

Bromine in halite and bromine and rubidium in carnallite of the Sergipe deposits indicate that they crystallized from marine brines. Some halite and carnallite contains more bromine than is typical for a marine deposit, and indicates a process of bromine enrichment. Bromine is also concentrated in relation to chlorine, in the Dead Sea, in a rare aspect which is a point of physico chemical similarity with the Sergipe deposits.

Sylvite is abnormally low in bromine content and high in rubidium content when compared with primary sylvite, and is thought to have been derived from carnallite, by leaching.

A very regular upward increase of bromine and a constancy of strocium through the upper tachyhydrite zone may only have been achieved where crystallization was uninterrupted by sudden influxes of marine waters and where the crystals were not subject to later solution or diagenetic alteration.

At this stage of deposition, the basin may have been completely closed to marine influxes and 100 m of tachyhydrite could have crystallized from little more than 200 m of tachyhydrite saturated brine.

Tachyhydrite could not have been preserved if it had been exposed to the atmosphere during or after deposition.

Although the theory of the origin of the Sergipe evaporites may be further explained by other settings similar to those already mentioned, any positive conclusion will only be accepted without further reserves after detailed knowledge of the geologic structure concerning the saliferous basin and its extension areas, mainly in the continental plataform is acquired allowing the definition of events which have fundamentally influenced the geologic parameters which gave conditions to the physico-chemical formation of the deposits.

Presently Petrobrás, DNPM, CPRM, with the collaboration of the Brazilian Navy through the Navigation and Hidrography Directorship, and CNPq (Brazilian Research Courcil) are interested in a global study of a project named "Reconaissance of the Brazilian Continental Margin" which, among many valuable aids will provide a better knowledge of the geologic aspects still obscure, thought these do not interfere with the economic feasibility of the exploitation of the deposit.

VII - RESERVES

The location in map, of all of the positive and negative holes drilled in the Sergipe Sedimentary basin, with regard to the presence of saliferous horizons gave may to the placement of a limit line of salt occurrences.

Analysing this map, we observe the occurrence of a subbasin, inter connected by channels in the past, shown by strangulation of several areas of occurrence of soluble salts, an indication that the potassium and rock salt deposits, object of the present Report represent a natural extension of the National Reserve Area deposits and, are in essence, "lato sensu", one whole economic deposit of evaporites lying in that sedimentary basin.

Elements of definition for the Potassium Project Report allied to a great mass of data provided by Petrobrás for the basin, including the drilling of 23 holes within the 29 requested areas made possible, with an admitted margin of confidence to calculate the reserves, bearing in mind the same phylosophic line adopted for the Potassium Project.

Besides the elements directly obtained, there was a need to complement information through the utilization of areas of influence of several holes located outside the poligonal areas of exploration and those helped to infer the limits of deposition and lateral enclosure of the deposits, indispensable to the calculation of reserves.

Interpretation of all of the direct and indirect elements of information permitted the make up of isopach maps related below, resultant from the global accordance of the parameters exposed in chapters IV and V:

Annex 11 - Isopach maps of the soluble salt sections and structural contour of the base of the section with a contour interval of approximately 100 m.

Annex 12 - Isopach maps of the rock salt section comprising the composite of the lower zones and the composite of the upper zones, with a contour interval of 20 m.

Annex 13 - Isopach map of the Carnallite C2 and C3-2 zones with a contour interval of 20 m.

The observation of annexes 11, 12 and 13 shows in a general way, that the isopachs with zero value, of the studied layers practically coincide with the limit line of salt occurrence (for calculation purposes). Exception is made when such isopachs were determined by drilling.

In the areas north of Siriri, rock salt occurs both in the lower cycles of saluble salts called lower zones, and in the upper cycles described as upper zones.

C-2 and C3-2 Carnallite zones as well as the lower rock salt 3 zone occur in the group of areas north of PKC-2 and PKC-3 drill holes. Carnallite C2 and C3-2 with fine layers of rock salt occur in the group of areas 6 to 13.

In the group of areas M.N.O.P. carnallite C-2 and C3-2 zones occur with a thick layer of rock salt, revealed through the drill hole LM-1-SE, showing anomalous saline section. The rock salt section of this drill hole presents an intercalation of fine layers of carnallite and sylvinite containing carnallite at the base, which makes difficult to correlate them with the nearest drill hole PU-1-SE showing a normal saline sequence.

Despite the thickness of the rock salt section intercalated between the two Carnallite C2 and C3-2 zones, it has not been included into the reserve calculations. This happened due to the verification realized in the cores of the Potassium Project's holes, where, in similar circumstances, the rock salt is recrystallized with carnallite disseminations, originated from leaching of C3-1 carnallite zone (See zoning, Annex 5), thus making it an ore with little economic significance to be developed.

It is worth to mention that in area D, despite the occurrences of the lower sylvinite S2-2 zone, in PKC-2 hole and of the lower tachyhydrite T4 zone, correlatable with the zone in PKC-3 hole, they were not included into the reserve calculations.

The other carnallite and rock salt zones, of the evaporitic sequence, occuring in the studied areas being thin and or intercalated with other salts, have not been considered for confidence purposes in the present reserve calculations.

In the group of areas north of the National Reserve Area, total reserveshave been calculated, considering those contained within the zero meter isopach limits.

Within the group of areas named from 1 to 13, and from M to P, respectively, the saline deposits show anomalous forms, similar to dome-like features in the Aguilhada area, with zero isopach and generally not well defined, possibly located close to the limit line of salt occurrences.

In the two latter groups of areas contained within the 20 m isopach limits, partial reserves were calculated considering the great thickness of the local geometry though admittedly carnallite does not exist out of the limits of this isopach.

From the experience and interpretation of data acquired from the drill holes, cores and gamma density logs in the National Reserve Area, it was admitted, in the present situation a 2.1 average fixed density for the rock salt and average variable densities for carnallite zones, taking into consideration the density logs and the carnallite content or the amount of contained K_2O, because carnallite zones contain halite beds, causing variations in their density.

In the Potassium Project the K_2O contents were determined by the analysis of the cored carnallite zone and/or through values obtained from gamma logs in API units, corrected for the mud density and hole diameter at the time of logging.

The indirect calculations of contents using radioactive logs was done with the use of an empiric chart constructed by Schlumberger which provides corrections in values obtained directly from the logs in API units for linearity, weight of drilling mud, noted in the top heading of the logs and the hole diameter, obtained from the caliper log.

With the corrected value, in API units, and using in a chart the corresponding factor of transformation, the percentage of contained K_2O is obtained.

Comparing the obtained contents from the cores and from the gamma logs in the sylvinite zones, it was observed that they are approximately equal, with differences of approximately 5%. In the carnallite zone, greater differences were observed reaching, sometimes 25%. In this case, the content calculated in the gamma log is higher than the obtained by the core analysis due to the loss of great part of carnallite, by deliquescence, during the sampling procedure. This fact does not occur with halite, for it is less soluble. Trying to mend such difficulty before cutting the sample for chemical purposes the cores are scoured to eliminate the excess halite, at the periphery of the cutting area. This cleaning operation is not always complete, due to deeper cavities originated from dissolution of carnallite crystals.

From what is above exposed, we conclude that at the carnallite zones the contents obtained from the gamma logs are more real than those determined by the chemical analysis, though in a non cored hole the contents of the insoluble residues are unknown and only determined by chemical analysis.

The reserves were calculated referring to saliferous zones.

The careful exam of isopach maps allowed the appraisal of the interesting areas and their respective average thicknesses for the blockage of the corresponding reserves which follow.

VII.I - Potassium Salt Reserves

- Carnallite -

Areas A to L	C2 Zone	C3-2 Zone
Areas in $10^6 m^2$	29.50	6,50
Average Thickness in m	27.85	35.00
Volume in 10^6 m^3	823.50	227.00
Density	1.77	1.80
Reserves in 10^6 ton (metric)	1456.50	408.00
Percentage of Contained K_2O	10.00	9.00
Equivalente in contained K_2O in 10^6 ton (metric)	145.60	36.70

Sub-Total: Reserves of Carnallite C-2 and C3-2 zones
1864.50×10^6 ton

Equivalent in contained K_2O - 182.30×10^6 tons

Areas M to P	C2 Zone	C3-2 Zone
Areas in 10^6 m^2	4.50	3.30
Average thickness in m	35.00	30.00
Volume in 10^6 m^3	157.00	99.00
Density	1.87	1.93
Reserves in 10^6 ton (metric)	294.00	191.00
Percentage of Contained K_2O	7.00	6.00
Equivalent in contained K_2O in 10^6 ton (metric)	20.60	11.40

Sub-Total: Reserves of Carnallite C-2 and C3-2 zones – 485.00 X 10^6 ton

Equivalent in contained K_2O – 32.04 X 10

Areas 1 to 13	C2 Zone	C3-2 Zone
Areas in 10^6 m^2	12.50	12.30
Average thickness in m	68.40	72.35
Volume in 10^6 m^3	855.00	890.00
Density	1.83	1.83
Reserves in 10^6 ton (metric)	1.563.00	1.628.00
Percentage of Contained K_2O	8.00	8.00
Equivalent in contained K_2O in 10^6 ton (metric)	125.04	130.24

Sub-Total: Reserves of Carnallite C-2 and C3-2 zones – 3,191.00 X 10^6 ton

Equivalent in contained K_2O – 255.10 X 10^6 ton

Total Reserves of Carnallite .... 5,540.50 X 10^6 ton
Equivalent in contained K_2O .... 469.62 X 10^6 ton

VII.II - Rock Salt Reserves

Areas A to L	Lower Zones	Upper zones
Area in 10^6 m^2	28.30	7.00
Average thickness in m	45.00	80.00
Volume in 10^6 m^3	1,032.30	560.00
Density	2.10	2.10
Reserves in 10^6 ton (metric)	2,168.00	1,176.00

Sub total Reserves of the Lower and Upper Zones
3,344.00 X 10^6 ton

Areas M to P	Lower Zones	Upper Zones
Area in 10^6 m^2	8.30	12.50
Average thickness in m	29.64	33.20
Volume in 10^6 m^3	246.00	415.00
Density	2.10	2.10
Reserves in 10^6 ton (metric)	516.00	871.00

Sub total of Reserves in the Lower and Upper Zones
1,387.00 X 10^6 ton

Areas 1 to 13	Lower Zones
Areas in 10^6 m^2	11.00
Average thickness in m	15.45
Volume in 10^6 m^3	170.00
Density	2.10
Reserves in 10^6 ton (metric)	358.00

Sub total of Reserves in the Lower Zones ... 358.00 X 10^6 ton

Total Rock Salt Reserve .... 5,088.90 X 10^6 ton

VII.III - Table of Reserves: Measured - Indicated - Inferred

To meet article 26 of the Brazilian Mining Code'Rule, specification of obtained reserves must be complete.

The reserves thus quantified confirm the potentiality of the Sedimentary Basin, enabling, on the other hand to consider the type and origin of the deposits with a degree of precision compatible with the exploration methods adopted to evaluate the measured and indicated reserves..

For greater confidence, trying to cover eventual geologic risks, only 40% of the total calculated was considered as meassured reserve while the remainder may be characterized as indicated reserve. Inferred reserves were also calculated, all the results computed in tables, per requested area, according to what is explained in tables 1, 2, 3, 4 and 5.

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POTASSIUM SALT RESERVES

CARNALLITE

C2 ZONE

TABLE 1

Reference	Area 10^6 m^2		Average Thickness (m)		Volume 10^6 m^3		Reserves 10^6 t				Ave. Cont.	K_2O Contained 10^6 t
	Mea+Ind	Inf	Mea+Ind	Inf	Mea+Ind	Inf	Mea	Ind	Inf	Total	K_2O %	
Area A - DNPM 808.584/72	6.0	-	30.0	-	180.0	-	-	318.0	-	318.0	10	31.8
Area B - DNPM 808.585/72	3.5	-	27.0	-	94.5	-	-	167.0	-	167.0	10	16.7
Area C - DNPM 808.586/72	1.0	-	15.0	-	15.0	-	-	26.5	-	26.5	10	2.6
Area D - DNPM 808.587/72	8.0	-	27.0	-	216.0	-	152.8	229.2	-	382.0	10	38.2
Area E - DNPM 808.588/72	7.0	-	30.0	-	210.0	-	148.8	223.2	-	372.0	10	37.2
Area F - DNPM 808.589/72	4.0	-	27.0	-	108.0	-	76.4	114.6	-	191.0	10	19.1
TOTAL OF C2 ZONE	29.5	-	-	-	823.5	-	378.0	1078.5	-	1456.5	-	145.6

C3-2 ZONE

Area D - DNPM 808.587/72.....	6.5	-	35.0	-	227.0	-	163.2	244.8	-	408.0	9	36.7
TOTAL C2 + C3-2 ZONES	36.0	-	-	-	1050.5	-	541.2	1323.3	-	1864.5	-	182.3

Observations:

1. Density of 1.77 was considered for C2 zone and 1.80 for C3-2 zone
2. For the calculation of inferred reserves, average thickness of 5 m was considered for confidence purposes
3. The percentages of K_2O contained were calculated, based on eletric and radioactive (gamma and caliper) logs and weight of the drilling mud

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POTASSIUM SALT RESERVES

CARNALLITE

C2 ZONE

TABLE 2

Reference	Area 10^6 m^2		Average Thickness (m)		Volume 10^6 m^3		Reserves 10^6 t				Ave. Cont.	K_2O Contained
	Mea+Ind	Inf	Mea+Ind	Inf	Mea+Ind	Inf	Mea	Ind	Inf	Total	K_2O %	10^6 t
Area M - DNPM 810.995/72 ..		8.0		5.0		40.0	-		74.8	74.8	6	4.48
Area N - DNPM 810.996/72 ..	2.0	8.0	35.0	5.0	70.0	40.0	52.4	78.6	74.8	205.8	7	14.40
Area O - DNPM 810.997/72 ..	2.5	8.5	35.0	5.0	87.0	42.5	65.2	97.8	79.5	242.5	7	16.97
Area P - DNPM 810.998/72 ..	-	8.0	-	5.0	-	40.0	-	-	74.8	74.8	6	4.48
TOTAL OF C2 ZONE	4.5	32.5	-	-	157.0	162.5	117.6	176.4	303.9	597.9	-	40.33

C3-2 ZONE

Area M - DNPM 810.995/72 ..	-	8.0	-	5.0	-	40.0	-	-	77.2	77.2	5	3.86
Area N - DNPM 810.996/72 ..	1.3	12.0	30.0	5.0	39.0	60.0	30.0	45.0	115.8	190.8	6	11.48
Area O - DNPM 810.997/72 ..	2.0	10.0	30.0	5.0	60.0	50.0	46.4	69.6	96.6	212.5	6	12.75
Area P - DNPM 810.997/72 ..	-	6.0	-	5.0	-	30.0	-	-	57.9	57.9	5	2.90
TOTAL OF C3-2 ZONE	3.3	36.0	-	-	99.0	180.0	76.4	114.6	347.4	538.4	-	30.99
TOTAL OF C2 AND C3-2 ZONES	7.8	68.5	-	-	256.0	342.5	194.0	291.0	651.3	1136.3	-	71.32

OBSERVATIONS: Same as for table 1, considering density 1.87 for C2 zone and 1.93 for C3-2 zone

CARNALLITE RESERVES

C2 ZONE

Table 3

Reference	Area 10^6 m^2		Average Thickness (m)		Volume 10^6 m^3		RESERVES 10^6 t				Ave. Cont. K_2O %	K_2O Contained 10^6 t
	Mea+Ind	Inf	Mea+Ind	Inf	Mea+Ind	Inf	Mea	Ind	Inf	Total		
Area 6 - DNPM 808.858/72 ...	-	3.0	-	5.0	-	15.0	-	-	27.4	27.4	6	1.64
Area 7 - DNPM 808.859/72 ...	-	7.0	-	5.0	-	35.0	-	-	64.0	64.0	6	3.84
Area 8 - DNPM 808.860/72 ...	-	8.0	-	5.0	-	40.0	-	-	73.2	73.2	6	4.39
Area 9 - DNPM 808.861/72 ...	2.0	4.5	40.0	5.0	80.0	22.5	58.4	87.6	41.2	187.2	8	14.97
Area 10 - DNPM 808.862/72 ...	3.5	4.0	70.0	5.0	245.0	20.0	179.2	268.8	36.6	484.6	8	38.76
Area 11 - DNPM 808.863/72 ...	3.0	3.0	85.0	5.0	255.0	15.0	186.4	279.6	27.4	493.4	8	39.47
Area 12 - DNPM 808.864/72....	2.5	4.0	80.0	5.0	200.0	20.0	146.4	219.6	36.6	402.6	8	32.20
Area 13 - DNPM 808.865/72 ...	1.5	4.0	50.0	5.0	75.0	20.0	54.8	82.2	36.6	173.6	8	13.88
TOTAL OF C2 ZONE	12.5	37.5	-	-	855.0	187.5	625.2	937.8	343.0	1906.0	-	149.15

C3-2 ZONE

Area 6 - DNPM 808.858/72 ...	-	3.0	-	5.0	-	15.0	-	-	27.4	27.4	6	1.64
Area 7 - DNPM 808.859/72 ...	-	8.0	-	5.0	-	40.0	-	-	73.2	73.2	6	4.39
Area 8 - DNPM 808.860/72 ...	-	8.0	-	5.0	-	40.0	-	-	73.2	73.2	6	4.39
Area 9 - DNPM 808.861/72 ...	2.0	5.0	50.0	5.0	100.0	25.0	73.2	109.8	45.7	228.7	8	18.30
Area 10 - DNPM 808.862/72 ...	4.0	4.0	100.0	5.0	400.0	20.0	292.8	439.2	36.6	768.6	8	61.48
Area 11 - DNPM 808.863/72 ...	4.0	3.0	80.0	5.0	320.0	15.0	234.0	351.0	27.4	612.4	8	49.00
Area 12 - DNPM 808.864/72 ...	2.3	4.0	30.0	5.0	70.0	20.0	51.2	76.8	36.6	164.6	8	13.16
Area 13 - DNPM 808.865/72 ...	-	6.0	-	5.0	-	30.0	-	-	54.9	54.9	6	3.29
TOTAL OF C3-2 ZONE...........	12.3	41.0	-	-	890.0	205.0	651.2	976.2	375.0	2003.0	-	155.65
TOTAL OF C2 AND C3-2 ZONES...	24.8	78.5	-	-	1745.0	392.5	1276.4	1914.6	718.0	3909.0	-	304.80

OBS: Same as for Table 1. Considered density of 1.83.

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ROCK SALT RESERVES

(Upper and lower Zones)

Table 4

Reference	Area 10^6 m^2		Average Thickness (m)		Volume 10^6 m^3		RESERVES 10^6 t				Zone
	Mea+Ind	Inf	Mea+Ind	Inf	Mea+Ind	Inf	Mea	Ind	Inf	Total	
Area A - DNPM 808.584/72	5.5	-	22.6	-	124.3	-	104.4	156.6	-	261.0	I
Area B - DNPM 808.585/72..........	2.5	-	12.0	-	30.0	-	25.2	37.8	-	63.0	I
Area C - DNPM 808.586/72	-	-	-	-	-	-	-	-	-	-	
Area D - DNPM 808.587/72	7.3	-	30.0	-	219.0	-	184.0	276.0	-	460.0	I
Area E - DNPM 808.588/72	6.0	-	16.5	-	99.0	-	83.2	124.8	-	208.0	I
Area F - DNPM 808.589/72	-	-	-	-	-	-	-	-	-	-	
Area G - DNPM 808.590/72	7.0	-	80.0	-	560.0	-	470.4	705.6	-	1176.0	I
	7.0	-	80.0	-	560.0	-	470.4	705.6	-	1176.0	S
Area H - DNPM 808.591/72	-	3.0	-	5.0	-	15.0	-	-	31.5	31.5	I
Area I - DNPM 808.592/72	-	2.0	-	5.0	-	10.0	-	-	21.0	21.0	I
Area J - DNPM 808.850/72	-	1.0	-	5.0	-	5.0	-	-	5.2	5.2	I
Area K - DNPM 808.851/72	-	2.0	-	5.0	-	10.0	-	-	21.0	21.0	I
Area L - DNPM 808.852/72	-	2.0	-	5.0	-	10.0	-	-	21.0	21.0	I
Subtotal	35.3	10.0	-	-	1592.3	50.0	1337.6	2006.4	99.7	3443.7	
Area M - DNPM 810.994/72	1.3	6.0	20.0	5.0	26.0	30.0	21.6	32.4	63.0	117.0	I
	3.0	10.0	20.0	5.0	60.0	50.0	50.4	75.6	105.0	231.0	S
Area N - DNPM 810.995/72	3.0	10.0	20.0	5.0	60.0	50.0	50.4	75.6	105.0	231.0	I
	4.0	10.0	20.0	5.0	80.0	50.0	67.2	100.8	105.0	273.0	S
Area O - DNPM 810.996/72	4.0	8.0	40.0	5.0	160.0	40.0	134.4	201.6	82.0	418.0	I
	5.5	10.0	50.0	5.0	275.0	50.0	230.8	346.2	105.0	682.0	S
Area P - DNPM 810.997/72	-	6.0	-	5.0	-	30.0	-	-	63.0	63.0	I
Subtotal	20.8	60.0	-	-	661.0	300.0	554.8	832.2	628.0	2015.0	
Area 01 - DNPM 808.853/72	-	0.5	-	5.0	-	2.5	-	-	5.2	5.2	I
Area 02 - DNPM 808.854/72	-	0.5	-	5.0	-	2.5	-	-	5.2	5.2	I
Area 03 - DNPM 808.855/72	-	0.5	-	5.0	-	2.5	-	-	5.2	5.2	I
Area 04 - DNPM 808.856/72	-	1.0	-	5.0	-	5.0	-	-	10.5	10.5	I
Area 05 - DNPM 808.857/72	-	2.0	-	5.0	-	10.0	-	-	21.0	21.0	I
Area 06 - DNPM 808.858/72	-	2.0	-	5.0	-	10.0	-	-	21.0	21.0	I
Area 07 - DNPM 808.859/72	-	3.0	-	5.0	-	15.0	-	-	31.5	31.5	I
Area 08 - DNPM 808.860/72	-	3.0	-	5.0	-	15.0	-	-	31.5	31.5	I
Area 09 - DNPM 808.861/72	-	3.0	-	5.0	-	15.0	-	-	31.5	31.5	I
Area 10 - DNPM 808.862/72	-	4.0	-	5.0	-	20.0	-	-	42.0	42.0	I
Area 11 - DNPM 808.863/72	3.0	4.0	10.0	5.0	30.0	20.0	-	63.0	42.0	105.0	I
Area 12 - DNPM 808.864/72	4.0	5.0	15.0	5.0	60.0	25.0	-	126.0	52.5	178.5	I
Area 13 - DNPM 808.865/72	4.0	5.0	20.0	5.0	80.0	25.0	67.2	100.8	52.5	220.5	I
Subtotal	11.0	33.5	-	-	170.0	167.5	67.2	289.8	351.6	708.6	
TOTAL RESERVE	67.1	103.5	-	-	2423.3	517.5	1959.6	3128.4	1079.3	6167.3	

OBS: Same as for Table 1. Density considered 2.1.
I - Lower Zone
S - Upper Zone

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TOTAL RESERVES OF THE REGION ADJACENT TO THE NATIONAL RESERVE AREA

TABLE 5

REFERENCE	POTASSIUM SALTS - CARNALLITE RESERVES 10^6 t						ROCK SALT RESERVES 10^6 t		
	MEASURED	IN K_2O	INDICATED	IN K_2O	INFERRED	IN K_2O	MEASURED	INDICATED	INFERRED
Area A - DNPM 808.584/72	-	-	318.0	31.80	-	-	104.4	156.6	-
Area B - DNPM 808.585/72	-	-	167.0	16.70	-	-	25.2	37.8	-
Area C - DNPM 808.586/72	-	-	26.5	2.60	-	-	-	-	-
Area D - DNPM 808.587/72	316.0	29.95	474.0	45.00	-	-	184.0	276.0	-
Area E - DNPM 808.588/72	148.8	14.88	223.2	22.32	-	-	83.2	124.8	-
Area F - DNPM 808.589/72	76.4	7.60	114.6	11.46	-	-	-	-	-
Area G - DNPM 808.590/72	-	-	-	-	-	-	940.8	1.411.2	-
Area H - DNPM 808.591/72	-	-	-	-	-	-	-	-	31.5
Area I - DNPM 808.592/72	-	-	-	-	-	-	-	-	21.0
Area J - DNPM 808.850/72	-	-	-	-	-	-	-	-	5.2
Area K - DNPM 808.851/72	-	-	-	-	-	-	-	-	21.0
Area L - DNPM 808.852/72	-	-	-	-	-	-	-	-	21.0
SUBTOTAL.....	541.2	52.43	1.323.3	129.88	-	-	1.337.6	2.006.4	99.7
Area M - DNPM 810.994/72	-	-	-	-	152.0	8.34	72.0	108.0	168.0
Area N - DNPM 810.995/72	82.4	5.47	123.6	8.20	190.6	12.18	117.6	176.4	210.0
Area O - DNPM 810.996/72	111.6	7.34	167.4	11.03	176.0	11.35	365.2	547.8	187.0
Area P - DNPM 810.997/72	-	-	-	-	132.7	7.38	-	-	63.0
SUBTOTAL.....	194.0	12.81	291.0	19.23	651.3	39.25	554.8	832.2	628.0
Area 01 - DNPM 808.853/72	-	-	-	-	-	-	-	-	5.2
Area 02 - DNPM 808.854/72	-	-	-	-	-	-	-	-	5.2
Area 03 - DNPM 808.855/72	-	-	-	-	-	-	-	-	5.2
Area 04 - DNPM 808.856/72	-	-	-	-	-	-	-	-	10.5
Area 05 - DNPM 808.857/72	-	-	-	-	-	-	-	-	21.0
Area 06 - DNPM 808.858/72	-	-	-	-	54.8	3.28	-	-	21.0
Area 07 - DNPM 808.859/72	-	-	-	-	137.2	8.23	-	-	31.5
Area 08 - DNPM 808.860/72	-	-	-	-	146.4	8.78	-	-	31.5
Area 09 - DNPM 808.861/72	131.6	10.53	197.4	15.78	86.9	6.95	-	-	31.5
Area 10 - DNPM 808.862/72	472.0	37.75	708.0	56.65	73.2	5.86	-	-	42.0
Area 11 - DNPM 808.863/72	420.4	33.63	630.6	50.41	54.8	4.38	-	63.0	42.0
Area 12 - DNPM 808.864/72	197.6	15.80	296.4	23.71	73.2	5.86	-	126.0	52.5
Area 13 - DNPM 808.865/72	54.8	4.38	82.2	6.57	91.5	6.22	67.2	100.8	52.5
SUBTOTAL.....	1.276.4	102.09	1.914.6	153.12	718.0	49.56	67.2	289.8	351.6
TOTAL RESERVES	2.011.6	167.33	3.528.9	302.23	1.369.3	88.81	1.959.6	3.128.4	1.079.3

TOTALS: CARNALLITE RESERVE: 6.909.8 x 10^6 tons

Equivalent in contained K_2O: 558.43 x 10^6 tons

ROCK SALT RESERVE: 6.167.3 x 10^6 tons

VIII - ANALYSIS AND DRESSING TESTS

The systematics for chemical analysis of the core samples was based on the utilization of the PERKIN-ELMER 303 Spectrophotometer of atomic absorption, besides a turbidimeter, potenciometer and equipament for dosage in humid media installed in a specialized laboratory in Aracaju, aiming at the following elements: Na, K, Mg, Co, Cl, SO_4, H_2O, and IR and also Special dosages for Br.

The contents observed were ionically balanced. In the development works the humidity of carnallite and of tachyhydrite samples will have to be determined because it is unknown the temperature limit between the evaporation of humidity and that of the formation water and particularly, that of the begining of samples alteration.

In view of the little frequency of carbonates in the potassic intervals the CO_2 dosage was omitted. This type of procedure is common in similar studies.

To confirm the analysis results, among other procedures, comparative studies of the contents obtained through chemical analysis were carried out to match the results obtained from the analysis of the data from electro-radioactive gamma and, caliper logs plus mud density.

Schlumberger has also carried out similar studies abroad using sinergetic log system. The results were confirmed with great approximation, indicating that, for the purpose of exploration and/or development of such type of deposit, this method is fully satisfactory.

The method of content determination for the areas of exploration, was adopted by CPRM for the new areas, in view of its previous knowledge. It was based on the referred tecnique of the gamma-ray radioactive logs whose values are dully corrected in function of the diameter of the holes observed in the caliper log and the mud density at the logging time.

During the works of the Potassium Project, the Battelle Memorial Institute became in charge of the semi quantitative spectrographic analysis for the minor elements in a compound sample of cores of the saliferous séquence. The results obtained were interesting in some cases, however they were not wholly confirmed by more selected sampling and by specific dosages, realized in 25 samples sent by CPRM to the United States Geological Survey Laboratory, according to the enclosed bulletins of partial analysis.

Some specific analysis frequently aiming at the solution of genetic problems were realized in cores, by N. C. Wardlaw, Professor of Geology, University of Calgary, Alberta, Canada.

The Columbus, Ohio laboratories of the Battelle Memorial Institute, (USA), based on their experiments trying to determine the technical feasibility to separate and recover the primary constituents of solution-mined tachyhydrite concluded that:

(1) Separation of the $MgCl_2$ and $CaCl_2$ constituents of tachyhydrite by a process involving evaporation and crystallization is technically feasible.

(2) The $MgCl_2$ hydrate product of the experiments was

enriched in magnesium to the extent that the Mg to Ca ratio was increased from 1.2 in the tachyhydrite ore head sample to over 14 in a magnesium-rich product formed by sucessive recrystallization. Further enrichment in Mg is believed possible with fewer recrystallizations if operations are conducted on a larger scale.

(3) Mass spectrographic analysis of the magnesium-rich product formed reveal that there are no contaminants present which should preclude the use of the partially dehydrated product for further processing to magnesium metal.

(4) The calcium chloride produced is probably of sufficient purity for use in highway construction.

(5) The NaCl constituent of the tachyhydrite deposit has a tendency not to dissolve in solutions approaching saturation with respect to tachyhydrite.

If dissolution of NaCl does occur a major partion can be crystallized from solution prior to cristallization of the calcium and magnesium chlorides.

(6) When crystallization of the $MgCl_2$ product is conducted at temperatures as low as 35 C, the product is enriched with the KCl constituent of the tachyhydrite deposit.

When crystallization temperatures as high as 75 C are used, the K to Mg ratio in the crystals formed is reduced appreciably.

The results of a preliminary assessment of the processing economics for a possible process to recover $MgCl_2.1.25\ H_2O$, $CaCl_2.\ 2\ H_2O$, MgO, and bromine from the solution-mined tachyhydrite have led to the economic feasibility of recovery.

The same Institute suggests that an experimental study be made for separation and purification of the above referred products in large scale, starting in a pilot plant, taking into consideration the possibility of using sun evaporation. Attention should be drawn to technical and economical aspects of solution mining as well as to the study of the market, and to the choice of different types of electrolytic cells, which might be used in the processing.

Hazen Research was also in charge of studying representative samples of the carnallite deposit, arriving at the following conclusion.

The preliminary studies show that separation of salts from a brine, produced by solution mining of a tachyhydrite-carnallite deposit is technically feasible. However there is a need for additional work to determine all the possible ways for better recovery and purity of the products.

Hazen recommends that further laboratory studies be carried out, covering the following objectives.

1. Study of carnallite/tachyhydrite rate and the best procedure for the optinum decomposition of the obtained mixture.

2. Study of the developed crystallization process from the standpoint of crystalline size of the solid produced. in

order to improve the solid-liquid separations.

3. Evaluate further recovery of magnesium values from the calcium chloride brine.

4. Study of water washing of the crystalline solids produced in order to improve the purity of the magnesium chloride streams.

5. Study of the bischofite recrystallization step to find if the final bischofite will meet electrolytic cell feed specification for magnesium metal production.

Once the above work is completed, a preliminary economical evaluation should be made to establish if the process justifies pilot plant testing.

The obtained rock salt, of high purity, may be successfully utilized as a raw material for the industry of caustic soda, and polymerized vynils. It should be stated that in the case of caustic soda production (solvay process) and soda ash, the needs for a high content $CaCO_2$ limestone may be met locally by the Maruim member of the Riachuelo Formation, in outcrops which occur in the requested areas.

Considering that the new areas, object of the present - report are integrated into the overall form of the same evaporitic basin, the results and recommendations for them are similar to those referred for the National Reserve Area.

In the long run, according to what is shown in the economic feasibility study, potassium whose technology of production is widely known, may define the mining condition of the deposit although it is true that the array of other associated elements, mainly rock salt, may greatly influence the success of the undertaking.

Considering the results obtained in the new areas and according to the integration planned for mining, in Mining Groups, including the deposit of the National Reserve Area, it will be possible to determine the operational limits to enable the integration of those new areas into the scale economics of the utilization of the Sergipe saliferous sequence. We do not lose sight of the need there is for a great enough reserve that may authorize the strong forecasted investment, nor underestimate the dynamic requirement of a mining industry to be able to count on a reasonable amount of mining wealth for its long lasting industrial needs and safety.

IX - ECONOMIC FEASIBILITY STUDY

As previously seen, the exploration areas, object of the present report, contain mainly carnallite, sylvinite and rock salt deposits.

Mining these deposits will ensure the exploitation of potassic and magnesium salts, as fundamental products and rock salt and others as by-products of co-products.

Comparing the different alternatives, by using the technological advances already established within the present outlook of the Brazilian Mining Sector and correlating the possibilites of the Sergipe evaporites, we conclude that the potassic fertilizer conjuncture will lastly define, the feasibility of mining the saliferous deposits, if we already accept the fact that the rock salt processing may decisively paramount the resolution of the problem.

The feasibility of this affirmative is reinforced when we notice that a domestic source of potassic fertilizer, aside any economic industrial setting is a strong support to the free and fair expansion of our agricultural economy, being a basic implement to our social economic progress and becoming an imperative subject of our national security.

The analysis of the product placement in face of the international market reveals that this fertilizer presents characteristics of super production which may persist up to 1975, at least.

The poorly organized growth of the world production of potassium caused a vilification of its prices, leading into a dumping stage in 1969, never attained by this fertilizer before as shown in the market curve.

For a more precise idea, we may observe that in the 50 - 60 decade, international price decreased from 72 dollars/ton of potassium (K) to 47 dollars/ton reflecting, at constant 1968 prices, a global decline of 34% in that period.

In the 1960 - 70 interval, during at least 2/3 of the period, price kept relatively stable, even with some tendencies of going up.

From 1966 on (beginning of great production in Canadian mines) price suffered an abrupt decrease, from 47 dollars/ton (1966) to about 23 dollars/ton, meaning a <u>50% reduction in four years</u>.

In 1970 - 71 price suffered slight increase, however the forescast up to 1975 considers the maintenance of the present status, unless new agreements between great producers, or entrances of new market suppliers and/or episodic discovery of a new and exceptional deposit, may change it.

In 1970 - 71 two events happened: great expansion of Israeli production and entrance of Congo-Brazaville in the world market of potassium, as well as greater production of the East European countries.

World production is presently estimated in 18 million tons of contained K_2O, being excepted that up to the year 2000 there is a possibility of, at least, duplicating it. More optimistic hypotheses consider it possible that up to the year 2000 the production be five times that of the present.

The following table explains, in numbers, the evolution of the world production, pre countries, in the period 1960/69. It is possible to notice that the present potassium in the world's superproduction is largely due to the great expansion realized in the 64 - 69 period by Canada and USSR.

WORLD PRODUCTION OF COMMERCIAL POTASSIUM

(1,000 short tons of K_2O equivalent

COUNTRIES	1960	1967	1968	1969	Oscillation 1967 - 1969
1) North America					
Canada	-	2,383	2,918	3,146	+ 32%
USA	2,393	3,299	2,722	2,804	- 15%
2) Europe					
France	1,580	2,136	2,047	2,134	Stable
East Germany	1,666	2,432	2,527	2,535	Stable
West Germany	1,978	2,712	2,823	2,853	Stable
Italy	26	270	298	309	-
Spain	265	629	679	617	-
USSR	1,084	3,161	3,439	3,505	+ 10,8%
3) Asia					
Israel	83	331	403	408	-
TOTAL	9,075	17,353	17,856	18,311	-

Alongside of Canada's upsurge and USSR's expansion of production, USA was showing a slight decline in production - between 1966 - 68 (-18%); West and East Germany and France keep their position in the world scene, being one of the world's six major producers.

Israel, despite losing its market to East Europe after the war with Egypt in 1967, intends to increase the capacity of production to reach 1.2 million tons in 1971 - 72, to gain other areas of compensation in the international market.

The world market, from 1971 on, counted with the participation of Australia, Congo Brazaville, (1.5 million tons/ year of KCl) and the United Kingdom, with installed capacity of a 1.5 million tons/year of KCl.

We observe, from the analysis of this conjuncture - that, with relative safety the upsurge of a new industry of fertilizers in any part of the world in the present terms will only be possible if supported by a vigorous captive market that with allow production in a economic scale.

Undoubtedly, such market conditions exist in Brazil, resting the final equation upon the problems of dependence on competitive costs of the variables production/transport to place the product at the Agriculture's hands. It is necessary to ponder that the question also involves aspects of security nature related with the economic development of the country.

Considering that Brazil is a net consumer of potassic fertilizers, its apparent consumption is identified with the import flow of this ore.

Figures 1 and 2, enclosed, respectively show an image of the Brazilian import of potassium chloride, annual growths of industrial potassic fertilizer imports and its unit price CIF - Brazil, ensuring a view on the behavior of those several items in the conduction of our industrial progress.

From the analysis of all the mentioned documents, providing a conjunctural diagnosis of the potassium consumption in Brazil it is evident that Brazil's growing demand will continue to move up and it will further raise in the coming years, in view of the nation's expansion. Direct and indirect Government measures to stimulate agriculture such as the creation of the programmes Proterra, Prodoeste, National Irrigation Plan, Policy of the Least Prices in Agriculture, Expansion of Agricultural Borders, Export Walls, etc are apt to keep the growth of the primary sector of economy at least in compatible levels with the national progress.

Intensive and extensive use of potassium as fertilizer accompanies the evolution of this sector since there is no substitute for it in its important macronutrient function beside phosphate.

The following chart shows in a global outlook how incipient the Brazilian fertilizer consumption is, a logic consequence for the absence of potassium and phosphate sources of production and for the low technological level of our agriculture.

Cultivated Areas (1,000 ha)

CULTURE	NORTHEAST (1)		SOUTH-CENTRAL (2)		SOUTH (3)	
	MANURED AREA	TOTAL	MANURED AREA	TOTAL	MANURED AREA	TOTAL
Cotton	-	448	636	1,212	-	-
Rice	-	17	250	1,010	191	383
Potato	-	-	88	88	-	61
Coffee	-	-	1,000	2,000	-	-
Sugar Cane	146	365	300	756	-	53
Beans	-	372	28	285	27	274
Tabacco	-	14	-	-	115	115
Manioc	-	185	5	104	13	274
Corn	-	443	1,800	3,600	500	1,670
Weat and Soybean	-	-	250	583	757	1,314
TOTAL	146	2,581	4,357	9,638	1,603	4,144

(1) Estimate referring to 1968.

(2) Study by Associação Nacional para Difusão de Adubos (ANDA) T. 13/70 refers to 1969.

(3) Estimate referring to 1968.

SOURCE: Perspectivas da Indústria de Fertilizantes no Brasil - Paulo Vieira Belotti - 1970.

It is also known that the North, Northeast and West Central Regions, object of concentrated development efforts of the Federal Government to not even have a significant apparent consumption of fertilizers.

The source of the previous chart, gives the data below, based on projections made by technicans of the Tennessee Valley Authority - TVA for the years of 1975 and 1980.

Brazil - Estimate of Fertilizer Consumption

In 1,000 tons (Metric)

Year	N	P_2O_5	K_2O	TOTAL
1975	515	646	371	1,532
1980	942	931	514	2,387

SOURCE: Perspectiva de Fertilizantes no Brasil -
Paulo Belotti - 1970

It is worth to repeat the same projection for potassium according to the same indexes, considering however that in 1970 imports have already reached the equivalent of 300,000 tons of contained K_2O.

Year	1970	300,000 tons K_2O
Year	1975	420,000 tons K_2O
Year	1980	590,000 tons K_2O

Figure 3, enclosed, makes possible to focus such - projection on Brazil, considering estimates of growth from 10 to 15% a year, respectively.

Even considering that the 1970 imports have suffered an increase beyond that expected, due to processes of stock and to stimulus of the price decline, which permitted greater utilization of the product in past years, the fact serves to bring up the problems of restrained demand.

One reason that could be exposed against the utilization of the Brazilian potassium would be the advantage of import at low prices at the present date.

Nevertheless considering the expected pressure relief in the international market at medium term, we would not incorporate to our industrial constellation a permanent and highly significant source of domestic production of potassium.

Such placement becomes stronger in terms of National Security if we consider the array of other recoverable products such as bromine, magnesium and rock salt, derived from the same deposits, joined by the same mining methods and all of them possible generators of new industries. A captive market modestly forecasted to omount to 600,000 t of K_2O/year of 1,000,000 ton of KCl/year, in 1980 allows the immediate creation of a large-size industry.

Only two of the eight largest producing canadian industries are authorized to commercialize the equivalent of over 4000,000 tons of contained K_2O/year and four of them are authorized to produce only 250 to 300,000 tons of contained K_2O/year, reflecting the complexity of the potassium conjuncture, activity directed by the government of that country.

Based on the present conditions of international productions and on the possibility of return freight, it is possible to forecast the placement of potassium from Sergipe, grade standard of 60% of K_2O (muriate) CIF-Santos at approximately US$ 40.00/ton (metric). Just to reinforce the possibilities of development of the Brazilian market of potassium, it is convenient to point out that our consumption is 12 times smaller than that of USA and, in 1969/70 despite the relative stability of the market, the consumption of the Western Europe increased 6%.

According to obtained data the implantation of a national industry suggests an economic production optimum at around the equivalent of 500,000 ton/year of contained K_2O which under the lights of avaliable statistics is acceptable for the Brazilian situation.

Emphasis given to the market problem reflects CPRM worries in the industrialization of the deposit knowing its commercial possibilities are both important to qualification and quantification of available reserves.

The compound mining of the deposits considered in this Report and those of the National Reserve Area must be fully planned for one sole mining unit, thus shaping one Mining Group, as defined in article 53 of the Brazilian Code of Mining.

The plans for mining, accordingly, will allow a rational utilization of the deposits preventing competitive groups to carry out predatory mining, which would make unfeasible the group of deposits producing incalculable losses to the national interest in the name of a fractionary rentability at short term, within the dispute of the same market.

While waiting for DNPM's approval of the present report, CPRM will proceed with the basic studies which will ensure to define the method or methods of mining to match the importance of the problem, in the Sergipe saliferous province.

Under the light of the available information, two mining methods have been suggested for the area: underground conventional mining and mining by solution. Each method admits multiple alternatives: nature of minerals, depth, structural arrangement, thickness of layers, mechanic behavior of the ore and of its wall rocks, termic gradient, besides the hidrodynamic characteristics of the saliferous sequence.

By the method of underground mining, through the system of rooms and pillars, according with the prevailing conditions of the evaporites in the National Reserve Area, it becomes necessary to firstly consider the development stage of the deposit with the opening of at least one shaft. It consists of one excavation with approximately seven meter diameter up to a thousand meter deep. This shaft would permit the acess to layers of interest to mining giving conditons to develop galleries where from the ore would be mined with the help of mechanic equipment. The shaft would also give conditions to the movement of personnel, equipment and material permitting on the other hand the access to the installation of the light and power fixtures and probably refrigration, besides vertical transportation of the dismounted ore from the working front to the surface.

In the shaft excavation the hydrodynamic conditon of the horizons to be crossed may require artificial freezing and further stoppage and coating.

The size of the rooms and pillars may be influenced by the nature of the layers immediately overlying, mainly related to the mechanic behavior of the rocks and of the undergroung water system.

International experience in mining such types of deposits by the room and pillar method reveals that shallower layers, around 500 m may be mined with a recovery of approximately 50 to 60%. At 1,000 m depth however the potassic salts are apt to be fluid, and under such conditons recovery is probably 25 to 35% and as low as 20%.

The establishment of a plant with 300,000 tons/year of K_2O capacity of production will require an investment of around 80 million dollars.

Adding to this amount about 15 million dollars for the shaft, reconaissance galleries, additional exploration and development, considering the cost of purchasing the results of the research, the total capital to be invested up to the beginning of full operation of the mine-surface-marine terminal-complex will amount to 110 million dollars.

The method of mining by solution consists of drilling tube shaped holes with rotary drills up to the minable zone. Through these tube-like holes two lines of tubes with compatible diameters are driven to the horizon of economic interest.

In the ring-type space between the tubes and the coating, oil circulates.

One of the tubes is used for injection of fresh water and the other for the brine mining resultant from the salt solution.

The third tube would be to control and to measure the depth of the hole.

The brine obtained by this process leaves an incipient cavity at the bottom. Fresh water trend is to dissolve the soluble salts in a vertical direction, originating a cyinder-type cavity of narrow diameter and great vertical dimension.

If the exploitation of the existent salts in the horizontal dimension is needed, a controlled solution is utilized, by means of oil level or of a fluid less dense than water. This fluid floats in the upper part of the cavity involving its ceiling, thus avoiding and controlling salt solution at this place.

This way, the cavity must grow in its latteral direction. This cavity must be kept full of brine at all times, with the objective of protecting the ceiling.

In view of the slow disintegration of salts the production of brines with operational concentration requires that the circulation (injection/extraction) rate be permanently under control.

The great difficulty of the system is to set the critical diameter of the cavity on which the economics and safety of the process depend.

Vertical control of the cavity dimension is made by manipulation of the tubes and it is taken from the level of the existing light fluid.

Normally, the operational life of each hole varies from 9 (nine) to 18 (eighteen) months and the production hole/year must reach theoretically about 100,000 ton of KCl.

The brine being brought to the surface through one of the tubes is purified and evaporated. This way we may obtain salt in a more concentrated form.

Depending on the nature of the brine and on the end products desired, the solutions may undergo complex and varied physico-chemical treatments including electrolysis and foundry for metallic material.

The method of mining by solution, besides ensuring an industrial take off, in a shorter term, with milder initial mining investments, introduces a very important component into the operational system-flexibility - a desirable parameter,considering the variable nature of profilable evaporites, the successive intercalations in the same vertical, their strucutral behavior and the lateral extension of the deposits.

In Sergipe, the brine will be concentrated also by sun evaporation depending on the workability of this process and on the results of experimental studies to be conducted during the development of the deposits.

At first, by the method of mining by solution, potassium and magnesium minerals and rock salt will be exploited. Several technological processes are employed the world over, depending on the mineral to be dissolved, on the required treatment and on the end products desired.

The choice of a certain method will previously depend on pilot tests and on the specific definition of the economics. New technologies have been developed and patented. Many of them have not yet undergone definite test for large scale economic utilization.

A method recently discovered and of ideal applicability in Sergipe seems to be the dissolution of carnallite with simultaneous exploitation of potassium, magnesium and other associated salts, patented by American technician Kenneth J. Kutz.

The method essentially consists of introducing water through the open hole into the carnallite layer to promote leaching of $MgCl_2$ from carnallite thus forming a cavity inside the layer.

Leaching of $MgCl_2$ leaves KCl, less soluble, as a pulp at the bottom of the hole. KCl in suspension is then removed through the columm of tubes in the hole, from $MgCl_2$ saturated brine solution. Separation of solid (KCl) and liquid ($MgCl_2$) stages is done by decantation and/or centrifugation.

In case this technology proves to be useful, a new door for the exploitation of extensive carnallite reserves is open, reducing considerably the size of pre-operational and production investment, besides great savings in time.

From the above exposed, we may define the amount of investment for the operation of the mine - surface - marine terminal complex, for a level of production equivalent to 500,000 tons of contained K_2O, knowing the presently estimated price of import CIF Santos to be around 40 dollars/ton of KCl, the transport Mine - Santos being 7 dollars/ton.

Also knowing that the cost of exploitation run of mine including depreciation of equipment and premium of investment depending upon the adopted mining plan to be set at a value of 14 to 18 dollars/ton of KCl, there will be a possibility of 15 to 19 dollars savings.

Such amount will be directed to compensate for the costs of dressing (according to the choice of the mining method it will vary from 4 to 1 dollar/ton of KCl), paying off the capital and industrial profit not being included the possibility of recovery and commercialization of by-products and/or co-products such as rock salt, with negligible mining costs. These considerations allow to infer a configuration of economic feasibility to the undertaking even in competitive terms with the present prices in the international market.

The indexes resulting from the investigation of the enterprise evaluation, in view of the expected levels of production are those normally found for a large size industry, especially a mining adventure large enough to call the attention and interest of competent and capable groups.

We may summarize that in terms of a captive market, there is economic feasibility to the exploitation and commercialization of soluble salts in Sergipe, resting the dependent technical feasibility to be determined upon the working up of an integrated mining plan.

We thus believe to have demonstrated the economic feasibility of mining and of the undertaking, by any of the mining methods suggested and mainly considering the significance of the exceptionally advantageous guarantee of a domestic market in continous expansion.

Rio de Janeiro,

Francisco Moacyr de Vasconcellos

Mining and Civil Engineer, CREA 526 D, 2ª Região

Technical Director of Operations

VOLUME I - APPENDIX

INFORMATION ON MINOR ELEMENTS IN THE SERGIPE EVAPORITES

The accomplishment of the Potassium Project included contracts made with the Columbus-Ohio Laboratories of the Battelle Memorial Institute and Hazen Research Inc. of Golden, Colorado to carry out a study of tachyhydrite's recovery and economic exploitation in the Sergipe evaporitic sequence.

The Battelle's program had in view the feasibility and costs of obtention of magnesium chloride and by-products, from tachyhydrite.

A composite sample was prepared, at the Potassium Project's headquarters in Aracaju, Sergipe, from continuous samples of the upper part of Upper Tachyhydrite zone (T6) in wells PKC-1, PKC-6, PKC-7, PKC-10. The composite sample, after mixing and quartering, was subdivided into three fractions of approximately 15 kg each, which were carefully packed. One sample was sent to Battelle and the other to Hazen.

Battelle presented a report in which it included two tables with results of minor elements analyses. Hazen also presented a report, without minor elements analyses.

The Battelle's referred tables (Annex No..1) contain the results of mass spectrographic analyses made for 68 minor elements in the head sample and in samples of recrystallized products. In both tables the contents are in p.p.m. (parts per million = g/ton).

The results of the head sample analyses show some elements or noble metals of high commercial value, with the following contents:

Gold	3.0 ppm	Platinum	.3 ppm	Germanium	60.0 ppm
		Palladium	7.0 ppm	Lanthanum	6.0 ppm
Silver	1.0 ppm	Rhodium	2.0 ppm	Cesium	6.0 ppm
		Ruthenium	5.0 ppm		
Europium	2.0 ppm	Iridium	.2 ppm		
Gadolinium	6.0 ppm	Osmium	.2 ppm		

These values, according to the method of analysis may be considerably higher or lower than the actual values.

Although some values are relatively high, the Battelle Institute mentions in page No. 12 of its report that: "The other minor elements do not appear to be present in sufficient quantity to consider recovering them". Exception is made for bromine.

There were no other analyses to compared with those results. In Robert Hite's report (Observations Pertaining to the Potassium Project) a table with the results of spectrographic analyses made in 3 isolated samples of Carnallite and Tachyhydrite by the USGS in Denver, Colorado, is found.

Only twelve common elements were detected, without interest to the present case.

Norman Wardlaw's report (Unusual Marine Evaporites...) based on local samples (non-continuous) of salt sections in well PKC-10 contains analyses of bromine, rubidium and stroncium in almost the entire column. The last study aimed at genetic purpose and it did not included however analyses of other minor elements.

In November 1971, three local (non continuous) samples of tachyhydrite were analysed by the USGS in Denver, Colorado by the semi-quantitative spectrographic, absorption, atomic and fire assay spectrographic methods. Twenty five composite samples of carnallite and tachyhydrite were recently (June 1972) prepared in Aracaju, Sergipe. The were representative of the usually thick zones of some wells in the Potassium Project (PKC-1, PKC-6,PKC-7, PKC-8, PKC-9, PKC-10, PKC-11 and PKC-18) distributed in the former area of the National Reserve (see table, annex No. 6).

Composite samples numbered 1 and 2 of PKC-1, 1 of PKC-6; 1 of PKC-7 and 1 of PKC-10 deliberately include all the intervals which the composite samples analysed by Battelle come from.

The twenty five samples were sent to the USGS in Denver Colorado and were analysed by semi-quantitative spectrographic, fire assay... spectrographic, atomic absorption (AA), fire assay. .. AA methods. The analyses results are enclosed.

Initially, in June 1972, the samples were analysed by the semi-quantitative spectrographic method. The results (annex no 14-5 of the Report) were generally negative, although this method is not sufficiently sensitive for the determination of gold (10 ppm lower limit) and of other elements. Besides the common elements, some others were observed, asfollows:

Lanthanum	50 ppm in sample No 2 of PKC-8 (shale/Tachyhydrite)
Ytterbium	20 ppm in the same sample
Scandium	10 ppm in the same sample
Lithium	500 ppm in sample No 1 of PKC-11 (Tachyhydrite)

In some samples gadolinium was also detected with 10 to 15 ppm; indium with 10 to 30 ppm. Stroncium occurs with 300 to 5000 ppm in various samples and rubidium with 300 ppm in sample No 2 of PKC-8.

Cerium was not analysed and cesium was not detected (a high lower limit of 500 ppm) as well as germanium (lower limit not registered).

In July 1972 the samples were analysed by the fire assay.... spectrographic method (Annex No 3). The following elements of the platinum group were detected, within the limits of determination shown between brackets: platinum (.005 ppm); ..... palladium (.002 ppm); rhodium (.002 ppm), ruthenium (.100 ppm), iridium (.050 ppm). Osmium was not analysed.

At the end of July, beginning of August 1972, the samples were analysed for gold, by the atomic absorption (AA) and fire assay ... AA methods.

The results were generally positive (Annexes No 4 and 5).

The table in annex No 6 contains besides the interval of depth and thickness of samples, the respective designation of the saline zone (zoning of evaporites) given by J. C. Fonseca, (April/1972) and the analyses results. We may compare, from this table, the methods of analyses and their resultant contents.

Using the atomic absorption method in not roasted samples, gold was not detected above the limit of .02 ppm. This fact suggests the absence of gold, in soluble form, from salts.

Using the same method but with roasted samples, variable values were detected, between .22 and 3.20 ppm (g/ton) indicating the presence of native gold or gold compounds (sulphides, tellurets etc.) with a particle form. Possibly these particles are capsuled or associated with substancies such as carbon and its compounds which make difficult or impair their enclosures by bromidic acid (H Br).

Previous roasting of the sample eliminates those substances enabling the aggregate to split.

The results of the fire assay ... AA, show less constant values, ranging between L (.05) and 2.50 ppm reaching the isolated value of 14 ppm in sample No 4 (C3-2 carnallite zone, 60 m thick) of well PKC-8.

In this method, the sample is melted with the help of a melting solvent, previous to the sollubilization in acid. The samples are dried at the temperature of 95°C before being weighed.

Comparing the results of the two methods, we observe that there is no equity of values, whereas on the contrary we find differences as such: 14.00 - .62; L (.05) - 2.70;L (.05)- 2.00. The occurrence of gold in the form of particles disseminated in the sample would explain statistically those variations.

During the uptake of small samples for analysis, from the head sample, a greater particle in one of the small samples would give way to different results.

These results seem to indicate, in fact, the presence of gold in several carnallite and tachyhydrite salline zones in the evaporitic sub-basins of Taquari-Vassouras and Santa Rosa de Lima, in the State of Sergipe.

It is necessary to determine the actual values, form of occurrence, association and vertical distribution, through a detailed and extensive program of sampling and specific analyses for gold and other valuable minor elements.

Carnallite and especially tachyhydrite are very deliquescent. Special care and techniques should be taken in the laboratory during manipulation and analysis of the samples. Some recomendations were presented by A.P. Marranzino (Advisor for Geochemical Laboratories, USGS) through Memo Nº 89/72, dated

August 17, 72 (Annex No 7).

In the sampling technique adopted in Aracaju, Sergipe the samples of deliquescent salts such as carnallite and tachyhydrite are triturated under the sun, a condition under which the salts dry and remain dried, with the recrystallization of the brine pellicle around the grains and crystals.

In cloudy or rainy days a simple stove made up of lamps on screens with different positions and temperaturs is used.

The sample is dried at the temperature of 40° to 60° C to avoid loss of the crystallization water of the salts. Soon after the sample is prepared, it is placed in bottles, mouths of which are polished and paraffined.

It is easy to evaluate the economic importance of the presence of gold in the evaporitic basin, provided that the systematic investigations to be developed conduct to average results, concordant with those obtained in the samples considered above.

Rio de Janeiro, August, 1972

TABLE 2. MASS SPECTROGRAPHIC ANALYSIS OF MINOR ELEMENTS IN COMPOSITE HEAD SAMPLE OF TACHYHYDRITE ORE[(a)]

Element	Parts Per Million By Weight	Element	Parts Per Million By Weight	Element	Parts Per Million By Weight
Li	1	Rb	10	Gd	6
Be	0.05	x Sr	600	Tb	1
B	30	Y	0.5	Dy	3
F	1	Nb	2	Ho	1
Al	100	Mo	10	Er	3
Si	700	x Ru	5	Tm	1
P	2	x Rh	2	Yb	1
S	300	x Pd	7	Lu	1
Sc	2	Ag	1	Hf	1
Ti	15	Cd	6	Ta	3
V	10	In	6	W	0.3
Cr	5	Sn	6	Re	0.6
Mn	100	Sb	4	x Os	0.2
Fe	500	Te	2	x Ir	0.2
Co	5	I	0.6	x Pt	0.3
Ni	10	x Cs	6	x Au	3
Cu	15	Ba	4	Hg	0.4
Zn	15	x La	6	Tl	0.2
x Ga	6	Ce	1	Pb	4
x Ge	60	Pr	1	Bi	1
As	100	Nd	1	Th	0.4
Se	10	Sm	1	U	0.1
x Br	2000	x Eu	2		

(a) Maximum values detected.

TABLE 4. MASS SPECTROGRAPHIC ANALYSES OF SAMPLES FROM EXPERIMENT 7 IN PARTS PER MILLION BY WEIGHT(a,b)

	Sample Designation(c)					Sample Designation			
Element	A	B	C	D	Element	A	B	C	D
Li	1	0.01	0.004	0.03	Y	0.5	0.3	0.3	ND
Be	0.05	0.02	0.02	ND(d)	Zr	ND	0.3	0.3	ND
B	30	1	0.1	0.3	Nb	2	0.5	0.5	ND
F	1	1	1	ND	Mo	10	1	1	ND
Al	100	4	1	2	× Ru	5	5	5	ND
Si	700	10	1	ND	× Rh	2	2	2	ND
P	2	0.5	0.2	ND	× Pd	7	4	4	ND
S	300	3	1	2	Ag	1	4	4	ND
K	high	high	high	300	Cd	6	6	6	ND
Ca	high	3000	200	high	In	6	2	2	ND
Na	high	high	high	600	Sn	6	6	6	ND
Sc	2	2	0.7	ND	Sb	4	4	4	ND
Ti	15	20	20	40	Te	2	0.6	0.6	ND
V	10	3	1	1	I	0.6	0.2	0.2	ND
Cr	5	15	5	ND	× Cs	6	0.6	0.6	ND
Mn	100	20	10	50	Ba	4	1	2	3
Fe	500	20	4	ND	× La	6	2	0.3	ND
Co	5	15	5	ND	Ce	1	1	1	ND
Ni	10	25	5	ND	Pr	1	1	1	ND
Cu	15	15	15	ND	Nd	1	2	1	ND
Zn	15	3	3	ND	Sm	1	1	1	ND
× Ga	6	0.6	0.6	ND	× Eu	2	1	1	ND
× Ge	60	60	60	ND	Gd	6	3	3	ND

TABLE 4. Continued

	Sample Designation(c)					Sample Designation			
Element	A	B	C	D	Element	A	B	C	D
As	100	40	4	100	Tb	1	1	1	ND
Se	10	20	20	ND	Dy	3	1	1	ND
x Br	2000	500	300	300	Ho	1	0.3	0.3	ND
Rb	10	100	100	2	Tm	1	0.3	0.3	ND
x Sr	600	100	15	1000	Lu	1	1	1	ND
Er	3	1	1	ND	Ta	3	1	1	ND
Yb	1	0.3	0.3	ND	Re	0.6	1	1	ND
Hf	1	1	1	ND	x Ir	0.2	1	1	ND
W	0.3	0.3	0.3	ND	x Au	3	1	1	ND
x Os	0.2	0.2	0.2	ND	Tl	0.2	3	3	ND
x Pt	0.3	1	1	ND	Bi	1	1	1	ND
Hg	0.4	0.4	0.4	ND	U	0.1	0.1	0.1	ND
Pb	4	4	4	2					
Th	0.4	0.1	0.1	ND					

(a) Head sample analysis repeated from Table 2 for comparison purposes.

(b) Maximum values detected.

(c) A = head sample of tachyhydrite ore
B = singly recrystallized product (not shown in Table 3)
C = doubly recrystallized product (shown in Table 3)
D = crystals formed by crystallizing mother liquor from 35 C crystallization at 75 C.

(d) ND = not determined.

Table 1 presents the measured results of the chemical analyses for major elements as well as a calculated head analyses based on the compositions of the individual core samples provided by the DNPM. The first and second determination agree with each other within about 4 percent for most components and these are within reasonable agreement with the calculated head analysis.

A material balance made on the ionic species shown in the second column of Table 1 indicated that the composite sample had the following approximate molecular composition: NaCl - 5 percent, KCl - 1.5 percent, $MgCl_2$ - 36 percent, $CaCl_2$ - 21.3 percent, Na_2SO_4 - 0.2 percent, and H_2O - 35.8 percent.*

Table 2 presents the analysis for the minor elements in the composite sample. It should be noted that about 2000 parts per million (ppm) bromine is present. This is comparable to the bromine content of the contained solids in brines which are known to have been worked for their bromine values. For example: the Michigan brines contained 500 to 3000 parts per million (ppm), Searles Lake, California, contains about 850 ppm, and the Dead Sea (the richest known source) contains about 5600 ppm of bromine.(13)

The other minor elements do not appear to be present in sufficient quantity to consider recovering them.

Mineralogical Characterization

The mineralogical character of the composite sample was determined microscopically. It was estimated that the sample contained 82 to 87 percent tachyhydrite ($CaCl_2 \cdot 2MgCl_2 \cdot 12H_2O$), 8 to 12 percent carnallite ($KCl \cdot MgCl_2 \cdot 6H_2O$), 3 to 5 percent sylvite (KCl), and 2 to 4 percent halite (NaCl).

The calculated mineral composition closely agrees with the microscopic analysis. A molecular balance based on the results of the chemical analyses was made. It was estimated from this balance that the composite sample contained about 89 percent tachyhydrite, 5 percent carnallite, 1 percent sylvite, and 5 percent halite.

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* H_2O determined by difference in all cases.

HM 4038 - Supplement spec. sheet
6-29-72

Apendice
ANEXO 2. a

	AMOSTRAS	Cs (500)	Li (200)	Rb (2)
1	BFZ-059	N(500)	L (200)	2
2	060		N (200)	2
3	061			2
4	062			2
5	063			70
6	064			70
7	065			30
8	066		L (200)	15
9	067		N(200)	2
10	068			2
11	069			3
12	070			20
13	071			5
14	072			300
15	073			70
16	074			15
17	075			50
18	076			30
19	077		L(200)	30
20	078		N(200)	7
21	079			N(2)
22	080			
23	081		500	
24	082		N(200)	10
25	083			15

06/72

Ge - não têm
Germânio

In VH1 N(10)
Índio

Samples	ppm
6	10
7	L (5)
15	30
19	L (5)

Ga
Gálio

Samples	ppm
6	L (10)
7	L (10)
15	15
16	L (10)
19	10
VH-1	15

Apendice
ANEXO 2 b

Requester: A.P. Marranzino
Analysts:
F/A: R.R. Carlson
Spec.: E. Cooley
AA:

FIELD SERVICES SECTION

FIRE ASSAY

Page No. 1 of 2.
Film No. 10-18A

HM 4038

			FIRE ASSAY---AA		FIRE ASSAY----SPECTROGRAPHIC				
		Date			7/7/72	7/7/72	7/7/72	7/7/72	7/7/72
		▨	32 / 1	32 / 8	32 / 15	32 / 22	32 / 29	32 / 36	32 / 50
Field No.	Tag No.	Sample Weight	Au ppm	Ag ppm	Pt ppm	Pd ppm	Rh ppm	Ru ppm	Ir ppm
1-PKC-1ET	BFZ 059	15.0g			N(0.005)	N(0.002)	N(0.002)	N(0.100)	N(0.050)
2	060								
3	061								
4	062								
5	063								
6	064								
7	065								
8	066								
1-PKC-6ET	067								
2	068								
1-PKC-7ET	069								
2	070								
1-PKC-8ET	071								
2	072								
3	073								
4	074								
5	075								
6	076								
1-PKC-9ET	077								
2	078								
1-PKC-10ET	079								
2	080								
1-PKC-11ET	081								
1-PKC-12ET	082								

ANEXO 3 a

Apendice

FIELD SERVICES SECTION

FIRE ASSAY

Page No. 2 of 2

Film No. 10-18A

Requester:

Analysts:

F/A:

Spec.:

AA:

HM 4038

			FIRE ASSAY---AA		FIRE ASSAY----SPECTROGRAPHIC				
		Date	32 / 1	32 / 8	32 / 15	32 / 22	32 / 29	32 / 36	32 / 50
Field No.	Tag No.	Sample Weight	Au ppm	Ag ppm	Pt ppm	Pd ppm	Rh ppm	Ru ppm	Ir ppm
2-PKC-13ET	BFZ 083	15.0			N(0.005)	N(0.002)	N(0.002)	N(0.100)	N(0.050)

Apendice

ANEXO 3 b

Apendice
ANEXO 4 a

Element Au
Sample Weight 10.0 g
Volume 10.0 ML
Method A.A. 103
Requisition Number 4038
Requestor A.P.M
Analyst M.A. Lisboa
Received
Completed

Not Roasted Roasted

Number		SAMPLE		ppm Reported	Number				ppm Reported
BE2059	N(.02)	1	PKC-1 ET		3.0 D				
60	N(.02)	2			.96				
61	N(.02)	3			2.01 D				
62	N(.02)	4			.60				
63	N(.02)	5			2.7 D				
64	N(.02)	6			.90				
65	N(.02)	7			.28				
66	N(.02)	8			.40				
67	N(.02)	1	PKC-6 ET		2.0 D				
68	N(.02)	2			1.6 D				
69	N(.02)	1	PKC-7 ET		1.8 D				
70	N(.02)	2			.30				
71	N(.02)	1	PKC-8 ET		.22				
72	N(.02)	2			.38				
73	N(.02)	3			.90				
74	N(.02)	4			.62				
75	N(.02)	5			1.1				
76	N(.02)	6			.92				
77	N(.02)	1	PKC-9 ET		.74				
78	N(.02)	2			.30				
79	N(.02)	1	PKC-10 ET		3.2 D				
80	N(.02)	2			1.6 D				
81	N(.02)	1	PKC-11 ET		2.8 D				
82	N(.02)	1	PKC-18 ET		3.0 D				
83	N(.02)	2			.76				

Remarks

AM 4038 - Au results (File para APM)

Method... AA 7-25-72

Apendice

ANEXO 4 b

1°) Placed in hot oven at 700°C. for 2 hrs
10 g samples in old crucibles
solids dissolved in H_2O and boiled to
dryness then digested in hot HBr for 2 hrs

Samples		Au-PPM
BFZ	059	3.0
	60	.96
	61	2.0
	62	.6
	63	2.7
	64	.9
	65	.28
	66	.40
	67	2.0
	68	1.6
	69	1.8
	70	.3
	71	.22
	72	.38
	73	.90
	74	.62
	75	1.1
	76	.92
	77	.74
	78	.30
	79	3.2
	80	1.6
	81	2.8
	82	3.0
	83	.76

Note: The samples swelled
and turn out from the
crucibles and melted

Apendice
ANEXO 4 c

2°) The samples were not roasted. 10 g sample was used. The normal procedure was followed.

Samples	PPM Au
BFZ 059	N(.02)
60	
61	
62	
63	
64	
65	
66	
67	
68	
69	
70	
71	
72	
73	
74	
75	
76	
77	
78	
79	
80	
81	
82	
83	

Requester: [illegible]

FIELD SERVICES [illegible]

[illegible] 1 [illegible] 2

Analysts:

F/A: R. R. Carlson

Spec.: ———

AA: R.R. Carlson

FIRE ASSAY

Film No. ____

HM 4038

			FIRE ASSAY---AA		FIRE ASSAY----SPECTROGRAPHIC				
		Date	8/2/72						
			32 / 1	32 / 8	32 / 15	32 / 22	32 / 29	32 / 36	32 / 50
Field No.	Tag No.	Sample Weight	Au ppm	Ag ppm	Pt ppm	Pd ppm	Rh ppm	Ru ppm	Ir ppm
1-PKC-1 E.T.	BFZ 059	15.0g	2.5	✓					
2	060	↓	0.05						
3	061		0.05						
4	062		0.05						
5	063		L(0.05)						
6	064	15.0	0.05						
7	065	3.0	0.55	✓					
8	066	15.0	0.05						
1-PKC-6 E.T.	067	↓	L(0.05)						
2	068		0.10						
1-PKC-7 E.T.	069		0.25	✓					
2	070		0.05						
1-PKC-8 E.T.	071		0.05						
2	072		0.05						
3	073		0.90	✓					
4	074		14	✓					
5	075		L(0.05)						
6	076		0.10						
1-PKC-9 E.T.	077		L(0.05)						
2	078		0.05						
1-PKC-10 E.T.	079		0.45	✓					
2	080		0.20	✓					
1-PKC-11 E.T.	081		0.10						
1-PKC-18 E.T.	082		0.55	✓					

Apendice
ANEXO 51a

Requester:
Analysts:
F/A:

Spec.:

AA:

HM 4038

FIELD SERVICES SECTION

FIRE ASSAY

Page 2 of 2

Film No.

			FIRE ASSAY---AA		FIRE ASSAY----SPECTROGRAPHIC				
		Date	32 / 1	32 / 8	32 / 15	32 / 22	32 / 29	32 / 36	32 / 50
Field No.	Tag No.	Sample Weight	Au ppm	Ag ppm	Pt ppm	Pd ppm	Rh ppm	Ru ppm	Ir ppm
2-PKC-18En	BFZ 083	15.0	0.05						

Samples dried for 5 hrs at 95°C. in drying oven with dessicant, then weighed. Those samples which were liquid at room temp. after drying, were frozen, then weighed.

Apendice
ANEXO 5 b

C.P.R.M.

Apendice
ANEXO 6

EVAPORITOS DE SERGIPE

Relação de Amostras Compostas para Análises de Elementos Traços - e Resultados de Análises

POÇOS	NÚMERO AMOSTRA EL. TRAÇOS	INTERVALO PROFUNDIDADE	ESPESSURA	NÚMEROS AMOSTRAS CONTÍNUAS DO INTERVALO	ZONAS SALINAS - ZONEAMENTO POR J. C. FONSECA (Abril/72)	RESULTADOS DE ANÁLISES EM ppm - (gr/t)											
						FIRE ASSAY ... AA	AA - ABSORÇÃO ATOMICA		FIRE ASSAY ...SPECT.	SEMI - QUANTITATIVE SPECTROGRAPHIC							
							Roasted	Not Roasted	Pt (.005) Ru (.10) Pd (.002) Rh Os (.002) Ir (.05)	Ag (0,5) Au (10) V (10) Cd (20) W (50)				Ce Cs (500) Ge (?)			
						Au (0.05)	Au (0.02)	Au (0.02)		La (20)	Sc (5)	Y (10)	Sr (100)	Ga (10)	In (10)	Rb (2)	Li (200)
PKC-1	1 ET	736 - 743 I.B.	8	48 a 54	C7, T6	2.50	3.00	N(0.02)					5000				
	2 ET	738 - 776 I.B.		55 a 70	T6	0.05	0.96	"					3000				
	3 ET	743 - 782	39	85 a 92	T6	0.05	2.00	"					3000				
	4 ET	732 - 837	55	93 a 105	T6	0.05	0.60	"					3000				
	5 ET	837 - 900	63	106 a 116	C6, H5	L (0.05)	2.70	"			L(5)					70	
	6 ET	900 - 947	47	117 a 125	T4, H4	0.05	0.90	"					1500	L (10)	10	70	
	7 ET	947 - 997	50	126 a 136	C3-2	0.55	0.28	"						L(10)	L(5)		
	8 ET	1037 - 1086	49	145 a 155	C2	0.05	0.40	"									
PKC-6	1 ET	560 - 563 I.B.	3	40 a 52	C7, T6	L (0.05)	2.00	"					5000				
	2 ET	563 - 607	44	70 a 77	T6	0.10	1.60	"					3000				
PKC-7	1 ET	471 - 474 I.B.	3	90 a 95	C7, T6	0.25	1.80	"					3000				
	2 ET	474 - 500	26	96 a 103	C6, F5	0.05	0.30	"									
				109 a 114													
PKC-8	1 ET	432 - 464	32	1 a 10	C6, H6	0.05	0.22	"									
	2 ET	464 - 490	26	11 a 16	F6, T5, F5	0.05	0.38	"		50	10	20	2000			300	
	3 ET	490 - 548	58	17 a 31	T4, H4	0.90	0.90	"			L(5)		3000	15	30	70	
	4 ET	548 - 608	60	32 a 48	C3-2	14.00	0.62	"						L(10)			
	5 ET	608 - 650	42	49 a 59	H3-2, C3-1, H3-1	L (0.05)	1.10	"								50	
	6 ET	650 - 715	65	60 a 76	C2, SC1	0.10	0.92	"									
PKC-9	1 ET	600 - 648	48	30 a 42	H5, T4, C3-2	L (0.05)	0.74	"						10	L(5)		
	2 ET	673 - 706	33	16 a 21	C2	0.05	0.30	"									
				47 a 55													
PKC-10	1 ET	680 - 692 I.B.	12	21 a 37	C7, T6	0.45	3.20	"					3000				
	2 ET	692 - 744	52	52 a 63	T6	0.20	1.60	"					3000				
PKC-11	1 ET	380 - 415	35	30 a 38	T6	0.10	2.80	"					3000				500
PKC-18	1 ET	777 - 830	53	71 a 102	T6	0.55	3.00	"					3000				Apendice ANEXO 6
	2 ET	830 - 850	20	103 a 107	C2	0.05	0.76	"									

Apendice
ANEXO 7 a

United States Department of the Interior
GEOLOGICAL SURVEY

No. 89/72 August 17, 1972

MEMORANDUM

TO : Director of Operations
C. P. R. M.

THRU : S. A. Stanin, Chief of Party
U. S. Geological Survey

FROM : A. P. Marranzino
Advisor for Geochemical Laboratories

SUBJECT : Analyses of Samples from the Area of Aracaju.

Persuant to conversations with LAMIN and the geologist the following is suggested:

1. Collect new samples from some or near-by locations.
2. Seal the sample in a new plastic bag upon collection.
3. Weigh the entire sample within 6 hours of collection.
4. Split sample using precautions to keep as dry as possible.
5. Send 1/2 split to mineral identification.
6. Send 1/2 split to chemical laboratory.
7. Hand prepare split for chemical analysis for gold.
8. As soon as sample has been prepared - weigh <u>10</u> aliguots. Dry 5 at 100º C and analyze for gold. Deep freeze 5 for further study.

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ANEXO 7 b

9. Remaining sample should be split half to be frozen and half to be dried at 100º C and placed in a dessicator.

10. Review all 5 results from all samples and determine course of action.

Previous work indicates that anomalous gold is present and verification in needed.

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