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Resource Estimation in a Rock Salt Deposit, Brazil- A case study

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***Keywords*— Estimation, Itaúnas member resources, salt deposit.**

***Abstract*— *This work presents the results of Geological Modeling and resource estimation of a salt deposit, in an eastern margin basin of the Espirito Santo state - Brazil. This work had, among other objectives, the geological evaluation of the evaporite sequence in the onshore part of the basin and delimitation of the area of occurrence of soluble salts. Therefore, the object of study focuses on the Mariricu Formation, which is composed of the fluvial continental Mucuri and evaporitic Itaúnas members. It is the essentially evaporitic unit, in which the rock salt deposit is found. Through modeling, a total resource of the order of* 4.65x10^9t *were estimated. Which are grouped into the following categories: measured resources of the order of 4,38x10^9t, with an average of 85,40% NaCl, indicated resources 0,23x10^9t, with an average of 84,63% NaCl and inferred resources 2,1x10^6t, with an average of 76,63% NaCl. These are interesting resources and should be considered*.

I. INTRODUCTION

This work presents the results of Geological Modeling and resource estimation of a salt deposit, in an eastern margin basin of the Espirito Santo state. This work had, among other objectives, the geological evaluation of the evaporite sequence in the onshore part of the basin and delimitation of the area of soluble salts occurrence.

Like other basins on the equatorial and eastern margins of Brazil, the Espirito Santo basin had its origin related to the breakup of the supercontinent Gondwana. In this basin, the rocks are related to the tectonics of the rift and drift phases, which were responsible for its evolution [1] (Matos, R.M.D. 1992).

The geology of the area consist of sediments from the Tertiary to Lower Cretaceous (Andar Rio da Serra). It comprises the Rio Doce, Urucutuca, Barra Nova and Mariricu formations, which unconformably overlap the basement. Only the Rio Doce Formation appears on the surface, locally covered by recent sediments. The others formations only occur in the subsurface.

The Mariricu Formation is composed of the fluvial continental Mucuri and evaporitic Itaúnas members. It is the essentially evaporitic unit, in which the rock salt deposit is found.

In this work, the Leapfrog software was applied to integrate geophysical data from subsurface, geological and geochemical data from wells in the Espirito Santo basin, 3D modeling and obtaining resource estimation.

II. MATERIAL AND METHODS

Preliminary search

The work carried out during the initial phase of research aimed to geologically evaluate the evaporite sequence of the Espirito Santo basin and delimit the area where soluble salts occur in the onshore part of the basin.

Around 300 km of seismic reflection lines were examined, in addition to gutter samples, cores and profiles, relating to 44 wells.

At this stage, the following works were developed:

1. analysis of electrical, radioactive and acoustic profiles of wells (DLL, GR, LDL, BHC, CNL, CDS and HRT), with the aim of identifying sequences of soluble salts, in places where there was no coring;

2. stratigraphic correlation through the profiles that intercepted the sequence of soluble salts;

3. detailed macroscopic description of the evaporite sequence of the pioneer wells in which coring was carried out;

4. identification of the clastic intercalations in the evaporite sequence, and consequently the determination of the quality of the salt for use through a viable mining method;

5. integration of subsurface and surface data, with the purpose of selecting the most favorable ones for detailed research.

Detail search

At this stage, holes were drilled and cored to identify and characterize the soluble salt zone.

The data obtained at this stage complemented the information obtained in the preliminary research. And seismic reflection was fundamental in making the decision where to locate the holes, instead of following a pre-established drilling network.

In each hole drilled, electrical, radioactive and acoustic profiles were run, which were used for lithological identification and stratigraphic correlations.

All data obtained at this stage were processed and interpreted, and served as support in updating the preliminary research data.

The database was organized and loaded into the Leapfrog software, where the 3D geological modeling was carried out. And from this, a resource estimate was obtained for a portion of this basin, as detailed below.

Geological 3D modeling

The modeling was carried out based on four main steps: import of drilling data (database containing geological and geochemical information of the wells in the study area), creation of the topography of the land surface of the area, creation of intervals (selecting the subdivision of the lithotypes), creating the contact surfaces and generating volumes.

Currently the representation of data made in a simple and direct way is extremely important in all area of geology, where the 3D models obtained stand out. Successor of block diagrams, and can be classified into two types: explicit and implicit modeling [2] (Garcia, L.M. & Gonçalves, I.G. 2021). Explicit modeling is essentially similar to an engineering drawing process. Implicit modeling is algorithmically generated directly from a combination of measured data and user interpretation [3] (Lane, R. 2015). This approach is faster, more flexible and fundamentally better suited for geological modeling. Then, geostatistical methods are used to interpolate the drilling data and thus seek the geological behavior of the solid to be modeled, optimizing the process. Applying this foundation of implicit modeling, the 3D geological model was generated.

III. RESULTS

Data statistics

From the 3D geological model, a statistical analysis of the information from the geochemical results of the well was carried out, to see the distribution of values in the model.

In this step, with the purpose of relating the information contained in the geochemical data of the well with the geology and others properties, the merged table was combined.

According to the statistical analysis, using scatter plot, Q-Q plot and Box plot alternative the data was explored to verify the relationships between NaCl concentration and evaporite grade designed as low, mid and high (Table 01, Figure 01 and 02).

Table 01: Statistics of samples.

Name %	Mean	Std. dv	Coef. var.	Variance	Minimum	Lower Q	Median	Upper Q	Maximum
Br2	0,09	0,65	7,56	0,43	0,00	0,03	0,04	0,05	9,96
Ca	1,45	1,65	1,14	2,72	0,08	0,42	0,72	1,72	7,85
Cl	46,89	17,02	0,36	289,66	0,17	36,73	56,51	58,85	60,01
H2O	1,26	7,05	5,62	49,72	0,01	0,17	0,33	0,57	70,00
K	0,02	0,01	0,40	0,00	0,01	0,02	0,02	0,03	0,06
Mg	0,05	0,10	2,11	0,01	0,01	0,02	0,03	0,04	1,20
Na	30,87	10,48	0,34	109,79	0,02	26,36	36,67	38,10	39,99
R1	15,07	22,53	1,50	507,67	0,02	0,67	1,94	23,09	77,32
SO4	3,78	6,46	1,71	41,69	0,03	0,81	1,42	4,15	58,40

From this verification of the consistency of the data, a careful analysis of the geostatistical parameters was carried out, starting with the search for the appropriate variogram for numerical modeling of the data on the X, Y and Z axes of the search ellipsoid in the estimation salt grade inside the rock salt deposit.

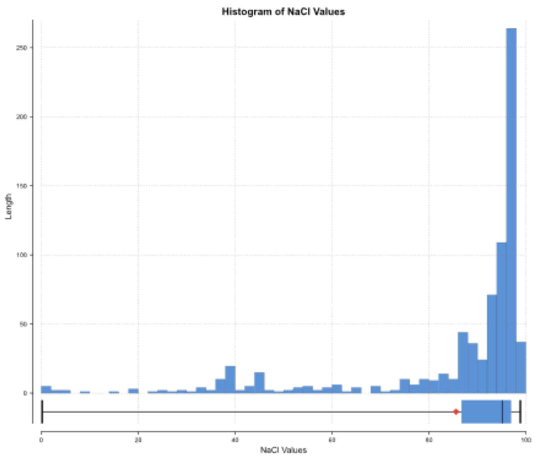

Fig. 01. Histogram of NaCl distribution in the deposit samples.

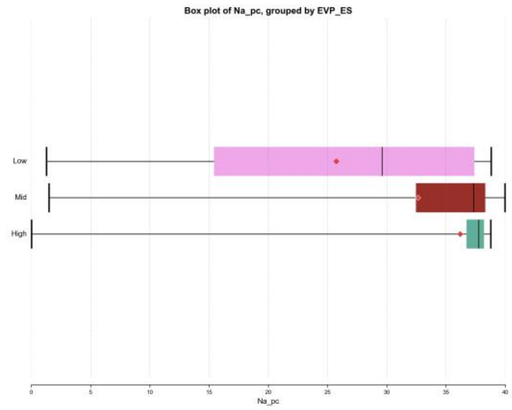

Fig. 02. Box plot Na % and relations with grade levels.

Data geostatistics

Variography

The variography of the data was carried out with the purpose of verifying the spatial behavior of the NaCl variable, aiming to determine directions of greatest, intermediate and least continuity of the samples as well as the range of the variogram (Figures 03 to 05).

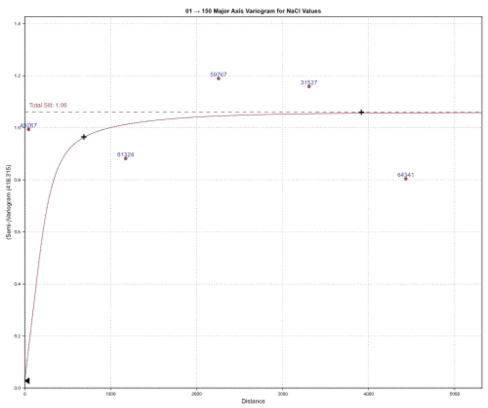

Fig. 03. Major axis variogram

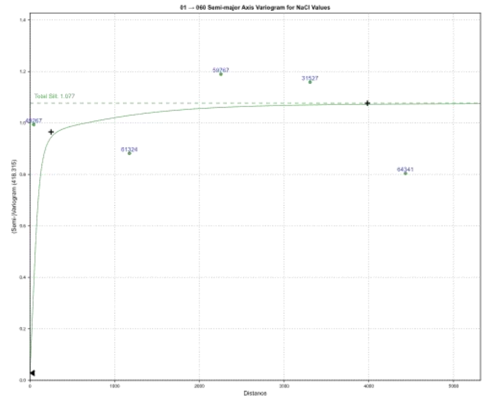

Fig. 04. Intermediate axis variogram

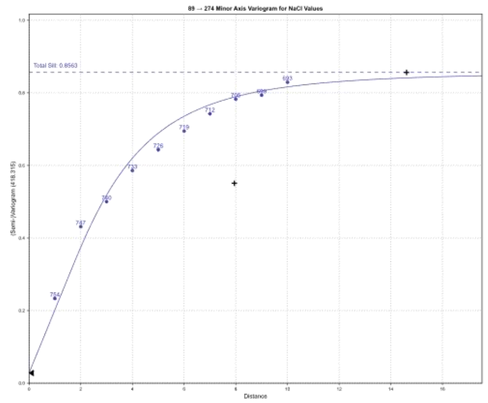

Fig. 05. Minor axis variogram

After the variographic study, the block model was created with the aim of estimating the volumes and contents of the salt deposit light blue color (Figure 06).

When estimating resources, simple and ordinary kriging was used, but simple kriging was chosen.

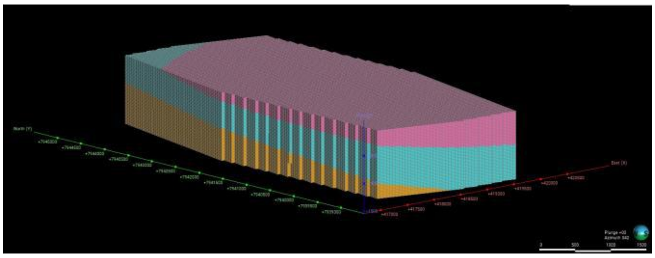

Fig. 06. 3D block model of the salt deposit (light blue).

Volume estimation

After the modeling and deposit estimation stage, total resources of the order of $4.65x10^9$t were estimated. Which are grouped into the following categories: measured resources of the order of $4,38x10^9$t, with an average of 85,40% NaCl, indicated resources $0,23x10^9$t, with an average of 84,63% NaCl and inferred resources $2,1x10^6$t, with an average of 76,63% NaCl (Table 02).

Table 02: Estimated volume of the study area

Resource	Volume	Mass	Mean NaCl%
measured	1.991.937.500	4.382.262.500	85,40
indicated	104.862.500	230.697.500	84,63
inferred	987.500	2.172.500	76,63

IV. CONCLUSION

After the modeling and deposit estimation stage, total resources of the order of $4{,}65x10^9$t were estimated. Which are grouped into the following categories: measured resources $4{,}38x10^9$t, indicated resources $0{,}23x10^9$t and inferred resources $2{,}17x10^6$t.

These are interesting resources and should be considered as carriers of alternative elements to support the energy transition.

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