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SHORT COMMUNICATION

CHEMICAL ANALYSIS OF THE ASSALE (ETHIOPIA) ROCK SALT DEPOSIT

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ABSTRACT. This paper describes the chemical analysis for the major constituents and trace (contaminants) elements found in the Assale (Ethiopia) rock salt. The results showed that the rock salt is found to be the best natural common salt. This was proved by comparison with the chemical requirement and trace elements in common and table salt set by the Ethiopian Quality and Standards Authority. However, during excavation together with the rock salt some soil, mud and other contaminants are found that require further processing or separation.

KEY WORDS: Rock salt, Assale (Ethiopia), Major elements, Trace elements

INTRODUCTION

Rich deposits of rock salt are found at the Assale locality in the Afar depression (Ethiopia). Assale, also called Reged, is located in the Danakil plain depression, Afar Regional National State. Assale is about 180 km northeast of Mekelle, and the road passes through Agulae – Berahle – Reged (Assale Lake) (Figure 1) [1].

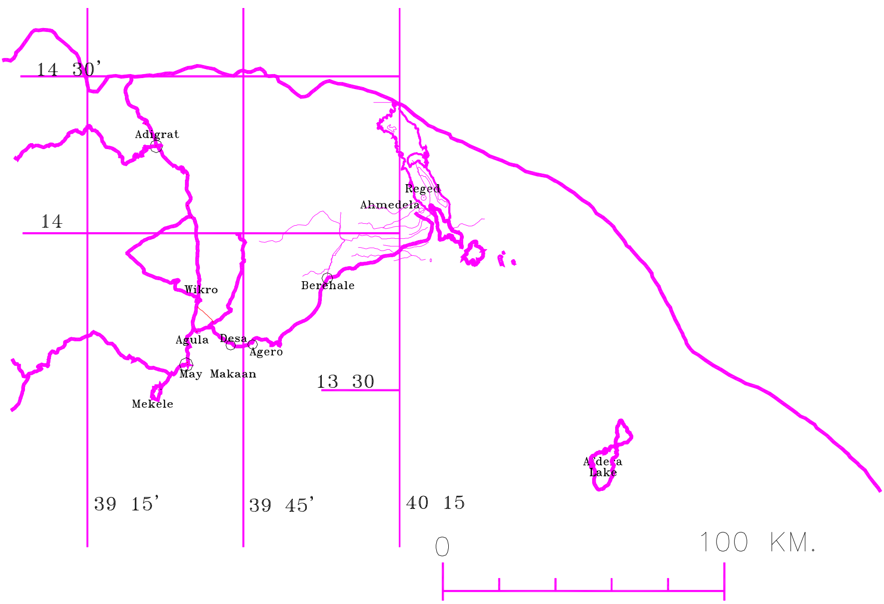

Figure 1. Location map of the Assale rock salt mine.

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The huge encrusted Assale rock salt deposit is probably the biggest rock salt deposit in the world. It is difficult to know exactly how and when this rock salt deposit formed, but the local people traditionally exploited for many years [2].

The distribution of rock salt is reached to consumers mainly to the regions of Afar, Tigray and Amhara from the mine site. The people who live in these regions are mostly engaged in agriculture rather than industrial sector [2]. In addition to human consumption, a large amount of salt is used for animal nutrition in these regions. There are millions of camels and goats in Afar region, and millions of cows, oxen, sheep and goats in the regions of Amhara and Tigray. Here it is necessary to mention that the consumption of salt by the animals in the above mentioned regions could be rated as equally important as consumption by human. Currently the production of rock salt from the mine site is estimated to be 35,000 tons per annum [1]. However, it is necessary to conduct the detailed chemical analysis for major and trace elements in the rock salt. The analysis will help to determine as to whether the rock salt falls within the standards of common and table salt set by the Ethiopian Quality and Standards Authority.

Regarding the reserves, Babolini has estimated that of the 8,000 square kilometers of the salt plain 1200 are actually covered by salt. If this is true and if we assume an average thickness of only 0.5 meter, a total reserve of over 1 billion tons is indicated [3]. This is obviously an enormous tonnage: what is commercially recoverable may be another figure. It is necessary to mention that the salt plain lies mainly in Ethiopia although there is an extension of only very few kilometers northward towards Eritrea [3].

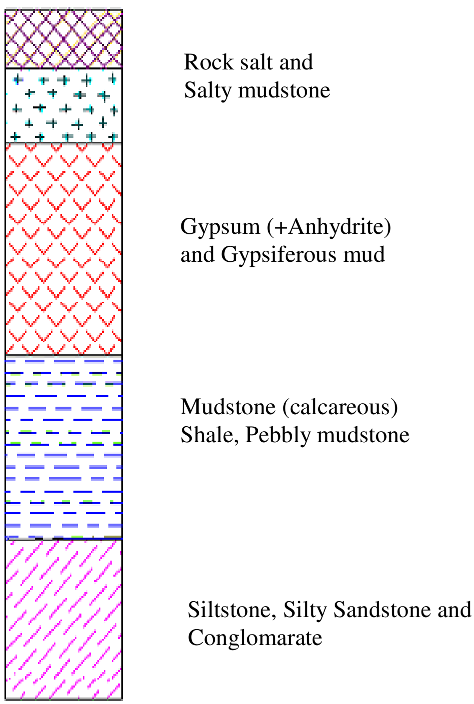

Figure 2. Strategraphic succession of the sedimentary deposit as observed at Lake Assale area of South Danakil Depression.

GEOLOGY OF THE ROCK-SALT DEPOSIT AREA

The Danakil Depression is a northwest-southeast elongated rift graben that developed in response to extensional tectonics in Late Tertiary. It had been connected with the Red sea till it got cut off from the sea by volcanic lavas in the Quaternary [4].

The central part of the depression is a salt encrusted plain and it is therefore known as 'salt plain'. It is bordered by clastic sediments of the Red-bed series, that comprises conglomerates, conglomeratic sandstone, siltstone and silty sandstone beds which form terraces. Mudstone (calcareous), pebbly mudstone, gypsiferous mudstones and shale constitute the bulk of the marine induced sedimentary succession. The evaporates, such as anhydrite, gypsum and halite, along with potash and magnesium salts, deposited next to the marine sediments towards the interior of the basin. These sediments lie below sea level in the southern part, whereas in the northern part of the Danakil they crop out 20 to 25 meters above sea level. The salt plain (the rock-salt crust (which is extensive) is composed predominantly of sodium chloride (halite) with minor amounts of sulphates (mainly gypsum) and calcium chloride [4].

Assale rock-salt deposit (which this study focused on) lies within the central portion of the depression close to Lake Assale. The encrusted salt seasonally dissolves with rise of the Assale Lake level by flooding. The size of Assale is therefore varies with lake-level highstands (transgressive events) and lowstands (regressive events) across the Danakil depression [2].

The salt crust progressively gets thicker, compact and purer (crystalline and white) towards the upper part. At greater depths it is earthy; the layers are thinner and have grains that soften quickly in the sun. The thickness of the salt is generally not more than half a meter although in some places it may reach up to ten meters [3]. On the water surface of the Lake Assale 10 to 15 meters thick salt rafts that exhibit prismatic polygonal fabric are commonly observed (Figure 2) [3].

EXPERIMENTAL

The rock salt bar sample was collected directly from the Assale rock salt mine, where artisanal miners produce rock salt. The location of the current traditional mining area (study area) is near Assale Lake. For sampling the rock salt excavation was done by an axe. The excavated rock salt was shaped to a rectangular form of bar to make it easily portable. The rock salt sample was taken at 25 cm depth from the surface, and its dimension was 12 cm thick and 40 cm long. The bar weighed 4 kg. After collecting the sample was covered immediately by plastic material and put into a carton. During analysis two different samples MOD-03/93 and MOD-06/93 were used to analyze in the laboratory.

1.0009 g of the solid salt sample was dissolved in 1 L of distilled water. The concentration of cations or anions in the sample solution was analysed by the procedures described in literature [6].

Electrometric titration method was used to determine the alkalinity of (CO_3^{2-}, HCO_3^-) of the sample solution. The concentration of bicarbonate was determined by titrating the sample solution with a standard solution of a strong acid to end point of pH 4.5. The carbonate end point was taken to be pH 8.6. Argentometric method was used to determine the concentration of chloride in the sample solution. The solution was titrated with silver nitrate using potassium chromate as an indicator. Turbidimetric method was used to determine the concentration of sulphate (SO_4^{2-}) in the sample solution. The sulphate ion was precipitated in a hydrochloric acid medium with barium chloride whereby the absorbance of barium sulphate suspension was measured by spectrophotometer. Ultraviolet spectrophotometric method was used to determine the concentration of nitrate (NO_3^-) in the sample solution. The concentration of nitrate was determined by measuring the UV absorption at 220 nm and at 275 nm. The second measurement (at 275 nm) was made to make sure that there is no interference from dissolved organic matter which absorbs UV light at 220 nm.

Atomic absorption spectrophotometry was used to determine the concentration of sodium (Na^+), potassium (K^+), calcium (Ca^{2+}) and magnesium (Mg^{2+}) in the sample solution. The concentration of sodium was determined with no pre-treatment. The concentration of potassium was determined after pre-treatment with cesium nitrate or chloride solution to suppress ionization in the air-acetylene flame. The concentration of calcium was determined after addition of lanthanum chloride to mask the interferences. The concentration of magnesium was determined in the same way to that of calcium except that samples whose magnesium concentration is greater than 20 mg/L must be diluted.

After completing the analysis, the reliability of the results was evaluated by balancing the sum of chemical equivalents of the major anions (CO_3^{2-}, SO_4^{2-}, NO_3^-, Cl^-) with the major cations (Na^+, K^+, Ca^{2+}, Mg^{2+}).

RESULTS AND DISCUSSION

A bar of rock salt sample from Assale rock salt mine was taken to the laboratory for chemical analysis to obtain the chemical constituents of the major and trace elements. The test was made for 15 major and four trace elements. The results of the analysis are shown in Tables 1 and 2. The chemical requirements, and trace elements contents for the common and table salt set by the Ethiopian Quality and Standards Authority are given in Table 3 and 4 [5].

Table 1. Chemical constituents of Assale rock salt sample.

No.	Rock salt sample No. MOD-03/93	
	Cation/anion	%
1	Carbonate (CO_3^{2-})	0.00
2	Bicarbonate (HCO_3^-)	1.39
3	Chloride (Cl^-)	60.86
4	Sulphate (SO_4^{2-})	0.09
5	Fluoride (F^-)	0.001
6	Nitrate (NO_3^-)	<0.003
7	Sodium (Na)	37.47
8	Potassium (K)	0.02
9	Calcium (Ca)	0.18
10	Magnesium (Mg)	0.01
11	Boron (HBO_2)	0.05
12	Silica (SiO_2)	0.02
13	Bromide (Br^-)	0.29
14	Iodide (I^-)	0.004

The pH of the solution of rock salt sample No. MOD-03/93 was 6.03.

Table 2. Trace elements (contaminants) in sample MOD-06/96.

No	Element	Chemical constituents (ppm)
1	Lead (Pb)	< 0.1
2	Copper (Cu)	<0.1
3	Total iron (Fe^{2+} + Fe^{3+})	44

Table 3. Chemical requirements for the common and table salt.

Characteristic	% by mass	
	Common salt	Table salt
Water insoluble, matter maximum	1.0	2.2
Chloride content (as NaCl), minimum	96.0	98.0
Acid insoluble matter, maximum	-	1.5
Matter soluble in water other than sodium chloride, maximum	3.0	-
Calcium (as Ca), water soluble, maximum	-	0.10
Magnesium (as Mg), water soluble, maximum	-	0.10
Sulphates (as SO_4^{2-}), maximum	-	0.50
Iodine (as potasisium iodate), ppm, minimum	38.2	38.2
Alkalinity (as CO_3^{2-}), maximum	-	0.20

Table 4. Trace elements in common and table salt.

Metal	Maximum allowable limits, mg/kg
Lead (Pb)	2.0
Iron (Fe)	50.0
Arsenic (As)	1.0
Copper (Cu)	15.0

The metal content in the common and table salt should not exceed the limits shown in Table 4. Comparison of data in Table 1 and 3 shows that the chloride content (as NaCl) of the salt taken from Assale rock salt deposit is below the standard requirement of the common salt set by the Ethiopian Quality and Standards Authority [5]. In other words the minimum requirement of chloride (as NaCl) in common salt as per the standard set by Ethiopian Quality and Standards Authority is 96 % (Table 3) whereas the chloride content (as NaCl) in the rock salt sampled from Assale is found to be 95.22 % (Table 1). This shows that with minor treatment of Assale rock salt it is possible to get common salt that meets the requirement of Ethiopian Quality and Standards Authority. With further treatment it is also possible to get table salt from the same deposit.

Like other industries mining industry has a contribution to gross domestic product (GDP) of the nation. Due to this fact currently mining is also helping in boosting the overall economic development of the country. The traditional miners used to mine only a small part of the rock salt deposit applying primitive mining method. However, the Ministry of Mines requires to prepare all necessary conditions for the deposit to be further explored in detail in its reserve evaluation and make it ready to promote for mining investors.

Despite the existence of ample reserves, sufficient to meet the national requirements for a long time, the country continues to imports common salt from abroad [3]. It is believed that beyond the benefits of gaining self-sufficiency in this most essential and primary requisite for life of human and animals, there are also advantages with which the local community and the country could benefit if exploitation of the salt deposit is carried out at large scale.

CONCLUSION

The Assale rock salt deposit is one of the huge salt deposits in the world, and its reserve is estimated in the order of hundreds of million tones. Comparison of the chemical analysis of the rock salt sample with that of the Ethiopian Quality and Standards Authority shows that the Assale rock salt deposit is below the minimum requirement of common salt. However, we recommend that the deposit should be further explored in detail in its reserve evaluation, and make it ready to promote the deposit for investors.

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