POTASH RESOURCE POTENTIAL IN ALBU-GHARIS SALTERN, WESTERN IRAQ

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ABSTRACT

An exploration survey has been carried out in Albu-Gharis Saltern, western Iraq to follow-up previously mentioned relatively high K concentrations in the salt and in the brine. The present work is based on field observations, sampling, mineralogical and chemical analyses of salt crust, brine and sediments.

The results showed that all salt samples analyzed by X-ray diffraction contained sylvite (KCl) with halite as the dominant constituent. The older (dust-contaminated) salt crust contained 1.63% KCl and the recent (freshly precipitated) crust contained 3.52% KCl, whereas the brine contained 1.3% KCl with 330 gm/l salinity. The major salt constituent is NaCl, making about 83% of total salts in the crust and about 30% in the brine.

Compared to average K content in seawater (0.39 gm/l) and in the Arabian Gulf water (0.5 gm/l), the Albu-Gharis Saltern may be considered a potential potash resource in Iraq. KCl may be produced from the bitter solution left after NaCl precipitation from the brine. The Albu-Gharis brine is lower (one third) in potash concentration, but comparable in salinity to the Dead Sea, which contains 4.4% KCl and 315 gm/l salinity. However, the Dead Sea is highly different in other chemical constituents.

مصادر محتملة للبوتاش في مملحة ألبوغارس، غرب العراق

خلدون صبحي البصام

المستخلص

أجريت مسوحات استكشافية في مملحة ألبوغارس، غرب العراق لمتابعة معلومات سابقة عن وجود تراكيز عالية من البوتاسيوم في الرواسب والمحاليل الملحية. البحث الحالي اعتمد على ملاحظات حقلية ونمذجة وتحليلات معدنية وكيميائية للرواسب الملحية والمحاليل الملحية المتدفقة عبر العيون فضلاً عن الرواسب الطينية.

بينت النتائج أن كافة العينات الملحية التي تم تحليلها بحيود الأشعة السينية احتوت على معدن السلفايت (KCl) مع وجود سائد لمعدن الهالايت. القشرة الملحية القديمة الملوثة بالأتربة احتوت على 1.63% KCl في حين احتوت القشرة الملحية حديثة التكون على 3.52% KCl، بالمقارنة مع تركيزه في المحاليل الملحية البالغ معدله 1.3% KCl وتركيز ملحي 330 gm/l. المكون الملحي السائد هو NaCl الذي يمثل حوالي 83% من مجمل المكونات في الرواسب الملحية وحوالي 30% في المحاليل الملحية.

بالمقارنة مع معدل محتوى البوتاسيوم في مياه البحر البالغ 0.39 gm/l ومحتواه في مياه الخليج العربي البالغ 0.5 gm/l يمكن تقييم مملحة ألبوغارس كمصدر للبوتاش في العراق، حيث يمكن استخلاصه بعد ترسيب كلوريد الصوديوم من المحاليل الملحية. إن هذه المحاليل الملحية تحتوي على حوالي ثلث تركيز البوتاسيوم في مياه البحر الميت وبدرجة ملوحة مقاربة، حيث تحتوي مياه البحر الميت على حوالي 4.4% KCl وملوحة تبلغ 315 gm/l، مع ملاحظة ان مياه البحر الميت تختلف بشكل كبير في المكونات الأخرى.

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INTRODUCTION

The Albu-Gharis Saltern is located in western Iraq, near the Iraq – Syria border (Fig.1). It is an elongated inland saltern; about 10 m lower than surroundings, 40 Km long, about 3 Km wide and extends in a N – S direction. Numerous active springs are located in the central part and are aligned linearly along the saltern extension with brine moderate flow (Fig.2).

In rainy seasons, the saltern is flooded with muddy water derived by several drainage wadis directed to the depression. However, the saltern is usually dry most of the year. The saltern is surrounded by outcrops of the Fatha Formation; Upper Member (Middle Miocene) (Fig.3). The exposed part around the saltern consists of pale brown mudstone. The location of the saltern coincides with Tayarat South Graben (Fig.4), and said to coincide with a N – S lineament, believed to be a fault or a major joint (Al-Hadithi *et al*., 1987). The salt in Albu-Gharis has been occasionally exploited by locals to produce NaCl.

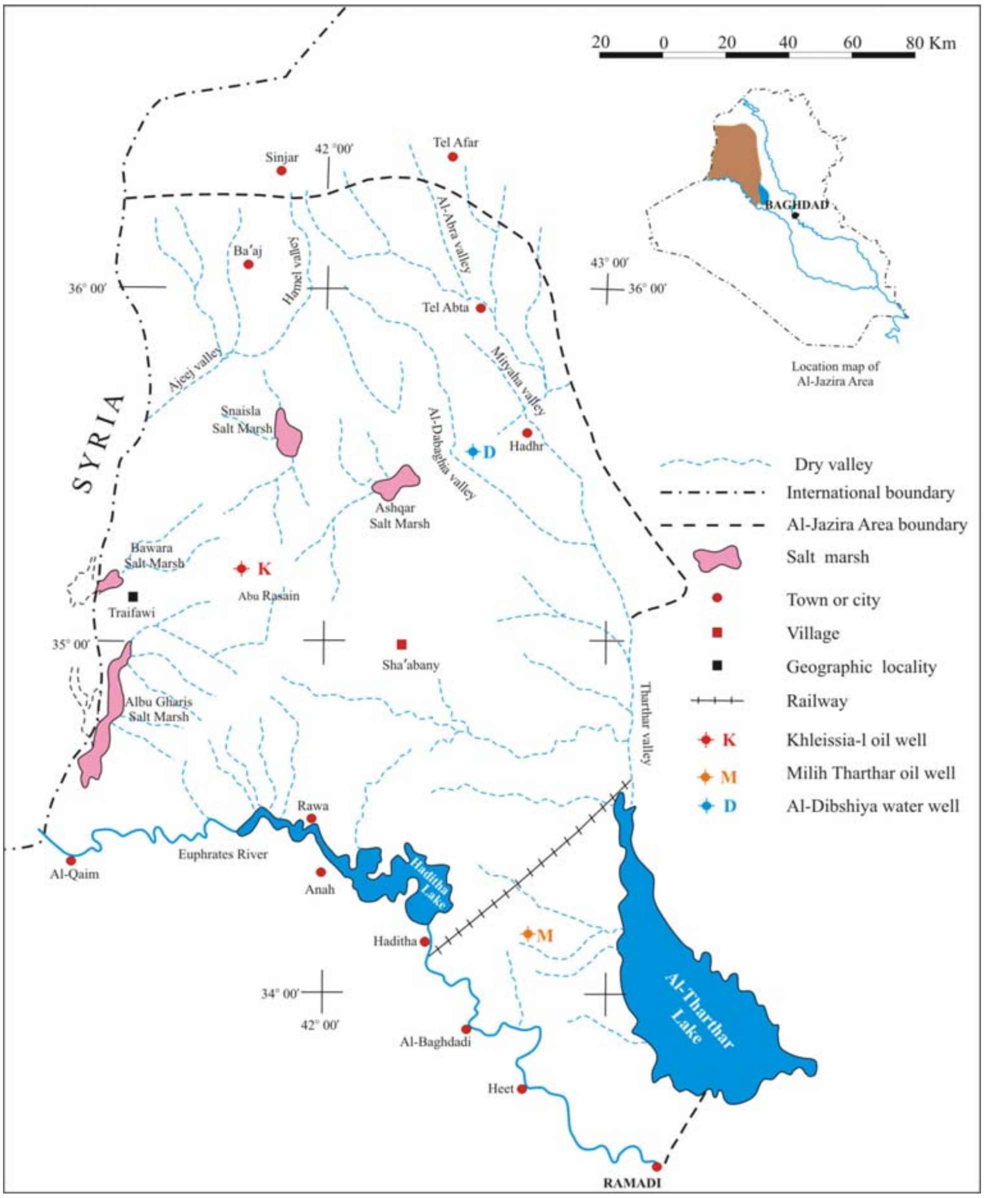

Fig.1: Location map of Albu-Gharis Saltern

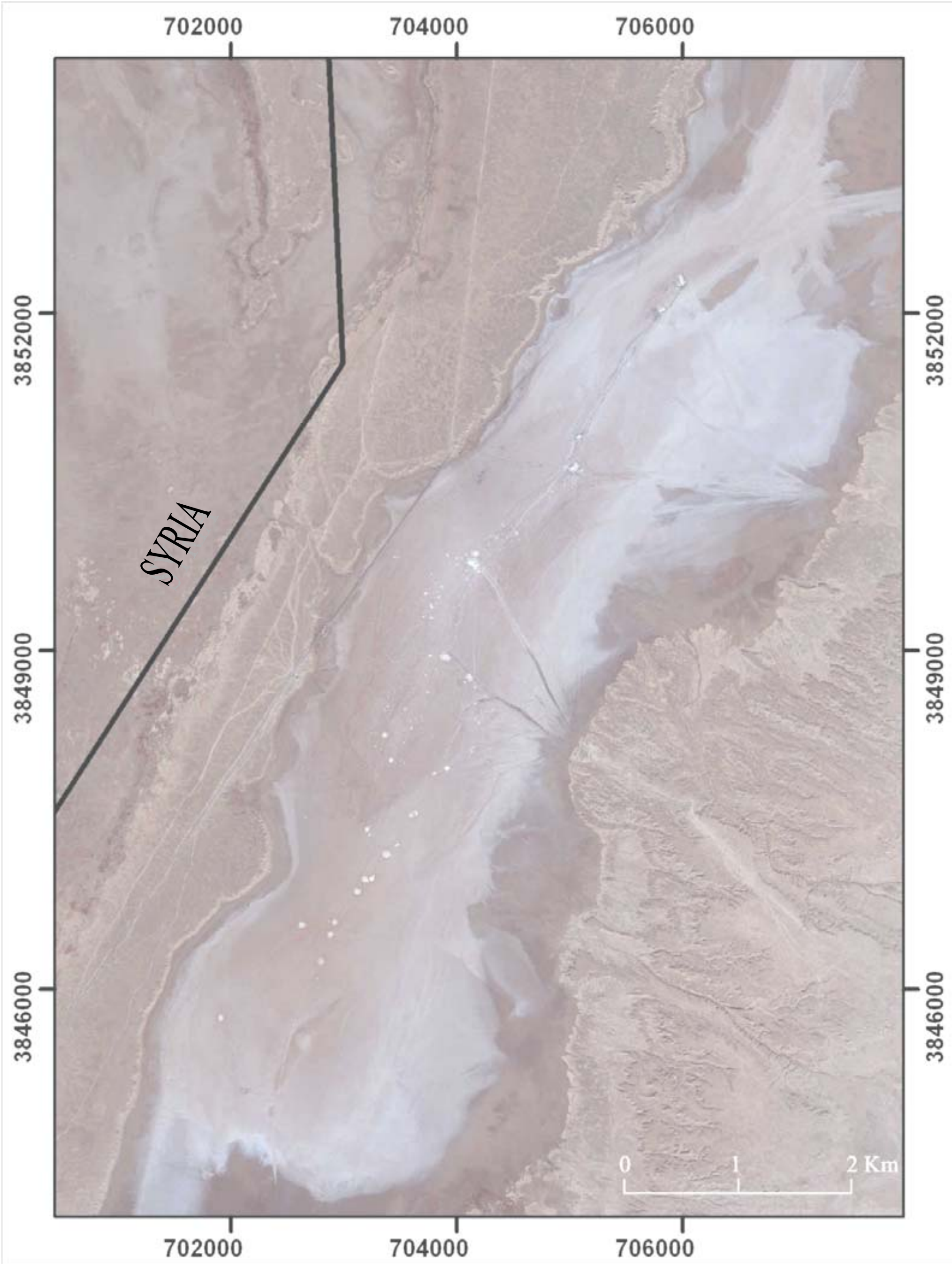

Fig.2: Satellite image of Albu-Gharis Saltern
(white spots are springs)
(Satellite: Quick Bird, Resolution: 61 cm, Date: 2004)

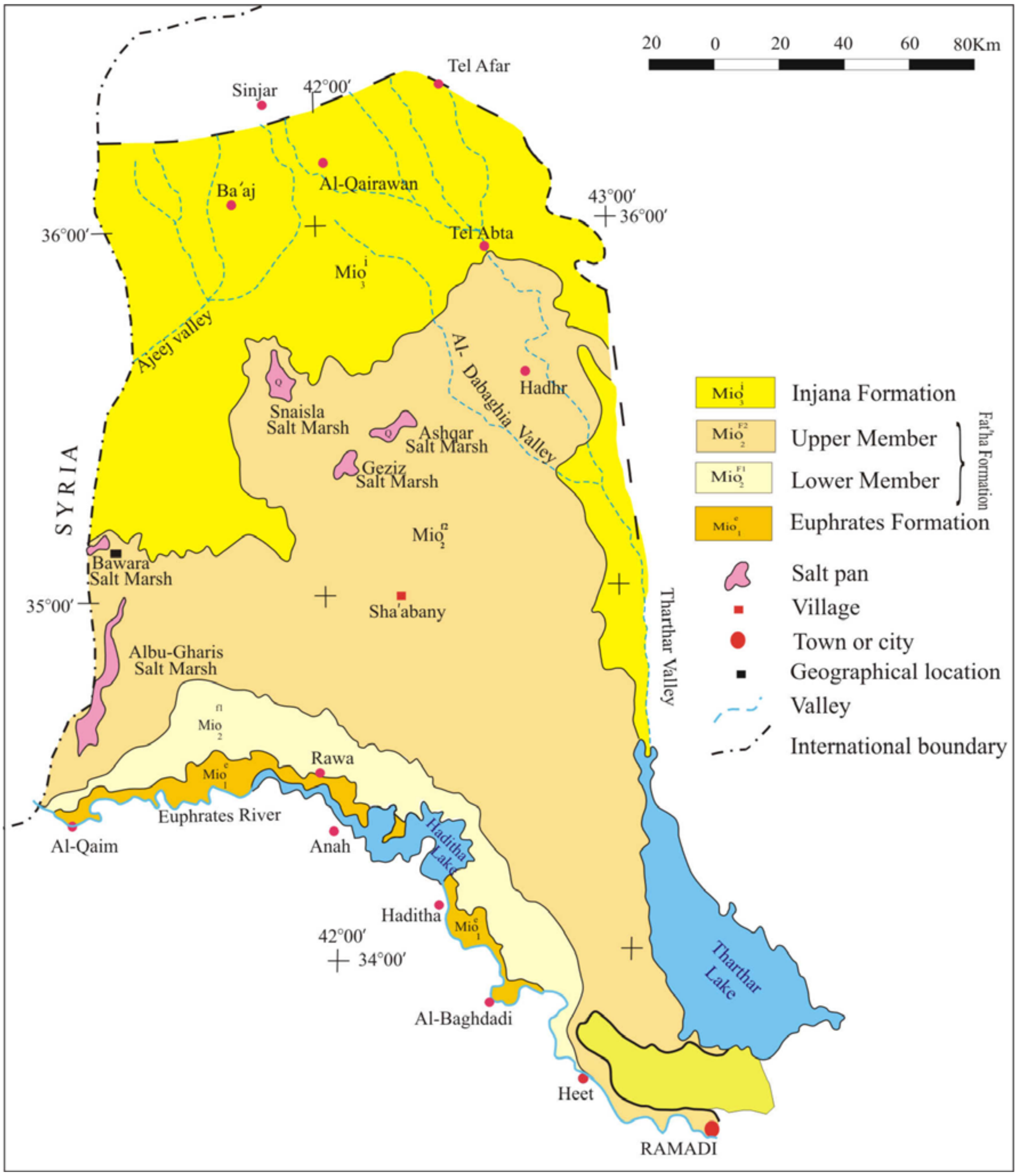

Fig.3: Geological Map of Al-Jazira Area
(after Sissakian, 2000)

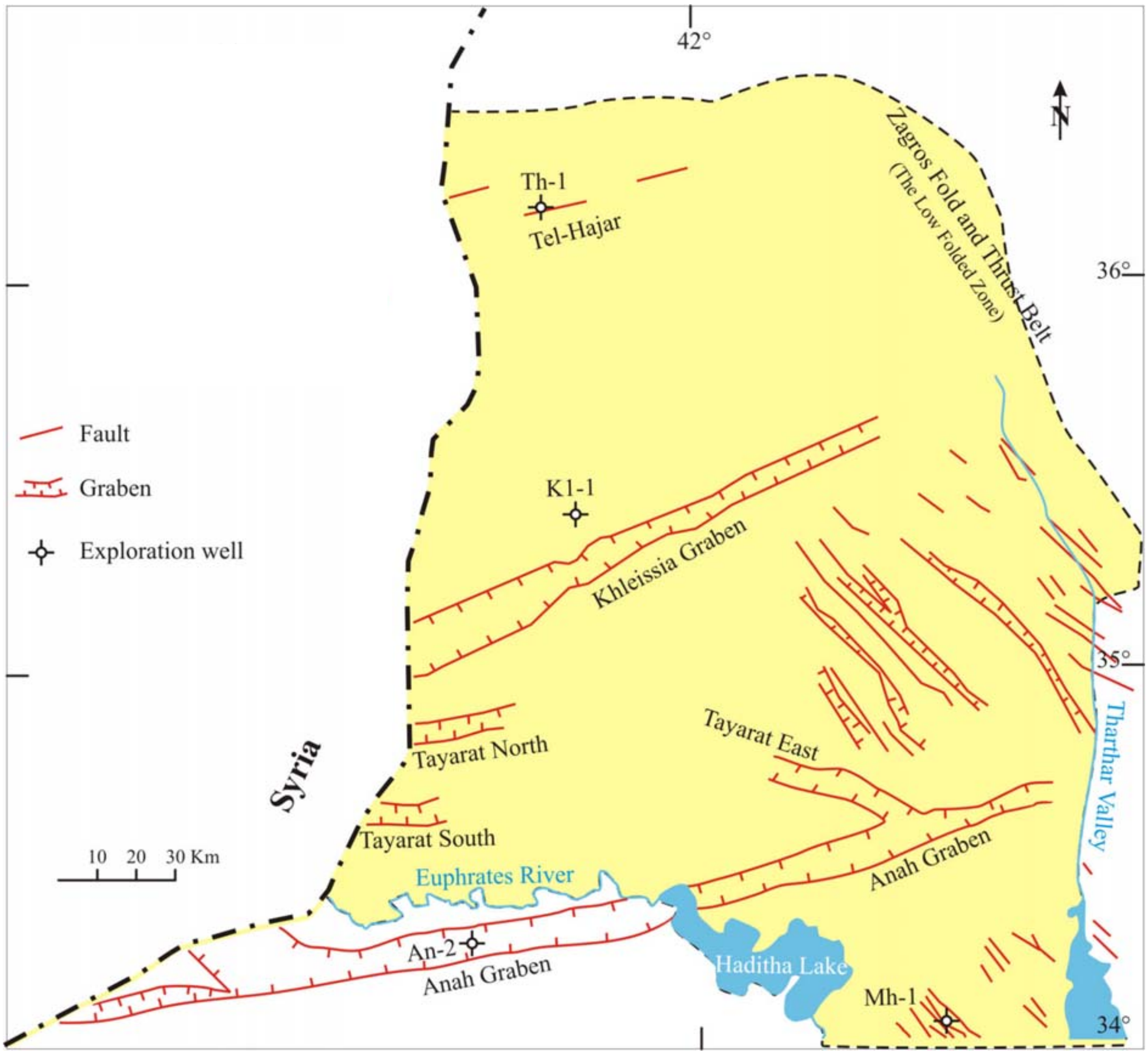

Fig.4: Structural map showing the subsurface extensional structures of Al-Jazira Area (after Fouad and Nasir, 2009)

PREVIOUS WORK

- Al-Rawi (1967) carried out a reconnaissance survey of the inland salterns of Al-Jazira Area.
- Al-Rawi (1970) assessed the potential of salt resources in Iraq including Albu-Gharis Saltern.
- Al-Rawi *et al*. (1973) studied the hydrogeology and potential of the Bawara and Albu-Gharis Salterns in Al-Jazira Area as potential NaCl resources. They recognized 3 water-bearing horizons (26 – 31) m deep; one of them is salty and was suggested to be the source of the salt crust via ascending brines.
- C.G.G. (1975) covered the area, as part of a wide coverage of Iraq, by airborne radiometric survey and recognized two K^{40} anomalies with up to 1200 cps total count compared to 800 cps background. These radiometric K^{40} anomalies coincided with the Albu-Gharis Saltern.

- Al-Bassam and Shehata (1978) followed up, by a ground geochemical survey, the radiometric anomalies at Albu-Gharis Saltern among other K^{40} anomalies in Iraq, and found that the Albu-Gharis anomalies are the only ones connected with salt rather than fine clayey soil. Analysis of the salt crust showed up to 4.0% KCl and the brine up to 4.5% KCl.
- Al-Hadithi *et al*. (1987) studied the salterns of Al-Jazira Area by aerial photographs and satellite images and related some of them to lineaments of possible structural origin. They recognized a well defined N – S lineament, believed to be a fault or a major joint, coincided with Albu-Gharis elongated depression, as well as with the springs linear arrangement in the saltern.
- Al-Badri and Qassim (1988) studied Al-Jazira Salterns and estimated the NaCl reserves in Albu-Gharis, at category Cl, by about 10 m.t. (salt crusts down to 1.2 m depth) and by about 3 m.t. in the brine (for the 1st meter depth).

  Sylvite was noticed among the salt minerals. Potassium content in the salt crust ranged from (0.08 – 2.3) % (mean 0.73%). The salinity of the brine reached 283.4 gm/l, dominated by NaCl composition (about 90%). The highest K concentration was encountered in the central part of the saltern. The Albu-Gharis Saltern was the highest in K content among the other Al-Jazira salterns.
- Al-Ajeel *et al*. (1989) carried out laboratory tests to extract potassium chloride from the brine of Albu-Gharis Saltern and achieved a product with 90% KCl purity and 70% recovery.
- Al-Jiburi and Al-Basrawi (2009) compiled the available data on the hydrogeological conditions and groundwater quality in Al-Jazira Area.
- Jassim (2009) compiled the available data on the mineral resources of Al-Jazira Area including salt deposits.
- Fouad and Nasir (2009) compiled a structural map for Al-Jazira Area and showed the presence of extensional structures (grabens), one of which (Tayarat South) is oriented in a E – W direction and coincided, but with an opposite direction, with the Albu-Gharis Saltern.

FIELD WORK

This paper is based on the results of field investigation carried out in Albu-Gharis Saltern in August, 2002. The saltern is an elongated depression, lower, at its central part, by about 10 m than surroundings. The Upper Member of the Fatha Formation (Middle Miocene) is exposed around the depression. The surface of the saltern is flat and covered by thinly laminated crust. Up to 10 cm thick salt crust forms the surface of the saltern with polygonal cracks. Below surface, several of these salt crusts are found, alternating with organic-rich black and brown mud. Two types of salt crusts were identified: Pale brown older salt crust contaminated with fine detritals, and white recent salt crust mostly found as circular zones around springs and making the polygonal cracks (Figs.5, 6, 7 and 8). Numerous springs with brine flow were found with a linear N – S trend following the elongation of the saltern.

A 10 Km long profile of 14 pits was made following the elongated trend of the saltern, in addition to two 2 Km long profiles across the width of the saltern, at the northern and southern sides (Fig.9). Fifteen samples of older salt crust, 8 samples of recent salt crust, 5 samples from the associated mud, 1 sample from the Fatha Formation mudstone and 4 samples of brine from springs were collected.

Fig.5: Polygonal cracks in the crust

Fig.6: Recent and older salt crusts along cracks

Fig.7: Organic-rich mud below the salt crust

Fig.8: Interlamination of salt and mud

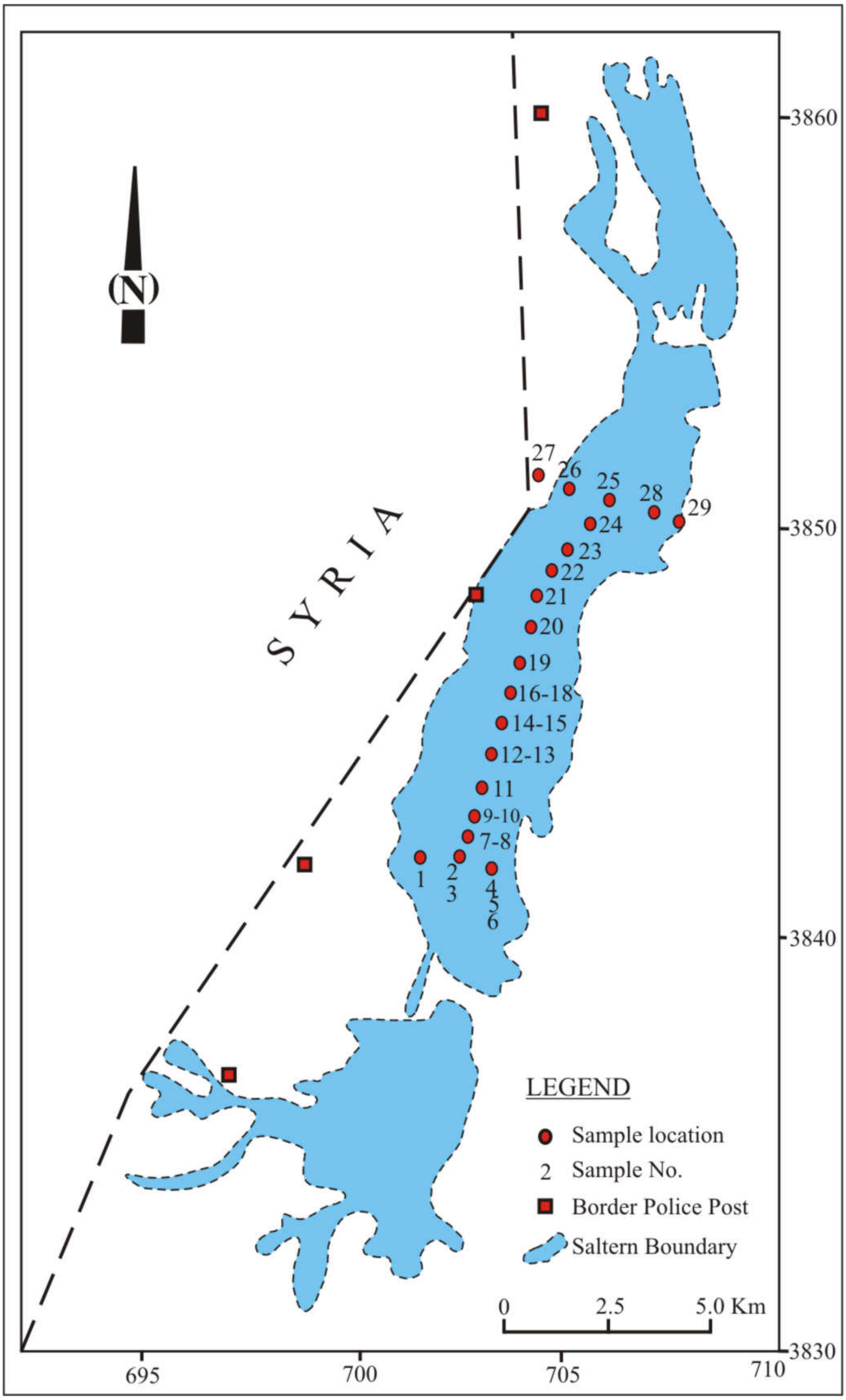

Fig.9: Samples location

LABORATORY WORK

All analyses were carried out at GEOSURV laboratories following standard work procedures (Al-Janabi *et al*., 1992) as follows:

- Seven salt crust samples (old and recent) and 7 mud and mudstone samples were analyzed by XRD for mineral analysis. Results are shown in Table (1).
- All salt crust samples were dissolved in water and the extract was analyzed (as water) for Ca, Mg, Na, K, SO_4 and Cl. The water insoluble residue (IR) was determined. Results are shown in Tables (2 and 3).
- The mud and mudstone samples, analyzed by XRD, were chemically analyzed as well as the water insoluble residues collected from all salt crust samples analyzed, which were mixed to form one composite sample. The analysis included SiO_2, TiO_2, Fe_2O_3, Al_2O_3, CaO, MgO, Na_2O and K_2O. Results are shown in Table (4).
- Four brine samples were analyzed, as water, for: Na, K, Ca, Mg, Cl, SO_4, HCO_3 and TDS. Results are shown in Table (5).

Table 1: X-ray diffraction mineral analysis of salt and mud samples

Samples No.	Salt samples
5	halite, calcite (tr.), sylvite (v.tr.)
7	halite, sylvite, calcite (tr.).
16	halite, sylvite, (v.tr.).
18	halite, sylvite, (v.tr.).
20	halite, sylvite, (v.tr.).
25	halite, gypsum, sylvite
27	halite, sylvite, quartz, calcite (tr.)
Mud Samples	
1	quartz, calcite, halite, feldspar, palygorskite, gypsum, mixed layer clay, dolomite (tr.).
3	quartz, calcite, halite, gypsum, mixed layer clay, feldspar, palygorskite, dolomite (tr.).
6	quartz, calcite, halite, gypsum, mixed layer clay, palygorskite, feldspar, dolomite (tr.).
8	quartz, calcite, halite, gypsum, mixed layer clay, palygorskite, feldspar, dolomite.
15	halite, calcite, quartz, gypsum, mixed layer clay, palygorskite, feldspar, dolomite.
17	halite, calcite, quartz, mixed layer clay, gypsum, palygorskite.
F	quartz, dolomite, halite, feldspar, palygorskite, gypsum.

F: Fatha Formation mudstone,
tr.: trace
For sample location refer to Fig.(9).

Table 2: Chemical analysis of the older salt crust (water extract, in wt.%)

Sample No.	IR	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	$SO_4^{=}$	Cl^{-}
2	38.69	0.75	0.24	21.6	0.63	1.8	34.61
4	14.82	0.70	0.26	31.12	0.65	1.68	49.39
7	5.70	0.40	0.41	35.76	0.35	0.96	54.58
9	10.58	0.80	1.10	30.60	1.08	1.92	51.41
11	1.75	0.70	0.48	35.67	1.16	1.68	57.51
12	0.75	0.35	0.39	36.79	0.81	0.84	58.66
19	1.14	0.45	1.02	35.18	2.40	1.08	57.68
20	n.d.	0.40	0.37	36.37	1.00	0.96	58.13
21	0.14	0.34	0.29	37.38	0.63	0.81	59.11
23	1.0	0.60	0.13	37.56	0.30	2.28	58.11
24	3.07	0.55	0.14	36.60	0.37	2.16	57.04
25	7.86	0.75	0.16	34.30	0.43	3.36	53.06
26	4.85	0.84	0.39	33.2	1.33	3.54	53.86
27	49.59	0.55	0.25	17.44	0.65	1.80	27.89
28	17.89	0.65	0.5	28.37	1.25	1.56	46.80
29	38.83	1.50	0.38	19.57	0.71	6.3	29.79
Mean	12.29	0.65	0.41	31.72	0.86	2.05	50.48

n.d.: not determined

Table 3: Chemical analysis of the recent salt crust (water extract, in wt.%)

Sample No.	IR	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	$SO_4^{=}$	Cl^{-}
5	3.82	0.4	0.78	34.25	1.83	0.96	56.8
10	0.64	0.6	0.90	34.47	2.32	1.44	58.31
13	1.69	0.4	1.26	33.51	3.0	0.96	58.13
14	n.d.	0.3	0.32	37.56	1.0	0.72	59.81
16	0.67	0.4	1.05	34.33	2.57	0.96	58.39
18	n.d.	0.3	0.18	37.76	0.79	0.72	59.46
22	0.29	0.34	0.13	37.19	1.41	0.81	59.82
Mean	1.02	0.39	0.66	35.58	1.85	0.94	58.67

n.d.: not determined

Table 4: Chemical analysis of mud, mudstone and IR samples (in wt.%)

	1	3	6	8	15	17	F	IR
SiO_2	45.88	33.3	34.94	35.12	21.4	27.68	39.42	51.96
Fe_2O_3	3.61	4.16	4.02	4.24	3.68	3.90	5.84	5.40
Al_2O_3	7.28	8.02	8.55	8.5	6.84	8.02	11.76	12.04
TiO_2	0.6	0.5	0.5	0.52	0.4	0.48	0.63	0.73
CaO	11.52	13.46	12.7	12.54	14.02	12.34	5.53	16.26
MgO	4.3	6.8	6.5	7.3	5.3	5.2	9.7	9.1
Na_2O	3.8	4.9	4.85	4.7	8.15	7.6	4.85	1.59
K_2O	1.45	1.7	1.8	1.82	1.87	1.76	2.64	1.72
SO_3	3.6	5.4	3.1	3.4	5.4	0.82	0.22	n.d.
Cl	2.58	4.51	4.8	4.25	11.54	10.08	3.45	n.d.
LOI	15.57	21.14	22.63	21.79	32.11	32.11	15.67	n.d.
OM	0.40	0.63	0.80	0.63	1.25	1.18	0.22	n.d.

F: Mudstone of the Fatha Formation (Sample 0)
IR: Water insoluble residue remaining after water extraction (composite sample)
OM: Organic matter
n.d: not determined

Table 5: Brine analysis (ppm)

	17 a	16 a	21 a	22 a	Mean	*Sea water
Na^+	116336.3	111497.1	114374.4	115308.2	114379.0	10752
K^+	6708.0	7203.3	7948.2	5463.9	6830.9	390
Ca^{2+}	2440.0	2740.0	2740.0	2460.0	2595.0	416
Mg^{2+}	2142.04	2394.76	2519.91	1764.3	2205.3	1295
Cl^-	193830.0	188150.0	193652.5	189925.0	191389.4	19345
SO_4^{2-}	3216.0	3120.0	3120.0	3408.0	3216.0	2701
HCO_3^-	85.40	91.50	61.00	42.70	70.2	145
TDS	329188	327088	332744	325576	328649.0	35044
pH	5.7	5.5	5.6	5.6	5.6	7.5-8.4

*After Turekian (1968)

DATA PROCESSING

The analyses data were processed to obtain more information. The processing included:

- Estimation of major salts content in the salt crusts from chemical and mineralogical analysis. Halite was estimated from Na content, sylvite from K content and gypsum from SO_4 content (Table 6).
- Simple correlation coefficient of chemical and mineralogical variables of the salt crust samples (Table 7).
- Hydrochemical formulae for the brine samples (Table 8).
- Estimation of hypothetical salt combinations for the brine samples following Collins (1975) Procedure (Table 9).

Table 6: Mineral composition of the salt crust*

	Mean (%)	Recent crust (%)	Older crust (%)
Halite	83.54	90.37	80.57
Sylvite	2.20	3.52	1.63
Gypsum	2.45	1.68	2.80
IR	8.86	1.02	12.29
Number of the samples	23	7	16

*Estimated from mean chemical analysis

Table 7: Correlation coefficients of main variables in the salt crust

Variable	IR	Ca	Mg	SO_4	Na	K	Cl	KCl	NaCl
Ca^{2+}	0.58								
Mg^{2+}	– 0.21	– 0.07							
$SO_4^{=}$	0.50	0.94	– 0.20						
Na^+	– 0.98	– 0.64	0.03	– 0.53					
K^+	– 0.31	– 0.22	0.85	– 0.29	0.13				
Cl^-	– 0.99	– 0.66	0.19	– 0.58	0.98	0.31			
KCl	– 0.31	– 0.22	0.85	– 0.29	0.13	1.00	0.31		
NaCl	– 0.98	– 0.64	0.03	– 0.53	1.00	0.13	0.98	0.31	
$CaSO_4$	0.51	0.98	– 0.04	0.94	– 0.57	– 0.20	– 0.59	– 0.20	– 0.57

Table 8: Hydrochemical formulae (epm%)

Sample (17 a) S = 329.2 gm/l $$\frac{\overset{Cl^-}{98.76}\quad \overset{SO_4^{=}}{1.21}\quad \overset{HCO_3^-}{0.03}}{\underset{Na^+}{91.49}\quad \underset{Mg^{2+}}{3.19}\quad \underset{K^+}{3.11}\quad \underset{Ca^{2+}}{2.21}}$$ pH 5.7

Sample (16 a) S = 327.1 gm/l $$\frac{\overset{Cl^-}{98.76}\quad \overset{SO_4^{=}}{1.21}\quad \overset{HCO_3^-}{0.03}}{\underset{Na^+}{90.33}\quad \underset{Mg^{2+}}{3.67}\quad \underset{K^+}{3.44}\quad \underset{Ca^{2+}}{2.55}}$$ pH 5.5

Sample (21a) S = 332.7 gm/l $$\frac{\overset{Cl^-}{98.80}\quad \overset{SO_4^{=}}{1.18}\quad \overset{HCO_3^-}{0.02}}{\underset{Na^+}{90.07}\quad \underset{Mg^{2+}}{3.76}\quad \underset{K^+}{3.69}\quad \underset{Ca^{2+}}{2.48}}$$ pH 5.6

Sample (22 a) S = 325.6 gm/l $$\frac{\overset{Cl^-}{98.68}\quad \overset{SO_4^{=}}{1.31}\quad \overset{HCO_3^-}{0.01}}{\underset{Na^+}{92.47}\quad \underset{Mg^{2+}}{2.68}\quad \underset{K^+}{2.58}\quad \underset{Ca^{2+}}{2.26}}$$

S: Salinity in gm/l

Table 9: Hypothetical salt combination of the brine (epm%)

	17 a	16 a	21 a	22 a
$CaHCO_3$	0.03	0.03	0.02	0.01
$CaSO_4$	2.81	2.52	2.46	2.26
$MgCO_3$	Nil	Nil	Nil	Nil
$MgSO_4$	1.21	3.67	3.76	1.31
$MgCl_2$	1.98	Nil	Nil	1.37
Na_2SO_4	Nil	Nil	Nil	Nil
NaCl	91.49	90.33	90.07	92.47
KCl	3.11	3.44	3.69	2.58

DISCUSSION

▪ Salt Crust

The results obtained in this work show increased KCl concentration relative to the results obtained by Al-Badri and Qassim (1988). The mean KCl content of all salt crust samples in the present work is 2.2% (range 0.7 – 5.7%). Compared to a mean of 0.73% (range 0.08 – 2.3 %) in the previous work. It is also noticed that recent salt crust contains higher K content than the older crust. The mean KCl content in the former is 3.5% compared to 1.6% in the later, which is explained by the dilution of the old crust by dust and detritals brought about by seasonal floods.

Sylvite was detected in all samples analyzed by XRD together with halite (dominant) and gypsum. The salt constituents in the older crust have been diluted by clays and fine detrital impurities derived mostly by floods and dust storms to the depression. The analysis of the water-insoluble residue in the older salt crust indicates clays of aluminum – magnesium silicates composition (smectite and palygorskite) with carbonate and quartz fine detritus. The source material may be mostly the exposures of the Fatha Formation mudstone in the area.

The analysis of the mudstone is comparable in some respects to the IR composition of the older salt crust. The former contains less silica and calcia and higher sodium and potassium. The relatively high K, Na and Cl contents in the Fatha Formation mudstone suggests presence of halite and sylvite in these country rocks, which could have been introduced diagenetically from brines in the saltern.

Interelement correlation coefficients show that the only significant positive correlation of K is with Mg (+0.85), which can be explained that both cations remain in solution after halite precipitation and their salts are the last to precipitate, which result in a geochemical affinity in the salt precipitation system. Other significant positive correlations includes Ca-SO_4 (+0.94), which signifies gypsum presence, and Na-Cl (+0.98), which is due to halite; the major salt in Albu-Gharis Saltern.

▪ Brine

The salinity of the brine in the saltern is about 330 gm/l with an acidic pH of 5.5. It is about 10 times the salinity of normal seawater (Turekian, 1968). Compared with the salinity recorded by Al-Badri and Qassim (1988) of 283 gm/l, there is a significant increase in salinity in about 14 years of time, which is explained by the increased regional aridity and warming of the climate over this period (Green Peace, 2000) as well as the exceptional pluvial year of 1988 in Iraq. The salinity of Albu-Gharis brine is comparable with that of the Dead Sea of about 337 gm/l (Steinhorn, 1983), but with completely different chemical composition.

The increase in salinity is due mainly to increase in Cl^-, Na^+ and to a lesser extent K^+ and Ca^{2+} concentrations. Comparing ion ratios and TDS of the brine of Albu-Gharis to that of seawater (Table 5) show the following ratios: Na 10.6, K 17.5, Ca 5.6, Mg 1.7, Cl 9.9, SO_4 1.2, HCO_3 0.5 and TDS 9.4. As far as Na and Cl, the concentration is about 10 times that of seawater. However, K concentration is remarkably higher by about 17 times, which indicates a potassium anomaly.

It is interesting to note that the near-surface ground water salinity in all the wells drilled in Al-Jazira Area rarely exceeds 25000 mg/l and is rarely of Na-chloride type (Al-Jiburi and Al-Basrawi, 2009). According to those authors the static water level of the first aquifer near the northern part of the saltern is 1.2 m, below ground surface and 180 m (a.s.l.) with a TDS content of 4520 mg/l, and flow direction from NE towards the saltern.

Based on the above information, it is obvious that the brine source is from deeper aquifers of much higher salinity and Na-Chloride type. The brine salinity and composition suggest contact with the rock salt deposits of the Dhiban and/ or the Fatha formations (Lower and Middle Miocene, respectively). These two rock units are known to have relatively thick rock salt deposits in Al-Jazira Area south of Sinjar structure, proved by deep drilling (Etabi, 1978 and Dimitrov *et al*., 1984).

The linear alignment of the springs (Fig.2) inside the saltern may suggest structural control, where the brine is ascending to surface via deep conduits. The linear trend of the springs following the elongate axis of the saltern may support the opinion of Al-Hadithi *et al*. (1987) that the depression is structurally controlled by deep seated fault or major joint.

Hydrochemical formulas of the brine (Table 8) show Na-chloride dominated type, followed by Mg, K and Ca (cations) and SO_4 and HCO_3 (anions). Hypothetical salt combinations derived from brine analysis (Table 9) shows KCl presence in significant amount of 3.2 epm%. It represents the second hypothetical salt after NaCl, followed by $MgSO_4$ and $CaSO_4$. All hydrochemical indices (ratios of ions to Cl) of the brine are less than unity and are comparable to those of normal seawater reflecting higher solubility of the chloride in the system (Kushnir, 1982).

▪ **Mud**

The salt crust at Albu-Gharis Saltern is interlaminated with organic-rich mud, which fill the depression. The mineral analysis by XRD showed: clay minerals (palygorskite and mixed layer smectite), non-clay minerals (quartz, calcite, dolomite and feldspar) and salt minerals (halite and gypsum). The mineralogy of the mud in the saltern is comparable to that found in the Fatha Formation mudstone exposed at the margins of the saltern. Considering this similarity and the drainage direction, these mudstones may have significant contribution to the mud of the saltern deposits. Organic matter is relatively high in the mud reaching up to 1.25%, which reflects low oxidation potential (Eh) due to stagnation in near-surface environment of the saltern.

RESOURCE POTENTIAL

The result of this work, supported by previous work of Al-Badri and Qassim (1988), enables a preliminary evaluation of the potash potential of the Albu-Gharis Saltern. Al-Badri and Qassim (1988) estimated the NaCl reserves by 10 m.t. in the crust (1.2 m thick). Considering the NaCl content in the raw salt of about 83%, the reserves of the raw salt in the crust is about 12 m.t. with 2.2% KCl, which brings the KCl reserves to about 264000 tons in the raw salt crust. In other words, for every 100000 tons of NaCl produced, there can be about 2200 tons of KCl recovered.

On the other hand, there is 1.3% KCl in the brine and the NaCl reserves were estimated in the brine by about 3 m.t. The NaCl concentration in the brine is about 30%, which brings the KCl reserve of the brine in the 1^{st} meter to about 135000 tons; about 94000 t. of which is recoverable considering 70% KCl recovery, according to the results obtained by Al-Ajeel *et al*. (1989). However, the brine resource is highly dependant on the stability of the composition and salinity while pumping. It is also dependent on the extraction recovery of KCl. In view of the lack of potash resources in Iraq, except the Arabian Gulf poor resources, the Albu-Gharis Saltern represents a potential source of potassium salts, which can be produced from the bitter solution after NaCl precipitation.

CONCLUSION

Albu-Gharis Saltern contains promising potassium concentrations in the salt crust and in the brine. About 400000 tons of KCl may be available in both of them. The present results encourage more detailed hydrogeological investigations of the brine and to have more accurate reserve estimation as well as pilot production of KCl.

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