SEDIMENTARY FACIES AND ENVIRONMENTS OF SHARI PLAYA, CENTRAL IRAQ

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ABSTRACT

Shari Playa, which is the only source of natural sodium sulphate in Iraq, is a longitudinal closed basin located about 150 Km to the north of Baghdad, Central Iraq. The playa receives its sediments from major ephemeral streams originated from Himreen Mountain, which surrounds the playa from the northeast and east, forming a seasonal lake. Most streams passes through sand dunes located between Himreen Mountain and the playa. The sediments brought by these ephemeral streams developed seven sedimentary facies, which are vertically and laterally interrelated, deposited in five sedimentary sub-environments over the underlying Clastic Substrata Facies. These include the salt bearing facies group (salt crust, black mud, glauberite-rich mud and gypsum-rich mud), Sand – Silt Facies, Coarse Sand Facies and Windblown Sand Facies. Their thickness are generally wedging out towards the periphery. The sediments distribution and geometry indicate that the playa is a subsiding N – S oriented graben.

البيئات والسحنات الرسوبية لمملحة الشاري، وسط العراق

يحيى توفيق الراوي، رافع زائر جاسم و حبيب رشيد حبيب

المستخلص

مملحة الشاري التي تعد المصدر الوحيد لكبريتات الصوديوم الطبيعية في العراق، هو منخفض مغلق طولي الشكل يبعد حوالي 150 كم شمال مدينة بغداد. يستلم هذا المنخفض رسوبياته من خلال الوديان الموسمية التي تأتي معظمها من جبل حمرين الذي يحيط هذا المنخفض من الشمال الشرقي والشرق مكوناً بحيرة موسمية. معظم هذه الوديان الموسمية يمر خلال الكثبان الرملية الواقعة بين جبل حمرين ومنخفض الشاري. كونت هذه الرسوبيات القادمة خلال الوديان الموسمية خمسة سحنات، إضافة الى سحنتي الكثبان الرملية والطبقات التحتية. هذه السحنات لها امتدادات وتداخلات عمودياً وأفقياً، وترسبت من خلال خمسة بيئات رسوبية معتلية الطبقة التحتية. هذه السحنات، من المركز الى الخارج تشمل مجموعة السحنات الحاوية على المجموعة الملحية (سحنة القشرة الملحية، سحنة الوحل الأسود، سحنة الطين الحاوي على الگلوبرايت وسحنة الطين الحاوي على الجبس)، سحنة الرمل – الغرين، سحنة الرمل الخشن التي تتواجد جميعها فوق سحنة الطبقة التحتية، إضافة الى سحنة الرمال الريحية التي تتواجد خارج حافات المنخفض. تتميز سماكات هذه السحنات بصورة عامة بالتناقص والتلاشي باتجاه الحافة. ان توزيع هذه الرسوبيات على السطح وبالعمق وشكلها يدل على ان هذا المنخفض هو منخسف طولي باتجاه شمال – جنوب حدثت عملية ترسيب السحنات الرسوبية فيه أثناء عملية الهبوط.

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INTRODUCTION

The topographically low area of the Shari Playa, which is 20 Km long and (3 – 5) Km wide, located about 150 Km north of Baghdad and 25 Km northeast Samarra (Fig.1) is surrounded by low cliffs from the west and north and by sand dune fields, from the east and south. Himreen Mountain surrounds the Shari Playa area from the east and northeast. Many ephemeral streams drain in Shari Playa are originated from Himreen Mountain. They carry water and sediments load in the flooded streams during winter. These main ephemeral streams are Assam, Edmath and Wadi Abu Al-Asuad. The sand dune fields are of Barchans and Transverse types. The association of these sand dune fields is similar to other salt lakes and playas in the arid and semi-arid regions, such as Searles Lake and Saline Valley in California (U.S.A.) and Magadi salt lake in Kenya (Hunt and Mabey, 1966 and Lombardi, 1963).

The exposed geological formations in the area surrounding to the Shari Playa are Fatha (Middle Miocene), Injana (Late Miocene) and Mukdadiya (Late Miocene – Pliocene), as well as Quaternary sediments. Rocks of Fatha and Injana formations are exposed in Himreen Mountain, located to the northeast of the playa. It has been found from the drilling data of Araim *et al*. (1976), Al-Kassab (1989), and Ahmid and Murad (1995) at the western and eastern sides of the playa, that Mukdadiya Formation was encountered at depth ranging between (40 – 60) m, and its lower contact with the Injana Formation was not recorded. The Mukdadiya Formation is composed of pebbly sandstone alternated with sandstone and mudstone (Buday, 1980, and Jassim and Goff, 2006). It is overlain by the Pleistocene fluvial sediments, which are composed of sand, silt and clay alternations. The Pleistocene sediments are considered as the substrata for the overlying playa sediments and saline deposits.

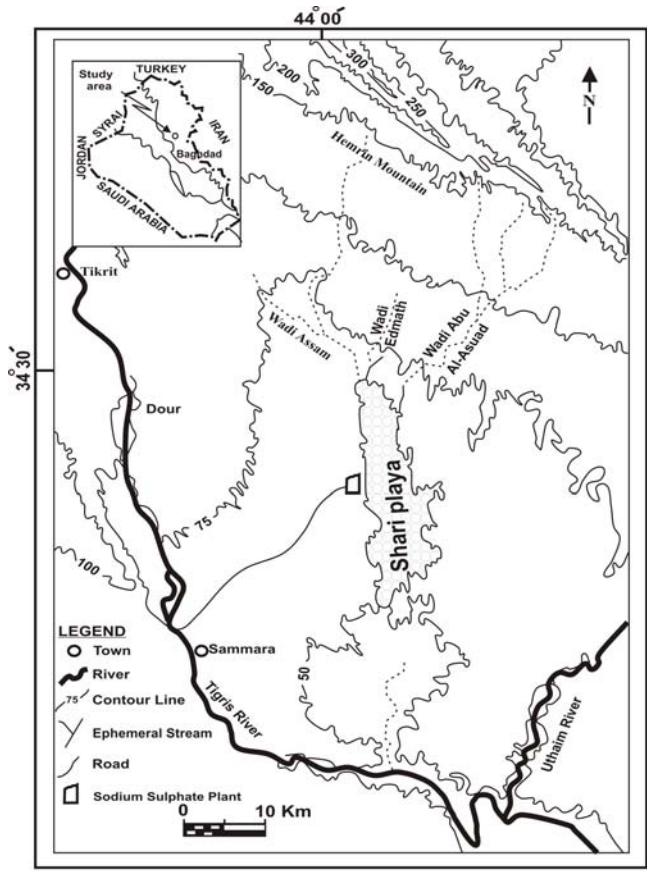

Fig.1: Location map of Shari Playa

PREVIOUS WORKS

The first study for the geology and geomorphology of Shari Playa was carried out by Bolton (1956), followed by Araim *et al*. (1978) they studied its economic potential. Jackoski and Hasan (1984) outlined the configuration of the sand dunes associated with the playa. Fatih (1989) studied the chemistry and mineralogy of the uppermost sediments of the playa lake in addition to the hydrochemistry of the lake brine. Jassim (1992) studied the chemistry, mineralogy and economic potential of the playa. Mohammed and Jassim (1994) studied the possible genesis of the salts in the playa. Jassim (1997) studied the mineralogy, geochemistry and origin of the playa while Jassim *et al*. (1997) studied the role of the bacteria in the formation of glauberite. Jassim *et al*. (1999 and 2006) studied the mineralogy of the salt minerals and the origin of the playa, respectively.

METHOD OF WORK AND RESULTS

Six hundred and thirty two samples from 20 boreholes and 26 auger holes were collected, studied and analyzed chemically. The results deduced from the study of the collected samples were the bases to describe the sedimentary facies and environments listed in this study.

SEDIMENTARY FACIES AND ENVIRONMENTS

Shari Playa occupies a topographically closed basin in a semi-arid region. The playa is subjected to seasonal flooding followed by periods of evaporation and desiccation. Therefore, the development of the sedimentary facies was affected by distinctive hydrological, chemical, biological and sedimentological processes that took place in various parts of the playa. These parts are termed subenvironment according to Hardie *et al*. (1978). Field observations and aerial photographs interpretation were used for the recognizing and mapping of these subenvironments.

Shari Playa shows a salt crust on the top of the lithological section, covering most of the playa surface. However, beneath this crust a variety of sedimentary facies are encountered. The relations between the different facies of the sedimentary sequence at Shari Playa is illustrated in Fig. (2). This figure is a three-dimensional diagram compiled from surface mapping and data from boreholes and auger holes (Jassim, 1992 and 1997). Playa sediments, which belong to the lake and associated subenvironments could be categorized into several sedimentary facies that are laterally and vertically interrelated. These include the Salt Bearing Facies Group (Salt Crust, Black Mud, Glauberite-rich Mud and Gypsum-rich Mud), Sand – Silt Facies, Coarse Sand Facies and Windblown Sand Facies. The playa sediments facies are underlain by the Clastic Substrata Facies, which belong to the fluvial system that occupied the area before the formation of the playa. Five major, almost concentrically arranged subenvironments are recognized these are from the center outwards: Glauberite Mudflat, Gypsum Mudflat, Sand-Flat, Flood Plain – Alluvial Fan and Dune Field subenvironments (Fig.3). These vertical and lateral relations are shown in Figs. (4 and 5). They are described hereinafter.

- **Salt Bearing Facies Group**

This group of facies is the most important from the economical and sedimentological points of view. It includes Salt Crust Facies, Black Mud Facies, Glauberite-rich Mud Facies and Gypsum-rich Mud Facies. Developments of these facies are mainly linked with the seasonal playa lake. All these facies, except the Gypsum-rich Mud Facies, represent the Glauberite Mudflat Subenvironment, which occupies the central part of the playa. The Glauberite Mudflat Subenvironment occupies the central part of the playa and is characterized by the development of the Glauberite-rich Mud Facies, overlain by the Black Mud Facies. This subenvironment is characterized by the development of thin salt crust in summer or accumulation of a body of lake water in winter. The Salt Crust Facies is well developed in this subenvironment in summer, but absent and replaced by lake water in winter. The salt crust forms upon drying of the shallow water body of the playa which accumulates in winter to a depth of up to1 m, and may dissolve by lake water of the next winter. Recharge of the playa lake is by surface runoff through the ephemeral streams and by seepages which rise up through weakness zones in the playa sediments. Surface runoff enters the playa from the ephemeral streams and spreads as sheet flood onto the playa surface. The surface brine is usually concentrated by evaporation and ultimately forms the salt crust. Similarly, the pore brine of the underlying sediments is concentrated through evaporative pumping. Thus, thenardite, halite and glauberite are precipitated in the crust and interstitial glauberite crystals are formed in the black mud slurry and the bluish green-gray mud of the Glauberite-rich Mud Facies. Growth of these crystals results in the destruction of the sedimentary structures. The slurry of Black Mud Facies is well developed in this pan of the playa, as a bottom layer of the playa lake and reaches about 0.5 m in thickness, in the central part of this subenvironment. Blue-green algae, aerobic and anaerobic bacteria have contributed to the development of the black mud slurry. Below this slurry the mud becomes more consolidated and bluish-gray in color. It also becomes characterized by the presence of crowded glauberite crystals. Glauberite is formed in this part of the playa either by alteration of gypsum in the presence of Na^+ in solution with enough activity to create such alteration, or by direct precipitation from surface brine and pore brine rich in sodium and calcium sulphate. This group contains the following facies:

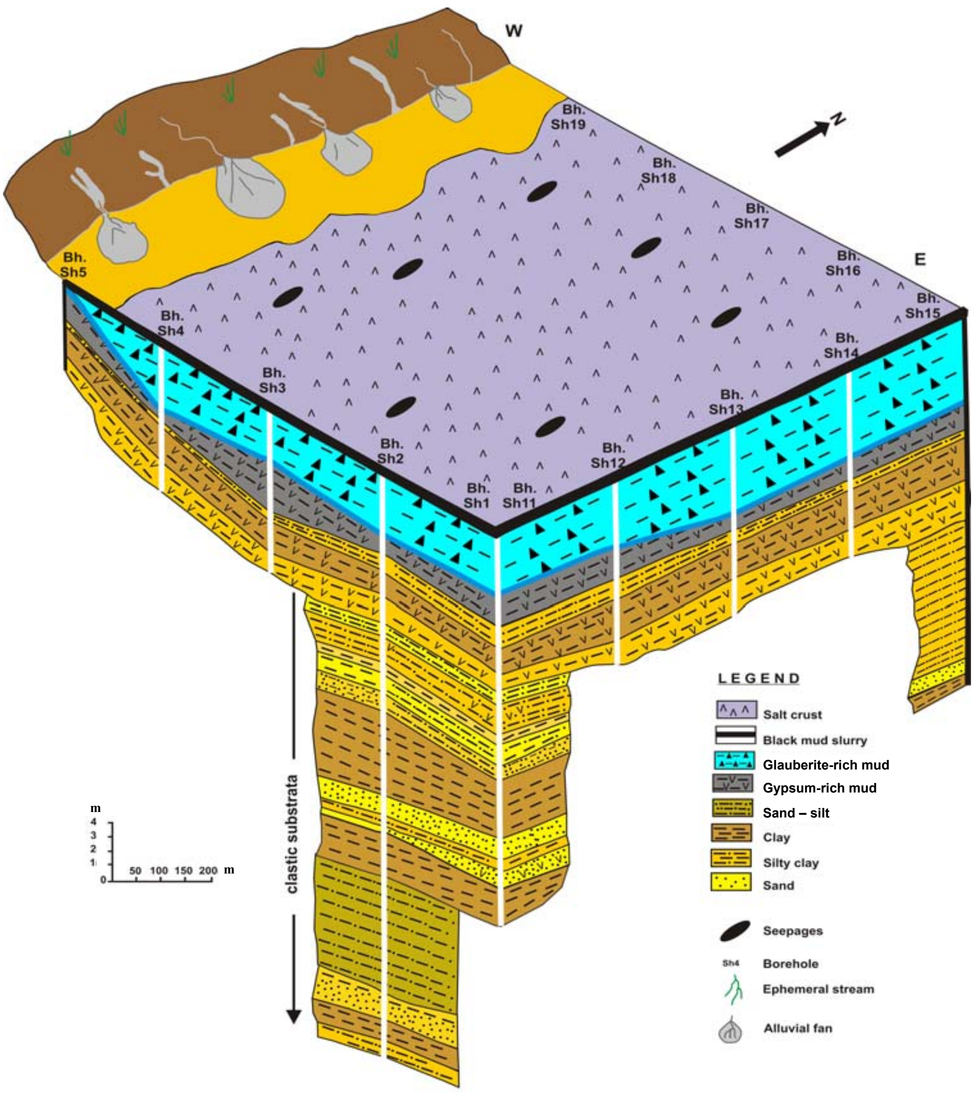

Fig.2: Three dimensional section through the western part of Shari Playa

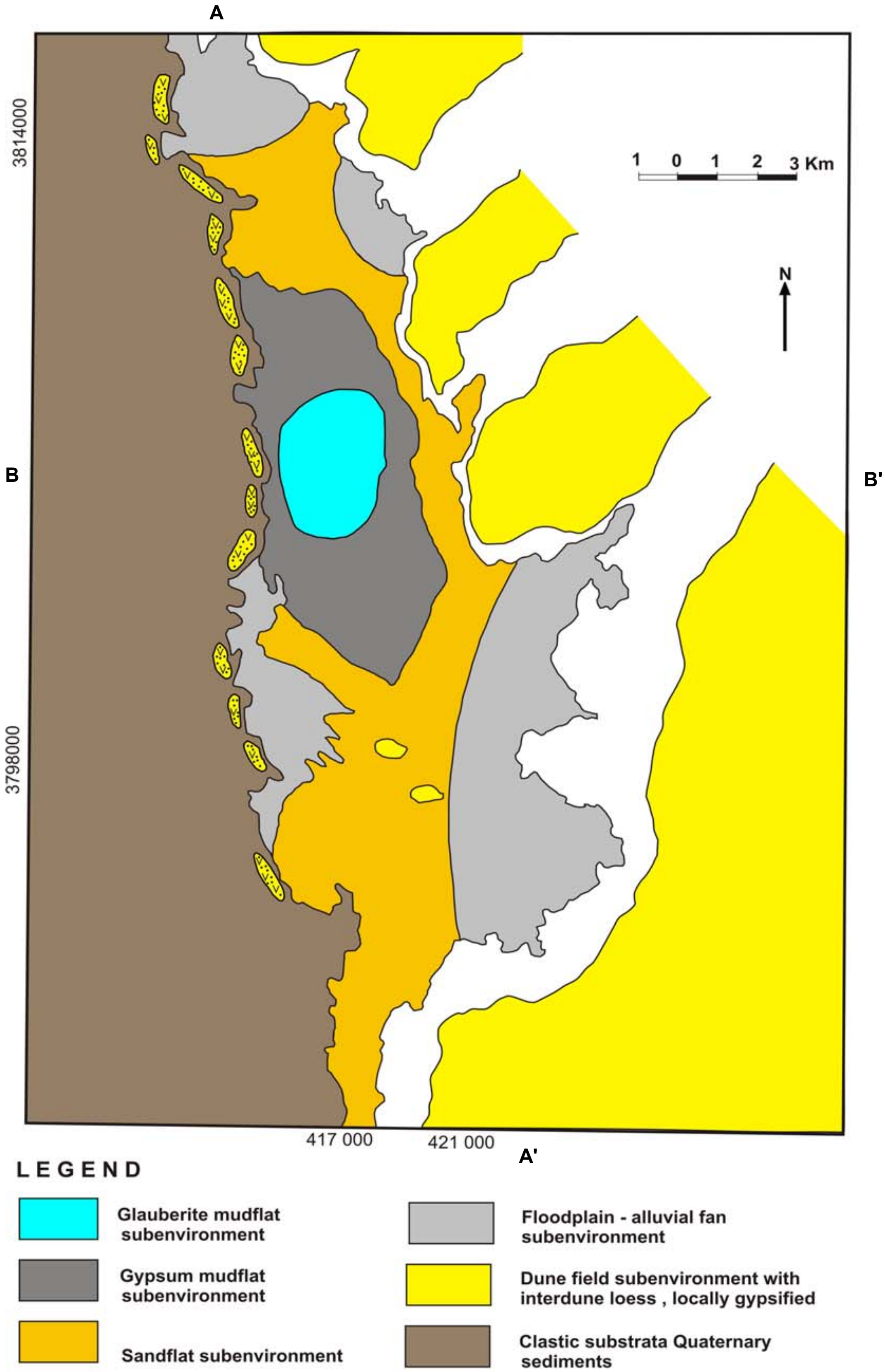

Fig.3: Surface subenvironment map of Shari Playa

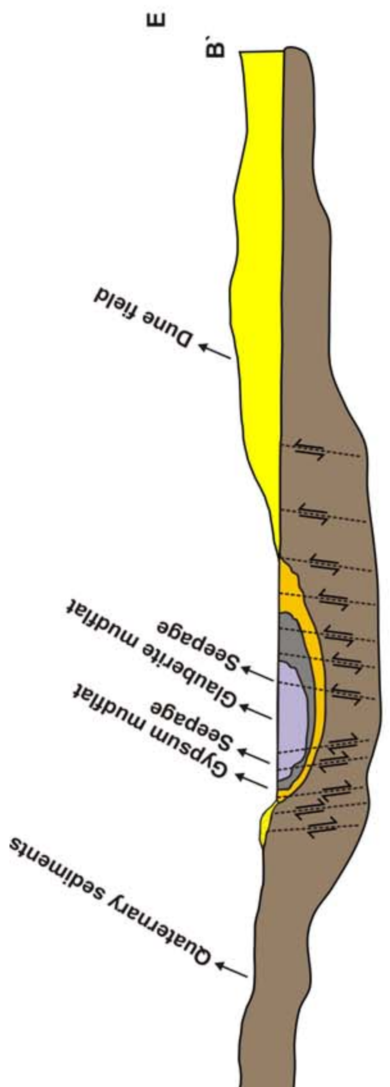

Fig.4: Schematic cross-section along E – W (B – B') line in Shari Playa

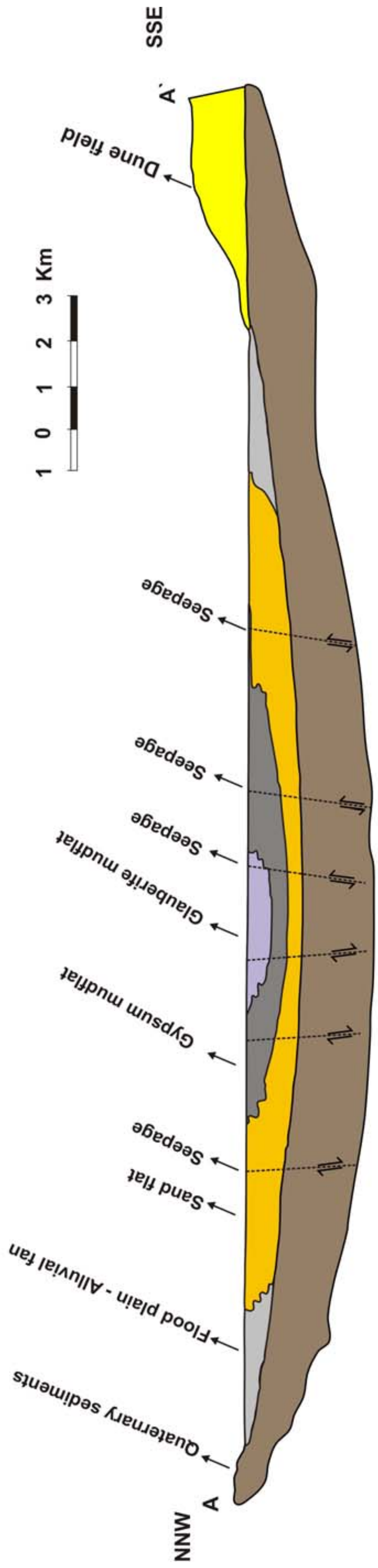

Fig.5: Schematic cross-section along NNW – SSE (A – A') line in Shari Playa

- **Salt Crust Facies and Environment**

Salt crusts are the most prominent features in playas and sabkhas, as they represent the surfacial beds, which generally are composed of salt minerals. The types and assemblages of the salt minerals depend on the chemistry of the lake brine and the sequential precipitation, due to evaporative concentration in the desiccation stage in the arid and semi-arid environments. In Shari Playa, this facies is primarily composed of thenardite (Na_2SO_4) and halite (NaCl), occasionally with glauberite ($Na_2SO_4 .CaSO_4$). Components of this facies are usually totally dissolved in the fresh water of the next winter flooding, and then re-deposited in the next summer (Fig.2). The salt crust's thickness shows increase towards the central part of the playa. It is about 1 cm thick, near the margins and about 7 cm, in the central part. The lower contact of the white efflorescent facies, with the underlying mud is marked by a sheet of red and green algae. Cracking of the salt crust after subjection to desiccation in summer is common, resulting in the formation of polygonal shapes ranging in diameter from (1 – 45) m. Such cracking are attributed to the growth of the salt crystals in the salt crust.

- **Black Mud Facies and Environment**

This facies is composed of black mud slurry, usually found directly below the Salt Crust Facies. It is mainly composed of clay, silt, organic matter, and fine crystals of salt minerals. The salt minerals found in this facies of the playa sediments include thenardite, glauberite and bassanite in summer; coarse crystals of mirabilite ($Na_2SO_4.10H_2O$) are found instead of thenardite in winter, due to the freezing out phenomenon. The thickness of this facies also shows an increase towards the central part of the playa. It ranges from less than 10 cm, near the margins to 50 cm, in the central part of the playa. Bacteriological study of the black mud shows the presence of both aerobic and anaerobic bacteria. Some of these bacteria are pathogenic (Jassim *et al.*, 1997). This facies is well developed in the area, which is occupied by the playa lake, during winter and spring seasons. Clastic components of this facies are deposited as a settle-out from suspension, when the turbulence of the flood waters subsides forming a thin layer over the playa lake bottom, whereas saline crystals are precipitated from the brine soaking the mud. Silt, clay and salt crystals accumulate at the bottom of the slurry; ultimately consolidate and become part of the underlying Glauberite-rich Mud Facies. The textural features of the salt crystals reflect nucleation of seed crystals.

- **Glauberite-rich Mud Facies and Environment**

This is a bluish green-gray mud, which underlies the Black Mud Facies. This facies is mainly composed of clayey or silty mud with high content of fine, medium and coarse crystals of glauberite. The crystals were either formed by alteration of gypsum in the presence of Na^+ in solution, or by direct precipitation from the solution. The dark color of the mud is due to the reducing environment created by the blue-green algae, and both aerobic and anaerobic bacteria in the overlying Black Mud Facies. The presence of the bacteria plays an important role in the enhancement of sulphate minerals formation. The thickness of this facies reaches about 6.20 m, in the central part of the playa and wedges out towards the periphery, where it passes laterally into the Gypsum-rich Mud Facies. There is a direct genetic relation between this facies and the overlying Black Mud Facies, in that its components form through accumulation and later consolidation at the bottom of the black mud slurry. Further growth of salt crystals (glauberite) from the pore brine leads to destruction of the primary sedimentary structures (layering).

- **Gypsum-rich Mud Facies and Environment**

This is a bluish green-gray and brownish mud overlain by Glauberite-rich Mud Facies, in the central part of the playa, but laterally interdigitates with it towards the margins, where it becomes exposed to the surface in a concentric manner around the Glauberite-rich Mud Facies (Fig.2). It is mainly composed of clayey or silty mud with high content of interstitial fine, medium and coarse gypsum crystals. Gypsum crystals were deposited from the solution when the concentration of $CaSO_4$ in solution exceeds 2 gm/1. The highest thickness of this mud is about 4 m, as recorded in B.H. Sh 3 (Fig.2) located at the mid-western part of the playa. It reaches the depth of 8.25 m, in B.H. Sh 14 (Fig.2), in the central part of the playa, and wedges out towards the playa margins with occasional thickening in B.H. Sh 3, where its thickness reaches 5.2 m. The silt and clay of this facies were deposited as a settle-down from suspension from lake water brought as turbulent floodwater by the ephemeral streams to the Shari Playa. Gypsum growth in this area of the playa is attributed to the chemistry of both the lake and the sediments pore brine. Its alteration to glauberite does not took place due to the low Na^+ activity in solution, i.e. the Na^+ concentration is not enough to create such alteration. This facies was developed in the Gypsum Mudflat Subenvironment, which surrounds the Glauberite Mudflat Subenvironment at the surface and is overlain by thin salt crust at the surface (< 1 cm in thickness) (Fig.3). Crowded fine, medium and coarse, prismatic and tabular gypsum crystals, with swallow tail twining and often may have clay inclusions, are found in this silty mud layer. Gypsum is formed by precipitation from lake water and brines in the sediments pore, when Ca^{+2} and $S0_4^=$ activity is high enough to form gypsum and Na^+ activity is too low to alter gypsum to glauberite. The growth of the gypsum crystals resulted in destruction of the sedimentary structures of the mud sediments. Gypsum-rich mud sediments, which are the characteristic of this subenvironment, pass laterally into glauberite-rich mud and underlie them in the central part of the playa. Thus, in part they reflect earlier stages of salt concentration in the playa, as well as present lateral variations in pore brine concentration. Pore brine concentration is lower in the gypsum rich mud, which is closer to the recharge area than in the glauberite-rich mud in the central part of the playa.

- **Sand – Silt Facies and Environment**

This facies is found around and at the bottom of the salt bearing, facies group and overlies the Clastic Substrata Facies. It extends outwards to the coarse sands of the flood plain – alluvial fan sediments. This facies interdigitates laterally with the Coarse Sand Facies towards the periphery of the basin, and with the Gypsum-rich Mud Facies towards the center of the playa. It thickens toward the central part of the playa due to contemporaneous subsidence of the depression (playa) and sedimentation. This facies is composed of a mixture of sand and silt, which basically consist of quartz and carbonate fragments brought from Himreen Mountain. This facies is usually forming the Sand-Flat Subenvironment, which is characteristic of closed lake environment. They are considered to be deposited from sheet floods (Allen and Collinson, 1986) that enter the depression (playa) from its peripheries. It roughly underlies and surrounds the Gypsum Mudflat Subenvironment (Fig.3). It is a fringing sandy – silty apron, which grades from the alluvial fan and ephemeral stream flood plains (Fig.5), and have characteristic features different from them. Therefore, it represents the transition zone from the ephemeral stream sediments (alluvial fans and flood plains) to the playa sediments. It is an area of sheet-flood sedimentation. The sediments show horizontal lamination with crumbled efflorescent crust on the top. Clay material content increases towards the Gypsum Mudflat Subenvironment associated with a decrease in the sand content. Fine gypsum crystals are locally found. They are formed by evaporation of the playa brine and by evaporative pumping concentration from the ground water body below the sand-flat surface. The sand-flat is recharged by the ephemeral flooding, perennial springs and see pages in the playa. Occasionally Aeolian sand dunes are found on the dry areas of the sand-flat, as a result of reworking and re-deposition of sand.

▪ **Coarse Sand Facies and Environment**

This facies is found at the mouths of the ephemeral streams that open into the playa from the northern, eastern and western sides forming alluvial fans and flood plains. It overlies the Clastic Substrata Facies, and extends to the Sand – Silt Facies and interdigitates laterally with it. It consists of coarse sand composed of quartz and carbonate grains brought from Himreen Mountain through ephemeral streams and deposited near their mouths, at the playa periphery as a heavy load of the runoff water. Ephemeral streams are usually dry, but occasionally flooded after heavy rainfall showers on the catchments area of the playa. The flooded ephemeral streams may form cone shaped sediments built out radially onto the clastic substrata of the playa floor. Therefore, the flood plains and alluvial fans consist of coarse sand and silty sediments. Braided channels are found on the surface of these sediments and may become less distinctive towards the toe. The sediments of this facies usually form the Flood Plain-Alluvial Fan Subenvironment. Sediments of this subenvironment lie directly on the Clastic Substrata Facies of Quaternary sediments and interdigitates laterally with the Sand – Silt Facies of the Sand-Flat Subenvironment. They occur on the northern, eastern and western margins of the playa at the mouths of the ephemeral streams. The main ephemeral streams are Wadi Assam and Wadi Edmath, in the northern side and Wadi Abu Al-Asuad, in the eastern side of the playa. Ephemeral streams in the western side are few, small and unnamed, but they form distinct, though smaller, alluvial fans. The presence of alluvial fans in the eastern and western sides of the playa basin, indicate the existence of block faults, which probably largely contributed to the formation of this depression. According to Hardie *et al*. (1978) alluvial fans found on saline lake basins are usually the result of block faulting. Few perennial springs flow on the surface of the flood plain sediments at the mouth of Wadi Assam. They probably are also related to the fault zones that formed the playa-graben (Jassim, 1997 and Jassim *et al*., 2006).

▪ **Wind Blown Sand Facies and Environment**

Sands of Aeolian origin are found in the eastern side of the Shari Playa, forming relatively stable Barchan and Transverse dunes. In this respect, Shari Playa is similar to many playas, salt pans and sabkhas, elsewhere in the world, which are characterized by the presence of windblown dune fields, such as the graben valleys of the Great Basin in western U.S.A, Lake Eyre in Australia, Etosha Pan in South West Africa, Death Valley and Saline Valley in California (Hunt and Mabey, 1966 and Lombardi, 1963). The sand dunes form NE – SW oriented dune fields separated by interdune loess. This may be attributed to the characteristically dry and hot climate, and the nature of the topography of their closed basins. The sand dune fields associated with Shari Playa are relatively stable (Jackowski and Hasan, 1984), and extend from the playa floor to Himreen Mountain, to the east and northeast. They are also found in relatively limited occurrences along the western margin of the playa (Fig.3). The dunes have an average height of about 50 m, above the playa surface. The NW – SE wind direction, primarily influences them, although there is evidence of multidirectional winds expressed by the sand ripples and the complexity of the dune forms (Jackowski and Hasan, 1984). The windblown sand grains that form the dunes are composed of carbonates, quartz, clays and to a lesser extent, soluble salts. The sand grains are rather coarse and angular containing rock fragments, which indicate relatively short distance from the supply source area (Jackowski and Hasan, 1984). The main bodies of sand dunes are directly underlain by the Quaternary Clastic Substrata Facies and are truncated by the ephemeral streams; some sand dunes lie on the Sand – Silt facies. Sand dunes lying in the western side of the playa are gypsified, showing gypcrete bodies and gypsum caps. Gypcrete is found in powder, fibrous massive and spongy forms (Hassan and Al-Jawadi, 1976). The thickness of the gypcrete ranges from few centimeters to about 5 m. It is thought that gypsification was formed by capillary solutions rich in sulphates brought up to the surface of sediments and precipitate secondary gypsum and probably sodium sulphate upon evaporation.

- **Clastic Substrata Facies**

The Clastic Substrata Facies represent the clastic sediments of Quaternary age on which the Sand – Silt Facies and salt bearing facies group were deposited. They are exposed on the western and northern sides of the playa and are covered by the sand dunes in the eastern side. The presences of these clastic sediments were also recorded in the drilled boreholes in the playa, B.H. Sh 1 to Sh 20 (Fig.2). The clastic substrata layers are fluvial sediments formed from erosion of the Miocene and Pliocene rocks, which are exposed in Himreen Mountain. They are composed of alternating layers of brown and reddish clay, silt and sand (Fig.2). The thickness of the Quaternary clastic substrata sediments is about 60 m (Jassim, 1992). They are underlain by pebbly sandstone or fine conglomerate of the Mukdadiya Formation (Araim *et al.*, 1976). Salts are absent in these sediments, except for some thin seams of friable gypsum crystals at different intervals.

DISCUSSION AND CONCLUSIONS

The sediments brought to the Shari Depression by the rain water from the surrounding area and Himreen Mountain were deposited in the subsiding depression, where the coarse pebbles were deposited near the mouths of streams, followed by the sand and finally the very fine sediments, represented by the clays, were deposited at the central part of the playa. The wedging out of these layers toward the periphery of the playa indicates that the deposition took place while the depression was subsiding.

The development of gypsum in the sand – silt and clay layers took place when the concentration of calcium and sulphate ions increased, year after year then resulted in the precipitation of gypsum. Glauberite was formed when the concentration of sodium increased, by time to a certain degree, which is enough to alter gypsum to glauberite (Jassim, 1997, and Jassim *et al.*, 1999). The alteration took place by the affect of bacteria present in the black slurry, which occupy the deepest part of the playa (Jassim *et al.*, 1997). It is worth mentioning that the brines are also supplied to the depression via springs formed by the intersection of fault systems that are responsible for the depression development (Jassim, 1997, and Jassim *et al.*, 2006).

REFERENCES

Ahmid, H.S. and Murad, N.Y., 1995. Drilling of production water wells in Shari Lake for sodium sulphate project. GEOSURV, int. rep. no. 2338.

Al-Kassab, S.Sh., 1989. Preliminary study about the groundwater quality and the possibility of extraction of sodium sulphate salts in Shari Lake. GEOSURV, int. rep. no. 1598 (in Arabic).

Allen, P.A. and Collinson, J.D., 1986. Lakes. In: H.G., Reading (Ed.) Sedimentary Environments and Facies, 2nd edit. Blackwell Scientific Pub., Oxford, 615pp.

Araim, H.I, Laboutka, M. and Ghazoul, S., 1976. Hydrogeological studies in Shari lake, Samarra. GEOSURV, int. rep. no. 709.

Araim, H.I., Butros, J. and Sherif, S., 1978. Hydrogeological studies and salt reserve estimation in Shari Lake, Samarra. GEOSURV, int. rep. no. 879 (in Arabic).

Bolton, C.M.G., 1956. Geological report on the saline deposits of Shari Lake, near Samarra. GEOSURV, int. rep. no. 239.

Buday, T., 1980. The Regional Geology of Iraq: Vol. 1. Stratigraphy and Paleogeography. In: I. I, Kassab and S.Z., Jassim (Eds.). GEOSURV, 445pp.

Fatih, A.S., 1989. Geochemical and mineralogical study of the Shari Lake near Samarra, Iraq. Unpub. M.Sc. Thesis, Baghdad University (in Arabic).

Hardie, L.A., Smoot, I.P. and Eugster, H.P., 1978. Saline lakes and their deposits: A sedimentological approach. Spec. Publs. Int. Ass. Sediment., Vol.2, p. 7 – 41.

Hassan, A.M. and Al-Jawadi, B., 1976. Report on the geology of Samarra – Baiji area. GEOSURV, int. rep. no. 719.

Hunt, C.B. and Mabey, D.R., 1966. Stratigraphy and Structure of Death Valley, California. Prof. Pap. U.S.G.S. 494-A.

Jackowski, W.F. and Hasan, A.A., 1984. The investigation of the sand dunes of Baiji – Tikrit – Shari area. GEOSURV, int. rep. no. 1375.
Jassim, R.Z., 1992. Investigation for sodium sulphate in Shari Lake. GEOSURV, int. rep. no. 2072 (in Arabic).
Jassim, R.Z., 1997. Mineralogy, geochemistry and origin of Shari Saltern Deposit, NE Samarra, Iraq. Unpub. Ph.D. Thesis, Baghdad University, Iraq, 173pp.
Jassim, R.Z., Al-Rawi, Y.T. and Flaih, M.T., 1997. The role of bacteria in Shari Playa and their pathogenic effect. A contribution to the microbial geochemistry. Jour. Babylon Univ., Vol. 3, p. 11 – 14.
Jassim, R.Z., Al-Rawi, Y.T. and Habib, R.H., 1999. Mineralogy of evaporate minerals in the Shari Playa Saltern Deposit. Iraqi Jour. Sci., Vol.40C, No.3, p. 7 – 20.
Jassim, R.Z., Al-Rawi, Y.T. and Habib R.H., 2006. Contribution to the structural evolution of the Shari Playa, Central Iraq. Iraqi Bull. Geol. Min., Vol.2, No.1. p. 1 – 11.
Jassim, S.Z. and Goff, J., 2006. Geology of Iraq. Dolin, Prague and Moravian Museum, Brno, 341pp.
Lombardi, O., 1963. Observations on the distribution of chemical elements in the terrestrial saline deposits of Saline Valley, California , U.S. Naval Ordnance Test Station, China Lake, Tech. Pub. 2916.
Mohammed, I.Q. and Jassim, R.Z., 1994. Mineralogy and origin of the saline succession of Shari Lake, near Samarra, Iraq. Iraqi Geol. Jour., Vol.27, No.2, p. 24 – 44.

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