CHAPTER FIVE

PETROGRAPHY, MINERALOGY AND FLUID INCLUSIONS CHARACTERISTICS OF THE STUDIED SAMPLES (ORIGIN AND SIGNIFICANCE)

Introduction:

The study of petrography, mineralogy and fluid inclusions of the investigated borehole evaporite rocks from the studied areas comprises the required details for understanding the process as well as the type(s) of how organic matter involvement(s) formulating the basic measure for hydrocarbon generation. Consequently, in this chapter the description of the encountered features (textures and fabrics) will focus on the required details as to answer the main query of the dissertation. The adopted terms and classification were based and implemented to serve the target; hence classical descriptions and tedious arguments are the scope of the present work. Rather focus will concentrate on the features that support or decline the link between evaporites being capable to generate hydrocarbons or not. Moreover, the daigenetic features will concentrate on how and when mineral alteration can serve as formulating the porosity requirements for hydrocarbons to escape (migrate) on macro- and/or micro-scale. The studied evaporite core samples include different laboratories techniques. These are as follows:

A- Petrographic description and SEM imaging for fabric and textural relationships

B- Mineral identification, semi-quantitative and XRD results

C- Fluid inclusions in studied evaporite rocks

A- PETROGRAPHIC DESCRIPTIONS AND DIAGENETIC CHANGES

The mineralogy, petrographic relationships and diagenetic changes of primary and penecontemporaneous precipitated and/or deposited evaporitic minerals were established long time ago. This knowledge and concept, as well, was refined on Trucial coast of Persian Gulf by further studies during mid 1960,s. These findings were the stimulus for further investigation of evaporites through a comparison with recent sediments.

A study of the main petrographic types (texture and fabric as well as the mineral composition) and diagenetic events was the main target of the subsurface evaporite core samples. The characteristics of the studied areas aim to outline the depositional environmental conditions formulating beside the presence and mode of occurrence of organic matter within these samples the second target as to consider these assemblages capable to generate hydrocarbons or not.

Petrographic descriptions (Thin-sections and SEM):

The description of the petrographic investigations was following the classification proposed and published by Ciarapica *et al*, 1985. The thin sections were prepared following the procedure of Miller (1988). The samples were chosen from subsurface cores belongs to the studied areas, representing different lithofacies in the cores intervals (Chapter Two). Also, investigating the micro-fabric relations was achieved using "JOEL" SEM instrument model (5300) with attached EDAX Unit. The following is description and SEM characteristics of the studied samples from different studied areas covering the different pre-existing lithofacies (see Chapter Two).

1. Ras Gemsa Area:

1.1. Laminated gypsum and clay facies (LGC):

This facies is recorded in well NO.Gs-89-03. It is composed of dark grey colored gypsum with finely laminated clay, Under the microscope, it is composed of large; vary sized interlocked subidiotopic to xenotopic gypsum crystals (Plate-1, Figs. A and B) or non-oriented, felty, prismatic, gypsum granular (Plate-1, Fig.C). Both are brecciated and disintegrated (arrows) into microcrystalline secondary gypsum showing partial alteration into anhydrite. The clay lamina is very thin and contains dense, black and opaque organic rich material (Plate.1, Fig. D).

1.2. Massive anhydrite with clay streaks Facies (MAC):

This facies is the most commonly recorded facies in all studied Gulf of Suez areas well cores (see Chapter Two). Under the microscope, it is composed of prismatic granular anhydrite or aligned felty anhydrite crystals (Plate-2, Fig. A), both possessing engulfed featured and corroded gypsum crystals leading to brecciation of relics gypsum (Plate-3, Fig. C) suggesting their epigenetic origin as a result of pressure-growth and/or crystalline volume differences between gypsum and secondary anhydrite.

The clay streaks are seen as dissected lamina enclosing and/or coating nodular pattern of composite gypsum grains (Plate-2, Fig. A) or as thin streaks enclosed in intercrystalline spaces (Plate-2, Figs. B and C). The recorded nodular and/or bouden-like appearance is believed to be the result of compressional stress leading into formation of the long shaped bodies due to presence of clay as lubricant material (Plate-2, Fig. A). The dense, black and opaque organic matter rich material is enriched the terrigenic clay matrix (Plate-2, Figs. B and C), suggesting the organic richness of this sediment.

The occurrence of small fractures and vugs that refilled by large swallow-tail secondary gypsum (Plate-2, Fig. D) or large deformed prismatic gypsum showing brecciating as detected in SEM (Plate-3, Figs. A and B), representing an example with great enlargements. Sometimes felty, straight gypsum crystals forms stellate textured represent a common feature (Plate-3, Fig. C) indicating dissolution followed by recrystallization phases. Halite crystals are believed to refill dissolution spaces (Plate-3, Fig. A) indicating the prevalence of hypersaline depositional regime. Also, bio-mineralized microbial matt enclosed within anhydrite is recorded as a common feature confirmed the organic richness of the deposited evaporite sediments.

1.3. Biogenic limestone facies (BL):

This facies is recorded in all studied subsurface cores from Ras Gemsa area as well as the others. Under the microscope, it is composed of biomicrite or biosparite in association with anhydrite forming isolated nodules within the micritic matrix. Signs of corrosion resulting into replacing anhydrite peripheries (Plate-3, Fig. D) are detected. The bioclasts, of different types, are completely replaced by microcrystalline carbonate and felty anhydrite crystals (Plate-4, Figs. A and B). This facies is highly enriched in its organic content based on the presence of dense, black organic matter enriched the micrite and microbial matt forming flat and laminated stromatolites as supported by Gerdes *et al,* 1991, (Plate-4, Figs. C and D). At least one laminae being biologically formed insitu by microbes that spread intergrowing microfibres and slime coating over sediments (Gerdes *et al,* 1991). Bio-capsule with rupture apex due to biogas escaping as a result of organic degradation mainly composed was recorded (Plate-5, Fig. A). The presence of halite hopper cubes and prismatic gypsum might support the prevalence of the hypersaline regime during saturation phases of both minerals (Plate-5, Fig. B).

1.4. Massive-nodular, brecciated anhydrite facies (MNA):

This facies is composed of coalesced anhydrite nodules displaying a contorted pattern resembling convolution of intense (see Chapter Two), which had led to English name entrolithic (Hahan, 1912) or chicken wire (Schreiber, 1985). Under the microscope, it composed of step-stair prismatic anhydrite crystals or streaks (Plate- 5, Figs. C and D) or as very small anhydrite grains (Plate-6, Fig. A) and as felty, straight, fibrous anhydrite displaying stellate texture embedded in microcrystalline anhydrite (Plate-6, fig. B). Other nodules are recorded as composed of amebiode gypsum pesudomorph floating in microcrystalline anhydrite (Plate-6, Fig. C) indicates their epigenetic origin. The thin clay or carbonaceous clayey streaks outline the nodules and are rich in black and opaque organic rich material (Plate-6, Figs. C and D).

The occurrence of floating anhydrite streaks (Plate-5, Fig. D), creeping with crystallization at maximum axis of stress and irregular fracturing displayed by enclosed gypsum crystals (Plate-7, Figs. A and B) were recorded. This feature might indicate the effect of intense deformation due to compaction stress as a result of regional tectonic affecting the area. The occurrence of mineralized organic matter forming algal matt (Plate-7, Fig. C), microbial matt that have spheroid or rode-shaped (Plate-7, Fig. D and Plate-8, Fig. A), or biocapsule (Plate-8, Fig. B) and lenticular gypsum of biogenetic formation in association with microbial matt embedded in anhydrite (Plate-8, Fig. C), beside the black and opaque organic rich matrix (Plate-6, Figs. C and D), all indicate the organic richness of evaporite sediments. The presence of irregular step and square shaped voids after halite dissolution (Plate-8, Fig. D and Plate-9, Fig. A) as well as halite hopper crystals (Plate-9, Fig B) indicating the hypersaline condition of the depositional regime. Also, the occurrence of frambiodal pyrite, replacing anhydrite, indicates the existence of reducing condition during the deposition (Plate-7, Figs. C and D).

1.5. Massive-nodular, brecciated anhydrite with clay lamination facies (MNAC):

This facies is composed of anhydrite nodules in association with anhydrite lathes and clay laminae, display laminated structure, previously described by Schreiber *et al*, 1976 (see Chapter Two) as nodular laminated evaporite. Under the microscope, the anhydrite nodules are composed of large swallow-tail gypsum pesudomorph now anhydrite (Plate-9, Fig. C) or xenotopic granular anhydrite engulfed gypsum crystals (Plate-9, Fig. D) indicating and supporting their epigenetic origin. The anhydrite laminae are composed of microcrystalline anhydrite crystals of massive texture (Plate-9, Figs. C and D). The clay is occurred as thin laminae or streaks outline the nodular shape (Plate-9, Figs. C and D). The clay streaks and laminae are enriched in black and opaque organic matter suggesting their organic richness.

1.6. Enterolithic (Chicken-wire) anhydrite facies (EA):

This facies comprises the elongated coalesced anhydrite nodules enclosing clay matrix (see Chapter Two). Under the microscope, anhydrite nodules are composed of felty epigenetic anhydrite or randomly oriented fibrous anhydrite crystals engulfed gypsum crystal and its relics which supporting their epigenetic origin (plate-10, Figs. A and B). The enclosed gypsum by anhydrite is displaying a brecciation and disintegration features along the cleavages (Plate-10, Figs. C and D and Plate-11, Figs. A and B). A very thin clay streaks that partly outline the nodular shape is recorded and encloses a dense, opaque organic matter (plate-10, Fig. A). The occurrence of microbial and algal matt, which enclosed by anhydrite crystals, (Plate-11, Figs. C and D and Plate-12, Figs. A and B) is confirming the organic richness of the evaporite sediments. The presence of prismatic secondary gypsum as replacive and displacive phases beside vugs fillings in association with microbial matt suggest different burial and uplifting stages responsible for the recorded dissolution and recrystallization features (Plate-12, Figs. C and D and Plate-13, Fig. A). The presences of halite cubic crystals replace the former evaporite indicate the hypersaline depositional environments (Plate-13, Fig. B).

1.7. Massive nodular brecciated gypsum facies (MNBG):

This facies is represented by rounded gypsum nodules with clays acting as a lubricant material through effects caused by deformation stress causing its squeezed appearance (Plate-13, Fig. C). The gypsum nodules are composed of xenotopic granular gypsum or swallow-tail and in association with microcrystalline gypsum (Plate-13, Fig. D and Plate-14, Fig. A). The squeezed clay is enriched with black and opaque organic matter and partly changed into micrite (Plate-13, Figs. C and D).

1.8. Laminated nodular, brecciated gypsum and clay facies (LNBGC):

Schreiber et al, (1976) described similar association of nodular and laminated gypsum in sulphate from Sicilian evaporite deposits. Under the microscope, this facies is composed of gypsum nodules with clay rich in black and opaque organic matter (Plate-14, Fig. B). The gypsum nodules are composed of felty, straight, fibrous gypsum crystals of stellate texture, which believed to be due to uplifting or unroofing evaporite bed (Warren *et al*, 1990), (Plate-14, Fig. C) or as xenotopic granular gypsum crystals (Plate-14, Fig. D). The interlaminated clay streaks are enriched with black and opaque organic material (Plate-14, Figs. C and D) suggesting the organic richness of this evaporite facies.

The biocapsule with rupture apex due to biogas escaping as a result of organic matter degradation and bio-mineralized algal remains enclosed by gypsum crystals were detected, which confirm the organic richness of these evaporite sediments. The presences of microfolding that displayed by large prismatic gypsum (Plate-15, Fig. C) and deformed prismatic gypsum fill vugs (Plate-15, Fig. D) indicate the intense deformation and dissolution due to compaction stresses as a result of tectonics (probably). Halite raft that replaced gypsum confirms the hypersaline condition of the depositional regime (Plate-16, Fig. A). The occurrence of xenomorphic calcite texture, which completely replacing gypsum nodules, suggested diagenetic effect as a result of uplifting (Plate-16, Fig. B).

1.9. Massive anhydrite facies (MA):

This facies is a repeated featured through the studied areas that show massive and powdering textured anhydrite crystals. Under the microscope, it composed of felty non-oriented anhydrite enclosing gypsum crystals with black and opaque organic matter (Plate-16, Fig. C), supporting its epigenetic origin and their high organic content.

1.10. Fractured, massive anhydrite facies (FA):

This facies represent the highly fractured anhydrite of massive texture. Under the microscope, it is composed of microcrystalline anhydrite or felty anhydrite crystals displaying a sweep color character of interference believed to be due to stress effect (Plate-16, Fig. D). The anhydrite crystal enclosed some clay streaks. The observed convolution pattern, Plate-16. Fig. D and minor unfilled fractured due to intense deformation (Plate-17, Fig. A). Also halite-replacing anhydrite is recorded (Plate-17, Fig. B).

1.11. Finley laminated anhydrite and clay facies (LAC):

This facies is recorded and repeated several times in Ras Gemsa wells and it is made of irregular, wavy and contorted anhydrite laminae alternating with black shale laminae or dense, opaque and black organic rich material (see Chapter Two). Under the microscope, the anhydrite lamina is composed of felty epigenetic anhydrite showing sweep color character or as microcrystalline anhydrite enclosing gypsum crystal and relics indicating their epigenetic origin (Plate-17, Figs. C and D). The clay laminae are composed of black and opaque organic rich material and enclosed anhydrite/ gypsum crystals as fibrous brecciated into fine sub-euhedral crystals (Plate-18, Fig. A), The bio-capsule enclosed by anhydrite is recorded as indicator of organic content of evaporite sediments (Plate-18, Fig. B).

1.12. Laminated anhydrite and halite facies (LAH):

This facies is composed of thin irregular halite lamina alternating with thick anhydrite lamina (see Chapter Two). Under the microscope, the anhydrite lamina is composed of felty or prismatic granular anhydrite (Plate-18, Fig. C) enclosing relics of gypsum crystals altered into fine anhydrite nodules (Plate-18, Fig. D). The halite occurred as irregular lamina and is composed of cumulate halite cubes showing different sizes (Plate-18, Fig. C and Plate-19, Fig. A) and partly replaces and/or associated with anhydrite (Plat-19, Fig. A). The lenticular gypsum of biogenic origin and biocapsule (Plate-19, Fig. B) that were recorded in anhydrite lamina confirm the organic richness of evaporite sediments

2. SOUTH EAST ZEIT AREA:

South Zeit area is located on small fault block that flanks the Zeit up lift (Bowman, 1931). The area is separated from the Zeit up lift by a fault (Bowman, 1931). Southeast Zeit uplift trends southeast in to the Gulf of Suez and is faulted bounded on north and south side. The following is the petrographic description of the recorded lithofacies of the subsurface cores (See Chapter Two).

2.1. Massive- nodular gypsum with clay streaks (NGC):

This facies is composed of massive to nodular gypsum with clay streaks (see Chapter Two). Under the microscope, it is composed of interlocked xenotopic granular gypsum (Plate-19,

Fig. C) or as gypsum aggregates forming coalesced nodules in association with idiotopic gypsum crystals as indicated by SEM studies (Plate-19, Fig. D). This idiotopic prismatic gypsum crystals show disintegration character into sub-euhedral secondary gypsum due to compaction stress (Plate-19, Fig. D and Plate-20, Fig. A). The xenotopic gypsum encloses anhydrite relics with liquid hydrocarbons indicating re-hydration believed to be the result of uplift (Plate-20, Fig. B). The clay streaks are occupying the intercrystalline spaces and altered into microsparite (Plate-19, Fig. C). Some selenite crystals were detected, which displaying folded and dissolution featured along the cleavage, which confirm the deformation due to compaction stress (Plate-20, Fig. C). The presence of algal remains enclosed within gypsum indicates the organic richness (Plate-20, Fig. D).

The recorded small halite cubes replacing gypsum (Plate-21, Fig. A) confirm the hypersaline condition of depositional regime.

2.2. Fractured, Massive anhydrite facies (FA):

It is a repeated feature through the studied areas and the recorded difference is that, under the microscope, it composed of felty or microcrystalline anhydrite, which engulfed gypsum relics and also rehyderated into interlocked granular secondary gypsum enclosed anhydrite relics (Plate-21, Fig. B). The felty anhydrite displayed a sweep interference color character (Plate-21, Fig. C). The fracture is filled by straight, fibrous secondary gypsum vertically oriented up on the fracture wall (Plate-21, Fig. C).

2.3. Massive-nodular, brecciated anhydrite and clay lamina (MNAC):

This facies consists of white-grey colored, brecciated nodular and massive anhydrite with clay lamination (see Chapter Two). Under the microscope, it composed of closely packed anhydrite nodules of sweeping color character floating in clays and brecciated anhydrite (Plate-

21, Fig. D). Some anhydrite nodules are composed of xenotopic granular anhydrite crystals in association with microcrystalline gypsum aggregates due to brecciation and rehydration of anhydrite (Plate-22, Figs. A-C). The clay lamina is very thin and partly altered and replaced by microcrystalline carbonates. Interested observed featured concerns the algal remains enclosed by anhydrite suggesting their organic richness (Plate-22, Fig. D). The presence of halite crystals replacing anhydrite confirms the prevalence of hypersaline condition in the depositional regime (Plate-23, Fig. A) and prismatic secondary fill vugs gypsum (plate-23, Fig. B) indicates intense dissolution and recrystallization of secondary former due to compaction stress. The occurrence of unfilled voids indicates the alteration of primary gypsum into anhydrite due to the difference of ionic radii and increasing the porosity of evaporite sediments (Plate-23, Fig. C).

2.4. Laminated-massive gypsum and anhydrite facies (LGA):

This facies, under the microscope, composed of microcrystalline gypsum/ anhydrite forming small nodules floated in dark clay matrix that laminated with anhydrite/gypsum lathes (Plate-23, Fig. D). The recorded bio-mineralized algal remains (Plate-24, Fig. A) confirm the organic richness. The convoluted and rupturing textured displayed by gypsum (Plate-24, Figs. B and C) indicates the intense deformation due to compaction stress.

2.5. Massive gypsum facies (MG):

It is a repeated featured in the studied areas, but the recorded difference in this area, it under the microscope, composed of large, irregular interlocked xenotopic gypsum crystals, which enclosed microcrystalline carbonates in intercrystalline spaces as a host sediments (Plate-24, Fig. D). The crystalline carbonate is intensively corroded the gypsum (Plate-25, Fig. A).

2.6. Massive anhydrite and clay streak facies (MA):

It is a repeated featured in the studied areas, but the recorded difference in this area is restricted to the presence of composed of xenotopic irregular anhydrite crystals engulfed gypsum relics confirmed their epigenetic origin and contains fracture refilled by swail tail selenite (Plate-25, Fig. B). The clay streak occupying the interspaces is replaced by crystalline carbonates that also corroded the anhydrite crystals.

3. RAS DIB AREA:

3.1. Massive anhydrite with clay streaks facies (MAC):

This facies contains the white-dark grey, massive textured anhydrite displaying fractures filled by selenite with thick clay and/or lime mud carbonate hosted a small gypsum nodules. Under the microscope, the anhydrite nodules are composed of large swallow-tail gypsum pesudomorph displayed by anhydrite forming brecciating and fragmenting characters along the cleavage due to the deformation compaction stress (Plate-25, Figs. C and D) or felty anhydrite crystals enclosed felty straight gypsum crystals and clay spot rich in dense, black organic matter (Plate-26, Fig. A), or microcrystalline anhydrite after gypsum alteration (Plate-26, Fig. B). The clay streaks are partly replaced by crystalline carbonate (Plate-26, Fig. C) and rich in black organic material indicating the organic richness. The enclosed small gypsum nodule (Plate-26, Fig. D) is composed of non-oriented prismatic and granular gypsum crystals engulfed microcrystalline carbonates enriched in dense, black and opaque organic matter

An important observed feature is: The presence of fractures refilled by felty, straight, fibrous gypsum crystals (Plate-27, Figs. A and B) or by large selenite crystals, which displayed a sign of deformation and dissolution with recrystallization due to stress effects (Plate-27, Figs. C and D). The occurrence of displacive and replacive prismatic gypsum, which indicate the effect of intense deformation due to pressure growth (Plate-28, Fig. A) and halite cubic crystals (Plate-28, Fig. A) confirms the hypersaline condition of the depositional regime. The recorded Bio-mineralized algal matt (Plate-28, Fig. C) and microbial matt (Plate-28, Fig. D) as well as the biocapsule (Plate-29, Fig. A) enclosed by evaporite sediment confirm their organic richness.

3.2. Chicken-wire nodular anhydrite facies (Ch A):

This facies comprises the elongated coalesced anhydrite nodules enclosing some clay matrix or floating in evaporite lathes (see Chapter Two). Under the microscope, the nodules composed of microcrystalline anhydrite crystals (Plate-29, Fig. B) or xenotopic anhydrite prism (Plate-29, Fig. C) or felty anhydrite crystals displayed sweeping interference color character (Plate-29, Fig. D). All enclosed and engulfed gypsum relics support the epigenetic origin. The evaporite lathes occupied the internodular spaces and composed of xenotopic granular gypsum/anhydrite crystals. The clay streaks are black in color and partly replaced by crystalline carbonate and enclosed black and dense organic matter.

The presence of mineralized algae, replaced by felty anhydrite and straight gypsum fibrous embedded in evaporite lathes due to directional stresses (Plate-30, Fig. A) indicates the organic richness and their ductile behavior as well. The occurrence of microcrystalline carbonate (micritic size) corroding and replacing gypsum anhydrite nodules of xenomorphic textured suggesting the uplifting and unroofing this facies after burial (Plate-30, Figs. A and B). Also, the different flow patterns reflect the effect of compressional stresses reflecting the ductility character degrees of the evaporate sediments and definitely affect their transformation phases between both minerals of gypsum and anhydrite.

3.3. Laminated gypsum and anhydrite facies (LGA):

This facies is composed of felty and/or prismatic anhydrite crystals forming dense, massive texture as lamina and elongated pattern. The dissected gypsum nodules forming lamina, which mainly composed of large, irregular and interlocked crystals partly, corroded by anhydrite or microcrystalline gypsum aggregates floating in black terrigenous clays rich in organic matter (Plate-30, Fig. C). In some cases the dense felty anhydrite laminae is intercalated with idiotopic prismatic gypsum with absence of clay host sediments as indicated by SEM investigation (Plate-30, Fig. D).

The detected biocapsule enclosed within gypsum and anhydrite suggests their organic richness (Plate-31, Fig. A). The presence of small fracture and cavities refilled by large secondary selenite displayed micro-folding and cracking as well as dissolution (Plate-31, Figs. B and C) confirm the intense deformation affect this facies

3.4. Shale with anhydrite mud Facies (SAN):

This facies comprises shale hosting large evaporite nodules (see Chapter Two). Under the microscope, the evaporite nodules are composed of small anhydrite nodules composed of felty or microcrystalline anhydrite crystals enclosing gypsum relics that floated in gypsum lathes and are made up of aligned felty or microcrystalline gypsum crystals (Plate-31, Fig. D). The occurred large idiotopic gypsum prism (Plate-32, Figs. A and B) shows commutative growth texture and small halite cubic crystals were recorded replacing anhydrite suggesting the dissolution with hypersaline condition of the depositional regime. Also the bio-mineralized microbial matt and algal remains were enclosed by anhydrite and gypsum confirms their organic richness (Plate32, Figs. C and D).

3.5. Massive-nodular and brecciated anhydrite Facies (MNA):

Under the microscope, this facies is composed of small separated and elongated anhydrite nodules floating in dense gypsum lathes or lime-mud carbonate. The anhydrite nodules are composed of xenotopic granular anhydrite crystals. The lathes were composed of aligned felty and microcrystalline gypsum crystals (plate-33, Fig. A). The microcrystalline carbonate encloses black and opaque organic rich material occupied the intercrystalline spaces of gypsum lathes (Plate-33, Fig. B).

3.6. Fractured, massive anhydrite Facies (F A):

It is a repeated feature. In this area a recorded difference is that it made up mainly of xenotopic anhydrite granules that enclosed lime mud streaks, which corroded and replace the anhydrite crystals (Plate-33, Fig. C). The recorded disoriented narrow fractures were filled by swallow-tail gypsum (Plate-33, Fig. D)

3.7. Laminated gypsum and clay facies (LG C):

This facies, under the microscope, is composed of felty or prismatic gypsum granules partly altered into anhydrite aggregates, which interlaminated with clay. The clay is dark colored, partly replaced by microcrystalline carbonate and engulfed organic material (Plate-34, Fig. A).

3.8. Biogenic limestone facies (BL):

It is a repeated feature. In this area a recorded difference is the presence of evaporite veins made mainly of felty, straight gypsum crystals that vertically oriented up on the veins wall (plate-34, Fig. B) and the black, dense opaque organic rich material dissemination in evaporite associated sediments.

3.9. Massive gypsum facies (MG):

The petrographic examination show that facies is composed of large, cloudy and irregular xenotopic granular gypsum crystals (Plate-34, Fig. C) leading to engulfing anhydrite relics suggesting their epigenetic origin (rehydration of anhydrite) and also brecciaing and disintegrated into microcrystalline aggregates (Plate-34, Fig. D) due to compaction deformation stress. A thin streak of terrigenous material enriched in black organic matter occurred occupying the intercrystalline spaces (Plate-35, Fig. A).

3.10. Massive anhydrite facies (M A):

It is a repeated feature through the studied areas but in this area a recorded difference is that it is made up of felty epigenetic anhydrite floated in fibrous and microcrystalline gypsum (Plate-35, Fig. A). Clay streaks were recorded that occupying the intercrystalline and enriched in organic matter (Plate- 35, Fig. B). Amebiode, irregular secondary gypsum fill vugs were recorded, which suggesting the dissolution followed by crystallization due to compaction stress.

3.11. Nodular gypsum facies (NG):

This facies, in this area, is composed of large, irregular xenotopic gypsum of corroded periphery forming a nodular texture, which floating in microcrystalline secondary gypsum (Plate-35, Fig. C). In some cases xenotopic granular gypsum nodule is disintegrated into microcrystalline gypsum aggregates

4. GUBAL ISLAND EREA:

4.1. Massive gypsum facies (MG):

Under the microscope, this facies indicates a large xenotopic agglutinated gypsum crystals, which brecciated and disintegrated into microcrystalline felty anhydrite/gypsum. The microcrystalline anhydrite crystals displayed sweep color character due to strain effect. (Plate-35, Fig. D). The brecciation is recorded in direction of strain due to compaction stress.

4.2. Massive-nodular, brecciated gypsum and clay streaks facies (MNGC):

This facies under the microscope is composed of brecciated and deformed xenotopic gypsum aggregates forming nodular texture, which partly altered to anhydrite due to rotational strain and compaction stress. The terrigenous clay streaks enriched in organic matter are intermixed with gypsum due to compaction forming interlocked deformed pattern (Plate-36, Fig. A).

4.3. Massive anhydrite with clay lamina facies (MAC):

It is a repeated feature but the petrographic examinations show that the difference in this area is it composed of admixture of deformed gypsum and clays intercalation. The gypsum is made up of xenotopic agglutinated gypsum crystals, which brecciated into felty anhydrite displaying sweep color character due to compaction strain effect. The terrigenous clay, which is black and enclosed dense and opaque organic matter, was admixed with gypsum and form deformed and convoluted pattern (Plate-36, Fig. B).

4.4. Massive-nodular, brecciated gypsum facies (MNG):

This facies composed of discrete, elongated gypsum nodules, which deformed and strung out along the planes to produce bedded gypsum nodules separated by gypsum lathes (see-Chapter Two). Under SEM microscope gypsum nodules are composed of compacted and folded gypsum crystals displaying dissolution and disintegrated into anhydrite (Plate-36, Figs. C and D) or microcrystalline aggregates of compact fabric (Plate-37, Fig. A) or bundle of prismatic secondary anhydrite (Plate-37, Fig. B). The evaporite lathes is composed of gypsum crystals displaying multidirectional of growing due to the compaction deformation (Plate-37, Fig. C).

The occurrence of composite lenticular anhydrite as bio-product of mineralized bio-capsule (Plate-37, Fig. D) confirms the high organic content. The presences of halite cubic crystals that replace gypsum (Plate-38, Fig. A) confirm the prevalence of hypersaline conditions of the depositional regime, the occurrence of dissolution pattern displayed by gypsum (Plate-38, Fig. B). The alteration steps between gypsum and anhydrite (Plate-38, Fig. C) and brecciation pattern displayed by halite (Plate-38, Fig. D) as well as dissolution vugs refilled by large gypsum (Plate-39, Fig. A) confirm the intense deformation due to compaction strain and stress affect this facies.

4.5. Massive-anhydrite with clay streaks facies (MAC):

It is a repeated feature, but the recorded difference is that it composed of gypsum pesudomorph of equigranular sized crystals displayed interlocked textured (Foam texture), which enclosed fine streaks of terrigenous clay partly replaced by crystalline carbonates and rich in black, opaque organic matter (Plate- 39, Fig. B). Also these organic matters were recorded occupying the intercrystals spaces (Plate-39, Fig. C).

4.6. Massive-nodular, brecciated anhydrite with clay streaks facies (MNAC):

The petrographic examination shows that anhydrite nodule is composed of xenotopic prismatic anhydrite, which brecciated into felty, and finer prismatic anhydrite and gypsum (Plate-39, Fig. D). The clay streaks were occupied the internodular spaces and out line their shapes and enclosed black organic rich material (Plate-40, Fig. A). Also sand sized, angular and poorly sorted quartz, feldspar and gypsum embedded in microcrystalline carbonates was associated with this facies confirm the unroofing and uplifting of this facies (Plate-40, Fig. B).

4.7. Massive-nodular, brecciated anhydrite facies (MNA):

This facies is composed of anhydrite nodules of stellate texture floating in anhydrite lathes. The anhydrite nodule is composed of fibrous anhydrite of radiating or stellate structure, which engulfed stellate gypsum crystals indicating their epigenetic origin and also brecciated into microcrystalline anhydrite aggregates (Plate-40, Fig. C). The anhydrite lathes is displayed a convoluted and wavy pattern and composed of aligned fibrous anhydrite (Plate-40, Fig. D). The black, dense and opaque organic rich material is recorded in the intercrystals spaces (Plate-41, Fig. A).

4.8. Massive anhydrite facies (MA):

It is a repeated feature. In this area a recorded difference is that it composed of prismatic anhydrite, which show a sign of compaction deformation and sweep color character due to rotational strain (Plate-41, Fig. B) and the terrigenous clays is recorded formed a thin lamina. Also some vugs are recorded, which are refilled by large selenite crystals (Plate-41, Fig. C).

5. SHAGAR AREA:

5.1. Massive gypsum facies (MG):

This facies, under the microscope, is composed of irregular and interlocked, xenotopic granular gypsum crystal of slkenside texture, which engulfed anhydrite relics and black organic material (Plate-41, Fig. D). Both microbial matt and biocapsule were recorded enclosed by gypsum suggesting the organic content of this facies (Plate-42, Figs. A and B). Also included prismatic gypsum, that was displayed a deformation and brecciation pattern (Plate-42, Fig. C), is recorded suggesting the intense deformation due to compaction stress and strain.

5.2. Fractured massive anhydrite facies (FA):

It is a repeated features, but in this area the petrographic examination show it composed of xenotopic agglutinated gypsum pesudomorph, which brecciated and disintegrated into secondary felty anhydrite displaying sweep color character due to rotational strain (Plate-42, Fig. D) or irregular corroded large anhydrite as fractured filling in prismatic granular anhydrite (Plate-43, Fig. A).

5.3. Massive-nodular, brecciated anhydrite facies (MNA):

It is a repeated feature except in this area the anhydrite nodule is composed of sand sized, angular, poorly sorted gypsum and anhydrite floated in microcrystalline carbonates (Plate-43, Fig. B), which enclosed black and opaque organic rich material.

5.4. Massive anhydrite with clay streaks facies (MA):

This facies consists of massive textured anhydrite that forms irregular, slightly wavy and deformed pattern (see-Chapter Two). The anhydrite is made up of felty to prismatic anhydrite crystals displaying contorted deformation pattern and the black, dense and opaque organic rich material is recorded occupying the intercrystals spaces (Plate-43, Fig. C). Also bio-mineralized algal and microbial matt as well as biocapsule were recorded enclosed by the anhydrite crystals suggesting their organic richness during the deposition (Plate-43, Fig. D and Plate-44, Figs. A and B). Large fractured selenite refill vugs and vein as well as void molds were recorded in this facies indicating the intense deformation and dissolution affected this facies (Plate-44, Figs. C and D, and Plate-45, Figs. A and B).

6. ESH EL MALLAHA AREA:

The petrographic examination of the selected samples from a tentative available subsurface core from this area show that these samples composed of felty epigenetic anhydrite crystals, which intergrowing in random orientation and engulfed corroded gypsums relics, which indicate their replacive origin (Plate-45, Figs. C and D), or xenotopic granular anhydrite enclosed prismatic gypsum (Plate-46, Fig. A), or non-oriented felty, fibrous gypsum enclosed anhydrite fibrous crystals (Plate-46, Fig. B).

An interested featured observed in these samples, is the occurrence irregular vugs of steep shaped (Plate-45, Figs. C and D) and sheet raft (Plate-46, Fig. C) formed after dissolution of square intersection-shaped halite crystals or raft (Schreiber, 1977), that indicate the existence of hypersaline condition during the deposition. The presence of xenomorphic calcite replace the felty gypsum indicates uplifting and redilution of depositional media. (Plate-46, Fig. B).

7. NORTH SINAI AREA:

The petrographic examination of the selected samples from a tentative available subsurface core from this area show that these samples composed of large, irregular, interlocked and amebiode xenotopic gypsum pesudomorph, which brecciated and disintegrated into microcrystalline anhydrite enclosed dense organic rich lamina (Plate-46, Fig. D and Plate-47, Fig. A), or xenotopic granular anhydrite enclosed prismatic gypsum relics (Plate-47, Fig. B) with irregular shaped vugs, which most probably due to halite dissolution. The lime mud carbonate and clays are recorded occupying the interspaces and engulfed black organic rich material (Plate-47, Fig. C). The amebiode secondary gypsum was recorded filling the small vugs as well as the sand size; subangular terrigenous clasts are present, which suggests the land input (Plate-47, Fig. D).

DIGENETIC CHANGES

Digenetic processes are deduced from changes, in mineralogical and/or texture. The petrographic examination of the studied subsurface evaporite cores resulted in identification of diagenetic sequence affect on the evaporite rocks. The following is the description of the inferred diagenetic changes:

1. Pressure growth changes:

Crystal precipitated from saturated brines will grow at rates that change with season. Continuous growth causes the formation cavoli structure. Cavoli structures displayed by gypsum were recorded in the studied core samples from different areas, which indicate those gypsum/ anhydrites were suffered from pressure growth deformation.

2. Intense deformations changes:

Intense deformation includes both fragmentation and brecciation effects existing between larger gypsum crystals and along the older cleavage of selenite crystal. Fragmentation is the result from continual growing from saturated and agitated brines, while brecciation is result from stress types due compaction deformation. The both fragmentation and brecciation signs were recorded as fragmentation and brecciation of larger gypsum crystals into associated smaller one along the cleavage and the folding, cracking and convolution of older cleavage of gypsum crystals in the studied samples as well as the presence of anhydrite streaks.

3. Formation of composite lenticular gypsum:

The link between lenticular gypsum and organic material on the crystal shape was established in petrography. The continual growing with compaction are the main factors to merge the single lenticular crystals into composite crystals. The composite form of lenticular gypsum was recorded and detected by SEM image in different samples from the studied areas.

4. Formation of stellate texture:

Some diagenetic processes are believed to occur during or after uplifting under the influence of exhumation, which permits rehydration, solution and calcitization. The recorded stellate shaped of nodular gypsum in studied areas, was taken by Warren *et al*, 1990 as a potential indicator of unroofing of evaporite bed. The stellate nodular structure was observed by Warren *et al*, 1990 to be an evaporite krast, such as dissolution and reprecipitation textures. Also stellate anhydrite was recorded in different facies of the studied areas, which believed to be formed by action of meteoric water moving through fractures in evaporite caused by salt diapirs and rifting in the Gulf of Suez region (Aref *et al,* 1995).

5. Mineralogical changes:

In addition to the textural and fabric changes due to compaction deformation compaction stress and pressure growths, mineralogical changes such as mineral changes, mineral replacive and displacive sprite and dolomitization as well as dissolution, are recorded:

5.1. Mineralogical transformation:

The compaction stress, due to deformation, effect not only fragmentation and brecciation, but also stress induced mineral changes such as transformation of gypsum into anhydrite, which were detected in different existed facies in cores of the studied samples and confirmed by difference in interference color under the microscope and presence of voids due to the difference in ionic radii.

5.2. Mineral replacive and displacive:

The development of halite cubes in anhydrite and gypsum and gypsum/ anhydrite replace the organic material, which led to formation of bio-moralized capsule, algal and microbial matt as well as development of frambiodal pyrite in clay and evaporite represents a replacive and displacive features were recorded in different facies and confirmed by SEM images.

5.3. Neomorphism (sparite):

The development of microcrystalline sparry calcite in clays represents a neomorphism feature, which appear in some cases replace and corroded gypsum and anhydrite, were recorded.

5.4. Dolomitization:

A well preserved dolomite rhombs were detected in the investigated samples, which were small in size and associated with calcite occurred replace and displace of gypsum and anhydrite and host sediments.

6. Dissolution:

A well preserved dissolution featured were detected in investigated samples as unfilled vugs and molds of irregular or square- shaped due to dissolution of pre-existing halite or due to dissolution followed by recrystallization of secondary mineralogy.

B- MINERALOGY

1. General:

XRD analysis provides the most efficient method in the analysis of fine-grained sediments, which is difficult to study by other means, so it was used to confirm the mineral component of studied samples.

The powder (bulk) of sixty eight evaporite core samples from the studied areas were using a Philips X-ray diffractometer model PW/1710 with Cu Kα radiation and Ni-filter at operation conditions of 36 KvA. The gonimeter was run in raped (2°/min) for qualitative identification of the mineral constituents. The resulting diffraction traces, corrected to the ASTM X-ray diffraction file index.

The results indicate that the anhydrite, gypsum, halite, polyhalite, sylvite and wavellite are the main sulphate and mineral phases, with minor amount of clays and calcite, dolomite, trona and pyrite as well as hematite, illmenite and siderite.

2. Mineral identification:

The identification of different minerals from the XRD pattern was done in bulk samples according to their main d spacing. The use of relative or absolute peak areas of an interference of free d spacing, as a measure of the mineral abundance, were adopted by many workers: (Biscay, 1965; Porrrenga, 1967; saw, 1972; Rossel, 1982; Decleer *et al,* 1983 and others).

The semi-quantitative analysis for the mineralogical composition of the bulk was carried out of bulk samples, where the area of the characteristic peaks of each specific mineral were determined and divided by the value of the reflecting power of each mineral to calculate the percent of that mineral (Table-3). The following is the identified minerals and the description of results.

3. The result:

3.1: The evaporite minerals.

3.1.1. Anhydrite.

Anhydrite is the most common detected sulphate minerals in the investigated samples (Table-3). The amount of anhydrite ranges from 11.2% to 93% of the total detected minerals. XRD result confirm the occurrence of anhydrite in all the studied samples by a reflection of a series of peaks at d (A°) = 3.50, 28.5 and 2.33.

3.1.2. Gypsum.

Gypsum followed anhydrite in the abundance in the investigated samples, where the semi-quantitative analysis indicates that gypsum amount ranges from 1.6% to 50.5% of the bulk samples (Table-3). The presence of gypsum was assured by a reflection of d (A°) = 7.56, 3.06 and 4.27.

3.1.3. Halite.

Halite is the most common salt, where it was detected in almost all analyzed samples, Semi-quantitative analysis show that the halite in amount ranges from 1.4% to 76.6% in the investigated samples (Table-3). XRD assured the presence of halite by a reflection of d (A°) = 2.82, 1.99 and 1.63.

3.14. Polyhalite.

The presence of polyhalite was assured by a reflection d (A°) = 3.18, 2.91 and 2.89 in some studied samples. The amount of polyhalite is ranging from 1.5% to 10.5% as indicated from the semi-quantitative analysis.

3.1.5: The others of sulphate minerals.

Other sulphate mineral such as sylvite, kieserite, bloelite and thenardite was detected in a minor amount in the investigated samples (Table-3). Their presences were assured by a reflection their characteristic of d (A°).

3.2. Carbonate minerals:

3.2.1 Calcite.

Calcite was detected by XRD analysis in some of analyses samples. The presence of calcite was assured by a reflection of d (A°) = 3.04, 2.29 and 3.86. The amount of calcite ranges from 2.5% to 12.8% as indicated by the semi-quantitative analysis (Table-3).

3.2.2. Dolomite.

Minor amount of dolomite were identified by XRD analysis in some of the investigated samples. It ranges from 1.8% to 12.5% (Table-3). The presence of dolomite was assured by a reflection of d (A°) = 2.89, 2.19 and 4.03.

3.2.3: The others of carbonate minerals.

Trona, sederite and ankarite were identified by XRD analysis for some of analyzed samples. Their presences were assured by a reflection of their characteristics d (A°), Table-3.

3.3: Others.

3.3.1 Pyrite.

In almost all of the investigated samples Pyrite was identified by XRD analyses in minor amounts (Table-3). The amount of pyrite ranges from 1.8% to 12.5%, (Table –3). The pyrite presence was assured by a reflection of d (A°) = 1.63, 2.7 and 2.42. Also hematite, illmenite and magnesite were identified by XRD analysis in some of the investigated samples. Their presence is reflected by their characteristics d (A°). The semi-quantitative analysis confirms their presence by very little amounts (Table-3).

C-FLUID INCLUSIONS IN THE STUDIED SAMPLES (ORIGIN AND SEGNIFICANCE)

1. Introduction:

Evaporites are commonly formed during continental rifting and the development of ocean basins by seafloor spreading (Allard and Hurst, 1969; Kinsman, 1975; Evans, 1978; Rona, 1981 and Haride, 1991). Evaporites are found in Cretaceous rift basin on either side of the South Atlantic (Brazil and West Africa, Evans, 1978) as well as in the Gulf of Suez, an Oligocene-Early Miocene rift basin (Hassan and El-Bashlouty, 1970). Stratigraphically, evaporites in the South Atlantic are underlain by Nonmarine siliciclastic facies and overlain by marine carbonates (Evans, 1978; Haride, 1991), which has led to the interpretation, that the evaporites mark the initial invasion of seawater into rift. In the Gulf of Suez, Middle Miocene evaporites are underlain by shale with marine fossiles, which overlain Non-marine siliciclastic facies (Hassan and El-Bashlouty, 1970; Scott and Govean, 1985).

The existence of marine shales alternating with evaporites indicates influx of seawater into the Gulf of Suez during the Middle Miocene. However, Haride, 1991, has recently pointed out that the mineralogy of some well known rift basins is not that expected from the evaporation of seawater, for example, the Cretaceous evaporites of Brazil and Gabon contain the extremely rare Ca-Mg chloride salt (Tachyhydrite) which has led Haride to question the strictly marine origin of evaporites in basin on either side of the South Atlantic. It is possible that some of these basins, during their early stage, were flooded in part or entirely by Non-marine parent waters (Haride, 1984; 1990 and 1991). A major unresolved problem regarding the relationship between evaporites and the early rifting and development of Ocean basins is whether the evaporites are: 1-marine and formed from seawater following Ocean flooding. 2-nonmarine and formed isolated from seawater influx in a closed of nonmarine or 3- hydride and formed from mixing of seawater water. Therefore any evaporite and rift basin evaporites in particular, it is important, to consider the origin of the parent waters. On approach that may be used resolve the problem of chemical composition and origin of evaporite parent waters is through the study of fluid inclusions in saline minerals.

Literatures about fluid inclusions in sedimentary, metamorphic and igneous minerals are enormous. Smith, 1953, wrote more than 400 papers on the fluid inclusion published before 1953. Sorby (1958) presented the first remarkable knowledge in field of fluid inclusions. Recently, Roedder (1984) introduces an excellent study on fluid inclusions in wide varieties of minerals deposits. Generally, a fluid inclusion is a term used to describe small drops of mother solutions, which are trapped in the intracrystalline cavities during crystals growth in a fluid medium of any kind (Roedder, 1984). Liquid inclusions in minerals of salt-bearing deposits have been drawing more attention from researchers as possible sources of information on the composition of the parent brines and on crystallization condition of particular minerals (Holser, 1979, Holland, 1984; Bein *et al* 1991, Attia *et al*, 1995 and Attia, 2003).

The occurrence of various defects in natural minerals during growth leads to the formation of inclusion owing to many factors. The major factors are the degree of mobility of mineral forming subsurfaces, concentration of solutions, energy of adsorption of secondary components on crystal surfaces and prosperities of crystal growth (Petrichenko, 1973 and Roedder, 1984). Each factor has some significance in crystallization of minerals in aqueous solutions.

Roedder (1984) represented the differentiation between primary, pseudo-secondary and secondary inclusions in minerals. According toRoedder, 1984, during crystal growth in a liquid medium of any kind, some growth irregularities of the crystals cause the trapping of small drops of liquid in the solid crystals. Such irregularities may be sealed off during the growth of the surrounding part of the host crystal during primary fluid inclusions. Healing of fractures formed at later time produces secondary inclusions.

This part examines the determined fluid inclusion in gypsum, anhydrite and halite of the examined subsurface Miocene core samples from the different study wells. Fluid inclusions and petrographic relations were used for investigating the relationships between hydrocarbons and evaporites as a source rock for the hydrocarbons generations.

2. The Petrography of Inclusions:

Millimeter-sized cleavage fragments of gypsum; anhydrite and halite beds of the different subsurface cores from study areas were examined under petrographic microscope to evaluate the shape, size, abundance of types and origins. Three types of inclusions were identified: Single phase (liquid or solid), two phases (liquid-solid) and three-phase (liquid-solid- algae)

2.1. Solid Inclusion:

Solid inclusions of various compositions and mode of arrangement were detected. These inclusions are calcite, anhydrite and dark organic matter. The Calcite and Anhydrite inclusion are identified by their morphology and birefringence. Careful examination organic matter inclusions show that they are rounded, dark in color and appear as unicellular cyanobactria and or organic residues, where they fluoresced by using the ultraviolet light attached to the microscope (Plate-48, Fig.1A). Two-phase (solid-liquid) inclusions also were detected in which the solid were organic material or carbonate (Plate-48, Fig.1B). No changes were observed in solid phase when two- phase (solid-liquid) were heated or cooled during microthermometric analysis and therefore trapped as solid during inclusion formation and not true daughter crystals (Roedder, 1984) where the daughter crystals should be formed from the trapped liquid in inclusions. Both of these inclusions are occurred in arranged planes parallel to the growth zones of host crystals so they interpreted as primary inclusions (Sabouraud-Rosset, 1969; Attia *et al,* 1995).

2.2. Fluid Inclusions:

The most abundant inclusions are single phase (liquid) inclusions that followed by two-phase (liquid-solid) and three-phase (liquid-solid-algae) those are less abundant. Fluid inclusions may be grouped into two general types according to their abundance, shape and arrangement as:

a- Primary fluid inclusions and b - Secondary fluid inclusions

a- Primary fluid inclusions:

Primary fluid inclusions are relatively large 20-90mm in diameter and occurred as single-phase (liquid), two-phase (liquid-solid), (Plate-49, Fig.6) and three-phase (liquid-solid-algae), (Plate-49, Fig. 8), inclusions. They are arranged in planes parallels to the growth direction of host crystals or trapped in crystal growth or occupying a single cavity (Plate-48, Figs. 1C, 3A, 3B, 4A, 4B, 5Aand5B and Plate-49, Fig.8A). When they viewed in microscope, primary fluid inclusions occur at different levels within the host crystals. The compositions of these primary fluid inclusions are hydrocarbon droplet, brines and organic material or algae (Plate-49, Figs. 7 and 8). Ice was only the solid phase formed during freezing of fluid inclusions that was identified with confidence is ice, which is characterized by low birefringence, low relief and rounded shape near the final melting (Plate-49, Figs.9B and10A). This is in agreement with observation or Roedder, 1984; Heynes, 1985; Goldestein and Reynolds, 1994 and Attia *et al*, 1995. In Some cases, the careful examination of the enclosed inclusions, show that they are sub-rounded, black to brown color and appear as organic material or unicellular algae. No changes occurred in these brown –black solid phases inclusions when two phase (liquid-solid) and three phase (liquid-solid-algae) inclusions were heated or cooled during microthermometric analysis and they were therefore, trapped as solid during inclusion formation and not true daughter crystals (Roedder, 1984), (Plate-49, Fig. 8). Consequently, they are considered to be organic remains and or unicellular cyanobacteria, where they fluoresced by using ultraviolet light attached to microscope (Plate-48, Fig.2). Also, many single phase (liquid inclusions appear to have two immiscible liquids, where with freezing one liquid phase was increased in size between -145C° to -150 C°. The increasing in size of these inclusions indicates the existence of hydrocarbons droplets as primary fluid inclusions (plate-49, Fig. 7).

The fluid inclusions described above are interpreted as primary inclusions due to they are: 1- associated with solid inclusions along parallel, oriented planes. 2- restricted and to the growth directions zone of the host crystals. 3-simillar in shape and distribution to the primary fluid inclusions formed in experimental studies of Sabouraud and Rosset, 1969). Conditions responsible for formation of fluid inclusions in gypsum have been studied by several workers among of them Sabouraud and Rosset, 1969. They noticed that primary fluid inclusions, in artificially grown Gypsum, occur in lines parallel to the liquid-crystal interface due to growth rate fluctuations and to change in salinity. Cody and Cody, 1987, mentioned from their experiments that adsorption of clay material on crystal faces of Gypsum increase their surface roughness, which may lead to the formation of fluid inclusion. Roedder, 1984, states that solids on crystal face during growth may cause entrapment of some of mother liquid as fluid inclusions so the fluid inclusions in evaporites are considered as source of direct information about the composition of parent liquor in which the host mineral was formed (Holser, 1979 and Holland, 1984 and Bein *et al*, 1991).

b. Secondary Fluid Inclusions:

Secondary Fluid Inclusions are tabular in shape, occur parallel to the {011} and {010} cleavage planes of the host crystals. Secondary fluid inclusions are single phases (liquid) inclusions. There is no zonal arrangement and they occur on planes different from those of primary inclusions. No solid inclusions are associated with theses secondary inclusion and they are unrelated to the growth bands of the host crystals.

3. Microthermometric Results:

First melting temperatures of frozen inclusions in gypsum up on heating and the final melting temperatures of ice were used to interpret the composition and salinity of parent brines from several modern and ancient Gypsum deposits (Sabouraud and Rosset, 1972). The freezing-melting behavior of primary fluid inclusions is reported in Table-1. Following stretching of single-phase primary fluid inclusions to nucleate a vapor bubble; two-phase (liquid-vapor) inclusions were frozen by lowering the temperature between -40 C° and -60 C°. Upon freezing, most of inclusions become light-dark brown with granular texture or clear glassy texture (Plate-49, Figs. 9 and10) between -41.3 C° to -60.5 C°. Vapor bubbles shrank and become irregular in shape (Plate-49, Fig. 9B). Increasing in transparency took place up on warming of the frozen inclusions as well as the recognition of frozen crystals boundaries (Plate-49, Fig. 10) and slight movement of the vapor bubble. These changes occur between -1.7 C° to -34.8 C° indicating first melting (Plate-49, Fig.10). This change was often subtle and could easily pass unnoticed. Therefore the observed eutectic temperature (first melting), was approximately, probably accurate to within 4 C° of the first melting temperature. Ice was only solid phase formed during freezing of fluid inclusions that was identified with confidence is ice, which is characterized by low birefringence, low relief and rounded shape near the final melting (Plate-49, Figs. 9B and 10A). This is in agreement with observation of Roedder, 1984; Heynes, 1985; Goldestein and Reynold, 1994 and Attia *et al*, 1995 and 2003. Near the final melting temperature, ice crystals decrease in size and the diameter of vapor bubble increase (Plate-49, Figs.9 and10). The final melting temperatures of ice in the primary fluid inclusions of both single and two-phase inclusions are recorded for the studied samples (Table-4).

The first melting temperatures in samples from different study areas range from 23.4C° to 60.5 C° with majority range from 27.8 C° to 48.3 C°. The final melting temperatures of ice range from 2.2 C° to 34.3 C° as shown in Table-1 and Figure 10 of Plate-49.The final melting temperature of ice had a relatively narrow range (01 C°-0.7 C°) along the single bands of primary fluid inclusions and wider range from one band to another (up to1.0 C°). The salinity increases from –3.4wt% NaCl equivalent for ice melts at – 2.3C° to 11.5 C° wt% NaCl equivalent for ice melt at 15.3C°

4. Discussions and Evaluations:

Petrographic study helps to differentiate between primary and secondary inclusions in studied samples based on the abundance, size and arrangement relative to the crystals face of host crystals. These observations are in agreement with the experimental studies of the Sabouraut-Rosset, 1969. The Petrographic evidences of the primary fluid inclusions are supported by Microthermometric results where final melting temperatures of ice in these primary inclusions show zonations also.

Large number of single-phase (liquid) primary fluid inclusions in the studied samples especially Gypsum indicates precipitation from relatively low-temperature solutions (40 C°-50 C°). This supported by observations of fluid inclusions in artificial and natural gypsum from different environments (Yermakov, 1965; Petrichenko, 1973; Sabouraud-Rosset, 1969, Attia *et al*, 1995 and Attia, 2003).

Salinity variations in fluid inclusions from single growth bands, as indicated by final melting temperature of ice, are relatively small which indicates that the individual growth bands developed under relatively uniform conditions. The large variations in salinity (i.e. final melting temperature of ice) of fluid inclusions along different growth bands suggest large fluctuations of water salinity during growth of single gypsum crystals.

Melting temperatures of ice in fluid inclusions indicate 1- evaporative concentration when final melting temperatures of ice decrease upward in single crystal. 2- inflow of new waters and recycling of $CaSO_4$, when final melting temperatures of ice increase upward in single crystal. 3- steady state, when final melting of ice occurs at uniform temperatures. The fluid inclusions data indicate evaporative concentrations as well as influx of new Seawater as indicated by existence of unicellular Cyanobacteria in the primary fluid inclusions.

Final melting temperature of ice in fluid inclusions constrains of parent water from which the Gypsum crystallized. The thermochemical model of Spencer *et al*, 1990 was used to calculate the following final melting temperatures of ice (Table-5).

a- 0.0C° for fresh water with Calcium sulfate.

b- -1.9 C° for normal Seawater.

c- -2.0 C° for recycled Seawater (i.e. Seawater with dissolved pre-existing gypsum).

d- -7.0 to –8.0 for evaporated Seawater at first of gypsum saturation.

Figure-39 shows that the measured final melting temperature of ice in the studied samples of different areas compared with the calculated final melting temperatures of ice from thermochemical model (Spencer *et al*, 1990). It clear that the higher final melting temperature of ice in the studied primary fluid inclusions excluded a normal evaporated Seawater origin of parent waters for the studied samples. Furthermore, Seawater evaporated to gypsum saturation should also contain mirabilite ($Na_2SO_4.10H_2O$) which characterized by it high birefringence during freezing /heating runs of fluid inclusions at low temperature (below-2.0 C°) but there is no mirabilite was observed so the normal Seawater origin is also excluded as possible origin. Consequently, there are three possibilities for the origin of the parent waters: 1- recycled Seawater. 2- mixed marine-nonmarine waters. 3- fresh water with calcium sulfate derived from the pre-existing marine deposits. Because of the salinity is too high for fresh water, the parent waters of the most samples of the old evaporite are probably either mixed marine-nonmarine or recycled Seawater. The structural setting of Gulf support the thermometric results which indicate that these evaporite deposits formed from mixed marine-nonmarine, where the faulted block were flooded by Seawater or water from land which supported by shallow, subaqeous, subsiding marginal rift basin (lagoon or salina) environment setting

The occurrence of black organic material and unicellular Cyanobacteria as primary inclusions in evaporite host crystals is evidence for the organic richness of the evaporite deposits which could yield hydrocarbons at optimum maturity. The presence of solid organic matter in association with droplets of hydrocarbons in the same cavities in the host evaporite crystal as a primary fluid inclusions support the view that the favorable conditions for transformation of organic matter into hydrocarbons existing during the time of formation of evaporite deposits.