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Morphological and Hydrogeochemical Studies of some Plains and Wadis in South Sinai, Egypt

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RAMLET Himeir and Dabbt El Quari plains as well as Wadi Nasseib, Wadi Baba and Wadi Nukhul are considered one of the promising parts of South Sinai, due to the presence of many characteristic features; wide areas of arable lands, high potential of groundwater and relatively high rainfall.

Geomorphologically, Baba basin is slightly elongated, triangular in shape, its base in the NE direction toward the scarp of El-Tih Plateau. Ramlet Himeir is a sandy plain represents a topographically controlled lacustrine playa. Nukhul basin lies toward the east of Abu Zenima town and drains to the Gulf of Suez. Seih-Sidri basin is occupied by elongated highland and mountainous terrain. The relief along this basin is high in average and is represented by Gabal Iqna, Gabal Abu Alaga and Gabal Saniya.

Hydrologically, the water-bearing formations are only restricted to the Precambrian fissured basement rocks, the Paleozoic sandstones, the Lower Eocene limestone and the Quaternary alluvial deposits. The aquifers are represented by fissured and fractured fine- to medium-grained granitic rocks. The electrical conductivity of the studied Bir El Seih is characterized by salinity (2.63 ds/m) than the other Birs. The total dissolved salts, (TDS), are 1678 ppm for Bir El Seih, 1540 ppm for Bir Rekas, 1478 ppm for Bir Alluga, 1278 ppm for Bir Ramsa while Bir Nasseib recorded 837 ppm only. The pH value of studied area range between 7.26 to 8.17, so the origin of studied water may be derived from sandstone, shale and limestone. Based on the amount of dissolved Ca and Mg in ground water, the studied sedimentary and alluvial aquifers range between soft to hard water. The orders of concentrations of cations and anions are arranged in the following order, sedimentary aquifers as Alluga and Nasseib aquifers and alluvial aquifers like El Seih, Ramsa and Rekas aquifers have the same order in $Na^{+} > Ca^{++} > K^{+} > Mg^{++}$ according to cations and most of aquifers water have anions as $Cl^{-} > SO_4^{--} > HCO_3^{--}$. The ground water in sedimentary aquifer and alluvial aquifers indicate moderately contaminated water of deep percolated meteoric type.

Ground water in the studied plains and wadis are save only for irrigation and agriculture, whereas uranium and thorium concentrations not exceeding 1 ppm which confirmed with the National Academy of Sciences (NAS).

Sinai Peninsula falls within the great arid belt crossing North Africa and the southwest Asia. Low rainfall, high evaporation and a wide daily range in temperature characterize most of Sinai. Rainfall controls the amount of water available for chemical weathering, while temperature influences the rate of chemical reactions particularly the rate of decomposition of organic matter. The mean annual rainfall in Sinai Peninsula is generally less than 100 mm. The heavier rainfall during all the winter months is generally occurring at November and January. Dames & Moore (1985) recorded the amount of rainfall which decreases from the northeast toward southwest, and it decreases in the south and west directions.

The study area provides potential recharge from direct rainfall. Most of the precipitation occurs during a relatively wet period extending from November to March when winter storms sweep inland during the second half of December, January and the first half of February. Rains during April are rather rare. The maximum rainfall varies between 33 to 140 mm / day on Wadi Fieran and its vicinities. These heavy rainfalls occur in very short periods and result in torrential floods along Wadis.

Saad *et al.* (1980) divided Sinai Peninsula into five hydrographic regions; Wadi El-Arish region, Wadi Girafi, Gulf of Aqaba, Gulf of Suez and coastal region (northern coastal zone east of Suez Canal). El-Ghawaby *et al.* (1983) stated that ground water in Fieran basin is found in basement rocks as well as in the Quaternary deposits and they found that ground water of the basement rocks is relatively more mineralized than that of the Quaternary deposits. El-Shamy (1983) studied the different factors affecting the water resources especially in Wadi Baba, Wadi Seih-Sidri and their tributaries. He stated that the Quaternary deposits form the important aquifers due to their wide distribution and good hydraulic properties. Hammad & Misak (1989) concluded that El-Garf Baba and Seih-Sidri basins have good ground water potentialities. Other basins such as Nukhul and El Tayiba are of circular shape and low drainage density and stream frequency values. Misak *et al.* (1989) discriminated the alluvial deposits aquifers in the Gulf of Suez region into fully saturated, partially saturated, and dry. They stated that water quality varies from brackish to highly saline.

Geological Studies

The studied plains which represent Ramlet Himeir, Dabbt El Quari , Wadi Nasseib, Wadi Nukhul and Wadi Baba are located in the Southwest Sinai between longitudes 33° 10' and 33° 40' E, and latitudes 28° 50' and 29° 10' N (Fig .1) . All the Wadis selected for this study are composed of soils of parent materials derived from almost the full suite of basement and sedimentary rocks represented in Sinai Peninsula.

According to the geological map of Sinai, the western and northern parts are characterized by Phanerozoic sedimentary rocks, while the Precambrian basement rocks are exposed at the southeastern parts.

The basement country rocks neighboring the studied areas, are generally differentiated from oldest to youngest into migmatites, gneisses and schist, diorites, older granitoids (granodiorite), pink granites and dykes (Shata, 1997) (Fig.1) .

The sedimentary rocks in the southwestern parts of the studied area are differentiated into:

1. The Cambro-Ordovician Rocks .
2. The Lower Carboniferous Rocks .
3. The Permo-Triassic Rocks .
4. The Lower Cretaceous Rocks .
5. The Upper Cretaceous Rocks .
6. Esna Shale Formation (Paleocene) .
7. Thebes Formation (Lower Eocene) .
8. Lower Tertiary Volcanic Rocks .
9. Miocene Rocks .
10. Quaternary Sediments .

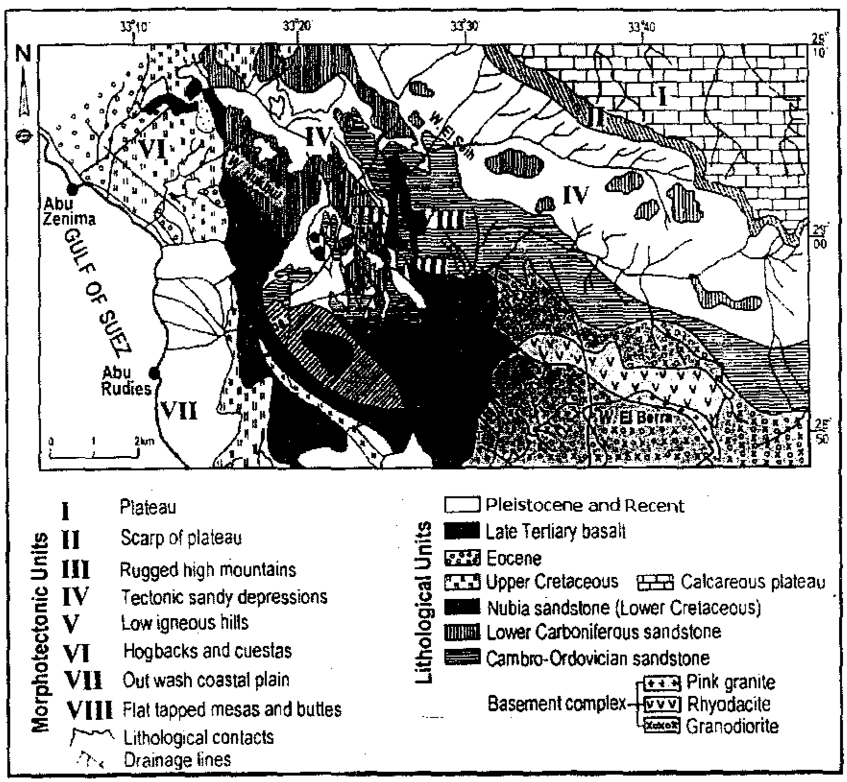

Fig. 1. Geological map of the studied area (after Shata, 1997).

Geomorphological Studies

Sinai Peninsula occupies the foreland shelf of the Arabo-Nubian massif and is generally dipping towards the Mediterranean Sea. It is located within the arid belt dominating the northern part of Africa and extends to the southwest of Asia.

Geomorphological districts

Sinai Peninsula comprises the following geomorphologic districts (Fig.2).

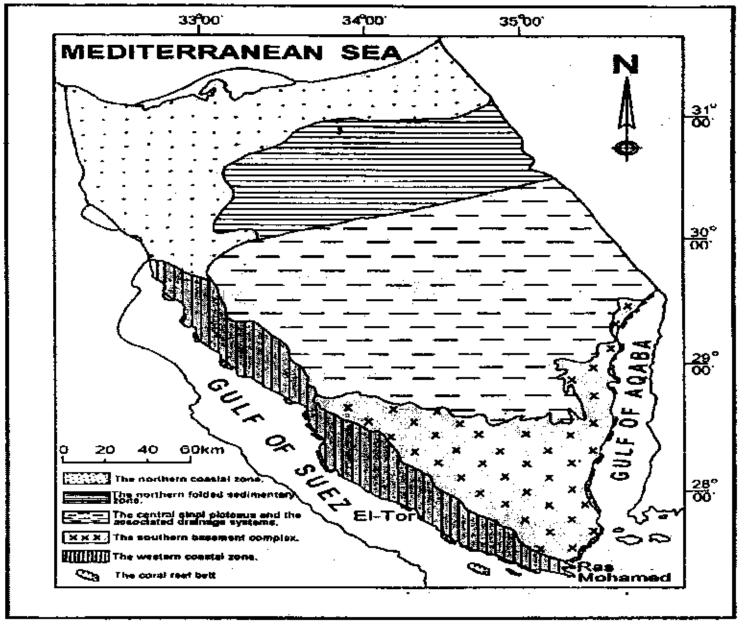

Fig. 2. Geomorphological map of Sinai Peninsula (after Abdel Kader, 1990).

The southern elevated mountains district

This district occupies the southern part of Sinai assuming a triangular shape, its apex at Ras Mohammed to the south. El Aqaba and Suez Gulfs bound it to the east and west respectively. This district characterized by an elevated mountainous belt (*e.g.*, Sant Kathryn, 2628m), composed of igneous and metamorphic rocks, is occupying a surface area of about 7000 km^2.

According to the density of the drainage lines and surface slopes, this district can be subdivided into the following geomorphic units:

a. The eastern side, characterized by numerous lines of weakness that appear in the form of faults and joints running generally parallel to the Gulf of Aqaba. The heterogeneity of the parent rocks, the geologic structure and the paleo climatic conditions led to the development of many drainage lines that cut their ways into the rocky surface leading to the formation of steep slopes.

b. The western side is rather of gentle slopes if compared with the eastern side. Meanwhile, the hydrographic basins are elongated and have limited catchment areas, thus adding to the development of coastal plains. Such situation can be also attributed to the shallowness of the Gulf of Suez (300m).
c. The surface of the southern elevated mountains district is rather rugged and dotted by several mesas of extrusive rocks. The latter followed the fault lines prevailing in the area, which are parallel to the direction of the Gulf of Aqaba (NE) and Gulf of Suez (NW). Generally, the surface is sloping towards the north and is locally pitted with closed depressions, which are filled with shallow coarse soil deposits.

The central plateaux district (El-Tieh and El-Egma)

These plateaux occupy the central part of Sinai Peninsula in the form of two main questas; El Egma to the southwest, and El Tieh to the north. This district appears as an extended curvature of the southern geomorphic province to the north and is bounded to the east and west by two main extended arms. The eastern arm is characterized by the tops of Gabal Arief El-Naga and Gabal Qadis (1000m). The western arm is characterized by the tops of Gabal El-Raha, Gabal El-Gadi and Gabal Sen Beshr (800m) and it occupies an area of about 19,000 km^2. The ground elevation of this district ranges between 500m and 1000m above sea level. Generally, the surface of this district is sloping towards the north.

The hydrographic basins, along the eastern side are quite extended with circular catchment areas (Saad *et al.*, 1980). This can be attributed to the ability of the limestones covering the district to chemical weathering during the wet periods of the Tertiary and the Quaternary (Wadi Grafi, Wadi Wasit, Wadi Dahab and Wadi Keed). The type of catchment along this side led to the rapid accumulation of surface rainwater and consequently quick run-off. This phenomenon allowed for a limited amount of water to recharge the shallow water bearing formations. The western side is characterized by elongated catchment areas with gentler slopes towards the Gulf of Suez. Such conditions allowed for a considerable amount of surface run-off recharging the shallow water bearing aquifers. The central part of this district is deeply weathered and well drained. The occurrence of Wadi El Arish basin, which lies within this district is responsible for its excavation and for the curvature of its northern part. Alluvial terraces and flood plains are important landforms along the drainage lines crossing this district.

The hilly district

This district lies to the northeast of Sinai Peninsula. It occupies an area of about 16000 km^2 and is gently sloping towards the northeast. It is characterized by local isolated hills. These hills are arranged in two parallel lines oriented in the WSW-ENE direction. Gabal El-Maghara and Gabal Lisan Enazia dominate the first northern line. The second southern line is dominated by the elevation of El-Gadi, Yalag and El-Hallal. These are several disoriented isolated hills further distributed to the south. Some of these hills are structurally controlled, while others are resulted from the weathering effect of Wadi El-Arish Tributaries. These hills are represented from east to west by; Gabal Wageer, Gabal El-Adyad, Gabal Umm Khoshaib, Gabal Delfa, Gabal Lobna, Talait El-Badan, Gabal Rakwa, Gabal El-Legma, Gabal kherba, Gabal khoriem, Gabal Abu Sweira, Gabal El-Hassana and Gabal Umm Ali. These Features are controlled by several lines of weakness, which led to the creation of several shallow and short Wadis. The latter groups of Wadis along the tributaries of Wadi El-Arish are responsible for the weathering and the formation of thick alluvial deposits in the depressions separating these hills. Local stranded sand dunes are accumulated on the slopes of some of these hills (Katheeb El-Seekh, Katheeb El-Nahdain and Katheeb Mandaret El-Ethely).

The north and northwest coastal plain district

This district occupies the northern and northwestern part of Sinai Peninsula with an area of about 7500 km^2. The surface of this area is gently undulated and marked by stranded ridges of thick sand dunes. The latter are separated by low depressions, which are filled with calcareous sandy soils. Such soils become saline in the areas lying near sea level. The sand dunes of this district are mostly washed from the weathering products of the inland formations besides the sandy loads, which came from the littoral currents (Nile sediments).

The marshy and sabakhas district

As the land surface, to the northwest and west of Sinai approaches the sea level, the condition endeavors the formation of muddy and marshy land. The Latter receives inundation and seepage from both the Mediterranean Sea and El-Bardweel Lake to the east. As the surface is getting higher towards the south and east, Sabakha areas become predominant on the sloppy surface. The Sabkha and marshy plains occupy an area of about 3000 km^2 and underlined by ancient Nile sediments and lagoonal deposits (Shata, 1997).

The alluvium plains district

This district occupies the coastal plains parallel to both of the Gulf of Suez and Gulf of Aqaba. Such plains result mainly from the coalescence of alluvial fans, formed by the numerous drainage basins dissecting the central plateau and southern mountain areas.

The lakes

El Bardaweel, El Temsah and the Bitter represent important lakes, surrounding Sinai Peninsula from the north and west. These, can be used as sites for draining the reclaimed areas.

Sedimentary basins

These basins include the following:

Baba basin

Baba basin is slightly elongated, triangular in shape, its base in the NE direction toward the scarp of El-Tih Plateau. The relief along Baba basin varies from high (Gabal Umm Reglin, 1037 m, Gabal Abu Triefia, 1024 m, Gabal Sarabit

El-Khadim (1096 m) to moderate (Gabal Lahian, 610 m and Gabal Alluga, 690 m) to low small hills in Wadi Moerid and Wadi Abu Thefriat.

Ramlet Himeir is a sandy plain occupying about 117 km^2 from the catchment area of the basin and represents a topographically controlled lacustrine playa, which has an internal drainage system. Along this basin various morphological features are formed in different geologic times, which are tectonically and lithologically controlled.

The sedimentary zone north of Wadi Baba (comprising Nukhul basin) with the exception of Gabal Samra (basement rock) is lesser dissected than the zone in the south. Areas capped by the resistant dolomite beds and basaltic flows are kept without denudation and form mesas and buttes.

Deep barren slopes and rugged peaks in the granitic terrains characterize Badland forms of Baba basin. Flat-topped badland forms are pronounced in Wadi El Shellal, Wadi Abu El Tiyur and Wadi Abu Zahloga.

Nukhul basin

It is a small hydrographic basin of 116 km^2 catchment area, lying toward the east of Abu Zenima town and drain to the Gulf of Suez. Paleozoic rocks in its eastern upper reaches (upthrown of eastern rifting fault) and Cretaceous to lower Eocene rocks in the downstream of rifting fault occupy the basin as a whole.

Seih-Sidri Basin

This basin is occupied by elongated highland and mountainous terrain, which shows moderate to high relief with very rugged granitic masses and extended in sedimentary zone of the middle E-W graben structure. The granitic terrain along the basin shows high precipitous ridges with steep peaks. They also show deep barren slopes with rugged peaks and sometimes flat topped. The relief along this basin is high in average and represented by Gabal Iqna, Gabal Abu Alaga and Gabal Saniya.

Several Wadis run along fractures and faults which trend mostly towered NW-SE as Wadi Umm Maghar, Wadi Umm Thormiem and Wadi Budra. Other Wadis run in the N-S trend such as Libin, Wadi Tiema and Wadi Qenia while Wadi Iqna and Wadi Sidri follow the NE-SW trend. The faulted blocks of Tertiary and Mesozoic rocks at downstream part show "hogback landforms" which are repeated along the extension of the great eastern rifting fault. These represent the extension of the ridges which exist at the downstream parts of Wadi Baba and Wadi Nukhul.

Sidri sub-basin includes the down stream half of Seih- Sidri basin, which are characterized by high drainage density and stream frequency values. These sub-basins include the granitic rock units.

Hydrological Studies

This work is dealing with the hydrologic regime of the studied area as well as the geological factors relating to and affecting this regime. In general, the water resources in Sinai Peninsula are depending on rainfall, springs and water-bearing formations. The important water-bearing formations in Sinai Peninsula as a whole include; fissured basement rocks, the Nubian sandstone, the Mesozoic and Tertiary carbonates, the Quaternary alluvial deposits and the sand dunes of the northern terrains (Hammad, 1980).

In the study area, the water-bearing formations are only restricted to the Precambrian fissured basement rocks, the Paleozoic sandstones (Lower Series of Cambro-Ordovician and Lower Carboniferous), the Lower Eocene limestone (Thebes Formation) and the Quaternary alluvial deposits.

Water samples collection

Based on the obtained geomorphic information, interpretation of uncontrolled aerial photographs scale 1:40.000 and the geological map of scale 1:100.000, the soil profiles were selected to represent the main geomorphic units and their associated soil groups in the study area.

The collected water samples in this work are confined to the ground water of the central part of the studied area. The locations of the wells from which the samples were obtained are shown in Fig.3. The type of sampling bottles and their cleaning methods are important. Conventional linear polyethylene bottles that are now almost universally used for the collection of ground water samples were chosen to be the containers. Their relatively small surface area helps the idea of neglecting losses of most metals present in the natural water samples during storage period. Polyethylene bottles were soaked in 1.5 ml. nitric acid for about 48 hours at room temperature in order to remove all leachable cations of heavy metals such as Cu, Pb, Cd and Zn. The bottles were washed with distilled water for at least four times. Natural waters were stored in bottles treated in this manner at 4° over periods of week and no loosening in their heavy metal constituents were observed. The previously cleaned bottles were completely filled with collected water samples after adding 5ml of concentrated HNO_3 acid to each liter of water samples. Acidification of the water samples is carried out to avoid adsorption of ware contents on the walls of the bottles and to prevent the hydrolysis of these elements. The bottles were closed tightly, kept in ice-boxes and transferred at low temperature to the laboratory.

Since the dissolved metal is defined, by convention, as the metal that passes a 0.45-μm-membrane filter, the filtration step was carried out using 0.45-μm membrane filters to remove the colloidal particles and any undissolved metals from the ground water samples.

The studied water wells were dispersed in the whole areas (Fig.3) and were previously drilled by the bed wins (desert dwellers). These are considered the main water resources in the area. They have been chosen to represent some sedimentary and alluvial aquifers and to discuss the behavior of uranium in different hydrostatic pressures characterizing them.

Hydrogeologic units

These units include basement, Cambro-Ordovician sandstone, Lower Carboniferous sandstone, Lower Cretaceous Nubian sandstone, Upper Cretaceous, Lower Eocene and Quaternary aquifers.

1. The basement aquifers

These aquifers represented by fissured and fractured fine- to medium-grained granitic rocks, which have hydrogeologic importance due to their interconnection of fissures. In the granitic aquifers, water is mainly fresh to brackish (Abdel Gawad, 1969). The gradual uplift of the area during Quaternary gave rise to flushing of water entrapped in shallow aquifers. The rate of flushing depends on the depth and distance of the aquifers area (Abdallah *et al.*,1995).

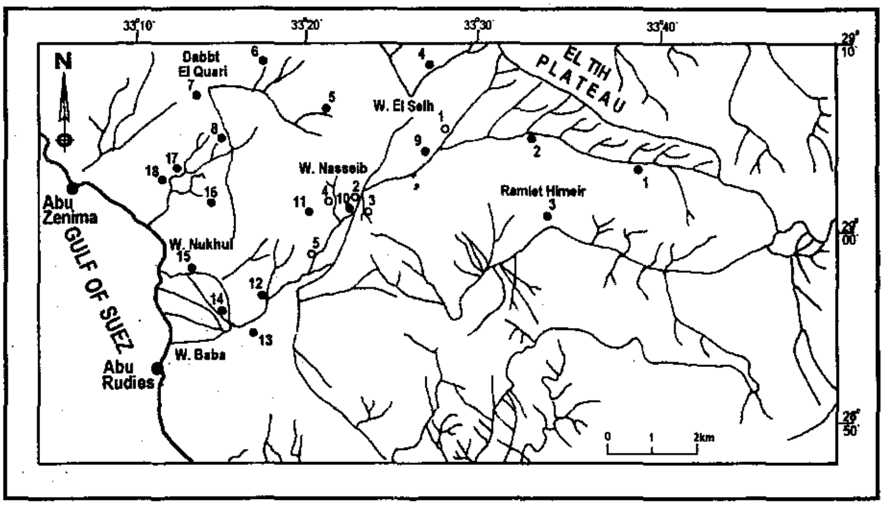

Fig. 3. Profiles and water wells location map of the studied area.

1: Bir El Seih 2: Bir Nasseib 3: Bir Alluga 4: Bir Ramsa 5: Bir Rekas

2. The cambro-ordovician sandstone aquifers

These are represented by two well-stored horizons of highly porous sandstone bodies. They form good yield aquifers especially when they are structurally dissected by faults. The Cambro–Ordovician aquifers (*e.g.*, Wadi Nasseib segment which represented by Bir Alluga and Bir Nasseib) are shallow in depth, which helps in the evaporation process. They are highly fractured which help in its recharges. Bir Alluga (water point = 9, absolute level = 440 m above sea level and water table = 4m) is located in the upstream of Wadi Nasseib and in the junction of Wadi EL Alluga with Wadi Nasseib at the downthrown of a normal fault trending NNW-SSE. Bir Nasseib (water point = 8, absolute level = 420 m above sea level and water table = 3m) is located at the middle part of the same segment. It is considered as an extension of the aquifer of Bir El-Alluga. Oscillation of water table is ± 0.5 m in different seasons. It represents the most important aquifer in Um Bogma area due to its huge yield and fresh taste. This aquifer is present in the sandstone of the Adiedia formation.

3. The lower carboniferous sandstone aquifers

The Lower Carboniferous sandstone aquifers represent the most important aquifers in Sinai Peninsula. They are represented by the sandstone of Abu Thora formation. These aquifers are parts of the lower horizon of the Nubian sandstone, that characterized by its good permeability.

4. The lower cretaceous nubian sandstone aquifers

The shallow phreatic water occurs in the local exposures of the Nubian sandstone and occupies the downstream of some major valleys in the studied area. (Shata, 1997). The average depths of water are about 3 m from the ground surface. The sandstone layers overlap sticky dark clay that act as impermeable base. At the downstream of Wadi Fieran, these aquifers formed of faulted controlled blocks. The fault plane serve as barrier for water and represents the highly discharge agent of Wadi Fieran which serves as enriching agent of the subsurface reservoir due to the gentle slope of the Wadi.

5. The upper cretaceous aquifers

The Upper Cretaceous aquifers are represented by the Matulla Formation which exhibits a good aquifer in EL-Tih plateau at the northern extreme part of the studied area. They are formed of both sandstone and fissured and jointed carbonate at the contact between El-Matulla and Surd Formations.

6. The lower eocene aquifers

The Lower Eocene aquifers are highly fractured limestone beds of good permeability. Bir Nukhul (water point =14) is located at the downstream of Wadi Nukhul; the water table is very close to the ground surface (1m), which is 50 m above sea level. This aquifer is so close to the coastal area of the Gulf of Suez, therefore assuming high salinity (total dissolved salts (TDS)) is attributed partially to the sea water intrusion and dissolution of carbonates.

7. The quaternary aquifers

The alluvial aquifers are composed of sandy gravel and gravelly sandstones of arkosic types.. In general the Quaternary alluvial deposits form unconfined aquifers in which water moves under the influence of the natural hydraulic gradient towards the Gulf of Suez. These alluvial aquifers are recharged from torrential floods and local precipitation. For example the drainage segment of Wadi Seih represented by Bir El-Seih (water point = 2, absolute level = 450 m above sea level and water table = 11m) is located at the downstream of the connection of Wadi Abu maragh and Wadi El-Seih. It is recharged by the water drained from these Wadis and direct local flooding. Oscillation in water table is unobservable during the different seasons. Drainage segment of Wadi Baba which is represented by Bir El-Ramsa and Bir El-Rekas. Bir Ramsa (water point =10, absolute level= 320 m above sea level and water table = 6m) is located at the downstream of Wadi El-Kharig and its connection with Wadi Baba. Recharged from the water drained to Wadi Sid El-Banat, Wadi El-Kharig and the upper reaches of Baba basin. The oscillation in water table is about 1 m between humid and dry seasons. Bir El-Rekas (water point =11, absolute level= 300 m above sea level and water Table = 7m) is the oldest water point existing in the area. It is recharged by the water drained from Wadi Abu Hamata, Wadi Abu Thor and Talet Selim area in large yield. The oscillation in water Table is ± 2 m. The water of this segment is characterized by moderate salinity (T.D.S. 1512.1-1984.9 ppm) and increase of T.D.S. is observed in the downstream direction.

Physical characteristics of ground water

The most important physical characteristics of ground water are temperature, clearance, color, odour, taste and electrical conductivity.

Temperature

Many factors can affect the temperature of ground water, e.g., geological factors, water depth and origin. Based on its temperature, ground water can be divided into seven categories starting from very cold springs of temperatures close to 0° and ends by the super hot springs of temperatures more than 100°. All the studied ground water samples have temperature ranging between 15° to 25° representing cold to hot springs.

Clearance

The kind and quantity of each of the dissolved salts, the suspended organic materials and clay present in ground water are the factors affecting its clearance. According to these factors, ground water can be subdivided into clear, semi-turbid, turbid and very turbid. All the studied ground water samples classified according these factors as semi-turbid.

Color

The ground water is often colorless, but the presence of certain dissolved salts, iron oxides and organic materials may cause change in color. The studied ground water samples are colorless.

Taste

The water taste depends on the kind and quality of the dissolved salts, *e.g.*, NaCl that cause water to be salty, organic materials that make it sweet and magnesium sulfate making the bitter taste. All the studied ground water samples are semi-salty because of dissolved NaCl.

Odour

The ground water is mostly odourless, but the dissolved sulfur dioxide and the bacteriological activities could cause bad ground water odour. The studied ground water samples are mostly odourless.

Electrical conductivity

This character depends on the concentration of the dissolved ionized salts. It can be used as a tool for measuring the salinity of the water (Table 1) . The electrical conductivity (EC.) of the studied ground water is ranging between 1.3 dS/m in Bir Nasseib to 2.63 dS/m in Bir El Seih.

Hydrochemical characteristics of ground water

As it is known, ground water tends to contain more dissolved contents than the surface water. Water in contact or recently in contact with atmosphere will have different chemistry from that which has long been out of contact with air. Most of the rocks forming water aquifers are of complex mixtures of minerals that differ widely in their solubility. The bulk of these rocks are made up of minerals that are not very soluble. Consequently, the contents that mostly affect water quality are different in concentrations and sometimes present only in traces. Several components determine the hydrochemical characteristics and water quality including total dissolved salts, (T.D.S), pH value and water hardness (TH) (Table 1) .

TABLE 1. Some geochemical parameters of ground water of the study wells.

Locations	Bir Nasseib	Bir Alluga	Bir El Seih	Bir Ramsa	Bir Rekas
Parameters					
TDS (ppm)	837	1464	1678	1299	1540
PH	7.26	8.17	7.78	7.92	7.72
E.C. (dS/m)	1.3	2.31	2.63	2.00	2.41
TH (ppm)	85.50	500.71	500.33	153.66	1400.92
TH (meq/L)	4.81	31.442	30.31	8.63	44.69
K+ Na +Ca + mg (meq/L)	12.86	22.26	26.28	19.71	29.28
Cl/HCO_3 + CO_3 (meq/L)	4.21	4.144	12.18	4.29	5.614
Uranium (ppm)	0.48	0.37	0.56	0.52	0.23
Thorium (ppm)	0.26	0.18	0.28	0.25	0.12

TH = total hardness by ppm according to Todd (1966) where :
TH= 2.497(Ca++ in ppm)+4.115 (Mg^{++} in ppm).
EC=Electrical Conductivity, TDS.=Total dissolved salts

pH value of ground water

The pH is an important factor to determine whether certain minerals will precipitate or not. In case of natural waters, its value ranges mostly between 6 and 8.5. Water from rocks with a more regular composition tend to have more narrow ranges of pH values. While those from igneous rocks and from limestone usually has pH values from 6.5 to 8, whereas water from sandstone and shale have pH values around 4 to over 9. The studied ground waters have pH values ranging from 7.26 to 8.17 (Table 2) , therefore the origin of this water may be derived from sandstone, shale and limestone and located in slight alkali class. Amit & Bentor (1971) suggested that the low pH values are due to deficiency of bicarbonate ion caused by high salt content of the medium.

TABLE 2. Chemical analyses of water samples of the studied area.

Bir Name	Units	Cations				Total Cations e.p.m	Anions				Total Anions e.p.m	PHc	SAR	Ad. SAR
		Na^{+}	Ca^{++}	Mg^{++}	K^{+}		CO^{-}_{3}	HCO^{-}_{3}	Cl^{-}	SO^{4+-}				
Bir Nasseib	ppm	253	26.00	5.00	7.00			110..0	269	167				
	e.p.m	11.00	1.30	0.38	0.18	12.86	00.0	1.8.00	7.58	3.48	12.86	7.2	13.09	28.79
	%	85.54	10.11	2.95	1.40			13.99	58.91	27.10				
Bir Alluga	ppm	276	12o.24	48.62	10.17	22.26		178	429	358				
	e.p.m	12.00	6.00	4.00	0.26		00.0	2.92	12.10	7.24	22.26	6.96	5.36	13.08
	%	53.91	26.95	17.97	1.17			13.12	54.36	32.52				
Bir El Seih	ppm	368	134.27	40.11	11.34	26.28		104	734	186				
	e.p.m	16.00	6.70	3.30	0.28		00.0	1.70	20.70	3.88	26.28	7.38	7.14	14.42
	%	60.88	25.49	12.56	1.07			6.47	78.77	14.76				
Bir Ramsa	Ppm	398	50.00	7.00	9.00			167	415	253				
	e.p.m	16.40	2.5.0	0.58	0.23	19.71	00.0	2.73	11.7	5.28	19.71	6.94	13.22	19.30
	%	83.21	12.68	2.94	1.17			13.85	59.4	26.8				
Bir Rekas	ppm	345	320.6	145.9	1o.95			174	567	499.8				
	e.p.m	15.00	8.00	6.oo	o.28	29.28	00.0	2.85	16.00	10.43	29.28	7.1o	5.66	13.02
	%	51.23	27.32	2o.50	o.96			9.73	54.64	35.62				

SAR = Sodium adsorption ratio. e.p.m = mq./l. pHc= calculated pH
Ad. SAR = adjusted sodium adsorption ratio.

Total salinity (T.D.S)

Salinity is defined as the total amount of dissolved salts that are present in water. The suspended materials and dissolved gases are not included. Water from rocks containing one or more chemically resistant minerals, such as felsic igneous rocks, tend to have a lower total ion content than water from rocks made up from chemically soluble minerals such as limestone. Waters from sedimentary rocks have high total ion contents, because most sedimentary rocks were deposited in a salty environment and because of its cementing material and adsorbed ions in these rocks tend to be easily soluble. Total dissolved salts of the studied ground water ranges from 837 ppm (Bir Nasseib) to 1678 ppm (Bir Seih) (Table 1) .

Hardness

Hardness of water is a property allocable to dissolved Ca and Mg in water. The total hardness is related to the total quantities of Ca and Mg in water, while the permanent hardness is due to the quantities of Ca and Mg that are still soluble in water after removing temporary hardness by boiling the water. These informations are important in order to make decision about water suitability for domestic usage. Based on the amount of dissolved Ca and Mg in ground water, its hardness can be divided into five categories starting with the very soft whose Ca and Mg constituents are not more than 1.5 meq/L, and ending with the very hard that contain more than 9 meq/L. Accordingly, the studied sedimentary and alluvial aquifers range between soft to hard water.

Cations and their variability

The concentration of the determined cations, Na^{+}, K^{+}, Ca^{+2} and Mg^{+2} are shown in Table 2. Sodium ranges between 253 ppm (Bir Nasseib) to 398 ppm (Bir Ramsa) with an average 328ppm. The potassium values range between 7 ppm (Bir Nasseib) to 11.34 ppm (Bir El Seih) with an average 9.69 ppm. The calcium contents range between 26 ppm (Bir Nasseib) to 320.60 ppm (Bir Rekas) with an average 130.22ppm. The magnesium values range between 5 ppm (Bir Nasseib) to145.90 ppm (Bir Rekas) with an average 49.33 ppm, (Fig. 4) .

Anions and their variability

The concentration of the determined anions CO_3, HCO_3, Cl and SO_4 are shown in Table 2 . Bicarbonates range between 104 ppm (Bir El Seih) to 178 ppm (Bir Alluga) with an average 146.60 ppm. Chloride ranges between 269 ppm (Bir Nasseib) to 734 ppm (Bir El Seih) with an average 482.80 ppm. Sulphate range between 167 (Bir Nasseib) to 499.8 ppm (Bir Rekas) with an average 292.76 ppm (Fig. 4) .

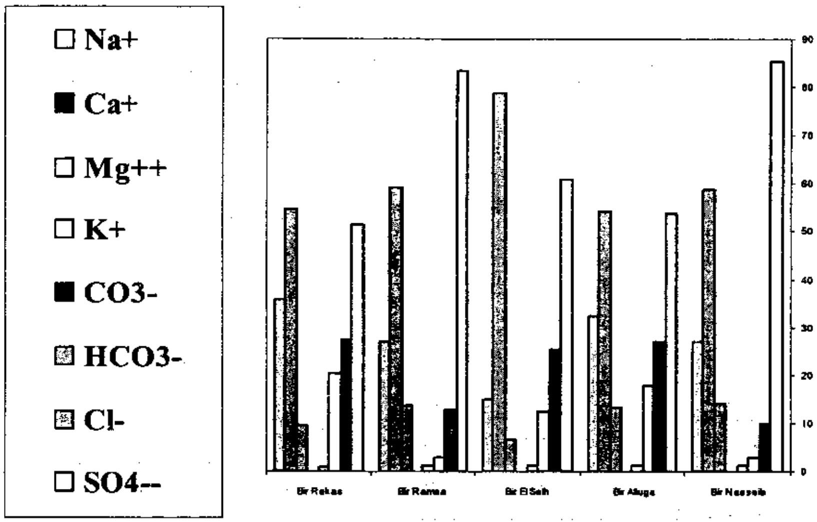

Fig. 4. Comparison between cations and anions variability histogram (relative %) in ground water of the study area.

Contamination of ground water

Todd (1959), using the parameter Cl/(HCO_3+CO_3) in meq/L (Table 1) to classify the water according to its contamination with marine water into the following:

- Normal ground water < 1
- Slightly contaminated water >1
- Moderately contaminated water >2
- Curiously contaminated water > 6
- Highly contaminated water >15
- Sea water > 200

According to this classification, the analyzed ground water in sedimentary and alluvial aquifers indicate moderately contaminated water to Curiously contaminated water

Classification of ground water

According to Palmer (1911) and Sulin (1946) ground water was classified on the basis of chemical relation between Na, K and Cl to meteoric or marine water. The orders of concentrations of cations are arranged in the following, $Na^{+} > Ca^{++} > Mg^{++} > K^{+}$ in sedimentary aquifers (Alluga and Nasseib aquifers) and alluvial aquifers (El Seih, Ramsa and Rekas aquifers) and also have the same order in anions as $Cl^{-} > SO_4^{--} > HCO_3^{--}$ in sedimentary and alluvial aquifers (Table 2) .

Water quality assessment for irrigation purpose is very important and is rather essential for any irrigation system construction. The important parameters used for estimation are, the total soluble salts referred to by electrical conductivity (EC), sodium adsorption ratio (SAR) and some other parameters like boron toxicity and pH. According to conductivity and SAR, waters of all wells mentioned have high salinity hazard and medium sodium hazard. Using these waters at least for irrigation purposes should entail growing highly salinity resistant plants while sodium sensitive plants may suffer injury. The coarse texture of the soil and leaching requirement would account for using these waters.

Hydrogenesis of the studied water points

The origin of the ground water in the study aquifers was interpreted according to the classification of Palmer (1911) and the diagram of Sulin (1946) (Fig.5) . All aquifers in the study area are characterized by parameters $(K + Na - Cl) / SO_4 < 1$ (except Bir Nasseib (1.03 epm) and Bir El Seih) and $Cl + SO_4 > K + Na < K + Na + Ca + Mg$. Accordingly, waters are equivalent to those of zones I and II of Sulin's diagram (Fig .5). These parameters indicate that this water is of deep percolated meteoric type in which $SO_4 > HCO_3$. This may be related to increasing solubility product of SO_4 with the increase of temperature with depths. On the other hand, HCO_3 decreases and so precipitated as carbonate.

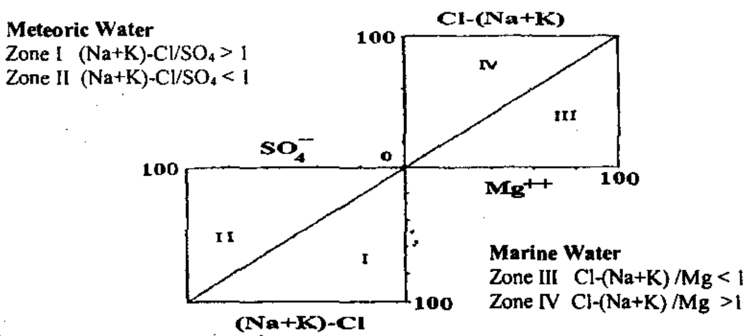

Fig. 5. Sulin's graph for representing hydrochemical compositions of the different waters in (meq/L) or (%).

The hydrochemical characteristics of the studied water samples are expressed from hydrochemical formula in which the anionic and cationic concentrations are presented in equivalent percentages and arranged in decreasing order of their decreasing concentrations (Table 3) . Table 3 shows that among the cationic concentration, sodium is the most dominated ions followed by calcium ions , magnesium ions and potassium . The chlorides concentration is the most dominated ions among the anions, followed by sulfate and finally by hydrocarbonates. Also, it is clear from Table 3 that salt combination (hypothetical) of the studied water are similar in their composition as, NaCl, Na_2SO_4, $NaHCO_3$, $CaCl_2$, $CaSO_4$, $CaHCO_3$ $MgCl_2$,$MgSO_4$ and $Mg(HCO_3,)_2$. However, the amounts of the similar salts are quietly different. The main hypothetical salts dominating in the studied water are Na_2SO_4, $MgCl_2$, $CaCl_2$ and $NaCOH_3$.

According to Palmer classes, these types of aquifers contain permanent hard water due to the reaction of Mg^{++} and Ca^{++} with sulphates to precipitate $CaSO_4$ and $MgSO_4$.

TABLE 3. Hydrochemical formula and hypothetical salt combination of the studied water.

Bir Name	Hydrochemical formula	Hypothetical salt combination
Bir Nasseib	$\frac{Cl\ 58.91\ SO_4\ 27.10\ HCO_3\ 13.99}{Na\ 85.54\ Ca\ 10.11\ Mg\ 2.95\ K1.40}$	NaCl, Na_2SO_4, $NaHCO_3$, $CaCl_2$, $CaSO_4$, $CaHCO_3$ $MgCl_2$,$MgSO_4$ $Mg(HCO_3,)_2$
Bir Alluga	$\frac{Cl\ 54.36\ SO_4\ 32.52\ HCO_3\ 13.12}{Na\ 53.91\ Ca\ 26.951\ Mg\ 17.97\ K1.17}$	
Bir El Seih	$\frac{Cl\ 78.77\ SO_4\ 14.76\ HCO_3\ 6.47}{Na\ 60.88\ Ca\ 25.49\ Mg\ 12.56\ K\ 1.07}$	
Bir Ramsa	$\frac{Cl\ 59.40\ SO_4\ 26.80\ HCO_3\ 13.85}{Na\ 83.21\ Ca\ 12.68\ Mg\ 2.94\ K\ 1.17}$	
Bir Rekas	$\frac{Cl\ 54.64.\ SO_4\ 35.62\ HCO_3\ 9.73}{Na51.23\ Ca\ 27.32Mg\ 20.50\ K\ 0.96}$	

Ground water evaluation for general uses

Generally, the water used for most domestic and industrial uses should contain less than 1000 ppm total dissolved salts (T.D.S), and that used for most agricultural uses should contain less than 3000 ppm T.D.S. The final classification of waters in relation to potential use, however, should be based on concentrations of ions rather than T.D.S. The evaluation of ground waters in the area of study is based on the standards established by the U.S. Public Service, (1962) (Table 4) .

TABLE 4. Quality criteria of ground water for various uses after U.S. Public Health Service (1962).

Water uses elements	Drinking water (ppm)	General domestic uses (ppm)	Irrigation uses (ppm)	Food processing (ppm)
HCO_3^-	500	150-500	200-500	300
Ca^{+2}	200	40-100	---	80
Cl^-	250	---	100-300	300
Mg^{+2}	125	20-100	----	40
Na^+	200	100-300	50-300	300
SO_4^{-2}	250	100-300	200-500	---
T.D.S	1500	300-2000	500-3000	1000

...= means not measured.

Evaluation of ground water for drinking uses

According to the standards of U.S. Public Health Service, the good potable water must contain less than 500 ppm chlorine and that for drinking water must have less than 250 ppm chlorine. With regard to other anions concentration, the chemical analyses indicate that most of available ground waters are not suitable for drinking.

Evaluation of ground water for domestic uses

For domestic uses, total hardness of ground water will be taken in consideration. The equation given by Todd (1966) :Total hardness =2.497 (Ca^{+2} in ppm) + 4.115 (Mg^{+2} in ppm) was used for calculating the total hardness in the studied ground water. Hardness of water determined in the different aquifers show the following

In sedimentary aquifers as Bir Nasseib the ground waters have total hardness = 83.85 ppm (hard water), while water of Bir Alluga has TH 121.88 ppm. Similarly, alluvial aquifers like Bir El-Seih, Bir Ramsa and Bir Rekas however, also have hard waters according to Table 1 .

Evaluation of ground water for agricultural uses

The evaluation of water for irrigation is based on sodium concentration in water as it is adsorbed on soil particles thus reduces its permeability. The effects take place by the replacement of Ca and Mg ions with Na^{+2} ions of soil clay and colloids. The sodium adsorption ratio (SAR) which is used by the salinity laboratory of U.S. Department of Agriculture (Richards, 1954) is a standard such for uses, $SAR=Na / \{(Ca+Mg/2)\}^{0.5}$.

In the study area, the water points were classified according to the values of sodium adsorption ratio (SAR) as follows:

According to Table 5 all waters of the studied wells are ranging between good and fair.

TABLE 5. Water classification based on SAR values .

SAR	Class
2.5-10	Excellent
10-18	Good
18-26	Fair
>26	Poor

Radioactivity in natural waters

Naturally occurring radioisotopes, U^{238} and Th^{232} and their progeny are the most important radio-nuclides, which are common in natural waters. Uranuim^{238}, Ra^{226} and Rn^{222} are all alpha emitters and are considered radiotoxic, chemically toxic and are responsible for a major fraction of the dose received by humans from the naturally occurring internal emitters. These radioisotopes may be present in natural waters, especially in ground waters, in concentrations that may cause dangerous effects on man's health and life (Hunacek & Kathren, 1995). Information about their concentrations in ground water are needed in order to evaluate water safety, and to propose solutions for the removal of problems of these radioactive isotopes (Reid *et al.*, 1985 and Mamdouh *et al.*, 2000) to assure water suitability for drinking and other usages.

Since the members of the naturally occurring uranium and thorium series are both chemo-toxic and since a significant part of the internal radiation dose in human beings is due to ingestion of these nuclides in drinking water, the exact estimation of these radio-nuclides data on Egyptian waters induced our interest in establishing the level (s) of natural radioactivity in the ground water of Sinai.

During the present study, all the measured uranium and thorium concentrations in water are not exceeding 1 ppm (Table 1), confirmed by the National Academy of Sciences (NAS) and National Academy of Engineering (1973) the concentration encountered indicates that the ground water of the study area are radiometrically safe for health, irrigation, agriculture and other uses.

Conclusions

Sinai Peninsula falls under the great arid belt crossing the north of Africa and the southwest Asia. Low rainfall, high evaporation and a wide daily range in temperature characterize most of Sinai. The highest degree of temperature at summer season ranges between 30° to 40° and the relative humidity is highest at the coastal plain and diminishes east and westward. The studied plains located within the rainy belt of Egypt general and Sinai in particular. Most of the precipitation in the studied plains and wadis occurs during a relatively wet period from November to March. The maximum rainfall varies between 33 to 140 mm/day on Wadi Fieran basin and its vicinities. These heavy rainfalls occur in very short periods and result in torrential floods in the Wadis. The evaporation ratios associated with temperature reach a minimum during December and a maximum during May and June.

Geologically, the western and northern parts of Sinai characterized by Phanerozoic sedimentary rocks, while the Precambrian basement rocks are exposed at the southeastern parts.

Geomorphologically, Sinai Peninsula occupies the foreland shelf of the Arabo-Nubian massif and is generally dipping towards the Mediterranean Sea. It comprises the following geomorphologic districts, the southern elevated mountains, the central plateaux (El-Tieh and El-Egma), the Billy, the north and northwest Coastal Plain, the Marshy and Sabakhas, the alluvium plains and the Lakes as well as basins. It is slightly elongated, triangular in shape, its base falls in the NE direction toward the scarp of El-Tih Plateau. Ramlet Himeir is a sandy plain occupies about 117 km^2 from the catchment area of the basin and represents a topographically controlled lacustrine playa. Nukhul basin is a small hydrographic basin of 116 km^2 catchment area, lies toward the east of Abu Zenima town and drains to the Gulf of Suez. Seih-Sidri basin is occupied by elongated highland and mountainous terrain. The relief along this basin is high in average and is represented by Gabal Iqma, Gabal Abu Alaga and Gabal Saniya.

Hydrologically, the water-bearing formations are only restricted to the Precambrian fissured basement rocks, the Paleozoic sandstones, the Lower Eocene limestone and the Quaternary alluvial deposits. The aquifers are represented by fissured and fractured fine- to medium-grained granitic rocks.

The electrical conductivity of the studied Bir El Seih is characterized by higher salinity (2.63 ds/m) than the other Birs. The total dissolved salts are1678 ppm for Bir El Seih, 1540 ppm for Bir Rekas, 1478 ppm for Bir Alluga, 1278 ppm for Bir Ramsa while Bir Nasseib recorded 837 ppm only. Cations, Na^+, K^+, Ca^{+2} and Mg^{+2} are measured in all studied Birs. Sodium ranges between 253 (Bir Nasseib) to 398 ppm (Bir Ramsa) with an average of 328 ppm. The potassium values ranging between 7 ppm (Bir Nasseib) to 10.95 ppm (Bir Rakes) with an average of 9.69 ppm. The calcium contents range from 26 ppm (Bir Nasseib) to 320 ppm (Bir Rakes) with an average 130.22 ppm. The magnesium values range between 5 ppm (Bir Nasseib) to 145 ppm (Bir Rekas) with an average 49.33 ppm. The concentration of the determined anions CO_3^{--}, HCO_3^-, Cl and SO_4^{--} are ranged between 104 ppm (Bir El Seih) to 178 ppm (Bir Alluga) with an average 146.60 ppm for bicarbonates. Chloride ranges between 269 ppm (Bir Nasseib) to 734 ppm (Bir El Seih) with an average 482.80 ppm. Sulphate range between 167 ppm (Bir Nasseib) to 499.8 ppm (Bir Rakes) with an average 292.76 ppm. The pH value of studied area range between 7.26 to 8.17, so the origin of studied water may be derived from sandstone, shale and limestone. Based on the amount of dissolved Ca and Mg in ground water, the studied sedimentary and alluvial aquifers range between soft to hard water. The orders of concentrations of cations and anions are arranged in the following order, sedimentary aquifers as Alluga and Nasseib aquifers and alluvial aquifers like El Seih, Ramsa and Rekas aquifers have the same order in $Na^{+} > Ca^{++} > K^{+} > Mg^{++}$ and most of aquifers water have anions in the sequence $Cl^{-} > SO_4^{--} > HCO_3^{-}$. The ground water in sedimentary aquifer and alluvial aquifers indicate moderately contaminated water of. deep percolated meteoric type. With regard to other ions concentration, the chemical analyses of the studied ground water show that most water is not suitable for drinking but suitable for irrigation.

All the measured uranium and thorium concentrations in water are not exceeding 1 ppm which may indicate that the ground water of the study area are safe for irrigation and agriculture as long as other usages.

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دراسات مورفولوجيـة و هيدروكيميائية لبعض سهول ووديان جنوب سيناء – مصر.

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يعتبر سهلي دابة الكرى و رملة حمير بالإضافة إلى وديان نصيب و بعبع و نخل من المناطق الواعدة في جنوب شبه جزيرة سيناء نتيجة لتمتعها ببعض الظواهر المميزة مثل إنبساط أراضيها و سعتها و وفرة المياه الجوفية و كثرة الأمطار.

أظهرت الدراسات المورفولوجية أن وادي بعبع يتخذ شكلا مثلثيا قاعدته في اتجاه شمال شرق ناحية هضبة التيه بينما سهل رملة حمير يتمتع بالعديد من الظواهر الطبوغرافية والسبخات الغرينية، أما بالنسبة لحوض نخل فهو يقع شرق منطقة أبو زنيمة و يصب في خليج السويس أما حوض سيح سدرى فيشمل العديد من المرتفعات و الجبال مثل جبل عكنة و جبل أبو علجة و جبل سنيه.

بينت الدراسات الهيدروجيولوجية أن التكوينات الحاوية للماء محصورة بالصخور القاعدية لعصر ما قبل الكامبرى و الحجر الرملي للعصر القديم ؛ الحجر الجيري لعصر الايوسين السفلي ورواسب وديان العصر الرباعي. تتمثل خزانات المياه الجوفية في الصخور الجرانيتية ذات التحبب المتوسط إلى الدقيق. وأظهرت الدراسات أن التوصيل الكهربي اظهر تميز بئر سيح بأنه الأكثر ملوحة من باقي الآبار أما مجمـوع الأملاح الصلبـة الذائبة فهي تصل إلى ١٦٧٨ جزء من المليون لبئر سيح، ١٥٤٠ جزء من المليون لبئر ركاس، ١٤٧٨ جزء من المليون لبئر علوجة، ١٢٧٨ جزء من المليون لبئر رمسة، أما بئر نصيب فسجل ٨٦٧ جزء من المليون. أما الأس الهيدروجيني (pH) فتراوح ما بين ٧,٢٦ إلى ٨,١٧ لذا فإن أصل المياه يمكن أن يقوم مساق من الحجر الرملي، الطين و الحجر الجيري. وبناء على نسبة أملاح الكالسيوم و الماغنسيوم الذائبة في المياه الجوفية فإن الخزانات الرسوبية و النهرية تراوحت نوعية المياه فيها من مياه عسره إلى مياه يسره. أما تركيزات الأنيونات و الكاتيونات فكان بالترتيب الخزانات الرسوبية مثل علوجة ونصيب ثم الخزانات النهرية مثل السيح ورمسة وركاس. دلت الدراسات أيضا" بأن المياه الجوفية للخزانات الرسوبية و النهرية هى مياه متوسطة التلوث أما المياه الجوفية للسهول و الوديان المدروسة فهي آمنة للري والزراعة حيث أن تركيزات اليورانيوم و الثوريوم لا تتعدى الواحد من المليون و تتوافق مع دراسات الأكاديمية القومية للعلوم.