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Geology and Water Resources of Palestine

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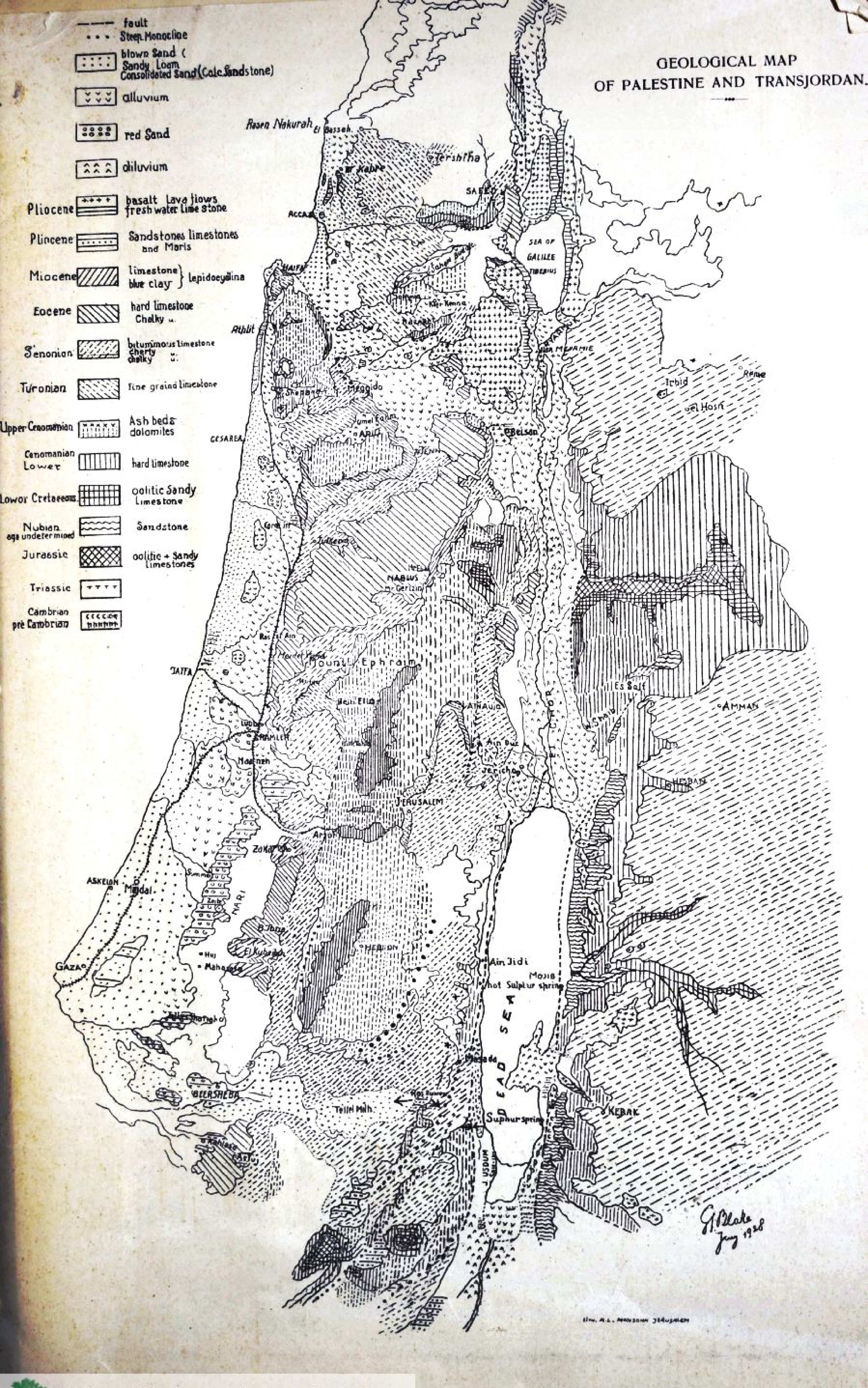

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FOREWORD.

PALESTINE is an agricultural country; its wealth or poverty is largely determined bv the success and character of its crops, cereal, fruit olives etc. The cereal crop depends upon the rainfall excepting in small irrigated areas and with olives is the main source of the livelihood of the fellahin and the wealth of the effendi. The orange groves are confined to the sandy belt along the coast, where water is obtained from shallow wells, and limited areas as at Jericho in which irrigation is by spring water. Returns from orange cultivations are generally of a highly profitable nature. Citrus and cereals are at present almost the only irrigation crops, banana cultivation is increasing in the irrigated areas.

It is one of the anomalies that in such a droughty land as Palestine practically all the large springs run to waste, the utilisation of the water of the Auja, Kurdanah, and the Jordan is one of the problems that awaits solution. Irrigation control is also required in connection with the smaller springs. In many parts of the country domestic supplies are very limited and irrigation water would be a source of wealth wherever it could be developed. The Government made a grant to permit of the examination of this side of the problem.

The report is principally a record of existing sources with a geological correlation of strata and source; the opportunity has been taken to give a resumé of the geology of Palestine. An attempt has been made to indicate the lines on which water supplies could be developed but it will be obvious that in many areas the depth of the water table would ever remain an obstacle to increased water supply by well sinking whereas pumping water from existing outlets such as the great springs may be cheaper if a systematic distribution and sale could be successfully followed.

I desire to acknowledge my indebtedness to Prof. Max Blanckenhorn for information in his valuable works, to the paleontogists of the British Museum for identification of many of the fossils, to the Jewish Colonisation Association and others, for logs of the wells and lastly to Sir Stewart, Symes K.B.E., C.M.G., D.S.O., the late Chief Secretary, for his suggestion to publish the report.

G. S. BLAKE.

Jerusalem, 1928.

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CHAPTER I.

TOPOGRAPHY & SURFACE WATERS:

Palestine consists of a ridge flattening out on the West to a low coastal plain and on the East precipitously descending to the sunken area of the Ghor. The height of the ridge varies from 2500 to 3500 feet but there are gaps in it such as the Plain of Esdraelon where the continuity is destroyed. The Carmel spur is possibly the remnant of a greater ridge that extended north-east and south-west. In the southern area around Beersheba the ridge flattens and spreads. The western flank therefore has a curved outline which varies in direction from north-east to north-north-east or even more northerly. The eastern flank however is almost due north.

The most noticeable heights are Jebel Safed in the Galilee District, Tel Asur in Samaria, the hills around Hebron and Beit Jala in Judea. Instances of great differences of relative height are common such as Little Hermon, Mount Tabor and the Carmel which not only provide conspicuous scenic effects but indicate great tectonic features.

The depressed area of the Ghor is roughly a long trough with almost rectangular but irregular sides. Its deepest part is the Dead Sea -1300 to -2600 and towards it the Ghor slopes from either direction. In the Northern District the depression is more irregular, the deepest and most beautiful part being the Lake of Galilee from which less sunken areas extend into the Amek, the Plain of Esdraelon and El Buttauf.

The coastal plain is, on its western section, largely composed of Nile sand first from marine deposition and later by the accumulation in wind blown drifts which after consolidation and effect of drainage action have formed rolling to hummocky surfaces and where cultivated for fruit farming as in many of the colonies the area provides some of the beauty spots of the country.

The drainage systems of the country are largely determined by the above mentioned features and are consequently east and west. In the northern block of strata the Wadi Kurn the Wadi Shaib and the Wadi Malek take a large part of the western surface waters but the underground drainage via Ain Kurdaneh in this area is also unusually great (150,000 M^3 per day). To the south, the Kishon meanders across the Plain of Esdraelon and empties its water into the brackish estuary in the Bay of Acca.

In the Samaria District the Wadi Selhab is remarkable for its long deep gorge and the drainage of many denudation flats and sunken areas back in the uplands. The Wadi Shaib which runs from Nablus and passes Tulkarem probably discharges the largest amount of water in the area. South, is the Wadi et Tin; the Wadi Ishkhar and Balut discharge into the Auja. (underground water discharge $8^1/_2$ M^3 per sec.)

In Judea the Wadi el Surar possesses the largest drainage system; the Wadi Burshein and others coming from the Hebron District show a considerable amount of north to south drainage development. Both these rivers have very noticeable grooves scoured in the walls of the gorge 20 to 100 feet higher than the present bed. The excavated valleys possess considerable grandeur but are remarkable for their insignificant beds a few kilometres after reaching the plain.

In the south the Wadi Ghuzze is an imposing topographical feature. Where it traverses the plain south of Gaza its bed is $^1/_4$ kilometre across and is hemmed in by precipitous banks of alluvium.

On the Eastern side the wadis are shorter and with some exception less developed. Both gorges and banks are extremely precipitous and generally impassable. The principal one in the north is the Wadi Farah which runs from the Nablus area to the Ghor and it corresponds in the developed character of the upper drainage with the Jabbok (Nahr es Zerka) on the Transjordan side. Both these rivers are doubtless intimately connected with the system of drainage existing before the later and main faulting of the Ghor.

The Wadi Nar starting as the Kidron at Jerusalem is noticeable for the steep smooth sides of the gorge which are carved in white chalk and render the wadi bed extremely hot during the summer. Where these eastern rivers have cut into the diluvial terrace material,

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their beds are extremely wide and the banks precipitous. Some of these in the south give the impression of having carried at one time enormous quantities of water which doubtless they did at the later stage of the Diluvial Period. The present wadi courses are dry, as their name implies. In winter most of them carry only small streams in the base of the wadi.

These southeast wadis e.g. W. Seial, Baqhot, Zuweira show at least two ages of erosion for the Diluvial sediments have been laid down in pre-existing enormous gorges and these sediments have again been cut through by the later drainage.

SURFACE WATERS.

The question of the possibility of impounding the waters of these rivers during the winter presents several problems the factors of which are at present insufficiently known to decide the value or otherwise of the method so much in use in many other countries.

1. Quantity. The rainy season differs considerably in character; sometimes the whole season may have only gentle showers of not long duration and while the crops may be satisfactory the water discharged into and by the wadis is often not worth considering. Other years such as the winter 1926-27 heavy continuous rains were experienced and the wadis both east and west discharged enormous quantities of water e.g. Wadi Shaib for 20 days probably delivered an average of 20,000,000 gallons daily and for 40 days an average of 5,000,000 gallons daily. On the East the wadi Kelt passed by Jericho for several days as a raging torrent of 20 to 30 million gallons a day.

2. Impounding areas. The points of greatest discharge are usually from comparatively bare rock areas of steep slope. The wadi bed itself may absorb a large amount of the water. At Kolonia the Wadi Surar has a considerable discharge which is often much less at Artuf but with continued rain the amount tends to increase until the gorge discharges its water into the plain. Generally a position well up the mountain gorge gives the best impounding site both in respect of quantity and impounding basin. The position above Kolonia (Motza) might be taken as giving the only possible chance in relation to Jerusalem. Provided 300 millions gallons during the season could be depended on, the question would be worth considering in relation to the next problem. The Wadi Shaib provides the most dependable discharge but it is doubtful whether at Tulkaram or above, it would pay to construct a basin or to what extent the water could be used.

3. Imperviousness. The rocks of the hills consists of (a) porous dolomites (b) hard limestone often fissured and full of natural water channels (c) chalk which is slowly porous. Clay beds are rare.

The water table in the hills is usually hundreds of feet below the surface, hence from general considerations an impounding reservoir would have to be rendered water tight by clay puddling.

It is not therefore surprising that up to the present time impounding reservoirs scarcely exist. Perhaps one exception is the Wadi Biar belonging to the Jerusalem Water Supply which is of little importance. The ancients constructed masonry basins such as Solomon's Pools capacity 30,000,000 gallons, Ziza basin 10,000,000 gallons.

The great natural impounding reservoir of Palestine is the sea of Galilee with an area of over 200 square kilometres. During December to March the rainfall is greater than the evaporation. From May to September the evaporation probably averages nearly 1 centimetre per day which would be equal to nearly 2,000,000 M^3 a day or about the volume of Ain Banias the largest spring flowing into the Upper Jordan. Consequently in February and March when the springs reach their maximum discharge and the surface flows are considerable whereas the evaporation of lakes Huleh and Galilee is negligible the Jordan floods. During late summer however when evaporation is still high the amount of water flowing out of Galilee may not be more than the evaporation figure.

CHAPTER II.

GEOLOGY, STRATIGRAPHY.

Palestine geology as limited to the present article is represented by three periods of marine sedimentation.

The first commenced at least as early as the Jurassic Period and continued to the end of Cretaceous or Eocene epoch. The second lasted for a short part of the Miocene epoch

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and the third was Pliocene to Pleistocene both of which were largely confined to the Coastal Plain area. During the Neogene period considerable areas inland were laid down with clays, fresh water limestone and oolitic sandy limestone. The general character of the rocks is indicated in the table given on page 10.

JURASSIC.

Nubian Sandstone. The term "Nubian Sandstone", has been used generally to denote the great thickness of sandstones exposed on the east side of the Dead Sea and elsewhere. It includes strata of **) Cambrian, Carboniferous, Triassic and Cretaceous age, The Dead Sea section shows about 2000 feet of a sandstone of remarkable uniform texture. It is often crossbedded, and generally the lower series are red in colour and the upper white. Further north however the lower beds become calcareous and ferruginous.

In such strata *) Jurassic fauna was discovered at the mouth of the Nahr es Zerka (Transjordan). Beds of this age extend a considerable distance up the wadi. Similar fauna viz. Cymatorhynchia quadriplicata and Lobothyris ventricosa (Bajocian) are found in oolitic sandy limestones at the Zerka crossing.

In Palestine the Upper Cenomanian limestones cover the major part of the hill country and very seldom do the wadis cut deep enough to expose any lower beds. Sandstones of Jurassic and Lower Cretaceous age are known to be exposed in the dissected anticlines of the Kornub area notably in the W. Figra and W. Hadira. In the Wadi Farah region also the great anticline has been cut through by the main wadi and some of its tributaries exposing a series of ferruginous sandstones and limestones above and soft sands associated with calcareous sandy beds below which contain poorly preserved fossils among which is Cidaris glandaria.

On the southern side and in the Wadi Maleh these beds are underlain by ferruginous limestones, tuffs and igneous rocks.

The section of these rocks are given in the Lower Cretaceous part.

(*) L. R. Cox Annals and Magazine of Natural History Feby 1925 p. 169.
(**) W.B.R. King Geol-Mag. 1923.

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SUMMARY OF GEOLOGICAL FORMATIONS.

	GAZA BEERSHEBA DISTRICT.		JUDEA SAMARIA.		GALILEE.	
	Coastal	Inland	Coastal	Inland	Coastal	Inland
Quaternary	Sand dunes (Gaza) Loams	Chalky coarse sands blue clays (W. Jeib)	Sand dunes Red sand formation Calc. sandstone.	Gypsum, chalk with silt Clay beds (Jordan)	Sand drifts clay beds of Kishon estuary Calc. sandstone	Gypseous chalk with loam Clay beds
Pliocene	Hard limestone } Beersheba oolitic " } Limestone, sand } Sheriah and clays }	Soft limestone } Usdum Shales } Sandstone } Hosb Gypseous beds }	Coral limestone (Tulkarem) Blue clays with sand layers (Bir Salim)	Crustal conglomerate of hill slopes Flinty sandstone (Jordan)	Oolitic sandy limestone Reddish limestone pebble Conglomerates	Basalt and ash beds Oolitic limestone Freshwater limestone, gypsum, limestone basalt and ash beds
Miocene	Chalky limestone } Kubeibeh with hard per } layers } Clay beds	Salt & Gypsum ?)	Limestone Blue clay (Ramleh)			part of ? above
Eocene	Lenses of flint and nummulites (Mishrafa) Chalky beds with bedded or nodular flints	?	Chalk beds capped by thick flinty nummulitic limestone	Judea-unknown Samaria largely covered in the west with nummulitic limestone.		Marble (Huleh) and marmorised limestone
Senonian	Chalk with thick brecciated chert bed	Gypseous limestone poor phosphates, chalk & flint beds. (Zuweira)	Chalk beds with flint breccia. In some parts thick bituminous limestone.	Gypseous limestone } Phosphatic " } Bituminous " } Judean Flinty " } wilderness Chalk beds with } Flint breccia }	Dolomite & hard limestone Hard flinty limestone Chalk beds	Hard limestonne, Chalk beds
Turonian		Hard limestone	Hard limestone	Hard limestone	Chalk beds	Hard limestone
upper Cenomanian lower		Hard limestone with some dolomite (Kornub)	Judea Red marmorised limestone, dolomite, argillaceous limestone, dolomitic limestone, hard limestone	Samaria Hard limestone with dolomite beds.	Hard limestone, massive dolomite platform (carmel)	Hard limestone } Buttauf Dolomites } Huleh } Ramle
L. Cretaceous		Gypseous and micaceous shaley limestone and Ferruginous limestone (Kornub)	Clay beds, hard limestone	Ash and basalt, oolitic sandy limestone, ferruginous limestone with clay beds Ferruginous sandstone (Farah)		Oolitic sandy limestone } Buttauf Ferruginous limestone } Huleh Ramle
Jurassic		Sandstone (Kornub)		Ash beds Sandstone Sands		

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LOWER CRETACEOUS ROCKS (NORTHERN PALESTINE).

In parts of Palestine and also Transjordan where the lower rocks have been exposed the position of the Lower Cretaceous beds has been inferred from the underlying Jurassic and the Cenomanian above. Recently however undoubted Lower Cretaceous (Albian) fossils have been discovered by the writer in the Wadi Farah and the sections are given below:

The identifications are by L.R. Cox of the British Museum.

	Altitude feet	
Upper Cenomanian	2400–2100	Mostly grey dolomite (much Nari covering)
Lower Cenomanian	2100–1500	Hard pink limestone with Strombus pervetus
		KH. TELL EL FOKHAR.
	1300	Yellow limestone with few fossils
		Ferruginous oolitic sandy limestone
		Massive limestone
Lower (Albian) Cretaceous	1050	Clay and Marl beds with Knemiceras (Buchiceras)
	900	
	800	syricum, Trigonia aliformis (gault)
	200	Covered with alluvium and scree material
		BELOW BEIT DAJAN.
Lower Cenomanian	1800	Yellow limestone
	1100	Nari cover
	1000	Ferruginous oolitic limestone and sandstone
Lower Cretaceous		Massive compact limestone with streaks and nodules of iron oxide, Knemiceras Zone
	700	
	650	Ferruginous Oolitic sandstone and limestone
	600	(small spring)
	550	Ferruginous calcareous sandstone
Jurassic	500	Hard ferruginous sandstone
		Loose yellow sandstone beds
	430	Ash beds (? decomposed basalt) with fresh igneous material (bombs) dolerite (augite, olivine, labradorite)
	350	Burnt clay bed (with iron ore)
	200	Scree material and alluvium

On the north side a partial section shows:

			thickness feet	
Lower Cretaceous	750	Massive ferruginous limestone—Knemiceras Zone		
	700	Ferruginous sandstone		
	650	Covered		
		Thin yellow sand beds	35	
		Soft sandstone	30	
		Calcareous sandstone	35	
		Hard calcareous sandstone	6	
Jurassic		Soft do do	10	
		Hard fossiliferous calcareous sandstone	6	glandaria zone
		Soft calcareous sandstone	10	
		Hard calcareous sandstone	15	

Radioles of Cidaris glandaria were found in the calcareous sandstone beds.

Ferruginous limestones and sandstones similar to the upper series occur to the north-west of Lake Huleh and in the mid-section (Ramleh) of the south fault scarp of Jebel Safed also north-east of El Buttauf, and in the lower part of the wadi north-east of Iksal (west of Tabor).

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CENOMANIAN.

The Cenomanian strata cover a large area of the Palestine Hills. They spread over the surface from south of Diahyrieh through Hebron, Jerusalem, Ramallah to East of Nablus whence they pass north-eastward towards the Baisan Plain. The width of the belt varies from 20 to 40 kilometres. In some parts they are covered with Turonian and Senonian beds but never completely denuded except in the limited areas mentioned. Although there are some difference there is also considerable general similarity in the beds composing them and they may roughly be divided as follows:

		Thickness	Fossils
Upper Cenomanian	Upper marmorised limestone	200	Acanthoceras rotomagense A. mantelli
	Mizzi Yehudi (dolomite)	200	
	Argillaceous limestone	150	Acanthoceras mantelli
	Dolomitic limestone	300 to 500	
Lower Cenomanian	Hard pink limestone associated with marls and clay beds below.	1000	Coronatica purporoidea Strombus pervetus Pleurotomaria cf. perspectiva

The upper divisions are due to their proximity and influence on building in Jerusalem. On the other hand the lower beds which have so much greater thickness are not so well known being only exposed in deep wadis and certain limited areas; their stones are seldom used and have no particular qualities better than the beds above. The junction of the Lower Cretaceous has not been determined. The lower beds differ from the Upper Cenomanian strata in being less dolomitised and are more generally a hard crystalline limestone. The common fossil is a large strombus and which is very general in these rocks.

The Upper Cenomanian strata have been described by Blanckenhorn and other writers. The top beds are semi-marmorised, hard, crystalline limestone often possessing a red or pink colour but with various shades of yellow and brown and are known locally as Mizzi Ahmar (the red stone). At the present day it is very largely used for exterior work. The hard varieties take a fair polish and are often used in place of marbles for ornamental purposes. The pillars of the Basilica of Bethlehem are of this stone as are many of the columns of Roman times though in this period the importation of Egyptian syenite, Italian and Greek marble is very common. The top bed is often a rose-pink, massive, homogeneous somewhat soft, yet crystalline (saccharoid) limestone. It may be quite white and is often weathered to a chalky rock as is the case in Solomon's quarries which are located below the city of Jerusalem. The name Meleke is often given to this variety.

The principal zone fossil is Acanthoceras rotomagense and it is very common in the Jerusalem area. At Tel Nasbeh, *)Exogyra mermeti major, Pholodomya Lugnesi, Heterodiadema lybicum, Holectypus Lartete, Hemiaster Lugnesi are common fossils.

The Mizzi Yehudi (Jewish stone) occurring below is essentially a dolomite of grey colour but often weathering to a crumbly condition in which the rock breaks down into rhombs of dolomite which gives it all the appearance of ordinary fine sand. The dolomitization is by no means confined to these beds but often passes up into the Mizzi Ahmar and in some case to the Turonian above.

At Malha and many other localities, the base of the series consists of quartz which in some cases show all the fossils of the original limestone. It is perhaps worth remarking that the Nerenia facies are very common in these quartzite beds. The quartz possesses the

(*) Exogyra mermeti major also occurs with the argillaceous beds as at Sinji K38 Nablus road. Exogyra olisoponensis in also common in these beds (El Khudr) but in Transjordan (Kerak, Tafile) it reaches the zone of Choffticeras spp. (Turonian) though the clay gypsum beds at this horizon may be the same horizon as the argillaceous limestones.

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texture and fracture of the dolomite but the hardness and toughness is greater than ordinary quartz. The stone has been used for road making and answers admirably but owing to the difficulty of drilling shot holes and breaking, its use has been limited. It occurs in many parts of which may be mentioned Malha, Ramallah. It occurs also above the tuffs of the Um El Fahm area.

The argillaceous limestone beds below are not dolomitised or not so generally; they are very fossiliferous and the fossil remains better preserved. They are associated with clay beds, sometimes with a definite clay horizon which may have a thickness of 2 to 5 metres. The character of the limestone, its preservation of fossils are doubtless interdependent. Its influence upon the life of the Judean hill district is beyond estimate owing to the fact that most of the springs have their origin in dolomite beds overlying the argillaceous limestones.

While these beds are wide spread in the hills there are areas such as parts of the Wadi Surar where the whole sections appears an endless series of dolomite beds without lithological change, fossil horizons or springs.

It is probable that in some areas there are two such horizons of fossiliferous argillaceous limestone.

The following Sections are typical of the Judean Hills.

Altitude Feet	Malha — Wadi West.
3000	(Old quarries)
2900	Yellow Mizzi with Acanthoceras rotomagense.
2810	Brownish red and pink marmorised limestone.
2800	Red marmorised limestone (Mizzi Ahmar) with Acanthoceras rotomagense.
2750	Neolobites Pervinguiere, Acanthoceras mantelli, Ostrea, Arca.
2700	Spotted white and streaked red crystalline limestone with Hemiaster Lugnesi Acanthoceras rotomagense, A. mantelli, Pholodomya vignesi, Vola detrugli.
2650	White or grey pink crystalline limestone with Echinobrisssus Lugnesi, Discoidea cylindrica, Venus, Radiolites.
2540	Hard purplish coloured dolomite.
2510	Very crystalline loose, sugary, white dolomite, no fossils.
2500	Quartzose rock with fossil casts replacing the limestone in the valley.
2400	White to brown crystalline fossiliferous limestone with Coronatica purpuroidea, Crassateila Zitteli, Janira Tricostata, Ostrea flabellata and Rudistae.

	Beit Jala to Bittir Valley.	
	3100-2900	Weathered to hard red crystalline limestone with Acanthoceras rotomagense.
Mizzi Yehudi	2900-2750	Grey crystalline dolomite
	2750-2700	Pink crystallIne dolomite
	2700-2590	Fine grey crystalline dolomite
Fossiliferous* limestone	2590-2560	Brown fossililerous limestone Pholodomya Vignesi.
	2560-2520	Hard limestone with Acanthoceras mantelli
	2520-2480	Hard flinty grey limestone with Orbitolina concava
	2480-2420	Hard white limestone with Rudistae
	2420-2370	Fossiliferous limestone
	2350	Oyster bed with clay bands with Ostrea flabellata
	2320	Grey and yellow dolomitic limestone.

A series of the flat flints are associated with these beds with abundant Neriuea (K.15) Hebron Rd., with quartz bands at Um Suffah and below El Khader occur oyster bank with large Ostrea olisoponensis and O. flabellata.

Under the argillaceous limestones are a series of dolomitic limestone of a fine texture grey or yellow colour generally unfossiliferous which may have a thickness of 300 feet or more.

Although water is not so plentiful in these beds springs occur such as the Zerka springs north of Hebron, St. Phillips spring K.28 Hebron Road.

*) Pecten, Vola, Inoceramus aratus, Exogyra olisoponensis, Plicatula, Lima, Liopistha, Cardium combei, Crassatella Zitteli, Anatina, Pholas, Natica, Coronatica purpuroidea, Turritella cf mausi, Pterodonticeras cf germari (Blanck?) Uintacrinus.

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Below these beds occur the lower Cenomanian consisting of thick massive limestone of a brown to reddish colour probably 1000 feet thick. Dolomite rocks are occasionally interbedded with them down to the lower Cretaceous strata and there occur clay beds towards the base. The varying thickness of the interbedded dolomites causes considerable difficulty in correlating these rocks. In the upper beds particularly round Ramallah, Um Suffah the common fossil is Coronatica purporoidea, Pterodonticeras Germeri (Blanckenhorn) and in the lower beds Strombus pervetus. Associated with the lowest strata in the Ramallah District (W. Jib) are marl and clay beds with abundant fauna including Pleurotomaria, Pholodomya, Cardita, Protocardia, seaurchins and numerous small ostrea and gasteropods.

Shalem creates seven divisions of the Cenomanian at Motza (Kolonia) of which III (from base) is the argillaceous limestone and V is the rotomagense zone but he places the Mizzi Yehudi VII above this instead of below. Though the fossil evidence is in favour of Cenomanian age the horizon appears to correspond with the Turonian, many areas of which are highly dolomitised around Jerusalem.

At Enjedi the following sections occur:

Blanckenhorn

		Age
Salty Chalk with Rudistale and Nerinea	120 metres	Doubtful Turonian
White chalk and grey marl with Exogyra olisiponensis E. flabellata and E. Africana	23 "	Cenomanian
Reddish and grey marl with Acanthoceras palestinense	45 "	"
Limestone with Exogyra mermeti minor, Pycnodontis vesiculosa, Pecten	30 "	"
White and coloured marl with gypsum	50 "	"
Hard limestone with Pycnodonta Vesicularis, Exogyra flabellata, Vola, Plicatula, Hemiaster	18	
Hard cavernous limestone Dolomite with impression of Exogyra Mermeti	150	
	436	

The general fossil facies of the chalk beds resembles that of Transjordan rather than other parts of Western Palestine. Ostrea Africana is a common fossil at Ain Hemar and below Es Salt where Acanthoceras mantelli or rotomogense have not been located here but species identified by Dr. Spath as Neolobites fourtani, Pervinquiere and Neoptychites sp. indet indicate upper Cenomanian to late Turonian.

The main fossil horizons at Ain Jidi occurs 200 to 300 feet above the spring in which are banks of oysters named in the sections given; below the spring is largely hard fault breccia.

In the Carmel area there occurs a platform of dolomite at least 1000 feet thick containing in their upper part limestone beds with Pholodomya vignesi, Hastula aceformi, Scalaria.

On the west, this platform is overlain by volcanic tuffs and basaltic flows which extend from known exposures from Tireh to Anin, south of Um el Fahm. The bombs and lava flows are mostly plagioclase, augite, olivine basalts but at Ikzim where only bombs occur with the tuffs they consist of augite-olivine pyroxenite with magnetite and pyrite.

The limestones overlying the tuffs at Zikron Jacob have yielded Ostrea diluviana, Pecten quadricostata, Trigonia arca (L.R. Cox) and Hemiaster Lugnesi. Beds two kilometres to the

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north some hundred feet above the tuffs have yielded Nerinea Noetlinga, Trochacteon; Ostrea vesicularis is a common fossil at the base of the Chalk beds (Esfia oyster beds); Exogyra Flabellata occurs in beds below above the dolomite platform. In the Arara, Um el Fahm, Anin areas the tuffs are overlain by dolomite which to the north pass sharply into a thick series of chalk beds (600 feet) of which the upper beds contain bedded nodular flints and also very large flint lenses. In the Carmel area at Makraka the tuffs are overlain by flinty hard pink limestone succeeded by coloured crystalline limestone above which is a milk white limestone full of empty casts of Nerinea. The sequence towards Esfia shows only dolomite followed by hard limestone and chalky limestones and to the west sometimes by dolomite with siliceous limestones already referred to or by massive white crystalline limestone which forms the crags between Tireh and Ain Haud (upper Nerinea limestone).

The general sequence of the Carmel area is as follows:

Senonian	Flint Series 300 feet	Dolomite or hard limestone with Nerinea and Acteonella cf. Syriaca Con. at Carmel Point. Chalk beds. thin flint beds or flat nodules in fine grained hard limestones. Hard chalky limestone with Turrilites.
Turonian	Chalk series to 300 feet	Very fossiliferous chalk with Hamites, Schloenbachia ? quattornodoso Roudaireia auressensis, Protocardia pauli, Liopistha pervinquieri. White Limestone with Protocardia, Strombus sp. ind. nodular flints. Yellow rubbly limestone, oyster beds of Esfia, very fossiliferous, with Gryphaea vesicularis,
Upper Cenomanian	Hard limestone series 250 feet.	Hard white limestone with large Nerinea e.g. (Zikron Jacob and South Esfia. Hard limestone, dolomite in some parts (Oyster & Rudistae beds east of Esfia with Acanthoceras rotomagense at Daliet Spring.
	Upper Dolomites	Tuffs { Basalt beds 80', Purple Dolomites 50', Ashes 100' } Um es Zeimat & West Carmel: Gonodon hebes whitfield, Hastula Nov. Sp, Pteria Nov. Sp. Grey and pink dolomites interbedded with limestone with Pholodomya Vignesi, Hastula, Scalaria, Radiolites.

The section given by L. Picard (between Belad es Sheikh and Wadi Rushmia) is as follows C.r. 15.11.26. P. 897.

100 m Chalky limestone with flat flints.
10—20 m Hard limestone with calcitic inclusions and fish remains and Acanthoceras Newboldi.
10—20 m Hard limestone with flint nodules with Orbitolina conica, Turtillites Bergeri Brg.; Hemiaster batnensis, Pecten Shawi.
10 m Crystalline limestone.
15—20 m Soft white limestone with Pecten Shawi, Discoidea cylindrica, Hemiaster Saulcyanus.
1—2 m Dolomite with Gryphea vesicularis.
10—20 m White chalky limestone with Orbitolina conica.
350 m Brown and grey dolomite.

There seems little doubt that the top beds of the chalk Series are Senonian in age and the lower beds are Upper Cenomanian; the boundary with the Turonian is as undefined as it is Judea. The flint series are doubtless Senonian and this receives confirmation from the fact that a series of strata of similar lithological characters occur throughout the Nazareth District and Galilee, the bedded flinty limestones being the most characteristic, which at Jebel Sih are overlain by nummulitic limestone of Eocene age. About Tiberias near Rabbi Mear occur remnants of chalk beds in which Schloenbachia quinquenodoso has been found.

There is considerable evidence in favour of the view that the ash beds of Mt. Carmel, the clay beds of Judea and the clay and gypsum beds of Es Salt, Masada, W Hesa all belong to the same horizon and indicate shallow sea conditions in late Cenomanian times.

TURONIAN.

Throughout Judea there occurs below the Senonian chalk a compact extremely fine grained stone having much the characters of a lithologic stone and known locally as Mizzi Helu. Stone of this character is extremely widespread in the Jerusalem District. The outcrop extends north along the Ramallah Road with large exposures of this rock to the east and along the Bethlehem Road to beyond the town with further outcrops again to the east:

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Typical sections are given below:

	altitude (feet)	Silwan (Jerusalem)
	2750	Soft chalk with sharks teeth and fish spines
Senonian	2680	Streaky red chalk.
	2650	Massive soft limestone.
	2600	Mizzi Helu
Turonian		Massive white stone crowded with Nerinea Requieniana D'Orb and Acteonella Salomonis.
	2570	Mizzi Helu
		Flaggy limestane.
	2540	Bedded Mizzi Helu
		Yellow limestone below (contains Acanthoceras rotomagense)
Cenomanian	2520	Massive red crystalline limestone.
	2500	do do do
	2480	White crystalline limestone

Generally the red marmorised limestone (Mizzi Ahmar) marks the top of the Cenomanian and contains Acanthoceras rotomagense. The thickness here would therefore be not much more than 140 feet between the two series but the range in inferred from the beds above and below. The red streaky chalk is unfossiliferous and though it resembles the Senonian chalk it may be of Turonian age.

In the Mar Elias area the Mizzi Helu type above the red crystalline rocks to base of the chalk is about 200 feet.

MAR ELIAS.

	altitude (feet)	
Senonian	2845	Chalk with Senonian fossils.
	2750	Chalk-Nari covered.
	2600	Red chalky limestone.
	2680	Red streaky soft limestone.
	2650	Brown streaky soft limestone.
	2645	Typical Mizzi Helu; some brown with red laminated chalk.
	2600	White Mizzi Helu. (Cyphosoma palestinense)
	2595	do do do
	2580	Brown Mizzi Helu.
		Mizzi with red streaks
	2570	Mizzi Helu white and fossiliferous. (Nerinea)
	2560	Mizzi Helu deep cream.
		do light brown. 5'—10' beds.
	2550	Crystalline light dirty brown limestone 5' bed with clean fracture.
	2530	Mizzi Helu cream, semi-crystalline.
	2490	Massive limestone, cream coloured semi-crystalline.
	2480	Thick bed Mizzi Helu type 4' beds
	2480	Flaggy limestone Mizzi Helu type 5' beds

At Bethlehem the Mizzi Helu beds contain few fossils other than those mentioned but layers of flint nodules commonly occur which associate them with beds of the Northern area; fish teeth are found in the upper beds. The thickness here is about 150 feet. North of Jerusalem (kilo 5) and towards Anata the Turonian beds are dolomitised to a fine grained compact stone of greenish grey colour.

A thick bed of white quartz rock caps the Turonian on the Nablus Road Kilo 2 and contains Nerinea and Acteonella. As already pointed out the Turonian of the Carmel, Nazareth, Galilee Districts is associated with nodular flints or quartz beds in which again the division between the Cenomanian and Turonian is not well defined.

North of Zicron Jacob, Nerinea cochlaeformis subgig, (Blanckenhorn) occurs in siliceous bands but immediately north of the town the limestones contain Ostrea diluviana Lim, Trigonarca cf thevestensis Coq. The white marmorised stone of Makraka (The Sacrifice) and the crags between Tireh and Ain Haud is also a Nerinea marble

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its age appears to be Turonian. The overlying beds consisting of the flinty chalk limestone and dolomites of Carmel are most probably Senonian.

In the Tiberias area as already mentioned chalk beds with Schloenbachia Quinquenodoso overlie "Mizzi Helu" type of rock which overlies the hard limestone series.

In the Nablus-Farah area rock of the Mizzi Helu type occurs below Senonian chalk in which Schloenbachia quinquenodoso and sharks teeth have been found but they grade quickly below into coloured hard crystalline limestone and dolomites.

SENONIAN.

Rocks of Senonian age occur throughout Palestine excepting along the crest of the main ridge where it is assumed these beds have been denuded.

They are divided by Blanckenhorn into three groups the Santonian, Campanian and Danian. In the Dead Sea basin these can be associated with distinct lithological characters viz: below, soft chalk with hard beds 300 feet; flinty limestone 100 to 300 feet; phosphatic limestones, bituminous limestone and gypseous limestone, 500 feet. In the Jerusalem area the Campanian chert formation has a less thickness and also in the north it gradually thins out and may disappear entirely (Jenin). Where they exist, these chert beds are usually brecciated and recemented to a chert breccia. In Western Palestine where the Senonian and Eocene beds have been greatly altered largely to a homogeneous soft chalk this band is extremely useful in approximating the horizon. In south east Judea the great chalk syncline which extends north north-east from Tel Arad consists of soft chalk rock about 300 feet thick overlain by a chert-limestone series at least 200 feet thick. The chalk formation appears to contain no clay beds and consequently even where ideal structures exist there are no spings or water seepages.

The thickness of the lower chalk beds also varies considerably. North and west of Nablus the thickness between the hard limestone containing Nerinea and the brecciated chert is less than 100 feet; the chert beds are usually not more than 15 feet. The red and yellow chalk overlying it varies from less than 100 feet in the west to nearly 300 feet east of Nablus. In the absence of fossils its age remains in doubt.

Around Jerusalem the lower Santonian beds consist of soft chalk containing impressions and remains of Arca, Pholodomya, Lucina, Apporhais, Turillites and other ammonites; well preserved sharks teeth and fish spines. The principal zone fossil is however the Schloenbachia quinquenodoso which appears very general at the base of the chalk.

Above the soft chalk beds are harder very fossiliferous calcitic beds full of Nucula, Leda perdita, Arca and these are capped in many parts of Jerusalem district, e.g. the Mount of Olives, by a thick bed of brecciated chert. The limestones associated with the chert beds in the Judean wilderness contain an abundant fauna including Protocardia moabitica, Cardium, dentalium, Turritella, large Cerithium, Baculites c. ovatus, B. asperoanceps and many ammonites.

The phosphatic beds which occur immediately above the flint formation extend from about Kilo 9 to Kilo 33 on the Jericho Road and from near Jericho in a belt running south-west. They exist as (a) coprolite bone bed (b) altered apatite bed (c) marmorised phosphatic limestone. The last variety has been largely used and gives an extremely beautiful, greenish red marble.

The phosphatic beds are crowded with coprolites, fish bones and spines; vertebra and paddle bones of reptiles also occur. The bituminous limestone which overlie them only in certain localities such as Nebi Musa commonly contain Pecten obrutus.

The phosphatic bituminous character of these rocks appears to be chiefly associated with definite conditions of the sea at the time probably shallow bays in which existed abundance of food for sustaining life.

Bituminous limestone occurs associated with chalk beds of the Safed District and contain abundance of Gryphea vesicularis. At Ain Zeitum below this horizon there occur 5 metres of bituminous shales and above 10 metres of massive bituminous limestone. Two kilometres to the south along the wadi, the beds at the same horizon are white chalk without bituminous matter. The total thickness of the chalk beds is close on 600 feet but the flint bed occurs about one third the way up. These beds must be widespread over the Northern District for they occur at Metullah, Safed and Tershiha.

Bituminous limestone and marl also occur in many places below the alluvium of the eastern part of the coastal plain. The few fossils that have been found would appear to place its age as Danian but this is at present by no means certain. No rock phosphate or phosphatic limestone is known in this area.

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At Kerkur the bituminous limestone has been shown to exist from 25 to 71 metres and has yielded from 12-15 per cent of bituminous matter.

The most complete Section of the Danian beds occurs in the Jebel el Karmuni (2 km. south-west of Nebi Musa) there the following section represents generally the formations.

altitude	thickness	
+ 200 feet	6 feet	hard pink marmorised limestone
	200	Soft gypseous limestone with red and yellow ochreous material.
	100	Green phosphatic limestone with segregations of apatite.
	100	Black gypseous organic shales with massive grey to black hard gypsum
	20	Brown phosphatic argillaceous limestone
	60	Hard black bituminous limestone with thin chert and limestone beds
	50	Rock phosphate with thin chert beds
	150	Shelly limestone with occasional beds of bituminous limestone and
— 480		rock phosphate.

The faulted down block of strata at the mouth of the W. Baghat shows the following series:—

Soft white limestone	40	feet
Thin laminated black shales	50	"
Greenish marly shales	90	"
Black carbonaceous shales	80	"
Hard limestone / Black shales / Limestone	40	"
Bituminous limestone	80	"
Gypseous salty shales	60	"

Blanckenhorn places the age of these strata as Senonian but if of this age and not later they belong to the higher horizon corresponding of the upper series of Jebel el Karmuni.

The gypseous limestone containing ochreous minerals strongly resemble the material at the Khan Hatrura and Ras Zuweira. There seems little doubt that before denudation the area generally west of the Dead Sea was covered with these gypseous limestones.

EOCENE:

Eocene rocks are not universal in Palestine, in fact there is considerable doubt as to whether Judea was ever covered by the Eocene sea. Going northward from Jerusalem, rocks of Eocene age are first encountered near Hawara on the dip side of the faulted monocline that runs north-north-east. The beds extend north and west covering a large part of Northern Samaria and passing into Galilee through the Jenin District. Nummulitic limestone occurs on the plain immediately north; it disappears in the Amek where the faulting is marked but occurs again in Little Hermon and continues with irregularities north of Lake Galilee and into Syria.

In the western plain nummulitic flinty limestone occur one kilometre west of Beit Jibrin. Similar fragments are found in the wadis to the south indicating a north to south strike. Beyond the Beersheba plain silicified nummulitic limestone caps the hills around Mishrafa.

In these western areas where most of the rocks are chalk, fossil nummulities are usually only preserved in the silicified beds. The beds below are usually chalky and devoid of fossils.

In the Nablus area however there exist an extensive development of Eocene rocks of over 1000 feet thickness. They overlie beds of Senonian age which are characterised mainly by a thick bed or beds of brecciated chert. Above this is a chalky limestone generally about 300 feet thick but at El Arak to the south of Nablus this decreases to 100 feet or less whereas the chert breccias increase in thickness and number. Beds of clay or clay marl occur towards the base of the upper chalk. The absence of fossils in the upper chalk beds leaves their age in doubt as also the existence of Lower Eocene beds around Nablus.

The distribution of the Eocene beds may have been determined by the movements indicated in the Danian epoch. Their extension westward is greater than was formerly held and they usually form the extreme beds on the western foot hills, where at an altitude of 100 metres or less they have been denuded by Pliocene Sea, for up against this old shore line occur beds of Pliocene gravels and shelly limestone. This old shore line passes west of

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Tulkarem, east of Kalkilieh, Ras-el-Ain, west of El Tireh, Nebi Daniel, and Abu Shusheh. West of this line the land is mostly covered with alluvium or sand but drilled wells have shown at short distance an unpenetrated great thickness of blue clay indicating a fault line somewhere west of this old shore line.

The following Sections are given as typical of the Eocene formatiou in the Nablus Tulkarem Districts.

Nablus East.

2720 White to pink marble with flint lenses and Nummulites Gizehensis.
2650 Massive limestone with Nummulites Gizehensis
2600 do. with Orbitoides.
2550 hard white limestone with Orbitoides.
2500 hard white limestone with Nummulites lucasanus.
2450 white limestore with large Orbitoides
2400 hard white massive crystalline limestone with Nummulites lucasanus (?)
2370 } bedded granular, thin green crystalline limestone passing into chalky material, at base
2300 } small Nummulites.
2250 } hard greenish granular limestone
2150 } with chalk beds.
2050 Chalk and green beds with flint
2000 Crystalline Limestone with small nummulites
1900 Grey crystalline limestone
1800 White chalk.

Sections from Nablus north and south are as follows:—

North of Nablus (South side of Mt. Ebol.

2500 Hard limestone with large nummulites (Orbitoides and N. lucasanus)
2400 Dull grey limestone part chalky with large flat flints.
2200 Grey to brown or white crystalline limestone with abundant silicified nummulites
2150 Grey semi crystalline limestone
2050 Fossiliferous white limestone with small nummulites (N. lucasanus)
2000 Nari ? chalk
1900 Massive limestone with large and small nummulites (")
1850 Massive white and pink crystalline limestone
1800 White semi crystalline limestone with flints containing nummulites
1750 Pinkish grey hard limestone
1700 Hard grey limestone
1650 Chalk (? Senonian) with clay marl (Ain el Kusab in wadi)

Nablus south Hill, (Mt. Gerizim)

2800 Slabby granular limestone
2600 Hard limestone with ? Lucina gigantea and Lima
2530 Nummulitic limestone
2320 Massive crystalline beds small nummulites
2250 Well bedded limestones
2200 Massive white finely crystalline hard limestones with nodular flints also flinty or silicious bands. (Large Orbitoides and Schizaster ? archiaci Cott)
1950 Chalk beds below (here Ras el Ain)
1850 Massive limestone with flat nodular flints and large nummulites
1770 Massive limestone and thin bedded flints
1750 Thin bedded flinty limestone
1730 Chalk limestone with small nummulites (? lucasamus) (here Balata, Ain Dufna)

The nummulitic limestone at Balata (E. of Nablus) contains coccolitic augite Below Rafidia (w. of Nablus) occur blocks of Alveolina limestone. At Jiflik (W. Farah) occurs a rose pink marmorised limestone with N. gizehensis. The flint series of limestone on the hills around Nazareth are at Mt. Sih overlain with foraminiferal limestone containing coccolitic augite.

North of Anebta the strata are very highly dolomitised and give the following section: Anebta to Jebel Bir Asur (wadi Shaib 400 ft.)

1600 Highly nummulitic limestone shaley chalk
1500 Chalky beds

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1451 White crystalline limestone
1350 White alabaster limestone with small nummulites
1300 Grey and brown crystalline limestone with nummulites
1250 Siliceous beds with nummulites
1200 Fine grained crystalline limestone, nearly white, with siliceous bands
1150 Hard limestone and grey dolomite
1050 Foraminiferal limestone
1000 Dolomite and flinty limestone
950 do do do
900 Massive limestone with chalky foraminiferal remains
800 (Discocylina and nummulites of Upper Landenian age) (L.R. Cox)
Wadi course with flinty limestone fragments
500 Mizzi helu with large flints
450 Chalk rock (? Senonian)

The age of the beds at Bir Asur is considered Lower Eocene whereas those of Nablus area are middle Eocene. If these deductions are correct the Eocene sea approached from the west and gradually spread eastward showing transgression the over partly denuded Senonian beds as far as the present position of the Jordan Valley.

MIOCENE.

In the area known at the Shaphelah there occurs a strip of country varying in height from 600 to 700 feet to a maximum of 1500 feet north of Artuf in which the surface is largely covered by *"Nari" but in places are exposed marls, clays, soft chalky limestones which generally give no indication of age. Some of these chalks occasionally as at Kubab are associated with thick bands of brecciated flint which is doubtless of Senonian age but definite horizons such as these are rare except near the faulted monocline which divides the area from the hills. Between Kilo 24 to 40 of the Jaffa Road and along the Railway from Artuf to Naaneh occur irregular outcrops of chalk many of which are probably Senonian or Eocene age and represent an old land surface that was thrown down at the time of fault movements mentioned. Above this old land surface occur beds of blue clay or marl which have again been denuded by the old drainage system represented by the present wadis.

These beds are well exposed north-west of Artuf where the recent erosion of the wadi has caused falls in the cliffs exposing above thick beds of marl and clay 200 feet thickness. These can be traced up the hill above Rafat from 700 to 1300 feet. Similar formations can be seen along the road to Beit Jemal but beyond and south exposed in the wadi are chalk beds with thin flint bands which are probably of Eocene age. These continue as far as Beit Jibrin and beyond. At El Kubeibeh the upper beds of these soft chalky limestones contain Pecten sp. and nummulites the latter containing Lepidocyclina which gives their age as Miocene. (Bullen Newton)

One kilometre South-East of Ramleh station a quarry was opened which showed

Sand	3 metres	
Hard limestone	6 metres	
Blue clay	50 "	(not penetrated)

Both the limestone and the clay contain abundance of Lepidocyclina and other fossils.

The section at Sarafand deep well shows beds of blue clay and sand from 450 to 900 feet (not penetrated) altitude 160 feet; the upper sandy beds are doubtless of Pliocene or later age.

The well at Sakia (V.p. 40) probably never reached Miocene beds; in the Ramleh-Ludd area the drill penetrates the blue clay at 130 to 160 metres showing a varying formation below of chalk, hard limestone and dolomite. At Bir Salem the drill was still in Pliocene clays at 230 metres.

These results indicate a fault of post Miocene age which doubtless ran northward, west of Ras el Ain producing the shore line referred to and the formation of coral limestone and other beds.

*) Nari is a surface crust common in many parts of Palestine. At Artuf the wadi gravels may be seen passing up into agglomerates; the chalk areas of the Shaphelah and eastern Judea are largely covered with a crust of secondary origin; the constituents are mostly limestone, sometimes as pebbles or as irregular fragments perhaps derived from disintegration of the rock in situ; fragments or blocks of flint are often present as also argillaceous material from ancient soils. When massive it can be quarried like a free stone (Sur Bahir). The builders of the Roman period were not averse to its use, for the viaduct at Jerash is built of this material.

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PLIOCENE.

To the west of the Miocene clay and limestone outcrop the greater part of the coastal plain is covered with sand, mostly blown. Near the limit of the sand excepting where eroded by the large wadis there exists an old shore line at 500 to 600 feet level consisting of cemented limestone boulders which passes Abu Shusha, Wadi Surar, Dhenabbeh, Tel el Safi, Bir Kusieh west of which is exposed (mostly seen in the wadis) a series of crossbedded sandstones underlain by pebbly sandstones. Where they consist entirely of sand they are fairly soft stone but occasionally hard enough as at Arak Sweidan near Faluje to be used for building stone. More to the south there occurs in the Wadi Sheriah calcareous sandstone and clay beds which give rise to water seepages and springs along the wadi.

From fossils obtained from them at El Buggar and Tell Sheriah Mr. L. R. Cox was unable to say whether the age was Pliocene or Pleistocene. On the shore at Jaffa the rocks of Andromeda, Jaffa shelly limestone occurs at sea level and at Jaffa, Tel Aviv, Gaza and other places hard shelly limestone are encountered at 20 to 30 metres below the surface, at other places the depth may be 50 metres and the age whether Pliocene or Pleistocene is not yet determined by the fossil remains. At Sakia, 10 kilometres east of Jaffa, blue grey shelly clays were encountered at only a few metres below the surface and as far as the bore hole to 150 metres. Well preserved shells from this borehole were considered to be probably of Pliocene age (Glycymeris pilosus, Lucina transversa, Venus gallina, Aporrhais pespelicany, L. R. Cox). Similar shells were obtained from a bore hole at Bir Salim from 85 to 200 metres.

These fossils have been indentified by L. R. Cox of the British Museum.

Gastropoda.

NATICA cf. HEBRAEA (Martyn)
NASSA SEMISTRIATA Brocchi
NASSA MUSIVA Brocchi *
NASSA n. sp. ? *
MUREX BRANDARIS LINNE
GIBBULA MAGA (Linne) ?
CERITHIUM cf. VARICOSUM Brocchi *
DENTALIUM VARIABILE Desh., var. OCTOCOSTULATA Cerulli-Irelli.

Lamellibranchia.

OSTREA sp.
GLYCYMERIS VIOLASCENS (Lamarck)
CARDIUM sp. (Fragments)
CARDITA ACULEATA Poli
TIMOCLEA OVATA (Pennant)
CALLISTA CHIONE (Linne)
CHAMA sp. juv.
SPISULA TRIANGULA (Renier)
CORBULA cf. GIBBA (Olivi)

Polyzoa.

CUPULARIA sp.

* EXTINCT.

From 200 to 230 metres were obtained fossiliferous clay and hard siliceous rocks containing foraminifera of Pliocene age.

North of Benjamina a coastal ridge of sandstone, shelly sandstone or shelly limestone may be partly Pliocene but the rocks up against the cliffs are almost entirely calcareous and are doubtless of Pliocene age. The old sea cliffs stretching along the north scarp of Carmel as far as Jajur and the west scarp of Carmel south as far as Tulkarem show remnants of shelly calcareous and gravel (Nari) crusts which reach up 300 feet altitude.

Hard oolitic limestone occurs 4 kilometres west of Beersheba and hard fossiliferous limestone overlies Senonian chalk to the north of the old well. These appear much older than the sandy formation to the west which overlies them. Similar hard oolitic limestone occur at Kurdaneh, south-east of Acca and continue along a belt to near Kabre springs. They pass up into sandy formations including pebble beds.

Coarse sand and remnants of coarse sandy formation and clay beds occur around Asluj and Khalasa. These are not blown sand but water-borne and in these parts are so abundant as to give the whole district a sandy character which otherwise is entirely chalk. The route from Beersheba to Kornub shows a continuation of the thick sandy loams covering the Senonian chalk also many surface crusts of conglomerate. On the ridge to the

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north of Kornub at 1800 feet are well defined calc-ferruginous sandstones and gypseous beds dipping south which extend northward and over a considerable area between the wadis Yerka and Yemen to beyond Ras Zuweira. Similar beds are found at 200 to 400 feet altitude north and south of Ain Hosb; they appear to be related to the Jebel Usdum series.

The general results along the coastal plain may be summarised as follows. At various altitudes either above or below sea level occur shelly and oolitic limestones containing very little sand and often abundant remains of badly preserved marine shells. Overlying these conformably are the sandy and calcareous sandstones well exposed along the coastal ridge from Benjamina to near Carmel Point. It is possible the junction marks the break through of the Nile into the Mediterranean. These beds show definite and considerable folding into a coastal ridge as at Napoleon's hill near Acca, and generally all exposures of the ridge along the coast.

These beds have been partly denuded, covered with blown sand and a water borne red sand has been deposited behind the ridge. The high ridges east of Gaza and towards Tell Gemmi are capped by hard quarzites resembling "Sarsen stones" with which are associated gypsum deposits.

PLIOCENE OF THE JORDAN-DEAD SEA BASIN.

Within the areas which have been subject to trough faulting exist deposits which have been folded, faulted and denuded within the period of the last and main rift movements. Blanckenhorn has already described the fresh water and ooltic limestone at Jisr el Mejami with Melanopsis Noetlingi etc. as of Pliocene age. These beds can be traced through extensive areas of the Upper Jordan, Lake Huleh, Galilee Yemma, Melhamiya, and the plains of Beisan and Esdraelon. They form the hills of Jedda, Jebata and many of the spurs sent out from the Nazareth-Bethlehem hills are of the same material. The exposed thickness varies from 100 in Esdraelon to nearly 300 feet in the Galilee and Upper Jordan District. The lower member contain numerous casts of Melania tuberculata, Cardium etc. (L.R. Cox) and the upper members of the series are sandy not unlike the sandy formation of the coast. The maximum altitude of these beds is 700 feet east of Tiberias and 300 to 500 in the plain of Esdraelon.

Below the limestone in the plain of Esdraelon are thick clay beds which in the Jedda bore were shown to persist to 140 metres depth without reaching the base or any indication of a change. The faulted scarp south of Tiberias and the W. Bireh, Jisr Mejami show the following sections:

Tiberius	altitude feet	W. Bireh	altitude feet
Basalt	750—500	Basalt (base)	-150
Calcareous rock fine pink limestone	500—250	Hard oolitic limestone	-150 to -200
with Melania - Porous grey limestone		Soft white limestone (melania)	
Pebble bed	250—150		-200 to -300
Pink limestone	150—0	Gypsum (ten feet thick)	
Basalt	0—100	Dolomite (15 feet thick)	
Pudding stone containing fragments of dolomite	100—150	Fine grained indurated clay and marl beds	-325 to -400
Red sandy dolomite rock	150	Cherty limestone *with foraminfera	-400 to -500

The beds south of Tiberias are faulted with a down throw to the east of +750 to −650 = 1400 as shown by the basalt bed at lake level.

A fault runs north west through Yemma—100 leaving the basalt beds (underlain by freshwater limestone) to the south-west at over 1100 feet. The basalt beds follow the east slopes of the Wadi Fejja (below Yemma) to over nearly 1000 feet on the crest overlooking the Sea of Galilee where the fault above referred to has dragged or faulted these beds to below the Sea of Galilee.

The western part of the Amek is underlain with fresh-water limestone deposits partly overlain with basalt and the extension eastward along Ain Harod fault must have been by a narrow strip of water. The eastern slope of the Amek is physiographically part of Beisan Plain. The presence of fresh water limestone not only along the main rift scarp underlying the basalt but also above Yemma indicates that the western extremity of the old Galilee Lake passed east of Kumieh (near Little Hermon) part Jebel et Tor (Mount Tabor), Sarona to Migdal in Galilee and hence along a north-north-east direction corresponding with the general direction of Miocene faulting. That it extended across the present position of the lake into the Hauran and northward into the Huleh District is probable from the occurrence of the fresh water limestone in the area where it regularly underlies the basalt.

*) Below Tireh similar beds are underlain by highly fossiliferous limestone and basalt beds. Shelly limestone underlain with ash beds occur at the east foot of Mt. Tabor. The age of these beds and other occurrences are discussed by L. Picard in Centralblatt F. Min etc. 1928 Abt. B Nos. 326-335.

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The late Tertiary basalt flows are largely confined to the northern freshwater basin. The known main points of extrusion are Little Hermon,*) the four cones west of Megido, and the volcanoes of the Hauran. The flows along the slopes and into the low-lying basins was followed by collapse along many old fault lines and probable elevation of considerable portions of the margins. A certain amount of lava flow possibly occurred during the movements. The lavas are mostly plagioclase, augite, olivine basalts with magnetite but some types contain much felspar and little olivine.

In the Melhamiya area there exist below the fresh water Melania limestone, beds of gypsum which show irregular outcrop due to step faulting. The material is extremely compact, hard and massive and attains a thickness of 15 metres west of Melhamiya. East its extension in mass is probable below the alluvium. The beds thin out southward for in the W. Bireh, Jisr Mejami they are only 3 metres thick. The underlying limestone contain foraminifera which have the appearance of Pliocene age. The massiveness and extent of these beds are comparable to the salt beds of Jebel Usdum.

This fresh water limestone type of sediment is not found south of the Beisan Plain. If it exists it is not exposed but in the southern area of the Dead Sea occur beds which have been folded and faulted by the later and main rift movements. At Jebel Usdum there are exposed arenaceous beds overlain by shales and gypsum with minor limestone bands. Similar beds occur east of the W. Jeib (W. Utluk) where 1000 feet of chert conglomerate interbedded with soft limestone are overlain by red sandstone 200 ft, green sandstone and shales 300 ft, gypseous limestone 200 ft. At Ain Hosb only the red sandstone series occur.

The series as a whole contain no conclusive evidence of a marine origin.

The rock salt of Jebel Usdum appears to be thrust up among gypseous shales and the sandstone series and also to underlie the greater part of the mountain.

Around Nebi Musa the larger hills are capped by pink dolomite and oolitic limestone.

The most complete section shows: —

Oolitic limestone with	(altitude 250 feet)
worn flints and gypsum	15 " thick
Gypseous chalk	6 " "
Pink dolomite (petroliferous)	3 " "
Soft chalk	10 " "

The underlying strata are covered with marl but the bituminous limestones crop out 50 feet below.

Sandy beds occur near Auja which may belong to this series. Their age is possibly Pliocene but the absence of the fossils leaves the question in doubt.

QUATERNARY.

MARINE.

The Quaternary deposits of Palestine are largely sand consisting invariably of quartz grains with a considerable proportion of hornblende and lesser amounts of mica, felspar and shell fragments. There is no doubt that their origin is the Nile silt and that while the present moving sand dunes are a menace to many areas the older sand dunes and other deposits which have become fixed and planted are the source at present of much of Palestine's most important fruit and other cultures.

As already stated the line of demarcation between Quaternary and Pliocene is poorly defined. Dr. P. Range places the whole of the coastal ridges and red sand formation as marine Diluvium. Where cuttings have been made in some of the deposits there appear limestones of undoubted marine origin but the ridges along the coastal line and exposed in places inland are mainly siliceous consisting of fine rounded grains with steep wind siopes.

These series may be divided into:

Younger sand dunes of yellow sand	Irregular dunes along the coastal plain sometimes as drifts inland.
Older sand dunes of deep red colour.	Richon, Kerkur.
Red sand formation of central plain or loam of the southern part.	Ramleh, Benjamina.
Calcareous sandstones; some very hard and compact.	Jaffa, Gaza, Benjamina (N) Athlit etc.

*) There are two smaller cones east of Little Hermon viz Tel el Ajjel and a cone almost completely of ash with large bombs, south of Naurah. The basalt which forms the ridge east through Tamrah passes below the whole series of Pliocene beds at Tireh where also the strata are folded along a north-east axis. Here the wadi Bireh has cut its bed through the basalt exposing 250 feet. Further east the upper basalts overlie the Pliocene series.

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Some of the Calcareous sandstones show all the characters of sand dune formation with steep slopes in varying directions representing angles of rest of the wind blown sand. The calcareous cementing material occurs between the layers of deposition. Typical sections exist at Jaffa and it is to be remarked that the cemented portion occurs in the lower beds which gradually show less as the upper part is reached. It appears therefore that the cementing of the sand grains is due to solution and redeposition of the calcium carbonate derived both from the contained calcareous matter and that above. Outcrops exist east peeping out from below the loose sand covering and many of the villages are built on these points of vantage.

These calcareous sandstones exist principally as a double ridge along the coastal plain the first from the coast line to 3 kilometres inland and the second from 4 to 5 and 6 to 7 kilometres or more. In the Gaza District they reach a height of 240 feet and the colour is usually a dull yellow. Range's map appears to place these as marine diluvium but the character of the upper beds seems to be against marine origin except where definite beds of sandstone and shelly limestones are exposed at the base and in some of the wadis which have already been referred to as possible Pliocene but it is admitted that discrimination between the two is often difficult.

The red sand formation in the middle plain and the sandy loams (or 'loess') formation of the Gaza-Beersheba District present considerable difficulties as to type of deposition. Though exhibiting considerable differences they all have certain characteristics in common. They contain a large proportion of fine quartz sand which has the appearance of having been wind blown and show more or less evidence of water deposition. Pectunculus, Planorbis and Melania occur in these beds the first being possibly wind blown.

Good sections can be seen along the Wadi Ghuzze near Tell Gemmi where the beds are as follows:—

Tell gemmi.

Debris	7	metres
Clay loam	2	"
Sandy loam	8	"
Reddish clay loam	5	"

These indicate fresh water deposition partly of fine wind blown sand mixed with a certain amount of clay probably derived from the hills. The banking up of the water by the coastal ridge produced by late Pliocene movements now partly hidden by dune sand and gradual deposition of these beds may explain their origin but there are many factors to be considered in relation to it.

To the west of the sand covered area bordering the ridge are stretches of alluvium consisting of clay soil which is entirely derived from and represents the down wash from the hills. This deposit is often of considerabie thickness. In the Beersheba plain the sandy loam continues east with increasing altitude until it merges with the definite sand formation of Kornub, Ras Zuweira and Abu Kidra at altitudes of 1800 to 1900 feet.

NON MARINE QUATERNARY DEPOSITS (Lacustrine & Fluviatile).

These deposits which are mainly in the Jordan valley are classed by Blanckenhorn as belonging to the Diluvial age corresponding to the Ice Age of Europe. Whereas in the preceding epoch considerable differences occur in the character of sedimentation between the northern and southern areas the Diluvial sediments are very similar and extend from the Lake of Galilee southward to the Dead Sea clothing the steep scarps of the Ghor with terraces which extend around and south into the Wadi Araba area.

Near the scarps where the wadis have carried down detritus from the hills the sediments consist of conglomerate, pebble beds and clays extending into the basin as clays and loams. The early dessication of the water caused the precipitation, first of calcium carbonate and finally also of gypsum. Winter rainy and drier summer seasons must have existed as to-day for a large portion of the deposits consist of alternate thin layers of Calcium carbonate and silt followed by gypsum. These beds near the Dead Sea show distinct terraces which stand at varying heights indicating definite periods of dessication of the waters of the old lake. That which starts near the Jericho Road is 650 feet above the Dead Sea and slopes to 550 when there is a rapid descent with steep slopes to 500. The second terrace slopes gradually to below 400 with steep slopes to 250 while the third slope reaches 150 feet above with steep slopes to Dead Sea level. If the total thickness is taken at 400

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feet and the average thickness 1/10 inch the period for this portion of sedimentation would be about 50,000 years.

The Jordan shows a terrace near the Dead Sea 2 to 3 metres above its present level, another about 10 metres which is poorly defined and is probably part of the extensive flats below Ain Hajla. The upper terraces bordering the rift fault scarps are largely covered with recent alluvium washed down from the hills.

A definite clay formation occurs a little above present Dead Sea level which probably extends upwards towards the hills and is exposed in places near the Jordan. It gives rise to many water seepages. South of the Dead Sea the Diluvial deposits consist of loose sand and calcium carbonate which form steep cliffs 200 high and are quite impassable. A similar clay bed occurs at the base, also producing many springs e. g. Ain Arus.

CHAPTER III.

TECTONICS.

The most important structural feature of Palestine is the great complex anticlinal fold which forms the main ridge of the country. There is every evidence that emergence from the sea began towards the end of the Cretaceous and continued with irregularities into or through the Eocene period. Later, large areas subsided, their boundaries now being marked by faulted monoclines. Portions of the subsided area on the Mediterranean side were covered by beds of Miocene age and in the Dead Sea-Jordan trough region by deposits which may be of Pliocene or earlier age.

The higher portions of the ridge comprising, western Judea and eastern Samaria is a simple arch with mostly low dips to east and west. To the south-east are further folds which include the great dissected anticline in the Kornub area. On the north-east side these folds terminate in the west rift fault. The central vault however passes through the country to the Baisan plain. Its flanks are destroyed or affected by faulted monoclines one of which starts near the Mount of Olives and passes through Ain Farah and east of Ain Auja again merging in the eastern flank of the Wadi Farah anticline. The general level of the country is depressed over 1000 feet and the downthrow in the centre is over 2000 feet. On the height of Kilia (2000 feet) east of Tayebeh one can view the expanse of Senonian chalk country stretching down to the Jordan valley.

On the western side of the central ridge a similar faulted monocline starts south of Artuf running through Bab el Wad thence extending in a steep monocline through Beit Ur el Fokka, Um Suffah to Nablus and disappearing in the western flank of the Wadi Farah anticline.

West of this monocline the topographical features of the country west and north-west of Nablus are produced by gentle dips which carry the Eocene beds from a height of 3000 feet at Mount Ebal to not many hundred feet altitude in the Tulkaram District. The alluvial plain west of Tulkaram and at Kerkur is underlain by bituminous limestone which appears to be of Senonian age and the position of any existing faults must be more to the west. Coral limestone outcrops along the railway one kilometre north of Tulkaram which corresponds with the evidence of the shelly sandy beds that the Pliocene sea washed the scarp of the Tulkaram hills.

A strong monoclinal fold which forms the west flank of the Hebron anticline goes south from Hausan, Nahalin, Terkumieh producing magnificent hill scenery with very steep slopes. The fold takes the place of the Bab el Wad-Artuf fault (which dies out ten kilometres to the south) in preserving the structure of the country. To the west of the fold occurs the great expanse of chalk rocks of the Shaphelah which have yielded fossils of Senonian, Eocene (Beit Jibrin) Miocene (El Kubeibeh). Within the ridge itself there are none but minor faults. East of Hebron and Yatta is another great monoclinal flexure running in a N.N.E. direction.

The sinking of wells in the Ramleh District which is largely covered with sand has revealed, one kilometre south-west of Ramleh, limestone underlain with blue clay to 50 metres (not penetrated) containing fossils of Miocene age (Leipidocyclina etc.). In the Ludd area the drill penetrates clay beds unfossiliferous at from 85 to 150 metres encountering below chalk (Senonian) hard limestone or dolomite (? Eocene or Cenomanian) but 3 to 5 kilometres to the west at Sakia the clays (160 metres not penetrated) yield shells of Pliocene age, At Sarafand blue shelly clays were encountered to 900 feet (not penetrated) and at Bir Salim

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200 metres which contained shells similar to the Sakia well. Further north at Kakoon blue clay was encountered to 90 metres. The fault appears to pass from here south near Ras el Ain, east of Ludd and Ramleh and southward in a direction at present unknown. East of this line is an old land surface indicated by both the existing exposures of Senonian and Eocene rocks and the varying depth of the wells and the strata found. The sea during the period must have covered a large part of the area (post Bab el Wad movement) as clay beds occur along the old wadis and are well exposed near Artuf on the north side of the Wadi Surar. The presence of the thick shelly clays (? Pliocene) indicate further movement on the hidden fault line which allowed further deposition. Above the shelly clay bed is a sharp division where the sands from the Nile commenced depositing along the Coast of Palestine. These later beds themselves are now at various altitudes: Beersheba 300 metres, Dhenabbe 100 metres, Sarafand (altitude 130) to 430 feet below the Surface.

These varying altitudes and the occurrence of gypsum beds on the west of the hills (200 feet) south of Gaza points to considerable elevation with some folding within recent geological periods followed by succesive marine and fresh water and wind action in producing the thick deposits of silt and sand occurring in south-west Palestine.

The geology of northern Palestine is too little known to state all the tectonic deatiis that have resulted in the present topogarphy.

There appears to have been a main arch embracing Carmel — Um el Fahm area to the south-west extending north-east through the Nazareth hills to the hills around Tershiha and Jebel Safad. On the western side no Eocene beds have been discovered and the general occurrence of Eocene beds on the eastern flank would correspond with a sea extending from this to the Judea ridge. The Carmel-Safad anticline has now been largely broken up by east-west faults marked by the plain of Esdraelon, the Acca Plain, El Buttauf and the Jebel Safad fault. The fringes of these "Sunken areas" are frequently bounded by sharp flexures on upthrow side; Tabor and Hermon both show antictinal features. The main fault of Carmel is however in a north-west direction but it turns south-west at Makraka (Elijah's place of sacrifice) and with the monocline of Um El Fahm produces the low intervening chalk country of Er-Ruhah. How far the down-throw of the Er-Ruhah block and subsequent faulting is connected with the formation of the Esdraelon basin is not very clear. The basin contains 2 to 20 metres of alluvium underlain by 30 metres of fresh water limestones containing Melania tuberculata, below which is an unknown thickness of red clay which bore holes Jedda 160 metres, Afula 110 have failed to penetrate. The position of the limestone strata indicate sagging of the beds since they were laid down: base at Jedda 350 feet, Ain El Beda 250, Afule 50, corresponding with the late rift faulting which emptied the lake.

The history of the rift faulting requires more study before it can be definitely unravelled. The work of Blanckenhorn has already indicated the age of freshwater limestone as Upper Pliocene and older beds are exposed in the Tiberias-Melhamiya area; the gypseous salt shales and sandstones of Jebel Usdum, El Lisan, El Utlak are highly folded and faulted, facts indicating that prior to the main rift faulting which was certainly later than the upper basalt flows, a basin or basins existed in the Jordan-Dead Sea area. That there was probably division in what later became the trough is indicated by the different character of the sediments in the Beisan-Galilee basin and those south of Farah-Nahr es Zerka drainage system. In the surrounding land area the highly developed drainage system of the Zerka and the alluvial flats above the Farah sources indicate approach to a peneplain surface which has been since cut into by streams rejuvenated by later rift movements.

The rift faults are by no means continuous. The greatest downthrow as well as the longest faults are in the Dead Sea area and this is true of either side. The strata on the eastern side are however at a much greater altitude than on the western side with a consequent exposure of 2000 feet of older strata (mostly Nubian sandstone) the age of which remains in considerable doubt except for some lower exposures of limestone in which Cambrian Trilobites have been found, and in the Paleozoic beds described by Blanckenhorn to the south. In the Nahr es Zerka the upper 1000 feet are yellow and red sandstones with some sandy shales in the middle carrying plant remains which are now considered to be Lower Cretaceous and below these are oolitic calcareous beds with fauna of undoubted Jurassic (Bajocian) age. In the lower sandstone beds of the Wadi Hesban found fauna of Triassic age. Along the Palestine main fault nothing older than Cenomanian has been found. The dip of the strata varies considerably. In some sections there is a continuous gentle dip towards the basin but in the mid section especially on the

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eastern side the strata are often horizontal or dip away from the rift. These dips partly result from the original folds which the main faults have cut through at an angle. Dr. Willis claims that the folded chert and associated limestone beds east of Marsaba showing definite reverse dips indicate compressive forces of late rift age. Corresponding features are seen in the chert beds and sheared chalk above Ain Kelt. The folds in the early Dead Sea (Usdum) beds are certainly of later rift date; at Ed Draa they may be mostly due to drag and at Jebel Usdum to upthrust of the salt body. The impregnation of the sandstones with oil and bitumen from south of Ed Draa to the Zerka might also be explained as resulting from overthrust along the main trench.

In the Kornub area there occurs a series of steep monoclines in step or zigzag succession of which the principal are the Magrun, the Hathira (Kornub) and the Hadira monoclines. They consist of a series of angular folds in the strata which produce a difference of 2000 feet in the altitude of similar beds. The remarkable feature of this area is the existence of sandstone beds presumably of Pliocene age—at Kornub and Zuweira 1800 to 2000 feet, Ain Hosb—200, Jebel Usdum—600. The elevation is distinctly connected with the steep monoclines in this area.

The length and steepness of these sharp bends in the strata is such as to make the passage to the hills one of considerable difficulty and the routes are known as Nagb (ascents). Their direction is here nearly south-west and they flatten out rapidly and with a quick but gentle reverse in the dip until the next fold. The last (Hadira) monocline gives place to a long stretch of chalk with a low dip to the east and the beds pass below the sandstone west of Hosb without further structural feature. Hence the depression is here not produced by a main fault but a series of folds. The type of structure and the elevation of the sandstone beds noted require a more ample theory than the simple graben to explain the movements.

North of the Dead Sea the main faults turn away from the rift and die out starting again further north; that on the west reappears near Jebel Kuranthal (Mount of Temptation) and this also dies out in a stretch of 10 kilometres but a great faulted monocline having its origin near the Mount of Olives creeps north-north-east past Ain Farah below Ain Auja northward. Here the beds on the upthrow side turn completely over and reverse showing again distinct indication of pressure associated with the rift movement. This faulted monocline appears to merge northward into the great arch of the Wadi Farah which carries the Eocene beds right into the Jordan valley where they disappear below the younger sediments. The exposure of Jurassic beds on the Transjordan side shows the only fault in this portion of the rift.

Northward the north-south faulting is less evident and the forces which brought about the repeated east-west faulting are evidenced by Esdraelon, El Buttauf, Jebel Safed resulted in the east-west extension of the sunken area and consequent formation of the extensive inland lakes which surrounded the present Galilee basin. The later rift faulting has exposed the greatest thickness of these extending from Baisan to Lake Huleh. These beds which were in their later stage covered partly by ash and basalt flows now stand at from 1000 feet above sea level to - 680 in the Sea of Galilee where they have been faulted below the lake.

The heights of the recent deposits of the coastal area indicate considerable differential movements in the Mediterranean area. The shelly limestone of Jaffa-Tel Aviv area are unpentrated at 45 metres, at Bir Salem 70 metres below the surface; there is a gradual rise to the south-east until in the Beersheba area Piocene shelly limestones occur at 900 feet altitude. The age of these is considered by Blanckenhorn as Pleistocene but there appears to be here two series of beds corresponding with the calcareous and the sandy conditions of sedimentation.

Some slight flexuring has taken place for the sandstone ridge along the shore line from Casarea to near Carmel Point possesses anticlinal features, the plain between the ridge and the hills being synclinal and there is a strong dip of the limestone of the hill scarp.

Though there are no basalt outflows along the rift fault west of the Dead Sea the occurrence of hydrogen sulphide brines similar to these of Tiberias point to the existence of basaltic magmas in depth.

The important movements connected with Palestine's present topography are therefore (a) recent re-elevation of the arch connected with the steep monoclines and (b) further depression of the trough at the close of the Pliocene Period. That the elevation of the land and the outpouring of basalt was prior to the last and main rift movements is demonstrated by the faulting down or drag of the basalt beds into the rift. The evidence of a connection between the uplift and the invasion of the strata with the basalt magma is mainly confined to the north where in Esdraelon, El Buttauf, Galilee and Huleh extrusions of basalt have occurred along faults in these regions of collapse or differential movement.

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CHAPTER IV.

UNDERGROUND WATER

GENERAL CONSIDERATIONS.

Most of the water supplies in Palestine are derived either from springs or wells.

The water problem resolves itself into two divisions; first—supply for inhabitants and cattle, second—water for irrigation purposes.

The first part of the problem is most serious in the Hill Country. A survey of the that area shows that wells are comparatively rare particularly in Judea. Villages have been built almost invariably where springs existed and have gradually grown according to the amount of water and agricultural conditions. Jerusalem is exceptional; Ophel depended on the spring of Silwan (Ain Sitt Mariam) but later the city grew beyond the capacity of the local springs and water was brought from a distance by gravitation in channels along the hill contours from the springs above Bethlehem and Arrub. But there are many areas particularly in the chalk country where neither springs nor wells exist though the rainfall may be and is often sufficient to produce good crops. The difficulty, was partly solved at some remote period by excavating cisterns which were rendered impervious and the winter rainfall collected in them for future use. Often a village has been built by preference possibly for health reasons and advantage of site in such a position rather than near a spring.

The report of the Department of Health shows that at the present time the supplies of water in the Hill Country are limited and inadequate in most villgaes and centres of population. This may seem strange when it is remembered that the population in the time of Israel was considerably greater than it is todly and may be due to lesser rainfall or possibly to the fact that the population is becoming centralised and requirements greater.

There do exist in fact many large springs which are used chiefly for irrigation purposes such as Ain Arik, Ain Karim and Ain Bittir. Their use for other villages or towns would be expensive both on account of compensation required and generally the distance and height which the water would have to be piped. The cessation of these irrigation cultivations in the hills is not, in any case, desirable as they are generally a necessity to the life of the local community.

It might be thought that the problem could be solved by sinking wells but here one is faced by a geological adversity in which the structure is almost a simple anticline certainly faulted and all the water tends to drain east and west. This disavantage is augmented by the rocks being generally so full of fissures and channels and impervious beds comparatively rare that the drainage is mostly vertically downwards, particularly in Judea.

In the northern area, which is mostly chalk, impervious beds exist and the structures are more suitable for holding water. Wells are therefore not infrequent.

The following rough general data may be of interest with regard to future developments.

(a) From Jerusalem south and beyond Hebron the area in which there is an effective rainfall of 50 c/m may be taken as at least 50 kilometres north to south and 20 kilometres east-west. It is probably considerably more. The amount of water falling on this area is 1/2 of 1000 million M^3. Supposing one half is lost by evaporation and 20 wadis deliver for 10 days 10 millions gallons a day each to the lower plains and the springs of Ain Fescha 25 million gallons per day, Ain Jide springs 10 millions we arrive at the following data:

Rainfall	500,000,000	M^3 per annum
Loss by evaporation	250,000.000	
" by surface drainage	10,000,000	
Ain Fescha & Ain Jide	60,000,000	
Other springs	10,000,000	
Balance unaccounted	170,000,000	M^3

or say 100,000,000 gallons a day.

There are no great springs to the west; the actual balance must drain westward first through the chalk strata where exist many wells and then through coastal sandstone to the sea.

South of Hebron there are no large springs either westward or towards the rift, and it is not known at present where or how the discharge of the enormous rainfall of the district is made.

Jerusalem to Kusah beyond Khan Lubban.

Effective rainfall of 50 c/m.

Over length 40 kilometres — width 40 kilometres.

Rainfall	800,000,000	M^3 per annum

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Loss by evaporation	400,000,000
" by surface drainage	10,000,000
Eastern Springs, Ain Sultan, Ain Duc, Ain Auja	45,000,000
Western springs, the Auja	250,000,000
Balance unaccounted	95,000,000 M^3

The unaccounted balance in this case is less and the proportionate amount much less. The figure for Ras el Ain (Auja) is that given by the Rutenberg Engineers as $8\frac{1}{2}$ M^3 per second which is certainly not over estimated. The greater yield of the springs is probably due to widespread impervious beds which underlie the area; there is a simple gentle anticline faulted at either end and the strata open to let out the water whereas in the previous case the west side is closed by chalk, marls and clay beds.

Samaria cannot be traced so simply. The structure is complicated. The Farah springs give about 25 million gallons a day from a comparatively small area of Eocene rocks. Then the springs of the Jordan (Beisan Area) are very large, probably 50 million gallons per day mostly from the Eocene-Senonian chalk beds. The area is $40 \times 40 = 800$ million M^3 rainfall and 180 million M^3 is delivered by springs on the east side.

In Western Samaria the springs are few. Some of the underground water probably passes to the Auja as already mentioned but mostly seaward through the sandstone formation as shown by the swamp areas.

Ain Kurdaneh passes 150,000 M^3 a day and drains probably largely from the sunken areas of El Buttauf. In this area the proportion passing underground is probably greater than in other parts of the country. The area is swampy in winter but the water in the well at the drainage end sinks to 14 metres below ground in summer.

There are therefore considerable differences between the rainfall and outgoings but the character of the rainfall seriously influences the underground supplies. For instance with light rainfalls the springs in winter remain dry or do not recover nor do the wadis pass water until heavy rains occur showing that the loss by evaporation may be almost complete under such conditions.

Again the larger springs decrease less rapidly than the smaller ones in the hills showing that the head of water may be considerable but the loss in height of the saturated water level is probably only from 10 to 20 metres per annum.

The curve of the water table under the hills is a question that has not yet been solved. In Judea, south of Jerusalem the drainage of Ain Fescha at-1300 feet must cause a steep dip in the slope.

The Nubian Sandstone has been a great attraction to oil geologists owing to its porosity and consequent capacity for storing petroleum. It is also an attractive feature for water for it probably lies at sea level below Jerusalem or 1500 feet below the Wadi Surar at Kalonia. No springs of any large size are however definitely known to issue from the Nubian Sandstone but most of the structures where these rocks are exposed are not very suitable for the storage of water. In the Palestine hills this horizon may however correspond with Finch's Static Zone and yield little water. Of springs in the lower beds of the Upper Cenomanian strata most of them issue at some small height above their junction with the lower Cenomanian. Water might therefore be found at several horizons before the Nubian Sandstone is reached.

In the irrigated areas of the Coastal plain very little of the water of the large springs is at present being utilised; domestic supplies for villages are generally obtained from comparatively shallow wells. It has been found also more convenient to sink wells at small cost and pump the water for irrigation of orange groves than to have a general system for using the water of the Auja, but a scheme is now being considered to utilise this source.

Plans are also in progress for using to some extent the waters of the Shuneh (Benjamina) area and those of the Kurdaneh. In the Beisan area irrigation is used mostly for cereal crops the yield of which would probably be uncertain without the use of the irrigation water; the question of producing several crops in the year does not seem to make much headway.

The employment of the water of the Jordan which is the biggest source, running to waste amounting to between 1000 to 2000 million gallons a day and the irrigation by these waters of the upper terraces, consisting of good soil washed down from the hills covering areas on each side of the Jordan of 200 square kilometres, has not yet been seriously considered.

The various districts will now be examined separately in some detail in regard to underground water supply:

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A. THE HILL COUNTRY:

JUDEA. The hill country of Judea is a mass of limestone at most 3000 feet thick in those sections that affect its water supplies. As already stated it varies from soft chalk to hard limestone of which the latter may be partly or wholly dolomitised. Neither one type nor the other appear to have much influence in producing springs unless beds of clay occur below. That these should occur in a mass of limestone mostly of deep sea origin is perhaps remarkable. The most definite horizon is that which occurs in the fossiliferous limestone beds which carry Acanthoceras mantelli and being overlain by the Mizzi Yehudi perhaps the most highly dolomitised and porous beds of the series it becomes one of the most important factors in the water supply and consequently the life of the Cenomanian Hill country which comprises Judea.

Unfortunately the clay bed is not always present; it was possibly laid down by marine currents and as its age approximates the tuffs of the Carmel region its origin may be connected with it.

The lower series of rocks also have occasional springs but they are not so well defined. Springs occur near the base of the lower dolomites or in the Strombus limestone below. Although large tracts of chalk rock occur in Judea particularly the Judean waste one may trace the whole area of the Wadi Nar as an example where sections of 500 feet of chalk rock occur down to the Turonian rocks at Mar Saba without finding a single spring. On the Road to Jericho there is one exception at the base of the hairpin bends where occurs the Apostles spring (Ain Haud) of small dimension. A similar waterless condition has already been mentioned with reference to the chalk area of south-eastern Judea.

The springs in Judea are as follows:—

		General Maximum gallons per day	General Minimum gallons per day	Geological formation	Remarks
JERUSALEM					
Ain Sitt Mariam	(Brackish)	250,000	50,000	M. Yehudi	
Bir Ayoub	(do)	Occasionally overflows in winter		do	
Ain Karim	Sweet	250,000		do	developed by channels (Roman)
Ain (Kh. el Los)	"	100,000		do	
Abu Ghosh	"			do	
Ain Farah	"	250,000	200,000	do	Jerusalem Supply
Ain Fuwah	"	500,000	nil	Turonian	Intermittent
Ain Kelt	"	1,200,000	1,000,000	do	Irrigation
Ain Urtas	"	200,000	80,000	M. Yehudi	Irrigation
Ain Attar	"	} 100,000			
Ain el Ferajeh	"				
Ain Saleh	"				
Bir Oneh	"				
HEBRON.					
Ain Arrub	"	600,000	50,000	M. Yehudi	Jerusalem Supply
Nahalin	"	100,000 }	to nil		
Ain Sirai	"	100,000 }		do	
Ain Ankar	"	15,000		Strombus limestone	
Zerka springs	"	20,000 }			Hebron Supply
Hebron springs	"	20,000 }		M. Yehudi	
RAMALLAH.				Strombus limestone	
Ain Arik	"	250,000			
" Ras el Wad	"	100,000	do	do	
Tireh	"	20,000		M. Yehudi	
Ramallah springs	"	10,000		do	
JERICHO.					
Ain Sultan	"	7,000,000	5,000,000	Senonian	Partly dissipates used for irrigation
Ain Duc	"	10,000,000		M. Yehudi	do
Ain Auja	"	10,000,000		do	Used for irrigation
Ain Feschka	brackish	25,000,000		Middle Cenomanian	Salt contamination from Dead Sea

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Wells. A ridge of limestone of the limited extent of Palestine hills does not provide ideal conditions for searching for water by means of wells; particularly is this the case with regard to Judea where in the first place closed basins hardly exist and secondly the impervious stratum is not always present or cannot be depended on to hold up the water. Even in respect of deep drilling to 1000 feet the prospects are not good as is indicated by many of the deep wadis as for instance the Wadi Surar that the railway travels along where no springs exist at the level of the wadi.

In the Hebron District shallow wells are quite common; these have been sunk everywhere above the clay bed associated with the fossiliferous limestone. The conditions here are rather unusual for wells are obtained at almost any position of the slope, usually at depths of 8 to 12 metres, with quantities up to 1000 gallons a day.

Around Abu Ghosh wells are obtained on the dip slope of clay overlain by dolomite. In this case the only wells are situated on the drainage end of the slope. The outcrop is partially sealed by the clay soil.

Ramallah is situated on an almost isolated flat hill top where a clay bed exists under the surface rock (a rotten dolomite). The bed has almost a basin shape and wells are obtained at all positions in the upper rock.

Attempts to supply towns by means of wells in Judea in the area of the Cenomanian have not so far met with much success. A trial test was made at Hebron in an almost closed structure starting below the clay bed horizon; the bore was carried to 75 metres. Small shows of water only were obtained.

While development of water supplies by means of wells either past or present has been attended with only small success storage of water by cisterns has been very widespread. Particularly is this the case in chalk areas where the rock is easily excavated. Cisterns exists all over the Judean wilderness and the bedoiun depend on them very largely for watering their flocks. Modern cisterns are pear shaped excavatious lined with cement; it is supposed that the ancients used hydraulic lime for that purpose. The cost of construction is comparatively small.

The possibility of obtaining underground water in the Judean waste has not yet been seriously considered. The top formation is of porous chalk but the slopes have few or no springs. The structures, however, many of which have synclinal features are not unpromising but the position of the water horizon would have to be determined by boring and might be deep. The outlet of the Feschka Springs on the Dead Sea is Upper Cenomanian; the horizon may correspond with the argillaceous limestone.

The Roman methods of developing small seepages by means of underground channels is one that appears to give the best results at small cost. Many of these old works have collapsed as in the Arrub area and west of Ain Karim and might well be reopened.

SAMARIA.

Nablus. The central and high part of Samaria is largely of Eocene age and most of its springs, some of which are very large, arise in the chalk beds of this formation. The fossiliferous Cenomanian formation with its clay bed is not evident here. In the eastern section it is hardly recognisable and no important springs occur in connection with the dolomite rocks which are probably about this age.

The main clay bed in this area occurs above the flint breccia. This formation can be traced over a large part of Palestine and is known to be Senonian (Campanian) age. It may be connected with the early uplift to the south. The clays possibly came from the drainage of these newly raised areas to the south-east. The chalk beds which overlie it vary from 100 feet at el Arak to 300 feet at Rafidia and in the Wadi Farah.

Nablus lies in a gorge cut in a synclinal structure by an old water course which at some date prior to the rift faulting carried a large part of the drainage westward. Springs arise at different levels of the town area from the clay chalk formation and from the middle Eocene chalk beds to the south.

The northern section of the Eocene rocks are affected and carried down by a steep north-east dip which meets the monocline of the Upper Farah the steep dip being suddenly reversed against the hills around Tubas. The Eocene beds deliver a large part of their water storage in this area, an amount averaging over 20 million gallons a day. At the present time it cannot be said that any great use is being made of the large quantity of water.

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Some of the more important springs are given below:

Spring	Qnantity gall. per day	Height Approx. feet	Geological formation	Remarks
Karion	170,000	1800	Upper Eocene	Nablus water supply
Ras el Ain	125,000	1900	do	do
Ain Rassa	50,000	1800	do	do
				(Overlow used for irrigation)
Ain Dufna (Balata)	100,000	1700	Lower Eocene	
Ain Kusab	100,000	1600	do	Irrigation
Ain Askar	150,000	1700	Eocene chalk	do
Ain el Beda	10,000,000 to	600	do	Part for irrigation
Farah Spring	15,000,000			
Ain El Farah	8,000,000	500	do	do
Ain el Duluk	1,000,000	600	do	do
Ain Harun (Nakureh)	150,000	1700	do	Several villages
Ain es Sherkieh	100,000	1800	do	
Ain es Sur	100,000	1700	do	
Ain Arak	50,000	1700	do	

In the lower Cretaceous Sandstone the only important spring occurs at the end of Wadi Maleh. The exposed structures of the Wadi Farah are not suitable for the production of springs. Associated however with the tuffs and basalt of this series is Ain Maleh. (hot spring).

The possibility of small wells in the Eocene-Senonian chalk rocks of this area is considerable. Wells have been sunk in some parts as at Till and Kusein on the dip slopes just above the clay marl horizon.

Wells giving small supplies might be considerably developed in certain areas of the Nablus District particularly on the slopes or in basin structures overlying the clay marl beds. Experimental drilling is to be tried in the near future to develop water supplies where they are not existent.

JENIN.

In the Jenin District there occur sunken areas such as the Merj el Ghuruk the formation of which is correlative with the Plain of Esdraelon. Others, such as the Sahel Araba are doubtful and may be due to the softness of the chalk beds and resulting rapid denudation.

This area is one of thick chalk capped in the higher parts by nummulitic limestone with a basement of hard dolomitic beds. From Tel Dothan along the main road to Jenin water occurs in wells and springs at shallow depths and at altitudes of 1000 to 700 feet; large springs discharge around Jenin. The chalk beds here are practically unfossiliferous. The chert breccia bed dies out at Tel Dothan but it is assumed that the clay bed persists and is the cause of the springs and that they are not due to anything of the nature of a permanent water level. The upper Jenin spring gives a yield of about half a million gallons a day and the lower spring which issues from a point under the old town, about one and a half million gallons a day. Several wells exist along the main road notably the old Crusador well above the upper spring and there are several others extending along the road as far as the track to Arrabeh. Recently a well was succesfully drilled for water at Jenin and it is proposed to try other bore holes in the district.

BEISAN.

The important section of Beisan is the area of Eocene-Senonian Strata of the Mts of Gilboa. At the base of these hills many springs arise, the most important of which are Ain el Asy, Ain El Jemain, Tawahin el Hasanieh. Others occur along the northern fault scarp and supply many of the Jewish colonies.

Spring	Quantity	Geological horizon	Height
Ain Harod	1,500,000	Cenomanian	- 120
Ain el Asy	25,000,000	Eocene Senonian	- 316
Ain el Jemain	15,000,000	do do	- 300
Towahin el Hasaniyeh	12,000,000	do do	- 366
Ain es Sakkneh	5,000,000	do do	
Ain el Madua	3,500,000	Pliocene limestone	- 400
Ain el Humra	4,000,000	do do	- 530
Ain el Nuseirah	1,500,000	do do	- 400
Ain el Fatur	250,000	do do	
Ain el Beda	1,000,000	do do	
Ain el Maleh *	5,000,000	Lower Cretaceous	

* The area of the Beisan Plain is about 130 square kilometres a large proportion of which is covered with soil and suitable for arable cultivations. The height of the springs is such that the whole of the water could be used for irrigation by gravitational methods.

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CARMEL.

The Cretaceous rocks of Carmel show that water horizons are connected with (a) the volcanic ashes and basalts (b) the badly defined Senonian-Turonian chalk flint beds (c) Cenomanian dolomites.

In true Carmel area the western part is largely supplied from the ash beds. In the part south of Carmel, the flint chalk rocks of Belad er Ruhah are the source of a great series of springs which flow both east and west. These rocks which have a thickness of 1000 feet and are soft chalk from base (marked by hard dolomites) to the top (marked by thin flint beds, or large flint nodules or lenses) which contain as far as examination goes neither impression nor casts of fossils.

Spring	Quantity Gall. per day.	Geological horizon	Remarks
Ain Saadah	1,500,000	Cenomanian	Saline
Ain el Sir	25,000	Senonian	Good
Shellaleh	100,000	Cenomanian tuffs	Good small in summer
Numerous spring of Belad er Ruhah east & west		Turonian Senonian Chalks	Good
Shune	3,000,000	" "	30 parts Chlorine per 100,000
do	2,000,000	" "	40 " "

This area is one in which considerable development has been made in obtaining water by shallow wells. In the sandy limestone of the coastal ridge fresh water is found at about sea level. Considerable work also has been done in the older rocks. Around Haifa, water is obtained in the dolomite limestone rocks at about sea level. The quality of the water varies considerably according to the position of the well in relation to the Carmel fault.

On the western side the wells are mostly obtained in the basalt or ash beds of Cenomanian age.

In the wadis of Belad er Ruhah both of the eastern and western drainage numerous wells exist.

The following list give some of the important wells in ash bed area:—

Place	Height	Geological horizon
Ikzim	300	Ash beds
Shefaia	250	Basalt ash bed
Umm Zeimat	400	dolomites below
Makraka	1100	ash beds
Ararah	650	do do
Um el Fahm	1400	do do
Anin	1100	do do

NAZARETH,—ACCA.

The Senonian-Turonian chalk of the Nazareth area also gives rise to many springs. The springs of Mary, Er Reineh, Kefr Kenna, Ain Mahil Yafa ,and Malul all belong to this formation and due to a clay bed near the base of the chalk. Most of them are small but last throughout the year.

Further west belonging to the same formation are the springs of Ras el Ain, the wells and seepages of Shefa Amr area.

The great springs of Kurdaneh doubtless derive the bulk of their water from the dolomite beds of the great sunken area of Sahel el Buttauf, though the overlying chalk must also contribute considerable quantities.

The springs of the Kabre area issue from the dolomite series.

The following is a list of springs in the above areas.

Name	Quantity Gall. per day	Geological Horizon	Remarks
W. Kurn	5,000,000	Cenomanian	good quality
Kabre Springs	4,000,000	do.	do.
Ain Suffurieh	250,000	Senonian-Turonian	do.
Ras el Ain	1,000,000	do do	do.
Well of Mary.	50,000	do do	do.
Reineh	50,000	do do	do.
Kefr Kenna	50,000	do do	do.
Ain el Mahil	250,000	do do	do.
Kurdaneh	30,000,000	Cenomanian	60 parts of chlorine per 100,000

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The detailed structure connected with many of these springs has still to be worked out but of considerable importance is the basin formed by the upturned edges along the fault scarp boundary of the Nazareth hills on the south and on the north by the sharp flexure which passes through Seffurieh. The opposing edges almost produce a trough with a main under ground drainage along a direction following the W. Melek. The principal discharge in the higher level is at Ain Seffurieh where the clay beds come to the surface giving rise to springs and much uncontrolled water. Further west the pressure of water brings the water to surface at some height above the clay beds e. g. Ras elAin. The interesting feature of this water stratum is the varying height of its discharge which is probably due to a general absence of fissures and a porosity (about. 13 p.c.) which only allows a slow fall of the surface of percolation.

Wells have been sunk from very ancient times at Shefa Amr and many of the wadis in the chalk formatiom of the area. Development of water by wells here would be a very easy matter.

Wells also occur along the Wadi Melek and are doubtless from the same horizon as the spring. Further east wells are obtained in the dolomite formation of El Buttauf. This water horizon is lower than that of the Melek and Shefa Amr. The thickness of the water bearing stratum and the position of the impervious bed is at present unknown. No doubt this is the main source of the Kurdaneh springs. Development of water supplies by wells in this area appear to have good prospects.

In the Nazareth area water supplies were developed by the Romans by tunnelling the chalk above the clay beds on the dip slopes above Reineh. These have recently been reopened to augment the supplies of Nazareth town.

TIBERIAS SAFED.

The basalt covered fresh water limestone gives rise to small springs around Tiberias. Springs rise in the basalt of Sarona above Yemma, Meshah and are due to a layer of clay beneath. The spring of Jewish Migdal also rises in basalt. The springs of Ain el Surar and Hattim rise in the flinty limestone (probably Turonian and the springs around Tagbah in Eocene limestone. The level here of the latter is 600 feet below Mediterranean which infuences the flow.

In the Safed area springs arise in the Eocene limestone and the underlying Senonian chalk. The latter gives the larger amount of water but the greater height of the upper horizon gives them importance for supply by gravitation as at Safed.

West of Safed much of the strata is of Cenomanian age and a considerable number of springs flow from these and pass into Plain of Migdal.

The springs along the main west rift fault in the region of Huleh are also numerous and some of them of considerable flow. In this section occur limestone of age varying from Pliocene, Eocene, Senonian, Upper and Lower Cenomanian and all but the latter give rise to springs.

The following are some of the important springs.

	Spring	Quantity	Geological formation	Remarks
	Ain el Mughrah	100,000	Basalt	
	Ain el Bijan	100,000	"	
	Ain el Mady	100,000	"	
	Sarona	150,000	"	
	Hattim	500,000	Turonian	
Migdal	Ain Surar	750,000	"	
Migdal	Rubidiyeh	2,000,000	? Cenomanian	
Migdal	Migdal	1,000,000	Basalt	
Migdal	Wadi Amud	1,000,000	Cenomanian	
	Ain Melaleh	5,000,000	"	
	Ain Jahulah	10,000,000	"	
	Ain Balata	3,000,000	"	
	Ain Sukur	3,000,000	Senonian	
	Ain Ruheineh	1,000,000	Eocene	

Ain Banias is stated to be very large more than 20 M^3 per second and a series of springs along the slopes make the area one of the main sources of the Jordan and largely the cause of the swamps around Lake Huleh.

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THE COASTAL PLAIN.

The water seepages and springs occurring behind the coastal ridge such as Ain Rubin, Birket Ramadam, Ayun Abu Shewan are generally thought to be considerable but the flow in most of these cases is difficult to measure and may not be as great as is often imagined. Where these backed up waters occur they indicate the position of the water table in the sand beds which is known to be very little above the sea level near the coast and is only slightly higher in most of these marshes.

The area covered by these sandy beds is very great. Between the Auja and the Crocodile River it is about 1200 sq. kms.; with a rainfall of 50cms the amount would be 600 million M^3 per annum. The drainage into the sea is general along the shore and it is a persistent steady flow which however is partly compensated by springs from the higher lands.

*) Orange groves are stated to require 300 M^3 per dunum per year and the amount may reach 500 M^3 that is 500,000 M^3 per sq. km. or about the rainfall of the orange grove. A good well will yield 100 M^3 per hour i. e. 1000 M^3 per ten hour day or 200,000 M^3 per 200 pumping days or the total rainfall for 40 hectares.

It is stated that the water level of the wells in the Petah Tikvah area is falling, and that the required quantity is only obtained by lowering the suction pipes. There should however be a recovery after the rainy season each year. Part of the trouble is also due to the fact that the wells or water bearing stratum become choked. New wells are stated to give satisfactory yields in this area.

Wells must have existed along the coastal plain from very early times but their history is not so well preserved as cases such as Job's well in the valley of Kidron which is 80 metres deep and the wells of Beersheba 20 metres, Tel el Milha 30 metres which belong to Jewish Patriarchal times. The wells of Beit Jibrin are 40 metres.

Modern methods of sinking wells have the advantage of being able to drill deep into the water stratum as against the excavation methed which experienced difficulty in sinking much below the water surface at its lowest summer level. Most of the drilled wells are less than 100 metres and the deepest are seldom more than 200 metres. Greater depths have not been necessary on the Coastal Plain and the question of drilling for water in the Hill Country has not so far been seriously considered owing to the difficulty of pumping from a great depth.

The coastal plain consist of rollings slopes with a coastal ridge which is a very characteristic feature of the topography. This ridge follows fairly closely the present shore line but the height and width differ considerably. At the northern extremity between Cesarea and Athlit it is a hard calcareous sandstone in thick beds which dip east and west with the slope but on the west slope are recent sands.

South from Cesarea to Jaffa the characters differ in that the ridge is covered not only with recent blown sand but passes into unconsolidated sands the lower beds of which may consist of calcareous sandstone and possess all the physical character of sand dune deposits.

The harder formation can be followed south into the Gaza region consisting generally of hard calcareous sandstone covered with fine blown sand but in the Gaza region hard quartzitic sandstones like Sarsen stones occur and these are associated with gypseous beds.

There appear therefore to be three stages of formation; the marine, the early sand dune and the later sand dune all of which are represented in the drilled wells.

JAFFA DISTRICT.

The coastal sand area consists of a belt varying from 7 to 15 kilometres in width. Near the coast the sand with clay beds continue to a depth 30 to 50 metres or even more; where the drill finally enters shelly limestone or calcareous sandstone (Kerkur) ,water freely flows. At the Tel Aviv Municipal wells volumes up to 80 M^3 per hour are pumped without greatly affecting the water level.

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*) Expert opinion on the amount required for irrigation of orange groves varies from 0.60 to 1.50 M^3 per dunum per day; probably 1.20 M^3 should be taken as the minimum. The period of irrigation is 10 days more or less. Actual practice may not conform to the expert opinion.

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The water horizon within five kilometres of the shore is not much above sea level bu the sands pass the water slowly and are so difficult to hold in even by gauze covered filter pipes that it pays to sink to hard sandstone or shell formation at greater depth where the water passes freely.

The depth of sand indicated may continue to a considerable distance back from the shore but it is irregular. Between Sakia and Ludd a grey blue shelly clay reaches the surface which contains shells of Pliocene age. At Bir Salem it is enountered at 80 metres.

In the Jaffa Electric Company's well the altitude is 26 metres the level of the water in the 12" bore is 25.20 and in the 8" bore 24 metres below the surface. Practically all the bores show a slight pressure. In this well the sand continues to a depth of 60 metres then 2.40 sand and gravel from which the 12" water is obtained after which there is a hard black clay for 30 metres then shelly limestone which give the main water.

At Sarafand which is 14 kilometres from the coast the altitude of the well is 159 feet water is struck at 104 giving a head of 55 feet or 17 metres in 14 kilometres. The formation here is sand down to 345 feet when blue clay in encountered.

The wells around Richon appear to give about the same head but the water is encountered in a fine sand (dune sand) which continues for another 10 metres before a formation is struck which will pass water. At Rehoboth the wells are stated to be about 30 metres deep with a height of about 70 metres which if correct, indicates a rapid increase in the slope. The waters of the area discharge above sea level at Ain Rubin. Around the Aujeh the wells show a slight height above the level of the river but this decreases eastward. At Petah Tikvah the wells are about 20 to 30 metres deep which against an altitude of 70 to 100 feet indicates no great head of water.

At Ludd there are many anomalies in the yield and depth at which water is found but this is no doubt due to the underneath ridge of argillaceous sands which occur between Ramleh and Ludd westward to Sakia and beyond also southward to Sarafand where well sections show a steep slope as also it does to the west. This formation contains sufficient clay to make it impervious to water. The abundant shells found in the Sakia well appear to be of Pliocene age.

The following logs give the type of strata encountered.

Depth in metres	No. 1 - Badrani New Well. Tel Aviv Description of samples obtained from Municipal Engineer.
Sea level 0	
0. - 2.5	Sand
2.5 - 4.0	Loose Calcareous Sandstone
4.0 - 5.5	Hard Calcareous sandstone
5.5 - 7.0	Sand (Quartz grains with hornblende)
7.0 - 10.5	Mostly quartz cemented into hard stone with Calcium Carbonate
10.5 - 12.5	do but more Calcareous
12.5 - 15.0	Dark chocolate coloured to almost black clay bed (forms an impervious covering to underneath water bearing strata).
15.0 - 16.5	Soft sandy limestone
16.0 - 18.0	Shelly limestone
18	Shelly limestone
22	Shelly limestone
	No. 2 well Tel Aviv
0. - 0.5	Red clay sand
0.5 - 2.0	Loose red sand
2.0 - 4.0	do
4.0 - 7.0	Sand and Calcareous sandstone
7.0 - 9.0	Clay bed containing sand
9.0	Shelly limestone
11.0 - 75.0	Sandy limestone with Pectunculus & Cardium
11.0 - 95.0	Shelly limestone

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JAFFA ELECTRIC COMPANY.

Boring in old well	
24.00	Old well
	Kurkar (Conglomerate of sand and limestone)
1.20	Water level
36.00	Sand
2.00	Sand and gravel
26.60	Hard black clay
1.00	Red clay
	Red and black clay
3.00	Black clay and carbonised wood.
5.80	Stratified hard sandstone with shells.

Boring "Zafon" for Municipality Tel Aviv

0.00 - 11.00	Sand with limestone
11.00 - 18.12	Sant
18.12 - 20.15	Sand
20.25 - 20.50	Sandstone
20.50 - 21.40	Sand with Kurkar
21.40 - 23.47	Sand with Kurkr
23.47 - 29.76	Sand
29.76 - 29.86	Sandstone
29.86 - 30.06	Sand

ANALYSIS OF WATER.

Name of well	Quantity of insoluble Substances	Quantity of Nacl.
Analysis made on 21.4.25	mg. per litre	mg. per litre
Nordia well	696^{2}	179^{7}
Badrani well	537^{4}	111^{4}
Analysis made on 30.11.24		
Rothschild Boulevard	1016^{5}	392^{9}
Allenby	524^{9}	121^{6}
Badrani	367	50
Nordia	472	122
Analysis made on 11.3.25		
Chlenov Quarter	1394	520
Rutenberg Station	1238	452

JAFFA (CUSTOMS BUILDING)

+	1.94 metre	Kurkur (red sandy loan)
	.08 "	
—	.73 "	Hard Kurkur
—	3.91 "	Sandstone
—	28 "	Hard sandstone with broken shell material
—	33 "	do do do
—	35 "	Very hard sandstone cemented with Calcareous matter
—	39 "	do do do
—	43 "	Hard sandstone with cavities containing yellow sand.
—	45 "	do., more sandy towards base

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The water pumped from 42—44 contained 1.27 per cent Sodium Chloride.

At Bir Salem (Sneller) the well is 9 metres across 26 metres deep. Water is pumped from several bore holes and as much as 200 M^3 per hour is stated to be raised.

The deepening of this well gave the following section:

Red earth and sand	26 metres
Pebbles and sand with water	81 „
Sand rock	3 „
Blue shelly clay	40 „
Shell band	
Blue clay with shells	80 „
	230 „

Most of wells are now excavated by hand to near the water horizon and a bore hole sunk in the base from which the water is obtained by pump suction.

At Herzlia the village well is sunk to 65 metres where it meets shelly limestone which yields abundant water. But many other wells in this area where the underlying rock is mostly hard Kerkur give abundant supplies at 30 to 35m. i.e. the bore hole is sunk 10 metres in the base of the excavated pit which reaches approximately sea level. Further east at Migdal altitude 130 feet, water is obtained at 16 metres whereas at Bir Adas 255 feet only a little water is obtained at 56 metres.

At Wilhelma 105 to 200 feet altitude, water is obtained at 23 to 35 metres the wells being sunk to 46 and 70 metres and an abundant supply is obtained.

GAZA DISTRICT.

In Gaza and district the conditions for sinking wells are similar to those which obtain in the Jaffa area. The depth to the shelly formation is about the same and the overlying sand is largely of the fine wind blown variety.

The constitution and nature of the high sand ridges appear to be of the sand dune character but this may be only the surface formation of the ridge aud the lower portion may be a fold of Pliocene sandstone. The occurrence of gypsum in part of these dune sand covered calcareous sandstone formations certainly appear to indicate a history more complicated than the ordinary dune. Wells however are only sunk in the synclines or valleys and the following example in Gaza is a general type of most of the wells of the district.

0 — 6 metres	Black clay (soil).
6 — 13 „	White sand
13 — 20 „	Yellow sandy loam
20	water horizon (Compact sandstone Calcareous).

Other records showing the depths are given below:

Name of Village	Name of Well	Depth metres	Remarks
Gaza town	Sakiet el Tawabin	24	
do	Um El Lamoun	25	
do	El Marajeh	19	
do	El Hussein	28	
do	Frass	25	
do	Karkash	18	
do	Sh. Nabak	22	
do	El Hakamieh	25	
do	Irfaieh	45	Municipal well
do	El Hai Ali	35	
do	Ijmakieh	22	Municipal well
Huj	Bir el balad	35	
Nejed	do do	26	
Jiyya	do do	28	
Bureir	do do	39	
Beit Jeria	do do	20	
Deir Sneid	do do	12	
Dimra	do do	20	
Nalia	Village well	39	
Jura	Itanin	19	
Hamama	Ali Agha	27	
Julis	Village well	24	
Beit Affa	do do	64	
Ijseir	do do	28	
Baalin	do do	24	
Beir Duras	do do	28	
Mejdel	do do	32	

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Analyses of the water, from the shallow and deep source of the Gaza Municipal well viz 21 and 45 metres is given below. Sandy formations only were encountered.

		Parts per 100,000	
Chlorine	(Cl) ...	18.4	23.4
Hardness	(a) Total	25.2	10.6
	(b) Permanent	7.0	5.0
	(c) Temporary	18.2	5.0
Calcium	(Ca) ...	4.28	1.4
Magnesium	(Mg)	3.03	1.46
Sulphates	(So_4) ...	6.78	5.64
Carbonates	(Co_3) ...	21.00	24.60
	Total solids at 140° C	74.00	77.10
PROBABLE COMBINATIONS:			
	Ca. Co_3	10.7	3.49
	Mg. Co_3	10.48	5.06
	Na_2. Co_3	12.61	33.39
	Na_2. So_4	10.03	8.33
	Na. Cl	30.34	35.92
	TOTAL	74.16	88.19

Many sections in the Gaza District were recorded by Range and are given below:

TINEH, 100 metres west of station.

metres	0.0 — 7.0	Loam with humus
	7.0 — 17.5	Calcareous sandstone with hard beds
	17.5 — 21.5	Sand
		Water level 16 metres, abundant.

TINEH, 1 kilometre south of station.

metres	0.0 — 5.1	Loam with humus
	5.1 — 6.0	Fine sand
	6.0 — 10.0	Chalk boulders
	10.0 — 15.7	Coarse sand
		Water struck at 13.5, abundant.

SAWAFIR.

metres	0.2 — 2.0	Brown loam
	2.0 — 16.0	Grey loam with calcareous concretions
	16.0 — 18.0	Brownish red sand
	18.0 — 21.0	Shelly broken limestone
	21.0 — 25.0	Grey clay sandstone with calcareous layers
	25.0 — 27.0	Coarse sand
	27.0 — 32.0	Dark blue clay with thin sand layers
	32.0 — 35.0	Conglomerate
	35.0 — 39.0	Blue clay
	39.0 — 42.0	Blue clay with sand
		Water at 33 metres, abundant

EL FALUJE.

metres	0.0 — 6.0	Brown loam
	6.0 — 34.0	Sand
	34.0 — 39.0	Sand with hard bed
	39.0 — 43.0	Sand
	43.0 — 47.5	Sand with hard beds
	47.5 — 49.5	Clays
		Water at 43 metres abundant.

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HULEIKAT.

Metres	0.0 — 1.0	Brown loam
	1.0 — 2.0	Grey clay with limestone concretions
	2.0 — 5.0	Red sand
	5.0 — 7.0	Yellow sand
	7.0 — 10.0	Red sand
	10.0 — 13.0	Coarse clay sand
	13.0 — 20.0	Calcalerous sandstone
	23.0 — 36.0	Sand
	36.0 — 43.0	Coarse sand
	43.0 — 59.0	Compact sandstone with hard beds.
	59.0 — 66.0	Coarse sand
	66.0 — 74.0	Gravel
	74.0 — 78.0	Sand
	78.0 — 81.0	Coarse gravel 0.5 to 2 c/m.
	81.5 — 85.0	Sand
		Water at 76 metres, 40 M³ daily.

BEIT JERJA. 2 kilometres south.

Metres	0.0 — 1.5	Sandy loam
	1.5 — 6.7	Yellow sand
	6.7 — 10.5	Sandy clay
	10.5 — 15.8	Yellow sand
	15.8 — 21.5	Fine white sand
	21.5 — 22.5	Coarse white sand
	22.5 — 34.0	Yellow sand
	34.0 — 36.0	Coarse white Calcareous Sandstone
	36.0 — 41.0	Yellow sand
	41.0 — 41.5	Sandy loam
	41.5 — 47.5	Yellow and Calcareous Sandstone
	47.5 — 53.2	White sand
		Water at 42.5, yield, 40 M³ daily.

BUREIR.

Metres	0.0 — 7.0	Brown loam
	7.0 — 13.0	Sandy loam
	13.0 — 31.0	Red brown sand
	31.0 — 46.0	Fine yellow sand
	46.0 — 47.0	Bright yellow sand
	47.0 — 47.3	Grey marl
	47.0 — 51.0	Brown sand
	51.0 — 54.0	Coarse sand
	51.0 — 59.0	Fine yellow sand
	59.0 — 66.0	Coarse gravel and sand
		Water at 57 metres, abundant.

DEIR SNEID.

Metres	0.0 — 18.0	Brown loam
	18.0 — 36.0	Sand

BEIT HANUN.

Metres	0.0 — 0.5	Sandy loam
	0.5 — 1.5	Hard loam with limestone layer
	1.5 — 20.0	Coarse sand
	20.0 — 24.0	Coarse grained Calcareous Sandstone
	24.0 — 28.0	Coarse grained sand
	28.0 — 35.0	Coarse grained sand with boulders
		Water at 28 metres, about 40 M³ per day.

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Kufeikeh. (South).

Metres		
	0.0 — 18.8	Loam
	18.8 — 20.8	Coarse sand
	20.8 — 29.0	Hard clay
	29.0 — 32.0	Sand
	32.4 — 35.8	Sandy clay
	35.8 — 39.0	Loose sand
	39.0 — 48.2	Coarse clay sand
	48.2 — 57.0	Loose sand
	57.0 — 58.3	Sandy clay
	58.3 — 63.0	Loose white sand
	63.0 — 65.0	Loose sand
	65.0 — 66.0	Calcareous sandstone
	66.0 — 67.0	Loose sand
	67.0 — 70.2	Gravel
		Water at 66 metres, about 40 M^3 per day.

Kufeikeh. (North).

Metres		
	0.0 — 11.0	Loess
	11.0 — 15.0	Coarse sand
	15.0 — 20.0	Coarse brown sand
	20.0 — 25.0	Fine brown sand
	25.0 — 36.0	Yellow sand
	36.0 — 45.0	Bright sand
	45.0 — 68.0	White sand
	68.0 — 74.5	Fine white sand
	74.5 — 77.0	Compact calcareous sandstone
		Water at 74.5 metres, about 40 M^3 per day.

Wadi Fuilis.

Metres		
	0.5 — 5.0	Loess
	5.0 — 20.0	Sandy clay
	20.0 — 38.0	Coarse brown sand
	38.0 — 44.0	Bonlders
	44.0 — 55.0	Sand with boulders
	55.0 — 59.0	Large boulders
	59.0 — 62.0	White sand
	62.0 — 77.0	Sand with sandstone fragments
	77.0 — 78.0	Fine grey sand
	78.0 — 80.0	White chalk
	80.0 — 82.0	Grey shale
	82.0 — 120.0	Grey marl
		Small amount of water at 77.

Muharaka. 1.5 kilometre east of town.

	0.0 — 16.0	Loess
	16.0 — 66.0	Sand
	66.0 — 75.0	Sand with hard calcareous sandstone beds
		No water but 1.5 kilometres west at 10 metres additional height water is found at 88 metres.

Ramleh District and the Shaphelah.

The Ramleh District with which may be included the Shaphelah is peculiar on account of the amount of clay and marl which is encountered in most parts on digging for water. To the west of Ramleh the sandy surface formation is often comparatively thin and very

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little water is obtained. Drilling to greater depths reveal grey argillaceous sand or in some areas blue clay but both are equally impervious and useless for water supplies. Near Ludd although similar conditions exist there are several anomalies. A few of the wells such as the Railway well give unlimited quanties of water.

The following bore sections will illustrate these conditions:

Sarafand Cantonment — Borehole No. 1.

0 — 104 feet	Red sand
	Water
104 — 154	Yellow sand
159	Sea level
159 — 228	Grey sand
	Trace of clay
228 — 285	White sand
	Water trace of clay
285 — 288	Pebble bed
288 — 295	Sand with calcareous concretions
295 — 301	Consolidated sand
301 — 320	Compact sand
320 — 335	Coarse sand
335 — 338	Yellow clay (water)
338 — 345	Coarse sand
345 — 390	Blue clay with shell fragments
390 — 395	Grey sand with shells and pebbles
405 { 412	Laminated blue clay
424	Bottom of well.

Sarafand Cantonment — Borehole No. 2.

0 — 100 feet	Red clay with sand
100 — 269	Yellow sand
269 — 273	Compact grey sand with calc. sandstone
273 — 330	Yellow sand
330 — 336	White clay
336 — 340	White sand and sandstone concretions
340 — 373	Blue clay, plastic
373 — 380	Grey sand with shells
380 — 420	Blue clay, plastic
	do shaley
420 — 422	Grey sand with shells
422 — 435	Blue clay, plastic
435 — 436	Sandstone with shells
436 — 490	Blue clay, very soft with sandy streaks
490 — 495	Consolidated sand (water impregnated with sulphureted hydrogen at this horizon.)
495 — 500	Blue clay
500 — 600	do shaley
600 — 615	do soft
615 — 700	do shaley
800	do do
900	do do

To the east of Ramleh the surface is mostly clay soil. The low hills are covered with conglomerate crust (nari), showing marl beds on the slopes or in some cases as in the Wadi Surar thick beds of blue and greenish blue clay overlain by limestone beds of considerable thickness. Most are unfossiliferous but the quarry and clay pit at one kilometre east of Ramleh Station yielded fossils of Miocene age whereas the argillaceous sands further west contain shells probably not older than Pliocene.

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The upper Section of these beds in other parts e. g. the hills north and south of Artuf are fairly porous limestones and give small wells as at Rafat and Beit Jemal. Small springs also flow from these beds in the same area and near Latron.

The excavation one kilometre from Ramleh station showed:

Fossiliferous hard limestone	6	metres
do Blue clay	55	„
not penetrated		

Near Ramleh Cemetery.

Grey argillaceous sand	43	metres	
Blue clay	40	„	
Chocolate coloured clay	25	„	
Hard white limestone	39	„	water in limestone
	174	metres	

Near Ludd (west one kilom.)

Sand	36	metres	
Blue clay	64	„	
Chalk	82	„	without water
Hard white limestone (fissured)	5	„	Water abundant
	187	metres	

Near Ludd NW 3 km.

Sand	16	metres
Clay with flint pebbles	23	„
Alternate layers of red & blue clay	61	„
Hard rock (grey dolomite)	7	„

Near Sakia (East one kilometre).

Grey argillaceous sand some red clay	13	metres	
do	50	„	
Green argillaceous sand with black clay bands	65	„	
Grey loam and clay	8	„	
Sand with gas	7	„	Inflammable gas
Loam with sand	8	„	Salt water
Greasy clay	10	„	
	160	metres	

At Artuf wells have been sunk at about the level of the wadi in a soft limestone which is bituminous and contains a fossil resembling Pecten obrutus (Danian). Only small amounts of water were obtained in these beds. Another well is said to have been sunk at at this level to 45 metres in entirely bituminous limestone.

At Latron the following section is given of a borehole made before the war.

Chalk	48	metres	
Blue clay	47	„	
Shale	120	„	(Dipping East).

No water was obtained. It is not known whether the shale is bituminous and of Danian age. The chalk and clay might be Eocene, Senonian or Miocene.
The western outcrop of these Miocene beds is seen as lows hills passing through Abu Shusheh, Wadi Surar, Jilia, Mughulis, Dkikrin, Zeita, El Kubeibeh.

They are overlain in their western slopes by sandstone which may be late Pliocene or Pleistocene. Several wells were sunk by the Germans and others and the following section given by Dr. Range. At Abu Shusheh water is obtained at 10 metres.

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Wadi Surar by mill at station.

0.0 — 6.1	Yellow loam
6.1 — 8.2	Gavels with interbedded loam
8.2 — 11.1	Yellow loam
11.1 — 19.2	White chalk
19.2 — 24.2	Grey bedded clay
	Water at 14 metres, abundant.

Regarding this bore it should be noted that white chalky limestone in a lateral wadi gives rise to a spring. The age may be Miocene if the clay bed is correct. At Kaukab however chalk beds of definitely Senonian age crop out showing the downthrow greater towards the hills.

To the west of Abu Shusheh, Wadi Surar, Mugalis, Berkunieh, Arak el Manshiye occur pebble sandstones overlain by thick sandstone which have al! the characteristics of marine beds where strong currents exsisted. At Dennabeh these beds are well exposed in the wadis and in the wells. Water is obtained at shallow depths of 7 to 10 metres and it is supposed that the sandstone overlies a clay bed at the unconformity or the clay beds of the older formation e.g. Miocene. The water bearing stratum extends to El Kheimeh and Et Tineh.

In the Summeil area although the sandstone and hard pebble beds exist (12 metres thick) they contain no water and the wells are sunk into chalk beds below, where it is obtained at 50 to 60 metres.

At Maharakah further south a hand excavated well is sunk to 90 metres and yields only a small amount of water of brackish quality. This again is in chalk.

Further south the Wadi Sheriah shows exposures of the calcareous sandstones in which many seepages of water occur. It is evident that these (?) Pliocene beds are very important for water supplies in the eastern part of the Gaza district.

BEERSHEBA.

The Beersheba wells are sunk through alluvium, gravels, conglomerates and shelly limestones but the water is mostly obtained in the chalk beds below at depths of 20 to 30 metres below the surface. It is very probable that the area which is all chalky and unfossiliferous belong to the Senonian-Eocene series of chalks with interbedded argillaceous marls which hold up the water. Such beds can be seen in the big quarry north of Beersheba where the beds dip south at 15° Once water is obtained the owners have generally been averse to deepening their wells lest the water should pass into the strata below. Small increases in depth have however given improved yields in the Government wells.

Generally wells are 20 to 30 metres deep and at least 4 metres wide. They are mostly studded along the wadis giving the impression that the wadi is connected with the supply This appears unlikely as wells are obtained both north, south, and east in similar beds but the depth near the wadi is least, and many of the wadis are in synclinal folds in which the water would concentrate.

The yield of these wells is sufficient for the domestic supplies and a few gardens. Whether the supply is sufficient to be used more extensively for irrigated cultivations has not been seriously considered. It is not known at present how mnch deeper the water bearing stratum extends and whether drilled wells would give a large supply by being sunk to a greater depth. There appear to be, however, possibilities the results of which would assist considerably in the development of the district.

To the east occurs Bir el Mashash height 1170 feet where wells or water holes poorly constructed are sunk mostly in the alluvium to 11 metres.

At Tel el Milah, height 1280 feet occur several wells, the deepest 16 metres being the best and contained when examined in July 1922, 3 metres of water. This well is probably very old.

Due south of Tel el Milah on the road to Kornub water holes 2 to 3 metres deep contain water during the spring. Several wells and water seepages occur as at Bir Arara Kasr es Sir and recently a small but reliable well has been obtained in gravels overlying Senonian chalk several kilometres east of Ras Zuweira at 300 feet altitude.

At Tel Arad many attempts have been made to get water. The Turkish Government

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sunk a well to 90 metres without obtaining water and in 1922 several holes were drilled by the Government and the Jewish Soldiers association but without result.

It should be noted with regard to this area that the Kornub anticline causes a westward dip and that the impervious argillaceous beds form a basin shaped area which extends east of Tel el Milah. In the case of Tel Arad experimental drillings the sites were limited to the Government lands around the Tel.

The evidence however is that a large area from west of Beersheba to east of Tel el Milah a breadth of at least 20 kilometres could be developed for water supplies. What is required in the first instance is to test the depth of the water bearing stratum by drilled wells in suitable locations and the quantity which is obtainable by these means.

From north to south some indications of the extent of the basin can be obtained from the following figures: North-east of Beersheba 15 kilometres, at Bir el Makraneh, height 1200 feet water is obtained at 20 metres, the quantity is unknown. The basin is probably denuded to the north and north-east.

South of Beersheba 20 kilometres, at Asluj, height 1000 feet are several wells 10 metres deep, supply said to be plentiful. The westerly dip due to the influence of the Kornub uplift probably affects the area to the North-East.

At Khalasa: Height 800 feet — 14 kilometres north-west of Asluj is a well 25 feet deep; supply said to be plentiful.

It is evident that the strata are dipping west. Wells and seepages occur in a direction from Khalasa west and north-west and probably represent the drainage from this basin.

At Mishrafa: Plain 1100 feet, hill 1380 feet, 18 kilometres south-west of Asluj the whole series of Eocene chalks occur capped by flinty nummulitic limestone. This is the centre of an early christian settlement but no wells have been discovered though the position appears satisfactory.

At El Aujah 800 feet 20 kilometres from Mishrafa the dug well is about 20 metres deep; south two wells exist 80 to 100 feet deep where a plentiful supply is obtained.

This water horizon must extend to the west-north-west and to the east and if the rainfall were sufficient for cultivations there appears to be a large area that could be developed. This is not the only water horizon for springs occur to the east in beds which belong to older rocks but little is known about these at present.

The great trough shaped basin which runs north-east from Tel Arad and is underlain by the chalk flint series contains no wells nor have any water seepages been discovered. The underlying dolomite limestone strata which are exposed toward the Dead Sea give rise to one important spring viz Ain Baghat which would not appear to account for more than a small fraction of the underground water of the region.

TULKARAM.

The Municipal wells at Tulkaram are 78,74 and 91 metres below the 100 metre datum line. Deepening in 1925 showed that the rock was of chalky Mizzi Helu type. The position in the centre of the town on the slope of the hill with strata dipping strongly to the west and possibly faulted to the west is not an ideal position for water but the results have not been unsatisfactory. On the outer slope occur very chalky rocks with fossil impressions and fish remains but the slopes to the east contain nummulites (Eocene). A site drilled further down the slope gave a show of water at 50 metres.

The section of the well at the Agricultural School is given by A. Range as follows:

Railway station.

0.0 — 5.0	Brown loam
5.0 — 22.5	Red sandy loam with gravel
22.5 — 25.0	Limestone boulders
25.0 — 30.2	Fine white sand
30.2 — 31.0	Clay with sand.
31.0 — 34.0	White chalk
34.5 — 37.5	Grey shale
37.5 — 43.5	Grey and brown shale
43.5 — 51.3	Black and brown shale
51.3 — 52.0	Grey shale
52.0 — 88.0	Black and brown shale

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A poor yield of water was obtained at 31 metres and an abundant supply at 80 metres.

The well has since become silted up and the yield was not satisfactory. Deepening of the excavated part at 45 metres have given increased yield. The rocks excavated consists of bituminous limestone with Pecten obrutus (Danian).

The beds are overlain by the sand formation which increases in thickness and depth to the west and in it as at Burg el Atar abundant supplies of water are obtained and springs comes from it further west. The depth however is variable for at Kakoon there is only about 20 metres after which clay or shale is encountered and water is not obtained until a depth of 90 metres is reached.

BENJAMINA—HUDEIRA.

Similar conditions hold here as at Tulkaram. Westward from the low limestone hills occurs alluvium or red sand increasing in depth and thickness to the west. At Hudeira consequently water is obtained in any position at 20 to 40 metres according to altitude; at Ghabie and Kerkur the western lands give good wells but in the eastern lands, shallow and poor wells are obtained. The further deepening beyond this red sand goes into white chalk or bituminous petroliferous shale which is possibly of Danian age like the shale of Tulkaram. The outcrop of white chalk south Jelameh has yield Pecten obrutus.

Sections in this area are as follows:

Barski No. 11 (Slazenger Farm) South of Kerkur.

Altitude 180 feet.

0.00 — 2.00 m.		Black earth
2.00 — 2.25		Sandy clay brown
2.50 — 3.00		do with calc. sandstone
3.00 — 3.50		Sandy clay with fragments of Pectunculus.
3.50 — 8.00		Red sand with do
8.00 — 9.50		do do
9.50 — 11.00		White and yellow sand
11.00 — 12.00		do with shell fragments
12.00 — 13.00		do do
13.00 — 15.00		Yellow clay and sand
15.00 — 17.00		White sandy clay with weathered bituminous limestone.
17.00 — 23.00		White clay sand
23.00 — 25.00		White calcareous clay
25.00 — 60.00	a	Black bituminous limestone
	b	do do do hard
	c	do do do do
	d	Shaley
	e	do limestone
	f	Clay bituminous limestone (? weathered)
60.00 — 71.00		Highly bituminous limestone

KERKUR — PALESTINE LAND DEVELOPMENT COMPANY.

0.00 — 0.50 m.	Humus
0.50 — 2.00	Dark iron ground
2.00 — 2.50	Light iron ground
2.50 — 4.00	Sandy loam
4.00 — 5.10	Fat loam
5.10 — 5.60	Loamy sand
5.60 — 6.10	Striped loam with clay
6.10 — 8.00	Blue clay
8.00 — 10.00	Clean sand
10.00 — 18.00	Loam with clay and sand
18.00 — 20.00	Clean yellow sand
20.00 — 23.00	Blue clay with sand
23.00 — 24.00	Limestone (—? Senonian chalk)

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GHABIE No. III Palestine Jewish Colonization Association P.I.C.A.

0.00 — 1.00	Heavy ferruginous soil
1.00 — 3.50	Black hard clay
3.50 — 5.00	Hard marl
5.00 — 11.00	Sandy, hard loam
11.00 — 13.00	Clean yellow sand
13.00 — 20.60	Sandy hard loam
20.60 — 22.00	Hard loam
22.00 — 22.50	Stones with loam
22.50 — 22.75	Loam
22.75 — 23.50	Rubble
23.50 — 28.00	Thin white sand (—? Pliocene shelly limestone)

GHABIE No. IV — Palestine Jewish Colonization Association P.I.C.A.

Height 32 metres.

0.00 — 0.80	Clay (Soil)
0.80 — 3.05	Black loam (Marine)
3.05 — 5.00	Hard loam (Marine)
5.00 — 11.00	Clay and sand
11,00 — 13.00	Yellow sand
13.00 — 20.06	Clay and sand
20.06 — 22.00	Clay
22.00 — 22.05	Clay and stones
22.05 — 22.75	Clay
22.07 — 23.50	White sand and stones
23.05 — 28.00	White sand
28,00	Hard limestone

The water is obtained from 22.08 to 27.08

GHABIE No. V

00.00 — 1.02	Red soil
1.02 — .104	Yellow sand
13.05	Water level
1.04 — 16.00	Clay sand
16.00 — 26.00	Sandy clay
26.00 — 34,00	Yellow sand with stones.

The water is obtained from 13.4 to 34 m.

GHABIE No. VI,

0.00 — 2.00	Blue loam
2.00 — 10.00	Clay sand
10.05 — 16.07	Sandy clay
16.07 — 28.07	Yellow sand
28.07 — 47.03	White sand
47.03 — 56.25	do do
56.59 — 59.00	White sand with stones.

The water is obtained from 30.6 to 59 m.

At Benjamina two wells sunk by the Palestine Jewish Colonization Association have approximately the following section,

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0.00 — 6.00	Sand
6.00 — 12.00	White sand with stones
12.00 — 14.00	Red sand
14.00 — 18.03	White sand with water (filter)
18.03 — 27.65	Clay (casing)
27.65 — 28.40	White sand } filter
28.40 — 29.50	Large stone } filter
	clay

In the trough formed between the ridge along the coast and the hills of the Zikron Jacob, the following section is obtained by the Palestine Jewish Colonization.

0.00 — 10.4	Pit
10.4 — 16.2	Stone (? calcareous sandstone)
16.2 — 16.5	Yellow sand
16.5 — 16.9	Clay
16.9 — 17.5	Stone (? Pliocene limestone)
17.5 — 18.3	Stone
18.3 -- 20.5	Stone
20.5 — 20.5	Stone
20.5 — 21.5	Stone with cavities (water source)
21.5 — 23.00	Stone

Numerous wells occur along the sandstone ridge abundant supplies of water being obtained at about sea level.

ACCA.

The Acca plain with which may be included the marsh and flat land behind Haifa Bay and the gentle alluvial and sandy slopes north of Acca are traversed by waters from many springs including Kurdaneh already mentioned, Fuwarah and the four Kabre springs to the north. Hence the area has had a rather plentiful supply for irrigation purposes.

Some wells have however been sunk and confirm the exposed geological features that the greater part of the area is underlain by formations corresponding with the great coastal plain to the south. Their thickness however is probably less. Marine limestone passing into sandstones occur above Kurdaneh, Tel Tantur, Jidru and at several places on the way to Kabre. Most of the wells behind the marshes are slightly saline just as is Kurdaneh but north wells of sweet water are obtained.

PLAIN OF ESDRAELON:

This area consists of undulating land drained by the meandering Kishon river to the west with a maximum fall of 100 feet within the plain and the Nahr Yalud to the east which has a straight course and a fall of many hundred feet before reaching Beisan.

The western plain is surrounded by the Nazareth-Bethlehem hills to the north and the Jenin-Um el Fahm hills to the south-west. The north hills are entirely Senonian-Turonian limestone but the spurs they send out into the plain are nari-covered fresh water limestones which dip southward under the alluvium of the plain. Between the exposed spurs the limestone beds are denuded and often entirely absent, only clay being found.

The southern hills pass from Upper Cenomanian age of the tuff series of Um El Fahm to Senonian and Eocene in the hills above Jenin. The numerous springs issuing from the western end of the southern scarp are from Senonian-Turonian chalk beds similar to the Carmel while those of Jenin and above are probably Senonian-Eocene though this at present is not certain. Many springs small but useful arise in the tuffs as at Um el Fahm, Anin and Ararah. The springs at Lejun (Megiddo) are associated with the late Tertiary basaltic ashes but may originate in the Turonian chalks. The volcanic cones of late Tertiary age of which there are four sent most of their ashes and lava down the existing water courses

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into the old Esdraelon Lake which was contemporaneously or subsequently drained by the faulting of the Ghor and the whole is now covered with alluvium. The spurs of the hills here show only 'nari.' It is probable that fresh water limestone occurs but with outflow of basalt there may have been later subsidences which as far as surface evidence goes has buried everything below the alluvium. The basalt flows of this area certainly do not reach far and it seems most likely that the later Tertiary faulting was chiefly to the southern side and that the outpoured basalt went entirely below the water of the lake.

Water supplies in the plain are drived from (a) springs from the exposed spurs of fresh water limestone (b) springs from the late Tertiary basalts (c) wells sunk into the fresh water limestone.

(a) The springs from these fresh water limestones are usually small. Opening up the limestones by excavation or drilling as at Ain el Beda produced as much as 15 M^3 per hour at a shallow depth which can be worked by gravitation suction. In this case the beds on the slope and the water concentrates in the thin wedge of rock. Nahalal is supplied by water from the small spring Ain El Aleik.

(b) Balfouria is supplied by developing several seepages in the basalt and ash beds to the west; at Junjar the well is in basalt 8 m. deep; at Tarboneh are also seepages developed by shallow wells in the basalt.

(c) Wells. Many wells have been drilled since the war to supply water to Jewish Colonies. Before or during the war the Germans sunk a well near Afule Station and obtained water. The well is 60 metres deep. A borehole was put down in 1923 by the American Zion Commonwealth to 120 metres, water being obtained principally between 30 to 50. Several wells were afterwards drilled at Jedda. The results show as already expressed that the beds dip from the exposed hill spurs under the plain and in the Afule area they are completely covered with thick alluvium. Results of some of the typical borings are given. So far the underlying red clays have not been penetrated and there remains to be exploited this second horizon which would give water of the artesian type.

AFULEH.

14.00 — 18.50 m.	Marl with limestone
18.50 — 20.00	Limestone with basalt
26.00 — 32.00	Basalt
32.00 — 34.00	Limestone with basalt
34.00 — 38.00	Soft limestone
38.00 — 42.00	Hard limestone
42.00 — 50.00	Limestone with basalt
50.00 — 51.00	Basalt
51.00 — 55.00	Soft limestone
55.00 — 60.00	Hard limestone
60.00 — 67.00	Sandstone
67.00 — 75.00	Soft limestone
75.00 — 80.00	Limestene with clay
80.00 — 98.00	Clay
98.00 — 120.00	Clay with sand beds some thin beds of coal.

Boring No. I. Jedda.

0.00 — 6.00 m.	Humus
6.00 — 19.00	Basalt and limestone pebbles
19.00 — 28.00	Loam with Boulders
28.00 — 29.00	Gravel
29.00 — 35.00	Loam with boulders
35.00 — 81.00	Loam
81.00 — 82.00	Sand, basalt, loam.

Boring No. II. Jedda

0.00 — 17.8 m.	Alluvium
7.8 — 47.5	Limestone beds with marls
47.5 — 99.0	Marls with occasional Calcareous beds
99.00 — 140.0	Red clay.

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SHUNAM.

0.00 — 9.75 m.	Mostly stiff red clay, some hard green argillaceous material with white calcareous nodules and some coaly matter
9.75 — 10.50	do do
11.35 — 12.30	Yellow clay with hard Calcitic stone.
11.20 — 14.32	Soft white fresh water limestone contains fragments of calcitic rock
14.30 — 16.35	Soft white fresh water limestone with hard yellow clay (Shale)
16.35 — 17.35	Soft limestone and green clay (argillite) mostly hard crystalline limestone with black spots
17.35 — 18.75	Hard limestone (fragments)
18.75 — 20.75	Chalky limestone (fossiliferous)
20.75 — 22.25	Hard and soft white limestone
21.30 — 22.35	Medium hard limestone some pieces crystalline showing crystal faces
22.35 — 23.75	Calcitic limestone with clay
23.75 — 26.50	Calcareous soft porous rock, banded
26.00 — 28.00	Soft chalk
28.25 — 29.35	Dark calcareous clay (marl) banded
29.35 — 32.30	Light grey calcareous clay
32.30 — 32.99	Mostly small fragments, some rounded, some hard clay and soft limestone = gravel
32.97 — 36.60	Bedded buff clay slightly Calcareous.

SUMMARY IN RELATION TO IRRIGATION PROBLEMS

Regarding the coastal area it has been shown from present borings that water is available at shallow depths up to a distance of from 5 to 10 kilometres from the coast. Where the depth of the well is such as to reach shelly limestone or calcareous sandstone "Kerkur" the amount available is limited only by the size of the pump and 40 to 80 M^3 per hour are commonly raised.

In certain areas such at Bir Yacob, Bir Salem the fine sand reaches to a considerable depth below present sea level and increases the cost of obtaining water in quantity in such localities.

Again the area between Benjamina to some distance south of Jaffa appears to give the the best results. This may be due partly to the fact that the sands are fed by many springs such as Shunum and the Auja whereas in the Gaza district there are no large springs and the rainfall is usually less. Nevertheless the quantities pumped near the coast are often equal to the Jaffa District.

Further to the south-east however wells have to be sunk to greater depths and the yields generally appear to be small and insufficient for irrigation purposes.

The development of the water supplies in the Beersheba district would appear an important problem the solution of which might allow of considerably greater agricultural activity. The approximate limits of the basin have been indicated and sites could be selected for testing. Even Beersheba has not yet been tested by a drilled well and the existing excavated wells are only taken a metre or so below the summer level.

The plain of Esdraelon has been seriously considered for irrigation cultivation but the wells while good have not given regular results. There remains yet to be investigated the deeper source below the unpenetrated red clay which should yield artesian water.

There are several areas on the Jordan Plain that may be considered for supplies of of water but generally the Jordan water could be pumped at a cheaper rate than it could be obtained by drilling.

The principal flowing sources of water in the country are:

1. The Jordan — quantity 50-100 M^3 per second. Land available for cultivation.

ON THE WEST: the upper terrace of the Jordan from 8 kilometres north of Wadi Farah to Jericho about 200 square kilometres at altitudes from-900 to-1050 feet.

ON THE EAST: South of the Nahr es Zerka about 200 square kilometres at altitudes from-850 to-1000.

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Two methods are available for using the waters of the Jordan: (a) damming the water above Jisr Damieh and distribution by canals; (b) pumping from various points.

2. Springs of the Jordan—Dead Sea Basin:

(a) Ain Jidi, Ain Sideir, Aid el Areijeh, total 10 to 20 million gallons per day. There is a small amout of cultivation carried on by the Bedouin but most of the water dissipates in the gravels and passes into the Dead Sea. Vineyards of Engedi are referred to the old Jewish writings and remains of extensive terraces can be seen still on the slopes of the scarp.

(b) Ain Feschka and other springs: 30,000,000 gallons a day—Chlorine 50 to 150 parts per 100,000.

The use of these waters would require either difficult constructional work or the the source would have to be tunnelled. The latter method would probably give sweet water. Area available at least 25 square kilometres. Pumping would be required unless tunneling raised the height of the source.

(c) Ain Auja, Ain Duc, Ain Sultan — Total quantity about 25,000,000 gallons per day. A considerable part of this water is used or wasted. The amount of land cultivated is possibly not more than five square kilometres and excepting Ain Sultan lands are big alluvial flats much higher than the upper terraces. Proper control of these waters would give greatly increased cultivations.

(d) Farah Springs about 25,000,000 gallons per day. Part of the waters are used for ordinary cereal cultivations.

(e) Beisan Springs — about 50,000,000 gallons a day. Much of the water is used or wasted and the conditions of irrigation give poor results.

3. Springs of the Western Plain:

(a) Kabre Springs and W. Kurn — 9,000,000 gallons a day — used for orange cultivations, generally wasteful irrigation.

(b) Ain Kurdaneh — 30,000,000 gallons a day (about 1 1/2 M^3 per second). Not used. Land available leased to the Haifa Bay Development Company.

(c) Ain Auja — 8 1/2 M^3 per second.

Land available for cultivation, the Coastal Plain. Could be used for irrigatlon of orange groves but at present this is all done by pumping.

(d) Ain Rubin: occurs to the south, discharges at sea level and would require pumping.

In conclusion it may be said that irrigation has only been developed to any extent in respect of orange cultivation. Small banana groves also exist and are being extended. Irrigation on the Jordan Plain is chiefly for cereals.

Immense possibilities exist in the irrigation cultivation of suitable crops that would give profitable returns and particularly allow of a bigger export trade.

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