PAVAO MILETIĆ

AN OUTLINE OF THE GEOLOGY AND HYDROGEOLOGY OF THE SOUTHERN DESERT AREA OF IRAQ

With 1 figure in text and 1 map enclosed.

To the south of the Euphrates observations were made of the regional ground-water flow, as well as presumptions in this connection. These are presented in this report jointly with a description of the manner in which such underground flow is acting on the characteristics of the ground-water and on the morphology of the terrain. The close dependence of the chemical composition of the ground-waters on the lithological development of the sediments is pointed out.

Contents:

PREFACE

At the end of 1959 INGRA Co. of Zagreb, was entrusted with the elaboration and setting-up of tree tenders for the drilling of 320 water-wells in Iraq on behalf of the Iraqi Government. A group of five experts left for Iraq and worked there from October 1959 till August 1960. In the meantime the program was enlarged by 110 waterwells, but nevertheless the task the group had undertaken was accomplishen within above time period.

In the tenders and in the supplementary plans the territory of the entire Republic was comprised, the only exception being a part of Mesopotamia (Fig. 1).

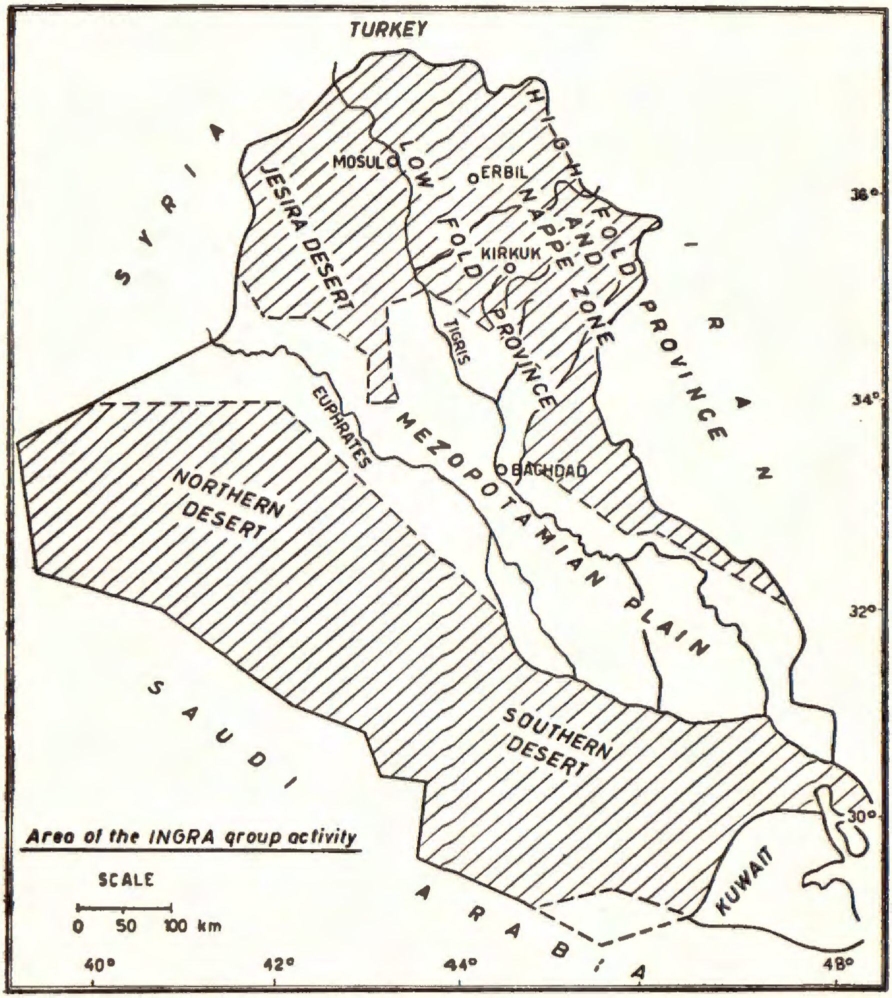

Fig. 1. Map of Iraq with the physiographic provinces and delineated area where the work of the INGRA Comp. group developed. South of the Euphrates is the region of the southern desert. (Southern and Northern Deserts), which is the subiect of our outline.

Sl. 1. Pregledna karta Iraka s fiziografskim provincijama i posebno označenom površinom na koju se odnosi rad ekipe INGRA comp. Južno od Eufrata je područje južnih pustinja (Sjeverna i Južna Pustinja), koje je obrađeno u ovom članku.

The Work was very strenuous since the area covered by the task is thousands and thousands of sq. km.

Another factor rendering the work still more difficult was the fact that all the geological and hydrological investigations executed formerly were but of regional character, so that all exact determination of the most favourable locations for the drilling of water wells was excluded on the basis of their results. Besides, geological investigations were made predominantly for the purpose of oil drilling, and they were made by various experts in the course of a longer period of time, covering separate and very extensive surfaces.

This resulted in discrepancies from the standpoint of stratigraphy and facies, as quoted by different authors for different localities. Up to that day no complete geological study had been available about Iraq. On the basis of data obtained from several authors who wore employees of the companies for the exploitation of crude oil a geologic map was made of the scale 1:1,000.000. The map is available in the Administrative Offices of the Oil Companies and in the respective offices of the Iraqi Government. This map has not yet been published for public use, so it is not enclosed with this report.

A most comprehensive and useful information on the stratigraphy of Iraq has been published by R. C. van Bellen, H. V. Dunigton, R. Wetzel and D. M. Morton (1959). Unfortunately this publication was not available to the INGRA group when working in Iraq. Therefore the stratigraphy and lithology presented in this outline are in original form, as it was used for the interpretation of hydrogeology. Neverthless the publication is mentioned here because of the exceptional importance it possesses as the first complete stratigraphical review of Iraq.

The first of the three tenders had to comprise the southern desert area to the south of the Euphrates. This area is known as the Northern and Southern Deserts. (Fig. 1). In the regional review included in this report by the southern desert area is meant the area of Ramadi Liwa, likewise south of the Euphrates. In setting up the geologic and hydrogeologic studies on the basis of wich the locations for the waterwells would be determined, use was made of the map of the scale 1:1,000.000 and of numerous reports of wich the most complete and useful were those made by the R. Parsons Company (1955) and by S. E. Bechor (1950). Use was also made of individual reports made by geologists employed by the oil companies, as well as of several publications found in the literature.

As already stated, to data supplied by various authors supplementary information had to be added so as to obtain as complete a view over the desert area as possible. All these data taken from various authors are presented in the first part of our report for the sake of better explanation and to create a basis for the intended hydrogeological observations. Further, it is our opinion that data collected in this way will facilitate their completing and correcting.

The second part of this outline treats of our opinion in regard to the laws according to which the regional hydrogeology has developed, wich we noticed during our work. Namely it has already been stated that the mutual dependence between the hydrogeological and morphological characteristics of the area was too strongly stressed in former studies. At the same time the studying of the depedence of the hydrological and hydrochemical characteristics on the lithological and tectonical structure of the ground was to a certain extent abandoned, as wehh as their common action on the development of the significant morphological features of the desert.

Therefore it is our intention to fill up such gaps in the existing collection of data by our new observations and presumptions based on established facts.

All occurrences of ground-water in the desert area have been already surveyed and described in detail in the report by R. Parsons Co. (1955). This report and the one made by S. E. Bechor (1950) treat of some hydrochemical characteristics of ground-water, i. e. total dissolved salts with their main anionic components. For the reason stated we will not repeat here the already establisched facts. In oder not to enter into details, and to get a general view of the whole matter, the facts of secondary importance and some exceptions are omitted, which anyhow are to be considered inevitable owing to the extent of the southern desert area, i. e. a surface of some 190.000 sq. km.

The result of our explanations, observations and presumptions about the hydrogeology and hydrodynamics are to give a general conception about the prospecting for ground-water to be executed within the Southeren Desert area. Up to this time explorations had been limited to registration of data and their local interpretation and explanation. We are of the opinion, howerer, that the entire desert area should be looked upon as a whole, within which the regional lithological and structural characteristics should be established, and within this framework the laws of hydrogeological development. After this a classification of the occurences and characteristics shall be made with the required explanations.

There are many advantages in such a manner of establishing the hydrogeological characteristics of an aera. First, the likelihood of giving erronous explanations is reduced also time and means are saved, and, third, a reasonable and safe exploitation of the avaible ground-water reserves is granted by an exact delimitation of its amount. This third advantage is of particular importance, because we are lacking an exact knowledge about the rainfall infiltrating the underground as well as about the surface of infiltration.

I would now like to express our joint gratitude for the assistance proffered to members of the INGRA group by the oficcer of the Iraqi Government, Mr. Jaffer, and by the senior geologist of Iraqi Petroleum Comp. Ltd. (IPC) Mr. Brown and junior-geologist of Basra Petroleum Comp. Ltd. (BPC) Keith Johnes. I would also like to thank Messrs. Z. Domačinović, M. Zgaga, I. Petolas, P. Howasapian — members of the INGRA group whose help was so precious in my collecting the necessary data and documentation.

My sincerest thanks are also due to Mrs. Petyò for the translation of this report.

A STRATIGRAPHIC-LITHOLOGICAL REVIEW OF THE SEDIMENTS

The following stratigraphic units were determined within the southern desert area:

Triassic, Jurassic, Cretaceous, Palaeocene, Eocene, Oligocene and Pliocene. The last mentioned was not exactly delimited from the stratigraphical point of view. The Dibdiba beds, which are considered to belong to the Pliocene, are believed by some authors to extend from the Miocene to the Pleistocene.

Quarternary beds are: sand detrituses, stream detrituses, disintegrated rocks blanket etc. They were not the subject of our investigations, since they did not exert any greater influence on the interpretation of the regional hydrogeological characteristics.

The below-mentioned text treats of the characteristic localites, lithology and detailed stratigraphical classification of each of the above-mentioned stratigraphic units.

TRIASSIC

To the Triassic belong the oldest rocks encountered in the area to the south of the Euphrates. On the surface they appear on the crest of a gentle anticline at Ga'ara depression, north of Rutba. Up to the recent time these rocks have been considered to be of Paleozoic age.

From the lithological point of view, predominant rock formations of the Triassic are limestones, with some clayey beds and sandstones known to be the bearers of very good freshwater. Below is a Table showing the classification of the Triassic formations in the Ga'ara depression — the Wadi Hauran area (Table 1).

Table I.

Rhaetic	Zor Hauran formation	45 m thick, approx.
Upper Triassic	Mulussa formation	160 m thick (?)
		unconformity
Middle Triassic	Ga'ara sandstone	50 m thick, approx.
	Nijili formation	

There are no autcrops of the Lower Triassic Formations.

Since no deep drilling was ever performed in this area, the Lower Triassic formations could not be determined in this way either.

Gradual transitional types of sediments were established within individual Triassic beds in the different localities of the Ga'ar area.

The Nijili formations consit of yellow and brown marls with a subordinate quantity of sandstones overlaid by concordantly deposited Ga'ara sandstones.

The thickness of the Ga'ara sandstones is about 50 m. (established coordinates 33°31' N and 42°28' E). These sandstones are composed of coarse-grained and crossbedded reddish to white sands. At the locality determined by the coordinates 33°32' N and 40°11' E they are concordantly overlaid by the Mulussa formation reaching circa 160 m. in tchickness. The Zor Hauran formation running also concordantly with the lower beds was located by the coordinates 33°26'25" N and 40°55'25" E. It reaches 45 m, its lower part being built of yelow and green gypsipherous marls and shales with marly and oolitic limestione intercalations, and its upper portion consists predominantly of dolomitized limestiones.

To the west of the typical locality of Wadi Hauran the Ga'ara sandstones are transgreissively overlaid by the Rutba sandstones.

JURASSIC

Jurassic sediments were encountered on the same geological structure, but in the northern limb of the anticline, close to the pipeline to Haifa, between H_1 and H_2 pump stations.

Lithologically, these sediments occur as fine-grained dense and recrystallized limestones and coarse-grained dolomites. Only two stages of the Jurassic were established viz.

Bathonian — Bajocian:	Muhawir formation
Pre Toarcian:	Ubaid formation

Between the Ubaid formation and that of Muhawir the sedimentation was discontineud. It has been stated that a wider hiatus took place after the sedimentation of the Bathonian and of the younger (upper) Jurassic, the latter disappearing completely in the Ga'ara area.

The Ubaid formation was located by the co-ordinates 33°32' N; 41°2'50" E ond 33°30'20" N; 40°58'40" E, to the north-west of the Wadi Husainia joining Wadi Hauran. This formation reaches 75 m. in thickness, but its upper boundary is not known. It is built of oolitic and dolomitized limestones with flint nodules. In its lower portion stratified marls occur sporadically.

The Muhawir formation, developed in its typical way, was located in two places, which is due to the too gentle dip of the beds. The lower locality was determined by co-ordinates 33°30'20" N and 41°15'20" E, the upper locality by the coordinates 33°33'20" N and 41°14'0" E. The lower portion of the Muhawir formation is dominated by oolitic and sandy limestiones, with subordinate sandstone occurrences. In its upper portion these kinds of rock are accompanied by marl. The formation reaches circa 50 m. in tchickness, as it was possible to establish on the surface. The whole formation, however, is transgressively overlaid by the Rutba sandstones.

CRETACEOUS

During the sedimentation of rocks belonging to the Cretaceous considerable mutations took place of the conditions of sedimentation. This refers especially to the Upper Cretaceous. While in the Triassic and the Jurassic the interruptions in sedimentation were due to epirogenetic movements so that the character of the sediments is typical for the broad regions, in the Cretaceous the orogenetic movements started with a frequent and uneven shifting of the coastline, so that there developed different rocks facies of the same age. Five principal erosion discordances and several less significant local unconformites were established. In the easternmost part of the country an almost continuous sedimentation was encountered, from the Valangien to the Turonian, and it is known as the Balambo formation composed of stratified limestones, marls and shales. According to the results obtained through exploration work within the Basra area, the following stratigraphic units of the middle and upper Cretaceous were established; they are shown in Table 2 (according to R. M. S. Owen and Sami N. Nasr (1958.)

Table 2.

Age	Group	Formation	Description
UPPER CRETACEOUS	ARUMA	Tayarat	Limestone, recrystallized, usually dolomitic, with some shale intercalations
		Quarna	Globigerine marl, sporadically dolomitic
		Hartha	Organogenic, glauconitic limestone
		Sa'di	White chalky and marly limestone
		Tanuma	Black shales
		Khhasib	Fine-grained marly limestone with shale intercalations
MIDDLE CRETACEOUS	WASI'A	Mishrif	Dense and organogenic detrital limestone with quantities of freshwater limestone at the top
		Rumaila	Fine-grained limestone, sporadically marly and chalky
		Ahmadi	Shales with prominent limestone intercalations
		Wara	Sandstone with dark shales intercalations
		Mauddud	Organogenic limestone, partially detrital
		Nahr Umr	Shales and sandstones with sporadical limestone intercalations in the upper part.

The Thamama group (Lower Cretaceons) was classified according to the following units:

Shua'iba
Zubair
and Ratawi

Representatives of the Ratawi formation are blackgreenish shales with limestone inclusions.

The Zubair formation is to be paid special attention to, it occurs in the oil-bearing area of Zubair. This formation is built of an approximatelly 380 m. thick series of sandstones and shales.

The opinion predominates that between Awasil and Wadi Amij it disappeared owing to a regional discordance.

The same is meant in respect of the absence of the Shuhaib formation on the surface to the west of Awasil. The Shuhaib formation also occurs in the Zubair area. Its main rock is limestone, which passes laterally into porous and cavernous dolomitized limestones.

Accordingly, in the western part of the desert area the Cretaceous sediments are completely different and reduced.

The oldest formation of the Upper Cretaceous found on the surface near Rutba is the Rutba sandstone overlying transgressively the Jurassic and Triassic sediments. The Rutba sandstones are concordantly overlaid by the M'sad limestones of a littoral facies. The only stratigraphical unit belonging to the Upper Cretaceous to the west of the Euphrates in the area south of Rutba is the Tayarat limestone: the neritic littoral facies of Mastrihtian, which passes in an easterly direction into the Pilsener limestone of the Awasil area.

Lithologically, the Rutba sandstone formation is built of coarse- and fine-grained sands and sandstones, sporadically of quartzite. The basal portion is maybe of continental origin, but the upper portion is undoubtedly marine. In the environs of Rutba and west of the Ga'ara depression this formation reaches about 18 m. in thickness. To the east, it grows considerably thicker.

The M'sad formation occuring in the typical locality of Wadi M'Sad al Rutba (immediatelly south of Rutba) is represented by reef and shallow marine limestones with some chalky limestones, marl and a few sandstone intercalations.

The Tayarat limestone is a light- coloured recrystallized and fossiliferous limestone. It is gritty in some places.

There follow Table 3, showing the division of the Cretaceous according to an old borehole drilled by IPC near Awasil.

Table 3.

Upper Cretaceous		uncomformity
	Pilsoner Limestone formation	Dibis anhydrite included
	Maotsi formation	
	Fahad formation	
		uncomformity
	Mahilban formation	
		uncomformity
	Mauddud formation	
Middle Cretaceous	Nahr Umr formation	equiwalent of the Rutba sandstone
		uncomformity
Lower Cretaceous	Shuhaiba limestone	
	Zubair formation	marine sandstones, equivalent to the Sarmod marls
	Garagu formation	sandstones, marls and coral limestones

PALEOCENE

The beds which are attributed to the Paleocene but have not yet been definitely established as such, cover a rather wide area to the south of the Euphrates. Two stratigraphical units have to be distinguished among these sediments known as the Aidah formation viz.

The Basita limestone: It consists of hard limestones and dolomites. The sediments are sporadically silicified and cherty, with anhydrite in places.

The Ghurra limestone: A chalky and cherty limestone, washed out on the surface. Some anhydrite can also be found in it.

Within the Kuwait-Basra area Paleocene sediments were not separately established.

No exact boundary can be drawn between the Basita limestones and the Ghurra limestones in the Southern Desert. Towards the Wagsa member (See Table 5) the boundary was drawn according to the difference in the lithologic composition.

The Aidah formation, as a whole, was divided in the Southern Desert from above downwards into the following:

1. The **upper Ghurra and Basita limestone,** reaching about 100—150 m. in thickness. It is characterized by a series of gray and marly limestones.
2. The **upper anhydrite and limestone** with thick anhydrite layers in its upper portion. The limestone-anhydrite ratio decreases eastwards, i. e. the anhydrite layers become thicker and thicker going eastwards.
3. The **interanhydritic limestone and marl** contain white chalky and marly limestones with some shales.
4. The **lower anhydrite and limestone:** two anhydrite sequences consisting of three layers each. Total thickness of this formation varies between 25 and 40 m.
5. The **pre-anhydrite limestone and dolomite.** The dolomitization is noticeable in the basal portion of the formation. The younger beds are argilloschistous, gypsous and anhydritic.

EOCENE

The Eocene beds in the various areas are stratigraphically variously divided. In the Kuwait-Basra region the following stratigraphical division was made: (see Table 4).

Table 4.

Age	Group	Formation	Remarks
EOCENE	HASSA	Dammam Rus Radhuma	Radhuma formation includes Basita and Ghurra limestones and is consequently considered of the Paleocene age in the previous chapter.

The Dammam formation is represented by numulitic limestones, recrystallized and dolmitized.

The Rus formation is predominantly of evaporitic facies, with thickly stratified anhydrite beds, some limestone and marl.

The Radhuma formation consists predominantly of marly limestones with some recrystallized and dolomitized limestones and thin anhydrite layers.

In Table 5 may be seen the division of the Eocene beds in the central part of the Southern Desert Area, The following division is chiefly according to R. F. Parsons's reports (1955). (No Upper Eocene was found in this area because of the stratigraphical hiatus.)

Table 5.

				Stragraphical Division of Eocene beds	Typical Locality
EOCENE	MIDDLE	DAMMAM	Tuquaid limestone	brown to gray silicified marine limestones. Thickness 65—100 m.	N-W of Al Busaiya
EOCENE	MIDDLE	DAMMAM	Rudhuma limestone	fine-grained recrystallized and chalky limestone	
EOCENE	MIDDLE	DAMMAM	Chabd limestone	fine recrystallized, but also dense, usually washed sporadically chalky limestone	
EOCENE	MIDDLE	DAMMAM	Shawiya limestone	Thinly stratified marl and limestone with chert (yelowish, white and reddish)	Shabicha Salman Takadid
EOCENE	LOWER	RUS	Huweimi limestone	limestone, chalky in lower portions. Thickness approx. 100 m.	Salman Takhadid
EOCENE	LOWER	RUS	Shabicha limestone	mottled, white to gray limestone, sporadically porous, with chert. Thickness: approx. 130 m.	Shabicha Takhadid
EOCENE	LOWER	RUS	Sharaf limestone	limestone, dark gray to yellow, usually silicified; thickness: approx. 50 m.	
EOCENE	LOWER	RUS	Wagsa limestone	white, chalky with yellow marly layers. Discordantly overlying the Basita formation; thickness: approx. 95 m.	

In this area only in the deeper portions of the Rus formation thick anhydrite intercalations colud be found (in the boreholes). In the borehole Abu Ghar 2 an anhydrite bed reaching circa 120 m. in thickness was established. To the east, the anhydrite bed grows thicker and thicker, so that in the Luquait borehole a thickness of 200 m. was recorded.

In spite of the above division of the Eocene sediments, the individual groups of members are very difficult to be distinguished in the field.

It should likewise be noted that there are some discrepancies in the stratigraphical grouping of the units listed in Table 5. According to some reports the Rus formation is recognized only in the deep wells sections, and consequently it was not found on the surface. The Wagsa, Sharaf, Shabicha and Huweimi units were thought of as belonging to the Damame group.

OLIGOCENE

To the Oligocene the sediments of the Zahra formation are attributed; this formation, however, has not yet been palaeontologically established to any precision. Its thickness ranges between 100 and 160 m.

The Oligocene sediments extend more to the east; they are built of fresh-water white limestone and red gritty marls. In the eastern part of the Southern Desert area the formation becomes thicker, but is very difficult to be distinguished from the Dibdibba beds. Therefore it is sometimes thought of as belonging to the Miocene.

The Table showing the relations between the Oligocene and Miocene formations is given in the following chapter.

According to T. F. Williamson and Rogers (1939), the Zahra formation includes the Tuquaiyid limestone (see Table 6). Some other authors consider this unit to belong to the Dammam group, and therefore the validity of the following Table is somewhat dubious.

MIOCENE

In several regions south of the Euphrates the variation in the sedimentation of the Miocene was considerably expressed, even in the vertical division of the sediments. Table 6 shows these variations discovered in the eastern part of the desert area on the basis of field observations (according to T. F. Williamson and De Rogers (1939.)

Table 6.

Eastern and western area near Abughar	Eastern and western area near Al Amghar	Kuwait
Upper Fars	Dibdibba beds (MacFadyen 1938)	Kuwait series (de Boeckh 1929)
Lower Fars very thin	Grit and marl	
Euphrates limestone (Williamson 1940)		
Tuqaiyid limestone (Williamson 1940)	Tuqaiyid limestone 1 m thick	
Zahra formation (Williamson 1940) normal facies: limestone and marls	Zahra formation Gritty facies	
Eocene limestone	Eocene limestone	Eocene limestone

The Euphrates limestone

The Euphrates limestone consists of Fossiliferous limestone with marls and some sandstone, and it occurs along the northern and north-eastern borders of the Southern Desert. Owing to its transgressive character its thickness varies considerably, and, for the same reason it can be found as an

Lower Fars

The Euphrates limestone is overlaid by a series of marls, limestones, sandstones and gypsum. If this series occurring in Southern Iraq is compared with the same series in Eastern Iraq, then the former is quite insignificant. At Zubair, its thickness reaches about 196 m., at Rumaila about 98 m.

Upper Fars

The Upper Fars can be distinguished very well in the northern part of the area. The formation is generally built of marl with sandstone intercalations. The lower portion of the formation includes dispersed selenite crystals. The marl is brownish-red and yellow in colour.

The sedimentation of the Miocene along the northern border of the Northern Desert began with lagunar beds. In the lower portion of the Euphrates limestone basal conglomerate occurs, and in the upper portion Jeribe limestone with Dhiban anhydrite. This stratigraphic unit may be found also at a distance of as much as 100 miles west of the Euphrates. It is transgressively overlaid by the Fars formation.

DIBDIBBA BEDS

The stratigraphic relations of these beds will not be dealt with separately here; first, because of the situation which is evident in Table 6, as it would seem that to the east the Miocene and even the Oligocene sediments pass laterally into the Dibdibba beds. The upper portion of the Dibdibba beds belongs very likely to the Pliocene. According to some authors the sedimentation of these beds had continued up to the Pleistocene. The beds occupy a rather large part of the Southern Desert, to the south and east of Al Busaiya. At Zubair, they reach 390 m. in thickness. They consist generally of grit layers and gravel sandstones with light-coloured marl intercalations. There are some limestone intercalations, but they are scanty.

TECTONICS

The tectonics of the Southtern Desert of Iraq are relatively simple if considered regionally. A gentle dip of the layers towards the north-east is the main tectonical characteristic. In accordance with such a gentle dip of the layers the occurrence of indivdual stratigraphic units on the surface may be followed up under the presumption that the older formations occur in a south-westerly direction. The only tectonical feature that can eb observed very clearly on the surface is a gentle anticline near Rutba. In the core of the structure the oldest stratigraphic members were registered, viz. Triassic and Jurassic sediments.

A significant morphologic feature of the Southern Desert is a series of depressions which may be followed up from Tukhadit to Salman, then at Shabicha and Galaib to the west and east of Salman respectively. This feature is most probably the consequence of a tectonic disturbance which has not yet been established. A much less expressive series of depressions runs towards the south-east of Salman.

The depressions are either rounded or elongated in form, with very steep escarpments. On their escarpments the layers became inclined, descending towards the centre of the depression. The depressions are usully the lowest points in the area, so that all the water is conveyed towards them and does not flow away. For this reason during the rainy seasons they are partially flooded over.

These depressions have been very often the subject of discussions and treatises, and their genesis was frequently studied. There are two basic conceptions treating of their-genesis. The one is to the effect that the depressions are of tectonical origin; the other is to the effect that they took their origion owing to a collapsing of layers which took place exclusiwely due to dissolution of the underlying anhydrite layers.

The opinion of the author of this report is to the effect that when trying to explain the origin of the depressions both of the above factors should be taken into consideration, since both of them must have played a very significant and important role during the development of the depressions. Namely, water can penetrate and dissolve anhydritd only if limestones, dolomites and anhydrites are broken. At the same time the origin of the depressions cannot be fully explained without taking the dissolution of the older soluble beds into consideration. An exception is the Ga ara depression, which is of quite another origin. Accordingly, the best supposition that can be offered is that there are two tectonically disturbed areas in the Southern Desert. But since these disturbances are not evidenced by geological feactures on the surface, their action was very likely concentrated exclusively on the breaking of sediments. It is not known why the tectonic disturbances took place here, but their action on the hydrogeology and — in this case — also the morphology is evident.

There is a geologic occurrrence on the surface on the northeastern border of the desert area that induced geologists to conclude that there was a deep fault which had been coverd and masked by younger sediments. Namely, there is a belt of springs which extends from Haglan (near Haditha) to Ain Hamud. Geophysical-seismic surveyings have proved the above conclusion, although the shape of the fault has not yet been definitely determined.

Besides the disturbances we have just mentioned there are many other lesser witnesses to the tectonic disturbances in this desert area - faults and folds that ere associated appearances either to the collapsing of layers owing to the dissolution of evarporite sediments or to the regional tectonic movements. Such tectonic disturbances have been plotted on detailed geological airphotogrametric maps enclosed with reports made by members of the oil companies. They do not play, howover, an important rôle for the regional geologic view, and therefore they are not presented in this paper.

HYDROGEOLOGY

All previous reports with the hydrogeological conditions of the Southern Desert display a manifestly common characteristic. Owing to the fact that no outstanding tectonic structure can be encountered here, the authors bring the hdrogeological occurences and their interpretations into close connection with the morphological characteristics of the terrain. According to them the following parts are to be distinguished in a general way:

a) High Desert, the western part of the desert area, west of Nukhaib,
b) The Wadian Area, comprising all the main wadis — Hauran, Ghadf, Ubaiyidh, Hamir etc.
c) The Hajjara - a stony desert comprising the areas of Jussuf, Shabicha and Salman,
d) The Dibdibba Plain, south and west of Al Busaiya.

This main division of the desert area is further divided by some authors (Parsons 1955 etc.) into yet smaller sections, but always according to the main morphological properties, i. e. elevation, plateau, number and shape of the wadis, depressions etc.

It is beyond doubt that the hydrologic occurrences are to a certain extent influenced by the morphology of the terrain; it is our opinion however, that as far as it concerns the southeren desert, area, a too great importance has been attributed to the morphology and a too small importance to the Lithology, to the facies of the sediments, and to the tectonic structure.

It was established that all over the Southern Desert — except in the environs of Rutba — the beds are inclined gently towards the north-east. Such a gentle descent over a great area — as in our case — brings the whole stratigraphic sequnce of sediments to the surface. Accordingly, each layer of the sequence is in the position to be fed with water, and therefore each one of them may be a ground water-bearing stratum, provided that the quantity and quality of the water depend on the amount of rainfall, lithology, tectonics and weathering of the rocks. Except the lithology and partially the tectonics, the other two factors influencing the amount of ground-water are nly presumed as far as it concerns the treated area, since the amount and distribution of rainfall as well as the depth to which weathering has reached and the local tectonics are unknown.

Consequently according to the data avilable the Southern Desert area can be classified into three lithologic-facial and hydro-chemical zones viz:

a) Area of Mesozoic sediments, to which the greater part of the Northern Desert belongs,

b) Area of Tertiary sediments, with thick evaporite sediments, to which the greatest part of the Southern Desert, i. e. the part to the west of Al Busiya across Salman, Shabicha and a small part of the Northern Desert ENE of Jussuf and Nukhaib belong.

c) Area of upper Miocene to Pleistocene sediments, noticeable particulary to the east and sotuh-east of Al Busaiya.

The elements of lithology of the above-mentioned areas were dealt with in detail in the lithologic — stratigraphical review; here it is our intention to give but a short summary, with stress laid on the characteristics of the hydrogeology of the area.

The first zone, i. e. zone of Mesozoic sediments, is built predominantly of carbonate rocks. In lesser amount there occur clastic rocks — sandstones and clays.

The second zone is built of carbonate rocks with evaporite intercalations, mainly anhydrite. Anhydrite occurences, however, are limited, and therefore they do not characterize the sedimentation nort-west of Jusuf, nor the parts towards the south.

The third zone, i. e. zone of Miocene to Pleistocene sediments, is characterized by its clastic beds, wich are particulary in evidence west of Al Busaiya.

Such division of the explored area was made according to the properties of the water-bearing lavers; nevertheless, it may also be made according to the hydrochemical characteristics which in this area are in very close connection vith the lithology and the rock facies.

The hydrochemical division is based on the total salt dissolved in water as well as on the predominant anion.

The content of the total dissolved salts varies between very large limits, from several hundred mg/1 to several thousand mg/1 in highly mineralized springs of asfalt lakes on the border of the Northern Desert. According to the usual standards for establishing whether a certain kind of water is utilizable or not, the greater part of the waters is not utilizable. Only a general shortage of water has induced the people there to use the available water of such a poor quality.

According to the content of dissolved salts in the water, the folowing classification of the ground-water was made after Parsons, and adjusted to this area viz.

up to 2500 mg/1 acceptable water
from 2500 to 4000 mg/1 marginal water
over 4000 mg/1 unacceptable water

Water of the most utilizable quality with regard to its content of dissolved salts exists in the first hydrogeological unit, especially in sandstones. Locally, the quality of the water worsens, as at Al Jid (west of Rutba), very likely owing to the dissolution of salts from intercalated clays.

To the east of Rutba the quality of the water gradually worsens, but it never surpasses the limits of the above-listed acceptable water quality. To a certain extent the increase of salinity may be due to older Tertiary sediments. Althoug in the Tertiary sediments evaporites do not occur to such an extent as in the second hydrogeologic zone, they may contain in some horizons an increased content of soluble minerals.

The quality of the ground-water in the second hydrogeologic zone worsens appreciably. This is very likely due to thick anhydrite intercalations within the Paleocene and Eocene series of beds. An specially bad quality of water is to be found within the above-mentioned zone of depressions.

The content of dissolved salts in the ground-water of the area south of the depressions along the border of Saudi Arabia is below 100 mg/1.

From the hydrogeological aspect poorest data are available for the hydrogeological zone lying to the east of Al Busaiya.

Within the sand and gravel strata of the Dibdibba beds there are intercalations of easily-soluble salts, and the beds of the Middle and of the Lower Miocene are intercalated by anhydrite. Obviously the effects of such a geological situation are noticeable in the quality of the ground-water. Thus it varies within the limits of the marginal to unacceptable water.

Here special consideration is given to the northern border of the desert and its neighbouring zone. There occur Miocene beds and members of the younger stratigraphic units. The oldest Miocene sediments — Euphrates limnestones — are directly overlaid by the Lower Fars beds containing numerous gypsum intercalations, owing to which the quality of the ground-water worsens considerably.

However, this zone is to be treated in connection with the springs, and we will refer to them later.

The zones under review differ among themselves by the content of total dissolved salts and by the kinds of dissolved salts.

In the first zone carbonate water prevails, except west of Rutba, where analysis reveales chloride water. Carbonate water occurs also in the southernmost part of the second zone along the Saudi Arabian border. In other parts of the second zone all waters are typically sulphate waters. The third zone is characterized by mixed sulphate and chloride waters.

Before proceeding with the description of the hydrogeology of the desert area, a few words may be said about the springs along the north-eastern border of the desert area.

Some 73 permanent and periodical springs occur along the border of the desert towards the Euphrates, i. e. from 34°05' to 31° N., over an approximate expanse of 500 km. The limits within which the capacities of the springs vary are rather large — from very small, meager springs, to such of very large capacity (Ain Chimara). They are all characterized by a high content of dissolved salts, raning from 1.000 mg/l to 10.000 mg/l, even more. Sulphates and chlorides prevail, sulphate water appearing more in the southern part, and chloride water in the north-western part of the zone.

There are numerous explanations in connection with the water coming up to the surface in the mentioned bordering zone. According to one of the oldest theories, water comes from the northern part of the country, passing below Mesopotamia. Another theory — which has been accepted as the most likely and is mentioned in all hydrogeologic treatises about those springs — is to the effect that this water is the one from the Euphrates River, which infiltrates the surrounding grounds of the river in its upper course and, flowing paralle with the river, appears on the surface in the lower parts of the country. Although the authors do not exclude the possibility of the water coming from the desert area, they take this view with great scepticism, mostly because of the great variation in the chemical composition of the spring water and the relatively poor rainfall in the feeding area.

We would like to point out that from the regional point of view all the mentioned occurences (belt of springs, depresions and the chemical composition of the waters) may be brought into connection with each other and explained after the generally accepted laws on hydrodynamics and tectonics.

When explaining the origin of the belt of spring it should be emphasized that the pressure surface map of ground-wiater has been drawn by experts of the R. Parsons Company, representing the desert area. The map was drawn on the basis of a very detailed list of the prospected water occurrences. Irrespective of the absolute exactness of the map, a very significant fact is evident, namely, that al the waters from the southern desert area gravitate towards the Euphrates. Since there is an established hydraulic gradient, or otherwise since the ground-water is in motion, it has to apper somewhere on the surface, so we have to reach the conclusion that this is an area characterized by the above-mentioned springs.

If so, the explanation of an occurrence being at the first sight in no relation with the springs will be much easier. It is the word about the depressions and the variation in the quality of the water, i. e. from the southernmost and that from the other parts of the Southern Desert.

It has been stressed already that at the extreme south of the Southern Desert water occurs with a low content of total dissolved salts and sulphates.

Owing to the structural conditions in this part of the desert the Paleocene sediments, which bear the lower anhydrite beds occur on the surface. In the north, the younger formations bearing younger auhydrite beds occur on the surface. If we take a look at the whole area, it will appear as a sequence of layers, within which possible porous carbonate rocks alternate with impervious but under certain conditions soluble anhydrite sediments.

The structural borings made at Tukhadid, Dimmama, Galaib, Abu Ghar and Rachi prove that along the line Tukhadid-Galaib the anhydrite horizons wedge out at the approximately same elevation bleow the surface. Presuming that there is a permanent washing action of the waters in the northern direction — and as we have seen this presumption may almost be considered a fact —, this elevation may be taken as the boundary of a more intensive washing out of easily soluble sediments. Geometrically it is visible that this is at the same time the aproximate absolute elevation of the thick Eocene anhydrite beds underlying the Salman depression, where according to the above presumtion they should have been washed out.

Owing to lack of other positive explanations as to the origin of the depressions, and referring to the above lay-uot, the conclusion may be reached that the belt of the depressions marks natural ways developed owing to tectonic actions, through which the ground-waters are moving most easily and most intensively. This supposition is supported by the presence of sink holes (an expressly Karst phenomenon) in the Salman and Shabicha depressions.

Beside the depressions from Tukhadid to Salman there is a whole series of less noticeable depressions stretching from the southeast towards Salman. From the regional point of view the zone of the richest springs along the border of the desert area extends as a continuation of this series of depresions.

In spite of the fact that such a statement seems to be rather bold, there is some evidence in favour of it, i. e. depressions, the rich number of springs along the border of the Northern Desert, and the gradual decrease of this number and of the capacity of the springs along the border of the Southern Desert, as well as the predominance of sulphate in the water of the south-eastern part of the area of springs. All this should not be neglected, but there is much to be done in order to prove the above presumptions in a scientific manner.

We might well have our doubts as to the value of the above presumptions because of the great differences in the chemical compositions and in total dissolved salts content of the water at the different springs and in the various ground-water horizons. It should be borne in mind, however, that we are concerned with very extensive area, from the lithological standpoint with verv different rocks and contents of easily soluble sediments, and with Karst phenomena within the waterbearing formations. On the other hand, a very high content of total dissolved salts, whereby also the increased density of a certain part of the ground-water may in some places partially cause a standstill of the salt ground-water in relation to the relatively fresh water. This presumption becomes even more likely if the small gradients and the established underground barriers are taken into account, wich in the above-mentioned suquence of layers constitute conditions for the creation of artesian water horizons. Such artesian wells are known to the southwest of Ramadi, at the structural borehole at Galaib (with a high content of sulphates, originating from the Palaeocene horizons), and at the shallow exploration holes in the vicinity of Najaf (a consanguinity from the chemical aspect between this water and the one from the desert has been proved) (K. E. Thompson, 1959).

Besides, mixing of this water with the connate water should also be expected owing to the asfalt occurrences and other phenomena found west of Ramadi.

At this juncture we would like to say a few words about the pressure suface map of ground-water made by R. Parsons Comp. In spite of the fact that in this map the gravitation of the groundwater towards the Euphrates is evident, it is not dependable enough to be used as a document for each part of the above-mentioned presumptions. This rather because this area yields very poor data about the topography of the southern desert area. Therefore for further interpretation it is very important to establish the absolute elevations of the most favourably located chek boreholes chosen.

SUMMARY

The author participated in the elaboration of a tender for the drilling of 120 wells in the Southern and Northern Desert, Iraq, in the winter of 1959/1960. The greatest obstacle encountered by the group was that the geological and hydrogeological data were of a regional character and gathered from various reports. This should not be wondered at, since the area of the Southern Desert covers some 190.000 sq. km., and because explorations and surveying were started a comparatively short time ago. Therefore a more complete view over the geological structure of the area had to be gained from the available reports and publications (see references).

The first part of this outline comprises a rather brief description of the stratigraphy and lithology of the area with the only aim to facilitate the future work of those who will be interested in studying the hydrogeology of this area. The author is convinced that the above-mentioned data will have to be completed and corrected.

For the sake of better guidance a topographic sketch is herewith enclosed, because the only geological map of the scale 1:1000000 made by experts of the Iraqi Petroleum Co. has not yet been published. Nevertheless the INGRA group was permitted to make use of this map.

The second part of this outline deals with hydrogeological problems arising from the area treated. It has been noted that the mutual depedence between the morphological and hydrogeological occurrences in the desert was the main thing dicsussed in all the previous reports. It is the author's opinion that this depedence was given a too great significance, and the depedence between the hydrogeology and the lithology and structure of the area was paid too little attention to.

From the regional point of view the conclusion is reached on the basis of the available data that the quality of the ground-water is in close relation to the lithology of the stratigraphic horizons. Bearing in mind this depedence, the whole desert area was divided into three main hydrogeological units. Into the first unit the rocks of the Mesozoic age were classified, into the second those belonging to the Tertiary, excluding the Miocene and younger beds, and to the third unit the Miopliocene sediments.

The report submitted by R. Parsons Company contains regional data on the gravitation of the ground-water towards the Euphrates, but nothing has as yet been made to bring this phenomenon into connection with the depressions of the Southern Desert area and the springs along the northern border of the Desert area. That is why to this mutual connection special attention was paid, in a way a new hypothesis of the regional groundn-water flows ad consequences of such flow explained. With regard to the regime of the ground-waters the author treats of it by bearing in mind that the individual local manifestations may be determined explained and exploited only if the regional laws are known. In this sence the above presumptions may be the key for a regional hydrogeologic prospecting and study of the desert area, which in any case should be made if an economical exploitation of the exactly delimited gronud-water quantities of the desert area is to be obtained.

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Ilica 1a

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P. MILETIĆ

O GEOLOŠKOJ GRAĐI I HIDROGEOLOGIJI PODRUČJA JUŽNIH PUSTINJA — IRAK

Tokom zime 1959/1960 godine autor ovog prikaza radio je u ekipi INGRA Comp. na izradi tendera za bušenje 120 bunara u Sjevernoj i Južnoj pustinji Iraka, južno od Eufrata. Jedna od najvećih poteškoća s kojom se je ekipa sudarila, bila je nesistematičnost i raspršenost u prvom redu geoloških podataka. Takvo stanje nije niti čudno, kada se uzme u obzir da južno pustinjsko područje pokriva oko 190.000 km², a da se je njegovim istraživanjima prišlo tek u skorije vrijeme. Zbog toga je bilo potrebno, da se upotrebom niza izvještaja izgradi cjelovitija slika geološke građe. U vrlo sažetoj formi takva geološka slika iznesena je u prvom dijelu ovog prikaza s isključivom željom da se olakša rad onima koji su zainteresirani za proučavanje hidrogeologije ovog područja. Autor je istovremeno svjestan da će biti potrebno gornje podatke nadopuniti i korigirati.

Za orijentaciju priložena je topografska skica terena, jer jedina geološka karta mjerila 1 : 1,000.000 koju su izradili stručnjaci Iraqi Petroleum Co. Ltd. još nije publicirana. Unatoč toga bila je ekipi INGRE dozvoljena njena upotreba.

Drugi dio ovog članka posvećen je hidrogeološkim problemima. Zapaženo je naime, da je u svim dosadašnjim izvještajima glavni naglasak stavljen na uzajamnu ovisnost morfoloških i hidrogeoloških pojava u pustinji. Autor smatra, da je ta povezanost i suviše naglašena i to na uštrb ovisnosti hidrogeologije i litološke i strukturne građe.

Na osnovu postojećih podataka došlo se je u regionalnom smislu do zaključka o nesumnjivoj uskoj povezanosti kvalitete podzemne vode i litološkog i facijelnog razvoja stratigrafskih horizonata. Na osnovu te ovisnosti je i čitavo pustinjsko područje podijeljeno u tri osnovne hidrogeološke jedinice. Prvu od njih sačinjavaju stijene mezozojske starosti, drugu tercijarne stijene do miocena, a treću miopliocenske taložine.

U izvještaju R. Parsons Comp. izneseni su regionalni podaci o toku podzemne vode prema Eufratu, ali do sada nije ništa učinjeno na povezivanju ovog fenomena s postojanjem depresija u južnoj pustinji i pojavom izvora na sjevernom rubu Sjeverne i Južne pustinje. Zbog toga je u ovom prikazu istaknuta ova povezanost, te je istovremeno iznesena hipoteza o regionalnom mehanizmu kretanja podzemnih voda.

Imajući u vidu ove osnovne ideje o režimu podzemnih voda autor ih ovdje prikazuje polazeći sa stanovišta da se pojedine lokalne manifestacije mogu shvatiti i objasniti tek ako su uokvirene u poznavanje regionalnih zakona. U tom smislu ove ideje i pretpostavke mogu da posluže kao polazna tačka za regionalno hidrogeološko istraživanje pustinjskog područja. Takvo istraživanje je opet neophodno, ako se želi korisno upotrebiti sigurno ograničene zalihe podzemne vode u pustinji.

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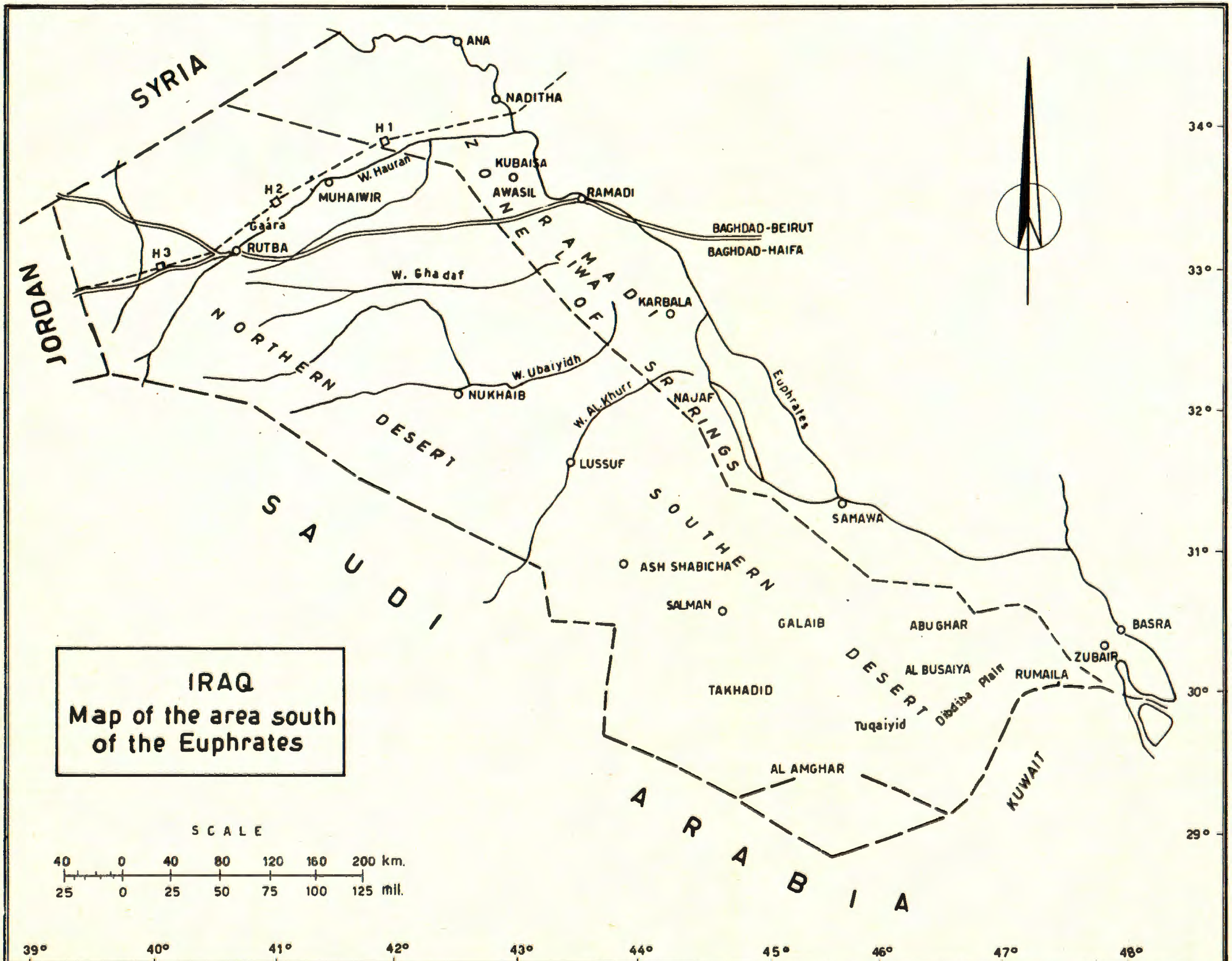
IRAQ
Map of the area south of the Euphrates
SYRIA
JORDAN
SAUDI ARABIA
KUWAIT
ANA
NADITHA
H 1
H 2
H 3
KUBAISA
AWASIL
RAMADI
MUHAIWIR
W. Hauran
Gaára
RUTBA
BAGHDAD-BEIRUT
BAGHDAD-HAIFA
W. Ghadaf
ZONE OF AMADI LIWA
KARBALA
NORTHERN DESERT
W. Ubaiyidh
NUKHAIB
SPRINGS
NAJAF
W. Al Khurr
Euphrates
LUSSUF
SOUTHERN DESERT
SAMAWA
ASH SHABICHA
SALMAN
GALAIB
ABU GHAR
BASRA
ZUBAIR
AL BUSAIYA
RUMAILA
Dibdiba Plain
TAKHADID
Tuqaiyid
AL AMGHAR
SCALE
40 0 40 80 120 160 200 km.
25 0 25 50 75 100 125 mil.
34°
33°
32°
31°
30°
29°
39° 40° 41° 42° 43° 44° 45° 46° 47° 48°