Geology and mineral deposits of Makhtesh Hathira (Southern Israel)

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Geology and Mineral Deposits of Makhtesh Hathira (Southern Israel)

by GABRIEL WIENER, Bern

Introduction

The Makhtesh Hathira or Makhtesh Hagadol (hebrew for «the great mortar»), in this paper referred to as the Makhtesh, is an anticlinal valley in the Kurnub-structure. It is situated at about 35 kilometers south-east of Beersheba in the northern Negev desert, i. e. the southern part of Israel (fig. 1).

The Makhtesh is on the top of the south-west—north-east trending anticlinorium of the Northern Negev Upland (PICARD 1951), marked in fig. 1 by a dash-dotted line, partly identical with the Central Negev Highlands of KALLNER-AMIRAN 1951. The mountains of this region rise up to 700 m above sea level, gently sloping towards the Mediterranean in the north-west and steeply sloping towards the Dead Sea Graben in the east.

Morphologically, the Makhtesh can be compared with an enlarged Combe such as of the Swiss Jura mountains, but there, the Wadi Hathira has forced its way through one single outlet in the Pirtsah (the hebrew word for «breach») in an otherwise closed ring of inward facing high escarpment cliffs. These cliffs in the Makhtesh are formed by lithologically more uniform anticlinal limbs than in the Combes. The northern cliff functions as the main water-divide between the Mediterranean to the west and the Araba-Dead Sea valley to the east.

Structurally, the anticlinal fold is a broad, rather asymmetric arch. The strata dip towards north-west at about 8 to 10 degrees; to the south-east, the dip is generally above 50 degrees, but near the Pirtsah, the strata are even slightly overturned (fig. 3).

Stratigraphy

In fig. 2 (Generalized Columnar Section) the stratigraphy of the Makhtesh region (especially of the Northern Negev Upland shown in fig. 1) is briefly exposed. Sedimentary rocks of Mesozoic and Caenozoic age crop out. A separate description of the *Upper Variegated Nubian Sandstone* will be given later in this paper, in the chapter on mineral deposits.

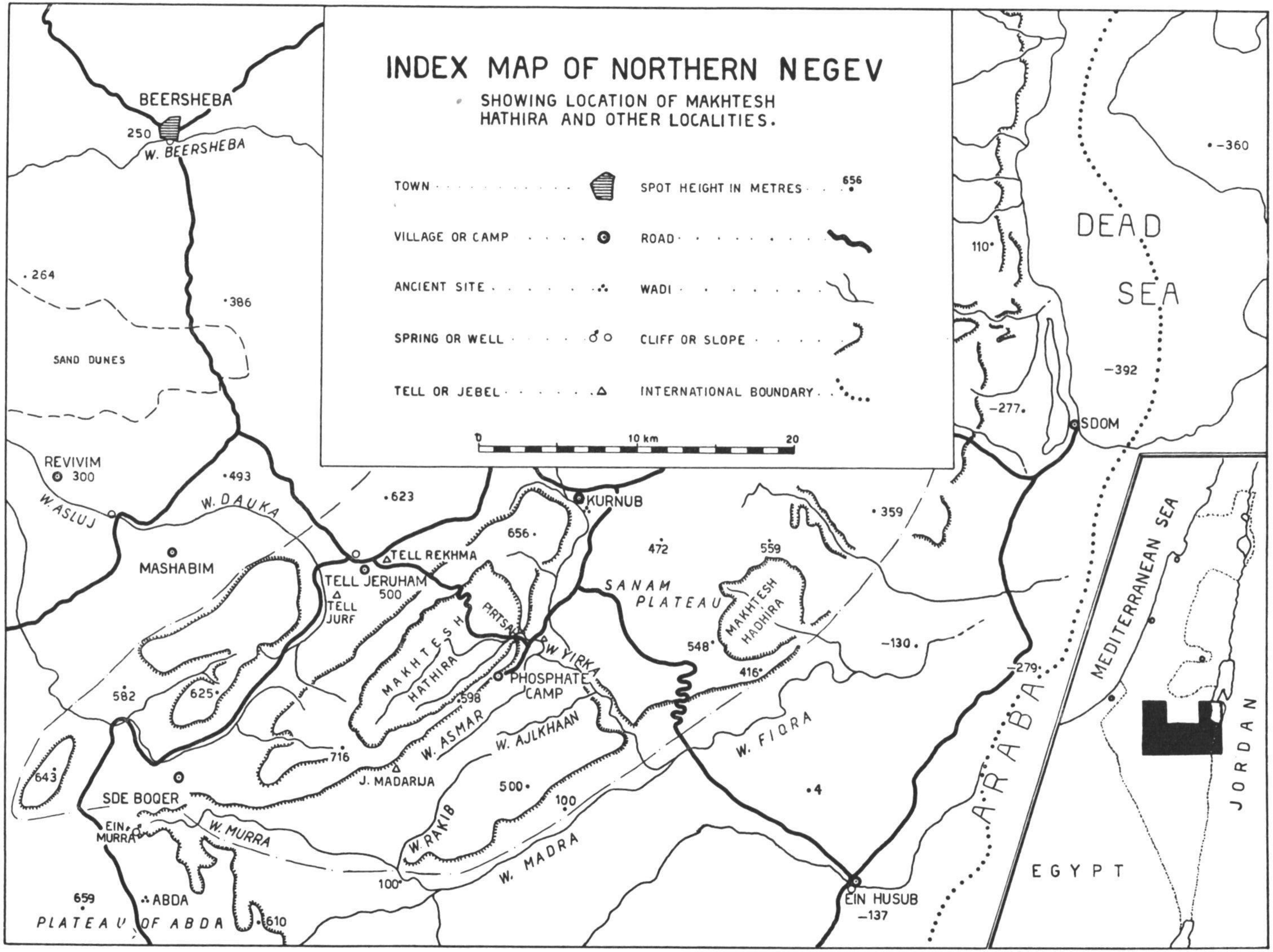

INDEX MAP OF NORTHERN NEGEV
SHOWING LOCATION OF MAKHTESH HATHIRA AND OTHER LOCALITIES.
TOWN
VILLAGE OR CAMP
ANCIENT SITE
SPRING OR WELL
TELL OR JEBEL
SPOT HEIGHT IN METRES
656
ROAD
WADI
CLIFF OR SLOPE
INTERNATIONAL BOUNDARY
0
10 km
20
BEERSHEBA
250
W. BEERSHEBA
264
386
SAND DUNES
REVIVIM
300
W. ASLUJ
493
W. DAUKA
623
MASHABIM
TELL REKHMA
TELL JERUHAM
500
TELL JURF
656
KURNUB
472
559
359
SANAM PLATEAU
MAKHTESH HADHIRA
548
416
-130
PIRTSA
W. YIRKA
PHOSPHATE CAMP
MAKHTESH HATHIRA
598
W. ASMAR
W. AJLKHAAN
716
J. MADARIJA
582
625
643
SDE BOQER
EIN MURRA
W. MURRA
W. RAKIB
500
100
W. MADRA
100
659
ABDA
PLATEAU OF ABDA
610
W. FIQRA
4
EIN HUSUB
-137
ARABA
-279
DEAD SEA
-360
-392
110
-277
SDOM
MEDITERRANEAN SEA
JORDAN
EGYPT

Fig. 1

GENERALIZED COLUMNAR SECTION · MAKHTESH HATHIRA REGION · SOUTHERN ISRAEL

NOT AT SCALE · BASEMENT NOT EXPOSED

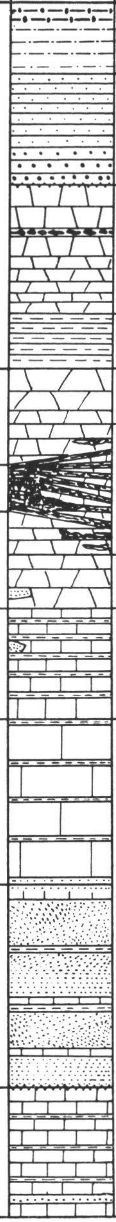
SYSTEM		SERIES	GROUP	DIVISION	ANTICLINES	COLUMNAR SECTION	SYNCLINES	CHARACTER OF SEDIMENT	LOCATION OF TYPICAL OUTCROP	MINERAL DEPOSITS	FOSSILS
QUATERNARY		RECENT HOLOCENE	ALLUVIUM BLOWN SAND LOESS	UPPER CLASTIC DIVISION	GENERALLY NOT PRESERVED		up to >50 m	ALLUVIAL MATERIAL AND "KURKAR" = CONSOLIDATED DUNES. BRIGHT-YELLOW, PARTLY WANDERING SAND DUNES. PALE-BROWN SANDY LOESS	COASTAL PLAIN, SYNCLINAL VALLEYS SOUTH OF BEERSHEBA	SULFUR AND BITUMEN-IMPREGNATION	
		PLEISTOCENE	HUSB-SANDSTONE AND CONGLOMERATE				>50 m	REDDISH SOFT FINE-GRAINED BEDDED TERRESTRIC CALCAREOUS AND MARLY SANDSTONE.	SANAM PLATEAU		
TERTIARY	UPPER	PLIOCENE ? MIOCENE ?						INTERCALATION OF WHITE CRYSTALLINE LACUSTRINE LIMESTONE WITH SOME ASPHALT VEINS. HARD COARSE LITORAL CONGLOMERATE	1.5km SE TELL JERUHAM T. JURF, WADI RAKIB	ASPHALT IN VEINS	GASTROPODA OSTREA sp.
			u-n-c-o-n-f-o-r-m								
	LOWER	EOCENE MIDDLE LOWER	WHITE CHALK AND BLACK FLINT	MIDDLE OR CALCAREOUS DIVISION			>200 m	WHITE SOFT PARTLY SILICIFIED COMPACT CHALK, IN LOWER PART INTERBEDDED WITH CHAINS OF BLACK NODULAR FLINT	TELL REKHMA EIN MURRA PLATEAU OF ABDA		FORAMINIFERA
		PALEOCENE	TAQIYA-MARL					GRAY- WHITE- OR BUFF-WEATHERING SOFT MARLY CHALK, SOMEWHAT LIMONITIC AND BITUMINEOUS	TELL REKHMA NORTH OF EIN MURRA	GYPSUM BARYTES AND STRONTIANITE (VEINS)	FORAMINIFERA
CRETACEOUS	UPPER	DANIAN					~ 70 m	GREENISH-GRAY TO BLUE CONCHOIDAL-BREAKING SOFT CALCAREOUS SHALE (VERY SALTY ON SURFACE)	TELL REKHMA, T. JURF JEBEL MADARIJA	SHALE SOME BITUMEN	FORAMINIFERA
		MAESTRICHTIAN	GHAREB-CHALK		0 to 100 m		~ 100 m	WHITE SOFT COMPACT CHALK AND MARL WITH LIMONITE SPECKS. PARTLY SLIGHTLY PHOSPHATIC	J. MADARIJA, W. ASMAR WADI RAKIB		MICRO- AND MACROFOSSILS
		CAMPANIAN	MISHASH-FLINT		20 m COMPACT FLINT		total ~ 60 m, ~30 m of thin FLINT BEDS intercalated	WHITE AND GRAY SOFT PHOSPHATIC CHALK WITH CONCRETIONS OF SILICIFIED CHALK. BROWN PHOSPHATE WITH INTERCALATED LIMESTONE HORIZON. COMPACT BROWN TO BLACK FLINT PARTLY INTERBEDDED WITH MORE (SYNCL.) OR LESS (ANTICLINES) THIK HORIZONS OF PHOSPHATIC CHALK	W. ASMAR, W. RAKIB W. AJLKHAAN FLINT PRESERVED ON MOST ANTICLINAL FLANCS AROUND TELL JERUHAM AS CAP-ROCK	PHOSPHATE (EXPLOITED) FLINT BITUMINEOUS CHALK	FISH REMAINS SHELL-BEDS PECTINIDAE OSTREA sp. HAMITES sp. OTHER FOSSILS
		SANTONIAN	MALIHA-CHALK		few m		>40 m	WHITE TO ROSE SOFT COMPACT CHALK AND LIMESTONE, FEW LUMPS OF VARIEGATED NUBIAN SANDST.	WADI DAUKA		FISH REMAINS PLICATULA sp.
	LOWER	TURONIAN	JUDEAN-LIMESTONE		few m		~ 70 m	GREY YELLOW ROSE AND BROWN WELL-BEDDED CRYSTALLINE LITHOGRAPHIC LIMESTONE INTERBEDDED WITH SOME CHERT WHITE MARLY LIMESTONE AND THIN HORIZONS OF YELLOW MARL. FEW LUMPS OF VARIEGATED NUBIAN SANDSTONE	WADI YIRKA, PIRTSAH EXPOSED ON MOST OF THE ANTICLINES	BUILDING-STONES	EXOGYRA flabellata LEONICERAS sp.
		CENOMANIAN			>400 m		NOWHERE TOTALLY EXPOSED	GRAY BROWN AND YELLOW OCCASIONALLY REDDISH-WEATHERING THICKLY-BEDDED HARD LIMESTONE AND DOLOMITE, PARTLY SILICIFIED AND CHERTY, INTERBEDDED WITH CALCAREOUS BRIGHT-YELLOW AND BROWN MARL AND GYPSEOUS SHALE, CONCRETIONS OF CHERT AND CHALCEDONY, SECRETIONS OF QUARTZ WITH FERRUGINOUS BROWN COATING INTERSPERSED. AT BASE SANDY GLAUCONITIC LIMESTONE AND MARL	WADI HATHIRA WADI HADHIRA WADI YIRKA PIRTSAH	LIMESTONE AND DOLOMITE FOR ROAD BUILDING, SOME BITUMEN IN FISSURES	AMMONITES EXOGYRA flabellata E. columba
		ALBIAN APTIAN	UPPER VARIEGATED NUBIAN-SANDSTONE	LOWER OR PRE-UPPER-CRETACEOUS DIVISION	>400 m			MULTICOLORED (VARIEGATED) SOFT SLIGHTLY CEMENTED FINE TO MEDIUM GRAINED BEDDED AND CROSS-BEDDED CONTINENTAL AND MARINE QUARTZ-SANDSTONE. INTERCALATIONS OF MARINE SHALE, OOLITHIC LIMESTONE, SANDY GLAUCONITIC LIMESTONE AND DOLOMITIC LIMESTONE OF VARIOUS COLORS. LIMNIC OR LAGUNARE BEDS OF WHITE AND COLORED CLAY AND BALL CLAY. CRUSTS OF LIMONITIC SANDSTONE. LIMONITE. AT BASE COLORED FAT SHALES OF CHANGING THICKNESS (see Text)	WADI HATHIRA, W. MADSUS, W. HADHIRA	GLAUCONITE GLASS SAND (EXPL.) BALL CLAY (EXPL.) IRON ORE BRICK CLAY	MARINE INTERCALATIONS WITH AMMONITES AND OTHER FOSSILS. SILICIFIED TREES
			u-n-c-o-n-f-o-r-m								
JURASSIC		UPPER JURASSIC	JURASSIC LIMESTONE AND MARL		250 m exposed			YELLOW AND GRAY HARD CRYSTALLINE BEDDED MARINE LIMESTONE, INTERCALATION OF THICK BEDS OF BROWN AND YELLOW MARL WITH GYPSUM, BEDS OF OOLITHIC AND OF SANDY LIMESTONE, BROWN CALCAREOUS SANDSTONE. AT BASE BLACK BITUMINEOUS LIMESTONE WITH PYRITE	WADI HATHIRA WADI MADSUS	HARD LIMESTONE CLAY GYPSUM BITUMINEOUS-LIMESTONE	PELECYPODA* GASTROPODA BRACHIOPODA ECHINOIDEA

Fig. 2

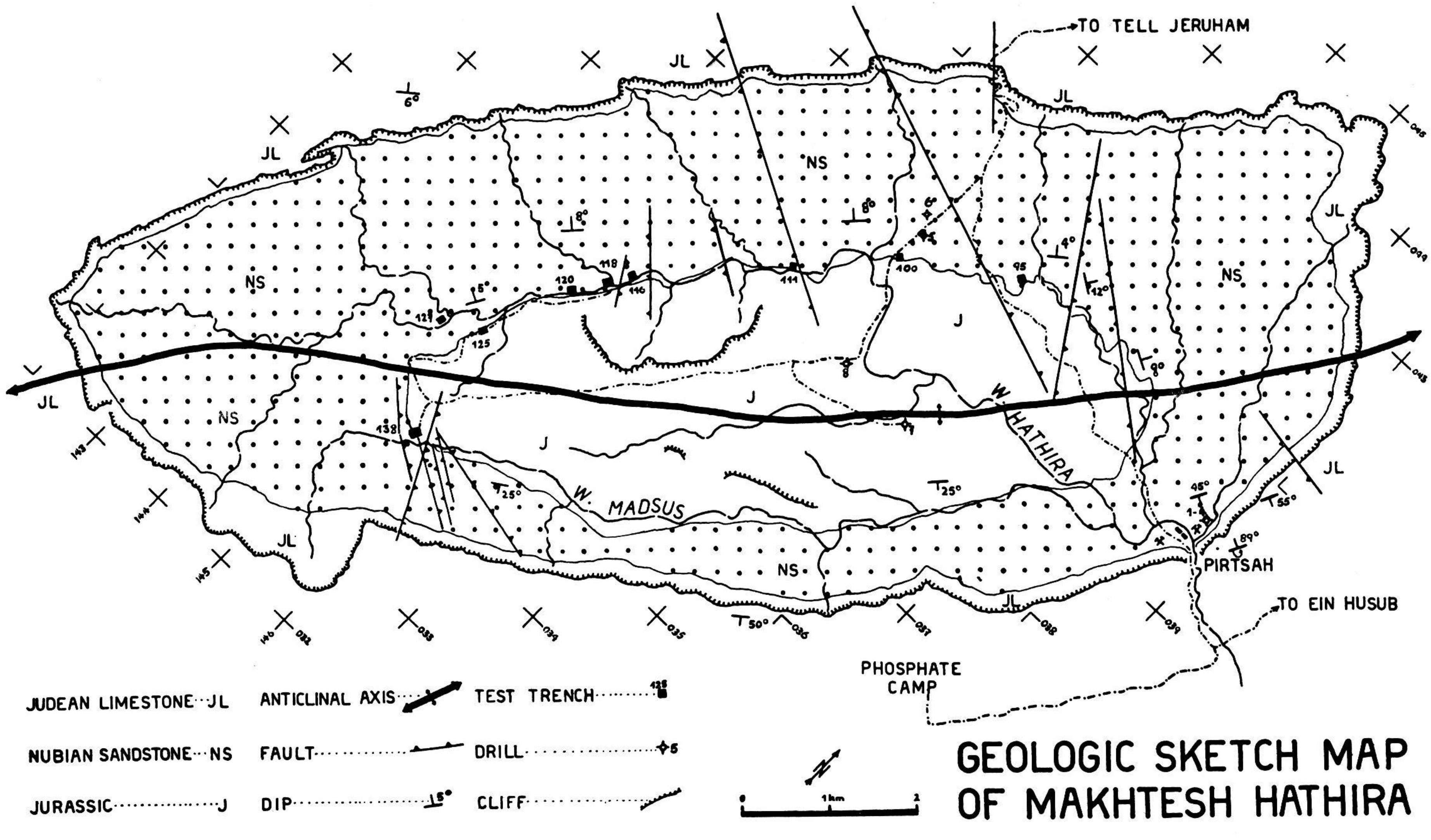


Fig. 3. Geologic sketch map of Makhtesh Hathira

Jurassic rocks occur but in the central part of the Makhtesh (figs. 3 and 4). Lower Jurassic is not exposed, the deepest known strata are hard bitumineous and pyritic limestone from the bottom of the cored drill No. 8. Bright-coloured marl and limestone characterize the whole outcrop. Upper Jurassic hard limestone on the top of this formation form the inner cliff shown in fig. 3 south of the upper course of Wadi Hathira.

Upper Variegated Nubian Sandstone is a series of predominantly terrestric continental quartz-sandstone with marine and lacustrine intercalations. The series rests unconformably on the Jurassic, marking a considerable regression of the sea during the lower Cretaceous. The annular outcrop in the Makhtesh gives a complete section which builds up the soft hills at the bottom of the valley between the steep ring of Judean Limestone above and the Jurassic cliffs in the core of the eroded anticline. The marine intercalations yeld a rich Aptian and Albian fauna. Further outcrops are in W. Yirka and Makhtesh Hadhira.

Judean Limestone, a series of marine limestones and dolomites of transgressive nature, is widely distributed in the mountainous part of the region. All anticlinal ridges and the characteristic wild and high cliffs of the Makhtesh consist of these Cenomanian-Turonian rocks.

Upper Cretaceous and *Lower Tertiary* chalk, shale, clay and marl form the very bright-coloured gentle hills of synclinal and basin regions of the northern Negev. *Mishash* flint covers most of the anticlinal limbs with a black coat, while, on top of the anticlines, it is generally eroded. A good section of Eocene chalk with chains of black flint interbedded is near Ein Murra.

The *Upper Clastic Division* follows after a strong erosion of the rocks, between Turonian and middle Eocene, took place. A coarse transgressive conglomerate of Miocene to lower Pliocene age is deposited on the older marine sediments. It is the projecting cap-rock of such hills as Tell Rekhma, Tell Jurf and many others. Most of the Sanam Plateau east of the Makhtesh is covered with *Husb* sandstone, a relatively fine-grained calcareous litoral sandstone with lacustrine intercalations of limestone, of Miocene to Pliocene age.

Alluvial fills in valleys and synclines are, as a rule, not very thick. *Sand dunes* regions of considerable extension are only to be found to the immediate south of Beersheba and towards the coastal plain.

In the *Upper Cretaceous,* two distinct *sedimentary facies* are developed. Thickness is up to now the most conspicuous attribute of the different facies, but surely, after thorough investigation, the paleontological content and the lithological character will produce additional evidence (BENTOR 1951 and 1953). Since Turonian or even earlier, the thickness of deposits has increased towards today's synclines and decreased towards today's anticlines. This phenomenon is especially interesting in that it explains the origin of phosphate and the deposition and splitting-up of flint-layers in chalky sediments. Possibly the occurence of lumps of Variegated Nubian Sandstone in Judean Limestone and in younger rocks is connected with the differentiation of the original place of deposition in newly growing anticlines and synclines as well.

Where no *Paleontological evidence* is available, the determination of age of the rocks is done by correlation with neighbouring regions. The extremely rich and well-preserved faunal assemblages of *Upper Jurassic* and *Upper Cretaceous* (especially *Campanian)* still await determination and interpretation. Paleontology and local nomenclature entirely depends on the work by geologists of the Irak Petroleum

Company (I.P.C.), of the Mandatory Government and of the Government of the State of Israel, as published by BLAKE, PICARD, SHAW and BALL.

Tectonics

The Northern Negev Upland is built up by an anticlinorium (Northern Negeb Arch or Kurnub Upwarp of PICARD 1943). The anticlines (open folds and asymmetric normal folds) appear as such at the surface and form long ridges, corresponding more or less in size and shape to their structure (cf. map in PICARD 1951 and section II, fig. 2, in PICARD 1943). Only in the Makhtesh, on the *Kurnub* or *Hathira* anticline, and in the Makhtesh Hadhira has erosion altered the original features into the present-day anticlinal valleys.

The culmination of the anticlinorium ist the *Hathira Anticline* extending north-east to south-west, a *simple asymmetric* fold inclined (even slightly overturned north of Pirtsah) toward south-east (fig. 4). The crest-line is slightly S-shaped,

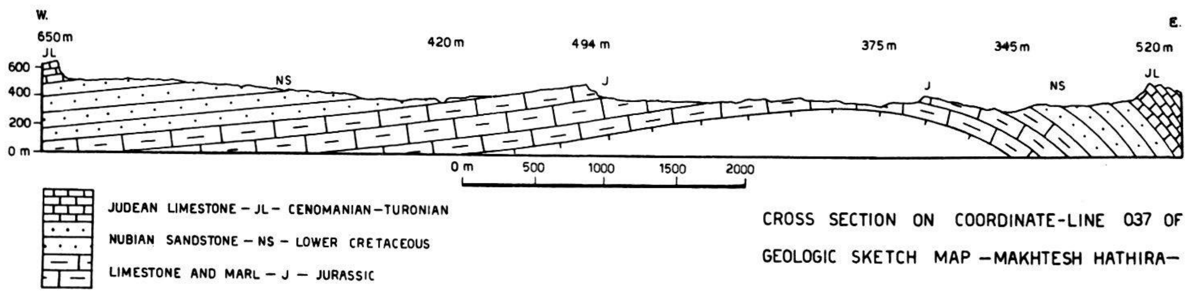


Fig. 4. Section across the Hathira or Kurnub-Anticline

its fold-axis plunging to the north into the Kurnub Depression; to the south it is cut by a major transversal fault where it plunges below the Eocene of the Abda Plateau. The culmination (dome) of the anticline is near Wadi Hathira in the center of the Makhtesh (fig. 3). The form of the center of the whole structure is best shown on map 16, BALL 1953.

Faulting in the Makhtesh itself had no greater effect on the structure. Only transversal and more or less vertical step-faults with maximal thrusts of 50 m could be detected. They cause minor *Graben* and *Horsts,* best developped in the *Judean Limestone* of the northern cliff. The region of the Pirtsah shows no major faulting, but intensive cleavage. The breaking-through of the wadi in this place is not due to transversal faulting, but to the steep inclination of the strata and the lowering of the erosion basis to the east of the Makhtesh by the sinking-off of the Dead Sea region. Most faults are restricted to either limb of the anticline and none evidently affect the lowest exposed Jurassic rocks. Endurated mylonites and, in the Nubian Sandstone, hard silicified sandstone and quartzolite dykes prominently mark the course of many major faults.

Joints, fissures and cleavage are very common in harder rocks of the Makhtesh. Upper Jurassic limestone shows in many parts a net of squarely intersecting joint-sets, which are due to folding or upwarping tension.

Chronology of structural events is, as yet, not completely known. Disposition of first minor folding took place in Paleozoic time. Between the Lower Cretaceous and the end of Turonian as well as in the Middle Tertiary, between Middle Eocene and lower Pliocene were the major folding phases. The uplift and formation of the anticlinorium very probably followed at the end of Tertiary. Minor faulting accompanied all of these phases. The influence of the Quaternary formation of the *Dead Sea—Graben* on faulting in the Makhtesh could not be proved here.

Mineral Deposits

In 1947, S. H. SHAW, then Government Geologist in Palistine, came to the following conclusion concerning «Mineral Deposits in the Southern Part of Palestine» (Negev): (SHAW 1947, p. 35) «The area is practically without any mineral deposits of economic value under present conditions and most of those that do occur are of low intrinsic value so that their relative inaccessibility makes it unlikely that they could be profitably exploited».

This statement has not been confirmed by the facts. Since the inauguration of the State of Israel, a thorough investigation of the Negev has been, and is still being, executed by many geologists on behalf of the government and especially on behalf of the Army. The latter promoted the geological mapping of the Negev on a scale of 1:100 000 by Drs. BENTOR and VROMAN. Much work has also been done by the geologists of the Israel Mining Company (Makhtsavei Israel), in prospecting and small scale-mapping of the mining areas.

The main problem for an economic exploitation of the Negev minerals lies in the excessive cost involved in their transport from the Negev to the industrial centers. To lower it, these centers would either have to be transferred to the Negev or connected with it by a direct railway.

Besides already known deposits (*copper* and *manganese* in the southern Negev near the harbour of Eilat), which proved of greater value than previously assumed, the recently detected and now exploited *phosphate, ball-clay* and *glass-sand* deposits made the local industry self-supporting as to these raw-materials and even enabled it to produce sufficient quantities for a moderate export of fertilizers, ceramics and glass-ware. The exploration of *iron ore* in the central Negev (Wadi Jirafi, cf. map No. 1 by BALL 1953) and in the Makhtesh has been less promising as yet, but exploitation is still under consideration. Lately, the search for *oil* and *gas* has been intensified and several companies are already drilling in the Negev.

Upper Variegated Nubian Sandstone

Mineral deposits in the Makhtesh are restricted to this series. The detailed section given here is a combination of two sections, one, the upper part, from near the Pirtsah, and the other, lower part, from the northern side of the anticline west of the road. The main horizons, i. e. the marine intercalations and the limnic ball-clay, are undisturbed and do not change much in thickness or composition throughout the whole annular outcrop. On the other hand, the continental series change considerably in composition, but less in thickness.

According to PICARD (1938) «the term *Nubian Sandstone* should be used as a facies name indicating the permanent struggle between the transgressive sea in the west and the aeolic or terrestrical ingressive forces of the east, the latter originating from the interior of the Arabian shield. The Nubian facies has governed the Arabian shield from the end of the Precambrium till the present time».

This definition was confirmed again by our section of the *Upper Variegated Nubian Sandstone* in the Makhtesh.

Petrologically the *Nubian Sandstone* is characterized by its great amount of stable minerals. In the light fraction, uniformly rounded quartz grains are the only components of importance, while in the heavy fraction, opaque minerals such as iron-oxydes and glauconite, are prevailing, zirkon, rutile and tourmaline being much scarcer (VROMAN 1944).

(The *Lower Variegated Nubian Sandstone* is exposed in southern Negev and in Transjordan and comprehends the more or less continental variegated sandstone series of Paleozoic and Triassic age.)

The *Upper Variegated Nubian Sandstone* in the Makhtesh is mainly the result of repeated reworking of the decomposed Kratogen of the Arabian Shield, a series of generally badly consolidated terrestric (continental) and marine medium-grained multicoloured quartz-sandstone with various intercalations as shown in the following section (marine fossils are marked by a *, plant remains by a †); most of the limy and marly fossiliferous intercalations are of either distinct marine character, while many of the sterile sandstone horizons could have been deposited in litoral or in terrestric environment.

Exploited Minerals

Glass Sand

The colour of the Upper Variegated Nubian Sandstone is entirely due to its content of iron-oxydes, mainly limonite and hematite, in the cement or as coating of the quartz-grains. Clay components and lime are generally restricted to distinct horizons. Where the limonite content is very small and clay and lime are almost absent, the unconsolidated quartz-sand is entirely white. If, in addition, the average size of the grains is uniformly small and outcrops are big enough, this sand can be mined for the glass-industry. The purity of this glass-sand is due to its repeted reworking throughout geologic history. The rounding of the quartz-grains is good and other minerals are very scarce and have been leached out and washed away by running water or shore waves.

In the Makhtesh, glass sand occurs in distinct horizons, especially in the upper part of the Nubian Sandstone section. The different outcrops display very extended lenses of white sand, interrupted by more coloured and consolidated streaks of limonitic, calcareous and marly sandstone.

The following table represents a summarized comparison, both as to average grain size and chemical analysis, between the Makhtesh glass sand from the Pirtsah corner, the formerly imported Belgian glass sand, and the famous occurrence of Hohenbocka (Saxony) (figures = per cent.):

Section of Upper Variegated Nubian Sandstone in the Makhtesh

TOP:	Cenomanian marine limestone	
0.50 m	brown hard dolomite with some glauconite interspresed	412 m
0.50 m	brown hard dolomitic limestone with some glauconite	
0.50 m	greenish-brown glauconitic limestone	
1.00 m	green glauconitic calcareous sandstone	
2.00 m	green sandy glauconitic marl	
2.00 m	hard brown calcareous quartz-sandstone	
14.00 m	soft grey violet and variegated quartz-sandstone	400 m
25.00 m	gray and brown soft marly sandstone with †	
5.00 m	white glass sand	
15.00 m	brown and variegated soft quartz-sandstone	
1.50 m	brown hard glauconitic limestone	
0.50 m	variegated hard dolomitic sandstone	
2.00 m	brown and yellow sandy marl	
1.00 m	yellow dolomitic and glauconitic limestone with *	3rd marine intercalation
2.00 m	brown, slightly sandy marl	
10.00 m	variegated sandy marl with gypsum	
3.00 m	variegated soft quartz-sandstone	
0.50 m	brown hard calcareous sandstone	
5.50 m	white glass sand	
1.00 m	variegated soft marly sandstone	
15.00 m	variegated hard sandstone and sandy marl	300 m
1.00 m	red and variegated sandstone	
6.00 m	white glass sand EXPLOITED	
14.00 m	variegated sandstone and sandy marl	
11.00 m	white sand with some coloured and consolidated streaks	
1.00 m	variegated shale	
2.00 m	hard red sandstone and marl	
1.50 m	gray to black soft ball clay with † No. 50 EXPLOITED	
1.00 m	red sandstone and marl	
6.00 m	variegated, partly consolidated sandstone	
10.00 m	white glass sand	
0.70 m	brown and gray sandy marl	
3.50 m	white glass sand	
5.00 m	brown and gray very finegrained sandstone	
5.00 m	red and variegated sandy shales	
1.00 m	variegated soft marly sandstone	
1.30 m	white ball clay (flint clay) No. 53 EXPLOITED	
0.30 m	red marly sandstone	
2.00 m	red hard calcareous sandstone	
0.05 m	brown limonitic sandstone crust	
11.50 m	variegated sandstone and sandy shale	
7.50 m	white glass sand EXPLOITED	
3.50 m	red marly sandstone with some ochre	
0.70 m	gray partly sandy ball clay	
18.00 m	brown and yellow crossbedded coarse sandstone	
39.00 m	variegated, partly crossbedded sandstone and sandy marl	200 m
5.00 m	white glass sand	
2.00 m	red hard coarse calcareous sandstone	
10.00 m	variegated shale and sandy marl	2nd marine intercalation
5.00 m	yellow soft dolomitic marly limestone with *	
0.20 m	sandy brown and red botryoidal limonite crust	
1.00. m	variegated sandy marl	
17.00 m	red and brown coarse partly crossbedded sandstone	
35.00 m	violet and red shales and clay with * and sandy mar	1st marine intercalation
1.00 m	brown dolomitic sandy limestone	
9.00 m	variegated sandy marl	
4.00 m	brown and violet hard calcareous sandstone	
0.20 m	brown and red botryoidal iron-oxyde crust with ochre	
0.50 m	variegated shales	100 m

100 m

43.00 m yellow red and gray partly crossbedded quartz-sandstone
5.00 m white fingrained sandstone
19.00 m brown soft marly limestone
0.25 m yellow and reddish botryoidal limonite
14.00 m variegated marl and coarse crossbedded sandstone with †
0.20 m brown and violet hard sandy iron-oxyde crust
18.00 m pale-violet to gray finegrained sandstone
0.25 m — 1.20 m more or less sandy IRON ORE
0.05 m — 1.20 m variegated fat shale
BOTTOM: Upper Jurassic fossiliferous marine limestone

0 m

	Makhtesh		Belgian	Hohenbocka
	Outcrop	2 m below	sand	
Chemical Analysis:				
SiO_2	98.85		99.10	99.61
Al_2O_3	0.65		0.25	0.055
Fe_2O_3	0.06		0.25	0.034
CaO	0.29		0.20	0.042
MgO	—		—	0.032
MnO	—		0.10	—
K_2O, Na_2O	—		—	0.042
loss of ign.	0.15		0.10	0.24
Grain Size:				
25 mesh	0.08		0.05	
35 mesh	0.28		0.77	
45 mesh	2.10		10.07	
60 mesh	9.52	19.0	30.21	
80 mesh	28.72	57.5	41.85	
100 mesh	30.49		12.20	
> 100 mesh (dust)	28.69	12.0	4.70	

The analysis shows that Makhtesh glass sand constitutes a good basic material for the manufacture of any glass except for crystal-glass. For special purposes, the raw material may, of course, be improved by sorting or by selective mining.

Mining is currently underway in several horizons in the Pirtsah-corner of the Makhtesh, where strata are inclined between 30 to 45 ^{0} to south-east (cf. fig. 3, in the vicinity of drills 1 to 4). The sand is mined by bulldozer along parallel strips following the outcrops on the north and south of the road. The loading of the trucks is still being done by men. The production cost might be considerably cut by improving the mechanization of the mining.

The amount of economically exploitable glass sand in the Makhtesh is estimated at 10 million tons at least. Production of glass sand in the Makhtesh started in 1950. Up to June 1953, 27 615 tons were produced. The estimated annual output will be 15 000 tons and may increase according to export possibilities. *Resources of glass sand in the Makhtesh are sufficient to satisfy large-scale demands for many hundred years.*

Ball Clay (Flint Clay)

Two horizons of clay are exploited in the Pirtsah-corner of the Makhtesh. Both are in the upper part of the Upper Variegated Nubian Sandstone, separated by a series of sandstone and glass sand of up to 30 m (cf. section of Upper Variegated Nubian Sandstone).

The average thickness of the lower horizon (referred to as No. 53) is 1.3 m. The central part of the deposit consists of hard white, conchoidal breaking flint-clay, grading upwards and downwards into white, slightly sandy clay. The upper horizon (referred to as No. 50) is soft, black to gray clay of an average thickness of 1.50 m. Its content of organic matter and fossil plants is much higher than in horizon No. 53. Here, too, the central part of the horizon is the best, regarding quality.

Both horizons, as far as we know, are continuous throughout the whole Makhtesh and form two concentric rings with the Nubian Sandstone outcrop. Other horizons of ball clay are either discontinuous (in pockets and lenses), or not economically exploitable because of their high content of limonitic colour or quartz-sand.

The limnic-terrestric nature of the redeposited ball clay horizons is proved by the content of plant remains (palm trees). Iron oxydes are leached out by the organic acids contained in Lower Cretaceous subtropical soil.

To ascertain the continuity of the thickness and quality of the two horizons underground, and to determine the gradual increase of the dip, four drills have been carried out in the region of exploitation (drills Nos. 1 to 4 in fig. 3):

Test Drills in Ball Clay Exploitation Area near the Pirtsah

(Map reference: 1 : 1250 local map of 3. 9. 1951, trig. points P. 1—29.)

	Drill No. 1	*Drill No. 2*	*Drill No. 3*	*Drill No. 4*
	40.5 m 95°E P. 8	54 m 22°E P. 12	31 m 206°W P. 16	37.4 m 88°E P. 26
top above sea level	299 m	308 m	311 m	322 m
remarks	—	stopped in clay No. 53		near anticl. axis
dip on outcrop	35°	40°	39°	15°
horizontal distance from outcrop No. 53	67 m	114 m	85 m	97 m
horizontal distance from outcrop No. 50	20 m	?	?	1 m
depth of core of No. 50	17.5-19.5 m	67.6-73.35 m	40.5-43.0 m	2.0-3.5 m
inclination in core of No. 50	40°	56°	47°	15°
depth of core of No. 53	61.0-62.3 m	160-170 m	89.5-103 m	26-27 m
inclination in core of No. 53	55°	70°	60°	17°
total depth	63.3 m	170 m	103 m	40 m

The results of the drills show that the horizons of clay are continuous both as to depth and surface. Thickness remains more or less steady and so does quality, as is shown below in different analyses. Average samples for analysis have been taken from outcrops Nos. 50 and 53 in the exploiting area, from No. 53 of a slightly inclined locality on the opposite side of the Makhtesh, near the road 150 m W of drill No. 5 (cf. map fig. 3) the latter analysis being marked K No. 53, and a last sample from the core of drill No. 4, from a depht of 26 to 27 m. For comparison, a chemical analysis of Bohemian flint-clay from Lubna has been added:

	No. 50	*No. 53*	*K No. 53*	*Drill No. 4*	*Lubna*
SiO_2	54.05	52.0	46.45	55.9	46.54
Al_2O_3	28.0	34.06	29.5	29.86	39.15
Fe_2O_3	3.8	0.97	0.97	0.85	0.85
CaO	0.8	0.24	9.83	2.5	0.15
NaCl etc.	0.5[1])	0.12[2])	1.19	0.08	—
Na_2O+K_2O	—	—	—	—	1.11
Ti_2O_3	traces	traces	traces	traces	—
loss of ign.	12.6	12.24	?	?	12.86
burns at 1000^0 C	creamy-	white			
burns at 1100^0 C	coloured	very light cream			

The clay contained in horizons Nos 53 and 50 is suited for the manufacture of fire-bricks, sanitary ware and simple table ceramics. By washing and selective mining, its quality may be improved.

Exploiting of ball clay in the Makhtesh is almost as simple as that of glass sand. The two horizons can be followed in their outcrops around the Makhtesh by opencast. On the steeply inclined side of the Makhtesh, overburden is generally small. On the northern side there are also outcrops, which can be enlarged by bulldozing the overburden. No expensive underground work is incurred. Improved mecanization of the exploiting methods will lower the cost of production considerably.

The production of ball clay from 1951 to June 1953 amounted to 11 488 tons. The annual demand may average 10 000 tons. The economically minable reserves on surface in the two horizons are estimated at 250 000 tons and more, the total reserves being much greater. *Ball clay sufficient for a normal demand of at least 25 years can be mined in the Makhtesh by opencast.*

Explored Minerals

Iron Ore

Besides its quartz-content the Upper Variegated Nubian Sandstone series displays a considerable amount of opaque minerals, especially iron-oxydes. These iron-oxydes are found either in close connection with the quartz-grains, as coating or dispersed in the cement of ferruginous sandstone, or in pockets as redeposited or reworked pure limonite or hematite. Up to the present, iron carbonate has not been in detected in the Makhtesh.

[1]) Disappears completely at a depht of 20 m, Ti_2O_3 and organic matter show slight increase.
[2]) Disappears at a depht of 3 m.

The iron content of the section might be traced to the decomposition of basaltic intrusions in the region. According to BENTOR (1952) the extensive intrusions of W a d i R a m a n in the central Negev (cf. map. 1 by BALL, 1953) are restricted to the Jurassic period, whilst authors from other Middle-East countries consider the volcanic paroxism to belong to the Upper Aptian age. In the M a k h t e s h itself, no intrusives could be noticed. Deposition of iron-oxydes had possibly been enriched in certain horizons by the precipitation out of iron salt solutions on quartz-grains, while other horizons have been leached out (glass sand). Redeposition of the iron-compounds has been promoted by the frequent change of marine and continental facies in the Nubian Sandstone section.

The thickest and best enrichment as to quality of iron-oxydes is that at the bottom of the Nubian Sandstone section in the Makhtesh. It marks the circumferring boundary between the Nubian Sandstone and the Upper Jurassic limestone. This horizon is the only one that can be considered an iron-ore deposit. It seems to be continuous throughout Nubian Sandstone section of the Negev. In the southern Negev, e. g. near E i l a t, where Jurassic is deposited as white, coarse-grained sandstone, a strongly ferruginous sandstone marks the transition from the Jurassic to the Upper Variegated Nubian Sandstone as well.

The theoretical outcrop of the iron ore in the M a k h t e s h is seen in map fig. 3 as the boundary line between Upper Jurassic and Nubian Sandstone. The steep dip on the south-eastern side of the anticline forbids an effective exploitation of the ore on this flanc. The whole exploration was therefore concentrated on the less inclined north-western slope. The outcrops are partly covered by alluvial deposits. The outliers of the horizon, which, as a rule, are partly eroded and have but reduced original thickness, are entirely left out in fig. 3, with the exception, however, of the outlier near trench No. 125 (cf. also fig. 4).

To check the thickness and quality of the ore in a certain depth and to avoid the weathered part of the horizon, test trenches were made along the whole outcrop from No. 95 to No. 138 (cf. fig. 3). The samples taken for analysis were taken both as average samples and as channel samples across the entire vertical extent of the horizon. The results of the analyses showed the quality of the ore to be very similar on the surface, in the test trenches and in the outliers. The following average analyses of test trenches may be representative as to thickness and quality of all outcrops of the whole horizon (about 150 samples were analysed):

Test trench No.	95	100	111	116	118	120	125	127	138
thickness of horizon in cm	47	90	105	65	120	30	35	25	35
average Fe_2O_3 content in %	47.4	48.7	42.6	60.5	45.0	37.2	73.6	69.1	26.3

The thickness of the horizon changes from 25 cm to 120 cm. In the northern part the horizon is generally thicker, but iron-oxyde is less concentrated than in the southern part of the M a k h t e s h. The average thickness is 65 cm, the average content of Fe_2O_3 is 50 %, the rest is almost entirely quartz and other silica.

Two drills, No. 5 and No. 6 in map fig. 3, have been brought down to the iron ore at a certain distance north of the outcrop of the horizon to determine the exact dip, the continuity, quality and thickness of the ore underground. No surprising results have been found, dip, thickness and iron content being the same as on the surface.

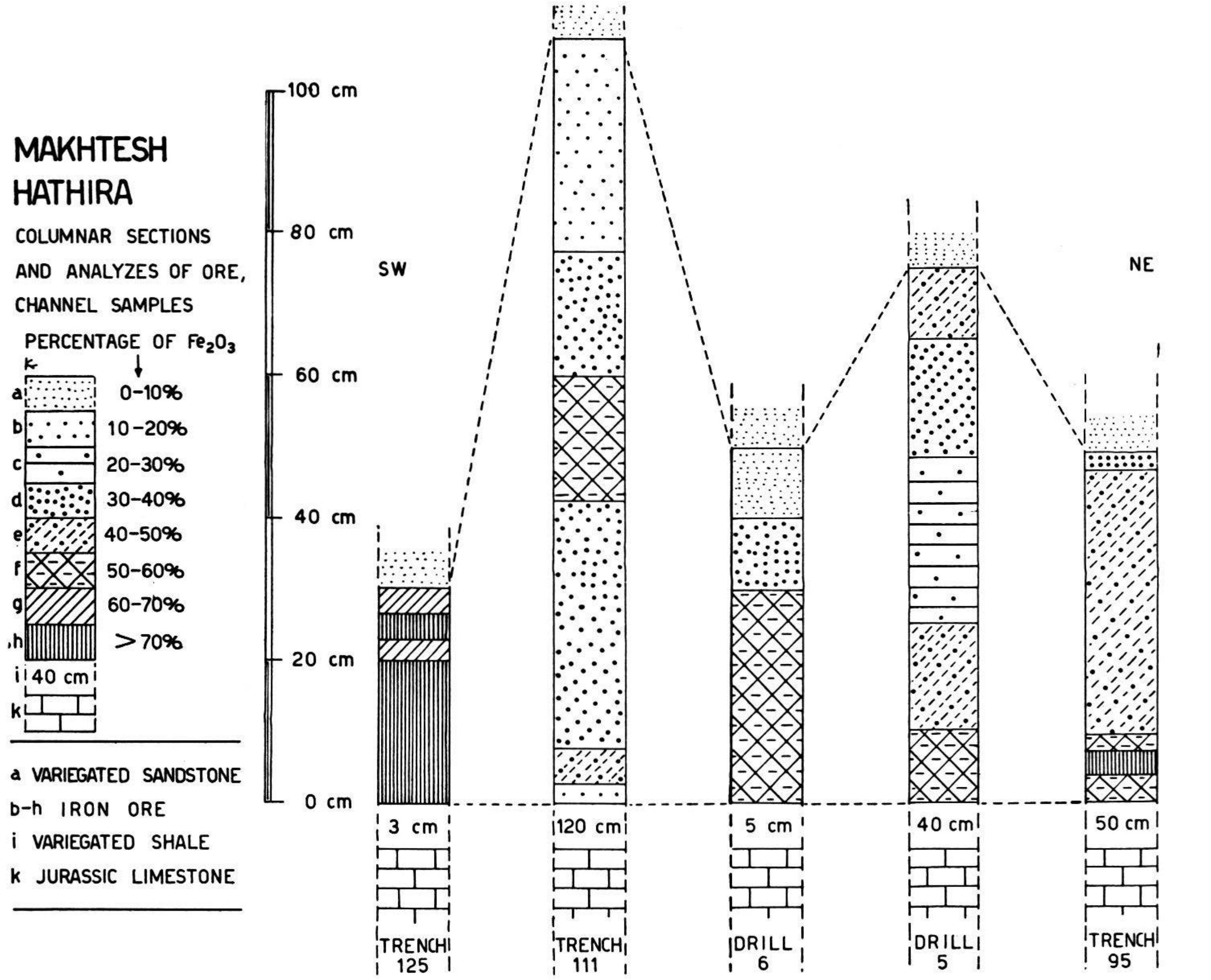


Fig. 5

The distribution of the ore in the horizon is very irregular. Even though a worker could, after a short initial period, distinguish between the different qualities of ore by their colour and weight, selective mining would be difficult because of the intense mixing, in vertical and lateral respect, of low and high contents of iron-oxydes in the horizon, as shown in the channel sections of fig. 5.

The following considerations show, that the iron ore of the Makhtesh is not a very promising mineral deposit:

The total amount of iron ore exploitable on surface on the northern flanc of the Makhtesh is evaluated at about 250 000 tons. That raw material shows a content of about 75 000 tons of Fe, which, in view of exploitation, is a tiny deposit. To exploit the more sizeable underground reserves, much higher investments would be required. Even then, said reserves would yield no more than 1.5 million tons of ore, i. e. 450 000 tons of Fe, which is a small deposit.

The large amount of silica contained in the ore (almost 50 % on an average) is very difficult to separate from the iron-oxyde and would greatly encumber economic exploitation.

Mining of such a generally hard and consolidated ore embedded in a small horizon of great extension incurs great investments in machinery. The insufficient transport conditions have been mentioned before.

The economic exploitation of iron ore under the present conditions is not possible.

Other Minerals Explored

Brick clay and *pottery clay* is present in different horizons of the whole section from Jurassic to Turonian. Best of all is the variegated fat shale with its high plasticity on top of Upper Jurassic, below the iron ore. It is generally eroded on surface but can be dug from below a very moderate overburden of Alluvium in many places. No doubt this clay constitutes a suitable raw material for any small industry in the surrounding settlements. Good *marls* and *clays* are also found in the Aptian and Albian marine layers (cf. section).

Limestone and *dolomite* for building purposes is abundant in the Judean Limestone of Cenomanian-Turonian age. Yet, cherty and flinty horizons must be avoided as well as the more chalky streaks, which occur especially in the Turonian.

Of interest is especially the occurrence of *ochre* in small outcrops in the iron ore as pure limonite powder and, also, in several upper limonitic crusts, particularly where these crusts are botryoidal (cf. section).

Coloured sand, which gives the whole Makhtesh its bizarre and beautiful character, furnishes the material for the filling of souvenir bottles for tourists, provided by local inhabitants with more or less taste, and for an artist in Beersheba for his famous sand-paintings. Almost any colour occurs or can be mixed from Makhtesh sand, except for sky-blue.

Material for natural or synthetic *molding-sand* and clay for foundries is abundantly available in the Makhtesh.

Oil Prospects

In his study (1953) BALL gave an excellent compilation on geological activity including research for oil in Israel up to 1951. In 1952, the Petroleum Law of the State of Israel was passed by Parliament. It stimulated the activity of private enterprise to a high extent. Several local and foreign companies now hold licences in different parts of the country. Drilling operations have already started.

The Northern Negev is one of the most promising oil provinces of Israel. The occurrence of bitumen and asphalt in many parts of the section is shown in fig. 2. Asphalt has been detected in considerable outcrops near the Dead Sea. In almost every drill executed in Cretaceous strata of the Northern Negev, the fresh layers show underground a certain amount of bitumen in many horizons.

The characteristic sediments of the Northern Negev, with their facial change in latteral and vertical respects, as well as the tectonics of the region are in many places very favourable to oil accumulation.

The Makhtesh is an ideal place for testing the oil possibilities of the Northern Negev. The complete section from Turonian to Upper Jurassic is exposed in a structure called by BALL «the kind oil men dream about». Its site is better than that of the Makhtesh Hadhira, which is too far from the Mediterranean coastal plain to be a moded outcrop for coastal plain subsurface conditions. If no intrusives are near below the Upper Jurassic in the Makhtesh, the sedimentary section may be concinuous for about another several hundred meters (according to BALL, «the remaining Jurassic, Triassic, possible Permian and Carboniferous should range from 1500—7000 feet in thickness, one-third to one-half marine»).

There are surely potential reservoir beds in and below the Jurassic of the Makhtesh. Test drills only could show if there is any sizeable oil accumulation. One drill was located by I.P.C. (in point 7 on map fig. 3), but drilling was not undertaken there because of the outbreak of the war.

A completely cored 50 m test drill near the anticlinal crest line had been carried out by the Israel Mining Co. under the direction of Dr. BENTOR (No. 8), in 1951. The log showed a marine limestone and marl series with some pyrite and several bituminous horizons.

The oil prospects of the older strata in the Northern Negev might be most fovourably checked in the Makhtesh, where a good section of the younger strata is exposed.

Literature

Avnimelech, M. (1949), Une grande discontinuité dans le Crétacé au Sud de la Palestine. Bull. Soc. géol. de France, 5. série, tome XIX, pp. 142–145.

Baker, N. E., and Henson, F. R. S. (1952), Geological conditions of Oil Occurrence in Middle East Fields. Bull. Am. Assoc. Petrol. Geol., Vol. 36, No. 10, pp. 1885–1901.

Ball, M. W. and D. (1953), Oil Prospects of Israel. Bull. Am. Assoc. Petrol. Geol., Vol. 37, No. 1, pp. 1–113.

Blake, G. S. (1928), Geology and Water Resources of Palestine, Jerusalem.
– (1936), The Stratigraphy of Palestine and its Building Stones, Jerusalem.
– (1939), Geological Map of Palestine 1 : 250 000 (north sheet).

Bentor, Y. K. (1951), Geological map of the Negev 1 : 100 000, sheet Abda with expl. notes (printed but not published, in hebrew).
– (1952 a), Magmatic Intrusions and Lavasheets in the Raman area of the Negev, Geol. Mag., Vol. LXXXIX (March-April), pp. 129–140.
– (1952 b), Air-Photographs and Geological mapping with special reference to the Geological conditions in the Negev (Southern Israel). Bull. Research Council of Israel, Vol. II, No. 2, pp. 157–186.
– (1953), Relations entre la tectonique et les depots de phosphates dans le Neguev Israelien. Congr. Géol. Internat., Comptes Rendus 19. Session Alger 1952, Section XI, Fasc. XI, pp. 93–101.

Bentor, Y. K., and Vroman, A. J. (1951), Découverte de grès à facies Nubien dans le Turonien supérieur du Neguev septentrional (Sud d'Israel). Bull. Soc. Géol. de France, 6. série, tome I, pp. 491–495.

Blanckenhorn, M. (1914), Syrien, Arabien und Mesopotamien. Handbuch der Regionalen Geo-

Clapp, F. G. (1936), Geology and Bitumens of the Dead Sea area Palestine and Transjordan.
logie, V. Bd., 4. Abt., 17. Heft, Heidelberg.
– (1921), Aegypten. Handbuch der Regionalen Geologie, VII. Bd., 9. Abt., 23. Heft, Heidelberg.
Bull. Am. Assoc. Petrol. Geol., Vol. 20, No. 7, pp. 881–909.

Fohs, J. F. (1927), Geology and the Petroleum and Natural Gas Possibilities of Palestine and Sinaitic Peninsula. Bull. Am. Assoc. Petrol. Geol., Vol. 11, No. 2, pp. 135–149.

Heater, W. E. (1953), Petroleum Developments in Middle East and Adjacent countries in 1953. Am. Assoc. Petrol. Geol., Vol. 38, No. 7 (Israel pp. 1520–1521).

Higgins, D. F. (1927), Oil and Gas Possibilities of Palestine and Sinai. Bull. Am. Assoc. Petrol. Geol., Vol. 11, No. 5, pp. 515–516.

Kallner-Amiran, D. H. (1950–51), Geomorphology of the Central Negev Highlands. Israel Exploration Journal, Vol. 1, No. 2, pp. 107–120, Jerusalem.

Loehnberg, A. and E. (1952), The Buried Structure of Rosh ha-'Ayin in the Central Coastal Plain of Israel. Israel Exploration Journal, Vol. 2, No. 3, pp. 145–152, Jerusalem.

Picard, Y. L. (1938), Synopsis of Stratigraphic terms in Palestinian Geology. Bull. Geol. Dep. Hebrew Univ., Vol. II, No. 2, Jerusalem.

— (1943), Structure and Evolution of Palestine. Bull. Geol. Dep. Hebrew Univ., Vol. IV, No. 2–4, Jerusalem.

— (1951), Geomorphogeny of Israel, Part I The Negev. Bull. of the Research Council of Israel, Vol. I, No. 1–2, Jerusalem.

Shaw, S. H. (1947), Southern Palestine, Geol. Map on a scale 1/250 000 with Expl. Notes. Government of Palestine, Jerusalem.

Vroman, J. (1944), The Petrology of Sandy Sediments of Palestine. Bull. Geol. Dep. Hebrew Univ., Vol. V, No. 1, Jerusalem.

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