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# PROCEEDINGS OF THE ISRAEL GEOLOGICAL SOCIETY 1963—1964

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## 1963—1964

### LECTURES



### SYMPOSIUM ON FERTILIZERS IN ISRAEL
April 3–4, 1963, Jerusalem



### LECTURES




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* No abstract received.

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## Fertilizer research in Israel

N. MOHR, *Ministry of Development, Jerusalem*

The fertilizer industry is the first heavy chemical industry to be established in Israel, deriving its raw materials from the Dead Sea and the Oron and Arad phosphates. Mining, harvesting and chemical processing is done by the Dead Sea Works Ltd., and Chemicals & Phosphates Ltd. Both companies are now in stages of large-scale expansion. Plans for a chemical complex at Arad are to be implemented soon.

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* No abstract received.

Research connected with current production, and more so with future planning, can be summed up as follows :

a. *Raw Materials.* Geological, mineralogical, hydrological, limnological and meteorological surveys are carried out by the Geological Survey and by other institutes, either for the Ministry of Development or in direct cooperation with the companies concerned.

b. *Benefication and chemical processing.* These are studied by the research departments of the companies, sometimes with the aid of the Israel Mining Industries' Institute for Research and Development, or of laboratories abroad. The aim of these studies is to improve the product or to bring the raw materials to marketable grades.

c. *Development of new processes.* This type of research is the particular field of the I.M.I. Institute for Research and Development, which has developed a series of Israel processes such as the I.M.I. phosphoric acid and potassium nitrate processes. The companies also display initiative in this fields.

d. *Feasibility and market studies.* These are being made as part of the planning activities of the Ministry of Development, or on its behalf.

The rapid development of Israel's fertilizer industry is evident from many data. Total expenditure for fertilizer research did not exceed IL 1,500,000 in 1962/63. On the other hand, mining of raw phosphate is expected to increase from about 250,000 t.p.a. in 1962/63 to about 1,500,000 t.p.a. in 1965/66 and about 2,000,000 t.p.a. in 1967/68. The output of phosphate fertilizers and related products will increase more than sixfold after the implementation of the Arad scheme.

Potash output will increase from 150,000 t.p.a. in 1962/63 to about 600,000 t.p.a. in 1965/66 rising to 900,000 t.p.a. by 1969.

The greatest part of the increased output will be geared to export. Research of all types is expected to expand accordingly, with an emphasis on marketing. Manpower will probably be increased to this purpose both in the companies and in the Ministry



**The development of the potash industry**

M. Makleff, *Dead Sea Works Ltd.*

Large-scale development plans for the Dead Sea potash industry have proven to be financially feasible. The first stage envisages a 400,000 tons p.a. increase in output during the next few years. This figure will rise by another 250,000 tons, reaching a total annual output of 850,000 to 900,000 tons by 1970. To this purpose another 100 square km of evaporation surface will be dammed in the shallow southern basin of the lake. A new potash plant and power unit with an initial capacity of 400 thousand tons p.a. is under construction, with arrangements to double this capacity. Carnallite production will continue mainly along the present lines, but potash will be produced by the hot leaching process instead of the present flotation method. This will assure a higher grade and larger crystal size. The power plant, with an output of 12,000 k.w.h., will operate by steam turbine and will utilize the Zohar gas. Service facilities are under construction, as are loading facilities at the Eilat and the Ashdod port. New installations for the bromine industry have already been completed. a plant for high-grade refined salt is under construction, and a magnesite plant is on the way.

With the increasing demand of the local market for potash, expected to reach 10.000 — 20,000 t.p.a., exports will still top the $20 m mark. In addition to its permanent staff, the industry will employ altogether some 800 workers in its various branches, and another 1500 will be engaged on construction activities during the next year.

The enlarged industry is expected to make more raw materials available to new industrial ventures.

**The origin of the sea and the evolution of Marine cycles during geological times**

S. LOEWENGART, *Technion — Israel Institute of Technology, Haifa*

After the initial formation of the oceans, salinity soon became constant. Most geologists agree that the oceanic salt composition changed very little during geologic times.

Sea salt, equivalent to $300.10^6$ tons of $Cl^-$ is spread yearly over the continents via the atmosphere and is brought by rivers back to the sea. However, the Na content of river water is 60% too high in relation to $Cl^-$ if it were all derived from airborne salts. This excess of Na, and an even higher excess of K and sulphate, would have changed the composition of sea water entirely if no compensatory mechanisms were at work.

The excess of Na is taken up by riverborne clays through ion exchange on first contact with ocean water. K and S are biophile elements, and become concentrated in phases of the biological cycle. On decomposition, S is liberated as $H_2S$ into the atmosphere, subsequently oxydized, and reprecipitated as sulphate on the continents. K, on entering the sea, is continually taken up by organisms, and on decay is absorbed into sediments. Were it not for the recurrent leaching of uplifted old sediments, all the potassium would accumulate in marine basins. As organic matter is slowly but permanently deposited in the central parts of the oceans, some K is permanently lost from the cycle. This explains observations by Vinogradov and others that the K content in marine clays decreases from older to younger formations.

**The origin of salts in deep groundwaters and oil brines**

S. LOEWENGART, *Technion — Israel Institute of Technology, Haifa*

The view that the salt content of deep groundwaters is derived from sea-water trapped in the sediments should be re-examined. Air-transported salts which percolated underground during geological times contribute much more to the salinity of the water in the pore spaces than do trapped sea waters or dissolved salt deposits.

Taking the present rate of circulation of salts as a yardstick, the total quantity of sea salts has gone through approximately five cycles since the Precambrian. Since large parts of the continents are without drainage to the sea, it can be assumed that the total $Cl^{2-}$ content in pore waters of the continental crust is 1/5 to 1/10 that of the oceans. All deep groundwaters are highly concentrated salt solutions, regardless of the proximity of marine sediments or any sediments at all.

The salinity of underground waters, which increases with depth, can be explained by continuous slow evaporation. Ion exchange between the main cations Na, Ca and Mg is also an important factor. Composition of the initial infiltrate, whether strongly or weakly saline, determines the final composition of the groundwater. $Cl^-$ becomes the dominant anion with increasing depth, while $SO_4^{2-}$ and $HCO_3^-$ are more and more eliminated, partly by precipitation. $SO_4^{2-}$ is generally reduced by anaeorobic bacteria.

No obvious differences exist between petroleum brines and other ground waters, but knowledge of the factors which determine the chemical composition of such waters may be helpful in explaining the origin of particular oil or gas deposits. Such is the case with the brines in the Zohar and neighbouring gas fields. These groundwaters are similar to the karst waters in the Judean arch, the salts of which are doubtlessly of atmospheric origin.

**Structural consequences of the Dead Sea strike-slip fault**

R. FREUND, *Department of Geology, The Hebrew University of Jerusalem*

Compressional folding is known in the Zagros-Taurus Range, Palmyra, Lebanon, Judea, Negev and northern Sinai since the Late Cretaceous, simultaneous with tensional faulting in the Red Sea, the Gulf of Suez, and northern Israel.

The Arabian block moved about 70–80 km northward along the Dead Sea fault since Late Cretaceous times. This movement is a part of the northward drift of the Arabian block away from Africa, which opened the gaps of the Red Sea, the Gulf of Suez and the Gulf of Aden. The excess of material in the north found place in the folds of the Zagros-Taurus.

The following structural elements of the south-eastern Mediterranean area may be explained as secondary effects of this sinistral strike slip movement, attaining about 70-80 km along the Dead Sea fault:

The rift valley was opened from the Gulf of Eilat to the Hula depression, being wider and deeper along the Gulf of Eilat, the Dead Sea and the Sea of Galilee, and narrower and higher near Ein Yahav and Wadi Faria.

The high structures of Lebanon and the synclinal shape of the Beka'a are due to a shortening of 25 km.

Folds and thrusts were developed by dragging along the contacts between the two blocks. These effects are strongly marked in the convex parts of the blocks and are accompanied by secondary dextral wrench faults.

E-W normal faults, with associated volcanism, and N–S secondary sinistral wrench faults, developed on the concave parts of the blocks east of the Dead Sea and west of the Kinneret-Hula depression.

**Finding oil in Palestine**

F. E. WELLINGS, *Orchard Bough, England*

I came to Palestine, first 32 years ago from Iraq, in January 1933, to inspect the Gaza sulphur discovery of L. Williams, on which G. M. Lees had applied 2 years before for a provisional oil exploration permit, because he thought it resembled a Persian "gach-i-turush" (sour gypsum caused by gas seepage). This application had not been followed up and had lapsed.

I was not only impressed by the sour gypsum and the peculiar, rubbery bitumen veins, but also by the Pleistocene sand ridge which ran north-north-east for about 50 kilometers, parallel to the Mediterranean coast. I was familiar with Quaternary uplifts in southern Iraq and the Gulf Coastal Plain of the U.S.A., so I took out four permits for £ 20, covering two thousand square kilometers from the Sinai border northwards, covering the Huleiqat ridge.

I brought over two assistants, L. Damesin and E. J. Daniel, to map the area while I investigated the geology of the Kurnub folds beyond Be'erSheva. I took a house in Jerusalem to keep in touch with the Geological and Mines Department and to obtain a proper Oil Mining Law, as the existing one on minerals restricted drilling leases to only 4 per cent of the permit area. Covering a structure which I envisaged as 50 km long and several km broad would have entailed taking permits over the entire coastal plain. Perhaps I was optimistic — all exploration geologists have to be — as the Heletz Field is now proved to be only 10 km long. I also had to sort out the mass of data and water well samples which the Government Geologist, G. S. Blake, had accumulated over the years. There was no geological map of the country and no contoured topographic one either. Blake was very helpful, and our F.R.S. Henson determined his foraminifera, by which Eocene and Senonian chalks could be distinguished.

A torsion balance survey in 1934 confirmed the Huleiqat ridge as a positive gravity anomaly, so we acquired more permits along the entire coastal plain. Under the new Mining Ordinance of 1938 we were obligated to start drilling on our first permits, the Gaza ones, in February 1940, but we could not obtain the equipment until after the war.

In 1946 we did a gravimeter survey over the entire coastal plain and a seismic survey, reflection and refraction, roughly between the sulphur site and Negba. The seismic map of F. A. Gibson showed the top of the Middle Cretaceous Judean limestone rising up from the east to within nearly 300 metres below the surface. This could only be explained by a big unconformity cutting out the Upper Cretaceous and Eocene chalks, such as I knew to exist in water wells of Jewish settlements north of Tel-Aviv and as had recently been found by the Standard Oil's well at Khabra, over the Sinai border. To allow for the suggested asymmetry, I located Huleiqat No. 1 high on the eastern flank, and drilling began on 25th September 1947.

When our drilling operations were suspended in February 1948 at 1055 metres, owing to the disturbed conditions prior to the Arab-Jewish war, we had encountered brackish water in the Cenomanian directly underlying the Mio-Pliocene and were some 300 metres short of the Kurnub sandstone. Five years later Max Ball wrote that our well was off structure, but I think it is to the credit of the present operators, Lapidoth, and their geological advisers, W. R. Fehr and H. J. Tschopp, that our hole was deepened as Heletz No. 1 to give Israel its first producer, in October 1955, 400 barrels per day of 30° oil, from the Lower Cretaceous Kurnub sandstone at 1515 m.

## The relation between environmental factors and soil distribution in the coastal plain

J. DAN, *Department of Soil and Water, The Vulcani Institute of Agricultural Research*

The soils of the undulating to rolling areas of the coastal plain are derived from sand, which was covered later on by fine-textured, calcareous aeolian sediments. In the south these sediments are silty, while in the north they contain mainly clay, or silicates from which clay is produced by weathering.

The rate of aeolian sedimentation is comparatively fast in the south, decreasing gradually towards the north. The aeolian sediments are thicker in the east owing to a longer period of sedimentation.

In the western part of the coastal plain the soils are coarse-textured owing to admixtures of the underlying sand. In the arid south-east they are mainly silty, while in the Mediterranean foothill region in the north they comprise mainly fine-textured clays. Many intergrade soils are found between these soil regions.

The soils of alluvial deposits resemble the aeolian soils as they are derived mainly from material redeposited from the latter. They are, however, usually more silty.

Among the soil-forming processes, leaching and redeposition of lime is prominent. This process reflects the annual rainfall, as the lime accumulates at the depth of the annual penetration of rain water. Accordingly, we distinguish between leached non-calcareous Hamra soils, dark brown soils with the ca horizon at 1–2 m, and light brown soils with a shallower lime-accumulation horizon. In the south, leaching is even more restricted, resulting in gypsum and salt horizons. Other widespread processes include clay illuviation in the coarse and medium-textured soils, and churning processes in the fine-textured ones.

The local soil pattern is very complex, conditioned mainly by morphology. Consequently, many catenary systems are recognized in the coastal plain.

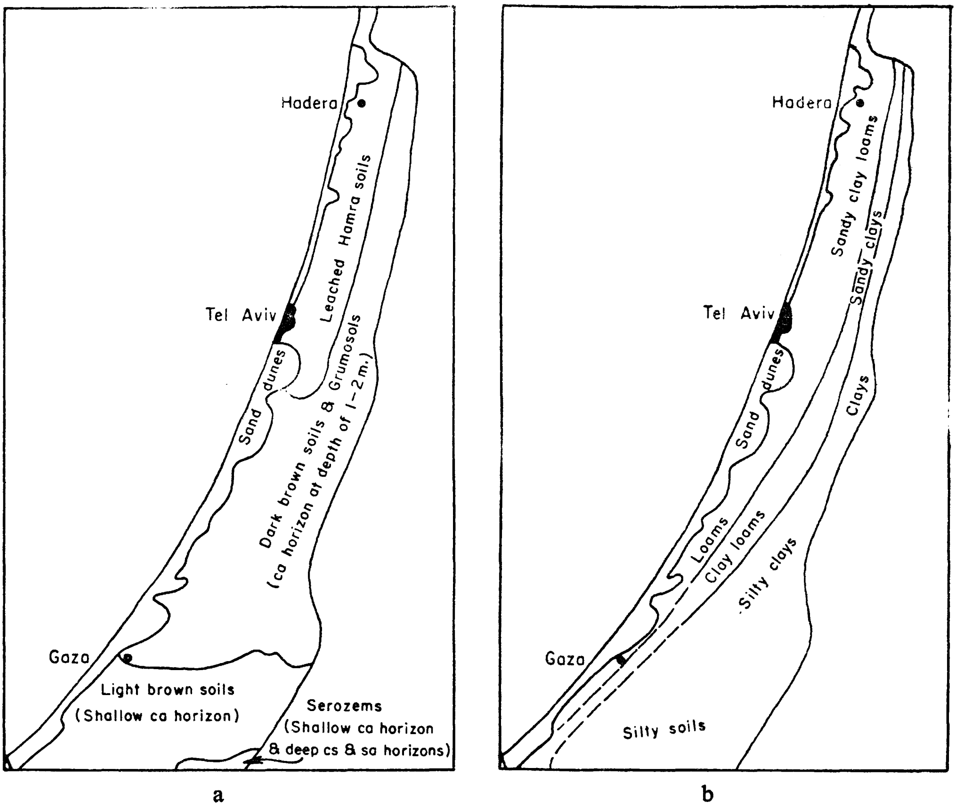


Figure 1

a. Schematic distribution of soil textures in the coastal plain
b. Schematic distribution of lime and ca horizons in soil of the coastal plain.

## Folding

R. S. W Carey, *University of Tasmania, Austrlia*

Concepts of folding and the implications of folding come so early in our geological training that they tend to become axiomatic. The validity of some of these "axioms" of structural geology has to be critically probed. Alternatives must be examined in the light of their implications in economic geology and tectonic theory.

## Oil and gas exploration in Israel

J. Coates, *Naphtha Israel Petroleum Corp., Tel-Aviv*

The recent years of petroleum exploration in Israel have been fruitful in terms of both discoveries made and of new information which can guide further exploration.

The oil discovered in Heletz and in the associated fields of Brur and Kokhav is in Lower Cretaceous sands, now seen to be productive along the strip where they wedge out westwards on the east flank of the structure. It is probable that this belt continues to the north and south in the same horizons, and it is hoped that other Lower Cretaceous horizons will be found, developing similar wedge-outs elsewhere.

The gas discovered in Zohai, Kidod, and Hakanaim is in Jurassic limestones, in which fracturing plays an important part in determining productivity. The equivalent limestone in the Coastal Plain has appeared promising on log interpretation, has occasionally shown live oil in cores further north, and may yet prove to be productive elsewhere.

The Neogene, which has yielded gas in several wells, has not yet been given to commercial production; but we have now an improved knowledge of its correlations and depositional history, which may be used in later search for accumulations in it.

Of the other main prospecting regions, the Dead Sea Valley exploration has currently been halted because of prohibitive expenditure. The Galilee has so far been relatively neglected and available data are still too scanty to allow a confident appraisal. The Negev, in spite of initial failures in the major anticlines, still offers hopes, particularly in the older rocks. The off-shore strip is now under exploration.

**Unconformities in the northern Juraba structure, north-eastern Negev, Israel**

E. AIZENBERG, *Naphtha Israel Petroleum Corp., Tel-Aviv*

Turon-Senonian as well as Cretaceous-Neogene unconformities are found in the northern part of the Juraba structure. Similar unconformities are reported by Israel geologists also from other parts of the country.

In the present paper some additional data on the above-mentioned unconformities are presented, and some of the previously known facts are put on a more quantitative basis.

The Senonian-Turonian unconformity is distinguisdhe as such mainly by:

a. Changing thicknesses of the Turonian complex (Shivta and Netser formations) and erosive channels in its upper horizons;

b. Variable thickness of the Menuha Formation (Santon-Campanian) overlying various Turonian horizons, partly conditioned by a Turonian relief;

c. Areas where the Campanian Mishash Formation lies directly on the Turonian.

Sediments of the Hatseva Formation (Neogene) are continental and consist mainly of conglomerates and sands, which directly overlie various horizons of the Upper Cretaceous.

There are reasons to assume that the Hatseva outcrops in the northern part of the area are connected to the Neogene Arad basin. The Hatseva outcrops in the southern parts are located along a structural low between the Barbur and Daya folds, representing a Neogene channel connected to the Rekhme basin.

## Subsurface geology of the Arad region

E. ROSENBERG and E. AHARONI, *Naphtha Israel Petroleum Corp., Tel-Aviv*

Subsurface Cretaceous beds in the northern Negev were studied and correlated by litho-electrical methods. Correlation within the Zohar — Hakanaim area seems well established, whereas in the Halutsa-Qeren area the correlation becomes doubtful.

Several transgressive and regressive phases can be followed throughout the region. The Kurnub Group (Lower Cretaceous) is subdivided into 4 formations (Type sections in the Zohar wells). The Kurnub Group, although representing a regressive phase, appears in all the wells in this region as unconformably overlying the various Jurassic beds. The cause of this unconformity is possibly a regional uplifting and tilting at the end of the Jurassic, whereby the south-eastern area became lifted higher than the north-western area, with subsequent greater truncation in the south.

Some rapid changes in thickness in the vicinity of the Zohar 7 well, which cuts through a reversed fault, indicate that this uplift may have been associated with faulting and possibly volcanic activity. Many asymmetric anticlines in the Negev may now be viewed in a different light, as reverse faulting in depth, which may have started as early as late Jurassic times, could have caused the steepness of the south-eastern flank in these structures.

Owing to a lack of paleontological control and the difficulty in litho-electrical correlation below the recently described Jurassic Arad Group, the question of an unconformity between the latter group and the Triassic remains undecided.

## Geological aspects of gas reserve estimations in the Zohar region

J. COATES, *Naphtha Israel Petroleum Corp., Tel-Aviv*

Even after the discovery of gas by exploration, geological aspects are still of major importance in the estimation of the reserves, particularly when the Volumetric Method is used, which is the only approach applicable in the early stages of production.

This method requires particularly a knowledge of the shape of the sub-surface structure, as well as of the reservoir porosity, water-saturation and bottom-water level.

In the Zohar region, estimation of sub-surface structures from surface data are complicated by the effects of intervening thickness changes and unconformities, and by sub-surface faulting and steep dips not apparent at the surface. Reservoir porosity varies both vertically and laterally, and the estimate of the total pore space that could hold gas is accordingly a matter of careful inference. Estimation of water saturation, to determine how much pore space remains available for gas, involves allowance for the differences in saturation corresponding to pore spaces of different sizes, and for the relatively great thickness of the "transition zone" above the level of fully water-saturated rock. The calculation of bottom-water level, essential for providing the vertical dimension in reservoir volume computation, is affected by variations in transition-zone thicknesses in beds of different textures. This makes it difficult to decide whether a general bottom-water level has actually been determined.

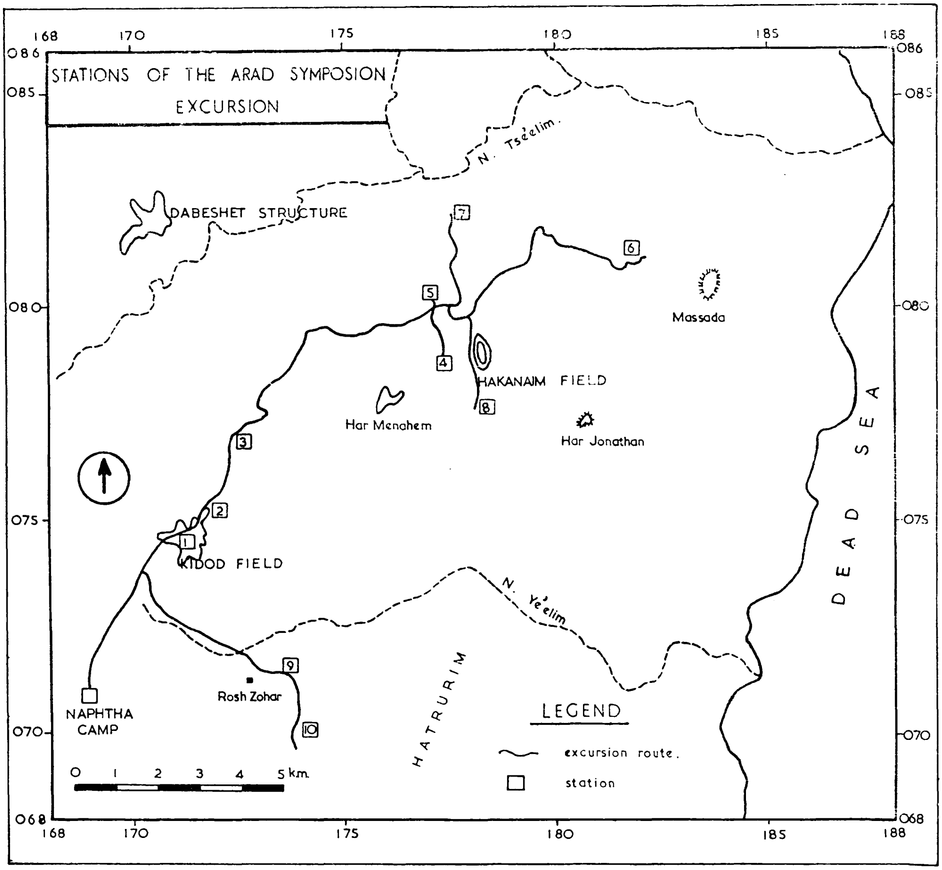


Figure 1
Map of the Arad region.

## Excursion to the Arad region

E. Aharoni, *Naphtha Israel Petroleum Corp., Tel-Aviv*

The following stations were visited during the Symposium's field excursion in the Arad region (see Map).

*Station* 1. Near the Kidod 1 gas well. To the south is the northern plunge of the Zohar axis and 2.5 km west of it the southern plunge of the Kidod axis. On the north-western Zohar flank the Hatzeva Formation overlaps uncomformably the Senonian formations. To the north-west, the steep flank of the Kuseifa anticline is seen west of the Dabeshet anticline.

*Station* 2. Near the southern Kidod cross-fault, which runs perpendicular to the anticlinal axis. Another such fault cuts the Kidod structure a few km to the north. These faults together divide the Kidod structure into three parts.

*Station* 3. Near the northern Kidod cross-fault. To the north-east a view of Hakanaim valley. This tectonic valley is bounded on the west by Kidod's steep flank, and on the east — by the western fault system of Hakanaim.

*Station* 4. An outcrop of Lower Eocene (chalk with flint nodules). The Eocene here is faulted against the "Judean Limestone" of Hakanaim block, and dips about 20° eastward towards the fault. This is the easternmost Eocene relict in the Arad region.

*Station* 5. Contact Turonian — Menuha Formation (Senonian). Although lithologically the difference between the limestone and the chalk is sharp, the relationship between these formations is not very clear.

*Station* 6. Toward the east — the Dead Sea and the Lashon (Lisan) Peninsula. West of the Dead Sea graben — the Massada horst. West of the Massada horst — the "Massada graben" with Senonian deposits. Toward the north and west — the flat top of Hakanaim block, consisting of horizontal limestones and of dolomites.

*Station* 7. Toward the north — the extension of Hakanaim block, bounded on the west by a V-shaped syncline, which is the northern extension of Hakanaim's western fault system. The Turonian and the upper and middle parts of the Cenomanian are exposed in the canyon of Nahal Tse'elim.

*Station* 8. Near Hakanaim 1 gas well. Gas is produced from the Jurassic "Zohar Formation" at a depth of 655 m below Mediterranean sea level. The gas is methane with 1.15% sulfur (by weight). The high rate of gas flow is possibly due to a well-developed joint system. Toward the southwest the steep flank of the Zohar anticline is seen, and to its east the rugged country of the Hatrurim bowl, with "Mottled Zone" outcrops.

*Station* 9. On the Arad — Sedom Road, low on the steep flank of the Zohar structure. The bituminous facies of the Mishash Formation.

*Station* 10. An outcrop of the "Mottled Zone": pseudo-metamorphic, hard rock, black, red and brown, with green, white and reddish veins.

## Problems of Jurassic stratigraphy in southern Israel

M. Goldberg, *Oil Division, Geological Survey of Israel*

The Arad Group represents the middle and lower part of the Jurassic sequence in the Negev. Its stratigraphy has been studied within the framework of a Ph.D. thesis at the Hebrew University. The sections exposed in the breached anticlines of Hamakhtesh Hagadol and Hamakhtesh Haqatan were studied, as well as the subsurface sections of eighteen deep boreholes. The main results show the following:

1. Good lithostratigraphic correlation is found between the sections studied.
2. The Flint Clay horizon, exposed at the base of the Ardon Fm. in Makhtesh Ramon, was encountered in many boreholes and provides a good marker. This horizon overlies unconformably different members of the Mohilla Fm. (see Figure 1).
3. The Massada region was uplifted in pre-Arad Group times. Most of the formations of the Arad Group wedge out in the NE against the Massada high.
4. There seems to be an unconformity between the Zohar and Kidod formations: erosion channels exposed in Hamakhtesh Haqatan are apparently connected with this unconformity.

A schematic composite columnar section (Figure 2) was compiled. summarizing the stratigraphy of the area.

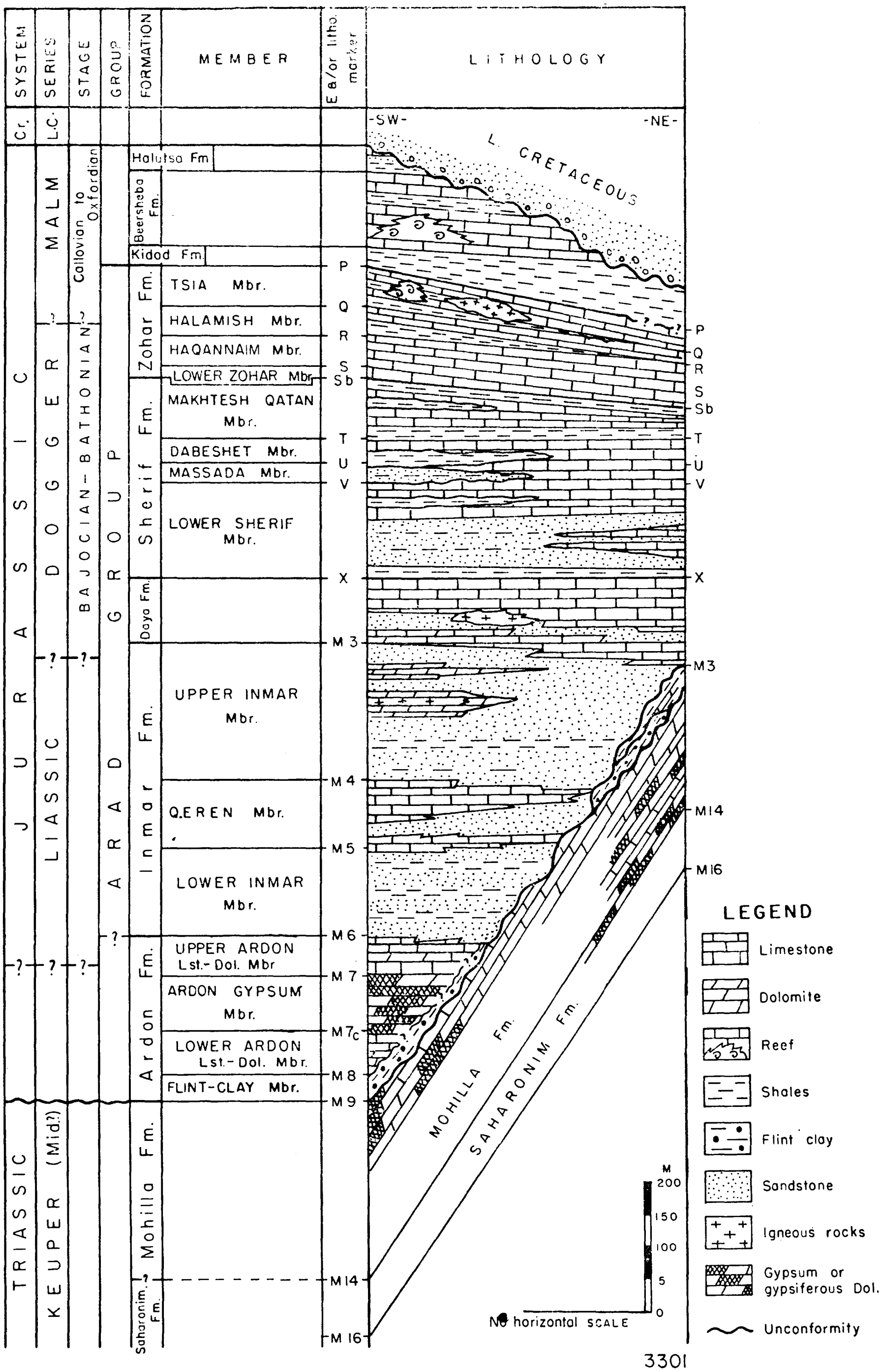


**Figure 2**

Schematic composite columnar section of the Jurassic in Southern Israel.

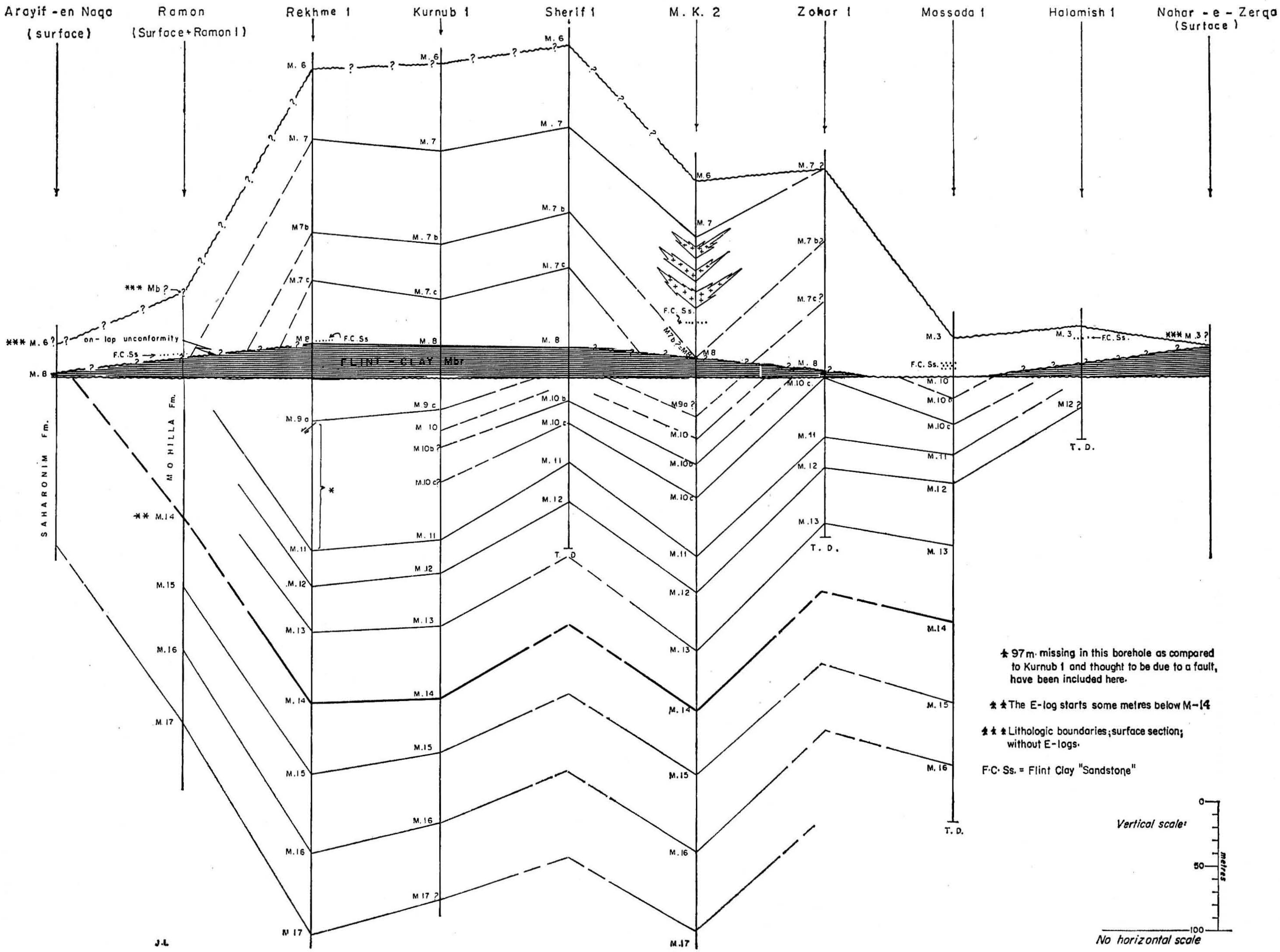


**Figure 1**
**Correlation chart based on electric and lithologic markers above and bellow "Flint Clay Mbr". Datum: Base "Flint Clay Mbr".**

## Paleontology and petroleum exploration in Israel — a review

Z. REISS, *Paleontology Division, Geological Survey of Israel*

The age of rock strata, their environment of deposition and post-depositional history, as well as their present-day position and correlations — all such data are of fundamental importance to oil exploration. Fossils represent one of the most valuable tools in obtaining these data. Paleontological research connected with oil exploration in Israel dates back to the days of the Palestine Development Petroleum Co. for which fossils were studied by British geologists and by staff members of the Hebrew University. Since 1949, and particularly since 1954, paleontological work pertaining to oil exploration is done by the Geological Survey of Israel, by the departments of Geology and Botany of the Hebrew University, by paleontologists of the operating companies, as well as by foreign specialists. During the last few years considerable advances have been made in the study of various groups of fossils: pollen, spores, hystrichosphaeres, calcareous algae, foraminifers, ostracods, brachiopods, gastropods, pelecypods and ammonites, as well as in the field of so-called "microfacies". The results have contributed to the solution of various stratigraphic problems. Some results also shed light on the question of oil origin and migration in Israel. New lines of research were initiated, local personnel was trained, and laboratory facilities expanded. A mass of various documents — specimen collections, records, professional literature — has accumulated. The extension of paleontology to oil exploration is, however, a rather recent development, and for this reason the possibilities of fossil studies have not yet been fully exploited. Closer cooperation between paleontology and the various branches of petroleum geology and technology is necessary in order to cope with the problems we face in the continuing search for oil.

## Palynological age determination of Mesozoic and Paleozoic horizons in the Negev

M. GLIKSON, *Department of Geology, The Hebrew University of Jerusalem*

Core samples from the Makhtesh Haqatan 2 borehole were examined, ranging from 482 to 2320 metres depth. About 50 species of spores and pollen grains were described, among them three species of hystrichosphaeres and one Algal type.

Samples from a depth of 483 m yielded a Middle Jurassic microflora. A Keuper microflora was identified between 866 and 1132 m. A Lower Triassic — Upper Permian microfloral assemblage was found between 1776 and 1779 m.

A typical Permian (Lower Permian?) microflora is abundant at 2213-2253 m, while Carboniferous (?) spores were identified at 2277 and 2319 m.

## Hydrodynamic conditions in the Northern Negev

B. K. DAVIS, *Lapidoth, Israel Oil Prospectors Corp., Tel Aviv*

Oil wells drilled in southern Israel show large variations in groundwater salinity of Lower Cretaceous and Jurassic strata, ranging from almost fresh waters to over 16 per cent total solids.

Data from water analyses and electric log calculations show the effects of flushing, apparently caused by intake of meteoric water at the outcrops.

**Radiometry and tellurometry in petroleum exploration in Israel**

T. MEIDAV, *The Institute for Petroleum Research and Geophysics, Azor*

Gamma radiation surveys over the Heletz field area indicate a close relationship between the radiometric anomaly and the boundaries of the oil field. This cannot be attributed to coincidence of surface properties with subsurface geology.

First experiments with telluric current measurements indicate that the technique is applicable in Israel, and could potentially be employed for deep structural studies.

**Suggestions for the geochemical research of gases in Israel**

E. MAZOR, *Israel Atomic Energy Commission and Weizmann Institute of Science, Rehovot*

Gases occur in nature as atmospheric components, as well as trapped in rocks or dissolved in oils, groundwaters, oceans and magmas. Chemical and isotopical analyses of such gases are geochemically highly important, and may be profitably applied in Israel. The following projects are suggested:

The organic gases from the Zohar (Coates *el al.*, 1963), the Heletz and the coastal plain wells should be analysed for radiogenic He and $Ar^{40}$ enrichments. Such enrichments are expected to be high in gases of old formations and low in young ones (Wasserburg *al el.*, 1963), so that a clue to their relative ages may be obtained. A search for helium might also have an economic aspect.

The radon-rich gases in the mineral waters of the Rift Valley should be further analysed. Traps of gases, water, brines and oil may exist in the Rift Valley (Mazor, 1962), in which case the accompanying gases are not recent decomposition products but have been trapped there probably long enough to show some He and $Ar^{40}$ enrichment. Seasonal water or gases may be distinguished from trapped ones by means of $C^{14}$ measurements of the gases and D/H and $O^{18}/O^{16}$ measurements of the accompanying waters. This was demonstrated by Degens (1961) and Munich and Vogel (1962) for apparently pluvial waters in the Egyptian Desert, which were proved to be actually trapped waters.

The dissolved gas composition in the groundwaters of the different aquifers in Israel varies greatly. A study of these gases may provide parameters for a classification of the waters, and throw light on the influence of aquifer rock on gas composition. It may enable us to distinguish between trapped and seasonal waters.

Oren (1962) measured $O_2$ in Lake Tiberias and Neev (1964) measured $O_2$ and $H_2S$ in the Dead Sea. These studies should be extended to include more components, and to include the Mediterranean and Red Sea.

K-Ar age determinations should be made on the Precambrian rocks of Eilat and the younger volcanic rocks in the Negev and in the north.

The above examples are part of a long list of problems to be tackled by gas geochemistry in Israel.

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## Sedimentology and lithostratigraphic units of the Sakiebeds in the coastal plain

G. GVIRTZMAN, *Oil Division, Geological Survey of Israel*

In addition to a previous subdivision of the Late Eocene to Early Pleistocene Sakiebeds into biostratigraphic units (Reiss and Gvirtzman, 1962), the Sakiebeds are subdivided into lithostratigraphic units. Three such units could be distinguished in the Jaffa-1 well, by sedimentological and mineralogical methods. In the upper unit, consisting mostly of clay, the <1 micron fraction is predominant, the calcite content is low, the quartz content is abundant. The middle unit, topped by an anhydrite bed, is coarser of grain (1-8 micron fractions predominant), the calcite content is higher, the quartz and clay contents are lower, and the predominant clay mineral is kaolinite, with more illite than in the other units. The lower unit consists mainly of the 1-8 micron fractions, the calcite content is very high, the quartz and clay contents are even lower, and the predominant clay mineral is montmorillonite.

The structural history of the coastal plain in the Neogene times was reviewed, and the oil prospects of the Sakiebeds were briefly discussed.

## On the structure of Israel's coastal plain

I. Z. ELIEZRI, *Israel National Oil Company Ltd., Tel Aviv*

The present structural pattern of the coastal plain is the result of several tectonic movements in different geological times. The information available from oil wells, structure holes, water wells and seismic surveys enables us to follow the tectonic history since the Late Jurassic.

The amount of Jurassic sediments eroded away enables us to reconstruct conditions at the end of the Jurassic. Figure 1 shows the isopachs of the Jurassic rocks above the Zohar limestone. If the assumption of a peneplanation at the end of the Jurassic is true. then the isopach map represents the structural setup (thinning at highs and thickening at lows). The results show a high in the Negev and the Judean Desert, a low along the Qeren — Be'er Sheva — Halhul line, and a narrow high along the coastal plain, from Nirim to Beer Ya'akov. The Jurassic structural pattern has a pronounced NE-SW direction, similar to the later Cretaceous folding. An indication can be found of a peneplain with a moderate slope towards the west, by observing the lowermost Lower Cretaceous beds overlapping the Jurassic.

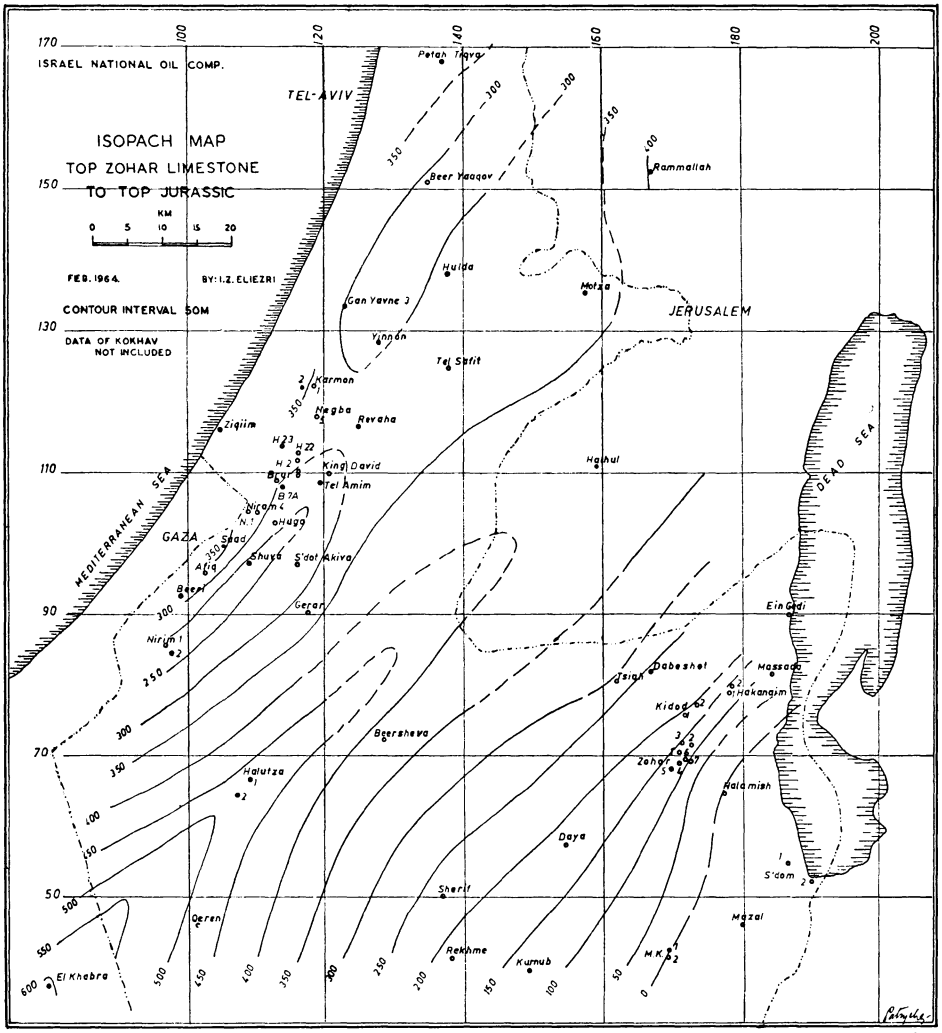


Figure 1

The late Cretaceous to early Tertiary folding gave rise to a most pronounced tectonical feature when a high structure was created west of Heletz. This structure had a closure of about 1,200 m towards the east and west. This can be studied also by calculating the amount of rock eroded during pre-Sakie times, when a second peneplanation is assumed to have cut away the high structures. Figure 2c shows a projected structural cross-section on top Turonian, with the pre-Sakie (peneplain) surface serving as datum. Since the early Neogene or even the late Eocene the coastal plain has subsided and probably was also faulted *en echelon* towards the west (Figure 2a). The amount of subsidence equals the thickness of the Sakie beds below sea level. In this stage the drainage system from the east, which was contemporaneously uplifted, cut valleys and channels towards the new transgressive shore line. Eventually, the Neogene beds covered the entire coastal plain, burying teh former structures.

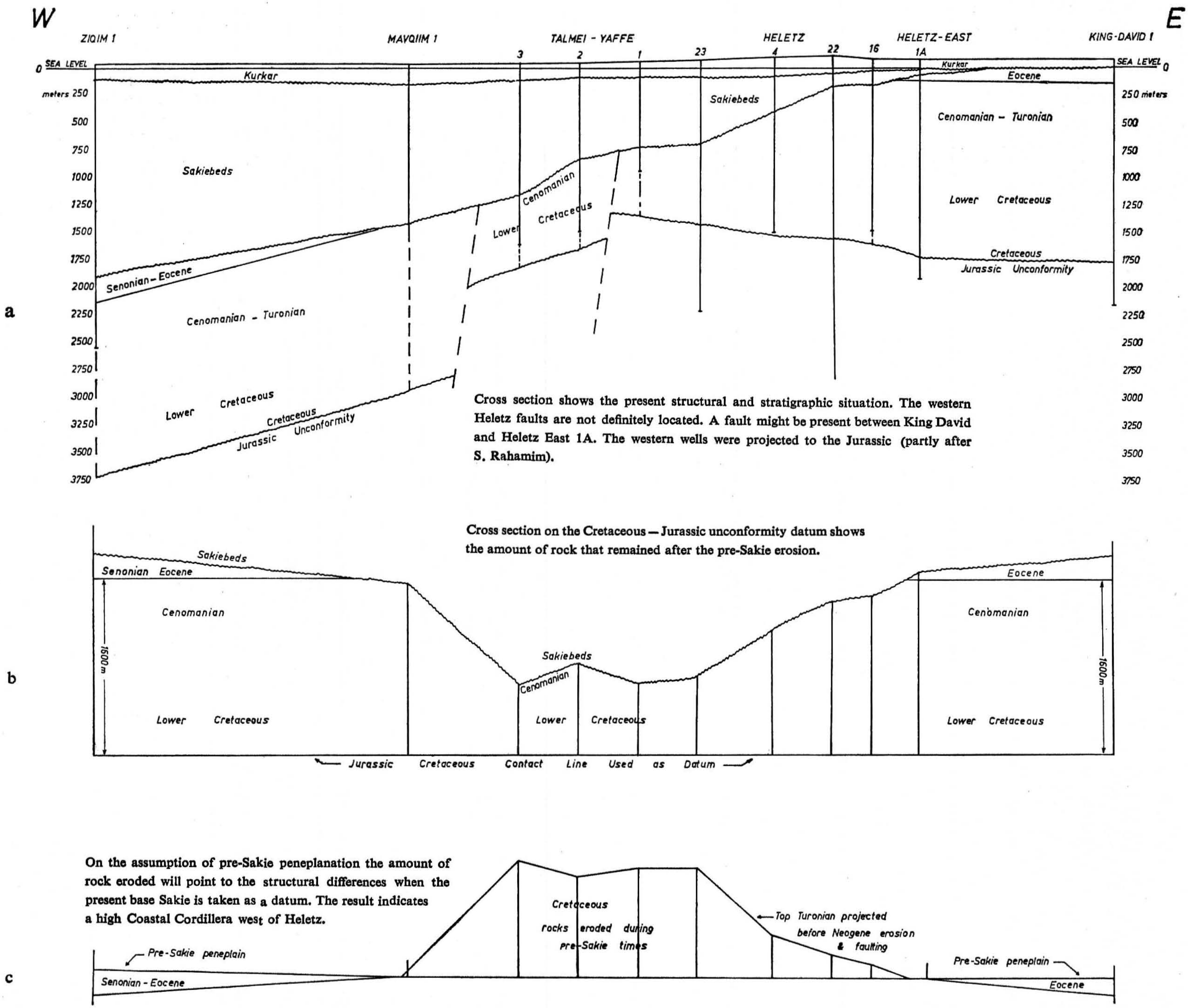
W
E
ZIQIM 1
MAVQIIM 1
TALMEI - YAFFE
HELETZ
HELETZ-EAST
KING-DAVID 1
3
2
1
23
4
22
16
1A
0 SEA LEVEL
SEA LEVEL 0
meters 250
250 meters
500
750
1000
1250
1500
1750
2000
2250
2500
2750
3000
3250
3500
3750
Kurkar
Eocene
Sakiebeds
Cenomanian - Turonian
Cenomanian
Lower Cretaceous
Senonian - Eocene
Cretaceous
Jurassic Unconformity
a
Cross section shows the present structural and stratigraphic situation. The western Heletz faults are not definitely located. A fault might be present between King David and Heletz East 1A. The western wells were projected to the Jurassic (partly after S. Rahamim).
b
Cross section on the Cretaceous — Jurassic unconformity datum shows the amount of rock that remained after the pre-Sakie erosion.
Sakiebeds
Senonian Eocene
Eocene
Cenomanian
1600m
Lower Cretaceous
Jurassic Cretaceous Contact Line Used as Datum
c
On the assumption of pre-Sakie peneplanation the amount of rock eroded will point to the structural differences when the present base Sakie is taken as a datum. The result indicates a high Coastal Cordillera west of Heletz.
Cretaceous
rocks eroded during
pre-Sakie times
Top Turonian projected
before Neogene erosion
& faulting
Pre-Sakie peneplain
Senonian - Eocene
Eocene

Figure 2

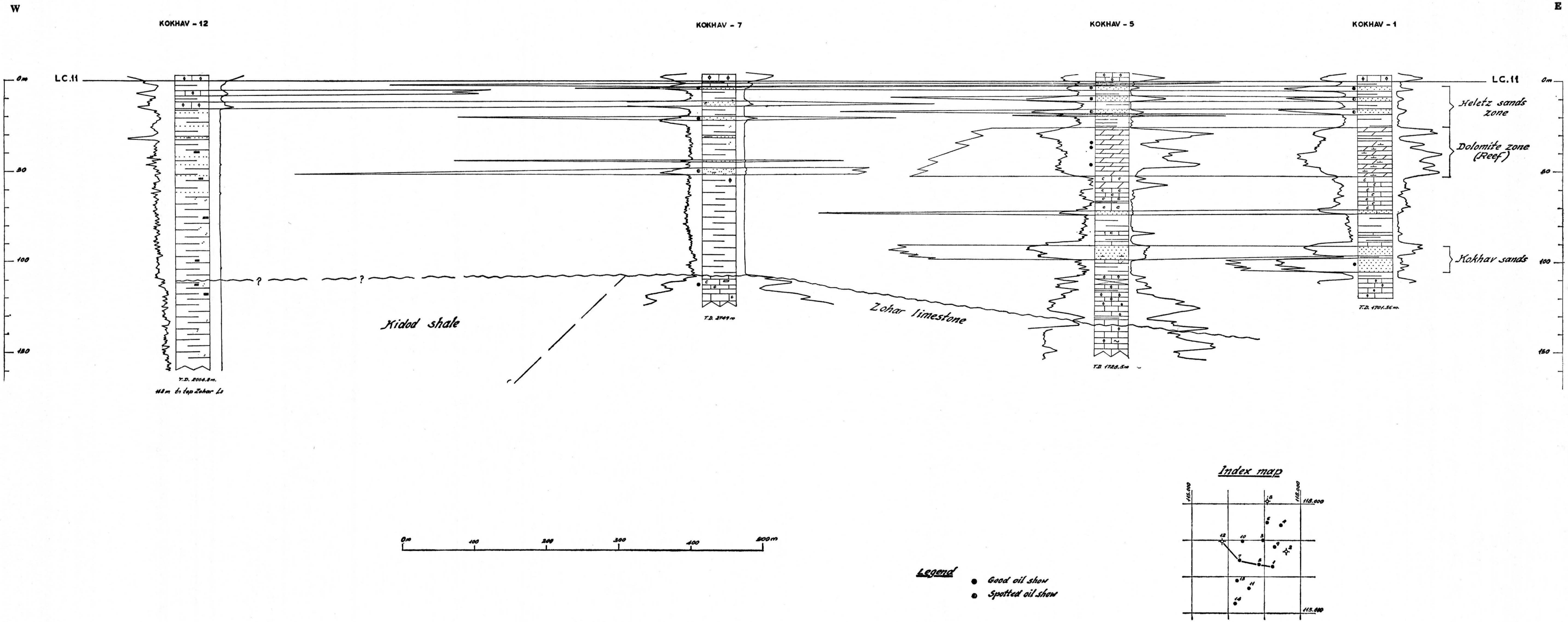


Figure 1
Cross-section: Kokhav 12 — Rehava 1.

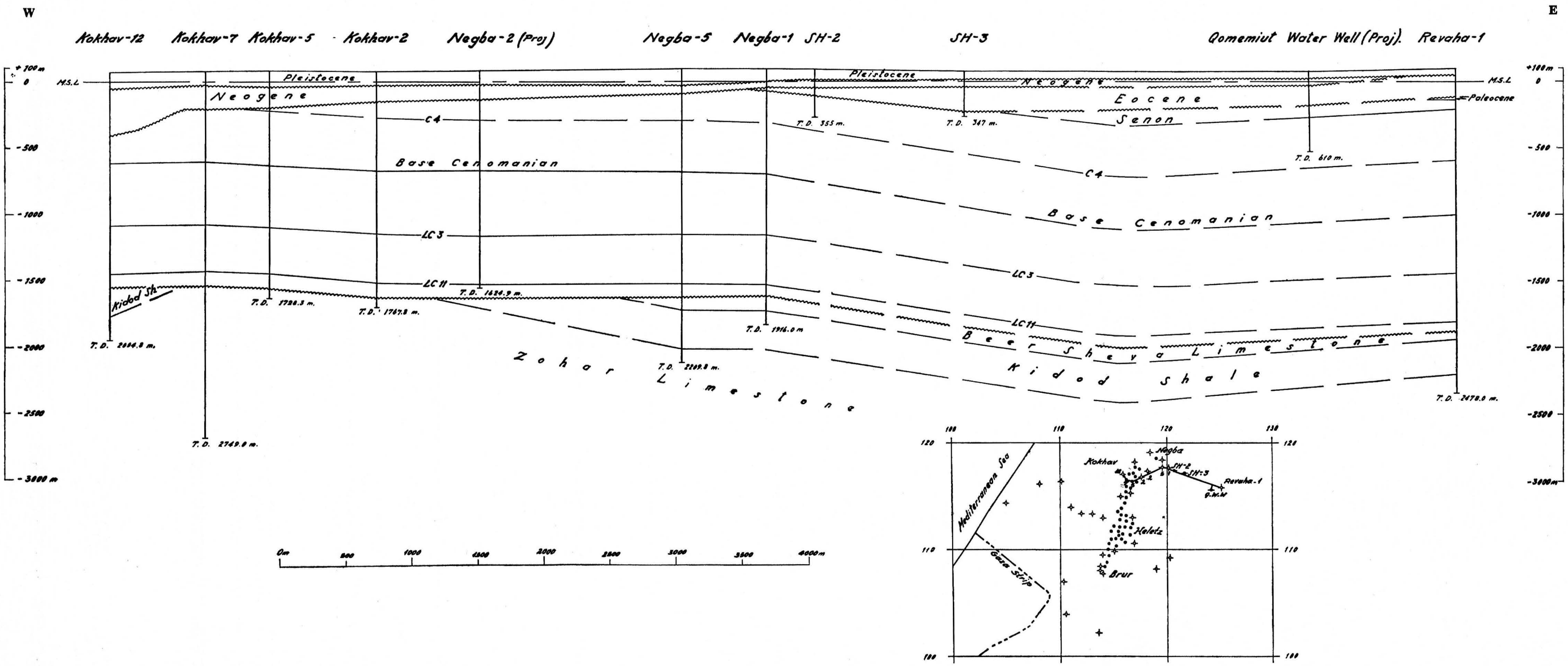


Figure 2

Stratigraphic section accross the Kokhav area.

## The geology of the Heletz — Brur — Kokhav field

ZFANIA COHEN, *Lapidoth, Israel Oil Prospectors Corp., Tel Aviv*

The Heletz-Brur-Kokhav field is located 50 km south of Tel Aviv and 10 km west of the Mediterranean shoreline. The field is situated on the buried NNE-SSW trending Gvar'am structure. Since the first strike on September 1955 a total of 51 wells has been drilled in the field; 30 wells in the Heletz area, 7 wells in the Brur area, and 14 wells in the Kokhav area. Of these, 39 are producers, 3 are watered out and 11 are dry. Total reserves of the Heletz-Brur area are estimated at 14 million barrels. No figures on the reserve of the Kokhav area are available as it is still under development. Till March 31, 1963, the field produced a total of 5,214,278 barrels of approximately 30 API gravity from various horizons.

The four main producing zones in the field are the Jurassic Zohar Limestone, the Lower Cretaceous Kokhav Sands, the Dolomite Zone and the Heletz Sands zone (Figure 1). The four producing zones are formed by stratigraphic traps that are associated with the transgressing early Cretaceous sea.

Folding first occurred either concurrent with or following the deposition of the Jurassic Kidod Shale. Emergence and extensive erosion followed, truncating the Jurassic structure that was in existence in the Kokhav area. The Kidod Shale as well as several hundred metres of the underlying Zohar Limestone are missing in the crestal area in Kokhav (Figure 2).

Subsidence and transgression followed, resulting in an angular unconformity between the Lower Cretaceous beds and the underlying folded Jurassic strata. The rest of the producing zones were deposited within 150 m above the unconformity. The Kokhav Sands are probably beach sands, the Dolomite Zone was formed as a reef, and the overlying Heletz Sands are isolated transgressive and regressive sand lenses that were deposited in a shifting shoreline environment as a result of the interplay of the rate of subsidence and the rate of supply of terrigenous material.

## Geochemical study of soils in the Heletz oil field

I. ZAK, *Geochemistry Division, Geological Survey of Israel*

Several geochemical methods of oil prospecting were tested in the Heletz area, in the southern coastal plain of Israel. An area of approximately one hundred square km was covered by the preliminary survey, and 165 samples, from a depth of 3 m each, were examined.

A low N-S ridge bisects the area, with hills mainly composed of calcareous sandstones (*kurkar*). The lowland area on both sides is characterized by residual and alluvial soils.

The purpose of the study was to determine whether any geochemical anomaly, connected with the deep-lying (1500 m) Heletz oil reservoir, may be found close to the surface. The study is still in progress, and the reported results are preliminary.

The following tests were carried out:

a. *Hydrocarbon tests.* The content of methane, ethane and heavier hydrocarbons in the soil samples was determined by Dr. L. Horvitz, Houston, Texas. Horvitz concluded (lecture at the Hebrew University) that: "outstanding halo-type anomalies are indicated by both the methane data and the ethane and heavier hydrocarbons over the Heletz oil field."

b. *Trace elements tests.* The content of V, Cr, Ni, Cu, and Zn in the soil samples was determined by means of X-ray fluorescence. This was done by I. Zak of the G.S.I. and A. Nissenbaum of the Hebrew University, Jerusalem.

c. *Salinity tests.* The content of water-soluble $Cl^-$, $SO_4^{2-}$, and $Na^+$ was determined in most samples by means of ion exchange.

d. *Radiometric tests.* The uranium content in some of the soil samples was determined in the laboratories of the Israel Atomic Energy Commission.

TABLE I

AVERAGE CONTENT OF CERTAIN COMPONENTS IN SOIL SAMPLES FROM THE HELETZ AREA *

| Group of soil samples (clay) | Percent by weight: Organic matter | $Fe_2O_3$ | $CO_2$ | soluble in water: $Cl^-$ | $SO_4^=$ | $Na^+$ | Parts per million by weight: Methane | Ethane and heavier hydrocarbons | U | V | Cr | Ni | Cu | Zn | Number* of samples |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| a. up to 15% average 7% | 0.05 | 1.3 | 8.3 | (0.01) | 0.03 | 0.01 | 0.12 | 0.05 | (0.7) | 100 | 25 | 10 | 10 | 10 | 45 |
| b. 16% to 30% average 23% | 0.10 | 2.5 | 6.6 | (0.03) | 0.04 | 0.02 | 0.21 | 0.06 | (0.9) | 180 | 30 | 20 | 15 | 20 | 30 |
| c. above 30% average 54% | 0.16 | 5.0 | 6.1 | (0.08) | 0.06 | 0.09 | 0.30 | 0.09 | (1.6) | 300 | 50 | 40 | 20 | 35 | 68 |

* The soil samples have been grouped into three groups according to their clay (< 0.002mm) content. The Cl— content was determined in 13, 11 and 47 samples respectively; The U content was determined in 10, 6 and 15 samples respectively.

An attempt was also made to elucidate the relationship between soil type and the distribution of the geochemical properties in the Heletz area. A series of soil tests was carried out, including mechanical analyses, and determinations of organic matter, $Fe_2O_3$ and $CO_2$.

The results indicate a firm relationship between the clay content and the content of trace elements, soluble $Cl^-$, $SO_4^{2-}$, and $Na^+$, uranium and $Fe_2O_3$ (see Table I). The $Fe_2O_3$/clay ratio is consistent, approximately 1 : 10, and thus the $Fe_2O_3$ content may be used as an indicator of the clay content in the Heletz soils.

The relationship between the hydrocarbons and the clay content is also constant. It is evident, however, that any interpretation of the geochemical properties of soils in the Heletz area, with its different soil types, should take into account the pedological factors.

## Trace elements in the soils of the Heletz oil field

I. ZAK AND A. NISSENBAUM, *Geochemistry Division, Geological Survey, and Department of Geology, The Hebrew University of Jerusalem*

The V, Cr, Ni, Cu and Zn content of some 150 soil samples from the Heletz oil field and its vicinity has been determined. This was done in order to test the theory that some of these trace elements have migrated from the underlying oil reservoir to the soils on the surface.

TABLE I

AVERAGE CONTENT OF V, Cr, Ni, Zn AND Cu IN SOILS, SEDIMENTS AND OIL (IN p.p.m.)

| | *Coastal plain of Israel* | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | *Heletz soils grouped according to clay content* | | | *Sandy soil* | *Brown soil* | *Soils average* | *Shales average* | *Carbonate rocks average* | *Heletz* crude oil ash* | *Asphalt and petroleum ash* |
| | *Up to* 15% | 16-30% | *above* 30% | (*Ravikovitch etal.* 1962) | | (*Vinogradov*, 1959) | | (*Graf*, 1960) | | (*Krauskopf*, 1955) |
| V | 100 | 180 | 300 | .. | .. | 100 | 130 | 15 | 1000-10000 | 500-25000 |
| Cr | 25 | 30 | 50 | .. | .. | 200 | 160 | 9 | 1000 | 200-3000 |
| Ni | 10 | 20 | 40 | .. | .. | 40 | 95 | 12 | 10000-100000 | 1000-45000 |
| Cu | 10 | 15 | 20 | 14 | 31 | 20 | 60 | 14 | 1000 | 200-8000 |
| Zn | 10 | 20 | 35 | 48 | 82 | 50 | 80 | 26 | 100 | 100-25u0 |
| No. of samples | 45 | 30 | 68 | | | | | | 1 | |

* The ash content of the crude oil of Heletz is 0.03%
The crude oil contains 12 p.p.m. Ni and 0.43 p.p.m. V (Lichtenstein, 1962)

The trace elements were determined by the X-ray fluorescence method developed by Z. Kalman and L. Heller (1962). Satisfactory results were obtained for Cr, Ni, and Zn, and for amounts of V up to 350 p.p.m. In the determination of Cu an error was introduced by scattered radiation from the instrument.

The average content of these trace elements in the Heletz soils is given in Table I. The parent rocks are mainly Quaternary calcareous sandstones and carbonate rocks of Cretaceous to Eocene age.

For comparison, the ash of Heletz crude oil was analysed semi-quantitatively in the spectrographic laboratory of the Weizmann Institute (for partial results see Table I).

Compared with other soils, the Heletz samples are found to be poor in Cr, Zn and Ni, normal in Cu, and rich in V. The Cr/V ratio in the Heletz soils is 1:5, about one tenth of the average for soils, and the Ni/V ratio is approximately 1:10, about a third of the average for soils. The Ni/V ratio of the Heletz crude oil is about 30:1, due to a very low V content. This is in striking contrast to the Ni/V ratio of the soil, which is 300 times smaller.

The results of the soil analyses show that the amounts of Ni and V are directly proportional to the clay content. This holds also for Zn and Cr, although less pronouncedly so. The more or less random distribution of Cu cannot be explained since data are not sufficiently accurate.

The results of this investigation do not show any trace element anomaly due to migration from the underlying oil reservoir to the surface soil.

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## Tectonic phenomena along the Ramon lineament

Z. GARFUNKEL, *Department of Geology, The Hebrew University of Jerusalem*

The southern wall of the Makhtesh Ramon is a line of strong tectonic deformation — the Ramon Lineament. This structure was formed by the superposition of repeated deformations of varying intensity and direction. Therefore, the older horizons are involved in progressively more complicated structures.

The time of the major deformation phases can be deduced from unconformities and abrupt variations of facies and thickness. Thus we can distinguish at least seven phases, proven by erosional and sometimes angular unconformities: during the late Triassic (Mohila Formation times); at the end of the Triassic (prior to the deposition of the Flint Clay); in the late Jurassic (prior to the deposition of the Ramon conglomerate); during the Turonian; between the deposition of the Menuha Formation and the Mishash flint; pre Middle Eocene; post Middle Eocene. Some activity during the early Senonian is also indicated. The first, third and fourth phases are not specifically connected with the Lineament, and have their structures oblique to it. Post Middle Eocene movements were slight.

The present structure consists of a very asymmetric anticline, or a monoclinal flexure, dissected by several upthrusts or vertical faults (the Ramon faults) parallel to its axis. In detail, this structure is complicated by numerous minor folds and faults oblique to the main line of deformation. The total deformation is such that the block north of the Lineament is upthrown in relation to the southern block and somewhat pushed over it. The Lineament is probably the surface expression of a deep-seated fault.

The details of the structures, especially of those of the southern wall of the Makhtesh, can be interpreted as due to lateral variations of the net slip of the thrusts. No major strike-slip movement has affected the exposed strata since early Cretaceous times, but a small dextral movement did occur, modifying the essentially thrusting movement. The variation in the net slip of the thrusts coupled with the minor strike-slip movement resulted in the formation of a series of brachy-anticlines superimposed on the main flexure, their axes not deviating much from the general trend of the Lineament.

Irregularities of the fault surfaces resulted in small faults branching off from the Ramon faults, and in some extra minor folding.

The origin of the structures of the Triassic rocks cropping out within the Makhtesh can be traced back to the late Triassic, after which they were reworked by a major folding phase of the Upper Jurassic. A large anticline resulted, part of which is now exposed from the foot of Mt. Ardon to the Gvanim fold. It was deeply eroded before the deposition of the Ramon conglomerate. Similar structures were probably formed elsewhere. The proven amplitude of the fold was at least 500 m. Later, these structures were involved in the Cretaceous and later movements, which were mostly confined to the Lineament.

The repeated folding (specifically cross-folding) accounts for the "unorganized" and irregular aspect of the folds inside the Makhtesh.

**The rare gases as geochemical tracers**

E. MAZOR, *Israel Atomic Energy Commission and Weizmann Institute of Science, Rehovot*

Valuable geochemical information can be gleaned from the relative abundances and isotopic compositions of He, Ne, Ar, Kr, Xe and Rn in natural gases, such as air, rock-trapped gases, gases dissolved in groundwater, oceans, oils and magmas, etc.

Several geochronological dating methods are based on analysis of the rare gases. The K-Ar method is the most widely used. Others are the Th, U-He and U-Xe age methods and the He-3 cosmic radiation age measurement.

Natural gases are often mixtures of atmospheric and non-atmospheric (deep-seated, juvenile, decompositional etc.) components. Ne, $Ar^{36}$ and Kr serve as tracers for atmospheric components as they are not produced in the present lithosphere in appreciable amounts. $He^4$, $Ar^{40}$ and $Xe^{136}$, on the other hand, are continuously formed by the decay of U, Th and $K^{40}$, and by fission of U. Hence any excess of these isotopes over their atmospheric abundances (e.g., $Ar^{40}/Ar^{36}$ larger than 296) indicates juvenile origin, i.e., gases that join the geochemical cycle for the first time. Gases (such as methane) trapped in old formations are enriched in He and $Ar^{40}$ ($Ar^{40}/Ar^{36}$ up to 50,000), while similar gases produced by recent organic decomposition have no such enrichmen ts (Wasserburg *el al.*, 1963).

The ratio of $N_2$ to $Ar^{36}$ in natural gases often indicates an excess of non-atmospheric$N_2$ ($N_2/Ar^{36}$ up to $200 \times 10^4$, compared with $2 \times 10^4$ in the atmosphere, Zartman *el al.*, 1961).

Brown (1948) and Suess (1949) used the relative abundances of the rare gases in the atmosphere to show that the earth has lost its original atmosphere and that our present one was formed by later outgassing of the crust.

Argon, because of its inertness, is used in oceanography in studies of biogenic consumption and supply of oxygen and nitrogen.

Radon-222, the decay product of $U^{238}$, with a half-life of only 3.8 days, is often highly concentrated in spring waters, a fact which might be used in estimating groundwater velocities.

These are only a few examples for the use of rare gases as tracers of geochemical processes.

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**Geochemical facts concerning metallurgical processes in ancient times**

C. A. KEY, *Geochemistry Division, Geological Survey of Israel, Jerusalem*

Quantitative spectrographic analyses were made of some copper and copper-arsenic alloy objects found in a cave near the Dead Sea. It appears that the craftsmen used the alloy for easier casting of the ornaments. The objects are approximately 5000 years old.

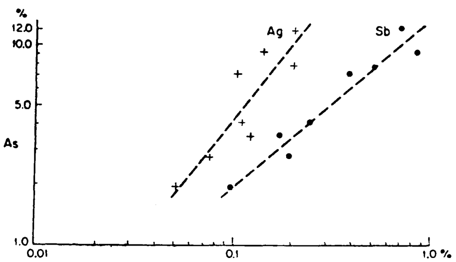


Figure 1
The relationships between the elements in the ornaments

TABLE I

| *No. of Specimen* | *As* % | *Sb* % | *Ag* % | *Bi* % |
|---|---|---|---|---|
| 252 | 1.90 | 0.0980 | 0.0515 | 0.0120 |
| 2 | 2.80 | 0.1930 | 0.0770 | 0.0170 |
| 351 | 3.50 | 0.1780 | 0.1230 | 0.0013 |
| 500 | 4.10 | 0.2500 | 0.1110 | 0.0125 |
| 231 | 7.20 | 0.4000 | 0.1080 | 0.0087 |
| 133 | 7.40 | 0.7050 | 0.2280 | 0.0152 |
| 131 | 9.20 | 0.8650 | 0.1440 | 0.0102 |
| 121 | 11.90 | 0.6090 | 0.2100 | 0.0240 |

The results of some analyses are presented in Table I. In contrast to most other analysed ancient artifacts and ores, known to be used in the Middle East, neither Sn nor Zn were found in any of the ornaments.

The scatter diagram (Figure 1) shows that the Sb, Ag and Bi contents are directly proportional to the As content. It appears therefore that a copper-sulf-arsenate ore was used, because this geochemical relationship cannot exist in the green copper carbonate ores.

This shows that the extraction of copper from sulfide ores, by the double process of roasting and smelting, was already known during Chalcolithic times.

The only copper-sulf-arsenate ores reported from the Middle East are found in Armenia.

**The geology of the western mountain border of the Hula Valley**

Y. Glikson, *Department of Geology, The Hebrew University of Jerusalem*

A field study was made in the Rosh Pina — Nebi Yusha' region, with an accompanying survey of the lacustrine sediments in the Kefar Giladi area.

The stratigraphic column is characterized by frequent lateral variations, with some rock units thinning towards the north. Marked facial changes in the $C_2$ strata are noticeable due to the existence of a marly guide horizon at the $C_1$-$C_2$ boundary. The Bi'na limestone is often dolomitized. Unconformities and truncation characterize the Senonian. Differentiated sedimentation which developed in the early Eocene came to an end with a general regression in Middle Eocene times. Lagunar and lacustrine conditions followed. Shallow continental basins developed in the present Hula Valley site. Volcanism is prominent toward the end of the Neogene. The main taphrogenic movement occurred during proto-Pleistocene times and was succeeded by eruptions of basalt and pyroclastics. Further faulting took place during the Pleistocene.

The main tectonic feature is the Western Hula fault, which is analogous to and forms the southern continuation of the Beka'a fault. It fades out into the Safad flexure through the down-faulted structural amphitheatre of the Dishon-Hatzor area. A main fold axis runs due NNE, and is truncated by the Hula fault. Genetical relations of folding to faulting trends are suggested.

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### Geophysical measurements in the Yizre'el Valley

A. GINZBURG, *Institute for Petroleum Research and Geophysics, Azor.*

Emeq Yizre'el (the Valley of Yizre'el) may be divided into two distinct depressions according to the Bouguer anomaly map. The Central Emeq and the Eastern Emeq depressions are separated by the Central Emeq high, running from Megiddo towards Mt. Tabor. The first depression is circular and is centered near Ramat David, while the second depression is elongated and opens out into the Jordan Valley. Through the use of deep resistivity profiles and quantitative gravity calculations it can be demonstrated that the Central Emeq is underlain by a ridge along which the denser Cenomanian-Turonian limestones are at a shallower depth than in the neighbouring areas. Likewise the post-Turonian fill of the depression may be calculated.