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ISRAEL GEOLOGICAL SOCIETY
JERUSALEM · P.O.B. 1239 ת.ד. · ירושלים

ANNUAL MEETING

Southern Sinai and the Gulf of Elat

Under the auspices of the
Ministry of Energy and Infrastructure
and the Head of the Administration for
the Development of Merhav Shelomo

Program, Abstracts, Annual Reports,
Explanatory Votes on the Excursions

Na'ama Field School, Ophira

23-27 March, 1980

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CERTAIN MECHANICAL ASPECTS IN COMPARATIVE CONTINENTAL RIFTING

Dov Bahat

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Rift initiation in the Rhine, Dead Sea and Baikal rifts is a process that reflects local upper mantle upwelling and can be independent from regional crustal forces. Possibly, characterization of crust/mantle boundaries in various rifts may add important information on the behaviour of these interfaces.

Distances between major bifurcations in the Rhine graben, the Dead Sea and the Baikal rifts are about 270, 290 and 50 km, respectively. This implies that in the former two rifts initial rifting was caused under considerably lower energy conditions, compared with the latter. This may or may not be connected with the proposition that whereas the Baikal initial rifting was strongly influenced by the neighbour resilient platform, the other two were not.

There is probably no connection between the intensity of initial fracture and bifurcation and the depth of the crust/mantle boundary during fracture.

Locations of fracture initiation of Cenozoic rifts (and possibly other rifts as well) seem to maintain their unique tectono-morphologic features.

Three aspects of fault bifurcation should be distinguished. These are intensity of fracture bifurcation, repetition of fracture branching and displacement along bifurcated fracture planes.

WAVINESS IN MANTLE UPLIFTS DETERMINED BY CRUSTAL BIFURCATIONS

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It has been suggested by Bahat and Rabinovitch (1979) that the crust mantle boundary is undulatory rather than flat. Locations of crustal fracture initiation and bifurcation in rifts are determined by uplifts in the crust or/and the upper mantle. Accordingly, distances between major bifurcations in the continents and the oceans were determined (Table 1). It appears that in continental rifts these distances are relatively short (order of 300 km) and in the oceans it is considerably longer (order of 4,000 km). Transitional distances are observed as well (order of 1,000 km in the Red Sea rift). Does it suggest undulatory crust/mantle boundary with low wave length under the continents and long wave length under the ocean crusts?

Table 1. Waviness in mantle uplifts determined by crustal bifurcations

No.	Location	Rift System	Distance Between Major Bifurcation (km)	Type
1	Europe	Rhinegraben	240	continental
2	Africa	Ethopia	225	continental
3	Africa	Gregory	300	continental
4	Africa	Rungwe	250	continental
5	Africa	Malawi	350	continental
6	Africa	Luangwa	350	continental
7	Asia	Jordan	145	continental
8	Asia	Red Sea	1000	transitional
9	Pacific	Philippine	500	transitional
10	S. America	Atacama	250	continental
11	U.S.A.	San Andreas	145 100-140	continental continental
12a	Canada	St. Lawrence	420	continental or transitional
12b	Canada	St. Lawrence	440	continental or transitional
12c	Canada	St. Lawrence	440	continental or transitional
13	Pacific Ocean	Easter Island Ridge	4,200	oceanic
14	Pacific Ocean	Easter Island Ridge	2,700	oceanic
15	Indian Ocean	Bab el Mandeb-Rodrigues	4,500	oceanic

RELATIONS BETWEEN CLASTIC SEDIMENTS AND TECTONIC HISTORY OF KARKOM GRABEN

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The Karkom rhomb-graben is located along the Paran-Arif fault, west of the Mitzpe Ramon-Elat road, and is 7x18 km in size. It is delimited mainly by normal faults, but portions of the Paran fault are vertical or reverse. The Paran fault is continuous while the other faults are arranged en-echelon.

The sediments within the graben are of Eocene and younger age. Late Eocene beds were found only east of the graben (Sakal, 1967), but not in it, nor along its borders. Within the graben are beds of the Hazeva Formation which comprise a basal conglomerate (Shahaq Member), a calcareous unit (Mashaq Member) and reddish sandstone and shale (Gidron Member), which include conglomerate beds built of allochthonous well rounded clasts similar to the "top conglomerate" of the formation. The Hazeva beds are faulted along the graben borders against Eocene beds, and dip up to 40°. There is no evidence for pre-Hazeva faulting, but the anomalous thickness of the formation (up to 350 m) records a local sedimentary basin. The similarity of the sequence to other Hazeva basins in the Negev indicates that they were interconnected. The uppermost part of the Hazeva Formation contains a conglomerate with angular clasts, mainly of limestone, which probably indicates tectonic rejuvenation of the relief.

A second clastic unit covers unconformably the Hazeva Formation and overlaps the marginal faults. In the central part of the graben this sequence becomes rich in chalky-marly lacustrine beds. The clasts are generally angular and consist of locally derived limestone and chert and igneous rocks transported from the Elat area. This conglomerate unit, probably correlative with the Arava conglomerate, extends also outside the graben to the Kuntila region. Northward its upper parts extend through a canyon to the Meshar plain. Hitherto brackish forams were found in a single locality in Nahal Karkom. Perhaps this indicates connection with other bodies of brackish water known from around the Dead Sea (Shahar et al., 1967;

Elron, 1980). The upper conglomeratic unit is undisturbed, but in few localities within the graben and along its borders it is faulted, with throws of 2-3 m. This unit was deposited in a fault controlled depression. The faulting essentially predates this unit.

DATING OF MAJOR STAGES IN THE DEVELOPMENT OF THE ARABO-NUBIAN MASSIF IN SINAI

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Rocks which represent important stages in the development of the crystalline basement in Sinai, were dated by means of the Rb-Sr method. The ages and initial $^{87}Sr/^{86}Sr$ ratios lead to the following conclusions:

1. Most of the basement rocks exposed in Sinai, are younger than 670 m.y.

2. The oldest plutonic phase (Elat-Fjord metamorphic complex) is dated at 650 ± 20 m.y. The earliest pluton intrudes schists that were already metamorphosed.

3. The ages of deformation phases as recognised in the Fjord complex (Eyal, 1976) are:

$$D_1 > 650 > D_2 > 640 > D_3, D_4 > 600$$

4. Intensive volcanism and sedimentation (the kid complex) occurred at 615 ± 15 m.y. These rocks were metamorphosed (D_3, D_4?) between 615 and 600 m.y.

5. A tremendous volume of post kinematic granites was formed and emplaced within a short period, 580-600 m.y., thereby the main features of the massif were established.

6. An additional thermal event (Igna Event) at 520-540 m.y. is responsible for the generation of granitic magma and rejuvenation of mineral ages. According to its radiometric age, this event postdates the peneplain.

SUBSIDENCE AND THERMAL HISTORY OF THE SOUTHERN OKLAHOMA AULACOGEN: IMPLICATION FOR PETROLEUM EXPLORATION

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A recent widely accepted concept of basin evolution consists of isostatic subsidence in response to an increasing load, primarily driven by conductive cooling of a rift related thermal anomaly. A reconstructed subsidence and thermal history of the Southern Oklahoma Aulacogen: 1, supports the application of this concept for the formation of the basin and, 2, stresses the significance of this concept for petroleum exploration.

Two distinct mechanisms are proposed for the evolution of the basin based on analysis of the aulacogen subsidence curve, considering variations in the rate of subsidence to be a significant recorder of the cumulative effect of the factors which control basin subsidence. A mechanism of elastic flexure of the lithosphere controlled the aulacogen subsidence during the first 20 m.y. Later it evolved to a differential subsidence of the aulacogen with respect to the adjacent stable platform as it became detached from the latter presumably along reactivated faults at the aulacogen boundaries.

A possible short phase of sediment compaction and fluid migration at the close of the subsidence stage is also suggested based on this analysis. This might indicate a change in the stress field from extension to compression, perhaps in relation to the regional tectonic settings.

Two methods are used for reconstruction of the thermal history. A theoretical tectonophysics model in combination with a history of basin evolution demonstrates: 1. both, geothermal gradient and depth-of-burial are dynamic variables during the subsidence stage, 2. maximum paleotemperatures were attained during Sylvan time (Late Ord.) near the close of subsidence, 3. most of the Arbuckle Group was subjected to the temperature conditions of oil formation (oil liquid window) at that stage, prior to the possible phase of fluid migration.

The second method, involving reconstruction of the geothermal history on the basis of geothermometry (palynomorph carbonization), suggests: 1) paleotemperatures exerted a significant effect on the level of organic metamorphism in the sedimentary rocks, 2) indications for the variable nature of the geothermal gradient during the subsidence stage, 3) higher paleotemperatures than those predicted by the theoretical model and in turn, 4) support for the hypothesis of formation of the basin by thermally controlled subsidence and the application of this concept for petroleum exploration.

JOINT PATTERN AND ITS INFLUENCE ON GEOHYDROLOGICAL CONDITIONS, NAHAL SHLOMO, ELAT

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An area near Elat was investigated for the purpose of identifying suitable sites for the construction of mined underground petroleum storage caverns. The area of study is located at the northern tip of the Arabo-Nubian Precambrian Massif, close to the big geo-suture known as the Syrian-African Rift Valley.

The area, built mainly of granite, has undergone during Late Precambrian, plastic and ruptural deformations accompanied by phases of basic and acidic dike intrusions. Tertiary tectonic activity, related to the Rift Valley, caused shattering and fracturing to both granite and injected numerous dikes.

Figure 1 schematically illustrates the predominant attitudes of the structural features within the study area and the relationship of the study area to the regional structural framework. The principal structures observed in the interior of the study area, listed in their probable order of occurrence are:

1. NE tension joints
2. EW thrust-plane fissures (some filled by pegmatite dikes).
3. Basic dikes and accompanying N-S (north-south) joint sets.

4. Acidic dikes and accompanying N-S (north-south) joint sets.

5. Northwest faults.

A combination of detailed geological mapping and core drilling was used to evaluate the body of rock selected for study. Geological mapping included the preparation of a series of joint frequency overlay maps to portray distribution patterns of the principal joint sets.

Comparison of structural features, including the frequency of jointing, in drill holes with that mapped on the surface led to the conclusion that the structural details observed on surface can be projected downward with reliability. (Fig. 2).

In order to evaluate the geohydrological conditions of the proposed site for underground oil storage, several packer tests were carried out in the drilled holes.

The results, though insufficient, reveal the following hydrological conditions:

a. The coefficient of permeability varies between 4×10^{-6} - 4×10^{-5} cm/sec through different rocks. Thus, a highly fractured quartz porphyry dike shows a permeability of 2.5 - 3.7×10^{-5} cm/sec while "massive" granite with pegmatitic features shows a permeability of 4-7 $\times 10^{-6}$ cm/sec. This range of permeabilities matches the range of permeabilities of clayey impervious soils.

b. The calculated gradients are not consistent, a fact which is also revealed in many semi-pervious to impervious strata. The gradient varies from 0.35° (at a distance larger than 0.5 km from the sea shore line) to 0.19° within the closer 0.5 km (Fig. 3). The idea that basic dikes act as waterproof dams is still an open question.

c. Data is insufficient to establish hydrological relationship between flow within the limits of Nahal Shlomo and flow in the granitic system on its boundaries.

d. Chemical analysis shows that the ground water beneath the study area is very saline, about 16,000 ppm. T.D.S.

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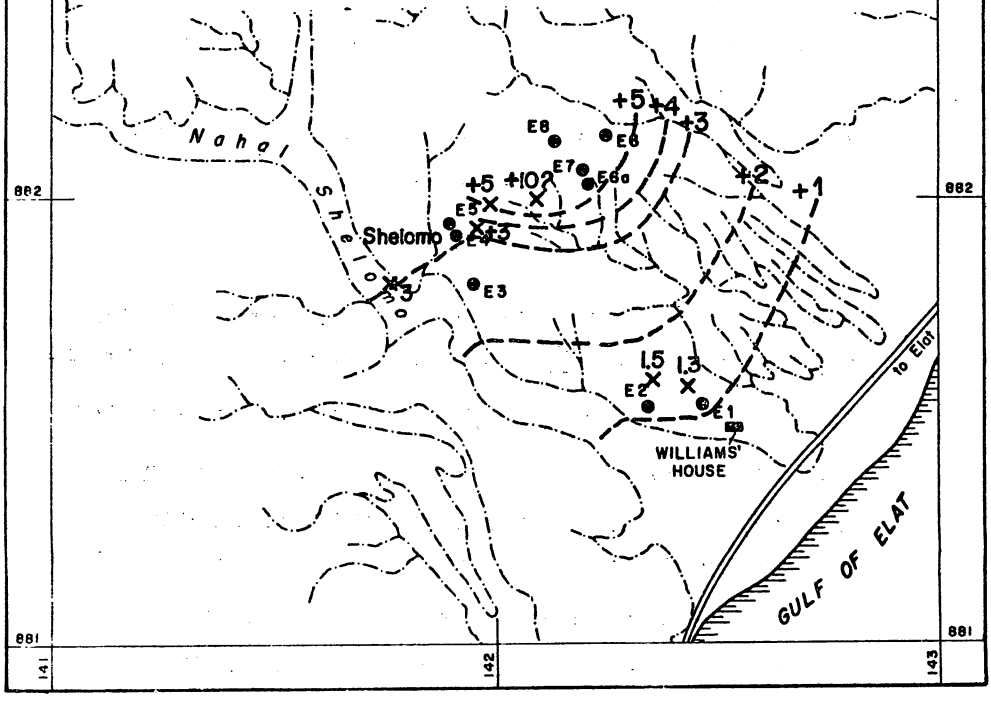
FIGURE 3

BOREHOLE LOCATION MAP AND

GROUND WATER TABLE (IN METERS)



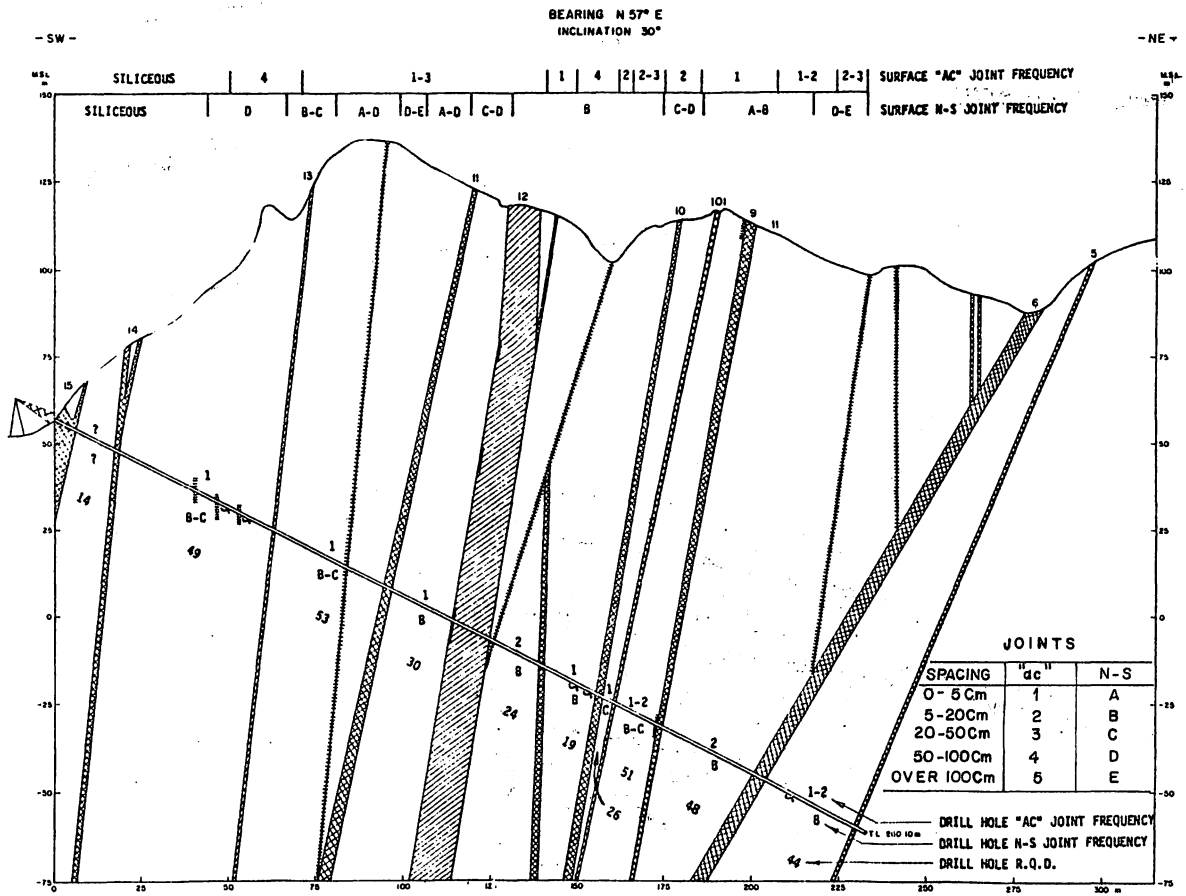


Fig. 2 VERTICAL CROSS SECTION DRILL HOLE NO. 5

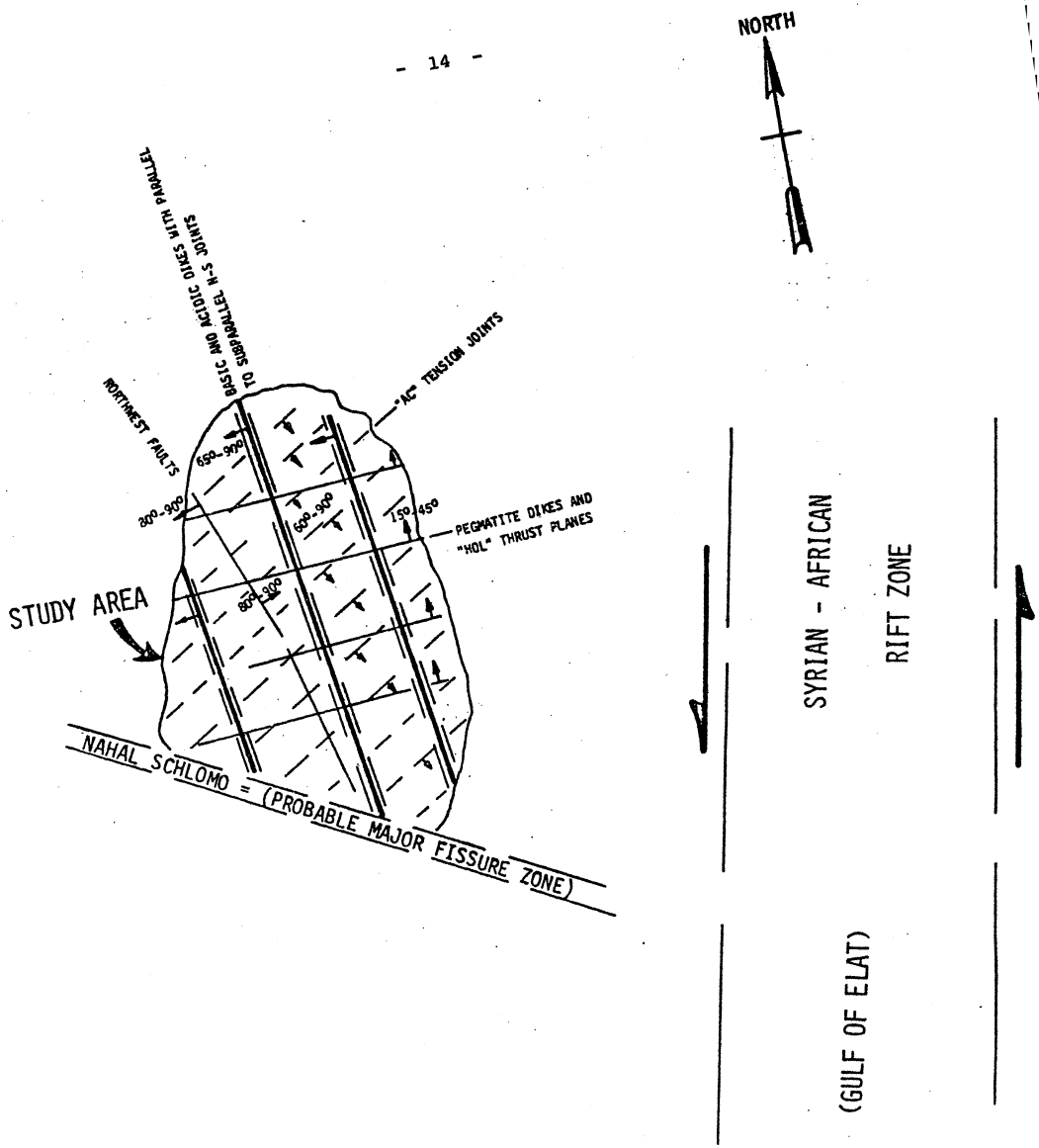


Figure 1. Schematic Diagram- Structural Geology, Elat Study Area

MEETING OF TWO SETS OF STRIKE SLIP FAULTS IN SOUTH-EASTERN SINAI.

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Two sets of conjugate strike slip faults occur in the Sharira Pass area in SE Sinai. One set of faults, trending NNE-SSW, are sinistral faults. The second set of dextral faults trends E-W. The horizontal displacement on the faults is recognized by offsets of dikes and of contacts in rock of Precambrian age. Some of the dikes may be younger (Miocene and Pliocene ?). It amounts to 2-4 Km, along the median portion of the main faults. The amount of displacement along the faults decreases towards their terminations.

The reconstruction of the area to the situation before the displacement demonstrates the relations between the two sets, which requires the mutual rotation of the two sets of faulted blocks. The amount of rotation of the faulted blocks can be obtained independently by measuring the direction of the dikes displaced on the faults. The results of the two methods are compared.

An example of the phenomena occurring at the meeting of the two sets is given on a more accurate map of the faults in an area where three faults meet.

STRUCTURAL FEATURES OF EL QAA PLAIN (Southwestern Sinai)

By

YAAKOV GILBOA

El Qaa Plain is a longitudinal, NW-SE trending, border trough in the southeastern part of the Suez Rift, that separates the elevated Igneous Massive of Southern Sinai from the internal uplifted structure belt of Gebel Qabeliat.

Block structures are dominant and major faulting, parallel to the direction of the rift, yields throws limited to few hundred meters. A combination of nearby consecutive faults results in throws over 2,000 m.

The longitudinal plain consists of a central depression and bordering tilted blocks , that are broken by numerous transversal faults. The central graben is composed of two major troughs; the northern one,between Wadi Feiran and Wadi Isla, is closed to the sea, by Gebel Qabeliat and its buried continuation, and is filled with thousands of meters of sediments. South of Wadi Isla, the southern trough , 2-7 Km wide, is open to the sea and is filled by more than 4,500m of sediments. To the East This longitudinal Coastal Depression is bounded by a shallow buried Igneous Basement..

Except for the outstanding Post Eocene unconformity, unconformities are encountered in most of the Miocene and younger formations. The tectonic activity culminated during the Miocene and the Plio-Pleistocene, as reflected by the throws of the faults and by the thickness of the young sediments.

ASSESSMENT OF ISRAEL'S NATURAL RESOURCE ENDOWMENT BY THE AREAL VALUE ESTIMATION METHOD

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The achievements of the mineral industry of Israel and a rough overall reconaissance appraisal of the natural resources endowment of the country have been evaluated by areal value estimation using the COMOD software package developed by J. C. Griffiths and his coworkers. In broad terms, the evaluation relies on cumulative past production records, which when prorated per unit area, yield a series of "unit regional value"(URV) or "areal valence" variables for individual commodities, resource sectors and total resources and on geological variables obtained from quantifying the geological map of the region in question. The two groups of variables facilitate conducting comparisons with other well developed and/or geologically similar regions from which the future potential of the region, with respect to both overall endowment and individual commodities, can be assessed. The fundamental notion which underlies the entire appraisal is the assumption that, with respect to total endowment in natural resources, all regions above a size of about 5000 sq. kms. are equally valuable, regardless of inherent geological characteristics. To date, areal value estimation studies have been carried out for 11 different countries, encompassing a total of 109 politically-administratively defined regions. These studies provide an adequate information base for between-region comparisons. The states of the U.S.A. and the U.S.A. as a whole, constituting what can be regarded as "well developed" regions, may serve as a standard of achievement and expectation for all such comparisons. The distribution of the URV of total resources of the individual states of the U.S.A. is lognormal with a mean of 54954 U.S. dollars per sq. km. Based on the above assumption, this value can serve as a conservative estimate for the total output any region can be expected to produce.

Twenty seven different mineral commodities are known to exist in Israel. Of these, 18 are economically exploited and the remaining 9 are at present uneconomical mineral occurrences. Past production records have been assembled for 14 of the exploited commodities for which records could be obtained. From these records a number of statistics and parameters were computed to evaluate the development of the mineral industry of the country, its overall achievements and its future potential.

In absolute figures, the overall cumulative production has been rather small, amounting to only 1679.8 millions deflated 1967 U.S. dollars (equivalent to 2082 millions current U.S. dollars or 10260 millions current Israeli Pounds). Only bromine, potash and phosphate are of any worldwide significance (amounting, respectively, to 10, 2.9, and 1 percent of the world production in 1977). Constructional materials, with the longest production history, have been the most valuable, accounting

for 54% of the total cumulative output. They are followed by nonmetals (35%), metals (8%) and fuels (4%). The value-ranking of individual commodities and their respective contribution to the total cumulative output is: cement, 35%; potash, 19%; stone, 15%; phosphate, 11%; copper, 8%; sand and gravel, 4%; bromine, 3%; petroleum, 2.5%; natural gas, 1%; periclase, 0.7%; clays, 0.7%; salt, 0.4% and glass sand, 0.2%.

Total annual output for the period 1948-1977 exhibits a constant growth with no indication of approaching a plateau of diminishing returns. Other indicative parameters also exhibit a steady long run growth trend. As new commodities became exploited the share of constructional materials in the total output gradually declined from 100% in 1948 to 45% in 1977. The contribution of the mineral industry to the annual gross national output has risen steadily from 0.55% in 1951 to 2.2% in 1964. Thereafter, it has fluctuated around an average of about 1.8%. Both total output and production of constructional materials (when expressed in current Israeli Pounds) correlate very highly with population size. For the period 1950-1973 the regressions explain, respectively, 91 and 94% of the variations. For the period 1950-1977 these coefficients drop to 57 and 56% due to the pronounced rise in prices following 1974.

The URV of Israel is 81154 deflated 1967 U.S. dollars per square kilometer. It exceeds the expected value for well developed regions. It can therefore be concluded that Israel is not exceptionally poor in natural resources, as is commonly felt. Despite its relatively short history it has already produced more than its expected value. This, in turn, implies that (unfortunately) its further development potential is rather limited. In comparison with the U.S.A. as a whole Israel is an overachiever in constructional materials and nonmetals, close to its expected value in metals and an underachiever in fuels and precious metals. It should be noted, however, that underachievement does not necessarily imply the existence of a promissing potential in the respective resource sector.

The URV estimates, which are based on area alone, can be refined to some degree by considering the geological characteristics of the investigated area. The geological composition of the country was quantified by point counting the geological map using a grid network of 40 sq. km. blocks. Each map unit was assigned to one of the 65 standard time-petrographic units employed in similar studies. This sampling density results in the recognition of 11 time-petrographic units (vs. 17 which are actually present). Based on the linear statistical association between mineral resource diversity and geological variability established for the states of the U.S.A. Israel can be expected to possess 31 different commodities. Since 27 have already been found, it can be predicted that only 4 additional ones are likely to be found, again indicating a limited development potential.

Basement Configuration in Israel from Seismic Refraction Measurements

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In the course of a seismic refraction study of central and northern Israel four refraction profiles were shot. Arrivals were recorded from the basement with a velocity of 6.2-6.6 km s^{-1}.

The basement refractor was recorded on all profiles and was used to construct a map of the configuration of the crystalline basement. The map indicates the presence of basement structures whose location does not coincide with the location of the surface structures. The depth to basement varies from 4 to 8 km. The highest structural area is in the vicinity of Beersheba-Hebron. From this culmination a ridge extends to the north separated from the crestal area by a down gradient running east west, with a downthrow of about 2 km. This ridge extends north of Ramallah. In the west, a basement ridge extends from the Carmel south along the Coastal Plain. The ridge is structurally separated from the Judean uplift region. A steep down gradient bounds the eastern flank of the coastal ridge and northern flank of the Ramallah structure. This gradient trends NNW-SSE and it runs from the Carmel to underneath the Shekhem syncline. The depth to basement on its downthrown side reaches over 8 km. It is concluded that the basement structures resulted from pre-Jurassic tectonic movements.

Location and Nature of Thermal Metamorphism in the Late Precambrian of Sinai

by
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Metamorphic rocks are associated with the volcanic series (ignimbrites, agglomerates, tuffs) of the eastern margins of Gebel Ferani (Pezaro, 1973; Bentor & Eyal, 1971) and Ardeni (Itamar, 1975), eastern Sinai.

The metamorphic event in these areas could have stratigraphic and petrogenetic influences in other areas of Sinai. The metamorphic rocks may have originated as a complex of acid hypabissalic intrusives (microgranites), dykes (quartz-feldspar porphyries) and intermediate to acid volcanics. The metamorphism appears to have been thermal (medium to low temperatures) at low pressures. It occurred in the following stages: cataclasm and mylonitozation; thermal metamorphism; contact metamorphism; hydrothermal alterations (sericitization, propyllitization, and others).

The characteristic metamorphic minerals are amphiboles (hornblende, edanite, tremolite-actinolite) grossular, hydrogrossular, andalusite, cordierite, wollastonite, biotite, muscovite.

The relative age of the cataclstic metamorphism is problematic. In our opinion, this post-dates the regional metamorphism of the Kid, Feiran and other areas (Shimron, 1972). It is also later than the major calc alkaline granite intrusions such as the Um Malak batholith. These conclusions are based on the following data: Partial metamorphism of a number of ignimbrite units in the Ferani area; partial metamorphism of the dykes which intrude the Um Malak granite and metamorphic rocks which are in part related to the intrusion of alkali granites and in part to the cataclastic event.

These metamorphic occurrences are found in the earliest to latest rocks of Firani, indicating that the Sinai Precambrian was mobile and active during the late stages of the development of the massif.

A SCHIZOHALINE MODEL FOR THE DEPOSITION OF THE MISHASH FORMATION

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The low $\delta^{13}C$ values in carbonates of the Mishash Fm, the sharp variability in $\delta^{18}O$ of its cherts, and the parallel variability in B concentration of Mishash cherts, can all be explained by assuming a strong fresh water input into the Mishash Sea. This evidence, when combined with that of facies changes and presence of evaporites in Mishash cherts leads to the interpretation of the Mishash sequence in terms of schizohaline "basin-basin" fractionation (Berger 1970). In such a model the environment in a basin is controlled by opening and/or closing of two sills - inlets: the marine one and the fresh water one. Various combinations of such opening-closure result in normal marine, evaporitic, fresh water, or stratified anoxic conditions in the basin.

HYDROLOGY OF ALLUVIAL FANS ON THE SHORES OF THE GULF OF EILAT

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Alluvial fans in arid regions are the product of a complex of geological, morphological and hydrological processes.

In the framework of hydrogeclogical research on the alluvial fans at Nuweiba, Dahab, Wadi Kid and others, geophysical surveys were made,and test wells, production wells were drilled and several series of hydrological tests were performed. From the findings, a geological and a hydrological model was obtained typical of similar fans in coastal desert areas.

The forming of the fan by sporadic non-continuous processes causes changes in the sedimentation of alluvial materials, both with regard to the extent of the fan and its profile. The river channel changes its route periodically, depositing coarse material in the centre of the channel and fine material on the banks and the banks and the flood plains. In addition, the size of the clastic component becomes gradually smaller from appex of the fan, moving towards the sea.

In this process a non-homogeneous and unizotropic aquifer is formed,composed of a random series of buried "channels" countaining coarse clastic material with high hydraulic transmissivity "covered" by fine material with low transmissivity. The hydrological regime of this kind of fan is dictated by the field relationship between the conveyance channels and the less permeable surroundings.

In the field investigations a sweet water body ,semi-lenticular in shape was found in the subsurface of the fan, juxtaposed to the sea water interface which saturates the lower part of the fan. The shape and size of the sweet water body are dictated by the aquifer's hydrological characteristics and its recharge regime.

Observation of recent geomorphological phenomena and build-up processes taking place in the fan, together with investigations of the subsurface structure and composition typical of fans in this region, provide the basis for an attempt to arrive at a model with whose help the most suitable well drilling sites for the production of sweet water might be identified. Such a model would save heavy investments in the means of research,and make possible management of the sweet water body ,and efficient planning of exploitation of the aquifer by recharge with floodwater and controlled pumpage.

Geohydrology of the Grofit - Yaalon Area.

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In the Arava, south of the Paran Fault to Grofit, water wells have been drilled to depths up to 900 m. Detailed geohydrologic understanding is needed to optimise the investment costs. The first deep subsurface geology of the Grofit-Yaalon area is presented here. The stratigraphic nomenclature of Bentor 1960 appears most suitable for correlations. The division of the nubian sandstone aquifer into two laterally adjacent subaquifers is corroborated.

South of Qetura the Alluvial, Cenomanian, Lower Cretaceous nubian sand and Paleozoic nubian sand aquifers are hydrologically connected, having the same water level. In the Arava proper, modern fresh water contributes to recharging all of the aquifers, though there is a vertical salinity stratification. Outside of this area the waters in the nubian sandstone have been found to be predominantly saltier paleowaters. The contribution of the freshwater recharge decreases westwards. In the rift north of Qetura the Lower Paleozoic nubian sandstone is distinctly more saline (>1000 mg/l Cl^-). Here we find a shale that separates this unit from the interconnected overlying aquifers that do receive fresh modern recharge contributions.

A QUANTITATIVE APPROACH TO THE RECENT HALITE PRECIPITATION IN THE DEAD SEA

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Marine Geology Division

Enrichment of magnesium in the Dead Sea as a result of evaporation during the period from 1959 to 1977 was used as a parameter for calculation of losses in water volume of the Dead Sea during the same period. The Dead Sea lost 11 km^3 of its volume during a period of 18 years (1959-77). Using volume balances of water in the Dead Sea during the period 1959-1977 the rate of evaporation is calculated to be 1.6 km^3/yr. Comparison of the enrichment factor for magnesium, 1.08, caused by evaporation only, to the enrichment factor for sodium during the same period, 1.02, clearly shows that sodium was precipitated from Dead Sea water as halite.

Mass balance for sodium shows that about 520 million tons of halite were precipitated from Dead Sea water (excluding precipitation in Dead Sea ponds and as "salt reefs") of which only about 30 million tons are found in the sediments of the northern basin (by mineralogical analysis of bottom sediments). The additional 490 million tons of halite probably precipitated in the eastern portion of the southern basin. Efficient circulation of brines from the southern basin to the northern basin till 1977 is suggested, since massive precipitation of halite in the evaporation ponds and in the southern basin are reflected by relatively low sodium concentration in the northern basin.

LATE QUATERNARY PALEOCEANOGRAPHY OF THE GULF OF 'AQABA (ELAT), RED SEA

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Abstract

The quantitative distribution of planktonic foraminifera, pteropods and coccolithophorids, as well as oxygen isotope analyses in 4 deep-sea cores from the Gulf of 'Aqaba (Elat) and the northernmost Red Sea are summarized. The core record covers about 150,000 years. Detailed stratigraphic subdivision is facilitated by combining all calcareous plankton groups. Time stratigraphic correlation and dating beyond the radiocarbon range are enabled by comparison of the oxygen isotope curves. During the Glacial maximum salinity rose to more than 60% while winter temperature of the upper waters fell by at least 4°C compared to the present. The rise in salinity can be accounted for by sea-strait dynamics and lowering of sea level. The G. of 'Aqaba and the Red Sea were continuously connected through the Straits of Tiran and there is no indication of desiccation during the Glacial Maximum.

RE-INTERPRETATION OF THE ^{18}O ISOTOPIC COMPOSITION OF THE TIBERIAS SUBGROUP HOT WATERS

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One of the puzzling results in the research of hot waters from the Jordan Rift Valley were the stable isotope composition of these waters. The $\delta^{18}O$ values vs. chlorinity of the Tiberias subgroup, which is the most saline in the lake Kinneret area, plot on a straight line (Gat et al., 1969, J. Hydr. 7, 334) which was interpreted as a mixture between seawater (or brine) and local fresh water. However, extrapolation to the seawater end-member resulted in $\delta^{18}O = -3°/_{oo}$. Since this value is lower than any known seawater, Gat et al. (1969) suggested that this end member-was itself the result of dilution by meteoric waters of a marine brine.

We suggest that the ^{18}O depletion observed in the hot waters results from interaction of seawater with basalts or volcanic rocks which are abundant in this area. It is well known that seawater which interacts with basalts at any temperature below 300°C will be depleted in ^{18}O. (Muehlenbachs and Clayton, 1972, Canad. J. Earth Sci., 9, 471; Lawrence et al., 1975, EPSL, 27, 1). This ^{18}O depletion will take place regardless of the minerals produced by the chemical reactions.

Seawater interaction with basalts will release Ca^{+2} from the pyroxenes and feldspars present in the rock, at any temperature in this range (25-300°C). This enrichment in Ca^{+2} is clearly shown by Mazor and Mero (1969, J. Hydr. 7, 318).

Temperature, pressure and the activity of hydrogen in the solution determine which ions will be removed from the seawater into the solid phases (Browne, 1978, Ann. Rev. Earth Plan. Sci., 6, 229). The depletion of sodium and only in a few cases of magnesium suggest albitization, zeolitization and minor smectites formation.

THE DOR STRUCTURE AT THE CONTINENTAL SLOPE OF ISRAEL

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The Dor structure is located at the continental slope of Israel NW of Caesarea. The structure extends southeastwards through the continental shelf to the Coastal Plain. A recent geophysical survey of the Dor structure indicates that the structure was shaped by two major tectonic elements:

a) Dextral, NW trending strike-slip faults, that bound the structure from the NE and the SW. These faults displaced the Pelusium Line by some 15 km, the shelf-break faults by some 5 km, and led to the development of brachi-anticlines and brachi-synclines at the margins of the NW trending faults. The northern fault was found to extend towards the northeastern faulted boundary of the Caesarea structure in the Coastal Plain. These faults probably developed during the Miocene and were tectonically rejuvenated since the Pleistocene, although the tectonic intensity decreased recently.

b) Shelf-break faults that separate the structure at the continental slope from its SE extension at the continental shelf. These are gravity faults and are presumably associated with the subsidence of the eastern Mediterranean Basin since the Pliocene. The amount of lateral displacement of these faults indicates that they succeeded the NW trending faults, but since the Plio-Pleistocene they were active simultaneously.

The data indicate further that the Pelusium Line, which is located at the base of the continental slope of Israel in many places, is absent in the Dor structure, although it is dextrally displaced across the structure. These findings indicate that the tectonic stresses that formed the Pelusium Line were released by displacement along the NW trending faults. Thus it is suggested that the NW trending faults and the Pelusium Line originated contemporaneously during the Miocene and are probably related to the Erythrean tectonic phase.

The morphological and structural similarity between the Dor, Palmahim and Gaza structures indicates that the tectonic parameters that shaped the continental slope of Israel since the Miocene are: the NW trending faults crossing the slope, the Pelusium Line compressional structures at the base of the slope, the gravity faults at the shelf-break, and the subsidence of the eastern Mediterranean Basin.

HAR AROD (MAKHTESH RAMON) - AN EXTRUSIVE OR INTRUSIVE BODY?

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The south-western part of Makhtesh Ramon is dominated by a Lower Cretaceous basaltic complex, called Karney Ramon. These are rounded black hills, who's field relations indicate that part of the lower ones are flows. In the area occur also dykes and tuffs. Yet, part of the hills are high, and field relations indicate they possess basaltic "roots", being volcanoes or intrusions. Most prominent is Har Arod, 250 m above its surroundings, with a diameter of 800 m. Har Arod has no central valley or other crater features - it is all built of hard, often prismatic, basalt. Its eastern slope is flanked by tuff. Har Arod is high, relative to the neighboring sandstone (Lower Cretaceous) and carbonates (Cenomanian), that make up the southern rim of the Makhtesh and it seems to protrude into the sandstone. Hence, it can not be a flow. Har Arod might be an intrusive body (of the Devil's Tower type) that was covered by the sandstone. This is mainly based on the absolute absence of crater remains, such as are seen at Karnei Hittin or in erosive sections of single and multi-stage volcanoes in the Golan.

METHOD OF STUDY FOR BETTER UNDERSTANDING THE HYDROLOGY OF DEEP POROUS AQUIFERS ON WHICH THERE IS LITTLE DATA

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To understand the hydrology of deep porous aquifers on which there is little data, a method of investigation was developed and applied to the Nubian Sandstone aquifer in Sinai and the Negev. The hydrological and economic advantages of this method are in its achievement of the following objectives: a) the construction of a hydrogeological model for the basin; b) the explanation of phenomena related to the quality of the water, the history of the recharge of the basin and the processes of flow in the aquifer; and c) the establishment of criteria which make the study more efficient and more economical. The technique of "Main Components" was used as a tool for processing the hydrological data.

In order to attain the above objectives it was necessary to identify groups of observation wells which were related to the parameters set and accordingly processed, to establish the water groups characterized by chemical data and isotopic composition, hence establishing flow patterns. The main results obtained with respect to the Nubian Sandstone aquifer are: a) the construction of a hydrogeological model in which the recharge originates in the intake areas in Sinai and the Negev. The flow within the aquifer becomes more saline from southeast to northwest, as mineralization becomes greater along the same line of flow from the recharge to the outlet area; b) the determination of several chemical groups of water which seem to belong to the cooler climates as well as more recent waters whose quality is related to phenomena of dissolution of rocks, evaporation, salination by the entrapped seawater and/or mixing of waters in various aquifers due to leakage caused by faults and/or changes in facies; c) the use of extended and complete series of parameters from few observation wells is of greater hydrological and economic value than that from a greater number of observation wells whose series of parameters are incomplete. In addition, it is evident in processing the data such as specific yield, depth and thickness of the aquifer bed which drillholes are situated in the area of the principal lines of flow.

The above conclusions show that the use of "Main Components" to develop a method for hydrological research is worthwhile. However, some of the results should be considered with reservation because of the inadequate spatial spread of the data and the large number of presumptions that had to be used.

ON THE OCCURRENCE OF SILICEOUS MICROORGANISMS (RADIOLARIA, DIATOMS, SILICOFLAGELLATES, ETC.) IN THE EOCENE BEDS (ZOR'A FORMATION) OF ISRAEL

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Investigation recently carried out on Eocene samples taken from various locations in Israel (Mazzuva, Bet Guvrin, Tel Azeqa, Tel Hasi) reveal the existence of horizons rich in siliceous microorganisms, particularly Radiolaria, Diatoms, Ebriidians, sponge spines and Silicoflagellates. These horizons were found only in the Zor'a Formation, at the base of the Maresha Member, in the white chalk above the silicecus limestone of the Adulam Member. Of this very diversified assemblage, the following species, which are of stratigraphic importance, are particularly noteworthy:

Pyxilla gracilis	(Diatoms)	Podocyrtis mitra	(Radiolaria)
Melosira architecturalis	"	P. ampla	"
Craspedodiscus oblongus	"	Sethochytris triconiscus	"
Hermiaulus spp.	"	Naviculopsis foliacea	(Silicoflagellates)

Generally, this association denotes a Middle Eocene age (upper part). Together with this assemblage, the above-mentioned chalk horizons contain large numbers of planktonic foraminifers and calcareous nannoplankton, which also indicate a Middle Eocene age. The Radiolaria in Eocene beds in our region have already been noted (Benjamini, 1979; Riedel, 1971; Reiss, 1952, 1954, pers. comm); however, Diatoms, Ebriidians and Silicoflagellates are reported here for the first time. From a global point of view, such findings of Middle Eocene age are still quite rare. Worth mentioning are the outcrops from California, Barbados, New Zealand, and particularly those from the U.S.S.R. (western Siberia, the Ural Mountains and Kazakhstan). Similar horizons were also discovered lately in various oceans, following the deep drillings of the DSDP.

At the present stage of this investigation, the detailed distribution of these horizons in Israel has not yet been studied. A preliminary investigation in the Negev area did not show like horizons there. If it is proved that the stratigraphic distribution of these rich, siliceous microorganism horizons is limited in thickness, we will have an additional important biostratigraphic marker for working out and solving geological problems of the Eocene in Israel.

STRUCTURAL EVOLUTION OF THE SA'AL - ZRARA METAMORPHIC BELT, SOUTH SINAI

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The Sa'al-Zrara metamorphic belt forms the northernmost group of metamorphosed geosynclinal rocks of Late Proterozoic age in Sinai. The belt consists of volcanic, volcaniclastic and sedimentary rocks and forms the approximate northern continuity of the Kid Group geosynclinal rocks which lie about 50 km to the south.

The complex shows a polyphase deformational history which can be divided into at least four phases of folding with metamorphism reaching its peak during the second phase under upper greenschist facies conditions (chloritoid - muscovite assemblages). The first phase of folding (F_1) formed ENE trending isoclinal folds and related penetrative cleavages. The second folding event (F_2) initially formed WSW gently plunging recumbent macrofolds which are only rarely well preserved. With continuous deformation the second phase recumbent folds culminated in thrusting in a NNE direction. The gently south dipping to undulating thrust zone is an extensive chaotic melange of crush powder and breccia, irregular folds and locally a horizontal, mylonitic, paper thin, slaty cleavage. Extensive Fe-metasomatism (hematitization) accompanied thrusting and the up to 20 meter thick zone is well exposed accompanying the Nubian Sandstone unconformity north of the Agramyiah Plane and northwards till the sedimentary cover of the Tih Plateau.

The third (F_3) and fourth (F_4) phases of deformation are represented by a conjugate set of NW (320°) and NE (030°) trending folds and spacially related mega-shears. The deformation here was inhomogeneous and confined to belts (meters to hundreds of meters broad) of ductile deformation (folds) which gave way to brittle deformation, shearing and the formation of major NW and NE trending mylonite belts. The shear belts roughly parallel the axial surfaces of F_3 and F_4 folds, formed during low greenschist facies conditions and manifest both ductile and brittle deformation. Both microbreccias and cataclastic rocks and rocks with a penetrative fabric including stretch lineations forming low grade mylonitic

augen and flaser gneisses from granitic rocks and a new slaty cleavage in pelitic rocks can be seen. The latter are superimposed on, or transpose to various degrees, earlier F_1 and F_2 fabric elements.

The configuration of major lithological units and structural elements on approaching the shear belts indicate dextral movements on the NW set of shears and sinistral on the NE set of shears. The NE set clearly displaces the NW set and is probably somewhat younger.

In the broader context the above, and other, data suggest the following:

1. Major NW and NE trending lineaments on Landsat imagery photographs in south - central Sinai follow Precambrian fold belts and temporarily and spacially related mega-shears containing cataclastic rocks. Deformation preceeded the emplacement of Late Proterozoic calc-alkaline and alkaline plutons, however older granites such as the Akhadr granodiorite appear to have been affected by the shear belts.
2. The bimodal (320° and 020°) trends of the Feiran and Sidry metamorphic belts are their structural grain, and the late NW and NE metamorphic fabric in the metamorphic rocks in the Kid Group may be related to the same major tectonic event(s) and thus similar stress field.
3. Tectonic and intrusive activity along the mega-shears continued, locally, up into the Miocene at which time small grabens and diabases were emplaced into previously established surfaces of weakness. A direct or indirect effect on the orientation of the Suez (and possibly Elat) rift can be rationalized.

STRUCTURAL EVOLUTION OF THE KID GROUP
A MULTIPLY DEFORMED OROGENIC SEQUENCE IN SOUTHEAST SINAI

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The Kid Group in SE Sinai comprises a complex metamorphic sequence of Late Proterozoic age which forms a portion of the northern limit of an extensive chain of volcanic islands, with volcanic, volcaniclastic and sedimentary rocks.

The polyphase deformational events of the Kid Group comprising the orogenic history can be divided into four, possibly five, phases of folding and associated regional metamorphism. The first phase of folding (F_1) formed EW and ENE trending isoclinal micro to macro-folds and related axial planar slaty cleavages. The Heib Formation turbidite sequence and the Tarr Formation metasediments show such first phase structures best. The second folding event (F_2) was the most widespread and the most intense. The F_2 recumbent folds on all scales show shallow north dipping to horizontal axial planes with bimodal fold axes plunging gently NW in the northern and SW in the southern Kid Group. Northwards from the Tarr into the Heib and Umm Zariq Formations, increasing metamorphic grades are accompanied by increasing intensity of deformation culminating in the complete errasure or transposition of first phase fabric into second phase (horizontal) structures. In this area (upper wadis Kid, Malchak, Madsus) S_2 subhorizontal schistosities, B-mineral and intersection lineations, intrafolial recumbent micro and meso-folds are the dominant tectonic manifestations. First phase structures are mainly evidenced in relict isoclinal folds, intersection (S_1/S_2) lineations and as relict internal schistosities in porphyroblasts of alumino-silicates such as garnet, andalusite and staurolite. Porphyroblastesis began during F_1 and extended into F_2 thus demonstrating continuous prograde metamorphism during the first and into the second event.

The second phase, recumbent fold events, culminated in thrusting and the formation of at least five distinct mylonite zones at various stratigraphic levels.

The superposition of rock units of differing metamorphic grades can in part be attributed to the SW-ward movement of late F_2 thrust sheets. The third (F_3) and fourth (F_4) phases of folding resulted in the local deformation of all previous fabric along NNE and E-W trending folds with steep axial planes. A dome and basin morphology is due to these latter events.

The E-W trending Madus-Dakar shear zone which truncates the northern margin of the Kid Group delineates a chaotic metamorphic-structural culmination with granulites and granulitic rocks, primary and secondary mylonites, a tectonic melange and thrusting. Fragmentary evidence suggests a pre-existing continental crust north of the Kid Group and along the western and eastern margins of the Madsus-Dakar shear zone (Amlag gneisses, Dahab migmatites, Elat-Neviot gneisses and shcists). The ultramafic and mafic rocks (Dahab meta-peridotite, Sharira layered meta-gabbros, Madsus greenstones and others) in this tectonic setting along an older basement and geosynclinal succession junction are interpreted as a slice of oceanic crust and hot upper mantle. Emplacement into the lithosphere probably took place during a phase of crustal shortening and orogenesis, along a deep fundamental fault or by a combination of factors such as diapirism and obduction during the collapse and folding of a marginal or inter-arc basin.

The Reaction Between Montmorillonitic Clay and Fatty Acids

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Fatty acids are important petroleum precursors. Fatty acids are converted by decarboxylation into the appropriate hydrocarbons ($R\text{-}CH_2COOH \rightarrow R\text{-}CH_3 + CO_2$). It has been suggested by many investigators that the interactions of clay minerals (especially montmorillonite) with fatty acids play an important role in the formation and primary migration of hydrocarbons in the diagenesis of organic material in argillaceous sediments. In the present investigation the sorption of acetic, lauric and stearic acids (from CCl_4 solutions) was studied by IR and X-ray methods. Two sorbed species were detected in the clay phase — the carboxylic acid (RCOOH) and the carboxylate anion ($RCOO^-$). The absolute amount sorbed by the clay and the ratio of the two sorbed species were found to be dependent both on the exchangeable cation and on the length of chain of the acid. Also, this ratio is affected by the presence of paraffin wax in the solution. It is known that the decarboxylation of the acid proceeds more readily than that of the carboxylate anion, and it is therefore expected that the ratio of the two sorbed species will affect the amount and nature of the hydrocarbons formed in the diagenesis of the argillaceous sediment.

OIL PROSPECTION IN THE DEAD SEA GRABEN
(analysis of past investigations and recommendations for further exploration)

by HAIM SOKOLIN

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The geological structure of the Dead Sea graben, general geological indications and direct signs of oil prospectivity have been analyzed together with the conceptions of past oil exploration and their correspondence to the geological features of the region. The results of the analysis are as follows: 1) Both the geological and geochemical data undoubtedly testify to the great possibility of the presence of commercial hydrocarbon accumulations in the Dead Sea graben. The main accumulations which are the sources of the numerous seeps and shows in the onshore and offshore must be located below the Sdom Salt Fm. under the Dead Sea bottom and southward of the Dead Sea in the Arvat Sdom district. Another favorable zone for oil accumulation is the narrow strip extending along the eastern side of the main fault. However, in this zone only small fields should be expected which are usually sattelites of large accumulations in every basin. 2) Two main conceptions which were put down as the basis of the oil exploration and which did not lead to positive results, do not correspond to the geological features of the region and have not been reviewed for almost 25 years. Actually the oil exploration in the Dead Sea graben in now in its initial stage.

On the basis of the results of this analysis practical recommendations for further exploration have been made.

OCCURRENCE OF SILICEOUS MICROFOSSILS (DIATOMS, SILICOFLAGELLATES AND SPONGE SPICULES) IN THE MISHASH FORMATION, EIN YAHAV AREA.

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Siliceous microfossils were found within the Porcellanite unit of the Mishash Formation, near Gevim High. According to preliminary investigations, their presence is limited to sporadic, thin lenses, interbedded with slightly phosphatic clays. In places, they have been found also within phosphate intraclasts. Preservation is rather poor. Among others, the following forms were recognized:

Triceratium spp. (Diatoms)	Lyramula furcula (Silicoflagellates)
Hemiaulus spp. (")	Sponge spicules.
Coscinodiscus sp. (")	

In spite of the world-wide extension of the Campanian siliceous sediments (cherts), these microfossils were reported very rarely (probably due to strong dissolution processes). Till now, they were found mainly in two regions (Ural and California) sometimes forming diatomites.

In Israel, they have not yet been traced till now in the cherty Mishash Formation. The present record may indicate a biogenic supply of the silica for these cherty rocks.

ON TRIPLE JUNCTIONS AND THE SINAI TRIPLE JUNCTION AS A SPECIAL CASE

A. J. Vroman

The triple junction formed by the radiating branches of the Gulf of Suez, Red Sea and Elat-Dead Sea rift does not follow the usual pattern: the three angles between the three banches are unequal. There is evidence that the Elat-Dead Sea branch has been guided along a dense and narrow system of Precambrian dykes (its southern end seems to be exposed in the Eastern Desert).

THRUST FAULT PHENOMENA IN ISRAEL AND NORTHERN SINAI

by

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The study of geophysical and geological material (gravity maps, seismic lines, some well data and also topographical maps) shows, that the whole territory of Israel and of the Northern Sinai is built by asymmetric folds, which usually end on thrust-faults with, generally, a NE - SW trend. The folds are more or less developed. The thrust-faults usually have a cylindrical form becoming, in depth, less steep. The angle varies from right (90^0) to 40^0 or even 30^0 in depth. The upthrust reaches from a few tens to some hundreds of meters and in the Sinai can reach up to 1000 m or more (Jebel Libni, Jebel Yallak and Jebel Maghara, etc).

The fault lines can be followed for tens of kilometers and are generally parallel. In Northern Sinai the trend is gradually changing into ENE-WSW. The same phenomenon is present on the continental shelf. The whole phenomenom is very similar to the tectonical structures of Algeria, Morocco and Egypt. The folds are probably of Late Senonian - Early Paleocene age and show that at that time there was a tectonic stress, originating in the Mediterranean from a subduction zone south of Cyprus. This led to the formation of asymmetric folds with the steep flank oriented to the SE, overthrusted on an older platform: the fault lines are sometimes displaced by NW - SE normal faults, which seem to be much younger. It is also possible, that these NW - SE faults already existed in older geological time, but were rejuvenated probably in Late Eocene or later, as the thickness of the Saqiye Formation shows.