PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

Mineral Occurrences Related to Stratigraphy and Tectonics in Tertiary Sediments near Umm Lajj, Eastern Red Sea Area, Saudi Arabia [and Dicussion]

P. Dadet, J. Marchesseau, R. Millon, E. Motti and H. M. E. Schurmann

Phil. Trans. R. Soc. Lond. A 1970 **267**, 99-106
doi: 10.1098/rsta.1970.0026

Phil. Trans. Roy. Soc. Lond. A. **267**, 99–106 (1970) [99]
Printed in Great Britain

Mineral occurrences related to stratigraphy and tectonics in Tertiary sediments near Umm Lajj, eastern Red Sea area, Saudi Arabia

By P. Dadet, J. Marchesseau, R. Millon and E. Motti

Bureau de Recherches Géologiques et Minieres, Saudi Arabian Government, Jeddah, Saudi Arabia

Several mineral occurrences of lead, copper and zinc, which were found recently in Tertiary sedimentary rocks on the coastal plain that stretches along the eastern margin of the Red Sea in Saudi Arabia between Umm Lajj and Al Wajh, are shown to be confined to definite stratigraphic levels (beds of arkose, reefoid limestone, and conglomerates). The mineralization is probably controlled by tectonic features trending NNW–SSE, the direction of the Red Sea fault system. These tectonic features can be seen on aeromagnetic maps provided by recent low altitude aerial surveys.

Similar mineral occurrences are known to exist on the opposite or western margin of the Red Sea at Um Gheig in Egypt.

It is suggested that such mineralization took place in connexion with the formation of the Red Sea depression.

Introduction

Lead-zinc deposits have been known for some time in the Miocene sediments on the Egyptian coast along the Red Sea. Seven deposits, the principal one of which is Um Gheig, are found in an alinement between Ras Banas and Al Qusayr, or between 24 and 26° N (figure 1).

In 1968 the Bureau de Recherches Géologiques et Minières, working for the Ministry of Petroleum and Mineral Resources of the Kingdom of Saudi Arabia, found a series of lead, zinc, copper and barite occurrences 50 km north of Umm Lajj in Tertiary sedimentary strata along the Arabian coast. These occurrences are grouped together in a hilly region called Jabal Dhaylan, located at approximately the same parallel as Um Gheig.

Geologic setting

(a) *Precambrian basement*

The Precambrian basement complex is composed of schist and granitic and dioritic rocks. Here, however, the Tertiary tectonics are primarily of interest. The basement is probably broken into step faults toward the Red Sea, but the western side of the basement is segmented into 'piano keys' by NNW–SSE striking faults (Eritrean direction, parallel to the Red Sea). From Yanbu to 28° N, one thus finds a succession of small grabens (Tertiary sedimentary basins) open toward the north and horsts connected on the south to the large body of rock of the basement complex. In the Jabal Dhaylan region, a Precambrian horst is limited on the east by a prominent fault striking NNW–SSE, visible on the aeromagnetic maps. The horst is partially eroded and broken by north–south, NE–SW, and WNW–ESE faults. As a result there is an island of the basement separated from the Precambrian mountains by a basin open to the north.

(*b*) *Oligocene* (?)

In this basin, which was created by movements which are not dated but are before the Miocene, a formation was deposited that contains alternating light to dark arkose and red shale, which shows a continuation of periodic movements during the period of this sedimentation. The arkose is locally conglomeratic at the base and in lenses higher in the section. The facies change vertically and laterally. After the deposition of this unit, new movements rocked it toward the east. There was local folding in the eastern part of the basin and doubtless this formation was cut into fault segments at the same time as the basement horst. The general strike of the bedding is NNW–SSE, and the average dip is 20° ENE. The thickness of this formation, which disappears to the east under the more recent formations and the colluvium, is not known. It is also not known if it extends west of the horst.

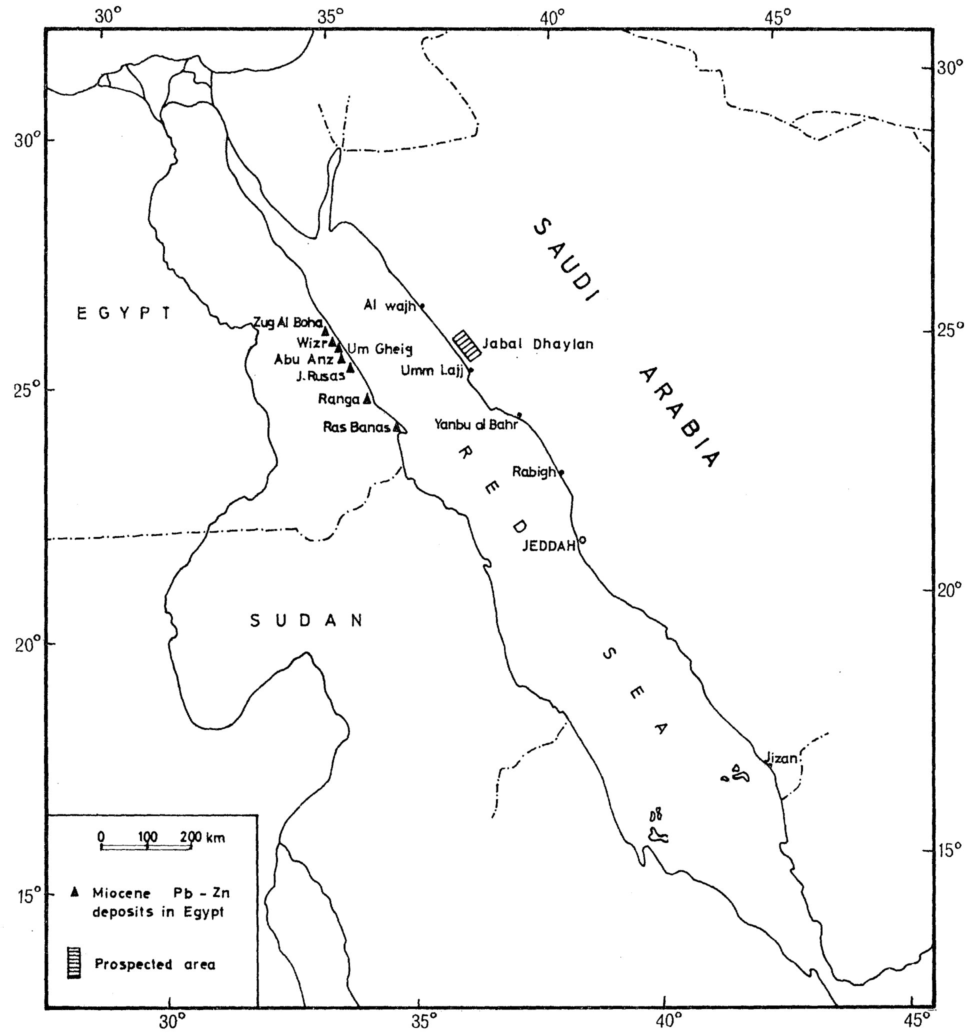

FIGURE 1

(*c*) *Miocene*

Formations dated as Miocene on the basis of faunal evidence were deposited on the basement or in angular discordance with the Oligocene. At the time of the deposit the paleogeography closely controlled the facies:

(1) Reefoid and subreefoid limestone (sandy or shelly) along the east coast of the basement island, with alternation or replacement by greenish gypsiferous marl according to the locales and the eustatic changes. The thickness is quite variable, and does not exceed 40 m.

(2) Behind this shoreline, marl is the dominant rock type. It is overlain by the following sequence: locally conglomeratic beige sandstone, red shale, beige sandstone, and conglomerate. Thus there is a filling of the basin by terrigenous sediments in regressive order, which

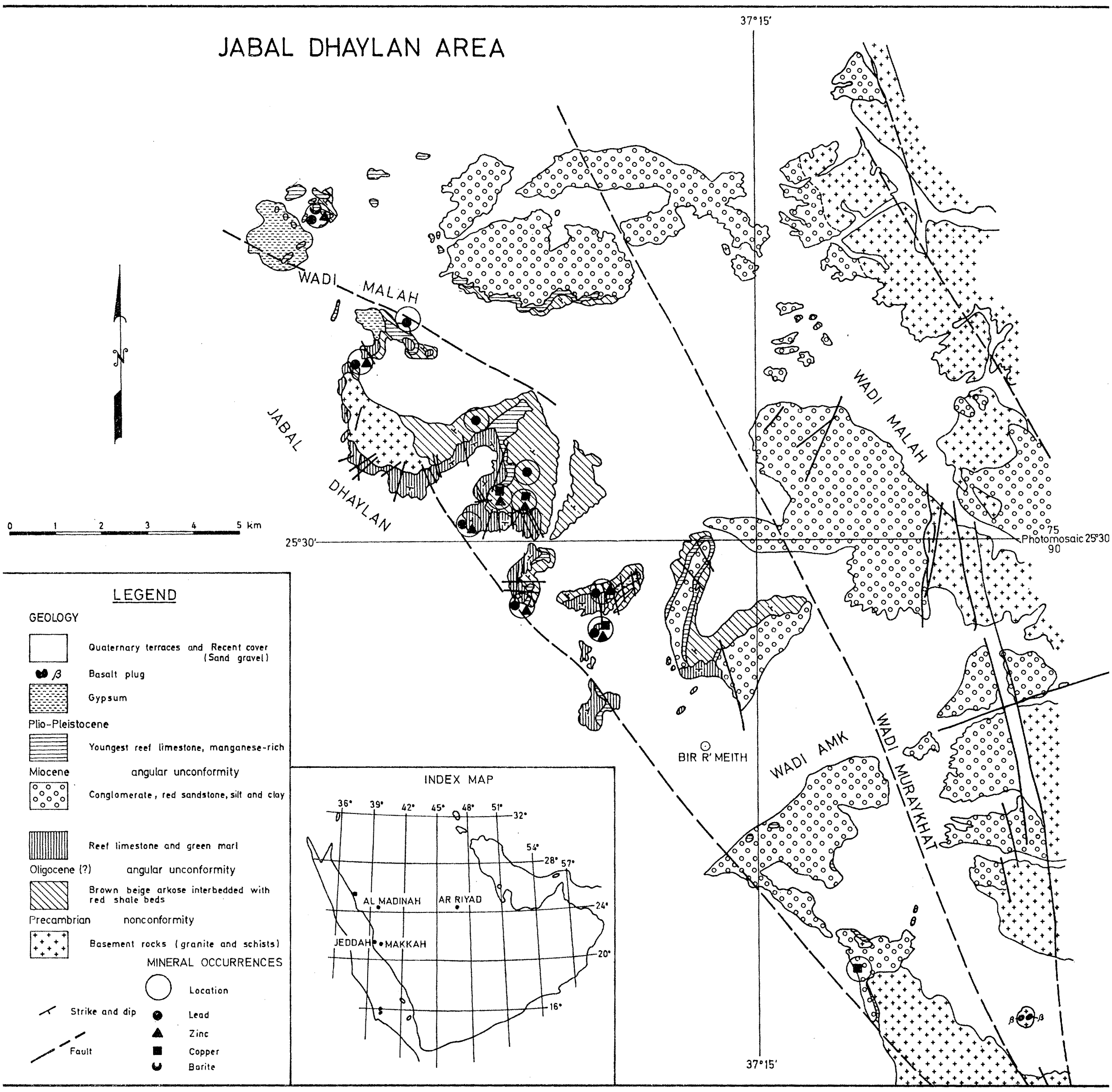

FIGURE 2

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

demonstrates an accentuation of the tectonic movements until the period of emergence. The series above the marl can attain some 20 m in thickness.

The Miocene formations are essentially horizontal.

(*d*) *Pliocene–Pleistocene*

A new reef became established to the west along the shoreline which included the island of basement rocks and the preceding formations. The morphology of the shore is reminiscent of the present coast with its 'sharm'. The courses of the wadis have varied but little since, apart from probable changes in the mouths of the wadis. Thus the point of debouchment of Wadi Malah has doubtless migrated north.

Thus one observes a reef cap, locally detrital or shelly, with horizons of shale following the outlines of the paleorelief. The phenomena of creeping and recementation accentuate the dip of these reef caps toward the former sea. This limestone is somewhat altered, which gives it a scoriaceous aspect, and is indurated at the surface and along the fractures. It is often rich in manganese, which might result from the leaching of the volcanic formations which were being formed in the interior at this time.

Positive movements of the sea shore caused small salt-water pools to separate from the sea. Gypsum was deposited in these pools, mainly near the mouths of the wadis.

(*e*) *Quaternary*

The following considerations are based on geomorphological features of the gravel fans north of Jabal Dhaylan and the terraces of Wadi Hamd, Wadi Malah, and, chiefly, Wadi Amk. Eustatic data alone cannot explain the evolution of the region between the basement and the sea. Meanwhile the disemboweled Jabal Karkuma (a hill located outside the limits of figure 2, more to the northwest, 50 km from Jabal Dhaylan) represents a diapir structure whose piercement took place toward the end of the Pliocene, continued during the Pleistocene, and probably into the Middle Quaternary.

Since the end of the Tertiary, the zone of gravel fans and the plain to the west of the presently emerged basement had evolved roughly as two subsiding segments, with a limit or boundary near the north bank of the present Wadi Malah. These segments were subdivided into numerous small horsts and 'grabens', in a context of general subsidence. A reworked Quaternary conglomerate may be found locally.

The faulting was dominantly along east–west directions, with some faults striking NW–SE.

At the end of the Pliocene and in the Pleistocene, subsidence stopped in the northern compartment and some positive movements took place. The piercement fold of Jabal Karkuma occurred at this time.

Negative movements in the southern compartments stopped in the Middle Quaternary, but continued for a time in the northern part of this compartment.

Quaternary volcanic activity is evidenced in the vicinity only by two small basalt plugs in the basement to the southeast. Farther south, small flows reach the sea shore.

Geophysics

The magnetic map shown in figure 3 portrays the major tectonic features in the area. Figure 3 respresents a square degree around Jabal Dhaylan. The main features are:

(1) In the southeastern corner of the map, a large area with a strong magnetic relief. This corresponds to the basalt flow at Al Ays (a small village located outside the limits of map 3, near its southeastern corner).

(2) Just a bit under the centre of the map, a large magnetic anomaly that correlates with ultrabasic rocks.

(3) Linear magnetic features are also quite visible. Most of them trend NNW–SSE and

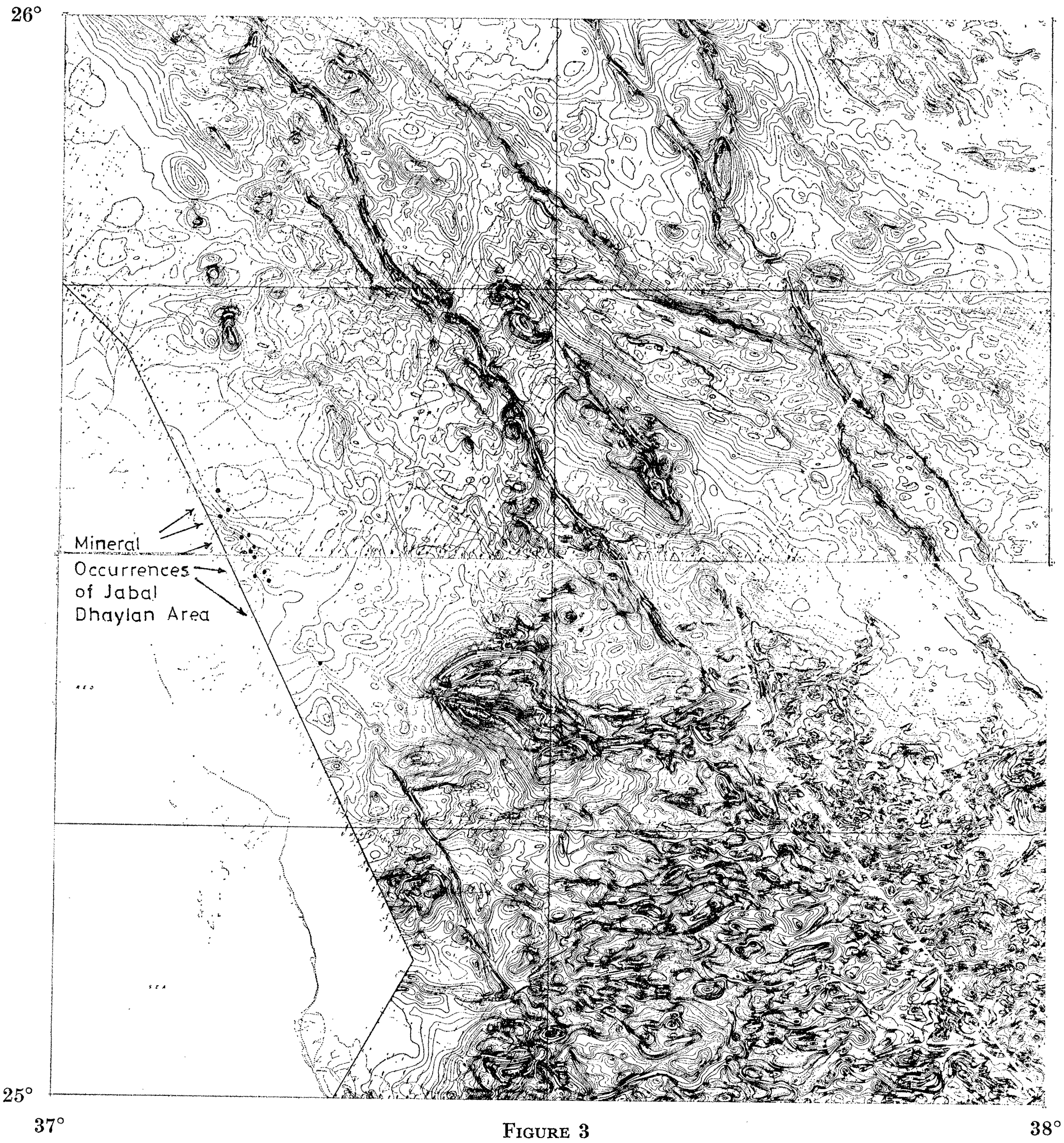

Figure 3
Scale 1/700 000

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

belong to the Red Sea rift system. However, in the northeastern corner of the map, north-south and WNW–ESE trends are apparent. The latter direction corresponds to the trend of the Najd fault system, at the place where it intersects the Red Sea rift system.

These linear magnetic anomalies are very probably caused by a magnetic material (basalt, andesite) injected in recent faults of the Red Sea system.

The Tertiary basin is limited on the east by a fault of the Red Sea rift system and on the north by another fault trending WNW–ESE. Both are visible on the magnetic map because of the magnetic contrast between Precambrian and Recent rocks.

We reported on the magnetic map the mineral occurrences (copper, lead and zinc) found in the Tertiary basis of Jabal Dhaylan. They line up exactly on the northern extension of a fault of the Red Sea rift system. Of course, this fault is more evident on the magnetic map in areas where the basement crops out (that is, to the south). On the other hand, the magnetic material in the sedimentary basin is deeper and the magnetic anomaly is less visible. This can be explained by the difference in the altitude of the surveying plane above the basement.

The sedimentary basin is well portrayed on the magnetic map. In actual fact, the sediments are not magnetic. The Precambrian basement is deep (except for the horst of Jabal Dhaylan) and, therefore, gives magnetic anomalies that can be characterized as slight in intensity and wide in configuration.

Mineralization

The occurrences of copper, lead zinc and barium discovered at Jabal Dhaylan can be classified into four types on the basis of their geologic context.

Type 1 occurs in the Oligocene arkose. It is involved in the impregnation and replacement of cementing material of the arkose, which naturally was not very coherent and resulted in the deposition of cerussite or chrysocolla, with some smithsonite and hydrozincite in each case. The mineralized zones occur in hazy or indistinct patches with dimensions from several centimetres up to some 20 m in the normal or conglomeratic arkose. The occurrences are almost all found on two NNW–SSE lines lying 1.0 and 1.8 km east of the large fault shown by geophysics. This is also the direction of strike of the arkose. The values as well as the dimensions of the occurrences are very low.

Type 2 occurs in channels with a calcareous-detrital filling incised in the green shale and forming part of the subreefoid facies (Miocene and Pliocene–Pleistocene) in the zones of alluvial debouchments (Wadi Malah, for example). However, fracture control seems to be added to facies control. One finds oxidized minerals of lead and zinc (cerussite, smithsonite, hydrozincite), nodules of galena, and thin discontinuous horizons of concretionary barite.

Type 3. The third type occurs in the reefoid limestone of Pliocene–Pleistocene age as an extensive impregnation of the limestone by oxidized minerals of zinc (smithsonite and well crystallized calamine geodes), galena in fissures, and caps of oxidized lead and zinc minerals with massive galena and manganese oxides. These gossans are localized along the fractures, particularly those with a NNW–SSE orientation. The occurrences are approximately alined in a NNW–SSE direction slightly east of the principal deep fault which has the same strike, which itself is marked by fractures containing iron oxide. The analyses show a clear predominance of zinc over lead, the oxide caps assaying more than 36 % zinc, 10 % lead, and 0.02 % silver. These could be reconcentrations in cracks or fissures and in highly receptive limestone, from a subjacent Type 2 mineralization.

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

Type 4 occurs in a reworked Quaternary conglomerate, with lentils of chrysocolla in the cement. This is the southernmost occurrence. It is not as large as the others but is also found a short distance east of the main deep fault striking NNW–SSE. It at least indicates the persistence as far as the Quaternary of the processes of mineralization.

Conclusions

At Um Gheig (Shazly, Mansour, Afia & Ghobrial 1959; Herbst, Bauer & Muller 1965) the stratigraphic series of Middle Miocene age contains, from the bottom to top: a basal conglomerate lying on the Precambrian basement shale with lenses of sandstone and conglomeratic sandstone with calcareous cementing material, mineralized and more or less conglomeratic limegrits, gypsum, and bituminous limestone. The locally conglomeratic limegrits, gently folded and faulted, contain lentils aligned along a NNW–SSE direction, impregnated with sphalerite with encrustations and nodules of galena, all of which is widely oxidized at the surface.

At Jabal Dhaylan, only the calcareous–detrital subreefoid facies of the wadi debouchments bears any resemblance to the lower part of the Um Gheig series. This facies is less frequent than at Um Gheig and not extensive. One also finds Type 2 occurrences in this facies.

On the two sides of the Red Sea, the occurrences—even the mineralized bodies themselves—are alined along the above-mentioned Eritrean direction of NNW–SSE, which is the direction of the great fractures which created the depression. At Jabal Dhaylan the occurrences are rather closely alined along one of the large fractures, which was revealed by the aeromagnetic prospecting by an anomaly probably due to the presence at depth of a magnetic material (basic lava?) in this fault.

Recently numerous authors took interest in the pools of hot acidic brines in the deepest part of the Red Sea and in the mineralized sediments under those brines.

In 1968 Kanasewich, summarizing the work of these authors, stated: 'The pools appear to be large natural chemical laboratories in which metals that have migrated from the upper mantle, through faults, are concentrated and precipitated, from colloidal suspension, on the sea floor.' The terrigenous deposits are very poorly represented in these deep, essentially pelagic sediments (Nesteroff 1959).

It seems possible that a process similar to the one described above for the Red Sea (and in other seas as well; the Salton Sea, for example) is the origin of the mineralization in the Tertiary sediments. The deposition of metals through the faults of the Red Sea system seems to be verified by the recent veins of barite in the basement at Rabigh and the barite-galena found in the basement rocks and in the Tertiary north of Yanbu, or in the Tertiary itself (Jabal Tayran, near the Gulf of Aqaba).

However, the Tertiary sediments are essentially terrigenous, and the great NNW–SSE fault could have exercised a purely morphologic intervention in creating the basin separated from the sea by the Jabal Dhaylan horst. In this basin, against the internal talus of the horst, a stratiform deposit of lead and zinc could have formed, as is known in Tunisia, for example. But although deposits of copper, lead, and zinc exist in Egypt in the Precambrian basement complex (Um Samiuki, for example), rather near occurrences in the Miocene, and which could be the primary source of the latter, nothing of note is known in the vicinity of Jabal Dhaylan. With the NNW–SSE and other fractures having undergone additional movement following the deposit and as late as Recent times, these fractures or faults may have served as a drain to displace and reconcentrate the elements in these deposits.

The research now in progress may define the role of the fractures responsible for the depression of the Red Sea in the genesis of these deposits, and have an important bearing on this type of research in general. One can at any rate already assert that the combination of these faults with certain sediments and their environments constitutes a favourable locale for the discovery of mineralization in this area.

References (Dadet *et al.*)

Brewer, P. G., Riley, J. P. & Culkin, F. 1965 *Nature, Lond.* **206**, 1345.
Brewer, P. G., Riley, J. P. & Culkin, F. 1965 *Deep Sea Res.* **12**, 497.
Craig, H. 1966 *Science, N.Y.* **154**, 1544.
El Shazly, E. M., Mansour, A. O., Afia, M. S. & Ghobrial, M. G. 1959 *Int. Geol. Congr. 20th Session, Mexico* 1956: §**13**, 119, Mexico, 1959.
El Shazly, E. M. & Hassan, A. K. 1962 *Report on the results of drilling at Um Gheig mine*, Eastern Desert-Gen. Organ. for Gov. Print. Offices, Cairo, 1962.
Guilcher, A. 1954 *Inf. géogr.* **18**, 56.
Herbst, F., Bauer, G. & Muller, G. H. 1965 *Z. Erzbergb. MetallhüttWes.* **28**, H, 9, 463.
Hunt, J. M., Hayes, E. E., Degens, E. T. & Ross, D. A. 1967 *Science, N.Y.* **156**, 514.
Kanasewich, E. R. 1968 *Science, N.Y.* **161**, 1002.
Marchesseau, J. J. 1969 Bureau de Recherches Geologiques et Minieres, *Jabal Dhaylan*, Report in progress.
Miller, A. R., Densmore, C. D., Degens, E. T., Hathaway, J. C., Manheim, F. T., McParlin, P. P., Pockington, R. & Jokela, A. 1966 *Geochim. cosmochim. Acta* **30**, 341.
Nesteroff, W. D. 1955 *Deep Sea Res.* **2**, 274.
Reh, H. 1965 *Z. angew. Geol.*, II, H. II, 608.
Riley, J. P. 1967 *Oceanogr. mar. Biol.* **5**, 141.
Ross, D. A. & Hunt, J. M. 1967 *Nature, Lond.* **313**, 687.
Russell, M. J. 1968 *Min. Metall.* B **117**.
Swallow, J. C. & Crease, J. 1965 *Nature, Lond.* **205**, 165.
Swartz, D. H. & Arden, D. D., 1960 *Bull. Am. Ass. Petrol. Geol.* **44**, 1621.
Westoll, T. S. 1965 *Phil. Trans. Roy. Soc. Lond.* A **258**, 12.

Discussion

H. M. E. Schürmann (*The Hague*). In connexion with the galena occurrences in the eastern Red Sea area, Saudia Arabia, it is suggested that isotopic age determinations be obtained to compare the lead occurrences with those of the Egyptian side of the Red Sea.