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

Review of Structural Geology of the Red Sea and Surrounding Areas [and Discussion]

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Review of structural geology of the Red Sea and surrounding areas

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The Red Sea structure as well as the appurtenant Dead Sea structure originated at the end of the Precambrian, as shown by many established observations. Their latest, Neogene phases of evolution have often too exclusively been considered to explain the present-day layout.

Many peculiar field features, which are cited as evidence for a northward drift of the Arabian peninsula (relative to Palestine and Sinai), may as well be explained by vertical movements. A 107 km northward drift of the Arabian peninsula, of which 40 km was in Pleistocene times, as asserted by Quennell and Freund, is not confirmed by recent surveys in the Dead Sea area and is inconsistent with the stratigraphy and the structure of Lebanon and Syria: therefore it should not be taken as geologically definitely proven and as leading to conclusions as to the Red Sea.

1. The Red Sea problem

Over 2000 km long the Red Sea cuts in a NNW to SSE direction across a Precambrian shield. In the north, it bifurcates into the Gulfs of Suez and Aqaba, defining thus the Sinai peninsula. In the south it connects through the Bab el Mandab Straits with the Gulf of Aden. Although the pattern of the Afar is quite peculiar, this area can be compared with the northern end of the Red Sea: some parts of the Afar, such as the Danakil Alps, are in certain respects similar to the Sinai peninsula.

In Precambrian times Africa, Sinai, Arabian peninsula and Afar built one single shield. The history of its dislocation starts in the late Precambrian, and is still going on.

The Red Sea problem can thus be summarized as follows: how did the original shield dislocate, and during which periods? Which deformations or relative movements were involved in the progressive dislocation, and of what magnitude? The first step towards an answer to these questions would be to determine the original fit of the various tectonic units resulting from the dislocation. It depends largely on the extension of Basement rocks underneath the Red Sea and Gulf of Suez bottoms and under the lavas of the Afar. One might question further the causes of the dislocation.

An attempt is made to give an account of the structural evolution of the Red Sea, as far as known to date.

2. The Red Sea

From 175 km width in the vicinity of the Sinai peninsula, the Red Sea widens to 350 km between Massawa and Jizan, then narrows to 30 to 40 km in the Straits of Bab al Mandab.

Cross-sections (Drake & Girdler 1964) show *marginal shelves*, narrow in the northern part, which become very extensive south of 20° N. A *main shallow trough* is distinctly demarcated by the steep edges of the shelves; its depth is from 600 to 1000 m. In its axial zone opens another trough, narrow and deep, reaching 2000 m in depth, the so-called *central fracture zone*.

The *margins of the African and Arabian Precambrian shields* have undergone a marked uplift; on the African side, the Basement reaches 1500 to 2000 m elevation in proximity of the Red

Sea shore, while at 100 to 150 km inland it averages 1000 m or less; on the Arabian side the uplift is even more pronounced, the basement reaching 2000 to 3000 m elevation against 1500 m at 100 to 150 km inland (Dubertret 1969).

Pre-Miocene marine sediments are scarce and scattered in the Red Sea basin proper, which makes the pre-Miocene structural evolution difficult to establish. Upper Cretacous occurs in the Qusair area (Heybroek 1965); uppermost Cretaceous has been drilled through on Maghersum Island, north of Port Sudan, latitude 20° 25′ (Carella & Scarpa 1962); Maestrichtian outcrops have been described north and east of Jiddah (Karpoff 1957*a*).

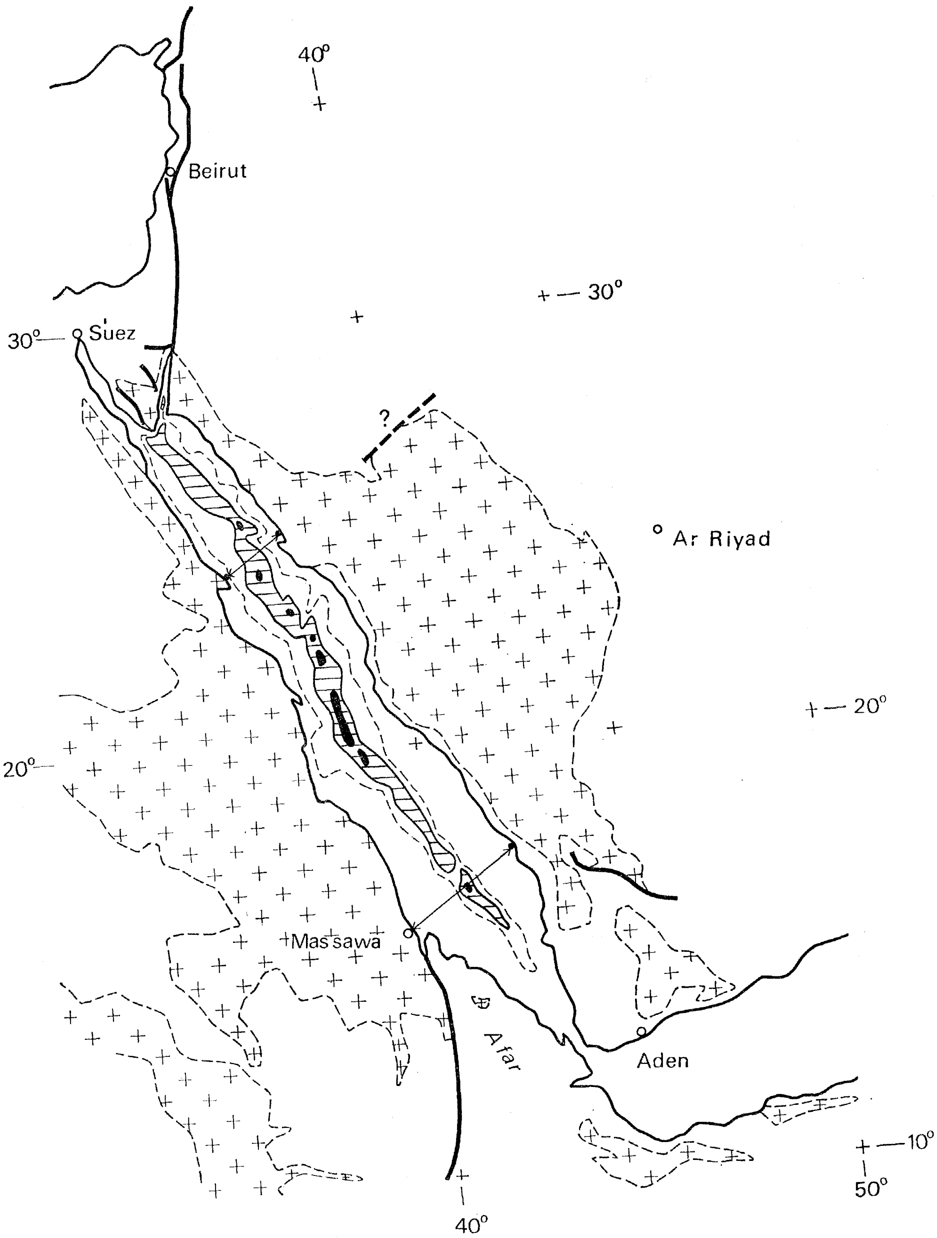

FIGURE 1. The Red Sea cutting through the Precambrian shield (crosses); the Gulf of Suez; the Gulf of Aqaba–Dead Sea fault and its northern extension. Central trough of the Red Sea: 1000 m isobath, and in black, depths of more than 2000 m.

Upper Cretaceous–Lower Eocene are known along the Egyptian Red Sea coast as far south as Quseir and beyond to 26° latitude north. As described by El-Sayed El-Tarabili (1966), these sediments were separated from the equivalent sediments of the Eastern Desert by a swell of basement rocks, which in Miocene accentuated into a 'Red Sea horst'.

Marine Miocene with Mediterranean fauna is recorded in the Red Sea from the Gulf of Suez as far south as 15° N, up to several thousand metres thick, composed mainly of evaporites. Marine Pliocene, with Indo-Western Pacific fauna, extended as far north as Ismailia, in the Suez canal area.

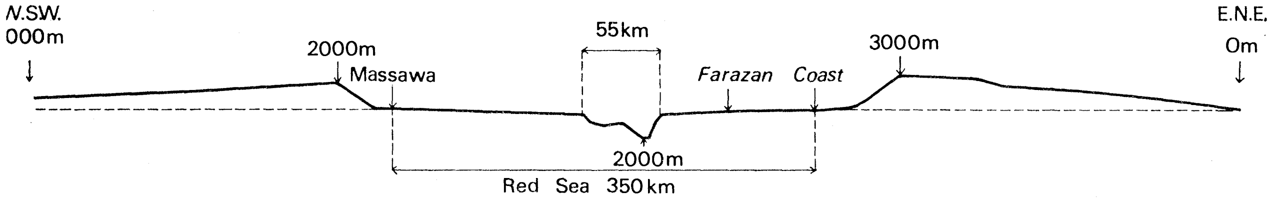

FIGURE 2. Orographic profile across the southern Red Sea, showing the uplift of the adjacent margins of the African and Arabian Precambrian shields.

The Red Sea is thus considered to be of Miocene and later age, and its Neogene history is summarized as follows (Heybroek 1965). Foundering from the Oligocene–Lower Miocene on, resulted in a Middle Miocene ingression of the Mediterranean into the Clysmic Gulf (Gulf of Suez) and Red Sea area, to approximately the southern end of the Red Sea. The gulf with Mediterranean water and Mediterranean fauna was separated from the Gulf of Aden by a land barrier. In late Miocene to early Pliocene, another swell rose in the Clysmic Gulf area and closed off the Red Sea from the Mediterranean. Then, in the Pliocene, the south barrier dropped down and Indian oceans waters invaded the Red Sea; they extended as far north as Ismailia, but did not connect with the Mediterranean. Faulting probably continued into the Pleistocene.

The Miocene and Pliocene ingressions into the Red Sea represent only the latest phases of the history of the Red Sea. The existence of the recently discovered earlier marine deposits has not yet been integrated in it, although suggestion of a Cretacous origin of the Red Sea has been made (Karpoff 1957*b*). And even in considering earlier phases of evolution, this account would remain incomplete, as no satisfactory explanation is given of the axial fracture zone, which makes of the Red Sea an exceptional type of structure, quite different from a classical rift.

The pronounced uplift of the edges of the margins of the African and Arabian Precambrian shields, as described above, would seem to have as complement the existence of the down-faulted former edges of these shields, now buried under the sediments of the Red Sea trough. Geophysical studies have led to the conclusion that the shelves and part of the main trough of the Red Sea are underlain by crystalline basement rocks (Drake & Girdler 1964), while the axial fracture zone should be underlain and injected by intrusions of basaltic composition. More recently, the precise extension of this buried basement rock has been queried, the question has been put forward if they may not be restricted to narrow strips along the banks of the Red Sea. One might ask too if the central and specially the axial troughs of the Red Sea are not due to a very recent evolution.

An answer to these questions may be sought in the neighbouring areas, in particular at the northern and southern ends of the Red Sea, where the Precambrian basement dips underneath and/or is covered with, marine sediments, ranging from Cambrian to Recent, of which the development enables us to recognize and date the tectonic events.

3. The area north of the Red Sea

The surface geology of this area has been investigated for a long time by numerous geologists; detailed mapping has been done in the near past. Oil exploration allowed drillings and geophysical prospection in the Gulf of Suez as well as in the Gulf of Aqaba–Dead Sea structure. The following remarks are based essentially on Heybroek (1965), Schürmann (1966) and Bender's (1968*a*, *b*) recent publications.

4. The Precambrian shield

This crops out in the Red Sea Hills and Eastern Desert, along the western shore of the Red Sea, in the southern part of the Sinai peninsula, and along the eastern edge of the Aqaba–Dead Sea structure, then farther south, in a much larger area, in Saudi Arabia.

Detailed survey in the Red Sea Hills led to a division of the Precambrian rocks into a succession of series, on the basis of lithological contrasts, of unconformities, of the presence of conglomerates or dispersed pebbles. Correlations have been established with equivalent series in the Sinai peninsula and in Arabia.

The latest or uppermost of the Precambrian series, the Hammamat series of the Quseir-Qena road, or Saramuj conglomerates of Jordan, a detrital series, rests on a major erosion surface cutting through the older Precambrian series, and is itself overlain by transgressive Palaeozoic sandstones of Nubian facies. To the southeast of the Dead Sea, at the foot of the Jordan plateau, Upper Lower Cambrian to Lower Middle Cambrian limestones with Trilobites are interbedded in the base of the sandstones. The Saramuj conglomerates may thus reach into the Lower Cambrian.

An attempt has been made to determine the absolute ages of the successive Precambrian series. But while evidently these cover a large span of time, the isotopic ages of the rocks collected in the Red Sea Hills and in the Gulf of Suez area were uniformly close to 550 Ma; on the other hand, isotopic ages up to 1000 Ma have been established for equivalent rocks of the Arabian shield. It appears thus that the rocks of the Red Sea area have undergone a rejuvenation in the early Cambrian. This rejuvenation, as located in the field, is considered as 'related with the start of the huge East African and Red Sea fracture pattern, which lasted until recent times' (Schürmann 1966, p. 217).

Intensive magmatic activity, the injection of a very dense system of acidic to basic dykes in the Precambrian basement, including the Hammamat series or Saramuj conglomerates, in the areas of the Gulf of Suez and the Gulf of Aqaba, would have accompanied this start of the fault pattern, i.e. of the Red Sea and of the Gulf of Aqaba–Dead Sea fracture zones or geosutures.

The contrast in development of late Precambrian to early Cambrian detritals in the West and East Jordan blocks confirms the existence of a contrast in relief, i.e. of a high position of the east Jordan block (Bender 1968, p. 183).

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5. The Gulf of Suez rift

In sharp contrast with the Red Sea, and even sharper with the Gulf of Aqaba, the Gulf of Suez is a shallow water basin. On both sides it is bounded by elongated Miocene depressions, which extend along the foot of the fault bounded ranges of Egypt and Sinai. The term of 'Clysmic Gulf' has been proposed by Hume (1921) for the whole of the Gulf of Suez and the adjacent Miocene depressions.

Cross-sections of the Clysmic Gulf show, throughout its width, the presence of downfaulted crystalline basement rocks, overlain by sandstone of Nubian facies, Cretaceous, Eocene, then Miocene and Pliocene.

The distribution of facies and shorelines has for many years led to the conclusion that as early as Palaeozoic and Mesozoic times the Clysmic Gulf formed a zone of continuous, quiet, subsidence, where marine Carboniferous, Permian and Jurassic were deposited within the sandstones of Nubian facies (Schürmann 1942). A depression approximately coinciding with the Gulf of Suez existed at least as early as the Carboniferous (Beets 1948). However, the point at which faulting brought the main graben into existence is post-Eocene: it was formed at the end of the Oligocene and/or Lower Miocene times (Heybroek 1965).

Heybroek mentions that 'the faults observed in the Clysmic gulf are all normal faults; there is *no single observation which might point to compressional or lateral movements*'. As described, the Clysmic Gulf appears as a classical type of rift, with downfaulted blocks throughout its width, which differentiates it from the Red Sea.

6. The Gulf of Aqaba–Dead Sea trough and its northward extension

This structure is of a type in which *one main fault* is responsible for the main structural layout, a kind of *fissure* in the Earth crust. From the entrance of the Gulf of Aqaba it extends northward over 1100 km, to the foot of the Taurus ranges. Along certain sections the main fault splits into two or more secondary faults; then horst and graben structures may appear, but these are not continuous.

Concordant statements assign to the fissure a very old origin:

Dubertret (1956, p. 382), refers to the extremely dense system of basic, intermediate and acid dykes in the Basement in the proximity of Aqaba:

'Le sillon de la mer Morte sépare deux régions de caractères structuraux fort différents. A l'W, la Cis-Jordanie est basse, voûtée, plissée, faillée; la Transjordanie à l'E est un plateau élevé, peu accidenté.'

'Il est clair qu'entre la Cis-Jordanie et la Transjordanie existe un rejet vertical, ce semble être là la véritable signification de la cassure (faille simple ou faisceau de failles) du sillon de la mer Morte... .'

'L'injection du granite rose' (du socle précambrien)' presque banc par banc évoque une image bien différente de celle d'un volcanisme banal. Elle fait songer à un évènement tectonique important, et pour préciser, à la répercussion de mouvements verticaux, avec déplacement du magma basique, comme suite à l'apparition de la grande cassure du golfe d'Akaba, du sillon de la mer Morte et de son prolongement jusqu'au Taurus.'

'*Cette cassure serait antécambrienne.*'

Bentor (1961, p. 345) wrote: 'Until the end of Mesozoic times the regions of the present Jordan–Araba "graben" was part of the mountain area of Palestine, but separated from the Transjordan block in the east by the *very old geosuture*, now forming the eastern border-fault of the rift. The Jordan–Araba "graben" came into existence during the earlier Tertiary, probably in Oligocene times, through tensional movements which pushed the Transjordan block eastward and led to a downbreak of the western border of the graben along a complicated system of faults.'

Bender (1968*b*, p. 178), after a detailed geological survey of Jordan wrote:

'The disposition of the Precambrian structural pattern and of parts of the Precambrian joint and dyke system, as well as the morphology of the surface of the Precambrian basement complex, suggest the existence of a geosuture (zone of weakness, hinge line) which, already in the Precambrian, followed the meridional zone of the present graben.'

The northern extension of the fissure or fracture system, in particular its main branch, the Yammouneh fault on the eastern flank of the Lebanon is at least of Jurassic origin, as in central Lebanon numerous secondary faults are injected with Upper Jurassic basalts (Dubertret 1947, p. 12).

Along the edge of the Jordan plateau, from Aqaba to the north, the Precambrian basement plunges gradually, and disappears at the southeastern end of the Dead Sea, covered by sandstones of Nubian facies. In these interfinger successively limestone of Cambrian, Triassic and Jurassic ages. Lower Cretaceous sandstones of the same facies, transgress over the older sandstones; they are overlain by Upper Cretaceous and Paleogene limestones and marls.

The edges of the interbedded Cambrian, Triassic and Jurassic limestones, formerly considered as shore-lines, have long attracted attention (Blake 1937) as they reach farther south on the Sinai–Palestine side than on the Jordan side (see figure 3*a*).

Bender (1968, p. 178) explains: 'The facies borders reveal the existence of an elevated 'Transjordan block' in the east of the southern (Wadi Araba) part of the hinge line, opposite a structurally deeper 'Palestine block'. These differences in elevation would explain the S shape of the Cambrian, Triassic and Jurassic 'shorelines' (figure 3*a*).

This difference in elevation would again be responsible for the sharp contrast of the pattern of the isopach map of the 'Judea limestone' (Cenomanian to Campanian) on either side of the geosuture (Wetzel & Morton 1959) (figure 3*b*).

Severe faulting and rifting of the Dead Sea trough started, as in the Gulf of Suez, in Oligocene times (Bentor 1961; Bender 1968), and continued until the Pleistocene.

In Lebanon and Syria, the structural evolution can be established only from the Jurassic onwards, as older sediments do not outcrop. An Upper Jurassic orogenic (epeirogenic) phase entailed emersion and erosion of part of the region (Hermon), faulting, basaltic volcanism, and injection of the faults by basalts. The area was uniformly covered by the Cenomanian transgression. The present-day massifs developed from the end of the Cenomanian on; they were well individualized in Eocene times, as is shown by the facies distribution (chalky marls and limestones). In Vindobonian times they had reached nearly their present-day vigour; from then on, large masses of conglomerates were deposited in the neighbouring depressions. Basaltic volcanism started in Miocene times, reached its maximum in the early Pliocene and continued until Pleistocene and Recent.

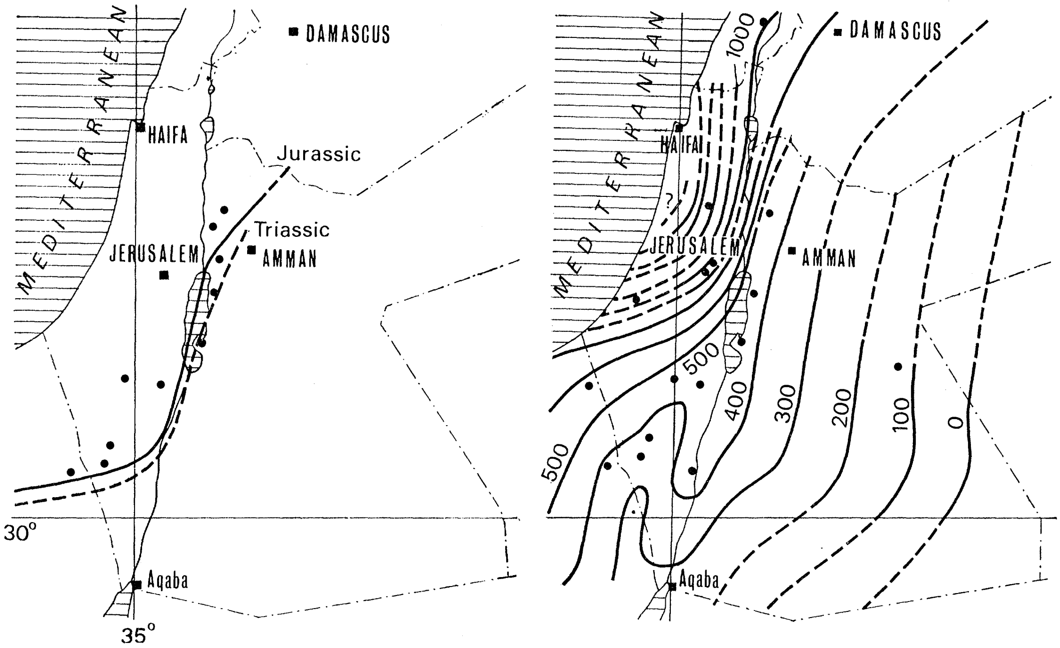

FIGURE 3. (*a*) Triassic and Jurassic 'shorelines' in the Dead Sea area. (*b*) Isopachs of the Judea limestone (Cenomanian to Campanian) in Jordan and Palestine: their pattern on either side of the Dead Sea trough is in sharp contrast. According to Wetzel & Morton (1959).

7. The southern end of the Red Sea structures

The consequential effects of the tectonic evolution of the Red Sea and Gulf of Aqaba–Dead Sea structure on the stratigraphic development of the Palaeozoic to Recent sediments of the northern Red Sea area should be reflected as well in the sediments of the southern area. But, owing to an old uplift the stratigraphic sequence is there incomplete, the Upper Jurassic Amran series being the only marine sediments which extend from Erytrea over Afar to the Yemen.

This series is probably not known at present in enough detail to allow the tectonic evolution to be checked. It must be remembered that the southern area is not as easy to explore as the northern. Anyhow, the problem has to be set (see Azzaroli 1968).

8. The drifting theory

Attempts have been made to explain the present-day structural layout by continental drift: Africa away from the Arabian peninsula, or the Arabian peninsula away from Africa. A figure of 1 to 2 cm a^{-1} has even been given for a drift of the Arabian peninsula towards the north in Pleistocene times.

The identical shapes of the two opposite shorelines of the Red Sea are indeed suggestive of a drift away from an original position in which Africa and the Arabian peninsula fitted together as one large shield unit.

Continental drift has been considered and discussed in many parts of the world, but nowhere is there such opportunity of checking it by the actual geology, as in the Red Sea area. If the Arabian peninsula has drifted towards the north, there should be consequential effects on its northern and northeastern margins which are contiguous with Turkey and Iran, and as well along the Gulf of Aqaba–Dead Sea fault and its northern extension.

In any theory of drifting there are two main features to determine: the magnitude of the drift, and the time. Certain authors who recognize drift did not mention its age.

The first suggestion of drift in the Red Sea area is by Lartet (1869): 'L'explication de la formation de la mer Rouge par une fracture de l'écorce terrestre, origine que Dolomieu avait pressentie, est mise en évidence par les contours des deux rivages opposés de ce golfe, qui se correspondent obliquement, ainsi que les deux lèvres d'une déchirure. En effet, si par la pensée

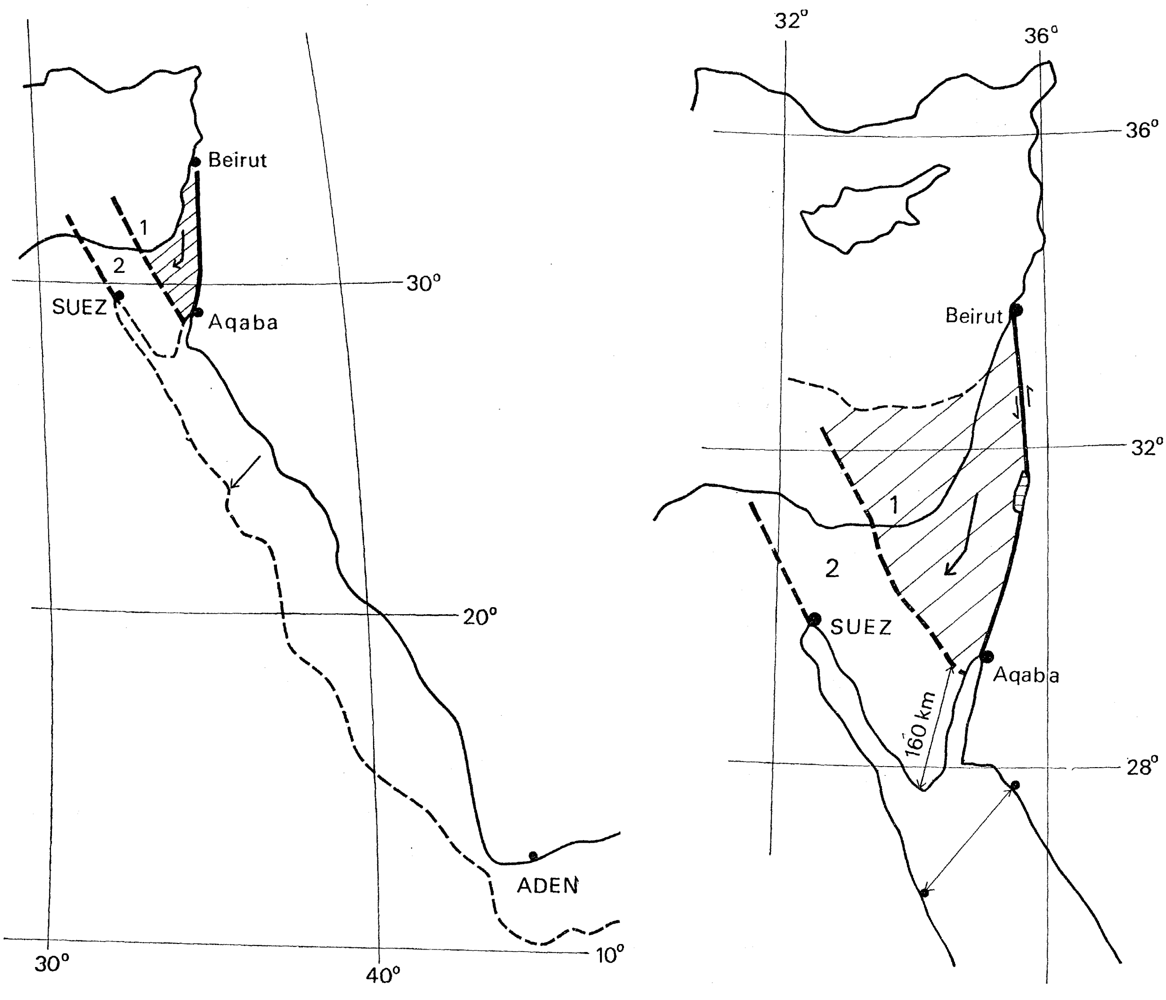

Figure 4. Dubertret's model (1932) of the drifting of Africa away from the Arabian peninsula and of Sinai peninsula towards south along the Dead Sea structure: (1) initial position, (2) present-day situation. The model supposes the Red Sea bottom free of Basement rocks.

on rapproche le rivage égyptien de la mer Rouge du rivage arabique, en faisant subir au premier un très léger déplacement vers le nord, on voit qu'ils s'appliqueraient exactement l'un sur l'autre, sauf toutefois vers l'entrée du golfe, où des accidents volcaniques d'une grande importance sont venus introduire de profondes modifications dans le relief du sol.'

Dubertret (1932) proposed the following *working hypothesis* to explain the present-day layout: '...l'ancient continent africain. Nous en connaissons trois fragments dans la Méditerranée orientale: le socle africain proprement dit, le socle de l'Arabie et le bloc du Sinai, celui-ci limité à l'Ouest par la cassure du canal de Suez, à l'Est par le golfe d'Akaba, la mer Morte, le Jourdain, puis par une ligne se poursuivant au Nord vers Beyrouth. L'hypothèse d'une dérive étant admise, et les déplacements rapportés au socle de l'Arabie supposé fixe, la dislocation

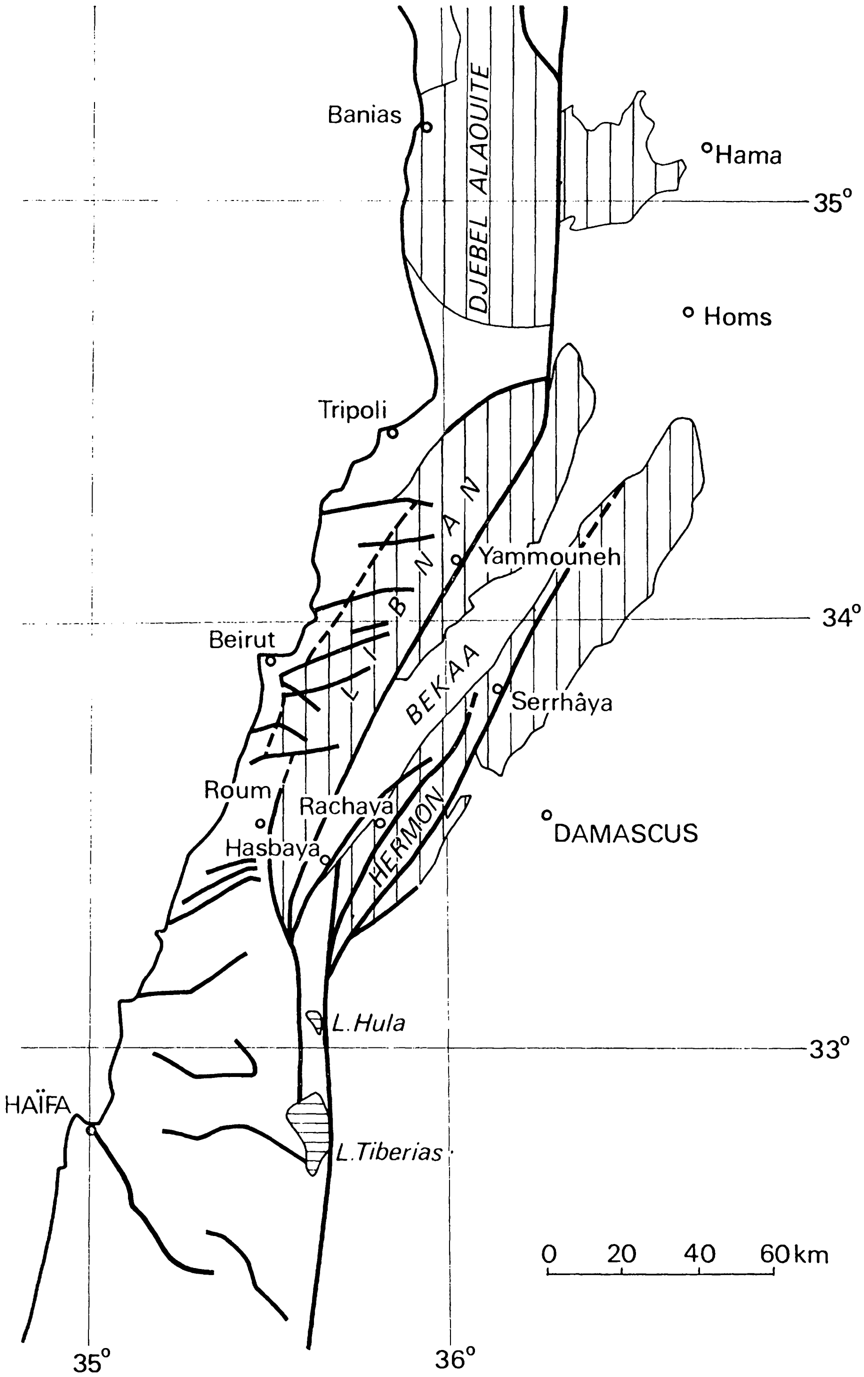

FIGURE 5. Northern extension of the Dead Sea trough fault system in Lebanon and Syria, according to Dubertret (1967). Quennell and Freund *et al.* suppose northward drift of the Arabian peninsula along the Yammouneh fault, which raises definite major objections. Drift along the Roum fault, trending towards Beirut, would be easier to accept, but it should be pre-Cretaceous, as the Cretaceous covers it without any sign of discontinuity.

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du continent primitif peut se ramener à: 1° un glissement du bloc du Sinaï de 160 km vers le Sud, le long de sa bordure orientale; 2° une rotation du socle africain de 6°4 dans le sens des aiguilles d'une montre, autour d'une centre situé dans la mer Ionienne.'

Such a model supposes that the two opposite shores of the Red Sea did originally fit together, i.e. that the bottom of the Red Sea is free of basement rocks. Since then the author has not mentioned his hypothesis again; it had met criticism from H. Douvilleé.

Quennel (1956) continued on the line of Dubertret's hypothesis. He suggested that the Arabian peninsula drifted northward along the Dead Sea fault system and farther north along the Yammouneh fault (eastern flank of Lebanon). From its initial position (stage A), it drifted 62 km in early Miocene times (stage B), then 45 km in Pleistocene times (stage C).

Freund (1965) asserted that 'the Arabian Block moved about 60 to 80 km northward along the Dead Sea Fault since the Upper Cretaceous. This movement is a part of the northward drift of the Arabian Block away from Africa, which opened the gap of the Red Sea, the Gulf of Suez and the Gulf of Aden'.

Freund, Zak & Garfunkel (1968) mention evidences of Recent lateral movements in the Dead Sea rift; they assess a Plio-Pleistocene movement of 40 to 45 km.

Freund (1969) reaches figures close to those of Quennell: a total displacement of 105 km, of which 60 km is in post-Turonian and pre-Miocene times, and 45 km in Plio-Pleistocene times.

Bender's (1968*b*) position on the subject of large-scale lateral movement along the Dead Sea fault system, based on recent detailed mapping in Jordan, is unambiguous. He would eventually admit post-Precambrian lateral movement of some 20 to 25 km, though proof remains to be found. Palaeogeographic and tectonic considerations of younger formations he considers are indicative of vertical differences in position on either side of the Jordan valley (see Bender's contribution to the discussion of Freund, p. 127).

I am of the opinion that continental drift has indeed to be considered as one possible explanation of the structural layout, but that the problem ought to be tackled on a wide regional scale. The models proposed by Quennell and Freund are unacceptable from the point of view of the Lebanese and Syrian geology. For instance, there exist close relations between the Lebanon and Anti-Lebanon, and it is hard to conceive that the Hermon massif originated 105 km south of its present position, in an area of plateaux.

Any model describing the evolution of the Red Sea, invoking the theory of drift, must take into account all the coeval geological events within the wide regional sphere of influence of such drift.

I acknowledge with thanks Miss Frances Delany's assistance in preparing this text.

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Discussion

J. V. Hepworth (*Institute of Geological Sciences*) displayed a slide of sheet 3 of the recently available Tectonic Map of Africa [*Ass. Afr. Geol. Surv.*/Unesco, 1968] at a scale of 1:5000000. This was the latest, most comprehensive compilation of tectonic data in existence. It demonstrated thickness of sediments, the disposition of the basement and cover, and the distribution of volcanic and plutonic rocks as well as structural data. As was to be expected with such a monumental compilation there were some deficiencies. For example, there were probably many more faults than were shown. Nevertheless, the tectonic map could not be ignored and ought to be taken as the background against which the Red Sea system was considered.

The most obvious dimension of the Red Sea system, i.e. its length, was about 2400 km and it should be considered in a regional context of appropriate order. The tectonic map showed clearly that this regional context must include the whole of the Afro-Arabian swell, as workers such as L. C. King and G. M. Lees have pointed out. It also looks as if the regional context must include the northeastern flank of Arabia, i.e. the post-Palaeozoic basin and the foredeep of the Alpine orogenic belt. In fact it is difficult, when looking at the tectonic map of the region, to consider the Red Sea–Gulf of Aden system as other than an integral part of a megatectonic system which contained the Zagros front of the Alpine orogenic belt, the Persian Gulf 'foredeep', and the Afro-Arabian swell with the Red Sea down-flexing its crest.

In this light the hypothesis that the Red Sea owed its conformation largely to dilatation becomes less insistent, and the notion that it is a down-warp, a sag, a belt of foundered blocks, superimposed on the crest of a great swell, and bounded at present by erosion scarps, becomes more attractive. Such a picture is much more in accord with the one which Whiteman ('Formation of the Red Sea depression', *Geol. Mag.* **105**, no. 3 (1968), pp. 231–246) has recently advocated. It was certainly more in accord with what we know of the developmental history of the East African Rifts, for example the Albert Rift. Here the main trough was developed by down-warping at the crest of a great swell (Congo–Uganda) with one side of the down-warp passing into faults (the primary rift faults) in some places. Eventually comparatively recent faulting occurred near the centre of the trough (Hepworth, J. V. 1964. Explanation of the geology of sheets 19, 20, 28, 29 (Southern West Nile). *Geol. Surv. Uganda.* Rep. 10).

He did not know how the movement across the Zagros front should be included in the regional tectonic picture except that it seemed to imply regional compression. It was worth pointing out that it is difficult to reconcile a down-warp of continuous crust with regional tension; that down-warping is more in accord with regional compression, but that it relates most satisfactorily to largely vertical crustal displacements.

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Dubertret's synopsis indicates the necessity of considering the evolution of the Red Sea in a broad framework. Movements elsewhere, contemporaneous on a geologic time scale, of orogenic or epeirogenic nature should complete and fit in with the picture. An analysis of events in the Persian Gulf and Taurus ranges, in the eastern Mediterranean and in East and Northeast Africa could contribute to the problem under discussion.

A critical reappraisal of field observations, especially in view of the new theories of ocean floor spreading, might bring more reliable evidence of past events than the unquestioning acceptance of interpretations. Several points might warrant further checking: is the offsetting of stratigraphic reference beds along the line of the Dead Sea due to faulting (and of what nature) or to palaeogeography? how does the area of eroded Jurassic of Beydoun (1964) and others fit in with Arkell's (1952) Arabo-Somali massif, emerged during the Jurassic? what are the true ages of the Maestrichtian of Karpoff (1957) and of the Jurassic basalts (148 ± 30 Ma) interbedded in Miocene sediments of Khor Shenab (Sudan)?

A series of palaeogeographic maps and a semi-detailed tectonic map of the Red Sea and its wider setting might usefully be compiled. Sheet 3 of the Tectonic Map of Africa, 1:5 000 000 (1968) shows part of this area; it was not compiled specifically for the Red Sea but as one of nine sheets illustrating the entire African continent. As such, a certain degree of homogenization and extrapolation of data was required.