OUTLINES OF THE STRATIGRAPHY AND STRUCTURAL FRAMEWORK OF SOUTHERN DHOFAR (SULTANATE OF OMAN)[1]

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ABSTRACT

Hawkins, T. R. W., D. Hindle & R. Strugnell 1981 Outlines of the stratigraphy and structural framework of Southern Dhofar (Sultanate of Oman) – Geol. Mijnbouw 60: 247-256.

Recently drilled deep water wells have provided new information of the succession and structure of Southern Dhofar. A small segment of the Pan-African Shield, composed of acid gneisses, granites, pegmatites, aplites and a basic dyke swarm underlies the Mirbat Plain. Furthermore, two windows of bedded basement rocks occur in south-west Dhofar. A restricted development of post-basement Palaeozoic clastics occurs as the Mirbat Formation, which may equate with the Ordovician to Permian Haima Formation elsewhere in Oman. The Cretaceous sequence (Mahra Group) is similar to that found in eastern South Yemen, except that a newly defined mixed clastic and carbonate Qamar Formation is recognized. The Kenozoic succession broadly resembles that of South Yemen and much of Saudi Arabia and the Gulf area. Structures in the post-basement rocks are: east-north-east trending folds which commenced in middle Eocene times, north-south open folds and arcuate normal faults subparallel to the coastline, associated with the Gulf of Aden Rift.

INTRODUCTION

Dhofar is the southern province of Oman bordering with South Yemen and Saudi Arabia (Fig. 1). There is little published work on the geology of this province, previous work being confined to observations by LEES (1928), FOX (1947), MORTON (1959) and surveys by petroleum companies, some of whose results are incorporated in papers essentially on the former Aden Protectorate (now P.D.R. of South Yemen) by BEYDOUN (1964, 1966) and BEYDOUN & GREENWOOD (1968).

This paper reports a summary of new geological information obtained during recent hydrogeological investigations in the southern part of the province. The surveys included over fifty deep wells (up to 840 m deep) in Jebel al Qamar and Jebel Qara and shallower holes in the Salalah and Mirbat Plains, together with surface observations at coastal settlements from the South Yemen border to east of Sudh (Fig. 1). From a combination of normal sample logging, thin section examination, interpretation of down-hole geophysical logs and determination of microfauna from selected horizons, the broad succession and structure of this little known region has been established and correlated with neighbouring areas. A summary of the overall succession is given in figure 2.

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PRE-CRETACEOUS ROCKS

Crystalline shield of the Mirbat Plain

The Mirbat Plain is a low dissected plateau cut into a crystalline complex comprising acid gneisses, irregular sheets of granite, pegmatite and aplite as well as a swarm of basic dykes.

Medium- to coarse-grained biotite-granite-gneisses predominate, sometimes also with hornblende, and subordinate schists of similar mineralogy. Albite and potash feldspar (microcline and perthite) are frequently sericitised and accessories are muscovite, apatite and opaque ores, while quartz-feldspar segregation veins are common. The foliation gen-

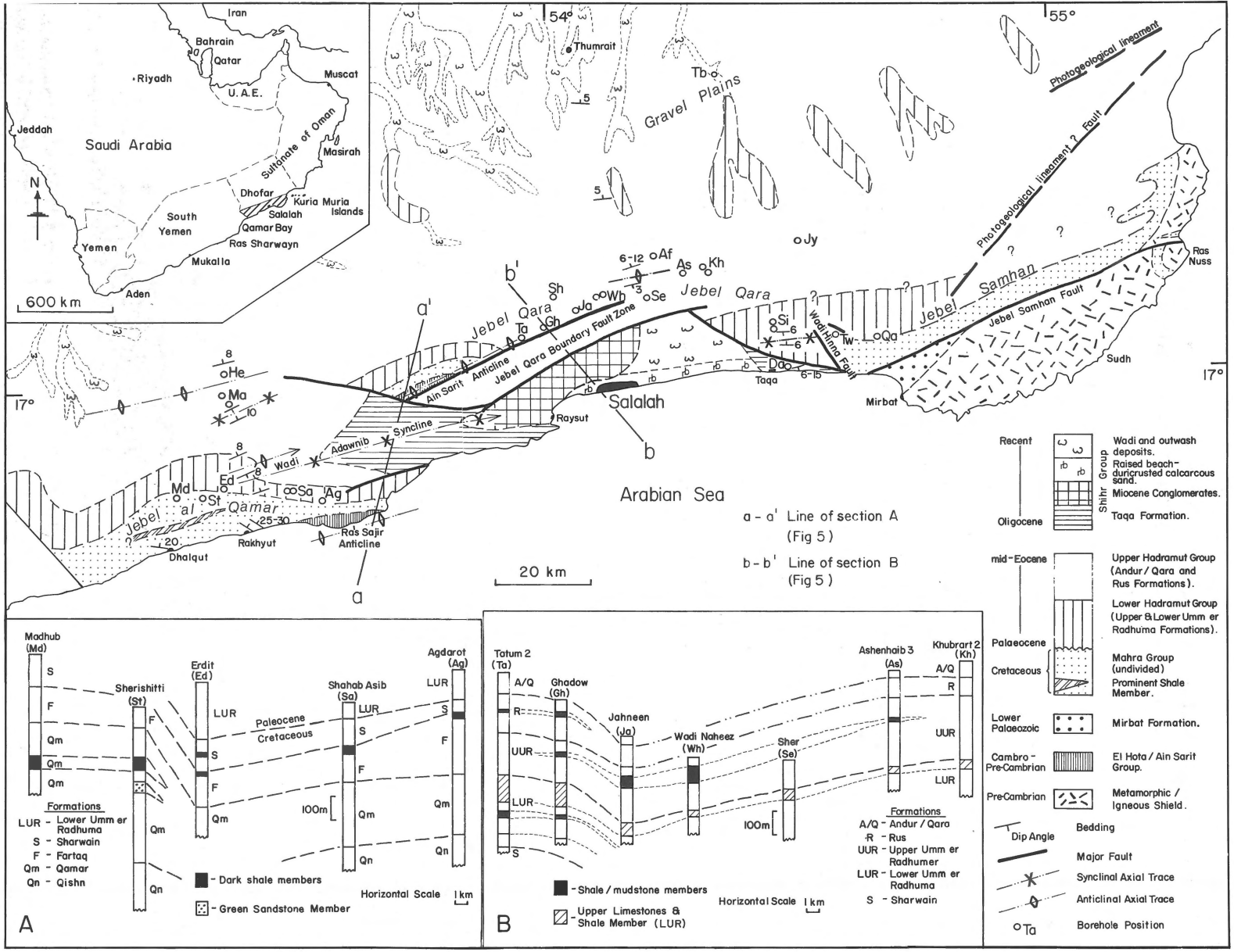

Fig. 1
Geological map of south Dhofar (modified from Brown, 1972, and Petroleum Department of Oman Drawing 1169).
A- Cross-section through boreholes in Jebel al Qamar.
B- Cross-section through boreholes in Jebel Qara.
Borehole positions shown on the map: Af-Adfirot, Ag-Agdarot, As-Ashenhaib, Da-wadi Darbat, Ed-Erdit, He-Heiron, Ja-Jahneen, Jy-Jib Jat, Kh-Khubrart, Ma-Manston, Md-Madhub, Qa-Qarhanoot, Sa-Shahab Asib, Se-Shir, Sh-Sheanot, Si-Sharhait, St-Sherishitti, Ta-Tatum, Tb-Thaboun and Tw-Tawi Atair.

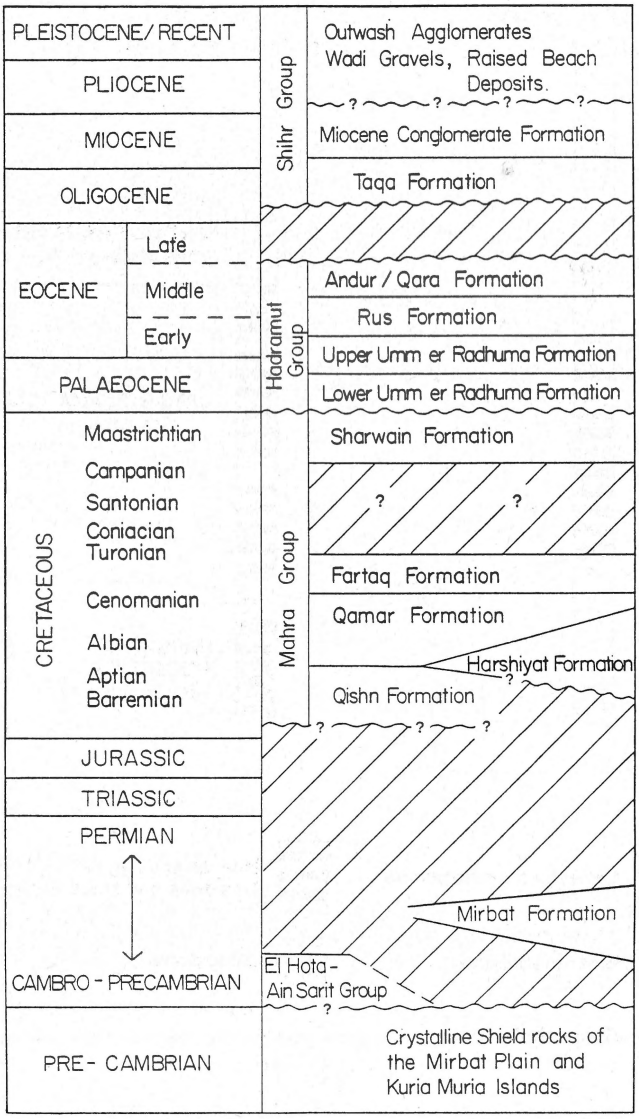

Fig. 2
Generalized stratigraphical succession of Southern Dhofar.

erally strikes north-east or north-north-east and dips between 40° and 50° northwest, and is locally deformed into tight north-west plunging minor folds.

The acid sheet intrusions are principally irregular dykes and these clearly post-date the gneisses and schists. They are pink-tinged biotite-granites with micropegmatite and aplite variants, and show, like the gneisses, a slight degree of cataclasis. The youngest rocks of the crystalline suite are dolerite dykes with highly sericitised plagioclase and chloritised clinopyroxene. Opaque ores are common and a distinctive feature is the presence of plentiful acicular natrolite. The dykes are anastomosing but have a mean north-westerly (Najd) trend.

El Hota – Ain Sarit Group

A sequence of greywackes and pelites occurs along the coast near Ra's Sajir (El Hota of BEYDOUN, 1964) and inland at Ain Sarit in the cores of two anticlines (Fig. 1). The exposures are peneplained and overlain unconformably by Mesozoic sediments.

The rocks have been superficially described by BEYDOUN (1964, 1966), Wetzel & Morton (unpublished data, 1948-50) and FOX (1947) and only a brief visit was made to Ain Sarit by one of the present writers. At Ain Sarit around 50 m of interbedded fine greywacke and grey-green laminated silty mudstone and shale are exposed. These dip 25° to 40° to the north-west below the shallower dipping Mesozoic succession. The greywackes consist of sub-angular strained quartz, altered plagioclase and lithic fragments and minor detrital muscovite with a fine matrix of sericite, chlorite, quartz and minor biotite. The rocks are unfoliated although BEYDOUN (1966) refers to the presence of cleavage and minor folding at El Hota. The age of this group is unknown although it is generally assumed to be Early Palaeozoic, probably Cambrian (BEYDOUN, 1964, 1966; BEYDOUN & GREENWOOD, 1968), and derived from an acidic igneous or metamorphic suite.

Mirbat Formation

At the western end of the Mirbat Plain the crystalline rocks are overlain by unmetamorphosed sediments of the Mirbat Formation. This sequence has previously been called the 'Mirbat Sandstone' (LEES, 1928; BEYDOUN, 1964, 1966; and BEYDOUN & GREENWOOD, 1968), and the exposed rocks are indeed largely brown-weathering fine- to coarse-grained sandstones.

A recent borehole (6 km north of Mirbat), however, has proved that there most of the 42 m penetrated consists of varicoloured laminated mudstones with only thin sandstone beds. The age of the formation is unknown although BEYDOUN (1964, 1966) tentatively suggested it is Ordovician on account of its resemblance to unfolded Ordovician rocks in South Oman.

MAHRA GROUP (CRETACEOUS)

Rocks of Cretaceous age crop out in the extreme south-west of Dhofar, in the Ain Sarit region and in the lower part of Jebel Samhan (Fig. 1) and a considerable part of the succession was penetrated by some of the recent water wells. It is possible that a thin development of Jurassic strata occurs immediately above the eroded surface of Palaeozoic rocks in the western area (BEYDOUN, 1964, 1966) but this has not been verified.

The Cretaceous of Dhofar and the Mahrah Province of South Yemen is assigned to the Mahra Group with an age range from Barremian to Maastrichtian (BEYDOUN, 1964,

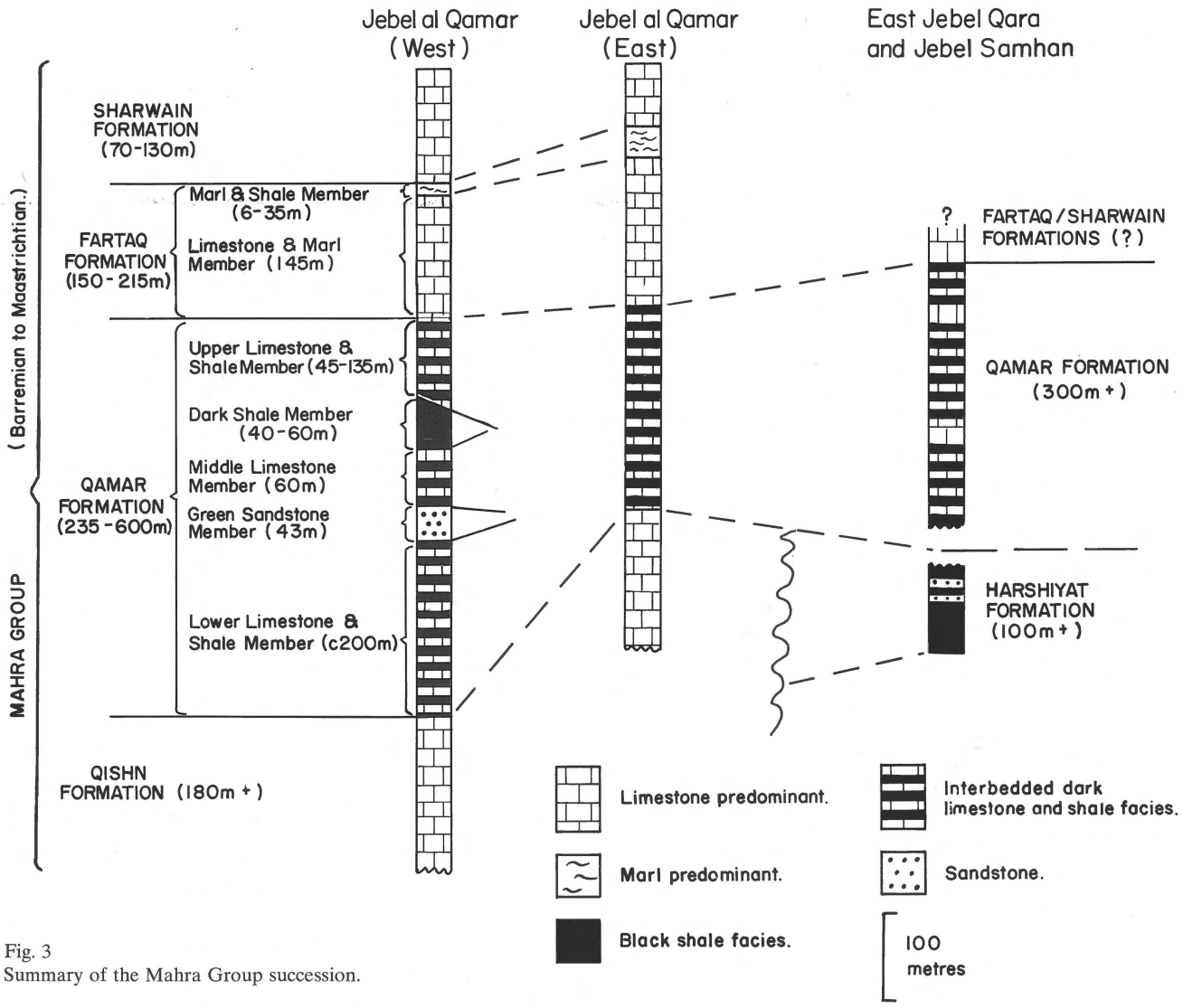

Fig. 3
Summary of the Mahra Group succession.

1966). A summary of the subdivision of this group as it occurs in Southern Dhofar is given in figure 3.

In South Yemen a clastic formation (Mukalla Formation) of early Maastrichtian, or Coniacian to Campanian, age occurs between the Fartaq and Sharwain successions but this has not been recognised during the recent drilling programme. The Harshiyat Formation dies out eastwards in South Yemen (BEYDOUN, 1966), and it is absent in Southwest Dhofar but reappears in Jebel Samhan as the earliest Cretaceous unit in that area. Throughout Dhofar a thick and distinctive sequence of interbedded biomicritic limestones and dark pyritous shales has been proved above the Qishn Formation. This lithofacies is dissimilar to any formation described in South Yemen and has been assigned to a new formation – the Qamar Formation.

Qishn Formation

The Qishn Formation crops out in the lower part of the cliffs from Qamar Bay to Ra's Sajir. A maximum of 180 m was proved by the drilling without reaching the base, while the thickness in the cliffs is at least 200 m. Downhole GR-ray logs suggest that the lower parts include minor pelitic horizons but the upper 100 m are carbonate sediments virtually free of shale beds.

The upper limestone beds consist predominantly of pale dolomitic dismicrite or fossiliferous micrite, containing clusters of zoned dolomite rhombohedra. The rocks have not been dated but are correlated with the Qishn of South Yemen as they form a thick limestone unit at the base of the Mahra Group.

Qamar Formation

The type sequence has been taken as that proved in the western part of Jebel al Qamar at Sherishitti (St) No. 2 Well (16°46'50" N, 53°19'30" E) and Madhub (Md) No. 1 Well (16°46'50" N, 53°15'30" E). The formation is also sporadically

exposed in the upper parts of the Jebel al Qamar cliffs and where the thicker shale beds, including the Dark Shale Member (Fig. 3), form a series of benches associated with perched springs.

The thickness of the formation proved throughout southern Dhofar varies from 235 to 600 m. In the western Jebel al Qamar the formation is divisible into five members (Fig. 3) due to the presence of a Green Sandstone Member (40 m) and a 40 to 60 m Dark Shale Member within the typical thinly interbedded sequence of limestone and shale. The limestones are generally grey biomicrites and biosparites with minor dolomitisation in the form of scattered zoned rhombohedra or partial sparry dolomite. The shales are brown-grey or green and frequently pyritous, while the Green Sandstone Member is composed of grey-green glauconitic and calcareous fine-grained sandstone with minor shale beds.

A number of shale horizons within the formation were examined for microfauna and they all contain *Orbitolina lenticularis* (Blumenbach), in some cases with *Orbitolina* cf. *concava* (Lamarck), *Hemicyclammina* sp., *Lituola* sp., *Marssonella* sp. and *Tritaxia* sp. These are associated with rare ostracods, and a sparse microflora with *Classopollis torosus, Cleistosphaeridium polypes* and *Dinopterygium cf. cladoides.* The age of the Qamar Formation is therefore within the range of Albian to Cenomanian.

Harshiyat Formation

This formation crops out in the lower slopes of the Jebel Samhan escarpment and along the numerous north-west trending wadis through that Jebel. Around 100 m of green, grey or olive laminated mudstones and siltstones with sporadic thin beds of grey, weathering brown, fine to medium sandstones are exposed. At the western end of the escarpment and in Wadi Hinna, sandstones and siltstones become more frequent towards the top of the sequence. A fossil collection made by CARTER (1852) from 'marly beds' at the top of the formation includes *Orbitolina* cf. *concava, Pecten quadricostata* and *Salenia scutigera* and indicates a Cenomanian age for these beds (BEYDOUN, 1964, 1966; BEYDOUN & GREENWOOD, 1968).

Fartaq Formation

This formation has been found throughout Jebel al Qamar and the boreholes have proved between 100 and 215 m of predominantly light-coloured limestone and marl. It can be divided into a Lower Limestone and Marl Member (90-185 m) and a thinner, but persistent, overlying Marl and Shale Member (10-30 m). In eastern Jebel Qara and Jebel Samhan the limestones immediately above the Qamar Formation have not been separated from possible Tertiary formations. It is likely, however, that the Fartaq Formation, like the Sharwain, is considerably thinner in the eastern Jebel areas than in the west (Fig. 3).

The limestones are grey to buff, sparse biosparites and biomicrites with shell and skeletal debris, rare ooliths and limited dolomitisation. The marl beds are composed of yellow to off-white marl and argillaceous micrite.

Sharwain Formation

From 70 to 130 m, of dolomitic dismicrite and sparite limestones, with a few marl and shale horizons, exists above the Fartaq Formation in Jebel al Qamar. At Erdit la Well a shale and marl bed, 70 m above the base of the formation, yielded a fauna with rare *Rotalia* sp. or primitive *Lockhartia* sp., possible *Loftusia* spp. and common small rotaliiform foraminifera. This horizon is believed to be either late Maastrichtian or very Early Palaeocene. From this evidence the limestones and marls below are equated with the predominantly Maastrichtian Sharwain Formation of eastern South Yemen.

HADRAMUT GROUP (PALAEOCENE – MID EOCENE)

A carbonate succession of Palaeocene to Middle Eocene age is widespread throughout south and east Arabia. In South Yemen and Dhofar this begins with a strongly transgressive Palaeocene sequence disconformable on the Cretaceous (BEYDOUN, 1964, 1966). Four formations are recognised in South Yemen within a Hadramut Group, namely and in ascending order, the Umm er Radhuma, the Jeza, the Rus and the Habshiya. In Dhofar, however, the Jeza is not recognised and is replaced by an Upper Umm er Radhuma Formation (Fig. 4), while the Habshiya Formation has previously been referred to as the Andur/Qara Formation in Dhofar (FOX, 1947; MORTON, 1959).

Lower Umm er Radhuma Formation

The Umm er Radhuma Formations are well exposed in the upper parts of the Jebel al Qamar and Jebel Samhan escarpments and in deeply incised wadis of the interior. Outcrops are characterised by their karstic features with extensive caverns, gorges and sinkholes.

The Lower Umm er Radhuma Formation can be divided into five members, three of which are persistent over the region (Fig. 4). The Lower Limestone and Shale Member was previously thought to comprise a single shale horizon known as the 'Shammer' and is referred to in commercial reports as a regional basal aquiclude in southern Dhofar. There is, however, not a single shale bed but rather an interbedded unit of carbonaceous dismicrite, black shale and green mudstone up to 66 m thick in central Jebel Qara. The sequence is highly variable, particularly in Jebel al Qamar where it does not act as an aquiclude. The shale beds consistently contain a sparse microfauna including *Lockhartia* sp,

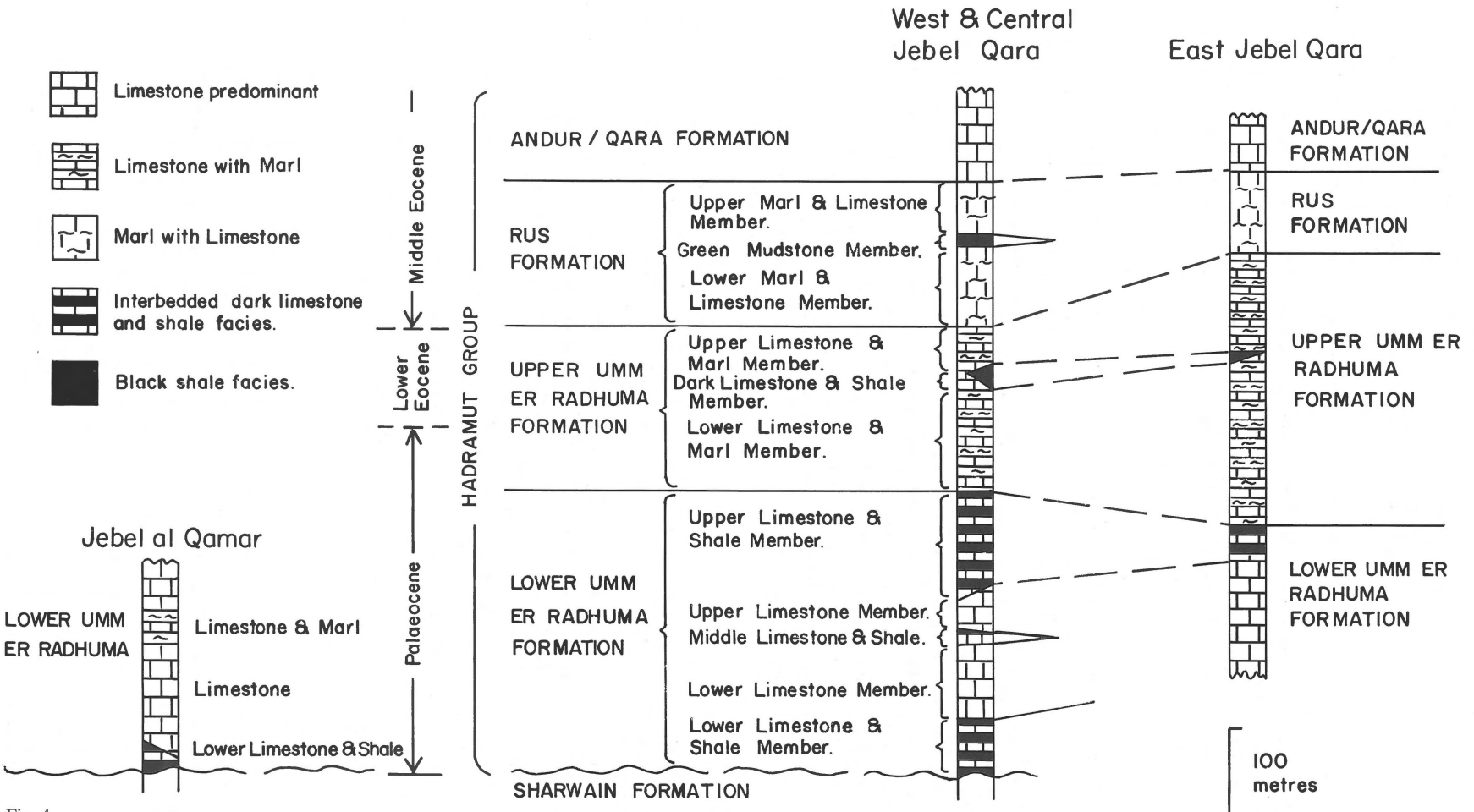

Fig. 4
Summary of the Hadramut Group succession.

which indicates a Palaeocene age.

Overlying the basal member is a predominantly limestone succession (130-140 m) of partly dolomitised biosparites interbedded with chalky horizons and sporadic marl beds and which can be divided into three members in western Jebel Qara (Fig. 4).

The upper part of the Formation (Upper Limestone and Shale Member) is generally a dark, very fossiliferous partially dolomitised biosparite with numerous laminae and thin beds of black shale, greenish mudstone and marl. The member is around 120 m thick in central Jebel Qara but thins to around 20 m in the east.

Upper Umm er Radhuma Formation

This formation increases in thickness across Jebel Qara from 170 m in the west at the Tatum wells to about 300 m in the east at Khubrart and Jib Jat (Figs. 1 and 4). Most of the formation consists of pale-coloured packed biomicrite with subordinate marl beds and apart from the thin and impersistant 'Dark Limestone and Shale Member' black shales and dark limestones are scarce or absent.

The upper part of the formation is well exposed along the Salalah-Thumrait road and in Wadi Naheez (Wh in Fig. 1) where nummulite-rich beds and two distinctive horizons containing large spheroidal sideritic limestone nodules can be observed.

Rus Formation

In southern Dhofar the Rus Formation differs from that of the type locality in Saudi Arabia (THRALLS & HASSON, 1956) by the absence of extensive gypsiferous beds. Nevertheless, the quantity of marl, mudstone and chalky limestones is far in excess of those present in the Upper Umm er Radhuma and Andur/Qara Formations, and hence the status of a separate formation is retained for this region.

The formation ranges in thickness from just under 100 m to about 150 m, and much of the succession consists of chalky limestones (in part recrystallised) with flint, chert and quartz geodes, white, yellow and green marl and shaly mudstones.

Andur/Qara Formation

This is predominantly a limestone sequence, at least 150 m thick, of pink to off-white sparse to packed biomicrites, chalks, coarsely recrystallised dolomitic limestones and relatively few beds of yellow and red marl. The formation is broadly equivalent to the Damman of Saudi Arabia and the Gulf area. The lower boundary is difficult to define in the field but in boreholes is taken where the succession becomes markedly more shaly as defined by gamma-ray logging.

SHIHR GROUP (OLIGOCENE – RECENT)

The Oligocene and younger Tertiary sediments of the Shihr Group are the equivalent of the Fars Formation of the Arabian Gulf area. In Dhofar the sequence is of different facies to that of the Gulf and has been divided by BEYDOUN (1964, 1966) into the Taqa Formation, of Early to Late Oligocene age, and the Miocene Conglomerate Formation.

Taqa Formation

This formation is believed to have been laid down in open-sea conditions after Late Eocene coastal faulting had taken place, and hence the formation only occurs south of the Jebel Boundary faults (Figs. 1 & 5B). The formation comprises a basal Green Silt Member overlain by the Taqa Limestone Member. The lower unit consists of calcareous and slightly glauconitic green-grey silt and fine sand, and a thickness of 104 m has been proved beneath the Salalah Plain without reaching the base (unpublished report by Sir William Halcrow and Partners, 1975).

The Taqa Limestone is well exposed in the Wadi Adawnib area and around Taqa and Wadi Darbat. The limestones at the surface are thinly bedded crystalline micrites and sparites with minor marl beds. Boreholes in the Salalah Plain, however, suggest that there the rocks are only patchily calcreted and include soft white-cream limestones. The thickness of the Taqa Limestone is believed to be between 110 and 140 m (unpublished report by Sir William Halcrow and Partners, 1975).

Miocene Conglomerate Formation

This formation crops out in the deeper wadis of the Salalah Plain and is typified by interbedded limestone conglomerates, pink marly limestone with smaller amounts of chalk and yellow marls. Rounded pebble and cobble-size fragments of limestone of Palaeocene and Eocene age are cemented by a matrix of calcareous, and sometimes gypsiferous, sand, silt and clay. The clasts are frequently concentrated in individual beds which may extend laterally from a few to several hundreds of metres. The thickness of this formation is not easy to determine as the upper conglomerates are difficult to distinguish from post-Miocene limestone gravels, but they are of the order of 60 to 100 m, which is considerably less than the 600 m originally estimated by Dhofar City Services (BEYDOUN, 1964).

Post-Miocene Deposits

These consist largely of fan agglomerates and wadi sands and gravels, up to 50 m thick. In coastal plain areas, patchily cemented crossbedded calcareous sands and pebble beds, up to 10 m thick, occur on low raised beaches.

STRUCTURE

The major structural elements of southern Dhofar are east-north-east trending folds, north-south folds and two sets of normal faults (Fig. 1).

East-north-east trending folds

Three major upright east-north-east plunging folds occur within the Jebel zone. These are the Ra's Sajir Anticline, the Wadi Adawnib Syncline and the Ain Sarit Anticline (Figs. 1 and 5A). These anticlines are partly responsible for bringing the El Hota/Ain Sarit Group to the surface. The southern limbs of the two anticlines are largely faulted out, and in the case of the Ra's Sajir fold, rift faulting has given rise to the current cliff line.

Smaller-scale folds with bedding dips in the limbs generally less than 10° occur in both Jebel al Qamar and Jebel Qara. These can be discerned between Manston and Rakhyut, along the Salalah-Thumrait Road and in the Wadi Darbat area, north-east of Taqa. The plunge direction of these folds can be either east-north-east or west-south-west due to the presence of plunge depressions caused by north-south folding (Fig. 1). These folds form part of the Hadramut Arch structure of southern Arabia which is discussed below.

North-south trending folds

Along the south-west coast the Cretaceous succession forms the northward dipping limb of the Ra's Sajir Anticline, but the beds have also been folded into open north-south trending folds with wavelengths of the order of a kilometre or more. These structures are particularly apparent between Dhalqut and Ra's Sajir.

Interborehole correlation has revealed the presence of larger-scale, more influential, cross folding in both Jebel al Qamar and Jebel Qara (Fig. 1). The precise orientation and age of the folds is not known but the two synclines found are both assymmetrical with steeper-dipping western limbs. A north-north-west plunging syncline has also been recently proved affecting Oligocene and Miocene formations in the central part of the Salalah Plain (unpublished report by John Taylor & Sons, 1979). This may possibly be a continuation of the Jahneen-Wadi Naheez Syncline (Fig. 1B) across the Jebel Qara Boundary Faults.

Faults

Two sets of major normal faults occur in the area. One trends approximately east-north-east, parallel to the mean coastline and major fold axial traces, the other strikes north-west or west-north-west. The faulting has produced prominent fault-line escarpments (Jebel Boundary Faults), which are largely responsible for the presence of the structural domains, and fault zones of shattered and mylonitised debris may exceed 100 m in width. The Jebel Qara boundary faulting behind the Salalah Plain consists of a complex fault zone several kilometres wide.

The east-north-east faults downthrow to the south. They are believed to have been initiated during the period of emergence in the Jebel areas during Late Eocene times, and the resulting cliff lines acting as a northern barrier for Oligocene and later marine transgressions.

DISCUSSION

The petrography of the Mirbat Plain basement suite is similar to Pan-African cratonised rocks found elsewhere in Arabia (GREENWOOD ET AL., 1976) and in view of the work of KRONER ET AL. (1979) it is likely that they are rocks formed or emplaced during the Pan-African thermo-tectonic event. They are also likely to correlate with similar rocks at Jebel Ja'alan in the Eastern Oman Mountains (GLENNIE, 1977) which have been dated as around 860 Ma (GLENNIE ET AL., 1974).

The bedded Palaeozoic rocks of southern Dhofar are thinner and less persistent than those in other parts of Oman and western Arabia. They are difficult to correlate with these areas although BEYDOUN (1964, 1966) broadly equated the El Hota/Ain Sarit Group with part of the Cambrian Hugf Group of South Oman. The Mirbat Formation would appear to represent a remnant of the clastic Haima Group in Oman (Ordovician to Permian) – which is shown by GLENNIE (1977) to be thinning towards Dhofar. Epeirogenic movements and consequent non-sequence or erosion during the Cambrian (Henson, unpublished data, 1954-60, quoted in BEYDOUN, 1966) may explain the absence of the El Hota/Ain Sarit sequence in south-east Dhofar, while the Mirbat Formation could have been largely removed by pre-Jurassic/Cretaceous periods of emergence and erosion.

Over much of southern Oman there was a widespread Carboniferous-Permian transgression, shown by the clastic sediments of the Haushi Formation (GLENNIE, 1977), but there is no trace of these deposits in south Dhofar, and the latter area appears to have been emergent from Early Palaeozoic time until the Cretaceous. A Jurassic sea existed in parts of South Yemen, but Dhofar seems to have been a 'high zone' during this time, similar to the Mukalla area of South Yemen (BEYDOUN, 1964, 1966). Beydoun further suggested that the Cretaceous sea advanced from west to east on account of the absence of the Qishn Formation in the east. The oldest Cretaceous formation in the east (the Harshiyat), however, has not been dated and hence this hypothesis remains conjectural.

Throughout Oman there was a period of uplift and non-sequence during Turonian and early Senonian times (GLENNIE, 1977). It is not clear whether or not this was also the case in southern Dhofar, but the absence or poor development of the Fartaq and Sharwain Formations in Jebel Samhan may reflect a non-sequence in this area.

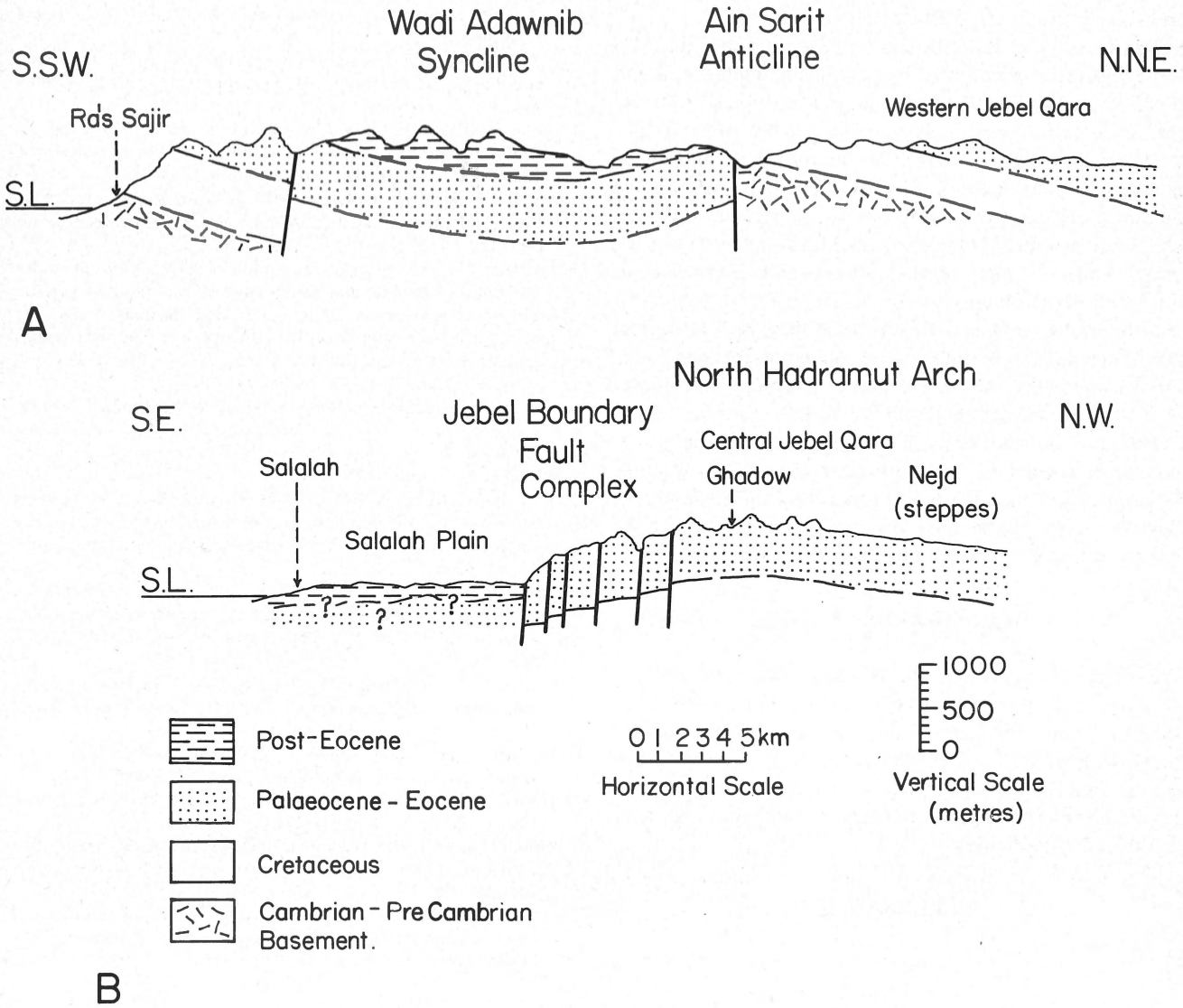

Fig. 5
Structural cross-sections in Southern Dhofar (see also Fig. 1).
A: SSW-NNE section from Ra's Sayir to Jebel Quara, north of Ain Sarit.
B: SE-NW section across the Salalah Plain and central Jebel Quara.

In a general sense the Tertiary history of Dhofar is more closely related to other parts of Arabia than in earlier Phanerozoic periods. The predominantly carbonate sediments of the Umm er Radhuma, Rus and Andur/Qara (equivalent to the Damman) Formations are widespread in Saudi Arabia, South Yemen and the Gulf areas. The paucity of gypsum and anhydrite beds within the Rus of the Dhofar Jebel areas may be related to the rise along the Hadramut Arch Zone (BEYDOUN, 1964, 1966). This began in the Palaeocene or Early Eocene, giving at times reduced sedimentation rates and greater current circulation than in areas to the north.

The major east-north-east trending structures reflect the movements along the Hadramut Arch zone. The folds parallel the 'Arch', which BEYDOUN (1964, 1966) described as a trio of open folds, two anticlines and an intervening syncline, which extend for around 600 km from the Yemen to the Jebel areas of Dhofar. The major Dhofar folds do not correlate directly with the Hadramut tripartite system, but appear together to represent the eastern extension of the north anticline ('Arch'). In eastern South Yemen (Al Mahrah Province) the Northern 'Arch' occurs well inland as a simple open anticline, while the syncline and the Southern 'Arch' (closer to the present coastline) are tighter flexures with subsidiary folds and numerous normal faults trending parallel to the fold-axial traces. In Dhofar it is apparent that the Northern 'Arch' has also attained a more complex and faulted form (Fig. 5A and 5B), and the central syncline and southern anticline are absent, cut-off by the coastlines of Al Qamar Bay

and Ras Sharwain respectively.

The coastal and Jebel Boundary Faults are arcuated and some intersect to form tilted blocks (Salalah Plain). This and their obvious association with the east-north-east folds are features typical of marginal zones along major rifts (ROBSON, 1971; CHAPMAN ET AL., 1978). An interesting feature of the northern margin of the Gulf of Aden Rift is the step-like feature which has given rise to a series of asymmetrical bays, viz. Ras Sharwain, Al Qamar, Kuria Muria and others. These bays have near straight north-south coastlines on their western sides, which may represent cross-faults to the Rift. It is because of the Al Qamar Bay line that the North Hadramut Anticline has been brought nearer to the present coastline in Dhofar and hence this 'Arch' has the more faulted complex form characteristic of the Southern Anticline further west.

The poorly sorted Miocene conglomerates may be in part submarine-fan deposits at the base of the failing rift slope, which were followed by terrestrial mudflows and wadi fluvial flows resulting in the post-Miocene conglomerates of the emergent Quaternary period.

ACKNOWLEDGEMENTS

We are greatly indebted to the Directorate General of Water Supply and Transport at the Office of the Minister of State & Wali of Dhofar for considerable help and advice. We also thank Messrs. H. Fordyce and B. Flynn of Pencol Engineering Consultants for advice and encouragement and Mrs. J. F. Gibbs of Middlesex Polytechnic for technical assistance and drawing the figures.

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