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Structural and Stratigraphical Setting of the Faiyah Range, Northwestern Oman Mountain Front, United Arab Emirates

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ABSTRACT

The Faiyah Range belongs to a group of regional ridges that formed by post-obduction folding of the Upper Cretaceous-Tertiary sedimentary rocks exposed along the western margin of the Northern Oman Mountains. The Faiyah Anticline, generally trends north-northeast to south-southwest with thrust faults striking parallel to the fold axis. The anticlinal hinge was later displaced by a dextral strike-slip fault, named here as the Faiyah Fault, into two segments. The northeastern segment includes Jebels Rumaylah, Faiyah and Mulayhah, and the southwestern segment includes Jebels Buhays and Aqabah. The anticline is interpreted to result from northeast-southwest compression during the Tertiary.

In the Faiyah Range the neoautochthonous sedimentary rocks are the Maastrichtian Qahlah and Simsima formations, and the Eocene Dammam Formation. Stratigraphic evidence shows that the lower part of the Qahlah was deposited in a non-marine environment while the upper part was deposited during a marine transgression. The Simsima was deposited in a shallow-marine environment. These units unconformably overlap the allochthonous Semail Ophiolite. The microfaunal content of the so-called Muthaymimah Formation (?Tertiary), of earlier authors, indicates that it is of Maastrichtian age in the Faiyah Range. This sequence is also conformable to the Simsima and therefore it is considered to be the upper member of the Simsima in this area.

INTRODUCTION

The Faiyah Range constitutes the northernmost outcrop of the western foothills of the Oman Mountains where Maastrichtian and Tertiary sedimentary rocks are exposed in a discontinuous belt of jebels (Figure 1). The range is located between the Dibba and Hatta Zones, and trends parallel to the Northern Oman Mountains Front. It consists of an elongated anticlinal structure, extending for about 21 kilometers (km) in length and 1 to 2 km in width. The range can be subdivided into five jebels (Figure 2): Buhays, Aqabah, Rumaylah, Faiyah and Mulayhah.

In the eastern United Arab Emirates region, several gas/condensate fields, such as Margham and Saja'a (Figure 1), highlight the prospective nature of this province. These fields are trapped in anticlinal structures along the thrust front which constitutes the main boundary between a nearly undeformed foredeep basin to the west, and the fold and thrust belt to the east (Dunne et al., 1990; Mount et al., 1995). The complex nature of these subsurface structures is generally difficult to image with seismic data (Mount et al., 1995; O'Donnell et al., 1995). The study of the Faiyah Range therefore contributes to our understanding of the structural and stratigraphic evolution of this hydrocarbon habitat.

Many recent studies describe the geology of the Northern Oman Mountains (for example, Searle et al., 1983; Searle, 1985, 1988a, b; Dunne et al., 1990; Woodward, 1994; Warrak, 1996; Noweir and Eloutefi, 1997). In addition, several published regional maps cover the entire Oman Mountains (Glennie et al., 1974 at a scale of 1:500,000) and the Northern Oman Mountains (Geological Map of the United Arab Emirates, Sheets 2 and 4, 1979 at a scale of 1:250,000; Open University Oman-Ophiolite Project, 1983 at a scale of 1:250,000). The Upper Cretaceous stratigraphy of the area is also described in several regional studies (for example, Nolan et al., 1990; Skelton et al., 1990; Hamdan and Anan, 1993; Alsharhan and Nasr, 1996; Alsharhan et al., in press). Alsharhan and Nairn (1990, 1994) outlined the regional setting of the Upper Cretaceous deposits around the fringes of the Oman Mountains.

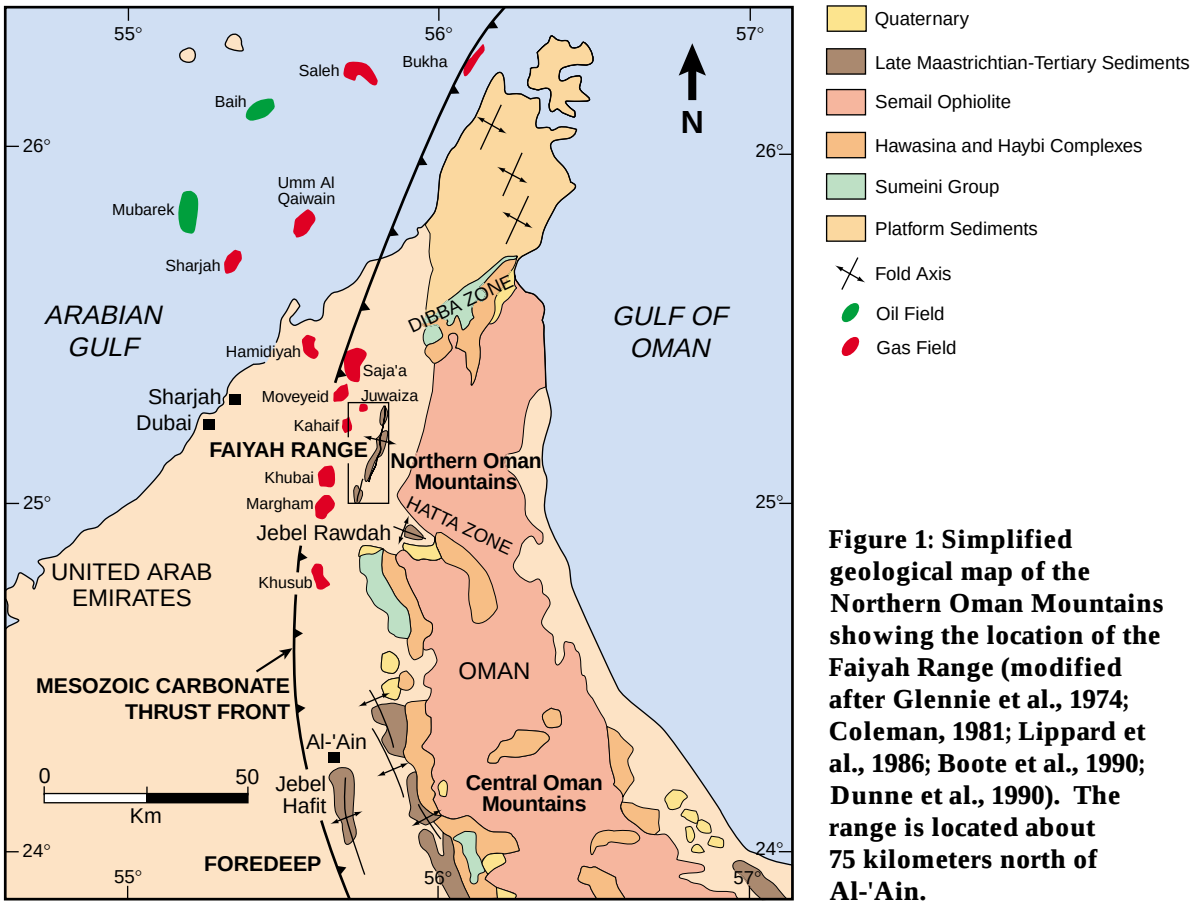


Figure 1: Simplified geological map of the Northern Oman Mountains showing the location of the Faiyah Range (modified after Glennie et al., 1974; Coleman, 1981; Lippard et al., 1986; Boote et al., 1990; Dunne et al., 1990). The range is located about 75 kilometers north of Al-'Ain.

None of the above regional studies, however, provides a detailed description of the Faiyah Range. This paper presents the results of a study which is focused on the structural and stratigraphic setting of this range. We present a geological map (Figure 2, originally constructed at a scale of 1:25,000) based on the examination of vertical aerial photographs and detailed field mapping. The study also presents paleontological results which clarify the age of the stratigraphic units in this region.

GEOLOGICAL SETTING

The Oman Mountains form a prominent arcuate range which is parallel to the Gulf of Oman in southeast Arabia (Figure 1). These mountains formed in response to two main compressional events. The first resulted from the Late Cretaceous (Coniacian-Maastrichtian) obduction of the Semail Ophiolite, and associated sedimentary and volcanic rocks (Sumeini, Hawasina and Haybi groups), onto the eastern margin of the Arabian Platform. As a result of the obduction a flexural foredeep developed along the western flank of the mountains and this basin was filled with Maastrichtian to Tertiary sediments (Glennie et al., 1973, 1974; Coleman, 1981; Searle et al., 1983; Lippard et al., 1986; Patton and O'Connor, 1988; Boote et al., 1990; Nolan et al., 1986, 1990; Robertson et al., 1990; Warburton et al., 1990).

In North Oman, a second compressional post-obduction event occurred in the Late Eocene-Miocene. It was mainly responsible for the formation of foreland folds (Warrak, 1996) and the folding of the Maastrichtian-Tertiary neoautochthonous units in the foredeep (Boote et al., 1990). The effects of this compression are visible in a series of large-scale folds fringing the western foothills of the Northern Oman Mountains, including the Faiyah Range. The second event is correlated by some authors to the Zagros Orogeny in Iran (Ricateau and Riche, 1980; Searle et al., 1983; Searle, 1985; Searle et al., 1990).

Jebel Faiyah trends north northeast-south southwest and is one of three sets of fold axis recognized in the Tertiary outcrops and structures of the Northern Oman Mountains (Figure 1). The second trend is

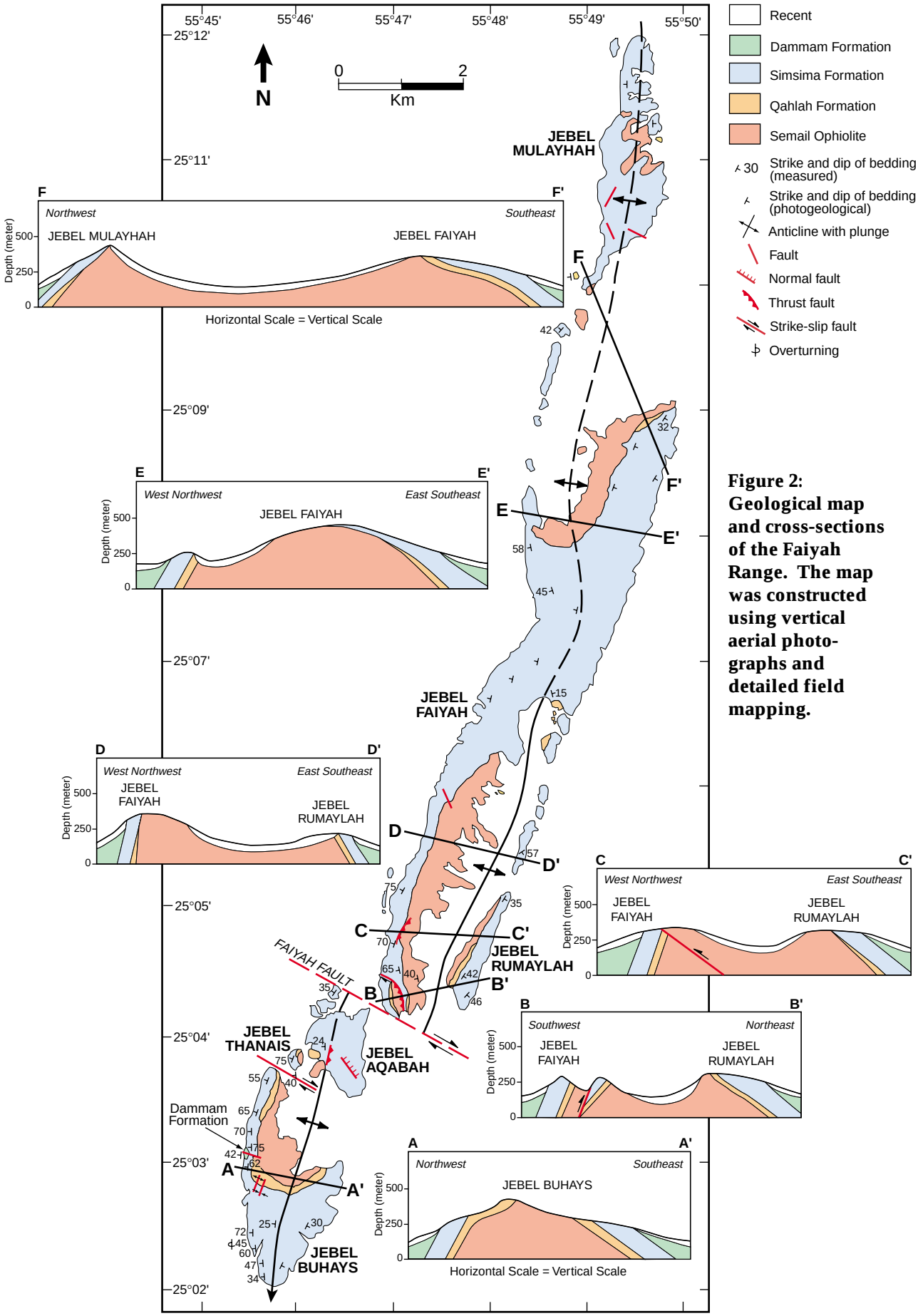


Figure 2: Geological map and cross-sections of the Faiyah Range. The map was constructed using vertical aerial photographs and detailed field mapping.

west northwest-east southeast and occurs at the extreme western end of the Hatta Zone (Jebel Rawdah), about 15 km south-southeast of the Faiyah area. This trend is generally at right angles to the north northeast-south southwest trend (Salah and Mersal, 1998). The third trend is more dominant, and trends north northwest-south southeast, parallel to the Central Oman Mountains, near Al-'Ain. Jebel Hafit is an example of this trend.

STRATIGRAPHY

The **Semail Ophiolite** forms the core of Jebel Faiyah. It is the oldest exposed rock and it consists of a slice of the emplaced Cretaceous oceanic crust and upper mantle which is composed of serpentinites and serpentinized peridotites (Glennie et al., 1974).

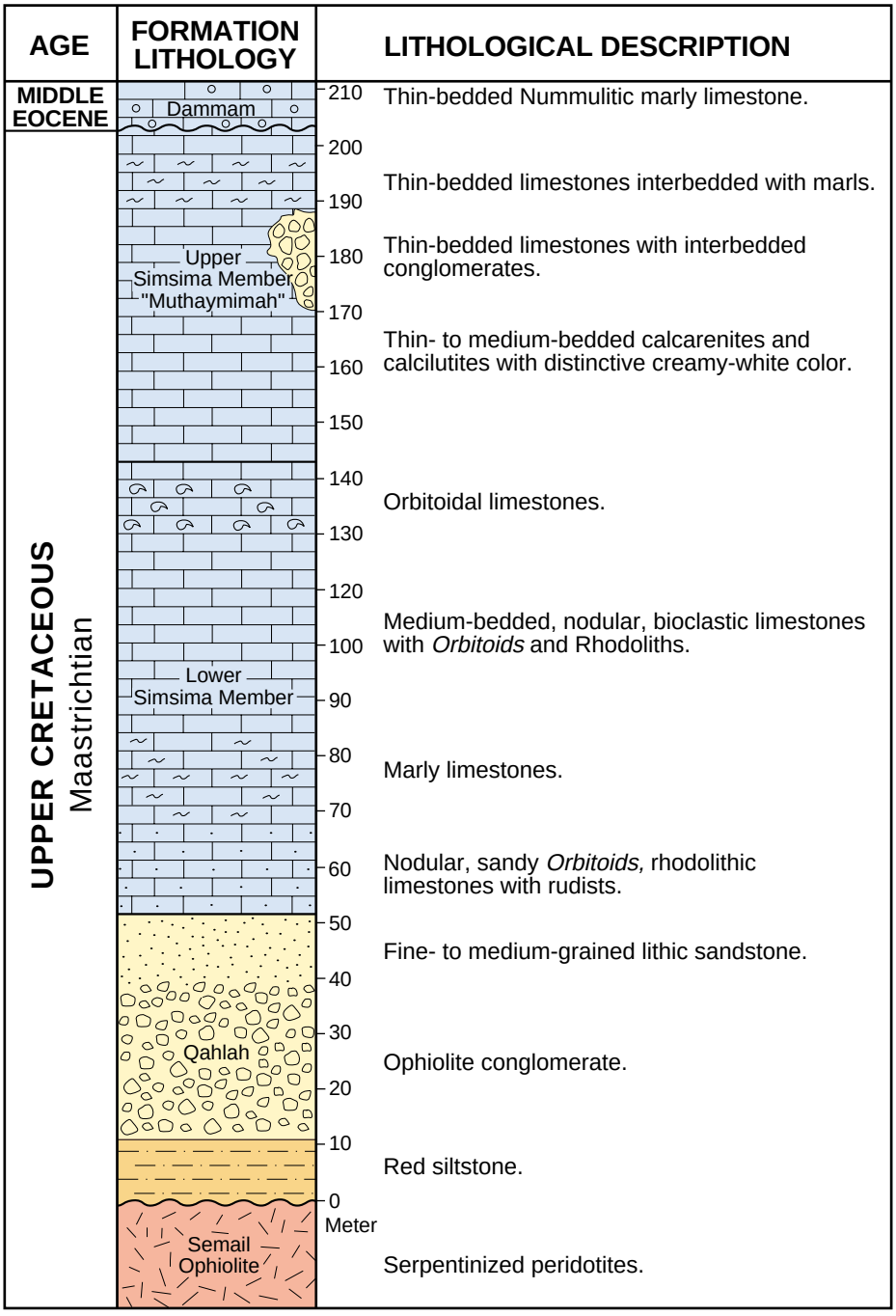


Figure 3: Generalized stratigraphic section for the Faiyah Range.

The Upper Cretaceous Maastrichtian **Qahlah Formation** unconformably overlies the peneplaned Semail Ophiolite (Figure 3). The thickness of the Qahlah ranges from 40 meters (m) at Jebel Faiyah and 70 m at Jebel Buhays (Alsharhan and Nasr, 1996). It consists of reddish-brown, lateritic, ferrugenous mudstone at the base, and grades upward into ophiolitic breccia and ophiolite-clast conglomerate derived from the underlying weathered ophiolite, with laminar and cross-bedded sandstone at the top.

A wide variety of non-marine fluviatile to shallow-marine facies are developed in the Qahlah (Nolan et al., 1990; Alsharhan and Nasr, 1996). Fluviatile facies are well-developed in its lower part, while evidence for a marine transgressive facies, in the upper part, is discernable by the presence of *Omphalocyclus macroporous* (Lamarck) (Figure 4).

The **Simsima Formation** (Figure 3) is about 140 m thick and is subdivided into two members (Alsharhan et al., in press). The lower member attains a thickness of about 80 m and consists of medium-bedded and shallow-marine bioclastic limestone. It contains common fauna such as *Orbitoids medius* (d'Archiac) (Figure 5a), *Loftusia gr. minor morgani*, rhodolithic algae, Rudistids (Figure 5b), Acteonellids as well as Scleractinian corals and echinoids (regular and irregular).

The upper member is about 60 m thick and consists of thin- to medium-bedded, often nodular, creamy white, dolomitic limestone with interbedded conglomerates and yellow marls. It was previously defined by Nolan et al. (1990) as the **Muthaymimah Formation** in a type section located at E55°49'50" and N24°06'30", further south from the study area near Al-'Ain (Figure 1).

The Muthaymimah type section of Nolan et al. (1990) is 300 m thick and consists mainly of limestone, marl and shale. They assign a Paleocene to (Middle?) Eocene age to the Muthaymimah, based on its stratigraphic position above the Maastrichtian "Simsima" and the presence

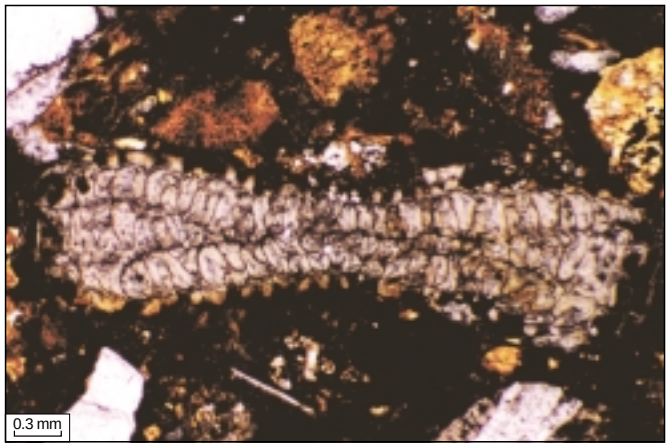


Figure 4: Qahlah Formation (Maastrichtian): conglomerate with *Omphalocyclus macroporous* (Lamarck) megalospheric generation. N.B. The juvenarium (Embryont).

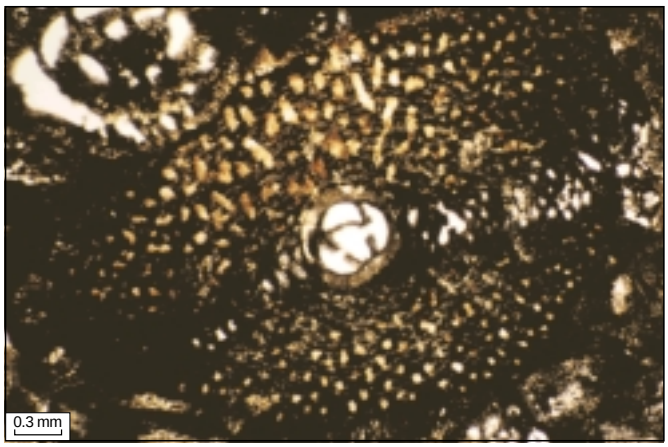


Figure 5a: Simsima Formation, Lower Member (Maastrichtian): limestone (packstone), orange-yellow, rich in *Orbitoids*, such as *Orbitoids medius* (d'Archiac).

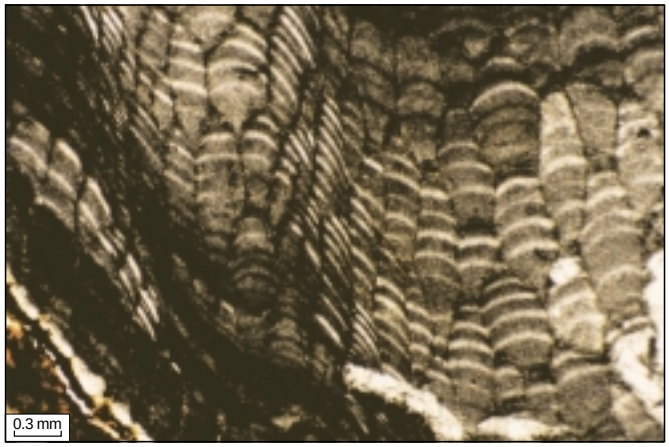
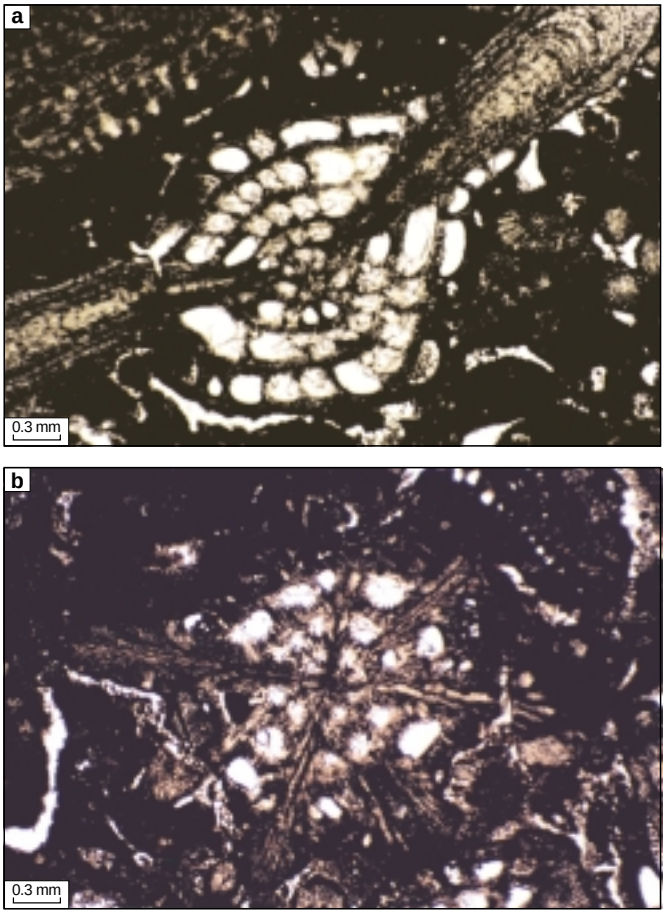


Figure 5b: Simsima Formation, Lower Member (Maastrichtian): wall structure of Rudistids.



Figures 6a and 6b: Simsima Formation, Upper Member (Maastrichtian): limestone (packstone), creamy white, rich in *Siderolites calcitrapoides* (Lamarck) subsp., microspheric generation. (a) Axial. (b) Equatorial.

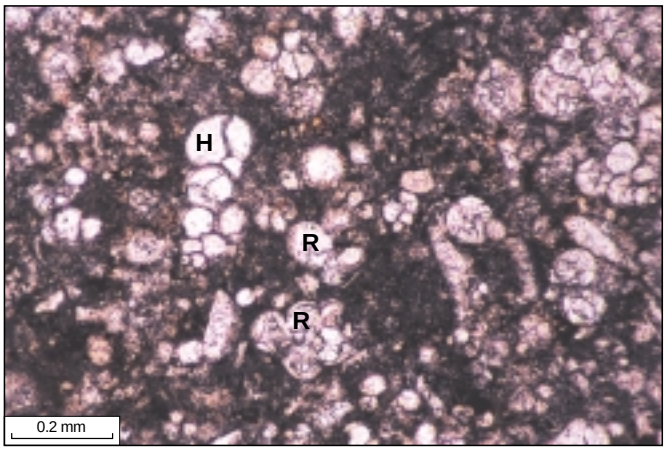


Figure 7: Simsima Formation, Upper Member (Maastrichtian): marl (wackestone), yellow, rich in planktonic foraminifera represented by *Rugoglobigerina* (R) and *Heterohelicidae* (H).

of occasional alveolinid and nummulitic foraminifera and reworked clasts of pene-contemporaneous Paleogene shelf limestones. In the Jebel Faiyah area, Nolan et al. (1990) describe the Muthaymimah as resting unconformably on the "Simsima". They also indicate that in Jebel Rawdah, the Muthaymimah interdigitates and is overlain by an unnamed Eocene basinal marl, shale and limestone lacking the conglomerates typical of the Muthaymimah.

Our field study in the Faiyah Range area indicates that the upper and lower Simsima members are conformable. Furthermore, the microfaunal studies suggest that the upper Simsima member (Muthaymimah of Nolan et al., 1990) is Late Cretaceous in age and we therefore incorporate it into the Simsima as its upper member. It contains *Omphalocyclus macroporous* (Lamarck) and *Siderolites calcitrapoides* Lamarck subsp. nov. (Figures 6a and 6b).

Marl intercalations near the top of the upper member yield a planktonic foraminiferal association which includes *Rugoglobigerina* and *Heterohelicidae* (Figure 7) of Maastrichtian age.

An Eocene outcrop in Jebel Faiyah is correlated here for the first time with the Dammam Formation and to Tle5 of Hunting (1979), from Jebel Hafit (reference section), where a complete sequence of the Eocene-Oligocene is exposed.

In Jebel Faiyah, the **Dammam Formation** is composed of a shallow-marine shelf Nummulitic limestone with thin-bedded marl. It crops out in one locality along the western flank of the Buhays-Aqabah anticline (Figure 2) and attains a thickness of about 10 m. The unit has been dated as latest Middle Eocene (Bartonian) by the presence of *Nummulites ptukhiani* Kacharava, *Nummulites* cf. *Lyelli* d'Archiac and Haime (Figure 8), *Sphaerogypsina globula* (Reuss), Asterocyclinids and Discocyclinids. The Nummulites were dated following Schaub's nummulitic scale (1981).

The depositional hiatus between the Eocene (Bartonian) Dammam and the Late Cretaceous (Maastrichtian) upper Simsima may have resulted from an epeirogenic movement which uplifted the Faiyah Range area.

STRUCTURE

Folds, rather than faults, dominate the structural style of the Faiyah Range. A west northwest-east southeast dextral strike-slip fault, named here as the Faiyah Fault, divides the anticline into two unequal segments (Figure 2). The Faiyah Fault is en-echelon to the Hatta Zone and could probably belong to the Wadi Hatta transform fault (Robertson et al., 1990).

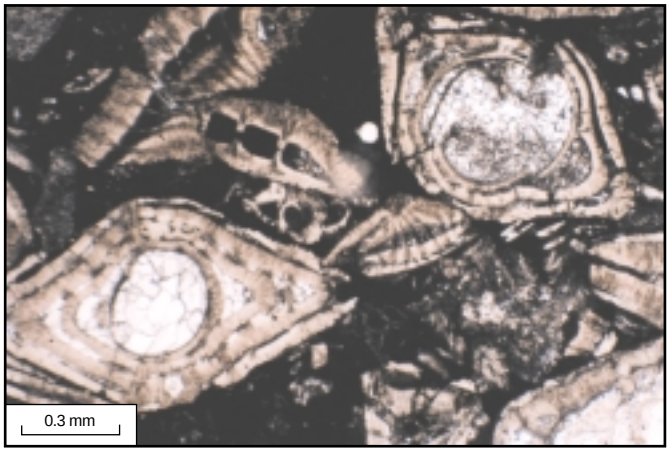


Figure 8: Dammam Formation (Bartonian): Nummulitic marly limestone (packstone), rich in Nummulites (N. cf. Lyelli d'Archiac and Haime) megalospheric generation.

The southern **Buhays-Aqabah segment** is a 5 km long, south-plunging anticline (Figure 2). Cross-section A-A' (Figure 2) shows that the fold is asymmetric with a moderately-dipping eastern flank (up to 30°) and a steeply-dipping western flank (up to 75° and locally vertical to overturned). The western flank is characterized by the presence of a small, shallow anticline and syncline which folds the Qahlah and Simsima formations. These folds may have formed due to flexural slip as shown by the presence of fibrous slickensides between the bedding in the lower part of the Simsima.

Jebel Aqabah was affected by two main faults. The first is a thrust fault which dips northeast thereby juxtaposing the yellow, lower member of the Simsima against its creamy-white, upper member (Figure 9). The second fault is normal and juxtaposes the down-dropped upper Simsima member against the yellow lower member (Figure 10). South of Jebel Thanais, the Faiyah anticline is cut by a west northwest-east southeast trending dextral strike-slip fault.

The northern **Rumaylah-Faiyah-Mulayhah segment** is about 16 km long. It is an asymmetric, undulating anticline in which Jebel Faiyah forms the western flank. An isolated outcrop forming Jebel Rumaylah (Figures 2 and 11) represents the eastern flank. The anticline continues northward for about 5 km at Jebel Mulayhah. Five cross-sections constructed across the fold of the study area (Figure 2, cross-sections B-B' to F-F') show that the anticlinal ridge has a moderately dipping eastern flank (up to 40°) and a steeper-dipping western flank (up to 65°).

Two thrust faults are recognized in the field in the steep, western flank of Jebel Faiyah. The first thrust fault dips southwest, trends parallel to the fold axis, and causes the repetition of the Semail Ophiolite, and the Qahlah and Simsima formations (Figures 2 (B-B') and 11). The second thrust fault strikes parallel to the fold axis and juxtaposes the Semail Ophiolite and the Simsima.

Warrak (1996), based on a stratigraphical and structural study of Jebel Hafit, located about 75 km south of Jebel Faiyah near Al-'Ain (Figure 1), concluded that deformation during the second orogenic event started from the east and migrated westwards. Deformation of the folds to the east of Jebel Hafit started in the Paleocene; while deformation at Jebel Hafit itself started just before the Middle Eocene. Growth continued at Jebel Hafit synchronously with sedimentation until the end of Miocene. Warrak (1996) concludes that Jebel Hafit and other foreland folds in the Northern Oman Mountains (for example, Faiyah) formed prior to the main Zagros deformation which started in very Late Miocene and culminated in the Late Plio-Pleistocene (Stöcklin, 1968; Murris, 1980).

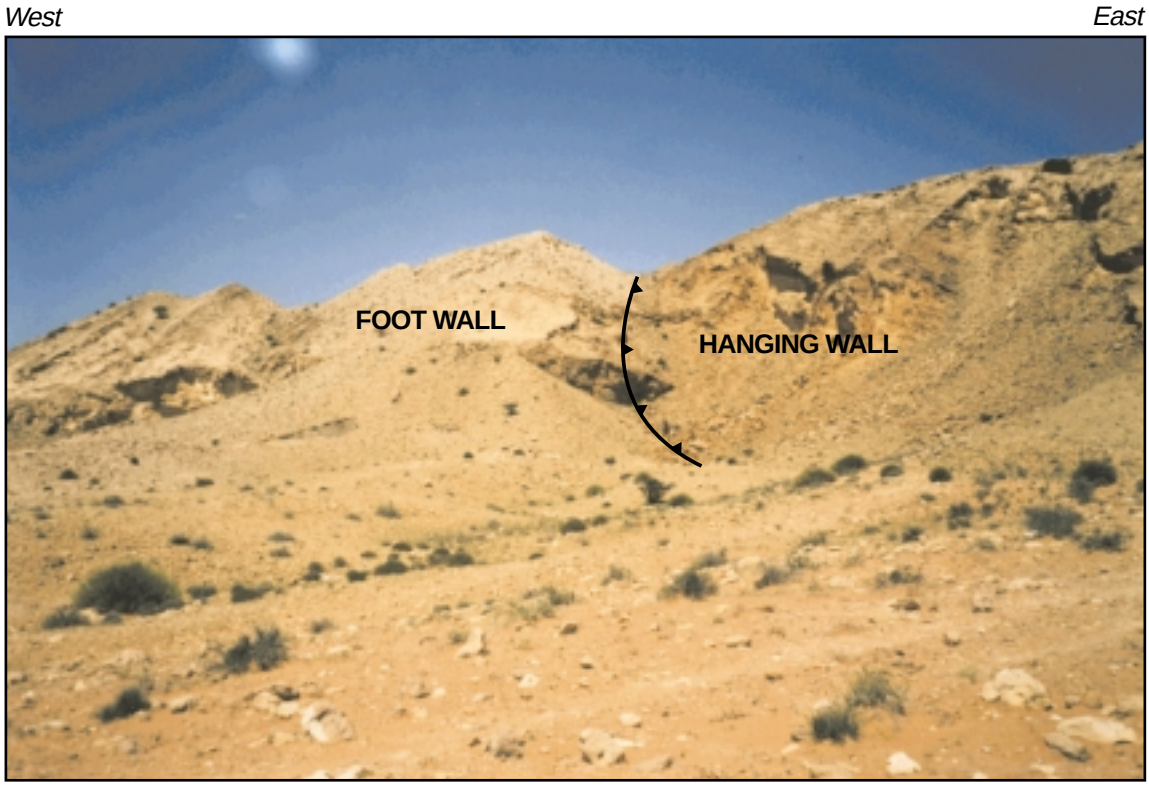


Figure 9: A thrust fault, dipping east, juxtaposing the yellow lower member against the creamy-white upper member (left) of the Simsima Formation, Jebel Aqabah (right).

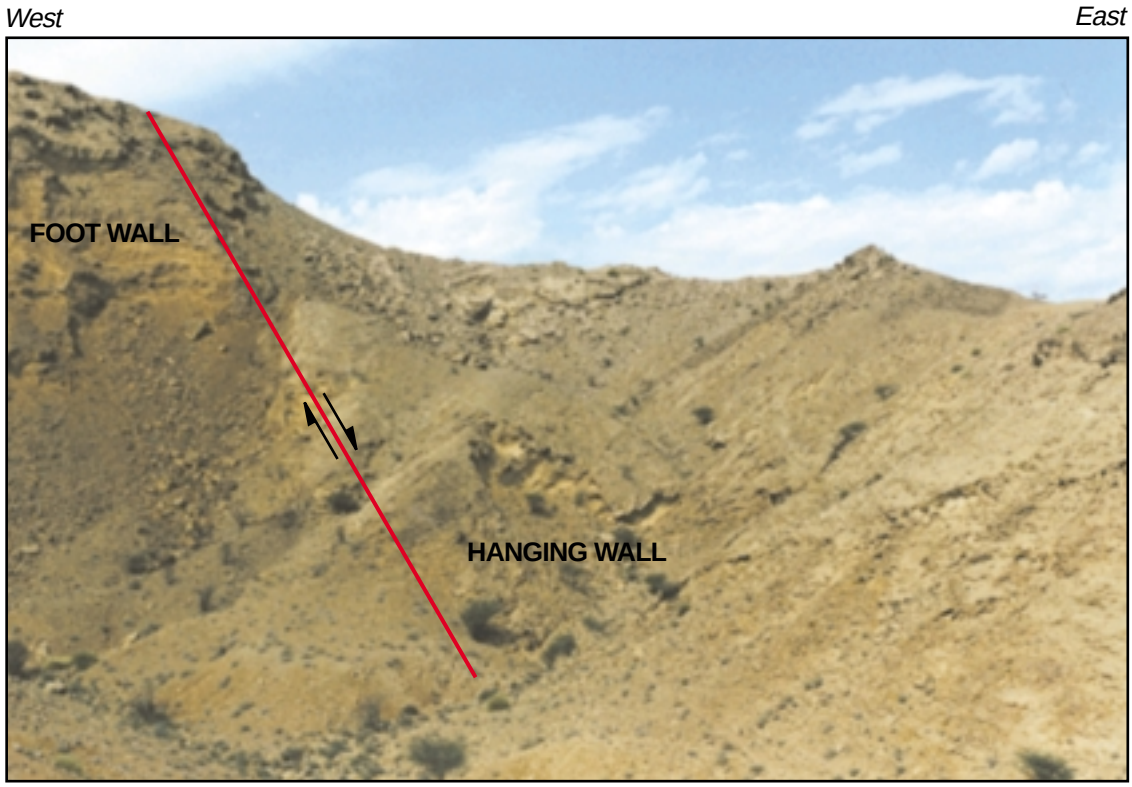


Figure 10: A normal fault, dipping east, causes the downthrow of the creamy-white upper member (right) of the Simsima Formation relative to the yellow lower member (left), Jebel Aqabah.

Figure 11: Panoramic view of the Faiyah-Rumaylah anticline. The fold axial trace trends north northeast-south southwest parallel to the road. A thrust fault, at left, causes the repetition of the Semail Ophiolite 'O', the Qahlah 'Q' and Simsima 'S' formations on the western flank, Jebel Faiyah.

Jebel Faiyah formed after the Middle Eocene Dammam Formation was deposited. The similar positions of Jebels Hafit and Faiyah, relative to the Oman Mountains and foredeep, and the similar timing of deformation (Middle Eocene to Miocene for Hafit and post-Middle Eocene for Faiyah in our study) indicates that these two structures share a similar tectonic evolution.

CONCLUSION

The Faiyah Range is a 21 km long, north northeast-south southwest trending anticline, which is parallel to the western front of the Oman Mountains. It is interrupted by a dextral strike-slip fault into a southwestern segment (Buhays-Aqabah Anticline) and a northeastern segment (Rumaylah-Faiyah-Mulayhah Anticline). The anticline is about 2 km wide and asymmetrical, with gently-dipping eastern flanks and steeply-dipping, sometimes vertical to overturned, western flanks. The anticline formed after the Middle Eocene as a result of regional deformation.

The outcrop formations in Jebel Faiyah consist of the Maastrichtian Qahlah and Simsima, and the Eocene Dammam formations. These units unconformably overlie the Semail Ophiolite. Faunal evidence from the so-called Muthaymimah Formation, which was assigned a tentative Paleocene to Middle Eocene age by Nolan et al. (1990), suggests that this sequence is of Maastrichtian age. It is proposed here that the latter unit be considered as the upper member of the Simsima Formation in the Faiyah Range area. The presence of the Dammam in the Faiyah Range was established in this study on the basis of fossil studies.

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REFERENCES

Alsharhan, A.S. and A.E.M. Nairn 1990. *A Review of the Cretaceous Formations in the Arabian Peninsula and Gulf, Part III, Upper Cretaceous (Aruma Group) Stratigraphy and Paleogeography.* Journal of Petroleum Geology, v. 13, p. 247-266.

Alsharhan, A.S. and A.E.M. Nairn 1994. *Carbonate Platform Models of Arabian Cretaceous Reservoirs.* In J.A. Toni Simo, R.W. Scott and J.P. Masse (Eds.), American Association of Petroleum Geologists, Memoir 56, p. 173-184.

Alsharhan, A.S. and S.J. Nasr 1996. *Sedimentological and Geochemical Interpretation of a Transgressive Sequence: The Late Cretaceous Qahlah Formation in the Western Oman Mountains, United Arab Emirates.* Sedimentary Geology, v. 101, p. 227-242.

Alsharhan, A.S., A. Ziko, H.T. Shebl and G.L. Whittle. *Microfacies Analysis of the Simsima Formation (Maastrichtian) in Northwestern Oman Mountains, United Arab Emirates.* (In press)

Boote, D.R.D., D. Mou and R.I. Waite 1990. *Structural Evolution of the Suneinah Foreland, Central Oman Mountains.* In A.H.F. Robertson, M.P. Searle and A.C. Ries (Eds.), The Geology and Tectonics of the Oman Region. Geological Society of London, Special Publication no. 49, p. 397-418.

Coleman, R.G. 1981. *Tectonic Setting for Ophiolite Obduction in Oman.* Journal of Geophysical Research, v. 86, p. 2497-2508.

Dunne, L.A., P.R. Manoogian and D.F. Pierini 1990. *Structural Style and Domains of the Northern Oman Mountains (Oman and United Arab Emirates).* In A.H.F. Robertson, M.P. Searle and A.C. Ries (Eds.), The Geology and Tectonics of the Oman Region. Geological Society of London, Special Publication no. 49, p. 375-386.

Government of the U.A.E. 1979. *Geological Map of the United Arab Emirates. Sheets 2 and 4. Scale 1:250,000.* Ministry of Petroleum and Mineral Resources. Abu Dhabi.

Glennie, K.W., M.G.A. Boeuf, M.W. Hughes Clarke, M. Moody-Stuart, W.F.H. Pilaar and B.M. Reinhardt 1973. *Late Cretaceous Nappes in Oman Mountains and their Geologic Evolution.* American Association of Petroleum Geologists Bulletin, v. 57, p. 5-27.

Glennie, K.W., M.G.A. Boeuf, M.W. Hughes Clarke, M. Moody Stuart, W.H.F. Pilaar and B.M. Reinhardt 1974. *Geology of the Oman Mountains.* Verhandelingen Koninklijk Nederlands Geologisch Mijnbouwkundig Genootschap, v. 31, 423 p.

Hamdan, A.A. and H.S. Anan 1993. *Cretaceous/Tertiary Boundary in United Arab Emirates.* Middle East Research Center, Ain Shams University, Earth Science Series, v. 7, p. 223-231.

Hunting Geology and Geophysics Limited 1979. *Report on a Mineral Survey of the U.A.E., Al-Ain Area.* Ministry of Petroleum and Mineral Resources, Abu Dhabi, v. 9, p. 1-29.

Lippard, S.J., A.W. Skelton and I.G. Gass 1986. *The Ophiolite of Northern Oman.* Geological Society of London Memoir, v. 11, p. 1-178.

Mount, V.S., S. Hertig, G.P. O'Donnell and R.W. Krantz 1995. *Structural Style and Timing of the Northern Oman Mountain Deformation Front.* In M.I. Al-Husseini (Ed.), Middle East Petroleum Geosciences, GEO'94. Gulf PetroLink, Bahrain, v. 2, p. 690-698.

Murris, R. 1980. *Middle East: Stratigraphic Evolution and Oil Habitat.* American Association of Petroleum Geologists Bulletin, v. 64, p. 597-618.

Nolan, S.C., B.P. Clissold, J.D. Smewing and P.W. Skelton 1986. *Late Campanian to Tertiary Palaeogeography of the Central and Northern Oman Mountains.* In Symposium on the Hydrocarbon Potential of Intense Thrust Zones. Ministry of Petroleum and Mineral Resources, UAE and OPEC, Kuwait, Abu Dhabi, p. 175-200.

Nolan, S.C., P.W. Skelton, B.P. Clissold and J.D. Smewing 1990. *Maastrichtian to Early Tertiary Stratigraphy and Palaeogeography of the Central and Northern Oman Mountains.* In A.H.F. Robertson, M.P. Searle and A.C. Ries (Eds.), The Geology and Tectonics of the Oman Region. Geological Society of London, Special Publication no. 49, p. 495-519.

Noweir, M.A. and N.S. Eloutefi 1997. *The Structure and Stratigraphy of Jabal Malaqet-Jabal Mundassa Area, Southeast Al-Ain, Northern Oman Mountains, United Arab Emirates.* Neues Jahrbuch fur Geologie und Palaontologie, Abhandlungen, v. 204, p. 263-284.

O'Donnell, G.P., C.B. Daly, V.S. Mount and R.W. Krantz 1995. *Seismic Modeling Over the Margham Field, Dubai, U.A.E.* In M.I. Al-Husseini (Ed.), Middle East Petroleum Geosciences, GEO'94. Gulf PetroLink, Bahrain, v. 2, p. 737-747.

Open University-Oman Ophiolite Project, Memoir Map. Scale 1:250,000. 1983. Department of Earth Sciences, Open University, U.K.

Patton, T.L. and S.J. O'Connor 1988. *Cretaceous Flexural History of Northern Oman Mountain Foredeep, United Arab Emirates.* American Association of Petroleum Geologists Bulletin, v. 72, p. 797-809.

Ricateau, R. and P.H. Riche 1980. *Geology of the Musandam Peninsula (Sultanate of Oman) and its Surroundings.* Journal of Petroleum Geology, v. 3, p. 139-152.

Robertson, A.H.F., A.E.S. Kemp, D.C. Rex and C.D. Blome 1990. *Sedimentary and Structural Evolution of a Continental Margin Transform Lineament: The Hatta Zone, Northern Oman Mountains.* In A.H.F. Robertson, M.P. Searle and A.C. Ries (Eds.), The Geology and Tectonics of the Oman Region. Geological Society of London, Special Publication no. 49, p. 285-305.

Salah, M.G. and M.A. Mersal 1998. *Surface Geology of Jebel Rawdah, Oman Mountains.* GeoArabia (this issue), v. 3, no. 3, p. 401-414.

Schaub, H. 1981. *Nummulites et Assilines de la Tethys Paleogene. Taxinomie, Phylogenese et Biostratigraphie.* Memoires Suisses de Paleontologie, v. 104, p. 1-236; v. 105 (Atlas I); v. 106 (Atlas II).

Searle, M.P. 1985. *Sequence of Thrusting and Origin of Culminations in the Northern and Central Oman Mountains.* Journal of Structural Geology, v. 7, p. 129-143.

Searle, M.P. 1988a. *Thrust Tectonics of the Dibba Zone and the Structural Evolution of the Arabian Continental Margin along the Musandam Mountains (Oman and United Arab Emirates).* Journal of Geological Society of London, v. 145, p. 43-53.

Searle, M.P. 1988b. *Structure of the Musandam Culmination (Sultanate of Oman and United Arab Emirates) and the Straits of Hormuz Syntaxis.* Journal of the Geological Society of London, v. 145, p. 831-845.

Searle, M.P., N.P. James, T.J. Calon and J.D. Smewing 1983. *Sedimentological and Structural Evolution of the Arabian Continental Margin in the Musandam Mountains and Dibba Zone, United Arab Emirates.* Geological Society of America Bulletin, v. 94, p. 1381-1400.

Searle, M.P., D.J.W. Cooper and K.F. Watts 1990. *Structure of the Jebel Sumeini-Jebel Ghawil Area, Northern Oman.* In A.H.F. Robertson, M.P. Searle and A.C. Ries (Eds.), The Geology and Tectonics of the Oman Region. Geological Society of London, Special Publication no. 49, p. 361-374.

Skelton, P.W., S.C. Nolan and R.W. Scott 1990. *The Maastrichtian Transgression onto the Northwestern Flank of the Proto-Oman Mountains: Sequences of Rudist-bearing Beach to Open Shelf Facies.* In A.H.F. Robertson, M.P. Searle and A.C. Ries (Eds.), The Geology and Tectonics of the Oman Region. Geological Society of London, Special Publication no. 49, p. 521-574.

Stöcklin, J. 1968. *Structural History and Tectonics of Iran. A Review.* American Association of Petroleum Geologists Bulletin, v. 52, p. 1229-1258.

Warburton, J., T.J. Burnhill, R.H. Graham and K.P. Issac 1990. *The Evolution of the Oman Mountains Foreland Basin.* In A.H.F. Robertson, M.P. Searle and A.C. Ries (Eds.), The Geology and Tectonics of the Oman Region. Geological Society of London, Special Publication no. 49, p. 419-427.

Warrak, M. 1996. *Origin of the Hafit Structure: Implications for Timing the Tertiary Deformation in the Northern Oman Mountains.* Journal of Structural Geology, v. 18, p. 803-818.

Woodward, D. 1994. *Contributions to a Shallow Aquifer Study by Reprocessed Seismic Sections from Petroleum Exploration Surveys, Eastern Abu Dhabi, United Arab Emirates.* Journal of Applied Geophysics, v. 31, p. 271-289.

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