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THE STRUCTURE OF WADI HAM AREA, NORTHERN OMAN MOUNTAINS, UNITED ARAB EMIRATES (UAE)

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ABSTRACT

This study presents the first detailed structural examination of the Wadi Ham area, near Fujairah in the Northern Oman Mountains, United Arab Emirate (UAE). Structural mapping and field measurements combined with analysis of satellite images of this area were carried out to clarify obduction and post-obduction tectonic events in the Northern Oman Mountains. The study area is largely represented by upper mantle peridotites and overlying oceanic crustal massive gabbros of the Semail Ophiolite. An unusually thick metamorphic sole is faulted into the overlying ophiolite contacts between the metamorphic sole and the serpentinized peridotite including both the original intra-oceanic detachment ductile shear zone and later brittle faults. Field investigation of the Wadi Ham document three main shear zone orientations with NW-SE, NE-SW and N-S trends and E-W trends. Strike-slip ductile shear zones and brittle faults also dominate the structural style elsewhere in the Wadi Ham area. The oldest (NW-SE) group of shear zones has steep dips and shows early dextral slip later reactivated by sinistral shears and oblique reverse motion. These shear zones are cut by later E-W trending sinistral shear zones and NE-SW normal faults. The normal faults can be related to the Tertiary (Alpine) compressional event, which has been correlated with Zagros thrusting. The NE-SW shears are themselves overprinted by N-S shear zones, which, with the E-W shear zones, can be related to local deformation affecting the Semail Ophiolite.

INTRODUCTION

The Oman Mountains lie at the eastern extremity of the Arabian plate and run in a broad arc parallel to the Gulf of Oman coastline (Figure 1). The mountains have an average width of about 75km, reaching a maximum of 130km in the central part, and rise to a height of about 3000m. The Oman Mountains formed in response to two main orogenic events in Late Cretaceous and mid-Tertiary. 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 [1-10]. The second occurred in the Late Eocene-Miocene. It was responsible for the formation of foreland folds [11] and folding of Maastrichtian – Tertiary neoautochthonous units in the foredeep [7].

The neoautochthonous sequence and underlying ophiolite and allochthonous units were deformed by post-obduction compression to form belts of folds and thrust faults along the western front of the Oman Mountains.

The study area is located along Wadi Ham (Figure 1) in the Northern Oman Mountains, United Arab Emirates (UAE), an area of mainly Semail ophiolite exposures. The Wadi Ham Zone is a narrow NW-SE trending valley within the Semail ophiolite. The area forms the southwestern boundary of the Khor Fakkan massif – a block of mainly peridotitic and gabbroic rocks of the Semail Ophiolite with in-faulted slices of subophiolitic metamorphic sole. The rocks exposed along Wadi Ham include the Semail Ophiolite and at its base the metamorphic sole at its base (Figure 1).

The lack of detailed structural analysis in the Wadi Ham area has encouraged us to conduct the current study. Combined structural mapping and field measurements combined with analysis of satellite images, were carried out an the Wadi Ham area to provide a detailed structural data for the Wadi Ham Fault Zone, and to clarify obduction and post-obduction tectonic events in the Northern Oman Mountains.

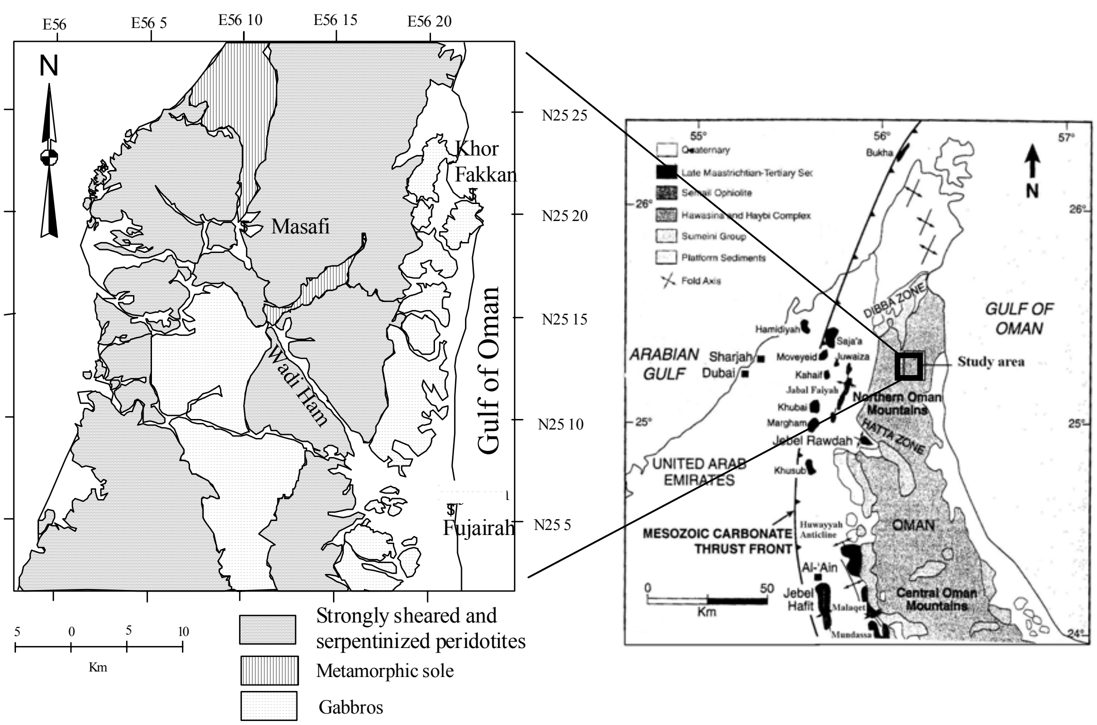

Fig. 1. Simplified geological map of the Wadi Ham area. See inset for location.

LITHOLOGIES OF THE WADI HAM AREA

Most of the study area exposes the Semail Ophiolite, essentially an upper mantle peridotite sequence with overlying oceanic crustal massive gabbros (Figure 1). An unusually thick metamorphic sole from beneath the peridotite has also been emplaced by faulting into the overlying Semail Ophiolite. The Semail Ophiolite is the largest and best exposed thrust sheet of oceanic crust and upper mantle. It was emplaced onto the Arabian continental margin during the Late Cretaceous time, and has been studied by many authors, e.g. [1,3,5,8,9,10,12,13].

The Semail Ophiolite comprises peridotite that is strongly sheared and serpentinized near the basal thrust, and contains banded migmatites and gabbro intrusions.

The base of the ophiolite is marked by metamorphic sole amphibolites and greenschists along the Semail thrust. The contacts between the metamorphic sole and the serpentinized peridotite include both the original intra-oceanic detachment ductile shear zone and later brittle faulting (Figure 2).

Fig. 2. The contact (black thick line) between the serpentinized peridotites and the metamorphic sole.

STRUCTURE OF THE WADI HAM AREA

This study presents the first detailed structural analysis of the Wadi Ham Zone. Field investigation shows that most of the structural elements are shear zones, faults and fractures (joints). Strike-slip ductile shear zones and brittle faults also predominate in the structural style elsewhere in the Wadi Ham area.

Ductile shear Zones

Shear zones are the most common structural element observed in the Wadi Ham area. Field observations from 10 separate sites (WH01-WH10) document four shear zone orientations. The three principal orientations trend NW-SE, NE-SW and N-S, but minor shears that strike E-W have been recorded in a few localities.

Most of the shear zones are steeply dipping (60^o to vertical; Figure 3). Clear field shear sense indicators reveal strike-slip, normal and reverse movements. Shear zones in peridotite show shear fabric and minor folding, and some show small pull-apart features consistent with strike-slip (Figure 4).

Figure 5 shows the main orientations of all shear measurements at each site in the Wadi Ham area. Some sites show all three of the principal shear orientations, whereas others show only one or two of these. Field observations show definite time relationships between these structures, with younger shear zones and faults cross cutting the older ones.

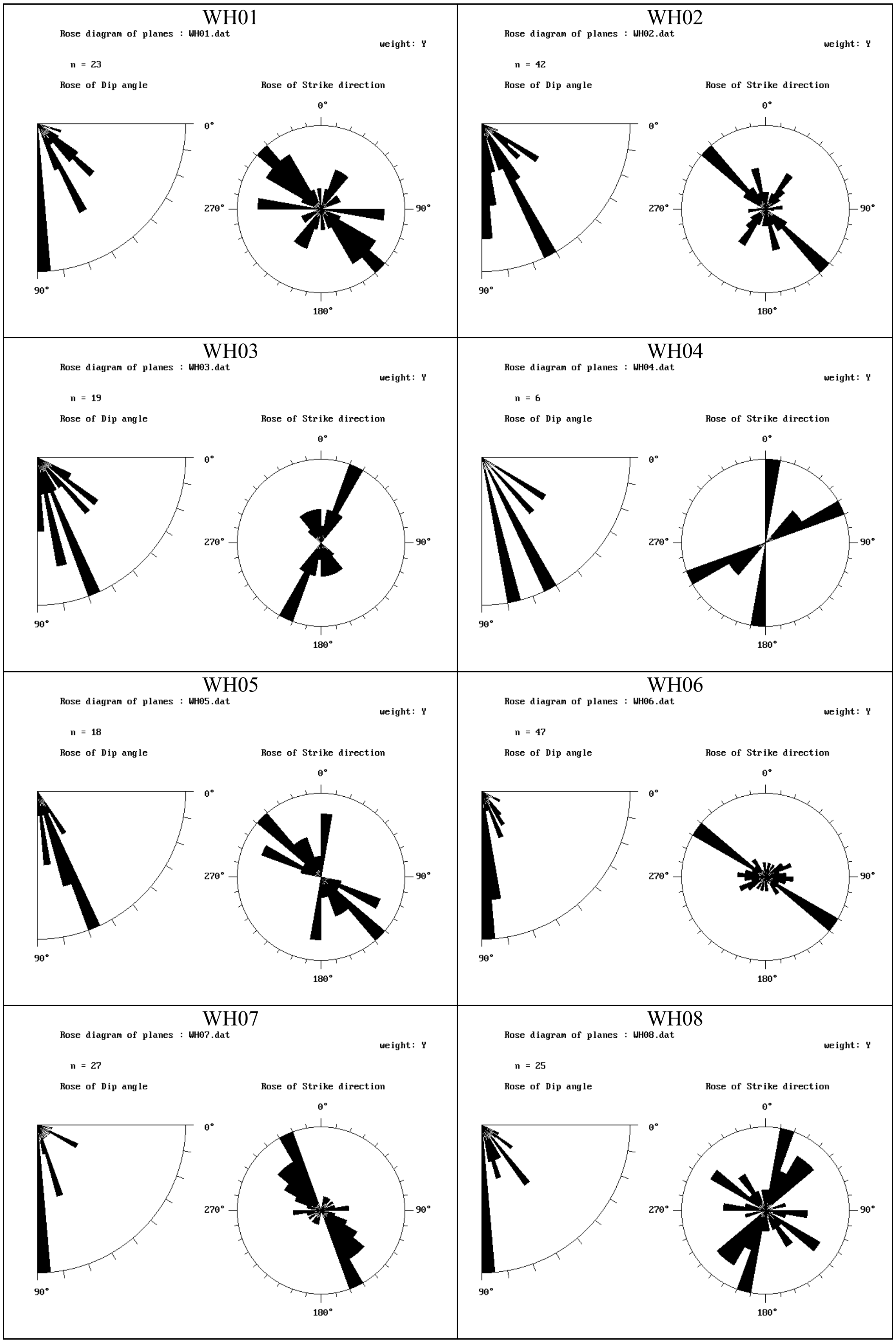

Fig. 3. Rose diagrams showing main orientations of shear zones at each site within the Wadi Ham study area.

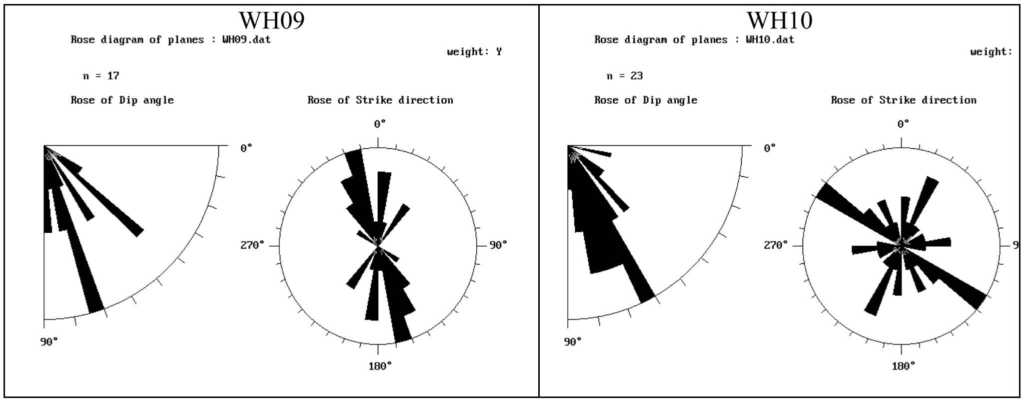

Fig. 3: … continued.

Fig. 4. Small vein-filled pull-apart feature showing sinistral shear sense.

NW-SE shear zones

The oldest group of shear zones is oriented NW-SE. These shear zones are steeply dipping and show an early dextral sense of shear. The foliation within these zones trends NW trend and dips NE. This confirms to the direction of obduction of the Semail Ophiolite, suggesting that the NW-SW shear zones were formed during the obduction. The shear zones were reactivated during later deformation as sinistral and oblique reverse brittle faults as can be inferred from the movement along them.

The NW-SE shear zones are interpreted to have been initially parallel to the SW dipping Semail thrust and were later steepened and reused as strike-slip structures. Some of these zones contain asbestos veins and most show dextral movement.

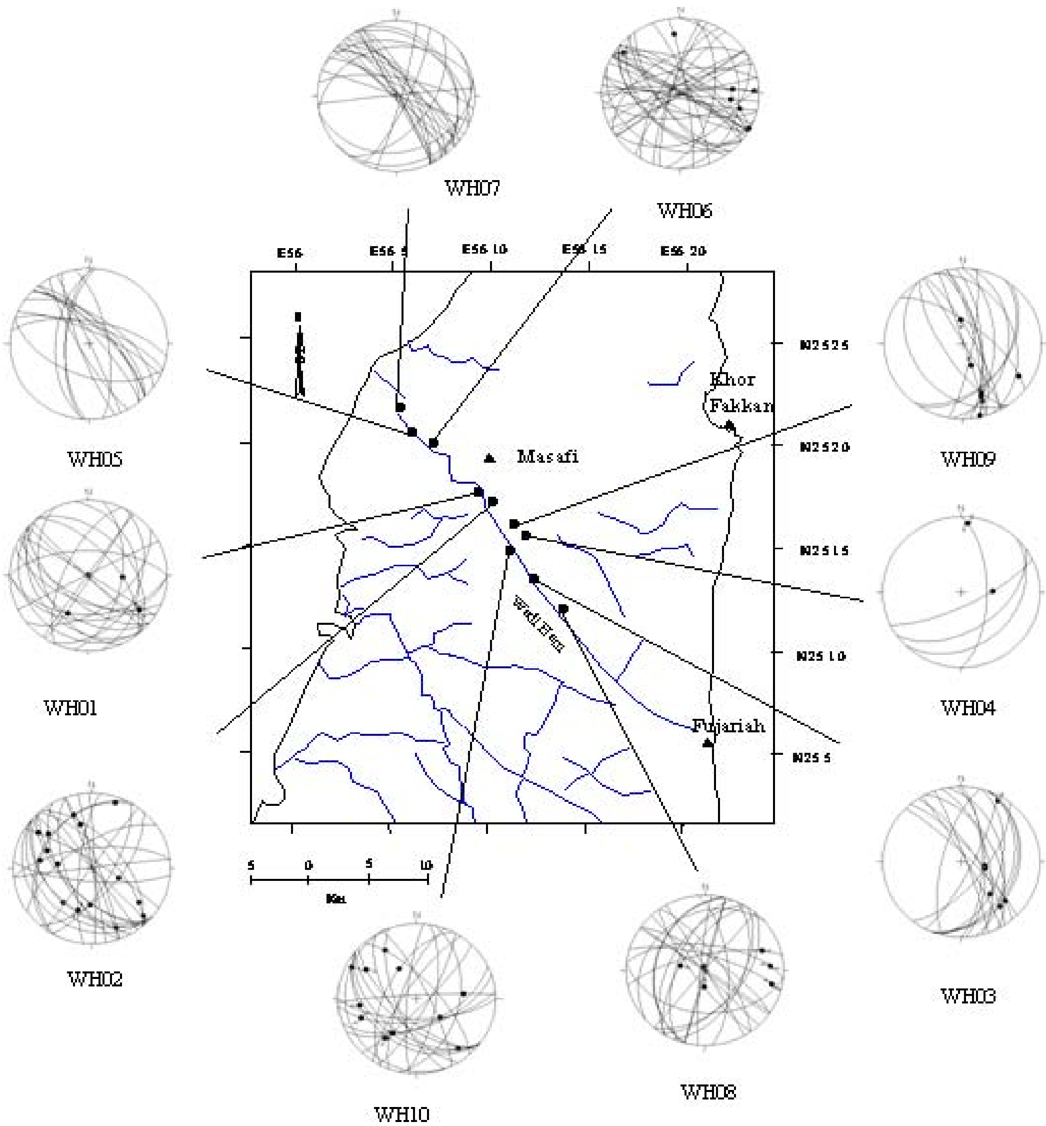

Fig. 5. Stereonet projections of shear zones observed at each site within the Wadi Ham study area.

NE-SW shear zones

The NE-SW shear zones dip steeply southeast. They are younger than the NW-SE shear zones, as inferred from cross-cutting relationships, and are overprinted by other shears oriented N-S.

N-S directed shear zones

The N-S shear zones are steeply dipping and show small pull-apart basins indicating sinistral strike-slip movement. They cut the earlier NE-SW shear zones indicating and the older NW-SE shears.

E-W shear zones

E-W shear zones are not observed at all stations in the study area. Field observations show that these shears are the oldest in the study area and, at one site, are cut by a NE-SW shear (Fig. 6).

Steeply oriented mylonitic textures occur in the shear zones in the southern part of the study area, and could be related to early movement along the Wadi Ham. At one location, a thin serpentinite was observed between the metamorphic sole and an intrusion of quartz porphyry. The quartz porphyry intrusion is locally mylonitic with a foliation trending NNE and dipping NW. The serpentinite shows pronounced crenulations trending NW-SE with axes plunging SE. These crenulations may have formed by compression during activity of the main NW-SE trending faults along the Wadi.

Brittle faults

Faults are the main structural feature observed in the study area. Interpretation of satellite images has allowed the identification of distinct structural trends (Figure 7). The majority of the faults trend NW-SE, NE-SW and NNE-SSW to NNW-SSE. The faults are vertical to sub-vertical and show both strike-slip and dip-slip movements. Most of them show clear signs of movement along their fault planes, as indicated by slickenlines (Figure 8). One of the major faults in the study area is the Wadi Ham Fault. It runs about > 30km NW-SE and shows dextral strike-slip movement. In the northwestern part of the study area, it is cut by another dextral strike-slip fault oriented NE-SW. Wadi Ham Fault is parallel to the obduction direction of the Semail Ophiolites, suggesting that it formed during the Late Cretaceous.

SW-directed thrusts are thought to be related to NE-directed subduction of the Arabian continental margin and SW-directed emplacement of the Semail Ophiolite. Some of the early SW-directed thrusts were reactivated by late NE-directed normal faulting.

Field investigations show that the NNE to NE-trending faults offset those trending NW, and that the NE-SW shear zones postdate the steep NNW-trending reverse faults.

Fig. 6. NE-SW shear offsetting an E-W shear.

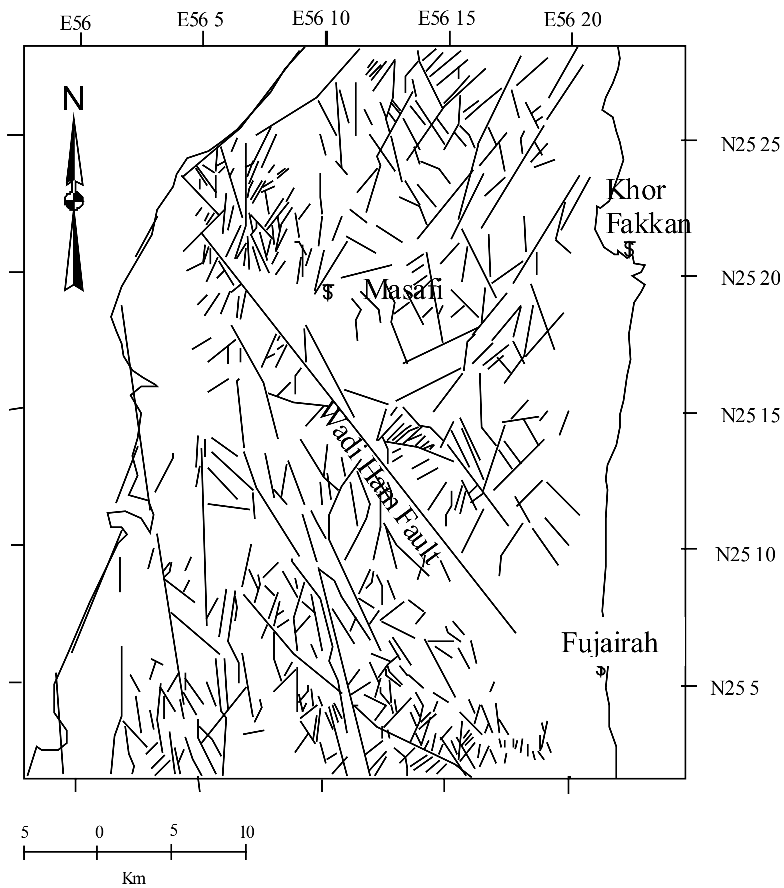

Fig. 7. Lineaments of the study area traced from satellite imagery.

Fig. 8. Fault plane with slickenlines (parallel to pencil).

DISCUSSION

A detailed structural study carried out in the Wadi Ham area of the Northern Oman Mountains has shown that the main structural elements are shear zones and faults. Four groups of shear zones have been identified, and trend E-W, NW-SE, NE-SW and N-S, in order of their relative age. Field observations show definite time relationships with younger shear cross-cutting older ones. Because the area is restricted to the Semail Ophiolite, it is not possible to provide precise ages for each group of shears zones. Therefore, we related these structures to the four compressional phases reported by others in different areas within the Northern Oman Mountains [14], respectively at the beginning of the Early Maastrichtian, in the late Early Maastrichtian, during the Early Paleocene time and at the Late Paleocene-Early Eocene boundary.

The shear zones in the Wadi Ham area are compatible with those of [14] such that we interpret the shear zones as follows: (1) The NW-SE directed shears are considered to have formed during the Late Cretaceous, at the time of the Semail Ophiolite obduction, the direction of which they parallel, (2) the NE-SW shears are assigned to the Early Paleocene deformation, and (3) the N-S shears are attributed to the Paleocene to Early Eocene deformation. The minor N-S shears are also considered to have formed during the Late Cretaceous, but prior to the NW-SE shear zones.

Analysis of the satellite imagery indicates that the dextral, NW-SE trending Wadi Ham Fault is cut by, and hence predates, a dextral NE-SW strike-slip fault. The NW-SE faults are therefore considered to be older than the NE-SW faults. The NW-SE faults are parallel to the emplacement direction of the Semail Ophiolite and are therefore believed to have formed in Late Cretaceous time. Since the NE-SW faults are younger than the NW-SE faults, they are considered to have formed during the Early Paleocene compressional stage.

CONCLUSION

Structural analysis along the Wadi Ham Fault between the cities of Masafi and Fujairah in the Northern Oman Mountains has revealed a tectonic evolution involving several deformational stages and related structural elements, and has clarified obduction and post-obduction tectonic events in the Northern Oman Mountains, United Arab Emirates.

Field observations indicate that a deformation along the Wadi Ham has been accommodated by shearing and faulting rather than by folding. Four generation of shear zones have been identified. The first is oriented E-W and formed at the beginning of the Late Cretaceous. The second is oriented NW-SE and formed during the Late Cretaceous. The third formed during the Early Paleocene and strikes NE-SW. The final generation is oriented N-S and formed during Paleocene - Early Eocene time.

The second major group of structural elements observed in the Wadi Ham area is brittle faults oriented NW-SE, NE-SW and NNE-SSW to NNW-SSE. The NW-SE faults were formed during the Late Cretaceous, whereas the NE-SW faults were formed in the Early Paleocene.

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