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Internal geometry and origin of the Hubat structural culmination, Oman Mountains

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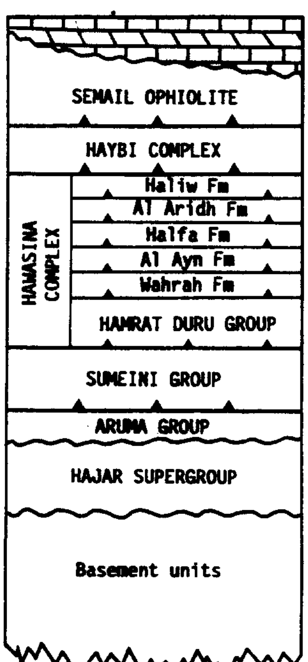
Abstract—The Hubat structure is a doubly plunging antiform affecting an allochthonous succession of Mesozoic sedimentary rocks (the Hawasina Complex) overlain by the Haybi Complex and the Semail Ophiolite. It is cored by a well exposed imbricated nappe of the Hamrat Duru Group. Detailed investigations of the Hamrat Duru Group led to the recognition of a main phase of imbrication, followed by a phase of meso- and macroscopic folding with axes at a high angle to the strike of the imbricates, parallel to their assumed transport direction. Thrust relationships displayed in this area indicate that the floor thrust of the Semail Ophiolite is younger than the emplacement of the lower units and therefore 'out-of-sequence'. This culmination may have originated either as a result of a post-emplacement regional compressive event of Tertiary age or during the emplacement of allochthons above an oblique ramp during the late Cretaceous orogeny.

INTRODUCTION

THE Oman Mountains record an orogenic event of late Cretaceous age that led to the south-westerly emplacement of a series of allochthonous units onto the north-eastern margin of the Arabian peninsula (Lees 1928, Allemann & Peters 1972, Glennie *et al.* 1973, 1974). These units comprise a telescoped slope to basinal Mesozoic succession of sedimentary rocks deposited along this margin (the Sumeini Group and the Hawasina Complex), remnants of within-plate oceanic islands or seamounts (the Haybi Complex) and the Semail Ophiolite, thought to have originated at an ancient oceanic spreading ridge of Cenomanian–Turonian age (Reinhardt 1969, Allemann & Peters 1972, Glennie *et al.* 1973, 1974, Searle & Malpas 1980, 1982, Watts & Garrison 1986) (Figs. 1 and 2). The emplacement of these allochthons was followed by a marine transgression and widespread deposition of shallow marine carbonate sequences of Maastrichtian–Paleogene age (Lees 1928, Morton 1959, Tschopp 1967, Wilson 1969).

This paper is concerned with the study of the Hubat



AGE	DESCRIPTION	ORIGIN
Maastrichtian to Early Tertiary	Limestones, dolostones	Shallow-marine epicontinental sea
Cenomanian to Turonian	Ultramafic and mafic igneous suite	Oceanic lithosphere generated at an ancient spreading ridge
Permian and Triassic	Olistostromal and volcanic mélanges, metamorphic rocks	Oceanic islands or seamounts, sub-ophiolitic metamorphic aureole
Triassic to Middle Cretaceous	Series of thrust-bounded sedimentary rock sequences dominated in the lower slices by calci-turbiditic grainstones and in the upper slices by red cherts and mudstones.	Continental slope to basin transition of the eastern margin of Arabia
Permian to Middle Cretaceous	Dolomites, sandstones, conglomerates, reefoid boundstones	NE-facing continental slope of Arabia
Late Cretaceous	Shales, conglomerates	Easterly-derived flysch deposited in a foredeep before the emplacement of the allochthons
Middle Permian to Middle Cretaceous	Limestones, dolostones, minor porcellanites	Arabian shelf platform
Pre-Permian	Crystalline rocks overlain by partly metamorphosed siliciclastics and carbonate rocks	Substrate to the Arabian shelf carbonate platform

Fig. 1. Stratigraphy of the Oman Mountains, modified after Glennie *et al.* (1973, 1974) and Searle & Malpas (1980, 1982). The shelf carbonate sequences of the Hajar Supergroup and the Aruma flysch unconformably overlie the basement units and are in turn tectonically overlain by a series of allochthons. These are, from bottom to top, the Sumeini Group, the Hawasina Complex, the Haybi Complex and the Semail Ophiolite. Maastrichtian and early Tertiary neo-autochthonous carbonate rocks unconformably overlie all the older rocks.

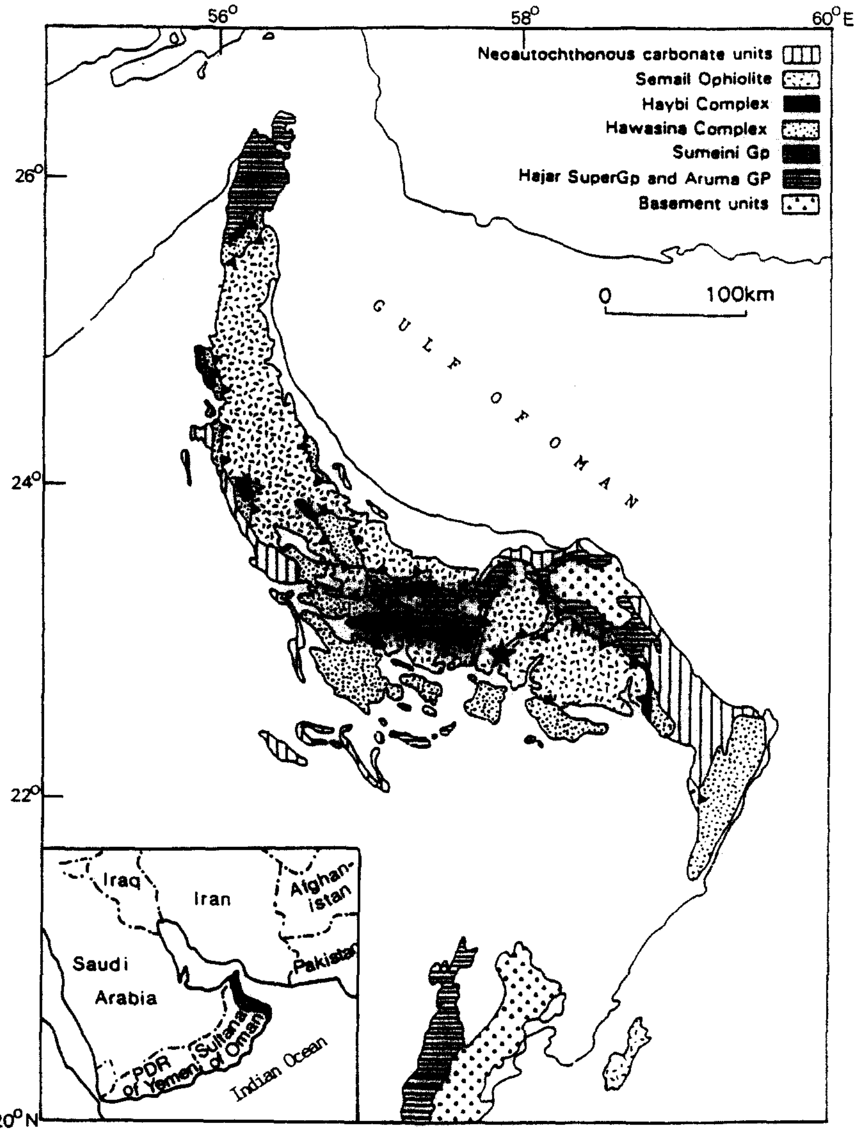


Fig. 2. General geological map of the Oman mountains, modified after Glennie *et al.* (1973, 1974). The pre-Permian basement and the Hajar Supergroup outcrop in tectonic windows aligned along a major antiformal axis which forms the backbone of the Oman Mountains (see also Fig. 9). The location of the Hubat structure is shown by a star.

structure, a doubly-plunging antiform exposing a series of nappes of the Hawasina Complex in a tectonic window through the Semail Ophiolite, in an area where the rock exposure ranges between 80 and 100%. This structure affects a series of imbricates of the Hamrat Duru Group, the structurally lowest and most proximal unit of the Hawasina Complex (Fig. 1), which displays numerous examples of classical fold and thrust configurations on the meso- and macroscopic scales.

TECTONOSTRATIGRAPHY IN THE STUDY AREA

The Hubat tectonic window has an elliptical outcrop pattern of approximately 70 km^2, with a long axis oriented in a NE–SW direction (Fig. 3a). It exposes three distinct units: the Hamrat Duru Group, the Al Ayn and the Haliw Formations. These were originally recognized in the study area by Glennie *et al.* (1974). They are known in the Oman orogen to exist as distinct thrust nappes, with the Hamrat Duru Nappe being the lowest and the Haliw Nappe the highest in the tectonostratigraphy (Fig. 1).

The Hamrat Duru Group outcrops in the core of the window (Fig. 3a) and comprises four formations (Cooper 1987): the Upper Triassic–Middle Jurassic Guwayza Sandstone Formation, the Middle–Upper Jurassic Guwayza Limestone Formation, the Upper Jurassic–Lower Cretaceous Sid'r Formation and the Lower–Middle Cretaceous Nayid Formation (Glennie *et al.* 1973, 1974, Cooper 1987). The Guwayza Sandstone Formation, whose lower boundary is not exposed in the study area, exceeds 200 m in thickness. It consists of brown, decimeter- to meter-bedded oolitic grainstones with varying amounts of detrital quartz, interbedded with thin sequences of light-coloured mudstone. This formation grades into the Guwayza Limestone Formation which has a thickness of 100 m

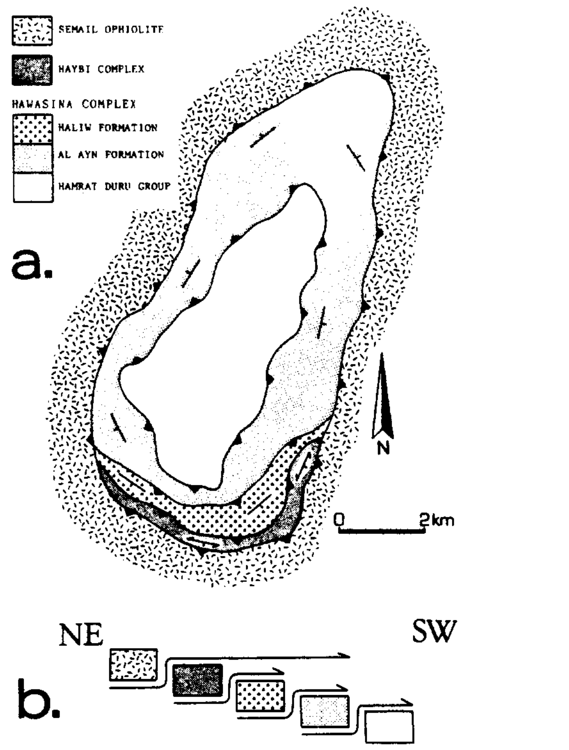


Fig. 3. (a) Distribution of the Hawasina units and the Haybi Complex in the Hubat tectonic window. The Hamrat Duru Group is completely surrounded by rocks of the Al Ayn Formation which dip consistently away from the center of the window. The Haliw Formation and the Haybi Complex outcrop only in the south as relatively thin tectonic slivers which abut on the floor thrust of the Semail Ophiolite. The bedding of the Haliw Formation and the main tectonic foliation in the pelitic schists of the Haybi Complex dip S; (b) tectonostratigraphic relationships of the Hawasina and Haybi Complexes and the Semail Ophiolite, as deduced from the above observations.

and is formed of light grey, meter-bedded well sorted oolitic grainstones and minor mudstones. The Sid'r Formation abruptly but conformably overlies the Guwayza Limestone Formation and comprises 50–80 m of largely silicified turbiditic grainstones of a distal nature. The characteristic rusty-brown colour and relative resistance to erosion make these rocks a useful marker in localities where the structure is complex. The Nayid Formation conformably overlies the Sid'r Formation and consists of over 100 m of partly silicified, light-coloured, centimeter- to decimeter-bedded grainstones, also of distal turbiditic affinity.

The Al Ayn Formation is of Upper Triassic–Lower Jurassic age (Bernoulli & Weissert 1987). It outcrops uniformly around the Hamrat Duru Group and comprises brown decimeter-bedded sandy grainstones and dark grey quartz arenites. Altered mafic igneous rocks observed locally were assigned to this formation. These rocks are known outside the study area to intrude the Al Ayn sequences (Glennie *et al.* 1974). In general, rocks of the Al Ayn Formation are openly folded, although tight to isoclinal angular folds also occur. The orientation of the fold axes does not follow a consistent pattern. The stratigraphic thickness of this formation is unknown, but in other parts of the orogen it attains 350 m (Glennie *et al.* 1974). The Haliw Formation, of Upper Triassic age (Bernoulli & Weissert 1987), occurs as small isolated hills in the south part of the study area. It consists of undeformed centimeter-bedded red radiolarian cherts and white fossiliferous limestones.

Apart from a stylolitic cleavage locally developed in the grainstone sequences of the Hamrat Duru Group, these rocks do not display any planar or linear tectonic fabrics.

The Haybi Complex is exposed in the south part of the study area and consists of strongly foliated quartz-pelitic schists, interpreted to belong to a sub-ophiolitic metamorphic aureole of Senonian age (Allemann & Peters 1972, Searle & Malpas 1980, 1982). The Semail Ophiolite completely surrounds the Hawasina and Haybi inlier. It is represented by highly altered peridotites and dunites cross-cut by trondjhemitic lenses, and coarse-grained slightly foliated gabbroic rocks. The tectonostratigraphic order of the Hawasina and Haybi Complexes and the Semail Ophiolite is shown in Fig. 3(b).

INTERNAL STRUCTURE OF THE HAMRAT DURU GROUP

A detailed geological map of the Hamrat Duru Group at the core of the Hubat window is shown in Fig. 4. Four structural cross-sections are drawn through this area (Fig. 5): two in a NE direction, parallel to the long axis of the window (sections AA' and BB') and two others normal to this axis (sections CC' and DD').

The deformational style of the Hamrat Duru Group is dominated by thrust faults causing the tectonic repetition of the stratigraphy in more than 12 imbricate slices, dipping and facing NE (Figs. 4 and 5; section AA'). In addition, at least four steeply overturned imbricates occur in the south-western part of the area which merge at a low angle with the projection of the Hamrat Duru roof thrust above the erosional level, while facing downwards (Fig. 5, section BB'). North-west-trending, SW-verging folds are developed within individual imbricates (Fig. 5, section AA'). Systematic measurement of meso- and macroscopic fold axes indicates a predominance of axes plunging shallowly to steeply NE, parallel to the long axis of the Hubat window (Fig. 6a). Sections CC' and DD' (Fig. 5) display some examples of these folds. The roof and floor thrusts of all major imbricates are openly folded along an antiformal axis which parallels the long axis of the window. This is clearly indicated by the curvature of the trace of the imbricate fault surfaces (Fig. 4) and is also demonstrated in section CC' and DD' (Fig. 5). This large-scale fold geometry is further reflected on a stereoplot of bedding in the Hamrat Duru lithologies (Fig. 6b).

High-angle faults occur widely across the study area. Their length ranges from several meters to 2 km, and their orientation generally follows a radial pattern with respect to the shape of the Hubat window. Although most of the faults bear an apparent strike-slip component, their true displacement has not been determined.

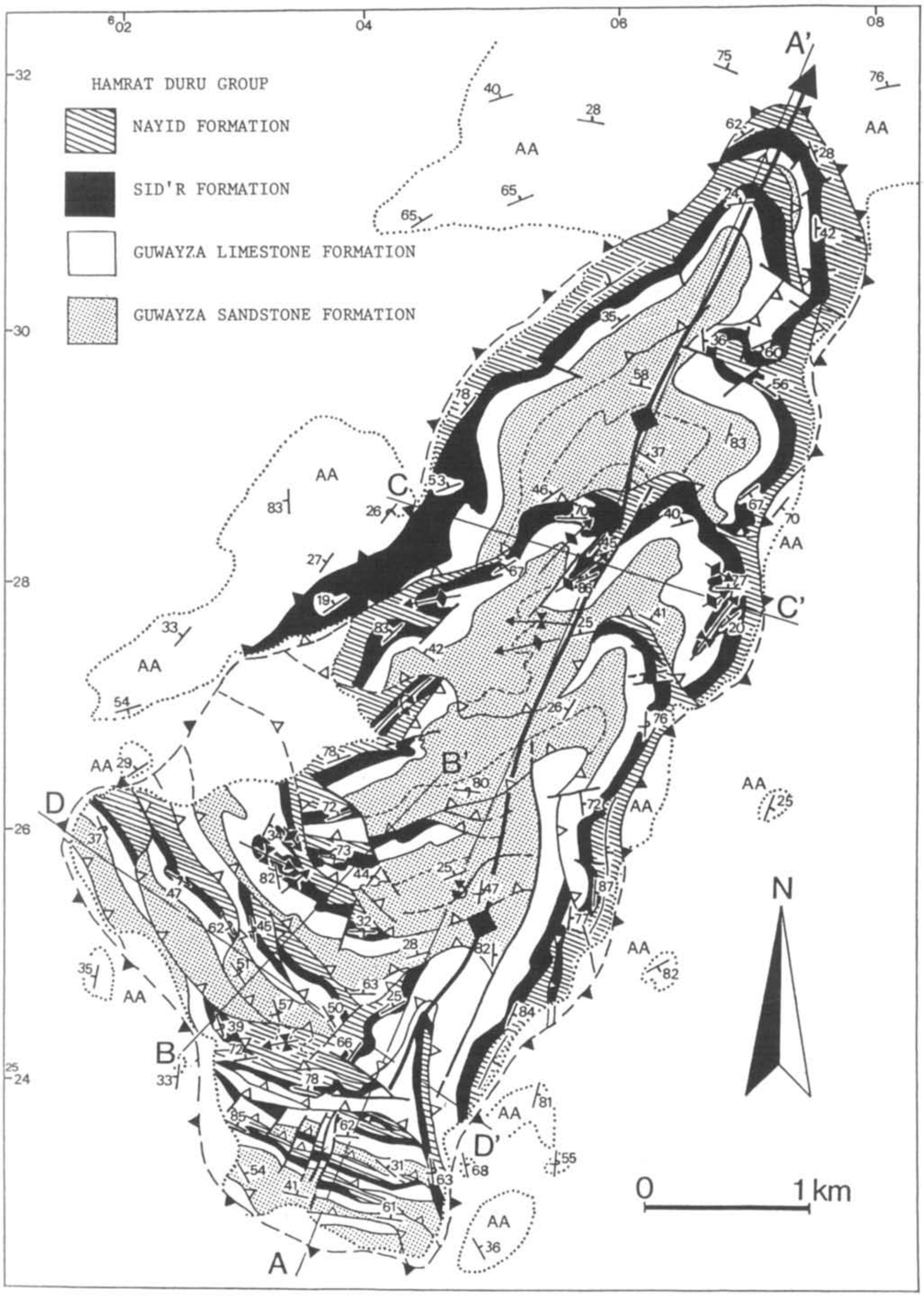


Fig. 4. Internal structure of the Hamrat Duru Group exposed at the center of the Hubat tectonic window, surrounded by the Al Ayn Formation (AA) (see Fig. 3a). The Hamrat Duru Group is structurally repeated in a number of NW-striking, NE-facing and NE-dipping imbricates. These are folded about a NE-oriented antiformal axis, as demonstrated by the curvature of the fault and bedding traces. The topography is shown in the cross-sections AA', BB', CC' and DD' of Fig. 5. The co-ordinates are from the Universal Transverse Mercator Grid (zone 40).

DISCUSSION

The order of superposition of the allochthons in the study area is in agreement with the tectonostratigraphic framework of the Oman Mountains (Figs. 1 and 3b). All Hawasina units are not represented in the Hubat window, probably due to the initial palaeogeographic extent of the units as well as their position relative to the continental margin prior to their emplacement.

The internal geometry of the Hamrat Duru Group in the Hubat culmination may be interpreted as an hinterland-dipping duplex (Boyer & Elliott 1982) whose floor thrust lies at an undetermined depth and whose roof thrust is the floor thrust of the tectonically overlying Al Ayn Formation. A south-westward emplacement of the Hamrat Duru Group may be inferred on the basis of the displacement along the imbricate thrust faults and the SW vergence of folds developed in the imbricates. Boyer & Elliott (1982) have shown that the imbricates within a duplex characteristically curve asymptotically upward to the roof thrust, while facing upwards. This configuration contrasts with the observations made in the southern

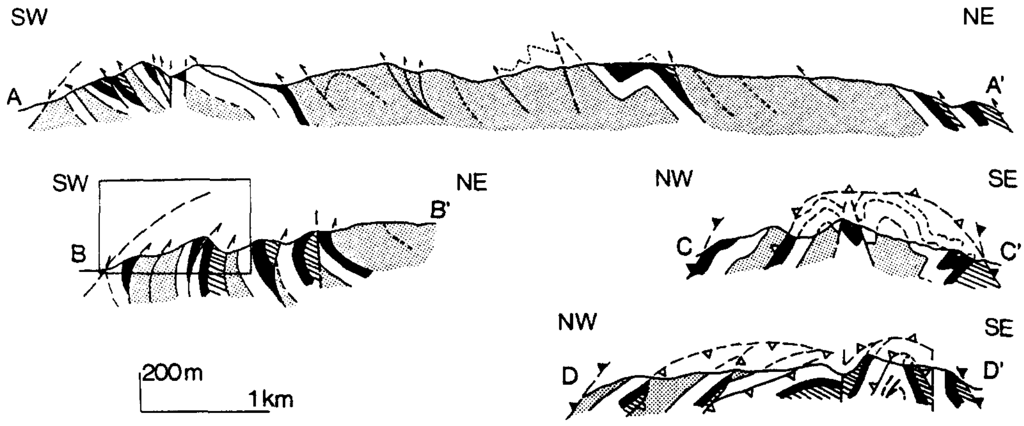


Fig. 5. Structural cross-sections of the deformed Hamrat Duru Group. See Fig. 4 for locations and lithological symbols. The inset on section BB′ depicts the angular relationships of the Hamrat Duru imbricates and the roof thrust of the duplex.

part of the study area where the imbricates curve asymptotically upwards to the roof thrust of the Hamrat Duru Group while facing *downwards* (Fig. 5; section BB′). These relationships suggest that the imbrication of the Hamrat Duru Group occurred prior to the emplacement of the overlying Al Ayn unit, causing the truncation of the imbricates. Such a process does not conform to the 'piggy-back' model of thrust propagation in which lower thrust surfaces in an imbricate system are younger than higher ones (Bally *et al.* 1966, Boyer & Elliott 1982). Alternatively, the angular relationship of the Hamrat Duru imbricates and the Al Ayn floor thrust may indicate a NE translation of the Al Ayn Nappe with respect to the Hamrat Duru Nappe due to back-thrusting.

The surface trace of the basal thrusts of the northern and the central imbricates cut down-section into the hinges of folds in the footwall rocks leading to the truncation of these folds by the floor thrust of the overlying imbricate and thereby suggesting that the thrust faults *post-date* folding of the footwall rocks. As shown in Fig. 7, however, this pattern can be obtained by

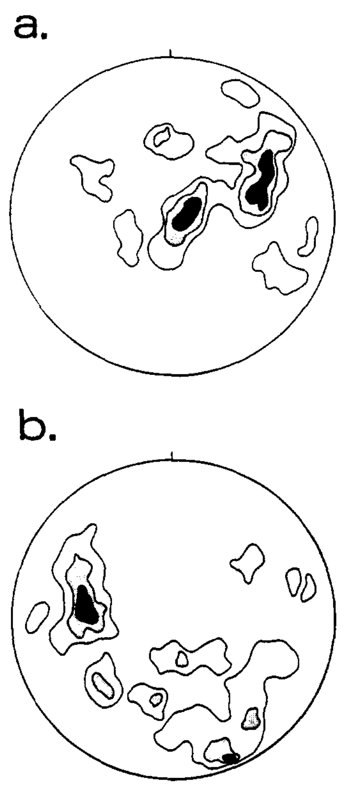


Fig. 6. (a) Equal-area, lower hemisphere projection of fold axes measured in the Hamrat Duru Group (n = 107, contours: 6, 4 and 2% per 1% area). The pattern indicates a predominance of steeply to moderately NE-plunging axes; (b) equal-area, lower hemisphere projection of poles to bedding in the Hamrat Duru Group (n = 282, contours: 4, 3, 2 and 1% per 1% area). The pattern defines a great circle girdle representing a NE-plunging antiform. The axial plane of this structure strikes NE but its dip cannot be estimated from the diagram.

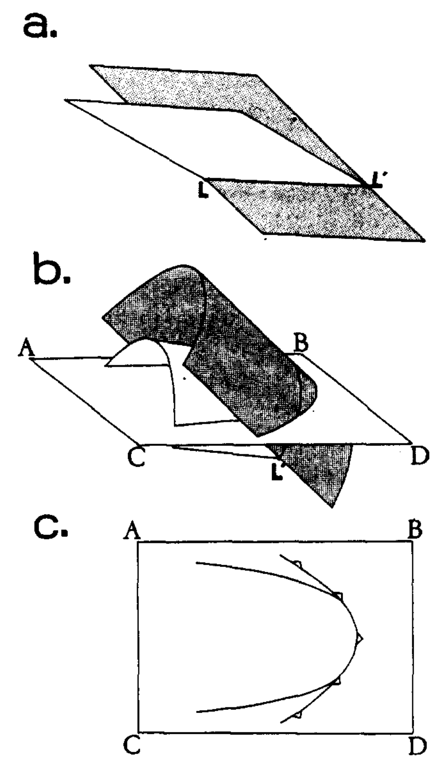


Fig. 7. (a) Spatial relationship of a moderately dipping thrust fault surface (stippled plane) and a given stratigraphic horizon lying in its footwall (unstippled plane). Line LL′ is the 'cut-off' line; (b) folding of these planes results in a curved cut-off line which intersects a horizontal plane ABCD at an oblique angle; (c) the pattern thereby obtained on the horizontal plane, representing the erosional surface, shows the trace of the folded thrust fault truncating the folded stratigraphic horizon lying in the footwall of this fault.

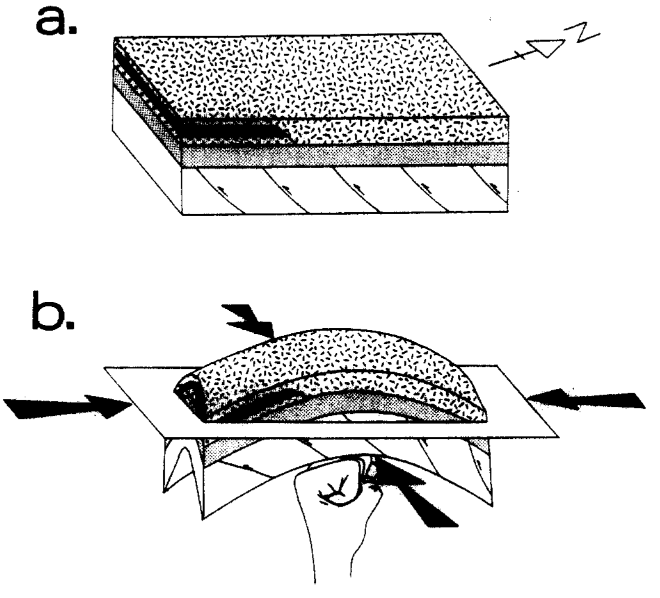


Fig. 8. (a) Block diagram summarizing the tectonostratigraphic setting of the Hawasina and Haybi Complexes and the Semail Ophiolite. The Semail Ophiolite overlies the Al Ayn Formation in the north but farther south, the floor thrust of the Semail Ophiolite climbs up-section over the Haliw Formation and the Haybi Complex. The Hamrat Duru Group underlies the Al Ayn Formation and is the lowest tectonic unit exposed in the study area. (b) These units are folded along a doubly-plunging antiform with a maximum shortening axis in the NE direction and a minimum shortening axis in the NW direction. This event may have been achieved by buckling of the nappes either during a regional horizontal compressive event of Tertiary age (as shown by the arrows) or through oblique ramping during the late Cretaceous emplacement of the nappes. Alternatively, this culmination could have resulted from upward-directed forces (as shown by the fist) induced by subsurface salt diapirism (see text for discussion). The lithological symbols are the same as in Fig. 3.

folding the thrust faults and the footwall rocks simultaneously.

The Haliw Formation and the Haybi Complex overlie the Al Ayn Formation only in the south part of the study area (Fig. 3a). These units are interpreted to lie in the footwall of a structural ramp above which the Semail Ophiolite was emplaced (Fig. 8a). The Semail Thrust thus climbs up-section towards the south-west in a previously established tectonostratigraphic succession. This interpretation is in agreement with Graham (1980a,b), Searle (1985) and Searle & Cooper (1986) who documented the truncation of the Hawasina Nappes by the overlying Semail Ophiolite in other parts of the Oman Mountains. Graham (1980a,b) accounted for this setting by a two-stage emplacement history of the late Cretaceous nappes: an early stage of telescoping of the Sumeini Group and the Hawasina and Haybi Complexes, followed by emplacement of the ophiolite. Additional complications in the sequence of nappe emplacement in the study area are suggested by the tectonic relationships of the Al Ayn and Hamrat Duru Nappes described earlier.

The tectonostratigraphic succession of the Hawasina and Haybi Complexes and the Semail Ophiolite is folded along a doubly-plunging antiform with a maximum shortening axis oriented in a NE direction, parallel to the long axis of the Hubat window and to the inferred direction of nappe emplacement, and a minimum shortening axis oriented in a NW direction (Fig. 8b). Northeast-plunging folds observed in the Hamrat Duru Group (Fig. 6a) are thought to be related to this event. The attitude of these folds as well as the attitude of bedding (Fig. 6b) imply that the Hamrat Duru imbricates were dipping NE prior to culmination development.

Regional setting and origin of the Hubat structure

The regional strike of the Mesozoic allochthons parallels the Oman coastline, trending NW–SE in the north and the central Oman Mountains, deflecting to a NE–SW orientation south of the southern end of the mountains along the Huqf axis (Gorin *et al.* 1982). Two major sets of fold axes are recognized (Fig. 9). Folds belonging to the predominant set parallel the strike of the orogen and affect all units of the Oman stratigraphy. The second set of folds is generally perpendicular to the first set and is not recorded in the neo-autochthonous carbonate units. The Jebel Akhdar–Jebel Nakhl–Saih Hatat culmination axis forms the backbone of the mountains (Figs. 2 and 9). It is variably plunging and bears an overall NW–SE orientation, thus being assigned to the predominant set of folds. This axis comprises a NE-oriented kink (Jebel Nakhl). The Hubat structure lies along a NE-oriented antiformal axis located 30 km SE of Jebel Nakhl (Fig. 9) that comprises other windows of the Hawasina Complex (see the geological map of Glennie *et al.* 1974). This axis parallels Jebel Nakhl and terminates north against Saih Hatat and is the main representative of the second set of folds.

The deformation of the Mesozoic allochthons in the Oman Mountains resulted from two main orogenic phases (Lees 1928, Glennie *et al.* 1974). The most important is the late Cretaceous emplacement of these allochthons on the Arabian continental margin. The

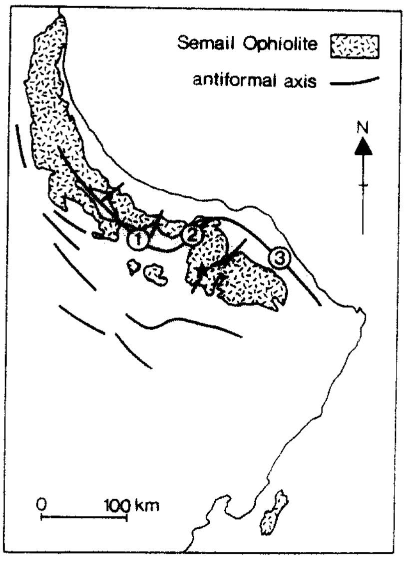


Fig. 9. Distribution of major fold trends in the Oman orogen (after Glennie *et al.* 1974). 1. Jebel Akhdar; 2. Jebel Nakhl; 3. Saih Hatat. The Hubat structure, shown by a star, is located along a NE-trending antiformal axis.

other is a regional NE–SW-oriented horizontal compressive movement of Paleogene age, correlatable with the Zagros orogeny of Iran (Stocklin 1974, Ricou 1971, 1976). Most of the early workers have assigned the formation of the Jebel Akhdar–Jebel Nakhl–Saih Hatat antiformal axis to a Tertiary age (Lees 1928, Morton 1959, Wilson 1969, Glennie *et al.* 1974, Glennie 1977). Hence, the fold trends observed in the Oman orogen (Fig. 9) may be regarded as a Tertiary interference pattern. Figure 8(b) illustrates the stress constraints for the Hubat culmination (arrows) related with such an event.

Evaporitic sequences in the pre-Permian basement units were documented from the SW foothills of the Oman Mountains by Gorin *et al.* (1982). These authors have invoked sub-surface salt diapirism to account for some of the structural doming observed in this area (see also Tschopp 1967). Salt piercement structures are known to be widespread in the Zagros belt in Iran (O'Brien 1957, Stocklin 1974). They occur either as isolated plugs or along the axial surface of anticlines exceeding 90 km in length (O'Brien 1957, fig. 3, p. 362). Diapirism generally involves upward-directed forces and is evidenced by layer-parallel extension (Billings 1954, p. 92, Ramberg 1963) and the absence of folding of the overlying strata (Stephansson 1977, Coward 1981). The lack of extensional structures and the intense folding recorded in the Hamrat Duru Group (Fig. 5; sections C and D) make this mechanism (symbolized by the fist in Fig. 8b) an unlikely cause for the formation of the Hubat structure.

Bernoulli & Weissert (1987) suggested that the Jebel Akhdar–Jebel Nakhl–Saih Hatat antiformal axis is a consequence of structural ramping at depth beneath the Hawasina Nappes and the Hajar Supergroup. Jebel Akhdar and Saih Hatat would represent hangingwall culminations that formed above two NE-dipping ramps, while Jebel Nakhl represents a culmination formed above a NW-dipping ramp (S. Hanna written communication 1983) (Fig. 10a&b). While these faults are exposed nowhere in Oman, it is conceivable that the distribution of fold trends observed in the orogen is governed by sub-surface ramp configurations created during the emplacement of the nappes onto the Arabian continental margin. The orientation of the ramps, in turn, may have been controlled by a pre-existing anisotropy along the margin of Arabia such as a fault pattern (cf. Laubscher 1981), paleofacies changes or paleotopography. The sole of this hypothetical thrust system is either blind (Bernoulli & Weissert 1987) or reaches the synorogenic erosion surface west of the Oman Mountains, beneath the Quaternary deposits of the Rub' al Khali desert. The Hubat culmination may have developed above a NE-oriented ramp lying at depth above the Hajar Supergroup, i.e. within the Sumeini Group or the Hawasina Complex (Fig. 10a). The doubly-plunging nature of the Hubat structure may be attributed to a variation in the amount of structural thickening by imbricate thrust accretion along the strike of the underlying ramp. Note that the footwall geometry

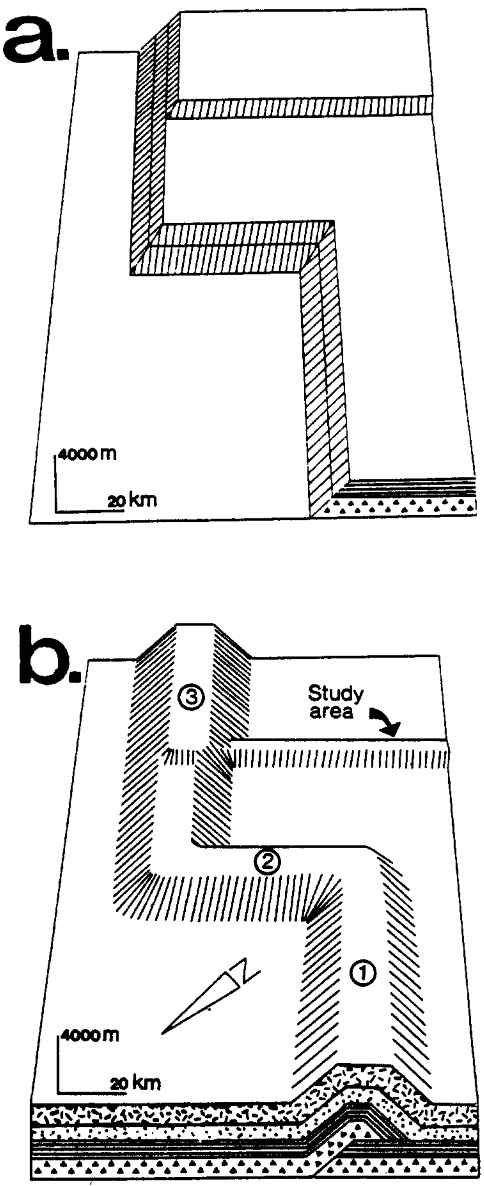


Fig. 10. (a) Sub-surface ramp configurations in the central Oman Mountains, as hypothesized by Bernoulli & Weissert (1987) and S. Hanna (written communication 1983), leading to the formation in (b) of the J. Akhdar–J. Nakhl–Saih Hatat antiformal axis (Fig. 9). 1. Jebel Akhdar; 2. Jebel Nakhl; 3. Saih Hatat. The Aruma Group and the Haybi Complex are scarcely exposed in the Oman orogen and were omitted from the tectonostratigraphy (see Fig. 2 for lithological symbols). The thickness of the units is not drawn to scale. Ramping may also account for the occurrence of a NE-oriented antiformal axis 30 km SE of Jebel Nakhl along which lies the Hubat structure (see text for discussion).

proposed beneath Saih Hatat leads to a hangingwall culmination wider than Jebel Nakhl or Jebel Akhdar (compare Figs. 2 and 10b). Structural ramping as a cause for the formation of major fold trends in Oman, however, is only possible if the finite-displacement vector of the allochthons is at an oblique angle to the orientation of the ramps (Fig. 11), which would then be referred to as oblique ramps (Butler 1982).

Culmination axes oriented at a high angle with the direction of nappe emplacement were documented from the Moine Thrust belt in Scotland (Peach *et al.* 1907, Elliott & Johnson 1980, fig. 1). These culminations

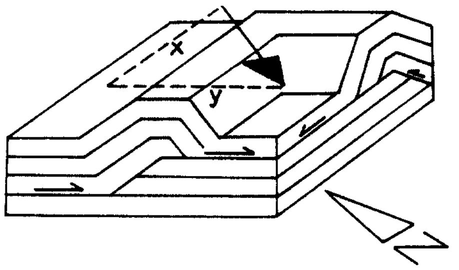


Fig. 11. The development of hangingwall culminations above two given ramps of different orientations requires that a component of the finite displacement vector of the allochthons (represented by an arrow) is perpendicular to each ramp. These components, labelled x and y, correspond to the amount of stratal shortening taking place above the NW- and NE-oriented ramps, respectively.

affect the uppermost of a series of thrust sheets. They extend up to 12 km in length and are less than 1 km in wavelength. Thrust configurations in the Langwell, Achall and Dundonnell culminations allowed Elliott & Johnson (1980) to account for these structures with a thrust sequence involving the early translation of the Moine Thrust sheet followed by the development and superposition of imbricate slices along oblique ramps at depth above a flat décollement. In Oman, the late development of structural culminations (documented by Searle 1985, Searle & Cooper 1986, Barrette 1985, Barrette & Calon 1987) was also interpreted as a result of ramping at depth but is associated with the re-imbrication of the overlying nappes. Searle (1985, p. 142) appealed to "at least two, and probably more, episodes of thrust stacking" to explain these structures. Alternatively, they may arise from the progressive footwall collapse in a 'normal' foreland-directed imbrication, where younger lower faults cut up-section through older higher faults (Barrette & Calon 1987), a process termed "breaching" by Butler (1987). While the Hubat culmination may have originated from sub-surface ramping, breaching, at least in the nappes exposed in this area, was not achieved.

Despite the quality of rock exposure, the data collected from the study area cannot discriminate between a compressive event of Tertiary age or structural ramping at depth for the origin of the Hubat structure. Part of the problem is that the Hawasina units record little evidence of their strain path in terms of microstructures such as stylolitic cleavages or deformed oolites. The limestones of the Hamrat Duru Group have a high oolith/matrix ratio and it is possible that the strain incurred by these lithologies was, in part, internally accommodated by the rotation of the ooliths in a ball-bearing fashion as opposed to their passive deformation. Moreover, slickensides were commonly observed along the bedding planes in the Hamrat Duru Group and hence some of the deformation undergone by these rocks was by flexural-slip folding. Previous studies (Wiltschko 1979, Berger & Johnson 1980, 1982, Fisher & Coward 1982, Sanderson 1982) have highlighted the effect of drag along the sliding surface in a thrust system leading to a complex history of extension and compression in the upper plate prior or during its translation above a ramp. Hence, while this process is incompatible with the relatively simple fold geometries displayed in the study area, it may have induced strains that are not otherwise expressed.

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