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TECTONIC EVOLUTION OF THE ARCHAEAN-NEOPROTEROZOIC BASEMENT COMPLEX OF DHI NA'IM-AL BAYDA DISTRICT, REPUBLIC OF YEMEN

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ABSTRACT: The Dhi Na'im-Al Bayda district constitutes an important part of the Precambrian basement in the western part of the Republic of Yemen. Its critical geographic position places it as a potentially important link between the Arabian-Nubian Shield and Mozambique Belt, leading to the necessity of a thorough investigation of the tectonic framework of the region.

New geologic and structural data from the district evoke a polyphase ductile deformational history, commenced with a NW-SE crustal shortening event and terminated with NE-SW open folding and later strike-slip shearing. The result was a highly deformed NE-SW belt, made up mainly of migmatized gneisses, ophiolitic mélange and island arc metavolcanic rocks. The entire pile has been intruded by syn- and post-tectonic granites. The deformational events disrupted both the ophiolitic and island-arc stratigraphy such that lithological contacts are tectonic, and thrusts and sets of strike-slip faults locally repeat the section.

These structures share a similar history with Pan-African and older fabrics west and east of the study area, and are collectively attributed to the same tectonothermal cycle.

***Keywords**: Dhi Na'im-Al Bayda, Yemen, Precambrian, tectonic evolution.*

INTRODUCTION.

The Precambrian basement complex of Yemen represents the southern extension of the Arabian-Nubian Shield. It occupies about 105,000 km², and is exposed as a vast triangular area in the western part of the country, and as smaller isolated masses to the west and north along the Red Sea coast. This complex occurs between the southern tip of the Arabian-Nubian Shield and the Mozambique Belt. It is dominated by parallel NE-SW to NNE-SSW trending, 10 to 30 km-wide, alternating strips of Archaean high grade migmatized gneisses and Neoproterozoic, greenschist facies grade, volcano-sedimentary successions of ophiolitic mélange and arc metavolcanics (Fig. 1).

Attempts to extrapolate the continuation of the main tectonic lines from the Arabian Shield to the Mozambique Belt are always hindered by the lack of significant information and detailed studies on the basement rocks of Yemen. In an attempt to address this problem, the present work deals with the tectonic evolution of Dhi Na'im-Al Bayda District as an important sector in the southwestern exposures of the Precambrian rocks of Yemen (Figs. 1and 2).

1. GEOLOGY.

Detailed geological mapping, based on the interpretation of ETM+ Landsat image (14.25 m/pixel, false color composite, 7/4/2 bands for R/B/G), and detailed field investigations, was carried out (Fig. 3). Five broad lithological units and dykes were distinguished and stated chronologically as follows:

- Dykes **(Youngest)**

Post-tectonic intrusions
- **Granite**
- **Gabbro**

Syn-tectonic intrusion
- **Sheared granite**

Island-arc assemblage
- **Metavolcaniclastic rocks**
- **Metavolcanics (mainly meta-andesite)**

Ophiolitic mélange
- **Mélange matrix (derivatives of highly sheared blocks)**
- **Mélange blocks (serpentinite, metagabbro, metabasalt, marble and banded iron ore)**

Gneisses and migmatites **(Oldest)**

The contacts between the oldest three rock units are tectonic, marked by major thrusts faults.

The gneisses are mainly orthogneisses of granodioritic composition that are affected by extensive migmatization (Fig. 4a). Chemical analyses of these rocks indicate a calc-alkaline composition (Al Selwi, 2005). They are intensively deformed on all scales and have thrust contacts against the younger metamorphosed rock units. Numerous bands and lenses of high grade pelitic paragneisses and of amphibolites are enclosed within these gneisses. They are highly stretched parallel to and have internal fabric conformable with the regional schistosity of the host rock. No older fabric has been detected within these bands and lenses.

This unit lies on the eastern edge of a regional belt of gneisses and migmatites (the Abas Gneiss Terrain, Fig. 1) that extends for about 60 km to the west of the study area and for about 150 km along a NE-SW trend. This belt was assigned Archaean ages (Windley *et al.*, 1996 and Whitehouse *et al.* 1998), and is metamorphosed up to the high grade granulite facies, documented by a garnet-sillimanite-orthoclase mineral association in the paragneisses and different varieties of garnet-pyroxene coronas in garnet amphibolites (Sakran, 1993 and Abdel Wahed *et al.*, 1996).

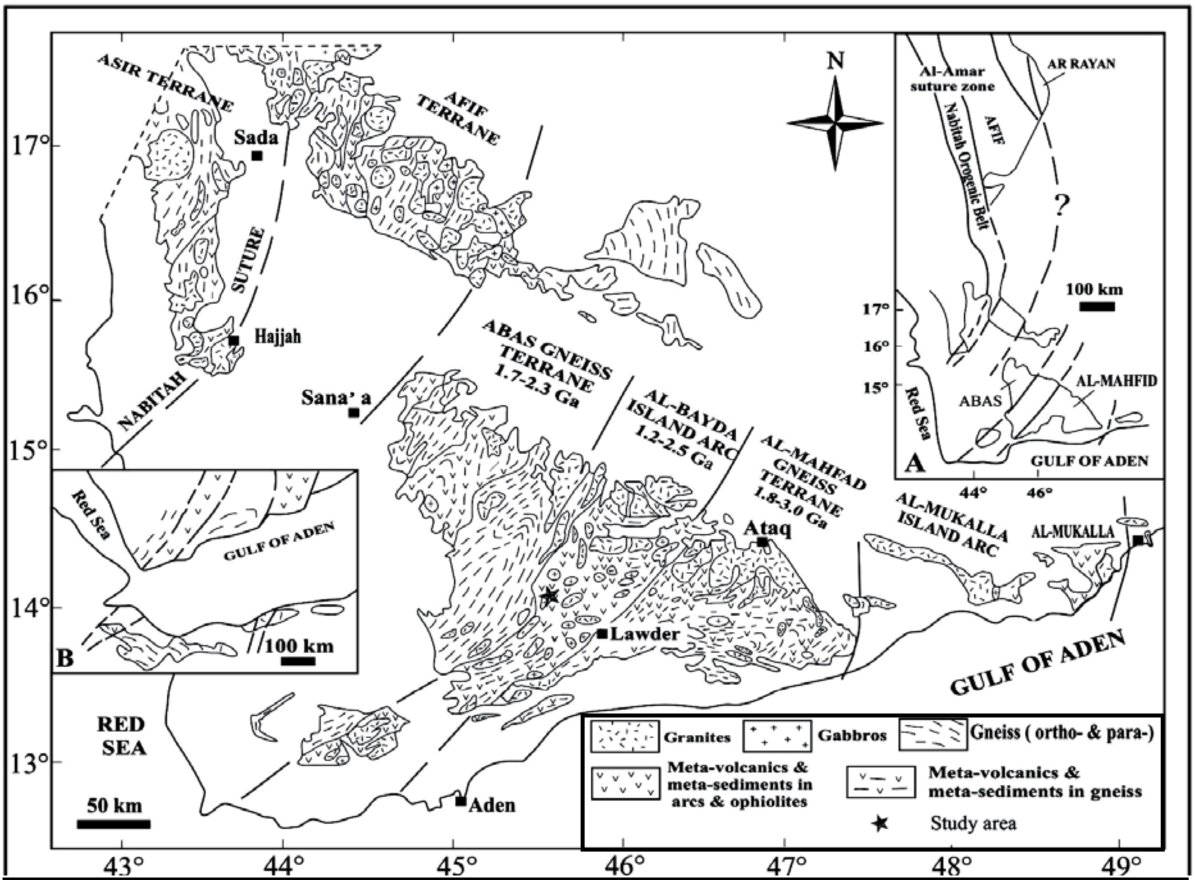


Fig. 1. The Precambrian outcrop map of Yemen showing delineation of the gneisses and ophiolitic melange / island arc terranes and correlation with the adjoining areas, in Saudi Arabia (A), and northern Somalia (B), (After Windley et al., 1996)

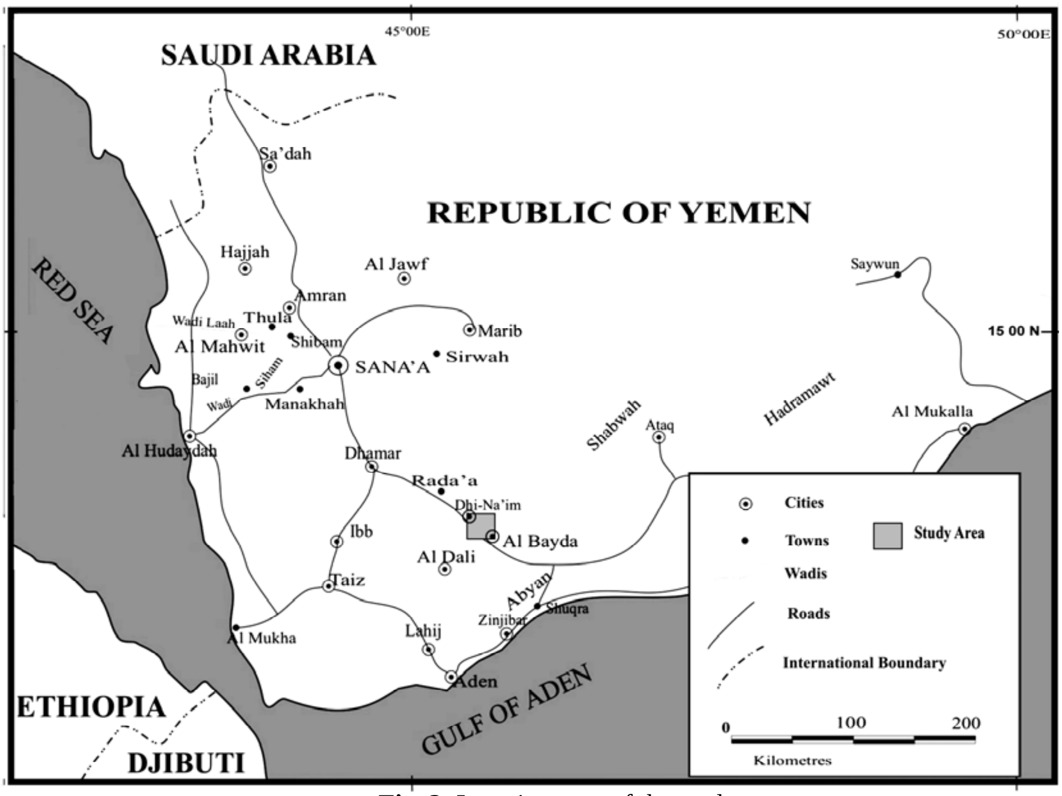


Fig. 2: Location map of the study area.

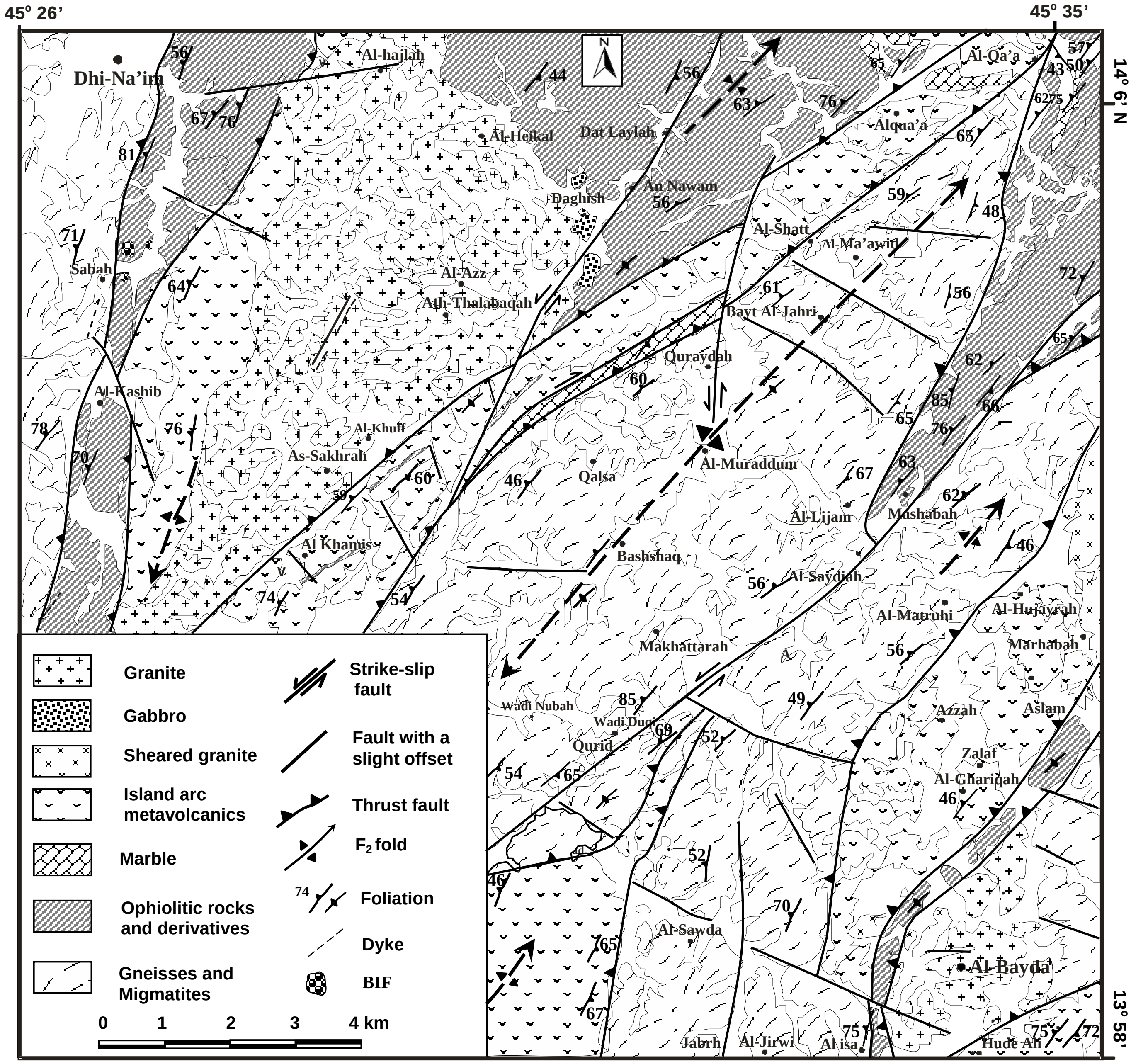


Fig. 3: Geological map of the study area.

The ophiolitic mélange rocks occur as thrust-bounded highly tectonized slices which are affected by folding and intensive shearing that resulted in repetition and tectonic mixing on all scales. Therefore the stratigraphic thickness of the unit is unrepresentative of that of the original pre-tectonic stratigraphy. The unit consists of variably sized blocks of serpentinites, variously altered ultramafics, metagabbros, metabasalts, marbles and banded iron ore set in a matrix composed of the sheared equivalents of blocks that were retrograded mainly to talc tremolite and talc carbonate schists together with local talc bands. Serpentinites are scarce in the study area. Metabasalts include both massive and pillowed metabasalts. The main exposure of the pillowed metabasalt is located east of Dhi- Na'im at the northwestern corner of the map (Fig. 4b). The pillows are highly deformed and stretched in a NNE-SSW to NE-SW direction, parallel to the regional mylonitic foliation near thrust zones (Fig. 4c), and are commonly recorded within marble bands (Fig. 4d). Marble occurs as folded and faulted bands that are concordant to the surrounding schistosity and attain few hundred meters in total thickness. The presence of pillowed basalts within the marble bands points to the fact that these marbles most probably represent the cap rock of the original ophiolitic sequence. The most important occurrence of iron ore in the study area is hosted by marble rocks located in Sabah village.

The island arc assemblage occurs as a well bedded succession (Fig. 4e) that consists mainly of fine-grained flows of massive metabasalts and basaltic

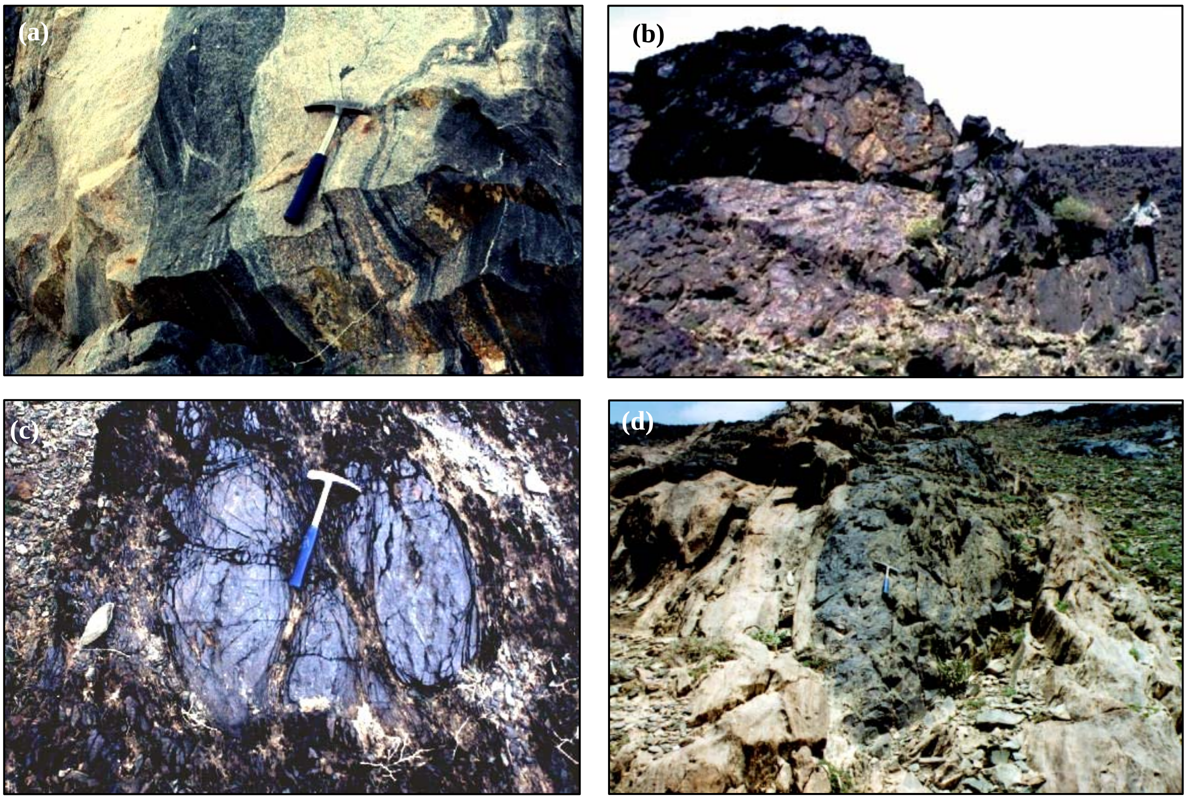


Fig. 4:

(a) Foliated migmatites in the western part of the study area. Looking SW
(b) Pillowed metabasalt block. Ophiolitic mélange, east of Dhi-Na'im. Looking SW.
(c) Deformed pillows in the thrust zone east of Dhi-Na'im. Ophiolitic mélange. Looking SW.
(d) A deformed pillow recorded within a marble band. Ophiolitic mélange in the northwestern part of the study area. Looking NE.
(e) Well preserved relict banding in the arc metavolcanics in the northern part of the study area. Looking NE.

andesites together with their volcaniclastics. The rocks display variable degrees of schistosity. This assemblage is thrust-bound, except at intrusive contacts against younger intrusions. Both the ophiolitic mélange rocks and the island arc assemblage are metamorphosed up to the upper greenschist facies.

Small intrusions of **sheared granite** forming highly eroded cones and ridges, cover limited areas in the southeastern and eastern parts of the study area. The outcrops vary in size and shape, and are generally elongate parallel to the regional foliation of the country rocks and highly affected by shearing and fracturing. The sheared appearance and local schistosity of this unit implies a syn-orogenic paragenesis. In places, the sheared granite includes abundant xenoliths of metagabbros.

Coarse-grained, undeformed, melanocratic **gabbros** are exposed in a few locations. The most prominent exposure is at Daghesh village (Wadi Daghesh) in the northeastern part of the study area. The gabbros have sharp intrusive contacts against the country rocks.

Two huge **granite** intrusions are exposed in the central and southeastern parts of the study area, forming the conspicuous Al-Bayda and Al-Heikal mountainous peaks. Generally, they are pinkish-white to white, leucocratic and coarse- to medium-grained and enclose randomly oriented xenoliths of mafic metavolcanics. They are intruded into the country gneisses and metavolcanics, and are characterized by irregular sharp boundaries that dip steeply outwards.

Numerous **dykes** of variable composition and trends traverse most of the rocks units in the study area. The majority of these dykes are mafic in composition, striking commonly NW-SE. They may reach up to 4 m in thickness and extend for several kilometers along their strike. Swarms of mafic dykes traverse the sheared and non- sheared granites in the southeastern part of the study area. Less commonly, scattered aplitic and pegmatitic acidic dykes of ENE-WSW trend are also observed in the study area.

Detailed petrography and geochemistry of the different rock units exposed in the area under consideration were given in detail (Al Selwi, 2005).

2. STRUCTURAL SETTING

2.1. Regional Sructural Framework.

The gneisses and migmatites unit in the study area are exposed in the extreme eastern part of a NE-SW-trending regional belt of gneisses and migmatites (the Abas Gneiss Terrain, Fig. 1) that extends west of the mapped area. This belt is affected by a complex pattern of major structures that represent the interference of more than one phase of deformation. The most prominent are two huge regional overturned folds (Fig. 5) that plunge to the NE (Abdel Wahed, 2000). The belt is also traversed by two regional ductile shear zones of NE-SW trend and steep NW dip.

The gneisses and migmatites unit is in structural contacts against the ophiolitic mélange and the island arc rock units along regional thrusts generally trending NE-SW and dipping steeply NW (Fig. 3). The ophiolitic mélange/island arc assemblage terrain is internally affected by a complex system of imbricate

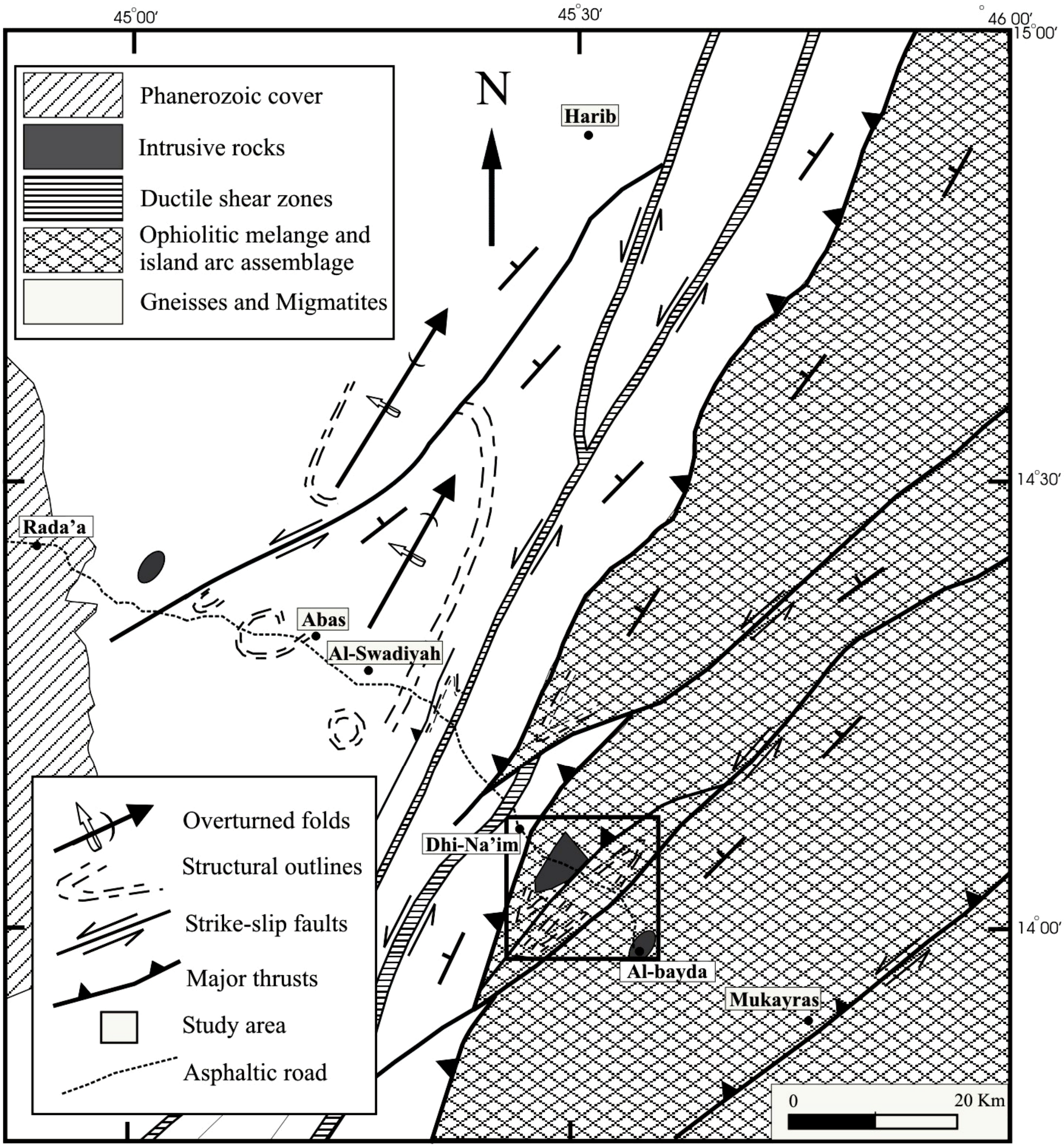


Fig. 5: Regional structures in the southeastern sector of the basement rocks of Yemen.

thrusts that are almost parallel to the main thrust and caused the repetition of these units together with the gneisses and migmatites, in thrust slices.

Several major NE-SW strike-slip faults of left lateral displacement traverse the region and increase its structural complexity.

2.2. Structural Analysis.

Extensive field work revealed that the studied sector is highly complicated from the structural point of view and affected by several phases of deformation and metamorphism. Three phases of ductile deformation overprinted by strike-slip faulting and shearing are recorded. Detailed description of the faults, folds, foliation and lineations and an analysis of the deformational phases are given hereunder.

Faults: The area is dissected by numerous faults, varying from high angle thrusts to almost vertical strike-slip faults. Numerous regional thrust faults control the contacts between the metamorphosed rock units. All are of NE-SW trend, dip steeply NW and are commonly associated with high strain mylonitic zones. Near the thrust planes, shear fabrics comprise a NE-SW striking mylonitization cleavage and a strong SE-steeply plunging stretching lineation. The steep dips of these thrusts can be attributed to progressive rotation of their planes through the tectonic transport.

The area is also traversed by two NNE-SSW strike-slip faults of regional scale and left lateral displacement. They cut and displace the regional thrust faults and are commonly associated with slickensides of low rake angles. Faulting along a NW-SE trend is also encountered in the form of normal faulting of somewhat small displacement.

Folds: Major folding is recognized in the study area as numerous map-scale coaxial plunging antiformal and synformal structures with axial planes trending NE-SW and plunging to the NE or SW (Fig. 3). The largest is a major asymmetric doubly plunging antiform fold which affects the gneissic rocks in the central part of the study area. Stereographic projection of the poles to foliation planes in the northern part of this structure defines a fold axis oriented 48º.N33ºE and an axial plane of N41ºE strike and 80ºNW dip (Fig. 6a). The southern part of this fold plunges 39º.S62ºW and has an axial plane that strikes N45ºE and dips 70ºNW (Fig. 6b). An asymmetric synform structure was detected in the northern part of the study area affecting the ophiolitic mélange. The orientation diagram of the poles to foliation planes indicates a fold axis plunging 23º.N45ºE and an axial plane striking N46ºE and dipping 86ºNW (Fig. 6c).Three other major folds are recognized in the western, eastern and southern parts of the study area. They are asymmetric and have axial planes parallel to the regional foliation, which in turn is roughly parallel to the trend of the belt. This suggests a strong NE–SW flattening parallel to the trend of the gneiss belt at this stage of deformation. These folds show considerable similarity in style and intensity of folding, as well as in orientation of their axial planes and folding axes pointing to the fact that they are related to the same deformational phase.

Minor folds show a wide variation in style and orientation. Detailed field study revealed that they are attributed to three phases of deformation, D_1, D_2 and D_3.

The first phase of deformation (D_1) produced folding on the minor scale only, and is represented by very tight overturned and isoclinal rootless intrafolial F_1 folds (Fig. 7a) of variable attitudes of axial planes and folding axes as a result of later deformation. The occurrence of such folds is restricted to the gneisses and migmatites domain.

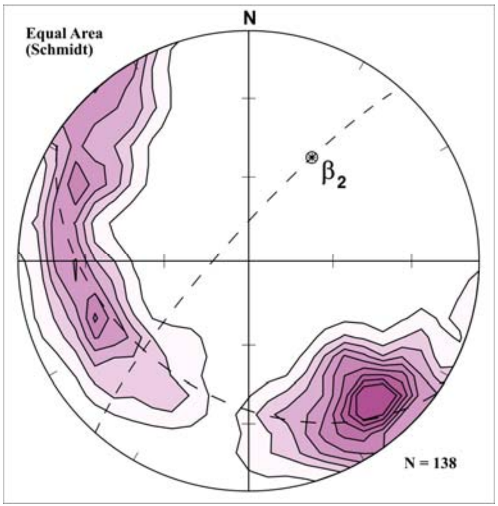
The second deformation (D_2) resulted in the formation of folds that have an asymmetric, moderately tight style and become tight overturned near thrust planes (Figs. 7b, c and d). Stereographic projection of the axes of F_2 minor folds indicates that these folds have NE-SW striking axial planes and plunge to the NE and SW at moderate to high angles (Fig. 6d). Folds of this generation are recorded in the gneisses and also in the ophiolites, themetavolcanics and the sheared granites as well.

Major folding and thrusting are coeval with the second phase (D_2), since the axial surfaces of the major folds and those of the (F_2) minor folds and the thrust planes are almost parallel.

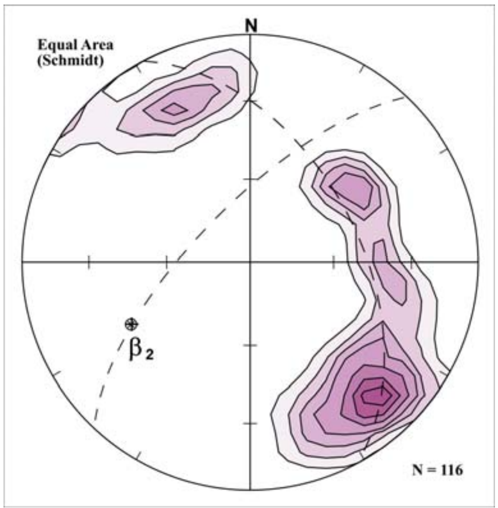
F_3 folds are generally macroscopic and minor in scale, with wavelengths of tens of centimeters to few meters. (Figs. 7e and f).These folds are formed during the third deformation , D_3, and are characterized by open to moderately tight, mainly symmetric styles; but they are less tight if compared with the F_2 folds. They have NW-SE striking and generally steep axial planes and plunge mildly to steeply to the NW or SE (Fig. 6e). F_3 folds deform and overprint the limbs of F_2 structures. The variability of their geometry is ascribed to the fact that they are developed on planes that were originally of variable attitudes. The relation between the three folding phases is illustrated in the refolding model shown in Figure 8.

Foliation: The metamorphosed rock units show well developed foliations that were formed through three phases of deformation.

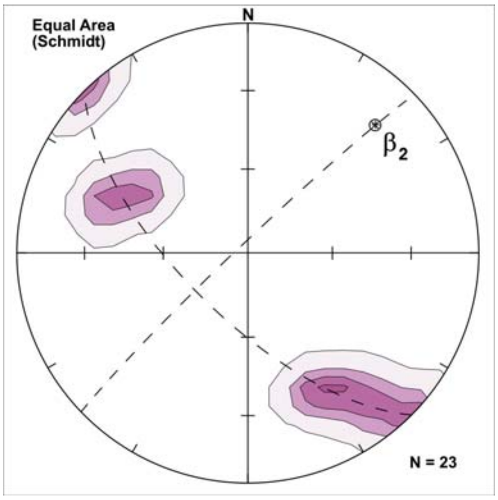
A gneissic foliation (S_1) is the earliest structural planar fabric element recognized in the study area (Fig. 4a). It is well represented in the gneisses and migmatites and not recorded in the younger metamorphosed units. It is generally defined by medium- to coarse-grained compositional banding with a preferred orientation of platy, tabular, and prismatic minerals, and by subparallel lenticular mineral grains and grain aggregates. The gneissic banding is migmatitic in nature particularly in locations where the gneissosity is pervaded by injections of granitic phases. The compositional banding occurs on all scales, from thick, continuous



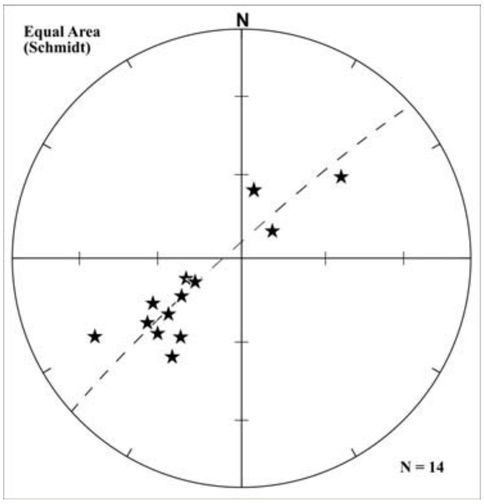
(a) Poles to foliation planes in the northern part of the major double plunging anticline. Contours: 0, 2, 4, 6, 8, 10, 12, 14, 16 %.



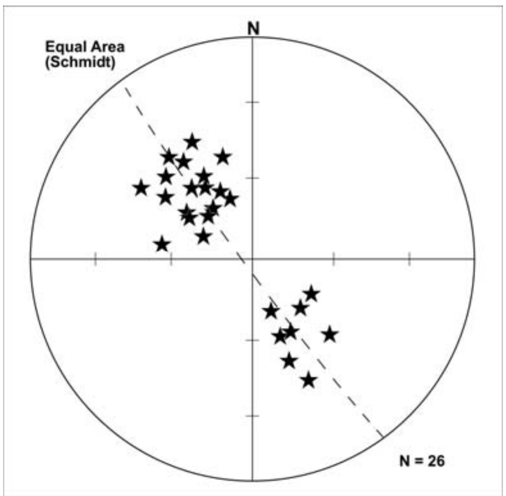
(b) Poles to foliation planes in the southern part of the major double plunging anticline. Contours: 0, 2, 4, 6, 10, 14, 16 %.



(c) Poles to foliation planes in the northern syncline. Contours: 0, 2, 4, 8 %.



(d) Stereographic projection of the axes of F_2 minor folds.



(e) Stereographic projection of the axes of F_3 minor folds.

Fig. 6: Lower hemisphere equal area projections of structural data from the study area.

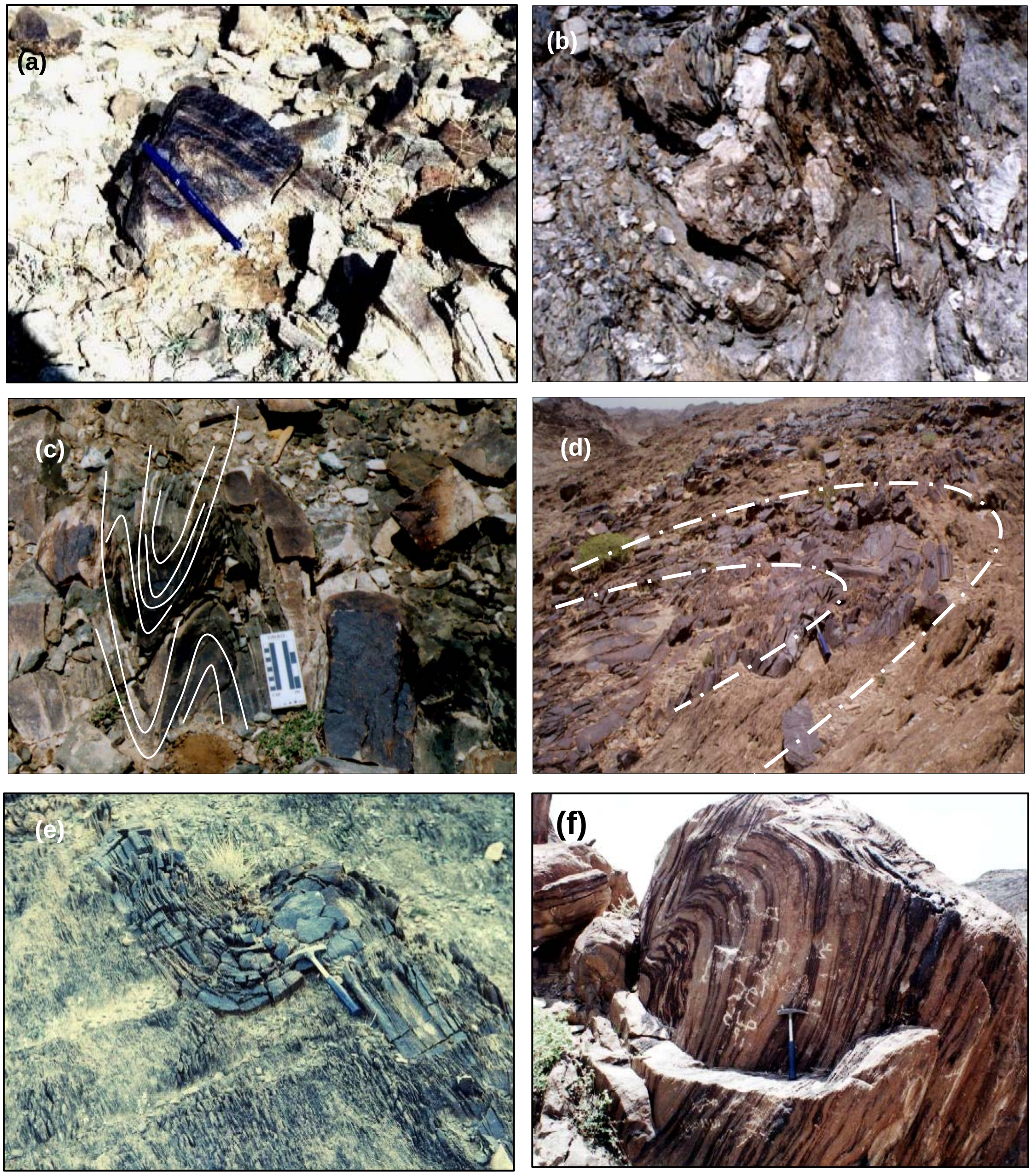


Fig. 7:

(a) Rootless intrafolial tight isoclinal minor F_1 fold in the gneisses. Southwestern part of the study area. Looking NE.

(b) Asymmetrical F_2 minor fold developed in the migmatites exposed in the central part of the study area. Looking S.

(c) Minor overturned F_2 fold developed in the gneisses in the central part of the study area. Looking N.

(d) F_2 minor fold steeply plunging NE. Arc metavolcanics in the northern part of the study area. Looking N.

(e) F_3 open fold in metabasalt. Arc metavolcanics in the northern part of the study area. Looking E.

(f) F_3 open minor folding in a marble band. Ophiolitic mélange in the northern part of the study area. Looking NE.

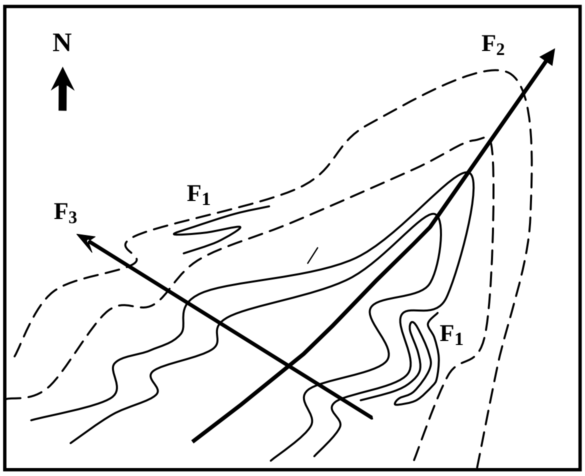


Fig. 8: Refolding model showing the superposition relations of F_1 by F_2 and F_3 folds, compiled from gneisses and ophiolitic mélange exposures within the study area.

bands and layers that can be recognized across the entire outcrop area, to discontinuous laminae that pinch out within an individual outcrop or hand specimen. The S_1 foliation is a complex transposed gneissosity as evident by the presence of the highly compressed rootless isoclinal folds that are included within the foliation planes on all scales. The S_1 foliation planes strike mainly NE–SW, roughly parallel to the elongation of the belt, and have varying dip directions due to subsequent phases of deformation.

The ophiolitic mélange matrix and to a lesser extent the mélange blocks and the arc metavolcanics, are well foliated. The foliation is mylonitic, S_2=S_M, developed during the tectonic transport and is oriented parallel to the mylonite zones along the major thrusts. It is worth mentioning that the S_1 foliation in the gneisses notably increases in intensity and becomes a mylonitic foliation (S_M) at the contacts against adjacent lithologies, along both the major and internal thrusts as well. S_2 is also developed as an axial plane foliation that is axial planar to F_2 minor folds. The S_2 foliation is generally of NE-SW strike and variable dip due to later folding.

The S_3 foliation is weakly developed axial planar to the F_3 open folds. It strikes mainly NW-SE, and has a very steep to vertical dip usually concentrated at the F_3 fold hinges. Where S_3 is restricted to fold hinges, the cleavage on the fold limbs is S_1 or S_2.

Lineations: On the outcrop scale, the three generations of folds are associated with well developed lineations. L_1 lineation is recognized in the gneisses and migmatites mainly as a mineral lineation, that is oriented parallel to the axes of F_1 folds at the same and adjacent exposures.

L_2 lineation is represented by mineral and crenulation lineations in the gneisses, and by mineral and crenulation lineations and stretched pebbles in the ophiolitic mélange and metamorphosed volcaniclastics. L_2 lineations are coaxial to F_2 folds. Near and along thrust planes, L_2 lineation is recorded as a strong stretching lineation.

L_3 lineation is recorded mainly as kinking axes in the ophiolitic mélange matrix and the gneisses. It is aligned parallel to the axes of F_3 folds in the adjacent exposures. The intersection of the S_2 and S_3 foliations commonly results in the development of a crude pencil structure locally observed in the metavolcanics.

2.3. Structural Evolution.

Based on the foregoing geometric elements, the structural evolution of the study area can be summarized in terms of three superimposed deformation phases (Table 1), and can be stated in a chronological sequence as follows:

D_1: Early deformation in the gneisses and migmatites.

This event is only recognized in the gneisses and migmatites. The development of very tight rootless intrafolial overturned and isoclinal, small scale F_1 folds were contemporaneous with D_1, which is attributed to an early crustal shortening event. This early deformation was accompanied by the formation of a penetrative cleavage, S_1, mainly of NE-SW strike. The S_1 cleavage is considered the main structural element in the gneisses and is distinguished by a strong preferred orientation of the mineral constituents. The degree of S_1 cleavage development is a sensitive indicator of lithology and tectonic strain. The S_1 foliation is manifested by a coarse- to medium-grained gneissosity in the gneisses and migmatites. The L_1 lineation is mainly a mineral lineation, defined by the preferred orientation of the deformed crystals on the S_1 foliation planes.

D_2 : Main deformation; Tectonic transport, thrusting and regional folding.

The regional tectonic transport of the ophiolitic blocks and the island arc sequences to overlie the gneisses and migmatites was likely coeval with initial regional folding and through propagation of F_2 major folds. This transposition caused strong shearing and deformation of the pre-existing fabrics and the formation of map-scale folding and thrust structures. These thrusts are confined mainly to the accretionary units (the ophiolites) and clearly truncate the early deformation D_1 domains. Tectonically, this phase coincides with a regional crustal thickening in a NW-SE direction. During this deformation event, various deformational fabrics were developed, including major folding along NE-SW axes, NE-SW trending thrust faults, mylonitization cleavage and stretching lineation.

D_3: Latest deformation; NE-SW weak ductile deformation

This phase is expressed by a new generation of folds (F_3) characterized by a relatively weak stress component, more or less normal to the compressional

Table 1: Compilation of deformational phases and magmatic activities in the study area.

Magmatic activity & sedimentation	Deformation phases	Structures	Evidence (Fabrics)
Post-tectonic granite intrusion	Extensional tectonics	- Jointing and faulting.	- Oval-shaped structures on (ETM) Landsat images. Intrusive Contacts and associated potassic alteration haloes.
Younger gabbroic intrusion			- Sharp, irregular, intrusive contacts against the country rocks.
	Latest deformation: NE-SW ductile deformation (D_3)	- F_3 minor open folds and crenulations developed in the ophiolites and the arc-related rocks and the gneisses.	- F_3 open minor folds of NE-SW axes -S_3 axial plane cleavage surfaces; kinking coaxial to F_3 axes**; all affect the pre- existing fabrics.**
Emplacement of syn-tectonic granitic intrusion		- Shearing, folding	- Weak foliation and open to moderately tight folding, mainly close to their contacts.
	Main deformation: Regional folding & thrusting (D_2)	- F_2 moderately tight asymmetrical folds on the major and minor scales, **become tight overturned near thrust planes**. - $S_2 = S_M$ mylonitic foliation in the ophiolites and metavolcanics. - Transposition of primary and D_1 structures into mylonitic cleavage close to thrust planes planes. - Narrow continuous high strain zones and thrust faults with stretching lineation and mylonitic foliation.	- major folding along NE-SW axes, NE-SW trending thrust faults. - Penetrative S_M (NNE-SSW to NE-SW) foliation overprints S_1 cleavage, commonly near thrust zones. - Amphibolite boudins and talc pockets are elongated parallel to mylonitic foliation. - Mineral lineation is coaxial with the transpression. Slickensides are common in thrust zones.
Extrusion of island arc andesite and basaltic andesite and related volcaniclastics.		- Primary bedding and Laminations and graded bedding in volcaniclastics and flow lamination in volcanic flows (S_o).	- Badly to well-preserved lamination and graded bedding.
Generation of an oceanic crust (elsewhere, then transportation)		- Primary differentiation banding in metagabbros. - Pillow structure in metabasalts.	- Slabs of ophiolitic units cover large areas.
	Early folding (D_1)	- Intensive folding, development of gneissosity and lineation.	- F_1 rootless intrafolial tight overturned isoclinal minor folds. - S_1 regional gneissosity. - L_1 mineral lineation coaxial to F_1 folds

stress of D_1. The F_1 and F_2 folds are overprinted by minor F_3 open folds of a NW-SE axial planes, S_3 axial plane cleavage and L_3 pencil-like structure and kinking axes.

This folding event was superposed by later kilometer-scale strike-slip faults extending in a NE-SW direction.

3. DISCUSSION

The present study revealed three phases of deformation, D_1, D_2, and D_3, affected the Dhi Na'im-Al Bayda district. The oldest is confined to the gneisses and migmatites. Similar deformation histories, comprising three main phases of ductile deformation, have been described east and west of the study area by Al Kotba (1992) in Abas area in the east (Fig. 3) and in Lawder-Mukayras area in the west (Al Kotba *et al.*, 2000).

Abdel Wahed (2000) described four phases of deformation, D_1, D_2, D_3, and D_4, in the gneisses and migmatites and ophiolitic mélange rocks in As-Swadiyah area, located to the west of the study area (Fig. 3). In that area, D_1 and D_2 phases are only observed in the gneisses, whereas D_3 and D_4 deformations affect both gneisses and island arc & ophiolitic mélange assemblages. D_2, D_3, and D_4 phases at As-Swadiy area are respectively equivalent to D_1, D_2, D_3 reported in the study area and its surroundings. D_1 described at the As-Swadiy area is not detected in Dhi Na'im-Al Bayda district due to the fact that the structural elements related to this phase are only locally preserved in the former area and are recorded as rarely exposed refolded fold closures and also as an old planar fabric (discordant to the regional gneissosity) in some of restrictedly distributed bands and lenses of paragneisses that are enclosed in other gneisses and migmatites.

The rocks in the Abas gneiss terrain (Fig. 1) experienced a complicated history of poly-deformation and poly-metamorphism associated with extensive migmatization at a regional scale. The rocks are metamorphosed up to the granulite facies of metamorphism (Sakran, 1993; and Abdel Wahed *et al.*, 1996). This points to the possibility that the Abas Terrain had an old continental origin (Abdel Wahed *et al.*, 1996). The gneisses of As-Swadiyah and Lawder-Mukayras areas (in the Abas and Al Mahfad gneiss terrains, respectively) were dated as Archaean in age by Windley *et al.* (1996) and Whitehouse *et al.* (1998).

Archaean ages are assigned to the Mozambique belt (Leggo, 1971). Several localities within the belt are metamorphosed up to the granulite facies (Kazmin, 1972; Clark, 1976 and Andriessen *et al.*, 1985). On the other hand, rocks of the Arabian-Nubian Shield are mostly metamorphosed under greenschist to amphibolite facies conditions and are considered to have been developed during the Neoproterozoic (Pan-African). However, Archaean ages were assigned to Gabal Khida gneisses on the southern edge of the Afif Terrain in southwest Saudi Arabia (Stacey and Stoeser, 1984; Stoeser and Stacey, 1988), and to the Uweinat gneiss terrain west of the Nile in Egypt (Schandelmeier *et al.* 1988). On basis of these data, the Afif terrain is supposed to represent a rifted fragment of the Mozambique Belt (Stoeser and Camp, 1985), and that the Uweinat gneisses are related to the Congo Craton (Sultan *et al.* 1994).

The complicated structural framework, high grade of metamorphism and available geochronological data, indicate that the gneisses and migmatites in the study area and surrounding region (the Abas gneiss terrain) are comparable to the Mozambique belt, therefore represent a potential link between the mainly Mesoproterozoic Mozambique belt and the Neoproterozoic Arabian-Nubian Shield.

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