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Nomenclature Review of the Rock Units in the Stratigraphic Lexicon of Yemen

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Abstract

The nomenclature. development of the Phanerozoic rock units mentioned in the stratigraphic lexicon of Yemen is revised. Forms violating the nomenclature rules are corrected in accordance with the international rules of the stratigraphic nomenclature. The concerned forms are categorized as: informally introduced, dropped, named or re-named units, all of these categories are discussed in detail.

Keywords: *Nomenclature Review, Rock Units, Stratigraphic, Lexicon, Yemen.*

1. Introduction

The Republic of Yemen occupies the southern corner of the Arabian Peninsula bordering the Red sea and the Gulf of Aden (Fig. 1). It was erected in (1990) as the result of the union of the previous Yemen Arab Republic (North Yemen) and the Peoples' Deomocratic Republic of Yemen (South Yemen). In the present study, these two parts will be referred to as the northern provinces and the southern provinces, respectively. Geological studies on the southern provinces commenced with the work of [1-3]. Detailed stratigraphical investigations were made by Wetzel and Morton for the Iraq Petroleum Company in unpublished reports during the period (1948-1950), [4]. Wetzel and Morton's nomenclature was revised by [5, 6], who also described groups, formations and members as new lithostratigraphic units. Beydoun and Greenwood re-emended these rock units which were published in [7] as the first edition of the international lexicon of the strtatigraphy of the former South Yemen. Beydoun et al. [8], published the second edition of the international lexicon of the stratigraphy of the Republic of Yemen, in which they adopted and repeated many of the previous erroneous terminology.

In the northern provinces, the first geological studies were provided by [9-14]. Detailed stratigraphical investigations were introduced by [12], who described the Kohlan, Amran, and Taouilah (=Tawilah) series. [15,16], compiled the available geological information and introduced the Medj-zir Series, as well as, he recognized the Wajid Formation in Yemen.

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El-Nakhal [17-32], during the period (1984-2004), introduced a series of comprehensive stratigraphical investigations covering the majority of the Yemeni Phanerozoic sequence. The present study is mainly devoted to revise the nomenclature development of most of the Phanerozoic lithostratigraphic units mentioned in the second edition of the lexicon of Yemen {8}, and to make the necessary corrections for the previously practised stratigraphic violations, in accordance with the international rules of the stratigraphic nomenclature. The treated units are categorized as:

I- Informally introduced or/dropped units.
II- Informally named units
III- Informally re-named units.

Each of These categories will be discussed in detail.

2. Summary of the Phanerozoic sequence in Yemen

In the Republic of Yemen, the three Phanerzoic erathems are represented (Fig. 2). The Paleozoic includes the Wajid and the Kooli Formations which are well exposed in the north and northwest of Yemen. The Wajid Formation consists of continental sandstones of Permian or older age. The Kooli is the lower formation of the Kohlan Group (Late Carboniferous-Early Jurassic) and consists of glaciogenic siltstone and shale which are assigned to the Late Carboniferous-Early Permian. It replaces the informal name Akbra Shales of authors. The Mesozoic is represented by the Jurassic and the Cretaceous Systems. The Jurassic includes the Affar Sandstone, and the Surdud Group. The Affar is the upper formation of the Kohlan Group.

It replaces the informal term Kohlan Formation in its restricted sense. The Surdud Group includes the Amran, Madbi, Sabatayn, and Neifa Formations. The Amran and Madbi Formations are well developed in the northern and southern provinces. The Madbi represents a shallow to open-marine environment. The Sabatayn was deposited in closed isolted isolated basins and it is restricted to the central parts of Yemen, The surface occurrence of the Neifa Formation is confined to the southern provinces. The Cretaceous System consists of the zone Zone without diagnostic Diagnostic fossils Fossils and the Ahwar/Mahra groups Groups. The three units are laterally equivalent and constitute the continental, transitional, and marine lithofacies of the Cretaceous, respectively. The zone Zone without diagnostic Diagnotic fossils Fossils consists of continental sandstone, occupies the lower and middle parts of the Taouilah (=Tawilah) Formation (Cretaceous-Paleocene), and confined to the northern provinces. The Ahwar/Mahra groups Groups are well developed in the western and eastern parts of the southern provinces, respectively. The Ahwar Group replaces the term Tawilah Group in the southern provinces. It includes the Qishn, Harshiyat, and Mukalla Formations. The Mahra Group is divisible into the Qishn, Fartaq, Mukalla, Tabut and Sharawayn Formations. The Cenozoic Erathem includes sedimentary and igneous rocks. The sedimentary successions consist of marine and nonmarine types included within the *Pulsiphonina prima* Zone, Shihr, Hadhramaut, and Tihama Groups. The *Pulsiphonina prima* Zone consists of alternations of nonmarine and fossiliferous marine sandstones of Paleocene age. It occupies the upper part of the Taouilah (=Tawilah) Formation, and replaces the informal name Medj-zir Series. Hadhramaut Group (Paleocene-Middle Eocene) consists of carbonates and evaporites, and it is divisible into Umm er Radhuma, Jeza', Rus and Habshiya Formations. The Shihr Group (Oligocene-Pliocene) occurs in the eastern parts and consists of clastics, carbonates, and evaporites. The Tihamah Group (Miocene-Holocene) includes the Abbas, Salif, and Kamaran Formations. The Abbas consists of continental clastics of Miocene-Holocene age. The Salif Formation (Middle-Late Miocene) consists of evaporites. Kamaran Formation includes the Quaraternary reefal limestone. The Cenozoic igneous rocks consist of intrusive and extrusive rocks with interlayered sediments, all of which are included within the Manakhah Volcanic Complex (Latest Cretaceous-Holocene). This complex is subdivided into the Haraz, and Aden Formations, and Bura' Lithodeme. The Haraz Formation includes the Latest Cretaceous-Tertiary volcanics and the interlayered sediments. It replaces the informal terms Trap Series, and Yemen Volcanics Goup. The interlayerd sediments are included within the Risabah Clastics Member (Oligocene-Miocene) which is introduced in the present study as a new unit. It replaces the informal terms inter-trap deposits, and Lahima Member. The Aden Formation includes the Late Tertiary-Holocene volcanics. It is an adoption of the Aden Trap Series. The Bura' Lithodeme includes the Tertairy granitic plutons. Worth of mention is that the geologic age of most of the above-mentioned units (Fig. 2), is tentative still a matter of dispute and needs to be confirmed.

3. Informally introduced or/dropped units

This category includes the units which were either informally introduced or informally dropped, as it is shown below.

3.1. Kohlan Series

The name Kohlan was introduced by Lamare (in [12]) as Kohlan Series which consists of siltstones and the overlying sandstones that lie between the Precambrian Basement Rocks below and the limestone of Amran Serie above, in the northwestern parts of Yemen. It was named after the Kohlan Town which lies about 65km northwest of Sana'a (Fig. 1). At its type locality, it consists of about 300m of dark green, gravelly siltstone and silt shale, overlain by fine to medium, white, yellow, and brown sandstone with numerous thin siltstone and shale interbeds, and occasional conglomeratic layers [19].

On the basis of its fossil contents and stratigraphical position, the Kohlan Series was dated as Late Carboniferous-Early Jurassic [19, 33]. Due to the absence of the diagnostic fossils, it is not possible to confirm whether or not the Triassic occurs in the Kohlan sequence. [34], recorded geological features which indicate that the siltstone and silt shale of the lower parts of the Kohlan Series in Sa'dah area, were deposited in glacial environment. Consequently, in the explanation of the geological map of Yemen, sheet of Sa'dah, [34], subdivided the Kohlan sequence into the Akbra Shales and the overlying Kohlan Sandstone (in its restricted sense). However, these two units were introduced in the explanation of a geological map only, without additional stratigraphic information, therefore, and according to the nomenclature rules, they represnt informal units [35, 36 (Article 4, Remark a)].Aadditionally Additionally, the subdivision of the Kohlan Series into the Akbra Shales and the Kohlan Sandstone (in its restricted sense), violates [35, 36 (Article 19, Remark g)]. Consequently, [19] dropped the two units, and gave the Kohlan Series a group rank which he divided into two formations, the Kooli to replace the Akbra Shales, and the Affar to replace the Kohlan Sandstone (in its restricted sense) [19].

In the southern provinces, the Kohlan sequence was treated as a formation. It is exposed in the coastal mountainous belt of southwest Hadhramaut west of

long. 48° 38', and it reappears eastwards in Al-Mahra at Sharawayn. A reference section was designated at Ma'abir, Wadi Hajar, Hadhramaut (lat. 14° 14', long. 48° 33'). In this region, the Kohlan sequence consists of 17-81m of arkosic sandstone with several conglomeratic horizons consisting of pebbles of vein quartz and igneous and metamorphic rocks and green and purple marl, siltstone and shale interbeds [5-7, 37]

3.1.1. Kooli Formation

The Kooli Formation was introduced by [19] to accommodate the glaciogenic gravelly siltstone and silt shale which constitute the lower part of the Kohlan Group in the northernwestern northwestern parts of Yemen. It replaces the informal terms Akbra Shales of [34] and ′Akbarah Formation of [8]. Its stratotype lies in Kohlan area (Fig. 1), near Beit Al-Kooli Village (lat. 15° 43' 57", long. 43° 42' 12"). It consists of a sequence of light green claystone, dark green siltstone, and dark green highly weathered silt shale with numerous thin interbeds of light gray, compact, thin-bedded sandy siltstone. Out-sized boulders and gravels of basement rocks, are found throughout the succession, some of these boulders and gravels are striated. Also, the sequence includes dropstones and polished pavements with parallel striations and grooves. All of these features indicate that the Kooli Formation was deposited in glaciolacustrine environment [17, 19, 24 and 33]. The maximum recorded thickness of this formation is 130m [38]. The Kooli Formation is well developed in the northwestern parts of Yemen [33]. Its lower contact with the basement rocks (in the type area) and with the Wajid Formation in Sa'dah area, and its upper contact with the Affar Formation are iunconformable unconformable .
On the basis of its stratigraphical position and fossil content, the Kooli Formation was dated as Early Permian [8,38], Permian [17, 19, 24, 28], Late Carboniferous-Early Permian [33], and Late Carboniferous [39].

3.1.2. Remarks

[38], referred to the occurrence of new exposures of glacial deposits in Kohlan area. Believing that the Akbra represents a valid formation, [38], included the newly recorded deposits within that unit.. [8], considered that the adoption of [38], to the term Akbra, gives it the formality and the date priority over the Kooli Formation of [19], and so, they erroneously dropped the term Kooli Formation.. Moreover, [8], considered [38] as being the authors who introduced the name Akbra instead of [34], despite the fact that [38], had never mentioned that they were introducing the Akbra as a new unit. However, the attempt of [8], to give the formality to the Akbra and to alter its author name and date, and as a consequence dropping the Kooli Formation, does not depend on or agree with any of the rules of the stratigraphic nomenclature [35, 36]. Consequently, the Akbra Shales of [34, 38], and the 'Akbarah Formation of [8, are informal terms which should be dropped from the stratigraphy of Yemen.

3.1. 3. Subdivision of the Kooli Formation

On the basis of its lithic charteristics characteristics the Kooli Formation, was subdivided into two members which are the Sharas Siltstone, and the overlying Khalaqah Shale [19].

3. 1. 4. Sharas Siltstone Member

This is the lower member of the Kooli Formation. It was introduced by [19] to include the gravelly siltstones and subordinate shales, which constitute the lower part of the Kooli Formation. The type section lies near Beit AI-Kooli Village, Kohlan area (Fig. 1), and it was named after Wadi Sharas and Sharas Village. It is well developed in the northwestern parts of Yemen. At its type area, it attains a thickness of 16m. Its upper surface is polished, with occasional parallel striations and grooves. Dropstones and striated gravels are common throughout the sequence indicating the glacial origin of the member. Its lower contact with the Precambrian rocks (in Kohlan area) and with the Wajid Formation (in Sa'dah area) is unconformable. Whereas its upper contact with the Khalaqah Shale Member in both areas, is confarmable. On the basis of the recorded palynomorphs in the overlying Khalaqah Shale Member and its stratigraphical position, the Sharas Member is assigned to the Late Carboniferous-Early Permian [33].

3. 1. 5. Khalaqah Shale Member

The Khalaqah Shale Member was introduced by [19]. Its type section lies in Kohlan area near Beit Al-Kooli Village (Fig. 1). It was named after the Khalaqah agricultural district. In its type locality, it consists of a thin basal tillite (0.5m), followed upwards by a thick sequence (89.5m) of gravelly, varved silt-shale including numerous thin compact siltstone interbeds. Dropstones and striated gravels are common throughout the member. Its lower contact with the Sharas Siltstone Member is conformable, whereas its upper contact with the Azzan Sandstone Member (of the Affar Formation) is unconformable. On palynoligical and stratigraphical grounds, the present member was dated as Late Carboniferous-Eaely Permian [33, 39,40].

3. 1. 6. Remarks

Despite the fact that the two members of the Kooli Fotmation Formation are clearly reccognizrd recognized in the field in a wide area and as the stratigraphical sections of [38], and [17, 19], demonstrate, [8], considered these members as having a limited geographical distribution. Consequently, they concluded that the division of the Kooli into members

is not justified, and suggested to drop the proposed divisions However, even if these units have a limited geographical distribution, as [8], had assumed, the wide distribution and mappability are not required for establishing the new formal members [35, 36 (Article 25, Remark a)]. Therefore, the suggestion of [8], to drop the component members of the Kooli Formation is unjustified and should be rejected.

3. 1. 7. Affar Formation

The Affar is the upper formation of the Kohlan Group, the Iower being the Kooli Formation. It was introduced by [19] to accommodate the fluvial sandstones which form the upper parts of the Kohlan Group in Yemen. It replaces the informal terms Kohlan Sandstone of [34], and Kuhlan Formation of [8], (in the restricted sense) in the northern provinces. Those terms violate [35, 36 (Article 19, Remark g)], which states that: "when a unit is divided into two units or more of the same rank as the original, the original name should not be used for any of the divisions". The type locality of the Affar Formation lies in Kohlan area, and it was named after Kohlan Affar Town (lat. 15° 43' 47" N, long. 43° 42' 13" E) , (Fig. 1). In its type locality, the Affar consists of about 190m of fine to medium, whitish, and brownish sandstones, with numerous thin, green and brownish claystone, siltstone interbeds, and occasional conglomeratic beds particularly in the middle parts. The lower contact with the Kooli Formation is unconformable, whereas its upper contact with the Amran Formation is gradational and conformable.

The upper part of the Affar Formation yielded a group of plant fossils of Liassic age [17], but [8], mentioned that a palynomorph assemblage recorded from the subsurface of the southern provinces suggests a Middle Jurassic age for the sequence of the Affar. [8], also added that the plant fossils which were recorded by [17], have a fragmentary nature and cannot be used for accurate dating. Therefore, and on the basis of the occurring palynomophs, [8], considered the age of the Affar Sandstone as ranging from possible latest Triassic, Liassic to Middle Jurassic. Recently, Stephenson and Al-Mashaikie [39, 40], recorded in the outcrops of the lower part of the Affar Formation (Azzan Sandstone Member), palynomorph assemblages which were considered to be of Late Carboniferous age, but this age seems to be doubtful.
The Affar is well exposed in the northwestern regions of the northern provinces [19]. Its equivalents (which were included within the Kohlan Formation, in its restricted sense), are recognized in the surface and subsurface of the southern provinces, [5-8, 41].

3.1.8. Subdivision of Affar Formation

In the northern provinces, the outcrops of he the Affar Fromation are clearly divisible within a wide area (including Kohlan, Hajjah, Al-Mahwit, Amran and Sa'dah regions), into three successive lithic units: a lower and an upper light colored sandstones, separated with a middle ferruginous sandstone sequence . These units were treated as members and they were formally named and described in ascending order as Azzan, Souq, and Hessn members [19].

3. 1. 8. 1. Azzan Sandstone Member

This member was introduced by [19]. It includes the lower part of the Affar Formation, and consists of fineto fine to medium, white, and yellow sandstones, with numerous green claystone and thin siltstone, interbeds. The type section lies near Kohlan Affar Town (lat. 15° 43' 57" N, long. 43° 42' 13" E), and it was named after Azzan Village. In that locality, it begins with a thin basal conglomeratic bed, and attains a thickness of 55m. On stratigraphical grounds it was assigned to the Early Jurassic [19]. The Azzan Member unconformably overlies the Khalaqah Shale Member (of the Kooli Formation), and conformably underlies the Souq Sandstone Member. [39, 40] equated the Azzan Sandstone Member with the A-unit of [42], which they dated as Late Carboniferous on the basis of the occurrence of palynmorph assemblages in lower part of the outcropping Affar Sanstone, but this age is considered to be doubtful.

3. 1. 8. 2. Souq Sandstone Member

The Souq Sandstone Member was proposed by [19], to include the middle part of the Affar Formation which consists of brownish, ferruginous, fine to medium sandstones, with thin brownish claystone and siltstone interbeds. Its middle part includes a brownish gravelly siltstone bed rich with basement boulders. This bed has a thickness of about 2m and it represents a mud flow. The boulders were interpreted as fluvially reworked deposits from the older glaciogenic Kooli Formation [19]. The type locality lies near Kohlan Affar Village (lat. 15° 43' 57" , long. 43° 42' 13") and it was named after the Souq of Kohlan (=Kohlan Market in the Arabic Language). At the type locality, the Souq Member attains a thickness of about 60m, and exhibits numerous polygonal cracks which were attributed to the effect of cooling and frost action during the Pleistocene Epoch [18, 19, 21, 25].

The Souq Member is barren of fossils and on stratigraphical grounds it was assigned to the Early Jurassic. It lies conformably between the underlying Azzan and the overlying Hessn Sandstone Members.

3. 1. 8. 3. Hessn Sandstone Member

This is the upper member of the Affar Formation. It was introduced by [19]. Its type section lies near Kohlan Affar town (lat. 15° 43' 57" N, long. 43° 42' 13" E) and it was named after Hessn Kohlan (=castle of Kohlan in the Arabic language), it consists of about75m of fine to medium, white, and yellow sandstones with thin greenish claystone interbeds.

The fossil plants and the trace fossils which were recorded in the Affar Formation [17, 19] were found in the Hessn Member. On the basis of these plant fossils, the Affar Formation and its component members were dated as Liassic. The lower contact with the Souq Member and the upper contact with the Amran Formation are conformable.

3. 1. 9. Remarks

[8], put aside the acceptance of the component members of the Affar Formation until further confirmation to their occurrence in other areas. However, Recently, [41] recorded the occurrence of the members of the Affar Formation (Azzan, Souq and Hessn) in wide regions of both the northern and southern provinces of Yemen including Kohlan, Jabal Maswar, Jabal Salab, Wadi Hajar, as well as Socotra Island, which provided a new evidence for the wide geographical distribution of these members.Worth of mention is that the erection of new formal members does not require a wide geographical distribution or mappability, [35, 36 (Article 25 , Remark a)].

3. 2. Surdud Group

The sequence of the Amran, Madbi, and Sabatayn Formations consists of marine sediments that represents a major transgression marine cycle [22], which is bounded by two continental clastics of the underlying Affar and the overlying Taouila (=Tawilah) Formations. To express the close stratigraphic relation among these formations, and to facilitate their mapping and correlation, [22] introduced the Surdud Group to combine them together as one major lithostratigraphic unit. Furthermore [27], added the Neifa Formation to be the upermost unit of the Surdud Group. The attachment of the Neifa Formation to the top of Surdud Group does not contradict with its original definition as it was established to include the marine sequence lying between the Affar and the Taouila (=Tawilah) Formations. The Surdud Group replaces the informal term Amran Group of [5, 6] in the southern provinces, in whuch he included the Shuqra, Madbi, Sabatayn, and Neifa Formations, but this does not agree with the original definition of the Amran Series (see details in Amran Series). The type area of this group lies in Wadi Surdud, where its thickness reaches 360m. This unit has yielded rich assemblages of micro- and macrofossils which date it as Bajothian-Tithonian [27].

3. 2. 1. Remarks

Despite the importance and the neeccesity necessity of the Surdud Group [8], included this Group within their list of discarded units, without providing the scientific reasons which led them to do that action. The abandonment of a formally identified and named geologic unit requires as much justification as establishment of a new unit [35, 36 (Article 17)]. Therefore, the abandonment of the Surdud Group by [8], is unjustified and it is rejected.

3. 2. 2. Amran Series

The term Amran was introduced by Lamare (in [12]) as Amran Series. It includes the Jurassic calcareous sequence lying between the Kohlan Series below and the transitional beds above (=Madbi and Sabatayn Formations). The type section of Amran Series was not precisely located by [12] but [15, 16], deduced that it lies in the southern side of Wadi La'ah at about 40km west-northwest of Sana'a. At the type locality it consists of about 320m of light gray limestone, with numerous shale and marl interbeds. The Amran sequence shows minor lithic varitions in the different parts of Yemen which makes it diffcult to be subdivided into mappable subunits [15, 16, 22] and therefore, [22], gave it a formational rank.

In the southern provinces, Beydoun (in [5]), treated the Amran Series as a group in which he included the Shuqra, Madbi, Sabatayn, and Neifa Formations. However, the attachment of these formations to the Amran does not agree with its original defenition. In their definition of the Amran and Taouilah (=Tawilah) Series, [12], (pages 52, 53, Fig. 17), attached the transitional beds (=Madbi and Sabatayn Formations) to the base of the Taouilah (=Tawilah) Series but not to the top of the Amaran Series. Also, the occurrence of the Neifa Formation is restricted to the southern provinces and it is absent in the northern provinces including the type area of the Amran Series. Moreover, the Shuqra and the Amran Formations are similar in their lithic and age characteristics indicating that they represent two synonymous units. As the Amran Series was introduced in 1930, and the Shuqra Limestone in 1954, the Amran has the date priority over the Shuqra and so it becomes the senior synonym. Consequently, and on the basis of the above-mentioned brief discussion [27], suggested that:

(a) To use the Amran within its original definition.

(b) To consider it as a formation and to stop its treatment as a group in any part of Yemen.

(c) To drop the Shuqra Formation from the Jurassic stratigraphy of Yemen and treat it as a junior synonym of the Amran Formation.

In the southern provinces, the junior synonym of Amran Formation (Shuqra Formation) consists of 39-80m of fossiliferous limestones and marls.

The exposures of the Amran Limestone are widely distributed in the northern and the southern provinces of Yemen as well as in southwestern Saudi Arabia. These exposures have yielded rich assemblages of fossils which date the Amran as Bajothian-Kimmeridgian.

3. 2. 3. Remarks

[8 (p. 57)], mentioned that El-Nakhal [22] attempted to break down Lamare's name of Amran

Series (in [12]), into mappable formational units documenting occurences of the Madbi Formation in the area west of Sana'a (and elsewhere) overlying the equivalent of the Shuqra Formation of former South Yemen. However, [22], had never attempted to break down the Amran Series into formations, but in contrast, he stressed on the difficulty to do that and therefore, he treated the Amran as a formation. The above-mentioned formations by [8], were considered by [22], as parts of the Surdud Group rather than parts of the Amran Series.

3. 3. Taouilah (=Tawilah) Series

This unit was introduced as Taouilah (=Tawilah) Series by Lamare (in [12]) in which he included the sandstone sequence lying between the Middle-Late Jurassic Amran Series, and the Tertiary Trap Seeirs (now formally named as Haraz Formation). Also, this author included within the Taouilah (=Tawilah) Series the underlying marls, siltstones and shales which form the transitional beds (=Madbi and Sabatayn Formations). At that time the Taouilah (=Tawilah) Series was believed to be non-fossiliferous, correlated with the Nubia Sandstone, and on stratigraphical grounds it was assigned to the Cretaceous. [15, 16]), recorded marine fossils of Eocene or Paleocene age in the upper parts of the Taaouilah (=Tawilah) Series. Accordingly, he subdivided the Taouilah (=Tawilah) Series into a lower part corresponding to the continental sandstones, and an upper part corresponding to the marine sandstones. Additionally, he restricted the term Taouilah (=Tawilah) Series to the lower continental part, and he introduced the term Medj-zir Series to accommodate the upper marine sandstones. [20], revised the original definition of the Taouilah (=Tawilah) Series, restricted it to the sandstone sequence lying between the transitional beds (Madbi and Sabatayn Formations) below, and the Tertiary volcanics of the Haraz Formatin above. He also gave the Taouilah (=Tawilah) Series a formational rank, and subdivided it into the Ghiras Sandstone Member (=Taouilah in its restricted sense) to include the Cretaceous continental sandstones, and the Medj-zir Sandstone Member which includes the Paleocene marine sandstones. However, [29], pointed out that these two members consist of similar sandstone sequences, which are not easily separable [8 (page 208)] and that [15, 16] and subsequent authors, differentiated the Medj-zir Series from the Taouilah (=Tawilah) Series (in its restrictrd sense) depending on the occurrence of the marine fossils and not on the basis of lithic diferences. Therefore, [29], concluded that these two units represent biostratigraphic rather than lithostratigraphic units, as rock units should be delineated on the basis of their observable lithic characteristics [35, 36]. Consequently, [29], considered the two units (and their synonyms) as being informal and he suggested dropping them from the stratigraphy of Yemen. Furthermore, he suggested to replace the Ghiras (=Taouilah in its restricted sense), and the Medj-zir Members (and their synonyms) with two new biostratigraphic units, namely, the Zone without Diagnostic Fossils, and the *Pulsiphonina prima* Zone, respectively.

The occurrence of the Taouilah (=Tawilah) Formation is restricted to the northern provinces of Yemen. Its type section lies in Jabal Al-Tawilah about 50km NW Sana'a (lat. 15° 30', long. 43° 42'), (Fig. 1). In its type locality the formation consists of about 300m of different types of sandstone. The lower contact with the Madbi and Sabatayn Formations is conformable, and the upper contact with the Tertiary volcanucs of the Haraz Formation is diachronous and conformable. On the basis of its stratigraphical position and fossil content the Taouilah (=Tawilah) Formation was assigned to the Cretaceous-Paleocene [20, 27, 29, 30, 44-47].

[5, 6, 8], considered the Tawilah as a group correlateable wih the Mahra Group.

In the present study, the T aoiulah (=Tawilah) is treated as a formation divisible into two biozones, namely, the Zone without Diagnostic Fossils and the *Pulsiphonina prima* Zone. A brief description of the stratigraphy of these two zones is given below:

3. 3. 1. Zone without Diagnostic Fossils

The present biozone occupies the lower and the middle parts of the Taouilah (=Tawilah) Formation. It forms the continental facies of the Cretaceous System in Yemen which is restricted to the northern provinces. It is equivalent to the Ahwar/Mahra Groups which are well developed in the western and eastern parts of the southern provinces, respectively. This zone was introduced by [29], to replace the informal name Ghiras Sandsone Member of [20] and subsequent workers. [29], has not designatied a stratoype. So, in the present study, the sequence at Jabal Al-Tawilah (lat. 15° 30', long. 43° 42'), (Fig. 1) is chosen to be the stratotype for this biozone, where it consists of about 250m of continental (fluvial) sandstones with few non-diagnostic fossils such as silicified wood and trace fossils. Lithically, the biozone consists of white, yellow, occasionally brown, fine to coarse, usually gravelly, cross-bedded sandstone, with clay, shale and siltstone interbeds, and occasional hematitic nodules. The sequence is cut by numerous fissures and dikes fed by the volcanics of the Tertiary Haraz Formation. In some localities, the zone includes in its middle part a brownish, ferruginous sandstone interval with thicknesses ranging from few meters to some tens of meters, which is considered as a key bed. It is believed that the sandstones of the present zone were deposited by braided rivers [44, 47]. On the basis of its

stratigraphical position the Zone without Diagnostic Fossils was assigned to the Cretaceous [29, 32].

3. 3. 2. Pulsiphonina prima Zone

The Pulsiphonina prima Zone was introduced by [29], to replace the informal name Medj-zir Series of [15, 16] and subsequent authors which violates the rules of stratigraphic nomenclature (see details in Taouilah=Tawilah Formation). It occupies the upper part of the Taouilah (=Tawilah) Formation. No staratoype was designated by [29]. Therefore, the sequence of sandstones at the cliffs that lie to the north of Mudjzer Village (Fig. 1), Al-Hazm Governorate (not Al-Ghiras area as mentioned by [15, 16], is chozen to be the stratotype for this biozones. At its type locality it includes alternative sequences of non-marine and fossiliferous marine sandstones and consists of 120m of white, usually fine to medium, compact occasionally gravelly sandstones, with clay, siltstone, and shale interbeds. The uppermost part contains ferruginous, spherulitic concretions and nodules which appear to be a paleosol that covered the area before the extrusion of the volcanics of the Tertiary Haraz Formation. The present biozone had yielded an assemblage of marine fossils including foraminifera, ostracoda, and internal casts of gastropods, brachiopods, echinoid spines, fish teeth, and trace fossils. On the basis of the recorded fossils the sequence was dated as Paleocene, [15, 16, 20, 29, 44-47].

The occurrence of the *Pulsiphonina prima Zone* is restricted to the northern provinces of Yemen, mainly in the central and northern parts around Sana'a. This indicates that the Paleocene marine transgression, which came from the east or southeast [20] and led to the deposition of the fossiliferous sandstones of this biozone, was of a limited distribution [15, 16, 20].

3. 4. Tihamah Group

The Tihamah Group was introduced by [26, 30]. It acommodates the syn-and post-rift surface and subsurface sedimentary successions in the Republic of Yemen which constitute the coastal plains bordering the Red Sea (Tihamah Plain) and the Gulf of Aden (Fig. 1). The Tihamah Plain was designated as the type area. On the basis of its stratigraphical position, and the few fossils recorded in some of its components [48], the group was dated as Miocene-Holocene. According to this definition, the *Pulsiphonina prima* Zone which replaces the informal unit Mudj-zir Member, and includes pre-rift sandstones of Paleocene age, is excluded from this group. Rocks correlatable with Tihamah Group in the southern provinces were included within the informal term "post-Miocene deposits" of [5].

The sequence of Tihama Group consists of three main types of sediments which are; a) continental clastics, b) evaporites and c) organic reefs. Each of these types is given a formational rank, and formally named as Abbas, Salif and Kamaran Formations, respectively. Furthermore, the Salif Formation is subdivided into the Qurayyah Salt Member, and the overlying Harafa Gypsum Member. [8], dated the Tihamah Group as Neogene-Pleistocene, and they attached to its base the Early Miocene Zaydiyah (mudstone and sandstone) and the Early-Middle Miocene Maqnah (Carbonate, anhydrite, shale, and mudstone) Formations which were encountered in the subsurface of the Red Sea and Tihama area.

3. 4. 1. Abbas Formation

This formation was introduced by [26, 30]. It includes the syn-and post-rift continental clastics which constitute the coastal plains of the Red Sea (Tihama Plain) and the Gulf of Aden. The type area lies in Tihamah Plain. The surface and subsurface sequence lying around Ibn Abbas Village (Fig. 1) constitutes its stratotype . It consists of valley-fill alluvial deposits including poorly sorted clastics such as gravel, sand, silt, and clay. The size of the fragments tends to decrease seawards. The thickness of the formation is variable. In Tihamah Plain it increases gradually westwards. Geophysical information indicates that the formation reaches its maximum thickness near the coasts of the Red Sea where it was estimated as 5000m [49]. A similar thickness was also mentioned for equivalent sediments in Jizan area, Saudi Arabia [50], but [8], attributed these high estimations to erroneous calculations.

On the basis of its stratigraphical position, the Abbas Formation was assigned to the Miocene-Holocene. Its lower contact is not exposed. Geophysical information however, indicates that the formation is underlain either by dense marine sediments or weathered basement rocks [49]. In both cases, the contact was considered to be unconformable. Usually the present formation is not overlain by other units. Occasionally it is unconformably overlain by Holocene sand dun**es.**

3. 4. 2. Remarks

[8], mentioned that the term Abbas was also proposed, but informally by Hughes and Beydoun [51] where it was introduced only in a stratigraphic section, [51(Fig. 5, p. 141)]. However, introducing a new rock unit in a stratigraphic section only, without any additional stratigraphic information, constitutes inadequate and informal publication [35, 36]. Despite their confirmed knowledge with the informality of the term Abbas of [51], [8], used it instead of the formal name Abbas Formation of [26, 30], in consequence, the term Abbas of [26, 30] is the senior homonym, whereas that of [51] represents the jnior junior one which mist be rejected and dropped .

[8], dated the Abbas Formation as Pliocene-Pleistocene, and included within it the mudstones and

sandstones which unconformably overly the Salif Formation. Also, they attached to its top the reefal limestone and marl that constitute the Kamaran sequence considering it as a member within Abbas Formation.

3. 4. 3. Salif Formation

The Salif Formation includes the evaporitic sequence which is intermittently exposed along the coastal region of the northern parts of the Tihamah Plain in Yemen. This sequence was previously correlated with and named after the Bad' Formation of Saudi Arabia [26, 30]. However, it has been proved that the Bad' Formation was introduced by [52], in the explanation of a geologic map only without additional stratigraphic information which indicates that it was informally published [35, 36]. Therefore, in the present study, the evaporitic sequence of Yemen is transformed, from the Bad' to the Salif Formation. The latter unit was introduced by [53] without designating a type section. So, the sequence of evaporites which is exposed and quarried in the Salif Village (Fig. 1), is designated to be the type section for the Salif Formation. The same sequence was previously selected by [26, 30] to be a reference section for the Bad' Formation, in Yemen. The Salif Village lies at 62km north of Hudaydah Town (Fig. 1). The exposed part of this section (base not exposed) consists of about 120m of coarse-grained, recrystallized rock salt (halite), with thin interbeds of pyrilic black shale, followed upwards by 10-20m of whitish, light brown gypsum beds and gypsiferous clastics. The formation is disconfbrmably overlain by marine sediments of Pliocene age. The recorded fossil microflora date the Salif evaporites as Middle-Late Miocene [48]. On the basis of its lithic characteristics the Salif Formation is subdivided into the Qurayyah Salt Member, and the overlying Harafa Gypsum Member.

3. 4. 4. Qurayyah Salt Member:

This member was introduced by [26, 30]. It includes the lower part of the Salif Formation, and consists of 120m of coarse-grained, recrystallized rock salt (halite), with thin interbeds of pyritic black shale. Its base is not exposed, and it is conformably overlain by the Harafa Gypsum Member. The type section lies in the rock salt and gypsum quarry at the Salif Village. It was named after the Qurayyah Village which lies at about one km east of the Salif Village (Fig. 1). The age and distribution of the present member are similar to those of the Salif Formation.

3. 4. 5. Harafa Gypsum Member

The Harafa Member was proposed by [26, 30] to accommodate the upper part of the Salif Formation. Its type section lies in the the Salif rock salt and gypsum quarry. It was named after Ras Harafa which lies at about 6km northeast the Salif Village. The member consists of 10-20m of whitish and light brown gypsum and gypsiferous clastics. It is conformably underlain by the Qurayyah Salt member. Its upper contact, microfossils, age and distribution are as those of the Salif Formation.

3.4. 6. Remarks

Ignoring the date priority [8], used the Ghawwas Member (of Hughes and Filatoff, 1994 in [8]), instead of the Harafa Gypsum Member of [26, 30]. The name Ghawwas is an adoption of the Ghawwas Formation which wais applied for a siliclastic sequence with scattered beds of anhydrite in the subsurface of Saudi Arabia. [8] designated the type section of the Harafa Member as described by [26, 30], to be the reference section for the Ghawwas Member in Yemen. However, dropping the Harafa Member and replacing it with the Ghawwas Member of Saudi Arabia, and in the same time designating the type section of Harafa Member to be the reference section for the Ghawwas Member in Yemen, is an odd and unjustified act practiced by those authors, which needs reasoning and which should be rejected.

3. 4, 7. Kamaran Formation

The Kamaran Formation was established by [26, 30], to include the organic reefs which constitute the Kamaran Island and the other similar islands in Yemen (Fig. 1). Its stratotype consists of the surface and subsurface sequence sequences, of the organic reefs which form Kamaran Island (It consists of yellow, green, marly limestone, and reefal limestone. The formation is rich with both fossil and Holocene exoskeletons of benthic marine organisms which date it as Pleistocene-Holocene [54, 56]. The Kamaran Formation is not overlain by other rock units. Its base is not exposed but its thickness may reach 300m [57]. A similar thickness was recorded for equivalent organic reefs that form the Farasan Islands in Saudi Arabia [50]. [8] treated the Kamaran as a member constituting the upper part of the Abbas Formation.

3. 5. Manakhah Complex

This complex was introduced by [31] as Manakhah Group. To include the intrusive and extrusive igneous rocks as well as the interlayered sediments, of the latest Cretaceoue-Holocene age in the Republic of Yemen. However as this unit includes a mixture of intrusive, extrusive and sedimtary sedimentary rocks, it is treated here as a lithodemic unit ([35, 36] Atricle 37), and its name is corrected to be Manakhah Volcanic Comoplex. It was named after Manakhah mountainous region (lat. 15° 05', long. 43° 41') which lies at about 60km west-southwest Sana'a City (Fig. 1). Main exposures of the complex are found in the western regions of Yemen. Minor exposures are also scattered elsewhere in the country. Its thickness is variable. The maximum

reported thickness reaches 2000-3000m at Sana'a region [47]. On the basis of its lithic characteristics, this unit is divided into two formations, one lithodeme and one member as follows:

1) Haraz Formation: accommodates the volcanics, pyroclastics, and the interlayered sediments, of latest Cretaceous-Tertiary age.

2) Risabah Clastics Member: introduced in the present study as a new rock unit to include the interlayered sediments of the Haraz Formation.

3) Aden Formation: includes the volcanics of the Late Tertiary-Holocene age.

3) Bura' Lithodeme: includes the Tertairy granitic plutons.

3. 5. 1. Haraz Formation

The Haraz Formation was introduced by [31] to aaccommodate the volcanics, pyroclastics and the interbedded sediments, of latest Cretaceous-Tertiary age in Yemen. It replaces the informal terms Trap Series of [15, 16], and Yemen Volcanices of [48] in the northern provinces, and the Aden Trap Series of [37] in the southern provinces. In the present study, the interbedded sediments are formally named as the Risabah Clastics Member. The Haraz Formation consists of basal volcaniclastics followed upwards by alternative sequences of basic and acidic volcanics, lavas, and paleosol on the top of the sequence. The volcaniclastics include dark gray and greenish tuffs, black shale, coal interbeds, limestone rich with gastropod shells, basaltic pillow. The basic volcanics are composed of basalt and pyroclastics with sills, and interbedded sediments. The acidic volcanics consist of ignimbrites and pyroclastics with dikes, stocks, occasional cones, and water-laid sandy tuffaceous intercalations and algal reef [58]. Most likely, the Haraz volcanics were formed from the eruption of fissure-fed basaltic flows, basaltic shield volcanoes, and individual calderas [47]. The type locality of the Haraz Formation lies in the Manakhah mountainous region. The exposed sequence around Jabal Haraz (lat. 15° 05', long. 43° 40') was designated as the stratotype. It is difficult to estimate the actual thickess of this formation due to repeated faulting, However, at its complete development it reaches 1200m [15,16] or 2000m [48] in the northern provinces , and 1100m in the southern provinces [7, 37].

[15, 23, 44] referred to the occurrence of lava flows and pyroclastics within the upper parts of the Taouilah (=Tawilah Formation). This indicates that the eruption of the volcanics of the Haraz Formation began during the deposition of the sandstones of the Taouilah (Tawilah). The arrived at conclusion is substantiated by [66, 67] who referred to the occurrence (at north of Aden), of Cretaceous sandstone interbeds within the trap volcanic sheets (=Haraz Formatin). Therefore, [23, 31 (Text-Fig. 2)], considered the contact between the Taouilah (=Tawilah) and the Haraz Formations as being diachronous and conformable whereas, [8], considered it as disconformable.

At its type locality, this formation is not overlain by other rock units. In other localities such as north of Sana'a, and Dhamar areas, it is unconformably overlain by the Aden Formation (=Aden Volcanic Series). Similarly, in the southern provinces it is usually not overlain by other rock units. Mattash and Balogh, 1994 (in [8]), mentioned that the Trap Series (which corresponds to Haraz Formation) is unconformably overlain by the Yemen Volcanic Series (which corresponds to the Aden Formation. On the basis of its stratigraphical position and the available radiometric age dating by a number of workers as [44, 59-63], the Haraz Formation is assigned to the latest Cretaceous - Tertiary. Major exposures of the present formation are found in the western parts of Yemen, minor exposures are also scattered in the country.

3. 5. 2 Remarks

[15, 16] included the volcanics and pyroclastics which constitute the Haraz Formation in the northern provinces, within the informal unit Trap Series. [48], introduced the term Yemen Volcanics to replace the name Trap Series. The new term of [48] was adopted by [47] and [8]. However, [31] pointed out that [48] introduced the term Yemen Volcanics in the explanation of the geological map of Yemen only, without additional information. This indicates that that term was inadequately published and it constitutes an informal unit [35, 36]. Consequently, it was dropped and replaced with the name Haraz Formation [31]. The Haraz Formation also replaces the term Aden Trap Series of [37] in the southern provinces despite the fact that the latter term has the date priority. This refers to that the name Aden had been applied as a geographical term for three different rock units, namely, the Aden Volcanic Series [64], Aden Trap Series and Aden Metamorphic Group [37]. This multiple usage however, does not agree with the rules of the stratigraphic nomenclature [35, 36]. According to these rules, the term Aden Volcanic Series of [64], has the date priority and therefore, it constitutes the senior homonym, whereas the other two terms (Aden Trap Series and Aden Metamorphic Group of [37] represent junior homonyms which should be dropped from the stratigraphy of Yemen and be replaced by new names. Addionally, the use of the term "series" in a lithostratigraphic sense, violates the rules of the straligraphic nomenclature [35, 36]. Therefore, the Aden Trap Series was replaced with the Haraz Formation, whereas the Aden Volcanic Series was corrected to the Aden Formation [31].

3. 5. 3. Risabah Clastics Member

Definition

The Risabah Clastics Member is introduced in the present study as a new rock unit to accommodate the

interlayered sediments within the volcanics and pyroelastics of the Haraz Formation in Yemen. It replaces the informal terms inter-Trap deposits of [15, 16], and the Lahimah Member of [58]. This member is named after the Risabah Village near which the stratotype lies.

Details of the stratotype

Location

The type locality lies in Dhamar-Ma'bar area. The interlayered sediments within the ignlmbrites and pyroolastics outcropping at the elongated hills which extend between Ma'bar and Qubatil, and lie to the west of the Risabah Village, are designated as the stratotype. The Risabah Village lies at about 70km south of Sana'a City. Geographical coordinatesofthe coordinates of the Risabah Village: Approx. lat. 14°, 42' and Approx. long. 44°, 21'

Lithic characteristics and thickness

The Risabah Clastics Member consists of fine to coarse terristial clastics including clay, shale, mudstone, silt, paleosols, calcareous sandstone, occasional conglomerate and reworked volcanic clasts. [8] referred to the occurrence of chert lenses and fossiliferous black limestone horizons. In many cases the interbedded sediments represent weathering products of the enclosing beds. They usually occur as sedimrntary lenses deposited in small shallow lakes formed in depressions on the volcanic landscape [15, 16].The maximum recorded thickness of the Risabah Member is 20m (north Ibb Town), but it is usually less than 10m. At its type locality, it consists of 1-2m of alluvial whitish sandstone, followed upwards by calcareous soil. These sediments are overlain by 1-5m of whitish yellow and light green tuffaceous layer. The sequence is exposed for a long distance at the elongated hills of the type locality.

Around Sana'a, and around Ta'iz, the Risabah Member consists of 2-4m of fossiliferous black shale, sandstone, and occasional conglomerate. Also, along Sana'a-Al Mahwit road, as well as in Jabal Samara, the member is represented by numerous paleosol horizons. Similarly, at the north and the west of Ibb Town, and at the northern side of Wadi Bana, alluvial deposits of 20, 10, and 2m thick, respectively, were recorded. Also, between the Irr and Wadi Khoub, fossiliferous sandy shale is found [15, 16].

[15, 16], included the interlayered sediments of the Risabah Clastics Member, within the informal unit "inter-Trap deposits" which he subdivided into four categories as follows:

1) Fossiliferous fresh-water deposits of probable lacustrine origin, generally containing bituminous beds, plant and fish remains.
2) Alluvial deposits with partially carbonized wood fragments.
3) Unfossiliferous sandy deposits of probable fluvioeolian origin.
4) Paleosol, generally lateritic, at some places developed along plane surfaces, and locally cutting different beds.

Fosils Fossils and age

The fossiliferous horizons of the Risabah Member bear fresh-water small gastropods, bivalves and ostraeods including: *Sphaerium* sp., *Amerlana* sp., *Melanoides* (*Tarebia*) sp, cf. *M.* (*T.*) *acuta* (Sowerby), *Candona* sp., *Cyprideis* sp., *Gomphocythere* sp,, *Cypridopsis* (?) sp. This assemblage of fossils was considered as an indication of Oligocene-Miocene age [15, 16].

In the present study, numerous shells of the snall gastropod species *Melanoides* (*Tarebia*) sp. cf, *M.* (*T.*) *acuta* (Sowerby), are recorded in the Risabah Member around Sana'a and around Ta'iz. Also imprints of plant leaves, and fish scales and vertebrae are recorded in this member along Sana'a-Kawkaban road (northwest Sana'a). Similarly, in Ar-Rhayashiya (Rada' area), this member consists of freshwater beds bearing fossil frogs, fish, imprints of plant leaves, and spicules of the fresh-water sponge genus *Sponagilla,* The recorded frogs were studied by [68] who assigned them to the new specues *Xenopus arabiensis* Henrici and Baez On the basis of the stratigraphic position and radiometric dating, the frogs-bearing beds were dated as Late Oligocene [68].

Distribution

As the Risabah Member consists of the interlayered sediments within the volcanics and pyroclastios of the Haraz Formation, its distribution is similar to that of the Haraz Formation Formation, i. e. the major exposures are found in the western parts of Yemen.

Remarks

In the explanation of the geological map of Yemen [58], introduced the term Lahimah Member in which they included the inter-Trap deposits of [15, 16]. Also, Al-Kadsi, 1994, and Al-Subbary, 1996 (in [8]) adopted that term in their unpublished Ph. D. theses. However, according to [35, 36], none of these three references can be considered to have adequate publication, being mentioned in the explanation of a map only, and in unpublished theses, respectively. Addtionally the provided information in those references is ambiguous. Consequently, the Lahimah Member represents an informal unit, which should be dropped from the stratigraphy of Yemen, and be replaced with the new unit Risabah Clastics Member which is introduced in the present study.

[8], considered the Lahimah as a member within the informal unit Medj-zir Formation. The occurrence of the sediments of the Risabah Clastics Member within the volcanies and pyroclaatics of the Haraz Formation, indicates that the Cenozoic volcanic activity in the Republic of Yemen was in the form of intermittent phases, and that there were quiet intervals, some of whioh which were of long duration. During these

quieecent quiet periods, the sediments of the Risabah Member accumulated [15, 16].

3. 5. 4. Aden Formation

The Aden Formation is an adoption of the Aden Volcanic Series of [64]). [64] applied the term to the immense development of volcanic rocks, amongst which many are recent, occurring along both shores of the southern portion of the Red Sea, and Gulf of Aden. He pointed out that the lava flows differ entirely from all the volcanic rocks of the highlands (=Haraz Formation) and of much later date, though some may be far from recent. [65] recognized two stages of activity, and [7] mentioned that more than one phase of extrusion occurred in the "Aden Volcanic Series". The present formation is well exposed along much of the coastal parts of the southern provinces from Bab al Mandab on the Red Sea to Qusay'ar-Sayhut area including parts of the plateau. In the northern provinces, the major exposures are concentrated in three regions or fields which are: the Marib-Sirwah, Sana'a-Amran, and Dhamar-Rada' fields. Minor exposures are also found in different parts of the country. [64] however, had not designated a type locality nor a stratotype for his "Aden Volcanic Series". Therefore, [31,] designated the exposed volcanics between Shuqra (lat. 13° 21' , long. 45° 42') and Ahwar (lat. 13° 33' , long. 46° 37'), to be the stratotype for Aden Formation. It consists essentially of basaltic flows and pyroclastics with numerous cinder volcanic cones, and with a thickness reaching about 500m. In the type locality the basaltic lava is associated with ash and agglomerate, and the basalt here as elsewhere, varies from scoriaceous, vesicular or ropy lava mixed with pyroclastics, to massive, columnar jointed basalt. In the Shuqra-Ahwar area the flows rest upon basement rocks or upon Jurassic and Cretaceous sedimentary rocks [7, 37]. Similarly, in the northern provinces the Aden Formation is represented by volcanics, pyroclastics, and numerous cinder volcanic cones. It consists of basic volcanic ash and lapilli, basaltic flows, obsidian, pumice flow and blocks, ignimbrites, with stocks and plugs [58]. In this part of Yemen, the formation is not overlain by other rock units, and it unconformably overlies older rocks. Mattash and Balogh, 1994, (in [8]), mentioned that the Trap Series (which corresponds to Haraz Formation) is unconformably overlain by the Yemen Volcanic Series (which corresponds to the Aden Formation. The age of the Aden Formation in the southern provinces was considered to be Late Miocene or Pliocene to Holocene [7, 37]. In the northern provinces, the radiometric dating of basaltic rock samples collected from the three volcanic fields, gave the following ages (Al-Jailani in [31]):

a) Sana'a-Amran Field: the age ranges between 3.37 ± 0.17, and 0.17 ± 0.47 Ma (i.e. Pliocene-Pleistocene).

b) Marib-Sirwah Field: the age ranges between 1.90 ± 0.21, and 0.190 ± 0.06 Ma (i.e. latest Pliocene-Pleistocene).

c) Dhamar-Rada' Field: the age ranges between 6.53 ± 0.33 and 0.0040 ± 0.0065 Ma (i.e. latest Miocene-Holocene).

These ranges indicate that the age of the Aden Formation in the northern provinces extends from the latest Miocene to the Holocene, and this agrees well with its age assignment in the southern provinces. The Holocene upper range age of the Aden Formation is substantiated by the fact that some of the basaltic sheets were extruded during historic times [48], most of its volcanoes retain their original shape, have fresh appearance, and some are from historic time; e.g. north of Sana'a [16]. Furthermore, the volcano of Jabal Alisi which lies in the Dhamar-Rada' Field and which has been visited several times by the present authors, still emits hot sulfurous vapor.

3. 5. 5. Bura' Lithodeme

This unit was originally established by [31] as Bura' Formation to include the post-tectonic alkaline granites of Tertiary age in Yemen. However due to the fact that this unit consists of granitic plutons which do not conform to the Law of Superposition, It is here treated as a lithodeminc rather than a lithostratigraphic unit [35, 36 (Article, 31)] and its name is corrected to Bura' lithodeme. . Its type area lies in the northern provinces at the western mountainous region. The granitic body which constitutes Jabal Bura' is designated as the stratotype. Jabal Bura' (lat. 14° 53' 54", long. 43° 28' 53") lies at about 48km east-northeast of Hudaydah Town (Fig. 1). Usually, it occurs as subvolcanic plugs, stocks and plutons. In its stratotype as well as in most parts of the type area, the Bura' Litodeme Lithodeme consists of alkali granite, which locally shows primary flow banding. In the southern provinces the Bura' Lithodeme occurs in two localities, namely, Jabal Manif (lat. 13° 17' , long. 44° 51') and north-northeast of Mukayras (lat. 13° 56' , long. 45° 41'). Where it consists of aegirine-riebeckite granite [7, 37]. In the type area, the granite is intruded through several rock units such as the Affar Sandstone (Early Jurassic), Amran Limestone (Middle-Late Jurassic), Taouilah (=Tawilah) Sandstone (Cretaceous-Paleocene), and Haraz Formation (latest Cretaceous-Tertiary). These rocks are not affected by contact metamorphism except over a very thin interval. In the southern provinces, it was intruded through the Cretaceous Taouila (=Tawilah sandstones, and the latest Cretaceous-Tertiary volcanics of the Haraz Formation. On the basis of its stratigraphical position the Bura' Lithodeme in the northern provinces was dated as Tertiary, probably Oligocene? to Miocene [58, 69, 70]. The K-Ar age of 22.7 ± 0.9Ma was reported by [48]. A similar age (21-23 Ma) was also mentioned by [59] which places Bura' plutons into the

Aquitanian (earliest Miocene). In the southern provinces, [37], dated it as probable later Tertiary, whereas [7], assigned it to the Late Cretaceous-Tertiary, probably Tertiary. Major exposures of the Bura' Lithodeme lie in the western mountainous region of Yemen along the contact with the Tihamah Plain. The exposures extend parallel to the Red Sea and they are almost restricted to the graben zone. This distribution may indicate that the development of the granitic bodies of the Bura' Lithodeme is connected with the Red Sea rifting.

4. Informally named units

Among the units memtioned in the lexicon of Yemen, there are five members having informal names which need to be formalized, and given new names, these are listed below as follows**:**

1. Lower Madbi Shales.
2. Upper Madbi Shales.
3. Neifa Breccia.
4. Qishn Clastics.
5. Qishn Carbonates.

The informality of these units refers to the multiple usage of the geographical component of their names which does not conform wlth with nomenclatures rules.

4.1. Madbi Formation

[8], included within the Madbi Formation ten members which are: Lower Madbi, Ayban, Henneye, Meem, Ma'abir, Raydan, Lam, Harib, Upper Madbi and Rafad. Among the above-mentioned members, the Lower Madbi Shales and the Upper Madbi Shales have informal names, which should be formalized. Therefore, it is suggestd to give them the formal names Bi'r 'Ali, and Ba Hawa members, repectively.

4. 1. 1. Lower Madbi Shales Member

The original author who introduced the term Lower Madbi Shales Member is not known, but it was informally used by the geological parties of the oil companies in Yemen. Its type section was measured by Smewing, 1992 (in [8]). It lies at Jabal Billum, lower Wadi Hajar, southwestern Hadramaut (lat. 14° 19', long. 48° 26'),(Fig. 1). In the present study, It is suggested to nomenate this unit as Bi'r 'Ali shale Member. It is named after Bi'r 'Ali Village which lies to the south of Jabal Madbi. The name of that village is used as a geographical component instead of Jabal Billum where the stratotype liesas lies as the t the name Billum has been pre-occupied with Billum Member of [71]).The type section consists of 110m of fossiliferous limestones, marls, and calcareous mudstones [8]. The member is conformably overlain by the Ma'abir Member (of Madbi Formation) and underlain by the Amran (=Shuqra) Formation. It is recognised in the surface and the subsurface of the southern provinces. On the basis of its fossil contents it was dated as Early Kimmeridgian-Early Tithonian [8].

4**. 1. 2. Upper Madbi Shales Member**

The Upper Madbi Shales member was introduced by anonymous author, and it was informally used by the geologists of the oil companies in Yemen. Its type section was designated and measured by Smewing, 1992 (in [8]), and it was located at Al Ma'abir, lower Wadi Hajar, Hadhramaut (lat. 14° 16', long. 48° 34'). The type section consists of 127m of fossiliferous marl, calcareous mudstone and shale, and argillaceous limestone [8]. The geographical names related to the type locality of this member have been pre-occupied by the Ma'abir Member, Hajar Formation and Hadramaut Group. So, a replacing geographical component will be used, namely, the Ba Hawa. Consequently its name becomes Ba Hawa Shale Member. It is named named after Jawl Ba Hawa which lies to the east- northeast of Jabal Madbi. This member occurs in most of the upper Jurassic exposed sections of the coastal area of the southern provinces, as well as in the subsurface of the Sabatayn, and Say'un-Masila basins. Its upper contact with the Qishn Formation is unconformable, whereas its lower contact with the Ma'abir Member is conformable. On the basis of its fossil contents the Ba Hawa shales Member, was assigned an Early-Middle Tithonian age [8].

4. 2. Neifa Formation

The Neifa Formation was introduced by Pike and Wofford in unpublished report (in [5- 7]). The sequence of the Neifa Formation is divisible into two main parts: a lower, consists predominantly of megabreccia; and an upper consists principally of porcellanous limestone. Smewing (in [8]), treated the megabreccia as a member which he named as Neifa Breccia Member. However, applying the same geographical name for two different units (a formation and a member), violates the rules of the stratigraphic nomenclature. Consequently, the term Neifa Breccia Member is informal and needs to be replaced with a new and formal name.

4. 2. 1. Neifa Breccia Member

This member constitutes the lower part of the Neifa Formation, its type section lies in Wadi Gharish, southwestern Hadramaut Province, (lat. 14° 13' long. 48° 13'). However, the geographical name Gharish, had been pre-occupied by the Gharish Group of [5], so, a replacing name is used to nominate this unit which is Zulm Ba Tha'lab Breccia Member. It is after Zulm Ba Tha'lab Village that lies to the south of the type section. This name is disdingisable from that of Tha'lab Group of Beydoun [5]. The type section consists (from base to top) of: (i) 8m megabreccia of blocks of

bedded limestone up to several metres across in matrix of smaller limestone blocks in fine argillaceous carbonate sand, with ammonites, foraminifera and calpionellids in the blocks, (ii) 20m slumped bedded limestones, parallel laminated limestones and planar lime mudstones with fissile calcareous shale interbeds, at the base, (iii) 20m calcareous shales, very weathered with very thin limestone interbeds, (iv) 6m internally brecciated limestone and internally slumped planar laminated lime mudstone (v) 4m , limestone megabreccia [8]. This sequence unconformably overlies the Madbi Formation, and conformably underlies the porcellanous limestone of the Neifa Formation . On the basis of the recorded fossils, the present member was dated as Late Tithonian [8].

4. 3. Qishn Formation

The Qishn Formation was introduced by [4]. It is the lowest unit of both the Ahwar and Mahra Groups. The type section lies in the Mahra at Ras Sharwayn, near Qishn (lat. 15° 25' N, long. 51° 37' E). It consists of 411m of fossiliferous limestone with marl interbeds [5-7, 72]. Smewing (in [8]) measured a new reference section (eastern composite section), near Qalana, Wadi Masilah, Mahra Province. The thickness of the reference section is 628m. The basal 22m consist of sandstones. This part of the section was treated as a member and was informally named as Qishn Clastics Member. The remaining upper 606m of the reference section, consist of alternations of fossiliferous dolomites, limestones, marls, and calcareous mudstones, with sandstone, conglomerate, gypsum and anhydrite thin interbeds. This part of the section was also considered as a member and given the name Qishn Carbonates Member. However, It is clear that the geographical term Qishn, was used in naming a formation and two members , but this violates the nomenclature rules and indicates that the three units are hononyms of which the two members are junior and informal needing formal names

4. 3. 1. Qishn clastcs Member

The original author who introduced the Qishn Clastics Member is not known, but it was informally used by the geologists of the oil companies working in Yemen. This member does not have a type section. . Therefore, the basal 22m of the Qishn new (eastern) reference section which was measured by Smewing (in [8]) are designated here, to be the type section for the present member. It lies near Qalana-Wadi Masilah-Mahra Qalana, Wadi Masila,, Mahra Province. It is suggested to nomenate this member as Hibun Clastics Member, after Wadi Hibun, east Wadi Masilah, and northwest Qalana, near which the type section lies. The designated type section consists of 22 m of rubbly poorly cemented, pebbly cross-bedded coarse quartz sandstone passing up into very fine sandstone. The member is largely composed of shallow marine sandstones and mudstones in the east and fluvio-deltaic sands, silts and conglomeratic deposits in the west; some intertonguning eastwards with carbonates occurs in the upper part [8]. This member is present in almost all sections exposing and/or boreholes penetrating Qishn Formation. Thickness varies from few metres to several tens of metres with the tendency to be less in the west. On the basis of its fossil contents, it was dated as Hauterivian-Early Barremian, especially in the eastern province, to Barremian-Early Aptian in the west [8].

4. 3. 2. Qishn Carbonates Member

This Qishn Carbonates Member was introduced by an anonymous author and informally used by operating oil companies in Yemen. No type section was selected, so the upper 606m of the new (eastern) reference section of the Qishn Formation which was measured by Smewing (in [8]) are chosen in the present study, to be the type section. In its type locality, the member consists of 606m of alternating sequences of fossiliferous dolomites, limestones, marls, and calcareous mudstones, with sandstone, conglomerate, and anhydrite thin interbeds. The member is principally carbonates but includes subordinate shales and occasional sands and generally reflects a neritic environment [8]. It is suggested to name this member as Sayhut Carbonates Member. The proposed name is after Sayhut Town which lies west of Qishn and south of Qalana near Wadi Masilah where the type section is located. This member is present in all sections exposing and/or all boreholes penetrating the full Qishn Formation. Thicknesses vary from several hundred metres in the east, to a few metres in the extreme west. On paleontological basis, the member was considered to be of Barremian to Aptian but in the extreme east may go down to Late Hauterivian and up to ?Early Albian age [8].

5. Informally re-named units

This assemblage includes the unts units whose spelling of the geographical component was altered by the Yemeni Stratigraphic Commission (in [8]) without consideration of the rules of the stratigraphic nomenclature. The total number of these units is 16 which are listed as follws:

1-Akbra Shales of [34], altered to 'Akbarah Formation, (in the present study this term is dropped).
2- Dha Sohis Limestone of [4], altered to Duha Suhis.
3- Habshiya Formation of [5], altered to Habshiyah..
4-Hadhramaut Group of [4], altered to Hadhramawt..
5-Henneye Member of Yemen Hunt Oil Company in [73], altered to Haniyah..
5-Jeza' Formation of [4], altered to Jiza'.
6- Kohlan Series of Lamare in [12], altered to Kuhlan.

Fig. 1a-b. Republic of Yemen, index map showing the approximate sites of the important localities cited in the text, compiled from [7, 8, 19, 27, 30, 31, 34, 58, 69, 70].

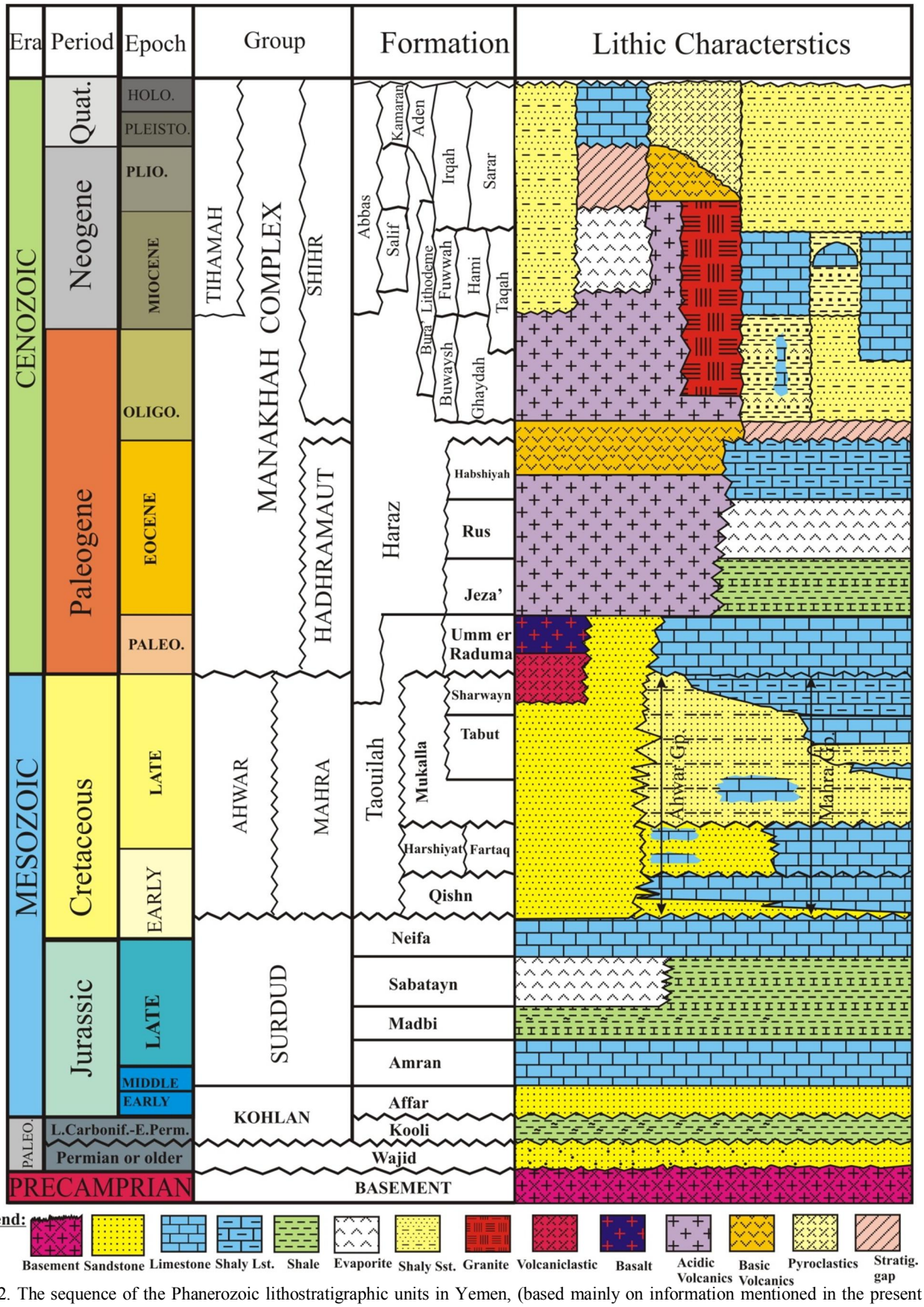

Fig. 2. The sequence of the Phanerozoic lithostratigraphic units in Yemen, (based mainly on information mentioned in the present study, the ages of these units are tentative).

7- Medj-zir Series of [15, 16], altered to Majzir (in the present study this unit is dropped).
9-M'qah Sandstone Member of [4], altered to Maqah.
10- Neifa Formation of Pike and Wfford in [5], altered to Nayfa.
11-Sabatayn Formation of [4], altered to Sab'atayn.
12- Safer Members of Yemen Hunt Oil Company in [73], altered to Safir.
13- Sarr Formation of Total Oil Company in [8], altered to Sa'ar.
14- Tabut Formation of [74], altered to Dabut.
15- Taoilah Series of Lamare in [12], altered to Tawilah...
16- Tihayr member of [5], altered to Tuhayr.

Whatever the reasons which led the Yemen Stratigraphic Commission [8], (in [8]), to alter these names, that action violates the rules of the statigraphic nomenclature [35, 36 (Article 7, Remark d)]. Therefore, the altered names are informal and should be dropped, and it is recommended to return back to the original names.

6. Summary and Conclusions

The revision of the nomenclature history of the Phanerozoic lithostratigraphic units mentioned in the stratigraphic lexicon of Yemen [8] showed that a large number of these units were informally introduced, dropped, named or re-named. In the present study, the previously practiced stratigraphic errors and violations were highlighted and corrected in accordance with the accepted international nomenclature rules, and in some cases new names were proposed. The large number of errors and violations indcattes that the authors of that lexicon are not aware with the rules of the stratigraphic nomenclature

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