

Review of the Stratigraphy of the Paleozoic Erathem in the Republic of Yemen

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ABSTRACT. In Yemen, the Paleozoic Erathem includes the Wajid Formation which consists of continental sandstone (Carboniferous-Early Permian) and the Kooli Formation which consists of glacial siltstone and silt-shale (Permian). The Kooli is the lower formation of the Kohlan Group (Permian-Early Jurassic) and it is subdivided into the Sharas Siltstone Member and the overlying Khalaqah Shale Member.

The Republic of Yemen embraces the southwestern corner of the Arabian Peninsula bordering the Red Sea and the Gulf of Aden (Fig. 1). It is a new country resulted from the union of the former "Yemen Arab Republic" (North Yemen), and the former "People's Democratic Republic of Yemen" (South Yemen). In this study I shall refer to the former "Yemen Arab Republic" as the northern provinces, and the former "People's Democratic Republic of Yemen" as the southern provinces.

The present work is a part of a comprehensive study which is concerned with the revision of the stratigraphy of the Phanerozoic Eonothem in the Republic of Yemen. It is planned to publish this study in a series of successive publications which will treat the three Phanerozoic Erathems. The present part is mainly devoted for the revision of the stratigraphy of the Paleozoic Erathem in the Republic of Yemen, whereas the Mesozoic and Cenozoic Erathems will be discussed elsewhere.

Rock units that belong to the Paleozoic Erathem in Yemen include the Wajid and the Kooli Formations (Fig. 2, Table 1). The Kooli is the lower formation of the Kohlan Group.

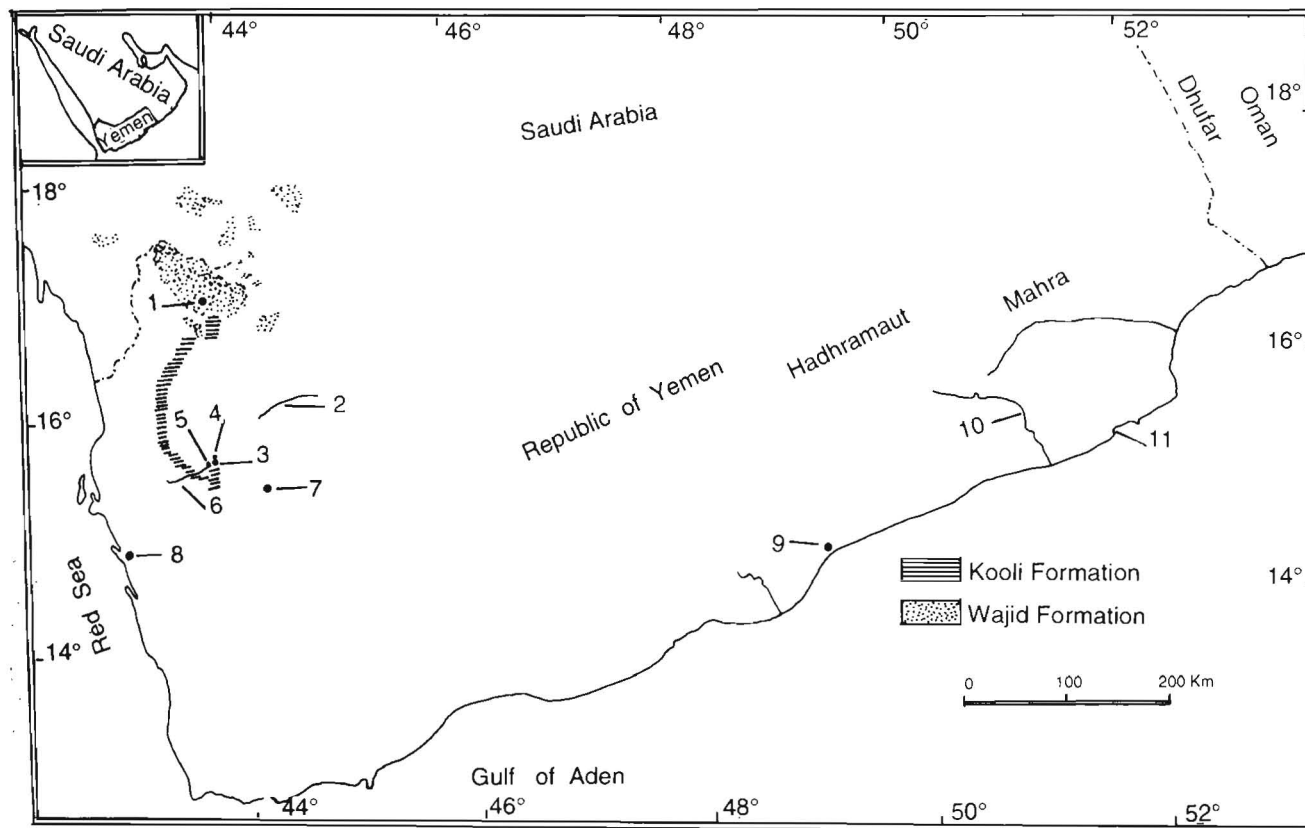


Fig 1. Republic of Yemen, index map showing a schematic distribution of the Paleozoic Erathem, and the important localities cited in the text (after Italconsult, 1973, Roland 1979, Kruck and Thiele 1983, Kruck and Schäffer, 1991): 1: Sa'dah, 2: Wadi Al-Jawf, 3: Kohlan, 4: Khalaqah, 5: Beit Al-Kooli, 6: Wadi Sharas, 7: Sana'a. 8: Hudaydah, 9: Mukalla, 10: Wadi Masila, 11: Ras Sharawaynn.

Aims of the present study:

The main aims and objectives of the present study are summarized as follows:

- (1) Compiling the available information on the Paleozoic Erathem in the Republic of Yemen.
- (2) Pursuing the distribution of the Paleozoic Erathem and its lithologic variation from the northern to the southern provinces of Yemen.
- (3) Detecting the paleogeographical significance of the distribution and lithologic variation of this erathem in Yemen.



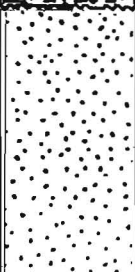
| Period | Group | Formation | Member | Lithology | Characteristics | Environment |
|---|-------------|-----------|------------------|---|---------------------------------------|-------------------|
| P E R M I A N | K O H L A N | Kooli | Khalaqah |  | Silt-shale and Siltstone interbeds | Glacio-lacustrine |
| | | | Shale | | | |
| | | (130 m) | Sharas Siltstone |  | Siltstone and Silt-shale | |
| C A R B O N I F E R O U S E. P E R M I A N | — | Wajid | Upper Wajid Ss. |  | Sandstone | Deltaic-eolian |
| | | | (200 m) | | | |

Fig 2. Columnar section showing the subdivisions and depositional environments of the Paleozoic Erathem in the Republic of Yemen (not to scale).

Table 1. Historical review of the subdivision and age assignment of the Paleozoic Era them in the Republic of Yemen

| Age | Geukens (1966) | Roland (1979) | | Kruck and Thiele (1983) | | El-Nakhal (1987) | | | Kruck and Schäffer (1991) | | The Present Study | | | | | |
|---------------|-------------------------------------|---|--|------------------------------------|--|---|-------------|---------------------------------|------------------------------------|-------------|---------------------|--------------------|---------------------|--|---------|---------------------|
| | | Akbra Shales (Permian) | | — | | Kohlalqah Member | Sharas Mem. | Permian | — | | Kohlalqah Member | Permian | Kohlalqah Member | | Permian | |
| Permian | Wajid Ss. (Permian? or older) | Akbra Shales (Permian) | | — | | | | | Kohlalqah Member | Sharas Mem. | | | Permian | — | | Kohlalqah Member |
| | | Upper Wajid Ss. (Permian to Carboniferous and older) | | Akbra Shales (Lower Permian) | | Upper Wajid Ss. (Early Permian to Late Carboniferous) | | Akbra Shales (Lower Permian) | | | Sharas Mem. | | | Sharas Mem. | | |
| Carboniferous | Wajid Sandstone | Upper Wajid Ss. (Permian to Carboniferous and older) | | — | | Upper Wajid Ss. (Early Permian to Late Carboniferous) | | | Upper Wajid Ss. (Carboniferous) | | Wajid Form. | Upper Wajid Ss. | | (Early Permian to Carboniferous) | | |
| Devonian | | Lower Wajid Ss. (Ordovician and younger to Cambrian ?) | | — | | — | | | Lower Wajid Ss. (Devonian?) | | | Lower Wajid Ss. | | | | |
| Silurian | | — | | — | | — | | | — | | — | | — | | — | |
| Ordovician | | — | | — | | — | | | — | | — | | — | | — | |
| | | — | | — | | — | | | — | | — | | — | | — | |
| Cambrian | | — | | — | | — | | | — | | — | | — | | — | |

The Wajid Formation:

The type locality of the present formation lies in southwestern Saudi Arabia, at Jabal Wajid (lat. 19° 06' N, long. 44° 27' E). It was introduced by Gierhart and Owen, in an unpublished report prepared in 1948 (cited in Powers *et al.* 1966, Powers 1968). It includes the sandstone sequence which covers the southeastern edge of the Arabian Shield, and crops out beneath the Permian Khuff Formation at Wadi ad Dawasir in Saudi Arabia. The Wajid Sandstone is continuously exposed from Wadi ad Dawasir (lat. 20° 30' N) south of Najran (lat. 17° 35' N) a distance of more than 300 km. Smaller isolated remnants capping the Precambrian basement occur to the southwest and extend into the northwestern parts of Yemen. In addition, the Wajid Formation has been drilled down to the east of the northern end of the outcrop (Powers, *et al.* 1966, Powers 1968, Brown *et al.* 1989).

In the type area, the Wajid consists of poorly to moderately sorted, friable, cross-bedded sandstone, with bands of conglomerate, quartzitic ironstone, silty shale and few lenses of dolomite in its upper part, with a maximum thickness reaching 950 m. It unconformably overlies the Precambrian basement rocks, and underlies the Khuff Formation (Permian). Only nondiagnostic fossils have been recorded in the Wajid Sandstone such as spores, algae, tree trunks, and the following trace fossils: *Scolithus (Tigillites)*, *Cruziana* sp., *Skolithos*, *Chitinozoa*, *Conchitina latifrons*, *C. micracantha robusta*, *Ancyrohitina nodosa* (Powers *et al.* 1966, Powers 1968, Hemer 1968, Alabouvette and Villemur 1973, Dabbagh 1981, Brown *et al.* 1989, Moshrif 1989).

Due to the absence of index fossils, the age of the Wajid Formation has been a matter of dispute (Table 2). Powers *et al.* (1966), and Powers (1968) dated it as Permian or older, whereas Hemer (1968) suggested a Cambrian-Ordovician age. Brown *et al.* (1989) assigned it to the latest Early Ordovician or possibly somewhat younger, and McClure (1980) considered it as being of latest Carboniferous or earliest Permian age. Moshrif (1989) on the basis of the occurrence of a fossil tree trunk, questioned the Cambrian-Ordovician age assignment, and suggested a Carboniferous-Permian age for the formation. On stratigraphical and paleontological views, the assignment of the Wajid Formation to the Carboniferous- Permian by Moshrif (1989) seems to be reasonable and therefore, it is here accepted.

Remarks:

Powers (1968) described the Wajid Sandstone as being of nonmarine origin. Hadley and Schmidt (1975) concluded on the basis of modal analysis, that the Wajid is of fluvial origin. Dabbagh and Rogers (1983), Moshrif (1989), and Moshrif and Hiti (1989) mentioned that the southern parts of the present formation, near the

Table 2. Historical review of age assignment of the Wajid Formation in Saudi Arabia

| Rock Unit | Powers <i>et al.</i> (1966), Powers (1968) | Hemer (1968) | Hadley and Schmidt (1975) | McClure (1980) | Moshrif (1989) | Brown <i>et al.</i> (1989) |
|-----------------|--|-----------------------------|------------------------------|--|--------------------------|--|
| Wajid Sandstone | Permian or older | Carboniferous to Ordovician | Carboniferous? and Cambrian? | Earliest Permian or Latest Carboniferous | Permian to Carboniferous | Latest Early Ordovician or possibly somewhat younger |

Yemen border, consist of fluvial sandstones and very minor siltstones and silty shales. The fluvial origin was demonstrated by the presence of fining-upward cycles, channels, trough cross-bedding, and absence of any organic traces or fossils. The northern part of the outcrop area consists of internally homogeneous, tabular cross-bedded, horizontally bedded sandstones apparently formed in a shallow marine environment. These marine rocks contain trace fossils broadly similar to *Skolithos*. Those authors added that abundant cross-bedding in both facies of the Wajid indicates a northward transport direction, toward what is now the center of the Arabian Shield. On the other hand, Helal (1963, 1965) and McClure (1980) referred to the occurrence of boulder beds considered to be of glacial origin in the upper parts of the Wajid Formation in the Khashm Khatmah and Jabal Umm Ghiran areas. Accordingly, it can be deduced that in the southern regions, the Wajid Formation was deposited in fluvial environment which grades northwards to shallow marine environment, whereas its upper parts were deposited in glacial environment.

The Wajid Formation in the Republic of Yemen:

In Yemen, the occurrence of the Wajid Formation is restricted to the northern provinces around Sa'dah and in Wadi Al-Jawf area (Fig. 1). It thins southward and wedges out rapidly where it becomes absent south of lat. 16° N (Kruck and Thiele 1983). (Fig. 3). In this locality it consists of well-rounded, white quartz sandstone and conglomeratic lenses. It represents deltaic deposition by rivers flowing from the southeast. In the northernmost regions, the Wajid Sandstone becomes less coarse-grained, possibly formed in part, of eolian deposits (Geukens 1966).

The maximum recorded thickness is about 200 m (in Jabal Dalhan, north of Sa'dah). The Wajid unconformably overlies the Precambrian basement rocks. The nature of its contact with the overlying Kooli Formation (Permian) is not known precisely. Kruck and Thiele (1983) considered it as being unconformable.

The Kohlan Group:

This rock unit was introduced as Kohlan "Series" by Lamare *et al.* (1930) to include the siltstones and the overlying sandstones that lie between the Precambrian basement rocks below, and the Amran Limestone above, which are well exposed in the northwestern parts of Yemen. It was named after the Kohlan Town which lies about 65 km northwest of Sana'a (Fig. 1). El-Nakhal (1987) gave the Kohlan "Series" a group rank.

The sequence of the Kohlan Group is well exposed in the northwestern parts of Yemen, and it was detected in the subsurface in Sana'a and Hudaydah areas (Italconsalt 1973, El-Nakhal 1987). In the southern provinces of Yemen, the Kohlan Group is exposed in the coastal mountain belt of southwest Hadhramaut west of long. 48° 38' E, and it reappears eastwards in Al-Mahra at the Sharawayn and probably at Al-Masila. Also, its exposures extend into Dhufar, Oman.

In its type locality, the group consists of about 300 m 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.

In the southern provinces, the Kohlan was treated as a formation, and a reference section was designated at Al-Ma'abir, Wadi Hajar, Hadhramaut (lat. 14° 14' N, long. 48° 33' E). In this part of Yemen, the Kohlan sequence consists of 17-81 m of arkosic sandstone with several conglomeratic horizons consisting of pebbles of vien quartz and igneous and metamorphic rocks and green and purple marl, siltstone and shale interbeds (Beydoun 1964, 1966, Greenwood and Bleackley 1967, Beydoun and Greenwood 1968).

In most parts of Yemen, the Kohlan Group unconformably overlies the Precambrian rocks. In the northwestern regions, in Sa'dah area, it overlies the Wajid Formation. The stratigraphic relation between these two rock units has not been studied in detail. Kruck and Thiele (1983) considered it as being unconformable. The upper contact with the Amran Formation is gradational and conformable.

The Kohlan Group has yielded an assemblage of fossils including trace fossils, plant remains, pollen grains and spores which dated the Kohlan sequence as Early Jurassic (Lias), (Carpentier and Lamare 1932). However, as it was proved that the lower siltstones and silt-shales of the Kohlan Group are of glacial origin, and on the basis of the recorded spores and pollen grains (see details in individual formations and members), the age of this group was modified to Permian-Early Jurassic (Roland

1978, Kruck and Thiele 1983, El-Nakhal 1984, 1987, 1992). However, due to the absence of diagnostic fossils, it was not possible to confirm whether or not the Triassic is represented in the Kohlan Group.

Subdivision:

In (1978) Roland recorded geological features which indicate that the siltstones and silt-shales that constitute the lower parts of the Kohlan Group in Sa'dah area, were deposited in a glacial environment. Consequently, he (1979) subdivided the Kohlan into two units, namely, the "Akbra Shales" and the overlying "Kohlan Sandstone". However, El-Nakhal (1987) pointed out that these two units violate the rules of the stratigraphic nomenclature (North American Stratigraphic Code, 1983, Article 4, Remark a, and Article 19, Remark g), and therefore, he rejected both of them. El-Nakhal (1987) treated the Kohlan as a group which he subdivided into two formations and five members as follows:

| | | | |
|-----------------|--------------------|-------------------------|--|
| Kohlan Group | Affar Formation | Hessn Sandstone Member | Early Jurassic to Triassic (?) |
| | | Souq Sandstone Member | |
| | | Azzan Sandstone Member | |
| | Kooli Formation | Khalaqah Shale Member | Permian |
| | | Sharas Siltstone Member | |

The Kooli Formation which has a Permian age, will be discussed below, whereas the Affar Formation being of Early Jurassic age will not be treated here.

The Kooli Formation:

This formation was introduced by El-Nakhal (1987) to accommodate the gravelly siltstones and silt-shales of glacial origin, which constitute the lower part of the Kohlan Group in the northern provinces of Yemen. It replaces the informal name "Akbra Shale" of Roland (1979). Its stratotype lies in Kohlan area, near Beit Al-Kooli Village (lat. 15° 43' 57" N, long. 43° 42' 12" E), (Fig. 1). 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 (Fig. 2). Variable-sized boulders and gravels of basement rocks with maximum diameter reaching 5 m, 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 indicated that the Kooli Formation was deposited in glacio-lacustrine environment. The maximum recorded thickness of this formation is 130 m (Kruck and Thiele 1983). The Kooli Formation is well developed in the northern provinces.

The lower contact of the Kooli Formation is similar to that of the Kohlan Group and its upper contact with the Affar Formation is unconformable.

The siltstones and silt-shales of the Kooli Formation have yielded numerous spores and pollens, algal remains, and trace fossils (Kruck and Thiele 1983), and these are listed as follows:

- a) Pollens: *Cordaitina* sp., *Vestigisporites* sp., *Potoniesporites novicus*, *Protohaploxylinus goraiensis*, *P. Jacobii*, *Leiotriletes* sp., *Apiculatisporitis* sp. aff. *A. abditus*, *Acanthotriletes* sp., *Apiculatisporis* sp., *Kraeuselisporites apiculatus*, *K. sp. cf. K. apiculatus*, *K. spinosus*, *K. punctatus*, *Punctatisporites* spp., *Reticulatisporites* sp.
- b) Algal remains: *Leiospheres* sp., *Tympanicysta* sp.
- c) Trace fossils: *Permichnium*, *Rhizocorallium*, *Scolicia*, tracks probably made by a *Polychaete*.

In addition to the above mentioned trace fossils, numerous tracks which are assigned to *Umfolozia sinuosa* Savage, are recorded in the present study in the Kooli Formation.

On the basis of its stratigraphical position and fossil content, the Kooli Formation was assigned to the Early Permian (Kruck and Thiele 1983), and to the Permian (El-Nakhal 1983, 1987, 1992), (Table 1).

Remarks:

In their description of the Kohlan Formation in the southern provinces, Greenwood and Bleackley (1967), mentioned that it consists of light colored sands, sandstones, and marls together with pebbly and conglomeratic basal layers incorporating recognizable fragments of basement rocks. These basal pebbly and conglomeratic layers are tentatively correlated with the Kooli Formation (Fig. 3), which is well developed in the northern provinces.

Similarly, McClure and others (1988) mentioned that a drill hole located about 200 km southeast of Khashm Khatmah, southwestern Saudi Arabia, penetrated over

300 m of glacial clastics. The top part of that interval represented by a core display fine clay-siltstone varving and was interpreted to be of glacio-lacustrine origin. Core from the bottom part of the 300 m interval was described to be a diamictite of unstratified clay-siltstone with pebble and granule clasts which was also considered to represent glacial tillite. On the basis of its spore and pollen content that interval was dated as Late Westphalian or Early Stephanian-Sakmarian (Late Carboniferous-Early Permian). In the present study this interval is equated with the Kooli Formation in Yemen.

Again, the Kooli Formation is correlated with similar glacial deposits found in both Oman and Ethiopia. The deposits of Oman belong to the Haushi Formation, and on the basis of the recorded microflora they were assigned to the Late Carboniferous-Early Permian (Braakman *et al.* 1982). Those of Ethiopia were dated as Permo-Carboniferous (Beyth 1973).

The Sharas Siltstone Member:

This is the lower member of the Kooli Formation. It was introduced by El-Nakhal (1987) to include the gravelly siltstones and subordinant shales, which constitute the lower part of the Kooli Formation. The type section lies near Beit Al-Kooli Village, Kohlan area (Fig. 1), and it was named after Wadi Sharas and Sharas Village. It is well developed in the northern provinces. At its type area, it attains a thickness of 16 m. Its upper surface is polished, with occasional parallel striations and grooves. Dropstones and striated gravels are common throughout the sequence. In Kohlan area, it unconformably overlies the Precambrian rocks, whereas in Sa'dah area it overlies the Wajid Sandstone with a probable unconformable contact.

On the basis of the recorded spores and its stratigraphical position, it is assigned to the latest Early Permian.

The Khalaqah Shale Member:

It is well developed in the northern provinces and its type section lies in Kohlan area near Beit Al-Kooli Village. It was named after the Khalaqah agricultural district (Fig. 1), and introduced by El-Nakhal (1987). In its type locality, it consists of a thin basal tillite (0.5 m), followed upwards by a thick sequence (89.5 m) of gravelly, varved silt-shale including numerous thin compact siltstone interbeds. Dropstones and striated gravels are common throughout this 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 the basis of its spores content and stratigraphical position it is dated as Late Permian (El-Nakhal

1987).

Summary and Conclusions

The revision of the stratigraphy of the Paleozoic Erathem in the Republic of Yemen has led to the following conclusions:

- (1) In Yemen, the Paleozoic Erathem is relatively poorly developed being represented by its upper part (Carboniferous-Permian) only.
- (2) Its occurrence is restricted to the northwestern regions of Yemen.
- (3) It consists of continental sandstones and glacial siltstones which form the Wajid (Carboniferous-Early Permian) and the Kooli (Permian) Formations, respectively.
- (4) The geographical distribution and the lithologic characteristics of the Paleozoic Erathem indicate that the Yemen during that time was occupying a continent in which the rivers and wind that laid down the Wajid Sandstone, and the glaciers which formed the Kooli Siltstone were flowing to the northwest.
- (5) The presence of the glacial features in the Kooli Formation indicates that the Yemen was effected with the Late Paleozoic glaciation and the Arabian Peninsula was part of Gondwana.
- (6) The occurrence of the glacial deposits in the Kooli Formation substantiates the previous records of similar and correlatable deposits in Oman, southwestern Saudi Arabia, and Ethiopia, and completes the picture of the Late Paleozoic Gondwana glaciation in the western Asia-eastern Africa region.

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مراجعة طبقية حقب الحياة القديمة في الجمهورية اليمنية

حامد أحمد النخال

قسم البيئة وعلوم الأرض - كلية العلوم - الجامعة الإسلامية - غزة - فلسطين
بواسطة مكتب ارتباط الجامعة الإسلامية - ص. ب. (٤٤٧) - الجبيلة - عمان - الأردن

يضم حقب الحياة القديمة في الجمهورية اليمنية تكويني الوجد والكوالي . يتكون تكوين الوجد من صخور رملية ، وتوجد مكاشفة في شمال الجمهورية اليمنية (حول صعدة ووادي الجوف) وجنوب غرب المملكة العربية السعودية حيث يوجد قطاعه النمطي .

وتمتد هذه المكاشف في المملكة العربية السعودية بشكل متواصل ما بين وادي الدواسر ونجران مسافة تصل إلى حوالي ٣٠٠ كم . ونظراً لعدم احتواء صخوره على أحافير مرشدة في كل من الجمهورية اليمنية والمملكة العربية السعودية فقد حدث جدل حول عمره ونُسب إلى عدة عصور جيولوجية مختلفة وفي مقدمة ذلك (العصر الكربوني - وأوائل العصر البرمي) . لقد ترسبت صخور الوجد في الجمهورية اليمنية وفي المناطق الجنوبية من المملكة العربية السعودية في بيئة قارية ، أما مكاشفة الشمالية والتي تقع في المملكة العربية السعودية فقد ترسبت في بيئة بحرية شاطئية ضحلة ، كما أن أجزاء العلوية في المملكة العربية السعودية فيعتقد بأنها ترسبت في بيئة جليدية . وقد قُسم هذا التكوين في الجمهورية اليمنية إلى عضوين علوي وسفلي ، أما في

المملكة العربية السعودية فقد قُسم إلى ثلاثة أعضاء سفلي وأوسط وعلوي .
ويصل أكبر سمك لتكوين الوجيد في الجمهورية اليمنية إلى ٢٠٠ متر ،
بينما يصل سمكه إلى ٩٥٠ متر في المملكة العربية السعودية .

أما تكوين الكولي فيتكون من صخور غرينية جليدية تنكشف في شمال
غرب الجمهورية اليمنية في مناطق صعدة وحجة وكحلان . والكولي هو
التكوين السفلي في مجموعة كحلان الصخرية (حيث التكوين العلوي هو
تكوين عفار الذي يتبع في عمره أوائل العصر الجوراسي) كما أنه السمي الأكبر
لتكوين أكبره الذي لا يتفق وقوانين التسمية الطباقية ، ويصل أكبر سمك لتكوين
الكولي إلى حوالي ١٣٠ متر .

وعلى أساس وضعه الطبقي وما يحتويه من أحافير حبوب اللقاح
والطحالب ، فقد نُسب عمره إلى العصر البرمي . وبناء على خواصه الصخرية
فقد قُسم تكوين الكولي إلى عضوين وهما شرس وخلقة . وعضو شرس هو
الأقدم ويتكون من صخور غرينية ويصل سمكه إلى حوالي ١٦ متر . أما عضو
خلقة فهو الأحدث ويتكون من صخور طفلية غرينية ، ويصل سمكه إلى
حوالي ٩٠ متر .