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Microfacies Analysis, Environmental Reconstruction and Determination of Sea-Level Fluctuations in Permian Deposits of the Kalmard Area, Khan Gorup (Kuh-e-Ahaki Section)

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Abstract

Lower Permian deposits in the Kalmard block, which are known as Khan Formation, enjoys different characteristics in various outcrops. This formation, from bottom to top, is interpreted to be a group of three formations, namely Chili, Sartakht and Hormoz. It is mainly composed of carbonate rocks, dolomite, sandstones, shale and marl. The Kuh-e-Ahaki section in Chili formation is 87 meters thick. According to lithological and microscopic studies, deposits of Khan Gorup in Kuh-e-Ahaki section are deposited in beach sub-environments, open to semi-restricted lagoon sub-environments, shoal sub-environment and open submarine sub-environment in the rocks of this part of formation, triggering fluctuations in sea level. Vertical changes of microfacies and the curve of its depth change point to the high thickness of the facies of shoal and open marine sub-environments. The rocks of Khan Gorup are deposited in a low-angle homoclinal ramp located in southern Paleotethys Ocean.

Keywords: Chili, Homoclinal, Kalmard, Khan Formation, Kuh-e-Ahaki Section, Paleotethys Ocean, Permian

1. Introduction

Central Iran, shaped like a triangle and as one of the major, largest and most complex geological units in Iran, is located in the center of Iran. The dominant structural pattern of this area is of separate blocks type, separated from each other by deep faults and thus, has distinct characteristics. Kalmard block forms a small part of this area and is located between Kalmard faults in the east and Naeini faults in the west[1,2].

Khan Gorup is mainly a group of limestone, sandy limestone and sandstone as well as a small amount of dolomite at its end. The lithology of this formation has consisted of limestone, sandy limestone, shale and marl. However, most of these events are only partly studied so far.

This section is located in the southwestern Tabas (at 1:250000 scale) and Eastwestern Robat khan (at 1:100000 scale) in the Kalmard block (eastern central Iran)[5]. This section is framed by the geographical coordinates of 33’32`09” N and 56’16`39” E (Figure 1).

The section studied is located about 65 km from Tabas, accessible by a one-kilometer-dirt road which has 1 km long (Figure 1).

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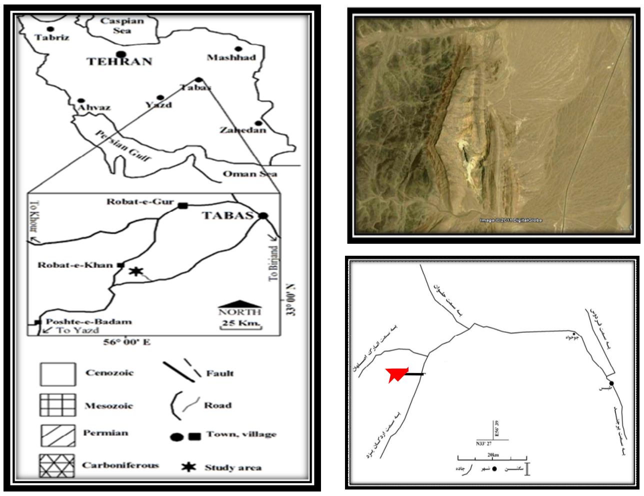

Figure 1. Geographical position, access ways, satellite images and outcrop.

2. Procedure

To detect the facies characteristics and conditions governing this sedimentary environment, the field studies were carried out. To do so, one of the most complete outcrops of Khan Gorup in Kuh-e-Ahaki section, with 87 meters long, in the Kalmard block is selected.

During field observations, the morphological characteristics of the sequence including thickness, sedimentary structures, types of fossils, etc. as well as number, type and thickness of parasequences are recorded and then the sampling program is commenced.

Various types of the cycles, namely shallowing, deepening, retrogradational, progradational, aggradational, brining, coarsening and fining are determined. The samples are collected from the sites where the most facies and cyclic changes are found and regarding the repetition of the sedimentary cycles, 55 samples were gathered.

During the experimental studies, a sample of 60 microscopic thin sections, one section for every rock sample and in some cases, to increase accuracy, two or three thin sections, were taken. These sections are determined in different directions so that two sections are perpendicular to the bedding plane and one another, and one section is parallel to the bedding plane.

Microscopic thin sections are employed to study the facies, fossils and conditions governing the sedimentary environment. Additionally, the sedimentary environment of this part of sequence is interpreted and depicted, and the studied sequence is discussed based on the existing evidence.

The facies and sedimentary environment of this section are determined based on the field observations and microscopic studies of the 60 thin sections. The carbonate rocks are also named based on[13], in which the maximum matrix grain size is 0.06.

Facies and facies groups of each sub-environment are determined based on type of skeletal and non-skeletal carbonate grains as well as their texture. Moreover, the comparative diagrams of[14] are employed to determine the frequency percentage of the facies components including echinoderm, bryozoa, Brachiopoda, Gastropod, Ooid, Pelloid and classtic particles.

The microfacies components can be divided into two groups of orthochem, consisting of matrix and cement, and allochem including skeletal and non-skeletal components. Walther's law of correlation of facies[17] is also used to restore and analyze the sedimentary environment of deposits. Considering[11,12,14,21,23], this study examined the marginal and vertical changes of facies and compared them with today's sedimentary environments. Additionally, the frequency distribution of the microfacies components of the studied section is presented and the depth changes of the sedimentary basin are also identified.

This study aims to achieve the following goals:

- Studying and analyzing the microfacies in Khan Gorup in Kuh-e-Ahaki section.
- Restoring the sedimentary conditions of the Kalmard block in Permian based on data gathered from microfacies and field observations in Khan Gorup in Kuh-e-Ahaki section.
- Depicting sea-level fluctuation curve and its relationship with sea-level fluctuation curve at global scale and in Permian era in Khan Gorup in Kuh-e-Ahaki section.

3. Discussion

Field observations and petrographic and microscopic analyzes of the sequence represent a couple of facies groups, indicating four sedimentary sub-environments.

3.1 Beach Sub-Environment (Facies A) Consists of the following Microfacies

3.1.1 Quartzarenite

The presence of 95 Quartz, sorting and low roundness suggests that this microfacies belongs to a beach. Pressure dissolution, a process occurring during sedimentation or after that, is also observed. The iron oxide layers are also seen in some parts of rock, pointing to shallow or near-level conditions (Figure 2).

3.1.1.1 Interpretation

Beach related facies, indicate relatively high energy conditions in this sub environment. Meanwhile, the presence of iron veins, can be the reason of large amounts solved oxygen, which is again other reason for low-depth of this environment. Therefore it can be concluded that this microfacies belongs to a sandy beach[18,23]. Moreover, maturity petrofacies to super maturity Qurtzarenite confirm high tidal regime[15].

3.2 Open and Semi-Restricted Lagoon Sub-Environment contains the following Microfacies

3.2.1 Bioclastic Benthic Foraminifera Pelloid Packstone

Pointing to a semi-restricted lagoon environment, this facies, laid down in a micrite matrix, contains skeletal fractures such as Benthic Foraminifera which consists of Globivalvulina, Pelecypoda and pelloid (Figure 3a).

3.2.2 Bioclastic Benthic Foraminifera Grainstone

The Benthic Foraminifera comprise up to 20% of the rock volume and consist of Globivalvulina, Staffellida and Tuberitina. This microfacies formed in conditions is similar to those seen in microfacies 3.2.1, though the formation environment of microfacies 3.2.2 enjoys more energy in the Sparite cement matrix (Figure 3b).

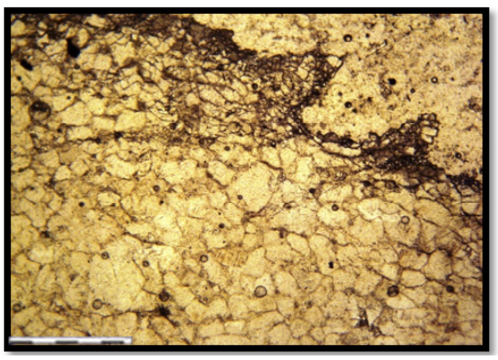

Figure 2. Beach sub-environments facies: quartzarenite (1 mm scale).

3.2.3 Bioclastic Intraclastic Pelloid Grainstone

In this microfacies, the fossils found are restricted to the pieces of 5% Pelecypoda. This microfacies consists of 20% Intraclast, 40% Pelloid set in a micrite matrix (Figure 3c).

3.2.3.1 Interpretation

Common characteristics among all microfacies of this group include the presence of lime mud between grains and bioclasts resulted from lagoon species, capable of surviving in restricted and semi-restricted conditions. The first common characteristic points to calmness in their formation environment (though, erosions observed in some sections indicate that hurricanes disturb the environment calmness). The second characteristic shows the high level of salinity in the sedimentary depositional environment. The microfacies of this group differ mainly in the type of fabric and size of grains[23].

The presence of micro Stylolites in this facies is due to lack of primary cementation, resulted from organisms' activities[3,20]. Since nutrients are limited in such conditions, sediment eaters' activities rise and activities of various burrows including distinct and indistinct ones are resulted from activities of such organisms[22]. Such organisms mostly continue their life through grazing[9]. The fundamental characteristic of some lagoon facies is high percentage of pelloid, gastropoda, benthic foraminifera, dasicladasea algea and intraclastics. Other elements including pelecypoda are also found in this facies, the presence of pelloid and gastropoda point to the formation of this facies in shallower part of lagoon environment[10].

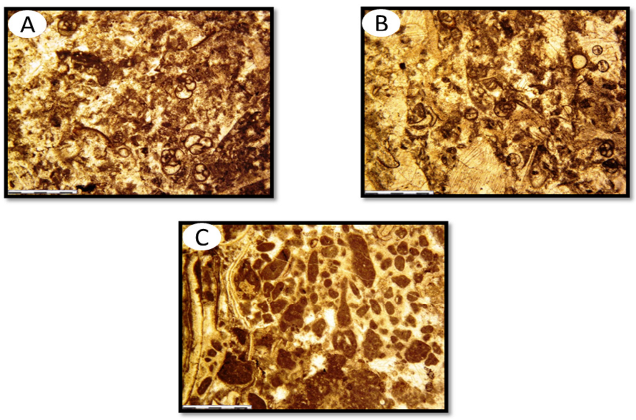

Figure 3. Open and semi-restricted lagoon microfacies. 3(a): Bioclastic Benthic foraminifera pelloid packestone. 3(b): Bioclastic Benthic foraminifera grainstone. 3(c): Bioclastic Intraclastic pelloid grainstone (1 mm scale).

3.3 Shoals and Bar Sub-Environment contains the following Microfacies

3.3.1 *Sandy Echinoderm Grainstone*

The most important allochem of this microfacies consists of Echinoderm particles (20-30%) and is more frequent than other fossil fragments. Echinoderm fragments are placed in sparite cement matrix and enjoy microstylolite in their contact level. These conditions reveal that this facies is formed in an environment with high energy (Figure 4a).

3.3.2 *Bioclastic Echinoderm Grainstone*

Due to the remarkable presence of echinoderms and other bioclasts, which comprise up to 50% of the rock volume, enjoy micritic covering and are placed in sparite cement matrix, this microfacies is likely to belong to the bioclastic shoal (Figure 4b).

3.3.3 *Oriented Bioclastic Grainstone*

Due to its high energy, this microfacies consists of echinoderm, pelecypoda and oriented bryzoa. Moreover, the sparite matrix of this microfacies confirms the presence of high energy. Another major characteristic of this microfacies is fractured grains, suggesting that this microfacies belongs to a bioclastic shoal (Figure 4c).

3.3.4 *Lithic Wacke*

One of the most important characteristics of this facies is a fine-grained matrix, resulting from the epitaxial growth of silt-sized quartz and feldspar. Among the sand-sized particles, quartz is seen more than rubbles and feldspars, indicating that this microfacies is likely to belong to the bioclastic bar (Figure 4d).

3.3.5 *Bioclastic Ooid Grainstone*

The most important allochem of this facies is 60% ooid, the core of some of which has consisted of quartz and is set in a sparite matrix. Echinoderm and pelecypoda as well as pressure dissolution are found here (Figure 4e).

3.3.5.1 *Interpretation*

The common characteristics of all bar facies is the lack of lime matrix among bar facies grains. This refers to the high rate of energy in their formation environment. In other words, these facies are formed above wave effect line.

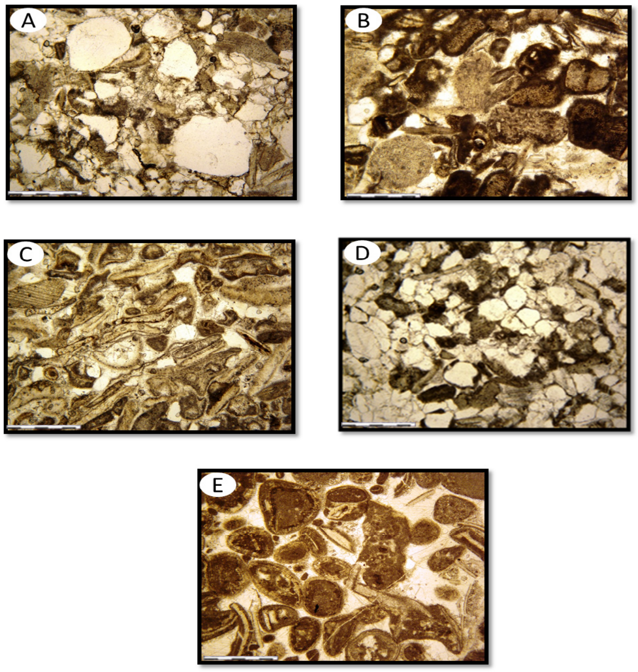

Figure 4. Shoals and Bar microfacies. 4(a): Sandy Echinoderm Grainstone. 4(b): Bioclastic Echinoderm Grainstone. 4(c): Oriented Bioclastic Grainstone. 4(d): Lithic Wacke. 4(e): Bioclastic Ooid Grainstone (1 mm scale).

Ooid, Bioclast and shoal bars facies are developed in platform margin sub-environment. Skeletal particles of organisms such as echinoderm are observed in slope zone and can lead to development of washed sand deposits in shoal and bars[4,23]. This sub-environment separates lagoon sub-environment from open marine. The presence of sparite cement, ooids abundance, mid-to-well sorting and lack of lime in facies confirm an environment with high energy. Today, the same facies can be found in southern coasts of Persian Gulf and Bahamas at the depth of less than 5 m.

Ooids abundance and lack of mud matrix indicate high energy in depositional environment, in which waves and currents transfer the carbonates. Such depositions point to washed sand forming carbonate bars. The skeletal particles forming these sands are usually originated from open marine[23].

Lack of micrite is the main cause of high energy in theses facies. Large size of these particles and their relative sorting are among factors determining high energy in this facies. In addition, small amount of Isopachous cement implies high deposit accumulation rate[16]. Lack of gravity cement is a sign of not moving out of water[11,23].

3.4 Open Marine Sub-Environment contains the following Microfacies

3.4.1 Bioclastic Bryozoa Packstone

50% bryozoa as well as a small amount of 20% echinoderm, placed in a micritic matrix is found in this microfacies, referring to the low level of energy in this environment (Figure 5a).

3.4.2 Spiculitic Ostracod Radiolaria Mudstone Wackestone

5% spiculite, 5% ostracod and 10% radiolaria are found in this microfacies. Spiculite, mostly single-axis, is dispersed and no specific orientation is seen. Spiculite together with radiolarian in a muddy matrix are among the most important components of deep and low-energy environment of open marine (Figure 5b).

3.4.3 Bryozoa Echinoderm Packston

The major allochem of this microfacies is echinoderm, enjoying more distribution than others. Bryozoa is also seen here and it is likely to belong to the open marine environment (Figure 5c).

3.4.4 Bioclastic Echinoderm Radiolaria Packston

Radiolar, crinoeid and spiculite, laid down in a micritic matrix, are found here (Figure 5d).

3.4.4.1 Interpretation

Fine-sized grains and lack of cement in microfacies 3.4.1 to 3.4.4 account for their deposition in an environment with low-to-mid energy. The presence of spiculitic and radiolaria in a wackestone texture is the sign of the formation of theses microfacies in a deeply open marine environment[6,14].

4. The frequency distribution of microscopic facies components

Microscopic facies are divided into two groups of orthochem including matrix and cement, and allochem including skeletal and non-skeletal elements. The frequency percentage of orthochem is computed by polarized microscope and depicted separately for each allochem.

The fluctuation curve of sea level is also depicted based on vertical changes in the characteristics of microscopic facies (Figure 6 and 7).

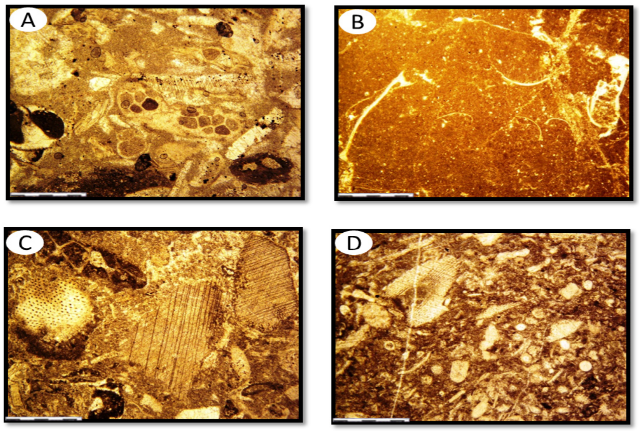

Figure 5. Open marine environment microfacies. 5(a): Bioclastic Bryozoa Packstone. 5(b): Spiculitic Ostracod Radiolaria Mudstone Wackestone. 5(c): Bryozoa Echinoderm Packston. 5(d): Bioclastic Echinoderm Radiolaria Packston (1mm scale).

5. Sedimentary Depositional Environment Model of Permian Deposits of Khan Gorup in Kuh-e-Ahaki Section

According to the results of microscopic and field observations and regarding the vertical relationship among facies and comparison between facies and other depositional facies, the depositional model of this section is presented as follow (Figure 8).

This model presents the formation system of carbonate facies in the mentioned section under four depositional sub-environments including beach, lagoon, shoal, bar and open marine. These facies are formed in a low-angle homoclinal carbonate ramp[6,7,8,15,19,21]. In the suggested model, the lagoon sub-environment is separated from open marine sub-environments. Shoal sub-environments are identified through organisms including ocinid, bryzoa, lagoon, and onchoeid, all contributing to the formation of shoal. Shoal sub-environment is relatively vast. As

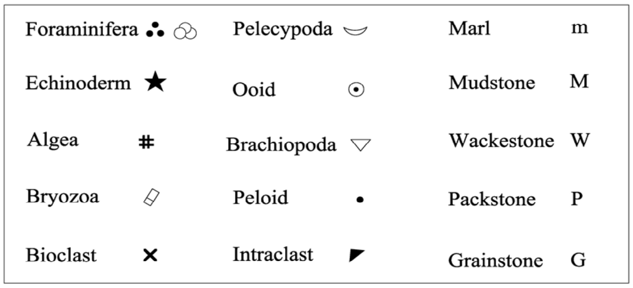

Figure 6. The guide for figure 7.

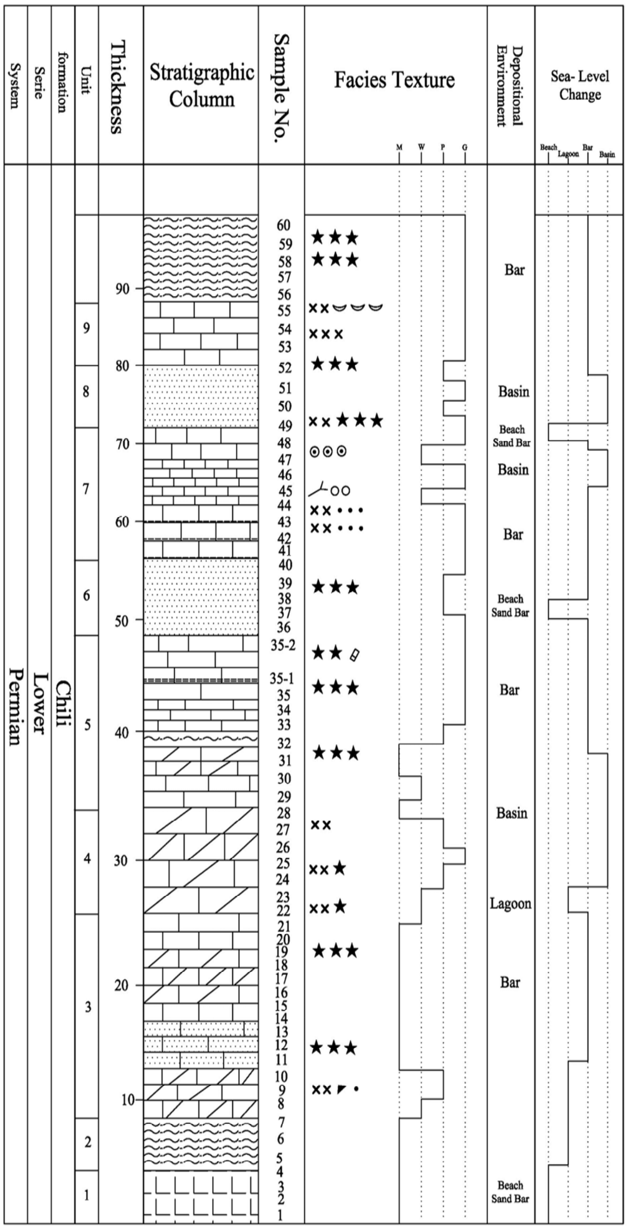

Figure 7. The frequency distribution of microscopic facies components and fluctuations in sea level.

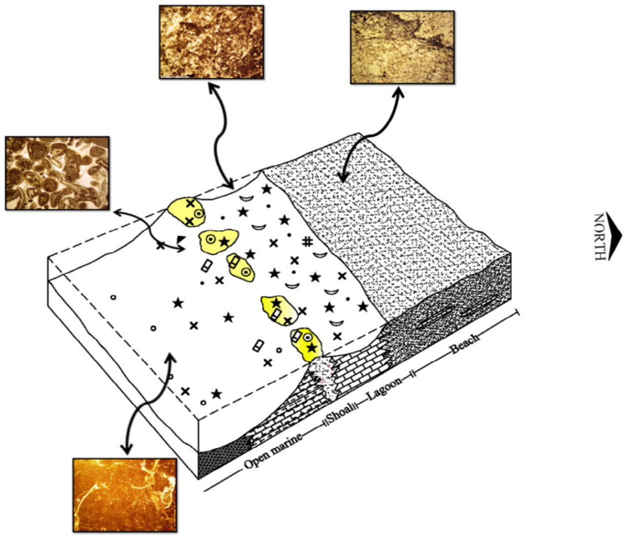

Figure 8. Depositional environment model of sediments of this part are created in a homoclinal ram Khan Gorup in Kuh-e-Ahaki section.

can be seen in the model, open marine sub environment microfacies enjoy the most thickness and are detected by components like spiculitic, radiolaria in deep parts and ochinid, ostracod and bryozoa in the shallow parts of the open marine environments. It is noteworthy that lagoon sub-environment shows the lowest microfacies in the above sections.

6. Conclusion

- Regarding the carbonate rocks in this formation together with substantially clastic sediments (Sandstones), one can conclude that these sediments are formed in a relatively moderate weather and close to the source of clastic sediments.
- According to the field observations and microscopic studies, the facies of this section are formed within four sedimentary sub-environments including beach sub-environment, open to semi-restricted Lagoon sub-environment, shoal and bar sub-environment and open marine sub-environment.
- The vertical and marginal changes of facies and comparing them with past and present sedimentary environments revealed that the above-mentioned deposits are deposited in a low-angle homoclinal ramp located in the passive margin of the southern paleotetis ocean.
- The remarkable volume of lime, dolomite lime and sandstone found in this section can account for the

tectonic, paleogeographic and lithologic complexities of the Kalmard Block, Central Iran and Palotetis Ocean. Therefore, it was necessary to restore the tectonic conditions and Paleogeography and geo-chemistry of the sedimentary basin during Permian, according to which, one can detect the geological history of central Iran which is one of the most complex and unknown geological units throughout the world.

- Studying the structure of shear zone in the Kalmard Block and presenting a geodynamic model for different microblocks of central Iran is a key to resolve many complexities observed in the stratigraphy, sedimentary environment and palogeography of the studied area.
- Restoration of the faults affecting the palogeography of the Kalmard Block can answer many questions on the geology of central Iran and Paleotethys Ocean.

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