



# Palaeogeographical peculiarities of the Pabdeh Formation (Paleogene) in Iran: New evidence of global diversity-determined geological heritage



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## ABSTRACT

Unique palaeogeographical peculiarities of sedimentary formations are important for geological heritage conservation and use for the purposes of tourism. The heritage value of the Pabdeh Formation (Paleocene–Oligocene) of the Zagros Fold-Thrust Belt in Iran has been investigated. The uniqueness of its palaeogeographical peculiarities has been assessed on the basis of the literature, field studies of three representative sections in the Fars Province (Kavar, Zanjiran, and Shahneshin sections), and comparison with the similar features known in Iran and globally. The Pabdeh Formation reflects the process of mixed siliciclastic-carbonate ramp progradation and the onset of a typical carbonate platform. The other unique features include representation of mesopelagic palaeohabitat, specific trace fossil assemblages, prehistoric bituminous artefacts (production of which was linked to the Pabdeh deposits), etc. It is established that the palaeogeographical type of geological heritage of the Pabdeh Formation is represented by all known subtypes, namely facies, palaeoecosystem, ichnological, taphonomical, event, and geo-archaeological subtypes. Their rank varies between regional and global. The very fact of co-occurrence of these subtypes determines the global importance of the entire palaeogeographical type in the case of this formation. The establishment of geopark in the Zagros Fold-Thrust Belt will facilitate adequate use of the Pabdeh Formation for the purpose of geotourism development. The aesthetic properties (rocks of different colour and striped patterns of outcrops) increase the attractiveness of this geological body to visitors.

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## 1. Introduction

Development of geological heritage conservation (geo-conservation) for the purposes of research, education, and tourism (geotourism) has become a global-scale activity (Prosser et al., 2006; Dowling, 2011; Henriques et al., 2011; Hose, 2012; Gray, 2013; Prosser, 2013; Ruban, 2015; Brilha, 2016; Necheş, 2016; Thomas, 2016; Gill, 2017; Suzuki and Takagi, 2017). Although it centered originally in Europe (Wimbledon et al., 1998; Wimbledon and Smith-Meyer, 2012), other parts of the world attract now the same attention. The Middle East is no exception. Particularly, the

geological heritage of Iran has been studied actively in the past decade (Farsani et al., 2012; Ghazi and Ghadiri, 2012; Ghazi et al., 2013; Habibi and Ruban, 2017a, b; Habibi et al., 2017; Mohammadzadeh and Kazemi, 2017; Shahhoseini et al., 2017). The outstanding heritage of this country is of international importance, though additional investigations are required.

Among the different types of geological heritage, the palaeogeographical type plays a special role because the relevant geological heritage sites (geosites) represent information about the Earth's history, ancient environments, and spectacular processes. The importance of palaeogeographical features as geological heritage was noted, particularly, by Wimbledon et al. (1998), Reynard et al. (2007), Bruschi and Cendrero (2009), Ruban (2010), Bruno et al. (2014), and Sallam and Ruban (2017). It has been established that the high value of many geosites is determined by the palaeogeographical type and subtypes. Therefore, it is of great

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interest to understand what determines the value of palaeogeographical peculiarities in the geological record.

Field studies in the Zagros Fold-Thrust Belt have permitted to find a new constituent of the geological heritage of Iran linked to the Pabdeh Formation, which is a Paleogene lithostratigraphical unit outcropped in a large area. The importance of the Pabdeh Formation is linked to its palaeogeographical peculiarities, visible in three sections in the Fars Province (Fig. 1). The objective of the present study is characteristics of this heritage. The attention is paid to the comprehensive description of the noted peculiarities, the argumentation for their uniqueness, and the determination of the heritage value of the entire formation. Moreover, the current rise of the Iranian tourism industry makes urgent the problem of diversification of tourism activities and, thus, geotourism has significant potential for flourishing in this country. The exploitation of this potential requires careful examination of the relevant resources, i.e., the geological heritage.

## 2. Geological setting

The Zagros Fold-Thrust Belt stretches from northwest to southeast in Iran. This is a large deformed tectonic domain that formed as a result of the Cenozoic collision between the Arabian and Iranian plates (Stöcklin, 1968; Sepehr and Cosgrove, 2004; Alavi, 2007; Agard et al., 2011; Wen et al., 2015). The Paleogene–Neogene sedimentary package of this belt is subdivided into several formations, the lowest of which is the Pabdeh Formation.

The Pabdeh Formation has been studied for decades (James and Wynd, 1965; Bordenave and Burwood, 1990; Jones and Racey, 1994; Goff et al., 1995; Mohseni and Al-Aasm, 2004; Bahrami, 2009; Reza et al., 2010; Mohseni et al., 2011; Tabatabaei et al., 2012; Afsari et al., 2014; Rezaee and Ali Nejad, 2014; Zabihi Zoeram et al., 2014; Soleimani and Zamani, 2015; Elyasi, 2016; Karimi et al., 2016; Nezhad and Ghasemi-Nejad, 2016). This lithostratigraphical unit consists of shales, marls, and limestones with a total thickness of up to 900 m (Fig. 2). It overlies disconformably the Gurpi Formation, and the contact with the overlying Asmari Formation is conformable. James and Wynd (1965) distinguished two informal members of the Pabdeh formation, namely the Purple shale member and the Tale Zang member. Other informal units were also recognized, including the Eocene blue and purple shales, the Eocene green and purple marls, the Lower Eocene marls, the Upper Eocene marls, the Eocene cherty limestone, the Eocene fissile limestone, and the Spatangid shales. This formation was also known earlier as the *Globigerina* Marl and the Dezek Marl.

The Pabdeh Formation bears rich fossil assemblages. These include representatives of foraminifera (benthic and planktic), calcareous nannofossils, dinoflagellate cysts, decapods, fishes, mollusks (bivalves and gastropods), and trace fossils. As a result, the biostratigraphical framework of the Pabdeh Formation is developed rather well. Wynd (1965) established 6 foraminifer-based biozones, namely the *Globorotalia–Globigerina–Globigerina daubejergensis* assemblage zone (biozone no. 41; Lower Paleocene), the *Globorotalia velascoensis–Globorotalia pseudomenardii* assemblage zone (biozone no. 42; Upper Paleocene), the *Globorotalia rex–G. formosa–G. aragonensis* assemblage zone (biozone no. 45; Lower Eocene), the *Truncotaloides–Porticulaphaera–Globorotalia spinolusa* assemblage zone (biozone no. 47; Middle Eocene), the *Globorotalia cerro–azulensis–Hantkenina* assemblage zone (biozone no. 52; Upper Eocene), and the small *Globigerinides–Haplophragmium slingeri–Zeauvigerina* assemblage zone (biozone no. 54; Oligocene). Generally, the age of main part of the Pabdeh Formation is Eocene–Oligocene. However, its lowermost part is Paleocene in age, and its uppermost part is Miocene in age. It appears the Pabdeh Formation is diachronous like the other

Cenozoic formations of the Zagros Fold-Thrust Belt.

The Pabdeh Formation accumulated in the Zagros sedimentary basin, which was a narrow and relatively deep Cenozoic foreland basin formed as a result of early collision between the Arabian and Iranian plates (Van Buchem et al., 2000; Golonka, 2004). Deposition occurred on a ramp (Sharland et al., 2001; Mohseni and Al-Aasm, 2004; Mohseni et al., 2011; Zabihi Zoeram et al., 2014) and centered in its internal basins (Ala et al., 1980; Murriss, 1980; Bordenave and Burwood, 1990; Ziegler, 2001; Mohseni et al., 2011). The basin was located in the tropical latitudes, which permitted life to flourish. The Pabdeh Formation is considered as one of the most important hydrocarbon source in the globally important Zagros oil province (Bordenave and Burwood, 1990; Jones and Racey, 1994; Goff et al., 1995; Soleimani and Zamani, 2015; Elyasi, 2016; Karimi et al., 2016; Nezhad and Ghasemi-Nejad, 2016).

## 3. Material and method

The palaeogeographical type of geological heritage is understood in this study similarly to the definition of Bruno et al. (2014). It comprises features that represent all aspects of palaeoenvironments of interest to science, education, and tourism. This type includes six subtypes, namely facies, palaeoecosystem, ichnological, taphonomical, event, and geoarchaeological subtypes (Bruno et al., 2014). As shown by Sallam and Ruban (2017), recognition of these subtypes contributes to a better evaluation of geodiversity.

In order to evaluate the palaeogeographical peculiarities of the Pabdeh Formation in the terms of geological heritage, knowledge of its development is required. For this purpose, the available information about the Pabdeh Formation has been compiled from the literature. Moreover, three representative sections of this formation have been investigated in detail and documented in the field. These are the Kavar, Zanjiran, and Shahneshtin sections (Figs. 1–4). The two former are located near the town of Kavar, and the latter is situated in the vicinities of the city of Kazeroon. All three sections



Fig. 1. Location of the studied area: a – general map, b – Kavar and Zanjiran sections (redrawn after Andalibi, 1998, c – Shahneshtin section (redrawn after MacLeod and Majedi, 1972).

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