Late Paleocene to early Oligocene dinoflagellate cysts of the Zagros basin, west Iran (palaeopalynology and palynostratigraphy)

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KEYWORDS: Pabdeh Formation; Dinoflagellate cyst; Paleogene; Palynostratigraphy; Thermal maturity.

ABSTRACT: Palynological investigation about 120 samples from 460m thick outcrop section of late Paleocene to early Oligocene of the Pabdeh Formation, southwestern in Iran yield 55 species of dinoflagellate results to defined 7 biozone. The quantities of marine palynomorph elements are indicated of open marine at this time, but a low increase number of spore and pollen in some of the sample indicated the condition for growth forest are suitable that consequent increase the harm climate and humidity. The species are common with different latitude and most of them cosmopolitan. Thermal maturity index measurement indicates oil prone in most of the samples.

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Introduction
The first studies on fossil dinoflagellates from Western Iran were made by Zahirin 1982 (Zahiri, 1982). The principal intent of these investigations was identification of dinoflagellate cysts. The stratigraphic application of dinoflagellate cysts in this area started only at the end of 1982 when a few boreholes were investigated and the first dinoflagellate cyst zones were erected (Zahiri, 1982). Later on more studies conducted on palynostratigraphy of some parts of the Zagros basin (e.g. Ghasemi-Nejad et al., 2006, Rabbani et al., 2013). As the Pabdeh Formation which is lithologically made up of shale, calcareous shale and limestone, is a relatively known source rock in the Zagros basin, palynological studies on these strata could help to establish a stratigraphic framework for the formation to be further investigated in terms of potential for petroleum generation.

MATERIALS AND METHODS
A total of 125 rock samples from the Siah anticline section were collected. The samples were processed using palynological techniques in several steps according to palynological standard methods (Traverse, 1988, pp.456-479). About 30 grams of rock samples was used for processing. The samples were first crushed and washed, then treated with 33% HCl and later with 40% HF. After these chemical preparation steps, the material was sieved through a 20 micron nylon mesh. The materials residue coarser than 20 micron were used for palynological study.

Previous Studies: There is a few record of dinoflagellate cysts from the Pabdeh Formation of the Zagros basin in the published literature (e.g. Rabbani et al., 2013). However, several good works have been published on foraminiferal biostratigraphy of the formation (e. g. Biranvand et al.) presenting precise biostratigraphy and giving in general an age of Paleocene to Miocene to the formation.

The Pabdeh Formation is known surcrock for the Asmari servoir, one of the largest source rocks in the Middle East (Motiei, 2003). For this reason, it is important to study palynology and palynostratigraphy of the formation and to establish a precise stratigraphic framework for this formation.

Geological Setting: The Pabdeh Formation crops out extensively in KohgiluyehvaBoyerahmad in Zagros basin, southwest Iran (Fig. 1). The lower contact with shalesand Limestones of the Gurpi Formation and the upper contact with limestone and marls of the Asmari Formation are both conformable.

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Fig1. Location map of the studied section.
Biostratigraphy: Stratigraphic distribution of dinoflagellate cysts recorded in this study are displayed in Figures 2. Based on the composition of the assemblages recorded seven dinoflagellate cyst zones are differentiated ranging in age from late Paleocene to early Oligocene. The most productive and rich associations have been revealed from the Maastrichtian, Danian and Ypresian intervals. The zones erected here can be compared with those of different parts in Europe and Urals (Table1) generally but a complete correlation and zonation has yet to be erected for the Tertiary basins around the world. The zonation established here is discussed below:

Biozone1: Apectodinium parvum interval zone
Age: late Paleocene (thanetian), Occurrence: from 45.55 to 50.91m
Definition: this zone has been defined as the interval from the LAD of Apectodinium parvum to the LAD of Areoligera gippingsensis. Accompanying taxa include: Apectodinium, homomorphus, Melitasphaeridium, pseudorecurvatum, Areosphaeridium capricornum.

The index species, Areoligera gippingsensis has been recorded from:

Paleocene, Germany (Gocht, 1969); Maastrichtian—Upper Paleocene, offshore South East Canada (Williams and Bujak, 1977a); Lower Eocene of England (Williams and Downie, 1966c); Upper Paleocene—basal Upper Eocene of North West Germany (Köhne, 1990)

Biozone 2: Phelodinium kozlowskii Interval zone
Age: Early Eocene (Eynsian), Occurrence: from 50.91m to 138.24m
Definition: this zone has been defined as the interval from the LAD of Enneadocysta arcauum to the LAD of Phelodinium kozlowskii. Accompanying taxa include Chiropteridium galea, Cleistosphaeridium diversispinosum, Distatodiniumtenerum, Impagidiniumsp.

Biozone 3: Deflandrea phosphoritica Interval zone
This has been introduced as a local biozone by Morgans et al. (2004) but it can be compared with Deflandrea obesifeldensis interval zone introduced by Nørh-Hansen (2002).

Age: Early Eocene (Eynsian), Occurrence: from 138.24m to 158.9m
Definition: this zone has been defined as the interval from the LAD of Deflandrea phosphoritica to the LAD of Lejeunecysta fallax. Accompanying taxa include Chiropteridium galea, Cleistosphaeridium diversispinosum, Distatodiniumtenerum, Impagidiniumsp.

Biozone 4: Systematophora placacantha Interval zone
This local biozone introduced by Vasilieva 1990 from Southern Ural region and by Bujak and Mudge (1994) and Mudge and Bujak (1996) from North Sea.

Age: Early Eocene (Lutetian) Occurrence: from 158.9m to 242.1m
Definition: this zone has been defined as the interval from the LAD of Systematophora placacantha to the LAD of Hystrichokolpoma cinctum. The accompanying taxa include: Distatodinium tenerum, Spiniferites mirabilis, Dapsilidinium pseudocoligerum, Linguolodinium machaerophorum.

Systematophora placacantha has stratigraphically been recorded from Paleocene, West Tasmania (Cookson and Eisenack, 1967)

Biozone 5: Cordosphaeridium cantharellus Interval zone
This local biozone is being introduced here. The index species Cordosphaeridium cantharellus has been reported from European region. Cordosphaeridium cantharellus has been reported from: Upper Eocene, South England (Bujak et al., 1980); Upper Eocene—Lower Miocene, off shore East Canada (Williams and Bujak, 1977a) Upper Middle Eocene—basal Miocene, General (Drugg and Stover, 1975)

Age: Eocene (Bartonian), Occurrence: from 242.1m to 325.33m
Definition: this zone has been defined as the interval from the FAD of Cordosphaeridium cantharellus to the LAD of Cleistosphaeridium placacantha. The accompanying taxa are Cordosphaeridium gracile, Distatodinium cf. biffl, Glaphyrocysta sp., Hystrichokolpoma eisenackii.

Cordosphaeridium gracile has been reported from Lower-Upper Eocene, South England (Bujak et al., 1980), Middle-Upper Eocene, off shore North West Africa (Williams, 1978).

Biozone 6: Spiniferites pseudosorcarus Interval zone
This local biozone was introduced by Bujak and Mudge (1994) from off shore West Greenland.

Age: Late Eocene (Priabonian) Occurrence: from 350.46m to 423.64m
Definition: this zone has been defined as the interval from the LAD of Spiniferites pseudosorcarus to the LAD of Acomosphaera albicornu.
accompanying taxa include: Impagidinium sp., Operculodinium cf. microtrainum.

Spiniferite spesuforcatus has stratigraphically been reported from Lower-Upper Eocene of South England(Buja, et al.,1980), Middle Eocene of Mexico (Helena, 1984).

Biozone 7: Polysphaeridium zohary Interval zone
Age: Early Oligocene (Rupelian), Occurrence: from 421.33 m to 457 m

Definition: This zone has been defined as the interval from the LAD of Thalassiphora delicate to the LAD of Polysphaeridium zohary. The accompanying taxa are: Operculodinium cf. microtrainum, Melitasphaeridiummasteriurn, Impagidinium sp., Fig.4. Thalassiphora delicate has been reported from Late Eocene of offshore West Greenland (Nøhr-Hansen, 2002), Homotribulium tenuispinosum has also been stratigraphically reported from Lower Oligocene of Central Italy (Biffy and Manum, 1988), Upper Eocene, Egypt (El-Beily, 1988b), Lower-Upper Eocene of England (Eaton, 1976) and Lower-Upper Eocene of off shore East Canada (Williams and Buja, 1977).

Table 1. Correlation of Paleogene dinoflagellate cyst biozones established for Zagros basin with those of Europe and Ural

<table>
<thead>
<tr>
<th>System/Epoch</th>
<th>Stage/Age</th>
<th>Biozone</th>
<th>Correlation of Paleogene dinoflagellate cyst biozones established for Zagros basin with those of Europe and Ural</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paleogene</td>
<td>Lower Paleogene</td>
<td>Polysphaeridium zohary</td>
<td>Includes: Impagidinium sp., Operculodinium cf. microtrainum</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Thermal maturity: The thermal maturity discussed and used in this study is based on changes in spore or pollen color. Thermal maturity was used for oil exploration as it is capable of characterizing organic matter type based on which kerogen type in the source rocks could be identified. The yellow color usually indicates a degree of maturation for the rocks that yet not attained a thermal maturation degree to generate petroleum. The brown range of color indicates a well maturation degree for oil generation. Seven samples that contain diverse assemblages of spore and pollen are selected to study for color change of their spore and pollen contents. Of these, five samples are located with in the oil prone sector and two samples indicated an over mature condition (Table 2). In general, these indicate that the Pabdeh Formation is a good source rock for the big reservoir rock unit, the Asmari Formation.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Biozone 7: Selenopemphix naphroides Interval zone</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>This local biozone is being introduced here. The index species Selenopemphix naphroides has been reported from European region. Selenopemphix naphroides has been stratigraphically reported from Lower Oligocene of Egypt (El-Bassiony et al., 1988), Upper Eocene – Lower Oligocene of Netherlands (de Coninck, 1986b), Oligocene of Nigeria (Biffy and Grignani, 1983) and Oligocene of North West Germany (Benedek, 1972)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Age: Early Oligocene (Rupelian), Occurrence: from 421.33 m to 457 m</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Definition: This zone has been defined as the interval from the LAD of Polysphaeridium zohary to the LAD of Selenopemphix naphroides. The accompanying taxon is Memranoploridium aspinatum, Fig.4.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Polysphaeridium zohary has stratigraphically been reported from Lower Eocene-Oligocene of off shore East Canada (Williams and Brideaux, 1975) and Middle Eocene of Pakistan (Köthe et al., 1988).</td>
</tr>
</tbody>
</table>
Table 2. Spore and pollen Color changes used for evaluation of thermal maturity

<table>
<thead>
<tr>
<th>Sample No</th>
<th>Color of spore and pollen grains</th>
<th>TAI</th>
<th>Maturity</th>
<th>Hydrocarbon</th>
</tr>
</thead>
<tbody>
<tr>
<td>38</td>
<td>Brown</td>
<td>3+</td>
<td>Mature</td>
<td>Liquid petroleum</td>
</tr>
<tr>
<td>46</td>
<td>Brown</td>
<td>3+</td>
<td>Mature</td>
<td>Liquid petroleum</td>
</tr>
<tr>
<td>48</td>
<td>Very Dark brown</td>
<td>4-</td>
<td>Overmature</td>
<td>Dry gas or barren</td>
</tr>
<tr>
<td>54</td>
<td>Light brown</td>
<td>3-</td>
<td>Mature</td>
<td>Liquid petroleum</td>
</tr>
<tr>
<td>74</td>
<td>Very Dark brown</td>
<td>4-</td>
<td>Overmature</td>
<td>Liquid petroleum</td>
</tr>
<tr>
<td>84</td>
<td>Brown</td>
<td>3+</td>
<td>Mature</td>
<td>Liquid petroleum</td>
</tr>
<tr>
<td>116</td>
<td>Light brown</td>
<td>3-</td>
<td>Mature</td>
<td>Liquid petroleum</td>
</tr>
</tbody>
</table>

Conclusions: The Siah anticline, located in the south western part of Iran, contains a rich Paleocene–Oligocene record of dinoflagellate cysts. The dinoflagellate cysts are abundant in the lower and upper parts of the section but, their abundance decreases in some parts of the section because of the limestone lithology of the layers. Seven biozones are established based on the presence of dinoflagellate cysts. These include: Areoligeragippingensis, Deflandreaphosphoritis, Systematophoraplacacanthus, Cordosphaeridiumcantharellus, Spiniferitespseudofurcatus, Thalassiphoradelicata, Selenopemphixnephroides. The zones in general confirm the late Paleocene to early Oligocene age for the Pabdeh Formation at this section which has also been gained from studies on foraminifera and nannofossils. Dinoflagellate cyst zones erected here are compatible with those of European countries.

Figure 2. Distribution of dinoflagellate cysts

Figure 3. Scale bar = 30 micron
3. Areosphaeridium capricornum (Cookson and Eisenack, 1965) Stover and Evitt, 1978
6. Cleistosphaeridium placacanthum (Deflandre and Cookson) Eaton et al., 2001

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