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

***[1]ALI AKBAR, JN; EBRAHIM,GN**

[1]*Department of Geology, Tehran Shomal Branch, Islamic Azad University, Tehran, Iran*
*(*Corresponding Author E- mail: ajanaky_15@yahoo.com)*
[2]*Department of Geology, University College of Science,*
University of Tehran, Tehran, Iran (eghasemi@khayam.ut.ac.ir)

KEYWORDS: Pabdeh Formation; Dinoflagellatecyst; Paleogene; Palynostratigraphy; Thermalmaturity.

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 Zahiryin 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 ANDMETHODS

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 afew 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 Formationisa known surcerock for the Asmarire 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 comformable.

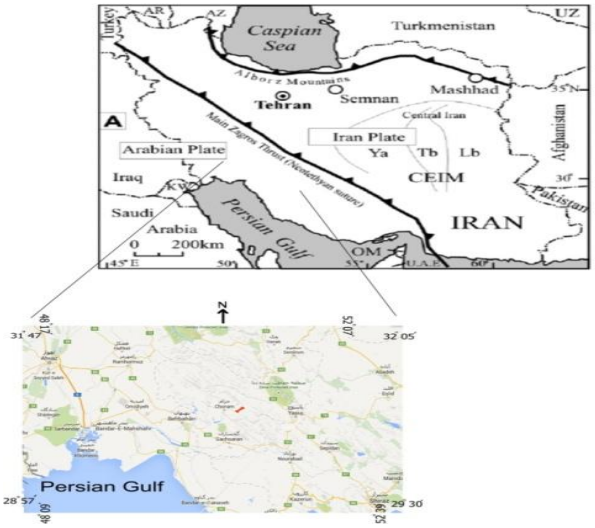


Fig1.Location map of the studied section.

**Corresponding Author E- mail: ajanaky_15@yahoo.com*

***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 gippingensis*. Acompanying taxa include: *Apectodinium , homomorphus, Melitasphaeridium , pseudorecurvatum, Areosphaeridium capricornum*.

The index species, *Areoligera gippingensis* has been recorded from:

Paleocene, Germany (Gocht, 1969); Maastrictian– 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 (Köthe, 1990)

Biozone 2: *Phelodinium kozlowskii* Interval zone
Age:Early Eocene (Eypresian), Occurrence: from50.91m to 138.24m

Definition:this zone has been defined as the interval from the LAD of *Enneadocysta arcuatum* to the LAD of *Phelodinium kozlowskii*. Acompanying taxa include *Chiropteridium galea ,Cleistosphaeridium diversispinosum, Distatodiniumtenerum, Impagidinium*sp.

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 oebisfeldensis* interval zone introduced by Nøhr-Hansen (2002).

Age:Early Eocene (Eypresian), Occurrence: from138.24m to 158.9m
Definition:this zone has been defined as the interval from the LAD of *Deflandrea phosphoritica* to the LAD of *Lejeunecysta fallax*. Acompanying taxa include *Chiropteridium galea ,Cleistosphaeridium diversispinosum,Distatodiniumtenerum, Impagidinium*sp.

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:from158.9m 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 companying taxa include: *Distatodinium tenerum, Spiniferites mirabilis, Dapsilidinium pseudocoligerum, Lingulodinium machaerophorom.*

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

Biozone5: *Cordosphaeridium cantharellus* Interval zone

This local biozone is being introduced here. The index species *Codosphaeridium cantharellus* has been reported from European region. *Cordosphaeridium cantharellus*has been reported from*:* Upper Eocene, South England (Bujaketal., 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: from242.1m to 325.33m.
Definition: this zone has been defined as the interval from the FAD of *Cordosphaeridium cantharellus* to the LAD of *Cleistosphaeridium placacanthum* . The accompanying taxa are *Cordosphaeridium gracile, Distatodinium* cf. *biffi ,Glaphyrocysta* sp., *Hystrichokolpoma eisenackii.*

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

Biozone 6: *Spiniferites pseudofurcatus* Interval zone
This local biozone was intruduced by Bujak and Mudge (1994) from off shore West Greenland.
Age: Late Eocene (Priabonian) Occurrence: from 350.46m to 423.64 m
Definition: this zone has been defined as the interval from the LAD of *Spiniferites pseudofurcatus* to the LAD of *Achomosphaera alcicornu*. The

accompanying taxa include: *Impagidinium* sp., *Operculodinium* cf. *microtrainum.*

Spiniferite spseudofurcatus has stratigraphically been reported from Lower-Upper Eocene of South England(Bujak et al.,1980), Middle Eocene of Mexico (Helenes, 1984).

Biozone7: *Polysphaeridium zohary* Interval zone
Age: Early Oligocene (Rupelian), Occurrence: from350.46 m to 423.6 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, Melitasphaeridiumasterium, Impagidinium*sp., Fig.4.
Thalassiphora delicata has been reported from Late Eocene of offshore West Greenland(Nøhr-Hansen,2002), *Homotriblium tenuispinosum* has also been stratigraphically reported from Lower Oligocene of CentralItaly (Biffi and Manum, 1988), Upper Eocene, Egypt (El-Beialy, 1988b), Lower-Upper Eocene of England (Eaton,1976) and Lower-Upper Eocene of off shore East Canada (Williams and Bujak, 1977)

Biozone7: *Selenopemphix nephroides* Interval zone
This local biozone is being introduced here. The index species *Selenopemphi nephroide s*has been reported from European region. *Selenopemphix nephroides* has been stratigraphically reported from Lower Oligocene of Egypt (El-Bassiounietal.,1988), Upper Eocene – Lower Oligocene of Netherlands (de Coninck, 1986b), Oligocene of Nigeria (Biffi and Grignani,1983) and Oligocene of North West Germany (Benedek, 1972)

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 *Polysphaeridium zohary* to the LAD of *Selenopemphix nephroides*. The accompanying taxon is *Memranophoridium aspinatum,* Fig.4.

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).

Table1.Correlation of Paleogene dinoflagellate cyst biozones established for Zagros basin with those of Europe and Ural

System/ Period	Series/ Epochs	Stage/ Age	Planc.Foram.Biozones (Berggren et al., 1995)	Calc.Nanno .Biozones (Martini, 1971)	DINOFLAGELLATE ZONES (Heilmann-Clausen, 1988)	Bujak(1984)	Dinoflagellate zones of Southern Ural region (Vasilieva, 1990)	Nøhr-Hansen,2002 Ikermiut-1,offshore West Greenland	North sea dino. cyst Bujak & mudge 1994 Mudge & bujak 1996	This study
PALEOGENE	Olig. up.	Chat.								
	Olig. Low.	Rupelian				Gelatia inflata				Selenopemphix nephroides
	Eocene Late	Priabonian	P17	Np20	Thalassiphora reticulata Zone	Spiniferites sp.cf. S. membranaceus	Ch.clathrata angulosa			Thalassiphora delicate
			P16	Np19					A.diktyoplokus	
			P15	Np18		Trinovantedinium boreale				Spiniferites pseudofurcatus
	Eocene Middle	Bartonian	P14	Np17	Enneadocysta arcuata Zone		Kisselevia ornata	G.semitecta	H.porosa	Cordosphaeridium cantharellus
			P13							
		Lutetian	P12	Np16			Systematophora placacantha		D.colligerum	Systematophora placacantha
			P11	Np15					S.placacantha	
			P10		Phthanoperidinium regalis Zone	Kallosphaeridium boreal			D. ficusoides	
				Np14						
	Eocene Early	Ypresian	P9	Np13			Ch.coleotrhypta plexus Dr.politum		E.ursulae	Deflandrea phosphoritica
			P8					A.medusettiformis		
			P7	Np12				F.bipolarris	A. medusettiformis	
			P6b	Np11			D.varielongitudum/ D.simile/W.meckelf.			
			P6a	Np10			Apectodinium homomorphum	D.oebisfeldensis	H.tubiferum	
			P5	Np9				Apectodinium acme	A.augustum	Areoligera gippingensis
	Paleocene Late	Thanetian	P4	Np8			Cerodinium speciosum	A.gippingensis	A.margarita	
				Np7				P.pyrophorum		
				Np6					P.pyrophorum	
			P3	Np3						

*Thermalmaturity***:** The thermal maturity discussed and used in this study is basen on changes in spore or pollen color. Thermal maturitywas 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 assemglages 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.

Table 2.Spore and pollen Color changesused for evaluation of thermal maturity

Sample No	Color of spore andpollen grains	TAI	Maturity	Hydrocarbon
38	*Brown*	3+	*Mature*	*Liquid petroleum*
46	*Brown*	3+	*Mature*	*Liquid petroleum*
48	*Very Dark brown*	4-	*Overmature*	*Dry gas or barren*
54	*Light brown*	3-	*Mature*	*Liquid petroleum*
74	*Very Dark brow*	4-	*Overmature*	*Liquid petroleum*
84	*Brown*	3+	*Mature*	*Liquid petroleum*
116	*Light brown*	3-	*Mature*	*Liquid petroleum*

*Conclusions***:** The Siah anticline, located in the south western 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,Deflandreaphosphoritica,Systematophoraplacacantha,Cordosphaeridiumcantharellus, Spiniferitespseudofurcatus , Thalassiphoradelicata, Selenopemphixnephroides.*Thezones in general confirm the late Paleocene to early Oligocene age forthe 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.

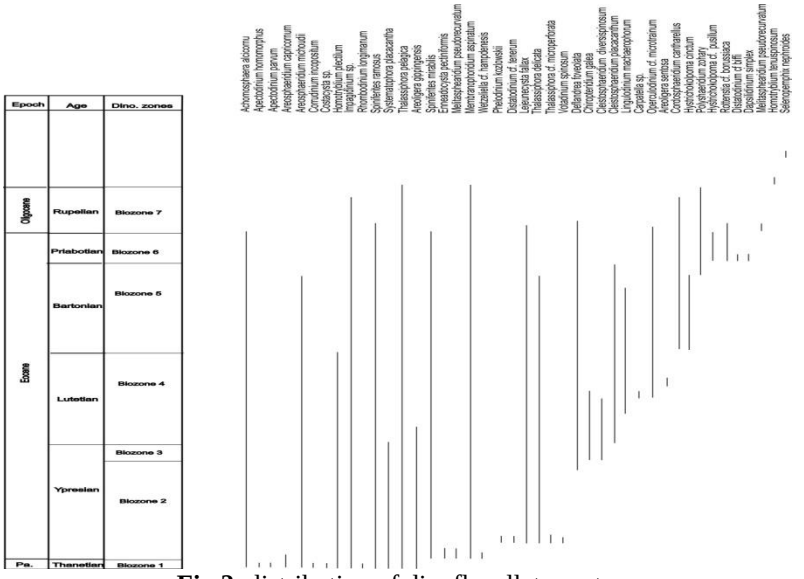


Fig 2. distribution of dinoflagellate cysts

Figure 3. scale bar = 30 micron
1. *Achomosphaera alcicornu* (Eisenack,) Davey and Williams, 1966; 2. *Areoligera gippingensis* Jolley, 1992
3. *Areosphaeridium capricornum* (Cookson and Eisenack, 1965) Stover and Evitt, 1978
4. *Areosphaeridium michoudii* Bujak, 1994; *5. Chiropteridium galea* (Maier, 1959) Sarjeant, 1983
6. *Cleistosphaeridium placacanthum* (Deflandre and Cookson) Eaton et al., 2001
7. *Cordosphaeridium cantharellus* (Brosius, 1963) Gocht, 1969; 8. *Corrudinium incompositum* (Drugg, 1970) Stover and Evitt, 1978; 9. *Dapsilidinium simplex* (White, 1842) Bujak et al., 1980; 10.*Deflandrea phosphoritica* Eisenack, 1938; 11. *Deflandrea foveolata* Wilson, 1984; 12. *Distatodinium* cf. *tenerum* (Benedek, 1972) Eaton, 1976

Figure 4. scale bar = 30 micron
13. *Distatodinium* cf. *Biffi* Brinkhuis et al., 1992; 14. *Membranophoridium aspinatum* Gerlach, 1961
15. *Enneadocysta pectiniformis* (Gerlach, 1961) Stover and Williams, 1995; 16.*Impagidinium* sp.
17. *Lejeunecysta fallax* (Morgenroth, 1966) Artzner and Dörhöfer, 1978; 18. *Melitasphearidium pseudorecurvatum* (Morgenroth 1966) Bujak et al. 1980; 19. *Polysphaeridium zoharyi* (Rossignol, 1962) Bujak et al., 1980; 20. *Selenopemphix nephroides*

Benedek, 1972; 21. *Spiniferites pseudofurcatus* (Klumpp, 1953) Sarjeant, 1970
22. *Hystrichokolpoma cinctum* Klumpp, 1953; 23. *Thalassiphora pelagica* (Eisenack, 1954) Eisenack and Gocht, 1960; 24. *Systematophora placacantha* (Deflandre and Cookson, 1955) Davey et al., 1969

Figure 4.

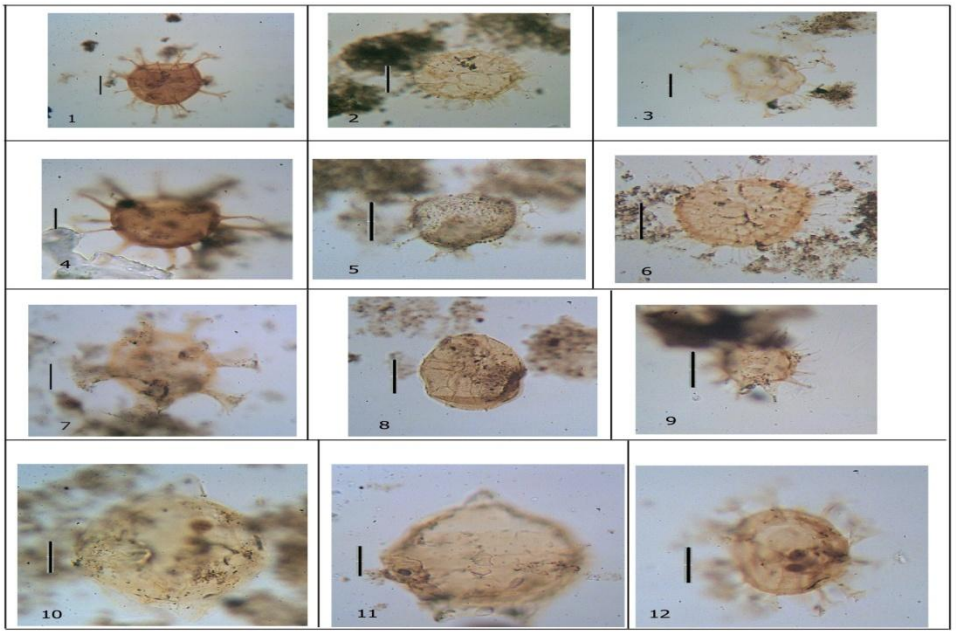
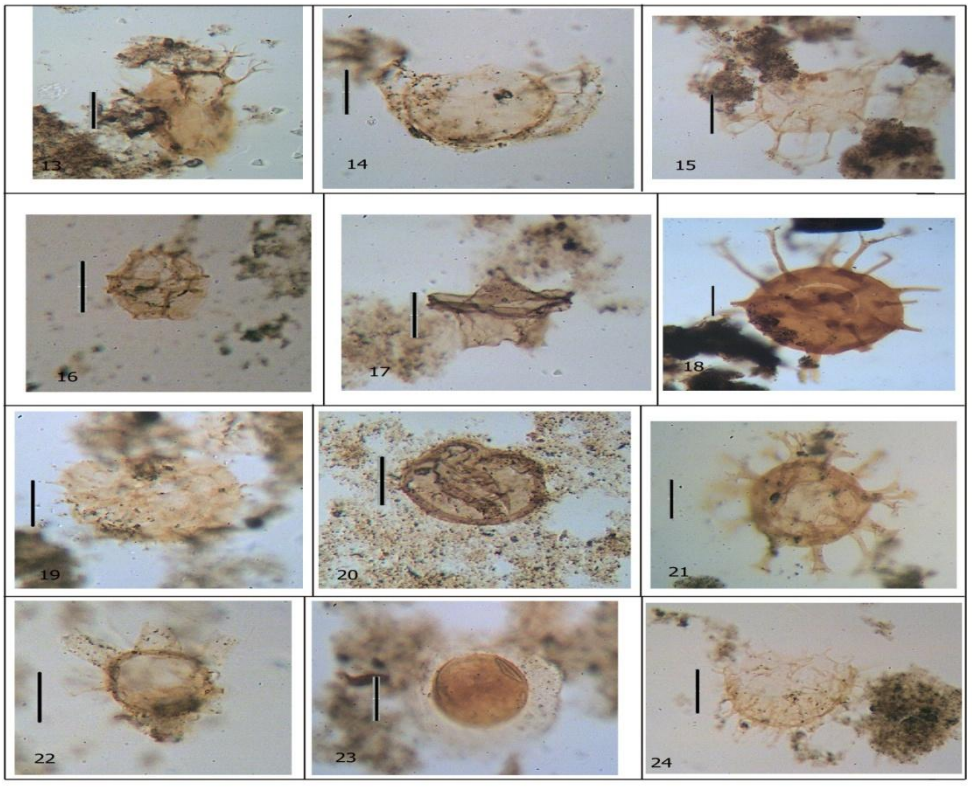


Figure 5.



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