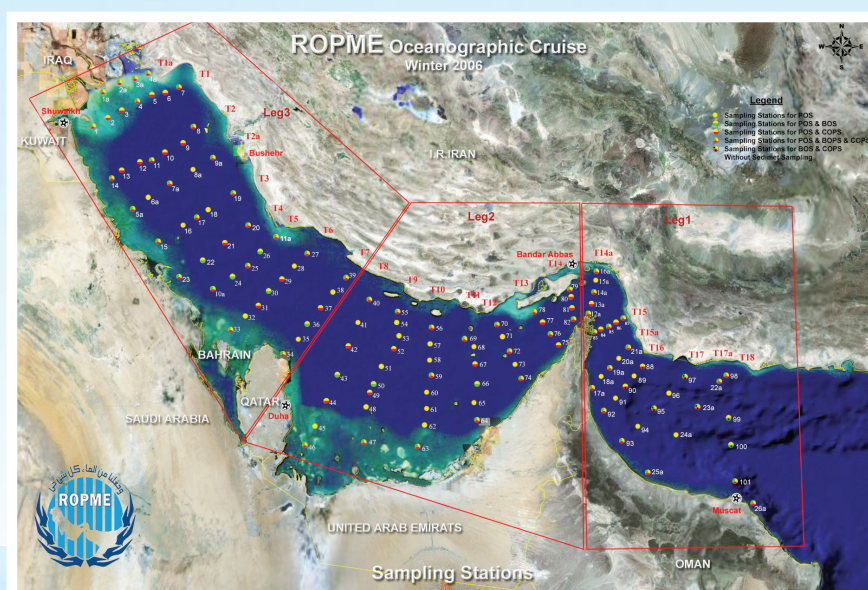


ROPME Oceanographic Cruise - Winter 2006



Monograph Series

Monograph : No. 3

Phytoplankton Cysts in the ROPME Sea Area

January 2020

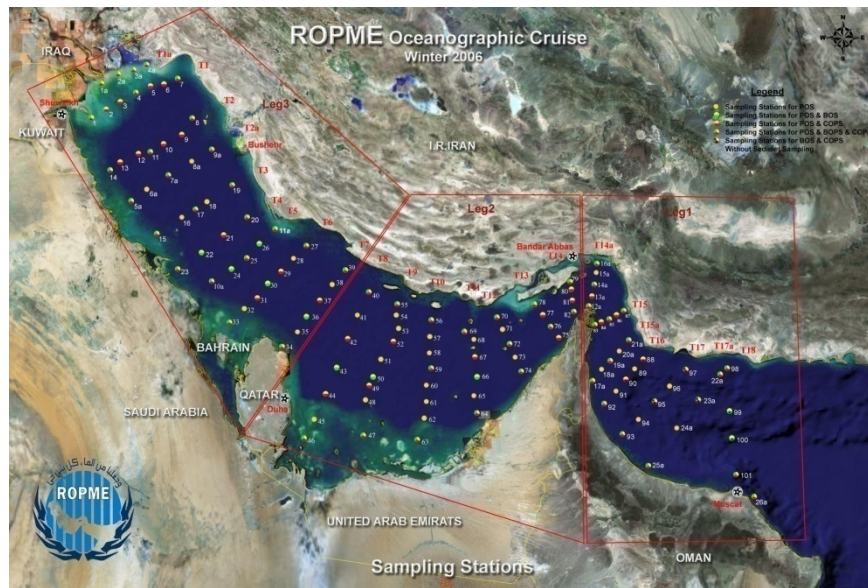


Regional Organization for the Protection of the Marine Environment



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ROPME Oceanographic Cruise – Winter 2006



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1. Phytoplankton
2. Zooplankton
3. Phytoplankton Cysts
4. Foraminifera
5. Macrobenthos

Disclaimer

This Monograph has been prepared by Dr Gilan Attaran-Fariman from Department of Marine Science of Chabahar Maritime University (CMU), using the samples of ROPME's Winter 2006 Cruise. This document is being brought out as part of a special Monograph Series in the very form in which it was submitted by the Principal Investigator. Owing to this reason, ROPME shall not accept responsibility on the accuracy of taxonomy of the species contained in this Monograph. ROPME does not also subscribe to the inappropriate terms used to denote parts or full of the ROPME Sea Area inadvertently used by the Principal Investigator or provided in the published references and citations.

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Preface

In recognition of the importance of the Oceanographic Cruises in the ROPME Sea Area (RSA) to understand the state of the marine environment, ROPME Council has assigned high priority to the ROPME scientific Cruises. In pursuance of the Council Decision CM12/7, ROPME was mandated to coordinate a comprehensive Oceanographic Cruise in Winter 2006. The Cruise was planned in such a way that the results and reports of the studies can find their way into the synthesis of ROPME State of the Marine Environment Report.

As a result of sustained efforts, cooperation of Member States, guidance of the designated scientific committee for the Cruise, encouragements from the Executive Committee of ROPME and the generous provisions made by the Council, the historic Winter Cruise was carried out successfully on board of M/V Ghods of I.R. Iran during 1st February and 11th March 2006.

Totally, 115 stations covering the RSA have been surveyed and 97 experts from ROPME Member States participated in the Cruise. The survey covered most of the main oceanographic disciplines.

The samples collected during the Cruise were distributed on a competitive basis to the competent laboratories in the Region and elsewhere for detailed analyses while sub-sample sets were kept in ROPME Marine Sample Bank to enable repetitive analyses in future, when required.

To enhance benefits from the reproduced results of the Cruise among Regional scientific community towards a better understanding of the marine environment in the RSA and to enable furtherance of marine researches, ROPME Secretariat decided on the publication of the results in a series of Monographs as follows:

1. Phytoplankton
2. Zooplankton
3. Phytoplankton Cysts
4. Foraminifera
5. Macrobenthos

The present Monograph is devoted to the taxonomy of phytoplankton cysts in the RSA. The analyses and reporting have been conducted by Dr. Gilan Attaran-Fariman, Associate Professor, Chabahar Maritime University, under a contract with ROPME.

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1. Introduction

Phytoplankton are primary producers in the marine ecosystem and are in the base of marine food chain. Many phytoplankton produce a dormant resting or cyst stage during their sexual life cycle or under unfavorable conditions such as hostile temperature, salinity fluctuation, nutrient depletions and low light (Anderson *et al.*, 2003; Wang *et al.*, 2004; Brown *et al.*, 2013). The main group that most researchers are focusing on their resting stages belong to Dinoflagellate and Raphidophytes, and a few studies on Diatoms (Dale, 1983; McQuoid and Hobson, 1996; Anderson *et al.*, 2003; Hallegraeff and Hara, 2003; Edvardsen and Imai, 2006). In Diatoms, two types (possibly three; Brown *et al.*, 2013) of resting stages have been identified; namely, resting spore or hyphospore, resting cell and probably winter stages. Raphidophytes that have resting cysts in sediment are generally in two genera, *Heterosigma* (Park *et al.*, 2016) and *Chattonella* (Imai 1986, Attaran-Fariman & Bolch 2014). Dinoflagellates produce a highly resistant resting cyst in sediment, and therefore are useful alternates especially in marine environment to reflect marine ecology of living cells in the water columns (Taylor 1987). Among phytoplankton, the most important resting cyst producer and dominant group is dinoflagellate. Beside their important role in the marine ecosystem dynamic, some of them are known as toxin producers to form Harmful Algae Blooms (HABs) in the coastal area around the globe. As many HABs species belong to the dinoflagellates, most researches have been concerned on the complex life cycle of this group (Figure 1). Almost 75% of HABs species are dinoflagellates (Smayda 1997). Approximately 10% of the 2000 motile marine dinoflagellates are known to produce benthic resting cysts as a part of their life history (Head, 1996; Bravo & Figueroa, 2014) including many harmful species that cause red tides and can survive under unfavorable conditions such as in ballast tanks (lack of light) and are introduced to new areas. The cysts can be preserved in the sediments for years, and even for a century (Ribeiro *et al.*, 2011), and thus are early warnings for the presence of toxic species in a particular area (Anderson *et al.*, 1983). This stage plays an important role at different harmful blooms phases; that is, switching from non-motile cysts to vegetative dividing population initiating blooms, and encystment could be responsible for sudden blooms termination.

The Motile and non-motile cysts stages are morphologically different in the life cycle of one species (Figure 2); therefore, these may have sometimes been wrongly classified as separate species.

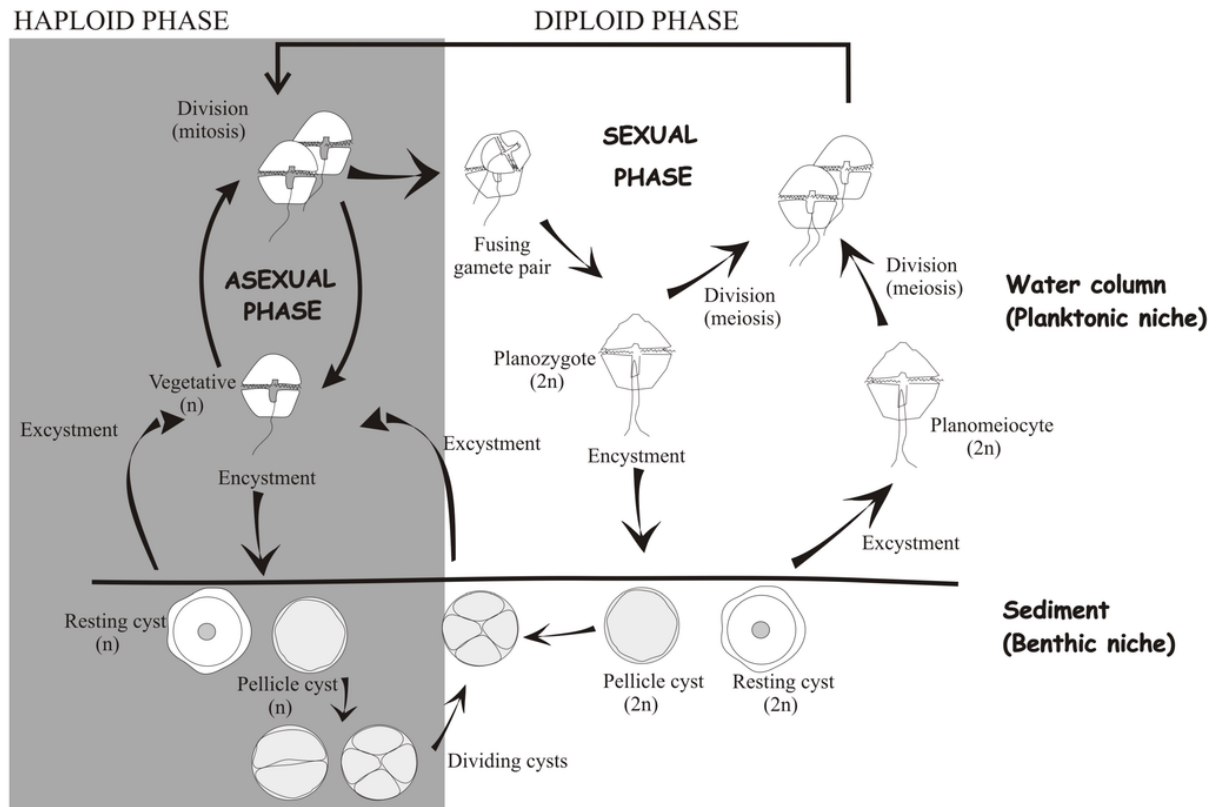


Figure 1: General Dinoflagellate Life Cycle including Benthic Cyst Stage (After Bravo and Figueroa 2013)

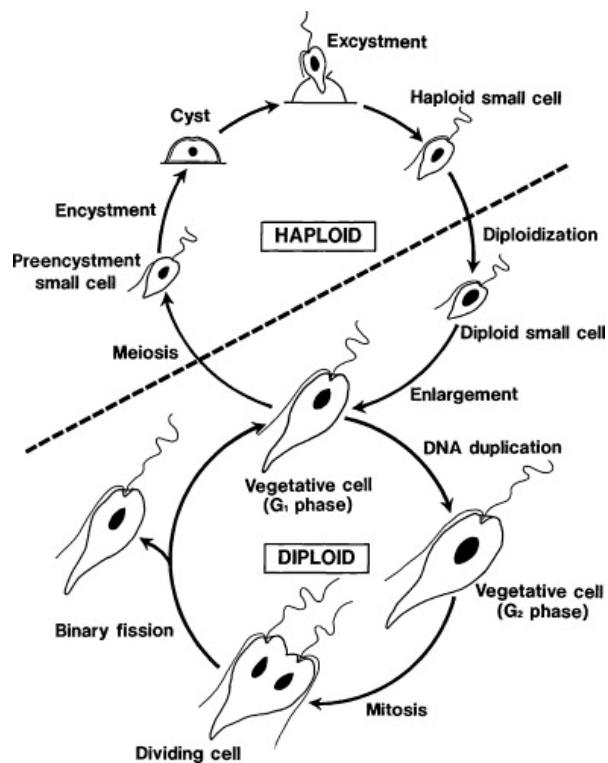


Figure 2: Raphidophytes Life Cycle including Resting Cyst (After Imai and Yamaguchi, 2012)

There is little study on the resting stage of phytoplankton in the ROPME Sea Area (RSA) and most of the studies focus on motile stage. A few studies have been carried out on the resting cells of diatom and resting cyst of raphidophytes in the sediments of the northern part of the Sea of Oman (Hendey, 1970; Basson and Mohammed, 1989; Attaran-Fariman and Bolch, 2014; Attaran-Fariman *et al.*, 2007). Dinoflagellate cysts surveys in the RSA have been limited to the Bradford (1975), Bradford and Wall (1984), Zonneveld (1997, 1999, 2000, 2001), Wendler (2002), and Marret and Zonneveld (2003). However, the majority of these works have focused on paleontological study of the cysts.

Biological study of cysts flora of some limited coastal area (9 sites) of the Sea of Oman (Iranian side) has been carried out by Attaran-Fariman (2007) and Attaran-Fariman *et al.*, (2012). Husain and Lewis (2004) also surveyed dinoflagellate cysts in the sediments of Kuwait coastal area.

Dispersion and diversity of phytoplankton cysts flora along the coastal area of the Sea of Oman to Strait of Hormuz (Northern part; Iranian side) in 4 seasons have been conducted from depths of 1m to 20m by Attaran-Fariman in 2015-2016. To understand the mechanism of harmful algal blooms in the RSA and to explain the potential of HABs forming species in the area, the research should also focus on cyst resting stage as an important part of phytoplankton (especially dinoflagellate) life cycle in different seasons in all parts of RSA. The present study examines the taxonomy and spatial distribution of phytoplankton resting cyst stage in the recent sediments of the RSA collected during Winter 2006 Cruise.

2. Materials and Methods

Sediment samplings were carried out by Van Veen grab from 27 stations located in three legs and 16 transects off the inner and northern part of the inner RSA, Strait of Hormuz and northern and southern part of the Sea of Oman (Figure 3). 25 sediment samples were collected in February and two samples in March 2006. The Surface sediments from each grab was kept in a little bottle and for long-term preservation formaldehyde 4% was used. The depths of sediment samplings for study of cyst flora in the RSA were from at least 26m to the maximum of 104m. Geographical position of the Stations in Cruise legs, sample IDs, sampling dates, sampling times and transects numbers are listed in Table 1.

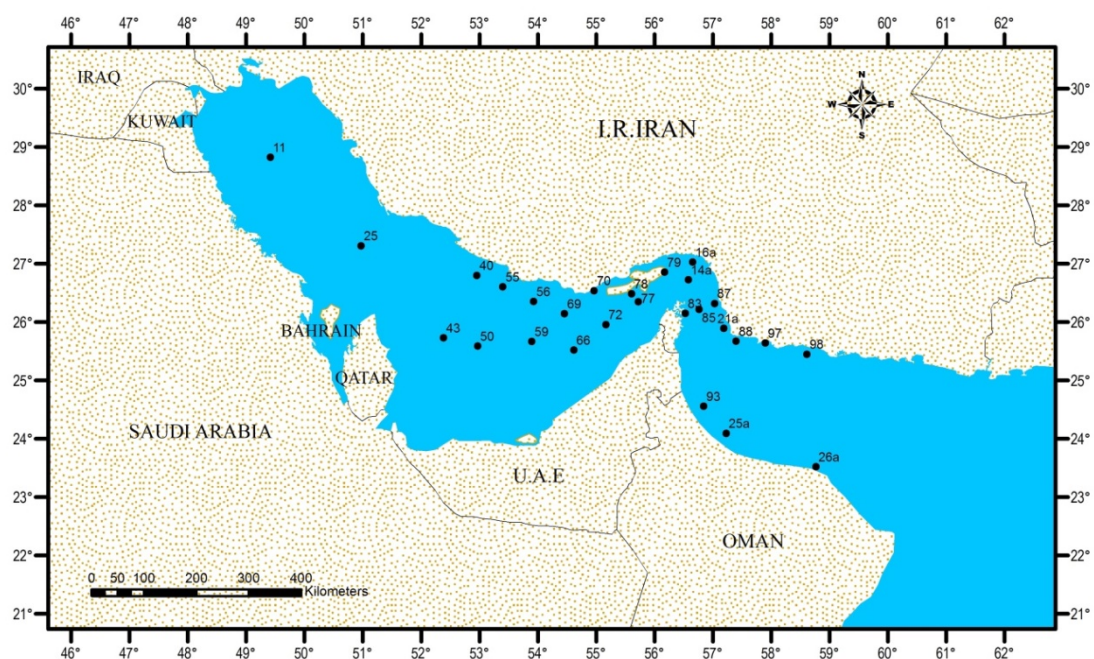


Figure 3: Map of ROPME Sampling Areas for Phytoplankton Cysts during Cruise-Winter 2006

Table 1: Description of Sediment Sampling Stations

Sampling	Leg	Sampling	Transect	Station	Position		Sample ID
Date		Time			Lat. (N)	Long. (E)	
2/2/2006	1	18:30	18	26a	23° 31.000¢	058° 46.100¢	T18S26a
3/2/2006		23:45	18	98	25° 26.801¢	058° 36.914¢	T18S98
4/2/2006		20:00	17a	25a	24° 05.505¢	057° 13.813¢	T17aS25a
5/2/2006		1:00	17	93	24° 33.147¢	056° 50.739¢	T17S93
5/2/2006		18:00	17	97	25° 38.200¢	057° 54.000¢	T17S97
5/2/2006		22:15	16	88	25° 40.043¢	057° 24.048¢	T16S88
7/2/2006		1:00	15a	21a	25° 53.400¢	057° 11.300¢	T15aS21a
7/2/2006		11:55	15	87	26° 18.900¢	057° 01.800¢	T15S87
8/2/2006		8:00	15	85	26° 13.000¢	056° 46.000¢	T15S85
8/2/2006		11:30	15	83	26° 08.763¢	056° 31.767¢	T15S83
8/2/2006		21:00	14a	14a	26° 43.200¢	56°34.900¢	T14aS14a
9/2/2006		11:30	14a	16a	27° 01.400¢	056° 39.300¢	T14aS16a

13/2/2006	8:30	14	79	26° 51.046'	56° 10.378'	T14S79
13/2/2006	19:40	13	77	26° 20.671'	55° 43.561'	T13S77
14/2/2006	10:15	13	78	26° 28.769'	55° 36.474'	T13S78
14/2/2006	14:15	12	70	26° 32.104'	54° 57.957'	T12S70
14/2/2006	18:45	12	72	25° 57.254'	55° 10.080'	T12S72
15/2/2006	2 16:30	11	66	25° 31.090'	54° 37.156'	T11S66
15/2/2006	21:45	11	69	26° 08.382'	54° 27.506'	T11S69
21/2/2006	5:45	10	56	26° 20.905'	53° 55.864'	10S56
21/2/2006	12:45	10	59	25° 39.885'	53° 53.944'	T10S59
22/2/2006	7:10	9	50	25° 35.092'	052° 58.225'	T9S50
22/2/2006	16:00	9	55	26° 36.057'	053° 24.057'	T9S55
22/2/2006	20:30	8	40	26° 47.800'	052° 57.400'	T8S40
23/2/2006	13:15	8	43	25° 43.513'	52° 23.170'	T8S43
3/3/2006	3 6:15	5	25	27° 18.290'	050° 58.400'	T5S25
7/3/2006	9:50	2	11	28° 49.120'	049° 25.120'	T2S11

For cyst identification, the sediments were processed and analysed using standard sieving method (Wall and Dale, 1968; Matsuoka and Fukuyo, 2000). 1-2g of sediments with six replicates from each station were processed. Both live (with cytoplasmic content) and empty cysts (already germinated) were identified and photographed under Olympus LM (light microscope) and inverted microscope (Nikon, Model TS100) equipped with digital camera. All the resting cyst morphotypes were identified on published literature and for each cyst morphotype, the references have been cited. Identification was done to the species level where possible.

3. Overall Taxonomy of the Cyst

Within phytoplankton groups that produce resting cyst, dinoflagellate and also diatoms resting spore have the capability to fossilize. Therefore, some cysts have two different names. Paleontologists have established a paleontological classification based on cyst features, while planktologists have classified them based on motile cells. Wall and Dale (1968) found

modern cysts of *Protoperidinium claudicans* with the same morphology as the fossil species *Votadinium spinosum*. These modern cysts have also been classified and described under the paleontological system. As each taxonomic system for classification is different, it is not surprising that one species sometimes has more than one scientific name.

There is little study on the resting spore of diatoms (i.e. Itakura *et al.*, 1997; Suto 2004) from biological point of view, and most of researches have focused on the benthic diatom resting cells, which morphologically are similar to the motile cell and are not considered in this study.

The taxonomy of living motile and fossil dinoflagellates with the emphasis on tabulation and paratabulation were combined by Fensome *et al.*, (1993). Their work identified six major tabulation types: gymnodinioid, suessoid, gonyaulacoid-peridinioid, dinophysoid, nannoceratopsoid and prorocentroid. The main morphological features for taxonomy of cysts are the whole shape of the cyst, colour and wall structure of the cyst, ornamentation of the cyst, archeopyle type and cyst content (Matsuoka & Fukuyo 2000). There is no published data on the taxonomy of the dinoflagellate cyst in the ROPME Sea Area (RSA). The aim of this work is to describe phytoplankton cysts with emphasis on dinoflagellate cyst morphology and taxonomy that have been isolated from sediment samples within RSA, and to provide description and distribution for each cyst.

3.1. Taxonomical Features of the Dinoflagellate Cysts

Morphology of the dinoflagellate cyst can be more complex than motile stage (Wall and Dale 1968). There are wide varieties of morphological overlaps between motile stage and non-motile cyst stage (Figure 4) that allow us to recognize cyst and motile stages. In the cyst, the identical terminologies are used as the motile stage, but are stated with the prefix 'para' (Evitt *et al.*, 1977). The main morphological features for taxonomy of cysts are the whole shape of the cyst, colour and wall structure of the cyst, ornamentation of the cyst, archeopyle type and cyst content (Matsuoka & Fukuyo 2000).

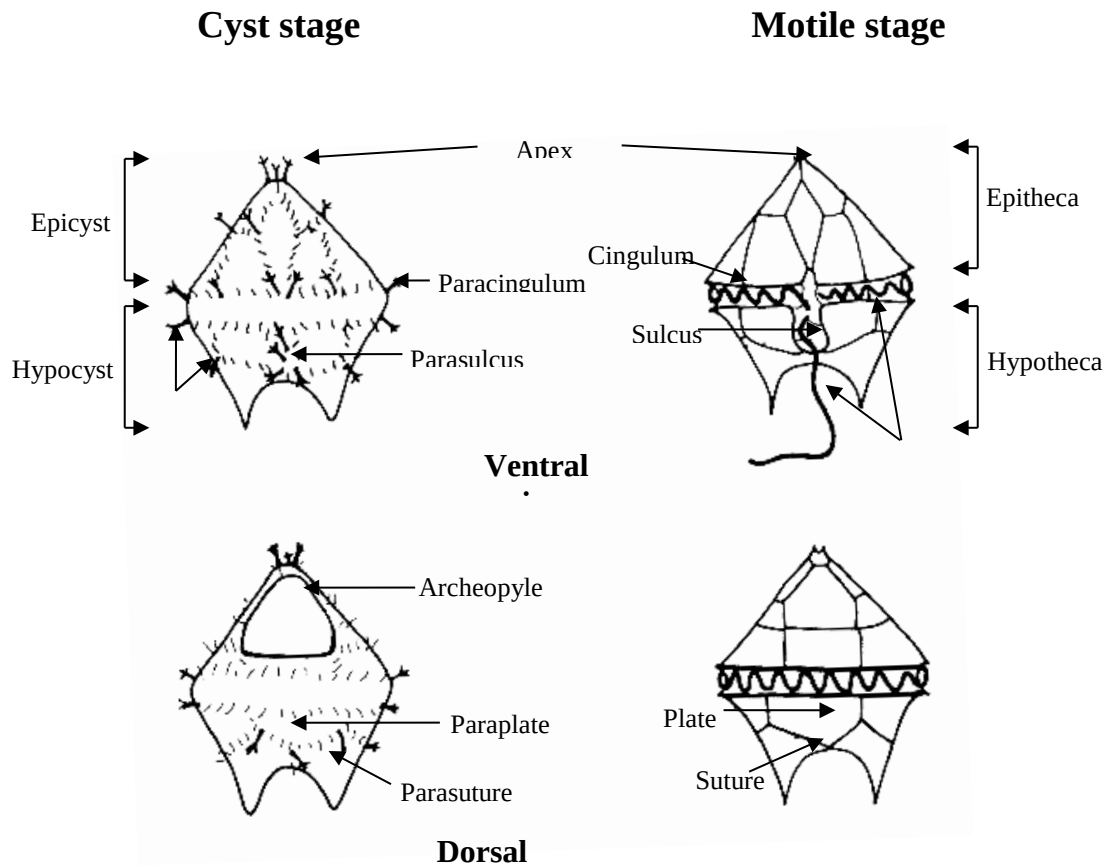


Figure 4: Cyst and Motile Cell; Main Description (After Dale 1983)

Archeopyle is one of the most important features in the morphology of a cyst and it is a species' specific. Archeopyle is formed when operculum is released along suture. It is simple when it consists of a single piece and complex when comprises more than one piece. The archeopyle was first defined by Evitt (1961) and five distinct types were later defined by Evitt and Davidson (1967). These types are: apical, intercalary, precingular, a combination of these series, and miscellaneous archeopyles. Matsuoka (1985) classified the archeopyles of modern dinoflagellate cysts to saphopylic, therapylic and cryptopylic archeopyles (Figure 5).

The type of process is another important feature in the morphology of cysts. The processes are usually solid or hollow, flat tipped, flared or pointed. The terms and descriptions for processes and morphology of dinoflagellates cysts were introduced by Sarjeant (1984) and modified by Matsuoka and Fukuyo (2000).

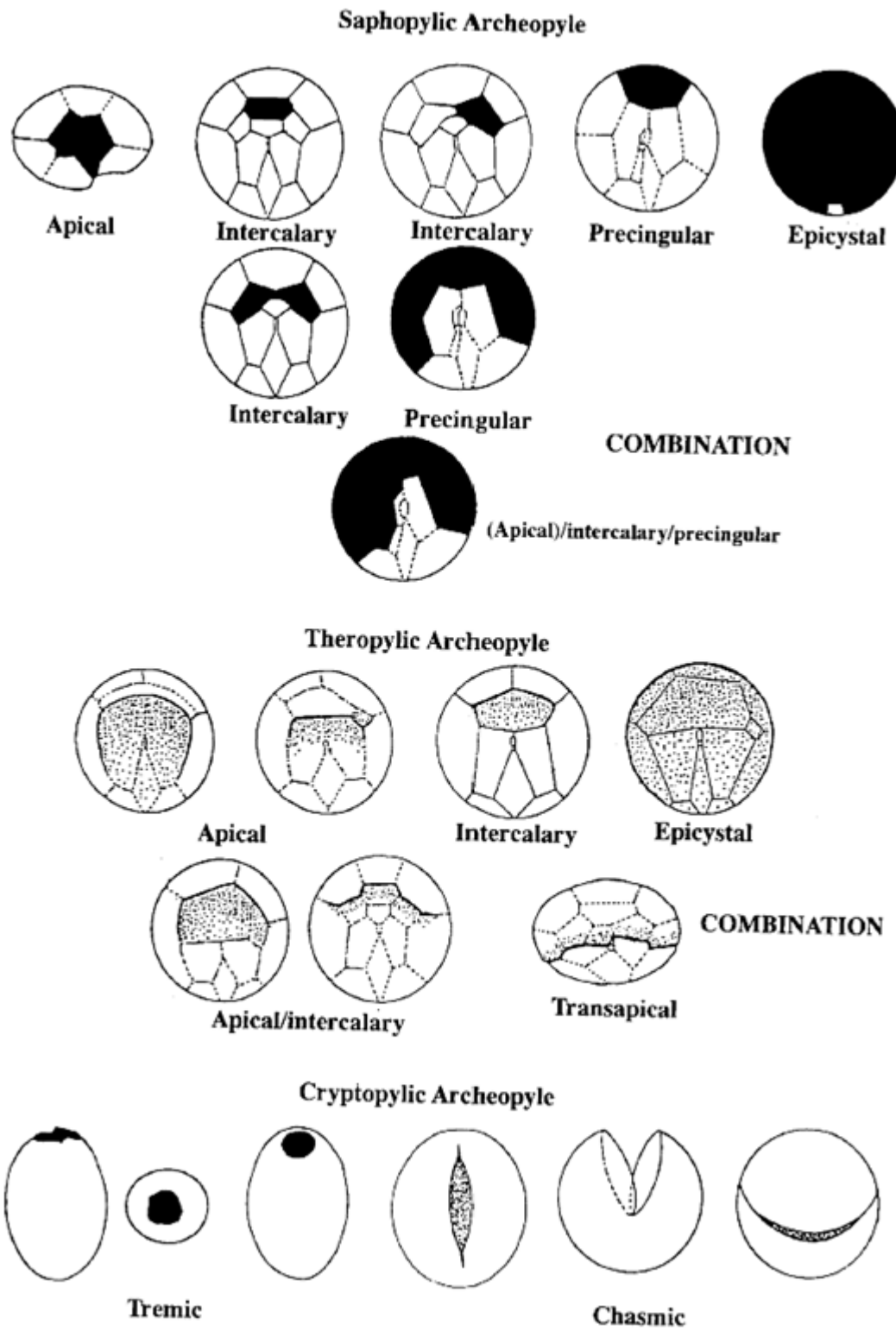


Figure 5: The Types of Archeopyle in the Dinoflagellate Resting Cysts (Adopted from Matsuoka & Fukuyo 2000)

3.2. Identification Key to Phytoplankton Cyst in RSA

Most species that have been identified in the RSA belong to the division of dinophyta, and a few species belong to diatom and raphidophytes. The identification guide and description of the phytoplankton cysts groups recorded in the RSA from samples of Winter Cruise 2006 are presented here. Identification guide is based on the main features of each taxa category for example order refer to (O.) or class (CL.) or family (F.). Identification keys are accompanied by cysts images and descriptions.

Key to general group

1. Cyst with ornaments and process.....3
 - Colourless cyst wall.....3
 - Brownish cyst wall.....5
 - Calcareous cyst wall.....2
2. Cyst without ornaments and process.....7
3. Furcate, gonol or intergonol, and randomly distributed long spines or dumbbell shape process.....**O. Gonyaulacales**
4. Hexagonal, peridinioids, or ellipsoids forms with short or spinate or shelf like spines.....**O. Peridinales**
5. Acuminate process.....6
6. Cysts ornamented, spinate process with a groove on the proximal base.....**O. Gymnodinales**
 - Large spinate process.....**F. Diplosalaceae**
7. Colourless cyst wall.....8
 - Brownish cyst wall.....10
8. Smooth surface, sometimes gelatinous material.....**O. Gonyaulacales**
9. Peridinioids forms and apical-antapical compressed, cyst wall with single or two layers.....**O. Peridinioids**
 - Spherical reticulate cyst forms **F. Gymnodinaceae**
10. Brown spherical triple layer wall cyst.....**O. Prorocentrales**
11. Yellow-greenish to brownish small spherical to hemispherical cyst with many dark spot or black materials.....**O. Chattonellales**

3.3. Taxonomy Description of Phytoplankton Cysts

Taxa categories that have been used are; phylum, class, order, genus and species level. Biological and paleontological names are used for description of each species. For those species that their motile stages have not been reported yet, only their paleontological names are used. Distribution of each species in the RSA is also shown on the maps. The classification of the phytoplankton cysts in the RSA are based on the classification presented in the Algae Base (Guiry and Guiry, 2017). All taxa belong to the Empire: Eukaryota and Kingdom: Protista. Abbreviations that are used in section of size include W: Width, L: Length, D: Diameter.

3.4. Identified Species in the RSA from Cruise-Winter 2006

Phytoplankton cysts that have been identified in the RSA belong to different orders and families, and are orderly listed in Table 2.

Table 2: List of Identified Phytoplankton Cysts in the Sediment Samples of RSA

Order; Peridiniales	Order; Peridiniales
Family: Protoperidiniaceae	Family: Thoracosphaeraceae
1- <i>Protoperidinium americanum</i>	51- <i>Calciodinellum operosum</i>
2- <i>Protoperidinium shanghaiense typeA</i>	52- <i>leonella granifera</i>
3- <i>Protoperidinium shanghaiense typeB</i>	53- <i>Pentapharsodinium tyrrhenicum</i>
4- <i>Protoperidinium oblongum</i>	54- <i>Pentapharsodinium cf. tyrrhenicum</i>
5- <i>Protoperidinium claudicans</i>	55- <i>Bicarinellum tricarinelloides</i>
6- <i>Protoperidinium leonis</i>	Order; Gonyaulacales
7- <i>Protoperidinium cf. leonis</i>	Family; Gonyaulacaceae
8- <i>Protoperidinium denticulatum</i>	56- <i>Bitectatodinium spongium</i>
9- <i>Protoperidinium humile</i>	57- <i>Nematosphaeropsis labyrinthus</i>
10- <i>Protoperidinium conicoides</i>	58- <i>Gonyaulax membranacea</i>
11- <i>Protoperidinium conicum</i>	59- <i>Spiniferites mirabilis</i>
12- <i>Protoperidinium latissimum</i>	60- <i>Gonyaulax digitale</i>
13- <i>Protoperidinium avellana</i>	61- <i>Gonyaulax cf. scrippsae</i>
14- <i>Protoperidinium punctulatum</i>	62- <i>Spiniferites ramosus</i>
15- <i>Protoperidinium divaricatum</i>	63- <i>Gonyaulax baltica</i>
16- <i>Protoperidinium subinermis</i>	64- <i>Spiniferites cf. delicatus</i>
17- <i>Protoperidinium c.f. tharianum</i>	65- <i>Spiniferites hyperacanthus</i>
18- <i>Protoperidinium compressum</i>	66- <i>Gonyaulax ellegaardiae</i>
19- <i>Protoperidinium mintum</i>	67- <i>Gonyaulax sp1</i>

20- <i>Protooperidinium</i> sp1	68- <i>Gonyaulax</i> sp2
21- <i>Protooperidinium</i> sp2	69- <i>Lingulodinium polyedra</i>
22- <i>Protooperidinium</i> sp3	70- <i>Lingulodinium</i> sp
23- <i>Protooperidinium</i> sp4	Family: Protoceratiaceae
24- <i>Protooperidinium</i> sp5	71- <i>Protoceratium reticulatum</i>
25- <i>Protooperidinium</i> sp6	Family: Pyrophacaceae
26- <i>Protooperidinium</i> sp.7	72- <i>Pyrophacus steinii</i>
27- <i>Niea torta</i>	Order; Gymnodiniales
Family; Congruentidiaceae	Family: Gymnodiniaceae
28- <i>Echinidinium delicatum</i>	73- <i>Gymnodinium catenatum</i>
29- <i>Echinidinium cf bispiniformum</i>	74- : <i>Gymnodinium nolleri/</i>
Family; Amphidiniopsidaceae	75- <i>Gymnodinium microreticulatum</i>
30- <i>Islandinium cf. minutum</i>	76- <i>Gymnodinium trapeziforme</i>
31- <i>Archaeoperidinium minutum</i>	77- <i>Gymnodinium inusitatum</i>
Family; Kolkwitzellaceae	78- <i>Gymnodinium</i> sp
32- <i>Diplopsalis lenticula</i>	79- <i>Cochlodinium polykrikoides</i>
33- <i>Diplopslis</i> sp.1	Family; Polykrikaceae
34- <i>Diplopslis</i> sp.2	80- <i>Polykrikos hartmannii</i>
35- <i>Diplopelta parva</i>	Family: Warnowiaceae
36- <i>Diplopelta symmetrica</i>	81- <i>Warnowia rosea</i>
Family: Thoracosphaeraceae	82- <i>Biecheleria cincta</i>
37- <i>Pyrodinium bahamense</i>	unknown
38- <i>Alexandrium pseudogonyaulax</i>	83- Dinocyst type1
39- <i>Alexandrium affine</i>	84- Dinocyst type 2
40- <i>Alexandrium cf. tamarense</i>	85- Inocyst type 3
41- <i>Alexandrium minutum</i>	86- Dinocyst type4
42- <i>Alexandrium</i> sp1	87- Dinocyst type5
43- <i>Alexandrium</i> sp2	88- Dinocyst type6
44- <i>Scrippsiella trifida</i>	Diatom
45- <i>Scrippsiella irregularis</i>	89- <i>Paralia</i> sp(diatom)
46- <i>Scrippsiella trochoidea</i>	90- Diatom unknown typeA
47- <i>Scrippsiella precaria</i>	91- Diatom unknown type B
48- <i>Scrippsiella cf. regalis</i>	Raphidophyds
49- <i>Calcioperidinium asymmetricum</i>	92- <i>Chattonella</i> sp(raphidophyceae)
50- <i>Calciodinellum albatrosianum</i>	93- <i>Hetrosigma</i> cf. akashiow

Phylum: Miozoa Cavalier-Smith 1987

Class; Dinophyceae Fritsch 1927

Order; Peridinales Haeckel 1894

Family; Protopteridiniaceae Balech, 1988

Genus; *Protopteridinium* R.S.Bergh, 1881

Species: *Protopteridinium americanum*

Scientific name: *Protopteridinium americanum* (Gran & Braarud) Balech 1974

Paleontological name: *Protopteridinium americanum* (Gran and Braarud) Balech

Figure No.: Plate 1

References:

Dale (1976), Plate 1 Figure16;

Lewis and Dodge (1987);

Matsuoka (1987), Plate 17;

Bolch & Hallegraeff (1990), Figure 29

Description:

Spherical brown cyst. The cyst wall is granular with a roughly attached, folded membranous external layer (Plate 1, A-B). The archeopyle is formed by the loss of the 3 apical paraplates (Plate 1, C-D). No other tabulation is reflected on the cyst wall. The cyst has been reported from southern part of the Sea of Oman, Arabian Sea (Marret and Zonneveld, 2003).

Size:

D: 45-50µm

Occurrence in RSA:

The presence of the species in the sediment sample of the Winter Cruise 2006 of RSA is shown on Map 1, in stations: 98, 83, and 11

The cyst is also reported by Attaran-Farimen (2016) from Iranian coastal area of the Sea of Oman.

Occurrence in the world:

North America (Eastern Pacific), NW Pacific, Chile (southeastern Pacific), NW and SW Africa.

South China Sea, coastal sites off South Australia, the western Indian coast and off the Iberian margin (Godhe *et al.*, 2000; Marret and Zonneveld, 2003; Wang *et al.*, 2004; Ribeiro and Amorim, 2008)

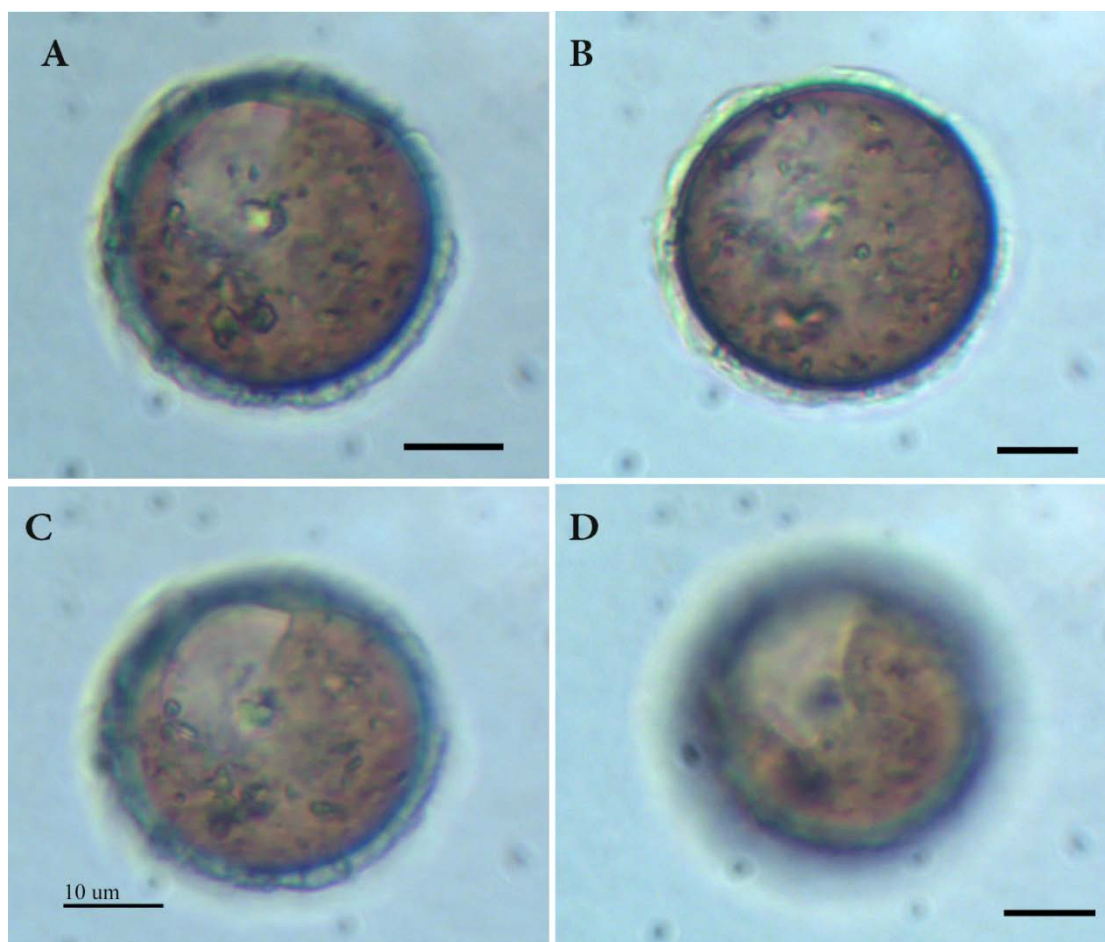
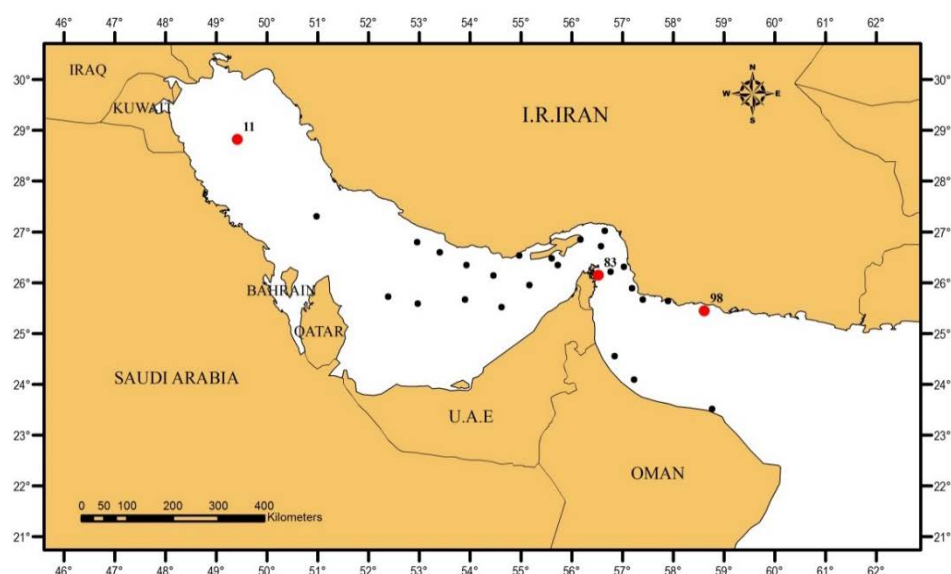


Plate 1: *P. americanum*; A-B, cyst wall with irregular folds of external membrane and granular inner wall; C-D, cyst shows archeopyle; All scale bar=10µm



Map 1: *Protopredinium americanum* occurrence in the RSA, Winter 2006

Phylum: Miozoa

Class; Dinophyceae Fritsch

Order; Peridinales Haeckel

Family; Protoperidiniaceae Balech

Genus; *Protoperidinium* Taylor 1987

Species; *Protoperidinium shanghaiense*

Scientific name: *Protoperidinium shanghaiense* H.Gu, T.Liu & K. Mertens 2015

Paleontological name: *Trinovantidium applanatum* (Bradford 1977) Bujak et Davies 1983

Figure No.: Plate 2

Reference:

Bradford (1977) Figure 2;

Gu *et al.*, (2015), Figures. 9-10;

Balkis *et al.*, (2016) Figure 50

Description:

Pentagonal dorsoventrally flat cyst. Cyst has an apical and two antapical horns. Each horn is pointed distally. Antapical horns are separated by shallow antapical depression. Epicyst and hypocyst are equal in size. The cyst wall is transparent and ornamented with short and solid spines. The epicyst has concave sides and the hypocyst has straight sides. The archeopyle was not observed in our samples. In many literatures the motile affinity and biological cyst name of the species has been referred as *Protoperidinium pentagonum* (e.g. Matsuoka 1985; Joyce 2004; Attaran-Fariman 2007; Zonneveld & Pospelova 2015). Fukuyo *et al.*, (1990) noticed that there is no displacement in the cingulum of *T. applanatum* theca stage in contrast to *P. pentagonum*. Gu *et al.*, (2015) showed cyst theca relationship of *T. applanatum* and introduced a new species as *P. shanghaiense* from this cyst type. In RSA sediments, there are two types of cysts attributed to *T. applanatum*.

Size:

W: 52um; L: 60um

Occurrence in RSA:

The presence of the species in the sediment sample of the Winter Cruise 2006 of RSA is shown on Map 2; in stations: 14a, 88, 98, 21a

Bradford (1971) reported this species from the inner RSA, the Sea of Oman and Strait of Hormuz, The species has also been reported from northern part of the Sea of Oman (Attaran-Fariman, 2007, 2016; Attaran-Fariman *et al.*, 2012)

Occurrence in the world:

California (Davidson 1964); Massachusetts (Wall & Dale 1968), Peruvian upwelling area (Biebow *et al.*, 1993); Arabian Sea and Musandam Peninsula (Bradford 1971); Japanese coast (Harada 1974); Africa (Zonneveld *et al.*, 2010); East China Sea (Gu *et al.*, 2015); South China Sea (Gu *et al.*, 2015)

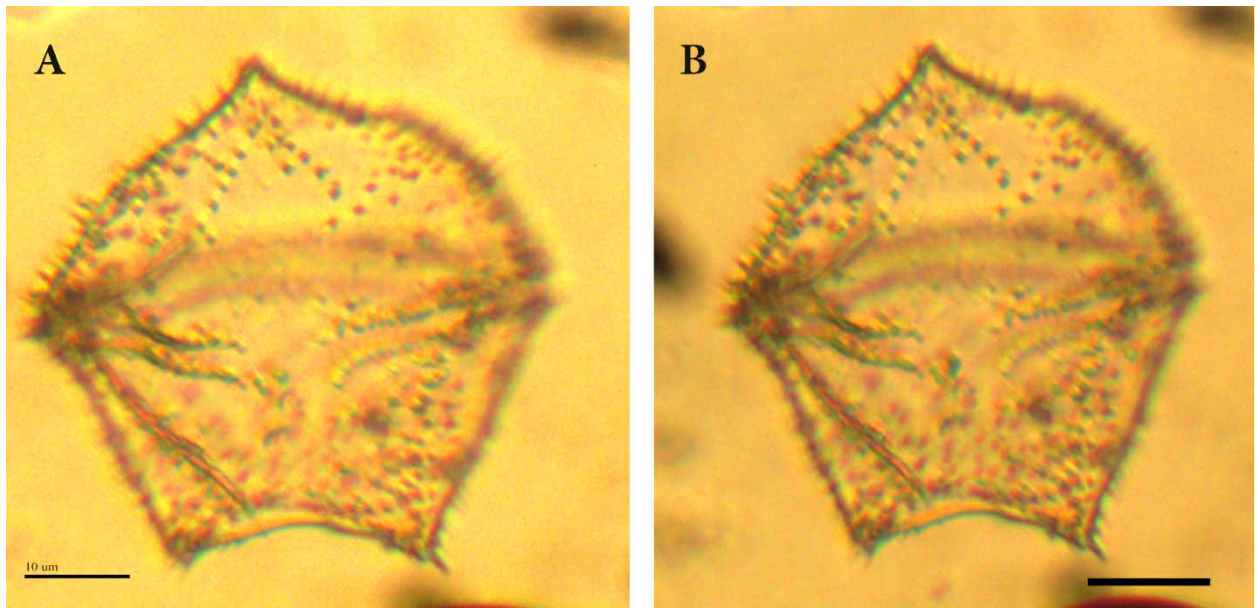
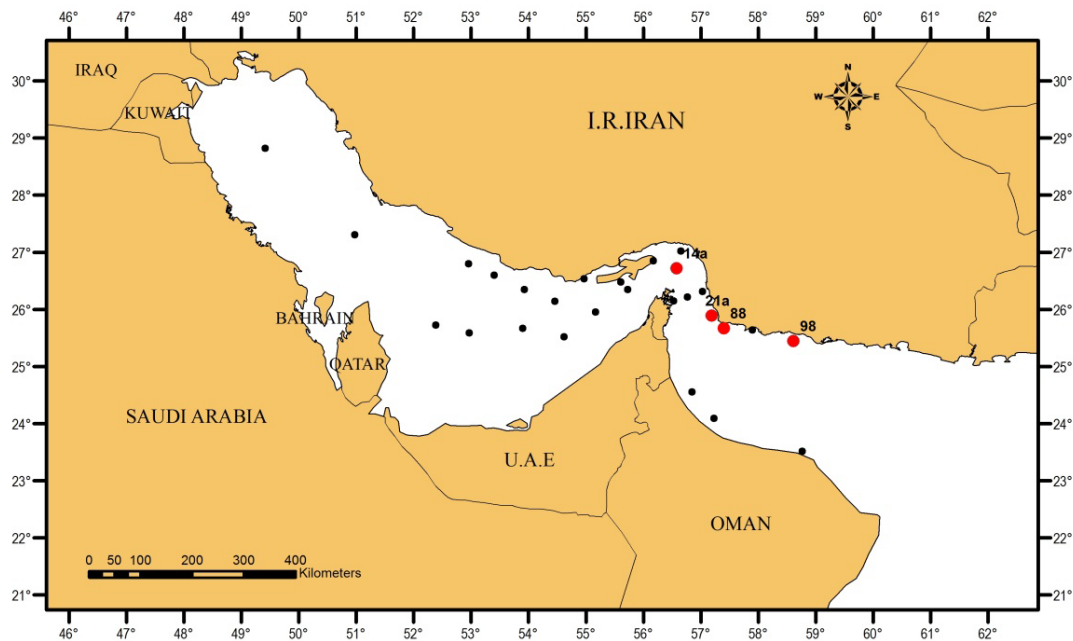


Plate 2: *Protoperidinium shanghaiense*; type A: A- cyst in dorsal view; B- cyst in ventral view shows sulcus



Map 2: *Protoperidinium shanghaiense* type A: sites of occurrence in the RSA, Winter 2006

Phylum: Miozoa

Class; Dinophyceae Fritsch 1927

Order; Peridiniales Haeckel 1894

Family; Protoperidiniaceae Balech, 1988

Genus; *Protoperidinium* R.S.Bergh, 1881

Species; *Protoperidinium shanghaiense* type B

Scientific name: *Protoperidinium shanghaiense* H.Gu, T.Liu & K.Mertens 2015

Paleontological name: *Trinovantidium applanatum* (Bradford 1977) Bujak et Davies 1983

Figure no: Plate 3

Reference:

Joyce (2004a), Figure 19;

Orlova *et al.*, (2004), Figures 56-60;

Joyce *et al.*, (2005),

Mertens *et al.*, (2016), Plate 5

Description:

A colourless, pentagonal, peridinioid-shaped cyst, dorsoventrally compressed. The cyst wall is ornamented with numerous short, rigid and pointed spines (Plate 3). The epicyst tapers into an apical boss and the hypocyst carries two short antapical horns (Plate 3, A and B). The epicyst and hypocyst have same size. Both the parasulcus and paracingulum are well developed and ornamented by rows of spines along their borders. The archeopyle was not observed in this study. The cyst outline resembles the *Protoperidinium louisianensis* Mertens, Gu, Price et Matsuoka n. sp. 2016; however, it differs from that by its transparent colour. The later species has brown colour and epicyst and hypocyst do not have same size. This cyst type differs from *T. applanatum* type A by its straight side of epicyst and also deeper depression between two antapical horns (Plates 2 and 3).

Size:

W: 48µm; L: 52 µm

Occurrence in RSA:

The presence of the species in the sediment sample of the Winter Cruise 2006 of RSA is shown on Map 3; in stations: 40, 55, 59, 79, 16a, 79, 14a, 98, 85, 26a

The species has been reported by Attaran-Fariman (2016) from northern part of the Sea of Oman

Occurrence in the world:

Gulf of Mexico

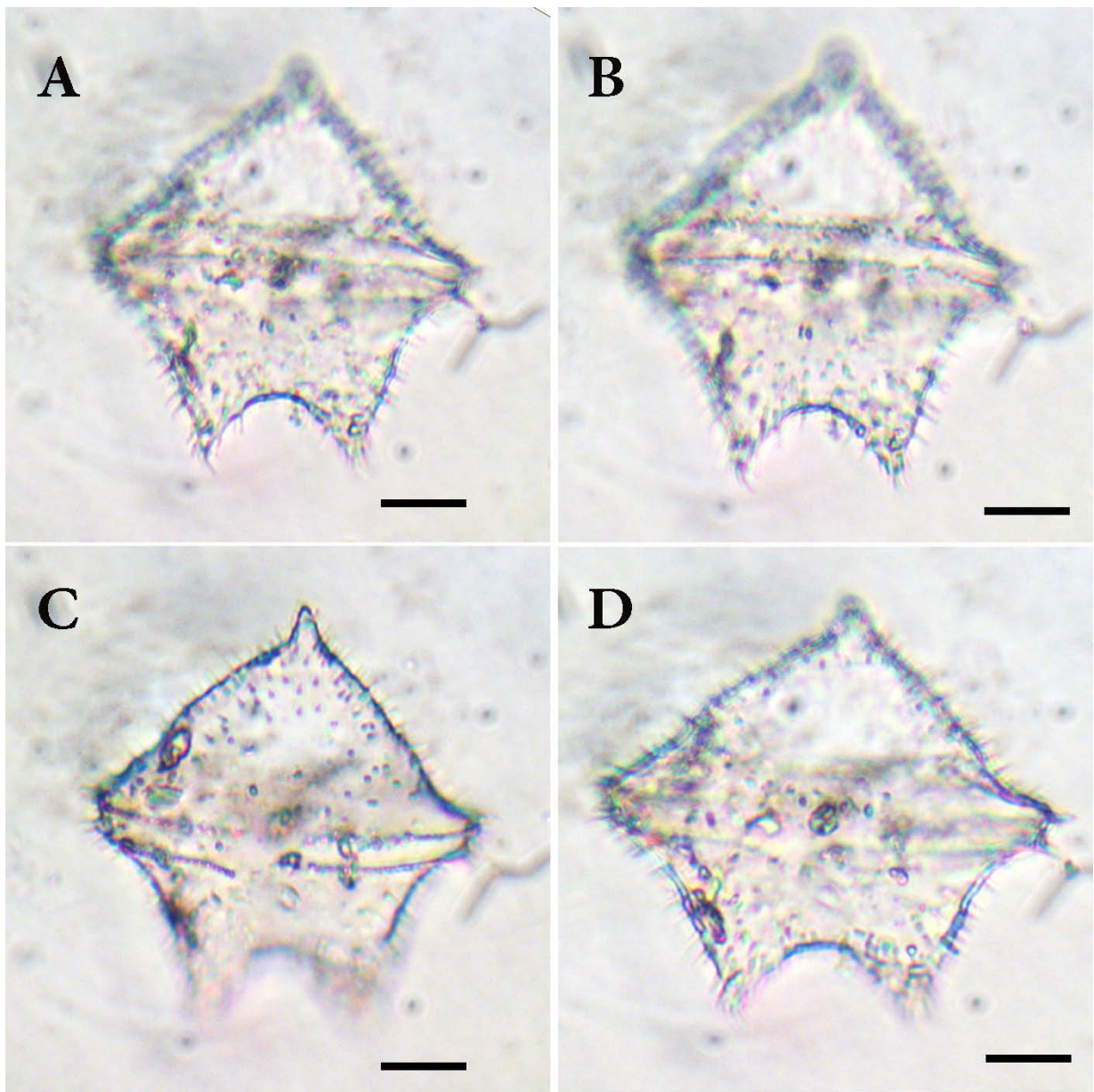
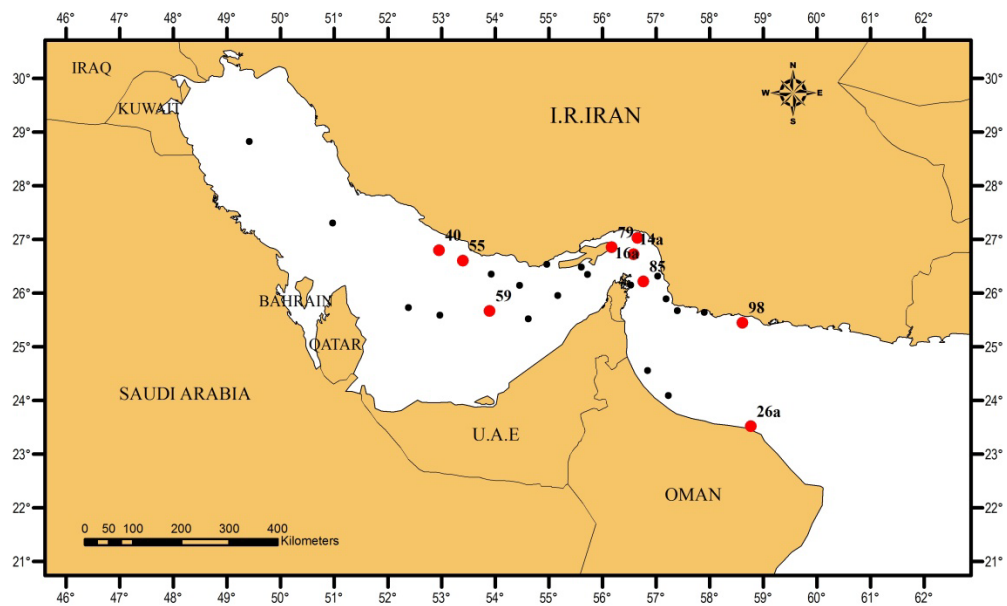


Plate 3: *Trinovantedinium applanatum*; type B: A and B showing antapical horn and paracingulum, C and D cysts show apical horn and short spine process



Map 3: *Trinovantedinium applanatum* type B: sites of occurrence in the RSA, Winter 2006

Phylum: Miozoa

Class; Dinophyceae Fritsch

Order; Peridinales Haeckel

Family; Protoperidiniaceae Balech

Genus; *Protoperidinium* Taylor 1987

Species; *Protoperidinium oblongum*

Scientific name: *Protoperidinium oblongum* (Aurivillius) Parke & Dodge

Paleontological name: *Votadinium calvum* Reid

Figure No: Plate 4

Reference:

Wall & Dale (1968), Plate 1, Figures 22-29;

Bolch & Hallegraeff (1990), Figure 19;

Sonneman & Hill (1997), Figure 26.

Joyce (2004a), Figure 18;

Joyce (2004b), Plate 8, Figures 1a-f.

Attaran-Fariman (2011), Figures 3-5

Description:

The cyst has a smooth-walled with a pale brown outer wall. The cyst of *P. oblongum* shows considerable variation in morphology; content and colour (Plate 4). Two types of *P. oblongum* were observed in the RSA; here referred to types A and B. The cyst type A has a broadly rounded apical and antapical horns, with short antapical horns, giving the cyst a truncated appearance (Plate 4, A-B). The cyst type B has conical apical and antapical horns and the depression between antapical horns is deeper (Plate 4, C-D). As shown in the Plate 4 the cyst content also differs in cyst types A and B. Dale and Wall (1968) described three cyst types according to variations on their apical and antapical shapes. Attaran-Fariman and Bolch (2011) also described three *P. oblongum* types from Southeast coast of Iran (northern part of the Sea of Oman). The cyst from RSA is similar to those described by Wall and Dale (1968, Figure 26) and type 2 from Iranian sediment (Attaran-Fariman and Bolch, 2011, Figure 3).

Size:

W: 51-58µm; L: 49-61µm

Occurrence in RSA:

The presence of the species in the sediment sample of the Winter Cruise 2006 of RSA is shown on Map 4, in stations: 21a, 14, 69, 59, 55, 40, and 11

Bradford (1971) reported this species from the inner RSA, the Sea of Oman and Strait of Hormuz. The species has also been reported from northern part of the Sea of Oman (Attaran-Fariman 2007, Attaran-Fariman *et al.*, 2012; Attaran-Fariman 2016)

Occurrence in the world:

Africa: Mauritania (Zonneveld *et al.*, 2010); Korea (Cho *et al.*, 2003); Iberian Peninsula (Ribeiro and Amorim, 2008) and the western Barents Sea (Solignac *et al.*, 2009)

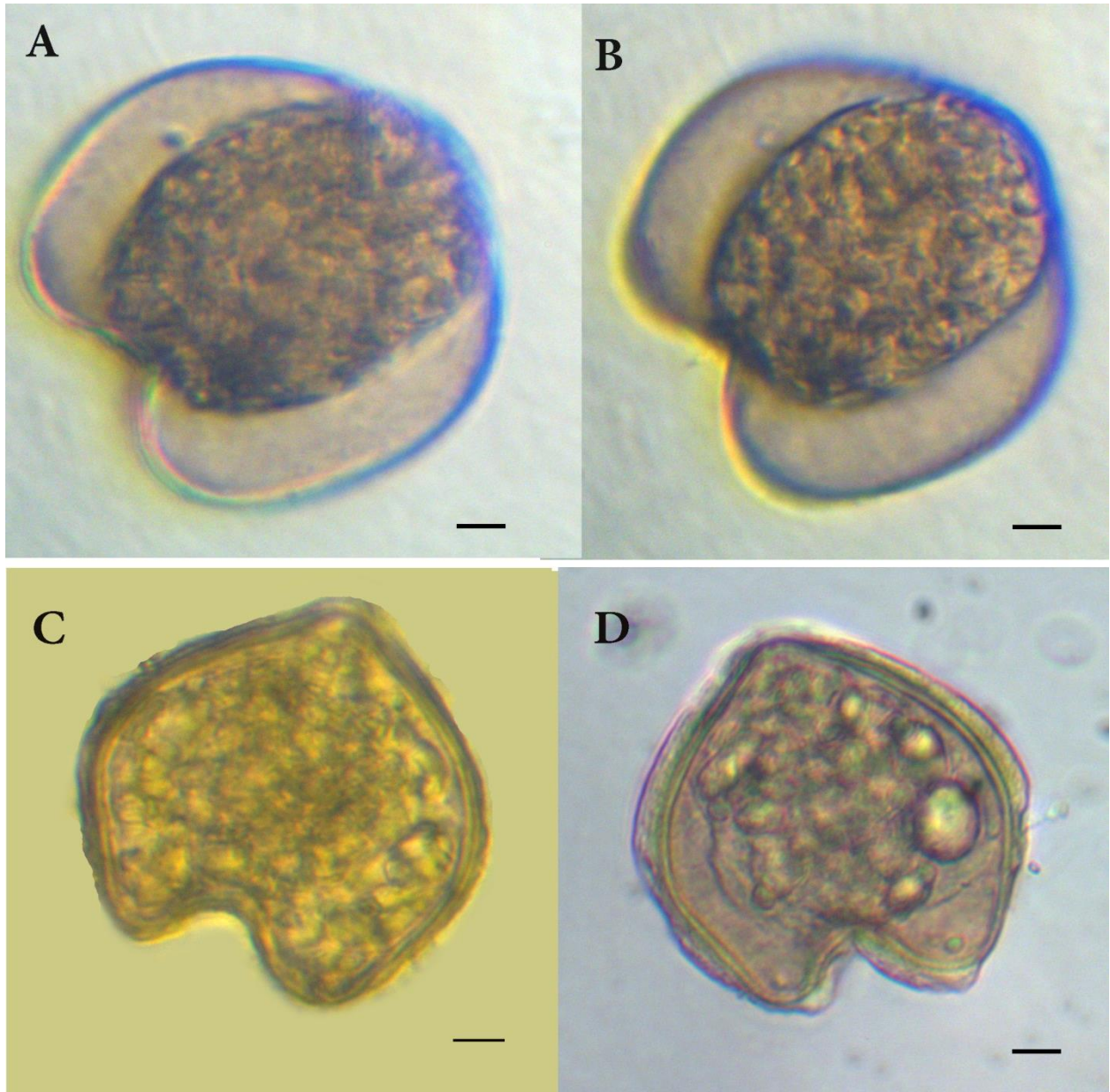
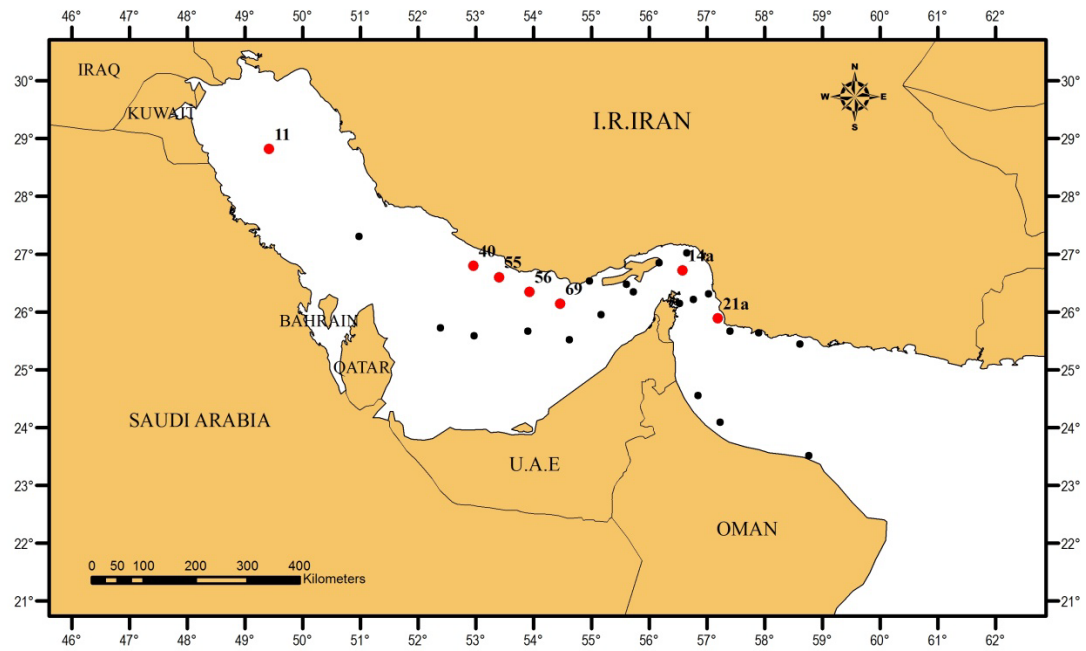


Plate 4: *Protoperidinium oblongum*: Type A: A-B from RSA show a greenish brown colour contents, type B: C-D



Map 4: *Protoperidinium oblongum* cyst occurrence in RSA, Winter 2006

Phylum: Miozoa

Class; Dinophyceae Fritsch 1927

Order; Peridiniales Haeckel 1894

Family; Protoperidiniaceae Balech, 1988

Genus; *Protoperidinium* R.S.Bergh, 1881

Species; Protoperidinium claudicans

Scientific name: *Protoperidinium claudicans* (Paulsen) Balech 1974

Paleontological name: *Vtadinium spinosum* Reid 1977

Figure No: Plate 5

Reference:

Wall & Dale (1968), Plate 1, Figure 30 and Plate 3, Figure 12.

Sonneman & Hill (1997), Figure 18c.

Description:

Cyst of *P. claudican* is heart-shaped (Plate 5); light brown and ornamented with numerous short pointed spines (Bolch & Hallegraeff 1990; Morquecho & Lechuga-Deveze 2003; Joyce 2004a; Orlova *et al.*, 2004).

Size:

W: 50µm; L: 46µm

Occurrence in RSA:

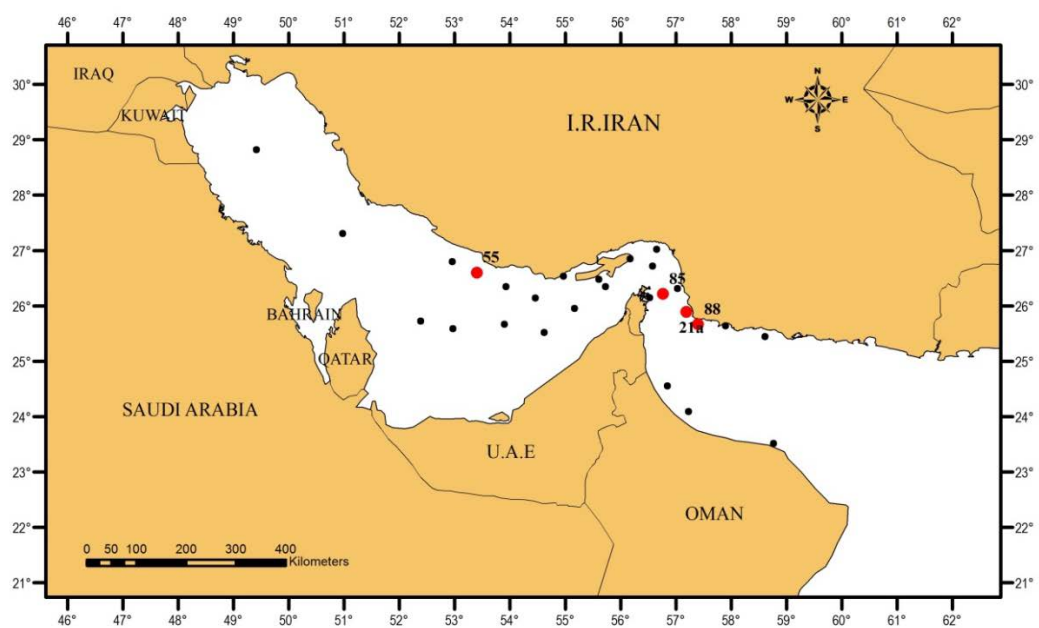
The presence of the species in the sediment sample of the Winter Cruise 2006 of RSA is shown on Map 5, in stations: 88, 21a, 85, 55

Occurrence in the world:

Not reported from anywhere else



Plate 5: *Protoperidinium claudicans* cyst with short spine



Map 5: *Protoperidinium claudicans* presence in the RSA, Winter Cruise 2006

Phylum: Miozoa

Class; Dinophyceae Fritsch 1927

Order; Peridinales Haeckel 1894

Family; Protoperidiniaceae Balech, 1988

Genus; *Protoperidinium* R.S.Bergh, 1881

Protoperidinium leonis

Scientific name: *Protoperidinium leonis* (Pavillard) Balech 1974

Paleontological name: *Quinquecuspis concretum* (Reid) Harland 1977

Figure No. Plate 6

Reference:

Bolch & Hallegraeff (1990), Figure 20;

Sonneman & Hill (1997), Figures 25c-d;

Joyce (2004), Plate 7, Figure 4;

Matsuoka & Koike (2012), Figure 5r;

Attaran-Fariman (2016)

Description:

Pale-brown to dark brown cysts, pentagonal in outline. The cyst is dorsoventrally compressed with a smooth or sometimes granular surface. The cyst has intercalary archeopyle (Plate 6, A-B). The epicyst is conical and may have shoulders (Plate 6, A). The hypocyst forms two antapical horns with pointed tips (Plate 6, B). The antapical horn is separated by relatively antapical depression (Plate 6, C-D). The cingulum is almost equatorial (Plate 6, C-D) and deep sulcus is clear on the cyst wall (Plate 6, D),

Size:

W: 50µm; L: 53µm

Occurrence in RSA:

The presence of the species in the sediment sample of the Winter Cruise 2006 of RSA is shown on Map 6, in stations: 98, 21a, 87, 14a, 16a, 59, 55, 11

This species was reported from north part of the Sea of Oman; Iranian south east coast (Attaran-Fariman *et al.*, 2012, 2016)

Occurrence in the world:

Peruvian upwelling area (Biebow *et al.*, 1993); Japan (Matsuoka *et al.*, 2003); Benguela and South African coasts (Joyce 2004); western Indian coast (D'Costa *et al.*, 2008); Chinese

coastal waters (Wang *et al.*, 2004),); the western Barents Sea (Solignac *et al.*, 2009; Grøsfjeld *et al.*, 2009); South Korean bays (Pospelova and Kim, 2010); Arabian Sea off Somalia (Zonneveld and Brummer, 2000).

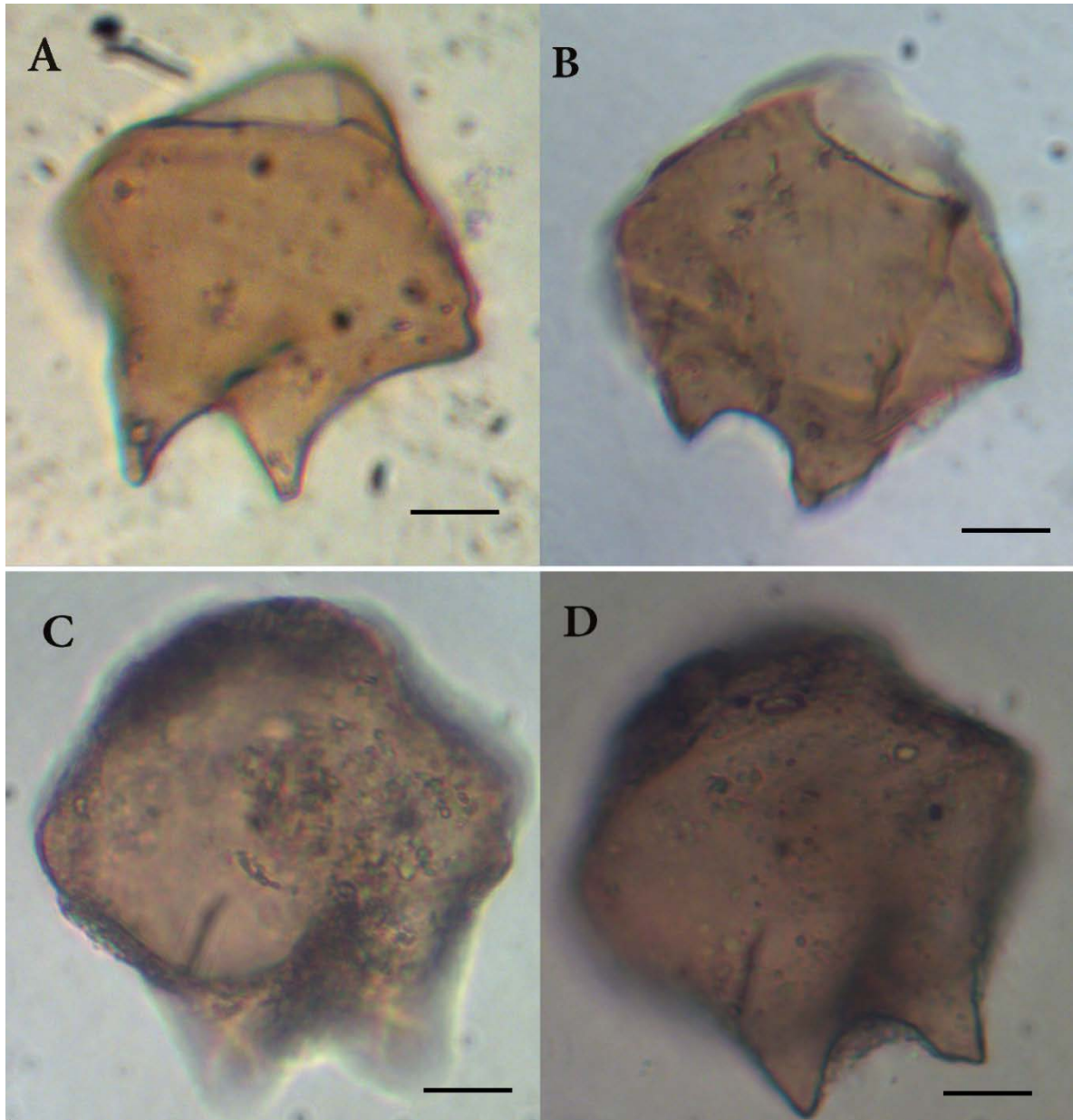
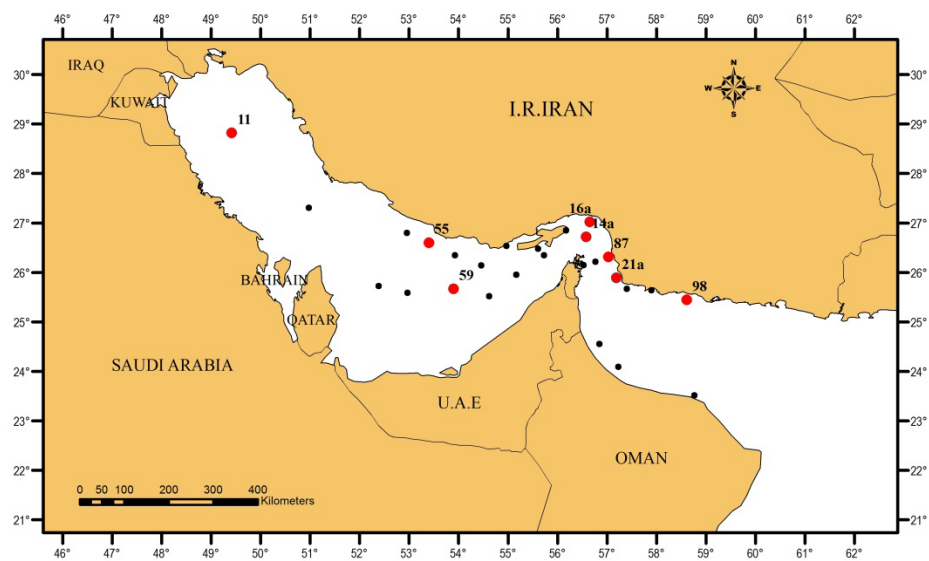


Plate 6: *Protoperidinium leonis*; A, surface focus cyst shows conical epicyst; B, deep focus shows antapical horn



Map 6: *Protoperidinium leonis*: presence in the RSA, Winter 2006

Phylum: Miozoa

Class; Dinophyceae Fritsch 1927

Order; Peridinales Haeckel 1894

Family; Protoperidiniaceae Balech, 1988

Genus; *Protoperidinium* R.S.Bergh, 1881

Species: *Protoperidinium cf. leonis*

Scientific name: *Protoperidinium cf. leonis* (Pavillard) Balech 1974

Paleontological name: *Quinquecuspis cf. concretum* (Reid) Harland 1977

Figure No. Plate 7

Reference:

Not found

Description:

Pale-brown cysts, pentagonal in outline. The cyst is dorsoventrally compressed with a smooth surface (Plate 7, A-B). The epicyst is conical and may have shoulders (Plate 7, C-D). The hypocyst forms two antapical horns with rounded tips. The antapical horn is separated by relatively thick antapical depression (Plate 7, C-D). The cingulum region is rounded and almost equatorial (Plate 7, C-D). This cyst type differs from *P. leoni* (Plate 6) by its colour, smooth cyst wall and rounded antapical horns

Size:

W: 44µm; L: 53µm

Occurrence in RSA:

The presence of the species in the sediment sample of the Winter Cruise 2006 of RSA is shown on Map 7, in station 69

Occurrence in the world:

Not reported from anywhere else

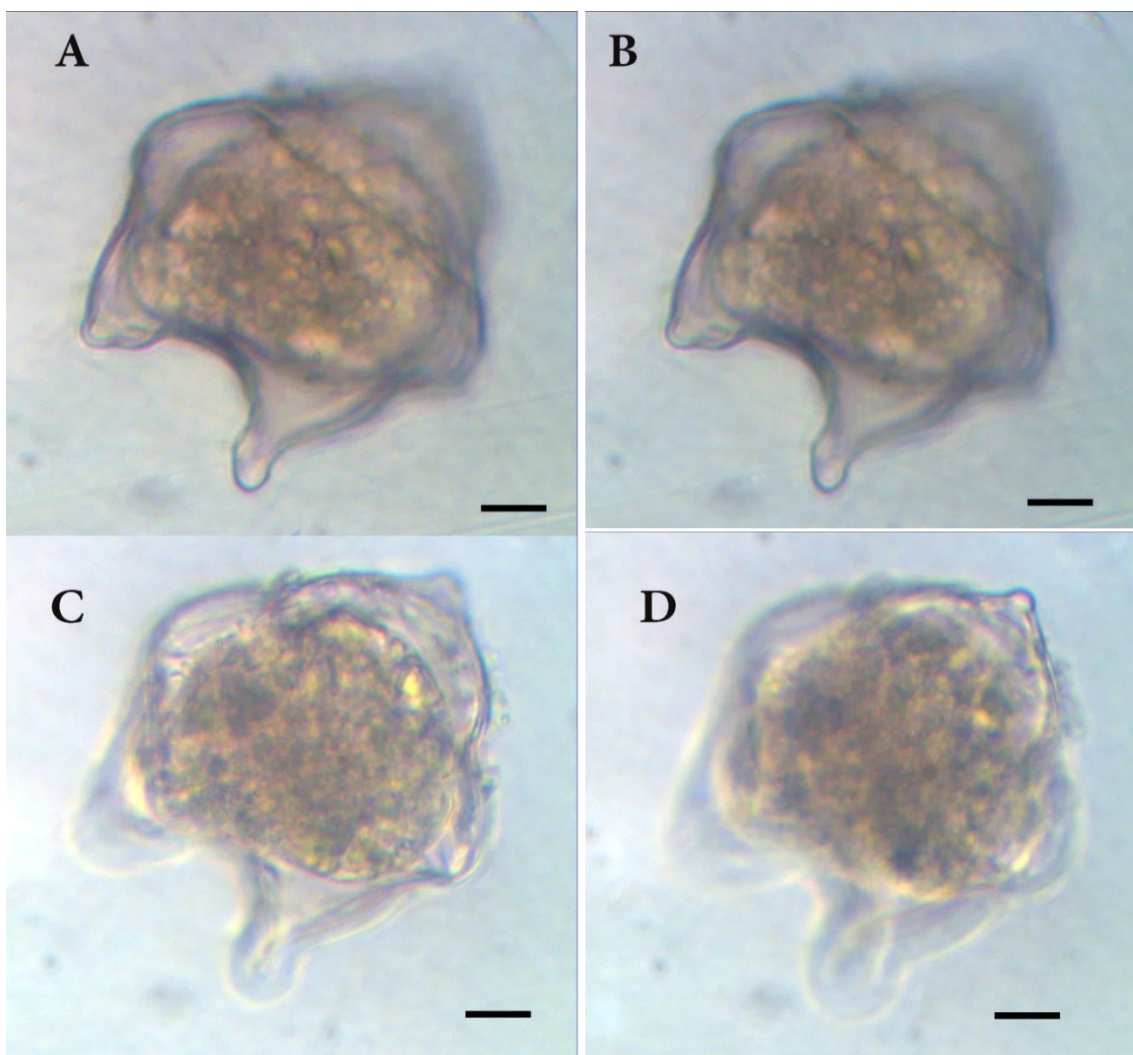
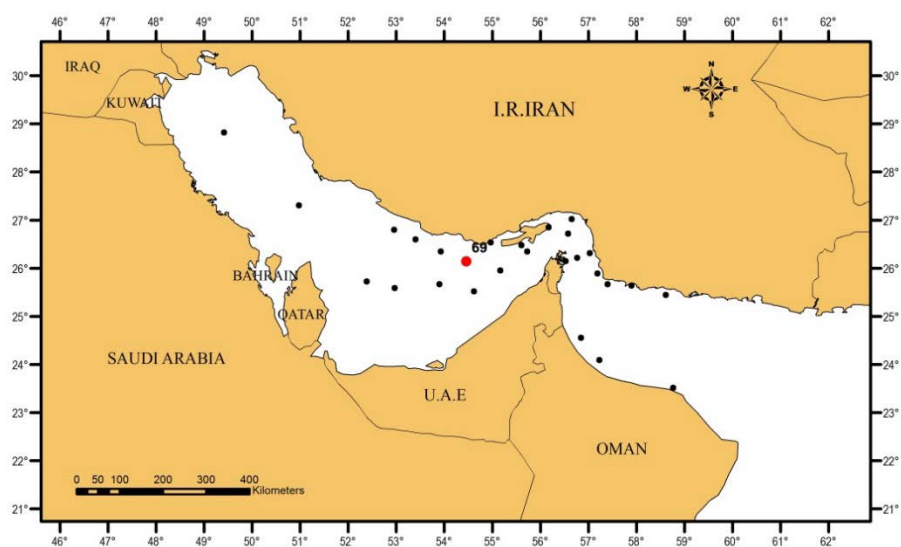


Plate 7: *Protoperidinium cf. leonis*; A and B show antapical horn surface; C and D show conical epicyst



Map 7: *Protoperidinium cf. leonis* presence in the RSA, Winter 2006

Phylum: Miozoa

Class; Dinophyceae Fritsch 1927

Order; Peridinales Haeckel 1894

Family; Protoperidiniaceae Balech, 1988

Genus; *Protoperidinium* R.S.Bergh, 1881

Species; *Protoperidinium denticulatum*

Scientific name: *Protoperidinium denticulatum* (Gran & Braarud) Balech 1974

Paleontological name: *Brigantedinium irregular* Matsuoka 1987

Figure No.: Plate 8

Reference:

Bolch & Hallegraeff (1990), Figure 24;

Joyce (2004), Plate 7 Figure 2;

Yoon & Shin (2013), Plate IV, Figure 9;

Description:

Dark brown spherical cyst. Cyst wall is smooth. The archeopyle is theropylic, hexagonal and laterally elongated and formed by loss of 1a and 2a intercalary paraplate. The morphological characteristics of the cyst of *P.cf. denticulatum* from RSA resemble to the cyst described by Wall & Dale (1968), Sonneman & Hill (1997) and Morquecho *et al.*, (2008).

Size:

D: 44µm

Occurrence in RSA:

The presence of the species in the sediment sample of the Winter Cruise 2006 of RSA is shown on Map 8, in stations: 26a, 88, 85, 14a, 16a, 79, 70, 69, 59, 55, 40.

Occurrence in the world:

Sea of Japan, Chinese coastal waters, southern Gulf of Mexico, the Mexican subtropical and tropical Pacific and the SW Atlantic,

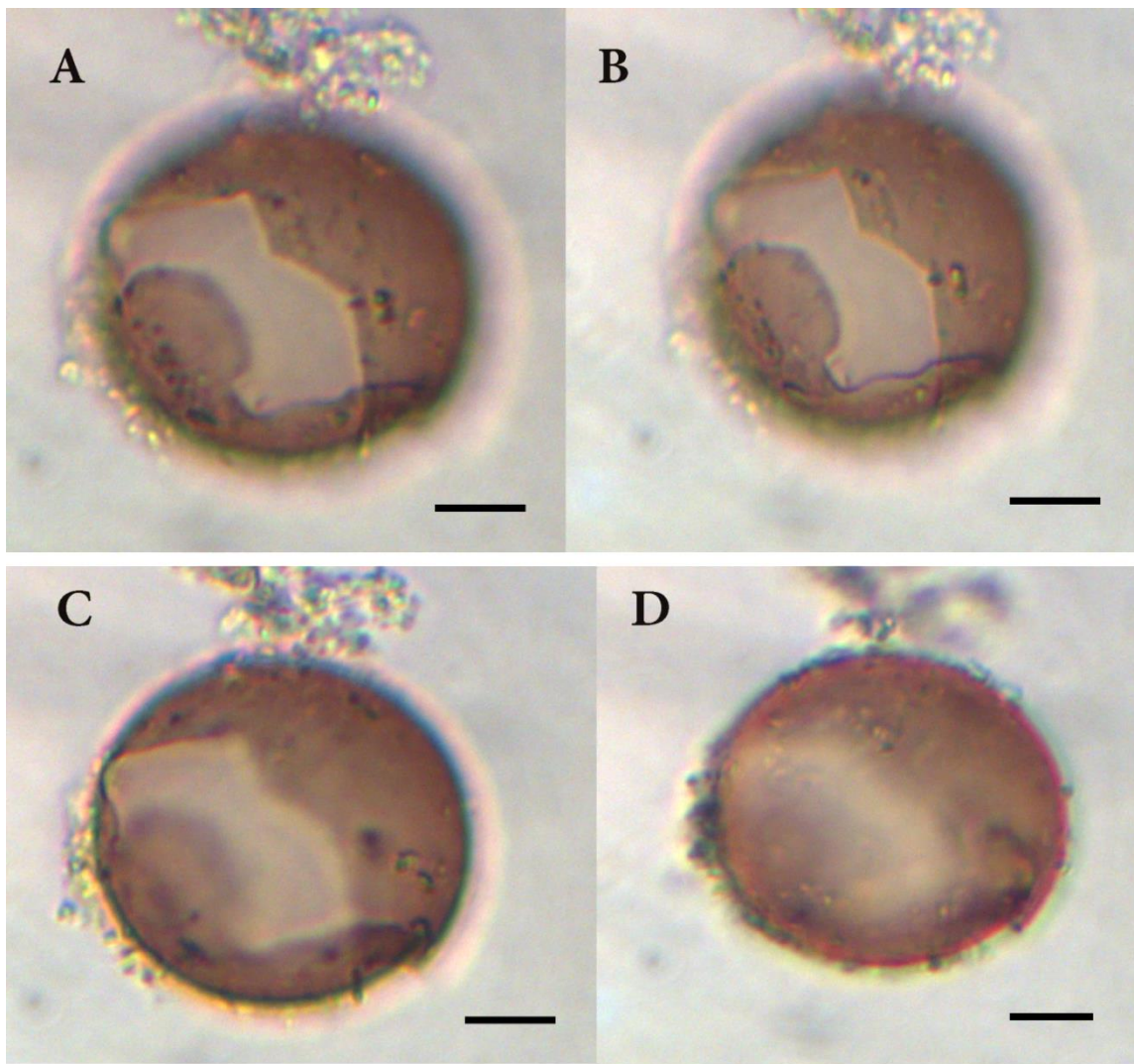
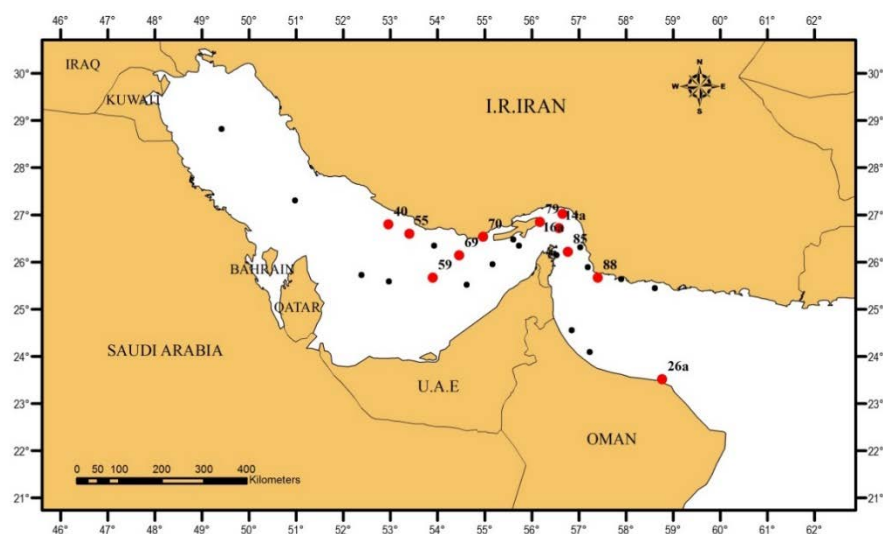


Plate 8: *P. denticulatum*: A-D; Cyst shows archeopyle, D; cysts in surface focus



Map 8: *P. denticulatum*, presence in the RSA, Winter 2006

Phylum: Miozoa

Class; Dinophyceae Fritsch 1927

Order; Peridiniales Haeckel 1894

Family; Protoperidiniaceae Balech, 1988

Genus; *Protoperidinium* R.S.Bergh, 1881

Species; *Protoperidinium humile*

Scientific name: *Protoperidinium humile* (Schiller) Balech 1974

Paleontological name: -

Figure No.: Plate 9

References:

Gu *et al.*, (2015), Figures. 55-56

Description:

Round brown cyst (Plate 9; A-D). Live cyst has many transparent granular content (Plate 9 C-D). The cyst wall bore groove (Plate 9 B). The archeopyle with sharp angles and corresponding to 3a Plate (Plate 9, A). Motile stage of this species is described by Schiller in 1937; however, the cyst stage for the first time described by Gu *et al.*, (2015), and they suggested the occurrence of the cyst and motile stage from temperate to tropical waters. Sometimes the cyst has an irregular shape when empty and reniform in polar view (Gu *et al.*, 2015). In this study, the reniform cyst was not observed.

Size:

D: 63µm

Occurrence in RSA:

The presence of the species in the sediment sample of the Winter Cruise 2006 of RSA is shown on Map 9, in stations: 72, 21a

Occurrence in the world:

Yellow Sea, South China Sea,

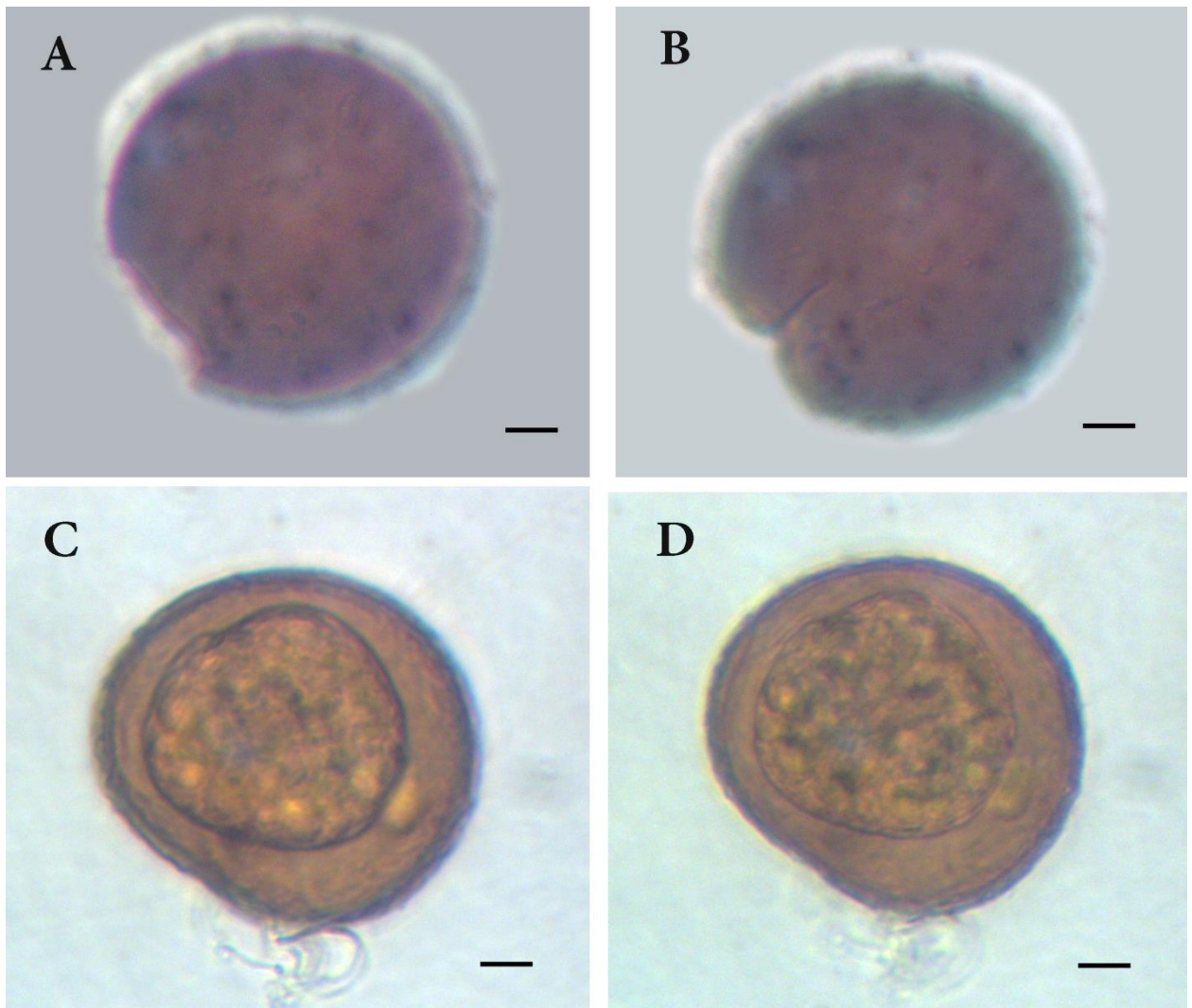
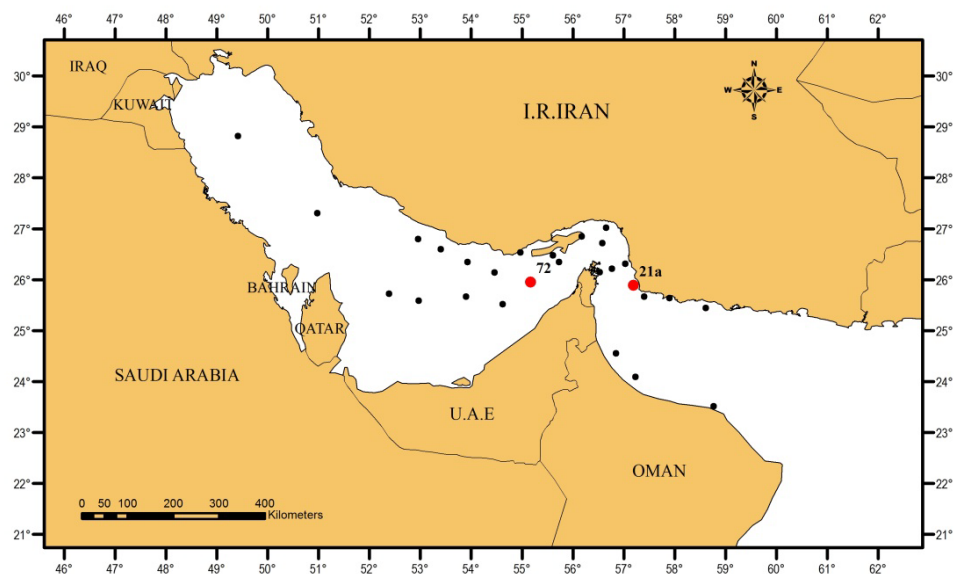


Plate 9: *Protoperidinium humile*; A, empty cyst shows archeopyle; B, empty cyst shows striation in the wall; C-D, Live cyst show cyst content



Map 9: *Protoperidinium humile* presence in the RSA, Winter 2006

Phylum: Miozoa

Class; Dinophyceae Fritsch 1927

Order; Peridinales Haeckel 1894

Family; Protoperidiniaceae Balech, 1988

Genus; *Protoperidinium* R.S.Bergh, 1881

Species; *Protoperidinium conicoides*

Scientific name: *Protoperidinium conicoides* (Paulsen) Balech 1973

Paleontological name: *Brigantedinium simplex* Reid 1977

Figure No.: Plate 10

References:

Wall & Dale (1968), Figures 28-30;

Ellegaard *et al.*, (1994), Figures 36-40; Qi *et al.*, (1996), Plate 4, Figure B1;

Sonneman & Hill (1997), Figure 20

Joyce (2004), Plate 6, Figure 5;

Yoon & Shin (2013), Plate IV, Figure 7

Description:

Dark brown spherical to sub-spherical cyst. The cyst wall is smooth to microgranulate surface. The intercalary trapezoidal archeopyle appear on the cyst (Plate 10, A-D). This species is generally cold water species (Bolch & Hallegraeff 1990); however, it has been reported from a broad range of temperatures (2.1°C- 27°C) by several researchers (e.g.; Marret and Zonneveld 2003; Attaran-Fariman 2007; Attaran-Fariman 2016) from Arabian Sea and the Sea of Oman.

Size

D: 35µm

Occurrence in RSA:

The presence of the species in the sediment sample of the Winter Cruise 2006 of RSA is shown on Map 10, in stations: 98, 25a, 88, 87, 83, 55, 25, 11

Occurrence in the world:

South-west Asia (Balkis *et al.*, 2016); Yellow Sea and East China Sea (Cho & Matsuoka 2001); Australia (Bolch and Hallegraeff 1990); South Africa, Namibia and Angola (Joyce 2004)

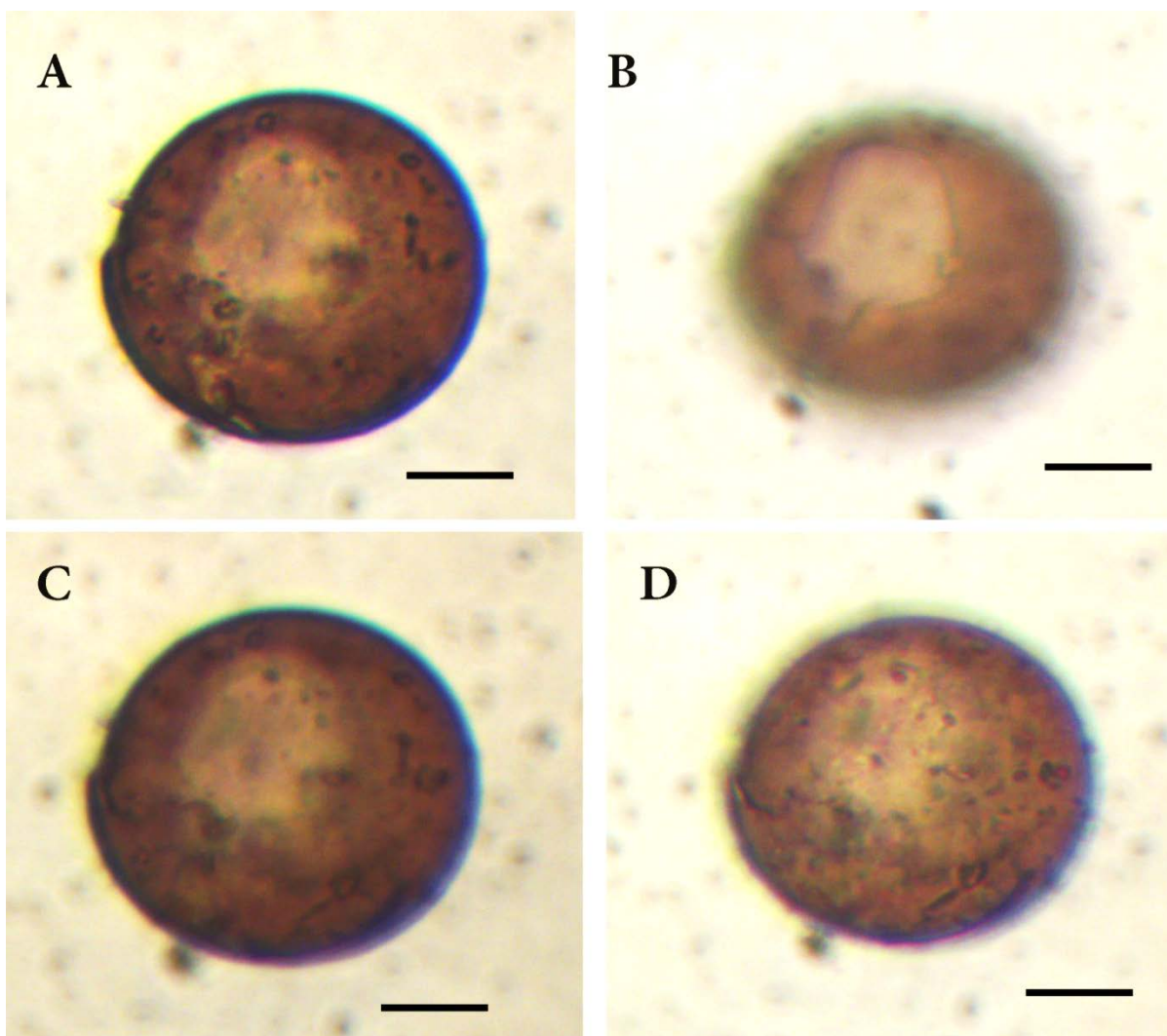
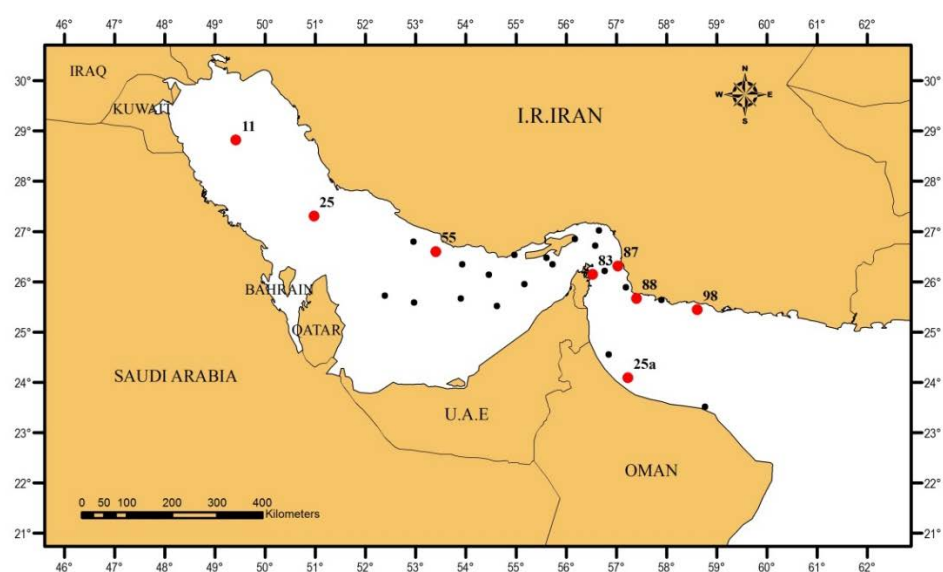


Plate 10: *Protoperidinium conicoides*, A-cyst shows brown colour, B-Cyst shows archeopyle, C, D show surface of cyst



Map 10: *Protoperidinium conicoides* occurrence in the RSA, Winter 2006

Phylum: Miozoa

Class; Dinophyceae Fritsch 1927

Order; Peridinales Haeckel 1894

Family; Protoperidiniaceae Balech, 1988

Genus; *Protoperidinium* R.S.Bergh, 1881

Species; *Protoperidinium conicum* (Gran) Balech 1974

Scientific name: *Protoperidinium conicum* (Gran) Balech 1974

Paleontological name: *Selenopemphix quanta* (M.R.Bradford) Matsuoka 1985

Figure No. Plate 11

References:

Bolch & Hallegraeff (1990), Figure 14a-c;

Sonneman & Hill (1997), Figure 21;

Howe *et al.*, (2010),

Description:

Light brown, kidney shaped, to ovoidal cyst. The smooth walled cyst is apically and antapically compressed and has several rows of almost long, solid and needle shaped processes. The cyst has hexagonal archeopyle that was not visible in our sample. This cyst type is often found in apical view. This species differs from *P. nudum* by its larger size and larger number of processes.

Size:

W: 54µm; L: 47µm

Occurrence in RSA:

The presence of the species in the sediment sample of the Winter Cruise 2006 of RSA is shown on Map 11, in stations: 88, 14a, 72, 66, 69, 55, 11

Coastal sites of the inner RSA (Bradford 1975). The species has been reported from northern part of the Sea of Oman (Attaran-Fariman, 2016)

Occurrence in the world:

Arabian Sea (Zonneveld and Brummer, 2000); NW Africa and in the Saanich Inlet (BC, Canada) (Zonneveld *et al.*, 2010; Price and Pospelova, 2011); Atlantic Water (Howe *et al.*, 2010); Greece (Ignatiades 2012); Helgoland (Hoppenrath 2004); Mediterranean (Gómez 2003); Sweden (Lundholm *et al.*, 2011); western South Sea (Shin *et al.*, 2007).

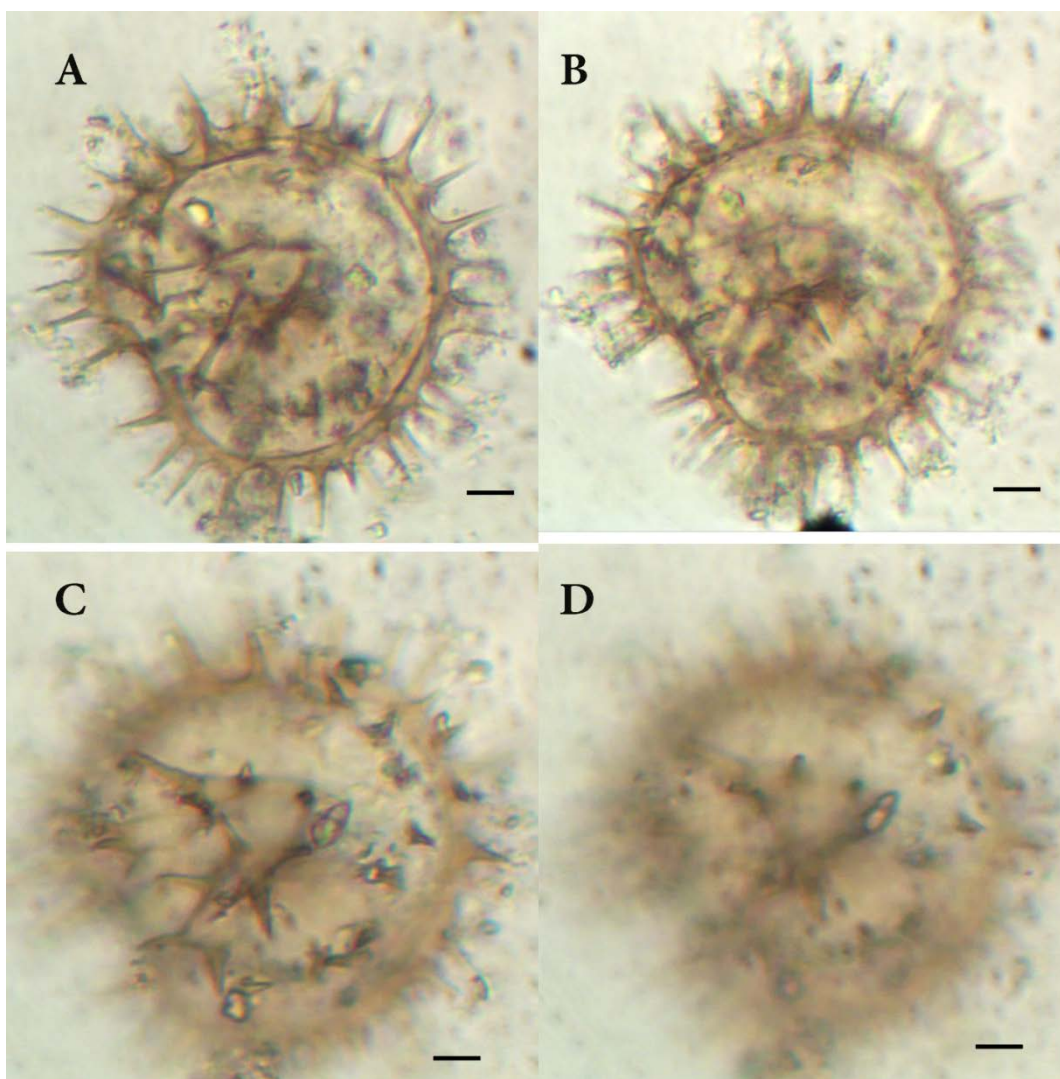
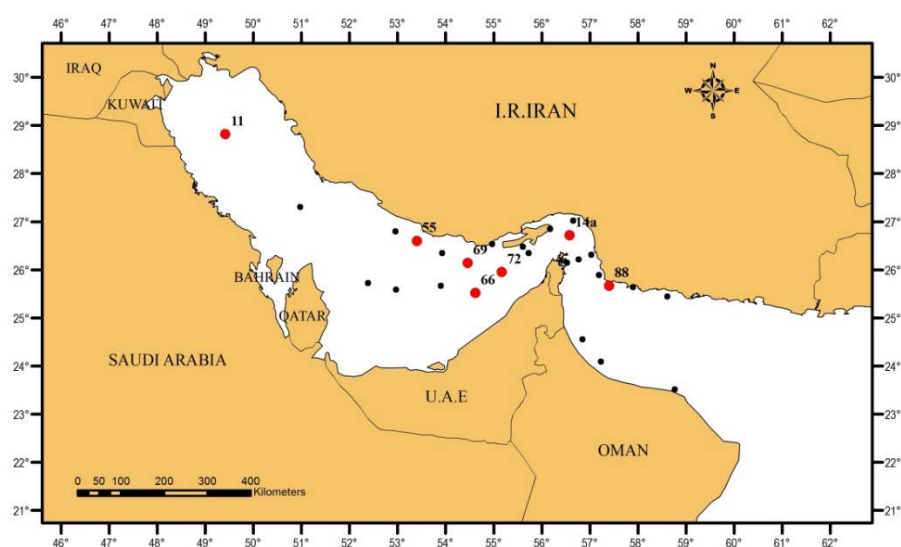


Plate 11: *Protoperidinium conicum*: Cyst from RSA in different focuses shows pointed spines



Map 11: *Protoperidinium conicum* presence in the RSA, Winter 2006

Phylum: Miozoa

Class; Dinophyceae Fritsch 1927

Order; Peridinales Haeckel 1894

Family; Protoperidiniaceae Balech, 1988

Genus; *Protoperidinium* R.S.Bergh, 1881

Species; *Protoperidinium latissimum*

Scientific name: *Protoperidinium latissimum* (Kofoid) Balech 1974

Paleontological name: Cyst of *Protoperidinium latissimum* (Kofoid) Balech 1974

Figure No.: Plate 12

References:

Sonneman & Hill (1997), Figure 24;

Narale *et al.*, (2013), Figure3j;

Yoon & Shin (2013), Plate IV, Figure 11;

Gu *et al.*, (2015), Figure 64

Description:

A pentagonal dorsoventrally compressed cyst. The cyst has a brown colour and smooth surface. The epicyst and hypocyst have almost same lengths (Plate 12, A-D). The epicyst has almost straight sides, whereas hypocyst has concave sides with two short antapical horns. The presingular region is clear by two curve arms that forwarded ventrally. The archeopyle is hexagonal and forms by loss of the second intercalary paraplate. In our specimen, archeopyle was not obvious. The cyst has been reported previously from Iranian south coast and north part of the Sea of Oman, by Attaran-Fariman (2016); however, there is no morphological description to compare with this cyst type.

Size:

W: 84µm; L: 93µm

Occurrence in RSA:

The presence of the species in the sediment sample of the Winter Cruise 2006 of RSA is shown on Map 12, in stations: 26a, 88, 21a, 85, 55

The species has been reported from northern part of the Sea of Oman (Attaran-Fariman, 2016)

Occurrence in the world:

East China Sea (Cho and Matsuoka 2001; Yellow Sea, Australia and New Zealand,

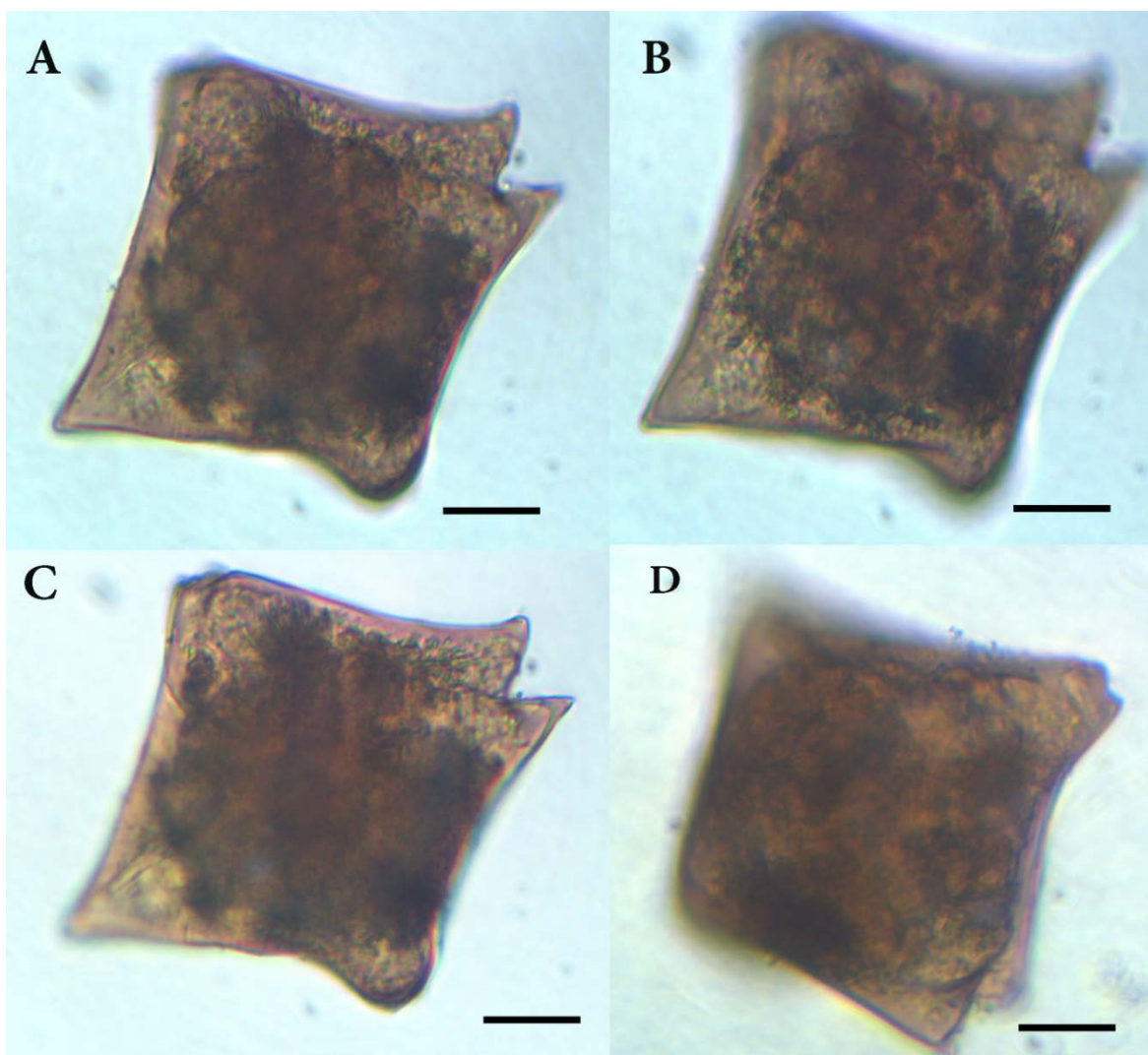
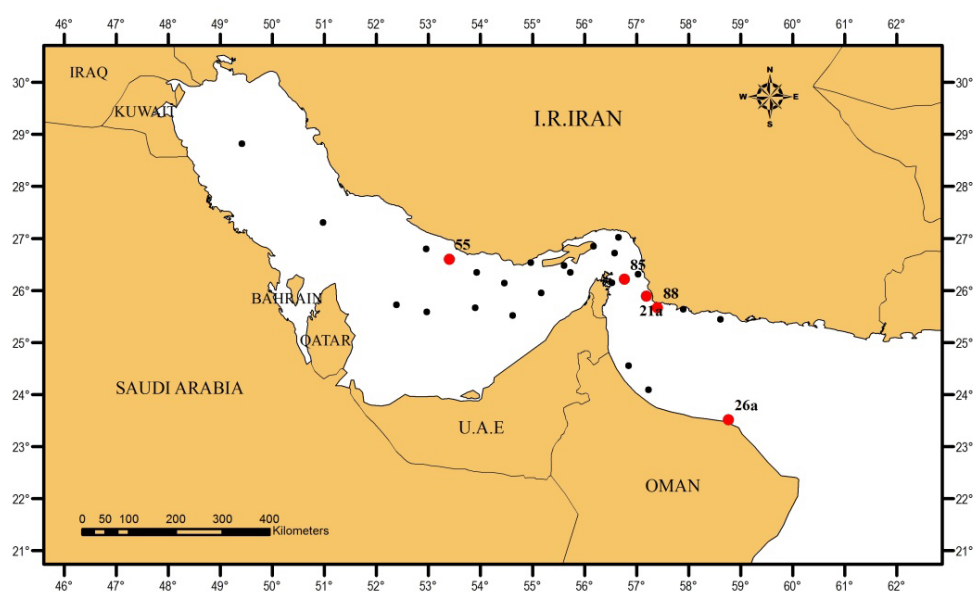


Plate 12: *Protoperidinium latissimum* cyst in different focuses (All scale bar=20μm)



Map 12: *Protoperidinium latissimum* presence in the RSA, Winter 2006

Phylum: Miozoa

Class; Dinophyceae Fritsch 1927

Order; Peridinales Haeckel 1894

Family; Protoperidiniaceae Balech, 1988

Genus; *Protoperidinium* R.S.Bergh, 1881

Species: *Protoperidinium avellana*

Scientific name: *Protoperidinium avellana* (Meunier) Balech 1974

Paleontological name: *Brigantedinium cariacense* (Wall) Reid 1977

Figure No.: Plate 13

References:

Matsuoka (1984), Plat e2 Figures 5-7;

Wall & Dale (1986), Plate 3, Figure 29;

Joyce (2004), Figure 13;

Myat *et al.*, (2012), Figure 5I;

Description:

Spherical dark brown cyst. The empty cyst has a single thin wall (Plate 13). The archeopyle shape is hexagonal reflecting loss of one or two intercalary plates. One of the four sides shows a weak arched line (Plate 13, A, B and D). The cyst was also reported by Attaran-Fariman (2007 and 2016) from Sea of Oman with a symmetrical archeopyle formed by loss of one intercalary plate, from the Arabian Sea and southwest India (Marret & Zonneveld 2003; Godhe *et al.*, 2000).

Size:

D: 55µm

Occurrence in RSA:

The presence of the species in the sediment sample of the Winter Cruise 2006 of RSA is shown on Map 13, in stations: 98, 93, 88, 21a, 85, 83, 14a, 16a, 79, 77, 66, 69, 56, 55, 43, 11.

The species has been reported from northern part of the Sea of Oman and Strait of Hormuz (Attaran-Fariman *et al.*, 2012; Attaran-Fariman, 2016)

Occurrence in the world:

British Isles (Dodge, 1982), Australia (McCarthy 2013), China Sea (Liu *et al.*, 2015)

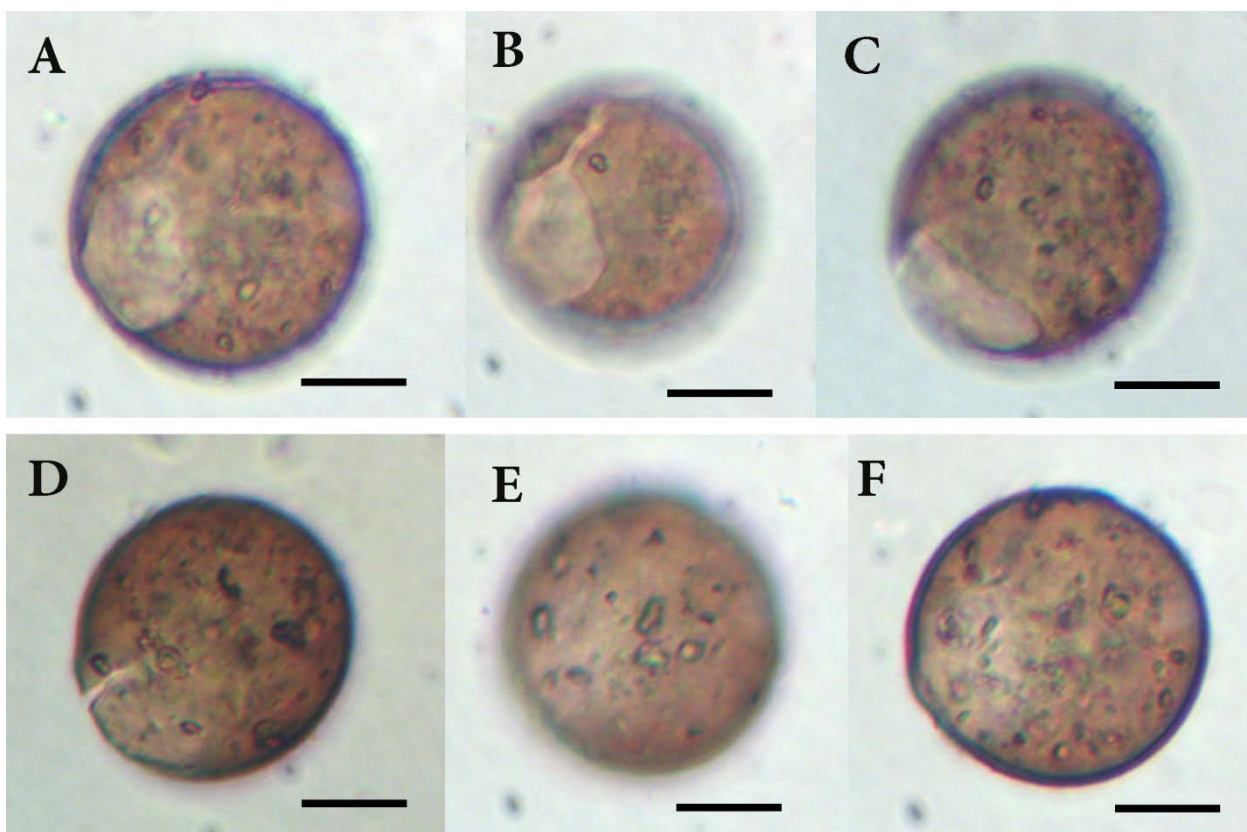
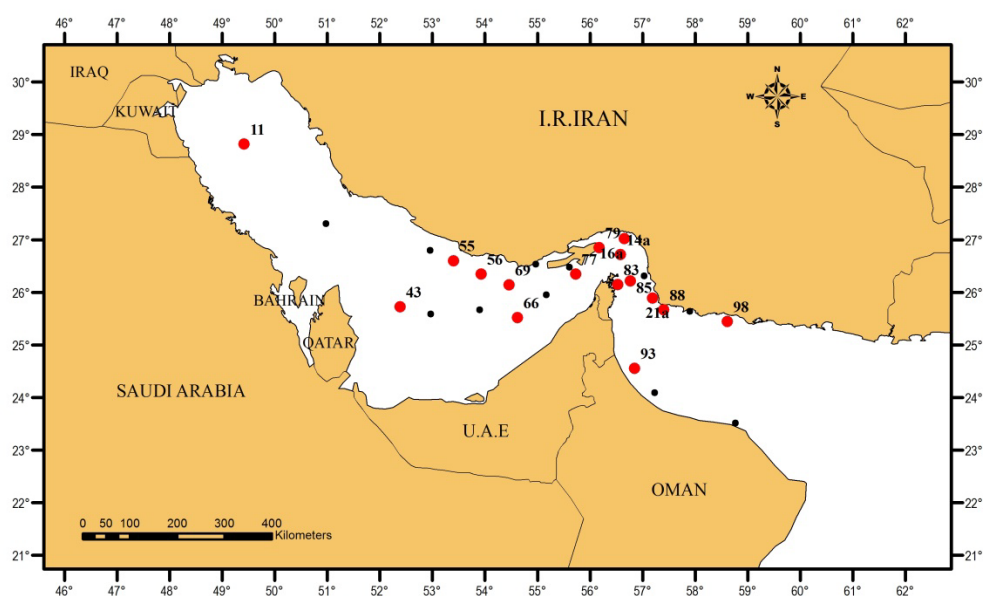


Plate 13: *Protoperidinium avellana* cyst from RSA in different focuses shows archeopyle (All scale bars=20µm)



Map 13 *Protoperidinium avellana* presence in the RSA, Winter 2006

Phylum: Miozoa

Class; Dinophyceae Fritsch 1927

Order; Peridinales Haeckel 1894

Family; Protoperidiniaceae Balech, 1988

Genus; *Protoperidinium* Bergh, 1881

Species: *Protoperidinium cf. punctulatum*

Scientific name: *Protoperidinium punctulatum* (Paulsen) Balech 1974

Paleontological name: -

Figure No.: Plate 14

References:

Wall & Dale (1968), Plate 3, Figure 24;

Nehring (1997), Figure 3A;

Sonneman & Hill (1997) Figure 29;

Attaran-Fariman (2007), Figure 28

Description:

Round Brown smooth walled cyst. The archeopyle is subhexagonal with rounded sides; the archeopyle is formed by loss of the second intercalary plate. The cyst type differs from that described by Sonneman and Hill (1997) by its archeopyle shape. The shape of archeopyle is almost similar to the shape of the second intercalary plate of the motile cell which documented by Wall and Dale (1968). The archeopyle shape is also similar to those described by Attaran-Fariman *et al.*, (2012)

Size:

D: 51µm

Occurrence in RSA:

The presence of the species in the sediment sample of the Winter Cruise 2006 of RSA is shown on Map 14, in stations: 26a, 88, 14a, 66, 69, 11

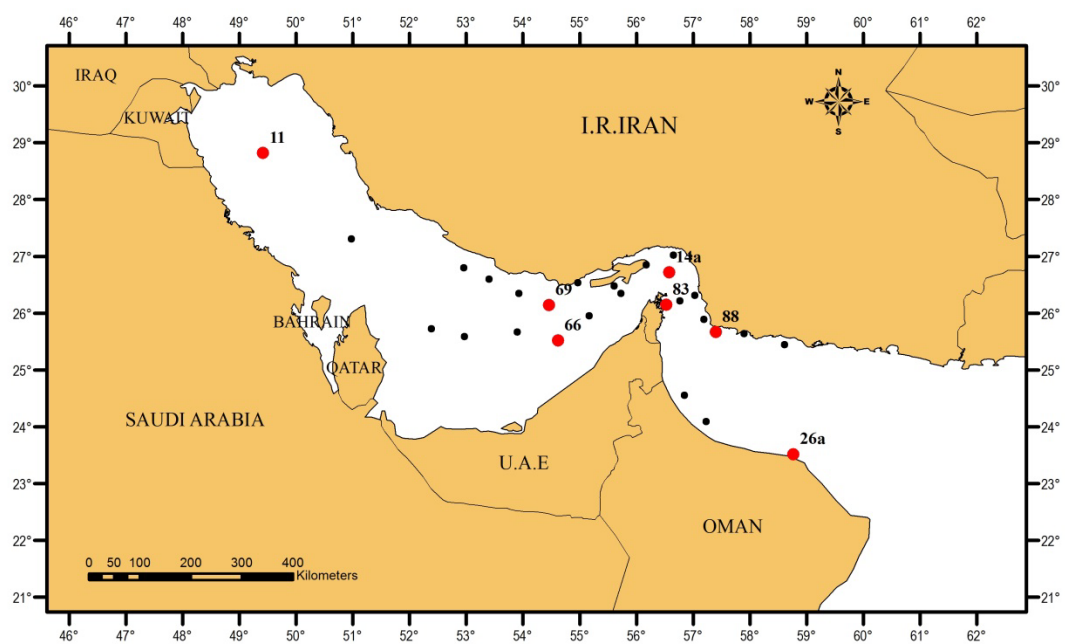
The species has been reported from the northern part of the Sea of Oman (Attaran-Fariman *et al.*, 2012)

Occurrence in the world:

China (Liu 2008), Japan (Matsuoka *et al.*, 2008), Mediterranean (Gómez 2003).



Plate 14: *Protoperidinium cf. punctulatum* from RSA shows archeopyle (scale bar=20µm)



Map 14: *Protoperidinium cf. punctulatum* presence in the RSA, Winter 2006

Phylum: Miozoa

Class; Dinophyceae Fritsch 1927

Order; Peridinales Haeckel 1894

Family; Protoperidiniaceae Balech, 1988

Genus; *Protoperidinium* R.S.Bergh, 1881

Species: *Protoperidinium divaricatum*

Scientific name: *Protoperidinium divaricatum* (Meunier 1919) Parke & Dodge 1976

Paleontological name: *Xandarodinium xantham* Reid 1977

Figure No.: Plate 15

References:

Bolch & Hallegraeff (1990), Figure 21;

Nehring (1997) Figure 20;

Sonneman and Hill (1997), Figure 23

Description:

Elliptical cyst with brown colour (Plate 15). The processes are hollow and tabular and formed by extensions from the wall, and are terminated with capitate or multifurcate extensions that are closed distally. The cyst has subhexagonal archeopyle and form by loss of second intercalary paraplate; however, it was not seen in our sample. The cyst is often folded. This cyst type is morphologically similar to the gonyaulacoid cysts; however, it can be distinguished from those by its brown colour; Gonyaulacoid cysts are generally colourless.

Size:

W: 45µm excluding processes; L: 33µm

Occurrence in RSA:

The presence of the species in the sediment sample of the Winter Cruise 2006 of RSA is shown on Map 15, in stations: 55, 59

Occurrence in the world:

China (Wang *et al.*, 2004), India (D'Costa *et al.*, 2008), Angola-Benguela Front region (Dale *et al.*, 2002)

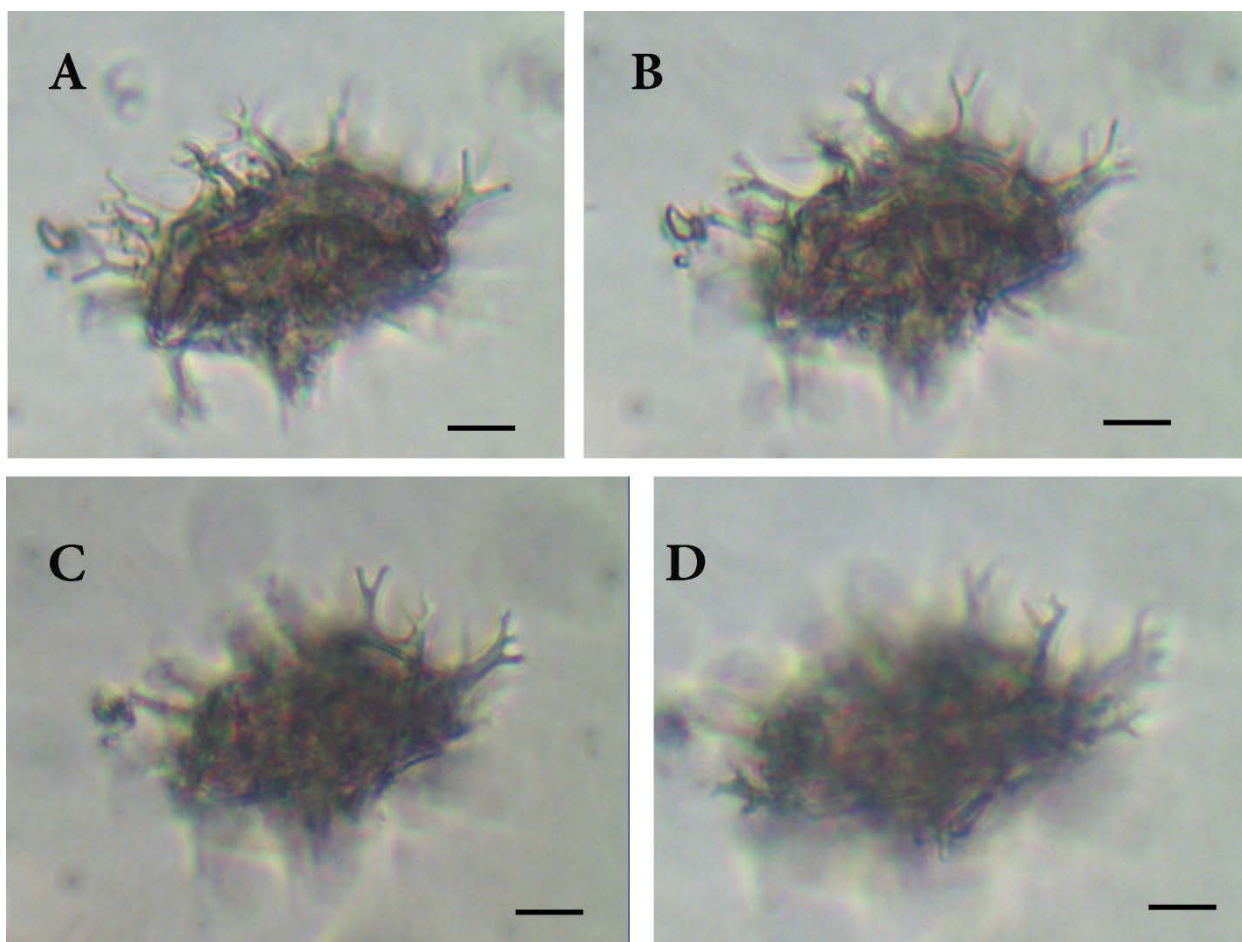
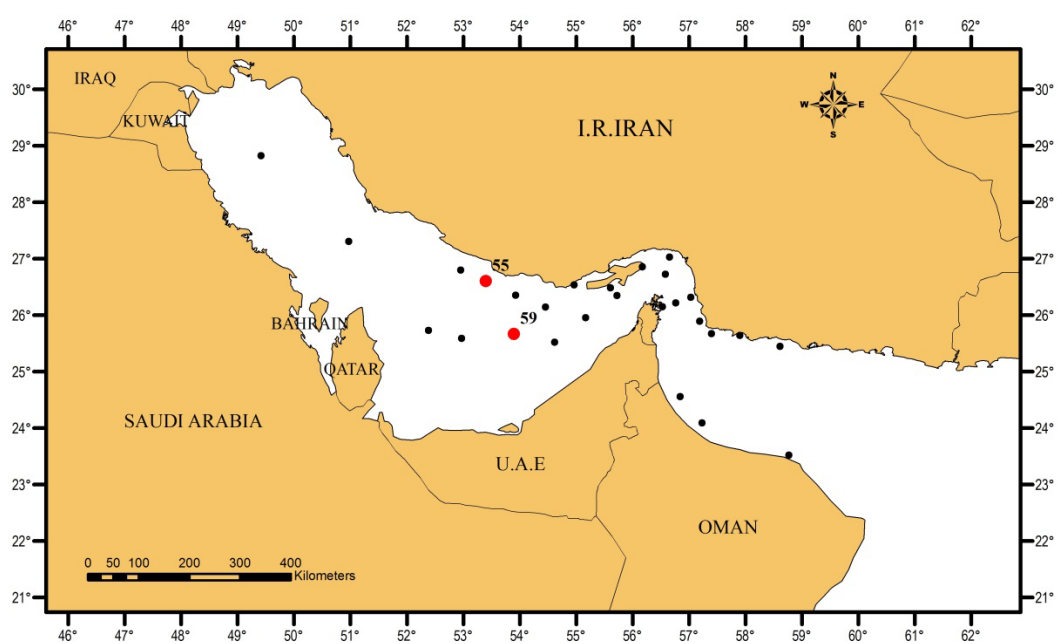


Plate 15: *Protoperidinium divaricatum* from RSA shows long process



Map 15: *Protoperidinium divaricatum* occurrence in the RSA, Winter 2006

Phylum: Miozoa

Class; Dinophyceae Fritsch 1927

Order; Peridinales Haeckel 1894

Family; Protopteridiniaceae Balech, 1988

Genus; Protopteridinium R.S.Bergh, 1881

Species: Protopteridinium *subinermis*

Scientific name: *Protopteridinium subinermis* (Paulsen) A.R.Loeblich III 1969

Paleontological name: *Selenopemphix nephroides* Benedek

Figure No.: Plate 16

References:

Bolch & Hallegraeff (1990), Figure 16;

Hassel *et al.*, (1996), Plate 51;

Sonneman & Hill (1997), Figure 30;

Morquendo & Lechuga-Devez (2003),

Attaran-Fariman (2007) Figure 34; Figure 6;

Limoges *et al.*, (2010), Plate 3, Figure 6.

Description:

Brown ovoidal cyst. There is no spine on cyst surface. The cyst is apically-antabically compressed and has excavated cingulum (Plate16, A-B). The hexagonal intercalary archeopyle was not observed in our sample.

Size:

W: 46µm; L: 41µm

Occurrence in RSA:

The presence of the species in the sediment sample of the Winter Cruise 2006 of RSA is shown on Map 16, in stations: 98, 25a, 83, 78

The cyst has been previously documented from the Sea of Oman and the inner RSA (Bradford & Wall 1984; Attaran-Fariman 2007, 2016)

Occurrence in the world:

Russian Pacific coast (Orlova *et al.*, 2004); south and east China Sea (Qi *et al.*, 1996); southwest India, Somalian (Bradford & Wall 1984; Zonneveld & Brummer 2000, Godhe *et al.*, 2000; Marret & Zonneveld 2003).

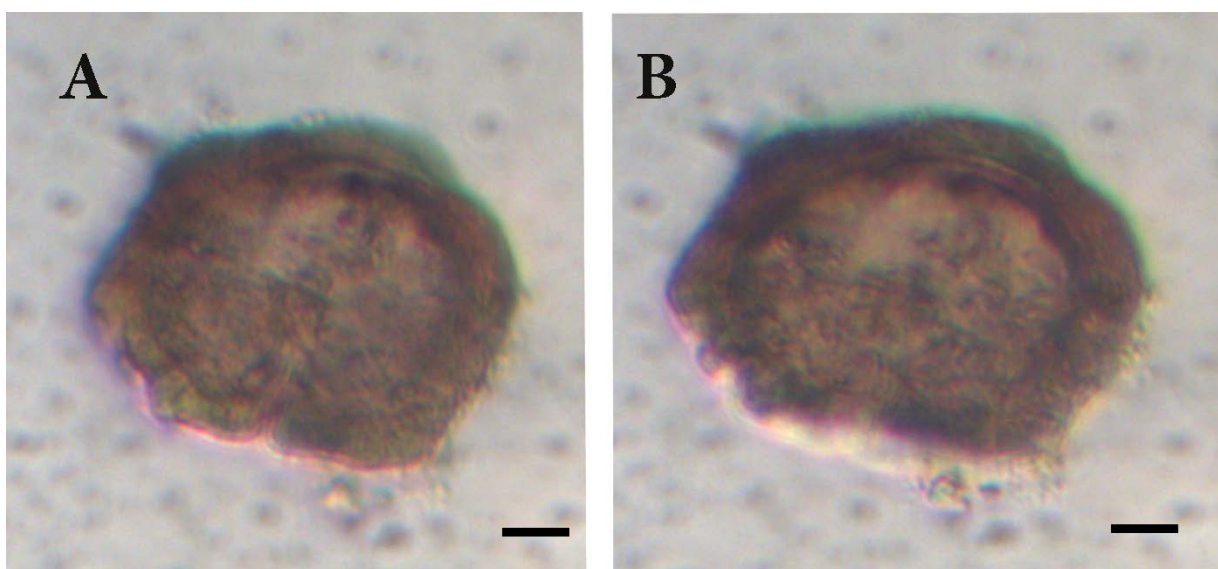
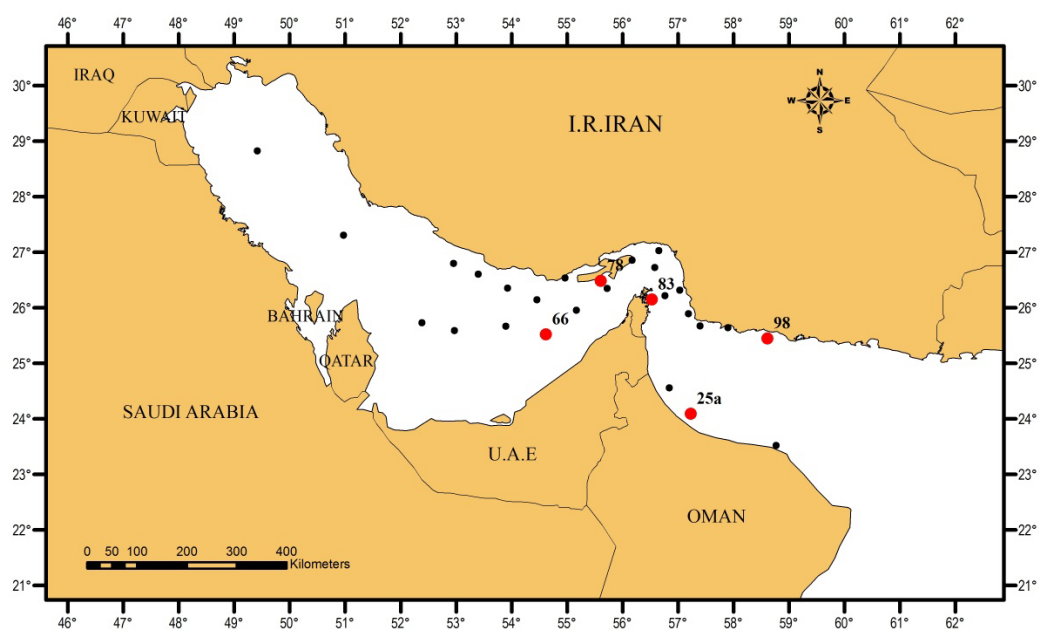


Plate 16: *Protoperidinium subinerme* cyst from RSA



Map 16: *Protoperidinium subinerme* presence in the RSA, Winter 2006

Phylum: Miozoa

Class; Dinophyceae Fritsch 1927

Order; Peridinales Haeckel 1894

Family; Protoperidiniaceae Balech, 1988

Genus; Protoperidinium R.S.Bergh, 1881

Species: *Protoperidinium* cf. *tharianum*

Scientific name: *Protoperidinium thorianum* (Paulsen) Balech 1974

Paleontological name: -

Figure No.: Plate 17

References:

Sonneman & Hill (1997), Figure 16;

Attaran-Fariman (2007) Figure 27;

Morquecho *et al.*, (2008), Figure 29

Description:

The cyst is spherical and has a brown colour. The cyst wall is smooth. The archeopyle is subhexagonal with rounded sides. The shape of the archeopyle shows variation (Sonneman & Hill, 1997). This cyst has been reported from the Arabian Sea (Zonneveld, 1997).

Size:

D: 45µm

Occurrence in RSA:

The presence of the species in the RSA from Cruise-Winter 2006 has been shown on Map 17. Presence of the cyst in sites: 21a, 83, 14a, 16a

The cyst has been previously reported from northern part of the Sea of Oman (Attaran-Fariman *et al.*, 2012)

Occurrence in the world:

Australia (Sonneman & Hill, 1997), Arabian Sea (Zonneveld, 1997), Gulf of California (Morquecho *et al.*, 2009)

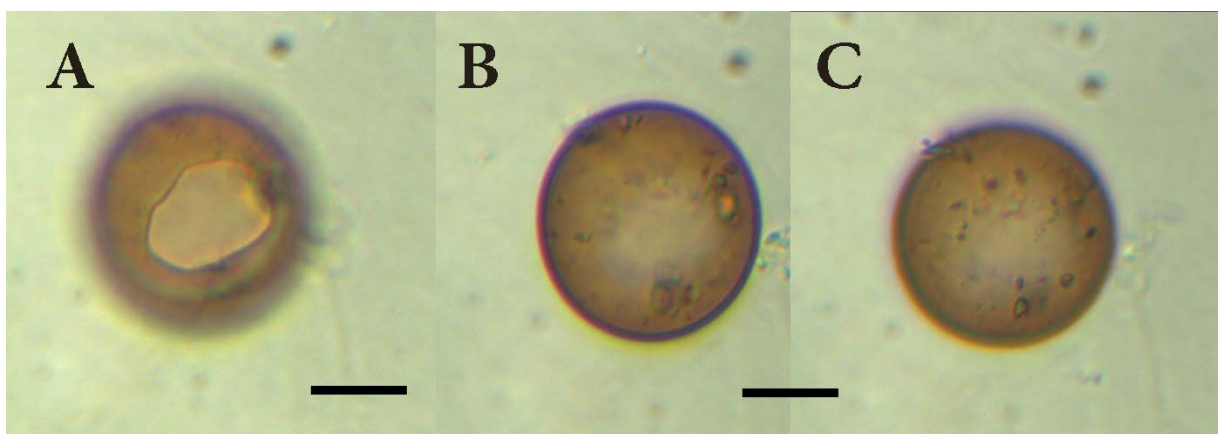
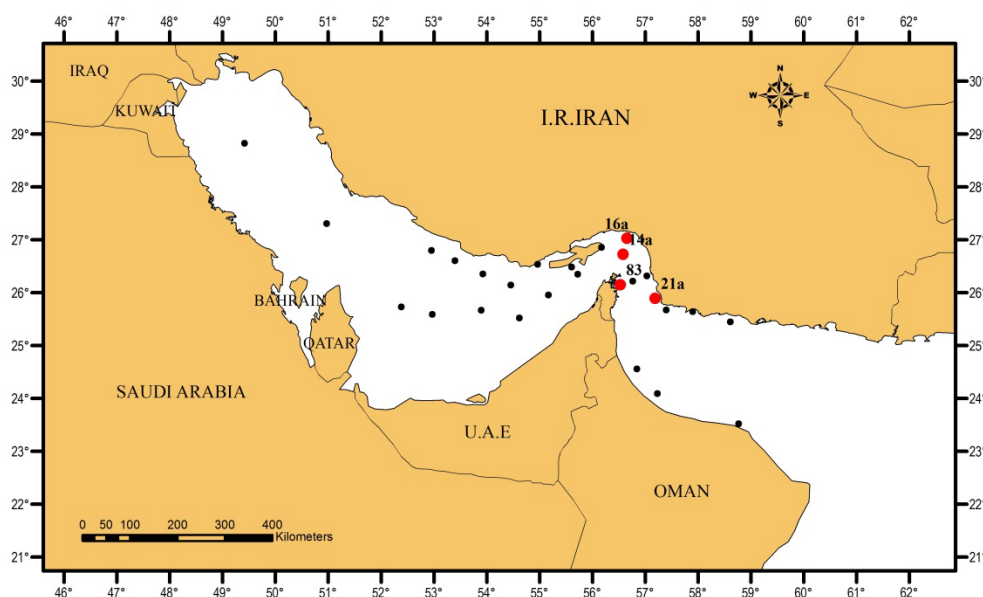


Plate 17: *Protoperidinium cf. tharianum* from RSA; A: in deep focus B-C: In surface focus All scale bars=2 μ m



Map 17: *Protoperidinium cf. tharianum* occurrence in the RSA, Winter 2006

Phylum: Miozoa

Class; Dinophyceae Fritsch 1927

Order; Peridinales Haeckel 1894

Family; Protoperidiniaceae Balech, 1988

Genus; *Protoperidinium* R.S.Bergh, 1881

Species: *Protoperidinium compressum*

Scientific name: *Protoperidinium compressum* (Abé) Balech 1974

Paleontological name: *Stelladinium stellatum* (Wall) Reid 1977

Figure No.: Plate 18

References:

Yoon and Shin (2013), plate, IV- 6

Description:

The pentagonal cyst is dorsoventrally compressed. The cyst colour is pale brown with a smooth thin wall. Distinct horns placed in each angle of the cyst body. The archeopyle is formed by the loss of 2a intercalary plate (Plate 18, A-B). Two cyst morphotypes of *P. compressum* have been reported from Iranian side of the Sea of Oman (Attaran-Fariman 2016), and their palantological names are *Stelladinium stellatum* and *S. robustum*. The *S. robustum* cyst has a larger size. In the RSA also two morphotypes of this cyst have been identified. The first cyst has a larger size and the depression is more straight between the horns (Plate 18, A-B), which is similar to *S. robustum*. The second type has smaller size and the depression between horns are round rather than straight (Plate 18, C-D), which resembles to the *S. stelatum*.

Size:

W: 64-75µm, horns included

Occurrence in RSA:

The presence of the species in the RSA from Cruise-Winter 2006 has been shown on Map 18. Presence of the cyst in sites: *S. robustum*; 85, and *S. stelatum*: 97, 88, 83

The cyst has been previously reported from northern part of the Sea of Oman (Attaran-Fariman 2016)

Occurrence in the world:

China (Wang *et al.*, 2004; Liu 2008); Peninsula (Sprangers *et al.*, 2004); Australia (McCarthy 2013); Africa and Somalia (Zonneveld and Brummer, 2000; Zonneveld *et al.*, 2010)

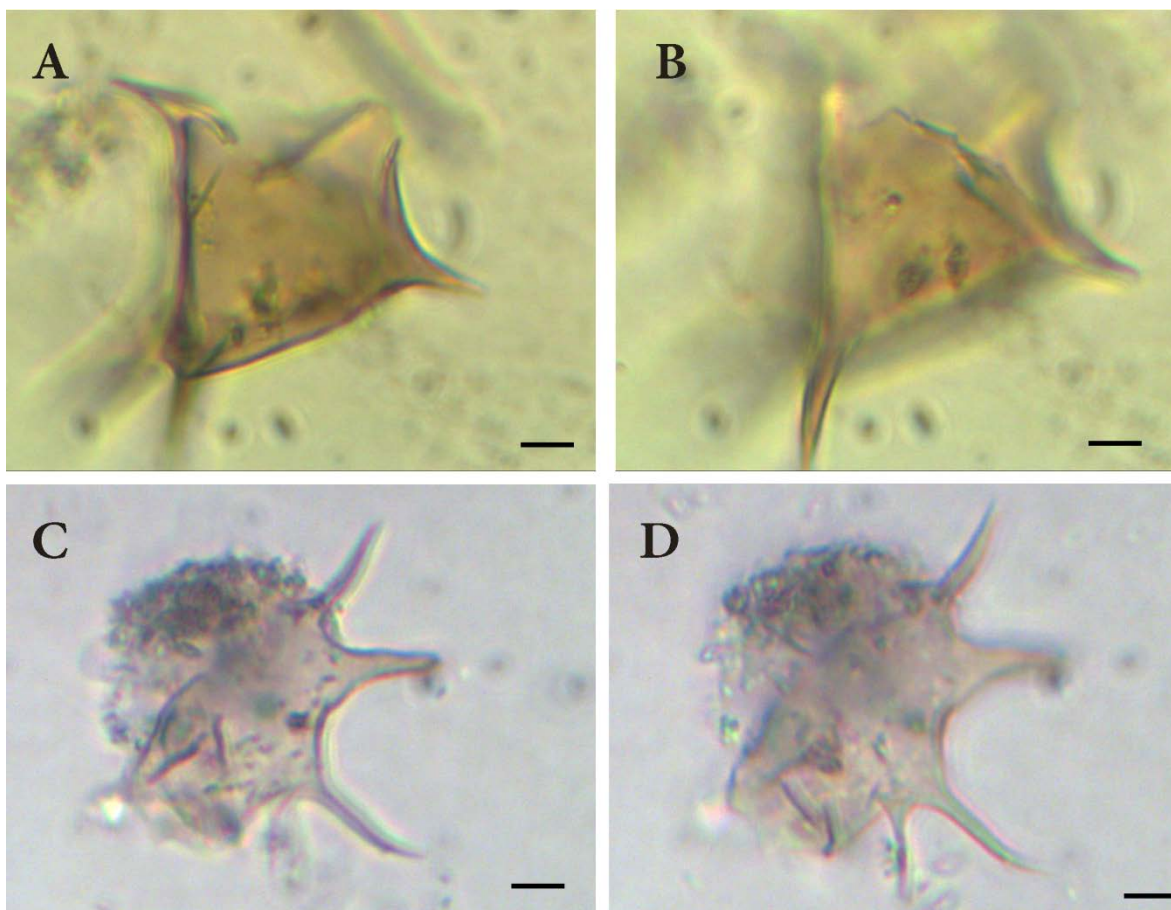
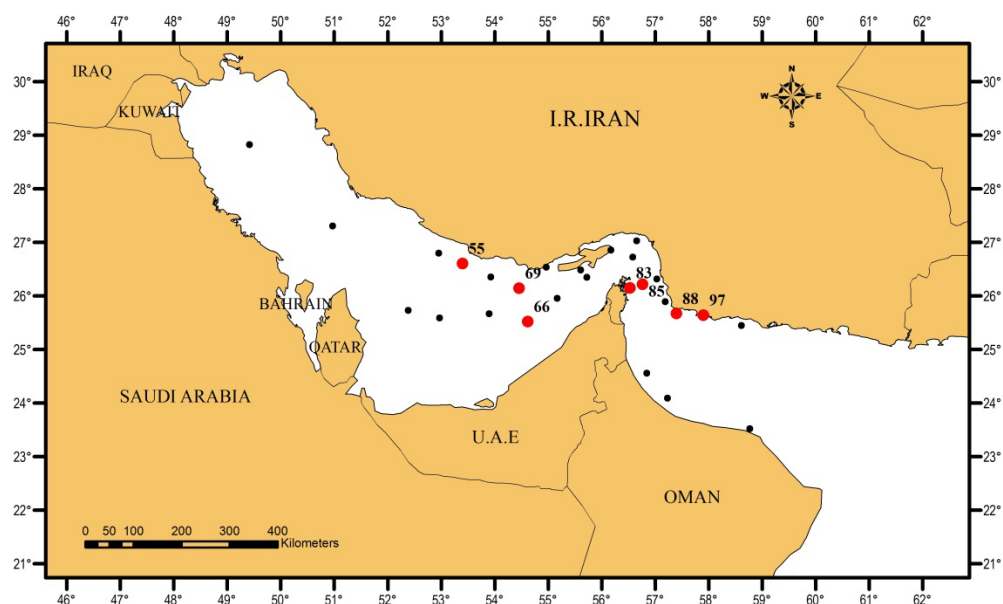


Plate 18: *Protoperidinium compressum*: A-B: *S. robustum* (palantological name), C-D: *S. stelatum* (plaentological name)



Map 18: *Protoperidinium compressum* occurrence in the RSA, Winter 2006

Phylum: Miozoa

Class; Dinophyceae Fritsch 1927

Order; Peridiniales Haeckel 1894

Family; Protoperidiniaceae Balech, 1988

Genus; *Protoperidinium* R.S.Bergh, 1881

Species: *Protoperidinium minutum*

Scientific name: *Protoperidinium minutum* (Kofoid) Loeblich III 1970

Paleontological name: -

Figure No.: Plate 19

References:

Sonneman and Hill (1997), Figure 15;

Ribeiro *et al.*, (2010), Figures 7-9

Size:

D: cyst body 35µm

Description:

Spherical dark brown cyst, which is ornamented with frequent short pointed spines. The spines are straight or may be curved and consistently distributed on the cyst. The live cyst shows yellowish-green content. The archeopyle is intercalary and theropylic; however, it was not observed in the cyst of the RSA.

Occurrence in RSA:

The presence of the species in the RSA from Cruise-Winter 2006 has been shown on Map 19. Presence of the cyst in sites: 98, 97, 83, 16a, 77, 78, 72, 11

The cyst has been previously reported from northern part of the Sea of Oman (Attaran-Fariman *et al.*, 2012; Attaran-Fariman 2016)

Occurrence in the world:

Australia (Sonneman and Hill, 1997); China (Liu 2008) Portugal (Ribeiro *et al.*, 2010); Romania (Caraus 2012); Turkey (Balkis *et al.*, 2016).

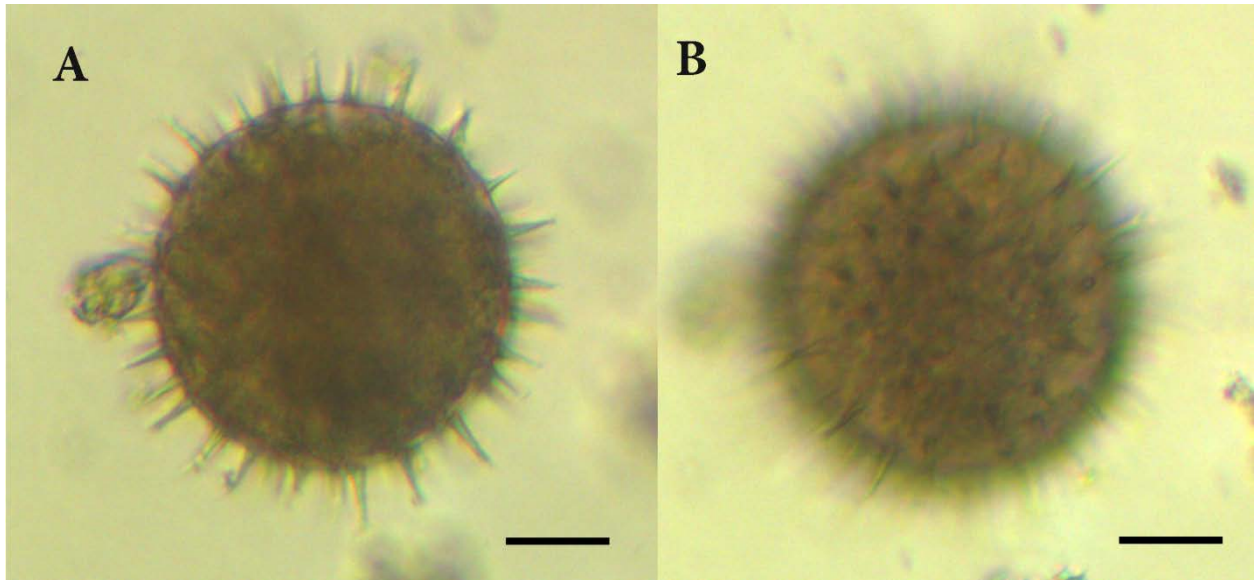
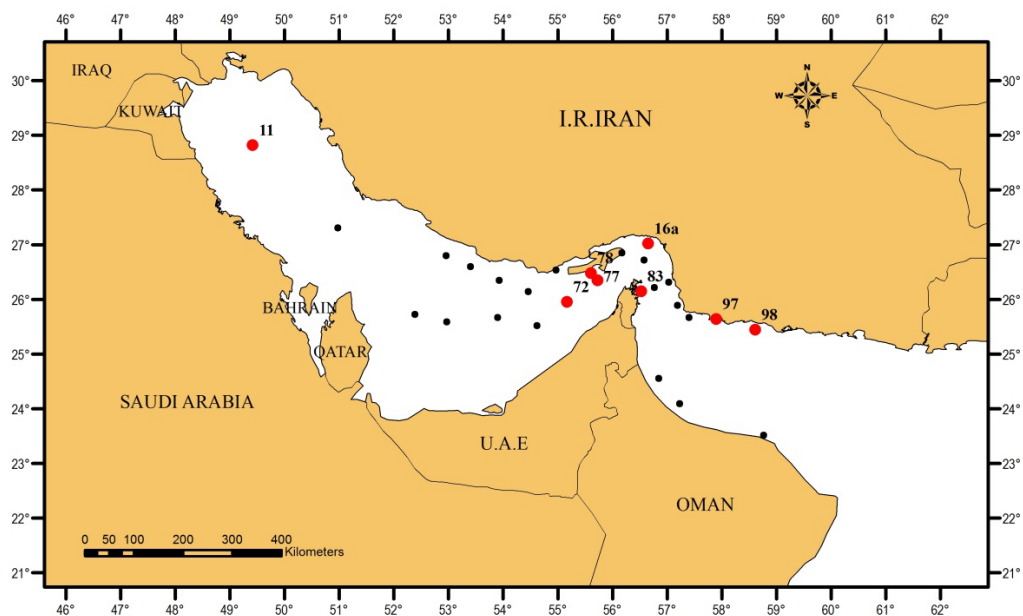


Plate 19: *Protoperidinium minutum* in two different focuses from RSA shows pointed process



Map 19: *Protoperidinium minutum* occurrence in the RSA, Winter 2006

It should be noted that as the RSA samples were preserved with Formaldehyde, germination experiments were impossible; and without germination, it was difficult to identify some *Protopredinium* cysts (as followings) to the species level.

Phylum: Miozoa

Class; Dinophyceae Fritsch 1927

Order; Peridiniales Haeckel 1894

Family; Protoperidiniaceae Balech, 1988

Genus; *Protoperidinium* R.S.Bergh, 1881

Species; *Protoperidinium* sp.1

Scientific name: *Protoperidinium* sp1.

Paleontological name: *Brigantedinium* spp

Figure No.: Plate 20

References:

Prebble *et al.*, (2013), Figure 3J

Description:

Spherical brown cyst. The outline of the cyst is round. The cyst surface in deep focus is smooth (Plate 20, A-C); however, surface focus shows randomly short, flexible distributed processes (Plate 20, A-C). The archeopyle is saphopylic intercalary and forms by loss of 2a paraplate (Plate 20, A-C). The cyst with similar shape of archeopyle has been only recorded from sediments of New Zealand (Prebble *et al.*, 2013); however, they did not describe the cyst features and did not show cyst surface in their images.

Size

D: 59µm

Occurrence in RSA:

The presence of the species in the sediment sample of the Winter Cruise 2006 of RSA is shown on Map 20, in stations: 88, 85, 77, 69, and 25

Occurrence in the world:

New Zealand (Prebble *et al.*, 2013)

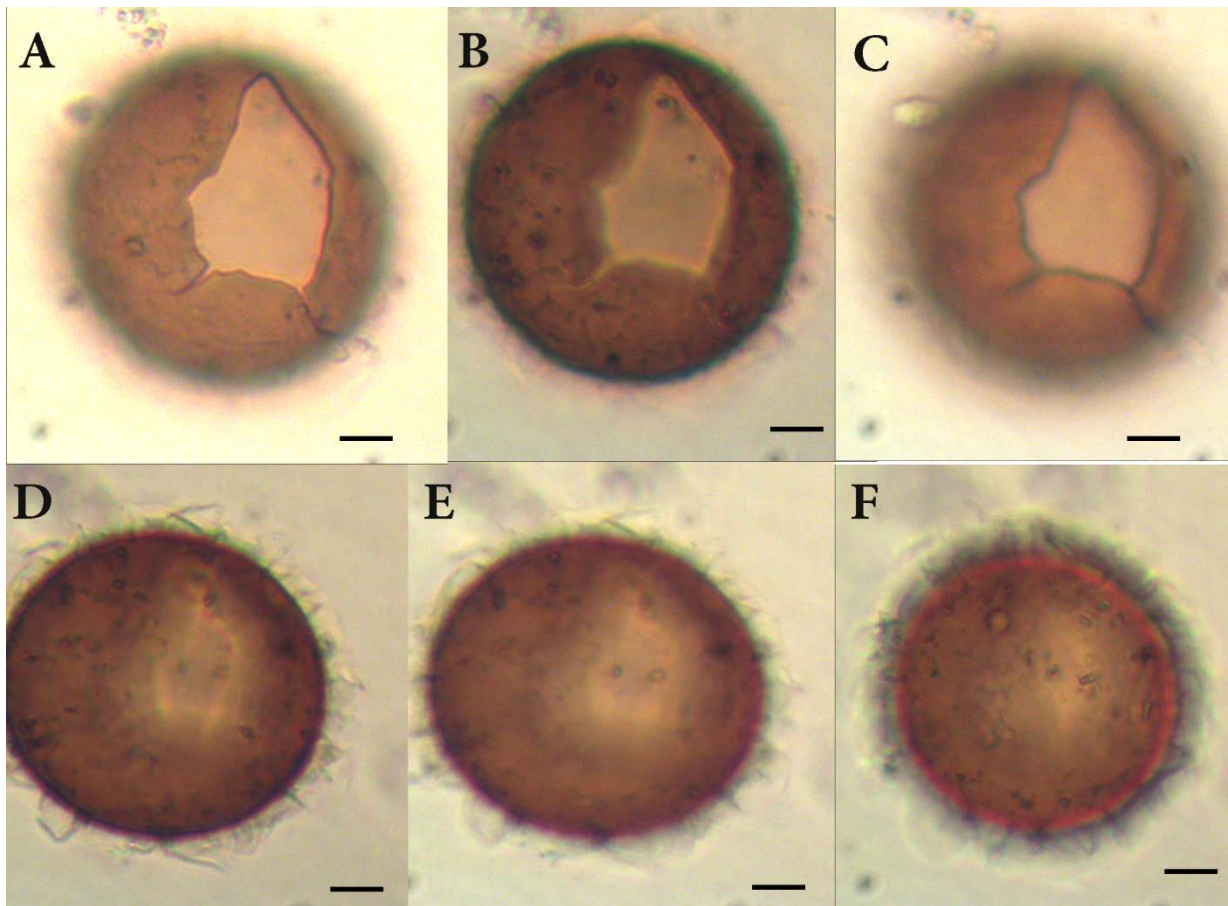
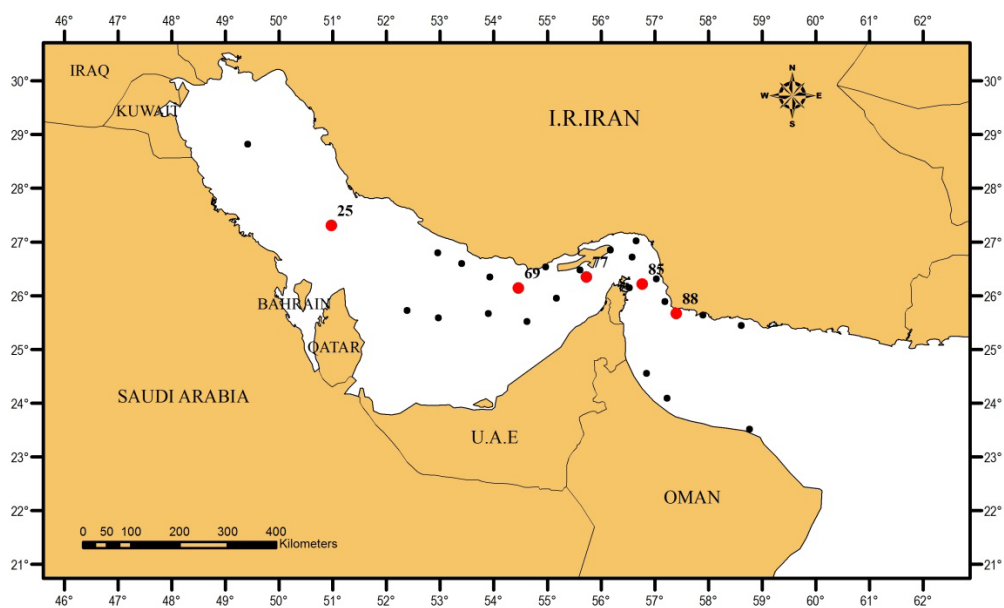


Plate 20: *Protoperidinium* sp.1; A-C cyst in deep focus shows archeopyle, D-F cyst in surface focus shows soft process (All scale bars=10µm)



Map 20: *Protoperidinium* sp.1 occurrence in the RSA, Winter 2006

Phylum: Miozoa

Class; Dinophyceae Fritsch 1927

Order; Peridiniales Haeckel 1894

Family; Protoperidiniaceae Balech, 1988

Genus; *Protoperidinium* R.S.Bergh, 1881

Species: *Protoperidinium* sp.2

Scientific name: *Protoperidinium* sp.2

Paleontological name: -

Figure No.: Plate 21

References:

Wall & Dale (1968), Plate 1, Figure 30 and Plate 3, Figure 12.

Sonneman & Hill (1997), Figure 18

(The references are for *P. claudican*; this morphotype has not been reported from anywhere else).

Description:

Colourless heart-shaped cyst with two round antapical horns that are separated by relatively deep depression and apical horns are rounded and conical. The cyst has dark cyst contents with a yellow accumulation body (Plate 21). The cyst processes are relatively long, hollow and some processes are fused at the base (Plate 21, A). Some processes are acuminate with bifid distal end (Plate 21, C-D). This cyst type differs from *P. claudican* and *P. conicum* by its transparent colour, deep antapical depression, and long hollow processes. Two later species have pointed solid short processes.

Size:

W: 47µm; L: 52µm

Occurrence in RSA:

The presence of the species in the sediment sample of the Winter Cruise 2006 of RSA is shown on Map 21, in stations: 69, 59, 25, and 11

Occurrence in the world:

Not reported from anywhere else

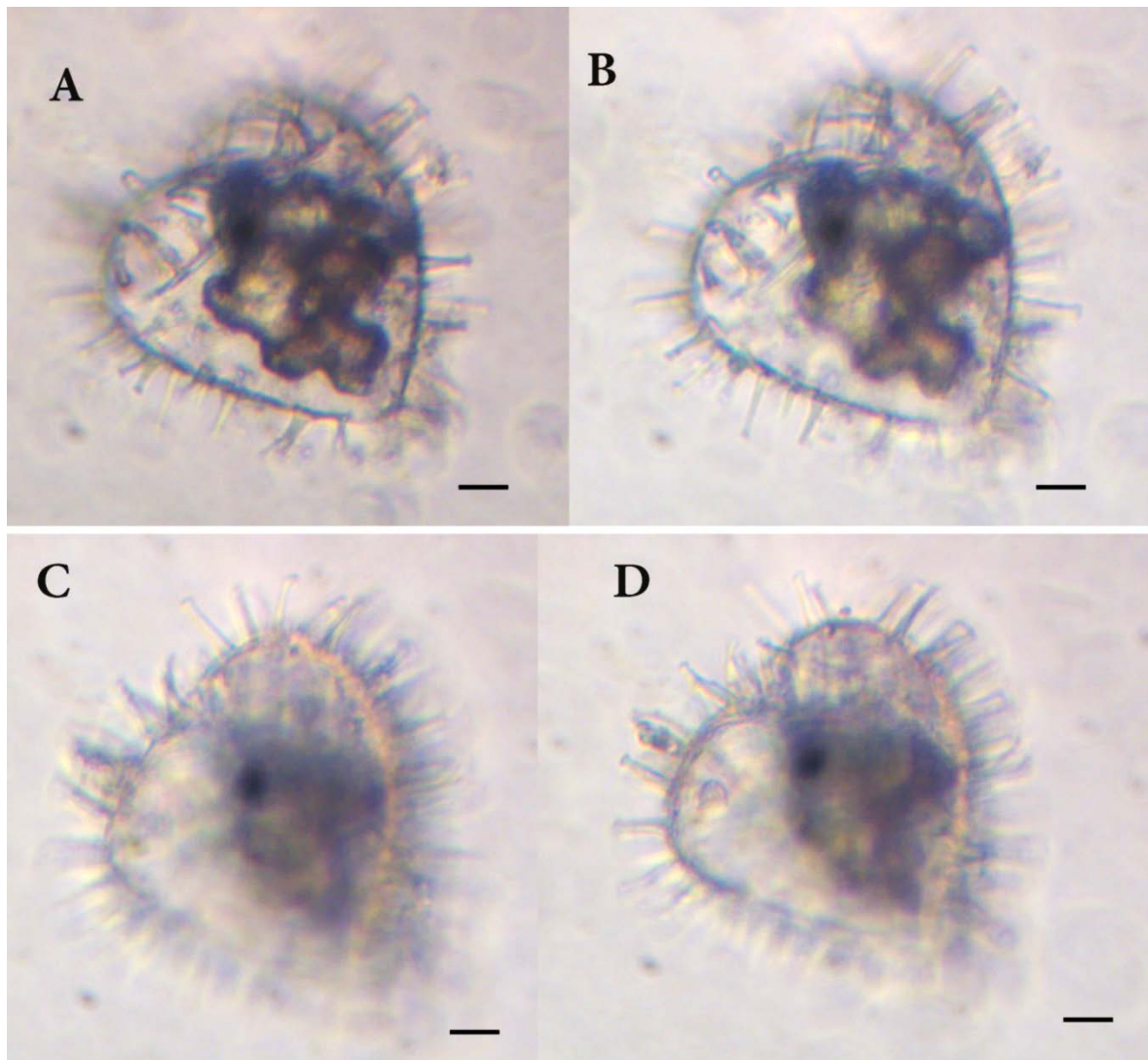
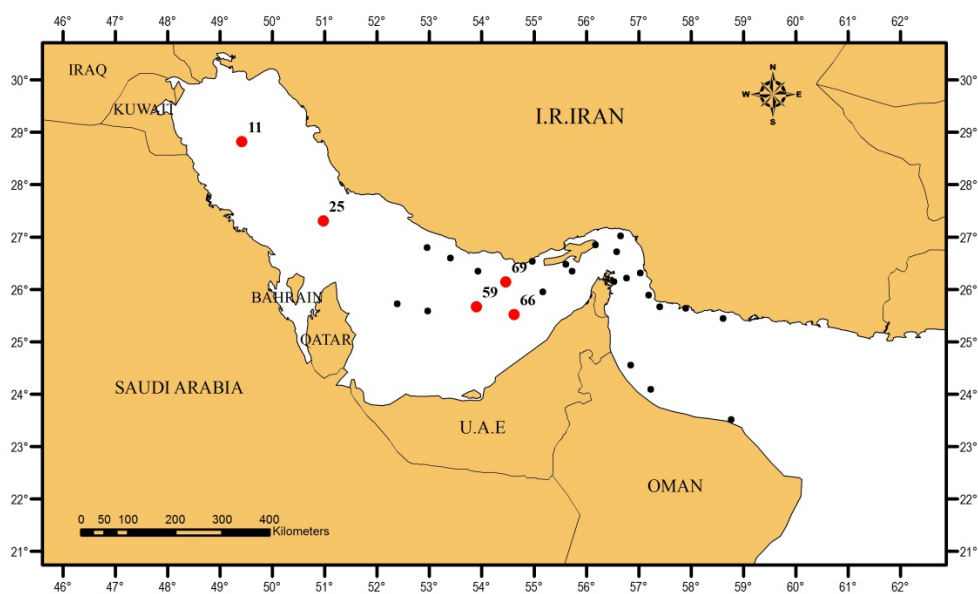


Plate 21: *Protopredinium* sp. 2: heart shape cyst from RSA in different focuses.



Map 21: *Protopredinium* sp. 2: presence in the RSA, Winter 2006

Phylum: Miozoa

Class; Dinophyceae Fritsch 1927

Order; Peridinales Haeckel 1894

Family; Protoperidiniaceae Balech, 1988

Genus; *Protoperidinium* R.S.Bergh, 1881

Species: *Protoperidinium* sp.3

Scientific name: *Protoperidinium* sp.3

Paleontological name: -

Figure No.: Plate 22

References:

Kawamura (2004); Figure 7;

Narale *et al.*, (2013), Figure 3n

Description:

Cyst has a pentagonal outline, smooth walled pink-brown, large cysts dorsoventrally compressed. The epicyst is conical with extended apical horn (Plate 22, A-D). Both hypocyst and epicyst have straight sides. Paracingulum is observed in the middle of the cyst (Plate 22, C-D). The cyst morphology is similar to the *P. latissimum* that has been reported from South China Sea (topical Sea) by Kawamura (2004; Figure 7), but the RSA cyst has larger size and longer epical horn.

Size:

L: 69µm

Occurrence in RSA:

The presence of the species in the sediment sample of the Winter Cruise 2006 of RSA is shown on Map 22, in stations: 93, 21a, 83, 59.

Similar cyst has been reported from northern part of the Sea of Oman as *Protopredinium* sp. (Attaran-Fariman *et al.*, 2012).

Occurrence in the world:

South east coast of India

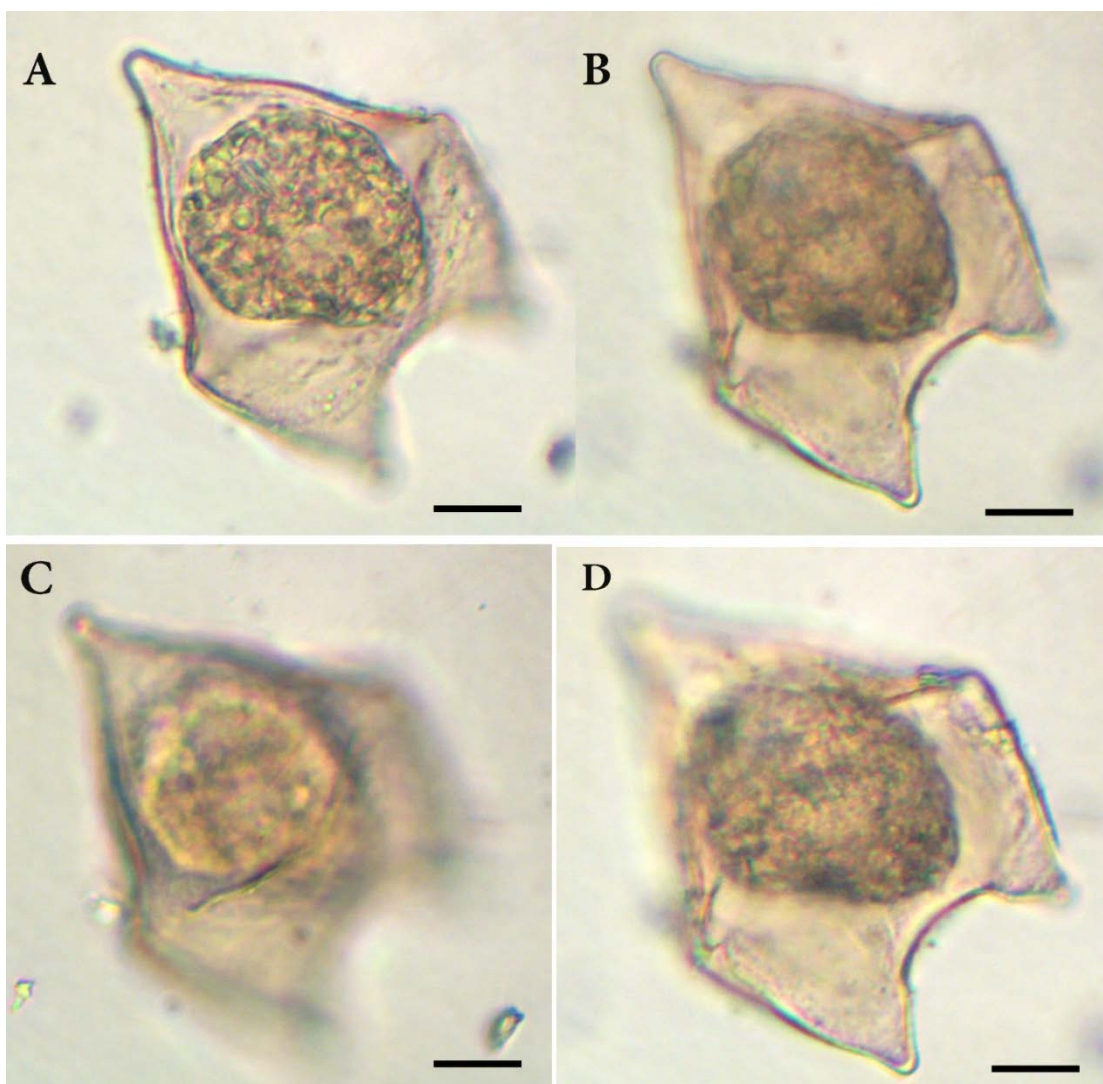
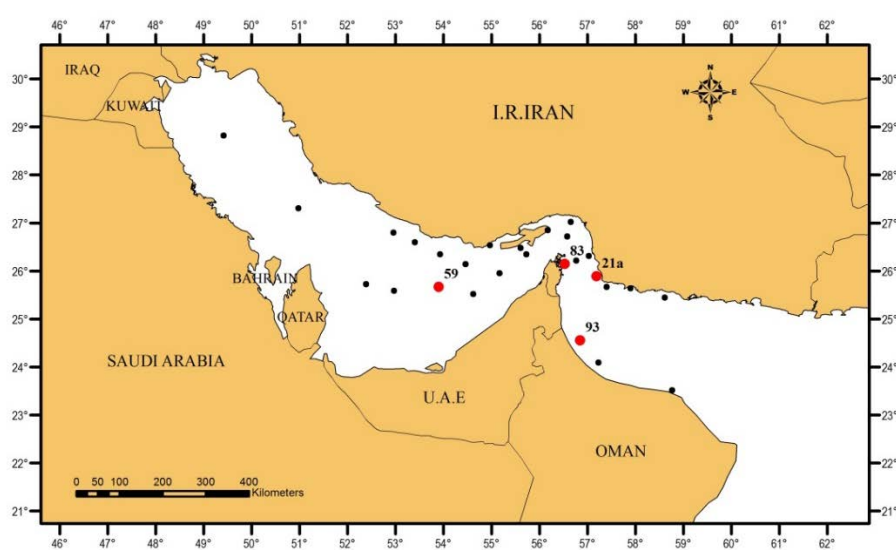


Plate 22: *Protopredinium* sp.3: large cyst with distinct apical and antapical horns



Map 22: *Protopredinium* sp. 3 presence in the RSA, Winter 2006

Phylum: Miozoa

Class; Dinophyceae Fritsch 1927

Order; Peridinales Haeckel 1894

Family; Protoperidiniaceae Balech, 1988

Genus; Protoperidinium R.S.Bergh, 1881

Species: *Protoperidinium* sp.4

Scientific name: *Protoperidinium* sp.4

Paleontological name: -

Figure No.: Plate 23

References:

Not found

Description:

Spherical dark brown cyst covered with numerous solid hairlike processes (Plate 23). The processes cannot be observed around the cyst archeopyle. It seems the saphopylic archeopyle is formed by loss precingular plates; however, in surface focus, cyst shows a slit archeopyle. This cyst type has not been reported from anywhere else.

Size:

D: 66µm

Occurrence in RSA:

The presence of the species in the sediment sample of the Winter Cruise 2006 of RSA is shown on Map 23, in station: 97

Occurrence in the world:

Not reported from anywhere else

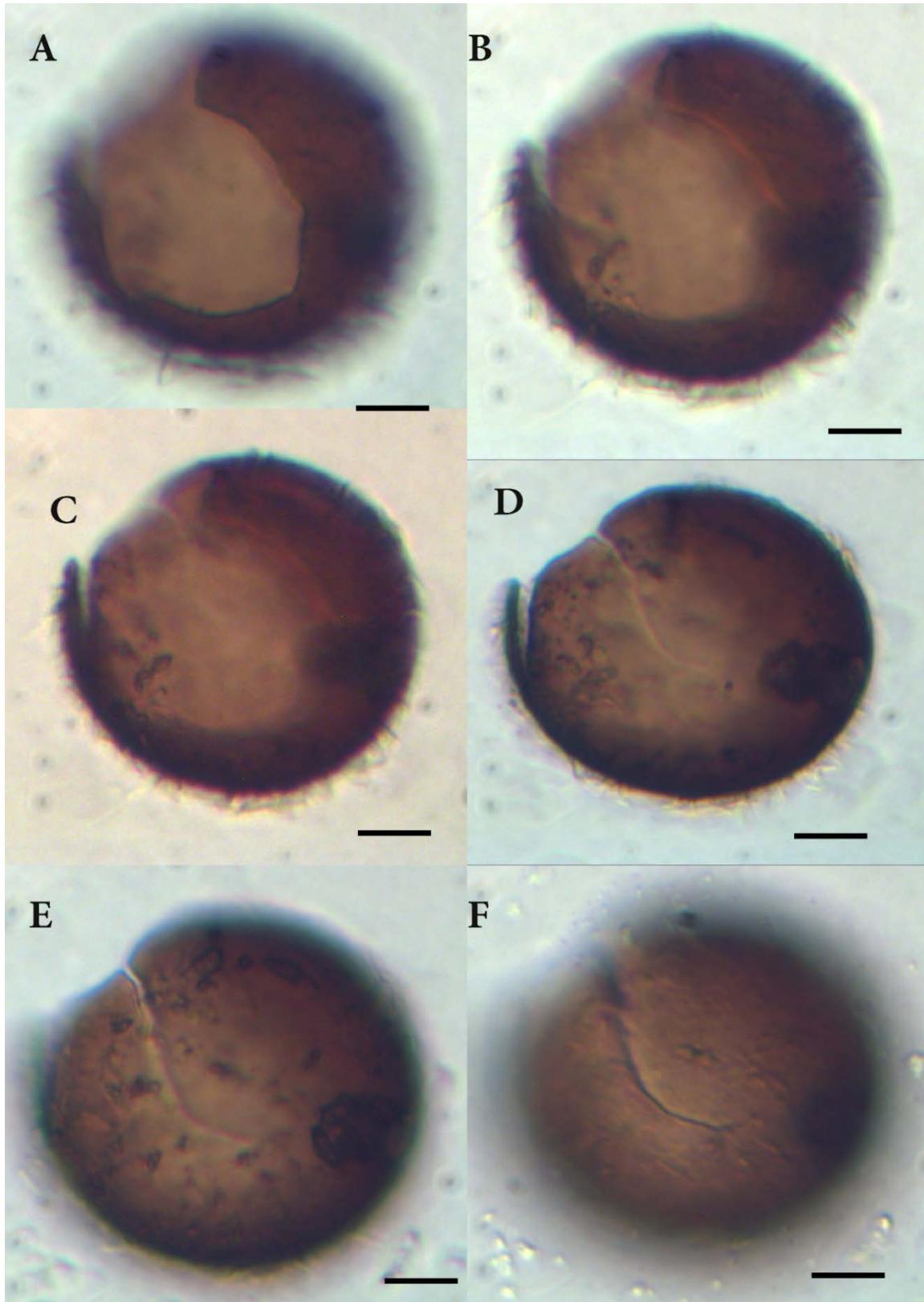
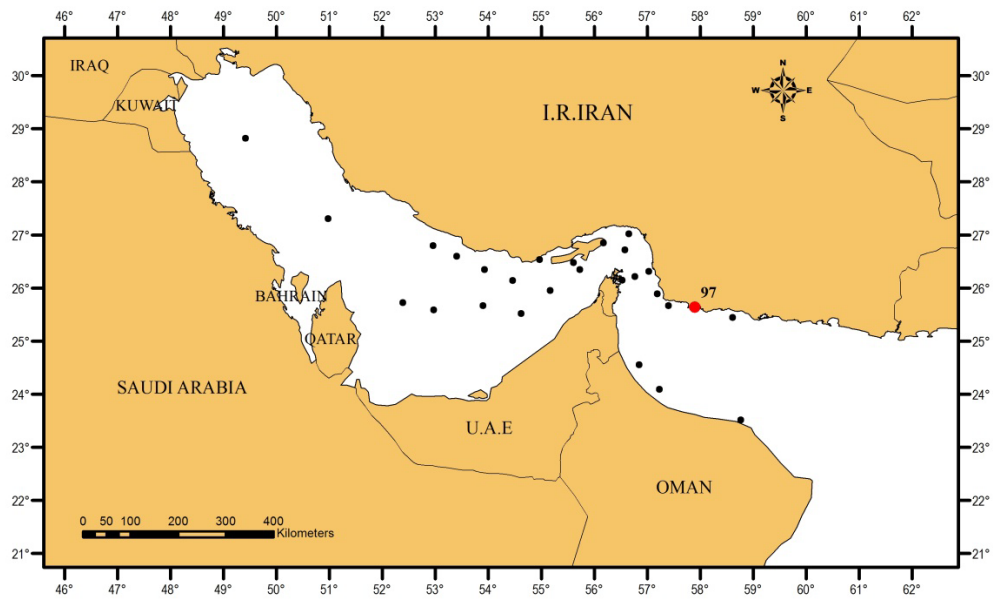


Plate 23: *Protoperidinium* sp.4: cyst in different focuses shows spiny wall and archeopyle



Map 23: *Protopredinium* sp.4 occurrence in the RSA, Winter 2006

Phylum: Miozoa

Class; Dinophyceae Fritsch 1927

Order; Peridiniales Haeckel 1894

Family; Protoperidiniaceae Balech, 1988

Genus; *Protoperidinium* R.S.Bergh, 1881

Species: *Protoperidinium* sp.5

Scientific name: *Protoperidinium* sp.5

Paleontological name: -

Figure No.: Plate 24

References:

Attaran-Fariman *et al.*, (2007), Figure 41;

Alves-de_Souza *et al.*, (2008), Figure 25;

Satta *et al.*, (2013), Plate 2, Figures J-I;

Description:

The cyst is spherical. It has a dark brown smoothed wall with globular content. The archeopyle and other paratabulations were not observed; therefore, identification to the species level is impossible, and several *Protopredinium* species may produce round brown cysts. As the RSA samples were preserved with formaldehyde, germination experiments were impossible and without germination, it is hard to identify the cyst to the species level.

Size:

D: 45µm

Occurrence in RSA:

The presence of the species in the sediment sample of the Winter Cruise 2006 of RSA is shown on Map 24, in stations: 77, 78, 72, 59, and 40

The cyst was previously reported from Iranian side of the Sea of Oman (Attaran-Fariman, 2007, 2016)

Occurrence in the world:

Southern Chile (Alves-de_Souza *et al.*, 2008); Mediterranean bay (Satta *et al.*, 2013)

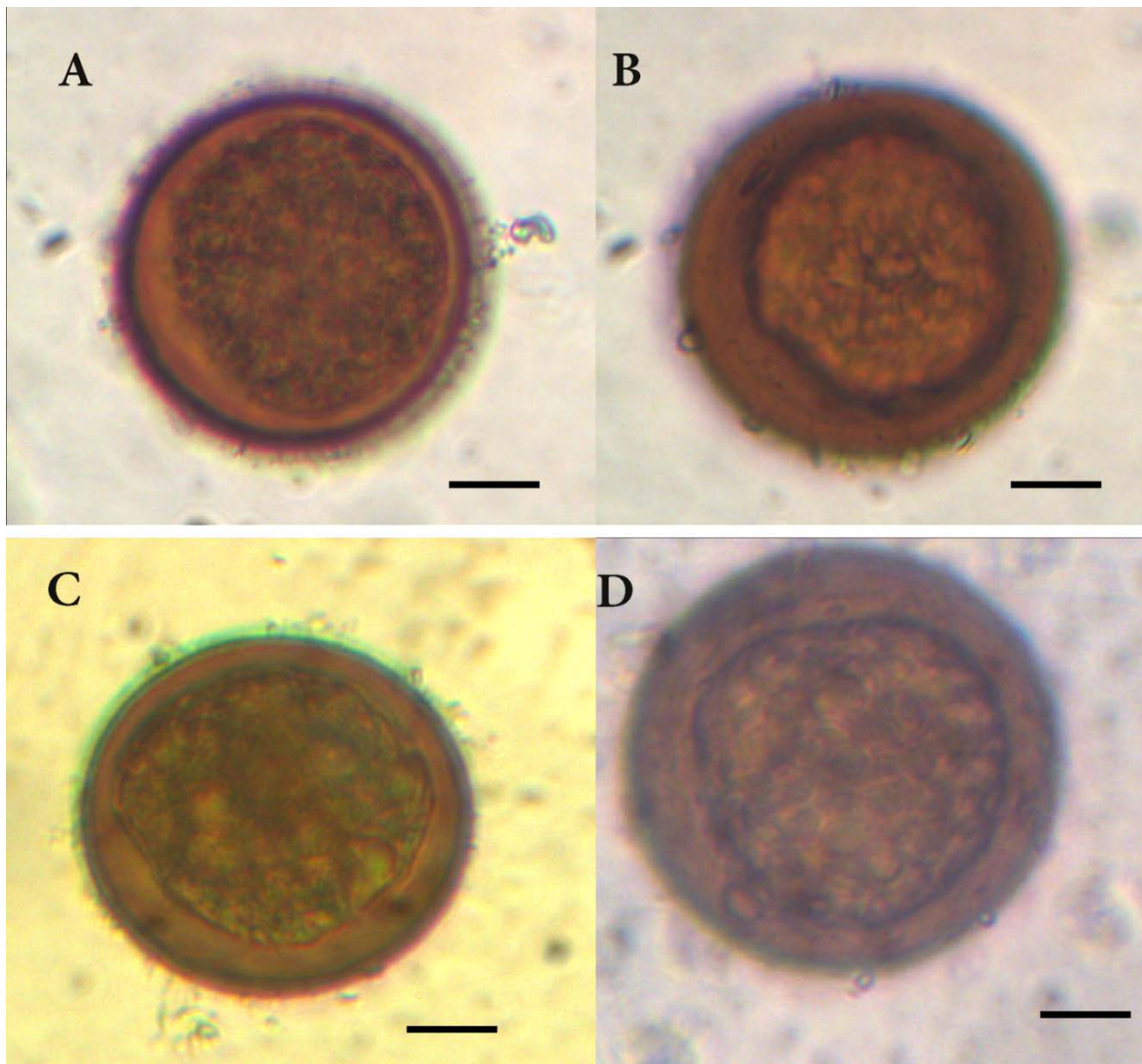
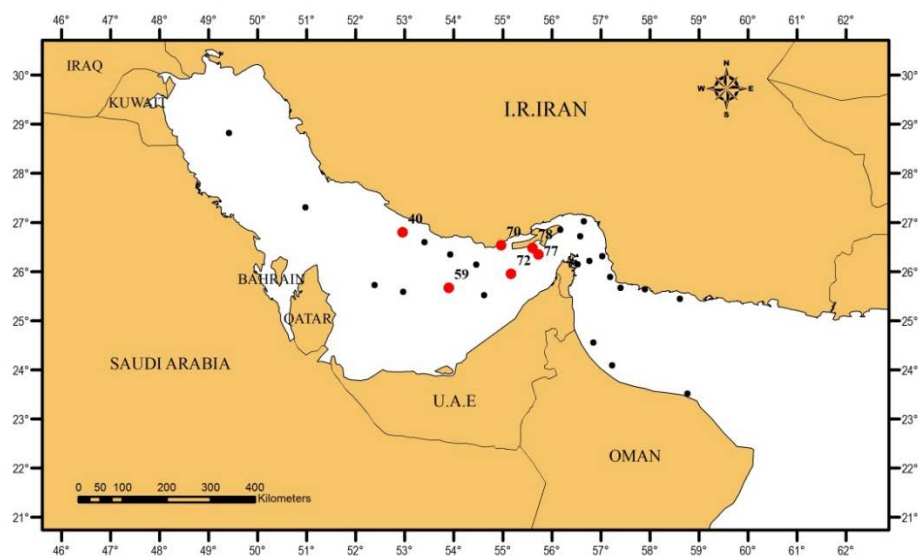


Plate 24: *Protopredinium* sp.5: round brown cyst on protopredinium (RBC)



Map 24: *protopredinium* sp.5 presence in the RSA, Winter 2006

Phylum: Miozoa

Class; Dinophyceae Fritsch 1927

Order; Peridiniales Haeckel 1894

Family; Protoperidiniaceae Balech, 1988

Genus; *Protoperidinium* R.S.Bergh, 1881

Species: *Protoperidinium* sp.6

Scientific name: *Protoperidinium* sp.6

Paleontological name: -

Figure No.: Plate 25

References:

Not found

Description:

Spherical brown cyst has a smooth single layer wall. The cyst wall is thin. It seems that the archeopyle is formed by loss of several plates, including apical, intercalary, and precingular plates. This cyst type has low density and has not been reported from anywhere else. There is not much other feature on the cyst to explain.

Size:

D: 42µm

Occurrence in RSA:

The presence of the species in the sediment sample of the Winter Cruise 2006 of RSA is shown on Map 25, in station: 50

This cyst type has not been reported from RSA.

Occurrence in the world:

Not reported from anywhere else

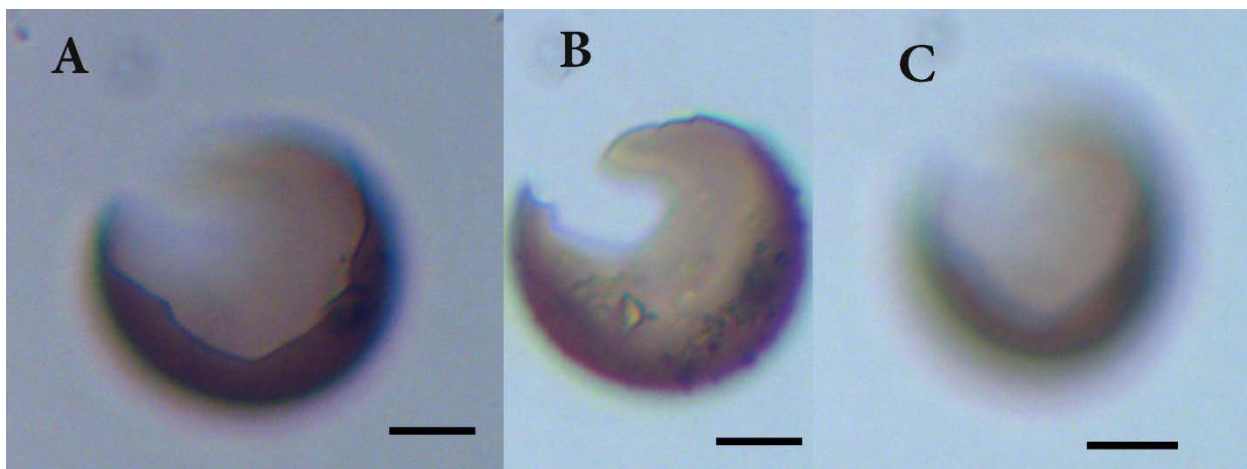
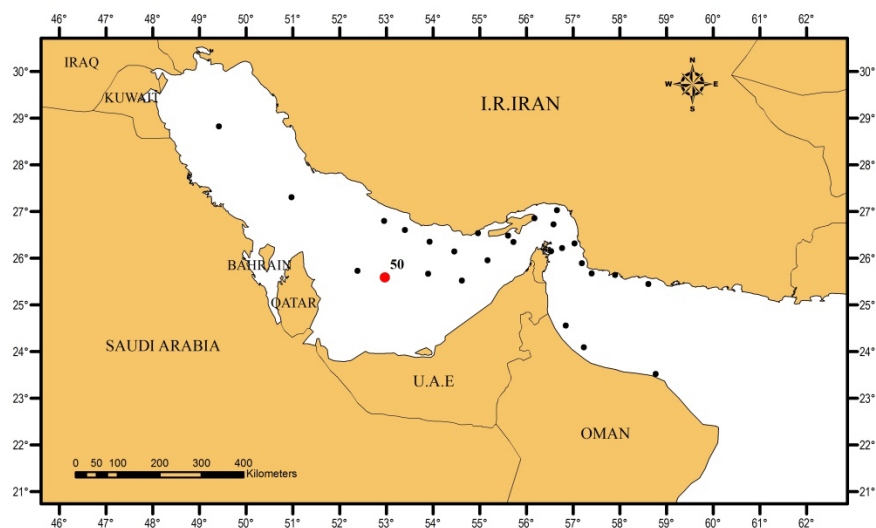


Plate 25: *Protopredinium* sp.6 in different focuses from RSA



Map 25: *Protopredinium* sp.6 occurrence in the RSA, Winter 2006

Phylum: Miozoa

Class; Dinophyceae Fritsch 1927

Order; Peridinales Haeckel 1894

Family; Protoperidiniaceae Balech, 1988

Genus; *Protoperidinium* R.S.Bergh, 1881

Species: *Protoperidinium* sp.7

Scientific name: *Protoperidinium* sp.7

Paleontological name: -

Figure No.: Plate 26

References:

Liu *et al.*, (2015), Figure 42

Description:

Brown round cyst, which has a smooth single wall layer (Plate 26). The cyst has a theropylic archeopyle. It is similar in size and shape of aecheopyle to the cyst of *Protoperidinium fuzhouense* Liu, Mertens & Gu that described by the Liu *et al.* (2015). However, this cyst is characterized by its anatpical paraplate reflecting the 1'''' plate that does not include archeopyle. In the cyst from RSA, antapical paraplate was not observed and it is hard to identify it to the species level without germination experiment.

Size:

D: 43µm

Occurrence in RSA:

The presence of the species in the RSA from Cruise-Winter 2006 has been shown on Map 26. Presence of the cyst in sites: 93, 88, 56.

Occurrence in the world:

Not reported from anywhere else

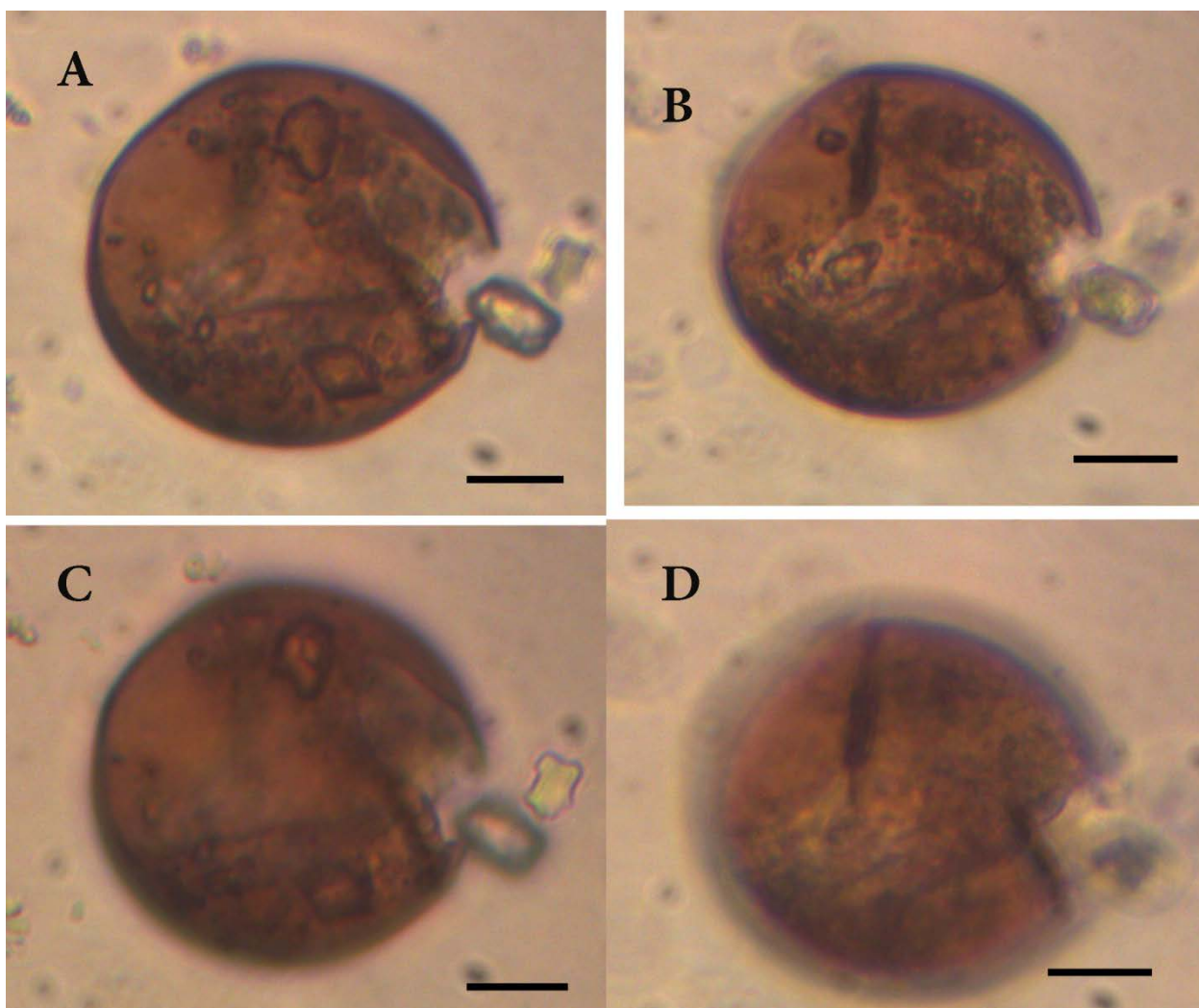
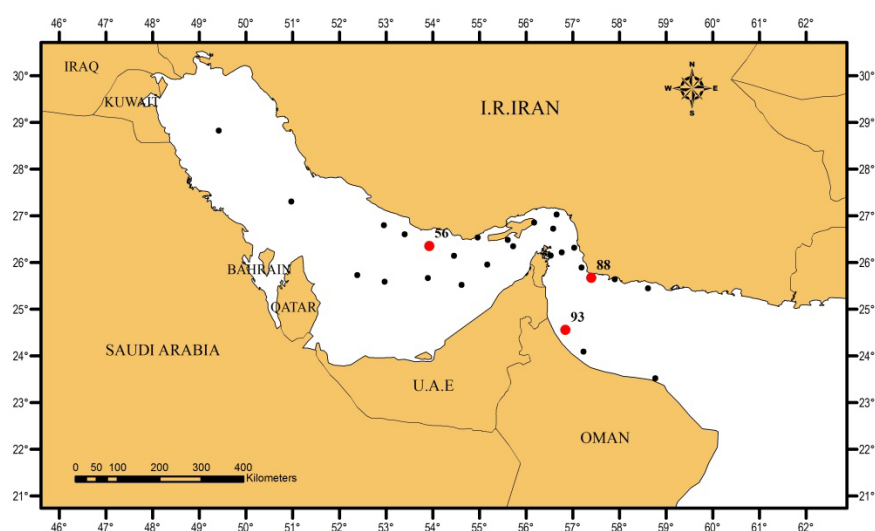


Plate 26: *Protopredinium* sp. 7 at different focal levels; All scale bars = 10μm



Map 26: *Prtotpredinium* sp. 7 occurrence in the RSA, Winter 2006

Phylum: Miozoa

Class; Dinophyceae Fritsch 1927

Order; Peridinales Haeckel 1894

Family; *Peridinales incertae sedis*

Genus; *Protoperidinium* R.S.Bergh, 1881

Species: *Niea torta* (Abé) Liu, Mertens & Gu 2015

Scientific name: *Niea torta* (Abé) T.Liu, K.N.Mertens & H.Gu 2015

Paleontological name: -

Figure No.: Plate 27

References:

Liu *et al.*, (2015), Figures 32-34

Description:

The large cyst is spherical and has a brown colour. The cyst wall is without any ornamentation (Plate 27). The epicystal archeopyle is theyropylic and formed by a slit along cingulum.

Size:

D: 55µm

Occurrence in RSA:

The presence of the species in the RSA from Cruise-Winter 2006 has been shown on Map 27. Presence of the cyst in site: 93

Occurrence in the world:

Japan (Liu *et al.*, 2015), Yellow Sea (Liu *et al.*, 2015)

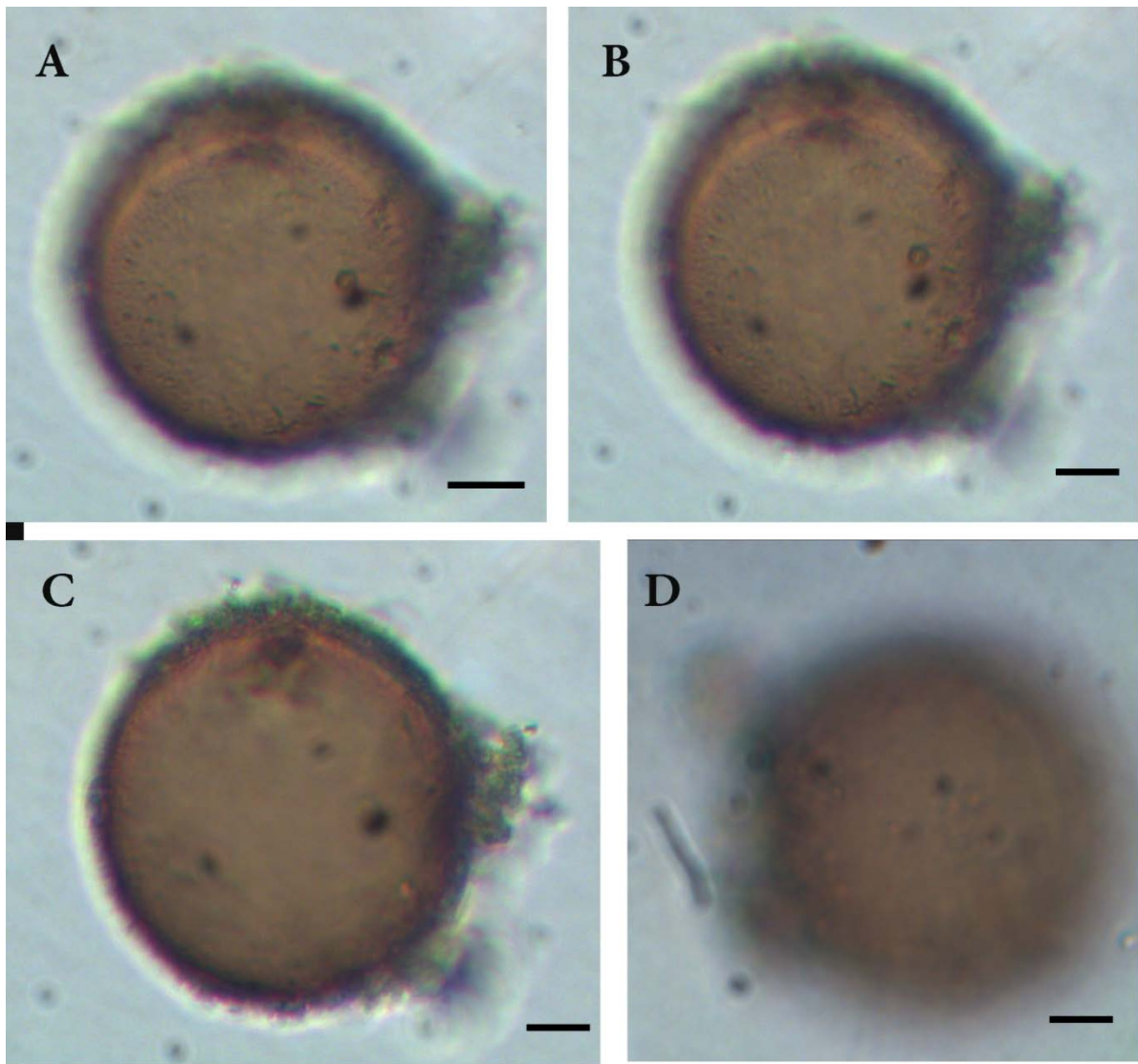
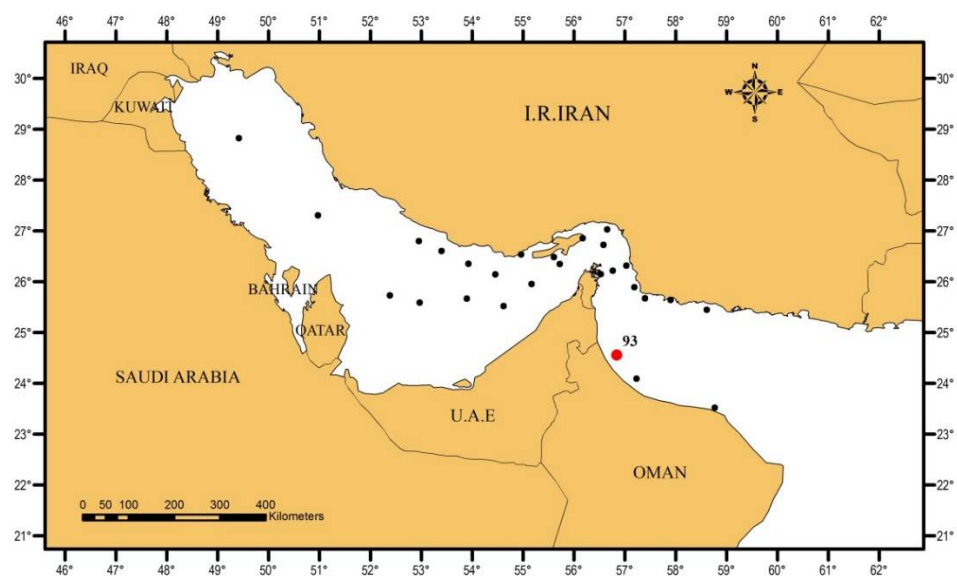


Plate 27: *Nieuwe tortia*: shows a thermophilic archaeon



Map 27: *Nieuwe tortia* presence in the RSA, Winter 2006

Phylum: Miozoa

Class; Dinophyceae Fritsch 1927

Order; Peridiniales Haeckel 1894

Family; Congruentidiaceae Schiller, 1935

Genus; *Echinidinium* Zonneveld ex Head et al., 2001

Species: *Echinidinium delicatum*

Scientific name: motile affinity is unknown

Paleontological name: *Echinidinium delicatum* (Zonneveld 1997) Head 2003

Figure No.: Plate 28

References:

Radi et al., (2013), Plate 1, Figures 17-20;

Yoon & Shin (2013), Plate VI, Figure 3

Description:

The cyst is spherical and brown in colour and ornamented with numerous regular distributed spines. The processes are inflexible hollow, acuminate and closed in distal ends (Plate28, A-D). The processes have a sub circular base and sharply pointed at their distal ends (Plate 28, D). The cyst has a chasmic archeopyle; however, it has not been observed in our samples.

Size:

W: 26µm

Occurrence in RSA:

The presence of the species in the RSA from Cruise-Winter 2006 has been shown on Map 28. Presence of the cyst in sites: 85, 83, 14a, 16a

Occurrence in the world:

North America, NW Africa, SW Africa and the Arabian Sea (Zonneveld and Brummer, 2000; Zonneveld et al., 2010); South Korea (Pospelova and Kim, 2010).

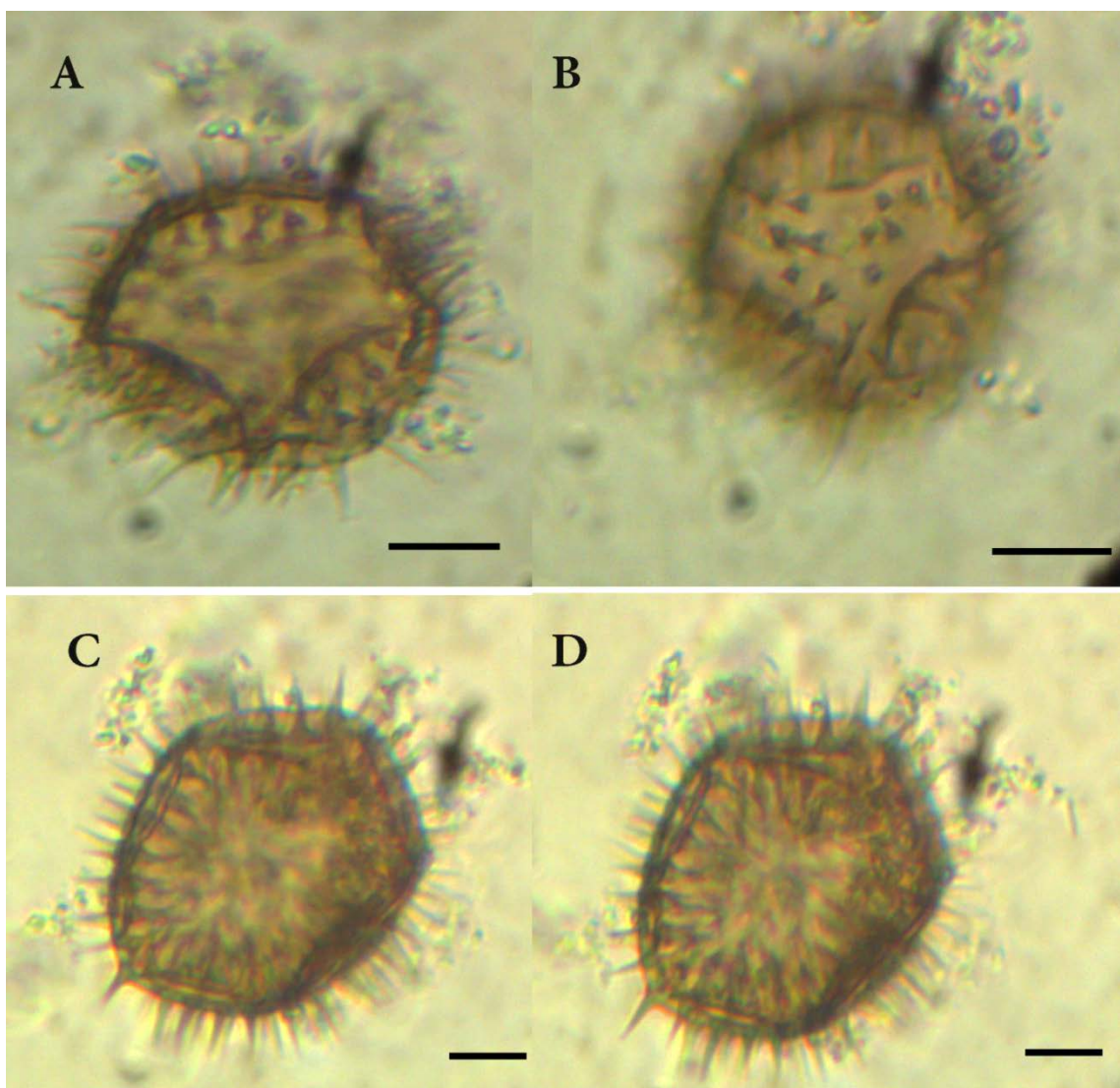
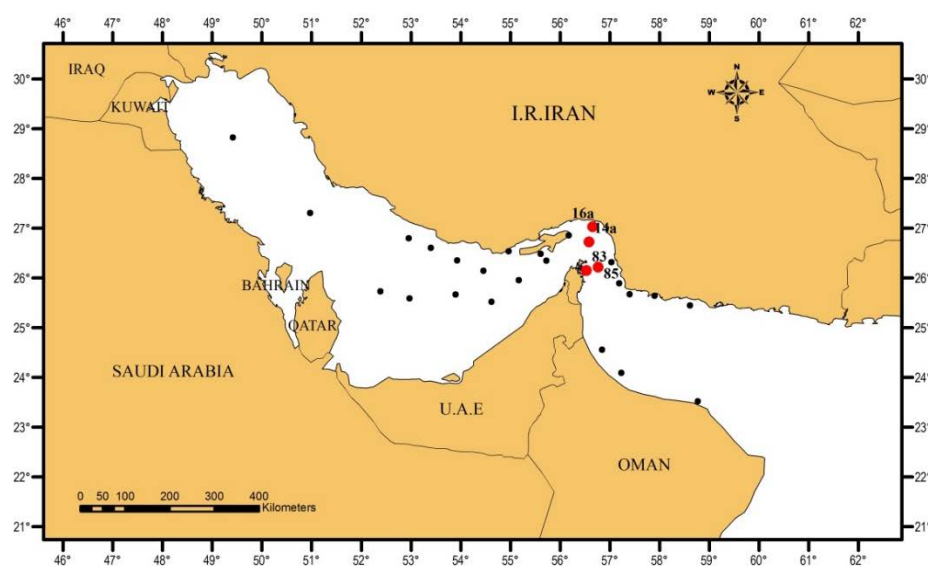


Plate 28: *Echinidinium delicatum* showing pointed spine. All scale bars =10µm



Map 28: *Echinidinium delicatum* occurrence in the RSA, Winter 2006

Phylum: Miozoa

Class; Dinophyceae Fritsch 1927

Order; Peridiniales Haeckel 1894

Family; Congruentidiaceae Schiller, 1935

Genus; *Echinidinium* Zonneveld ex Head et al., 2001

Species: *Echinidinium* cf. *bispiniformum*

Scientific name: motile affinity is unknown

Paleontological name: *Echinidinium bispiniformum* Zonneveld 1997, Figure No.: 28

Figure No.: Plate 29

References:

Zonneveld (1997), Plate IV, 1-4

Description:

The cyst is spherical and brown in colour and ornamented with two different spines. The cell wall is pigmented. The first type of spine is large, flexible and bulbous. The second type of spine is solid and randomly distributed between the large spines. The cyst has a chasmic and consists of a split along several sutures. In the samples from RSA, large spines on the cyst surface were observed.

Size:

W: 46 µm

Occurrence in RSA:

The presence of the species in the RSA from Cruise-Winter 2006 has been shown on Map 29. Presence of the cyst in sites: 85, 83, 14a, 16a

Occurrence in the world:

Arabian Sea (Zonneveld and Brummer, 2000)

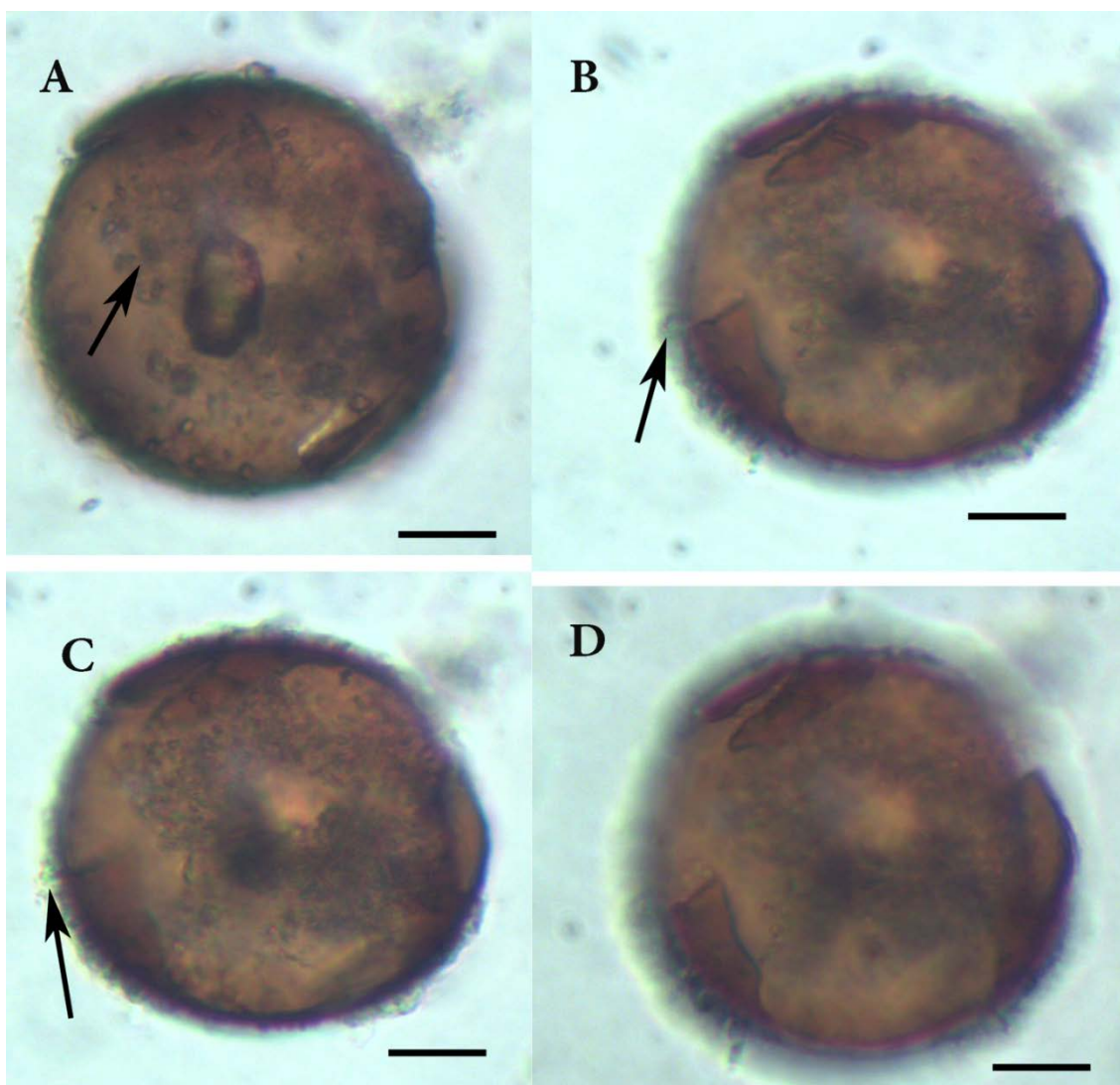
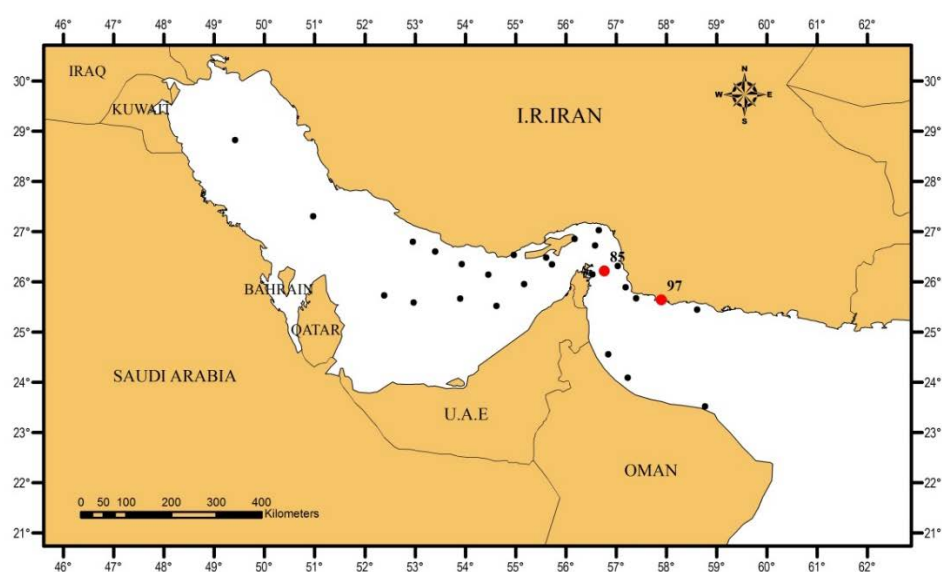


Plate 29: *Echinidinium bispiniformum* A-B: showing a bulbous flexible spine (arrows), C-D cyst showing short spine (arrow)



Map 29: *Echinidinium bispiniformum* occurrence in the RSA, Winter 2006

Phylum: Miozoa

Class; Dinophyceae Fritsch 1927

Order; Peridiniales Haeckel 1894

Family; Amphidiniopsidaceae J.D.Dodge, 1984

Genus; *Islandinium* Head *et al.*, 2001

Species: *Islandinium cf. minutum* (Harland and Reid in Harland *et al.*, 1980) Head *et al.*, 2001

Scientific name: unknown

Paleontological name: *Islandinium cf. minutum*

Figure No.: Plate 30

References: 30

Pienkowski *et al.*, (2013), Figure 3A;

Radi *et al.*, (2013), Plate 1, Plate 1.1 Figure3;

Yoon & Shin (2013), Plate VI, Figure 8

Description:

Spherical light to dark brown cyst (Plate 30). The processes are both apiculocavate with acuminate tips. The cyst surface is granular. The species is morphologically similar to *Echinidinium sleipnerensis* and may misidentify, but the later species are associated with cool conditions (Radi *et al.*, 2013).

Size:

D: 43 µm

Occurrence in RSA:

The presence of the species in the RSA from Cruise-Winter 2006 has been shown on Map 30. Presence of the cyst in sites: 98, 83, 72

Occurrence in the world:

Arctic Ocean, northern North Atlantic and Bering Sea, subtropical to polar and estuarine to oceanic environments (Radi *et al.*, 2013), China Sea (Yoon & Shin, 2013)

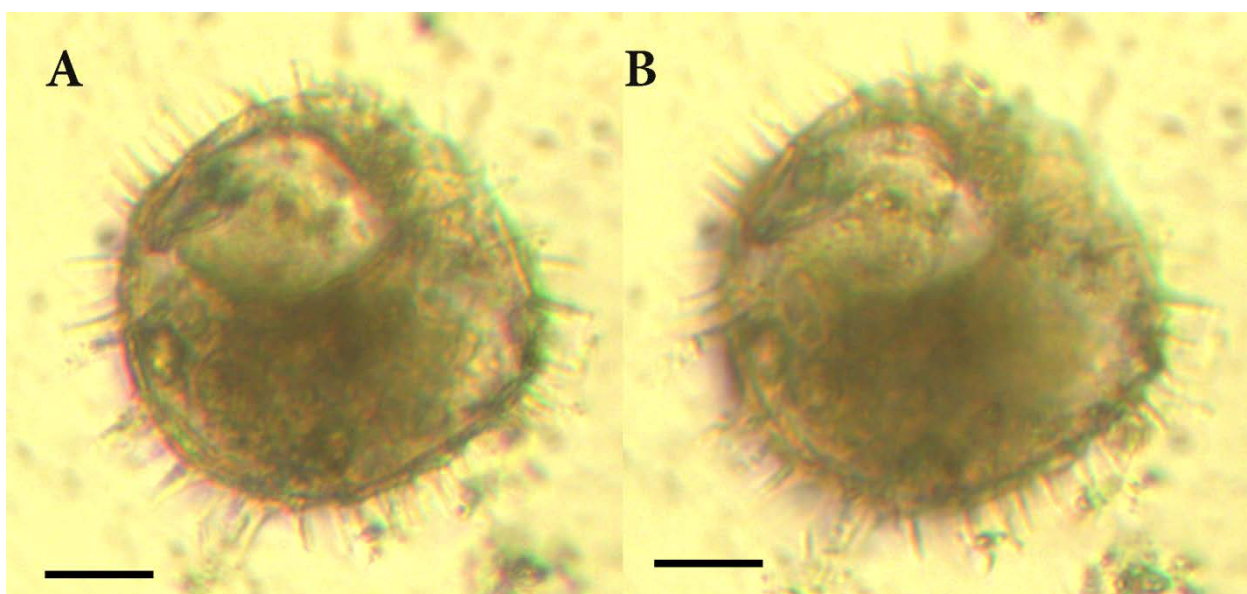
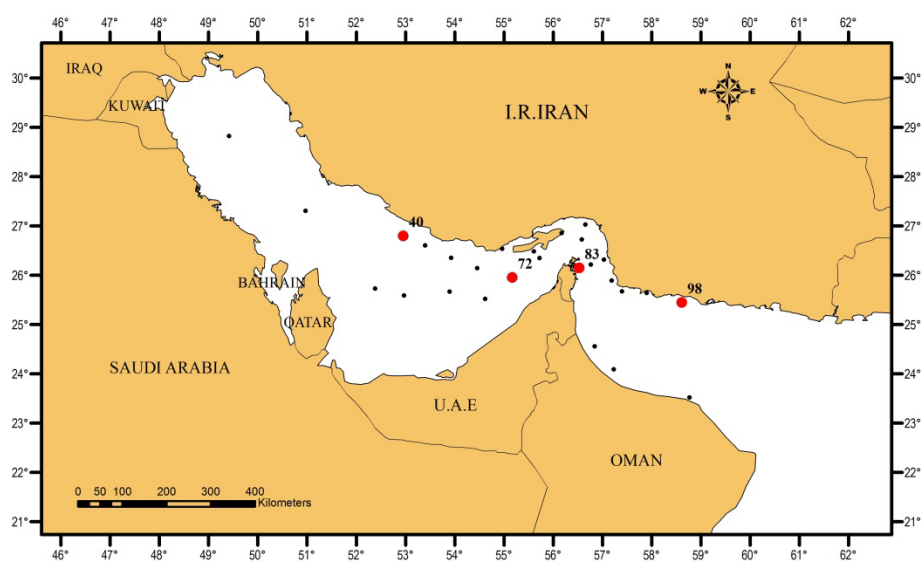


Plate 30: *Islandinium cf. minutum* with unknown motile affinity



Map 30: *Islandinium cf. minutum* occurrence in the RSA, Winter 2006

Phylum: Miozoa

Class; Dinophyceae Fritsch 1927

Order; Peridinales Haeckel 1894

Family; Protoperidiniaceae Balech, 1988

Genus; *Archaeoperidinium* Jörgensen 1912 emend. A. Yamaguchi,
Hoppenrath, Pospelova, T. Horiguchi & B.S. Leander 2011

Species; *Archaeoperidinium minutum*

Scientific name: *Archaeoperidinium minutum* Yamaguchi *et al.*, 2011

Paleontological name: -

Figure No.: Plate 31

References:

Liu *et al.*, (2015), Figure 34

Description

The cyst has spherical to subspherical cyst body. Cyst is dark brown when it is alive, and light brown when empty (Plate 31). The cyst surface is smooth and ornamented with acuminate erect and equidistance processes. The processes are not fused or branched. The theropylic archeopyle was not observed

Size:

D: 32µm

Occurrence in RSA:

The presence of the species in the RSA from Cruise-Winter 2006 has been shown on Map 31. Presence of the cyst in sites: 55

Occurrence in the world:

Mexico (Okolodkov 2005); Portugal (Ribeiro *et al.*, 2010); British Columbia (Yamaguchi *et al.*, 2011)

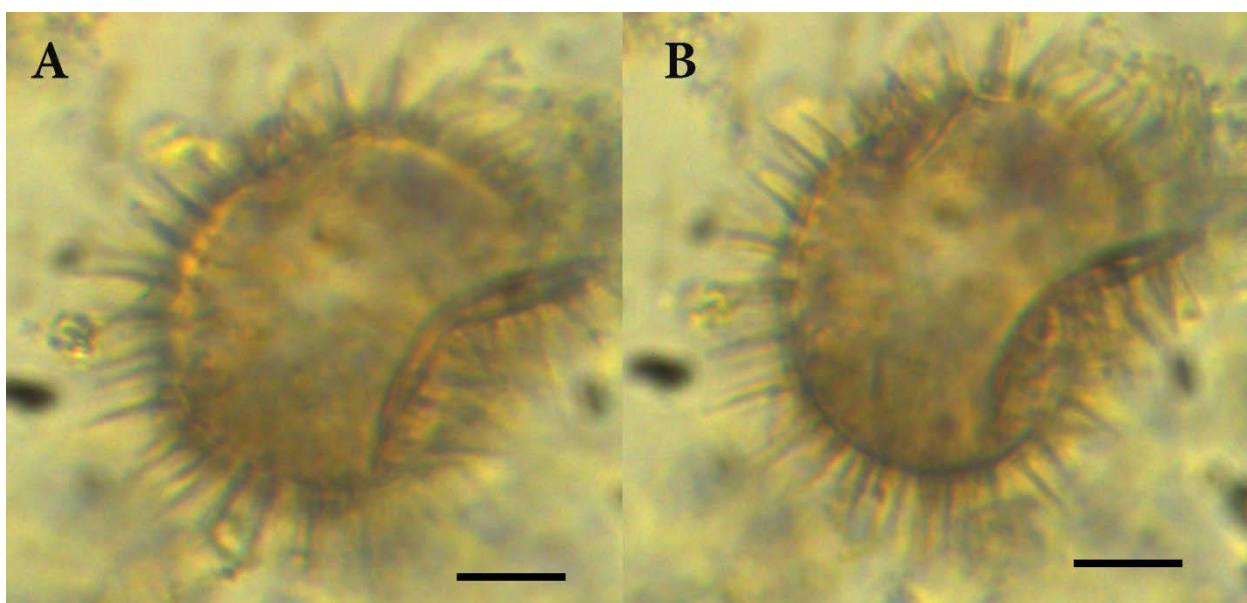
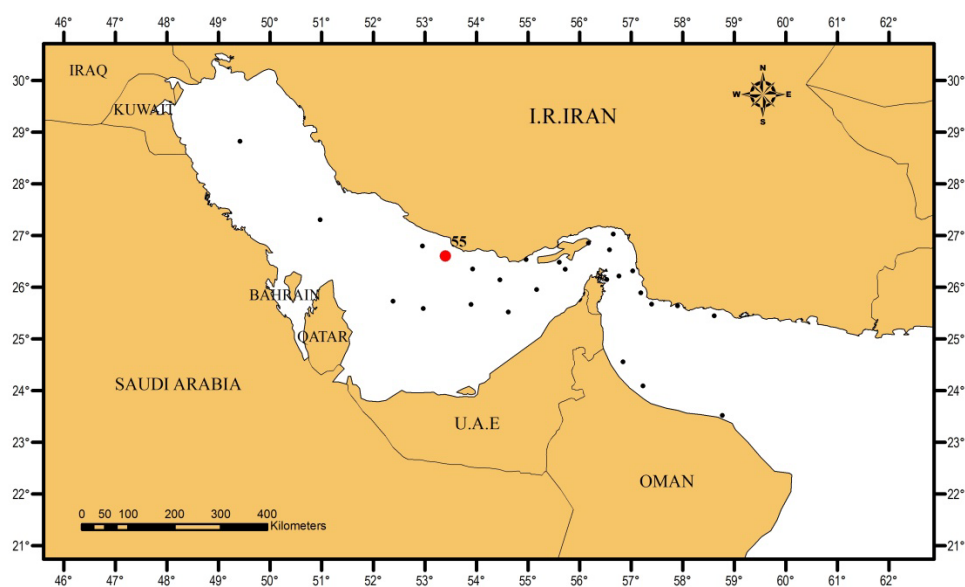


Plate 31: *Archaeoperidinium minutum*: cyst shows erect process



Map 31: *Archaeoperidinium minutum* occurrence in the RSA, Winter 2006

Phylum: Miozoa

Class; Dinophyceae Fritsch 1927

Order; Peridiniales Haeckel 1894

Family; Kolkwitiellaceae Lindemann, 1928

Genus; *Diplopsalis* R.S.Bergh, 1881

Species: *Diplopsalis lenticula*

Scientific name: *Diplopsalis lenticula* Bergh 1881

Paleontological name: -

Figure No.: Plate 32

References:

Sonneman and Hill (1997), fig 34; Orlova *et al.*, (2004), Figure 12;

Description:

Spherical and single layer walled cyst, which has a brown colour. The cyst surface is without any ornamentations and paratabulation (Plate 32, A-D). The archeopyle is theropylic and epicysta, and formed by a suture stretching along almost half of the cyst boundary and reflected between the dorsal of epicystal plate.

Size:

D: 49µm

Occurrence in RSA:

The presence of the species in the RSA from Cruise Winter 2006 has been shown on Map 32. Presence of the cyst in sites: 98, 21a, 83, 78, 72, 55, 25

Occurrence in the world:

Australia (Sonneman and Hill 1997), South China Sea (Liu *et al.*, 2015), Yellow Sea (Liu *et al.*, 2015), Turkey (Balkis *et al.*, 2016).

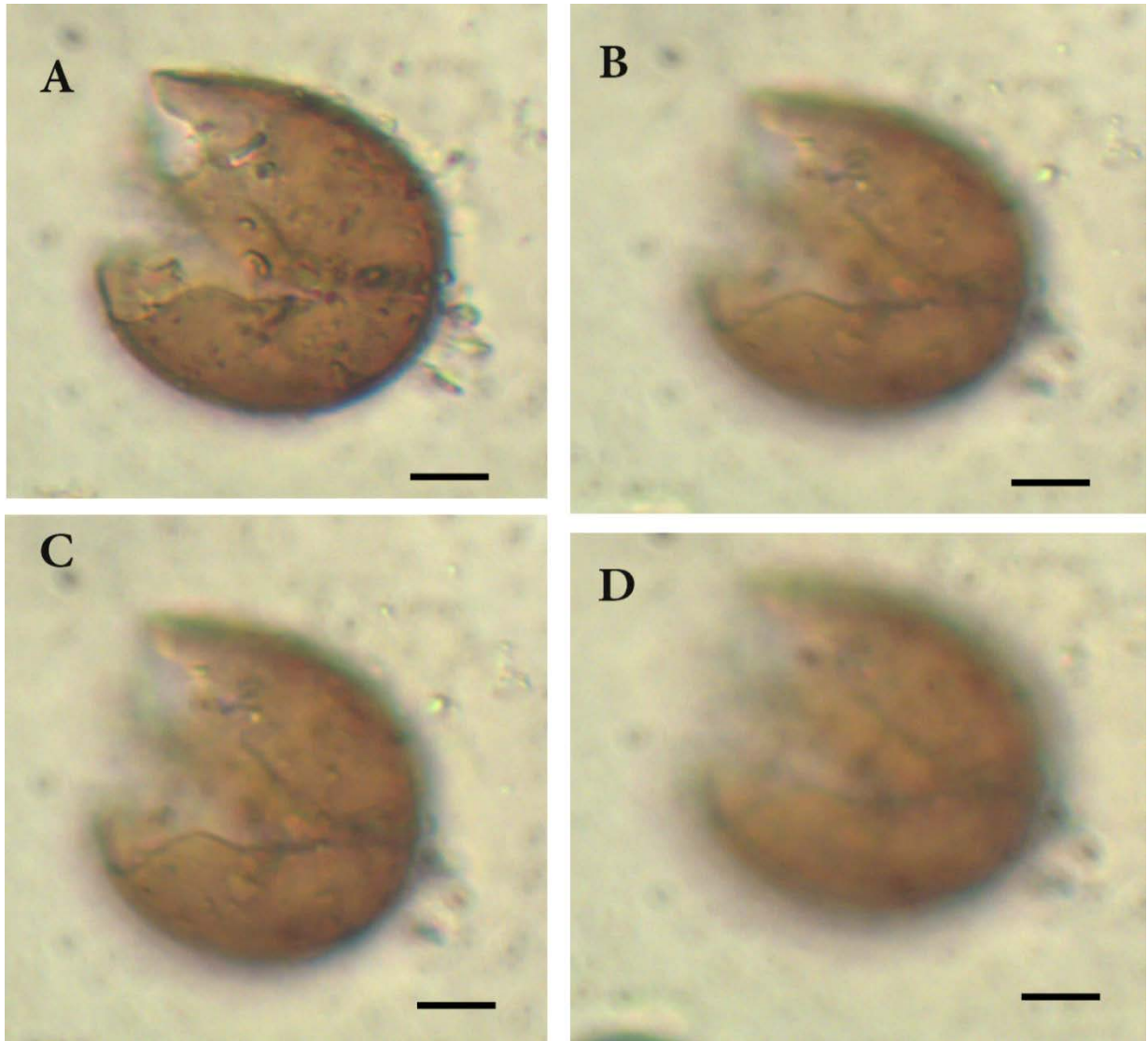
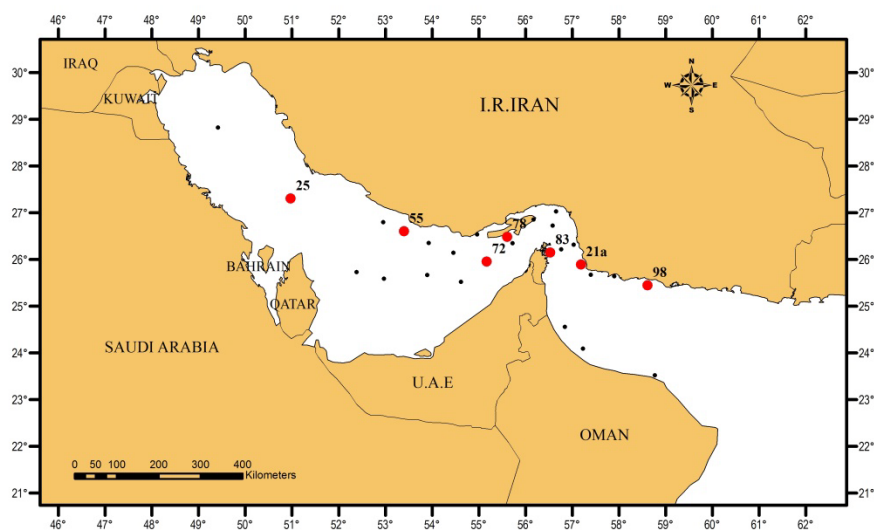


Plate 32: *Diplopsalis lenticula*: brown cyst shows theropylic and epicystal archeopyle



Map 32: *Diplopsalis lenticular* occurrence in the RSA, Winter 2006

Phylum: Miozoa

Class; Dinophyceae Fritsch 1927

Order; Peridiniales Haeckel 1894

Family; Kolkwitziellaceae Lindemann, 1928

Genus; *Diplopsalis* R.S.Bergh, 1881

Species: *Diplopsalis* sp.1

Scientific name: *Diplopsalis* sp.1

Paleontological name: *Durbridinium* sp.1

Figure No.: Plate 33

References:

Bolch *et al.*, (1990), Figure 30;

Sonneman & Hill (1997), Figure 35;

Attaran-Fariman (2007), Figure 44;

Attaran-Fariman *et al.*, (2012), Figure 39

Description:

This is a spherical dark brown smooth walled single layer cyst (Plate33). The thecal plate is sub-trapezoidal and the larger parallel side is not straight with a little concave in this side and is formed by loss of intercalary and prismatic plates (Plate 33, A-B).

Size:

D: 55µm

Occurrence in RSA:

The presence of the species in the RSA from Cruise Winter 2006 has been shown on Map 33. Presence of the cyst in sites: 98, 16a

The cyst has been reported from northern part of the Sea of Oman (Attaran-Fariman, 2007)

Occurrence in the world:

Australia (Bolch *et al.*, 1990); Sonneman & Hill (1997),

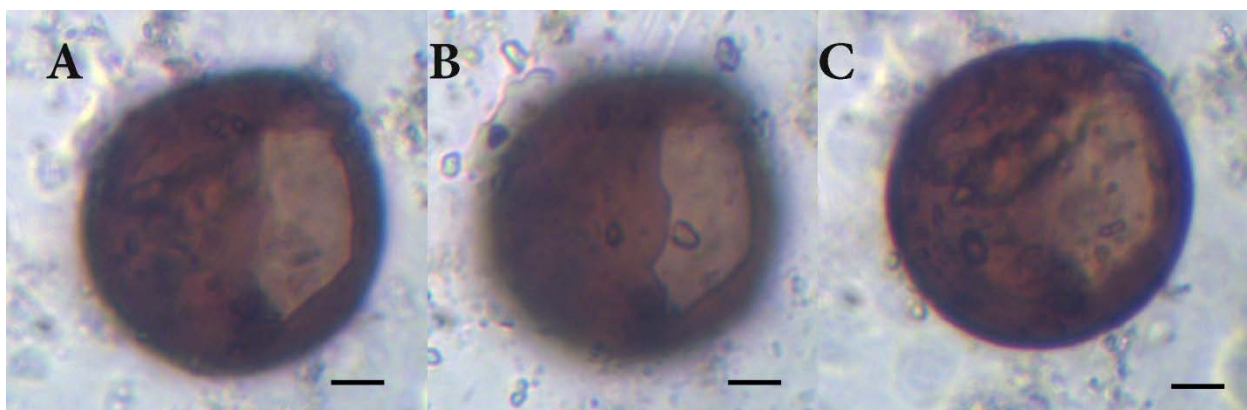


Plate 33: *Diplopsalis* sp.: cyst shows archeopyle in different focuses



Map 33: *Diplosalis* sp. 1 occurrence in the RSA, Winter 2006

Phylum: Miozoa

Class; Dinophyceae Fritsch 1927

Order; Peridinales Haeckel 1894

Family; Kolkwitziellaceae Lindemann, 1928

Genus; *Diplopsalis* R.S.Bergh, 1881

Species: *Diplopsalis* sp.2

Scientific name: *Diplopsalis* sp.2

Paleontological name: -

Figure No.: Plate 34

References:

Not found

Size:

D: 54µm

Description:

Spherical smooth walled dark brown cyst. The archeopyle is parallelogram and is probably formed by loss of 1a intercalary plate. A quadrilateral whose opposite sides are parallel and unequal, one of the smaller sides is convexed (Plate 34, A-B). No other feature is observed in this dinocyst. This cyst type differs from *Diplopsalis* sp1. by its parallelogram shape of archeopyle.

Occurrence in RSA:

The presence of the species in the RSA from Cruise Winter 2006 has been shown on Map 34. Presence of the cyst in sites: 98

Occurrence in the world:

Not reported from anywhere else

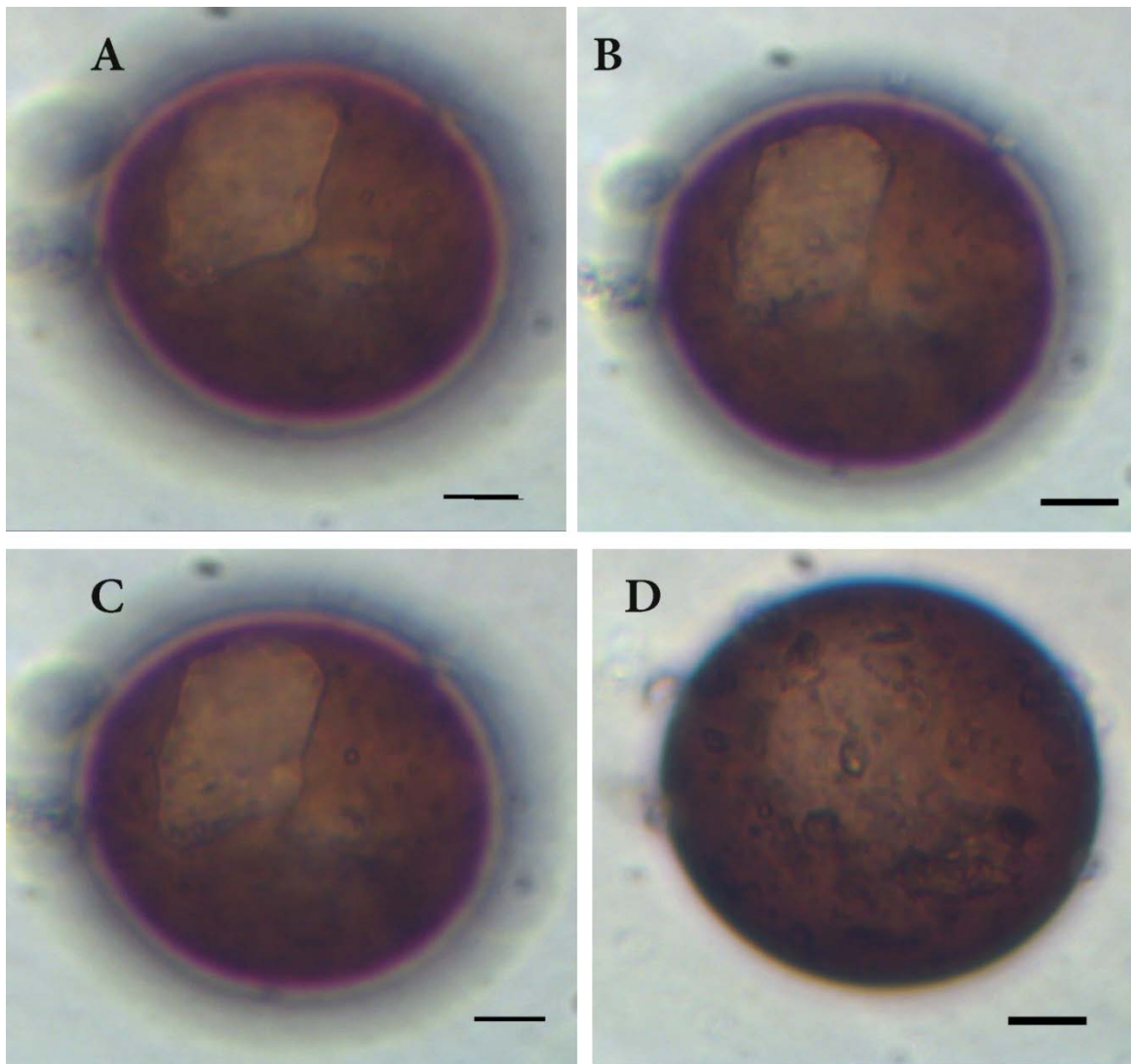
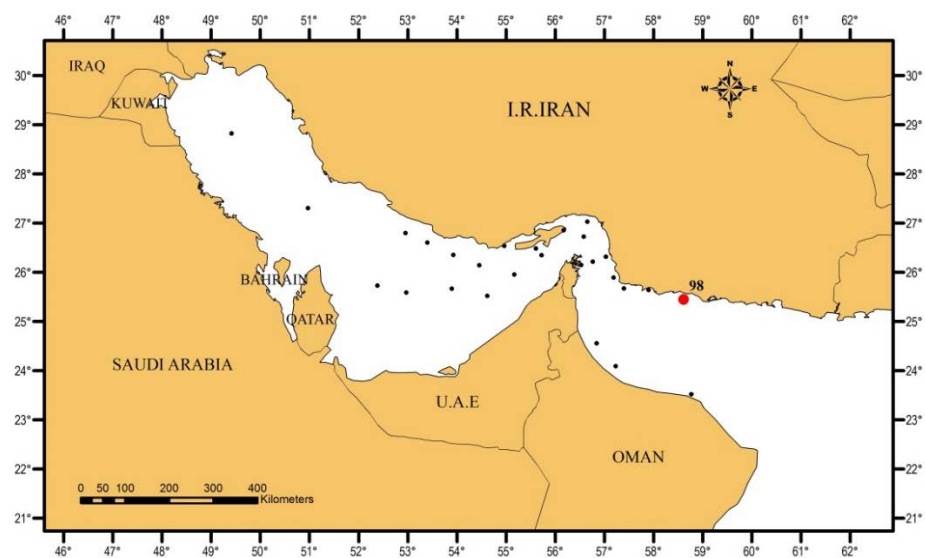


Plate 34: *Diplopsalis* sp.2: cyst shows archeopyle in the different focuses



Map 34: *Diplopsalis* sp. 2, occurrence in the RSA, Winter 2006

Phylum: Miozoa

Class; Dinophyceae Fritsch 1927

Order; Peridiniales Haeckel 1894

Family; Kolkwitziellaceae Lindemann, 1928

Genus; *Diplopelta* Stein.Jørgensen, 1912

Species: *Diplopelta parva*

Scientific name: *Diplopelta parva* (Abé) Matsuoka 1988

Paleontological name:

Figure No.: Plate 35

References:

Orlova *et al.*, (2004), Figures 8-9

Uzar *et al.*, (2010), Figure 18;

Size:

D: 35µm

Description:

The cyst is round with brownish colour. The cyst wall is ornamented with pointed tips spines. All cysts in the *Diplopsalis* group have a spherical brown cyst and characterized by having a theropylic archeopyle that reflected complete or incomplete parasutures, often in combination (Dale *et al.*, 1993). In this group, only *D. symmetrica* and *D. Parva* are ornamented cysts. *D. Symmetrica* has dense hair-like spines and distinctly differed from aciculate, slightly curved and scattered spines of *D. parva*.

Occurrence in RSA:

The presence of the species in the RSA from Cruise Winter 2006 has been shown on Map 35. Presence of the cyst in sites: 97, 88, 85

The cyst has been reported previously from northern part of the Sea of Oman (Iranian side, Attaran-Fariman 2013)

Occurrence in the world:

Mediterranean Sea (Uzar *et al.*, 2013)

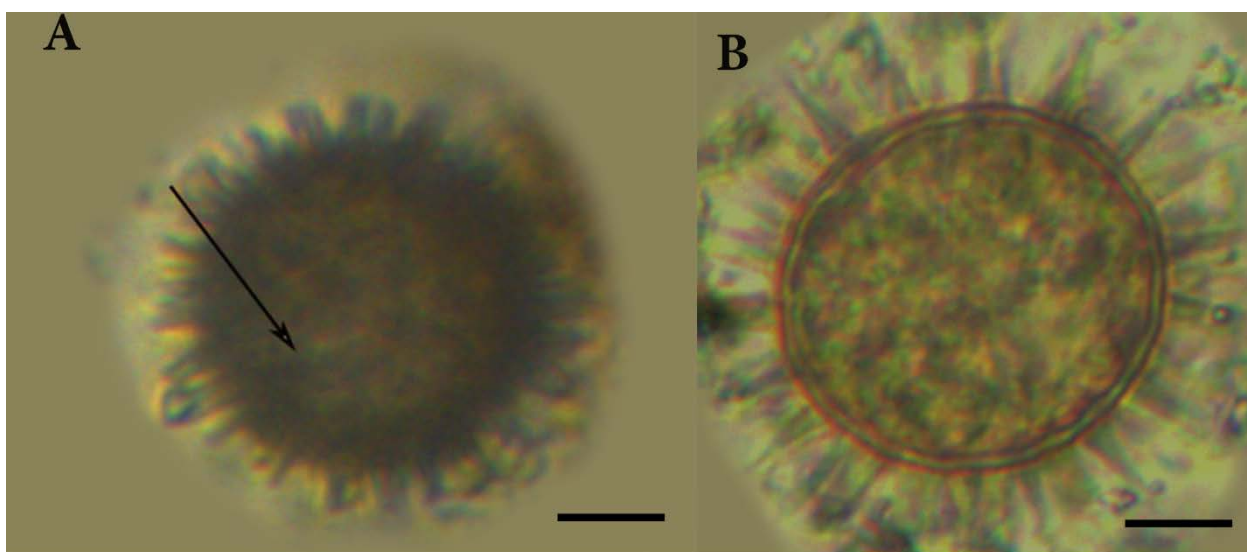
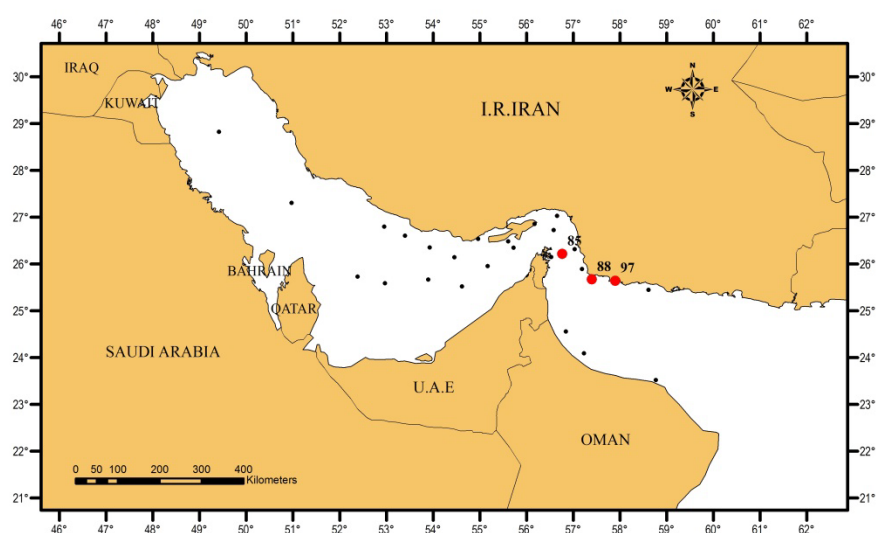


Plate 35: *Diplopelta parva*; A-empty cyst shows archeopyle, B- live cyst shows cyst content



Map 35: *Diplopelta parva* presence in the RSA, Winter 2006

Phylum: Miozoa

Class; Dinophyceae Fritsch 1927

Order; Peridinales Haeckel 1894

Family; Kolkwitzellaceae Lindemann, 1928

Genus; *Diplopelta* Stein.Jørgensen, 1912

Species: *Diplopelta symmetrica*

Scientific name: *Diplopelta symmetrica* Pavillard 1913

Paleontological name: -

Figure No.: Plate 36

References:

Dale *et al.*, (1993), Figures 5-8

Description:

The cyst is spherical to subspherical and dark brown in colour when it has content, and light brown when it is empty. The cyst wall is thick and densely ornamented with hair like processes. The processes do not cover the cyst wall completely, and rounded empty part of ornaments can be noted (Plate 36). The areas without processes vary in size and frequency (Dale *et al.*, 1993). The cyst has a theropylic zigzag split-like archeopyle.

Size:

D: 48µm

Occurrence in RSA:

The presence of the species in the RSA from Cruise Winter 2006 has been shown on Map 36. Presence of the cyst in sites: 93, 97

Occurrence in the world:

Nepal (Dale *et al.*, 1993)

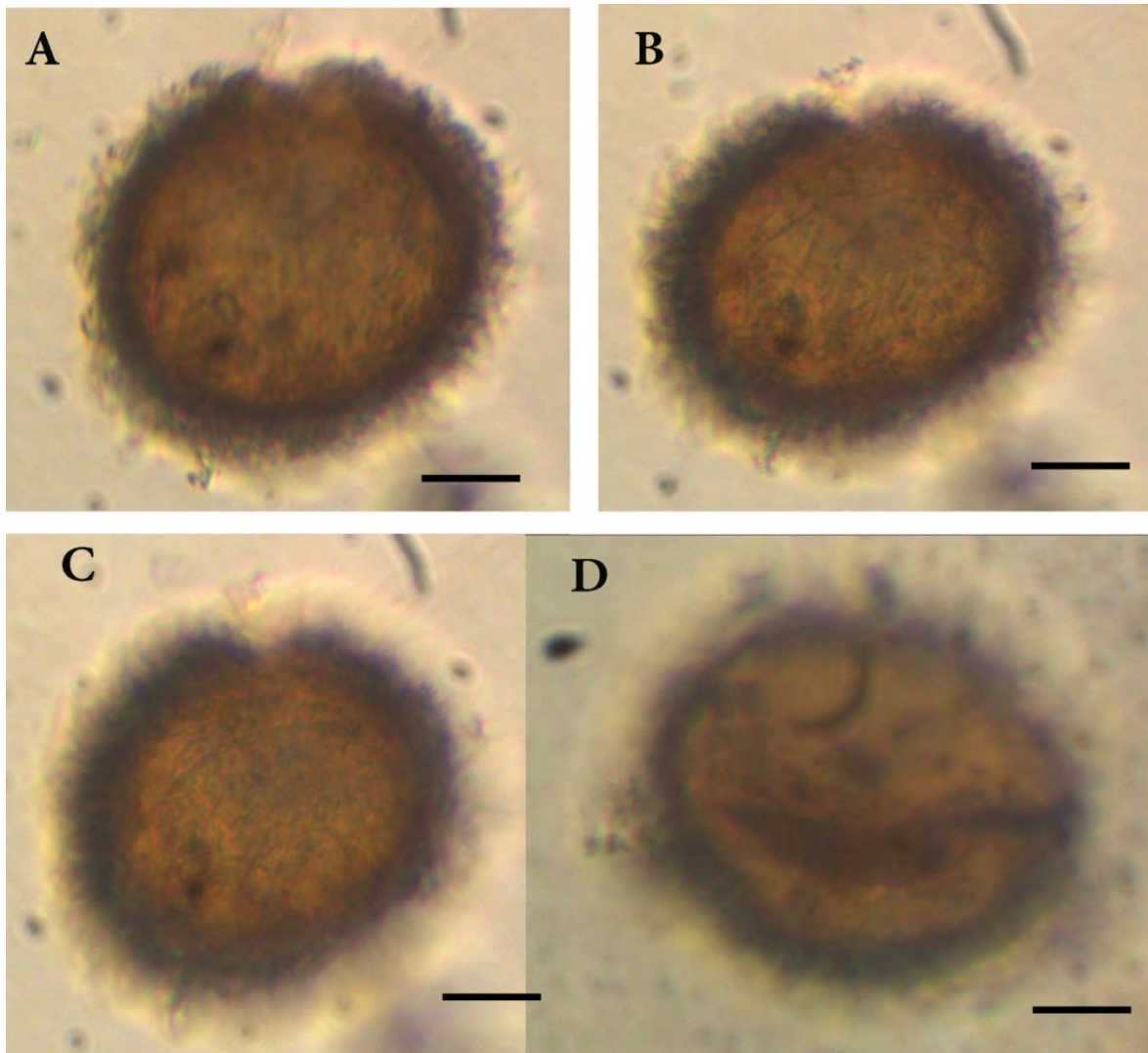
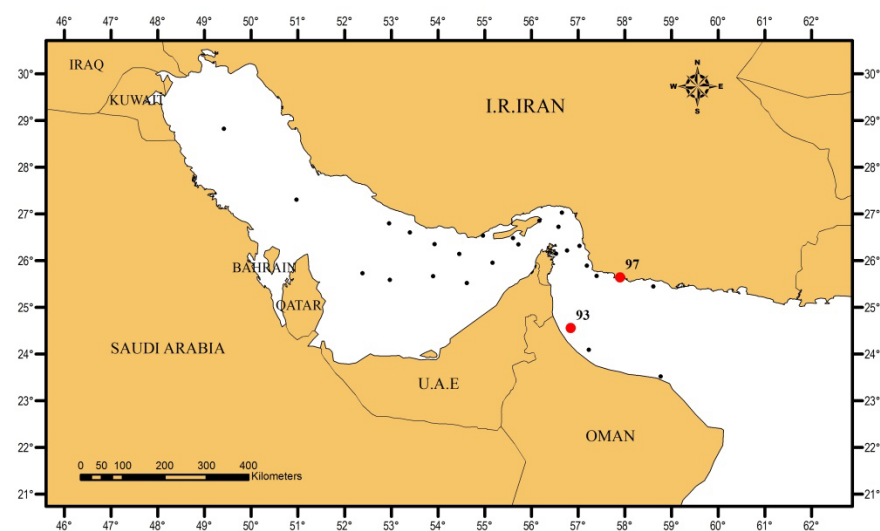


Plate 36: *Diplopelta symmetrica*: A-C cysts show hair like process; D- cyst shows archeopyle



Map 36: *Diplopelta symmetrica* presence in the RSA, Winter 2006

Phylum: Miozoa Cavalier-Smith 1987

Class; Dinophyceae Fritsch 1927

Order; Peridiniales Haeckel 1894

Family: Thoracosphaeraceae Schiller, 1930

Genus; Pyrodinium Plate 1906

Species; *Pyrodinium bahamense*

Scientific name: *Pyrodinium bahamense* Plate 1906

Paleontological name: *Polysphaeridium zoharyi* Rossignol 1962

Figure No.: Plates 37A,B

Reference:

Plate (1906), Plate 19;

Morquecho *et al.*, (2014) Plate II;

Usup *et al.*, (2012), Figure 5;

Description:

Spherical cyst with microgranular to granular, transparent and thick cyst wall. Processes are frequent (Plate 37A-B), hollow with open and aculeate distal ends (Plates 37, C-F), and the processes have variable lengths (Plates 37, C-F). The archeopyle is epicystal and most of the times cyst splits to parts (Plate 37, G). The species is a warm water species (Wall *et al.*, 1997) and is one of the most important causative species of Paralytic Shellfish Poisoning (PSP). The oval cyst shapes were found in RSA. The process resembles the *P. bahamense*; it seems cyst is folded (Plate 37B).

Size:

D: 48–54 µm

Occurrence in RSA:

The presence of the species in the sediment sample of the Winter Cruise 2006 of RSA is shown on Map 37, in stations: 25, 97, 83, 16a, 77, 70, 72, 66, 56, 55, and 11.

Bradford and Wall (1984) previously reported this species from the inner RSA as dominant species. It has been reported also from Kuwait sediment (Husain and Lewis 2004); extreme west of the inner RSA and from northern part of the Sea of Oman (Attaran-Fariman 2016).

Occurrence in the world:

Southwest Asia; Philippines, Turkey, Colombia, Caribbean Islands, South Atlantic and Pacific Oceans, Gulf of Mexico and the Banda Sea (off Indonesia) southern Korea, the South China Sea, the Sea of Oman, Bay of Bengal, Coastal areas off North Australia and off the NW Iberian Peninsula, Papua New Guinea.

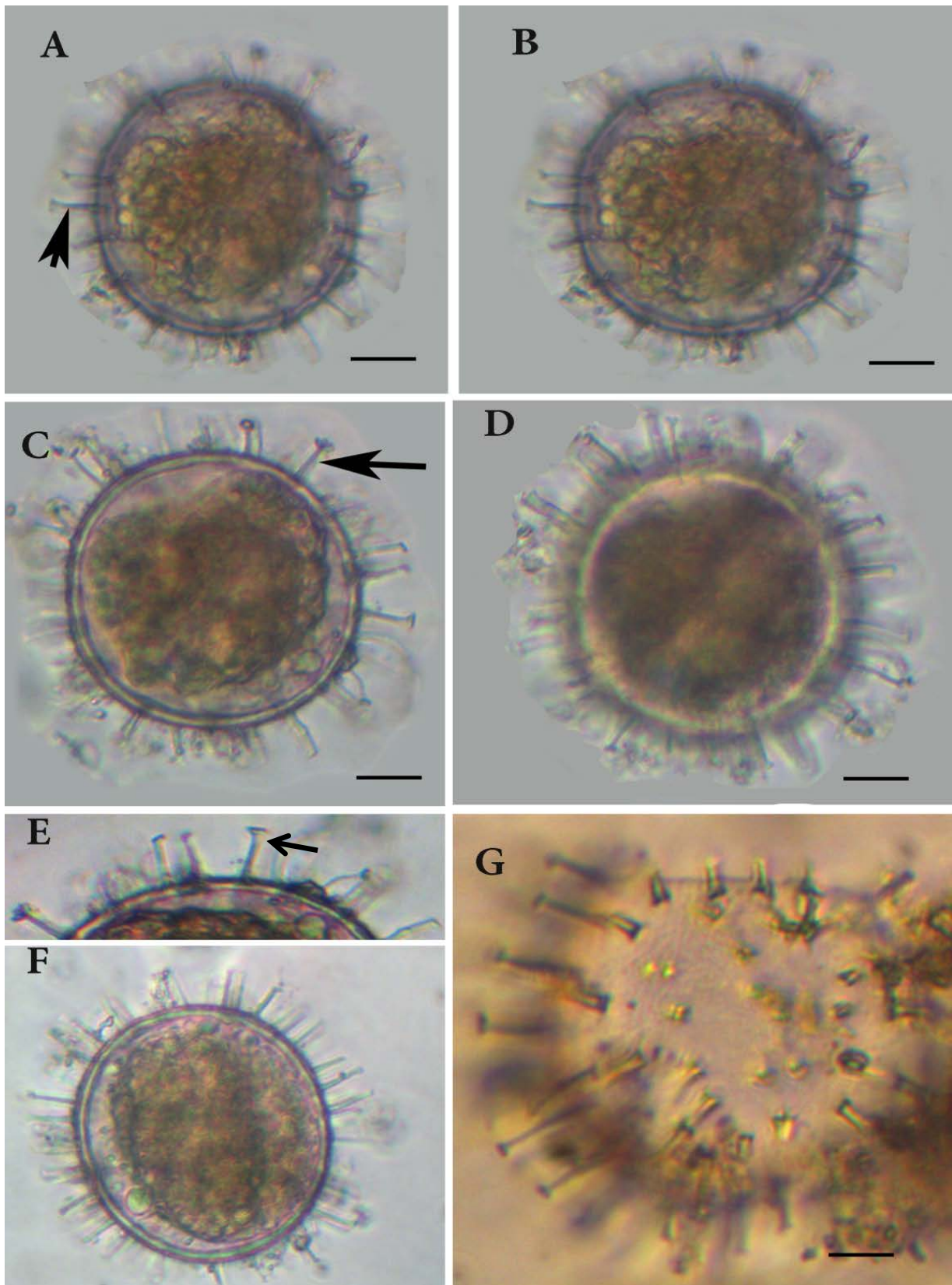


Plate 37A: *Pyrodinium bahamense*; A-B cyst in the deep focus showing cyst content and red accumulation body, C-D cyst in surface focus showing hollow process, E-F live cyst shows distally bifurcate process(Arrow), G- empty cyst

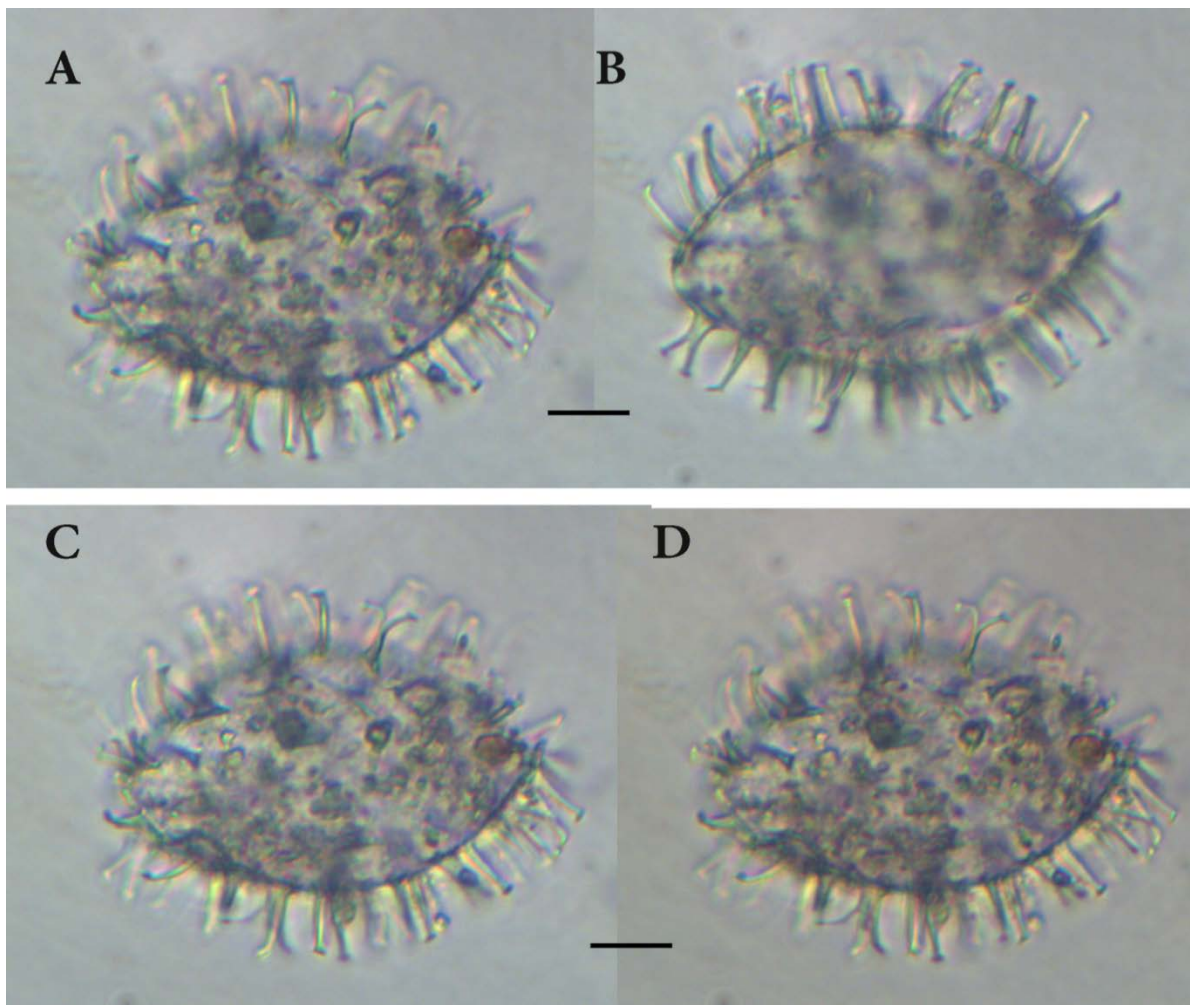
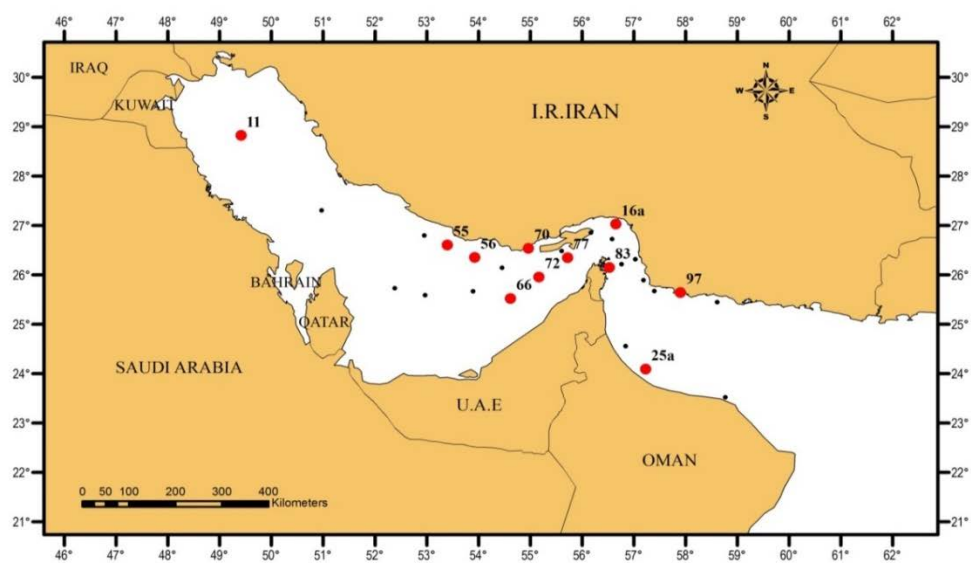


Plate 37B: *Pyrodinium bahamense*: cyst in different focuses shows bifurcate processes



Map 37: *Pyrodinium bahamense*: occurrence in the RSA, Winter 2006

Phylum: Miozoa Cavalier-Smith 1987

Class; Dinophyceae Fritsch 1927

Order; Peridiniales Haeckel 1894

Family: Thoracosphaeraceae Schiller 1930

Genus: *Alexandrium* Halim, 1960

Species: *Alexandrium pseudogonyaulax*

Scientific name: *Alexandrium pseudogonyaulax* (Biecheler) Horiguchi ex Kita & Fukuyo 1992

Paleontological name: -

Figure No.: Plate 38

Reference:

Montresor 1995, Figures 8-15;

Bravo *et al.*, (2006), Figures 2-18;

Zmerli *et al.*, (2016), Figure 2.

Description:

Spherical cyst has a thick paratabulated cyst wall and an outer thin membrane (Plate 38). This cyst type with different cysts wall, size, and contents have been reported (i.e.; Montresor *et al.*, 1995; Bravo *et al.*, 2006; Zmerli *et al.*, 2016). The cyst wall is paratabulated or smoothed. In ROPME samples, both cyst walls have been observed (Plate 38, A and D). Montresor (1995) documented that smooth outer membrane surrounded the cyst for a prolonged period and never been observed in the cyst collected from natural sediments. In the study of Bravo *et al.*, (2006) also the cultured cyst (Figure 12) shows smooth outer membrane. However, in the ROPME natural samples, two types of cysts were observed; first type cysts were surrounded with an outer membrane (Plate 38, A-B). Two types of cyst walls were observed in our samples; one type shows paratabulation on the wall (Plate 38, A-C) corresponding to the description of Montresor (1995) and it has yellowish-brown green granular content with red accumulation body. The second type is without any paratabulation (Plate 38, D). The second type is almost spherical with one flattened side and it has brownish- green vesicular contents and minor red accumulation body

Size:

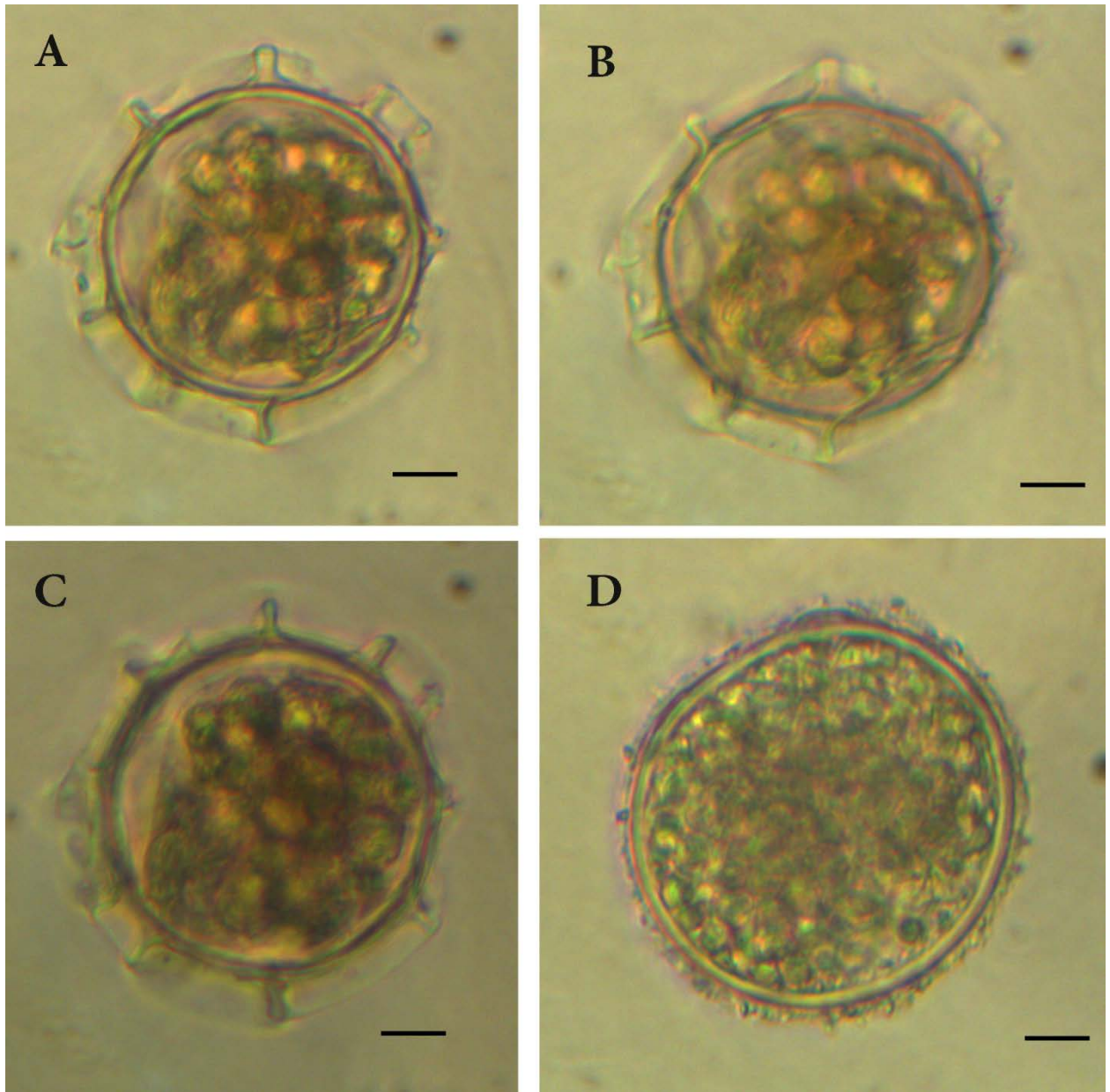
D: 57µm

Occurrence in RSA:

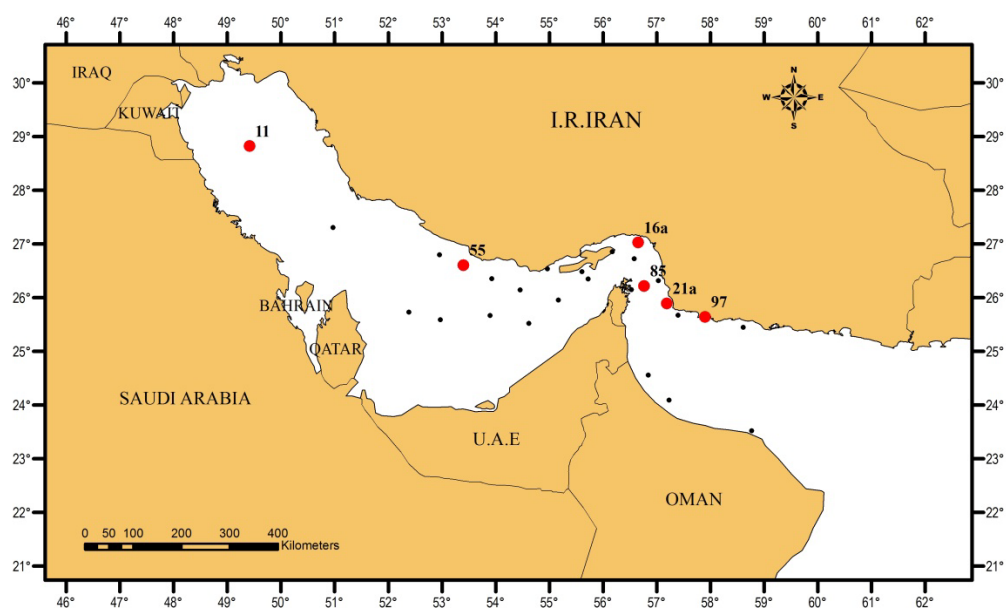
The presence of the species in the RSA from Cruise Winter 2006 has been shown on Map 38. Presence of the cyst in sites: 97, 21a, 85, 16a, 55, 11

Occurrence in the world:

Spain (Bravo *et al.*, 2006, Penna *et al.*, 2008); Tunisia (Zmerli *et al.*, 2015). Mediterranean coast (Satta *et al.*, 2010; Genovesi *et al.*, 2013).



**Plate 38: *Alexandrium pseudogonyaulax*: cyst shows a thin membrane around process
(all scale bar =10µm)**



Map 38: *Alexandrium pseudogonyaulax*: presence in the RSA, Winter 2006

Phylum: Miozoa Cavalier-Smith 1987

Class; Dinophyceae Fritsch 1927

Order; Peridiniales Haeckel 1894

Family: Thoracosphaeraceae Schiller 1930

Genus: *Alexandrium* Halim, 1960

Species: *Alexandrium* cf. *affine*

Scientific name: *Alexandrium affine* (H.Inoue & Y.Fukuyo) Balech

Paleontological name: -

Figure No.: Plate 39

Reference:

Bolch *et al.*, (1991), Figure 15;

Band-Schmidt *et al.*, (2003), Figure11;

Aydın *et al.*, (2015), Figure 2a

Description:

Spherical cyst with a thick single layer wall. Cyst is without any ornamentation. The cyst is surrounded with a gelatinous layer containing many attached fine particles. The live cyst has one or two red accumulation body. The morphology of *Alexandrium* spp are very simple without any exclusive characteristic. Their exact identification without germination experiment is very difficult (Shin *et al.*, 2014). As RSA samples were preserved in the formalin, the germination experiment was not possible and the cyst is only identified based on cyst morphology. The cyst of *A. affine* resembles to the cyst of *A. leei*. The later species has a bright yellow accumulation body; the former species has a bright red accumulation body (Gu & Liu, 2013).

Size:

D: 31µm

Occurrence in RSA:

The presence of the species in the RSA from Cruise Winter 2006 has been shown on Map 39. Presence of the cyst in sites: 26a, 98, 25a, 97, 88, 87, 16a, 77, 66, 69, 55, 40, 43

The cyst has been reported from northern part of the Sea of Oman (Attaran-Fariman, 2016)

Occurrence in the world:

Gulf of California (Band-Schmidt *et al.*, 2003); South-east Asia: Malaysia (Leaw *et al.*, 2005); China, Yellow sea (Liu *et al.*, 2012); Aliğa Bay (Eastern Aegean Sea) (Aydın *et al.*, 2015);

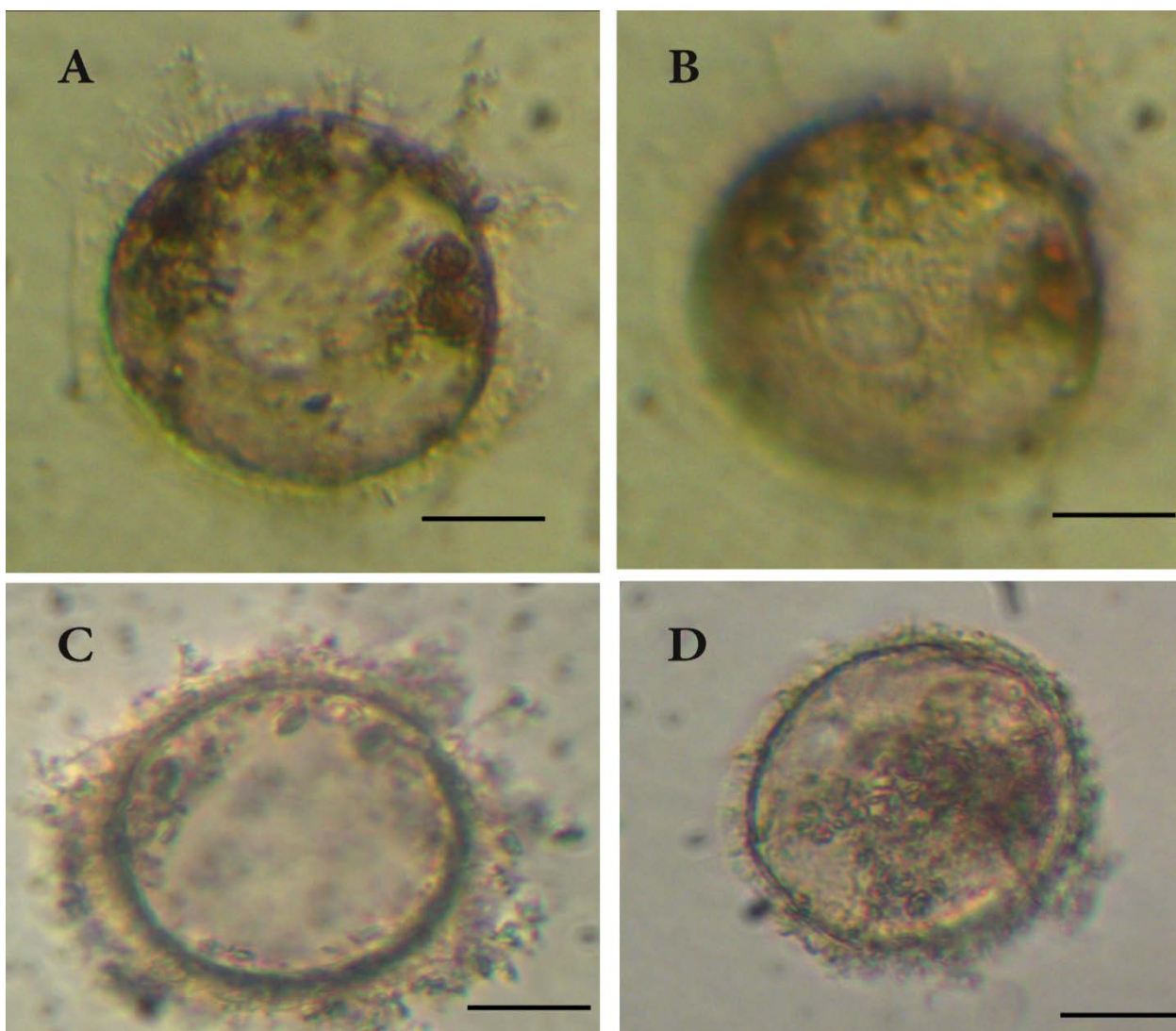
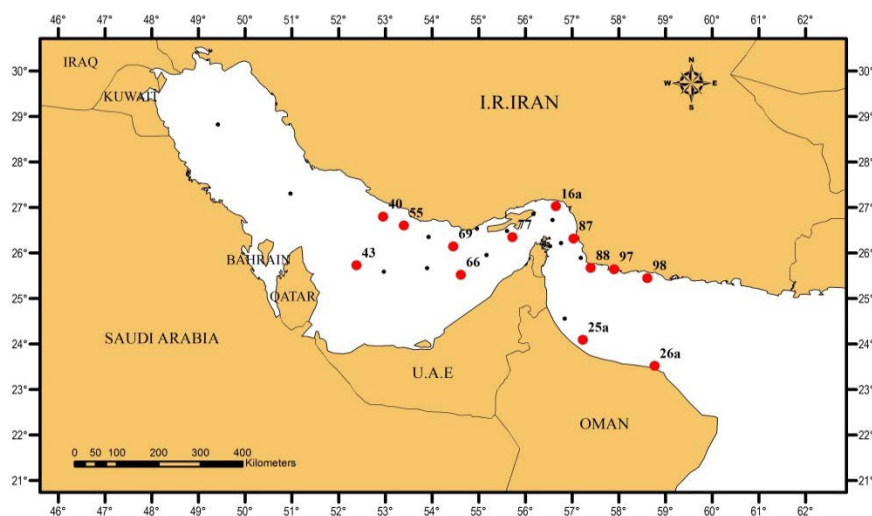


Plate 39: *Alexandrium* cf. *affine*, A-B, cyst shows two red accumulation body, C-D empty cyst shows with a mucilaginous layer



Map 39: *Alexandrium* cf. *affine* occurrence in the RSA, Winter 2006

Phylum: Miozoa Cavalier-Smith 1987

Class; Dinophyceae Fritsch 1927

Order; Peridinales Haeckel 1894

Family: Thoracosphaeraceae Schiller 1930

Genus: *Alexandrium* Halim, 1960

Species: *Alexandrium* cf. *tamarense*/A. *cattenella*

Scientific name: *Alexandrium tamarense* (Lebour) Balech 1995

Paleontological name: -

Figure No.: Plate 40

Reference:

Bolch *et al.*, (1991) Figure 14;

Bolch and Hallegraeff (1997) Figures. 7-9;

Satta *et al.*, (2011), Figure3

Description:

The cyst has an elongated ellipsoidal outline with rounded ends. Cyst contains colourless starch granule and red accumulation body; however, we found only empty cysts. The morphology of the cyst is very similar to the ellipsoid cyst of *A. catenella*, and in the literature, it is referred to as *A. tamarense*/ *A. catenella* complex (i.e.; Matsuoka & Fukuyo 2000; Shin *et al.*, 2008) and almost impossible to distinguish their cysts from each other.

Size:

W: 28µm

Occurrence in RSA:

The presence of the species in the RSA from Cruise Winter 2006 has been shown on Map 40. Presence of the cyst in sites: 11

The cyst has been reported from northern part of the Sea of Oman (Attaran-Fariman 2007; Attaran-Fariman, 2016)

Occurrence in the world:

Tasmania (Bolch & Hallegraeff 1991); South-west Asia: Turkey (Asia) (Balkis *et al.*, 2016); Western Mediterranean coast (Bravo *et al.*, 2006);

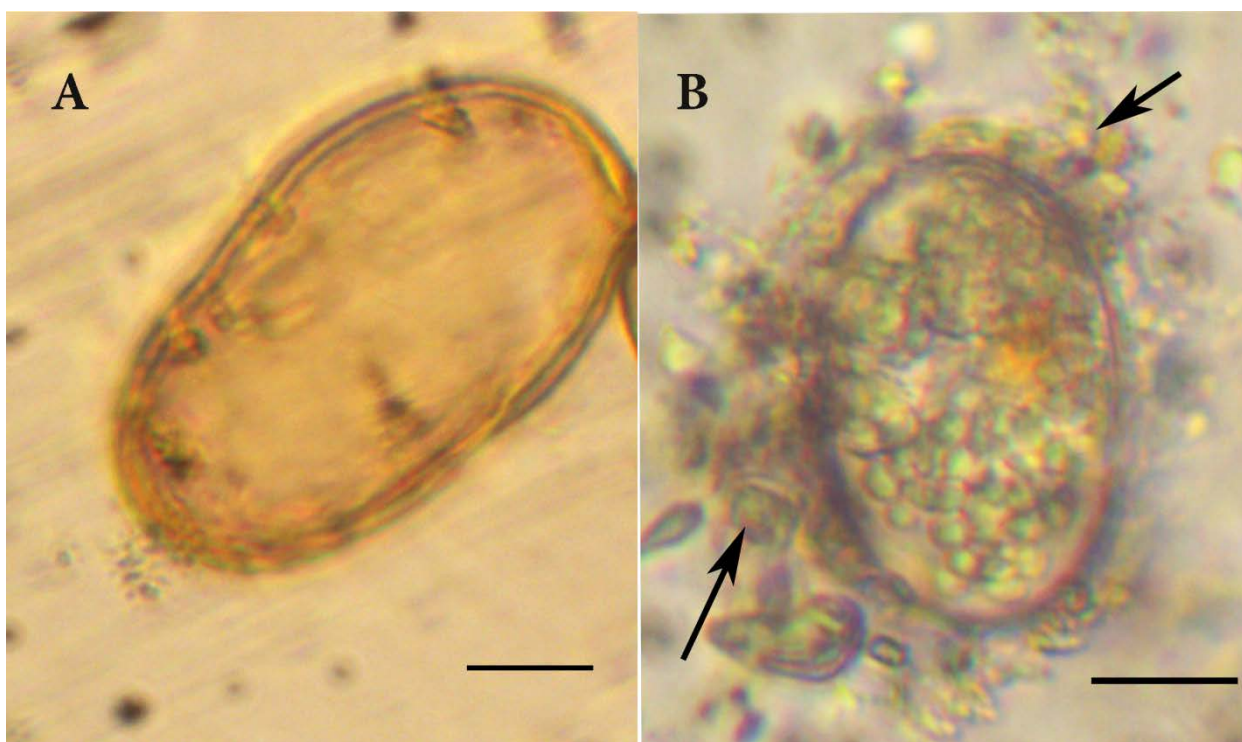
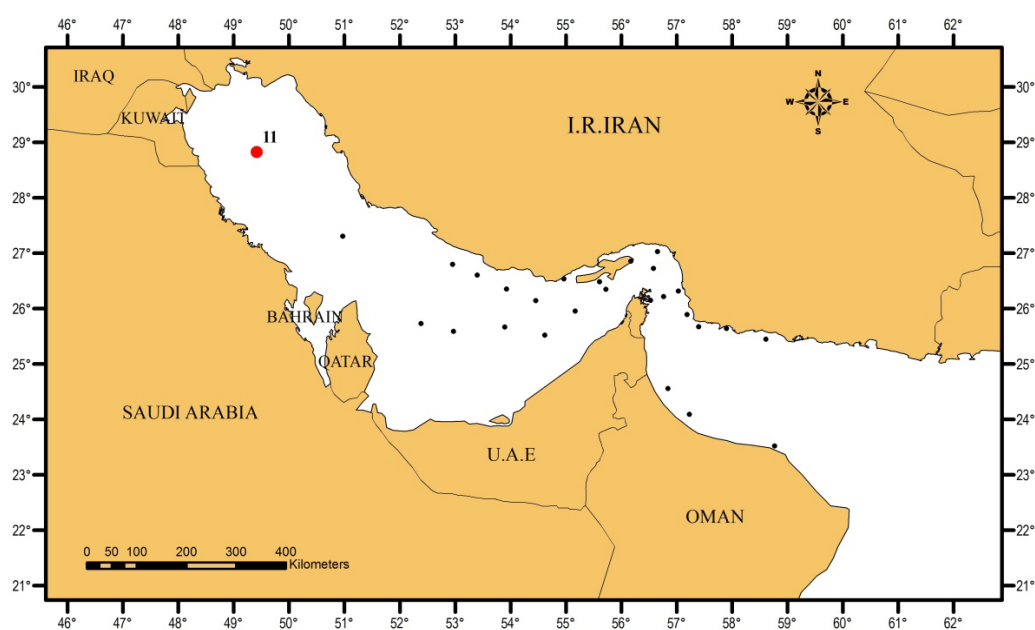


Plate 40: *Alexandrium cf. tamarense*, *A. cattenella*: empty cyst showing ellipsoidal shape B: live cyst showing mucilaginous layer (arrow)



Map 40: *Alexandrium cf. tamarense*/*A. cattenella* occurrence in the RSA, Winter 2006

Phylum: Miozoa Cavalier-Smith 1987

Class; Dinophyceae Fritsch 1927

Order; Peridiniales Haeckel 1894

Family: Thoracosphaeraceae Schiller 1930

Genus: *Alexandrium* Halim, 1960

Species: *Alexandrium* cf. *minutum*

Scientific name: *Alexandrium minutum* Halim 1960

Paleontological name: -

Figure No.: Plate 41

Reference:

Graces *et al.*, (2004), Figure 4;

Aydin *et al.*, (2013), Figure 1C;

Yoon & Shin (2013), Figure 8

Description:

The cyst is almost circular. Cysts are sometimes hemispherical in shape. The cyst wall is clear and lightly covered with mucilage layer (Plate 41B). The cyst contains granular with orange-red accumulation body.

Size:

D: 29µm

Occurrence in RSA:

The presence of the species in the RSA from Cruise Winter 2006 has been shown on Map 41. Presence of the cyst in sites: 98, 77

The cyst has been previously reported from northern part of the Sea of Oman (Attaran-Fariman, 2016)

Occurrence in the world:

Egypt (Ismaeal and Khadr, 2003); Mediterranean Sea (Anglès *et al.*, 2010); Korea (Yoon and Shin 2013)

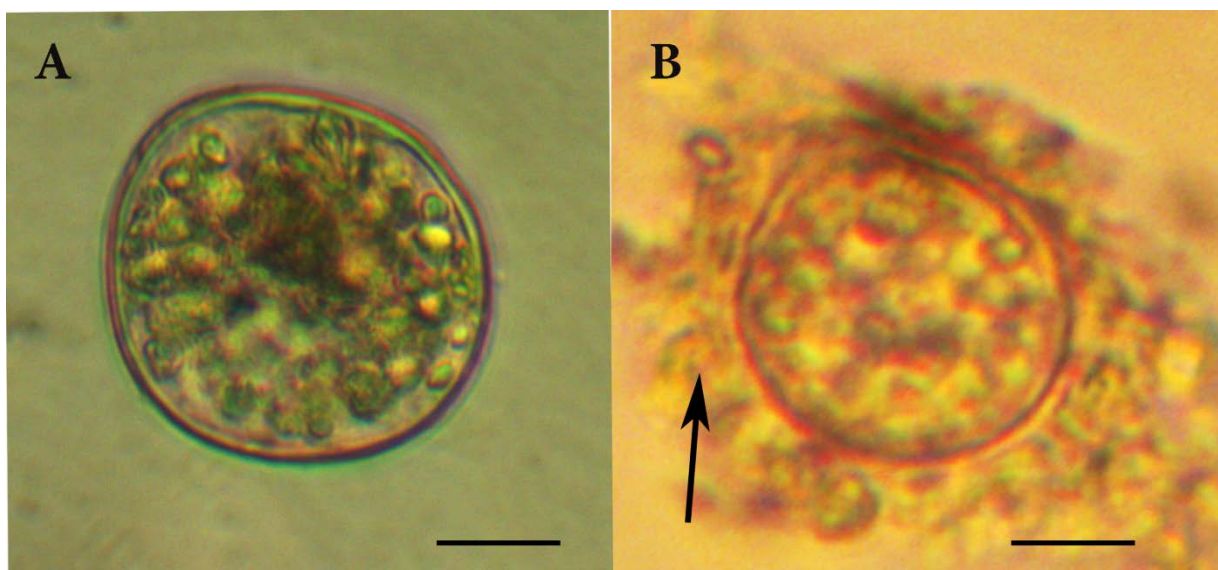
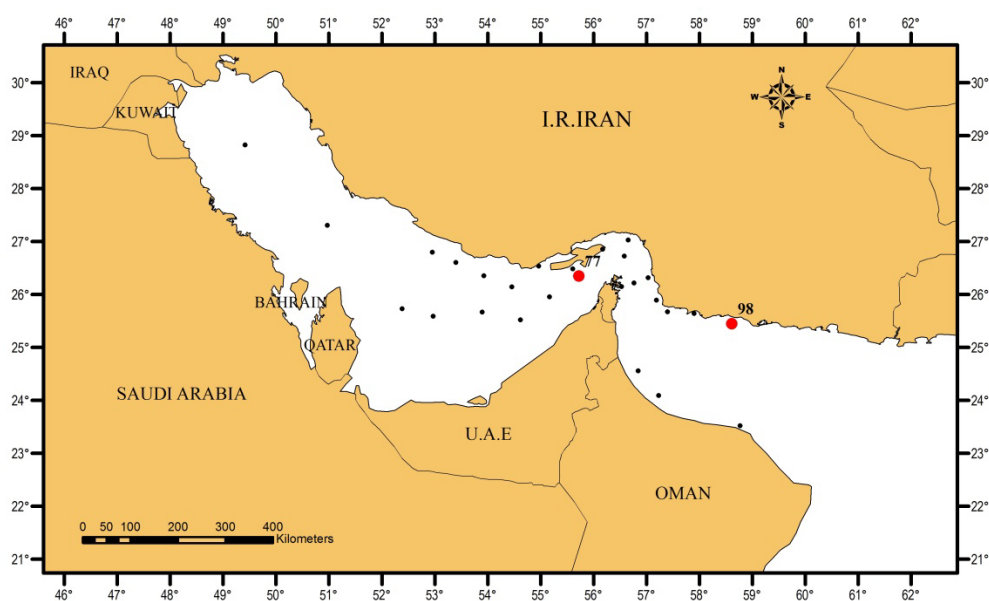


Plate 41: *Alexandrium minutum*: A; showing contents B; cyst showing mucilaginous layer (arrow)



Map 41: *Alexandrium minutum* occurrence in the RSA, Winter 2006

Phylum: Miozoa Cavalier-Smith 1987

Class; Dinophyceae Fritsch 1927

Order; Peridinales Haeckel 1894

Family: Thoracosphaeraceae Schiller 1930

Genus: *Alexandrium* Halim, 1960

Species: *Alexandrium* sp.1

Scientific name: *Alexandrium* sp.1

Paleontological name: -

Figure No.: Plate 42

Reference:

Morquecho & Lechuga-Deveze (2003), Figure 19

Description:

Spherical cyst has relatively thick single layer wall. The cyst is surrounded by a circular mucilaginous layer with attached particles. Cyst contains yellow-greenish granular materials. Dark yellow accumulation body was observed. This cyst type is morphologically similar to *A. margalefii* that was documented by Morquecho & Lechuga-Deveze (2003); however, the cyst from RSA has more regular circular mucilaginous layer.

Size:

D: 33µm

Occurrence in RSA:

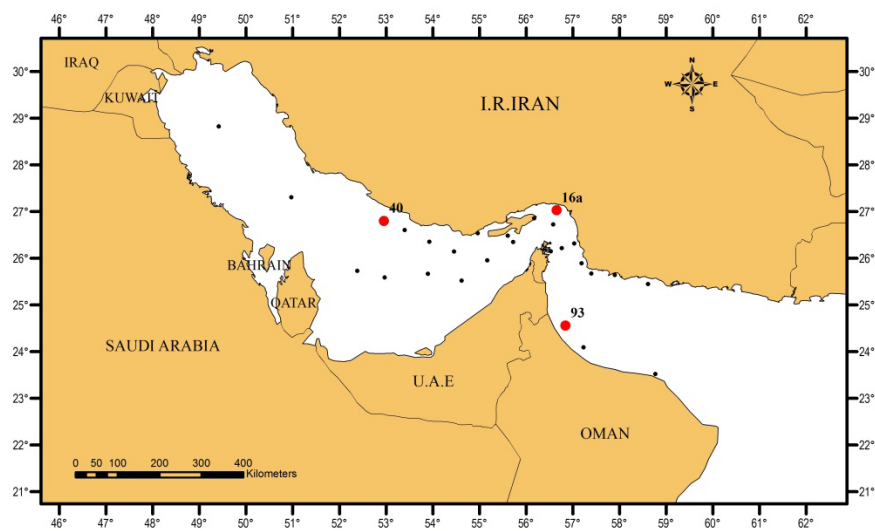
The presence of the species in the RSA from Cruise Winter 2006 has been shown on Map 42. Presence of the cyst in sites: 93, 16a, 40

Occurrence in the world:

Gulf of California (Morquecho & Lechuga-Deveze, 2003)



Plate 42: *Alexandrium* sp.1 cyst with circular mucilaginous layer



Map 42: *Alexandrium* sp.1 presence in the RSA, Winter 2006

Phylum: Miozoa Cavalier-Smith 1987

Class; Dinophyceae Fritsch 1927

Order; Peridiniales Haeckel 1894

Family: Thoracosphaeraceae Schiller 1930

Genus: *Alexandrium* Halim, 1960

Species: *Alexandrium* sp.2

Scientific name: *Alexandrium* sp.2

Paleontological name: -

Figure No.: Plate 43

Reference:

Rao & Stewart (2011), Figure 2G

Description:

Spherical cyst without any surface ornamentation. The cyst contains many food reservoirs and oil droplets with red accumulation body. The cyst has two layer walls. There is a transparent gelatinous material containing fine sediments and particles around the cyst. There is no detail of the archeopyle type in this species. As the empty cyst has a fragile and thin wall, it is not preservable in the consolidated sediment

Size:

D: 32µm

Occurrence in RSA:

The presence of the species in the RSA from Cruise Winter 2006 has been shown on Map 43. Presence of the cyst in sites: 69, 56, 11.

Occurrence in the world:

Not reported from anywhere else

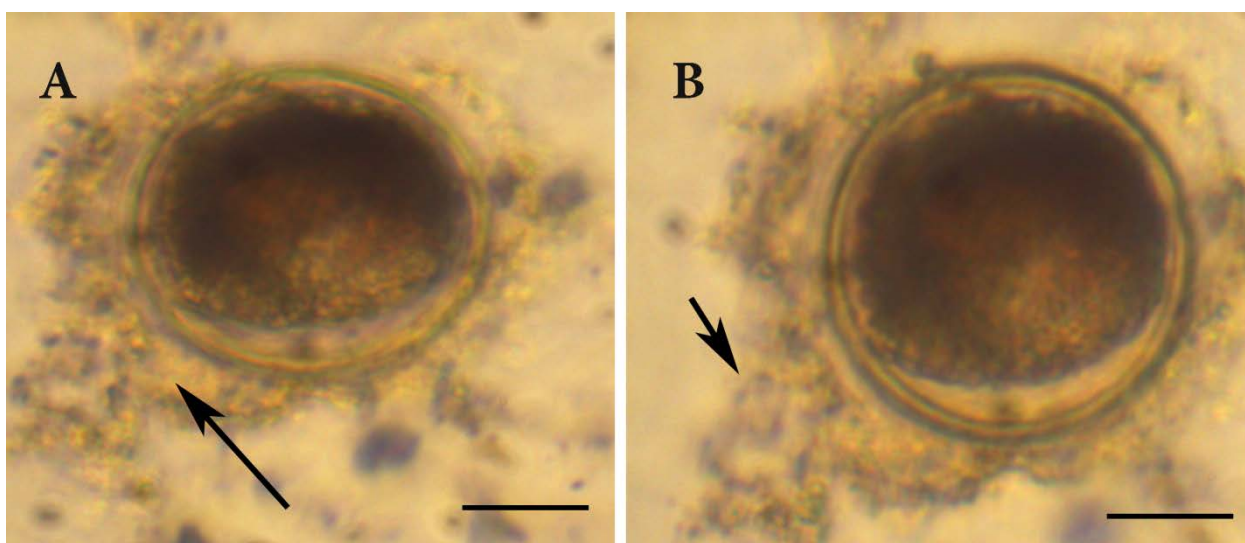
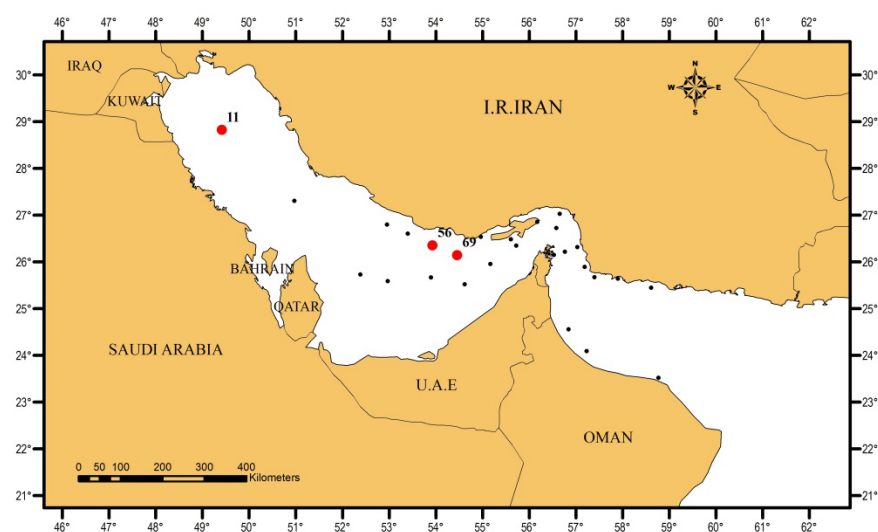


Plate 43: *Alexandrium* sp.2 cyst with mucilaginous layer shows yellow accumulation body (arrow)



Map 43: *Alexandrium* sp.2 presences in the RSA, Winter 2006

Phylum: Miozoa Cavalier-Smith 1987

Class; Dinophyceae Fritsch 1927

Order; Peridinales Haeckel 1894

Family: Thoracosphaeraceae Schiller, 1930

Genus: *Scrippsiella* Balech ex A.R.Loeblich III, 19

Species: *Scrippsiella trifida*

Scientific name: *Scrippsiella trifida* Lewis 1991

Paleontological name: -

Figure no. Plate 44

Reference:

Head *et al.*, (2006), Figures 2-16;

Description:

Ovoidal shape cyst with blunt and weakly trifurcate calcareous process (Plate 44). The calcareous process is between two organic layers; the inner layer covers the ovoidal central body and the outer layer has an irregular shape. Nearly large red-orange accumulation body is observed. Wild motile stage of this cyst type has not been reported yet (Head *et al.*, 2006).

Size:

L: 42µm; W: 25µm.

Occurrence in RSA:

The presence of the species in the RSA from Cruise Winter 2006 has been shown on Map 44. Presence of the cyst in site: 40

Occurrence in the world:

Britain (Lewis 1991); German Bight (North Sea) (Nehring 1994); Scotland (Joyce 2004); Sweden (Godhe *et al.*, 2001); Spain (Gottschling *et al.*, 2005); Turkey (Balkis *et al.*, 2016);

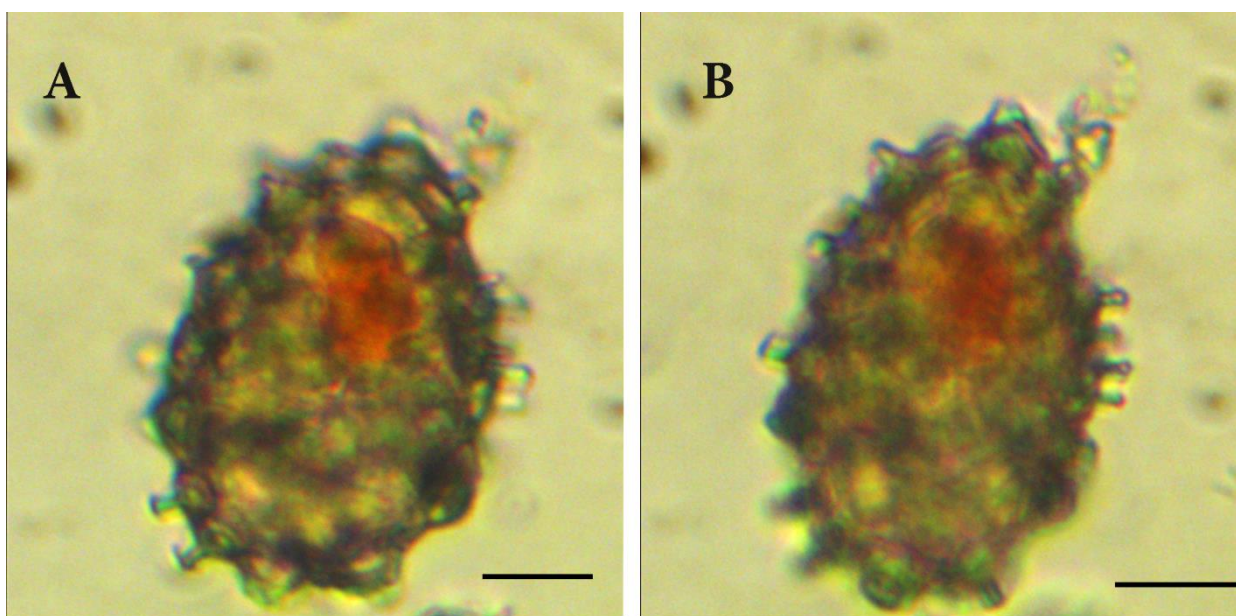
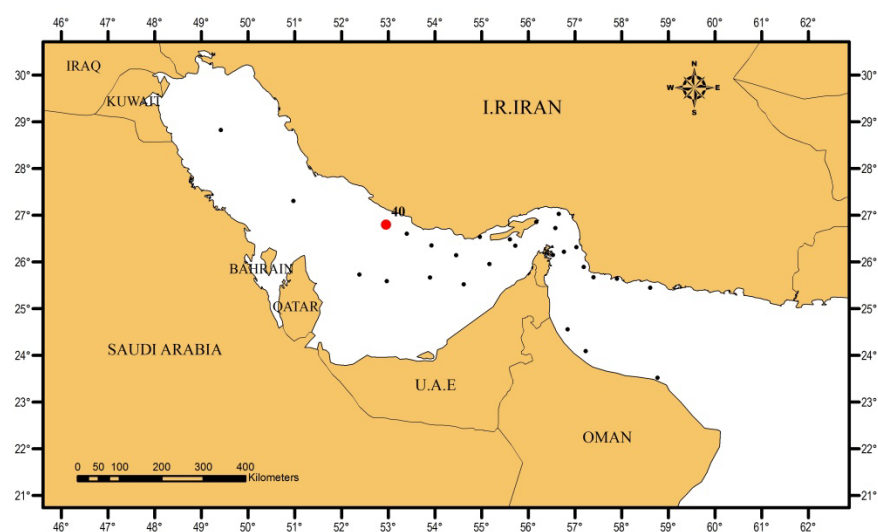


Plate 44: *Scrippsiella trifida* cyst shows big orange accumulation body



Map 44: *Scrippsiella trifida* distribution in the RSA, Winter 2006

Phylum: Miozoa Cavalier-Smith 1987

Class; Dinophyceae Fritsch 1927

Order; Peridinales Haeckel 1894

Family: Thoracosphaeraceae Schiller, 1930

Genus: *Scrippsiella* Balech ex A.R.Loeblich III, 1965

Species: *Scrippsiella irregularis*

Scientific name: *Scrippsiella irregularis* Attaran-Fariman & Bolch 2007

Paleontological name: -

Figure no.: Plate 45

Reference:

Attaran-Fariman (2007), Figures 16-19;

Gu *et al.*, (2011), Figures 14-17

Description:

Spherical to sub spherical cyst with light brown to light grey colour. Cyst is ornamented with numerous non-tabular long calcareous pointed spines (Plate 45, A-C). Cyst of *S. irregularis* as a new species is described from south east coast of Iran (northern part of the Sea of Oman) from coastal sediment. It has been reported that the culture cyst has a thin outer membrane surrounding the cyst spines and the spines are capitated (Attaran-Fariman 2007). In our sample, the wild *S. irregularis* also shows a pointed and capitate spines (Plate 45 C). The red accumulation body is always present in the cyst. Sometimes cysts are without spines in the sediment (Plate 45 D). A mesoepycystal archeopyle form by loss of 2-4' and 1-3a paraplate (Gu *et al.*, 2011), however, no archeopyle was observed in our samples

Size:

D: 20-26µm

Occurrence in RSA:

The presence of the species in the RSA from Cruise Winter 2006 has been shown on Map 45. Presence of the cyst in site: 98, 88, 97, 83, 14a, 77, 69, 59, 55, 11

The cyst has been formerly reported from south east coast of Iran; northern part of Sea of Oman (Attaran-Fariman *et al.*, 2007; Attaran-Fariman, 2016

Occurrence in the world:

South-west Asia: Iran (Attaran-Fariman & Bolch 2007), China Sea (Gu *et al.*, 2012)

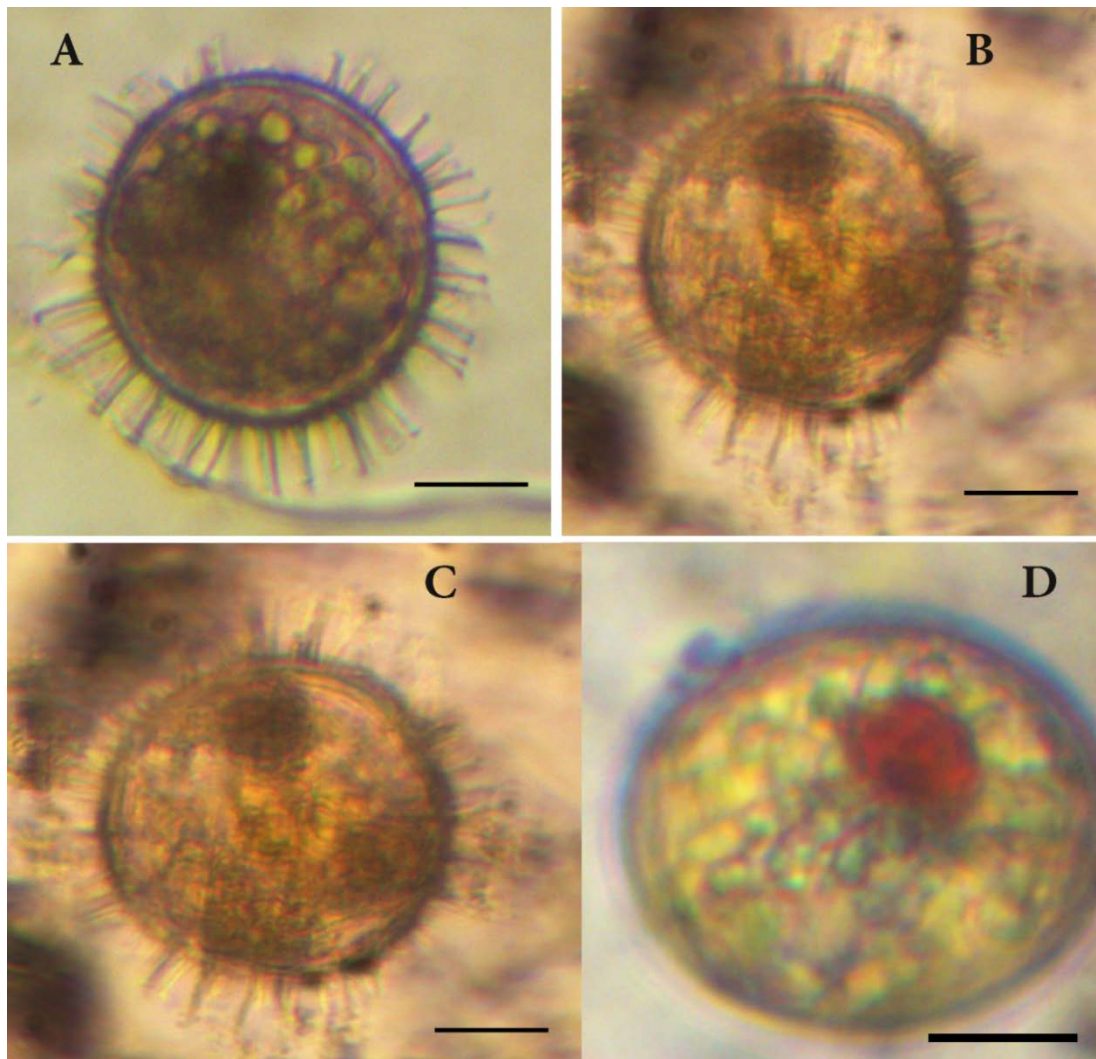
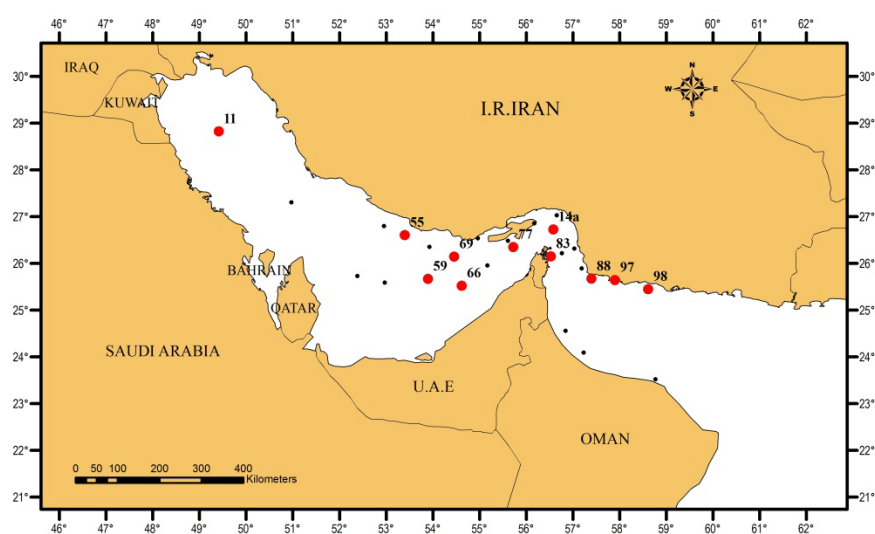


Plate 45: *Scrippsiella irregularis* cyst showing cyst with processes and without processes



Map 45: *Scrippsiella irregularis* occurrence in the RSA, Winter 2006

Phylum: Miozoa Cavalier-Smith 1987

Class; Dinophyceae Fritsch 1927

Order; Peridiniales Haeckel 1894

Family: Thoracosphaeraceae Schiller, 1930

Genus: *Scrippsiella* Balech ex A.R.Loeblich III, 19

Species: *Scrippsiella trochoidea* (Stein) Loeblich III 1976

Scientific name: *Scrippsiella trochoidea* (Stein) Loeblich III 1976

Paleontological name: *Rhabdothorax erinaceus* (Kamptner) Kamptner 1958

Figure No: Plate 46

Reference:

Attaran-Fariman (2007), Figures 16-19;

Gu *et al.*, (2011), Figure 24;

Attaran-Fariman & Bolch (2012), Figures 16-19;

Shin *et al.*, (2013), Figure 5;

Satta *et al.*, (2014) Figures 2q-s;

Description:

Ovoidal to round cyst with dark brown colour (Plate 46). The cyst wall is ornamented with triangular calcareous spines. The length of spines are variable. A red accumulation body is observed in intact cysts (Plate 46 A-D). A mesoepeycystal archeopyle forms by loss of 2-4' and 1-3a paraplate and splits about ¼ of the cyst diameter (Plate 46 F).

S. trochoidea is complex species with variability in the morphology of the cyst and motile cell (Attaran-Fariman 2012). Sometimes wild cysts are without any processes (Plate 46 D). Therefore, cyst/theca relationship and molecular analysis should be considered to identify this complex species.

Size:

D: 31µm; L: 37µm

Occurrence in RSA:

The presence of the species in the RSA from Cruise Winter 2006 has been shown on Map 46. Presence of the cyst in site: 98, 25a, 97, 88, 21a, 85, 83, 77, 78, 69, 59, 55, 11, 25

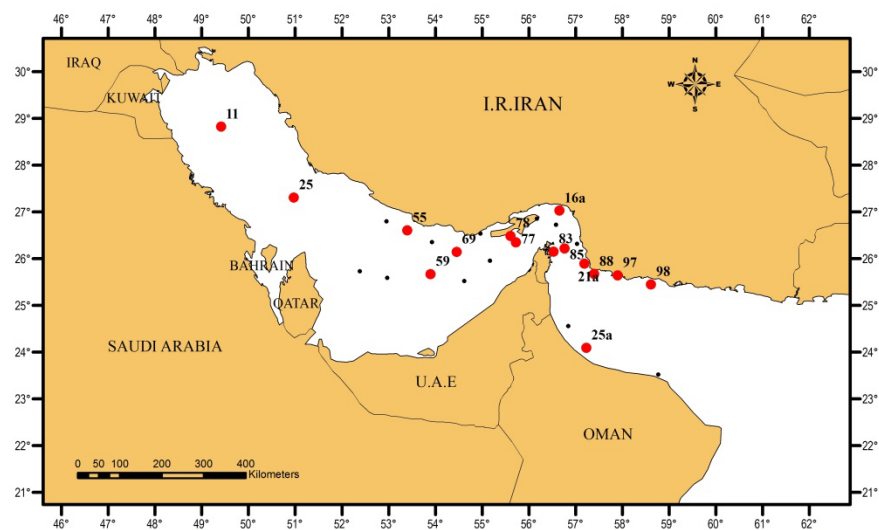
The cyst has been formerly reported from south east coast of Iran; northern part of Sea of Oman (Attaran-Fariman *et al.*, 2012; Attaran-Fariman, 2016)

Occurrence in the world:

South-west Asia: Turkey (Asia) (Balkis *et al.*, 2016); China (Gu *et al.*, 2008, Liu 2008, Tan *et al.*, 2015); Japan (Gottschling *et al.*, 2005); Russia (Far East) (Medvedeva & Nikulina 2014, Morozova *et al.*, 2016).



Plate 46: *Scrippsiella trochoidea* cyst shows variety in shape



Map 46: *Scrippsiella trochoidea* occurrence in the RSA, Winter 2006

Phylum: Miozoa Cavalier-Smith 1987

Class; Dinophyceae Fritsch 1927

Order; Peridinales Haeckel 1894

Family: Thoracosphaeraceae Schiller, 1930

Genus: *Scrippsiella* Balech ex A.R.Loeblich III, 1965

Species: *Scrippsiella precaria*

Scientific name: *Scrippsiella precaria* M.Montresor & A.Zingone 1988

Paleontological name: -

Figure no.: Plate 47

Reference:

Joyce (2004), Figure 2;

Gu *et al.*, (2008), Figure 3I;

Satta *et al.*, (2014), Figure 2Q

Description:

A spherical cyst with dark brown colour (Plate 47). The cyst is ornamented with numerous pointed spines. The red accumulation body is always present. The cyst of this species is very similar to the cyst of *S. irregularis* and the separation of these two without cyst germination and molecular analysis is very difficult. Because ROPME sediment samples were fixed, we were not able to do cyst germination experiment. Therefore, the separation of these two cysts is only based on cyst morphology. The presence of red accumulation body and the shape of archeopyle are constant among *Scrippsiella* species and potentially useful features in taxonomy of the species; whereas, spine length and shape are variable among these species (Gu *et al.*, 2008). Sometimes wild species are without any process.

Size:

D: 26µm

Occurrence in RSA:

The presence of the species in the RSA from Cruise Winter 2006 has been shown on Map 47. Presence of the cyst in site: 85, 66, 11

The cyst has been formerly reported from south east coast of Iran; northern part of the Sea of Oman (Attaran-Fariman *et al.*, 2012; Attaran-Fariman, 2016)

Occurrence in the world

Italy (Montresor & Zingone 1988), Mediterranean (Gómez 2003); South-west Asia: Turkey (Asia) (Balkis *et al.*, 2016); China (Gu *et al.*, 2008); Australia (Gottschling *et al.*, 2005)

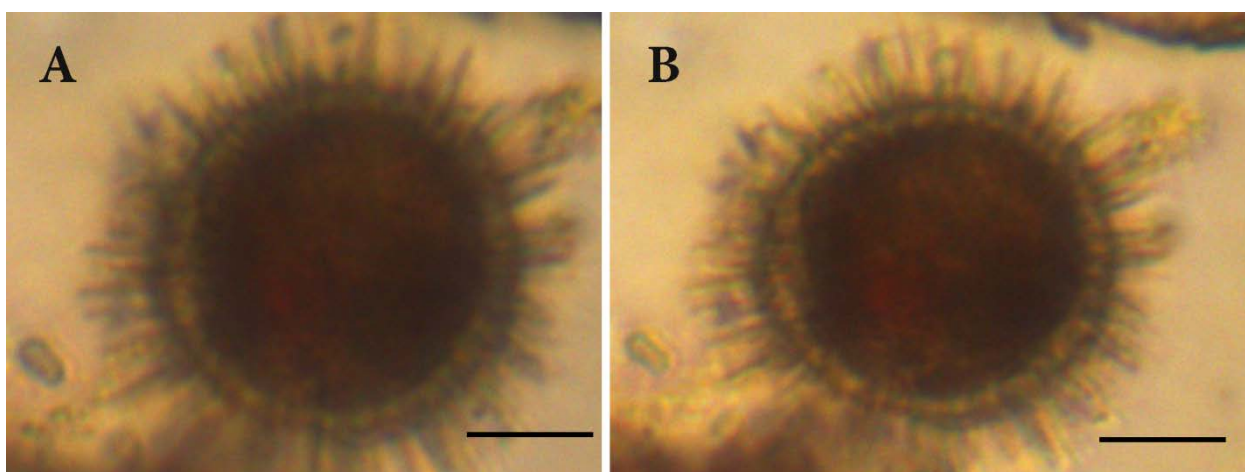
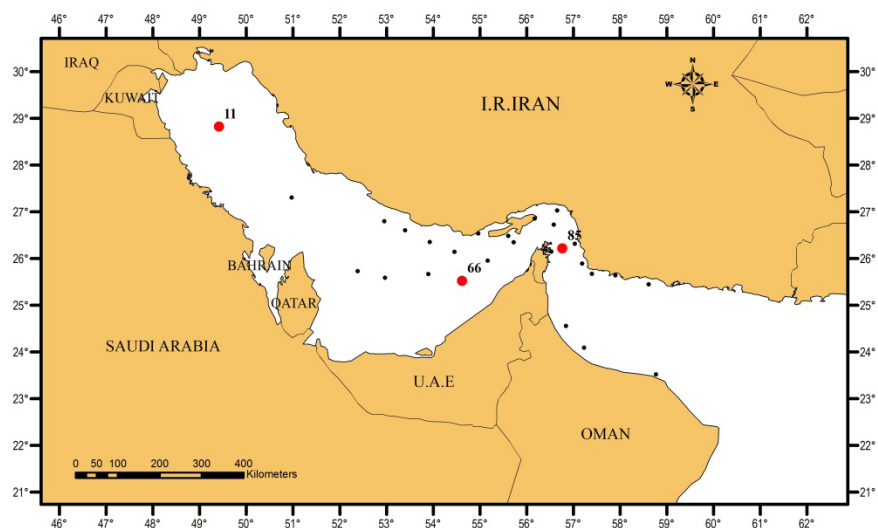


Plate 47: *Scrippsiella precaria* cyst shows processes



Map 47: *Scrippsiella precaria* occurrence in the RSA, Winter 2006

Phylum: Miozoa Cavalier-Smith 1987

Class; Dinophyceae Fritsch 1927

Order; Peridinales Haeckel 1894

Family: Thoracosphaeraceae Schiller, 1930

Genus: *Scrippsiella* Balech ex A.R.Loeblich III, 1965

Species: *Scrippsiella* cf. *regalis* (K.R.Gaarder) D.Janofske 2000

Scientific name: *Scrippsiella regalis* (K.R.Gaarder) D.Janofske 2000

Paleontological name: -

Figure no.: Plate 48

Reference:

Janofske (2000), Figure 22

Description:

Spherical cyst has brown colour, slightly compressed and relatively solid sphere. The cyst is ornamented with solid calcareous spines (Plate 48, A-B). The tips of the triangular spines are cleft, blunt, capitated or pointed. In the RSA, the cysts with blunt spines have been found. Janofske (2000) described *S. regalis* with all kinds of the process tips. This cyst can be distinguished from *S. trochoidea* by its solid appearance. The potential of fossilization of *S. regalis* cyst is remarkably higher than *S. trochoidea* (Janofske 2000).

Size:

W: 27µm

Occurrence in RSA:

The presence of the species in the RSA from Cruise Winter 2006 has been shown on Map 48. Presence of the cyst in site: 85

Occurrence in the World:

Mediterranean Sea (Meier *et al.*, 2002)

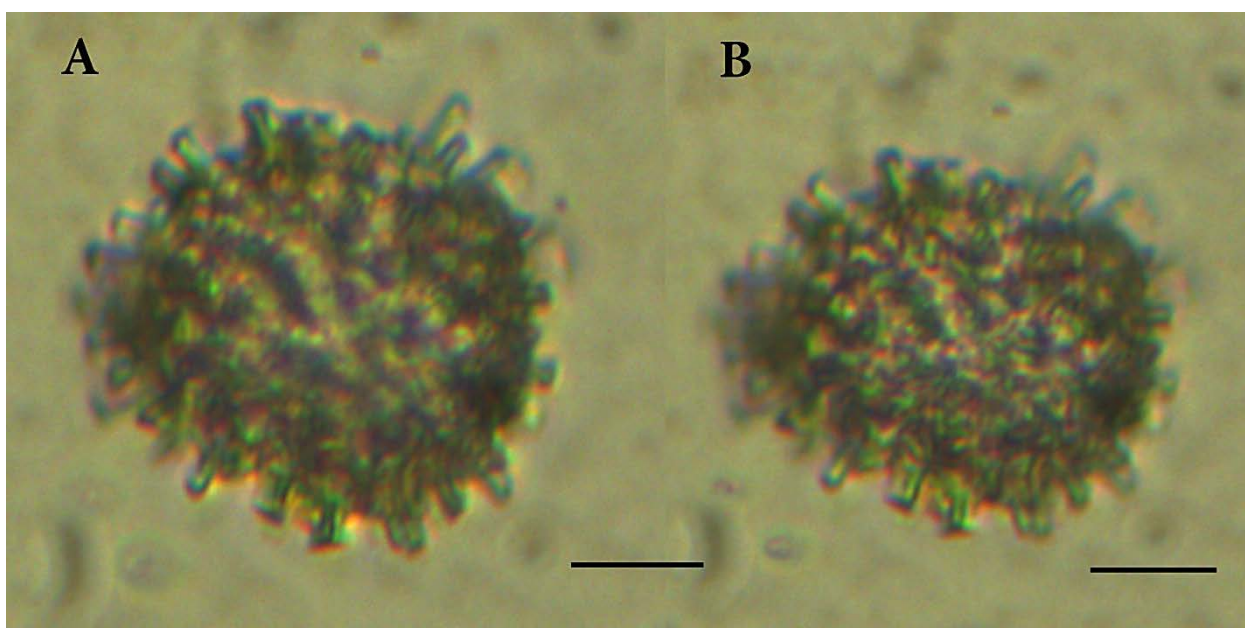
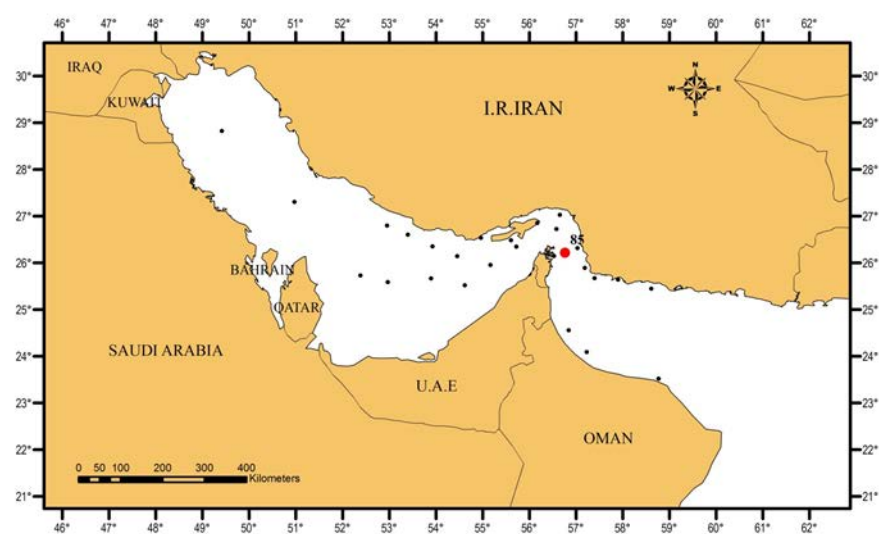


Plate 48: *Scrippsiella regalis* cyst with calcareous spines



Map 48: *Scrippsiella regalis* occurrence in the RSA, Winter 2006

Phylum: Miozoa

Class; Dinophyceae Fritsch 1927

Order; Peridinales Haeckel 1894

Family; Thoracosphaeraceae Schiller, 1930

Genus; *Calciperidinium* Versteegh, 1993

Species; *Calciperidinium asymmetricum*

Scientific name: *Calciperidinium asymmetricum* Versteegh, 1993

Paleontological name: *Calciperidinium asymmetricum* Versteegh, 1993

Figure No.: Plate 49

References:

Tammaasa *et al.*, (2004) Figure 2f;

Susek *et al.*, (2005), Figure 3B

Description:

Heart shape cyst with biolobate antapex (Plate 49, A-B). The apex is rounded and has subhexagonal archeopyle with a rounded side; the cyst is probably formed by the loss of one or more intercalary plates. This cyst is the only calcareous cyst with a pridinoid outline. This cyst type has been recorded from upper Pleistocene fossil (Versteeg 1993) and from recent sediment of the coastal South Carolina (Wall *et al.*, 1973)

Size:

W: 29µm; L: 48µm

Occurrence in RSA:

The presence of the species in the RSA from Cruise Winter 2006 has been shown on Map 49. Presence of the cyst in site: 83, 14a, 16a, 72, 55

Occurrence in the world:

Southern Italy (Versteegh, 1993); Mediterranean Sea (Tammaasa *et al.*, 2004); Carolina (Wall *et al.*, 1973)

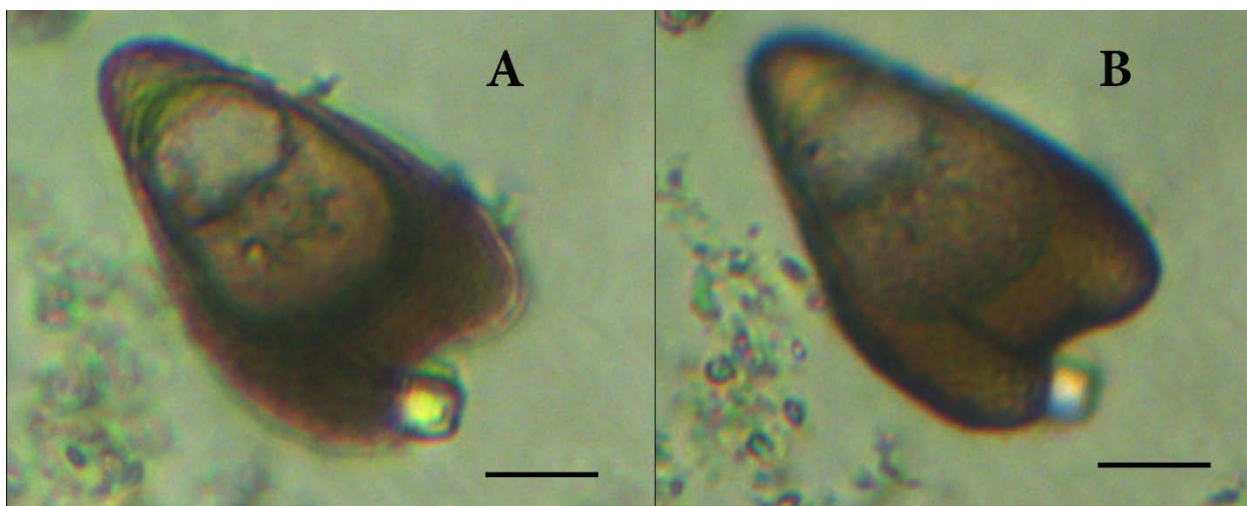
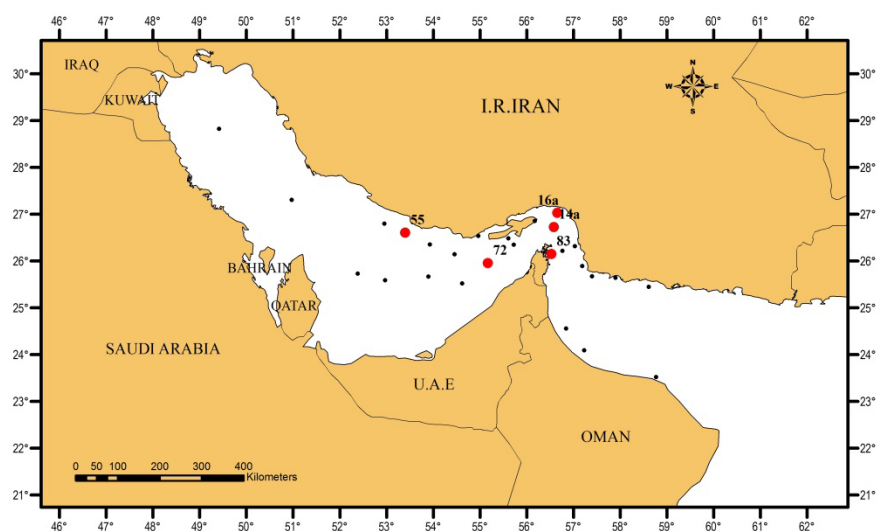


Plate 49: *Calciperidinium asymmetricum*; A-B heart shape cyst showing archeopyle



Map 49: *Calciperidinium asymmetricum* occurrence in the RSA, Winter 2006

Phylum: Miozoa

Class; Dinophyceae Fritsch 1927

Order; Peridinales Haeckel 1894

Family; Thoracosphaeraceae Schiller, 1930

Genus; *Calciodinellum* Deflandre, 1947

Species: *Calciodinellum albatrosianum*

Scientific name: *Calciodinellum albatrosianum* (Kamptner) Janofske & Karwath 2000

Paleontological name: *Calciodinellum albatrosianum* (Kamptner) Janofske & Karwath 2000

Figure No.: Plate 50

References:

Wendler *et al.*, (2001), Plate 1d;

Gottschling *et al.*, (2005) Figure 39;

Susek *et al.*, (2005) Figure 4b;

Gu *et al.*, (2011), Figures 2-3

Description:

Spherical small cyst has brown colour. Cyst surface is scaled. The archeopyle is meso-epicystal (Plate 50 B-C). No other paratabulation has been observed in RSA samples. This cyst has also been recorded as *Torachosphaera albatrosianum* by Dale and Dale (1992) from pacific deep area (Della *et al.*, 2004). The cyst with low density was not common in the RSA and found only in one site (Map 50).

Size:

D: 27µm

Occurrence in RSA:

The presence of the species in the RSA from Cruise Winter 2006 has been shown on Map 50. Presence of the cyst in site: 43

Occurrence in the world:

Atlantic Ocean (Kerntopf, 1997; Janofske and Karwath, 2000); Atlantic and Pacific Oceans (Vink *et al.*, 2000); Mediterranean sea (Della Tommasa, 2004); Arabian Sea.

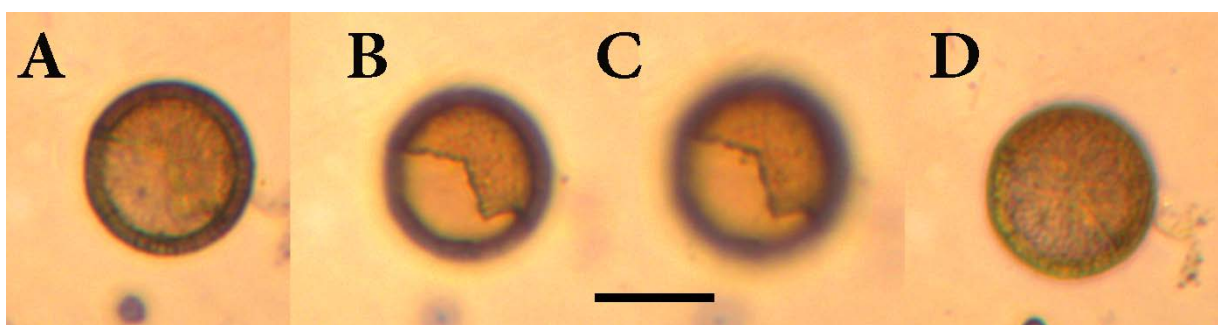
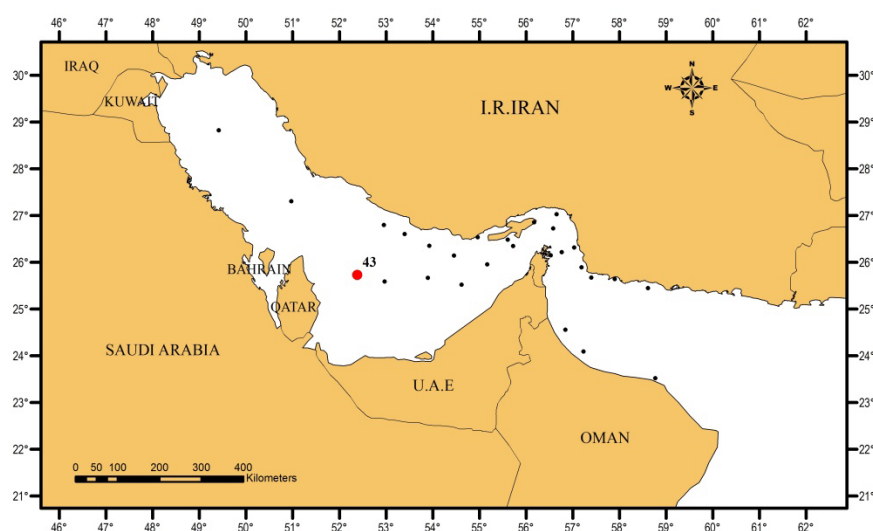


Plate 50: *Calciadinellum albatrosianum*: cyst at different focal levels; A & D show cyst surface; B & C show archeopyle (scale bars= 20µm)



Map 50: *Calciadinellum albatrosianum* presence in the RSA, Winter 2006

Phylum: Miozoa

Class; Dinophyceae Fritsch 1927

Order; Peridiniales Haeckel 1894

Family; Thoracosphaeraceae Schiller, 1930

Genus; *Calciodinellum* Deflandre, 1947

Species: *Calciodinellum operosum*

Scientific name: *Calciodinellum operosum* Deflandre 1947

Paleontological name: *Calciodinellum operosum* Deflandre 1947

Figure No.: Plate 51

References:

Montresor *et al.*, (1997), Figures 7, 10, 11, 13-21

Description:

Spherical cyst with a calcareous layer (Plate 51A). This layer is like a fence around the cyst. A spongy-reticulate structure is formed by a composed small crystal around the layer (Plate 51B). The cyst shows unusual paratabulation (Plate 51B). The cyst has brown contents, without any accumulation body.

Size:

Inner diameter 24µm; Calca layer 2.2 µm

Occurrence in RSA:

The presence of the species in the RSA from Cruise Winter 2006 has been shown on Map 51. Presence of the cyst in site: 26a, 69, 55

Occurrence in the world:

Bay of Nepal, Italy (Montresor *et al.*, 1997, Gottschling *et al.*, 2005), Mediterranean (Gómez 2003), Mediterranean Sea (Meier *et al.*, 2002)

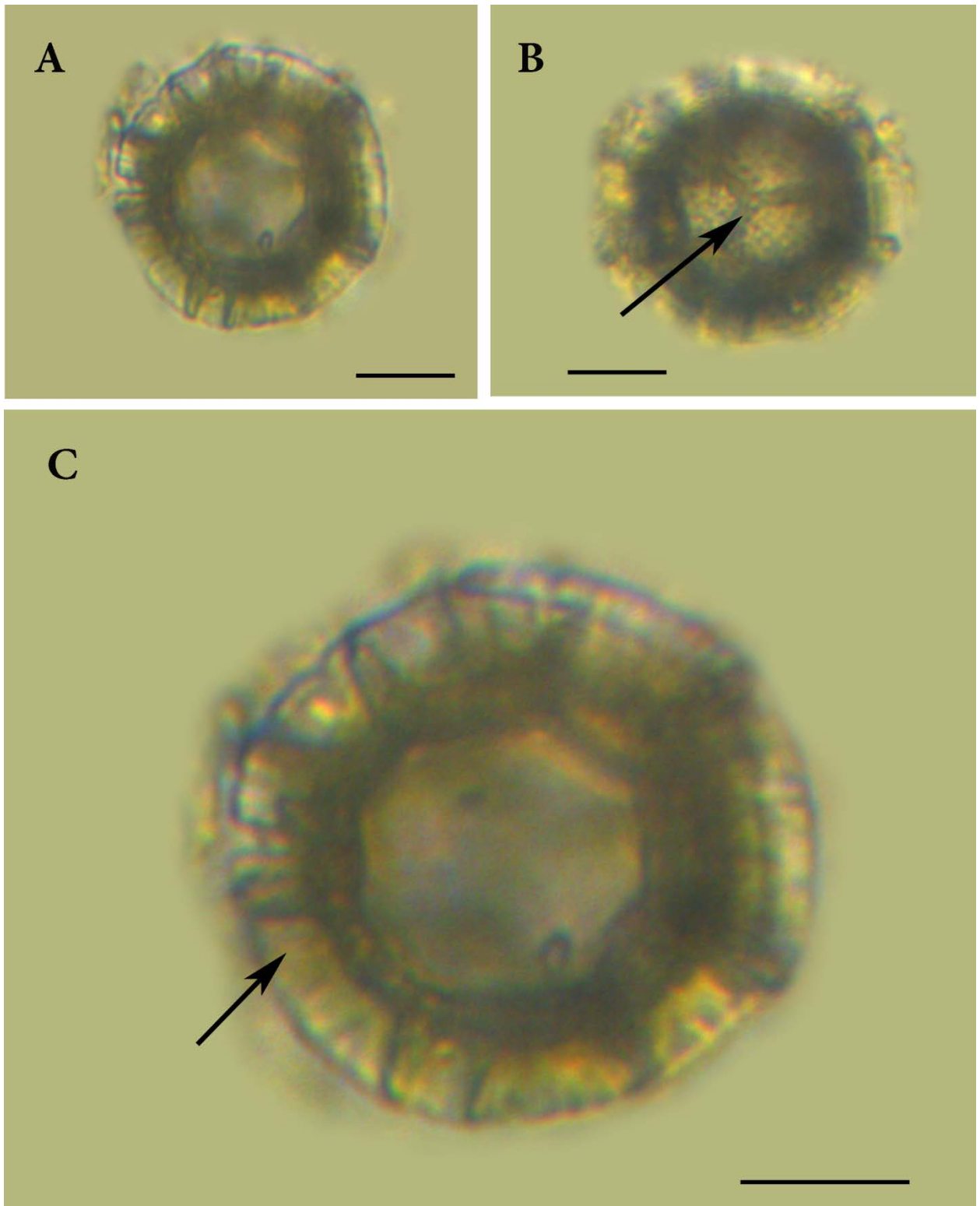
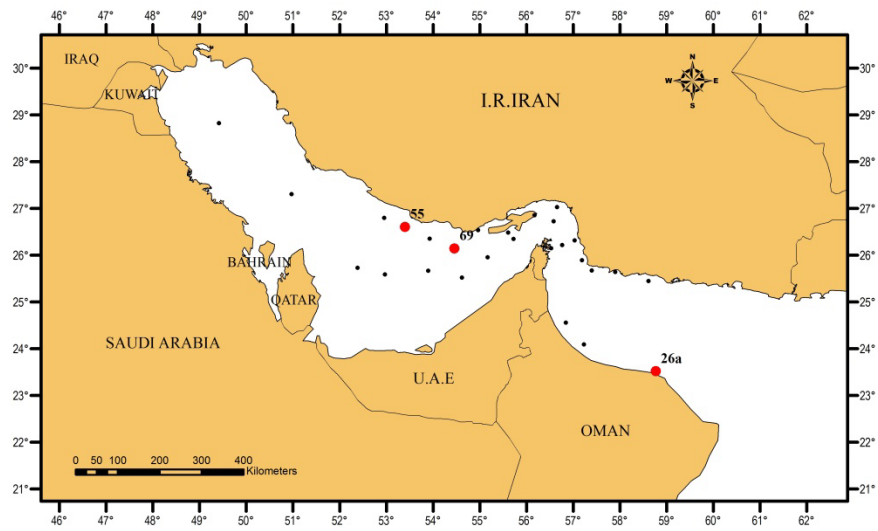


Plate 51: *Calciodinellum operosum*; A- C cyst showing calcareous layer (arrow, C) and reticulate cyst wall (arrow, B)



Map 51: *Calcidinellum operosum* occurrence in the RSA, Winter 2006

Phylum: Miozoa

Class; Dinophyceae Fritsch 1927

Order; Peridinales Haeckel 1894

Family; Thoracosphaeraceae Schiller, 1930

Genus; *Leonella* Janofske & B.Karwath, 2000

Species: *leonella granifera*

Scientific name: *Leonella granifera* (D.Fütterer) Janofske & Karwath 2000

Paleontological name: *Leonella granifera* (D.Fütterer) Janofske & Karwath 2000

Figure No.: Plate 52

References:

Della Tommasa (2004), Figure 2g;

Gu *et al.*, (2011), Figures 10-11

Description:

Small spherical cyst without any ornamentation. The cyst has a brown colour. The archeopyle is circular or hexagonal with rounded corners. This cyst type can be distinguished from other round brown pridinials cysts by its very small size and the shape of archeopyle.

Size:

D: 23µm

Occurrence in RSA:

The presence of the species in the RSA from Cruise Winter 2006 has been shown on Map 52.

Presence of the cyst in site: 83, 69, 16a, 11

Occurrence in the world:

Atlantic Ocean (Kerntopf, 1997; Janofske and Karwath, 2000); Atlantic and Pacific Oceans (Vink *et al.*, 2000); Mediterranean Sea (Della Tommasa, 2004)

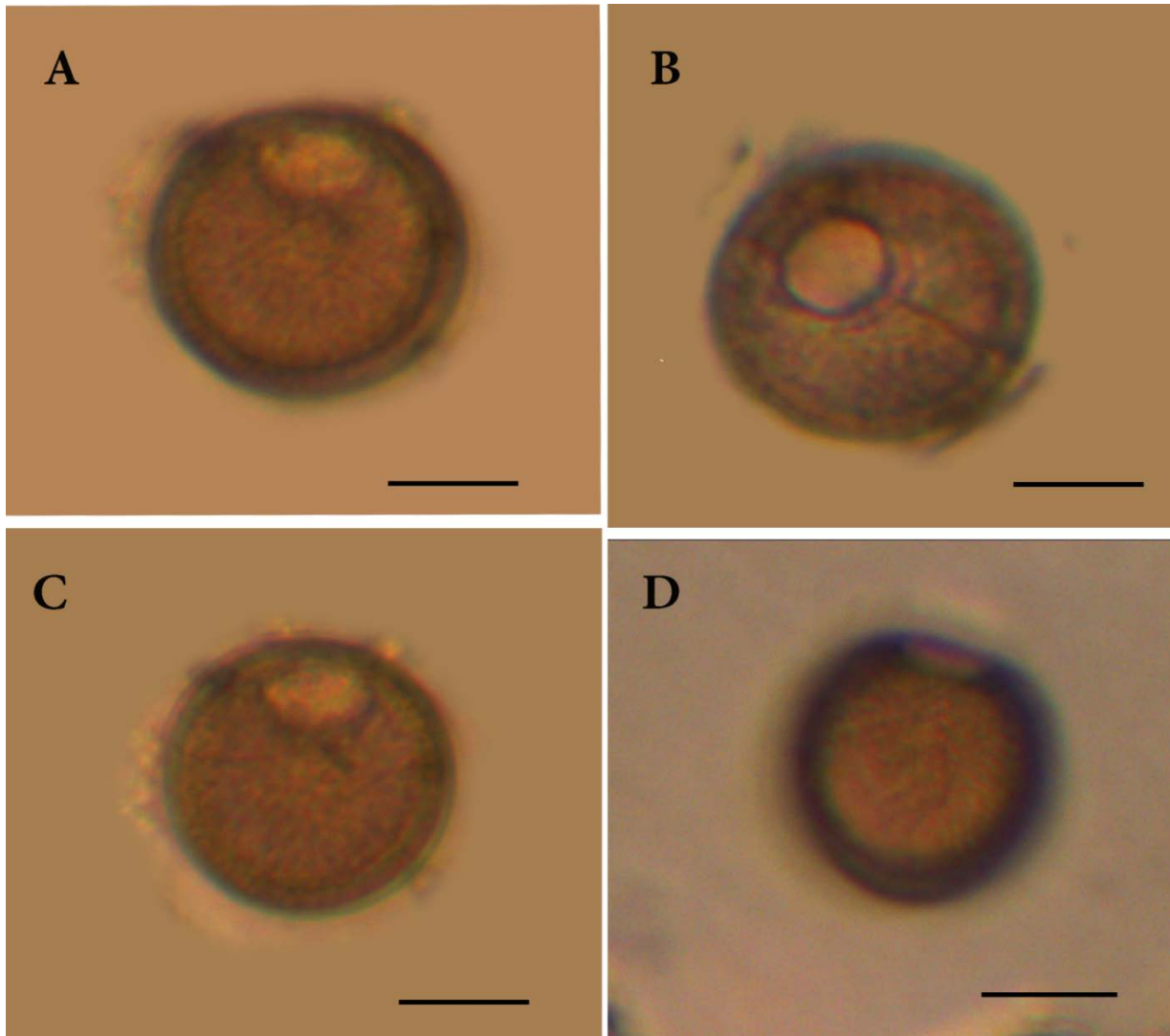
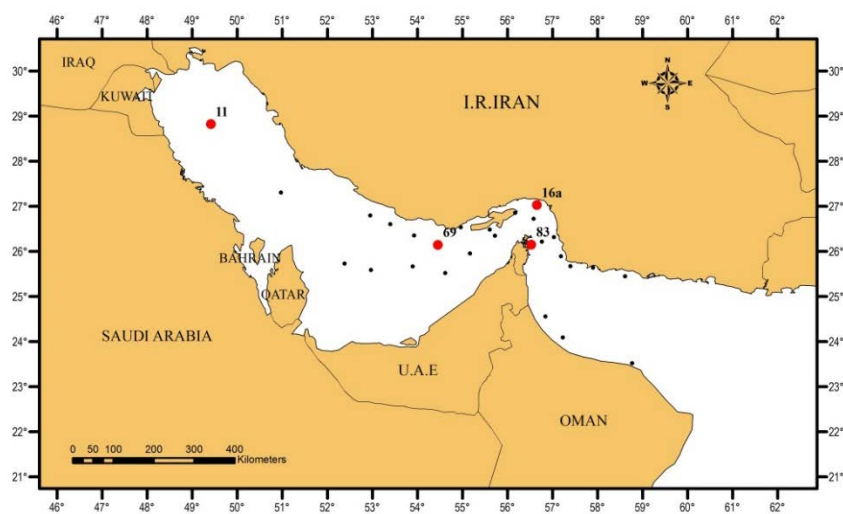


Plate 52: *Leonella granifera*: small cyst shows the archeopyle in different focuces



Map 52: *Leonella granifera* cyst occurrence in the RSA, Winter 2006

Phylum: Miozoa Cavalier-Smith 1987

Class; Dinophyceae Fritsch 1927

Order; Peridinales Haeckel, 1894

Family; Thoracosphaeraceae Schiller, 1930

Genus; *Pentapharsodinium Indelicato & Loeblich III, 1986.*

Species; *Pentapharsodinium tyrrhenicum*

Scientific name: *Pentapharsodinium tyrrhenicum* (Balech) Montessor, Zingone & Marino 1993

Paleontological name: *Calcicarpinum bivalvum* Versteegh 1993

Figure No.: Plate 53

References:

Montresor *et al.*, (1993), Figures 1-6; Orlova *et al.*, (2004), Figures 31-32

Size:

Central body: 24-27µm, excluding calca

Description:

The cyst has a round body surrounded by mineral layers of different thickness (Plate 53). The outer layer is probably calcium carbonate. Mineral layers have entirely encircled the cyst and given a shape of Napoleon hat (Montresor *et al.*, 1993). The external mineral layer is quadrangular, oval or circular (Plate 53 A-D).

Occurrence in RSA:

The presence of the species in the RSA from Cruise Winter 2006 has been shown on Map 53. Presence of the cyst in sites: 25a, 21a, 85, 77, 69, 55

The cyst has been formerly reported from south east coast of Iran; northern part of the Sea of Oman (Attaran-Fariman, 2016)

Occurrence in the World:

Italy (Montresor *et al.*, 1993; Gottschling *et al.*, 2005); Mediterranean (Gómez 2003); Russia (Orlova *et al.*, 2004)

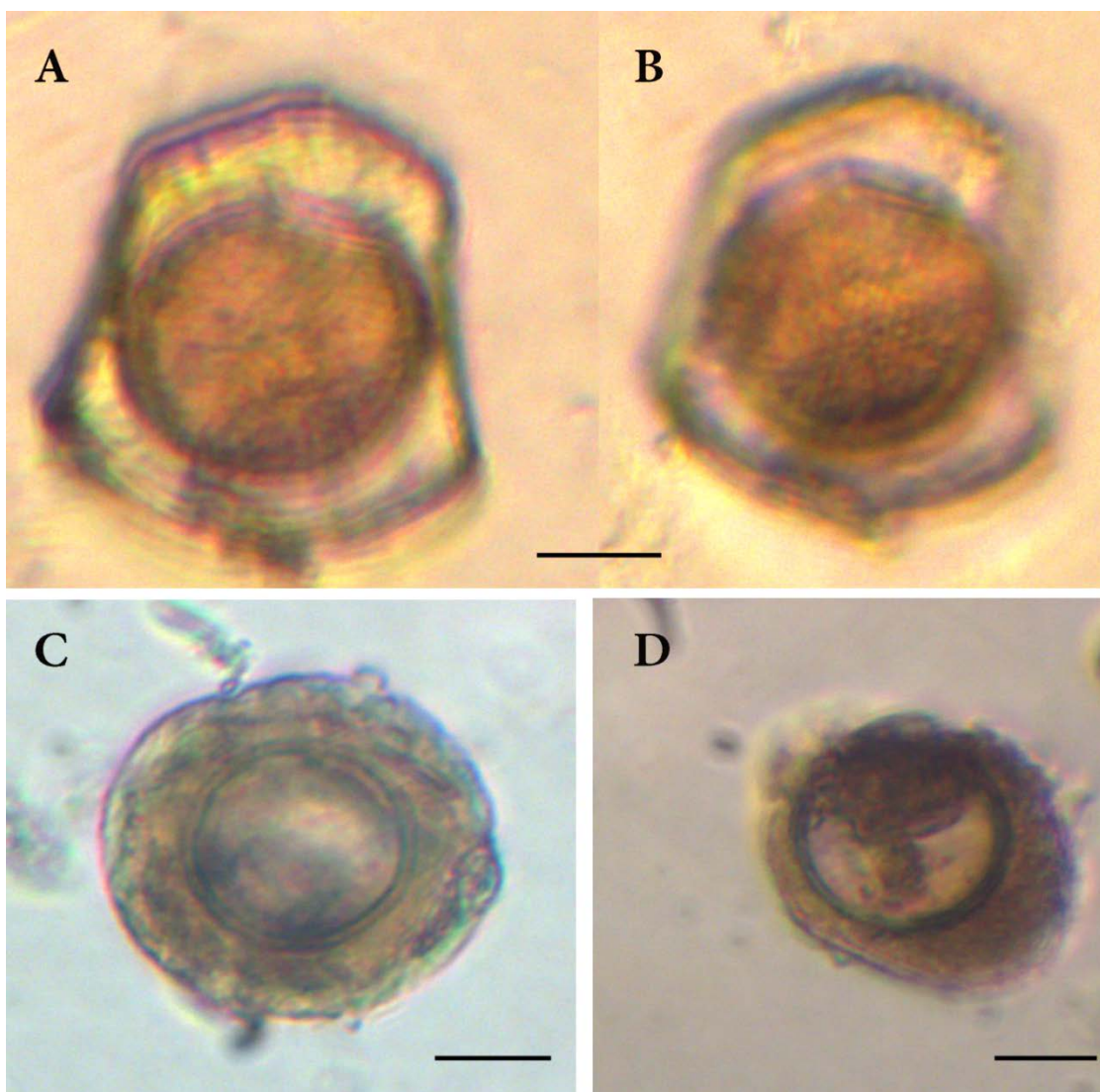
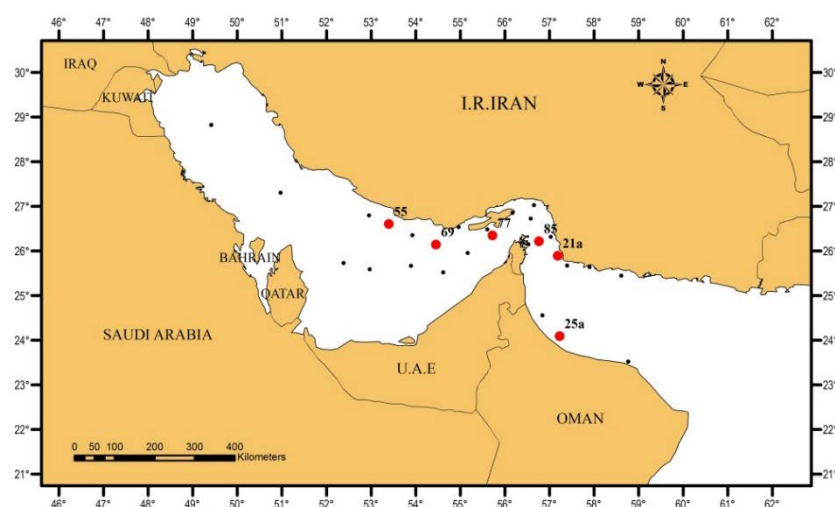


Plate 53: *Pentapharsodinium tyrrhenicum*: central body of the cyst surrounded with a calcareous layer



Map 53: *Pentapharsodinium tyrrhenicum* occurrence in the RSA, Winter 2006

Phylum: Miozoa Cavalier-Smith 1987

Class; Dinophyceae Fritsch 1927

Order; Peridiniales Haeckel, 1894

Family; Thoracosphaeraceae Schiller, 1930

Genus; *Pentapharsodinium Indelicato & Loeblich III, 1986.*

Species; *Pentapharsodinium cf. tyrrhenicum*

Scientific name: *Pentapharsodinium tyrrhenicum* (Balech) Montessor, Zingone & Marino 1993

Paleontological name: *Calcicarpinum cf. bivalvum* Versteegh 1993

Figure No.: Plate 54

References:

Montresor *et al.*, (1993), Figures 1-6

Size:

Central body: 32µm excluding calca

Description:

The cyst has round body surrounded by a thick layer (Plate 54). The external layer is circular (Plate 54, A-D). The live cyst is full of granular material. This cyst type differs from *P.tyrrhenicum* (Plate 53) by its bigger size of central body and the darker brown colour of the cyst. This cyst type was not found previously in the sediments of RSA.

Occurrence in RSA:

The presence of the species in the RSA from Cruise Winter 2006 has been shown on Map 54, in sites: 21a, 40

Occurrence in the World:

Italy (Montresor *et al.*, 1993)

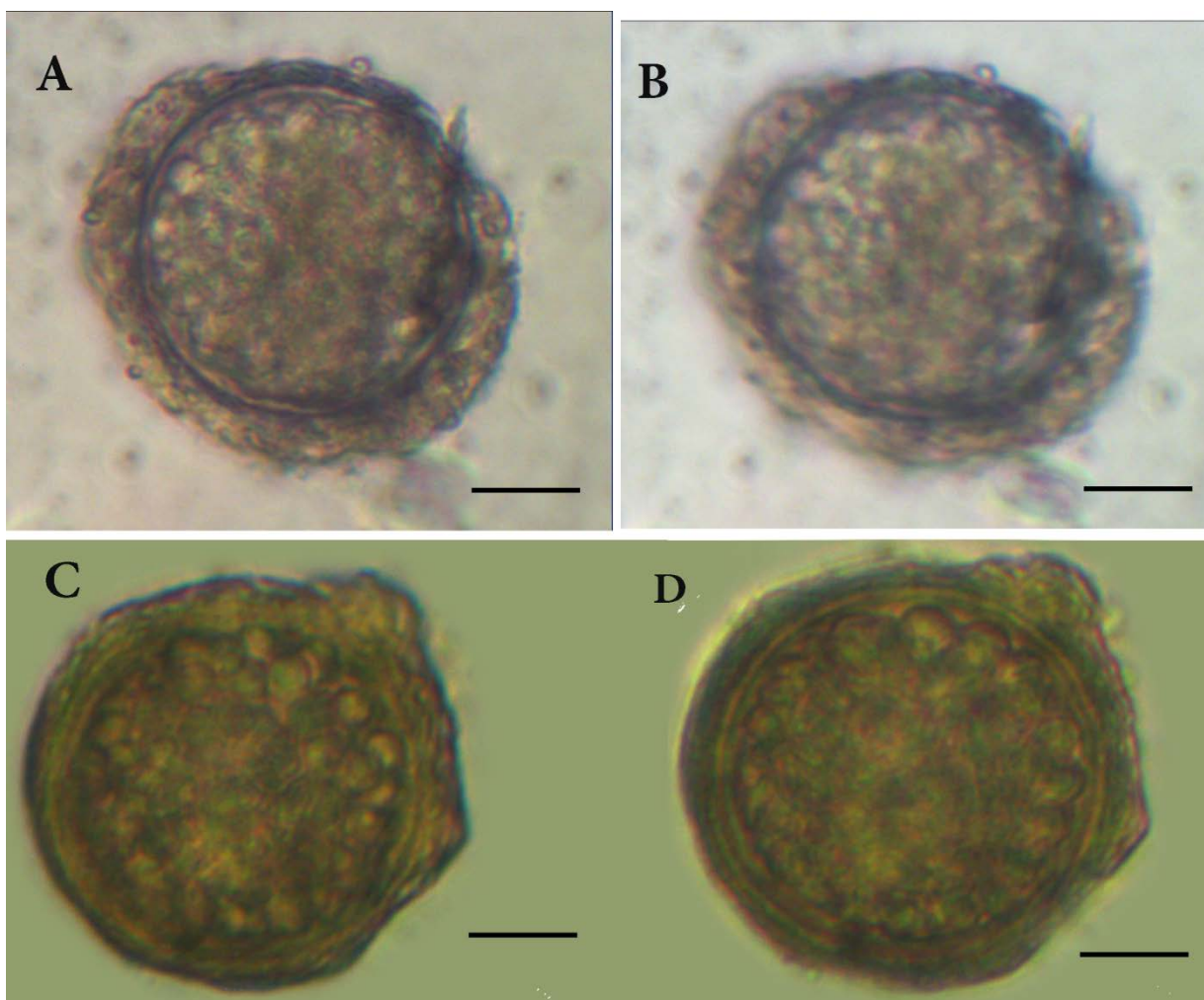
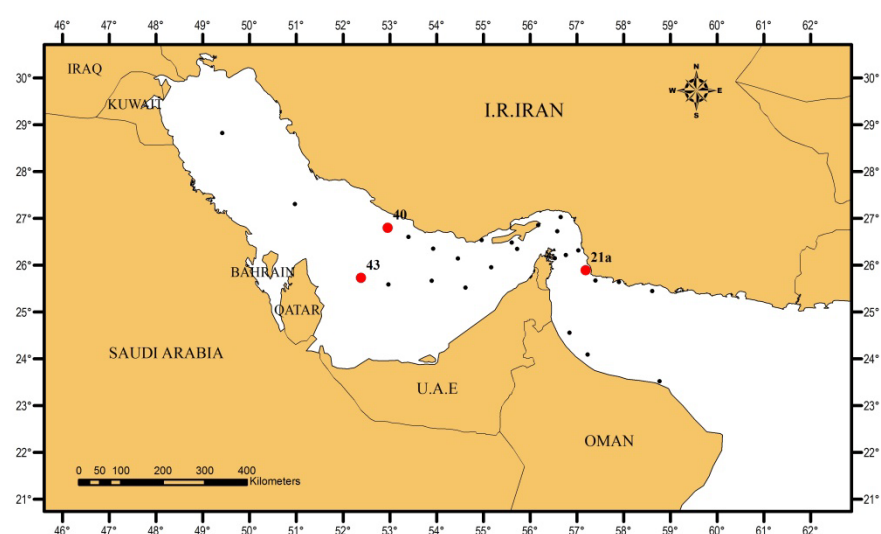


Plate 54: *Pentapharsodinium cf. tyrrhenicum*: central body of the live cyst surrounded with a thick layer



Map 54: *Pentapharsodinium cf. tyrrhenicum* occurrence in the RSA, Winter 2006

Phylum: Miozoa

Class; Dinophyceae Fritsch 1927

Order; Peridinales Haeckel 1894

Family; Thoracosphaeraceae Schiller, 1930

Genus; *Bicarinellum* Deflandre, 1949

Species: *Bicarinellum tricarinelloides* Versteegh 1993

Scientific name: *Bicarinellum tricarinelloides*

Paleontological name: *Bicarinellum tricarinelloides* Versteegh 1993

Figure No.: Plate 55

References:

Versteegh (1993), Plate I, Figures 1-5;

Montresor *et al.*, (1994), Plates I, 7; Plate III, 16

Description:

Spherical to subspherical cyst body surrounded by a thick calcareous layer (Plate 55). The cyst is characterized by broad ridges and well developed polar needle-like horn (Plate 55). From polar horn, two parallel subcircular ridges are present in the epicyst; these ridges can be seen in SEM images of the cyst (Versteegh 1993, Figure 2); however, in light microscopy of the cyst, these are same as two shoulders on both sides of the polar horn (Plate 55). In the hypocyst, ridges may reflect the margins of the lower part of the sulcus area. This cyst type has been described as fossil from Pleistocene; however, the species has been reported from recent sediment of the inner RSA and Adriatic Sea by Fiitterer (1977).

Size:

L: 44µm; W: 41µm

Occurrence in RSA:

The presence of the species in the RSA from Cruise - Winter 2006 has been shown on Map 55, in site 69.

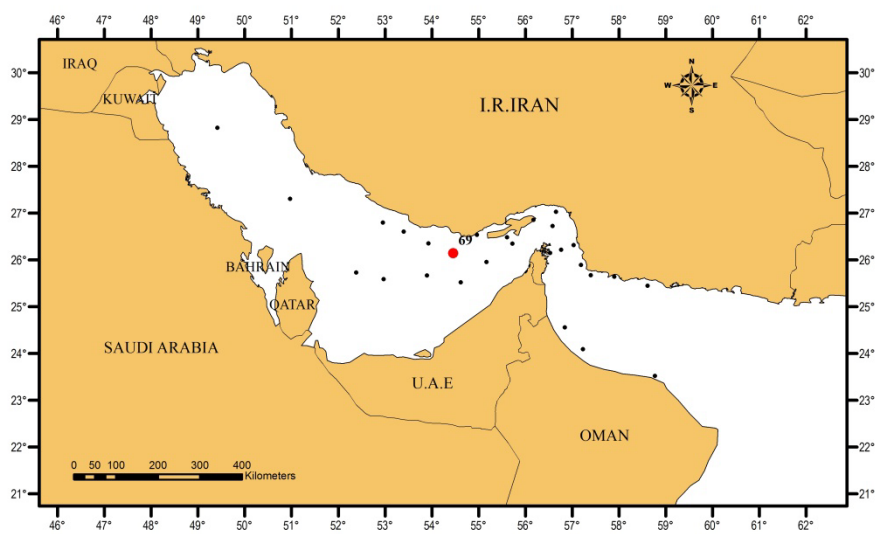
The species has been reported from recent sediment of the inner RSA (1977)

Occurrence in the world:

Mediterranean Sea (Meier *et al.*, 2002); Bay of Nepal, Italy (Montresor *et al.*, 1997)



Plate 55: *Bicarinellum tricarinelloides*: needle like apical horn is noted on the cyst



Map 55: *Bicarinellum tricarinelloides* occurrence in the RSA, Winter 2006

Phylum: Miozoa

Class; Dinophyceae Fritsch 1927

Order; Gonyaulacales Taylor 1980

Family; Gonyaulacaceae Lindemann 1928

Genus; Bitectatodinium Wilson 1973

Species: *Bitectatodinium spongium*

Scientific name: the affinity of the motile cell has not been described for this cyst

Paleontological name: *Bitectatodinium spongium* Zonneveld et Jurkschat 1998

Figure No.: Plate 56

References:

Zonneveld (1997), Plate1 Figures 1-6;

Limoges *et al.*, (2013) Plate 1, Figures 1-3

Description:

A spherical light brown with almost yellow appearance, with a thin pedium and a spongy luxuria of numerous capitate spines (Plate 56). The cyst has a chasmic archeopyle and is formed by a split sideways several sutures and cysts are often folded and the archeopyle is not visible. The species previously described by Zonneveld (1997) as *Algidasphaeridium spongium*. This species differs from *A. capillatum* by its spongy cyst wall and larger size.

Size:

D: 54µm

Occurrence in RSA:

The presence of the species in the RSA from Cruise Winter 2006 has been shown on Map 56. Presence of the cyst in sites: 98, 83

Occurrence in the world:

Pakistan, Somalia and Arabian Sea (Esper and Zonneveld 2002), Gulf of Mexico (Limoges *et al.*, 2013), Vietnam South China Sea, (Mizushima, 2007), NW Africa and in the Indian Ocean; (Zonneveld and Brummer, 2000; Susek *et al.*, 2005; Zonneveld *et al.*, 2010)

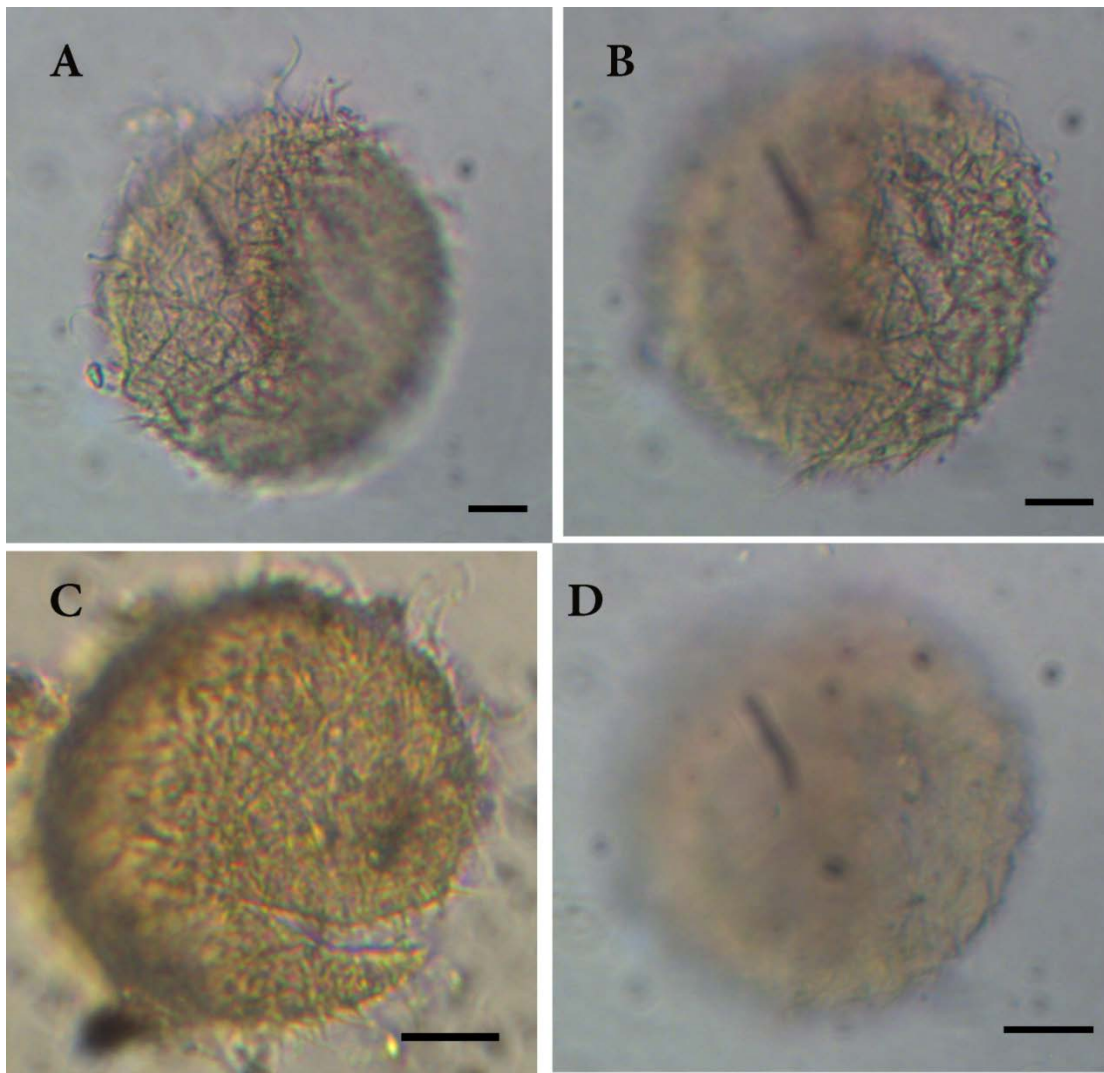
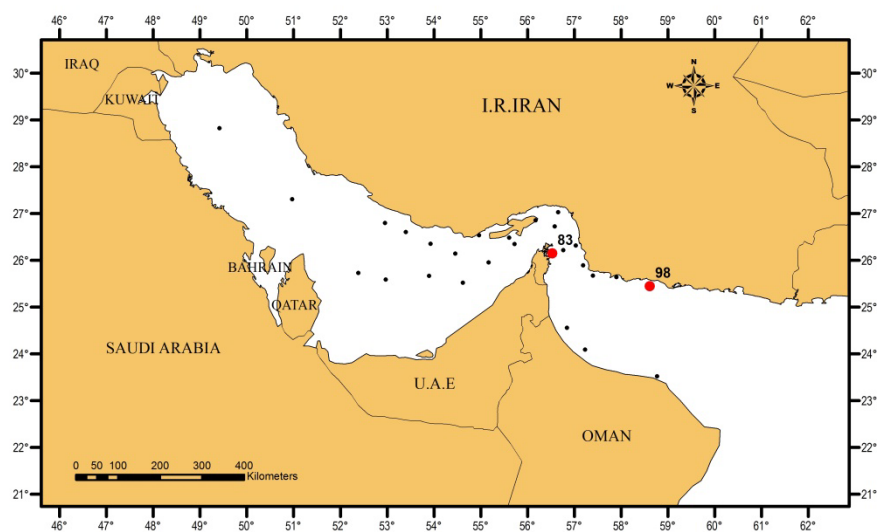


Plate 56: *Bitectatodinium spongium* cyst in different focuses, shows spongy appearance, C: shows archeopyle



Map 56: *Bitectatodinium spongium* occurrence in the RSA, Winter 2006

Phylum: Miozoa Cavalier-Smith 1987

Class; Dinophyceae Fritsch 1927

Order; Gonyaulacales Taylor 1980

Family: Gonyaulacaceae Lindemann, 1928

Genus: *Gonyaulax* Diesing, 1866

Species; *Gonyaulax spinifera*

Scientific name: *Gonyaulax spinifera* (Claparède et Lachmann 1859) Diesing 1866

Paleontological name: *Nematosphaeropsis labyrinthus* (Ostenfeld) Reid 1974

Figure No.: Plate 57

References:

Joyce (2004), Plate 2, Figure 1;

Zonneveld & Pospelva (2015)

Description:

Chorate trabeculate cyst with an ovoid central body and processes joined by trabeculae. Surface of the central cyst body and processes are smooth. Slender, tall gonol processes with trifurcate and secondarily bifurcate tips arise from the periphragm. The bifurcate tips are connected to adjacent processes by parallel ribbon-like trabeculae. These trabeculae replicate the parasutures joining the processes at their bases. The cyst body can have an apical protuberance. Archeopyle is precingular and was not observed in the RSA cyst.

Size:

Cyst body: 28µm; length of processes: 10µm.

Occurrence in RSA:

The presence of the species in the RSA from Cruise Winter 2006 has been shown on Map 57. Presence of the cyst in sites: 66, 59, 40.

Occurrence in the world:

White Sea (Golovnina and Polyakova, 2005); Peruvian upwelling area (Biebow *et al.*, 1993); Africa and off NW Iberia, (Ribeiro and Amorim, 2008; Zonneveld *et al.*, 2010).

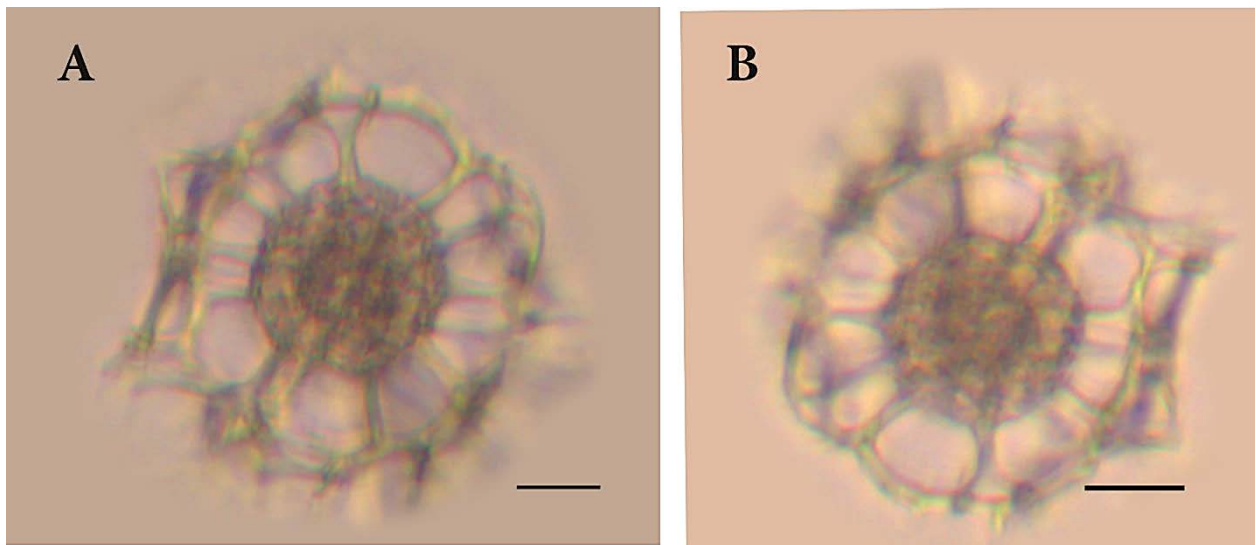
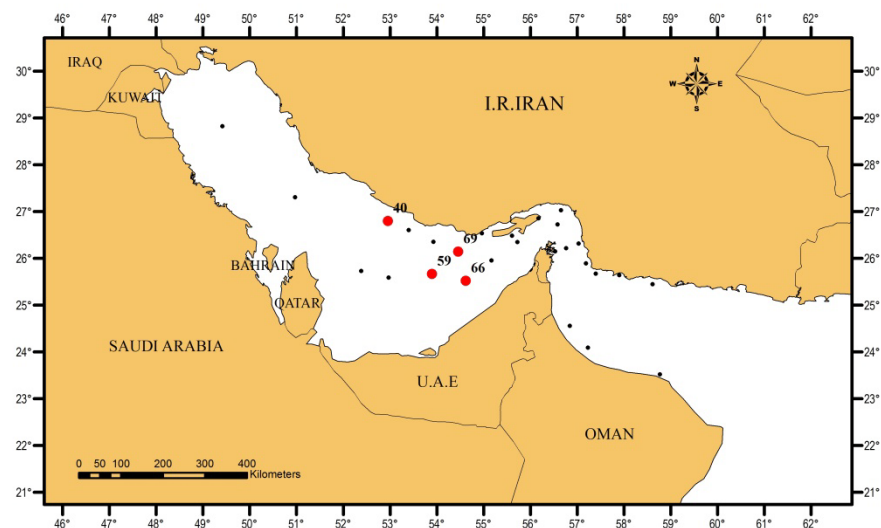


Plate 57: *Nematosphaeropsis labyrinthus* cyst shows distally joined process



Map 57: *Nematosphaeropsis labyrinthus* occurrence in the RSA, Winter 2006

Phylum: Miozoa Cavalier-Smith 1987

Class; Dinophyceae Fritsch 1927

Order; Gonyaulacales Taylor 1980

Family: Gonyaulacaceae Lindemann, 1928

Genus: *Gonyaulax* Diesing, 1866

Species: *Gonyaulax membranacea*

Scientific name: *Gonyaulax membranacea* (M.R.Rossignol) Ellegaard, Daugbjerg, Rochon, J.Lewis & Harding 2003

Paleontological name: *Spiniferites membranaceus* (Rossignol 1964) Sarjeant 1970

Figure No.: Plate 58

Reference:

Ellegaard *et al.*, (2003);

Pospelova and Kim (2010);

Srivilai *et al.*, (2012);

Attaran-Fariman *et al.*, (2012)

Description:

Transparent and ornamented cyst is spherical to ovoidal. The cyst has 35-41µm length and 32-36µm width. Paratabulations on the cyst sample are quite clear (Plate 58 A and B). The cyst has precingular archeopyle (Plate 58C). Plate 58D shows cell contents. The processes are trifurcate with bifid tips and antapical flags that are shown in µm in plate 58E.

The cyst size is slightly smaller than those described by Attaran-Fariman (2007).

Size:

W: 32-36 µm; L: 35-41µm

Occurrence in RSA:

The cyst type has formerly been reported from the central part of the inner RSA, Straits of Hormuz (Bradford & Wall 1984; Attaran-Fariman *et al.*, 2012; Attaran-Fariman 2016)

Occurrence in the world:

Arabian Sea (Bradford & Wall 1984); Southwest of India (Southeast Arabian Sea) (Godhe *et al.*, 2000). Britain (Ellegaard *et al.*, 2003), Ireland (Ellegaard *et al.*, 2003)

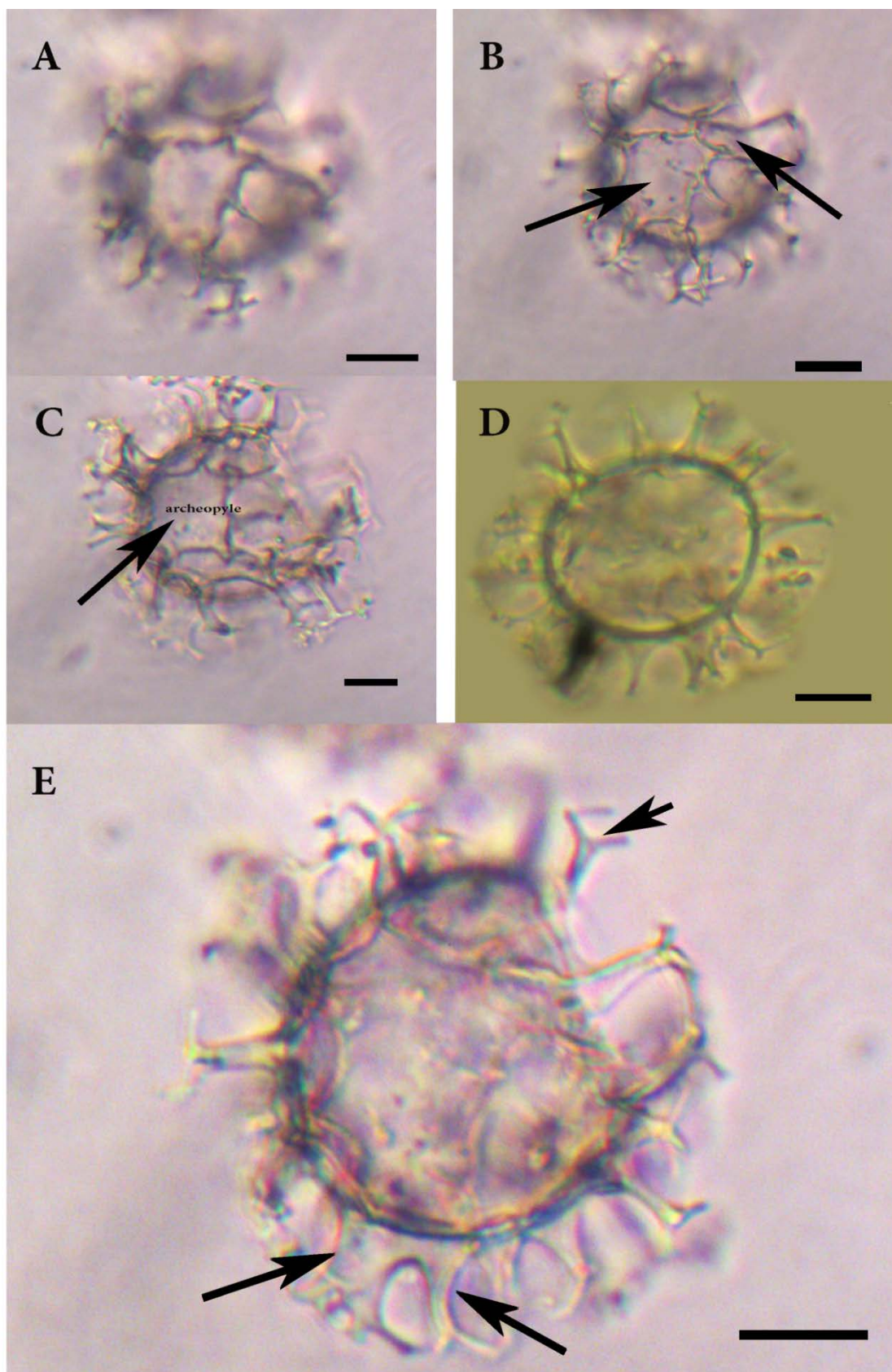
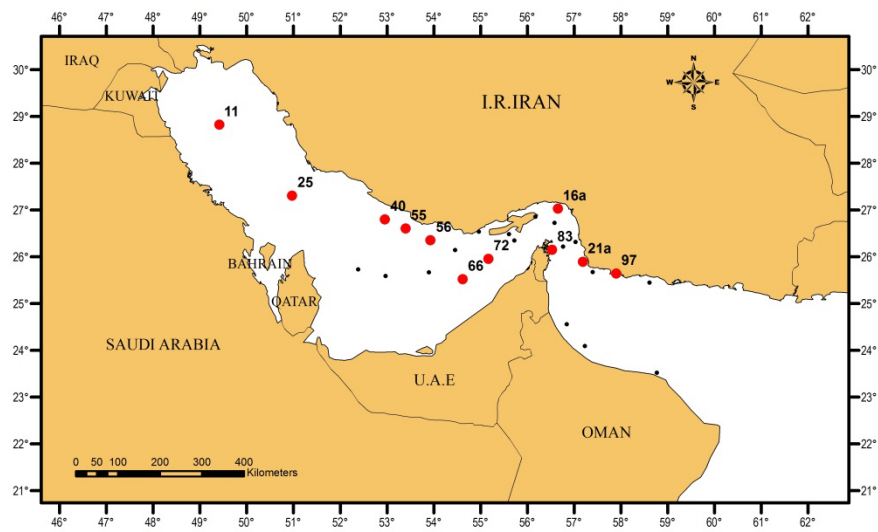


Plate 58: L.M. *Gonyaulax membranaceus* cyst from ROPME Sea Area; A: cyst in the surface focus; B: cyst showing paratabulation; C: arrow shows archeopyle on the cyst; D-E: deep focus showing bifid process (top arrow) and antapical flanges (bottom arrows).



Map 58: *Gonyaulax membranaceus* occurrence in the RSA, Winter 2006

Phylum: Miozoa Cavalier-Smith 1987

Class; Dinophyceae Fritsch 1927

Order; Gonyaulacales Taylor 1980

Family: Gonyaulacaceae Lindemann, 1928

Genus: *Gonyaulax* Diesing, 1866

Species: *Gonyaulax spinifera*

Scientific name: *Gonyaulax spinifera* (Claparède & Lachmann) Diesing 1866

Paleontological name: *Spiniferites mirabilis* (Rossignol) Matsuka

Figure No.: Plate 59

Reference:

Sonneman & Hill (1997), Figure 4a;

Joyce (2004), Figure 3;

Orlova *et al.*, (2004), Figures 24-25.

Balkis *et al.*, 2016, Figure 2, Plate 1, Figure 3.

Description:

Transparent large cyst has spherical to ovoidal shape. The processes are tabular and relatively short, bi- or trifurcate with almost broad distal bifid Y-shape tips. The cyst has a distinctive antapical flange containing several tubular process extended distally (Plate 59, arrows). The archeopyle is not seen on the cyst. This cyst is known only by its paleontological names.

Size:

W: 45µm; L: 48µm

Occurrence in RSA:

In the RSA cyst observed (Map 59) in stations; 85, 83, 78, 66, 69, 59, 55, 40, 11

The cyst has been reported from the inner RSA by Bradford and Wall (1984); the Sea of Oman (Godhe *et al.*, 2000; Marret and Zonneveld, 2003).

Occurrence in the world:

Spiniferites mirabilis is distributed from temperate to equatorial and in coastal as well in open oceanic environments (Zonneveld *et al.*, 2013). The cyst has been also reported from South China Sea

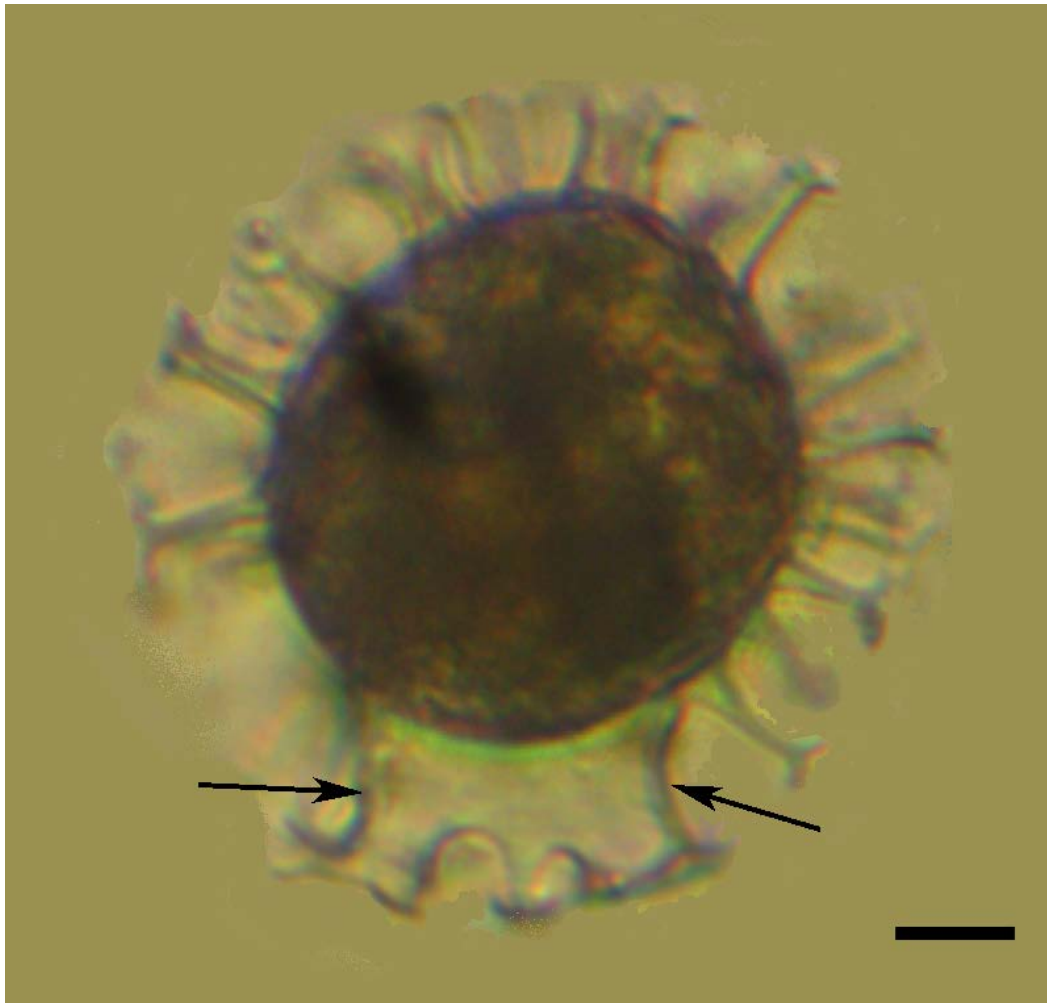
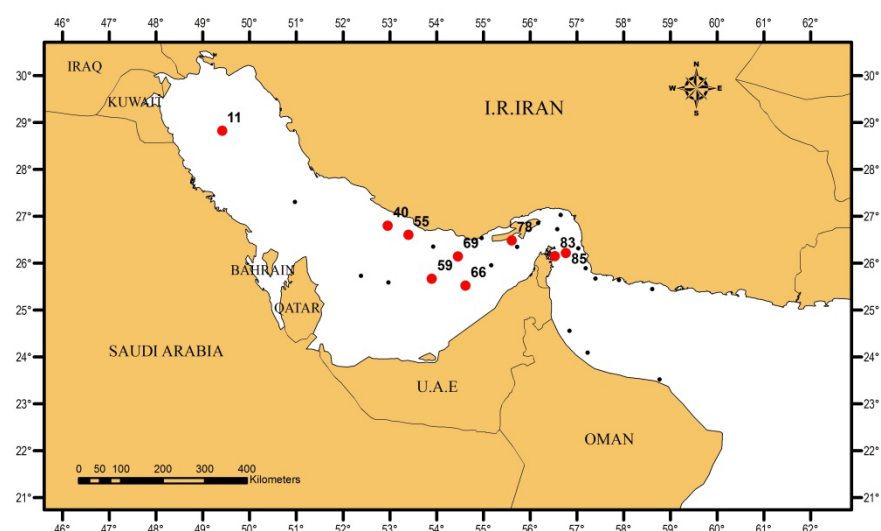


Plate 59: LM. Cyst of *Gonaulax spinifera*; paleontological taxon *Spiniferites mirabilis*, cyst showing conical process with branch tips, arrows show indistinct antapical crown shape process



Map 59: *Spiniferites mirabilis* occurrence in the RSA, Winter 2006

Phylum: Miozoa Cavalier-Smith 1987

Class; Dinophyceae Fritsch 1927

Order; Gonyaulacales Taylor 1980

Family: Gonyaulacaceae Lindemann, 1928

Genus: *Gonyaulax* Diesing, 1866

Species: *Gonyaulax digitale* (Pouchet 1883) Kofoid 1911

Scientific name: *Gonyaulax digitale*

Paleontological name: *Spiniferites bentori* (R.Ross.) Wall & Dale 1970

Figure No.: Plate 60

Reference:

Attaran-Fariman (2007), Figure 2

Description:

The cyst is ovoidal to pear-shape with bifurcate and trifurcate processes. The cyst has a pronounced apical boss. The archeopyle is precingular but not observed in our samples. The processes are slender and long when fully formed, otherwise are short. The long processes and cyst outline are more similar to that described by Bradford and Wall (1984) and Attaran-Fariman (2007) and differed from Yellow Sea, China (Liu *et al.*, 2012) cyst with short processes.

Size:

W: 37 µm; L: 45µm

Occurrence in RSA:

In the RSA cyst observed (Map 60) in stations 43

The cyst has been reported from Sea of Oman (Bradford, 1975; Attaran-Fariman 2007, 2016)

Occurrence in the world:

Black Sea, the Marmara Sea (Mudie *et al.*, 2001; 2004) Marmara Sea, Turkey (Balkis *et al.*, 2016); Yellow Sea (Liu *et al.*, 2012); southwestern Australia (Marret and Zonneveld, 2003); Canada (Price and Pospelova, 2011).

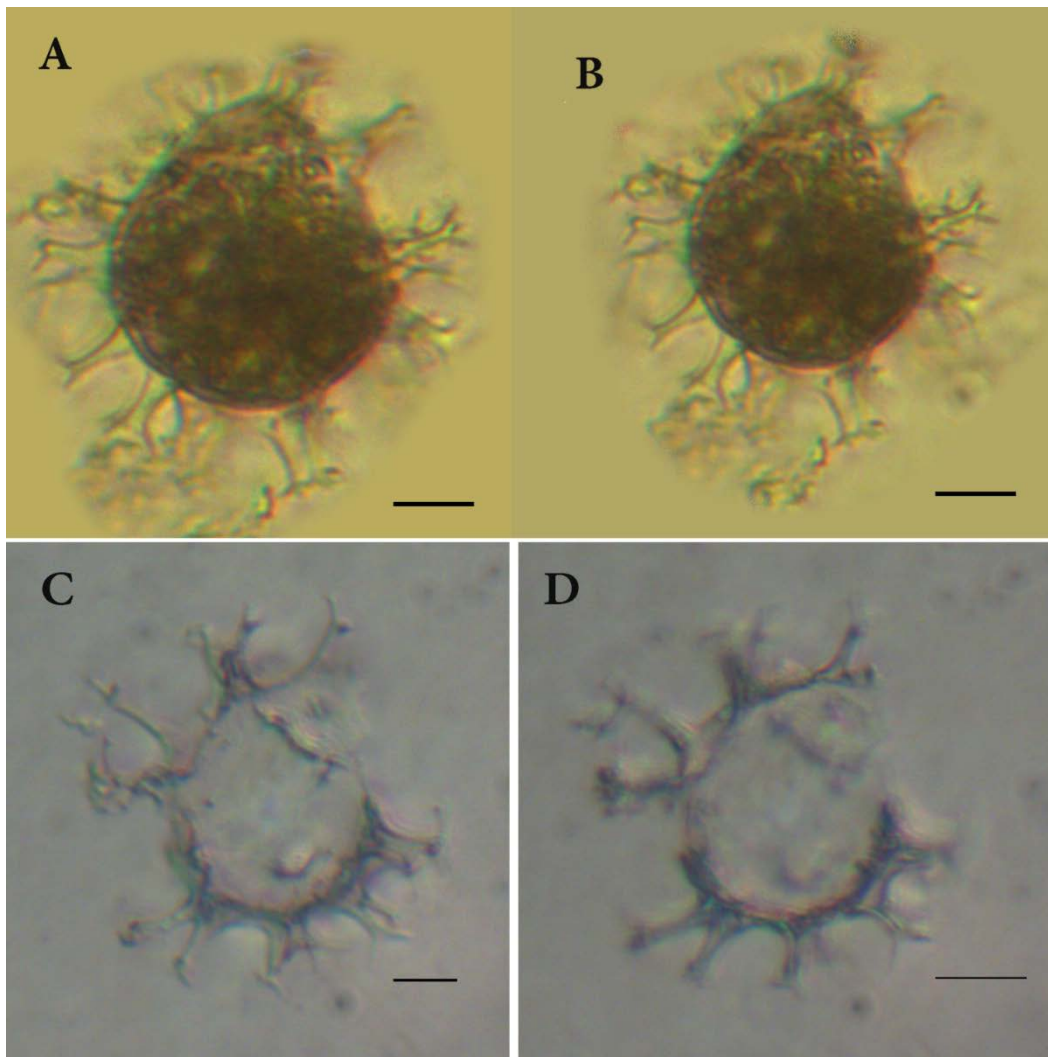
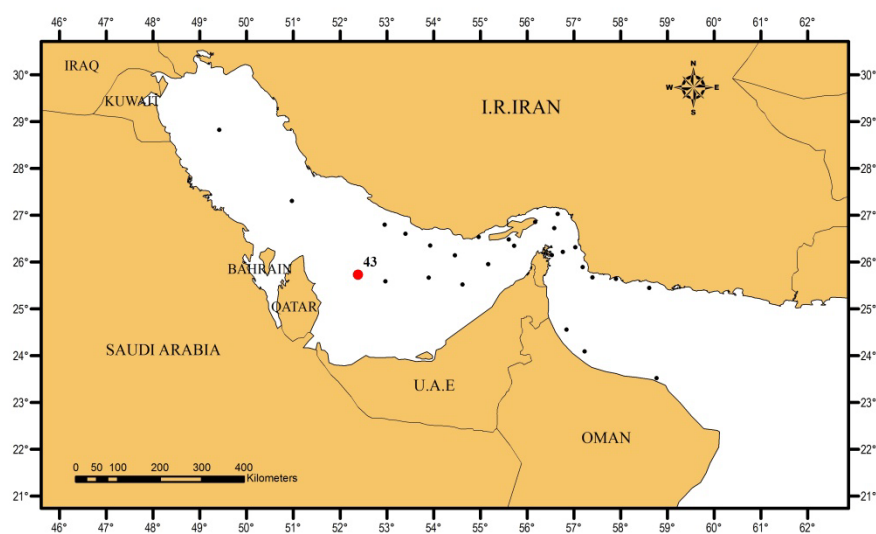


Plate 60: *Gonyaulax digitale* cyst with a pronounced apical horn



Map 60: *Gonyaulax digitale* occurrence in the RSA, Winter 2006

Phylum: Miozoa

Class; Dinophyceae Fritsch

Order; Gonyaulacales Tylor

Family: Gonyaulacaceae Lindemann

Genus: *Gonyaulax* Diesing

Species: *Gonyaulax* cf. *scrippsae* Kofoid

Scientific name: *Gonyaulax scrippsae* Kofoid 1911

Paleontological name: *Spiniferites bulloideus* (Deflandre et Cookson) Sarjeant

Figure No.: Plate 61

Reference:

Kofoid (1911), Plate 13, Figure 26 and Plate 16, Figure 38;

Bolch and Hallegraeff (1990), Figure 5;

Sonneman and Hill (1997), Figure 3;

Orlova *et al.*, (2004), Figure 22-23

Description:

Ovoid to subspherical cysts. The cyst size is small. Cyst processes are trifurcate with bifid tips and processes interconnected by sutural septa and define the paraplate borders and a paracingular region (Plate 61 A and B). The antapical flange is not seen in this cyst (Plate 61 C and D). The archeopyle is pre-cingular plate and form in the dorsal surface. The cyst resembles to *G. baltica* Ellegaard, Lewis and Harding. Ellegaard *et al.*, (2002) separate this cyst from *G. baltica* by variation in process morphology and septa found in *G. baltica*.

Size:

W: 33µm; L: 38µm

Occurrence in RSA:

The occurrence of the species in the sediment sample of the Winter Cruise 2006 of RSA is shown on Map 61, stations: 93, 21a, 87, 14a, 77, 70, 72, 59

The cyst of *S. bulloideus* has been reported from the Sea of Oman in low numbers (Bradford and Wall 1984).

Occurrence in the world:

Black Sea, Mediterranean, Brazil, southwest coast of India, east coast of Russia, Coast of Tasmania, New South Wales, Coast of Victoria Australia.

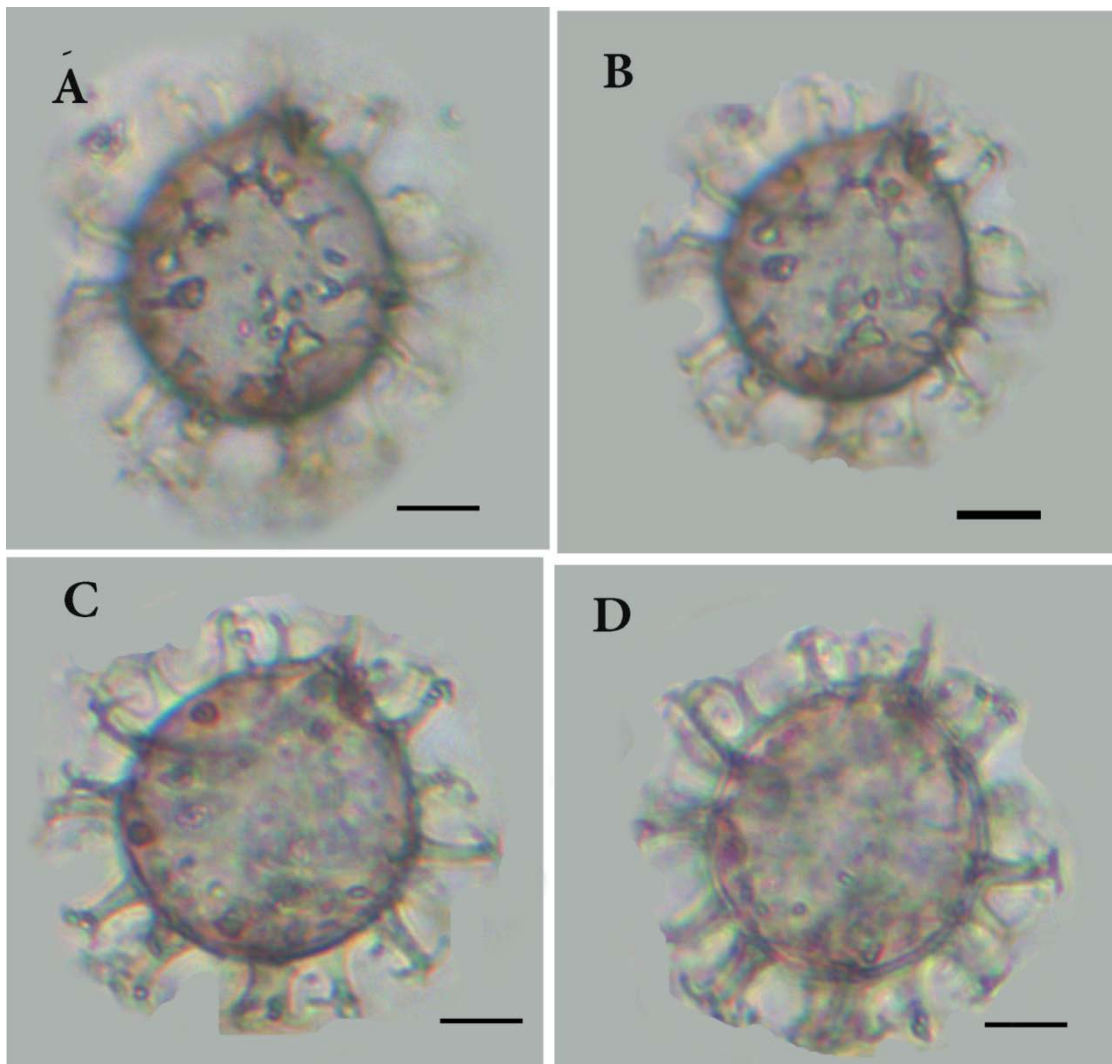
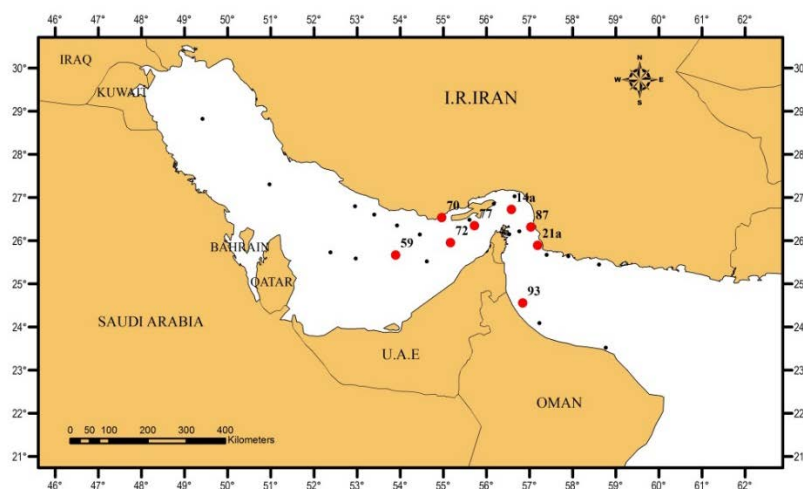


Plate 61: *Gonyaulax cf. scrippsae*, A and B surface focus showing paratabulation in the cyst; C and D deep focus showing the process



Map 61: *Gonyaulax cf. scrippsae* occurrence in the RSA, Winter 2006

Phylum: Miozoa Cavalier-Smith 1987

Class; Dinophyceae Fritsch 1927

Order; Gonyaulacales Taylor 1980

Family: Gonyaulacaceae Lindemann, 1928

Genus: *Gonyaulax* Diesing, 1866

Species: *Gonyaulax spinifera*

Scientific name: *Gonyaulax spinifera* (Claparède & Lachmann) Diesing 1866

Paleontological name: *Gonyaulax spinifera* (Ehrenberg 1838) Mantell 1854

Figure No.: Plate 62

Reference:

Attaran-Fariman (2007), Figure 9;

Rochon *et al.*, (2009) Figure 2;

Liu *et al.*, (2012) Figure 3j;

Balkis *et al.*, (2016), Figure 18

Description:

Ovoidal to spherical cyst with brown colour. The cyst has hollow processes distally furcate with bifurcate tips. This cyst type can be distinguished from other species by two pronounced antapical processes (Plate 62).

Size:

W: 29µm; L: 34µm

Occurrence in RSA:

The occurrence of the species in the sediment sample of the Winter Cruise 2006 of RSA is shown on Map 62, stations: 88, 85, 59, and 40

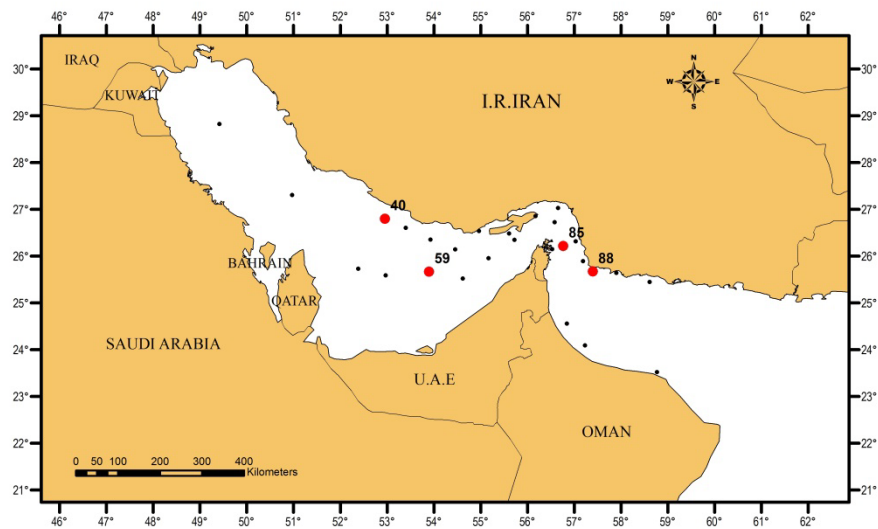
The cyst of *S. ramosus* has been reported from the Sea of Oman (Attaran-Fariman 2007)

Occurrence in the world:

Arabian Sea (Zonneveld and Brummer, 2000). North Atlantic (Dale and Dale, 1992) Arctic sediments (Radi and de Vernal, 2008), Yellow Sea, China (Liu *et al.*, 2012) Marmara Sea, Turkey (Balkis *et al.*, 2016),



Plate 62: *Spiniferites ramosus* showing long antapical processes



Map 62: *Spiniferites ramosus* occurrence in the RSA, Winter 2006

Phylum: Miozoa Cavalier-Smith 1987

Class; Dinophyceae Fritsch 1927

Order; Gonyaulacales Taylor 1980

Family: Gonyaulacaceae Lindemann, 1928

Genus: *Gonyaulax* Diesing, 1866

Species: *Gonyaulax baltica*

Scientific name: *Gonyaulax spinifera* (Ehrenberg 1838) Mantell 1854

Paleontological name: *Gonyaulax baltica* Ellegaard, Lewis & Harding 2002

Figure No.: Plate 63

Reference:

Sonneman & Hill (1997), Figures 3a-b;

Ellegaard *et al.*, (2002), Figure 4G-D;

Ellegaard *et al.*, (2003), Figures 1-5;

Attaran-Fariman (2007), Figures 7a-d

Description:

Central cyst body ovoidal to subspherical (Plate 63). The process is gonial with bifid tips. The process length is variable; some cysts found with short spines and some specimens with long spines (Plate 63 E-F). Cyst has sometimes membranous flange process in the antapical and paracingular regions (Plate 63. C-D). Apical boss is clear in some specimens (Plate 63 A, E).

This cyst type shows variations in length and shape processes (Ellegaard *et al.*, 2002)

Size:

W: 31µm; L: 35µm

Occurrence in RSA:

The occurrence of the species in the sediment sample of the Winter Cruise 2006 of RSA is shown on Map 63, stations: 97, 85, 83, 14a, 55

The cyst of *G. baltica* has been reported from the Sea of Oman (Attaran-Fariman *et al.*, 2012)

Occurrence in the world:

The Sea of Oman and Arabian Sea (Bradford & wall 1984; Attaran-Fariman 2003); Marret & Zonneveld 2003; Baltic Sea (Ellegaard *et al.*, 2002); Australia (Sonneman & Hill 1997)

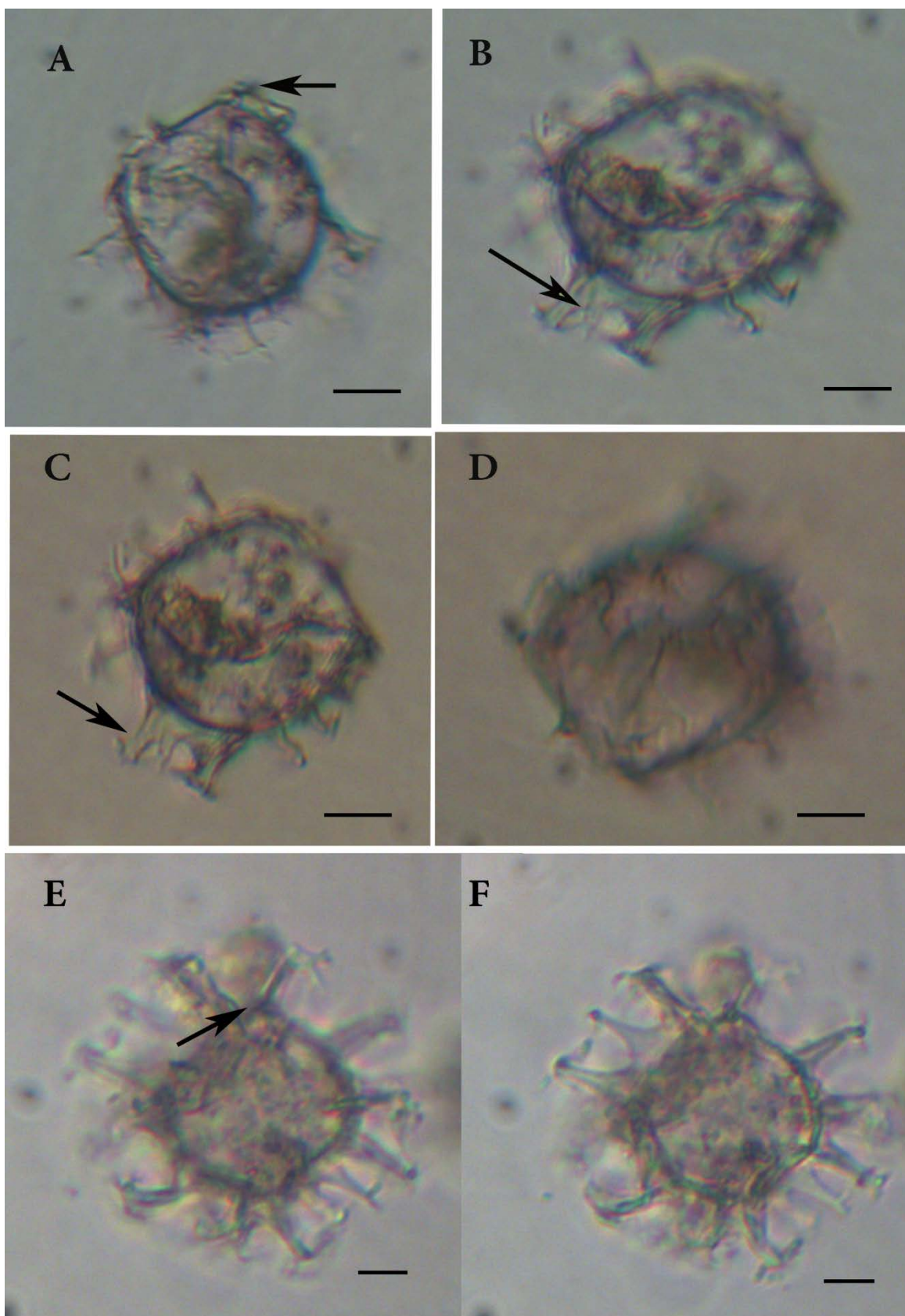
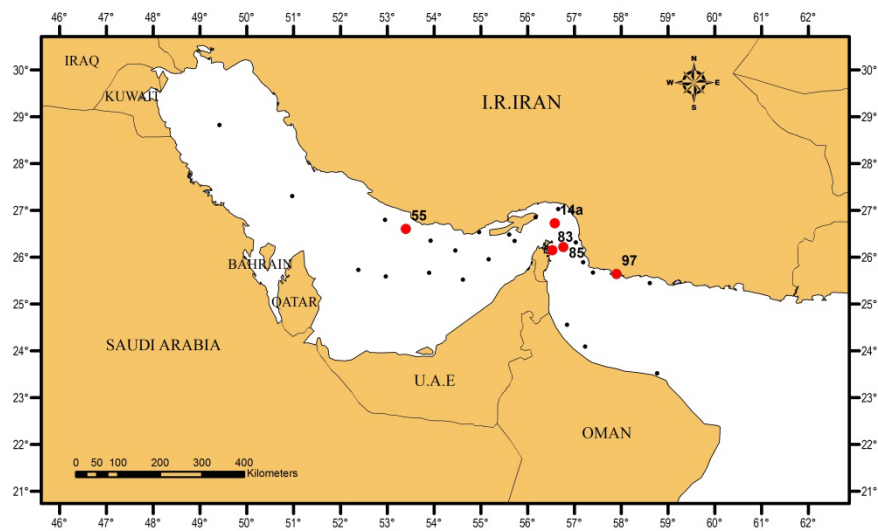


Plate 63: *Gonyaulax baltica* cyst showing apical boss



Map 63: *Gonyaulax Baltica* presence in the RSA, Winter 2006

Phylum: Miozoa Cavalier-Smith 1987

Class; Dinophyceae Fritsch 1927

Order; Gonyaulacales Taylor 1980

Family: Gonyaulacaceae Lindemann, 1928

Genus: *Gonyaulax* Diesing, 1866

Species: *Gonyaulax spinifera*

Scientific name: *Gonyaulax spinifera* (Claparède & Lachmann) Diesing 1866

Paleontological name: *Spiniferites* cf. *delicatus* Reid 1974

Figure No. Plate 64

Reference:

Joyce (2004), Plate1, Figure1;

Liu (2012), Figure 3E, I

Description:

The cyst is spherical to ovoidal without any apical boss. The gonol process of the cyst is connected with almost high septa. The processes are also hollow with petaloid tips. (Plate 64) The skeletal rod connects the process (Plate 64 B, D). The prismatic archeopyle was not observed in our sample. This species resembles to the *Gonyaulax baltica* in shape and processes; however, the presence of the skeletal rod and lack of apical boss in the *S. delicatus* is different.

Size:

W: 39µm; L: 44µm

Occurrence in RSA:

The occurrence of the species in the sediment sample of the Winter Cruise 2006 of RSA is shown on Map 64, stations: 97, 72, and 59

Occurrence in the world:

South Korea (Yun *et al.*, 2000); China Sea (Kawamura 2004); Mediterranean Sea (Turon *et al.*, 1988); Japan (Fujii and Matsuoka, 2006).

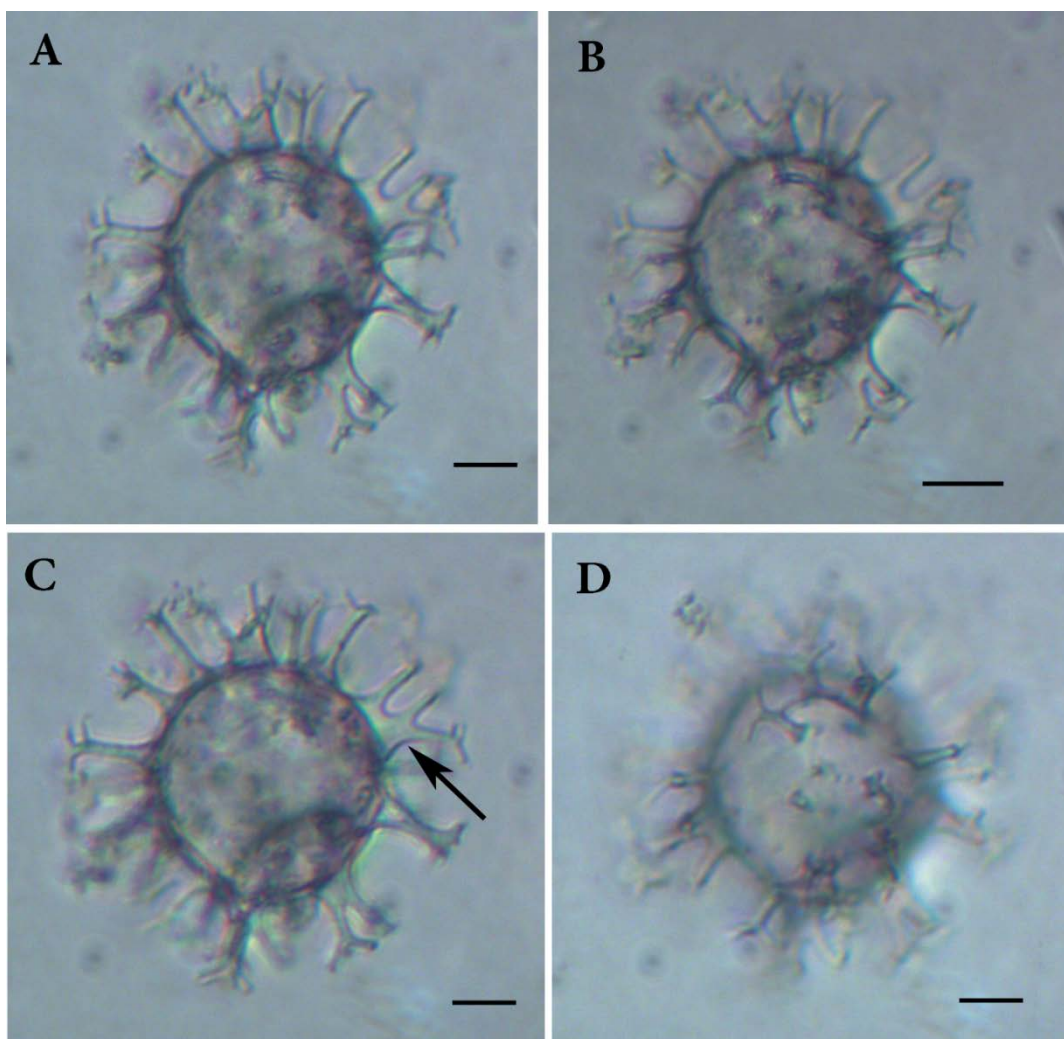
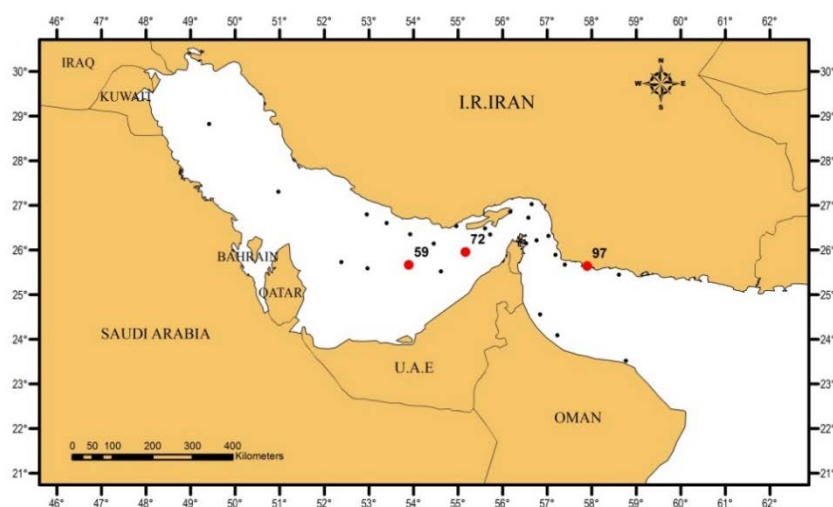


Plate 64: LM. Cyst of *Gonyaulax spinifera*; paleontological taxon: *Spiniferites cf. delicatus*, cyst showing conical process with branch tips; arrow shows indistinct antapical crown shape process



Map 64: *Spiniferites cf. delicatus* occurrence in the RSA, Winter 2006

Phylum: Miozoa Cavalier-Smith 1987

Class; Dinophyceae Fritsch 1927

Order; Gonyaulacales Taylor 1980

Family: Gonyaulacaceae Lindemann, 1928

Genus: *Gonyaulax* Diesing, 1866

Species: *Gonyaulax spinifera* complex

Scientific name: *Gonyaulax spinifera* (Claparède & Lachmann) Diesing 1866

Paleontological name: *Spiniferites hyperacanthus* (Deflandre & Cookson) Cookson & Eisenack 1974

Figure No.: Plate 65

Reference:

Qi *et al.*, (1996), Plate 1E;

Liu (2012), Figure 3F;

Yoon & Shin (2013), Figure 6

Description:

Spherical cyst with the outer smooth two layers wall. The cyst is ornamented with gonal hollow and both bifurcate and trifurcate process (Plate 65). Tabulation in this cyst is weakly expressed and not seen in our samples. Live cyst has globular content with red accumulation body (Plate 65, C). The morphology of the cyst resembles the *S. mirabilis*; however, the antapical flange is missing in this species.

Size:

D: 53µm

Occurrence in RSA:

The occurrence of the species in the sediment sample of the Winter Cruise 2006 of RSA is shown on Map 65, stations: 14a

Occurrence in the world:

South-west Asia; Turkey (Balkis *et al.*, 2016); Yellow Sea, China (Liu *et al.*, 2012);

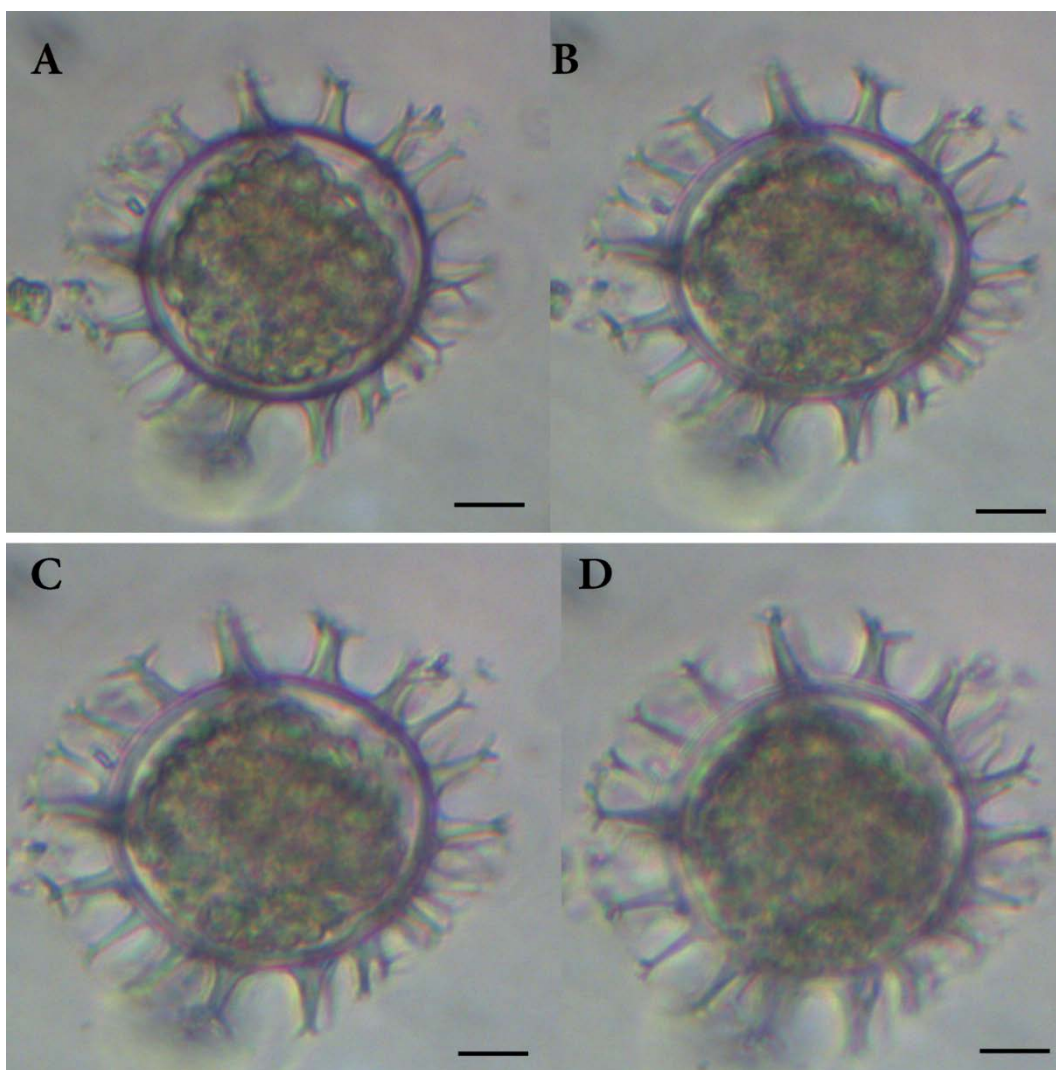
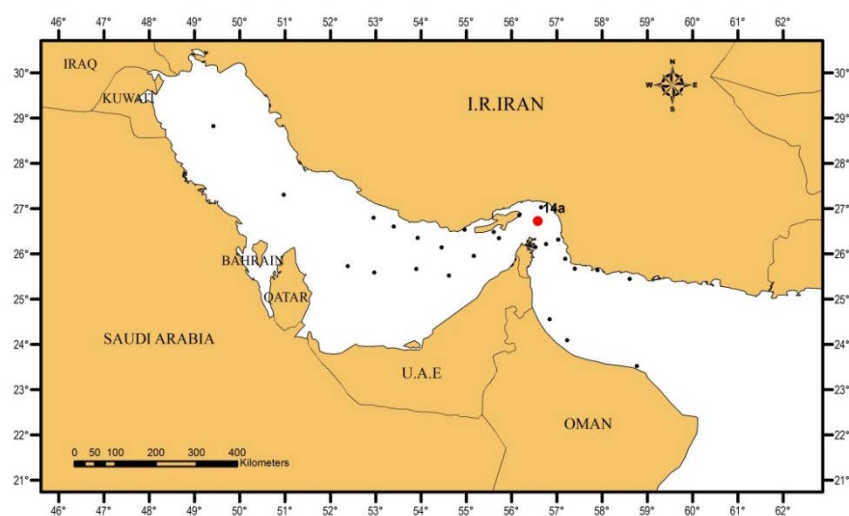


Plate 65: Cyst of *Gonyaulax spinifera* complex; paleontological taxon: *Spiniferites hyperacanthus*, cyst showing bifurcate and trifurcate processes



Map 65: *Spiniferites hyperacanthus* presence in the RSA, Winter 2006

Phylum: Miozoa Cavalier-Smith 1987

Class; Dinophyceae Fritsch 1927

Order; Gonyaulacales Taylor 1980

Family: Gonyaulacaceae Lindemann, 1928

Genus: *Gonyaulax* Diesing, 1866

Species: *Gonyaulax ellegaardiae*

Scientific name: *Gonyaulax ellegaardiae* Mertens, Aydin, Takano, Yamaguchi & Matsuoka in Mertens *et al.*, 2015

Paleontological name: *Spiniferites pachydermus* (Rossignol) Reid 1974

Figure No.: Plate 66

Reference:

Merten *et al.*, (2015) Figures 5-7;

Description:

An ovoid cyst with microgranulate to reticulate wall (Plate 66). A low apical boss is present (Plate 66). The cyst has gonal trifurcate process with bifurcate tip. Paratabulation is expressed by low stural septa that connect the process. The precingular archeopyle is formed by loss of third plate. The motile affinity of this species was unknown before 2015. The cyst theca relationship of the *S. pachydermus* species was established, and based on morphology of the cyst and motile cell, the new species is introduced (Mertens *et al.*, 2015). But they differ from *G. spiniferits*.

Size:

W: 33µm; L: 40µm

Occurrence in RSA:

The occurrence of the species in the sediment sample of the Winter Cruise 2006 of RSA is shown on Map 66, stations: 83, 40

Occurrence in the world:

Izmir Bay, Turkey (Mertens *et al.*, 2015)

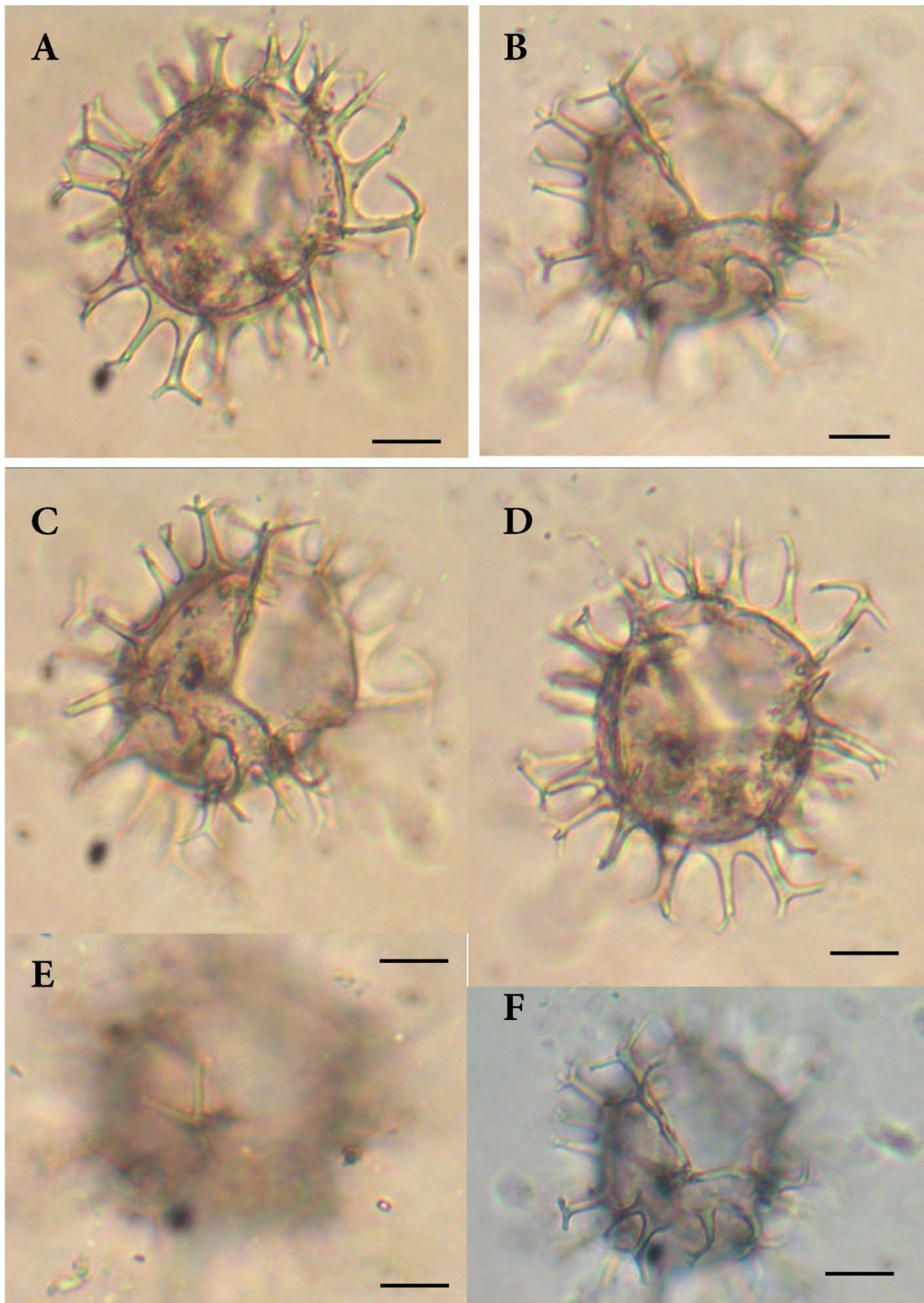


Plate 66: *Gonyaulax ellegardiae* cyst showing archeopyle ant processes



Map 66: *Gonyaulax ellegardiae* occurrence in the RSA, Winter 2006

Phylum: Miozoa Cavalier-Smith 1987

Class; Dinophyceae Fritsch 1927

Order; Gonyaulacales Taylor 1980

Family: Gonyaulacaceae Lindemann, 1928

Genus: *Gonyaulax* Diesing, 1866

Species: *Gonyaulax* sp.1

Scientific name: *Gonyaulax* sp.1

Paleontological name: *Spiniferites* sp.1

Figure No.: Plate 67

Reference:

Zonneveld & Pospelova (2015)

Description:

This cyst type has an asymmetrical almost extended outline wall. The cyst wall is colourless and has a single layer. The process seems solid with bifurcate tips (Plate 67). The processes are connected and supported by skeletal rods (Plate 67). The cyst resembles *S. delicatus* in having skeletal rods; however, it can be distinguished from that by the cyst outline and the process. The morphology of the *Spiniferites* can be varying extremely under different environmental conditions and hard to separate this complex group from each other.

Size:

W: 42µm; L: 50µm

Occurrence in RSA:

The occurrence of the species in the sediment sample of the Winter Cruise 2006 of RSA is shown on Map 67, stations: 56, 59

Occurrence in the world:

Not reported from anywhere else.

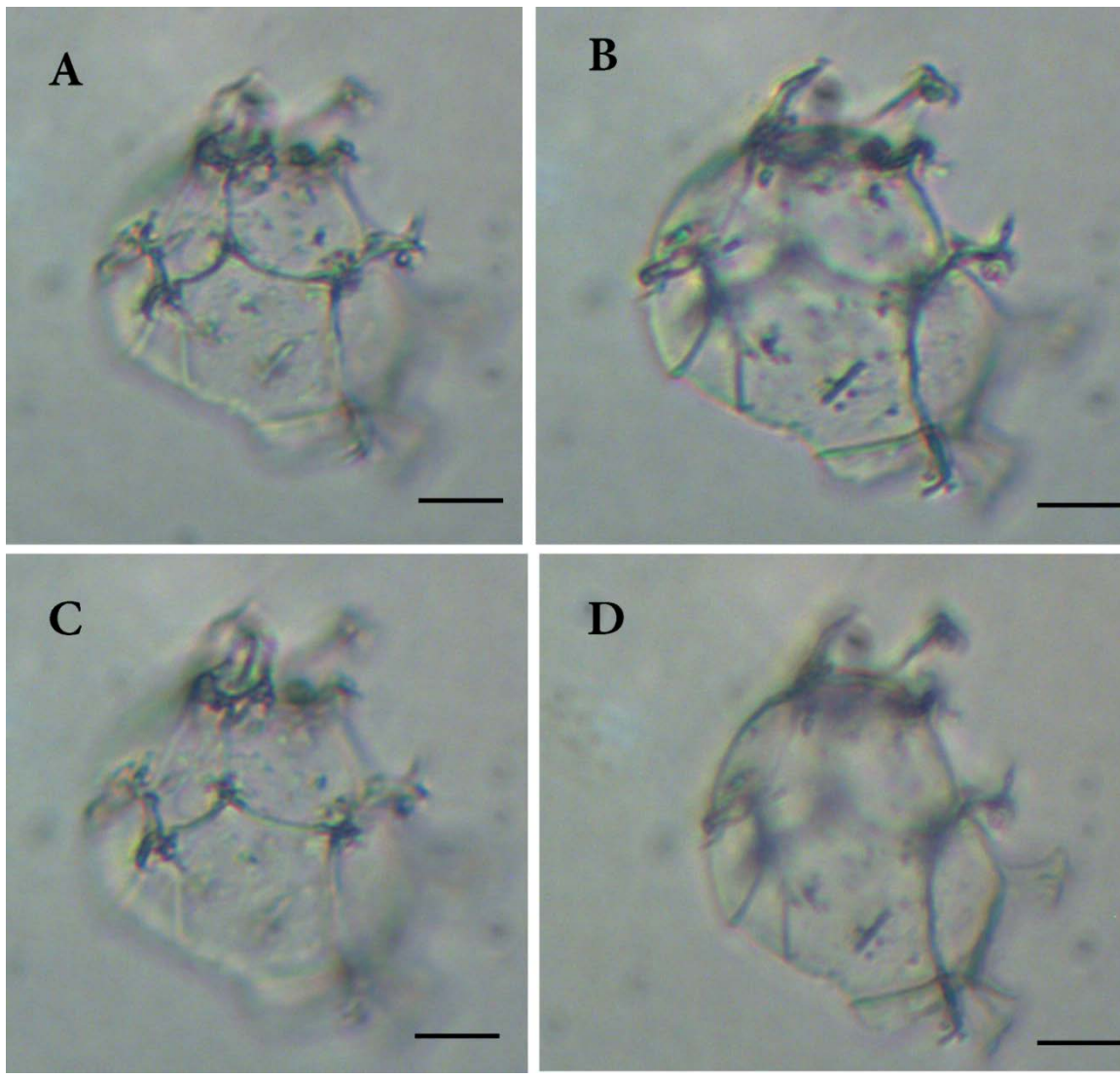
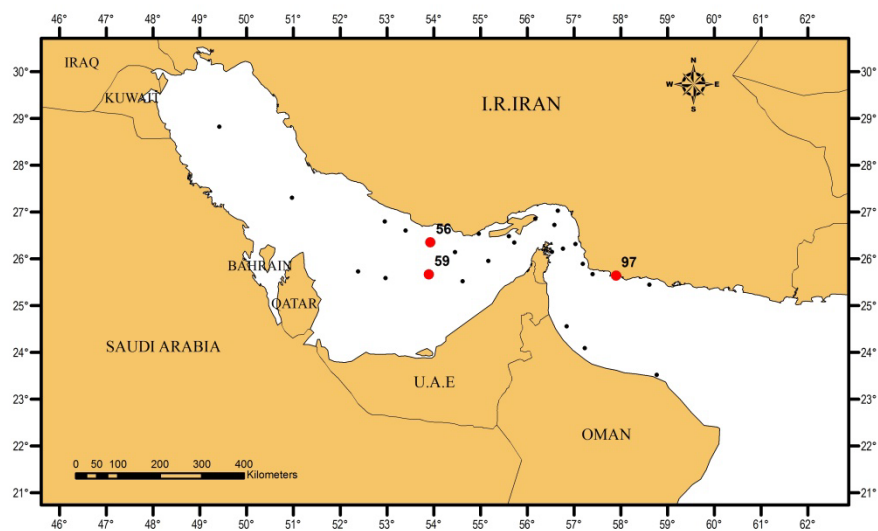


Plate 67: *Gonyaulax* sp.1 cyst at different focal level showing processes



Map 67: *Gonyaulax* sp.1 occurrence in the RSA, Winter 2006

Phylum: Miozoa Cavalier-Smith 1987

Class; Dinophyceae Fritsch 1927

Order; Gonyaulacales Taylor 1980

Family: Gonyaulacaceae Lindemann, 1928

Genus: *Gonyaulax* Diesing, 1866

Species: *Gonyaulax* sp2

Scientific name: *Gonyaulax* sp. 2

Paleontological name: *Spiniferites* sp.1

Figure No.: Plate 68

Reference:

Srivila *et al.*, (2012) Figure 2j

Description:

The cyst is hemisphere in outline. The hollow processes are gonal with bifurcate end. The processes are inter-connected and parasutural region are well defined (Plate 68A). The cyst differs from *Gonyaulax* sp.1 by its cyst shape and process. This cyst outline resembles the cyst of *Areoligera senonensis*; however, it differs from this species in having paratabulation. The species in the later species form fossil

Size:

W: 39µm

Occurrence in RSA:

The occurrence of the species in the sediment sample of the Winter Cruise 2006 of RSA is shown on Map 68, stations: 77, 40

Occurrence in the world:

Thailand (Srivila *et al.*, 2012)

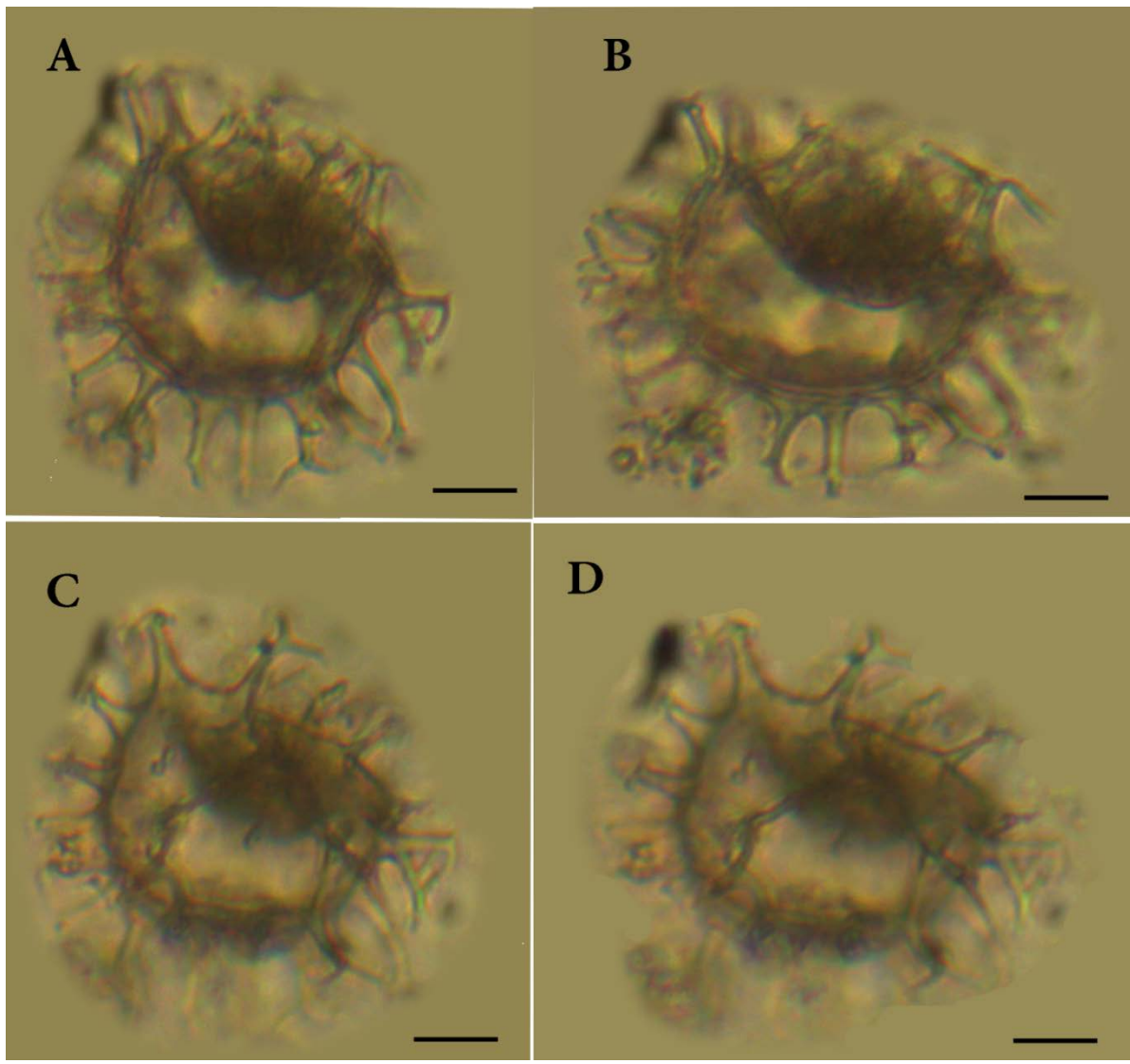
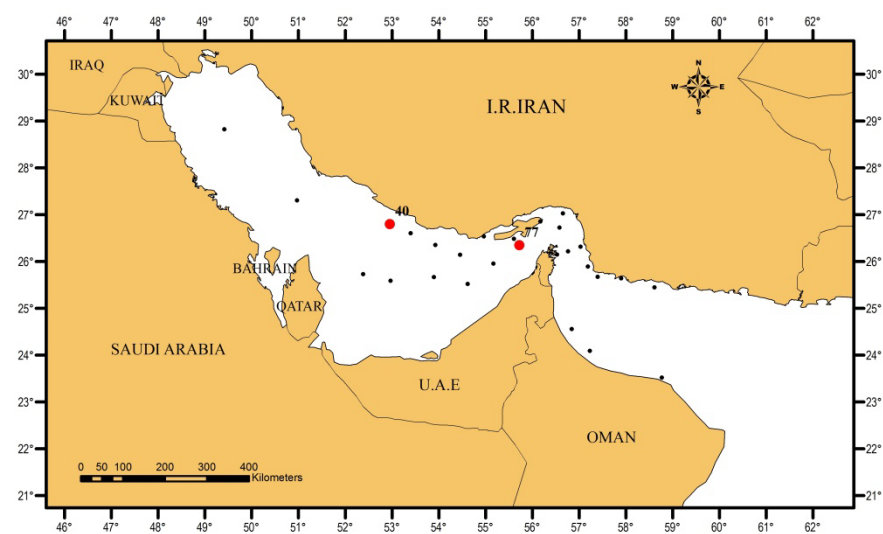


Plate 68: *Gonyaulax* sp.2 cyst at different focal levels showing hollow processes



Map 68: *Gonyaulax* sp.2 occurrence in the RSA, Winter 2006

Phylum: Miozoa Cavalier-Smith 1987

Class; Dinophyceae Fritsch 1927

Order; Gonyaulacales Taylor 1980

Family: Gonyaulacaceae Lindemann, 1928

Genus: *Lingulodinium* D.Wall, 1967

Species: *Lingulodinium polyedra*

Scientific name: *Lingulodinium polyedra* (F.Stein) J.D.Dodge 1989

Paleontological name: *Lingulodinium machaerophorum* (Deflandre & Cookson) Wall

Figure No.: Plate 69

Reference:

Wall & Dale (1968), Plate 1, Figures 17-18;

Joyce (2004) Plate 1, Figure 6;

Kawamura (2004) Figures 24-25;

Attaran-Fariman (2007), Figure 8;

Head *et al.*, (2007), Figure 6b;

Mertens *et al.*, (2009a) Plate 3, Figures 1-20;

Mertens *et al.*, (2009b), Plates I-IV

Description:

The cyst is chorate spherical to subspherical or ovoidal (Plate 69). The cyst with two-layer wall that is thick and granulated. Cyst processes are distally closed, hollow, tubular and non-tubular. The archeopyle is formed by loss of one to five precingular paraplates. The archeopyle is observed in lateral view (Plate 69, E-F). Live cyst has a dark red accumulation body (Plate 69, C-D). This cyst type shows variation in process from short to long and from acuminate to round in different salinities and temperatures (Mertens *et al.*, 2009b). This cyst type was very common in the sediment of the RSA.

Size:

D: 35-45µm

Occurrence in RSA:

The occurrence of the species in the sediment sample of the Winter Cruise 2006 of RSA is shown on Map 69, in stations: 26, 98, 93, 97, 88, 21a, 87, 85, 83, 14a, 16a, 77, 78, 72, 66, 69, 56, 59, 50, 55, 40, 25, 11

This cyst type has also been previously reported from the Sea of Oman and the inner RSA (Bradford & Wall 1984; Attaran-Fariman 2007, 2016), and coastal sediment of Kuwait (Husain & Lewis 2004)

Occurrence in the world:

Arabian Sea and southwest coast of India (Godhe *et al.*, 2000; Marret & Zonneveld 2003) Bahía Concepción, Gulf of California (Morquecho & Lechuga-Devéze, 2004); Japan (Fujii & Matsuoka, 2006). Africa (Richter *et al.*, 2007); Red Sea (Sangiorgi *et al.*, 2005). Black Sea and Marmara Sea, South-west Asia, Turkey (Asia) (Balkis *et al.*, 2016);

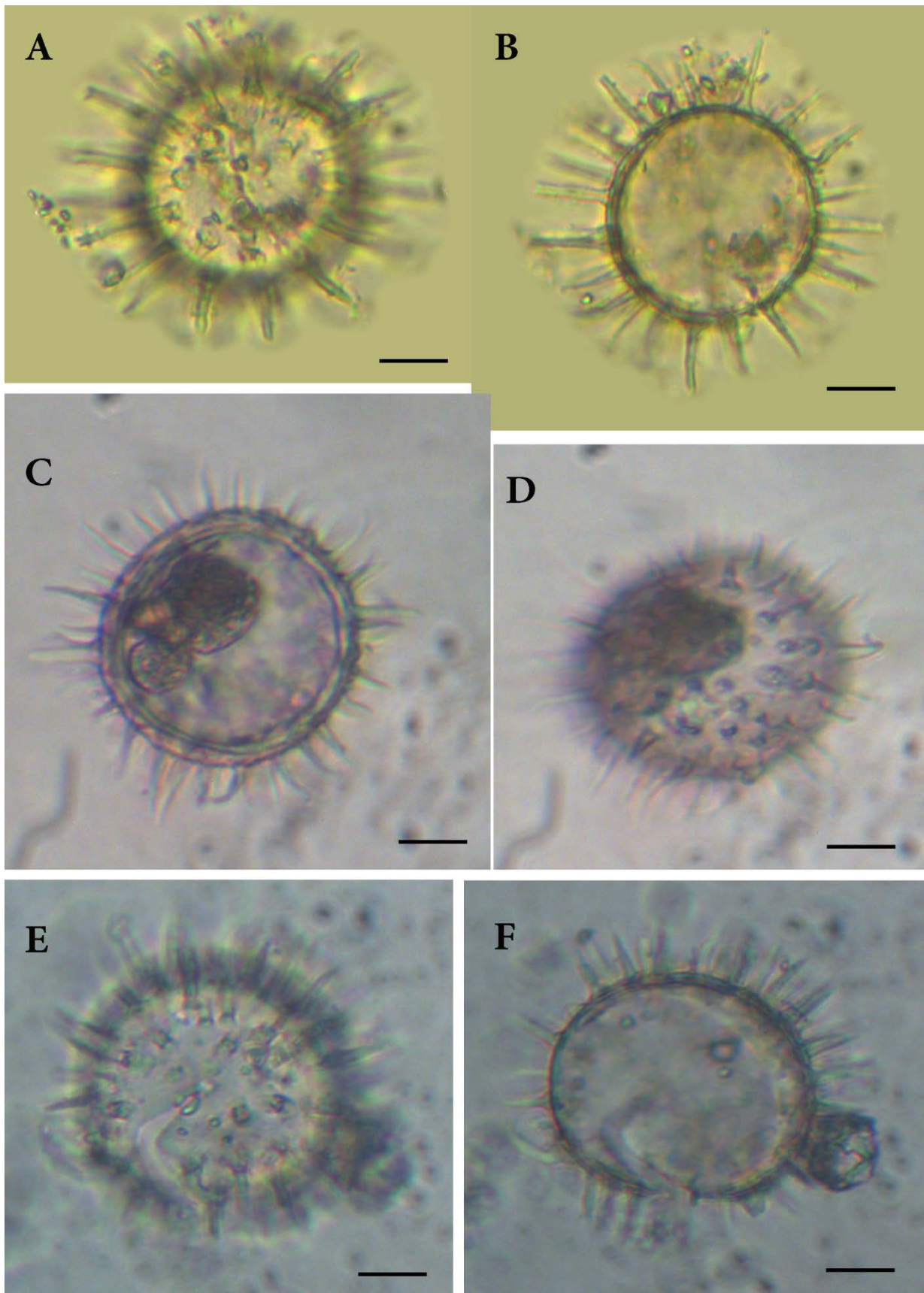
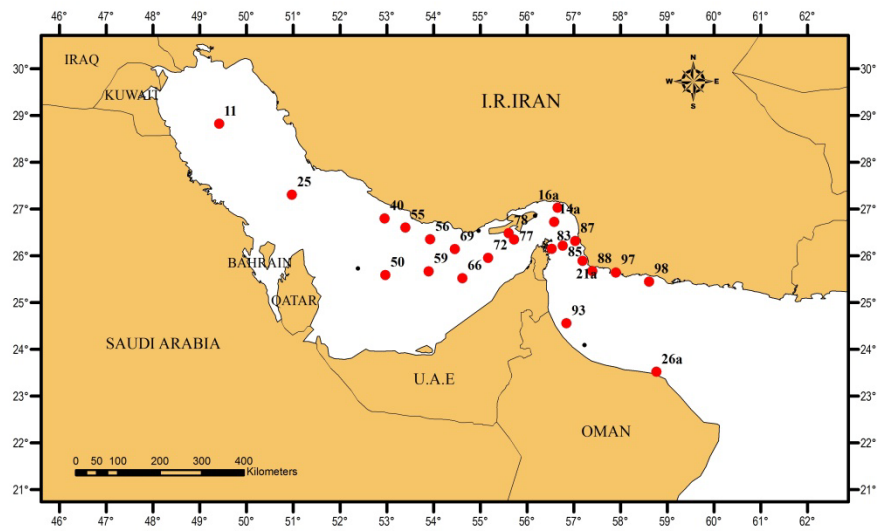


Plate 69: *Lingulodinium polyedra* cyst showing variation in processes length



Map 69: *Lingulodinium polyedra* occurrence in the RSA, Winter 2006

Phylum: Miozoa Cavalier-Smith 1987

Class; Dinophyceae Fritsch 1927

Order; Gonyaulacales Taylor 1980

Family: Gonyaulacaceae Lindemann, 1928

Genus: *Lingulodinium* D.Wall, 1967

Species: *Lingulodinium* sp.1

Scientific name: *Lingulodinium* sp. (F.Stein) J.D.Dodge 1989

Paleontological name: *Lingulodinium machaerophorum* (Deflandre & Cookson) Wall

Figure No.: Plate 70

Reference:

Not found

Description:

Transparent cyst is hexagonal in shape with rounded corners (Plate 70). The cyst has a single layer wall. The processes are hallowing with distally closed tips and some processes folded. The processes are wide in the base. The archeopyle is epicystdal split along the corner of the smaller parallel side (Plate 69 D). The cyst processes resemble to *L. polyedra*; however, they differ from that by the cyst shape. All *L. polyedra* cysts that have been stated until now are spherical to oval in shape, in spite of that the later species has variation in the processes (Mertens *et al.*, 2009). There is no report on the hexagonal shape of *L. polyedra*; therefore, the species from RSA is probably belonging to this genus, but without germination experiment, it is hard to identify the species.

Size:

W: 45µm; L: 50µm

Occurrence in RSA:

The occurrence of the species in the sediment sample of the Winter Cruise 2006 of RSA is shown on Map 70, in stations: 88, 85, 66

Occurrence in the world:

Not reported from anywhere else

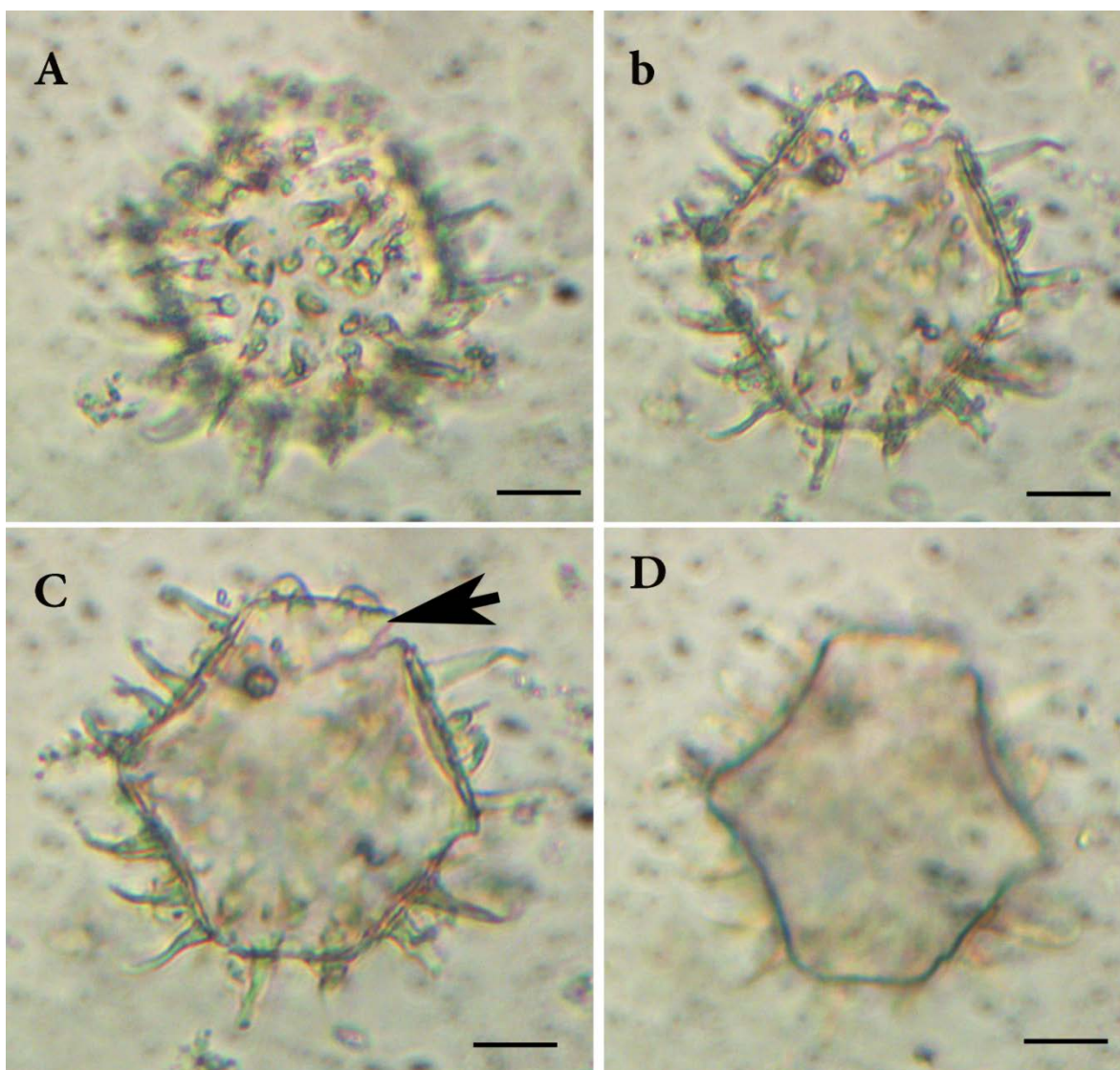
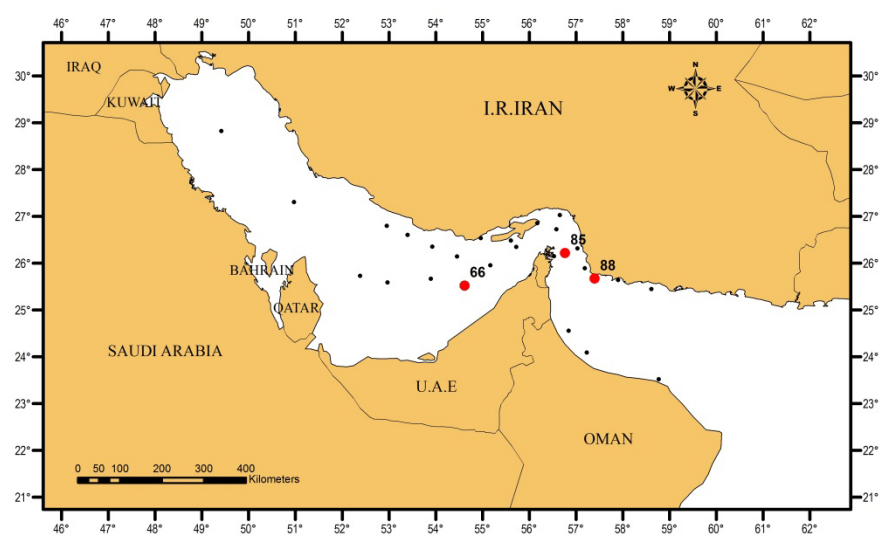


Plate 70: *Lingulodinium* sp. cyst showing hexagonal shape and chasmic archeopyle



Map 70: *Lingulodinium* sp. occurrence in the RSA, Winter 2006

Phylum: Miozoa Cavalier-Smith 1987

Class; Dinophyceae Fritsch 1927

Order; Gonyaulacales Taylor 1980

Family: Protoceratiaceae Lindemann, 1928

Genus: *Protoceratium* Bergh 1881

Species: *Protoceratium reticulatum*

Scientific name: *Protoceratium reticulatum* (Claparède & Lachmann) Bütschli 1885

Paleontological name: *Operculodinium centrocarpum* (Deflandre & Cookson) Wall 1967

Figure No.: Plate 71

Reference:

Bolch & Hallegraeff (1990), Figure 2;

Sonneman & Hill (1997), Figure 7;

Joyce (2004), Plate 3 Figure 1;

Mertens (2012), Figure 2;

Akselman *et al.*, (2015), Figure 2;

Description:

Spherical to subspherical cyst with numerous hollow capitate process. The processes have variable morphology and lengths. Some processes may be slightly curved (Plate 71, D) and have same thickness from the base to the distal ends. Distal end of the process is closed and may be bifid or branched and some cyst may have fused process (Plate 71, B and D). The cyst wall is often granulated (Plate 71, C). The archeopyle is precingular but was not observed in our samples. This species is synonym of *Gonyaulax grindlleyi* Reinecke

Size:

D: 38µm

Occurrence in RSA:

The occurrence of the species in the sediment sample of the Winter Cruise 2006 of RSA is shown on Map 71, in stations: 88, 16a, 79, 69, 59, 55. 11

This cyst type has also been previously reported from the Sea of Oman (Attaran-Fariman, 2016).

Occurrence in the world:

Australia (Bolch & Hallegraeff 1990; Sonneman & Hill 1997); SW Indian (Godhe *et al.*, 2000); South China Sea, (Kawamura 2004) south Africa (Joyce 2004); Arctic (Radi and de Vernal, 2008); north Pacific (Pospelova & Kim 2010); Baltic estuarine system (Mertens *et al.*, 2012); Argentina (Akselman *et al.*, 2015); South-west Asia: Turkey (Asia) (Balkis *et al.*, 2016).

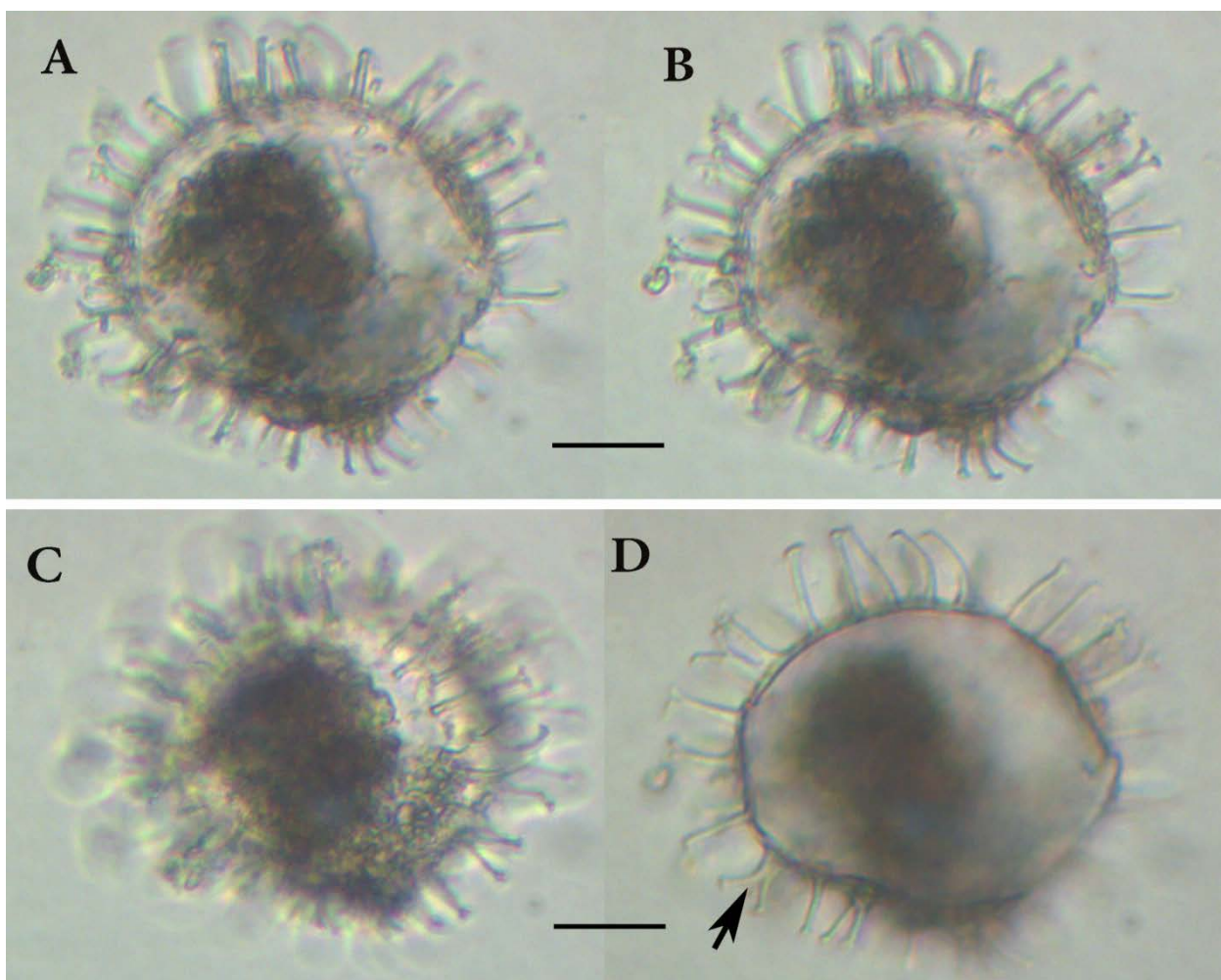
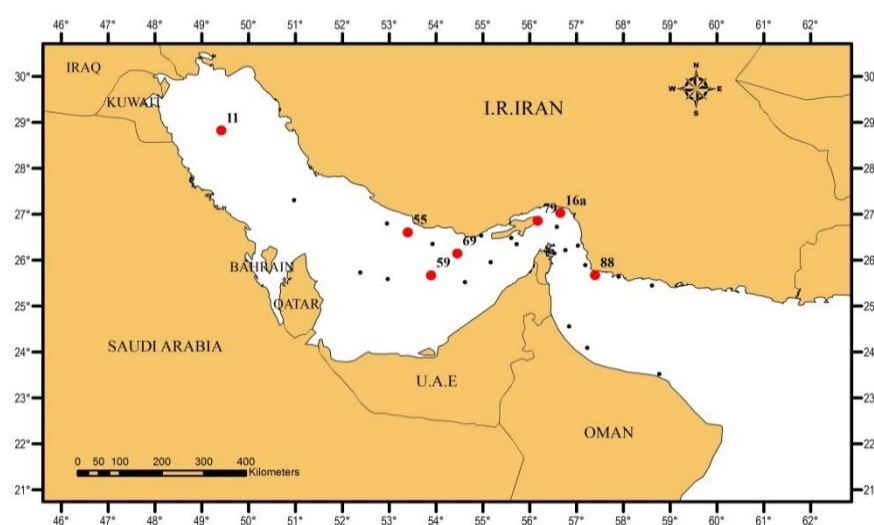


Plate 71: *Protoceratium reticulatum* cyst showing processes in different focuses, arrow shows fused processes



Map 71: *Protoceratium reticulatum* presence in the RSA, Winter 2006

Phylum: Miozoa Cavalier-Smith 1987

Class; Dinophyceae Fritsch 1927

Order; Gonyaulacales Taylor 1980

Family: Pyrophacaceae Lindemann, 1928

Genus: *Pyrophacus* F.Stein, 1883

Species: *Pyrophacus steinii*

Scientific name: *Pyrophacus steinii* (Schiller 1935) Wall et Dale 1971

Paleontological name: *Tuberculodinium vancampoe* (Rossignol 1962) Wall 1967

Figure No.: Plate 72

Reference:

Sonneman & Hill (1997), Figure10;

Morquecho & Lechuga-Deveze (2003) Figures14-15;

Attaran-Fariman (2007), Figure 14

Description:

This cyst type is easily distinguished from other morphotypes by its process shape. Subspherical large cyst has an outer transparent membrane. The cyst possesses two separate wall layers with dumbbell shape tubercles between them (Plate 72). The central cyst body is spherical in apical and antapical view and subrectangular in lateral view. The archeopyle is subtrapozoidal and is formed by loss of 3-5 antapical plate (Fensome *et al.*, 1993).

Size:

D: 55µm

Occurrence in RSA:

The occurrence of the species in the sediment sample of the Winter Cruise 2006 of RSA is shown on Map 72, in stations: 98, 88, 85, 83, 14a, 16a, 70, 73, 66,69,59,55, 43, 25, 11

This cyst type has also been previously reported from the Sea of Oman (Marret and Zonneveld, 2003; Attaran-Fariman, 2007, 2016).

Occurrence in the world:

Japan (Zonneveld & Susek 2007); Arabian Sea, central western equatorial Atlantic, off the Iberian Peninsula and the eastern equatorial Pacific (Marret and Zonneveld, 2003; Usup *et al.*, 2012)

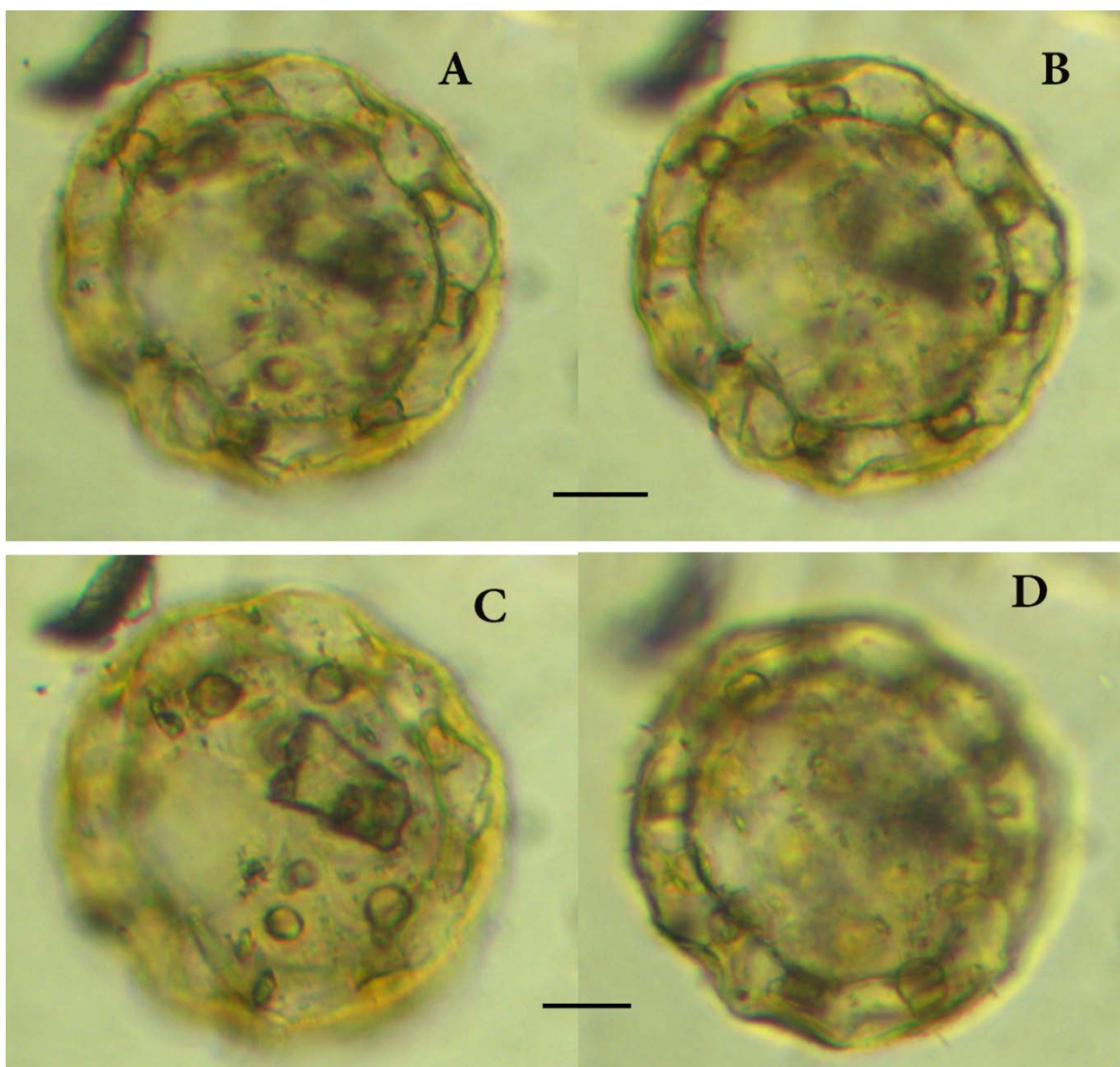
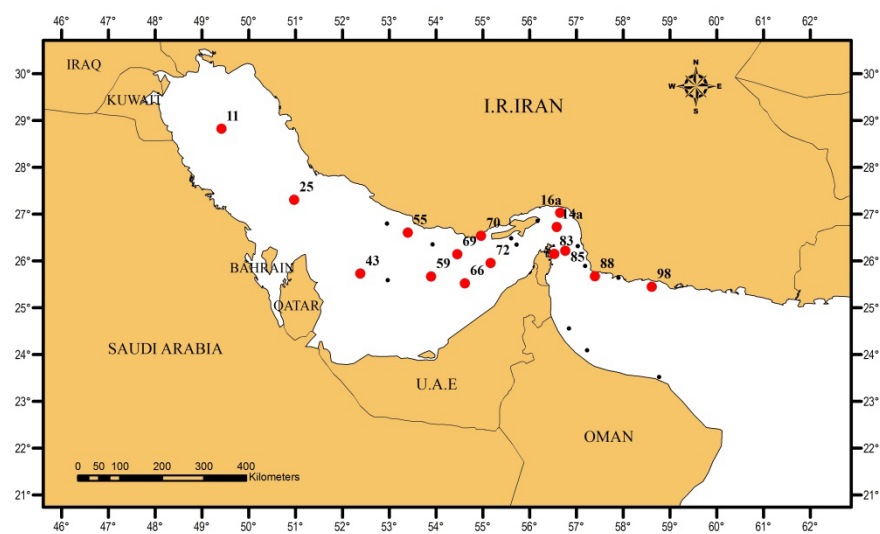


Plate 72: *Pyrophacus steinii* cyst at different focal levels



Map 72: *Pyrophacus steinii* presence in the RSA, Winter 2006

Phylum: Miozoa Cavalier-Smith 1987

Class; Dinophyceae Fritsch 1927

Order; Gymnodiniales Apstein 1909

Family: Gymnodiniaceae Lankester, 1885

Genus: *Gymnodinium* Stein, 1878

Species: *Gymnodinium catenatum*

Scientific name: *Gymnodinium catenatum* Graham 1943

Paleontological name: -

Figure No.: Plate 73

Reference:

Bolch & Hallegraeff (1990), Figures 33;

Description:

Brown spherical cyst has globular contents. Cyst wall with a microreticulate surface that reflects the pattern of amphiesmal vesicle of the motile cells (Plate 73). Girdle is defined by rows of flattened paravesicles (Plate 73 A-B). The archeopyle is chasmic; however, was not observed in our sample. The cyst of this species is often split along edge of cingulum. Among spherical reticulate gymnodiniales cysts, this cyst can be distinguished from *G. nolleri* and *G. microreticulatum* by its larger size. *G. catenatum* has potential to form toxic algal bloom.

Size:

D: 44µm

Occurrence in RSA:

The occurrence of the species in the sediment sample of the Winter Cruise 2006 of RSA is shown on Map 73, in stations: 97, 88, 87, 83, 14a, 78, 72, 69, 55, 40

This cyst type has also been previously reported from the Sea of Oman (Attaran-Fariman, 2016).

Occurrence in the world:

Coastal sediments off Australia and Tasmania (Bolch & Hallegraeff 1990); Philippines (Kita *et al.*, 1993); Gulf of Thailand (Matsuoka and Fukuyo 1994); Morocco (Atlantic Coast) (Tagmouti *et al.*, 1995); Western India (Godhe *et al.*, 2000; D'Costa *et al.*, 2008); Singapore (Holmes *et al.*, 2002); Yellow Sea, China (Gu *et al.*, 2013); Turkey (Balkis *et al.*, 2016).

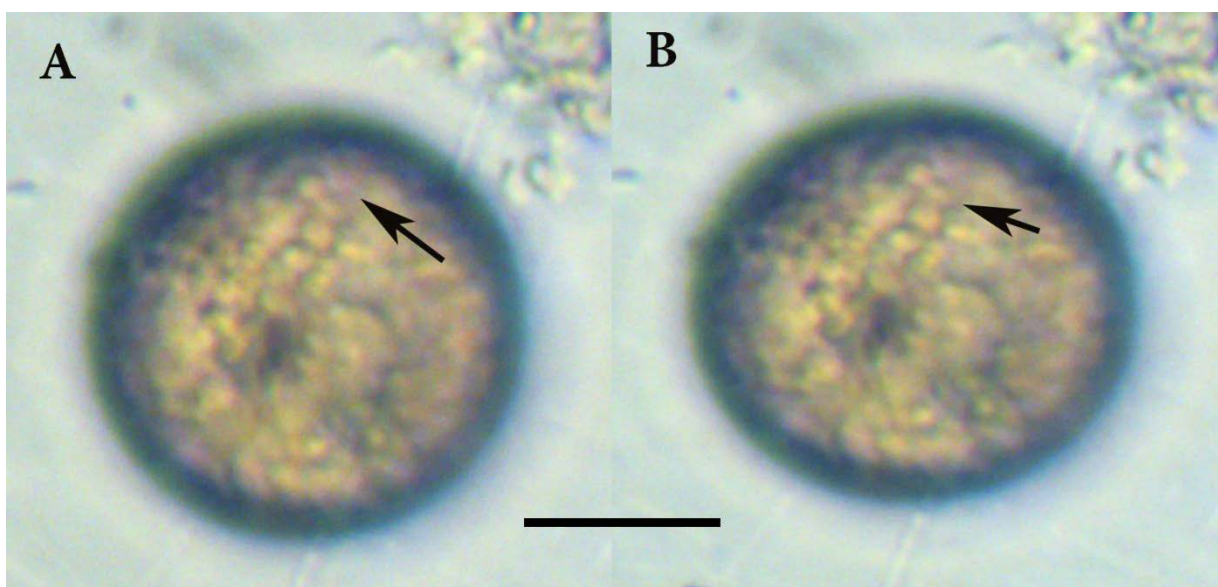
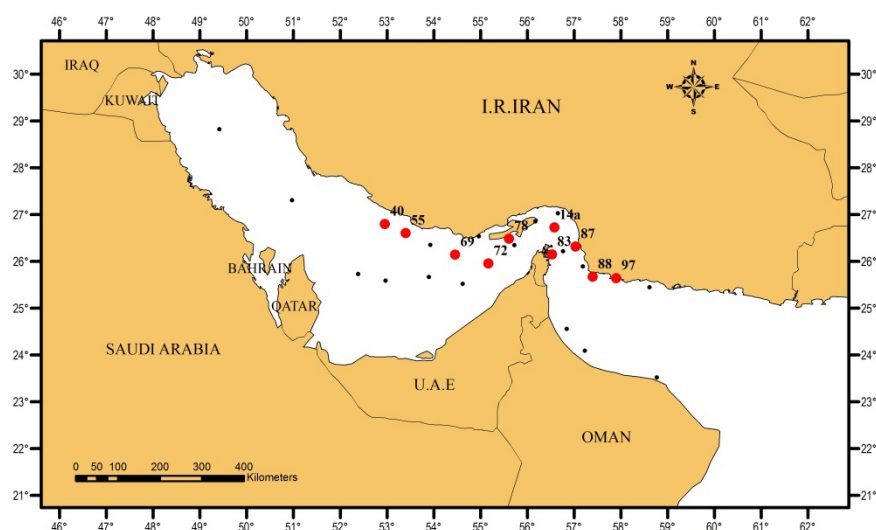


Plate 73: *Gymnodinium catenatum* cyst showing a reticulate surface (Scale bar=20µm)



Map 73: *Gymnodinium catenatum* presence in the RSA, Winter 2006

Phylum: Miozoa Cavalier-Smith 1987

Class; Dinophyceae Fritsch 1927

Order; Gymnodiniales Apstein 1909

Family: Gymnodiniaceae Lankester, 1885

Genus: *Gymnodinium* Stein, 1878

Species: *Gymnodinium nolleri*/ *Gymnodinium microreticulatum*

Scientific name: *Gymnodinium nolleri* Ellegaard & Ø.Moestrup 199/ *Gymnodinium microreticulatum* .Bolch, Negri & Hallegraeff 1999

Paleontological name: -

Figure No.: Plate74

Reference:

Ellegaard *et al.*, (1998), Figure 4;

Bolch *et al.*, (1999), Figures 7-9;

Hallegraeff *et al.*, (2012), Figure 1;

Description:

Both cysts, *G. microreticulatum* and *G. nolleri*, have pale purple-brown cyst wall. Paracingulum of the both cysts are 0.25 larger than cyst diameter. The cyst size of the *G. microreticulatum* (17-28µm) is smaller than *G. nolleri*, (28-38 µm); however, there is overlap in their size and they cannot be separated by their size. None of the studies documented that size ranges to differentiate between these reticulate cysts (Hallegraeff *et al.*, 2012). The spherical reticulate cysts with the size >40 are true *G. catenatum* (Hallegraeff *et al.*, 2012). There are some differences in the pattern of the reticulation of the cyst wall but these patterns are difficult to measure (Bolch *et al.*, 1999). *G. microreticulatum* have chasmic archeopyle along parasulcus and the second species has chasmic archeopyle usually along parasingulum (Bolch *et al.*, 1999; Ellegaard *et al.*, 1990). In the ROPME cyst sample, the archeopyle was not observed. As the samples were fixed, germination experiment was not possible to distinguish between these two cyst morphotype based on their size. Plates 74 A and B are considered as *G. nolleri* and Plates 74 C and D as *G. microreticulatum*. *G. catenatum* separated from these two only by its larger size.

Size:

D: *G. nolleri* A-B: 35µm; D: *G. microreticulatum* C-D: 28µm

Occurrence in RSA:

The occurrence of the species in the sediment sample of the Winter Cruise 2006 of RSA is shown on Map 74 A & B, in stations: *G. nolleri*: 98, 21a, 77, 72; *G. microreticulatum*: 88, 43

Occurrence in the world:

Mediterranean Sea, and the eastern Pacific, NW Africa (Zonneveld and Pospelova 2015). Portugal (Amorim *et al.*, 2002); Uruguay (Bolch *et al.*, 1999); around Australia, Tasmania (Bolch and Reynolds, 2002); Australia (McCarthy 2013); Yellow Sea, China (Gu *et al.*, 2013)

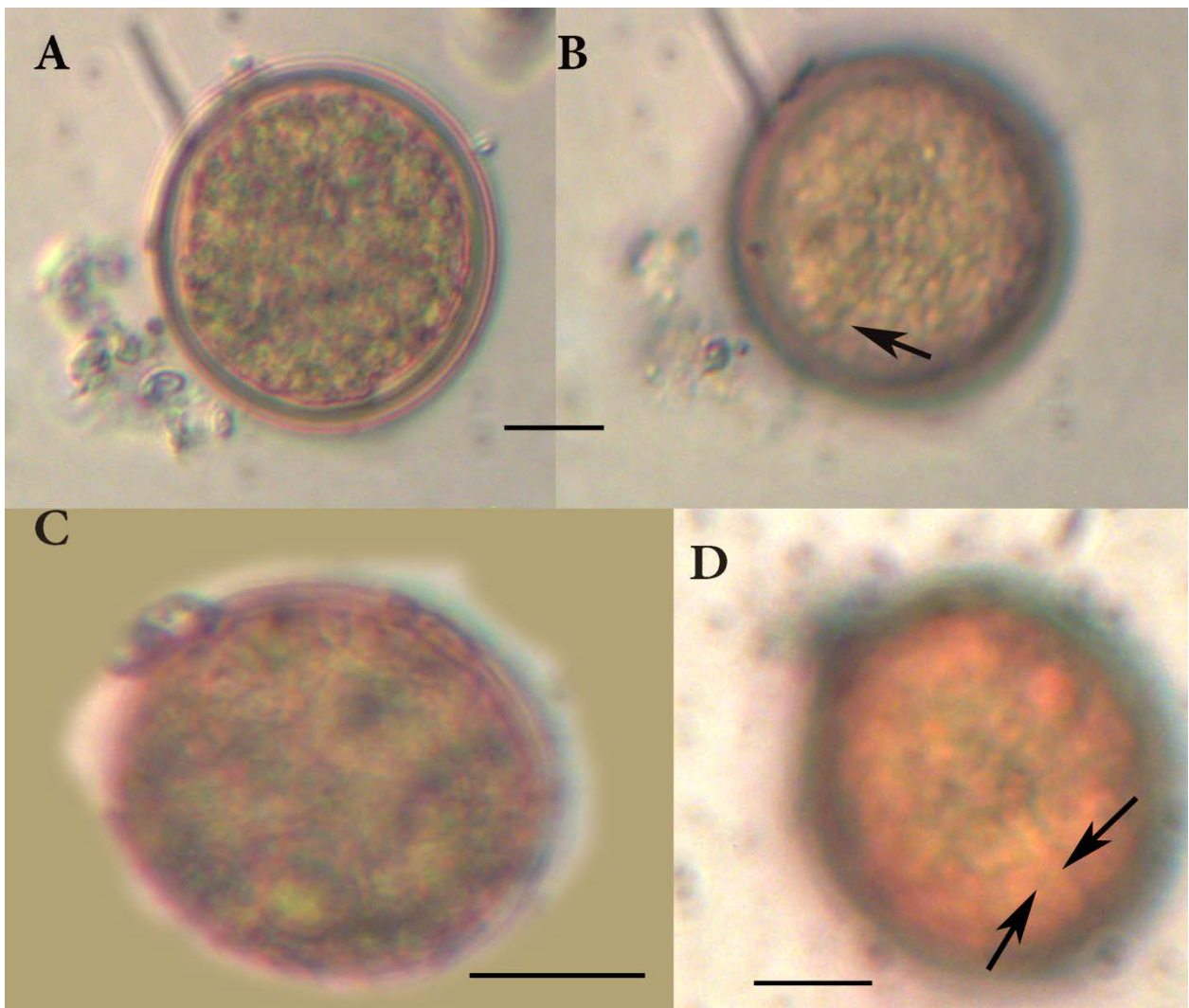
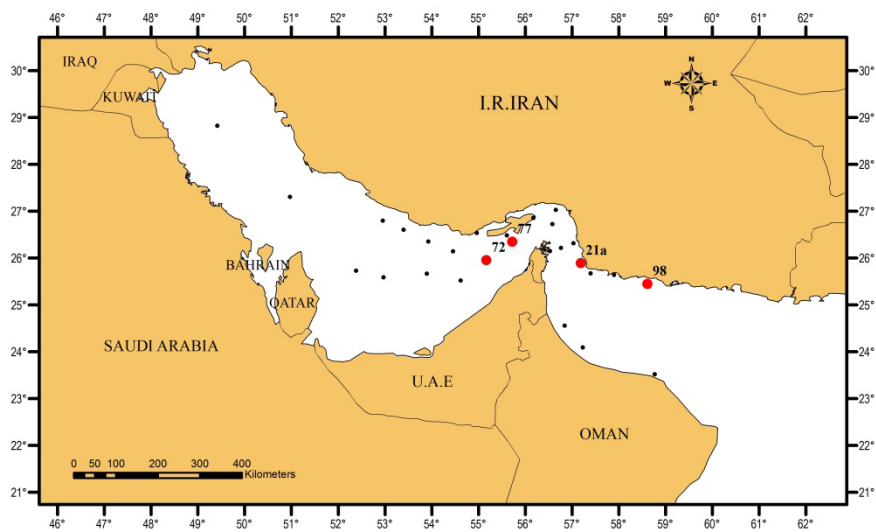
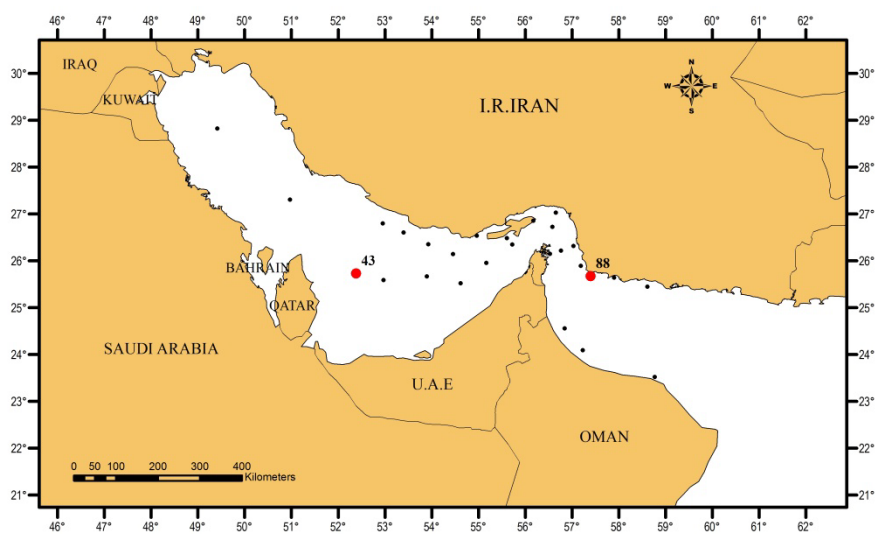


Plate 74: *Gymnodinium nolleri* (A-B)/ *G. microreticulatum*(C-D)



Map 74A: *Gymnodinium nolleri* presence in the RSA, Winter 2006



Map 74B: *G. microreticulatum* presence in the RSA, Winter 2006

Phylum: Miozoa Cavalier-Smith 1987

Class; Dinophyceae Fritsch 1927

Order; Gymnodiniales Apstein 1909

Family: Gymnodiniaceae Lankester, 1885

Genus: *Gymnodinium* Stein, 1878

Species: *Gymnodinium trapeziforme*

Scientific name: *Gymnodinium trapeziforme* Attaran-Fariman & Bolch 2007

Paleontological name: -

Figure No.: Plate 75

Reference:

Attaran-Fariman *et al.*, (2007), Figures 2-22

Description:

Pale brown cyst has trapezoidal to rectangular outline. The cyst is rounded on two parallel-elongated sides and slightly concave on the two shorter sides (Plate 75). The cyst wall has a reticulate structure and paracingulum region is clear on Plate 75C. The epicyst is often smaller than hypocyst (Plate 75 A-C). The archeopyle is chasmic (Plate 75 D). Type locality of this species is South coast of Iran and northern part of the Sea of Oman (Attaran-Fariman 2007; 2016). Zonneveld & Pospelova (2015) reported high abundance of these cysts in sediments from the Pakistan shelf Oxygen Minimum Zone.

Size:

W: 26; L: 30

Occurrence in RSA:

The occurrence of the species in the sediment sample of the Winter Cruise 2006 of RSA is shown on Map 75, in stations 21a, 55, 11

This cyst type has also been previously reported from the Sea of Oman (Attaran-Fariman *et al.*, 2007; Attaran-Fariman, 2016).

Occurrence in the world:

Pakistan (Zonneveld & Pospelova 2015)

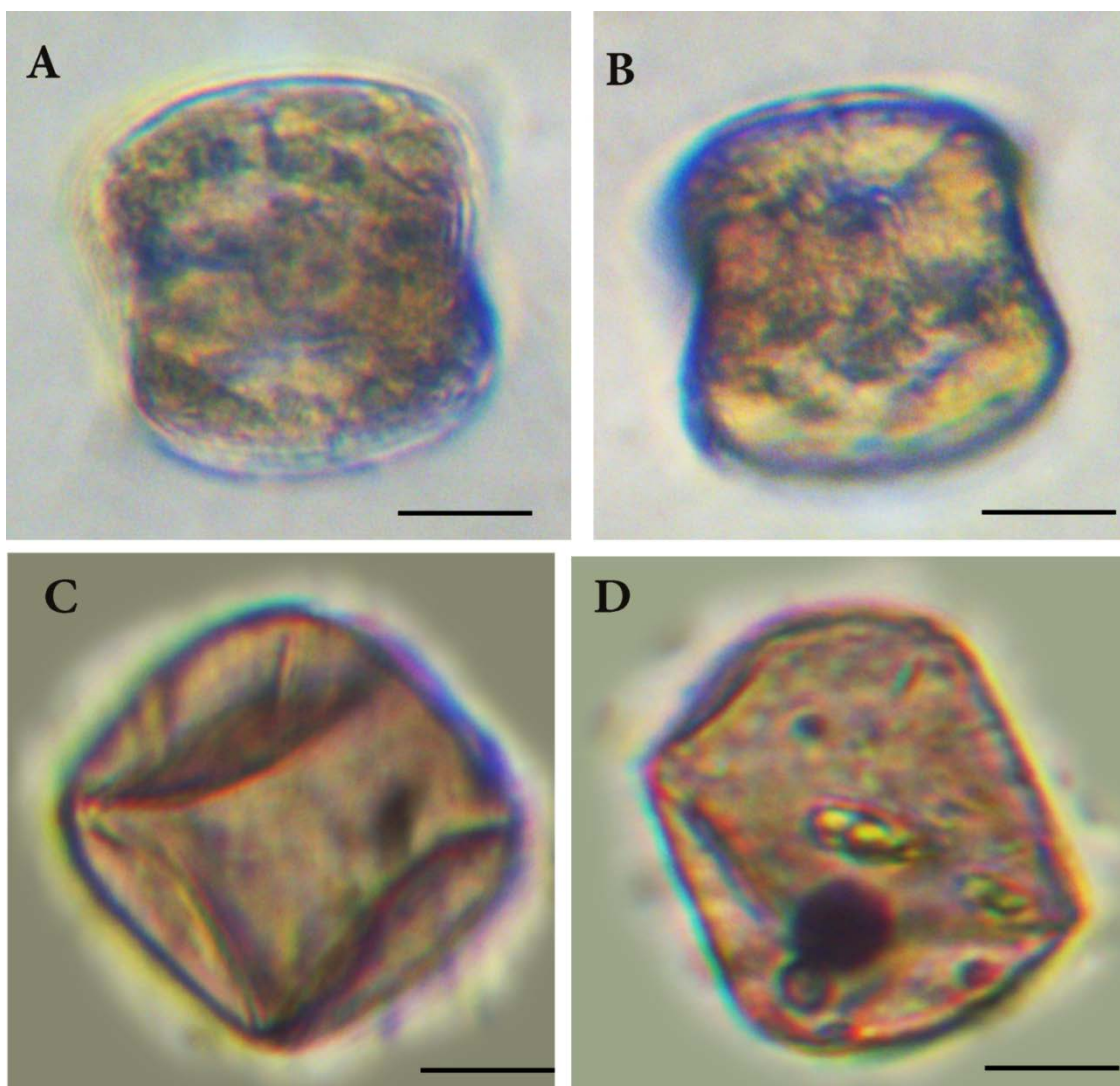
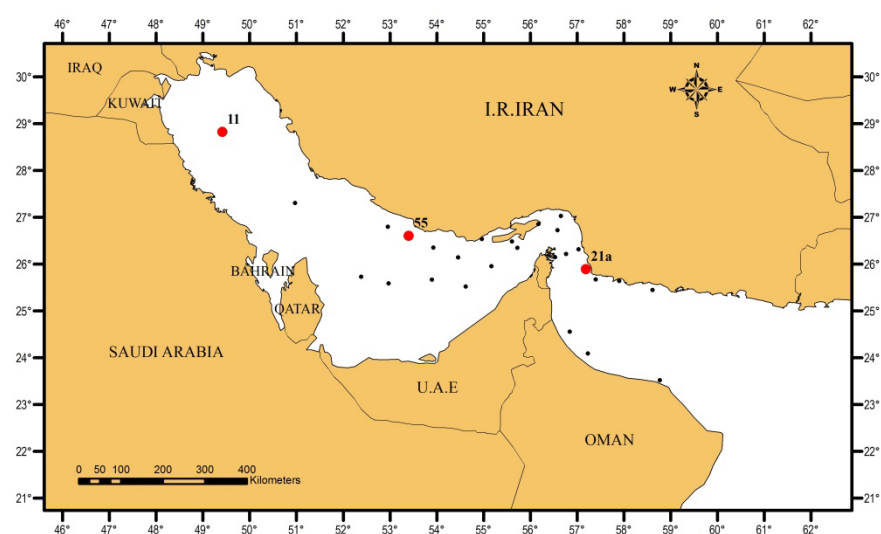


Plate 75: *Gymnodinium trapeziforme* cyst showing trapezoidal outline in shape



Map 75: *Gymnodinium trapeziforme* occurrence in the RSA, Winter 2006

Phylum: Miozoa Cavalier-Smith 1987

Class; Dinophyceae Fritsch 1927

Order; Gymnodiniales Apstein 1909

Family: Gymnodiniaceae Lankester, 1885

Genus: *Gymnodinium* Stein, 1878

Species: *Gymnodinium inusitatum*

Scientific name: *Gymnodinium inusitatum* H.Gu in Gu et al., 2013

Paleontological name: -

Figure No.: Plate 76

Reference:

Gu et al., (2013), Figure 3

Description:

The cyst is brown in colour and polygonal in shape (Plate 76). The cyst composes of concave polygonal sections. The cyst surface shows a microreticulate pattern .The archeopyle is chasmic; however, it was not observed in the RSA samples. This cyst differs from other Gymnodinoids cyst by its polygonal shape, and like all other reticulate cyst shows this pattern on the cyst wall.

Size:

W: 38µm; L: 49µm

Occurrence in RSA:

The occurrence of the species in the sediment sample of the Winter Cruise 2006 of RSA is shown on Map 76, in stations: 21a, 25

Occurrence in the world:

Yellow Sea China (Gu et al., 2013)

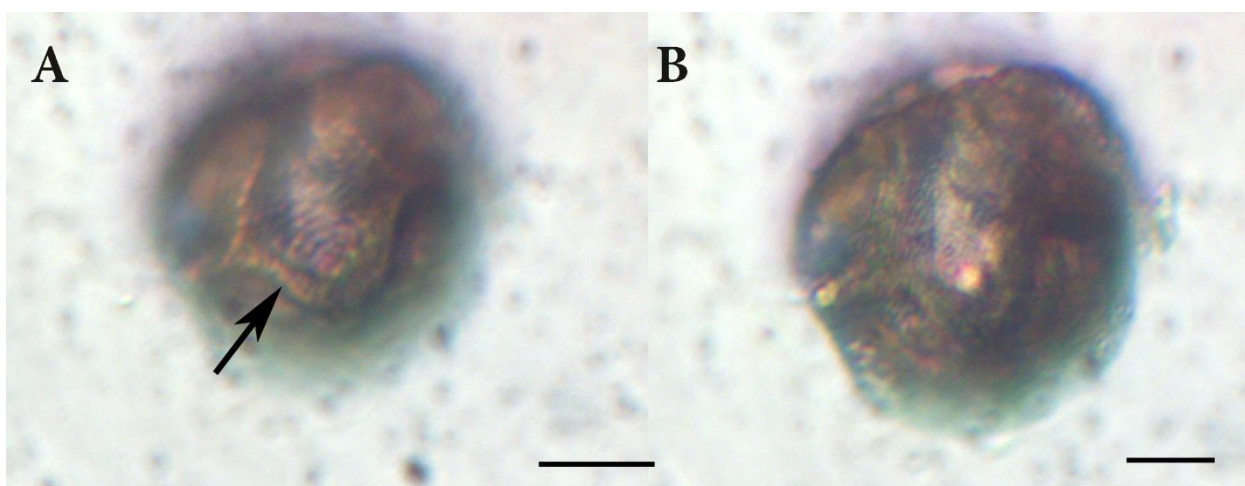
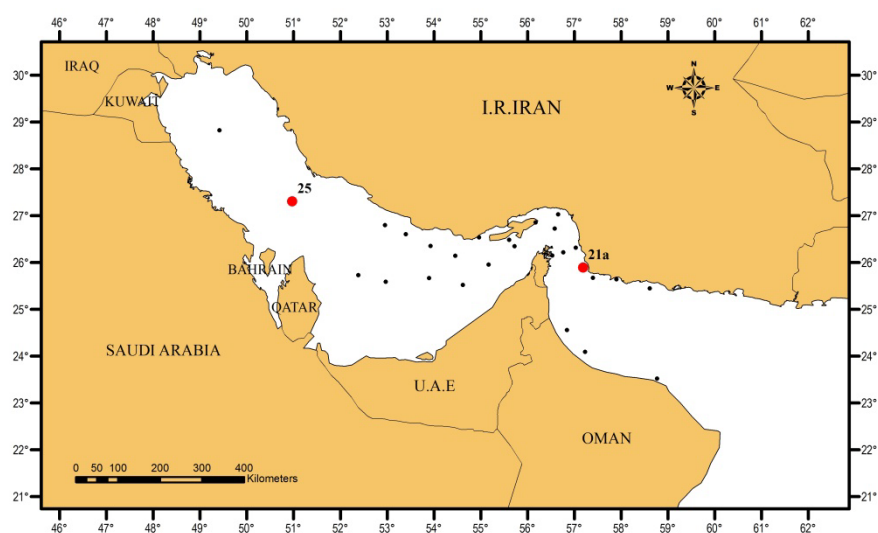


Plate 76: *Gymnodinium inusitatum* cyst represent polygonal section (arrow)



Map 76: *Gymnodinium inusitatum* occurrence in the RSA, Winter 2006

Phylum: Miozoa Cavalier-Smith 1987

Class; Dinophyceae Fritsch 1927

Order; Gymnodiniales Apstein 1909

Family: Gymnodiniaceae Lankester, 1885

Genus: *Gymnodinium* Stein, 1878

Species: *Gymnodinium* sp.

Scientific name: *Gymnodinium* sp.

Paleontological name: -

Figure No.: Plate 77

Reference:

Gu *et al.*, (2013) Figures 6

Description:

Large cyst is spherical and pink-brown in colour (Plate 77). Cyst contains greenish-brown granules and a red accumulation body in the center. The reticulate cyst wall is thick and a thin transparent membrane covers the outer wall and only part of this membrane is clear (Plate 77, A-B). This cyst differs from *Gymnodinium nolleri*/ *Gymnodinium microreticulatum* by presence of the outer transparent membrane and its larger size (Plate 77, C-D). Cyst is similar to the *G. catenatum* in the size and colour; however, it differs from that by its outer membrane. The cyst has a chiasmic archeopyle (Plate 77, D).

Size:

D: 47µm

Occurrence in RSA:

The occurrence of the species in the sediment sample of the Winter Cruise 2006 of RSA is shown on Map 77, in station: 97

Occurrence in the world:

Not reported from anywhere else from anywhere else

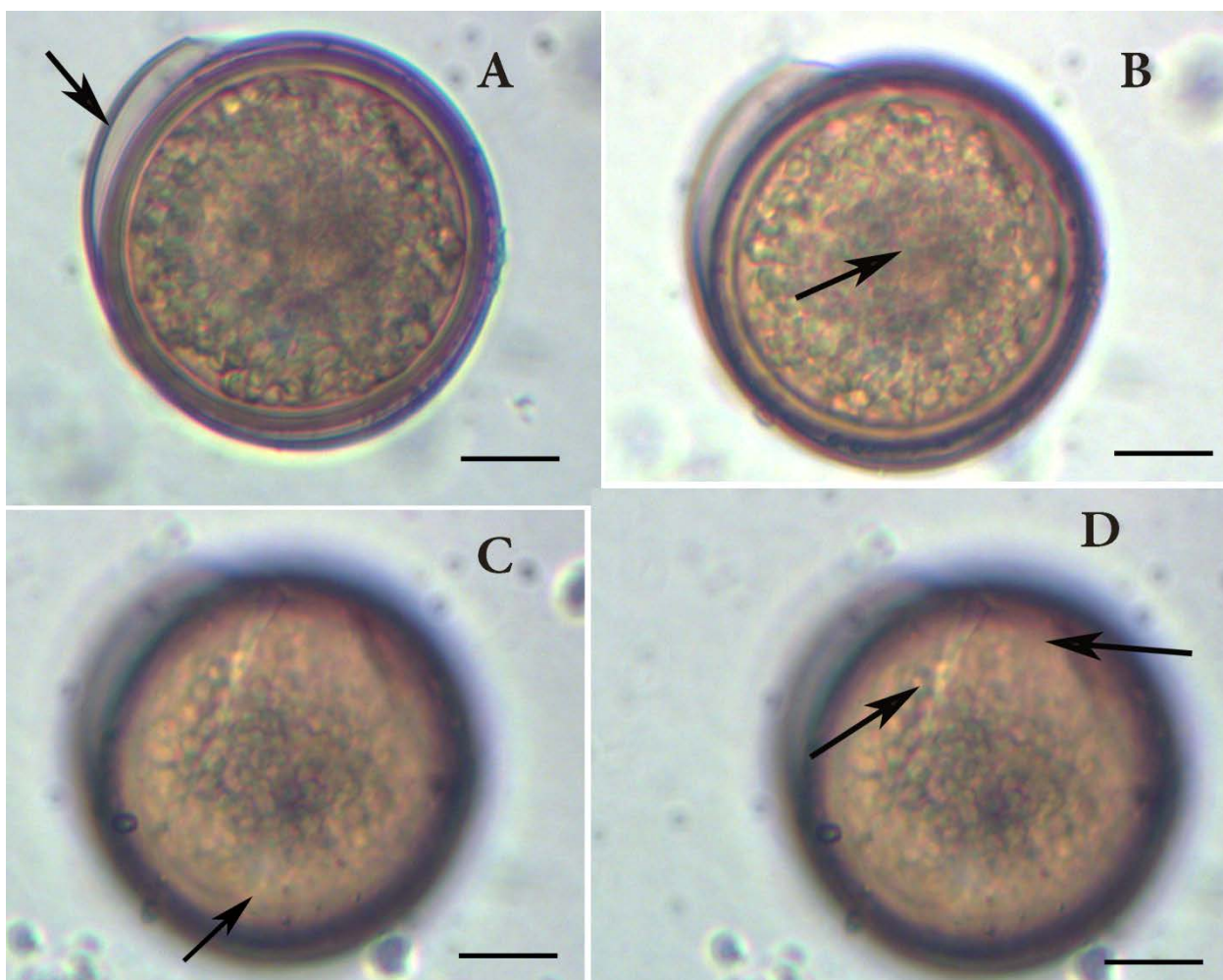
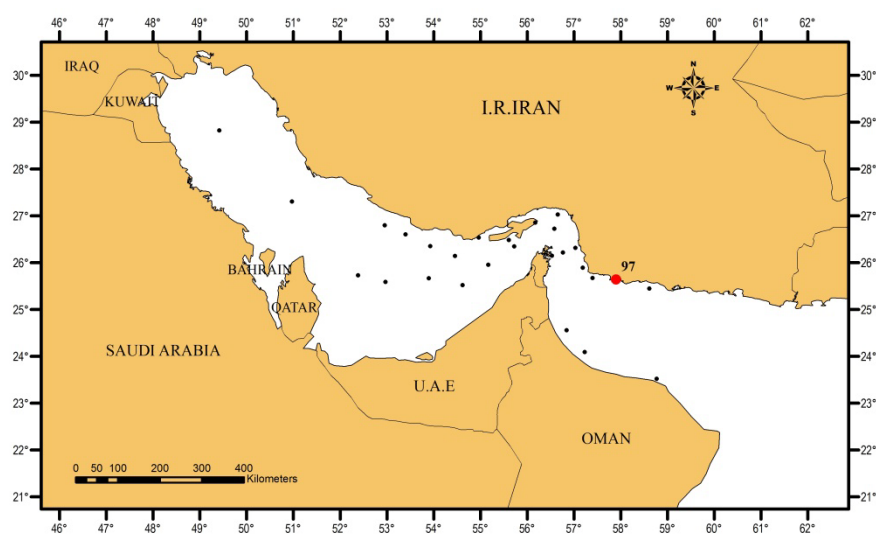


Plate 77:*Gymnodinium* sp. A-B cysts showing a transparent membrane and a red accumulation body; C- showing chasmic archeopyle position, D- cyst with a reticulate pattern showing para cingulum region



Map 77: *Gymnodinium* sp. occurrence in the RSA, Winter 2006

Phylum: Miozoa

Class; Dinophyceae Fritsch 1927

Subclass Gymnodiniphyceae Fensome *et al.*, 1993

Order; Gymnodiniales Apstein, 1909

Family: Gymnodiniaceae Lankester, 1885

Genus: *Cochlodinium* F.Schütt, 1896

Species: *Cochlodinium polykrikoides*

Scientific name: *Cochlodinium polykrikoides* Margalef 1961

Paleontological name: -

Figure No.: Plate 78

References:

Tang and Gobler (2012), Figure1, I

Description:

The spherical cyst has brown yellowish colour (Plate 78). The cyst is ornamented with thick spines and has a reticulate wall. The reticulate pattern in the empty cyst is very clear polygonal shape (Plate 78C). The cyst is full of granules and an accumulation body is present in the live cysts. There are several studies on the identification of the cyst from the natural sediments for this species. Li *et al.*, (2015) confirm the presence and identification of the cyst by isolation of the cyst from natural sediment and carrying out germination experiment. They have documented that *C. polykrikoides* have an ornamented and reticulate cysts. The cysts of *C. polykrikoides* found in the sediment of RSA were two kinds. The first type of cyst (Plate 78 A-D) is ornamented with thick spines and has articulate wall, similar to those described by Li *et al.*, (2015). The second type resembles those described by Tang and Gobler (2012). The cyst surface is smooth and contains one or two accumulation body and cyst do not have any ornamentation (Plate 78 E-F). Nevertheless, this study confirms the presence of the *C. polykrikoides* in the sediment of the RSA in 2006. The catastrophe of Red tide caused by this species happened in 2009 in the RSA, as cysts acted as seed bank in the sediment. It seemed that the red tide was initiated by the germination of the seed from sediment.

Size:

D: 28-38µm

Occurrence in RSA:

The occurrence of the species in the sediment sample of the Winter Cruise 2006 of RSA is shown on Map 78, in stations: 97, 88, 21a, 14a, 16a, 78, 72, 66, 69, 59, 55, 40

This cyst type has also been reported from the Sea of Oman (Attaran-Fariman, 2016).

Occurrence in the world:

Korean and Japanese coastal areas (Iwataki *et al.*, 2008, Matsuoka *et al.*, 2008; Pospelov and Kim, 2010); United Arab Emirates (Li *et al.*, 2015); Malaysia (Li *et al.*, 2015); Philippines (Li *et al.*, 2015); Spain (Li *et al.*, 2015); Sweden (Lundholm *et al.*, 2011).

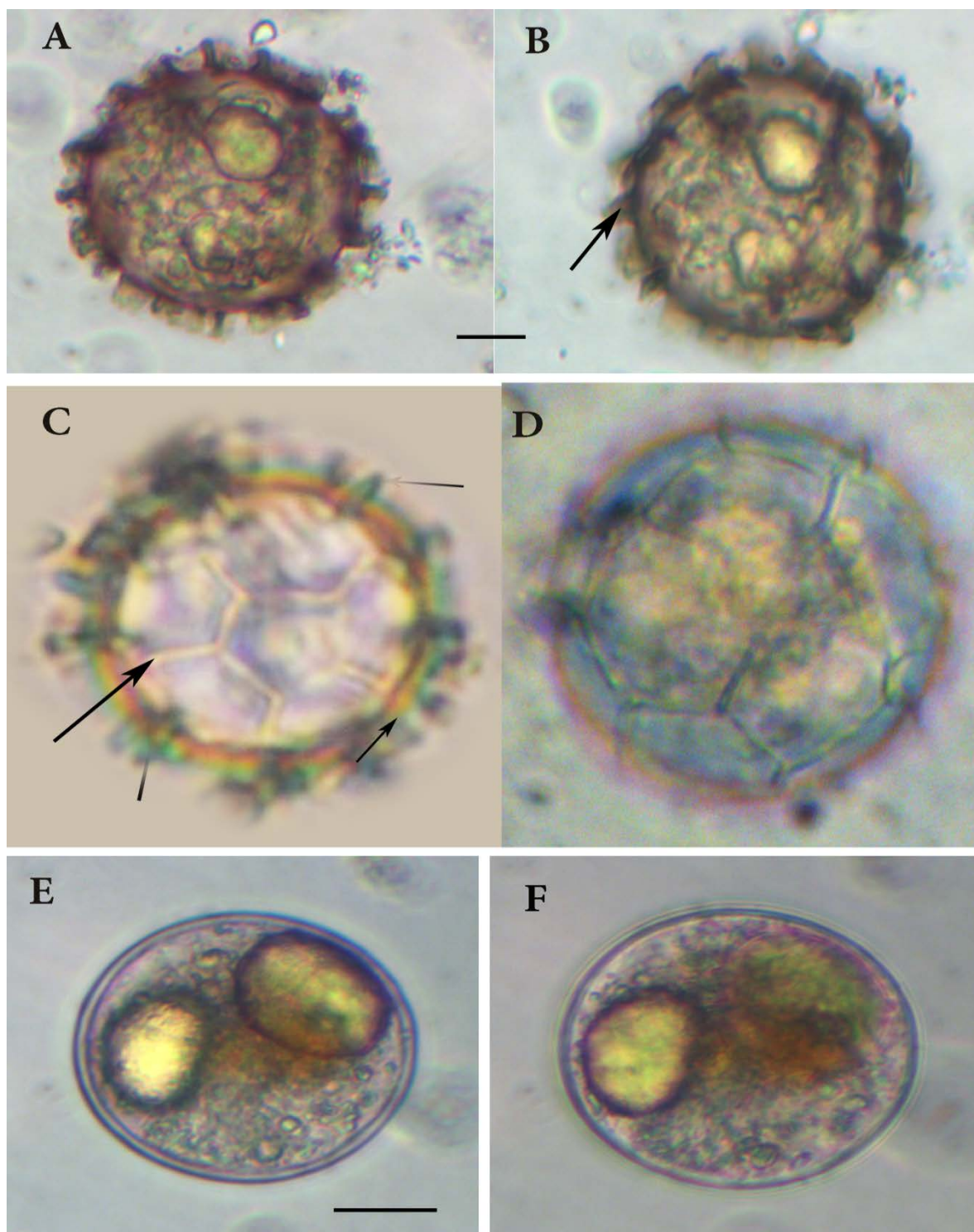
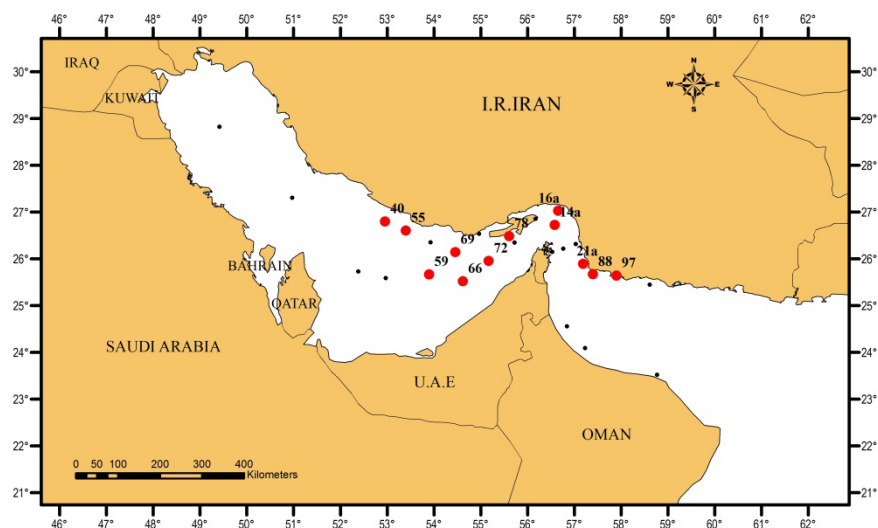


Plate 78: *Cochlodinium polykrikoides*: A-B, live cyst showing cyst content and ornamented cyst wall; C-D, cyst showing a reticulate cyst wall and thick spines; E-F, cyst showing red accumulation body and smoother cyst wall (All scale bars= 10µm)



Map 78: *Cochlodinium polykrikoides* cyst occurrence in the RSA, Winter 2006

Phylum: Miozoa

Class; Dinophyceae Fritsch 1927

Subclass Gymnodiniphyceae Fensome *et al.*, 1993

Order; Gymnodiniales Apstein, 1909

Family; Polykrikaceae Kofoed and Swezy, 1921

Genus; *Polykrikos* Bütschli, 1873

Species: *Polykrikos hartmannii*

Scientific name: *Polykrikos hartmannii* Zimmermann 1930

Paleontological name: *Polykrikos hartmannii* (W.Zimmermann) Matsuoka & Fukuyo 1986

Figure No.: Plate 79

References:

Matsuoka & Fukuyo (1986), Figures 17-18;

Radi *et al.*, (2013), Plate 3 Figures 13-16

Description:

Spherical cyst is sometimes almost transparent. The cyst has hollow distally acuminate processes; the base of process with different length shows few striations. Cyst wall is granular (Plate 79 A) to smooth. Morphotype with granulation cyst wall was only found in our sediment. The archeopyle is a split (Plate 79 B-D). This cyst type is similar to the *Echinidium granulatum* cyst; however, it differs from that by its larger size and having process with different thickness in one specimen. The basis of the process in *E. granulatum* is smooth (Zonneveld & Pospelva 2015)

Size:

D: 48µm

Occurrence in RSA:

The occurrence of the species in the sediment sample of the Winter Cruise 2006 of RSA is shown on Map 79, in stations: 88, 69, and 55

This cyst type has also been reported from the Sea of Oman (Attaran-Fariman, 2016).

Occurrence in the world:

Gulf of California (Tang *et al.*, 2013), Mediterranean (Gómez 2003); India (Godhe *et al.*, 2000)

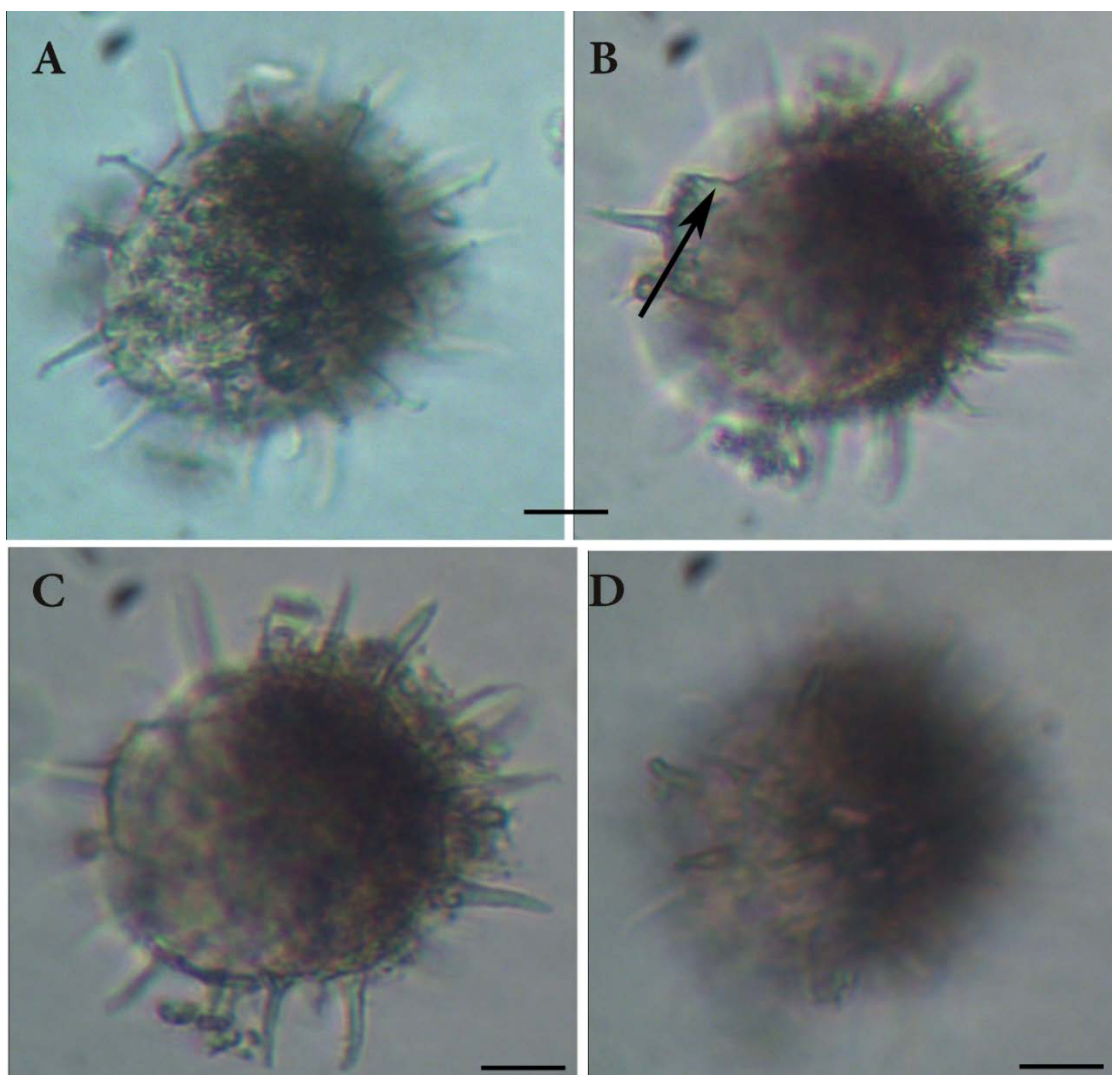
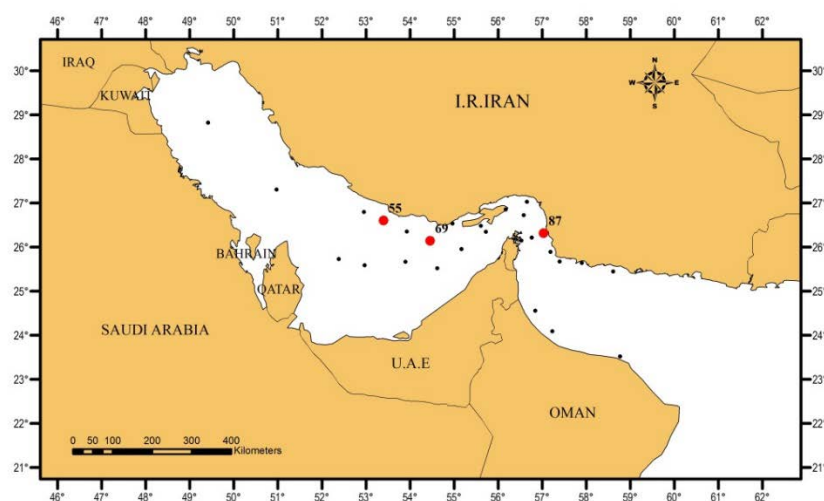


Plate 79: *Polykrikos hartmannii* cyst at different focal levels showing granular cyst wall and split archeopyle (arrowhead)



Map 79: Presence of *Polykrikos hartmannii* in the sediment of RSA, Winter 2006

Phylum: Miozoa

Class; Dinophyceae Fritsch 1927

Order; Gymnodiniales Apstein 1909

Family: Warnowiaceae Lindemann, 1928

Genus: Warnowia Lindemann, 1928

Species: *Warnowia cf. rosea*

Scientific name: *Warnowia rosea* (Pouchet) Kofoid & Swezy 1921

Paleontological name: -

Figure No.: Plate 80

Reference:

Ellegaard *et al.*, (2002), Figures 2–9;

Orlova *et al.*, (2004), Figures 75–78

Description:

The cyst is brown in colour. The cyst has process with darker brown colour and irregular tufts of darker brown material that are fused to the processes. The archeopyle is simple almost median split (Plate 80 C). The cyst surface is not smooth and a reticulate pattern is observed (Plate 80 D).

Size:

W: 41µm; L: 44µm

Occurrence in RSA:

The occurrence of the species in the sediment sample of the Winter Cruise 2006 of RSA is shown on Map 80, in stations: 87, 83

Occurrence in the world:

Norway (Ellegaard *et al.*, 2002); Portugal (Ellegaard *et al.*, 2002); East coast of Russia (Orlova *et al.*, 2004).

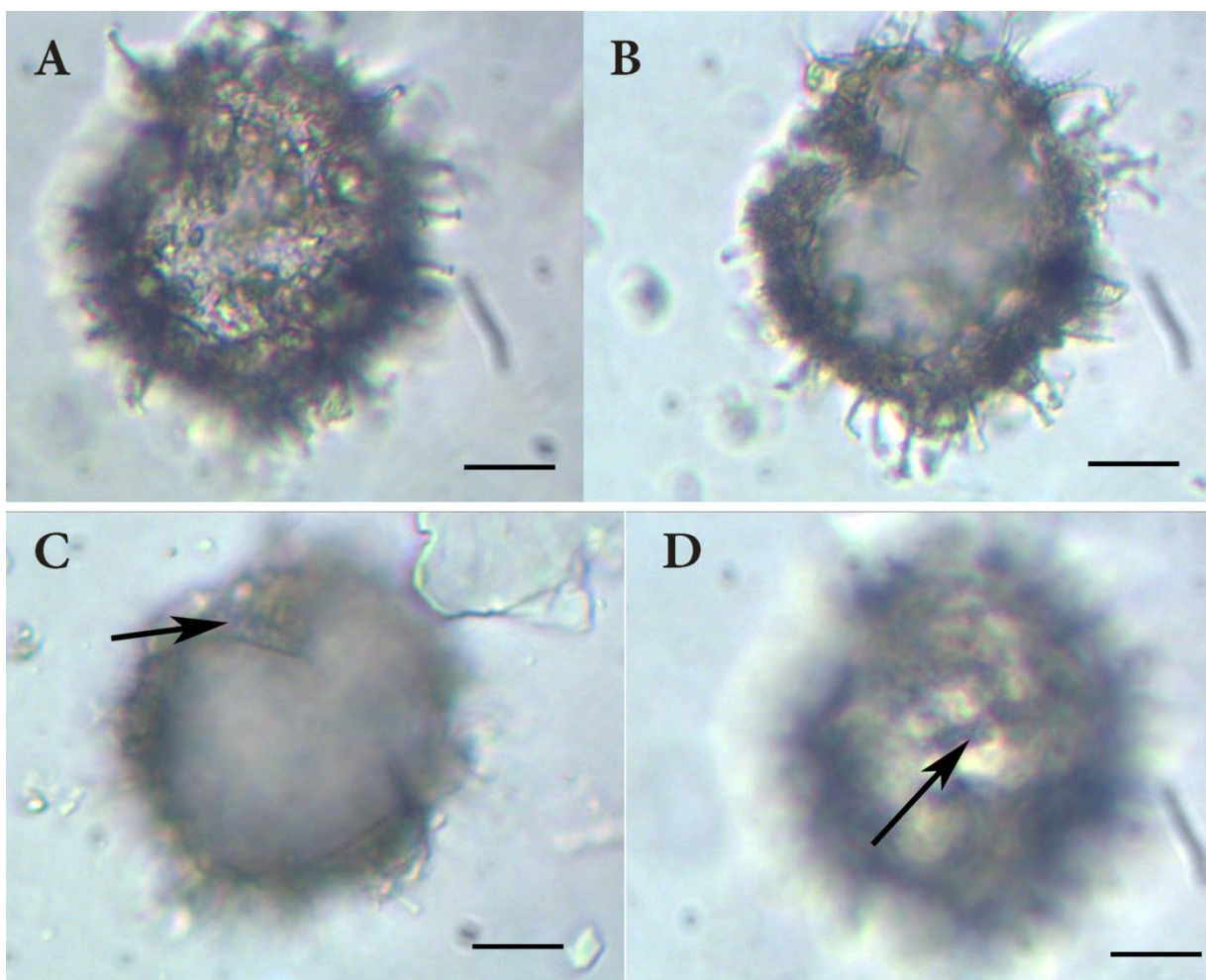
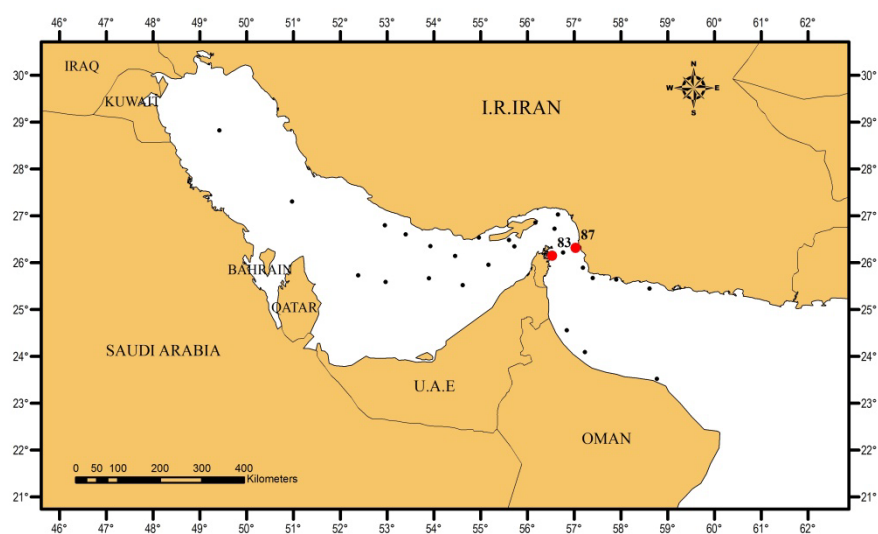


Plate 80: *Warnowia rosea*: A-B, cyst showing a brown material attached to the processes; C, median split of archeopyle on the cyst; D, note on reticulate pattern on the cyst (arrow)



Map 80: *Warnowia rosea* occurrence in the RSA, Winter 2006

Phylum: Miozoa

Class; Dinophyceae Fritsch 1927

Order; Suessiales Fensome, Taylor, Norris, Sarjeant, Wharton, Williams 1993

Family; Suessiaceae Fensome et al., 1993

Genus; *Biecheleria* Moestrup, Lindberg & Daugbjerg, 2009

Species: *Biecheleria cincta*,

Scientific name: *Biecheleria cincta* Zhaohe et al., 2013

Paleontological name: -

Figure No.: Plate 81

References:

Satta et al., (2013), Plat 4g;

Zhaohe et al., (2013), Figures. 1e-f

Description:

The cyst is spherical and brown with a rarely transparent wall. The cyst wall is ornamented by a small grains and short randomly distributed process (Plate 81). A weak paratabulation is noticeable on the cyst wall that probably reflects the arrangements of the amphiesmal vesicles of the motile cell (Plate 81). The circular archeopyle is a small hole. The species is described in Siano et al., (2009) as *Woloszynskia cincta*, which is basionym of *B. cincta*.

Size:

D: 29µm,

Occurrence in RSA:

The occurrence of the species in the sediment sample of the Winter Cruise 2006 of RSA is shown on Map 81, in station: 14a

Occurrence in the world:

Mediterranean Sea (Siano et al., 2009); Chinese coast (Satta et al., 2013)

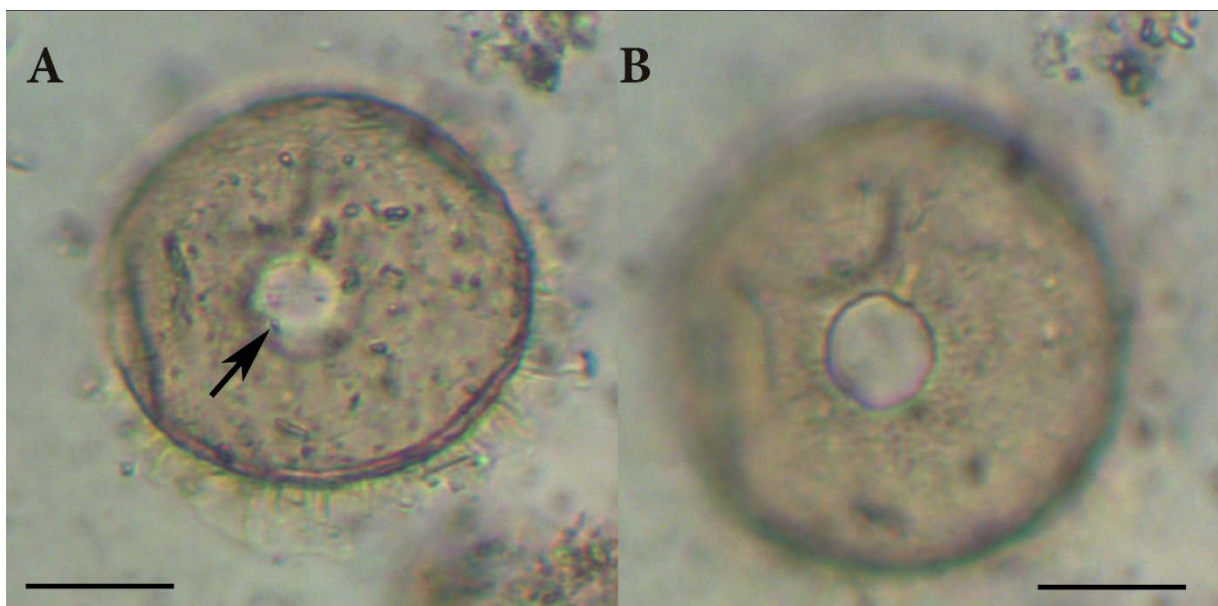
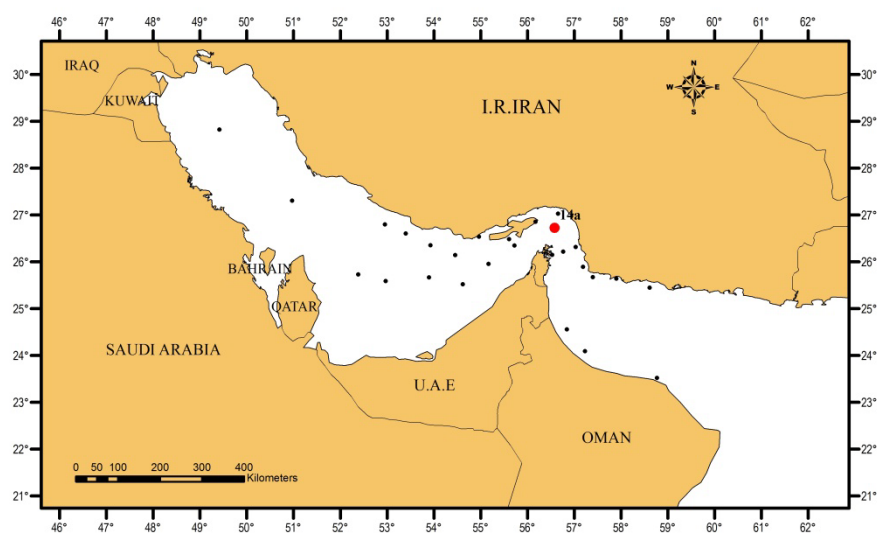


Plate 81: *Biecheleria cincta* cyst showing process and small hole archeopyle



Map 81: Occurrence of *Biecheleria cincta* in the RSA, Winter 2006

Six unknown species belonging to dinophyceae were found in the RSA sediments.

Phylum: Miozoa

Class; Dinophyceae Fritsch 1927

Species: Dinocyst type 1

Figure No.: Plate 82

References:

Not found

Description:

Round brown cyst has single or double layers wall (Plate 82). The live cyst was filling with greenish granule and yellowish red accumulation body. The cyst wall is ornamented with paratabulation reflected by suture of moderately low septa (Plate, 82 A). This species differs from other brown spiny cyst by its paratabulation reflection and low septa. The cyst paratabulation and reticulate hexagonal pattern, size, colour and processes resemble *Cochlodinium polykrikoides*; however, the processes in the later species are thicker (see Plate 79). The cyst parataulation also resembles that of *Cryodinium meridianum* Esper and Zonneveld (2001, Plate 2, Figures 4-9), However, this is a cold water species and the shape of archeopyle was not observed in our cyst because the cyst was not empty. The other round brown cyst of predinoids species demonstrated tabulation pattern, as proved only by the shape of archeopyle.

Size:

D: 31µm

Occurrence in RSA:

The occurrence of the species in the sediment sample of the Winter Cruise 2006 of RSA is shown on Map 82, in stations: 97, 56

Occurrence in the world:

Not reported from anywhere else

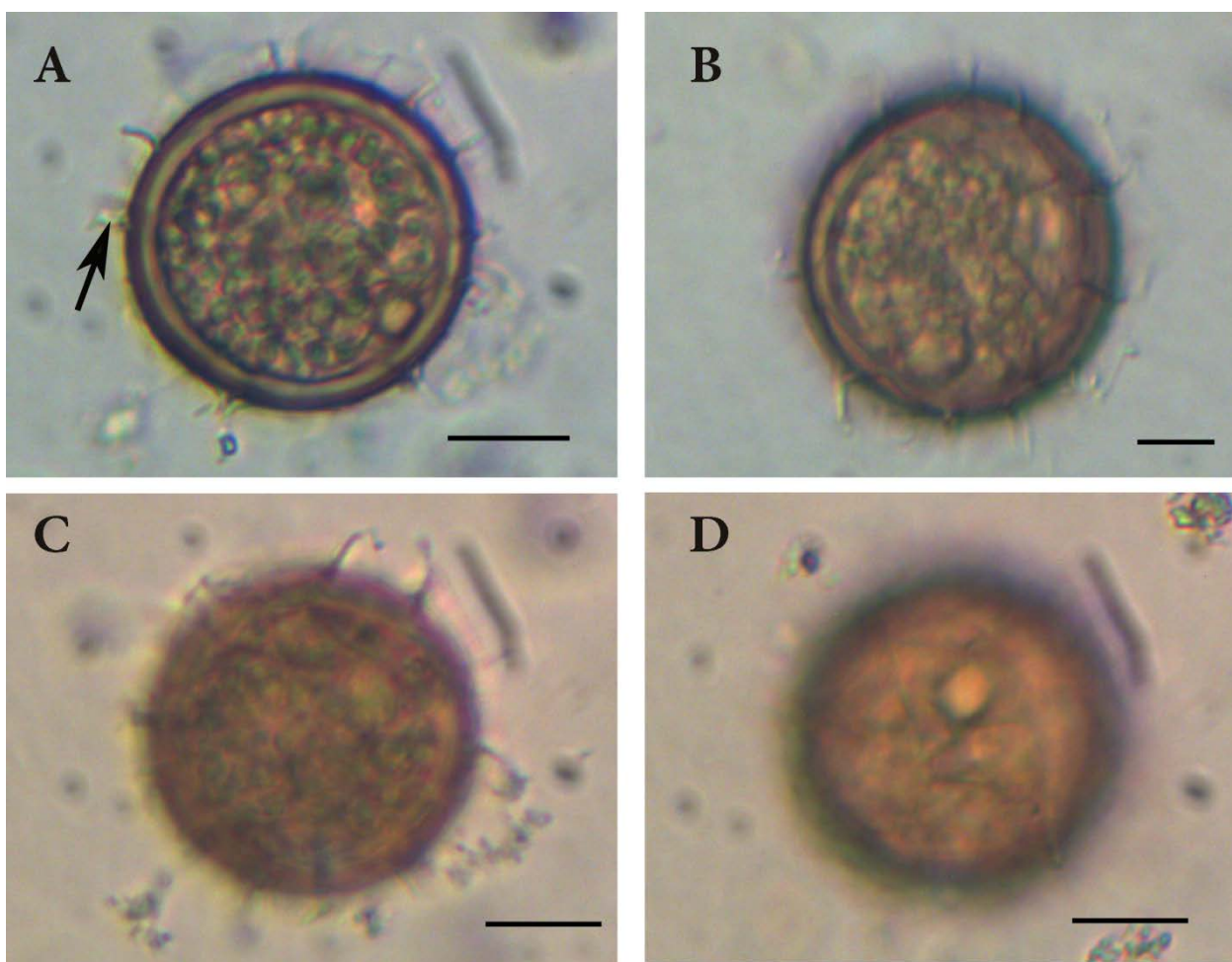
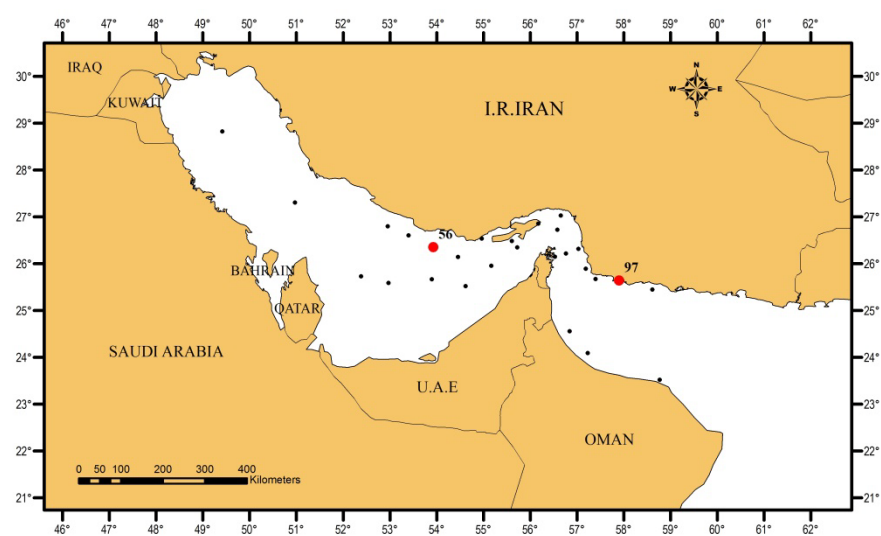


Plate 82: Dinocyst type 1 cyst at different focal levels showing processes and reticulates paratabulation on cyst (B)



Map 82: Occurrence of Dinocyst type 1 in the RSA, Winter 2006

Phylum: Miozoa

Class; Dinophyceae Fritsch 1927

Species: Dinocyst type 2

Figure No.: Plate 83

References:

Not found

Description:

The spherical cyst has dark brown colour. A thick mucilaginous external layer surrounding the cyst and many particles are attached to this layer. A reticulate pattern was noted on the cyst surface (Plate 83D) and a slit-like archeopyle was observed (Plate 83).

Size:

D: 34µm

Occurrence in RSA:

The occurrence of the species in the sediment sample of the Winter Cruise 2006 of RSA is shown on Map 83, in stations: 93, 16a, 40

Occurrence in the world:

Not reported from anywhere else

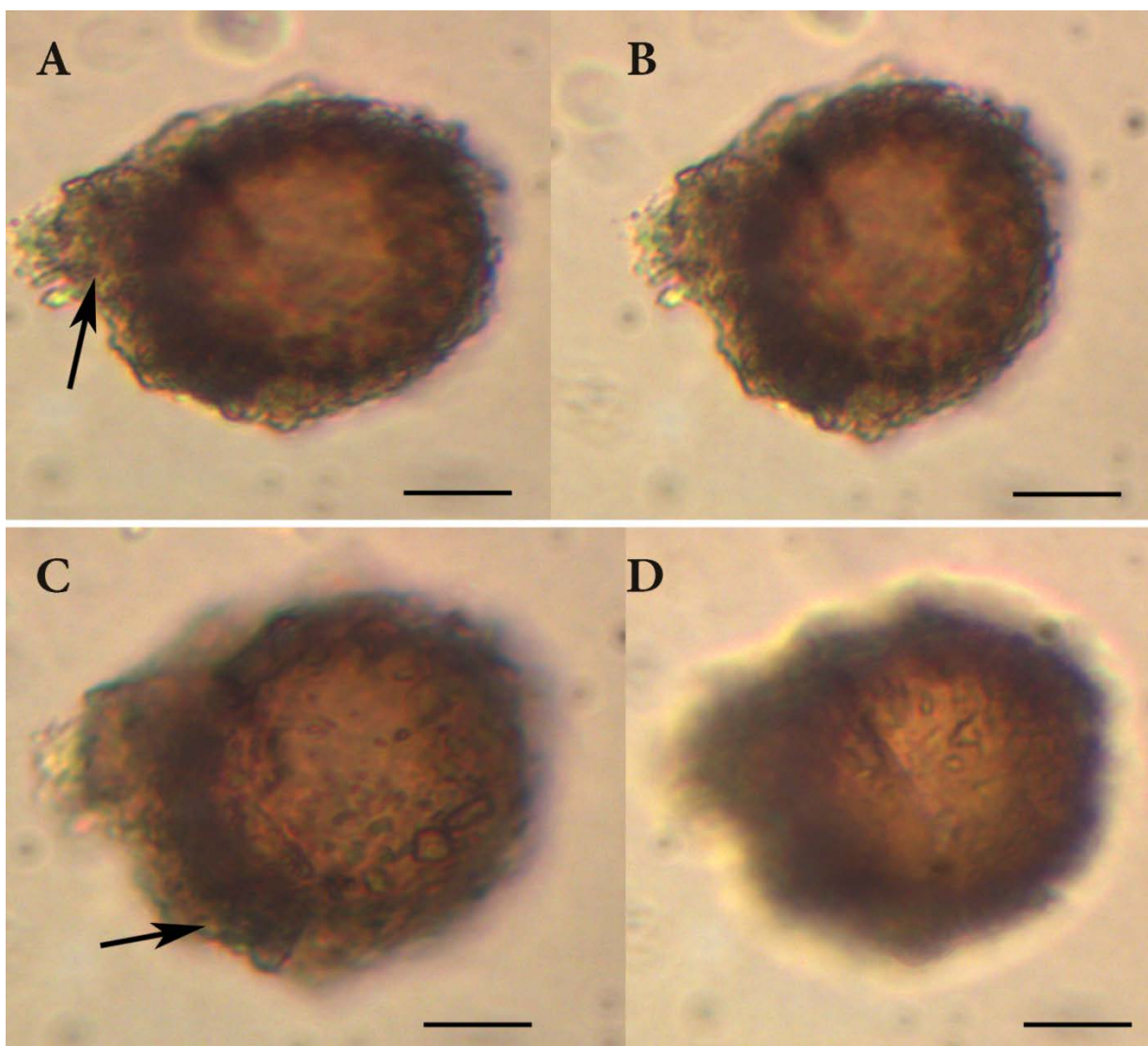
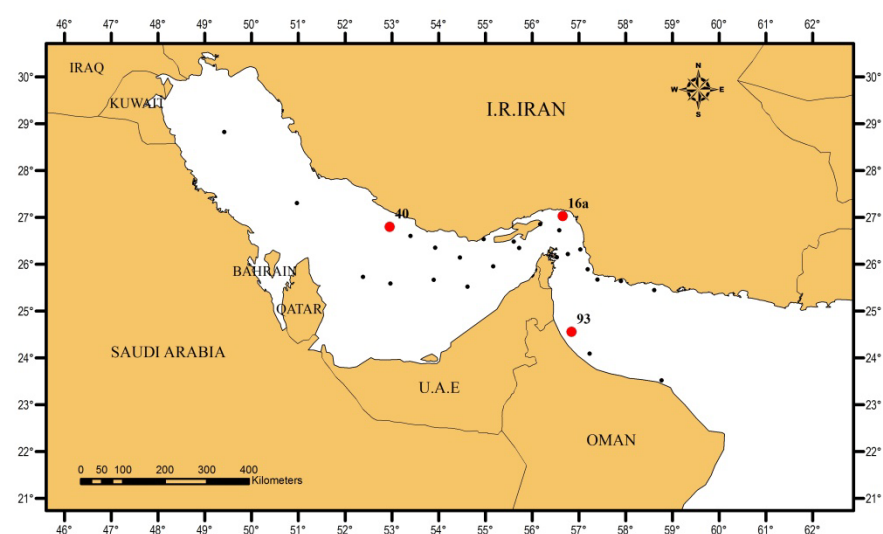


Plate 83: Dinocyst type 2 at different focal levels



Map 83: Occurrence of Dinocyst type 2 in the RSA, Winter 2006

Phylum: Miozoa

Class; Dinophyceae Fritsch 1927

Species: Dinocyst type 3

Figure No.: Plate 84

References:

Attaran-Fariman (2007), Figure 18

Description:

The spherical cyst has dark brown colour. Cyst is ornamented with irregular particle with gaps between them on the cyst wall (Plate 84 C-D). The cyst resembles *Scrippsiella* sp.1 described by Attaran-Fariman (2007); however, the number of particle on the cyst surface in the later species is denser and the cyst confirms by germination. It is hard to identify the cyst from RSA without germination experiment; therefore, our specimen remains unknown.

Size:

D: 33µm

Occurrence in RSA:

The occurrence of the species in the sediment sample of the Winter Cruise 2006 of RSA is shown on Map 84, in station: 87

Occurrence in the world:

Not reported from anywhere else

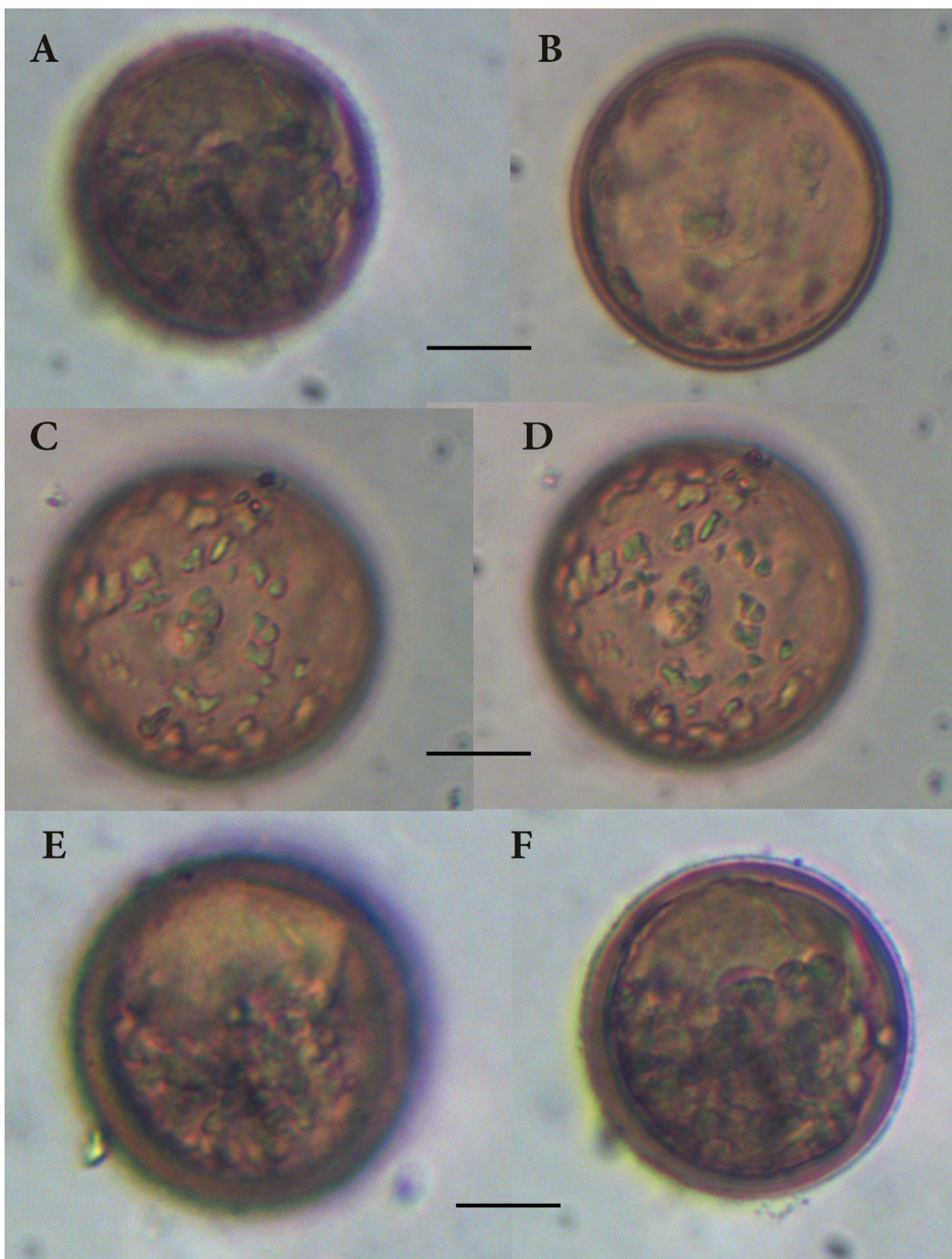
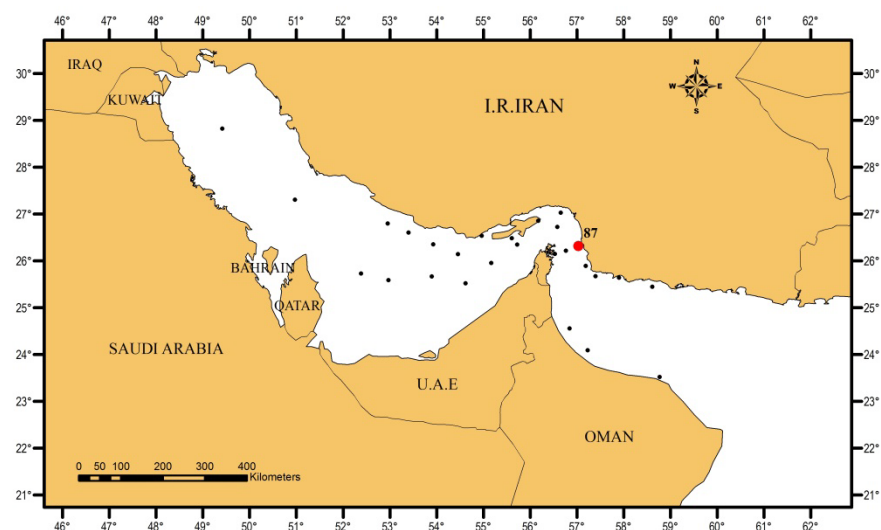


Plate 84: Dinocyst type 3 at different focal levels



Map 84: Occurrence of Dinocyst type 3 in the RSA, Winter 2006

Phylum: Miozoa

Class; Dinophyceae Fritsch 1927

Species: Dinocyst type 4

Figure No.: Plate 85

References:

Not found

Description:

Spherical brown cyst has a thick double-layered wall. The processes are hollow, flexible and pointed tips. The cyst contents are granular and dark brownish green with a big yellow accumulation body. There are no ornamentation reflecting paratabulation.

Size:

D: 37µm

Occurrence in RSA:

The occurrence of the species in the sediment sample of the Winter Cruise 2006 of RSA is shown on Map 85, in stations: 93, 43

Occurrence in the world:

Not reported from anywhere else

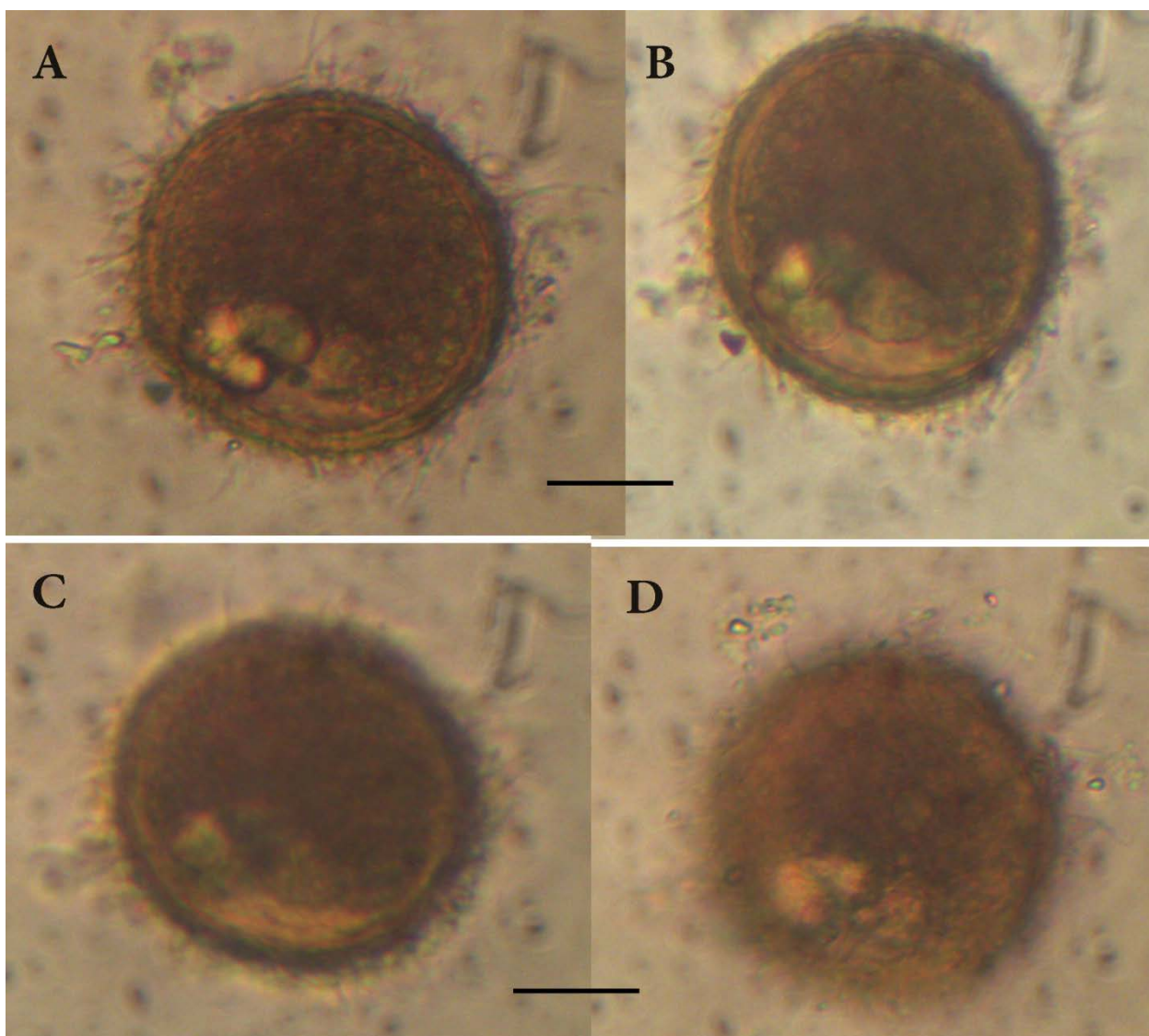
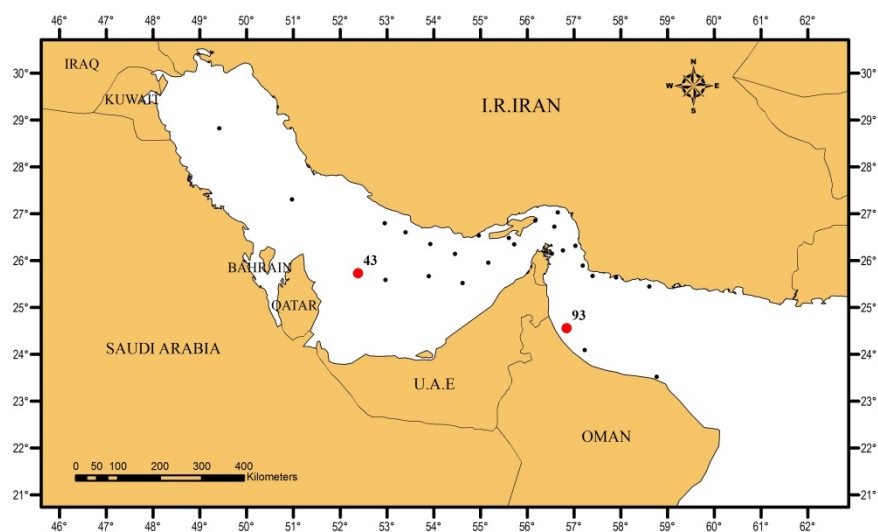


Plate 85: Dinocyst type 4 at different focal levels



Map 85: Dinocyst type 4 occurrence in the RSA, Winter 2006

Phylum: Miozoa

Class; Dinophyceae Fritsch 1927

Species: Dinocyst type 5

Figure No.: Plate 86

References:

Not found

Description:

The small cyst is subspherical and brown in colour. The cyst is ornamented with small solid uniform process. The cyst has big globular yellow contents in the deep focus, and green in surface focus (Plate 86 C). No archeopyle and any other paratabulations were observed.

Size:

D: 27µm

Occurrence in RSA:

The occurrence of the species in the sediment sample of the Winter Cruise 2006 of RSA is shown on Map 86, in station: 21a

Occurrence in the world:

Not reported from anywhere else

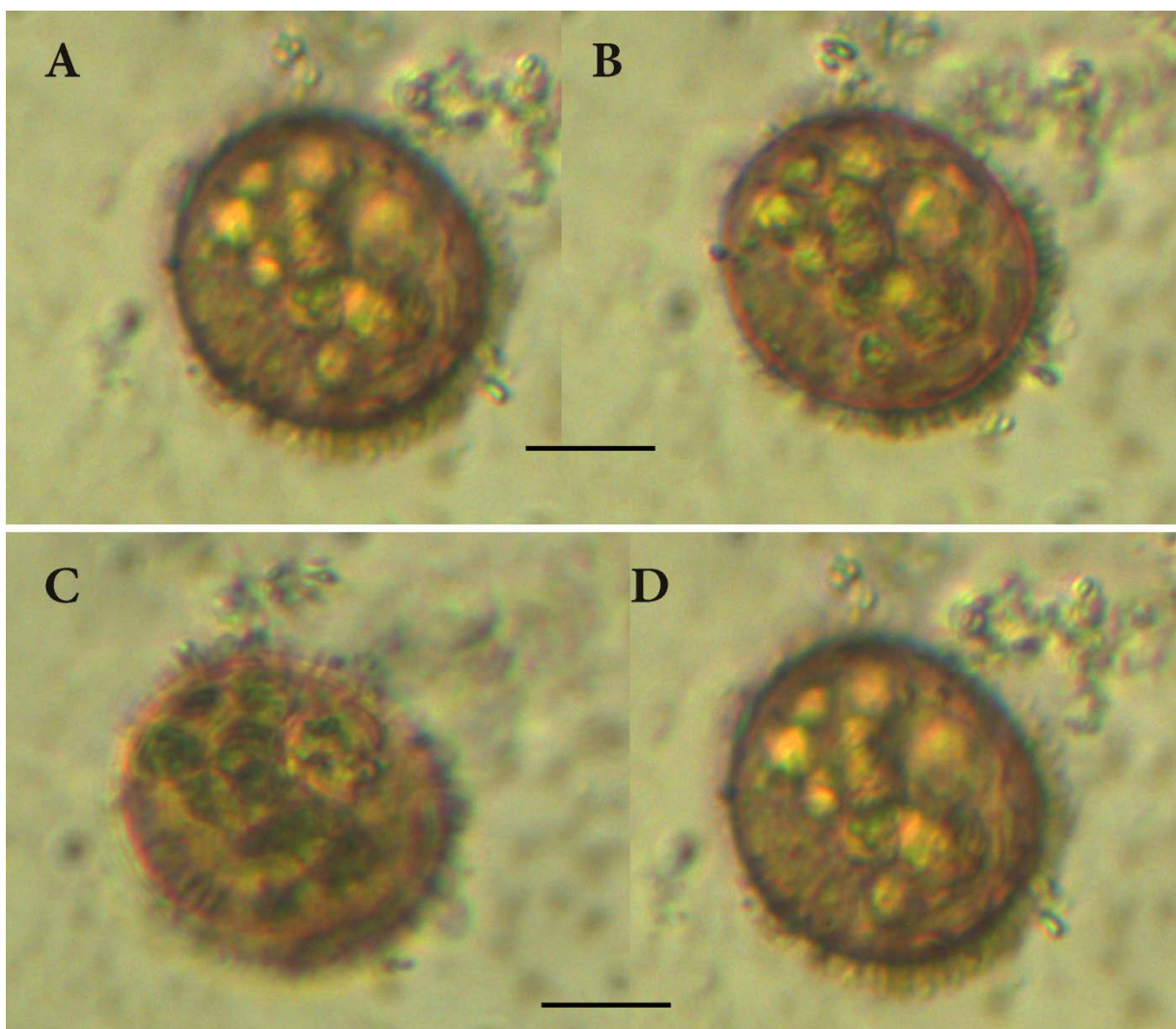
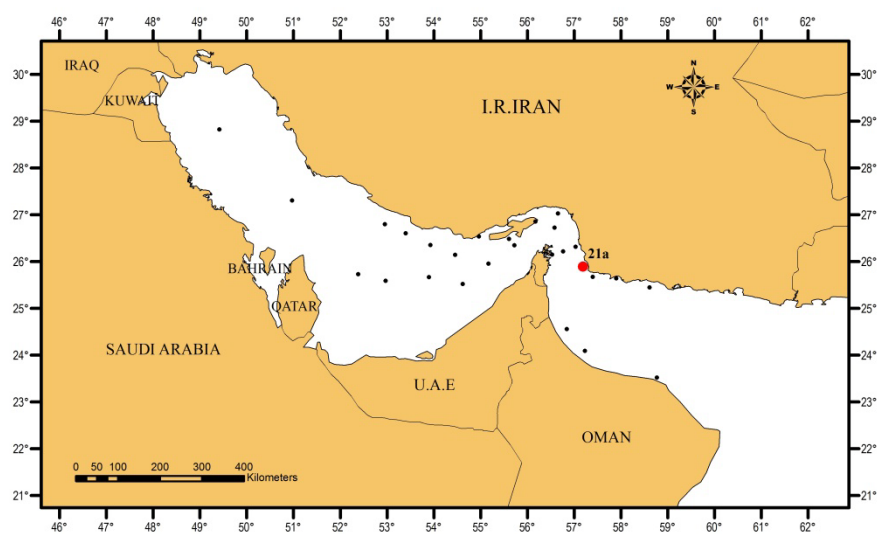


Plate 86: Dinocyst type 5 cyst at different focal levels showing contents and processes



Map 86: Dinocyst type 5 occurrence in the RSA, Winter 2006

Phylum: Miozoa

Class; Dinophyceae Fritsch 1927

Species: Dinocyst type 6

Figure No.: Plate 87

References:

Not found

Description:

The spherical light brown cyst. The cyst has two layers smooth wall. The archeopyle and other paratabulation were not observed. The cyst was not common in RSA sediments.

Size:

D: 40µm

Occurrence in RSA:

The occurrence of the species in the sediment sample of the Winter Cruise 2006 of RSA is shown on Map 87, in station: 98, 85, 83

Occurrence in the world:

Not reported from anywhere else

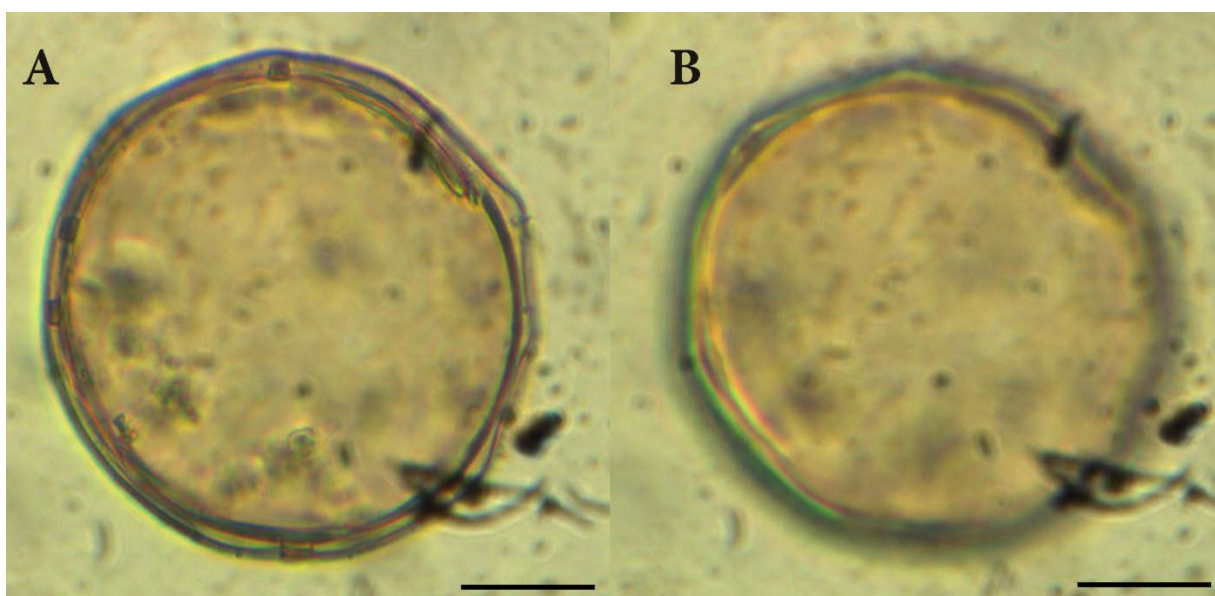
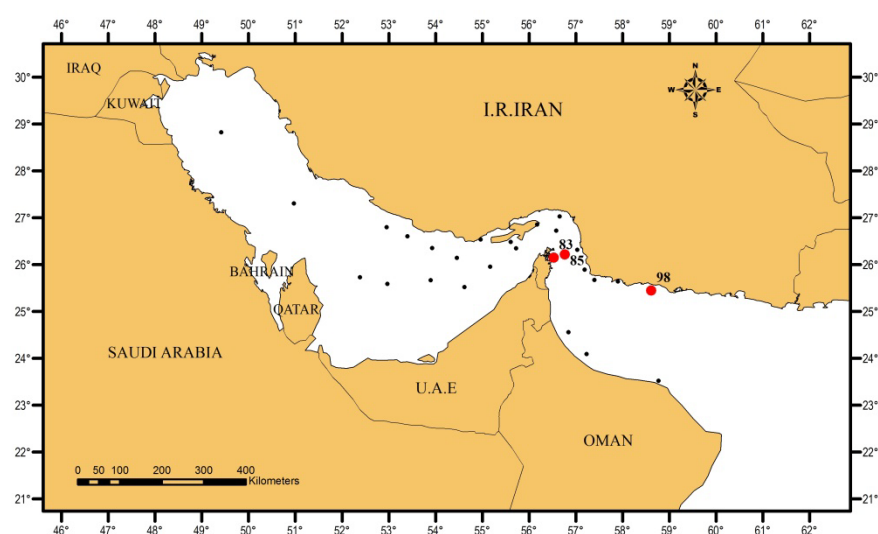


Plate 87: Dinocyst type 6 at different focal levels



Map 87: Dinocyst type 6 occurrence in the RSA, Winter 2006

Phylum: Bacillariophyta L.S.Dillon, 1963

Class; Coscinodiscophyceae Round & Crawford, 1990

Order: Arachnoidiscales Round

Family: Arachnoidiscaceae Round

Genus: *Paralia* Heiberg, 1863

Species: *Paralia* sp.1

Scientific name: *Paralia* sp.

Figure No.: Plate 88 (A-B)

References:

Cremer *et al.*, (2007), Plate 3, fig 3

Description:

Centric diatom, frustule in the apical view is spherical. The cyst centre is separated from adjacent marginal costae

Size:

D: 29µm

Occurrence in RSA:

The occurrence of the species in the sediment sample of the Winter Cruise 2006 of RSA is shown on Map 88, in stations: 16a, 83, 55, 25

Occurrence in the world:

Florida (Cremer *et al.*, 2007)

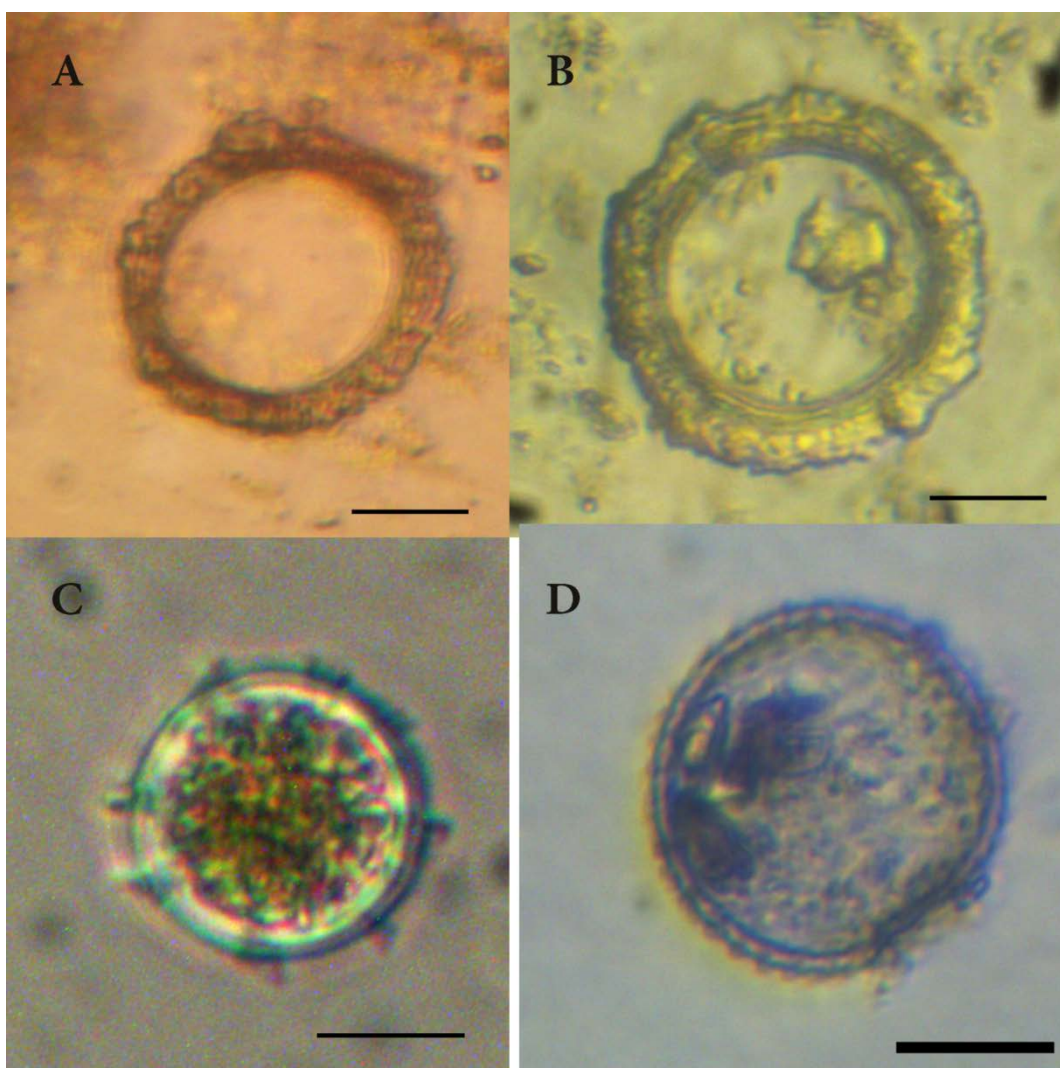
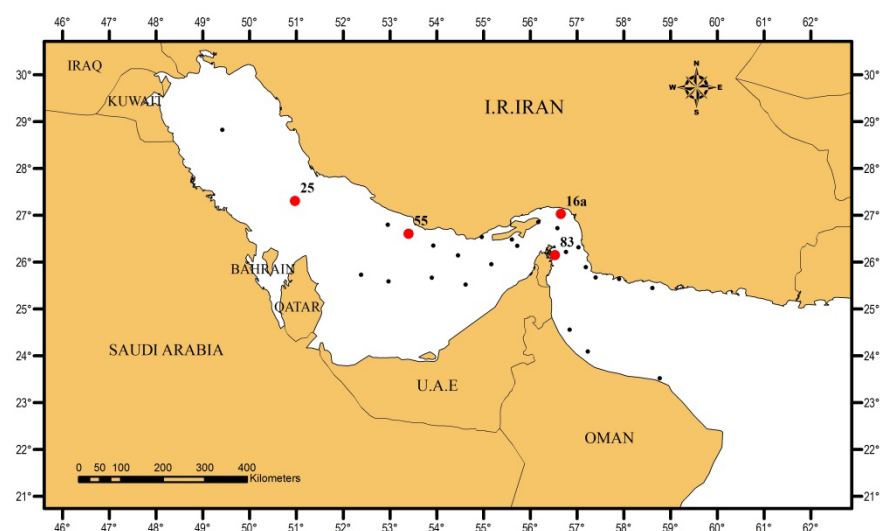


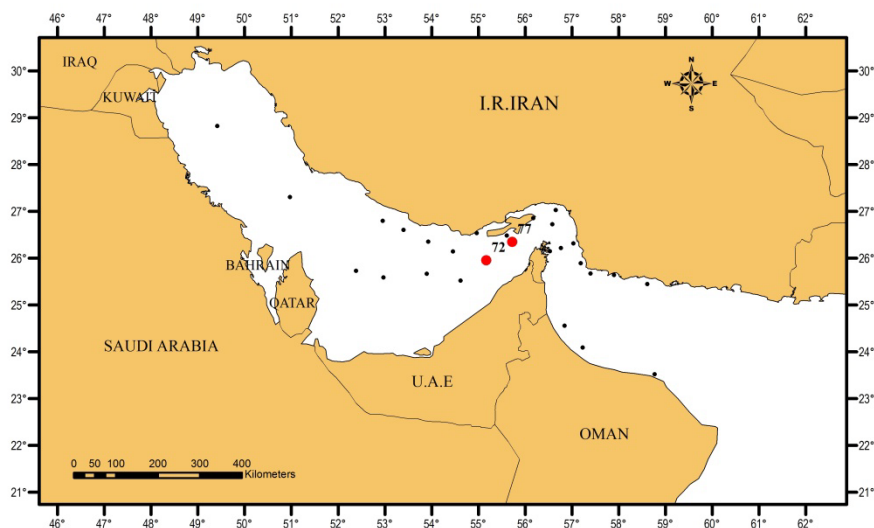
Plate 88: Diatoms resting spores: A-B; *Paralia* sp., C; unknown1, D; unknown 2



Map 88: Occurrence of *Paralia* sp. in RSA, Winter 2006

Unknown 1 Diatom (Plate 88C)

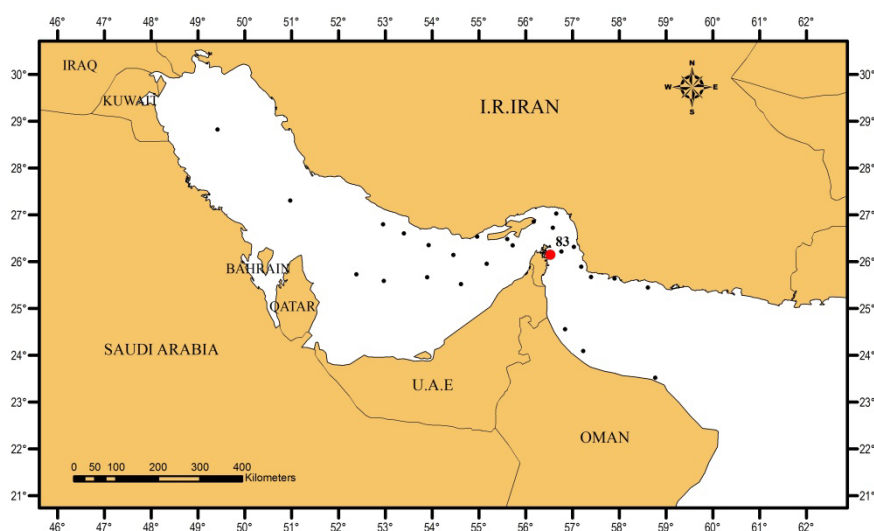
This resting cyst belongs to the centric diatom type; margin of valve bears numerous radial spines. Cyst was small in size with a diameter of 20µm and found in two stations: 77, 72 (Map 89).



Map 89: Occurrence of unknown 1 diatom in the RSA, Winter 2006

Unknown 2 Diatom (Plate 88D)

Centric diatom frustule is ornamented with numerous short solid spines that distributed regularly. This cyst diameter is 25µm and found only in one station: 83 (Map 90).



Map 90: Occurrence of unknown 2 diatom in the RSA, Winter 2006

Phylum: Ochrophyta Cavalier-Smith, 1996

Class; Raphidophyceae Chadeffaud ex P.C.Silva 1980

Order: Chattonellales J.Throndsen 1993

Family: Chattonellaceae J.Throndsen 1993.

Genus: *Heterosigma* Y.Hada ex Y.Hara & M.Chihara, 1987

Species: *Heterosigma* cf. *akashiwo*

Scientific name: *Heterosigma akashiwo* Hada ex Y.Hara & M.Chihara 1987

Figure No.: Plate 89 (A-B)

References: -

Park *et al.*, (2016) Figures 1-6

Description:

Spherical small cyst is yellow-green in colour. A mucilaginous layer surrounded the cyst. This cyst type because of its small size often missing from the samples. During this research, very small cyst that resembles in size and colour to the cyst of *Heterosigma*, described by Park *et al.*, (2016) was found in the sediment of the RSA. We used 20µm mesh sieve. As a mucilaginous layer adhered to the cysts, they can remain on the sieve; but some samples may pass from sieve. Because of small size of raphidophyds cyst, their identification without germination is difficult.

Size:

D: 12µm

Occurrence in RSA:

The occurrence of the species in the sediment sample of the Winter Cruise 2006 of RSA is shown on Map 91, in stations: 97, 11

Occurrence in the world:

Korea (Park *et al.*, 2016)

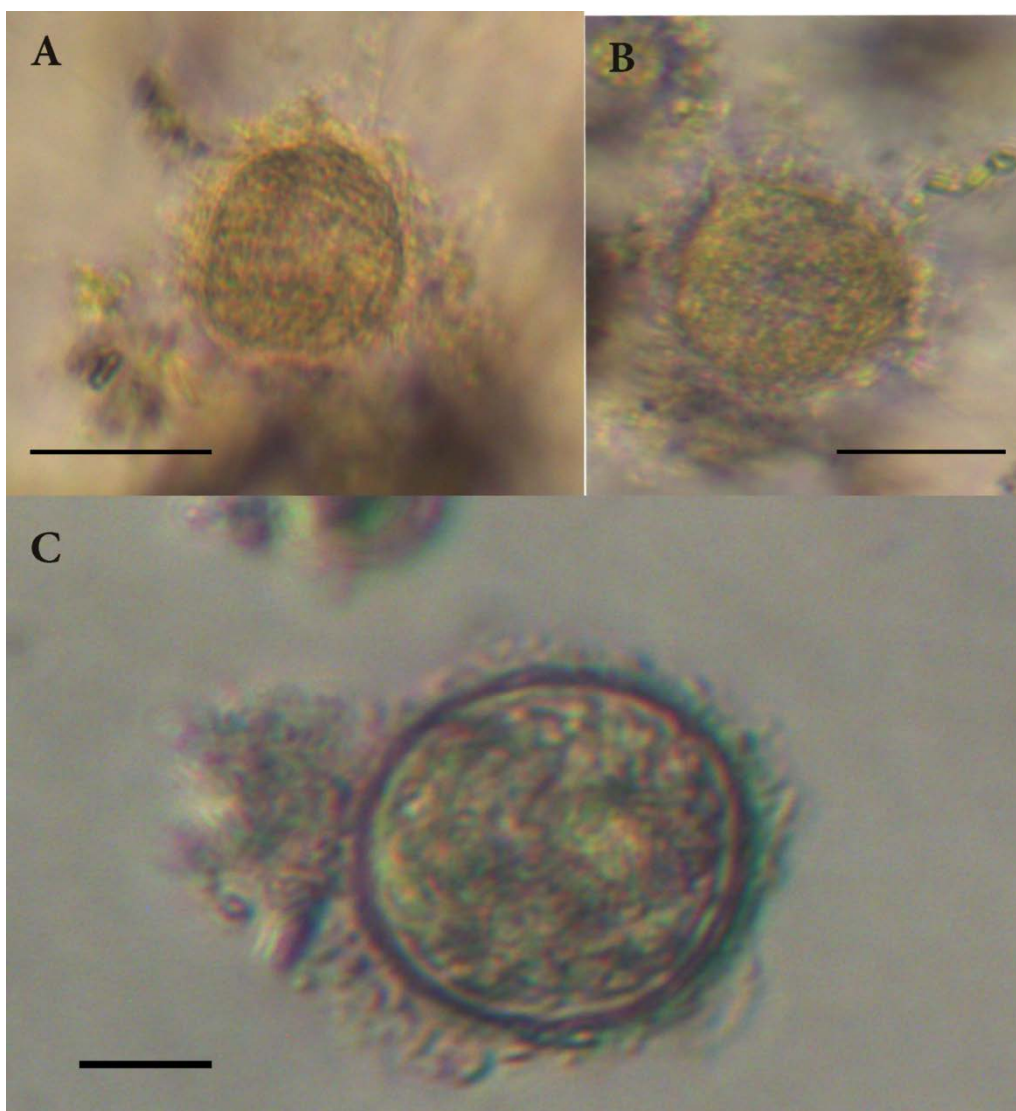
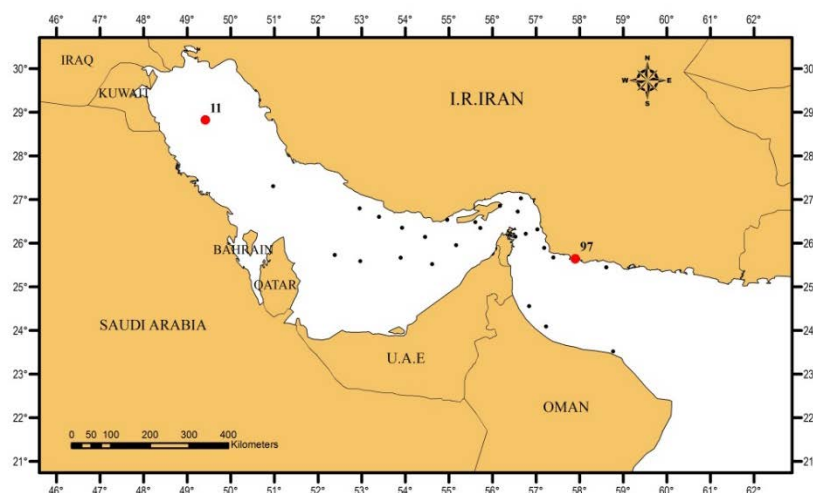


Plate 89: Raphidophyceae cyst: A-B; *Heterosigma cf. akashiwo* cyst showing mucilaginous layer, C; *Chattonella* sp.



Map 91: Occurrence of *Heterosigma cf. akashiwo* in the RSA, Winter 2006

Phylum: Ochrophyta Cavalier-Smith, 1996

Class; Raphidophyceae Chadeffaud ex P.C.Silva 1980

Order: Chattonellales J.Throndsen 1993

Family: Chattonellaceae J.Throndsen 1993

Genus: *Chattonella* B.Biecheler, 1936

Species: cf. *Chattonella* sp.

Figure No.: Plate 89C

References:

Attaran-Fariman and Bolch (2014), Figures 2 B-C

Description:

Small spherical cyst with the diameter of 20µm and brown in colour (Plat 89C). A mucilaginous layer surrounded the cyst and a yellow accumulation body was observed in it. This cyst type is different from that described by Attaran-Fariman and Bolch (2014) from natural sediment, by its smaller size of accumulation body.

Size:

D: 20µm

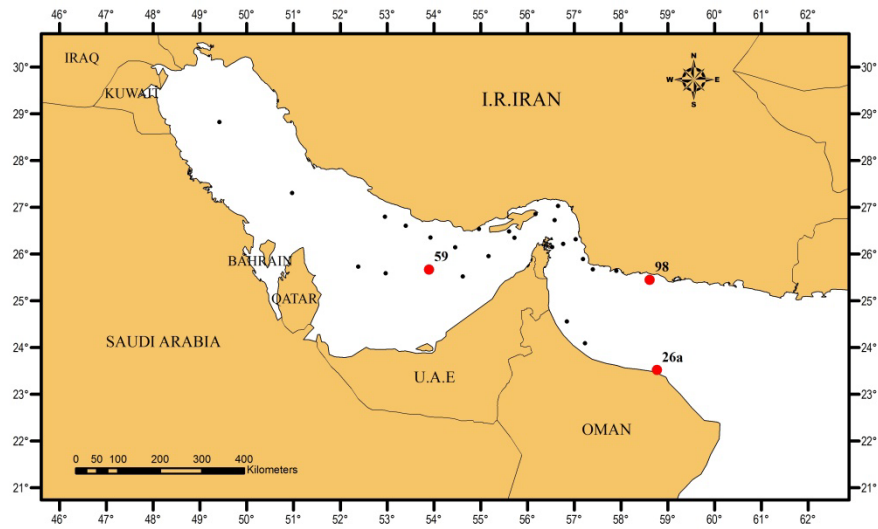
Occurrence in RSA:

The occurrence of the species in the sediment sample of the Winter Cruise 2006 of RSA is shown on Map 92, in stations: 26a, 98, 59

The cyst previously has been reported from northern part of the Sea of Oman (Attaran-Fariman and Bolch 2014)

Occurrence in the world:

China (Liu 2008), Dutch Wadden Sea (Gittenberger *et al.*, 2010)



Map 92: Occurrence of *Chattonella* sp. in the RSA

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