

Palynology and Evaluation of Petroleum Potential Source of Chaman-Bid Formation (Upper Bajocian-Tithonian) in the Eastern Kopet-Dagh Basin, NE Iran

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Abstract

The Kopet-Dagh Basin located in NE Iran, southern Turkmenistan and northern Afghanistan. It contains sediments of Mesozoic and Tertiary Eras. The Chaman-Bid Formation (Bajocian-Tithonian) is composed of shale, marl and marly limestone deposited after the Mid-Kimmerian orogeny in a shallow marine and lagoonal environments. In order to study palynostratigraphy, palynofacies and possibility of hydrocarbon generation, 45 samples were collected and processed palynologically. The studied section can be correlated with Tethyan realm and two events have been identified in the middle part of this section. Based on identified events, the age of Middle part of this section is Oxfordian-Kimmeridgian, while the upper part is Tithonian in age. The lower part of studied section, based on dinoflagellate cysts such as *Nannoceratopsis gracilis* and *N. ridingii*, is late Bajocian. Palynofacies study has led to recognition of two types of alternation in the sequence indicating a stagnant anaerobic-dysaerobic bottom condition followed by an energetic and oxygenated condition. Twelve samples rich in dinoflagellate cysts were selected for evaluation of Total Organic Carbon (TOC). These indices show that the potential of hydrocarbon bearing is fair to good and the type of production can be a wet and probably sweet gas; however at this stage the Chaman-Bid Formation is overmature in eastern Kopet-Dagh basin.

Keywords: *Palynology, Petroleum, Chaman-Bid, Bajocian-Tithonian Kopet-Dagh, NE Iran*

Introduction

The Kopet-Dagh Basin is formed after the early Kimmerian Orogeny in NE Iran (Berberian and King, 1981). This basin was a site of relatively continuous sedimentation from Jurassic through Miocene. The Jurassic sediments are composed of two different groups. First the siliciclastic Kashafrud Formation and the second is carbonate sediment that consists of Khaneh-Zoo, Chaman-Bid and Mozduran formations. The Chaman-Bid Formation (Bajocian-Tithonian) is about 1722 meters at its Type locality in the western part of the basin (Afshar-Harb, 1979). At the studied section (Sandug-Shekan) this formation is about 411 meters thick and is mainly composed of calcareous shale and marly- limestone (Fig. 1). Based on TOC measurements Afshar-Harb (1979) reported that this formation may be a source rock for a giant gas-bearing reservoir in NE Iran.

The aim of this study is to identify dinoflagellate cysts and palynofacies; therefore to interpret the paleoenvironmental condition and evaluate hydrocarbon generation potentiality of Chaman-Bid Formation at the studied section, based on palynomorph.

We hope that this study could help in a better understanding of the source rocks of gas in the eastern part of the basin as well as can be used for further exploration on other parts of this basin in Iran and Turkmenistan.

Sampling and Methods

A total of 45 samples were collected from a stratigraphic section measured at the Sandug-Shekan Mountain located in north of Mashhad along the Mashhad-Kalat road (Fig. 1).

The samples were processed for palynological study, using nearly standard method described by Traverse (1988). The samples were first put in HCL and HF and then centrifuged with zinc-bromide. The residues, after heavy liquid separation, were sieved (20 micron) and slides were made.

Twelve samples rich in dinoflagellate were selected for source rock evaluation, using Rock- Evall II Technique at the Research Institute of Petroleum Industry (RIPI), NIOC. Other data about the source rock analysis have been provided by RIPI.

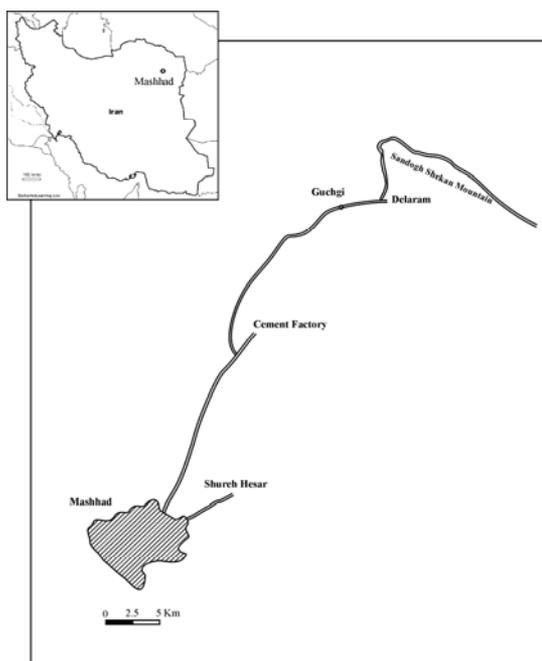


Figure 1. Location map of the Chaman-Bid Formation in Sandugh-Shekan.

Stratigraphy

The Chaman-Bid Formation is about 411 meters thick at the Sandugh-Shekan section and consists of interbedded of gray to black shale and dark-gray marly limestone. The average thickness of limestone beds is about 15-20 centimeters (Fig. 2). It conformably overlies the Khaneh-Zoo Formation, and underlies the Mozduran Formation. These three formations are called as Mago Group that has been deposited after Mid Kimmerian Orogeny in a shallow marine condition (Aghanabati, 1998).

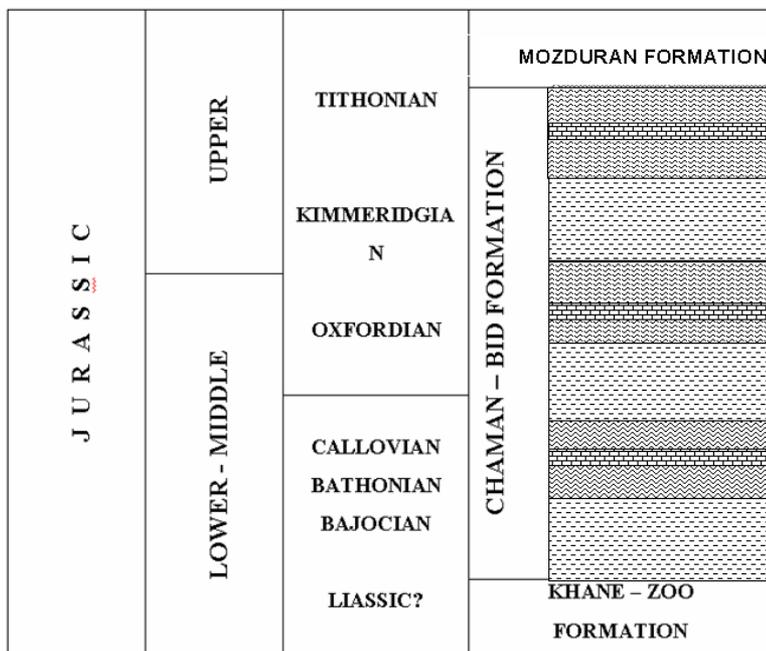


Figure 2. Stratigraphic column of the Chaman- Bid Formation in Sandugh-Shekan section.

Palynostratigraphy

Palynological studies led to identification of a relatively rich assemblage of dinoflagellate cysts with mostly proximate forms. They are poorly preserved and are mainly related to warm water environmental conditions (Ridding and Hubbard, 1999). The studied section could be correlated with the Tethyan realm and two correlatable events identical to those of Jan du Chêne *et al.* (1999), were identified (Fig. 3). These are as follow:

1) Cribroperidinium globatum event: This event starts at Mid Oxfordian and ends in Early Kimmeridgian. This palynomorph zone can be matched with the *Plicatilis to platynota* ammonite Zones of Jan du Chêne *et al.* (1999) (Fig. 4 a).

2) Scriniodinium crystallinum event: This event occurs during the Lower Kimmeridgian time, and can be matched with *Platynota* ammonite Zone of Jan du Chêne *et al.* (1999) (Fig. 4c).

	TETHYAN PALYNOLOGICAL EVENTS		TETHYAN AMMONITES	THIS STUDY
STAGE	BASE	TOP	ZONES	
	OCCURANCE			
UPPER KIMM.			ACANTHICUM	
LOWER KIMMERIDGIAN.			DIVISUM	
		Abundant Top	HYPSELOCYCLUM	<i>R. cladophora</i>
		<i>R. cladophora</i>	PLANTYNOTA	<i>S. crystallinum</i>
		<i>S. crystallinum</i>	PLANULA	
UPPER OXFORDIAN		<i>E. galeritum</i>	BIMAMMATUM	
			BIFURCATUS	
MID. OXFORDIAN		<i>C. globatum</i>	TRANSVERSARIUM	<i>C. globatum</i>
			PLICATILIS	

Figure 3. Correlation of Sandug-Shekan section's events with their equal deposits of Tethyan realm.

The upper part of the studied section can be correlated with DSI30-34 zone of Poulsen and Riding (2003) which is characteristic zone of Tithonian age and started with the first occurrence of *Egmontodinium polyplacophorum*, *Endoscrinium luridum* and *Gochteodinium antenata* (Fig. 4, d-f).

Based on *Nanoceratopsis ridingi* and *N. gracilis* (Fig. 4, g-h), the age of the lower part of the sequence is Bathonian-Bajocian

Palynofacies

Palynofacies analyses deal with total acid resistant organic residue. It can be used in organic geochemistry in order to determine maturity and environment of deposition. The palynodebris found in this palynological study can be subdivided into an allochthonous and an autochthonous as described by Van der Zwan (1990).

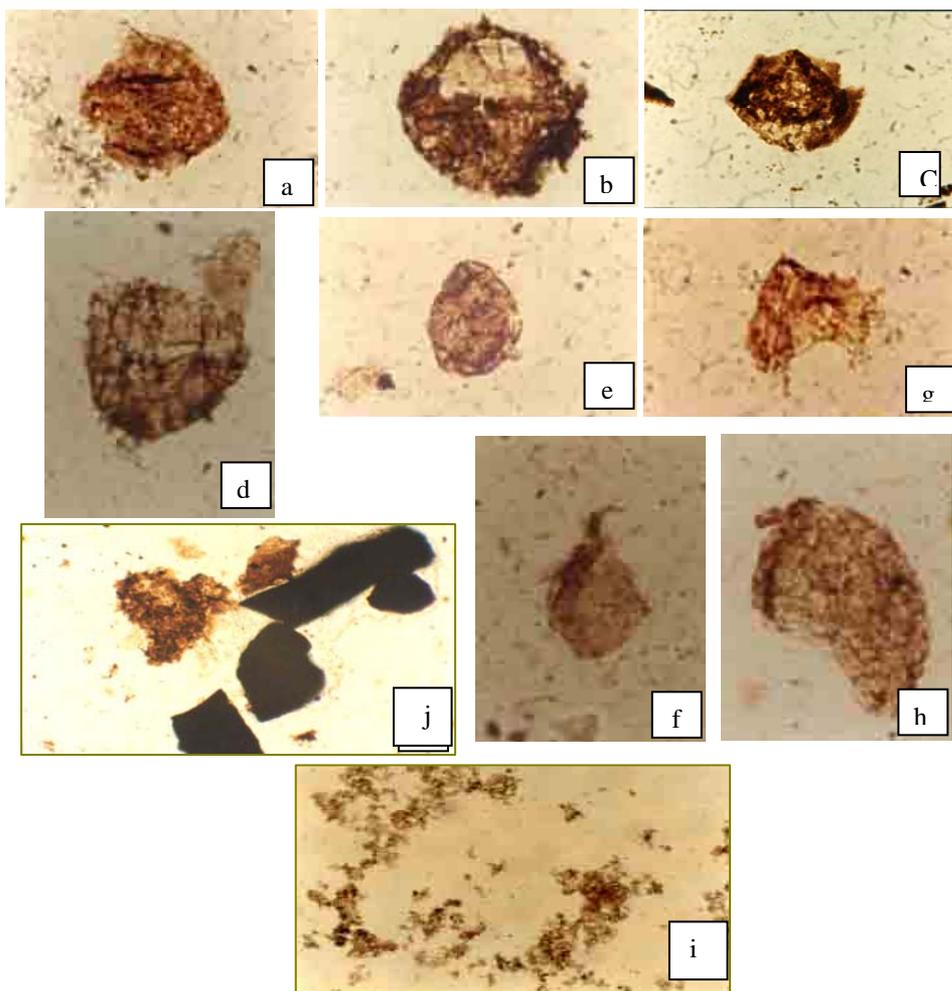


Figure 4. a to h: photomicrographs of the recorded index diatom species; i and j palynofacies.

a: *Cribroperidinium globatum*, b: *Rhynchodiniopsis cladophora*, c: *Scrinium crystallinum*, d: *Egmontodinium polyplacophorum*, e: *Endoscrinium luridum*, f: *Gochteodinium antenata*, g: *Nannoceratopsis ridingii*, h: *Nannoceratopsis gracilis*, i: Palynofacies Type I, j: Palynofacies Type II.

The identified palynomorphs were mostly of marine forms (dinoflagellate cysts); however, in the uppermost part of the section a few of terrestrial forms (sporomorphs) were recovered.

Palynofacies study has led to differentiation of two types of facies: Palynofacies type I is characterized by a greater amount of structure-less organic matter (SOM) and a lesser amount of maceral (Fig. 4i). This palynofacies is comparable with palynofacies II of Van Der Zwan (1989) from the Upper Jurassic to Lowermost Cretaceous palynofacies of the offshore Mid Norway. The abundance of SOM is characteristic of bottom conditions, and indication of an aerobic alternated with dysaerobic conditions (Ghasemi- Nejad *et al.*, 2003). Palynofacies type II is characterized with a low content of SOM and shows high percentage of macerals (Fig. 4j). This facies is comparable with palynofacies IV of Van der Zwan (1989). The lower percentage of SOM in this palynofacies indicates more oxygenated bottom conditions.

In general, dinocysts are relatively high in the uppermost part of the section but SOM and macerals have followed a cyclic trend (Fig. 5).

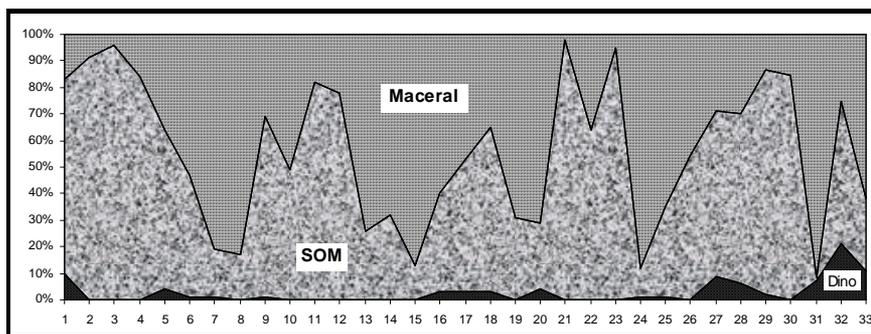


Figure 5. Relative proportions of the three main palynological groups throughout the stratigraphic section.

Evaluation of petroleum generation in Chaman-Bid Formation

Dinoflagellate accompanied with diatoms and coccolithophorids are the most prominent marine producers in the oceans today and play an important role in the global carbon cycle (Brasier, 1985). Over the past decades, the importance of dinocyst analysis and dinocyst palynostratigraphy has been increasingly used as a tool in hydrocarbon exploration (Sluijs, *et al.*, 2005). A higher resolution of

palynostratigraphy is more than calcareous microfossils; therefore it can be given a more control in unknown stratigraphic sequences (Grastien *et al.*, 1992). Since the diatoms can store lipids; therefore their remains can form major components of petroleum source rocks. Based on this study and the studies done by RIPI on other sections (Chaman-Bid and Kalat sections) of the Chaman- Bid Formation, we will discuss the possibility of source rock of this formation.

The position of data from different sections of the Chaman-Bid Formation in the plot of hydrogen index versus Tmax (Table 1), for sections that vary in thermal maturity from a vitrinite reflectance of 0.5 to 1.96, is shown in figure 6. The position of the samples from NE Kopet-Dagh sections suggests that the area is over mature.

Table 1. Rock Eval analysis of the Chaman-Bib Formation samples from Sandug-Shekan section

Sample	S1	S2	S3	TPI	Tmax	TOC	HI	OI CO2
MH01	0.07	0.02	0.11	0.78	487	0.31	6	0
MH02	0.12	0.1	0	0.55	484	0.38	26	0
MH03	0.07	0.03	0	0.70	496	0.28	11	0
MH07	0.08	0.03	0	0.73	504	0.31	10	0
MH09	0.06	0	0	1.0	494	0.09	0	0
MH15	0.15	0.18	0.09	0.45	490	0.57	32	16
MH16	0.19	0.18	0.26	0.51	491	0.60	30	43
MH21	0.21	0.29	0.25	0.42	490	0.79	37	32
MH23	0.10	0.09	0.08	0.53	487	0.30	30	27
MH32	0.16	0.13	0.06	0.55	472	0.45	29	13
MH36	0.11	0.08	0.05	0.58	487	0.27	29	19
MH38	0.07	0.04	0.11	0.64	478	0.24	17	46

The quantitative microscopy of kerogen petrographic composition from the NE Kopet- Dagh (Fig. 7) shows the following:

The Chaman-Bid kerogen in the Kalat section (KL; provided by RIPI) includes 81% amorphous algal organic matter, 12% woody and 7% coaly and/or inertinitic organic matter, comparable with a Type II marine kerogen (RIPI, unpublished internal report, IR 920 B-1298/03).

The Chaman-Bid kerogen in the studied section (CH-B) includes 47% amorphous organic matter, and around 50% terrestrial organic matter, comparable with a mixed marine–terrestrial kerogen.

The chromatograms of the extractable organic matter from the less mature part of the formation show an alkane distribution that picks around C17 and C19 (IR 920 B- 1298/03) consistent with dominantly algal and bacterial derived organic matter, and with the predominance of amorphous organic matter in the kerogen petrographic composition. The average maturity data from the NE Kopet- Dagh (e.g., average Tmax = 488) indicates that the NE Kopet Dagh is overmature. This implies that (a) the NE Kopet-Dagh rocks have been exposed to temperatures in the geological past that could have been high enough for oil cracking to take place, and (b) the Chaman-Bid in the NE Kopet-Dagh must have been uplifted several kilometers, regardless of whether or not the strata were subjected to high or low heating rates during the burial history. The cooler the basin, the deeper the maximum depth of burial and the more extensive the uplift.

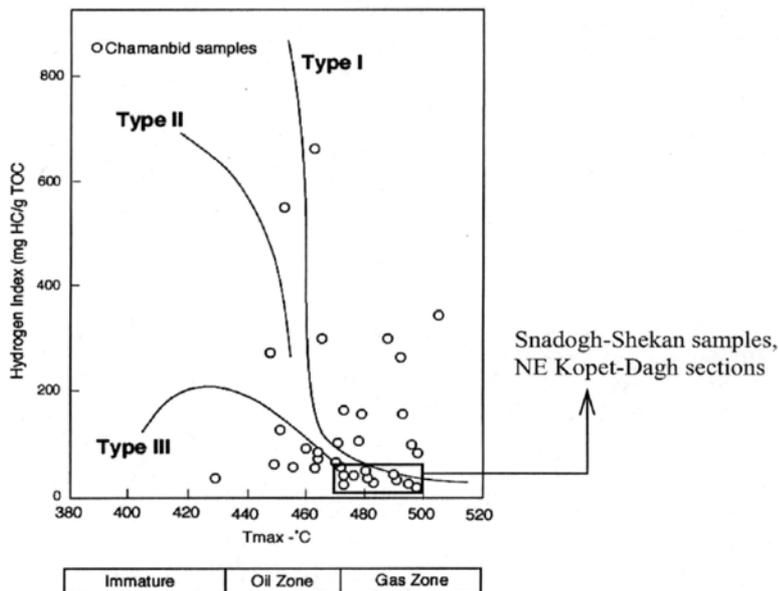


Figure 6. The position of samples from the immature to overmature sections of the Chaman-Bid sections in the plot of hydrogen index versus Tmax.

With uplift of several kilometers and complex structural features, it is plausible that some of the present day's gas reservoirs could be the result of remigration due to extensive deformation and uplift of the area. With the currently available information, no conclusion can be made regarding the relative proportion of the gas that has been generated from the very mature part of the possible source rocks and of the gas has been accumulated related to remigration and expansion of gas during the uplift.

The currently available data (due to too high maturity and/or lack of systematic data) are not conclusive with respect to the possible source rock potential of the Chaman-Bid Formation. However, since the formation is of marine origin with predominance of amorphous algal organic matter and since a significant part of the formation is mature to overmature, the following systematic studies are warranted to determine the exact role of the Chaman-Bid in the presence of the discovered petroleum reserves in the Kopet- Dagh area.

a) A systematic geological study of immature to mature Chaman-Bid Formation.

b) A comprehensive study of the variations in the geohistory of the formation.

c) Using the result of (a) and (b), it should provide enough information to calculate how much oil and gas could have been generated and expelled from the formation, and how extensive the secondary cracking (oil- to- gas cracking) could have been in the overmature part of the formation, prior to uplift of the area.

d) By integrating the result from (a) to (c) with structural features of the area, and looking into the possible migration pathways, it should be possible to provide a reasonable picture of the petroleum system(s), possible remigration during uplift, and the interrelationship between the source rocks, carrier beds and reservoir rocks.

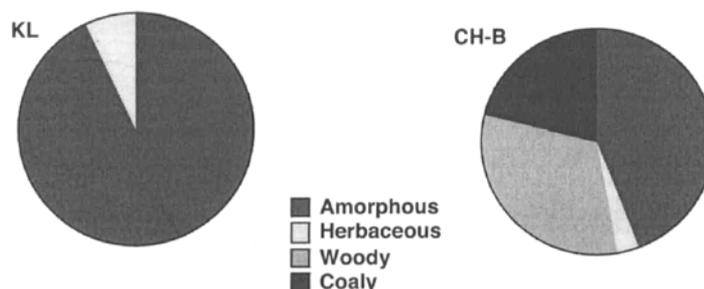
Kerogen Petrographic Composition of Chamanbid Formation

Figure 7. Average petrographic composition of kerogen from the Chaman-Bid Formation, NE Kopet- Dagh.

Conclusion

Palynofacies study of the Chaman-Bid led to identification of two different types of palynofacies. Type I indicates suboxic-anoxic environmental condition, while type II represents suboxic-oxic conditions. Based on correlation between the Sandug-Shekan section and the studied Tethyan realm, two different events have been identified during the Middle Oxfordian and Lower Kimmeridgian. Total organic carbon analysis along with palynological study show that this formation may have had fair to good potential source for hydrocarbon generation as wet and probably sweet gas, but it is in overmature stage in the eastern Kopet-Dagh basin.

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