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Short note on the first record of fossil shark teeth in the Chehel-Kaman Formation, Iran

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Key words:
fossil fish, Tethys Sea, Paleogene, Kopet-Dagh basin.

Abstract. Shark teeth discovered in the late Paleocene-early Eocene Chehel-Kaman Formation in NE Iran bring new data on the fossil fish record from this country. Two genera from the location are described and figured. The present record is one of the very few reports of fossil shark teeth from the Cenozoic of Iran and the first one from this formation and region. The marine vertebrates known from this region of the Tethys Sea are very scarce.

Кључне речи:
фосилне рибе, Тетис, палеоген, Kopet-Dagh басен

Апстракт. Зуби ајкула откривени у горњопалеоценско-доњоеоценској формацији Chehel-Kaman у североисточном Ирану пружају нове податке о фосилним рибама ове земље. Са ове локације су описана и приказана два рода. Овај фосилни проналазак представља један од ретких извештаја о фосилним зубима ајкула из кенозоика Ирана и уједно из ове формације. Морски кичмењаци овог дела Тетиса су веома ретки.

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Introduction

The Cenozoic fossil sharks are poorly known in Iran. Only a few other records from this country are known (Adnet et al., 2009; Owfi et al., 2016), but their exact origin is in general vague and none of them originate in the Kopet-Dagh Basin. The rest of fossil Chondrichthyes reported from Iran belong exclusively to the Paleozoic, forming a rather diverse fauna (Hampe, 2000; Long & Hairapetian, 2000; Yazdi & Turner, 2000; Hairapetian et al., 2008; Hairapetian & Ginter, 2010; Habibi & Ginter, 2011). The present discovery completes the taxonomic list of the vertebrate marine fauna in Iran and brings new data on the presence of the Paleogene sharks in this region of the Tethys.

Geological Setting

The study area is located in the North-Khorasan province, northeast Iran (Fig. 1). Although during the last decades a lot of geological investigations have been led in this region, especially in the fields of litho- and biostratigraphy, this tectono-sedimentary zone requires additional further studies in other different fields of research as well. In this paper, we concentrated our attention on a sequence of strata known as Chehel-Kaman Formation that unconformable covers a succession of Cretaceous units. It should be reminded that vertical succession in the study area is relatively different from the usual Kopet-Dagh sedimentary package, especially in the eastern Kopet-Dagh sedimentary basin (more data and new results will be published in the near future by the authors). This paper is the first one to focus on the fossil data, more exactly on the shark teeth in the Kopet-Dagh sedimentary basin.

The Kopet-Dagh (or Koppeh-Dagh) mountain range represents a NE-trending active fold belt at the border between Iran and Turkmenistan, about 650 km long and 200 km wide stretching northwest–southeast from near the Caspian Sea in the northwest to the Harirud River in the southeast.

The active fold belt of NE Iran, Kopet-Dagh, was formed on a Hercynian metamorphosed basement, at the SW margin of the Turan Platform. The belt consists of about 10 km of Mesozoic (the Kashafrud,

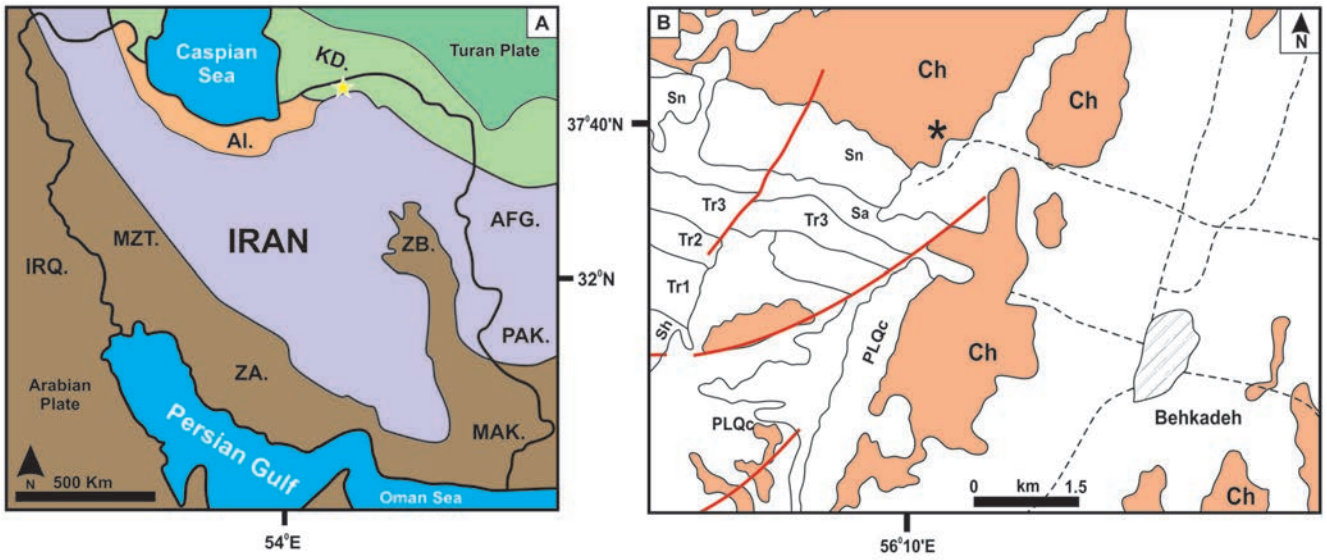

Fig. 1. *The location of the studied area.* ***A****. The subdivisions of structural zones of Iran. Studied area is marked by yellow star symbol. KD Kopet-Dagh, Al Alborz, MZT Main Zagros Thrust, ZA Zagros, MAK Makran, ZB Zabol-Baluch (after Poursoltani & Pe-Piper, 2015 with minor revision);* ***B****. The location map of the studied stratigraphic section on the Seyed-Abad geological map (1:100000):* ***Sn*** *- Sanganeh Formation;* ***Sa*** *- Sarcheshmenh Formation;* ***Ch*** *– Chehel-Kaman Formation;* ***Tr1*** *- Tirgan unit 1;* ***Tr2*** *- Tirgan unit 2;* ***Tr3*** *- Tirgan unit 3;* ***Sh*** *- Shourijeh Formation;* ***PlQc*** *- Plio-Quaternary; the black star symbol marks the location of the outcrop.*

Chaman Bid, Mozduran, Shourijeh, Tirgan, Sarcheshmeh, Sanganeh, Aitamir, Abderaz, Abtalkh, Neyzar and Kalat formations) and Cenozoic sediments (the Pestehligh, Chehel-Kaman and Khanigiran formations), mostly containing carbonates (Ghorbani, 2019).

Like the Zagros Mountains, the Kopet-Dagh formed linear NW-SE trending folds during the last Plio-Pleistocene phase of the Alpine orogenesis. No magmatic rocks crop out in the Kopet-Dagh, except those in the basement of the Aghdarband Window and some Triassic basic dikes (e.g., Berberian & King, 1981; Afshar-Harb, 1994; Golonka, 2004; Taherpour-Khalil-Abad et al., 2010, 2013; Raisossadat & Shokri, 2011).

Like other regions of Iran, tectonical movements in the early Tertiary, equal to Laramian orogenesis, led to sea retrogradation from south to north in such a way that a continental succession (Pestehligh Formation - Early Paleocene) is deposited in the south of the Kopet-Dagh sedimentary basin. During the middle Paleocene, except for the Sheikh area, a fossiliferous limestone (Chehel-Kaman Formation) is deposited because of the subsidence of the basin. During early Eocene the Sheikh area was also covered, so the marine Eocene strata are present (Khangiran Formation) (Afshar-Harb, 1994, Aghanabati, 2004) (Fig. 2).

The Chehel-Kaman Formation (Paleogene) in the Kopet-Dagh basin is mainly composed of limestone, dolomite and interbeds of marl, shale and evaporite sediments. It conformably overlies the siliclastic sediments of Pestehligh Formation and underlies the olive shale of Khangiran Formation. The upper contact is marked by a coquina bed that is taken as base of the Khangiran Formation. In the upper part, the limestone contains echinoids, gastropods and large oysters. The Chehel-Kaman Formation is named after the Chehel-Kaman locality in the Sarakhs area, southeastern Kopet-Dagh. This name is used by the geologists of the National Iranian Oil Company (NIOC) (Afshar-Harb, 1969). The name has been used to designate a unit of dense or chalky, massively bedded, ridge-forming organodetrital limestone developed in the eastern Kopet-Dagh sedimentary basin. In some other localities (such as Gonbadli oil well no. 3) there are some layers of sandstone as well as gypsum beds. In the type area (Chehel-Kaman) the unit reaches a thickness of 250 m (Rivandi et al., 2013). Based on the fauna and flora (Afshar-Harb, 1969), the Chehel-Kaman Formation is assigned to Paleocene-Early Eocene (Stöcklin & Setudehnia, 1991; Aghanabati, 2004).

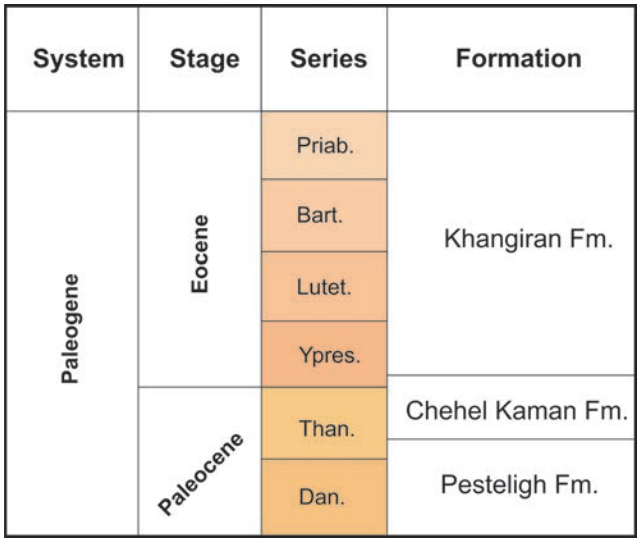

Fig. 2. *Paleogene stratigraphic chart of the Kopet-Dagh sedimentary basin (with minor changes from Aghanabati, 2004).*

The locality from which the samples containing the shark teeth were collected is named "Behkadeh stratigraphic section" and is located about 2.5 km northwest of the Behkadeh village. At the Behkadeh stratigraphic section, the Chehel-Kaman Formation is about 12 m thick. It is overlaid by the Quaternary deposits and underlaid unconformably in some areas by the Sanganeh and in some other areas by the Aitamir formations (Fig. 3). The Chehel-Kaman Formation starts with a light grey sandy limestone which is rich in bivalve remains and continues with medium to thick-bedded fossiliferous limestone accompanied by thick-bedded white to grey sandy limestone. For the purpose of understanding the exact biostratigraphic position of the strata, we collected limestone samples. Micropaleontological investigations led to the identification of the following foraminifera assemblages, with an age ranging from the late Paleocene to the early Eocene: *Globigerina centeralis, G. kugleri*, *Aragonella* sp. cf. *A. mexicanam*, *Morozovella crassuta*, *Nummulites* sp., *Assilina* sp., *Operculina* sp., *Kathina* sp., and *Sakesaria* sp. cf. *S. cotteri*.

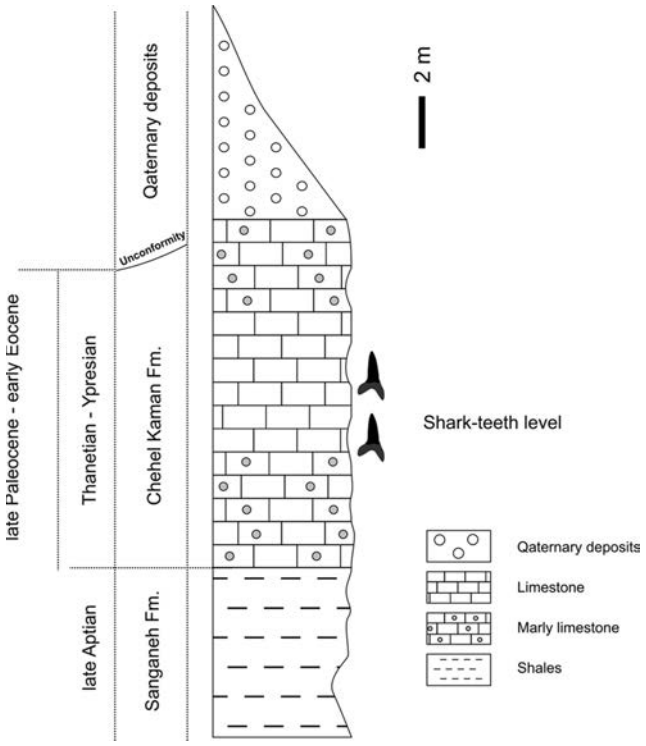

Fig. 3. *The stratigraphic column of the Chehel-Kaman Formation in the Behkadeh locality.*

Materials and methods

The material comprises 18 specimens, only eight of which could be determined systematically. All of the studied samples, hand-picked by the authors, are housed in the inventory system of the Geological Survey of Iran and Geosciences Research Center, NE Territory, Geoscience Museum of Mashhad (Jafar Taheri collection), with the GMM (Geoscience Museum of Mashhad) prefix, under the official depository numbers GMM97FTO246, GMM97FTO248, GMM97FTO252, GMM97FTO254, GMM97FTO261, GMM97FTO262 and GMM97FTO263. The pictures were taken by using a Canon EOS 80D and a tripod. For the systematics we follow Cappetta (2012) and Cappetta & Nolf (2005).

Systematic paleontology

Class: Chondrichthyes Huxley 1880
Subclass: Elasmobranchii Bonaparte 1838
Order: Lamniformes Berg 1958
Family: Mitsukurinidae Jordan 1898
Genus: *Striatolamia* Glikman 1964

***Striatolamia* sp.**
Fig. 4 (a–o)

Material. 17 teeth; Inventory numbers: anterior tooth GMM97FTO248 (a–c), GMM97FTO261 (d–e), GMM97FTO254 (f–h), upper laterals GMM97FTO263 (i–j), GMM97FTO262 (k–l), upper anterior GMM97FTO246 (m–o).

Origin. Chehel-Kaman Formation, Behkadeh village, North Khorasan province, Iran.

Description. The material includes both anterior and lateral teeth. Anterior main cusps are long, slender, with a convex lingual side and a flat or almost flat labial side. The main cusps representing lateral teeth are smaller, distally inclined and labio-lingually compressed. All the teeth have well marked cutting edges. Only one specimen (GMM97FTO246, Fig. 4, m–o) preserves the root and the lateral cusplets. Its main cusp is long and slender, with faint striations on the lingual crown face. The tooth preserves a partial root and the lateral cusplets. The cutting edge does not reach the base of the crown. The lateral cusplets are divergent, reduced and circular in cross-section view. The root is bilobate, the lobes meet in an acute angle, forming a strong lingual protuberance. The ends of the lobes are broken and we cannot observe if they are round or sharp.

Discussions. The described morphology of our specimens corresponds well with the descriptions of the *Striatolamia* genus (Cappetta, 2012, p. 189; Zhelezko & Kozlov, 1999, p. 128). Taking into consideration that our specimens come from a Paleocene-Eocene formation, we compared our specimens with the three valid species of *Striatolamia* from this interval, *S. cederstroemi*, *S. striata* and *S. macrota.* We found that *Striatolamia macrota* can be easily distinguished from the Paleocene species *S. cederstroemi* by the different morphology of the lateral cusplets. In *S. cederstroemi* these lateral cusplets are flat, labio-lingually compressed even in the anterior teeth while in *S. macrota* are cone like, low and pointed (Siverson, 1995, p. 9). The distinction between *S. macrota* and *S. striata* is more difficult to

make. The description of *S. striata* (Cappetta, 1987, p. 88; Herman, 1977, p. 239) indicates that the striations on the lingual face are in general more pronounced than in *S. macrota* and the lateral denticles of the anterior teeth are barely perceptible. The size is also indicated as a differentiating characteristic (Herman, 1977; Nolf, 1988), but without a certain threshold. It is likely that *S. striata* evolved into *S. macrota* increasing in size and reducing the striations of the main cusp's lingual face. Considering the very small differences between *S. macrota* and *S. striata* and the large time interval included in the Chehel-Kaman Formation we assign our specimens only to the genus level.

Family: Odontaspididae Muller & Henle, 1839
Genus: *Jaekelotodus* Menner, 1928

***Jaekelotodus* sp.**
Fig. 4 (p–s)

Material. 1, ?lower, anterior tooth; Inventory number: GMM97FTO252 (p–s)

Origin. Chehel-Kaman Formation, Behkadeh village, North Khorasan province, Iran.

Description: The tooth is incomplete, with the apex of the main crown missing and only one half of the root and one lateral cusplet preserved. The crown of the tooth is convex on the lingual side and flat on the labial side with a well marked basal depression. Both crown faces are completely smooth. The cutting edge reaches the base of the crown and the base of the lateral cusplet. In lateral view we can notice that the main cusp is arched lingually. The only preserved cusplet is sharp, convergent and strongly bent lingually. The preserved root lobe is moderately long, has a rounded end and meets with the rest of the other lobe in an acute angle. The central furrow cannot be observed due to the hardened sediment still present on the tooth.

Discussions. For the identification we considered the analysis of several genera belonging to the family Odontaspididae. These genera were reported from the Thanetian-Ypresian interval and have a similar general morphology. From the beginning we excluded some of them based on the characteristic defined by the extension of the cutting edge along the crown of the tooth. Thus we excluded the *Carcharias* and *Odontaspis* genera in which the cutting edge does not reach the base of the crown in the anterior teeth (Cappetta & Nolf, 2005). We also excluded the *Glueckmanotodus* genus where the cutting edge reaches the base of the crown but the cusp has a torsion on the vertical axes. The lobes of the root are sharply pointed in *Glueckmanotodus* (Zhelezko & Kozlov, 1999, p. 114; Cappetta & Nolf, 2005, p. 243), differing from our specimen. The *Brachycarcharias* genus was also excluded. This genus has short folds of the enamel on the lingual face and the lateral cusplet is aligned with the cutting edge of the crown (Cappetta & Nolf, 2005, p. 241), both characteristics missing in our case. A distinction can also be made in regards to the *Hypotodus* genus, which has a labial base of the crown slightly convex in the contact region with the root (Cappetta & Nolf, 2005, p. 244), sometimes with a small short basal median ridge (Carlsen & Cuny, 2014, p. 57).

The described morphology of our specimen corresponds with the descriptions and illustrations of the various species in the *Jaekelotodus* genus (Cappetta, 2012, p. 199; Eckhaut & De Schutter, 2009, p. 45).

Results and discussion

Both genera figured and described here are very common around the world and have a similar stratigraphic distribution. *Striatolamia* can be found from the Lower Paleocene (Müller, 1992; Dutheil, 1992) up to the Priabonian (Cappetta, 2012) while *Jaekelotodus* was described from the Danian to Priabonian (Cappetta, 2012). Taking into account the paleogeography of the lower part of the Eocene (Fig. 1), we consider that the Behkadeh area still has potential for other taxa finds. The lower Eocene rich fauna of the close-by Caspian Sea area is well known to researchers (Glikman, 1964; King et al., 2013), so we expect that future studies will improve the fauna list.

The white colour of some of the specimens indicates that the teeth were exposed to sunlight and acidic environment (acid precipitations or acids of the soil) for a long time. Considering that the mate-

Fig. 4. *Striatolamia sp. - GMM97FTO248 (a-c); GMM97FTO261 (d-e); GMM97FTO254 (f-h); GMM97FTO263 (i-j); GMM97FTO262 (k-l); GMM97FTO246 (m-o); Jaekelotodus sp. - GMM97FTO252 (p-s). The white triangles indicate the extent of the cutting edge along the side of the main cusp.*

rial comes from surface finds, from a taphonomic point of view we cannot make too many comments, the fragmentation of the teeth could be entirely the result of recent processes.

This is the first report of shark teeth in this area of this sedimentary basin situated on the northern border of the Tethyan realm, northeast of Iran (Fig. 5). Both genera were found in varied ecologic conditions starting from shallow marine environments (Eckhaut & De Schutter, 2009) to moderately deep waters (Trif et al., 2010) and deep, open waters (Carlsen & Cuny, 2004; Rayner et al., 2009). Such data brings additional knowledge for future paleoenvironmental reconstructions of the Chehel-Kaman Formation.

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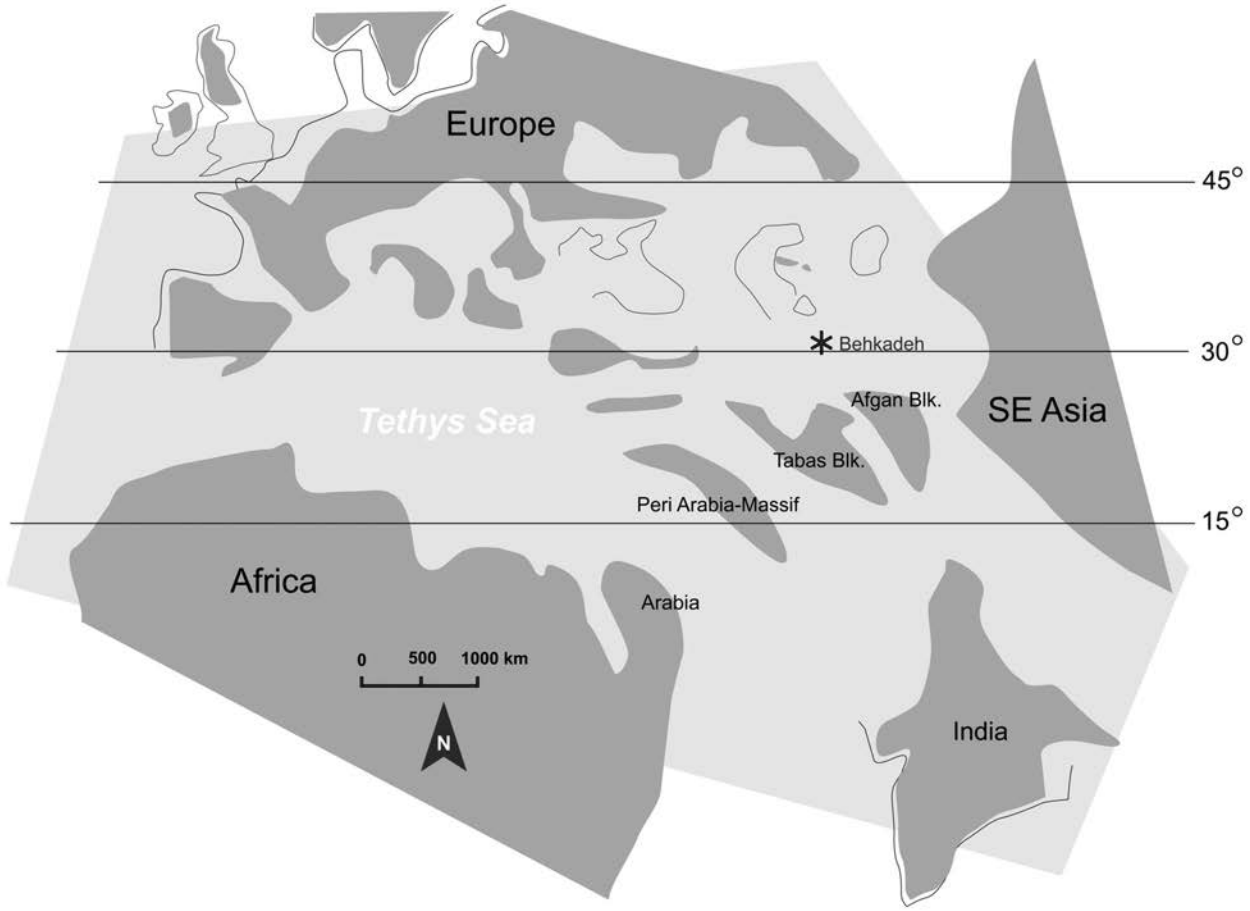

***Fig. 5**. Schematic Tethys palaeogeography in Ypresian (compiled after Barrier & Vrielynck, 2008 and Scotese, 2014, modified and simplified). The star marks the approximate place of the collecting locality.*

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Резиме

Кратка белешка о првом запису зуба фосилних ајкула у формацији Chehel-Kaman, Иран

Палеогена формација Chehel-Kaman у Kopet-Dagh басену је углавном изграђена од кречњака, доломита и прослојака лапораца, глинаца и евапорита. Назив је добила по истоименом локалитету у ЈИ делу Kopet-Dagh басена. Конкордантно належе преко силицикластичне Pestehligh формације, а покривена је са маслинастим глинцима Khangiran формације. У вишим нивоима формације кречњаци садрже ехиниде, гастроподе и крупне остреје. Укупна дебљина формације је 250 m и хронострстиграфски одговара палеоцену/доњем еоцену.

Зуби ајкула су пронађени на локалитету Behkadeh који се налази 2,5 km северозападно од истоименог села. На овом локалитету Chehel-Kaman формација има дебљину од 12 m, а преко ње належу квартарне наслаге. Изграђена је од светлосивих песковитих кречњака који садрже доста остатака бивалвија и горњопалеоценских-доњоеоценских фораминифера: *Globigerina centeralis, G. kugleri*, *Aragonella* sp. cf. *A. mexicanam*, *Morozovella crassuta*, *Nummulites* sp., *Assilina* sp., *Operculina* sp., *Kathina* sp. и *Sakesaria* sp. cf. *S. cotteri.*

У овим слојевима су пронађени фосилни зуби ајкула који одговарају родовима *Striatolamia* и *Jaekelotodus.* Оба рода су честа и имају слично стратиграфско распрострањење које одговара палеоцену/еоцену. Укупно је сакупљено 18 примерака зуба, од којих 17 припада роду *Striatolamia,* а један роду *Jaekelotodus*.

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