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First report of the SardinellaSardinites (Heckel, 1850) in the Kond formation in the Saran area, Central Alborz in Iran

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Abstract
Investigating the fossil-bearing horizons of the Kond Formation in the Saran area resulted in the identification of Sardinellasardinites (Heckel 1850) belonging to the family of Clupeidae Bonaparte (1831) for the first time the east of Tehran province. Furthermore, biostratigraphic analyses based on the presence of benthic and planktonic foraminifera in this area demonstrate that the sedimentary sequence including strata of conglomerate, tuff, shale, gypsum, limestone, and marl with a thickness of 376 m in the Saran area belongs to the Priabonian, which is discontinuously located on Middle Eocene green tuffaceousshales. In the present study, 18 species belonging to 9 genera from the benthic foraminifera were identified. In the late Middle Eocene, the performance of the orogenic Pyrenean phase led to the rising of the sedimentary strata and subsequent retreat of the sea and then the sea re-advanced during the Priabonian stage. The presence of a conglomerate at the base of the formation reveals the next activity of the tectonic phase. In this study, the rock unit of the Lower Red Formation belonging to the Oligo-Miocene is located on the deposits of the Kond Formation.
Keywords: *Alborz, Kond Formation, Eocene, Fish-bearing horizon, Tethys.*

1. Introduction
In the Paleogene, a very thick sequence of marine deposits is observed in the southern part of the Alborz Mountain range. It should be noted that Paleocene rocks are more common conglomerate and sandstone deposits that are sometimes found associated along with lava and gradually reach the Lower Eocene shallow-marine Nummulitic limestone. In the Middle Eocene, a remarkable amount of tuff and green tuff (approximately 3000 meters) was deposited in the southern Alborz subsidence, which finally reaches the shallow and evaporative sediments of the Upper Eocene. Here, relatively thin layers of conglomerate with disconformity were put on the sediments of the Karaj Formation (Darvishzadeh 2003). Then, tectonic shifts associated with the orogenic Pyrenean phase took place in the late Eocene, so that it resulted in the extensive emergence of southern Alborz and Oligocene depositional sequences are not found (Motiei 2003).The first study on bony fish of the Paleogene in Iran in Ilam was carried out by Arambourg (1967). Then Haghipour and Brantz (1971) investigated the fish layers of northern Ilam. Adent et al. (2009), Ghasemi-Nejad and Hosseinzadeh (2001) also surveyed the fish-bearing horizons of those areas. Afsari et al. (2014) reported a new species of Hatchetfish (Teleostei: Stomiiformes: Sternoptychidae) from the Ilam area. Also, in the central Alborz region, the Kond Formation has an outcrop in the Saran area (Borna et al. 2013). Saran Mountain is considered as a wide area of the Alborz syncline in the eastern part of Tehran, where fish fossils have initially been identified in the fossil-bearing layers. Therefore, this study was conducted to investigate biostratigraphy and determine the precise geological age, and also introduce the fossil bed in this area.

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2. Research area
2. 1. Geological setting
The studied section is located in the structural zone of Central Alborz and in the east of Tehran province (Fig 1). The geographical coordinates of the studied area are longitude E 35◦ 30′ and latitude N 52◦10′ (1: 250,000 geological sheet of Tehran). Here, there are sedimentary layers having 376 m thickness with an east-west trend and a slope of 40 degrees toward the north (Figs. 2 and 3).

3. Materials and methods
To survey the fossil-bearing horizons of the Kond Formation in the Saran area, from the thick 376 m, sampling was accomplished with an average distance of 1 meter (376 samples). Moreover, the location of fossil fish-bearing horizons was identified and their precise location relative to the other layers was documented. In this research, the layers of interest were explored using special tools designed to extract fish fossils from the layers. For disaggregating hard samples in the laboratory, the acetic acid solution was used. Samples obtained were washed. In this study, 6 fish fossils with specific codes were found (99-KN-5, 99-KN-10, 99-KN-12, 99-KN-13, 99-KN-16, 99-KN-22) (Figs. 5 and 7).
The samples were collected in certain pre-numbered bags. Several samples were also taken to study the

foraminifera and then were examined after preparing thin sections by utilizing polarized light microscopy.

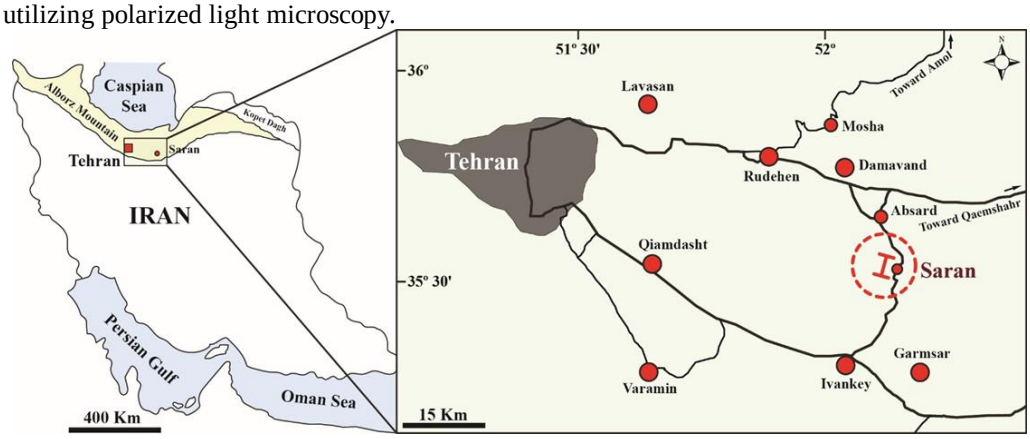

Fig 1. Location of the Saran section in eastern Tehran.

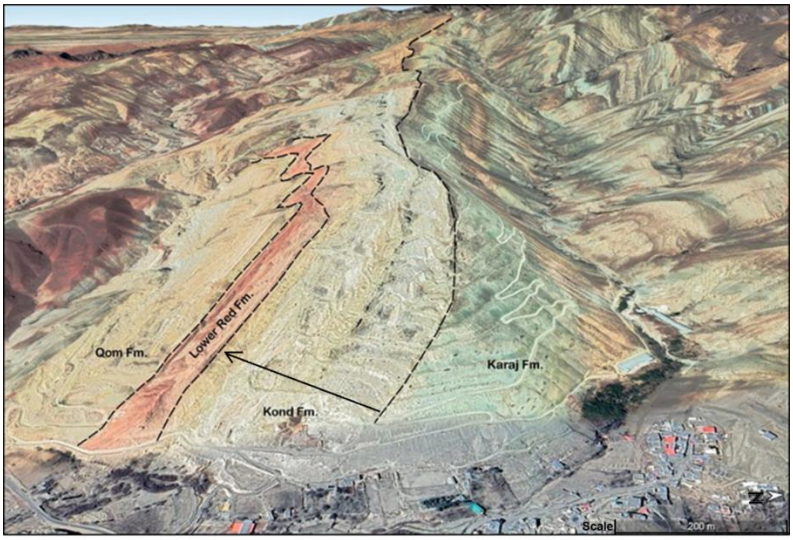

Fig 2. The sedimentary sequence of different formations according to Google Earth in the Saran area, east of Tehran (north is the right side of the figure). Scale is 200 meters.

The specimens described in this paper are housed in the Palaeontology Laboratory. Collected data on the skeletons was gathered from the primary literature, mainly from the studies by Grande (1985),Cailliet et al. (1986), Eschmeyer (2013),and Paknejad et al. (2014).

4. Results and Discussion

4. 1. Lithostratigraphy and biostratigraphy (Indications for paleoecology research)

Paleogeography and paleoecology investigations are very important in any study. With the investigations carried out, in the Saran section located in the Alborz range, the progression of the Late Eocene Sea (Priabonian stage) with conglomerate and sandstone on the layers of the Karaj Formation with a disconformity started (Allah Madadi and Partoazar 2005; GhasemShirazi et al. 2014-a). Between those strata, there are layers of tuff and tuffaceous shale and a layer of the basal conglomerate. In this region, on the basal conglomerate, layers of tuffaceous marl with Nummulites are observed. These deposits imply that the sea in the Saran area has been deep at that time. In the section of interest, thick layers of evaporative rocks (gypsum) were gradually placed on the marl and shale layers, which were thicker. Here, thin layers of tuff, shale, limestone, and gypsum are still recognized between the gypsum layers of the Saran section. The presence of gypsum in the Saran section confirms less depth and higher heat intensity. In the studied section, the presence of the layers of marl, gypsum, and some salt rock indicate the presence of an evaporation basin (Sabkha). In this region, on the last Late Eocene deposits (Priabonian), there are layers of red silty shale along with gypsum as an unconformity. Based on the observed Nummulites and Alveolina species, the Kond Formation emerged in Upper Eocene (Priabonian). Therefore, it seems that the gradual subsidence of the basin floor and the reduction of submarine eruptions

began in the Middle Eocene, and the limestone facies were replaced by sandstone and gypsum of the Kond Formation in the Upper Eocene, which indicates the retreat of the sea, and establishment of lagoons in the sedimentary environment of that time. Moreover, the presence of tuff layers and extreme changes in marine facies as well as the high thickness of gypsum layers demonstrate the continuation of tectonic activity in this region. Eventually, the gypsum layers of this sedimentary basin (Late Eocene) have been created by red sediments with disconformity through the activity of the alpine orogenic phase (Pyrenees) (James and Wind 1965). Eocene Fish-bearing sedimentary layers are found in marly limestone of formations such as the Pabdeh Formation in different regions of Iran including Zagros (Koohrang region), Ilam and Fars (Fadaeifard et al. 2012, MasuodSoheilfarid et al. 2014; GhasemShirazi et al. 2014-b;Jehangir Khan et al. 2021).

The Priabonian is of great importance in the geological history of Iran, in terms of Stratigraphy and Paleogeography. The performance of the orogenic Pyrenean phase at this time is the primary factor giving rise to change and diversity of sedimentary environment in different parts of Iran, the effects of which are disruptions in the sedimentation process, sedimentation interruption and sometimes the occurrence of magmatic phases (Aghanabati 2006). In this regard, the deposits of the Saran section were examined from a lithological point of view. These deposits are composed of evaporitic rocks that are divided from bottom to top according to lithological characteristics into five sedimentary units, among which are 6 thin layers with fish fossils. The units are as follows (Figs. 3 and 4).

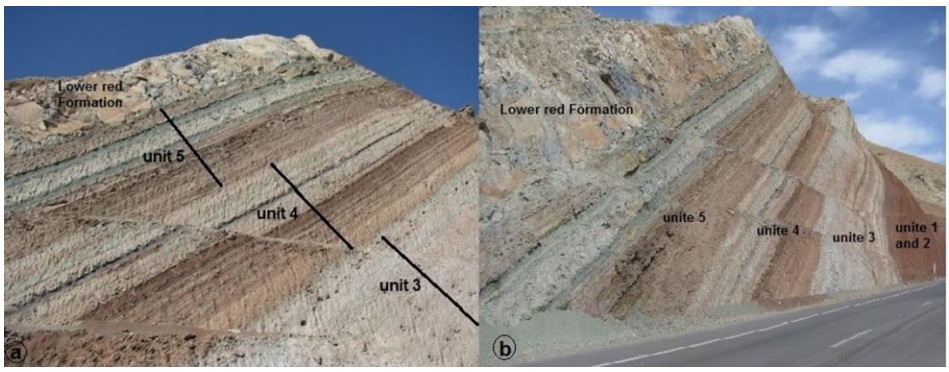

Fig 3. a) The sedimentary units of the Kond Formation according to lithological characteristics in the Saran area, east of Tehran. Here, units 3, 4 and 5 have fish fossils. b) You can see the all of units completely.

4. 1. 1.Unit 1 (4 m). This unit is composed of conglomerate, sandstone, and shale, and is located on the green tuffaceousshales of Karaj Formation with a disconformity (the presence of iron oxide). This rock unit has bioclasticmicrofacies and consists of the following microfossils (Fig 6).

*Nummulites*cf.*striatus, Operculina*sp., *Discocyclina*sp., *Rotalia*sp., *Globigerina* sp., *Radiolaria,* Bryozoa.

4. 1. 2.Unit 2 (22 m). This unit includes a sequence of conglomerate associated with tuffaceousshales and contains Nummulites. This unit is composed of bioclasticmicrofacies and its fossils are as follows (Figs. 5 and 6):

*Nummulitesstriatus, Nummulitesincrassatus, Nummulites*sp., *Operculina*sp., *Discocyclina*sp., *Cibicides*sp., *Valvulina*sp., *Elphidium*sp., *Asterigerina*sp., *Amphisteginа*sp., *Rotalia*sp., *Globorotalia*aff.*cerroazulensis, Globigerina* sp., *Globigerina yeguaensis,* Miliolids, Echinoidspine.

4. 1. 3.Unit 3 (94 m). This unit contains thick cream to green tuffaceous marls, with a primary appearance and contains oyster, pectin, and bivalve fossils along with fish fossils (99-KN-5, 99-KN-10, 99-KN-12, 99-KN-13). In the upper part of this unit, thin layers of limestone can be recognized. The base part has bioclastic and glauconitic microfacies and its fossils common include are as follows (Figs. 5, 6 and 7):

*Nummulites*sp., *Asterigerinarotula, Rotalia*sp., *Discocyclina*sp., *Operculina*sp., Globigerinid, Radiolaria, Echinoidspine.

The upper part of this unit consisted of clastic and glauconitic microfacies and it has no fossils.

4. 1. 4.Unit 4(167 m). This unit is composed of thick white anhydrite with several thin layers of tuff, shale and, limestone. Its appearance is prominent and bulk-like. In the microscopic examinations conducted on the samples of this unit, it has marly limestone microfacies and anhydrite (Sabkha) and has no fossils. This unit is made of bioclasticmicrofacies in the calcareous part and micrite in another part. Its fossils as followed by the fish fossils (99-KN-16) are rare (Fig 6):

*Nummulitesstriatus, Nummulites*cf. *fabiani, Nummulites*cf. *globolus, Nummulites*sp., *Discocyclina*sp., *Operculina*sp., Miliolids, Bryozoa, Echinoidspine.

4. 1. 5.Unit 5 (87 m). This unit contains anhydrite with interlayers of shale and tuff and some salt. Its appearance is cream in color. This unit has anhydrite microfacies and

is almost rare regarding the presence of fossils (fish fossils: 99-KN-22).

This unit is covered with red silt and anhydrite shales. Taking into account the stratigraphic position of this unit means the presence of red layers to the age of Rupelian upward and on it, its age can be attributed to date back to the Priabonian.In fact,the upper layers in this sedimentary basin (Late Eocene) are covered with red sediments (Lower Red Formation) of the Alpine (Pyrenean) orogenic phase disconformable.

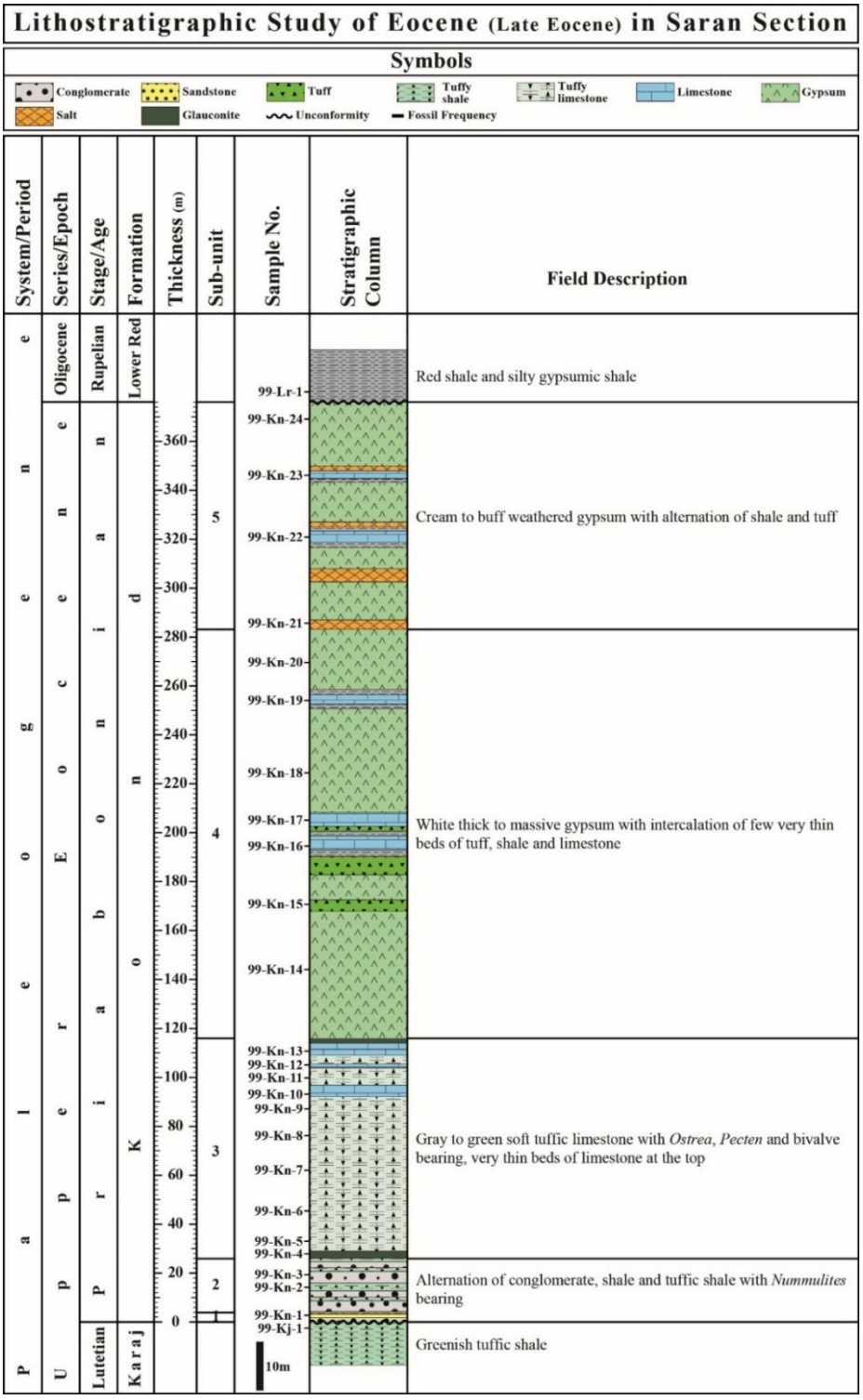

Fig 4. Lithological characterizes of the Kond Formation in Saran section (upper Eocene-Oligocene).

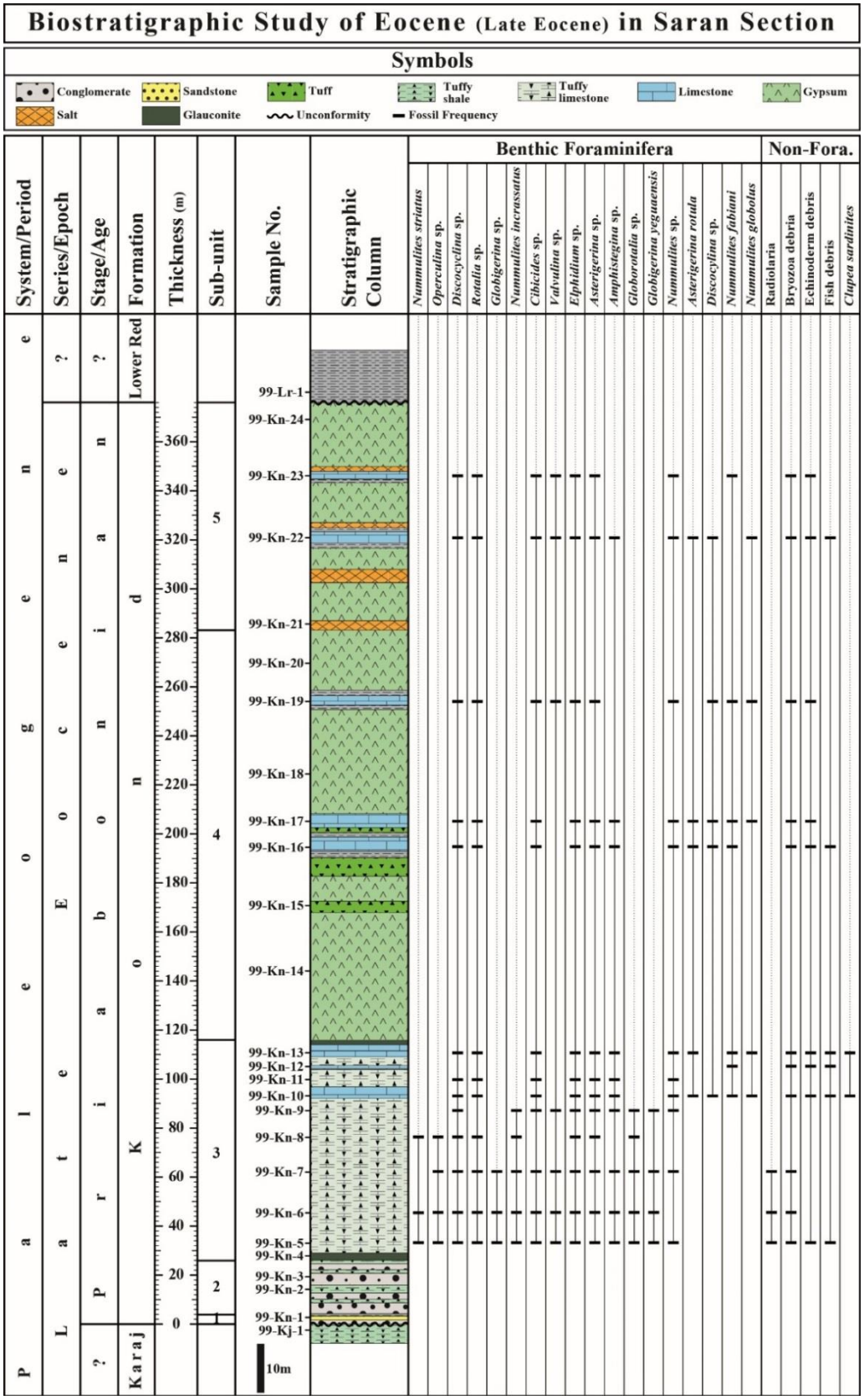

Fig 5. Lithostratigraphical and biostratigraphical characterizes of the Kond Formation in Saran area, central Alborz, east of Tehran (upper Eocene-Oligocene)

Fig 6. a) Echinoid, b) Bryozoa debris, c) Echinoderm debris, d) *Rotalia* sp., e) *Asterigerinarotula* (Kaufmann 1867) and *Rotalia* sp., f) *Operculinacomplanata* (Defrance in Blainville 1822) and Ostrea, g) *Asterigerinarotula* (Kaufmann 1867), h) *Rotaliaviennoti* (Greig 1935), i) *Nummulitesglobolus* (Leymerie 1846), j) *Nummulitesstriatus* (Bruguière 1792), k) *Nummulitesfabiani* (Prever in Fabiani 1905), l) *Nummulites* sp., m) *Rotalia* sp., and skeletal debris, n) *Discocyclina* test, Bryozoa debris, o) *Nummulitesglobulus*(Leymerie 1846).

5. Systematic Palaeontology

Bonefish (Teleostei) are taken into account as the predominant group of Actinopterygii fish with internal skeleton (Lavoué et al. 2007;Di Dário 2009). These fish has been found there from the Triassic to the present age (Romano et al. 2012). In general, the studied samples systematically belong to the following hierarchy. In the present study, we aimed to investigate the discovered fish meticulously and determine the age of the studied horizon.

Infra Class: Teleostei
Class: Actinopterygii Klein (1885)
Super Order: Clupeomorpha
Order: ClupeiformesBleeker (1859)
Family: Clupeidae Bonaparte (1831)
Genus: *Sardinella*Valenciennes (1847)
*Sardinellasardinites*Heckel (1850)
Fig 7a-c

Description: The length of this fish is 5 cm and its tail is 2 to 3 cm and the whole body is long and thin in terms of morphology. The trunk of the fish is spindle-shaped, with an oval in the cross-section and abdominal column. The caudal fin is deeply incised, V-shaped and symmetrical, and the upper fins are short. The pelvic fins of the fish start from the center of the fish body. The thoracic vertebrae are relatively short and the midline of the thoracic vertebrae is not very thinand slim. The caudal vertebra and the tail bones are relatively short. Furthermore, the middle area of the tailbone is not regarded as too thin (Fig 7a, b). As it is clear, teleost fish are fish with internal skeletons. The eyes are large and the bones in the skull are not particularly prominent in the eye area. Moreover, the structure of the skull is unclear due to the thinner bones. There are changes in the jaws of bony fish which make the outward movement of the jaw possible. So the lower jawbones are shorter than the upper ones (Fig 7c). Another characteristic of their classification, evolved spine is perceived as another characteristic, which in the body reaches up to 60 vertebral.

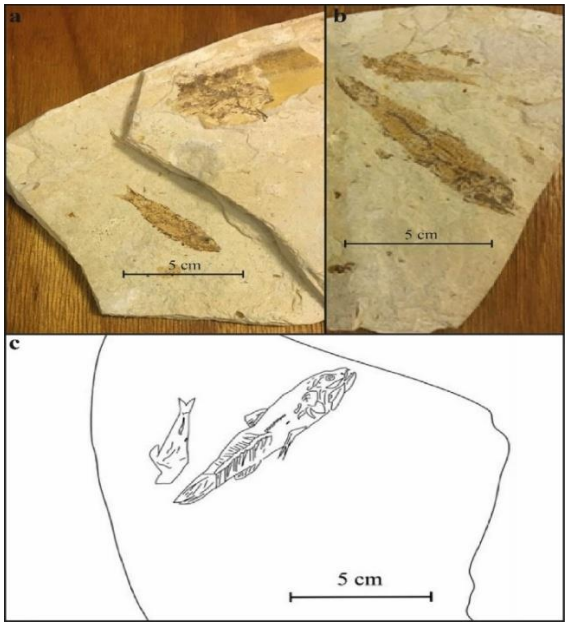

Fig 7.*Sardinellasardinites* (Heckel 1850),from the Kond Formation in Saran section (The actual scale is 5 cm.).

This fish lives in rivers, streams, lakes, and open waters (Nelson 1994). The geological age of these bonyfish was estimated from Eocene to Pleistocene (Nelson et al. 2016). The bonefish fauna is usually found in Eocene deposits in most parts of the world including Iran, Italy, and the United States. Arambourg (1967) described 23 bonyfish species (Teleostei) in Ilam and also suggested proposed that the formation of the fish-bearing layer dates back to the Middle Oligocene (Afsariet al. 2014).Bahrami-Samani and Aryaee (2002) introduced several species of teleost fish in the Shahre-Kord area. Walker and Ward (1992) discovered bony fish in Italy. In the United States, bony fish-like fauna has also been found (Nuddes and Selden 2008).

All of the mentioned above, demonstrate the environmental similarity of the Eocene fossil-bearing horizons in Iran and other parts worldwide. In the studied section, this fish is reported for the first time in Kond Formation in Saran area in the Alborz area. In order to determine the exact age of the fish-bearing horizon from the marl layers of Unit 3, several samples were also taken to study foraminifera. Therefore, considering the age range of planktonic foraminifera (Permoli Silva et al. 2003) the age of Priabonian from the Eocene was confirmed.

6. Conclusions

Kuh-e Saran is a part of the south of Alborz Geosyncline in the eastern area of Tehran. Stratigraphy and biostratigraphy studies performed on the Saran section show that the tectonic movements of the Pyrenean orogenic phase with weaker performance were performed in the late Middle Eocene and early Late Eocene. As the thin layers of conglomerate with disconformity are located on the deposits of Karaj Formation. The presence of tuffaceous layers and intense changes in marine facies and the large thickness of gypsum layers indicate the continuation of tectonic activity in this area. The upper layers of gypsum in this sedimentary basin (Late Eocene) are covered with red sediments (Lower Red Formation) of the Alpine (Pyrenean) orogenic phase disconformable. In the present study, 18 species belonging to 9 genera from the benthic foraminifera and 6 fish fossils with specific codes were identified. The presence of Teleost fish alongside planktonic foraminifera and benthic foraminifera in marine basins reveals the fact that this marine basin existed in the area during the Eocene. Furthermore, the morphological similarities of the studied group with similar fauna in Italy and the United States indicate the paleoecological and paleogeographic relationship of these regions.

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