Moncharmontia De Castro 1967, benthic foraminifera from the middle–upper Cenomanian of the Sarvak Formation of SW Iran (Zagros Zone): a CTB survivor taxon

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ABSTRACT: *Moncharmontia apenninca* (De Castro 1966) is widely reported in the Upper Cretaceous (Turonian-Campanian) shallow-water successions of the Neotethyan realm (e.g., Italy, Croatia). With its "First Appearance Datum" (FAD) in the lowermost Turonian, it is considered a newcomer taxon in the aftermath of the Cenomanian/Turonian boundary (CTB) extinction event, and therefore a member of the Upper Cretaceous Global Community Maturation Cycle. Its common presence in the middle–pro parte upper Cenomanian Sarvak Formation and time-equivalent strata in Mexico (Valles-San Luis Potosí Platform) document that it represents a CTB extinction survivor taxon like *Dicyclina, Nezzazata, Reticulinella* and several others. The different local "FAD's" of *Moncharmontia* might possibly be linked to latitudinal differences, i.e., an earlier evolution of the species in the near-equatorial area (Mexico, Iran) compared to the low-middle latitudinal occurrences in the peri-Mediterranean realm (e.g., Italy, Turkey).

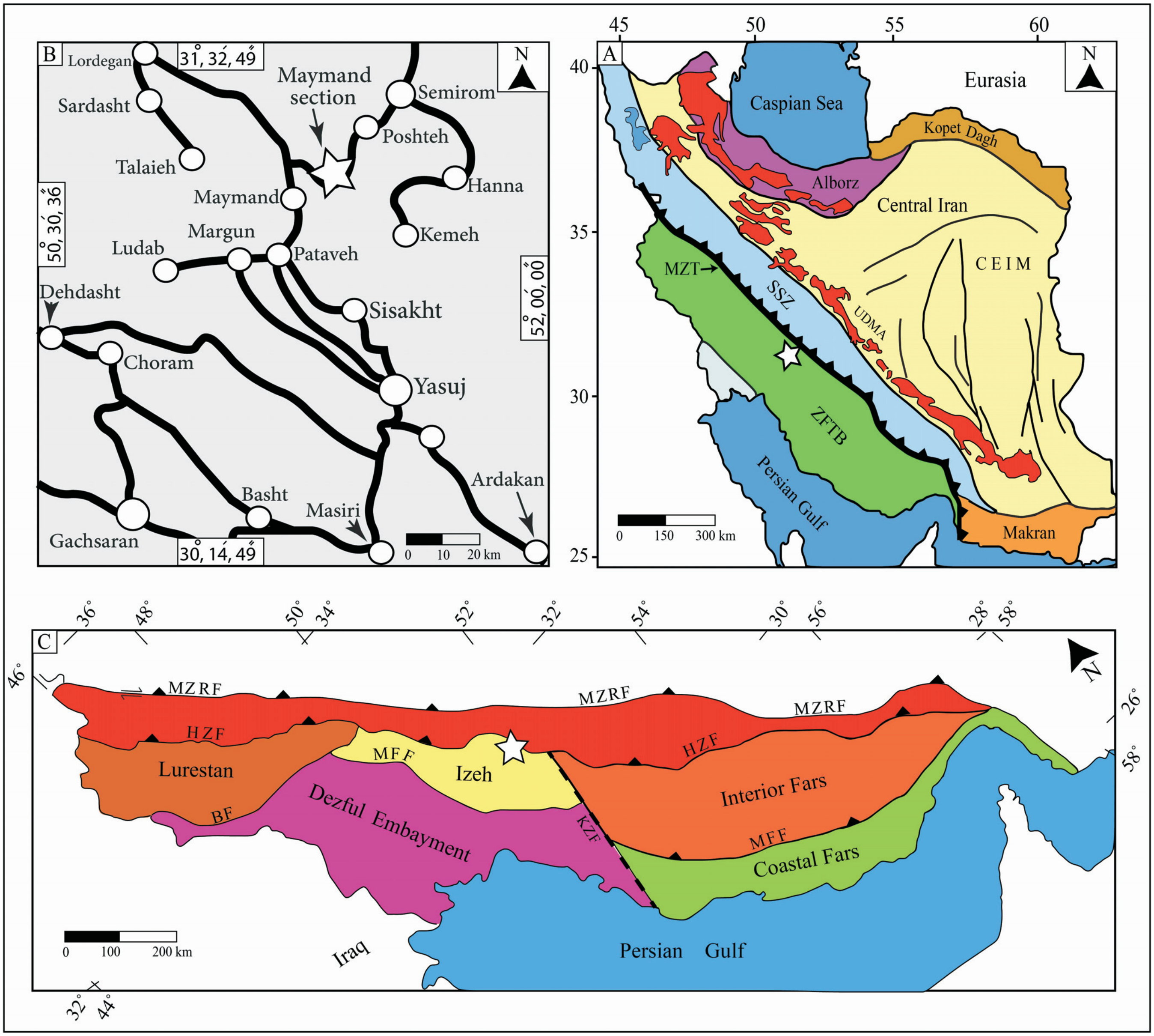
Keywords: Foraminifera, Systematics, Palaeobiogeoraphy, Upper Cretaceous, Cenomanian, Iran

INTRODUCTION

The Sarvak Formation of southwestern Iran represents a thick and predominantly carbonate unit of shallow-water facies rich in smaller and larger benthic foraminifera (LBF) (Sampó 1969; Ahmadi et al. 2008, 2017; Afghah and Dookh 2014; Afghah et al. 2014; Omidvar et al. 2014; Afghah and Fadaei 2015; Consorti et al. 2015; Assadi et al. 2016; Rikhtegarzadeh et al. 2017; Yazdi-Moghadam and Schlagintweit 2020; Schlagintweit and Yazdi-Moghadam 2020a). Besides Orbitolinidae, the assemblages include nezzazatids, cuneolinids, chrysalidinids, alveolinids, praerhapydioninae, and others. A large scale extinction event around the Cenomanian/Turonian boundary (CTB) affected almost all of these carbonate-platform thriving LBF (Calonge et al. 2002; Hart et al. 2005; Shahin and Elbaz 2013; Frijia et al. 2015; Consorti et al. 2015; 2016; Bomou et al. 2019) in a two-step pattern of disappearance (Parente et al. 2008; Caus et al. 2009; Arnaud-Vanneau et al. 2017; Solak et al. 2020). This extinction event linked to eutrophication is recognized worldwide in Cenomanian shallow-water carbonate platforms, from Mexico (Bomou et al., 2019), Spain (Caus et al. 2009), Italy (Parente et al. 2008), Egypt (Shahin and Elbaz 2013), Turkey (Solak et al. 2020), Syria (Ghanem and Kuss 2013), and Iran (Yazdi-Moghadam and Schlagintweit 2020). Recent investigations of the Cenomanian Sarvak Formation yielded the occurrence of new Orbitolinidae (Yazdi-Moghadam and Schlagintweit 2020; Schlagintweit and Yazdi-Moghadam 2020b). The thin-sections also contain common specimens of *Moncharmontia apenninica* (De Castro), the type-species of the genus. This observation is rather unexpected, since *M. apenninica* is consistently said to represent a Turonian newcomer species that originated in the aftermath of the CTB extinction event (De Castro 1966; Moro and Jelaska 1994; Koch et al. 1998; Chiocchini 2012; Frijia et al. 2015; Arriaga 2016; Arriaga et al. 2016; Solak et al. 2020). The new data from Iran along with some general considerations on the CTB are presented and discussed in the present contribution.

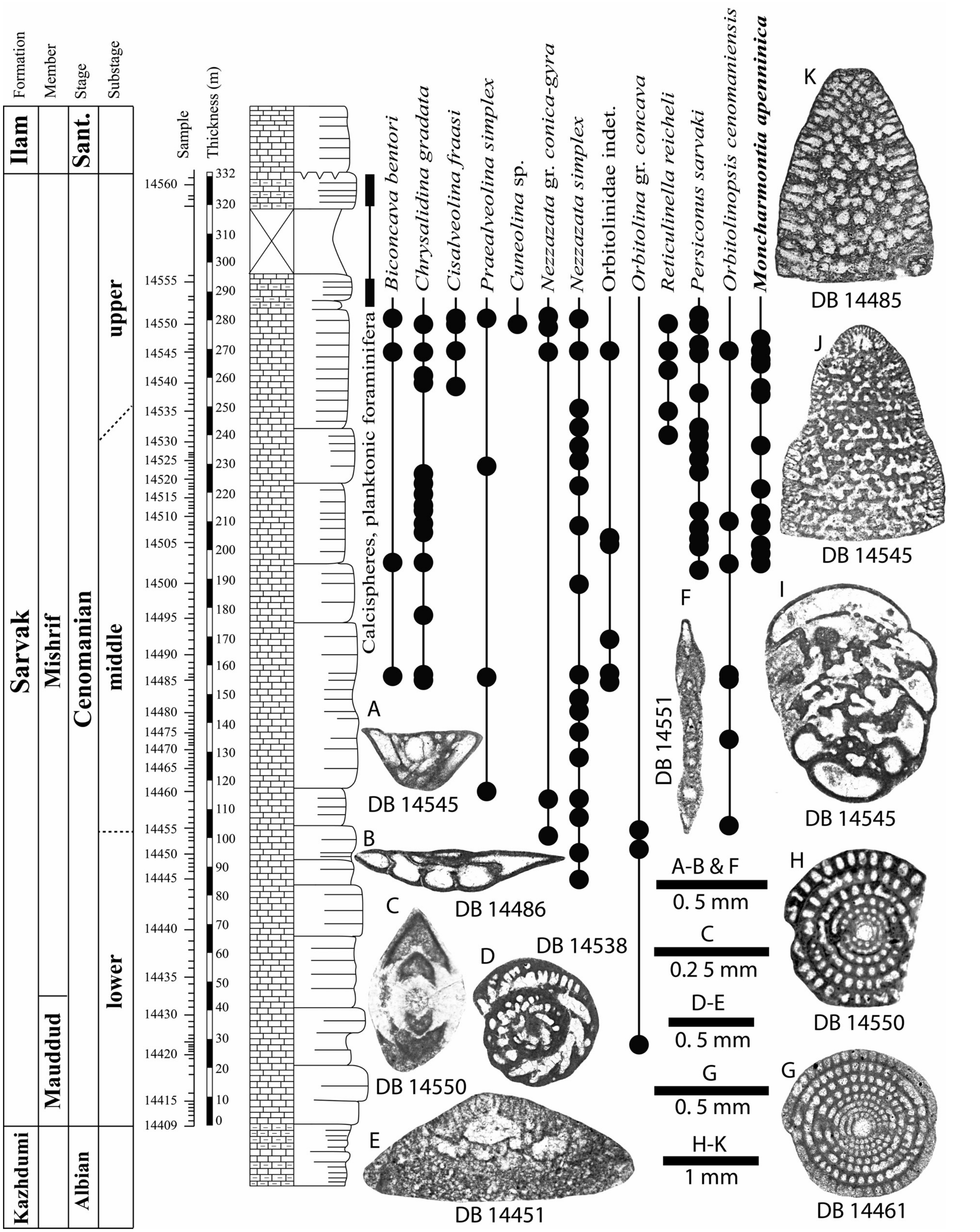
GEOLOGICAL SETTING

As a part of the Alpine-Himalayan system, the Zagros fold and thrust belt of SW Iran formed along the Arabian-Eurasian collision zone following the closure of the Neotethys ocean (Berberian and King 1981; Golonka 2004). It extends from the NW Iranian border to SE Iran, up to the Strait of Hormoz (Heidari et al. 2003) (text-fig. 1A). The Zagros belt can be subdivided into several tectono-stratigraphic units based on their structural style and sedimentary history, including Fars Province (Interior Fars and Coastal Fars), Dezful Embayment, Izeh Zone, High Zagros, and Lurestan Province (e.g., Falcon 1974; Motiei 1993, Sherkati and Letouzey 2004; Sherkati et al. 2006; Heydari 2008; Farzipour-Sain et al. 2009). The structural map is characterized by the main NW–SE trend of the Zagros thrust belt, within which two major thrusts can be distinguished, the Mountain Front Fault and the High Zagros Fault. The NW–SE trending Zagros Mountains in Iran formed owing to the Late Cretaceous compressive phases that in turn controlled the overall sedimentation on the Arabian Plate (James and Wynd 1965; Motiei 1993; Sherkati and Letouzey 2004; van Buchem et al. 2010; Dill et al. 2019). The investigated area is located in the northeast of Izeh Zone, close to the High Zagros boundary (text-figs. 1B, C). The material of this study comes from one outcrop of the Sarvak Formation, here named the Maymand section. It is located south of the Semirom town, approximately 12 km northeast of Maymand village. Structurally, the outcrop is situated in the northern part of the Izeh Zone, close to the boundary with the High Zagros. The 332-m-thick Sarvak Formation in this area rests conformably on thin-bedded argilla-

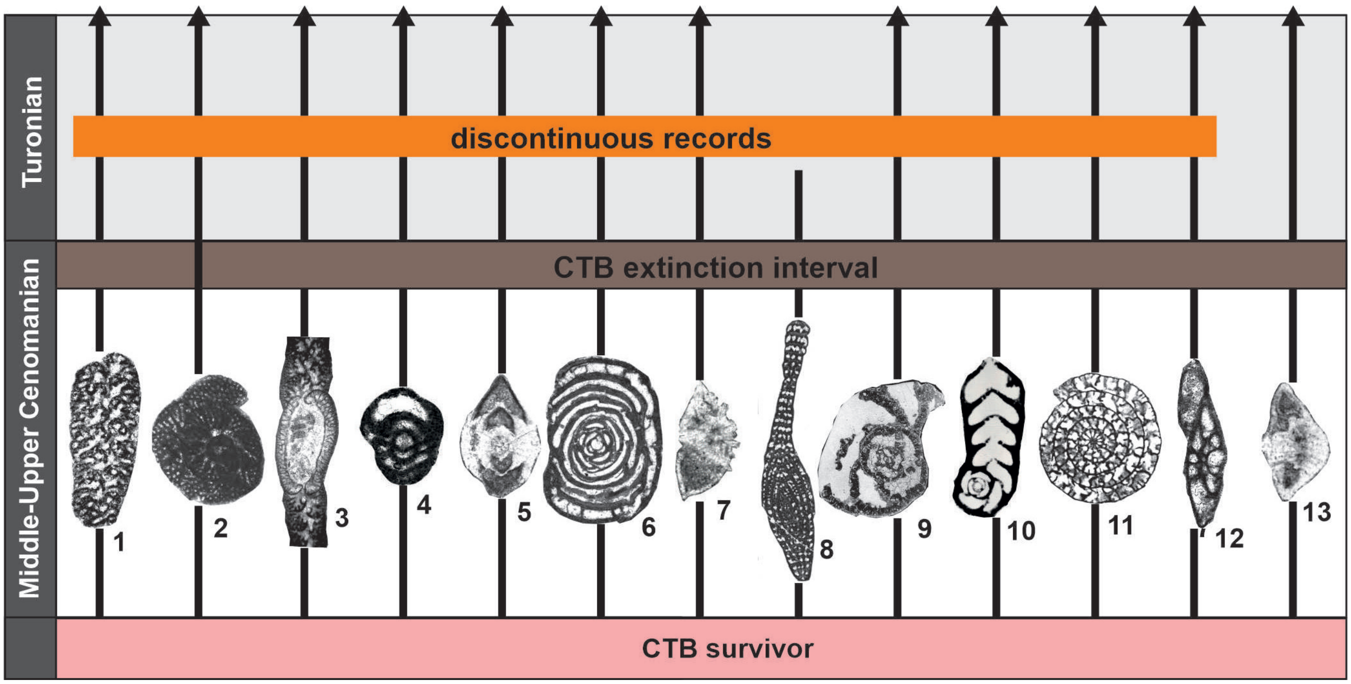


TEXT-FIGURE 1
A) Simplified geological map of Iran (modified after Agard et al. 2011) showing the main tectonic subdivisions. B) Road map of the study area. C) Tectono-stratigraphic units of the Zagros belt (modified after Farzipour-Sain et al. 2009). The position of the Maymand section is marked by an asterisk. BF: Balarud Fault, CEIM: Central East Iran Microplate, HZF: High Zagros Fault, KZF: Kazerun Fault, MFF: Mountain Front Fault, MZRF: Main Zagros Revers Fault, MZT: Main Zagros Thrust, SSZ: Sanandaj-Sirjan Zone, UDMA: Uromia Dokhtar Magmatic Arc, ZFTB: Zagros Fold Thrust Belt.

ceous limestones of the Kazhdumi Formation and is unconformably overlain by thick bedded neritic limestones of the Ilam Formation. In the Fars and Persian Gulf, and parts of the Izeh Zone, the Sarvak Formation is subdivided into three members including the Mauddud limestones, Ahmadi shales/marls, and Mishrif argillaceous/limestones that are the equivalents of the Mauddud, Ahmadi, and Mishrif formations of the Arabian countries, respectively, i.e., southern Iraq, Kuwait, Bahrain, the UAE, and Qatar. In Oman, the Natih Formation is the time equivalent of the Sarvak Formation (Van Buchem et al. 1996, 2002). In the Maymand section, the Ahmadi shales/marls are not present and the Mishrif limestones directly overly the Mauddud massive limestones. Here, the Sarvak Formation is composed of two lithotypes. The lower 285 m of the formation consists of medium to thick-bedded shallow marine bioclastic limestones, containing benthic foraminifera and calcareous green algae. Its upper 47- m–thick interval (samples DB 14552 to DB 14561) is composed of thin to medium bedded argillaceous hemipelagic limestones rich in calcispheres and planktonic foraminifera documenting the platform drowning of the Sarvak Formation (text-fig. 2). The assemblage of planktonic foraminifera includes *Planoheterohelix moremani* (Cushman), *Helvetoglobotruncana praehelvetica* (Trujillo), and *Globigerinelloides ultramicrus* (Subbotina). The occurrence of



TEXT-FIGURE 2
Lithostratigraphic log of the Maymand section showing the distribution of some (larger) benthic foraminifera and *Montcharmontia apenninica* (De Castro). A) *Nezzazata* gr. *gyra-conica* (Smout). B) *Nezzazata simplex* Omara. C) *Nummofallotia*? *cenomana* Luperto Sinni. D) *Rajkanella hottingerinaformis* Schlagintweit & Rigaud. E) *Orbitolina* gr. *concava* (Lamarck). F) *Biconcava bentori* Hamnaoui & Saint-Marc. G) *Praealveolina simplex* Reichel. H) *Cisalveolina fraasi* (Gümbel). I) *Chrysalidina gradata* d'Orbigny. J) *Persiconus sarvaki* Yazdi-Moghadam & Schlagintweit. K) *Orbitolinopsis cenomaniensis* Schlagintweit & Yazdi-Moghadam.



TEXT-FIGURE 3
Examples of Cenomanian mostly larger benthic foraminifera (agglutinated: 1–4, 9, 11–12; porcelaneous: 6, 8, 10; and lamellar-perforate: 5, 7, 13) that survived the Cenomanian-Turonian boundary extinction event. Note that some of these survivors may have gaps in their post-Cenomanian records. 1: *Cuneolina* d'Orbigny; 2: *Dictyopsella* Munier-Chalmas; 3: *Dicyclina* Munier-Chalmas; 4: *Moncharmontia* De Castro; 5: *Murgeina* Luperto-Sinni; 6: *Pseudonummoloculina* Calvez; 7: *Pararotalia* Le Calvez; 8: *Perouvianella* Bizon et al.; 9: *Pseudocyclammina* Yabe and Hanzawa; 10: *Pseudorhapydionina* De Castro; 11: *Reticulinella* Cuvillier et al.; 12: *Nezzazata* Omara; 13: *Rotorbinella* Bandy (see also text-figure 4). 1, 3–5, 10–12: Cenomanian Sarvak Fm., Iran; 2: Cenomanian of France (from Loeblich and Tappan 1985, pl. 2, fig. 4); 6: Cenomanian of Mt. Pastrik, Kosovo (leg. R. Radoičić); 7: Cenomanian of Oman (from Piuz and Meister 2013, fig. 4m); 8: Cenomanian of Peru (from Consorti et al. 2018, fig. 3o); 9: Cenomanian of France (from Maync 1952, pl. 12, fig. 10); 10: Cenomanian of Italy (from Schroeder and Neumann, 1985, pl. 40, fig. 2); 13: Cenomanian of Spain (see Rosales and Schlagintweit 2015).

H. praehelvetica in the absence of both *Whiteinella archaeocretacea* Pessagno and representatives of thalmaninellids indicates a late Cenomanian age. The specimens of benthic foraminifera *Moncharmontia apenninica* (De Castro) are from the Maymand section.

MATERIAL AND METHODS

The material of *Moncharmontia* has been collected 12 km northeast of Maymand village, situated in the Izeh Zone (base coordinates: 31º 09' 15½ N, 51º 11' 53½ E) (text-fig. 1B). *Moncharmontia apenninica* was observed in random cuts of 24 thin sections belonging to 12 cemented carbonate rock samples of the upper part of the Sarvak Formation. Here in the Maymand section the lower part of the overlying Ilam Formation is characterized by several occurrences of rotaliids (mainly *Rotorbinella*) together with calcareous green algae. The rock samples and thin sections are housed in the collection of National Iranian Oil Company Exploration Directorate (NIOCEXP) under the acronyms DB 14493-DB 14551.

SYSTEMATIC PALEONTOLOGY

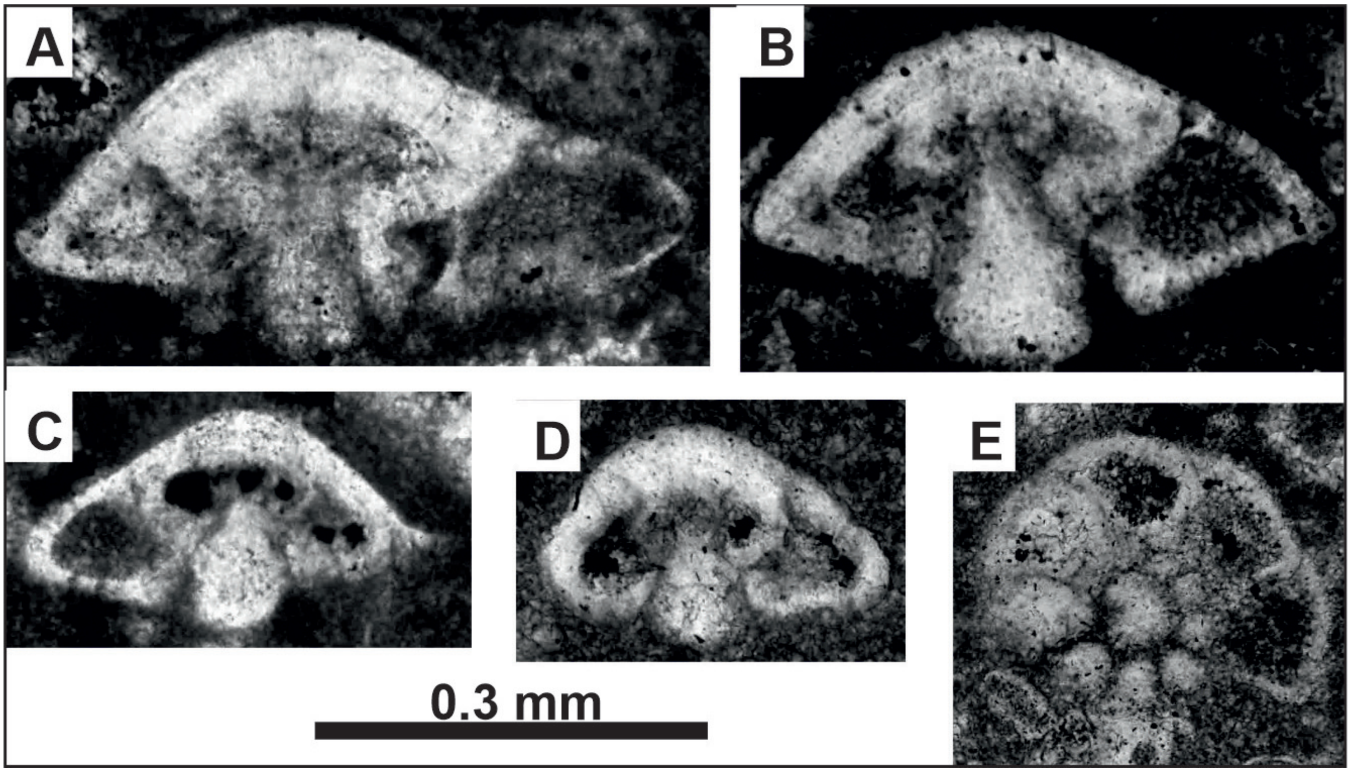
In the following we provide a synonymy of *Moncharmontia apenninica* list in order to demonstrate its distribution. For the description, we refer to the (as standard for this author) very detailed information and data provided by De Castro (1966).

Phylum FORAMINIFERA d'Orbigny 1826
Class GLOBOTHALAMEA Pawlowski et al. 2013
Order LOFTUSIIDA Kaminski and Mikhalevich 2004
Suborder BIOKOVININA Kaminski 2004
Superfamily BIOKOVINOIDEA Gusiè 1977
Family Charentiidae Loeblich and Tappan 1985
Genus *Moncharmontia* De Castro 1967
Type-species. *Neoendothyra apenninica* De Castro 1966

Moncharmontia apenninica (De Castro 1967)
Plate 1, figures A–L

Neoendothyra apenninica DE CASTRO 1966, p. 328, text-figs. 5–6, pls. 1–2, pl. 3, figs. 1–3, 9–12.
Moncharmontia apenninica (De Castro) nom. nov. – DE CASTRO, 1967.
Moncharmontia apenninica (De Castro). – SCHLAGINTWEIT 1992, text-fig. 5, pl. 1, figs. 10–12.– pars MORO and JELASKA 1994, pl. 2, fig. 5.– RAMIREU DEL POZO and MARTIN-CHIVELET 1994, pl. 1, fig. 5 pars, fig. 8 (*M. apenninica compressa*).– KOCH et al. 1998, pl. 2, fig. 7.– CHECCHONI et al. 2008, pl. 1, figs. 4–7.– JEZ et al. 2011, fig. 7D pars, 7F, 7G (*M. apenninica compressa*).– OMAÑA et al. 2013, p. 485.– OMIDVAR et al. 2014, fig. 4/4–6.– FRIJIA et al. 2015, fig. 8H–I.– ARRIAGA et al. 2016, 14, fig. 5.– SOLAK et al. 2017, fig. 11A–B.– LE GOFF et al. 2019, fig. 5C.

Remarks: No new observations can be added to the very detailed description of De Castro (1966). The Iranian specimens



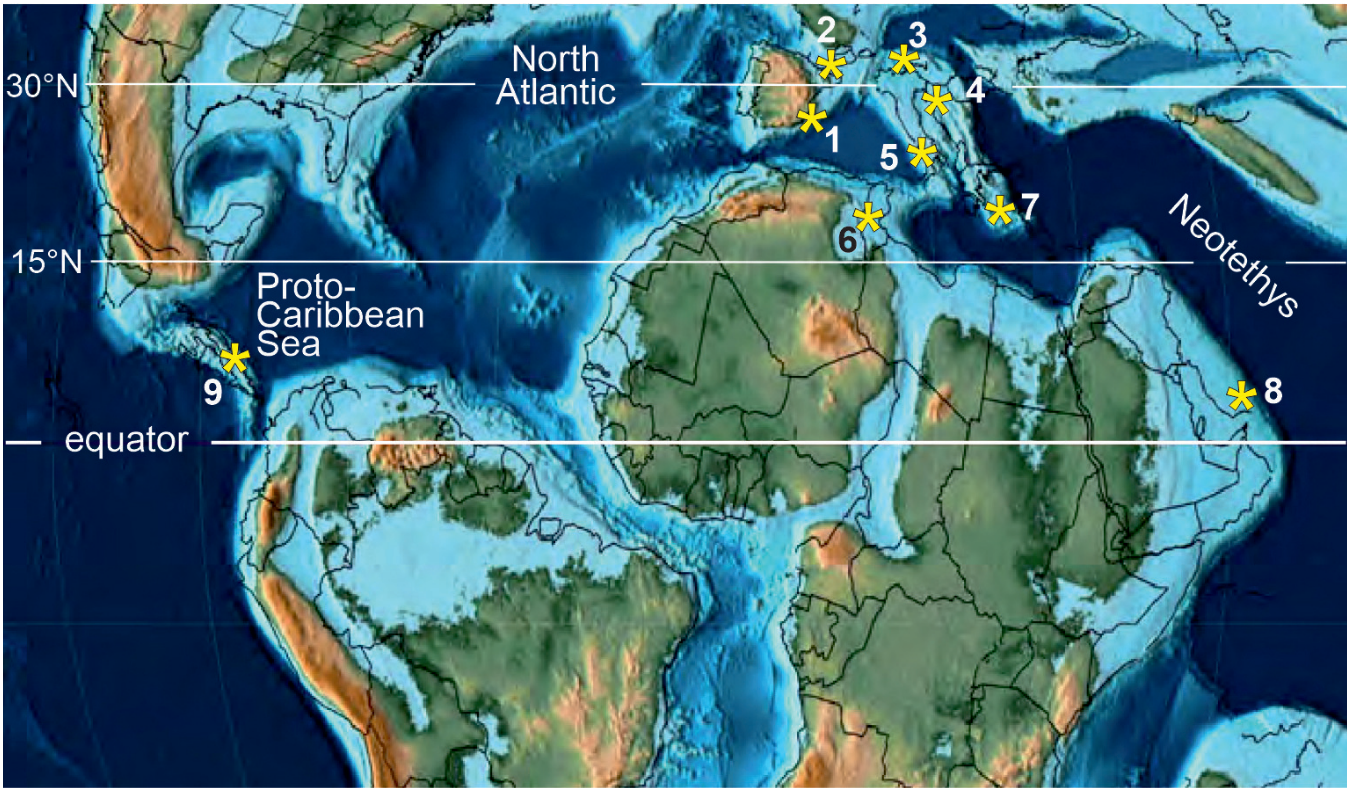
TEXT-FIGURE 4
Rotorbinella mesogeensis (Tronchetti) from the Santonian? Ilam Formation of SW Iran (Zagros Zone). A-C) Axial sections. D) Transverse section.

belong to *M. apenninica*; the variety *M. apenninica compressa* has not been observed.

Stratigraphy: M. apenninica is a rather long-ranging species reported frequently from the lower/upper Turonian to Campanian/Maastrichtian interval (see synonymy). For the post-Cenomanian strata, notably the microfaunistic impoverished Turonian carbonates, *M. apenninica* was included in assemblage zones. In the middle part of Apenninic Platform of Italy, De Castro (1991) established an upper Turonian-Maastrichtian Biozone. In the Bolkar Mountains of South Turkey, Tasli et al. (2006) indicated a *Montcharmontia compressa* and *Dicyclina schlumbergeri* Cenozone with a Coniacian–Santonian range. For the Turonian part of the Sarvak Formation, Omidvar et al. (2014) introduced a *Montcharmontia apenninica-Nezzazatinella-Dicyclina* assemblage zone. Based on the finds in the Sarvak Formation of Iran, the FAD of *M. apenninica* can be assigned to the middle Cenomanian.

DISCUSSION

The late Cenomanian–early Turonian oceanic anoxic event (OAE2 or Bonarelli Event, Schlanger and Jenkyns 1976) resulted in a biotic turnover in the oceans. These pronounced geochemical perturbations lasted roughly 0.7 m.y. (Harries 1999). With respect to the planktonic foraminifera studied in basinal sequences, these “experienced a severe turnover though no mass extinction” (Keller et al. 2008, p. 976). In fact, during that time the diversity dropped drastically and a low diversity high-stress assemblage of opportunistic heterohelicids was dominating (Keller et al. 2008; Shahin and Elbaz 2013; Reolid et al. 2013). For the benthic foraminifera, the effect of the OAE2 is generally considered a mass extinction event. Concerning the small-sized taxa, “50–60% of species went extinct or temporarily disappeared during the CTBE” in both “shallow and deep basins” (Peryt 2004, p. 831-832). The proliferation of buliminds and the increase in palaeoproductivity proxies, give evidence for an eutrophication of the sea-water during that time (Hart et al. 2005, fig. 8; Reolid et al. 2013). In shallow-water platform carbonates, the extinction of larger benthic foraminifers (LBF) associated with the CTB event, was a two step-process as evidenced by Parente et al. (2008) in the southern Apennine Mountains of Italy, a platform that did not drown during the OAE2. Note that for other marine benthic groups, the available data display even seven steps of extinction (Harries 1999). The first extinction of LBF eliminated the alveolinids and the second one taxa like *Chrysalidina gradata* d’Orbigny and *Pseudolituonella reicheli* Marie (Parente et al. 2008). This two-step exintinction pattern has been also observed in the Western Taurides of Turkey (Solak et al. 2020) and west-Central Sinai, Egypt (Orabi et al. 2012). In the Western Taurides, the Cenomanian/Turonian boundary has been fixed by the last occurrences of *C. gradata* and *P. reicheli* and the immedeately following apperance of *Pseudocyclammina sphaeroidea* Gendrot, *Moncharmontia apenninica* and others (Solak et al. 2020, fig. 7). It is worth mentioning here, that in the Apennine Mountains, the second extinction event did not take place directly at the CTB, but in the upper part of the *geslinianum* ammonoid zone of the upper Cenomanian, ~160 ka before the CTB (Parente et al. 2008, fig. 1). *Moncharmontia apenninica* was described by De Castro (1966) from Turonian-„Senonian“



TEXT-FIGURE 5
Disjunct distribution of *Moncharmontia apenninica* (De Castro) plotted on a Cenomanian paleomap (modified from Scotese 2016). 1: Spain (Ramirez del Pozo and Martin-Chivelet 1994). 2: France (Bilotte 1985). 3: Austria (Schlagintweit 1992). 4: Croatia (Moro and Jelaska 1994). 5: Italy (De Castro 1967, type-area; Frijia et al. 2015; Arriaga 2016). 6: Tunisia (Salmouna et al. 2014). 7: Turkey (Solak et al. 2017, 2020). 8: Iran (this work). 9: Mexico (Omaña et al. 2019).

shallow-water carbonates of various localities in southern Italy. Its "FAD" (and also the one of *P. sphaeroidea*) in the Apennine Mountains was fixed precisely by strontium isotope data as within the *coloradoense/devonense* ammonoid zone of the lowermost Turonian (Frijia et al. 2015, fig. 15; Arriaga et al. 2016, fig. 3). Therefore, *M. apenninica* was claimed to represent a Turonian newcomer and one of the first taxa of the Upper Cretaceous Global Community Maturation Cycle (GCMC; see e.g., Hottinger, 1997, 2001) in the aftermath of the CTB extinction event (Arriaga 2016, p. 130). In the Dinarides of Croatia, the first record of *M. apenninica* is reported later, from the upper Turonian (Velić 2007). Our results from the Cenomanian Sarvak Formation clearly display that *M. apenninica* is not a Turonian newcomer and that its "FAD" in the Apenninic Mountains represents just a local date.

Due to test size and the simple internal structure (e.g., lack of exo-/endoskeleton), *M. apenninica* belongs to the smaller benthic foraminifera. In contrast hereto, larger benthic foraminifera (LBF) display larger dimensions (>1 mm) and usually a complex test interior (e.g., Hottinger 2006). With respect to the CTB, only a few K-strategy LBF survived such as *Dicyclina* Munier-Chalmas or *Perouvianella* Bizon et al. (text-fig. 3). In this context, it is worth mentioning that *Dicyclina* represents an example of a new species in surviving genera (Harries et al., 1996). The two species *D. sampoi* Cherchi and Schroeder and *D. simplex* Cherchi and Schroeder are only known from the Cenomanian (Cherchi and Schroeder 1990a, b). The post-Cenomanian records of the genus instead refer to the third species *D. schlumbergeri* Munier-Chalmas (e.g., Schlagintweit and Rashidi 2018). *Montcharmontia* was probably a (more or less) cosmopolitan r-strategist allowing the genus to survive the CTB. Its "FAD" in the Iranian Sarvak Formation is somewhere in the upper part of the middle Cenomanian (Fig. 2) which in turn means that *M. apenninica* does not represent a so-called crisis progenitor taxa sensu Kaufman and Harries (1996). The latter arise *per definitionem* during the main extinctional phases and subsequent survivorship. Among the survivor taxa presented in text-figure 3, some remarks are here provided for the small-sized calcareous taxon *Rotorbinella mesogeensis* (Tronchetti) that is considered the progenitor of all Rotorbinellas (text-fig. 4). It is a common consensus, that *R. mesogeensis* represents a Cenomanian marker taxon not surpassing the CTB (Boix et al. 2009 fig. 2; Piuz and Meister 2013). This species has been observed in the Ilam Formation of SW Iran (Zagros Zone), considered of Santonian age (Wynd 1965).

Interestingly, *Moncharmontia apenninica* has already been reported from pre-CTB strata in Mexico, but without stressing its contrasting stratigraphy compared to the peri-Mediterranean finds. In the El Abra Formation of the Valles-San Luis Potosí Platform, it has been reported from the upper Cenomanian together with *C. gradata* by Omaña et al. (2012, 2013, 2019). Both, the occurrences of *Moncharmontia* in Iran and Mexico (= Cenomanian newcomer and CTB survivor taxon) are from a

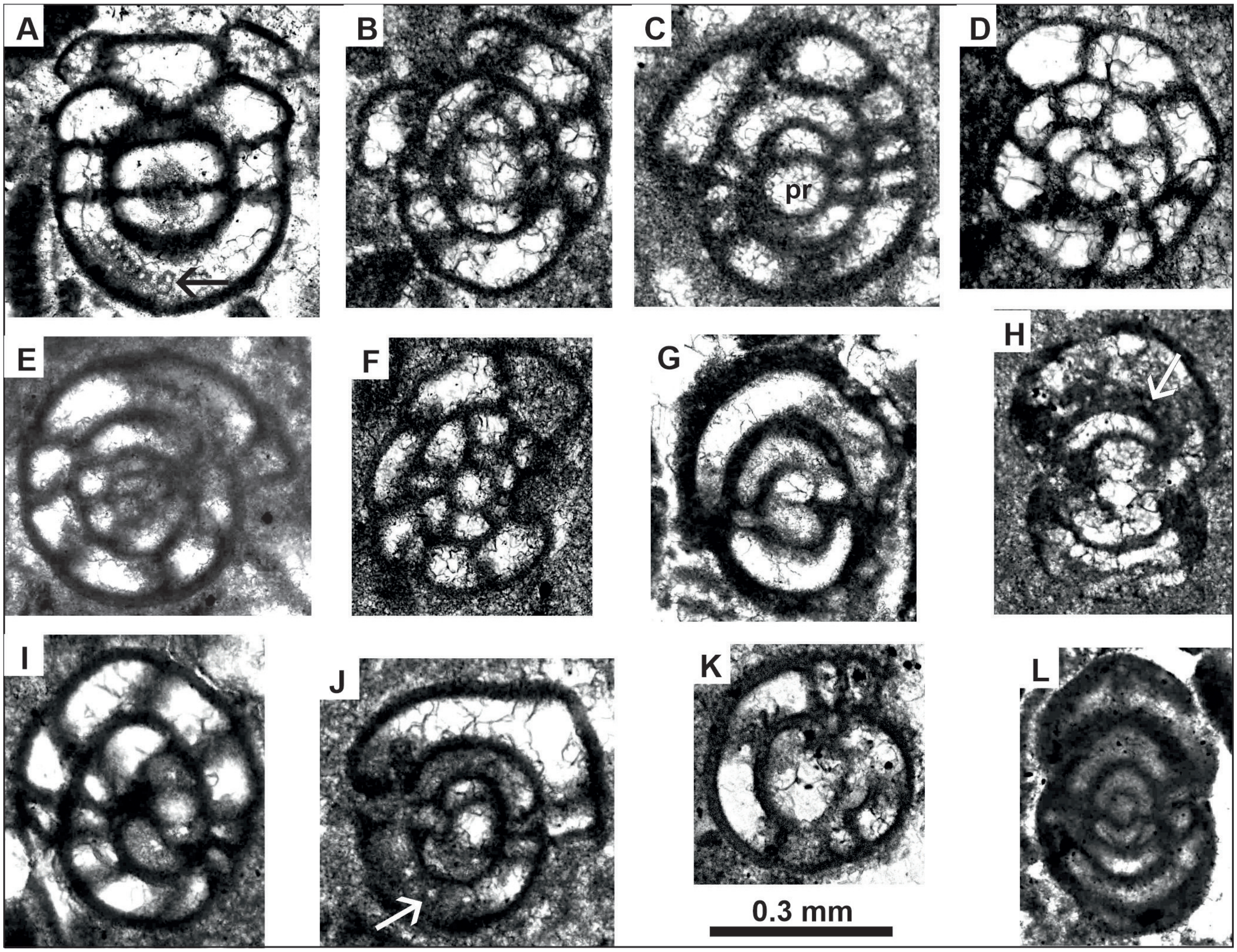


PLATE 1

Moncharmontia apenninica (De Castro) from the Cenomanian Sarvak Formation of the Maymand section, SW Iran.

A, G Subaxial sections.

B–C, I–J Oblique sections. Arrow in J: Multiple foramina.

D, F Equatorial sections.

E, K Oblique equatorial sections.

H, L Axial sections.

near-equatorial position, whereas those from the peri-Mediterranean realm (e.g., Croatia, Italy, Turkey = Turonian newcomer taxon) are from low-middle latitudes (text-fig. 5). These differences might be explained by migration from equatorial belt region towards northern low latitudinal areas. It is worth mentioning here that an equivalent hypothesis was put forward by Kahsnitz et al. (2016) for the *Lockhartia* species of the so-called Paleocene Lockhartia Sea. The authors also observed an earlier evolution of some species in the near-equatorial belt (e.g., Tibet) compared to the western region (= peri-Mediterranean realm) of low-middle latitudes. Separated by thousands of miles of the Atlantic Ocean (degree of longitudes), *Moncharmontia* displays a global disjunct distribution.

CONCLUSIONS

The smaller benthic foraminifera *Moncharmontia apenninica* (De Castro) is reported from prae-CTB strata of the Sarvak Formation in southwestern Iran as already evidenced from Mexico. In the Italian type-area its "FAD" is from the lower Turonian, leading several authors to conclude that it represents a newcomer species of this stage in the aftermath of the CTB extinction event. *Moncharmontia* represents a small-sized and simple structured r-strategist foraminifera that originated before and survived the CTB event. Therefore *Moncharmontia* is not an early member of the Upper Cretaceous GCMC, but displayed a late origin in the Middle Cretaceous GCMC. It might be speculated that its origination took place in near-equatorial areas (Mexico, Iran) followed by subsequent northward migration into low-middle latitudes of the peri-Mediterranean realm. Referring to longitudinal distribution pattern, *Moncharmontia* displays a disjunct distribution. The example of the smaller rotaliid *Rotorbinella mesogeensis*, another CTB survivor taxon, provides another good example that occurrences (e.g., FAD's) in certain areas (also type-areas) and resulting stratigraphic conclusions should be cautiously transferred to other regions and generalizations be avoided or at least carefully worded.

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