Journal of Geosciences and Geomatics, 2014, Vol. 2, No. 4, 139-144
Available online at http://pubs.sciepub.com/jgg/2/4/1

DOI:10.12691/jgg-2-4-1

Platform Carbonates Distribution in the Carboniferous of Iran

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Received June 03, 2014; Revised June 18, 2014; Accepted June 23, 2014

Abstract In the Lower Carboniferous, the Iranian Platform represented the area of marine sedimentation. Carboniferous sequences of the Baluchestan Basin, Central Iran and Alborz are correlated. Distribution of corals in the Lower Carboniferous of Iran is influenced by both regional and world transgression and regression episodes. Tournaisian- Middle Serpukhovian marine deposits are well-developed and rich in fossil corals in the Alborz, and Baluchestan. They are extended from southeast to northwest in the area of Lower Carboniferous deposition. In the Middle Serpukhovian-Gzhelian marine sedimentation was restricted to the East Iran (Tabas area). However, fossil evidence suggests Late Carboniferous age only for part of the Tabas area sequence.

Keywords: *Carboniferous, platform carbonate, corals, correlation, platform, Iran*

Cite This Article: Kaveh Khaksar, and Keyvan Khaksar, "Platform Carbonates Distribution in the Carboniferous of Iran." *Journal of Geosciences and Geomatics*, vol. 2, no. 4 (2014): 139-144. doi: 10.12691/jgg-2-4-1.

1. Introduction

The Carboniferous of the Iranian Platform is represented by thick sequence extending from southeast to northwest of Iran and developed in the Alborz Mountain (North Iran), in the East and Central Iran. Geological studies of the Carboniferous of Iran were started by [1]. The current lithostratigraphic nomenclature and sedimentological interpretations of major lithofacies were established due to his contribution and also due to research made by [2-39].

Carbonates yielding abundant solitary and colonial corals are exposed in the Central Alborz, in the eastern part of Central Iran and in Baluchestan. They belong to the Mobarak, Geirud, Shishtu, Ghachal and Sardar formations. Corals are also reported from the Baluchestan Basin. Deposits yielding corals, specifically Tournaisian and Visean, are represented by black limestones rich in corals and brachiopods. Upper Carboniferous deposits are developed only locally; their age is established based on brachiopods and corals.

The first systematic research on Iranian Carboniferous corals was made by [4], who described Permo-Carboniferous corals from Iranian Baluchestan. Since then many scholars studied corals in various parts of the country. Rugose and tabulate genera were used for correlation of different sections. Rugose complex typically includes solitary genera; only in the Vali-Abad a patch reef built by colonial *Siphonodendron* and Zaladu section, Ozbak kuh mountains, East Iran is known. Tabulate corals are widely distributed in Carboniferous deposits of the Iranian Platform.

Some descriptive papers have been published on Lower Carboniferous corals from several localities in the Central Alborz [19,26,27,37,40,41]. The paper by [19] is the most important for understanding of the Lower Carboniferous coral fauna of Iran. Carboniferous sequence of the Central Alborz is represented by more than 400 m of limestones yielding abundant rugose corals, brachiopods, foraminifers and other fossils. The Mobarak Formation developed in this area contains rich and diverse coral fauna [6]. Biostratigraphy of the Mobarak Formation is based on conodonts and brachiopods [14], and also on corals [23,26].

Correlations suggested in the present paper are mainly based on corals.

2. Material and Methods

This paper is the result of more than 15 years of our investigations on Carboniferous corals of Iran. The data used in this paper are from all compiled studies that includes of all rugose taxa occurring in the Carboniferous of Iran. For this study all of Carboniferous sections were investigated and correlated from north to south and Central. In order to determinate Iranian Carboniferous platform we have studied all of geological formations and Carboniferous sections and we have investigated on corals. The collected corals of their sections have been selected in 3 groups: cyathaxonia fauna, dissepimented and Colonial

corals. Stratigraphical sections and these groups of corals show regressive sequences.

3. Results

Carboniferous geological formations of Iran: general characteristic, age and coral complexes:

3.1. Mobarak Formation

The Mobarak Formation is developed in the northwest through the northeast of Iran. It comprises thick Lower Carboniferous sequence (Tournaisian through the Serpukhovian) in different parts of Central Alborz. Its lateral equivalents are developed in the Central Iran and East Iran Basins, and extended from northwest to northeast of Iran. The Mobarak Formation is represented by dark fossiliferous limestones with subordinate black shale intercalations in its lower part. In the type section, it rests disconformably on sandy-argillaceous beds of the Upper Devonian and is overlain by marly limestone with ironstone lenses Upper Permian fossils (possibly, the Nesen Formation).

From the interval corresponding to the Second Lithozone of the Mobarak Formation, [6,7] reported rugose genera *Siphonophyllia*, *Caninia* and *Caninophyllum*, and tabulate genus *Michelinia*. From the Tournaisian of Mobarak Formation (Flugel in [42] and [2] reported *Siphonophyllia*, *Caninia*, *Caninophyllum*, *Zaphrentites*, *Zaphrentoides*, *Cladochonus* and *Michelinia*. From the First and Second Lithozones of this formation in Kandowan and Valli-abad, (Flugel in [42] reported *Caninophyllum*, *Cladochonus*, *Caninia*, *Michelinia*, *Siphonophyllia*, *Zaphrentoides*, *Cyathoclisia*, *Bothrophyllum*, *Clisiphyllum*, and from the Visean of Mobarak-Abad *Amygdalophyllum*, *Clisiphyllum* and *Michelinia*. *[6]* reported from this interval *Caninia*, *Siphonophyllia*, *Caninophyllum*. [26,27,32] reported from the Lower Carboniferous of the Central Alborz rugosans *Bradyphyllum*, *Claviphyllum*, *Allotropiophyllum*, *Amplexocarinia*, *Zaphrentites*, *Amplexizaphrentis*, *Neozaphrentis*, *Sychnoelasma*, *Zaphrentoides*, *Caninia*, *Melanophyllum*, *Pseudozaphrentoides*, *Siphonophyllia*, *Skolekophyllum*, *Bothrophyllum*, *Caninophyllum*, *Auloclisia*, *Carruthersella*, *Clisiphyllum*, *Cyathoclisia*, *Dibunophyllum*, *Arachnolasma*, *Faberolasma*, *Haplolasma*, *Turbinatocaninia*, *Kueichouphyllum*, *Zaphriphyllum*, *Quinghaiphyllum*, *Siphonodendron*, *Campophyllum*, *Tehranophyllum*, *Ekvasophyllum*, *Kizilia*, *Kailingophyllum* and *Corwenia*, and tabulates *Michelinia* and *Syringopora*.

Rugose genera Amplexizaphrentis, Zaphriphyllum, Kueichouphyllum, Bothrophyllum and Siphonophyllia are dominanting in the Tournaisian complex.

Visean coral complex has less abundant and diverse. According to [19], the *Kueichouphyllum* Biozone (Upper Visean) of the Talar and northern Semnan is defined by *Kueichouphyllum*, *Caninophyllum*, *Bothrophyllum*, *Siphonophyllia*, *Humboldtia*, *Polythecalis*, *Clisiphyllum*, *Amygdalophyllum*, *and Michelinia*. From the Visean of the Mobarak Formation of Central Alborz he [23] reported *Bothrophyllum*, and [28,29], *Claviphyllum*, *Amplexizaphrentis*, *Zaphrentites*, *Caninia*, *Siphonophyllia*, *Skolekophyllum*, *Caninophyllum*, *Carruthersella*, *Arachnolasma*, *Kueichouphyllum*, *Tehranophyllum*, *Zaphriphyllum*, *Michelinia*, *Siringopora*.

The Mobarak Formation in the Vali-abad section (south of Marzan-abad central Alborz) consisting of alternation of limestones and interbeddeds of shale, which is divided into three lithological units, attains 200 m in thickness. It has formed in a shallow carbonate Ramp based on the evidences from corals fauna, microfacieses, lithological composition and field data**.** According to the extent of corals fauna it has been determined that the Mobarak Formation deposits in this region are included Tournaisian to Namurian in age.

Table 1. The genera of Iranian Tournaisian to Upper Visean and their distribution in the different part

Genera \ Formation	Mobarak F.	Geirud F.	Shishtu F.	Gachal F.	Rock units of Baluchistan
RUGOSA CORALS					
Kizilia	*				
Amplexocarinia	*		*		
Campophyllum	*				
Bradyphyllum	*			*	
Claviphyllum	*		*	*	
Allotropiophyllum	*	*		*	*
Amplexizaphrentis	*	*		*	
Neozaphrentis	*				
Zaphrentites	*	*		*	*
Cyathaxonia			*		
Pentaphyllum			*		
Ufimia	*		*		
Plerophyllum			*		
Zaphrentoides	*				
Sychnoelasma	*				
Marzanophyllum	*				
Caninia	*		*	*	*
Melanophyllum	*				
Pseudozaphrentoides	*			*	
Siphonophyllia	*	*	*	*	*
Skolekophyllum	*				
Bothrophyllum	*	*			
Caninophyllum	*	*			
Auloclisia	*	*			
Kailingophyllum	*				
Carruthersella	*				
Clisiphyllum	*	*			
Cyathoclisia	*	*			
Dibunophyllum	*				
Arachnolasma	*				
Corwenia	*				
Faberolasma	*	*			
Haplolasma	*			*	
Turbinatocaninia	*	*			
Kueichouphyllum	*	*		*	
Tehranophyllum	*			*	
Ekvasophyllum	*				
Zaphriphyllum	*	*		*	
Quinghaiphyllum	*	*			
Humbuldita	*				
Amygdalophyllum	*				
Siphonodendron	*				
TABULATA CORALS					
Cladochonus	*				
Michelinia	*	*		*	
Syringopora	*			*	
Polytecalis	*				
Syringopora	*	*		*	

From member A and B of the Mobarak Formation of Vali-Abad section reported *Kueichophyllum*, *Siphonophyllia*, *Caninia*, *Pesudozaphrentoides*,

Bothrophyllum, Zapheriphyllum, Zaphrentoides, Allotropiophyllum. The Member A and B is assigned to the Tournaisian to Upper Visean in age [41,40].

The Member C of Vali-Abad section consists of *Kailingophyllum, Marzanophyllum, Hapsiphyllum, Zaphrentoides, Ufimia, Zaphrentites, Syringopora*. The age of this association is upper Visean to Namurian [41].

Also authors recorded following corals assigned to Lower Carboniferous: *Siphonophilia, Bothrophyllum* and *Kueichouphyllum*, from the Esfahan area of Central Iran.

3.2. Geirud Formation, Members B and C

The type section of the Geirud Formation was studied by [8,19] subdivided this formation into four members (A, B, C and D), of which the latter in the type section is missing. The Member A in its lower part consists of sandstones, shales and fossiliferous sandy limestones containing few phosphatic layers. According to the original definition, thickness of the Member A is 235 m; however [7] estimates thickness of this unit as approximately equal to 140 m. The Member B consists of massive fossiliferous limestones alternating in its lower part with black shales, and the Member C is represented by uniform light-colored thick-bedded dolomithic limestones. For its position, the latter is considered to be Visean in age. The overlying Member D consists of 300 m thick black oolitic sparry limestones intercalating in the upper part with thin black marly intercalations.

Flugel in [7] reported from the Member B Zaphrentites, Siphonophyllia and Caninophyllum, and [26,27,34] Allotropiophyllum, Zaphrentites, Amplexizaphrentis, Turbinatocaninia, Auloclisia, Cyathoclisia. Clisiphyllum. Faberolasma, Bothrophyllum, Siphonophyllia, Qinghaiphyllum, Kueichouphyllum, Zaphriphyllum and Michelinia. This complex is indicative of the Tournaisian.

3.3. Shishtu Formation

The type area of the Shishtu Formation is in the Ozbak-Kuh Mountains, East Iran. The name is given for the Shishtu village and has been used so far only in the wider Tabas-Ozbak Kuh area. However, this formation is also traced through the Shirgesht area into the Shotori Range. The Shishtu Formation in the type section [3], is represented by alternating shales, marls and limestones. It conformably overlies the Devonian Bahram Formation limestones and is conformably underlying the Sardar Formation. The Shishtu Formation subdivided into two subformations, Shishtu I and Shishtu II. The Shishtu I is Frasnian–Famennian in age, and the Shishtu II Tournasian through the Middle Visean. The limit between the two subformations is marked by black shale ("Mush Horizon") at the top of the Shishtu I. The Shishtu II includes the "Goniatite Horizon 2" near its base. The Shishtu I includes the "Goniatite Horizon 1"; however, it is missing in the type area.

Coral complex of the Shishtu II was considered by [17] and [24] as Tournaisian–Visean. In the Shotori Range (Howz-e-Dorah section) this subformation yields in its lower part *Siphonophyllia* and *Caninia* [16].

Rotiphyllum, Claviphyllum, Ufimia, Plerophyllum, Sochkineophyllum, Cyathaxonia, Siphonophyllia, Amplexocarinia, Pseudowannerophyllum.

3.4. Gachal Formation

The type section of the Gachal Formation is in the Kalmard Province, Tabas region (Central Iran), where this unit is developed as a block. The Gachal Formation is subdividd into two units (members A and B). The best section for coral studies is in the Rahdar Mountain about 70 km W. of Tabas, East Iran. Only the Member A yields corals; it is represented by alternation of limestones and black shales intercalated with sandstone layers in its basal part. The Member B consists of 70-90 m thick of massive grey dolomites. Records of *Allotropiophyllum, Amplexizaphrentis, Bradyphyllum, Caninia, Claviphyllum, Haplolasma, Kueichouphyllum, pseudozaphrentoides, Siphonophyllia, Siphonophylli, Tehranophyllum, Zaphrentites, Zaphrentoides, Zaphriphyllum* [31,32,44] suggest Tournaisian age of the Member A. The Member B is assigned to the Visean for its position in the section. The Gachal Formation is overlain by Permian deposits.

3.5. Rock units of Baluchestan

In the southeast of Iran and in Baluchistan, Carboniferous–Permian sequence, is relatively thin, occurs, in an isolated mountainous massive extending from Bur-kuh to Taftab, it is situated in the Bampur Basin, about 195 km SE of the Bam. It is built of limestones which are strongly folded and disturbed by thrust-faults and by strikes running approximately NNW-SSE. Five members are recognized, in descending order is as follows:

D: nonfossiliferous yellow and light brown dolomitic limestones,

C: dark flaggy limestones interbedded with calcareous shales and fossiliferous near the base,

B: nonfossiliferous dark thin-bedded shales, flaggy limestones and grey dolomites,

A: purple shales and fossiliferous limestone beds,

Z: dark flaggy limestones with cherts, locally dolomitized.

The members A and B are attributed to the Lower Carboniferous.

[4] reported from the Carboniferous *Siphonophyllia, Caninophyllum, Zaphrentites, Allotropiophyllum* and *Caninia*.

3.6. Sardar Formation

The name was introduced by [9] for a predominantly shaly-sandy unit disconformably resting on the lithologically more complex Shishtu Formation and overlain by massive reef limestones of the Jamal Formation in the Shotori Range. The type section of the Sardar is in the western foothills of the Kuh-e-Shotori South of the Sardar River. This formation comprises the uppermost part of the Ozbak-Kuh Group. Sandy-shaly facies of the Sardar are rather unique for the Carboniferous of Iran, which is commonly represented by carbonates.

The estimated thickness of the Sardrar Formation is 710–760 m; 660 m which are exposed, the basal part is not exposed. The base of the Sardar is marked by up to 30 m thick conglomerate. This formation includes the Lower/Upper Carboniferous transition. The upper 200 m of the Sardrar are represented by argillaceous to silty soft weathered pale olive-green shales with rare thin

intercalations of quartzitic sandstone. They are barren except for one layer yielding bryozoans. The major part of the Sardar sequence is composed of similar shales intercalated with quartzite, sandstone and highly fossiliferous sandy limestones.

A tentative subdivision of the Sardar Formation into two subformations (Sardar I and Sardar II) was suggested by [44] in the Ozbak-Kuh and by [45] in the Sardar type section. The position of the limit between the subformations has not been fixed precisely. This limit lies approximately 350 m above the base of the measured Sardar type section.

Age of the Sardar I Subformation is estimated as the Middle Visean through the Middle Serpukhovian. From the type section of Sardar I, [18] reported Visean–Serpukhovian coral complex comprising *Cyathaxonia*, *Fasciculophyllum*, *Plerophyllum*, *Soshkineophyllum* and *Michelinia*. From the Sardar I in the Shotori Range he [20,22,25] also reported Visean–Serpukhovian genera *Ufimia*, *Pseudowannerophyllum*, *Plerophyllum*, *Cyathaxonia*, *Caninia*, *Amplexus*, *Amplexocarinia*, *Minatoa.*

From the Sardar II he [20,21] reported Donetzites, Minatoa and Pseudowannerophyllum, and from the Sardar II in the Ozbak-Kuh [22,25] Koninkophyllum, Minatoa, Amandophyllum, Palaeosmilia, Heritschioides, Paraheritschioides, Kleopatriana, Opiphyllum, Fomichevella, Donetzites, Multithecopora. This complex is indicative of the Serpukhovian–Bashkirian. The Sardar II in the Shirgesht area has yielded Claviphyllum in its lower part (Table 1).

According to studied corals, a shallow carbonate ramp environment is considered for these beds of the formation. The mentioned Fauna has only been introduced from Ozbak-Kuh Mountains and paleogeographically is unique in the world and Iran. This complex is indicative of the Serpukhovian [37,46].

[46], from Sardar I sub. Formation of Zaladu section in Ozbak-kuh Mountains with age of Late Serpukhovian have been described and presented following genera: *Heritschioides*, *Paraheritschiodes*, *Multithecopora*, *Orygmophyllum* and *Durhamina.*

Also in the unit 2 of the formation has been identified the following genera:

Fomichevella, *Multithecopora*, *Minatoa*, *Lithostrotion*, *Michelinia*.

The age of this unit in base of corals [46], Foraminifera and Conodonts [46] is Lower Bashkirian.

[37,46] identified the following large and dissepimented genus with the age of Gzhelian: *Pseudozaphrentoides*.

Despite the use of extensive data on foraminifera [47] and on the evidence of the conodont fauna [48] its age is Upper Gzelian.

From the type section of Sardar I, have been reported Serpukhovian coral complex comprising *Cyathaxonia*, *Fasciculophyllum*, *Plerophyllum*, *Soshkineophyllum* and *Michelinia*.

From the Sardar I in the Shotori Range have been also reported Upper Visean–Serpukhovian genera *Ufimia*, *Plerophyllum*, *Cyathaxonia*, *Caninia*, *Amplexus*, *Amplexocarinia*, *Pseudowannerophyllum*, *Minatoa*. From the Sardar II have been reported *Donetzites*, *Minatoa* and *Pseudowannerophyllum*, and from the Sardar II in the Ozbak-Kuh *Koninkophyllum*, *Minatoa*, *Amandophyllum*, *Palaeosmilia*, *Heritschioides*, *Paraheritschioides*, *Kleopatriana*, *Opiphyllum*, *Fomichevella*, *Donetzites*, *Multithecopora*. This complex is indicative of the Visean-Serpukhovian–Bashkirian. The Sardar II in the Shirgesht area has yielded *Claviphyllum* in its lower part. In the Serpukhovian marine sedimentation was restricted to the Central and East Iran and in the Bashkirian to the eastern part of the Central Iran.

Table 2. The genera of Iranian Upper Visean to Serpukhovian and their distribution in the different part

Genera \ Formation	Sardar I-Sub F.	Mobarak F.	Sardar II-Sub F.
RUGOSA CORALS			
Bothrophyllum	*		
Minatoa	*		*
Kleopatrina			*
Praheritschioides			*
Opiphyllum			*
Ufimia	*	*	
Fomichevella			*
Palaeosmilia			*
Claviphyllum	*		
Kailingophyllum		*	
Cyathaxonia	*		
Paraheritschioides			
Orygmophyllum	*		
Durhamina	*		
Koninkophyllum			*
Plerophyllum	*		*
Caninia	*		
Amplexocarinia	*		
Rotiphyllum	*		*
Fasciculophyllum	*		
Hapsiphyllum		*	
Zaphrentites		*	
Amplexus	*		
Paraheritschioides			*
Heritschioides			*
Marzanophyllum		*	
Zaphrentoides		*	
Pseudowanerophyllum	*		*
Cyathaxonia	*		
Soshkineophyllum	*		
Amplexus	*		
Claviphyllum			*
Kleopatriana	*		*
Amandophyllum	*		
Lithostrotion	*		*
Pseudozaphrentoides	*		*
TABULATA CORALS			
Multithecopora			*
Cyclochaetetes	*		
Syringopora		*	
Michelinia	*		
Favositidae		*	
Soshkineophyllum	*		
Donetzites			*

4. Conclusion

Studies of Iranian Carboniferous corals contribute to the understanding of marine sedimentation pattern during the Palaeozoic in this region. Regression at the end of the

Devonian was followed by transgression at the beginning of the Carboniferous. Late Devonian sedimentation pattern generally persisted in the Carboniferous; Carboniferous deposits represented by limestones and black shales rest on Devonian sandstones.

Detailed studies of Carboniferous sequence which made mainly in the Alborz Mountains, Shotori Range and wider Tabas area confirmed that in most areas, marine sedimentation was restricted to the Early Carboniferous (Tournaisian through the Visean). Only in the some areas of Central and East Iran it remained through the Serpukhovian (Figure 1). Therefore, we can assume, that at the beginning of Late Carboniferous, Hercynian tectonics affected the Iranian Platform and resulted in epeirogenic episode, wide uplifting and local disturbances. A vast area was exposed to denudation which caused local erosion of thick Lower Paleozoic rocks. However, we may also suggest that important sea-level changes contributed to the erosion. After a general regression in the Late Carboniferous, a new phase of transgression started during the Permian. Permian deposits covered the older formations with important disconformities.

The Mobarak, Geirud, Gachal and Shishtu formations, as well as Carboniferous sequence of Baluchistan comprise carbonates and shales deposited at the beginning of the Tournaisian. Basal limestone and black shale indicate a transgression peak marking beginning of Carboniferous sedimentation. Tournaisian limestones and black shales comprising the members 1 and 2 of the Mobarak Formation of Central Alborz correspond to the Member B of Geirud Formation of Alborz, to the Shishtu II of Ozback-Kuh and to the Member A of the Gachal Formation of East Iran (Kalmard area). The Lower Carboniferous of the Central Alborz is represented by dark limestones with subordinate shales and sandstones (upper part of the members B and C of the Geirud Formation) or by more uniform limestone unit (Mobarak Limestone). In these units, both the Tournaisian and Visean are well documented by rich brachiopod and coral complexes. In Central Iran, well-bedded dark brachiopod limestones of the Late Devonian–Early Carboniferous approximately correlate with the Geirud Formation of the Alborz. More sandy-shaly facies with subordinate carbonates are characteristic of the Early Carboniferous of the eastern Alborz and of the Tabas area, East Iran (upper part of the Shishtu Formation and lower part of the Sardar Formation). They yield abundant brachiopods and corals indicative of the Tournaisian, to Serpukhovian. Farther south, in the Kerman area, as well as in Baluchistan, dark brachiopod limestones are developed (Table 2).

Figure 1. Tournaisian to Serpukhovian carbonates platform distribution in Iran

Figure 2. Upper Serpukhovian to Ghazelian carbonate platform distribution in Iran

Table 3. Carboniferous stratigraphy of Iran based on corals

System	Serie	Stage	Alborz Range		Ozbak kuh Mountains	Shotori Range	Kalmard Area	Baluchestan
Permian								
CARBONIFEROUS Pennsylvanian	U. Carboniferous	Gzhelian						
		Kasimovian						
		Moscowian			Sardar II Sub. F.			
		Bashkirian						
Mississipian	Lower Carboniferous	Serpukhovian			Sardar I Sub. F.			
		Visean	Mobarak F.					
				Memb. C Girud F.			Member B	Carbonif. Rock Units
		Tournaisian		Memb. B of Geirud F.	Shishtu II	Shishtu II	Gachal F. Member A	
Devonian		UPPER DEVONIAN						

Carboniferous sequence of Iran is mostly represented by Lower Carboniferous deposits which are overlain by the Permian. In earlier publications these deposits were attributed to the Carboniferous or to the Permian (Table 3 and Figure 1 - Figure 2). However, fossil evidence suggests Late Carboniferous age only for part of the Tabas area sequence. In this area, predominantly sandy-shaly facies of the Lower Carboniferous are overlain by lithologically similar Upper Carboniferous and Lower Permian deposits (upper part of the Sardar Formation).

Subaerial erosion of the Late Carboniferous and Permian destroyed important part of Carboniferous sequence, particularly in the Alborz Mountain and Eastern of Iran. In the areas where Carboniferous deposits are developed, they are usually unconformably overlain by the Permian. Thickness of the Carboniferous sequences in the Alborz and in the Tabas region is about of 400 to 500 m.

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