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Biostratigraphy of the Upper Devonian–Lower Carboniferous deposits in Til-Abad section, northeast Shahrud, Eastern Alborz

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Abstract
The biostratigraphy of Devonian–Carboniferous (D/C) boundary of Til-Abad section in Eastern alborz is carried out in this study. The studied section is located about 85 km of northeast Shahrud city and close to the Shahrud–Azadshahr road. The uppermost sediments of Devonian and lowermost Carboniferous strata in Til-Abad section (467 m thick) systematically studied and in general led to discrimination of seven following zonal boundaries: *Bispathodus aculeatus aculeatus* zone, *Bispathodus costatus* zone, *Bispathodus ultimus* zone, ?*praesulcata* zone, *ck*I, *sulcate* zone, *typicus* Zone and *anchoralis- latus* Zone. The D/C transition interval contains a bioclastic limestone and a coaly shale bed (3 cm thick) with interbedded of very thin gypsum layer. The first horizon of Carboniferous strata is begun with grey marls interbedding fossiliferous limestone. This unit has large amounts of very small corals and brachiopods with high preservation. Interpreted conodont data shows lack of *kockeli* Zone at the D/C boundary and Carboniferous deposits disconformably overlays the Devonian deposits of the Khoshyeilagh Formation.
Keywords: Biostratigraphy, Late Devonian, Early Carboniferous, Devonian–Carboniferous boundary, Hangenberg Crisis, Til-Abad, Eastern Alborz.

Introduction

Conodonts have been studied by paleontologists as a very important tool for identifying and defining the D/C transition and for partial investigation of the Hangberg event (Ziegler 1962a; 1969; Sandberg et al. 1978; Ziegler and Sandberg 1990; Paproth and Streel 1984; Corradini 2003; Kaiser and Corradini 2008; Kaiser et al. 2009; Corradini et al. 2011; Hartenfels 2011; Corradini et al. 2016; Spalletta et al. 2017). After a prolonged period of warm climate from Silurian to the late Frasnian, in the Famennian regime, global climate change caused a decrease in temperature and environmental changes from greenhouse to icehouse condition (Caputo et al. 2008; Isaacson et al. 2008; Streel et al. 2000). But again in the late Famennian world climate was warmed abruptly and this warming continued until early Carboniferous, resulting in a sudden change in temperature leading to the Hangenberg Event on the D/C boundary. (Walliser 1984; Caplan et al. 1996; Caplan and Bustin 1999; Kaiser et al. 2006, 2011; Marynowski and Filipiak 2007; Marynowski et al. 2012; Kumpan et al. 2014). This increase in global temperatures triggered sea level rise, creating eutrophic conditions, anoxic conditions, increased buried carbon, the formation of the dark shale (Hangenberg Black Shale) and a reduction in shallow and especially deep marine organisms (Caplan et al. 1996; Caplan and Bustin 1999; De Vleeschouwer et al. 2013). However, this part of the Hangberg event in some sections, particularly Poland (Marynowski et al. 2012), is associated with volcanic activity and acidic magmatic intrusion into the ocean that contributed to the creation of anoxic to bioxigenic conditions. In most of the studied global sections, a Hangenberg sandstone horizon occasionally several centimeters thick can sometimes be observed following sudden anoxic events and the formation of dark shales due to sudden cooling. Therefore, global sea level fall happened at the D/C boundary (Isaacson et al. 2008; Wicander et al. 2011). As a result of the Hangberg event, the late palmatolpid and Icriodid conodonts went generally extinct (Ziegler and Sandberg 1984), but species of siphonodelids and protogonatoids were less severely damaged and entering Carboniferous, however, these

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conodonts were able to recover quickly and to prosper after the extinction event with their maximum reproduction strategy and reduced size and diversity. Some researchers believe that one of the reasons for this high rate of extinction at the D/C boundary is due to the vulnerability of the bio-fauna that began to recover and flourish after the significant extinction of the Frasnian–Famennian boundary but still lacked the ability to tolerate the environmental change during Hahenberg event (Morrow et al. 1996). In Iran, Devonian-Carboniferous successions are found in limited areas, but their distribution is more extensive and widespread in eastern and central Alborz and central Iran (Wendt et al. 2005). However, the presence of these deposits in different structural blocks with different depositional environments have led to different sedimentary sequences, facies and bio-fauna (Ashuri 1990, 1997, 1998, 2001, 2002, 2004, 2006; Bahrami et al. 2011; Habibi et al. 2008; Sardar Abadi et al. 2015; Yazdi 1999, Yazdi and Turner 2000; Wendt et al. 2002, 2005).
The main purposes of this study are to summarize a detailed stratigraphy below and above the D/C boundary in the Til-Abad section on the basis of conodonts according to new global zonation.

Material &Methods
During field work, 467 m of the Upper Devonian–Lower Carboniferous successions at Til-Abad section has been measured and samples and about 93 conodont samples (3–4 kg each) were collected. The samples were processed with diluted acetic/formic acid (20%). The conodonts were extracted from residues by hand picking and heavy liquid technique at the University of Isfahan, I.R. Iran and also State Museum of Natural History Stuttgart, Germany.

Discussion of Results &Conclusions
Tilabad Abad section is located about 85 km from Shahrud city, near Shahrud–Azadshahr Road, adjacent to Til-Abad village in East Alborz structural zone. Geographical coordinates of the base and top of this studied section are: N: 36° 55' 46.58", E: 55° 26' 54.07" base and, N: 36° 55' 46.58", E: 55° 26' 54.07" top. This section includes Late Devonian uppermost sediments of Khoshyeilagh Formation (322 m thick) and the lowermost Carboniferous of Mobarak Formation (145 m thick), which is subdivided into eight lithological units (units A to H).
The conodont zonation scheme proposed by Corradini et al. (2016) and Spalletta et al. (2017) for the Upper Devonian and Lower Carboniferous strata were utilized for lower part of the Til-Abad section in this study. According to these conodont zonations, *Protognathodus kuheni* is considered as the base of the Carbonoferous. However, due to the lack of *Protognathodus* in the Til-Abad section, we used conodont zonations of Kaiser et al. (2009) to define D/C boundary based on the appearance of *Siphonodella praesulcata* and *Siphonodella sulcate*. TheZiegler and sandberg (1990) biozones were used for the highest part of this section. Totally seven bio-intervals have been discriminated in the Til-Abad section: *Bi. aculeatus aculeatus* Zone, *Bi. costatus* Zone, *Bi. ultimus* Zone, The ?*praesulcta* Zone, The *Costatus-kockeli interregnum (CK*I), and the *sulcata* Zone, *typicus* Zone, *anchoralis- latus* Zone. It should be noted that in the studied section in the strata about 41.5 m thick consisting of dark gray to shale, yellow to cream, yellow shale with layers of gray to brown limestone, no conodont fossils were found between *Siphonodella sulcata* biozone and *typicus* biozone. Therefore, the biozones of *duplicata, Sandbergi*, Lower *crenulata, isosticha*-Upper *crenulata* cannot be recovered between *siphonodella* sulcata and *typicus* zones. This distance is considered equivalent to the barren zone. The reason for the lack of these biozones may have been due to facies changes or tectonic structures such as faults in the area. Despite intensive sampling in this study, no latest Famennian *kockeli* Zone was recognized at the studied section implying the presence of disconformity and discontinuity of deposition.

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