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THE EARLY-MIDDLE PALEOZOIC VOLCANISM AND GEODYNAMIC EVOLUTION OF THE HERLEN MASSIF, CENTRAL PART OF THE CAOB: CONSTRAINS FROM GEOCHEMISTRY, U-PB GEOCHRONOLOGY, LU-HF AND RB-SR ISOTOPES OF VOLCANIC ROCKS

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Mongolia lies in the central part of the Central Asian Orogenic Belt [*Mossakovsky et al., 1994; Zorin, 1999; Jahn, 2004; Khain et al., 2003; Badarch et al., 2002; Windley et al., 2007; Zhang et al, 2008*], or Altaids [*Şengör et al., 1993; Şengör, Natal'in, 1996; Wilhem et al., 2012*], which is fringed by the Siberian craton in the north and by the Tarim and Sino-Korean Cratons in the south. According to the recent tectonic subdivision, the territory of Mongolia is subdivided into Northern and Southern domains which are separated by the so called Mid Mongolian Tectonic Line [*Tomurtogoo, 2012*]. The Herlen Massif is one of the important tectonic units of the South Mongolian domain in the Argun-Idermeg super terrane extending through the territories of Russia and China [*Parfenov et al., 2009; Tomurtogoo, 2014b*]. The Herlen massif, also known as Herlen superterrane [*Tomurtogoo, 2012*] or Idermeg terrane [*Tomurtogoo, 2014a*] is composed of Ereendavaa, Undur-Khaan, Idermeg and Gobian Altay-Baruun Urt terranes converged at the end of the Cambrian-beginning of the Ordovician [*Badarch et al., 2002; Tomurtogoo, 2014b*].

The Ereendavaa terrane is situated in extreme northeast and contains metamorphic rocks of Paleoproterozoic and Mesoproterozoic Khaychin-gol and Ereendavaa formations overlying by Late Neoproterozoic-Early Cambrian formations [*Marinov et al., 1973; Blagonravov et al., 1990; Dorjnamjaa, Bat-Ireedui, 1991; Byamba, 1991; Dorjnamjaa et al., 2011; Tomurtogoo, 2012*]. Lower Paleozoic granitoids and Late Ordovician to Late Carboniferous marine sedimentary and terrigenous-volcanic rocks widely distribute in this terrane [*Tomurtogoo, 2012*].

In this paper, we present new geochronological, geochemical and isotopic data for the Late Neoproterozoic-Early Cambrian volcanic rocks from Tsarigiin gol area, southern part of Ereendavaa terrane in order to examine their formation time, petrogenesis and tectonic environment.

The Tsarigiin gol area is located in the south of the Ereendavaa terrane, bordered by the Undurkhaan terrane in the southeast. Middle to Upper Neoproterozoic Zamttolgoi metamorphic complex, mainly composed of gneiss, various schists, quartzite, and minor amphibolite, are the oldest stratum in this area [*Narantsetseg et al., 2015*]. The Zamttolgoi metamorphic complex is overlain by the thin basal conglomerate and schistose sandstone, followed by volcanic successions erupted at Lower Paleozoic [*Kalimulin et al., 1968; Chongradi et al., 1985*], or Neoproterozoic-Early Cambrian [*Makhbadar, Delgertsogt, 1990*] without precise dating and detailed geochemical data.

The 2000–3500 m thick volcanic strata is well exposed around the Undurkhaan Mountain in the Tsarigiin gol area. Three sections were identified. Section I is a rhyolitic composition, and consists of only felsic volcanic rocks. Section II is characterized by intermediate to felsic volcanic rocks which were intensively subjected to green schist facies metamorphism. Section III has a bimodal distribution and is composed of mainly felsic and minor mafic volcanic rocks.

A subset of 18 samples was collected from I–III sections to obtain mineralogical and geochemical characteristics of volcanic rocks Tsarigiin gol area in the Ereendavaa terrane. A total of 3 rhyolite samples were dated by LA-ICPMS, two of them were analyzed for Hf isotopic compositions. Also, Sr and Nd isotopic compositions of one mafic and three intermediate volcanic rock samples were used for this study.

Zircons from rhyolite samples previously believed to be Neoproterozoic-Early Cambrian, are euhedral-subhedral in shape and show fine-scale oscillatory growth zoning and high Th/U ratios ranging between 0.47 and 1.24, indicating a magmatic origin. LA-ICPMS zircon U-Pb dating indicate that the volcanic activity in the southern part of Ereendavaa terrane took place in two stages: Late Ordovician (~462–455 Ma), and Early Devonian (~418 Ma) instead of Neoproterozoic-Early Cambrian or Lower Paleozoic. The Late Ordovician volcanic rocks are intermediate to felsic in composition, and characterized by an enrichment of the LILE and LREE and depletion of HFSE, accompanied by positive $\varepsilon_{Hf}(t)$ and $\varepsilon_{Nd}(t)$ values and slightly negative $\varepsilon_{Hf}(t)$ values. Early Devonian volcanic rocks display a typical bimodal distribution in composition with dominant rhyolite and minor trachybasalt and basaltic trachyandesite. Basalts are medium K-calk-alkaline, whereas felsic end member is high K-calk-alkaline and display the geochemical characteristics of A2-type granites and characterized by mostly negative $\varepsilon_{Hf}(t)$ and $\varepsilon_{Nd}(t)$ values. The geochemical similarities of Late Ordovician and Early Devonian volcanic rocks are implying that magmas were generated at subduction zone which is consistent with the geology of area. But, spatial and temporal distribution of volcanic rocks and their different composition together with some geochemical characteristics are indicating that these rocks were originated in different tectonic setting. The Late Ordovician volcanic rocks probably formed in continental arc setting developed in active continental margin, by extensive fractional crystallization of basaltic magmas with minor involvement of Mesoproterozoic continental crust, whereas Early Devonian bimodal volcanic rocks occur in post collisional extensional rift setting. Basalts were derived from high degrees partial melting of lithospheric mantle and the felsic rocks may derived by partial melting of crustal material with involvement of juvenile mantle materials.

Combined our new data, a Neoproterozoic to Paleozoic tectonic evolution model of southern part of Ereendavaa terrane can be set. Neoproterozoic to Late Ordovician, active continental margin setting developed in the southern part of Ereendavaa terrane and northwestward subduction (present coordinates) of Undurkhaan oceanic plate beneath the Ereendavaa continental terrane took place with medium to high-K calc-alkaline volcanic eruption in the Tsarigiin gol area. In the Late Silurian, Ereendavaa and Idermeg terranes collided, and the post collisional Early Devonian bimodal volcanic association with A2-type felsic end-members distributed in the southern margin of Ereendavaa terrane.

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