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Paleomagnetism of upper Ediacaran clastics from the South Urals: Implications to paleogeography of Baltica and the opening of the Iapetus Ocean

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ABSTRACT

The progress in understanding the evolution of the Earth during the Ediacaran–Cambrian is greatly hindered by the scarcity and inconsistency of paleomagnetic data for this time interval. In order to acquire new data and clarify the confusing situation, Upper Ediacaran clastic rocks of the Basu Formation were sampled at several localities in the westernmost parts of the South Urals that is the deformed margin of Baltica at least since the beginning of the Neoproterozoic. With the aid of stepwise thermal demagnetization, a dual-polarity high-temperature component (HTC) was reliably isolated from gray and maroon sandstones and siltstones at 34/49 sites. The HTC mean direction D° = 55, inclination I° = −35 (k = 31, α_{95}° = 4.5) corresponds to a paleolatitude of 19° ± 3°. The reversal and fold tests are positive for the HTC. The slump test on two meter-sized slumps shows that the HTC predates slumping in one case and is coeval with it, in the other, thus convincingly indicating the primary origin of the HTC. Also, we demonstrate that inclination shallowing is either absent altogether, or, at worst, less than 10°, in these rocks; hence the position of Baltica can be reliably reconstructed for time 560–575 Ma. We reviewed paleomagnetic data with ages from 615 to 530 Ma for Baltica and Laurentia and come to the conclusion that there is still no uncontestable scenario for the opening of the Iapetus Ocean that is based on non-controversial geologic and paleomagnetic data.

1. Introduction

The Ediacaran–Early Ordovician interval is one of the most intriguing epochs of geologic time. The onset of the Ediacaran corresponds to the approximate end of the so-called "Snowball glaciations" and the terminal Ediacaran (~542 Ma) is followed by a great radiation of life forms commonly referred to as the "Cambrian Explosion". It has been argued that Ediacaran–Cambrian time period was also a time where continents underwent rapid changes in their latitudinal positions due to unusually rapid plate motions (Meert et al., 1993), inertial interchange true polar wander (Kirschvink et al., 1997), true polar wander (Evans, 1998) or interactions with superplumes (Meert and Tamrat, 2004). Abrajevitch and Van der Voo (2010) argue that the seeming complexities of continental motion in the Ediacaran–Cambrian are the result of the geomagnetic field switching between a dominant axial dipole field and an equatorial dipole field. These changes may be interrelated and connected, at least in part, to the distribution of continents across the globe.

The chief tool in deciphering paleogeography is paleomagnetism, and there are numerous attempts to provide a robust Ediacaran–Cambrian paleogeography using paleomagnetic data. Yet, it is precisely the Ediacaran–Cambrian time period (~635–488 Ma) where the paleomagnetic data are the most controversial (Meert et al., 1998; McCausland et al., 2007; Meert et al., 2007; Pisarevsky et al., 2008; Abrajevitch and Van der Voo, 2010; Meert, 2014). The problems are particularly acute for Laurentia and Baltica; most probably because they have the largest dataset.

There are very few, if any, Cambrian–Ediacaran targets on the platform of Baltica that are suitable for paleomagnetic studies and remain unstudied. However, there is a nearly thousand-kilometer-long band of Neoproterozoic and Ediacaran rocks in the western part of the South and Middle Urals along the Baltica margin (Fig. 1a). In particular, a nearly 2 kilometer thick Ediacaran terrigenous sequence is located in the South Urals (Stratotype of the Riphean: Stratigraphy, Geochronology, 1983; Bekker, 1988). These para-autochthonous units offer an opportunity to obtain new paleomagnetic data for the Ediacaran of Baltica. Because the units are considered to be para-autochthonous, the rocks must yield high-quality paleomagnetic results (including the age of the rocks) that can be evaluated for post-remanent rotations and translations with respect to the craton.

The western parts of the Uralian fold belt are similar to those of cratonic Baltica. In particular, a more than 10 km thick succession of

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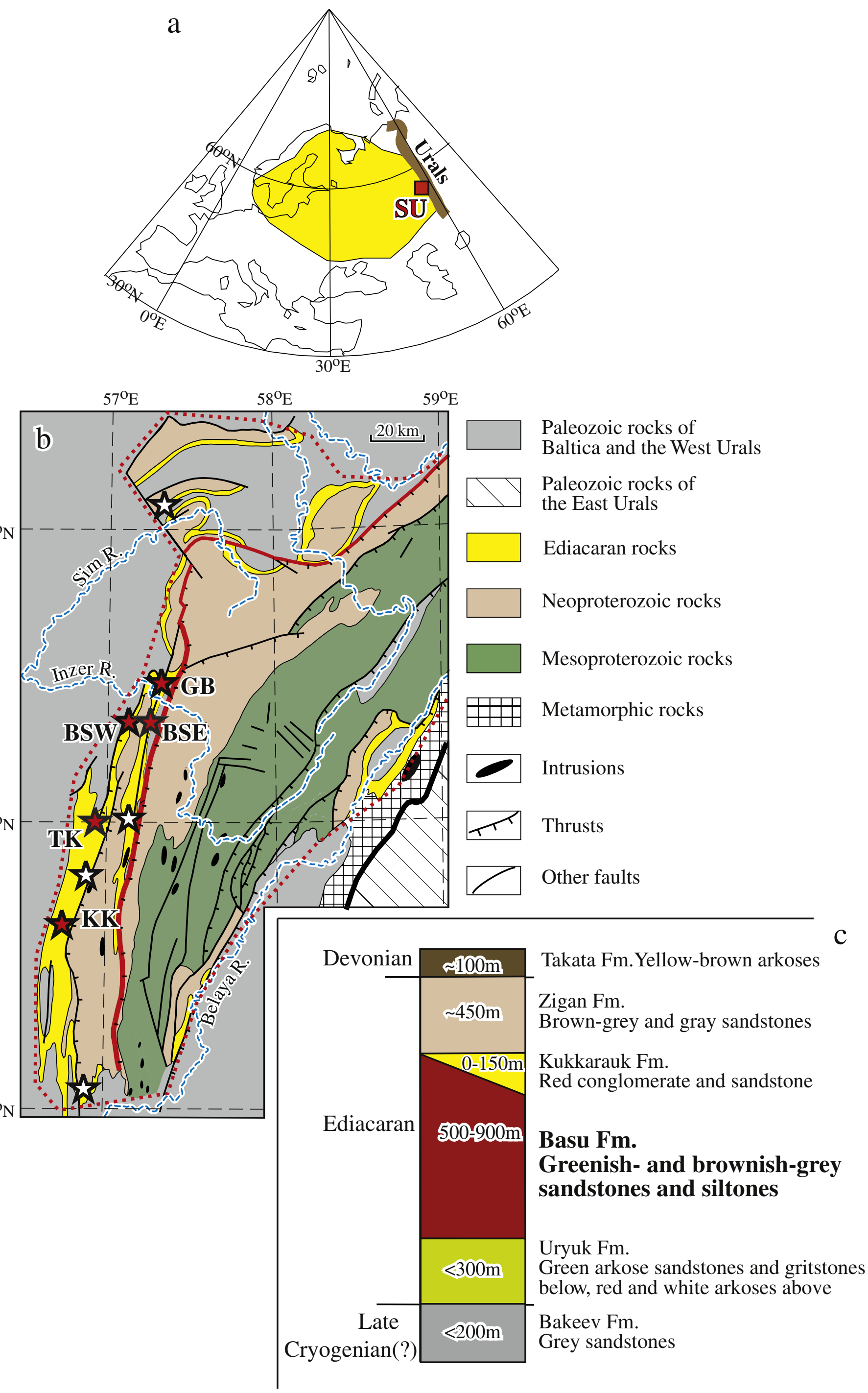

Fig. 1. (a) Location of the Baltica block with Precambrian basement (shaded), the Urals (brown band), and the study area in the South Urals (SU, red square). (b) Schematic map of the SW Urals with the limits of the Bashkir Anticlinorium (Uplift) shown as thick dotted line (simplified after Kozlov, 2002). The thickest red line denotes the Zilmerdak Fault, to the west of which Ediacaran rocks are overlain by Paleozoic rocks without angular unconformity. Thick black line is the Main Uralian Fault. Red stars denote the sampling localities numbered as in the text and Table 1, where the Upper Ediacaran Basu Formation was studied; white unlabeled stars denote localities, where no consistent results were obtained. (c) Simplified stratigraphic column of the Ediacaran sequence of the SW Urals.

Mesoproterozoic and Neoproterozoic mostly sedimentary rocks is exposed in the Bashkir anticlinorium (Uplift) in the western South Urals (Fig. 1b). This succession is reliably correlated with sections in the Ural Foredeep and the eastern parts of Baltica sensu stricto. Correlation is further supported by a series of matched seismic profiles (Stratotype of the Riphean: Stratigraphy, Geochronology, 1983; Puchkov et al., 2001). Although eastward-dipping seismic boundaries under the Bashkir Uplift are interpreted as the consequence of westward thrusting of the Uralian units over the craton in Permian time (Puchkov et al., 2001), the inferred transport along the thrusts is not considered to be significant. In light of this, these units are considered to be part of the Baltica deformed margin since the early Neoproterozoic (~1 Ga; Puchkov, 2003).

Exposed within the Bashkir Uplift is a nearly 10 kilometer thick succession of Mesoproterozoic and Neoproterozoic age clastic sediments and carbonates with subordinate Mesoproterozoic volcanics (Stratotype