Precambrian Research 256 (2015) 170–188

Contents lists available at ScienceDirect

Precambrian Research

journal homepage: www.elsevier.com/locate/precamres

Petrology, mineralogy and geochemical climofunctions of the Neoproterozoic Baltic paleosol

Sirle Liivamägi[a,*], Peeter Somelar[a], Ilze Vircava[a], William C. Mahaney[b], Juho Kirs[a], Kalle Kirsimäe[a]

[a] University of Tartu, Department of Geology, 50411 Tartu, Estonia
[b] Quaternary Surveys, 26 Thornhill Ave., Thornhill, Ontario, Canada L4J1J4

ARTICLE INFO

Article history:
Received 3 June 2014
Received in revised form 7 October 2014
Accepted 2 November 2014
Available online 13 November 2014

Keywords:
Neoproterozoic
Paleosol
Baltica paleocontinent
Weathering

ABSTRACT

The Oxisolic Baltic paleosol is a well preserved Neoproterozoic weathering sequence located in the Russian Platform of the East-European Craton, former Baltica continent. The Baltic paleosol is developed on different host rock types ranging from amphibolites and metagabbros to gneissic rocks and is characterized by up to several metres of thick weathered uppermost residuum composed of kaolinite (>60%), Fe-oxyhydroxides and residual quartz. The mineral index of alteration (MIA) and molecular weathering indices (CIA, CIA – K, PIA) all indicate strong and deep weathering most likely under warm and humid climate. Geochemical climofunctions, although not directly applicable to the Precambrian Baltic paleosol, agree with this interpretation suggesting high mean annual temperatures (>17 °C) and precipitation (1300–1800 mm yr^{-1}) similar to modern day tropical conditions. The age of the weathering is between 560 and 600 Ma. During that time interval the Baltica continent was not drifting at tropical latitudes, but it is plausible that the Baltic paleosol was formed as a consequence of increased weathering rates during greenhouse event(s) possibly related to the termination of the Ediacaran Gaskiers and/or Fauquier glaciations, or in the relation to the Shuram–Wonoka isotope excursion. The Baltic paleosol is most likely one of the few well preserved examples of paleosol formation in the latest Neoproterozoic because it developed in a tectonically stable interior of the Baltica paleocontinent while physical denudation prevailed on other continental blocks due to the build-up of Gondwana that erased weathering profiles from the geological record.

© 2014 Elsevier B.V. All rights reserved.

1. Introduction

Paleosols, unlike marine sedimentary records, are formed in direct contact with episodic environmental conditions that prevail at the time of their formation (Sheldon and Tabor, 2009). They are valuable proxies for reconstructing paleoenvironmental and paleoclimatic conditions, especially with respect to the evolution of Early Earth. Paleosols formed at the Archaean–Proterozoic and Proterozoic–Palaeozoic transition are of special interest for the evolution of atmospheric oxygen in symbiosis with bioevolution (Campbell and Squire, 2010; Och and Shields-Zhou, 2012). Paleoweathering patterns are not time-sensitive indicators of environmental changes and result from the complex interplay between several independent factors. However, they still provide a basis for understanding past conditions (e.g., Sheldon and Tabor, 2009; Nordt and Driese, 2010b).

The Proterozoic–Phanerozoic transition between 1000 and 500 Ma is marked by the final oxygenation of the atmosphere, global glaciation events, disturbances in the global C-cycle and onset of eukaryotic diversification with the emergence of animal life (Holland, 2006; Gaidos et al., 2007; Hoffman et al., 1998; Harland, 2007; Pierrehumbert et al., 2011), but the mechanisms behind these major milestones are still debated (e.g., Canfield et al., 2007; Johnston et al., 2012). The Proterozoic–Phanerozoic boundary is marked by a widespread stratigraphic unconformity (Great Unconformity *sensu*; Peters and Gaines, 2012) found in all major continents of that time – Avalonia, Baltica, Gondwana, Laurentia and Siberia (Avigad et al., 2005; Brasier, 1980; Peters and Gaines, 2012). Formation of the Great Unconformity also denotes a significant and intriguing change in mineralogical evolution on Earth (Hazen et al., 2008, 2013). It is evident that this large-scale weathering episode and consequent reworking of weathering products in a continental-scale marine transgression of the Phanerozoic, as

* Corresponding author. Tel.: +372 737 6689.
E-mail address: sirle.liivamagi@ut.ee (S. Liivamägi).

http://dx.doi.org/10.1016/j.precamres.2014.11.008
0301-9268/© 2014 Elsevier B.V. All rights reserved.

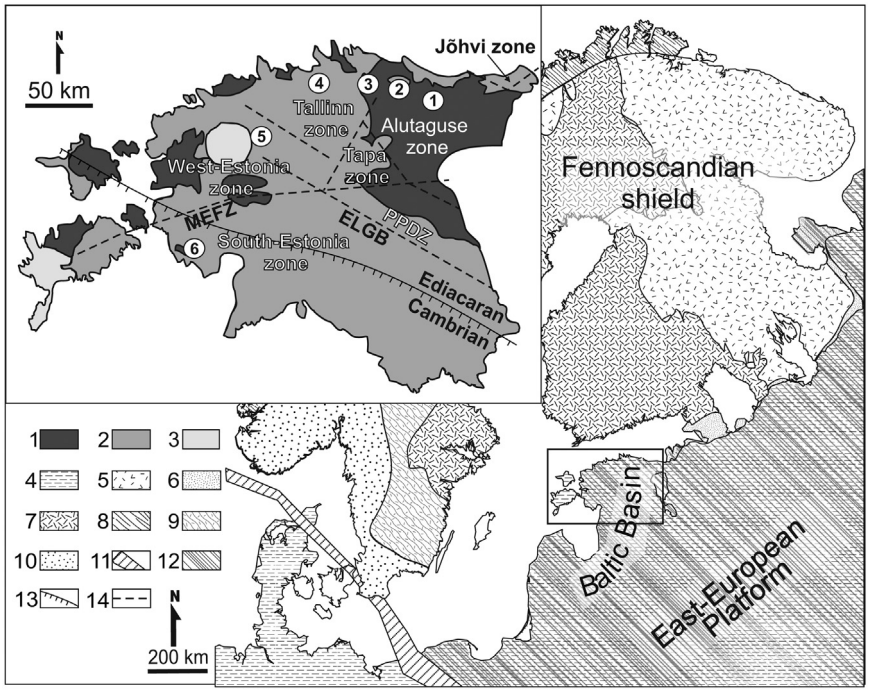

Fig. 1. Simplified geological setting of the crystalline basement of the study area and locations of studied profiles: 1, Varja (F195); 2, Pada-Aru (F185); 3, Nudi (F266); 4, Sigula (F124); 5, Lohu (F280) and 6, Varbla (502). Legend: 1 – metasedimentary rocks; 2 – metavolcanics; 3 – rapakivi granites; 4 – Phanerozoic; 5 – Archaean; 6 – Ediacaran; 7 – Svecofennian Domain; 8 – Caledonides; 9 – Transscandinavian Igneous Belt; 10 – Sveconorwegian Domain; 11 – Tornquist Line; 12 – distribution of the Baltic paleosol; 13 – boundary between overlying Ediacaran and Cambrian sediments. 14 – shear or thrust zones. PPDZ – Paldiski-Pihkva Deformation Zone; MEFZ – Middle Estonian fault Zone; ELGB – Estonian–Latvian Granulite Belt.

evidenced for example also by mass-production of first-cycle mature Cambrian–Ordovician quartz sand at Pan-African margins (Avigad et al., 2005), had a profound influence on seawater chemistry and global biogeochemical cycling, and it may have been an environmental trigger for the evolution of biomineralization (Peters and Gaines, 2012).

One of the reasons behind the formation of globally recognized Precambrian denudation-weathering surfaces is possibly rooted in the climatic variability of the Neoproterozoic characterized by periodically cool climate reaching snowball glaciation states (Harland, 2007). During snowball glacial periods the CO_2 concentration reaching 400–600 times the present atmospheric level (PAL; Pierrehumbert, 2004) was accumulating in atmosphere, eventually attaining super greenhouse conditions that triggered avalanching deglaciation followed by rapid deposition of chemogenic "cap" carbonates superposed on glacigenic sediments. This is explained by an intensified alkalinity flux into sea basins as the result of boosted continental weathering, subsequently causing drawdowns of atmospheric CO_2 (e.g. Ridgwell et al., 2003; Pierrehumbert et al., 2011).

These well-defined warm-humid periods punctuating glacial periods are also evidenced by a strong increase in chemical weathering indices in nonglacigenic marine successions subsequent to deposition of Neoproterozoic glacigenic sedimentary rocks (Rieu et al., 2007a,b). However, continental equivalents of these deep weathering and denudation events are not known, mostly because the paleosols have a low preservation potential (Retallack, 1992; Sheldon and Tabor, 2009; Sandler et al., 2012) and as typical for all Precambrian paleosols the Precambrian Great Unconformity itself is preserved as a continental denudation surface, with the weathering crust rarely preserved.

A well preserved and unmetamorphosed Neoproterozoic Baltic paleosol formed on the crystalline basement of the Baltic Basin in Estonia, Latvia, Lithuania and NW Russia is possibly one of the few preserved examples of paleosol morphogenesis in that critical time in Earth history (Liivamägi et al., 2014). The Baltic paleosol is buried under the Ediacaran–Paleozoic sedimentary cover being accessible only in drillcores and is characterized by a zonal alteration profile reaching tens of metres in depth. It is the aim of this paper to study the petrology, mineralogy and geochemistry of the Baltic paleosol profiles to determine, firstly, weathering intensity and alteration paths across the area and distribution of alteration phases in the weathering profiles; and secondly, to model geochemical climofunctions to determine environmental conditions at the time of weathering.

2. Geological setting

The study area is located in the NW part of the Russian Platform of the East-European Craton, at the southern margin of the Baltic Shield, Estonia (Fig. 1). The peneplain of the crystalline basement and sedimentary formations on top of the basement are gradually sloping by 2–4 m km^{-1} towards the south to a depth of about 100 m in North Estonia and >700 m in northern Latvia.

The Paleoproterozoic crystalline basement in Estonia represents a crustal segment of 1.7–1.9 Ga old Svecofennian Domain (Puura and Huhma, 1993; Kirs et al., 2009) composed of metasedimentary–metavolcanic rocks regionally metamorphosed in amphibolite-to-granulite (with some retrograde changes) facies conditions and intersected by Paleo-Mesoproterozoic (1.6–1.4 Ga) anorogenic plutons of rapakivi granites (Fig. 1) (Haapala et al., 2005; Kirs et al., 2009).

The metamorphosed and migmatized amphibolite facies Svecofennian orogenic rocks of northern Estonia are divided into the Tallinn Zone (NW Estonia) amphibolites, biotite–amphibole gneisses and the Alutaguse Zone (NE Estonia) high-alumina gneisses with Tapa block amphibolites and biotite–amphibole gneisses between them. In the northeastern part of the Alutaguse zone small E–W trending Jõhvi zone consisting of

Download English Version:

https://daneshyari.com/en/article/4722911

Download Persian Version:

https://daneshyari.com/article/4722911

Daneshyari.com