Gondwana Research 35 (2016) 305–322

Contents lists available at ScienceDirect

Gondwana Research

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

The De Long Islands: A missing link in unraveling the Paleozoic paleogeography of the Arctic

Victoria B. Ershova [a,b,*], Henning Lorenz [c], Andrei V. Prokopiev [d], Nikolay N. Sobolev [a], Andrei K. Khudoley [a,b], Eugeny O. Petrov [a], Solveig Estrada [e], Sergey Sergeev [a,b], Alexander Larionov [a], Tonny B. Thomsen [f]

[a] All Russian Geological Institute, Sredniy Prospect 74, Saint Petersburg 199106, Russia
[b] Institute of Earth Science, St. Petersburg State University, Universitetskaya nab. 7/9, St. Petersburg 199034, Russia
[c] Uppsala University, Department of Earth Sciences, Villavägen 16, 752 36 Uppsala, Sweden
[d] Diamond and Precious Metal Geology Institute, Siberian Branch, Russian Academy of Sciences, Lenin Prospect 39, Yakutsk, 677980, Russia
[e] Federal Institute for Geosciences and Natural Resources (BGR), Stilleweg 2, 30655 Hannover, Germany
[f] Geological Survey of Denmark and Greenland (GEUS), Department of Petrology and Economic Geology, Øster Voldgade 10, 1350 Copenhagen, Denmark

ARTICLE INFO

Article history:
Received 28 December 2014
Received in revised form 16 May 2015
Accepted 18 May 2015
Available online 26 June 2015

Handling Editor: A.R.A. Aitken

Keywords:
De Long Islands
New Siberian Islands
Arctic
Early Paleozoic
Paleogeography

ABSTRACT

The vast Laptev and East Siberian shelves in the eastern Russian Arctic, largely covered by a shallow sea and buried beneath sea ice for 9 months of the year, remain one of the least studied parts of continental crust of the Earth and represent a big unknown when performing pre-Cenozoic reconstructions of the Arctic. The De Long Islands provide an important window into the geology of this area and are a key for understanding the Early Paleozoic history of the Amerasian Arctic. Four of them (Jeannette, Henrietta, Bennett and Zhokhov islands) were studied using structural data, petrographic and geochemical analyses and U–Pb zircon age dating to offer the following new constraints for the Early Paleozoic paleogeography of the Arctic realm. The basement beneath the De Long Islands is of Late Neoproterozoic to earliest Cambrian age, about 670–535 Ma. In the Early Paleozoic, the De Long Islands were located along the broad Timanian margin of Baltica, with a clastic sediment provenance from the Timanian, Grenville–Sveconorwegian, and Baltic Shield domains. The Cambro-Ordovician volcaniclastic successions on Jeannette and Henrietta islands formed part of a continental volcanic arc with a corresponding back-arc basin located to the south (in present co-ordinates). On the continent-ward side of the back-arc basin, shallow marine shelf clastic and carbonate rocks were deposited, which are exposed today on Bennett Island in the south-west of the archipelago (in modern coordinates). The De Long Islands together with other continental blocks, such as Severnaya Zemlya, Arctic Alaska–Chukotka, and the Alexander Terrane, formed the contiguous active continental margin of Baltica during the Early Paleozoic. Today however, these terranes are spread out over a distance of 5000 km across the Arctic and eastern Pacific margins due to the subsequent opening of a series of Late Paleozoic, Mesozoic and Cenozoic oceanic basins.

1. Introduction

Despite an increasing interest in the geology of the high Arctic region in recent years for its potentially significant volume of undiscovered hydrocarbon resources (Lane, 1997; Embry, 1998; Lawver et al., 2002; Miller et al., 2006; Lorenz et al., 2008; Amato et al., 2009; Miller et al., 2010; Colpron and Nelson, 2011; Lemieux et al., 2011; Anfinson et al., 2012a,b; Beranek et al., 2012; Ershova et al., 2013,; Lorenz et al., 2013; Prokopiev et al., 2013; Ershova et al., 2015a,b,c) the Russian Arctic shelves remain little studied. Geological studies here are particularly problematic as these shelves are covered by extensive shallow seas, which are frozen for 9 months of the year. As a consequence of lacking infrastructure and the remote location, deep offshore drilling is expensive and difficult and hence deep wells were not drilled to date. The scattered islands which expose small segments of the shelves are the main source of geological information, offering discrete windows into the geology of this frontier region and key-information for piecing together the enigmatic geological history of the Eurasian high Arctic. One of these high Arctic archipelagos, the New Siberian Islands, is located in the eastern part of the Russian Arctic on the border between the Laptev and East Siberian seas and exposes Paleozoic and Mesozoic strata (Fig. 1). This archipelago consists of three island groups: the Anzhu Islands (Kotel'ny, Bel'kovsky and Novaya Sibir islands) in the center, the Lyakhovsky Islands in the south close to the Siberian mainland (Malyi Lyakhovsky and Bolshoy Lyakhovsky islands), and the small De Long Islands in the far north (Jeannette, Henrietta, Bennett, Zhokhov and Vil'kitskiy islands).

* Corresponding author at: All Russian Geological Institute, Sredniy Prospect 74, Saint Petersburg 199106, Russia.
E-mail address: ershovavictoria@gmail.com (V.B. Ershova).

http://dx.doi.org/10.1016/j.gr.2015.05.016
1342-937X/

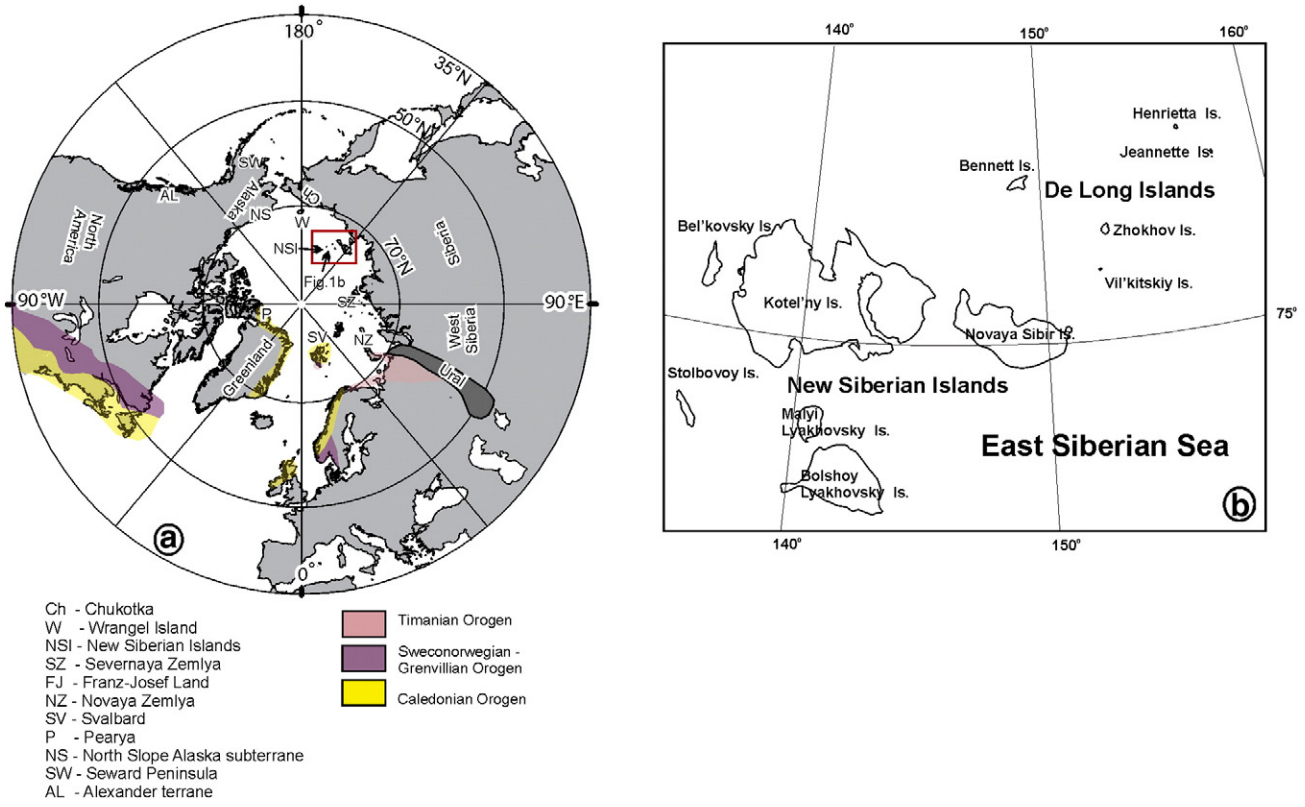

Fig. 1. (a) Regional setting of the study area; (b) sketch map of New Siberian Islands Archipelago. Modified after Colpron and Nelson (2011).

The New Siberian Islands were extensively studied 30–40 years ago by Kos'ko et al. (1985), when the first geological maps were constructed. The few more recent studies were focused on the geology of the Anzhu Islands, which comprise the largest islands within the archipelago with the most extensive exposures (Meledina, 1999; Kos'ko and Trufanov, 2002; Kuzmichev, 2009; Ershova et al., 2015a,b and references therein). By contrast, comparatively few studies have focused on the small De Long Island group, with many aspects of their geological history still up for debate (Sobolev et al., 2014).

Zhokhov and Vil'kitsky islands are almost entirely covered by Cenozoic basalts and therefore offer a limited insight into the Paleozoic and Mesozoic geology of this part of the archipelago (Silantyev et al., 1991, 2004). By contrast, Paleozoic and Mesozoic strata are exposed on Jeannette, Henrietta and Bennett islands. An in-depth study of these deposits is important for understanding the history of the vast eastern Siberian shelves and, thus, for any plate tectonic reconstructions and paleogeographic inferences for the Arctic realm during the Paleozoic.

Bennett Island is the best studied within the island group, containing exposures of Cambrian–Ordovician sedimentary rocks (mainly carbonates) overlain by Early Cretaceous (Aptian–Albian) basalts (Vol'nov and Sorokov, 1961; Kos'ko et al., 1985; Drachev and Saunders, 2006; Kos'ko et al., 2013; Danukalova et al., 2014). Basic geological mapping was carried out on Henrietta Island during a single field excursion in the 1970s. The stratigraphic relationships between the strata were defined and a broad but debatable "Paleozoic" age was assigned (Vinogradov et al., 1975). Jeannette Island was visited be M.M. Ermolaev in the 1930s and almost no data appear to be available from this trip. The principle aim of this paper is to fill in these critical gaps in geological knowledge and present data and interpretations obtained from two expeditions to the De Long Islands carried out during the summers of 2011 and 2013.

Our primary objectives were to: (1) study the geological structure, (2) provide a description of the sedimentary rocks and determine their depositional environments, (3) study the provenance of the sedimentary succession by means of U/Pb geochronology of detrital zircons, (4) determine the age of the sedimentary successions of Henrietta and Jeannette islands, (5) date the various magmatic rocks that occur on the De Long Islands, and (6) therefore shed light on the paleogeographic history of the De Long Islands and broader Arctic realm.

2. Sampling and analytical procedure

2.1. U–Pb zircon dating

Detrital zircons of four sedimentary rock samples have been dated using the SHRIMP-II facility at VSEGEI (St. Petersburg), two samples using Cameca IMS 1280 (NORDSIM, Stockholm), four samples in LA-ICP-MS in Washington State University (Apatite to Zircon Inc.) and four at the Geological Survey of Denmark and Greenland (GEUS). Following Gehrels (2012), only analyses with discordance between 30% and -10% were used for the following interpretation. The analytical procedure and data tables are presented in Supplementary 1. U–Pb dating of magmatic rocks was carried out using the SHRIMP-II facility at VSEGEI (St. Petersburg) (six samples) and the Cameca IMS 1280 (NORDSIM, Stockholm) (two samples). $^{207}Pb/^{206}Pb$ ages are reported for >1.0 Ga grains and $^{206}Pb/^{238}U$ ages for ≤1.0 Ga grains.

2.2. Ar–Ar dating

The whole-rock fraction >200 μm of sample HL 11-014 was selected for $^{40}Ar/^{39}Ar$ incremental-heating dating performed by Activation