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NEOARCHEAN GABBROIDS OF THE SOUTHERN BUNDELKHAND TERRANE, BUNDELKHAND CRATON: NEW GEOCHRONOLOGY DATA AND GEODYNAMIC SETTINGS

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Mafic magmatism is an important indicator of large-scale thermal events associated with the involvement of the mantle. It is also common in Archean cratons, including those of the Indian Shield, and is used for correlation of endogenic activity in them. Distinguished in the Bundelkhand Craton, which is part of a northern group of Indian Shield cratons, is Archean mafic magmatism, which took place before Neoarchean (2.5 Ga) cratonization, and Paleoproterozoic magmatism. The Lalitpur group of gabbroic rock massifs, which has not been studied previously, was revealed in the western South Bundelkhand terrane of the Bundelkhand Craton. The gabbroic rocks are cut by Neoarchean granites and are, therefore, Archean. The massifs consist of leucocratic amphibole gabbro to diorite, and display coarse-grained structure but no signs of layering. The gabbro contains zircon occurring as semi-transparent to transparent pale-brown crystals of elongated prismatic habit. The grains are very coarse, varying in size from 200 to 500 μm. Mineral inclusions in the zircon are abundant. They consist of amphibole, pyroxene, plagioclase, quartz and apatite. The zircon grains were dated using the laser ablation method (LA-ICP-MS). The isotopic age of the late stage in the formation of the massifs is 2551 ± 5 Ma. Neither individual grains nor older cores in the zircon grains analyzed have been found. Thus, the age of the gabbroic rocks in the Lalitpur group of massifs is comparable with that of subduction volcanism in the Central Bundelkhand terrane. The geochemical features of the gabbroic rocks suggest that their formation is also associated with subduction geodynamics. The above mafic intrusions were probably formed in the suprasubduction zone of an active continental margin.

Keywords: Bundelkhand Craton; Indian Shield; Neoarchean; zircon; gabbro

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НЕОАРХЕЙСКИЕ ГАББРОИДЫ ЮЖНО-БУНДЕЛКХАНДСКОГО ТЕРРЕЙНА БУНДЕЛКХАНДСКОГО КРАТОНА (ИНДИЯ): НОВЫЕ ГЕОХРОНОЛОГИЧЕСКИЕ ДАННЫЕ И ГЕОДИНАМИЧЕСКИЕ СЛЕДСТВИЯ

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Основной магматизм является важным индикатором крупных термальных событий, связанных с вовлечением в петрогенезис мантии. Он обычен и в архейских кратонах, в том числе Индийского щита, и используется для корреляции проявления в них эндогенной активности. В пределах Бунделкхандского кратона, входящего в северную группу кратонов Индийского щита, выделяется архейский основной магматизм, проявлявшийся до неоархейской (2,5 млрд лет) кратонизации, и палеопротерозойский. В западной части Южно-Бунделкхандского террейна рассматриваемого кратона установлена ранее не исследованная Лалитпурская группа габброидных массивов. Эти габброиды секутся неоархейскими гранитами и, следовательно, относятся к архейским. Массивы сложены лейкократовыми амфиболовыми габбро до диоритов, характеризуются крупнозернистой структурой, признаков расслоенности в них не установлено. Габбро содержат цирконы. Они представлены прозрачными, полупрозрачными бледноокрашенными в коричневые тона кристаллами удлиненно-призматического габитуса. Зерна очень крупные, от 200 мкм, и некоторые достигают 500 мкм. Характерно большое количество минеральных включений в цирконе. Они представлены амфиболом, пироксеном, плагиоклазом, кварцем и апатитом. Датирование циркона проведено методом лазерной абляции (LA-ICP-MS). Изотопный возраст поздней магматической стадии становления массивов оценивается в 2551 ± 5 млн лет. Среди изученных цирконов не установлено ни отдельных зерен, ни ядер более древнего возраста. Таким образом, возраст габброидов Лалитпурской группы массивов сопоставим с таковым для субдукционного вулканизма в Центрально-Бунделкхандском террейне. С учетом геохимических особенностей габброидов их формирование также, вероятно, связано с субдукционной геодинамикой. Формирование рассмотренных основных интрузий, вероятно, происходило в надсубдукционной зоне активной континентальной окраины.

Ключевые слова: Бунделкхандский кратон; Индийский щит; неоархей; циркон; габбро

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Mafic magmatism is an important indicator of large-scale thermal events associated with the involvement of the mantle and its products into petrogenesis. It is an essential constituent of large igneous provinces (LIP) [Ernst, 2014]. It is also common in Archean cratons, including those of the Indian Shield, and is used for correlation of endogenic activity in them [Slabunov et al., 2024a].

The Indian Shield is a mosaic of cratonic blocks that divides the Central Indian tectonic zone into the Northern and Southern groups. The Western Dharwar, Eastern Dharwar, Singhbum and Bastar Cratons make up the southern group, and the Bundelkhand and Aravalli Cratons – the Northern Group (Fig. 1). The Bundelkhand Craton consists mainly of Neoarchean granites, with Paleo-to-Neoarcheane TTG-granitoids, amphibolites (Paleoarchean basic rocks), greenstone complexes, and layered mafic-ultramafic intrusions among them [Singh et al., 2021; Joshi et al., 2022]. The Bundelkhand Craton is further subdivided into the Northern-, Central- and Southern Bundelkhand terranes (Fig. 1) [Singh et al., 2021].

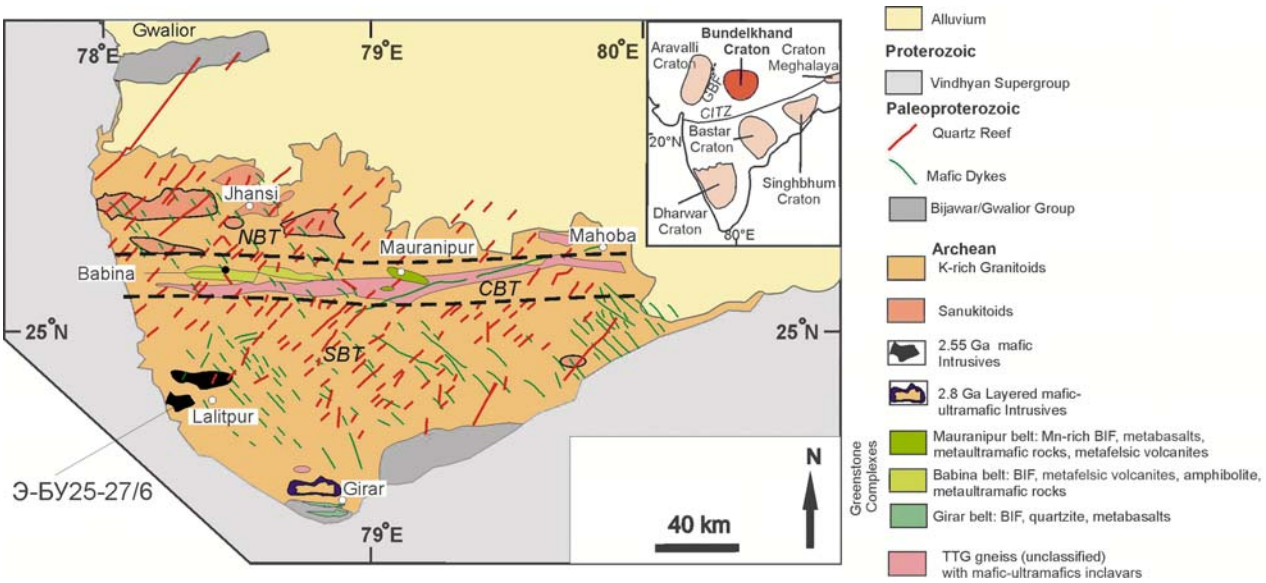

Fig. 1. Geological map of the Bundelkhand Craton [Singh et al., 2021; Slabunov et al., 2024b]. NBT, CBT, and SBT denote the Northern, Central, and Southern Bundelkhand terranes, respectively. The inset shows a tectonic map of the Indian Shield with the main cratons and Central Indian tectonic zone (CITZ)

Proterozoic mafic magmatism, represented by a system of dikes, is widespread in the craton [Pradhan et al., 2012]. Gabbroids and mafic-ultramafic intrusions are also common in the Southern Bundelkhand terrane (SBT) of the craton. The age of the large Ikauna mafic-ultramafic lopolith (Fig. 1) is 2798 ± 17 Ma [Slabunov et al., 2024a]. However, the age of the gabbroids near Lalitpur (Fig. 1) remains unknown.

The available geological record indicates that the gabbroic rock massifs in the western portion of the SBT are of Archean age, as they are crosscut by pink granites (Fig. 2, a) similar in composition to K-rich Bundelkhand granite.

The gabbroic rocks of the massifs exhibit coarse-grained to pegmatoid textures (Fig. 2, b), less commonly fine-grained textures, and correspond in composition to amphibole leucogabbro and normal-series diorites. Amphibole occurs as hornblende and actinolite, while plagioclase occurs as albite. Quartz, epidote and chlorite are also common (Fig. 2, c, d). Ore minerals include magnetite, ilmenite, titanite and minor pyrite. Apatite, zircon and rutile are present as accessories.

Zircon for geochronological studies was extracted from a 1 kg leucogabbro sample in the laboratory at the Institute of Geology, Karelian Research Centre RAS. Zircon was dated by LA-Q-ICP-MS using equipment provided by Y. Schmidt Institute of Physics of the Earth, RAS, Moscow: Agilent 7900 (quadrupole) mass spectrometer and MassHunter 5 software. Zircons 1) Plešovice ($^{206}Pb/^{238}U$ age – 337.1 ± 0.4 Ma) and 2) GJ-1 ($^{206}Pb/^{238}U$ – 601.9 ± 0.4 Ma, $^{207}Pb/^{206}Pb$ – 607.7 ± 0.7 Ma)

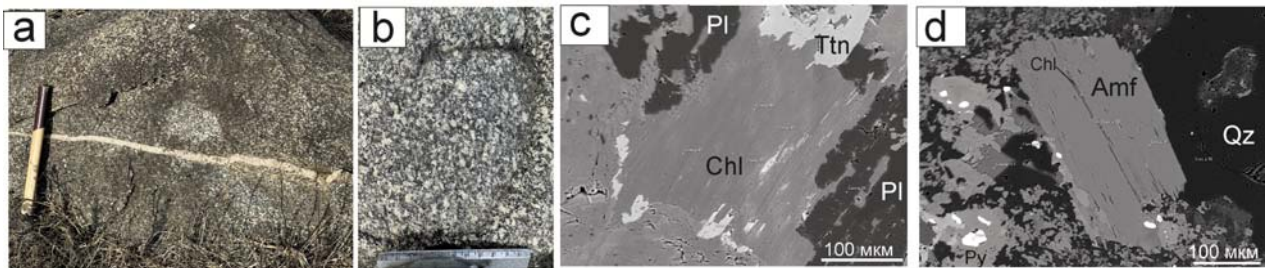

Fig. 2. Gabbroids of the Lalitpur Group of intrusions in outcrops (a, b) and thin sections (c, d):

a) Leucogabbro is cut by granite (scale: hammer handle 30 cm long); b) coarse-grained leucogabbro (scale: compass – 10 cm); c, d) BSE images of a leucogabbro thin section (Pl – plagioclase (albite), Amf – hornblende, Chl – chlorite, Qz – quartz, Ttn – titanite, Py – pyrite)

were used as standards. The median ages of the standards obtained during this study are the following: Plešovice – $^{206}Pb/^{238}U$ age – 339.1 ± 1.5 Ma; GJ-1 – $^{206}Pb/^{238}U$ – 605.5 ± 2.4 Ma, $^{207}Pb/^{206}Pb$ – 600.9 ± 22 Ma.

Zircons occur as transparent to semi-transparent, pale-brown elongate prismatic crystals (Fig. 3, a) ranging in size from 200 to 500 μm. Coarser crystals exhibit moderate to strong fracturing and contain abundant inclusions of amphibole (up to 150 μm), pyroxene, plagioclase, quartz, and apatite (Fig. 3, a). The distinctive internal structure of the zircons visible in translucent light was also observed when examining the zircons in BSE mode and cathodoluminescence (CL). Transparent portions of the grains show homogeneous structure in CL and well-defined zoning, while semi-transparent and opaque parts show heterogeneous CL patterns with mottled zoning. Most grains have non-transparent portions composed of metamict zircons. The features are characteristic of zircons from pegmatites, although similar textures also occur in gabbro [Volodichev et al., 2012].

The zircons were dated at 60 analytical points. Of these, 49 points showed a discordance of less than 2 % and corresponded to the age 2539 ± 3.4 Ma, based on the upper intercept with the Concordia curve. However, a more reliable age value for this group of zircons is estimated from 14 analytical points, enabling us to calculate a Concordia age of 2551 ± 5 Ma (Fig. 3, b).

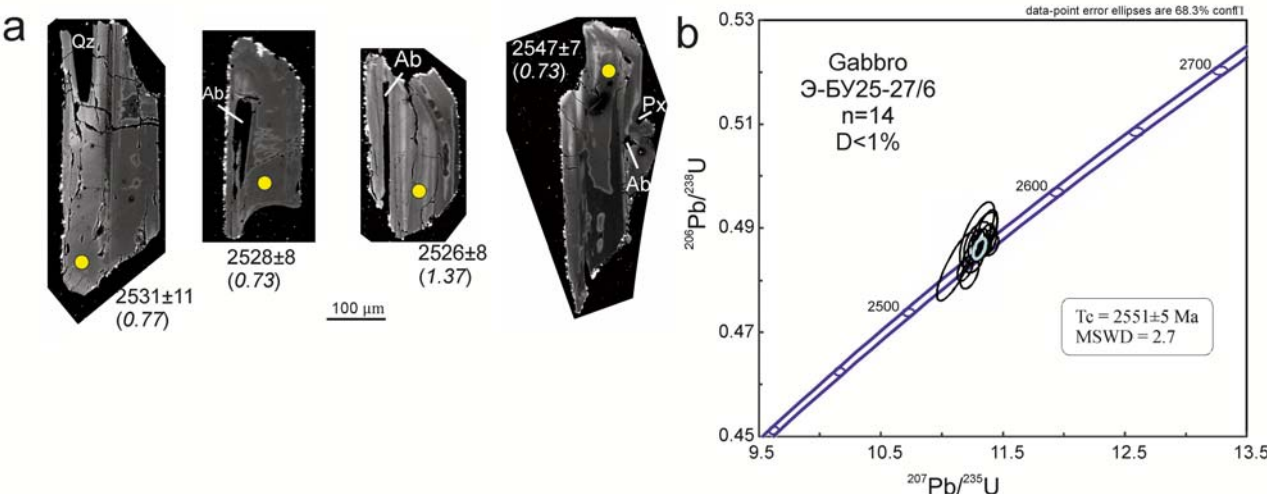

Fig. 3. Morphology and U-Pb age (by LA-ICP-MS) of zircon from gabbroids:

a) image of zircons in cathodoluminescence (CL) with the position of analytical points and their ^{207}Pb-^{206}Pb age values in Ma; shown in parentheses is Th/U ratio, with mineral inclusions (Ab – albite, Qz – quartz, Px – pyroxene); b) Concordia diagram (Tc – U-Pb Concordia age)

Thus, the age of Lalitpur-group gabbroic rocks is comparable to that of subduction-related volcanism, 2557 ± 33 – 2543 ± 17 [Singh, Slabunov, 2015; Slabunov, Singh, 2019], in the Central Bundelkhand terrane. Neither separate grains nor older cores were found in the zircons studied, in contrast to their presence in the Ikauna mafic-ultramafic lopolith [Slabunov et al., 2024a]. The geochemical signature of the gabbroic rocks, notably their low Nb and Zr contents, indicate their formation in supra-subduction zone of an active continental margin.

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