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GEOLOGY

# A New Type of Large-Scale Manifestation of Within-Plate Intrusive Trap Magmatism (West Siberian Craton)

**Yu. R. Vasil'ev, S. N. Prusskaya, and M. P. Mazurov**

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In terms of the manifestation of within-plate trap magmatism, the Siberian Craton (SC) is comparable only to the large-scale plateau basalt magmatism of oceans [1–3]. At the present-day erosion level, trap magmatism of the SC with a huge volume of rocks of different facies ($2.0 \times 10^6$ km$^3$ [4]) includes nearly equal proportions of volcanic and intrusive formations. Trap intrusive bodies (up to $500 \times 10^3$ km$^3$) are mainly confined to the western sector of the SC in the Tungus syneclise (near the Yenisei zone). The abundance of intrusive trap rocks in the study region was first noted by Sobolev [5]. The subsequent geological survey, prospecting, exploration, geophysical works, and particularly the drilling of numerous oil wells revealed that intrusive trap structures are extremely diverse in dimension, morphology, and mineral composition [6–9].

Analysis of the information obtained revealed the following specific features:

(1) Intrusions are located not only along flanks of negative structures (syneclises, depressions, and others), as was considered previously, but also over the entire region.

(2) The distribution of intrusions along the lateral and vertical sections of the sedimentary cover is very irregular (the amount of intrusions in the sedimentary cover can reach 70% in some boreholes).

(3) The intrusions are characterized by a wide range of variation in morphology and dimension (generally, layered intrusions with thickness varying from $n$ to $100n$ m). Various crosscutting dike-, arc-, and ring-shaped, as well as radial and stepwise, bodies also occur.

(4) Morphologically diverse intrusions make up large intricate multistage frameworks confined to rises of the basement and cover of the platform. Such structures are represented by basins of the Chupa, Chamba, Soba, and Bakhta rivers. Among them, an important place is occupied by the Oneka Uplift located in the northern sector of the Bakhta Ridge and investigated by several boreholes [10]. Trap intrusions of the Oneka Complex characterized by different volumes are confined to this sector with a 4.2-km-thick sedimentary cover (Fig. 1).

Rocks of the Oneka Complex (~40 000 km$^2$ in area) make up an uplift complicated by a terrace at the northern margin of the Bakhta Ridge. In general, the Oneka Complex of interrelated trap intrusions of variable dimension, morphology, and internal structure represent an intricate tectonomagmatic structure.

Areal drilling data and geological profiles based on these data demonstrate the morphological diversity of intrusions. For example, the northern part of the tectonic block under investigation incorporates a large near-surface intrusive chamber ($100 \times 100$ km in size) drilled to a depth of 1.5 km (Fig. 2). Offshoots from this central massif extend over 70 km. The central intrusive massif is surrounded by dikes in the region of Lake Oneka. Deep borehole sections show that the massif incorporates approximately 15 intrusions with a total thickness of 3.0 km. The sheeted bodies pass from one stratigraphic level to another level, pinchout, and split off into several small bodies. They have a specific framework-type structure: large blocks of sedimentary rocks are delineated by horizontal and vertical intrusions. Deep boreholes have penetrated up to 500-m-thick intrusions located at a depth of 2.8–3.5 km in the lower part of the sedimentary cover. Deep seismic sounding and drilling data suggest that this structure can include multistage magma chambers not only in the sedimentary cover, but also in the Earth's crust. According to our calculations, intrusive rocks of the Oneka Complex have a volume of ~50 000 km$^3$. Therefore, we identify this rock complex as a new type of large-scale manifestation of trap magmatism in the Siberian Craton.

*Institute of Geology and Mineralogy, Siberian Division, Russian Academy of Sciences, pr. akademika Koptyuga 3, Novosibirsk, 630090 Russia; e-mail: meimech@uiggm.nsc.ru*

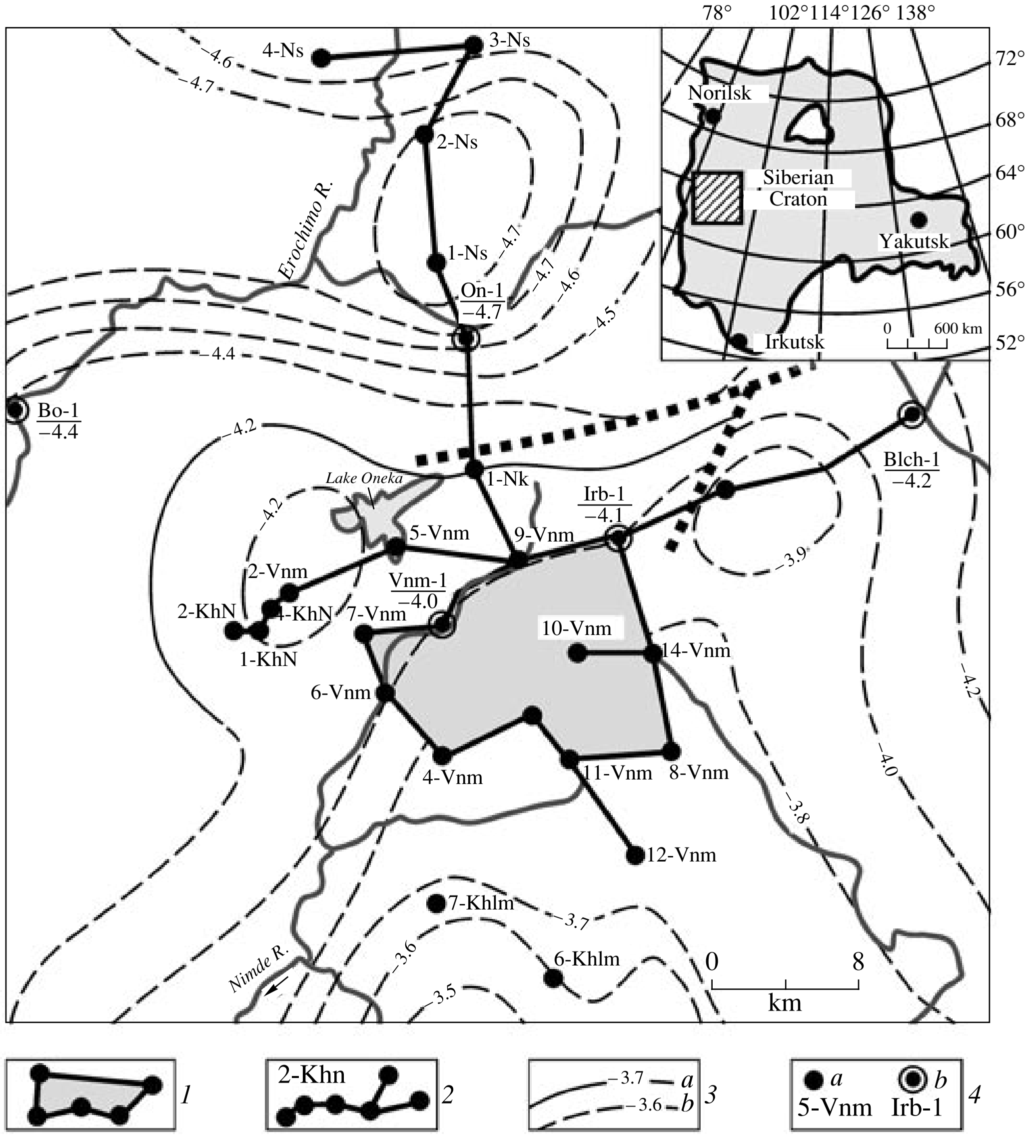


**Fig. 1.** Morphological contour of the Oneka intrusion in the sedimentary cover. (*1*) Contour of the intrusion in the sedimentary cover; (*2*) branches of the intrusion (based on borehole data); (*3*) isohypses (km) of the Lower Cambrian reflector horizon IV along the roof of the Platonov Formation (and its analogues): (*a*) proven, (*b*) inferred; (*4*) boreholes: (*a*) deep, (*b*) structural core drilling.

The numerous boreholes drilled on the Oneka Uplift are mainly represented by 1.2- to 1.5-km-deep prospecting-exploration boreholes. Therefore, intrusions located at such depths are best studied and reconstructed. We carried out a comprehensive petrological investigation of the near-surface central intrusion and revealed its distinct layered structure. This intrusive massif can be divided into three (upper, central, and lower) horizons of approximately equal thickness. They lack distinct boundaries and differ from each other in terms of the set of differentiates and their compositions.

The upper horizon located near the roof of the massif is mainly composed of leucocratic, taxitic, and trachytoid gabbrodolerites with gabbropegmatite schlieren. The thickness of this horizon varies from 180 to 490 m. The central horizon is dominated by olivine-bearing troctolitic and troctolitic-picritic gabbrodolerites with typical ophitic-coccolithic and taxitic-ophitic textures. The central horizon has a thickness of 440 m. The lower horizon located near the base of the massif is composed of olivine-bearing dolerites and olivine-free glomeroporphyric dolerites with rare schlieren of gabbrodolerites and microdolerites near the lower contact zone. The thickness of this horizon is 48 m or more. The variation diagram (Fig. 3A) presents the differentiation pattern of this massif in the section of borehole Gf-4. Figure 3B illustrates the distribution of normative compositions of mineral phases. One can see a distinct intrachamber differentiation of material along the steep and other lateral branches of the Oneka Massif [7].

The Oneka intrusive complex has been investigated by hundreds of chemical analyses of rocks. The samples were taken irregularly over the entire plutonic area and depth. Data on the average contents of the major oxides indicate that the primary melt was sufficiently enriched in Mg (~9.0 wt % MgO). The table shows that this value is close to the average MgO content in the central intrusion. Based on 115 analyses of rocks sampled from the best-studied sections, the MgO content in this body varies from 3.33 to 17.94 wt % (average 9.26 ± 2.68 wt %), suggesting a high degree of intrachamber differentiation. Comparison with the previously identified petrochemical types of intrusive trap rocks in the Siberian Craton [11] revealed that the primary melt for all rocks of the Oneka Complex was similar to the protolith for the western Siberian Craton in terms of the majority of rock-forming oxides. The contents of $TiO_2$, MgO, and $K_2O$ in the melt were similar to those in differentiated intrusions of the Norilsk–Kharaelakh province. Specific compositional features of the silicate and oxide mineral phases emphasize the evolution mode of the primary melt in the central intrusion and its offsets [12]. The silicate phases are characterized by a wide range of composition. In this respect, they are similar to the silicate phases from other differentiated intrusive trap rocks in the western Siberian Craton [7].

The mode of intrachamber differentiation, compositional variation, and quantitative proportions of mineral phases (olivine, pyroxene, and plagioclase), the distribution of trace and rare earth elements, and the high average Mg content in rocks testify to the picritoid composition of the primary melt and its generation from the lithospheric mantle. The numerical simulation [13–15] based on consideration of the specific features (structure and physical state) of the lithosphere and factor of time revealed that melting zones beneath the Siberian Craton can be located at a depth of no less than 170 km from the Earth's surface. Moreover, the primary melts can only be represented by the picritoid variety in the case of the development of thermochemical superplumes in the lower mantle. Hence, tectonomagmatic structures of the Oneka type can be produced by abyssal (mantle) processes expressed as the development of a mantle magma source and the deformation of overlying rocks in the lithosphere and sedimentary cover. These processes promoted the formation of conduits for the injection of basic and ultrabasic melts. Processes of the subsequent formation of chambers and their filling with magma were related to the dynamics of hydrostatic forces of the melt, on the one hand, and interactions of hot fluids at the front of melts with carbonate and saliferous sediments of the platform cover, on the other hand.

Thus, the study of superstructures, such as the Oneka intrusive tectonomagmatic complex, provided new insight into the generation and evolution of the within-plate basic–ultrabasic magmatism. The qualitatively new approach proposed in this paper takes into consideration other models of the dynamics of basic magma intrusion. The results obtained indicate that the large Oneka intrusive complex can be identified as an autonomous type of trap magmatism.

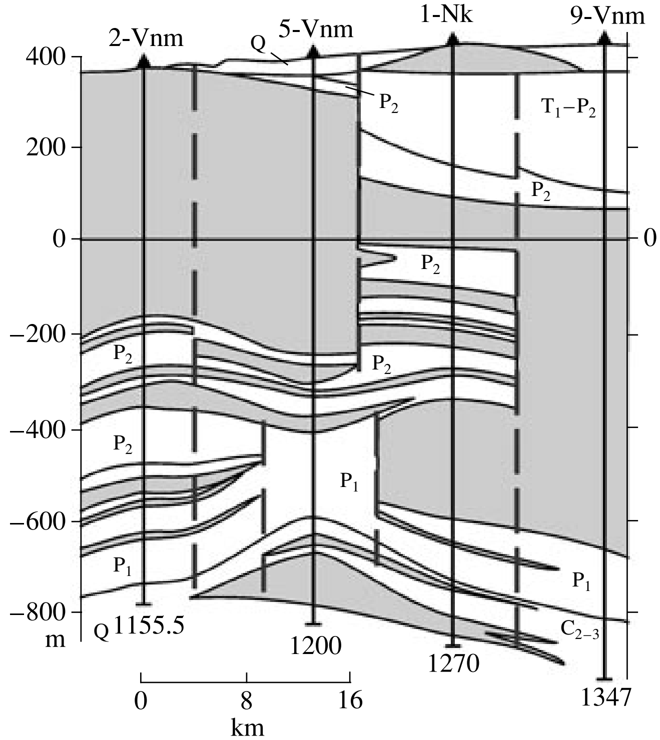


**Fig. 2.** The central part of the large Oneka layered intrusion (profile 2 Vnm–5 Vnm–1 Nk–9 Vnm).

Average chemical composition of rocks of the Oneka intrusive complex (based on 115 analyses of rocks)

| Oxide | $\bar{x}$ | $S$ | min | max |
|---|---|---|---|---|
| $SiO_2$ | 47.95 | 2.63 | 40.7 | 54.34 |
| $TiO_2$ | 1.10 | 0.45 | 0.22 | 2.637 |
| $Al_2O_3$ | 15.11 | 2.02 | 7.2 | 20.62 |
| $Cr_2O_3$ | 0.05 | 0.04 | 0 | 0.11 |
| $Fe_2O_3$ | 8.35 | 6.08 | 0 | 19.46 |
| FeO | 8.91 | 1.89 | 6.07 | 12.88 |
| Total FeO | 10.91 | 4.40 | 0.54 | 19.46 |
| MnO | 0.19 | 0.05 | 0.043 | 0.297 |
| MgO | 9.26 | 2.68 | 3.33 | 17.94 |
| CaO | 11.45 | 1.55 | 8.55 | 19 |
| $Na_2O$ | 2.29 | 0.64 | 0.89 | 3.56 |
| $K_2O$ | 0.61 | 0.27 | 0.17 | 2.19 |
| $CO_2$ | 0.17 | 0.27 | 0 | 1.47 |
| $S_{bulk}$ | 0.01 | 0.03 | 0 | 0.13 |
| $P_2O_5$ | 0.09 | 0.05 | 0.01 | 0.253 |
| Ba | 0.01 | 0.01 | 0.001 | 0.075 |
| L.O.I. | 1.12 | 1.99 | 0.02 | 17.99 |

Note: (Total FeO) the total amount of Fe given as FeO.

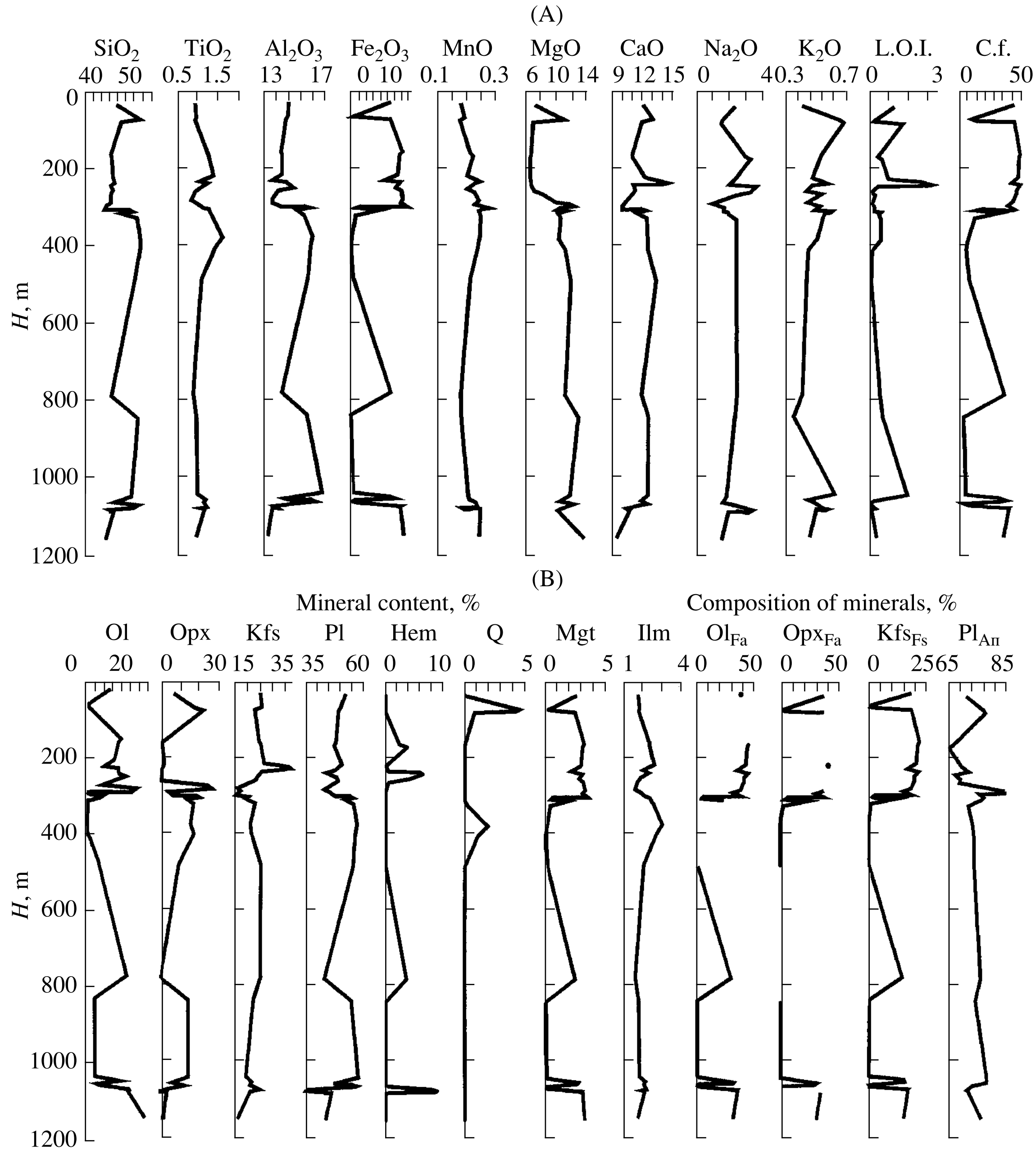


**Fig. 3.** Variation diagrams: (A) contents of the major oxides (wt %), (B) contents and compositions of normative minerals in rocks along the vertical section of the Oneka intrusion (borehole Gf-4).


## ACKNOWLEDGMENTS

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## REFERENCES


1. N. L. Dobretsov, Russ. Geol. Geofiz. **46**, 870 (2005).
2. V. V. Zolotukhin, V. A. Simonov, A. I. Al'mukhamedov, et al., Russ. Geol. Geofiz. **44**, 1339 (2003).
3. C. R. Neal, J. J. Mahoney, L. W. Kroenke, et al., Am. Geophys. Union, 183 (1997).
4. Yu. R. Vasil'ev, V. V. Zolotukhin, G. D. Feoktistov, and S. N. Prusskaya, Russ. Geol. Geofiz. **41**, 1696 (2000).
5. V. S. Sobolev, *Petrology of Trap Rocks in the Siberian Craton* (Glavsevmorput', Leningrad, 1936) [in Russian].
6. *Geological Structure of the Soviet Union and Regularities in the Distribution of Mineral Resources: The Siberian Craton*, Ed. by N.S. Malich, V.L. Masaitis, and V.S. Surkov (Nedra, Leningrad, 1987), Vol. 4 [in Russian].

7. *Magnesian Basic Rocks in the Western Siberian Craton and Problems of Nickel Mineralization,* Ed. by V.S. Sobolev (Nauka, Novosibirsk, 1984) [in Russian].
8. A. D. Kaminskii, *Candidate's Dissertation in Geology and Mineralogy* (Moscow, 1991).
9. V.L. Masaitis, *Petrology of the Alamdzhakh Trap Intrusion, the Vilyui River Basin* (Gosgeoltekhizdat, Leningrad, 1958) [in Russian].
10. S. N. Prusskaya and Yu. R. Vasil'ev, in *Petrology of Igneous and Metamorphic Complexes* (TsNTI, Tomsk, 2004), Issue 4, pp. 182–186 [in Russian].
11. V. N. Sharapov, Yu. R. Vasil'ev, and S. N. Prusskaya, Russ. Geol. Geofiz. **42**, 1299 (2001).
12. M. P. Mazurov, Yu. R. Vasil'ev, M. P. Gora, and A. T. Titov, in *Petrology of Igneous and Metamorphic Complexes* (TsNTI, Tomsk, 2004), Issue 4, pp. 152–156 [in Russian].
13. Yu. V. V. Perepechko, V. N. Sharapov, and A. S. Zhmodik, in *Evolution of the Petrogenesis and Differentiation of the Earth's Matter* (Kol'sk. Nauchn. Tsentr, Apatity, 2005), Vol. 1, pp. 157–158 [in Russian].
14. V. N. Sharapov, A. S. Zhmodik, and Yu. R. Vasil'ev, in *Evolution of the Petrogenesis and Differentiation of the Earth's Matter* (Kol'sk. Nauchn. Tsentr, Apatity, 2005), Vol. 1, pp. 271–273 [in Russian].
15. V. A. Simonov, S. V. Kovyazin, Yu. R. Vasil'ev, and J. Mahoni, Russ. Geol. Geofiz. **46**, 908 (2005).