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GEOLOGY AND GEODYNAMICS OF THE MAGNITOGORSK AREA, SOUTH URALS:

the experience of geodynamic mapping

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CONTENT

Preface

The paper of R.G. Yazeva and the late V.V. Bochkaryov is a recent documentation and geodynamic interpretation of plate tectonic environment and development of magmatic belts in the Magnitogorsk area, Southern Urals, Russia. It allows an insight into the Variscan geodynamics of the Urals. The material is based on a Russian monograph, printed in Ekaterinburg 1998, but significantly improved for this English edition. The figures contain now the sampling points for geochemical analyses. Furthermore the text is enlarged by modern literature. It is an advantage that Rare Earth Elements are used for rock classification and that the treated suites are compared with global volcanic suites, mostly from the ocean floor.

The authors have tried to include isolated occurrences of volcanic series into their concepts of magmatic cycles. This seems to be a little risky if later on the biostratigraphic classification of these series will demand another stratigraphic position. Another disadvantage is related to the old and wrong former Russian times-scale of the Devonian, where the Emsian stage was missing. Therefore the Na-tholeiitic Karamalytash formation belongs now into the Eifelian and the Ulutau formation into the Givetian up to the lowermost Frasnian stage.

We have to thank several colleagues. The English language was brought on an international level by John Rupp, Geological Survey of Indiana, Bloomington, USA. He also took care to made the manuscript more clear and understandable. The reviews of Dr. W. Kramer, GeoForschungsZentrum Potsdam, and Dr. B. Buschmann, Mining Academy (TU) Freiberg have seriously improved the manuscript in many regards. The manuscript received its final version by Prof. Dr. P. Bankwitz, Potsdam.

The present monograph of Yazeva and Bochkaryov is for all foreign readers and for those earth scientists who work in the Urals and in Russia a valuable source for information and interpretation.

Manfred Störr

Geology and geodynamics of the Magnitogorsk area, South Urals: the experience of geodynamic mapping
Geologie und Geodynamik des Magnitogorsker Gebietes, Südural: Ergebnisse einer geodynamischen Kartierung

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Abstract

Paleozoic polystage collage of Tthe Magnitogorsk area ofat the South Urals is the most representative territory for observing the Palaeozoic polystage tectonic collage that resulted from along strike Palaeotethyan correlation is consequence of island arc and active continental margin geodynamics. GSpecial geological and geochemical researches aimed at understanding the palaeotectonic and stratigraphic implications of the region resulted in the elaboration of the legend for and the and compilation of the first Geodynamic Map (1:200,000). Compositional Matterand structural indicators of distinct divergent, convergent and intraplate Palaeozoic regimes were documented using after comparisons with the recent as well as other and Uralian standards. Based on these indicators specific tTypomorphic complexes or divisions were determined including: of an epicontinental riftogenic depression, passive continental margin, an amagmatic backarc basin, backarc spreading centrres, barrier uplifted s of barriers of young, developed and mature island arcs stages, arc-continent collision zones, post-collisional obducted overriding of a continental terranes,domain and final hypercollision zones. are divided. A long term Evidences for permanent geochemical polarity related to eastward polarity for the (Siberian) Devonian subduction of oceanic crust was determined based on are followed as result of new geochemical data obtained for magmatic sequences situated along the eastern rim of the study area inat the Gumbeika River basin. Newly discovered At first pointed ooccurrences of shoshonite and hawaiite series magmatites support the allow to argueconcept of a backarc collapse relatinged to a mature arc-continent collision in the Early Carboniferous. Tectonic elements for of syn-volcanic, arc-continent collision, continental obductionverriding and hypercollision stages of recent crustal architecture were inferred and are displayed shownon atthe Geodynamic Map. An Aanalysis of vergency and space-time sequences of thrusts, underthrusts and slip faults was adoptedadapted to assist metallogenic prospecting efforts to estimations of deep crustal levels in some mining districts.

Zusammenfassung

Das Gebiet von Magnitogorsk im Südural ist sehr geeignet, um Einsicht zu nehmen in den paläozoischen, polystadialen tektonischen Krustenaufbau, wie er sich aus der Geodynamik von Inselbögen und aktiven Kontinentalrändern der Paläotethys ergeben hat. Geologische und geochemische Untersuchungen hatten ein besseres Verständnis der Schlußfolgerungen aus paläotektonischen und stratigraphischen Ergebnissen zum Ziel. Sie führten zur ersten Geodynamischen Karte (1:200,000), einschließlich ihrer Legende. Indikatoren der Zusammensetzung und Struktur von ausgeprägten divergenten, konvergenten

und Intraplatten-Regimes wurden dokumentiert, im Vergleich mit globalen rezenten und anderen Ural-Gegebenheiten. Auf der Grundlage dieser Indikatoren wurden spezifische typomorphe Komplexe und ihre Untergliederungen ausgehalten: epikontinentale riftogene Senke, passiver Kontinentalrand, ein amagmatisches backarc-Becken, backarc-spreading-Zentren, herausgehobene Barrieren von jungen sowie entwickelten und reifen Inselbögen, Inselbogen-Kontinent-Kollisionszonen, post-kollisional obduzierte kontinentale Terranes, finale Hyperkollisionszonen. Eine lang-andauernde ostwärts gerichtete Polarität der (Sibirischen) devonischen Subduktion ozeanischer Kruste wurde festgestellt auf der Grundlage neuer geochemischer Daten für magmatische Sequenzen am Ostrand des Untersuchungsgebietes im Gumbeika-Becken. Neu entdeckte Magmatit-Vorkommen von Shoshonit- und Hawaiit-Serien stützen das Konzept eines backarc-Kollapses in Verbindung mit einer reifen Inselbogen-Kontinent-Kollision im Unterkarbon. Tektonische Kennzeichen für syn-vulkanische Inselbogen-Kontinent-Kollision, kontinentale Obduktion und Hyperkollisionsstadien wurden abgeleitet und in der Geodynamischen Karte dargestellt. Die Vergenz und die Raum-Zeit-Entwicklung von Überschiebungen, Unterschiebungen und Blattverschiebungen wurden analysiert, um die metallogenetische Erkundung von tieferen Krustenniveaus in einigen Bergbaugebieten zu unterstützen.

INTRODUCTION

Geodynamic reconstructions based on plate tectonic concepts are especially useful for regional geological investigations and mineral evaluations in the Uralian type intracontinental orogenic belt. The crustal architecture underlying the Uralides as well as other Variscan orogenic belts, caused by polystage changes in the geodynamic regime, including both destructive and constructive transformations of the crust, has resulted in the generation of a distinctive suite of magmatic, sedimentary and mineral complexes. The diagnostics for such typomorphic formations are proposed relative to objective information of crustal forming processes.

The geodynamic research which forms the basis of this monograph was conducted in 1993-1995 according to an order and financial support from the Chelyabinsk Territorial Committee of Geology and Mineral Resources in connection with intermediate scale geological mapping for mineral targets. The compilation of the legend to the geodynamic map at a scale of 1:200,000 and the associated model (Appendices 1 and 2) is the first practical experience of such kind at the Urals. Similar maps were made some years before for the Central Kazakhstanian and South Tyan-Shanian geodynamic polygons. The maps became the basis for a series of multi-authored methodological books summarizing common principles of geodynamic analysis. These texts were not sufficient for use in assessing the Uralian orogenic belt.

The Magnitogorsk province of the mapped Uralian geodynamic polygon is situated on the eastern slope of the Southern Urals in the Ural and Gumbeika River basins (Fig. 1). In geological terms, the area represents a segment of the Euro-Asian Variscan system; a part of the active margin of the Uralian ocean accreted to the continental Kazakhstanides (Fig. 2). It is important to note that the corridor of the “Europrobe” transect and a transcontinental seismic profile crossing the Uralian folded belt took place in this territory in 1995 in association with the international Europrobe program.

Based on age scale of tectonical imbrication and a deep crustal structure the mapped area is divided into submeridional segments or zones including the Central- and Eastern Mag-nitogorsk, Gumbeika and East Uralian zones. The first and second zones contain Fe-skarn, Ti-magnetite and Cu-Zn sulphide ore deposits and, thus, the territory near Magnitogorsk and Verkhneuralsk (Ural River basin) has long been the object of study for generations of geologists. Volcanogenic,

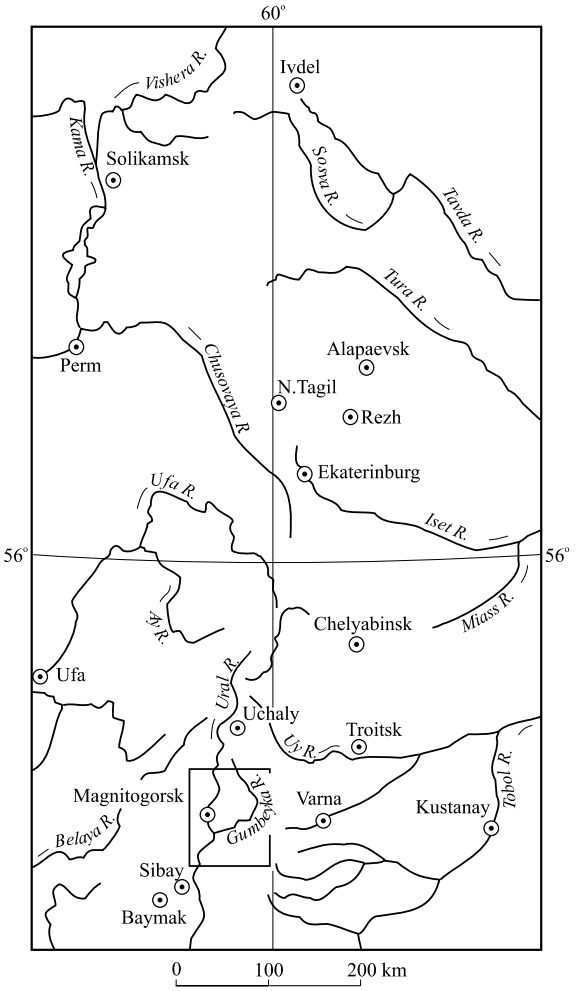

Fig. 1. Geographical location of the Magnitogorsk area (contoured by heavy lines).

intrusive and sedimentary units composing these zones are considered as Uralian formational standards or stratotypes including:

- bimodal Na-tholeiitic, the Karamalytash (D_2g_1);
- basalt-andesite-dacitic, the Ulutau (D_2g_2-D_3f_1);
- basalt-basaltic andesitic, the Koltuban (D_3f_2);
- shoshonite-latitic, the Verkhneuralsk (D_3fm);
- greywacke, flyshoidal, the Zilair (D_3-C_1);
- bimodal K-Na tholeiitic, the Beryosovsky (C_1t);
- limestones, the Kizil (C_1t-v_2).

Formally the magmatic and sedimentary formations of this industrially developed and well studied province were interpreted as the inner filling of the Middle Palaeozoic Magnitogorsk synclinorium. This concept was based on the geosynclinal theory. According to plate tectonic models, the same units are interpreted to be deposits associated with the youngest volcanic chain of the double Devonian island arc and Carboniferous collisional and post-collisional volcanic-sedimentary sequen-ces. The older, initial barrier zone of this palaeoarc is interpreted to be the Irendik Ridge west of the mapped area which composed of Na-calc-alkaline porphyritic basalts of the Ems-Eifelian (see Fig. 2).

Geology of the Gumbeika zone east of central mining districts has key interest for several reasons. First, it has a distinctive tectonic setting between the epioceanic and epicontinental east Uralian sequences. Secondly, this area as compared with neighbouring mining districts, is a “terra incognita” in the sense of age data and geochemical characteristics of basaltic pyroclastic units which are most voluminous here. Thirdly, because basaltic volcanism of the Gumbeika zone was poorly understood, it was used as an argument against geodynamic models. For example, the petrographical similarity of Gumbeika and Irendik porphyritic basalts allowed them to be interpreted as the eastern and western wings of the Magnitogorsk synclinorium. But it is the same external resemblance that forms the basis of the arc splitting hypothesis.

The main volume of new data was generated for the eastern area (Fig. 3). As a result, we have established there numerous volcanic-sedimentary and volcanic-intrusive nappes composed of rock units indicative of different geodynamic regimes. Namely, there are suboceanic tholeiitic complexes of backarc spreading centres, shoshonite-absarokitic units of backarc shelf and abyssal, rhyolite-basaltic and hawaiite-mugearitic lavas of syn-collisional grabens, post-collisional gabbro and granitoides of the Andean type marginal belt and so on. Surprisingly there is a total absence of Na-calc-alkaline basalts of the Irendik (or Tonga, Mariana Graben) type.

The discussed geochemical and structural data provide a new comprehensive interpretation of the recent crustal framework and its history which may be useful for correlation of the principle geological events that formed the European and Urals-Mongolian Variscan belts.

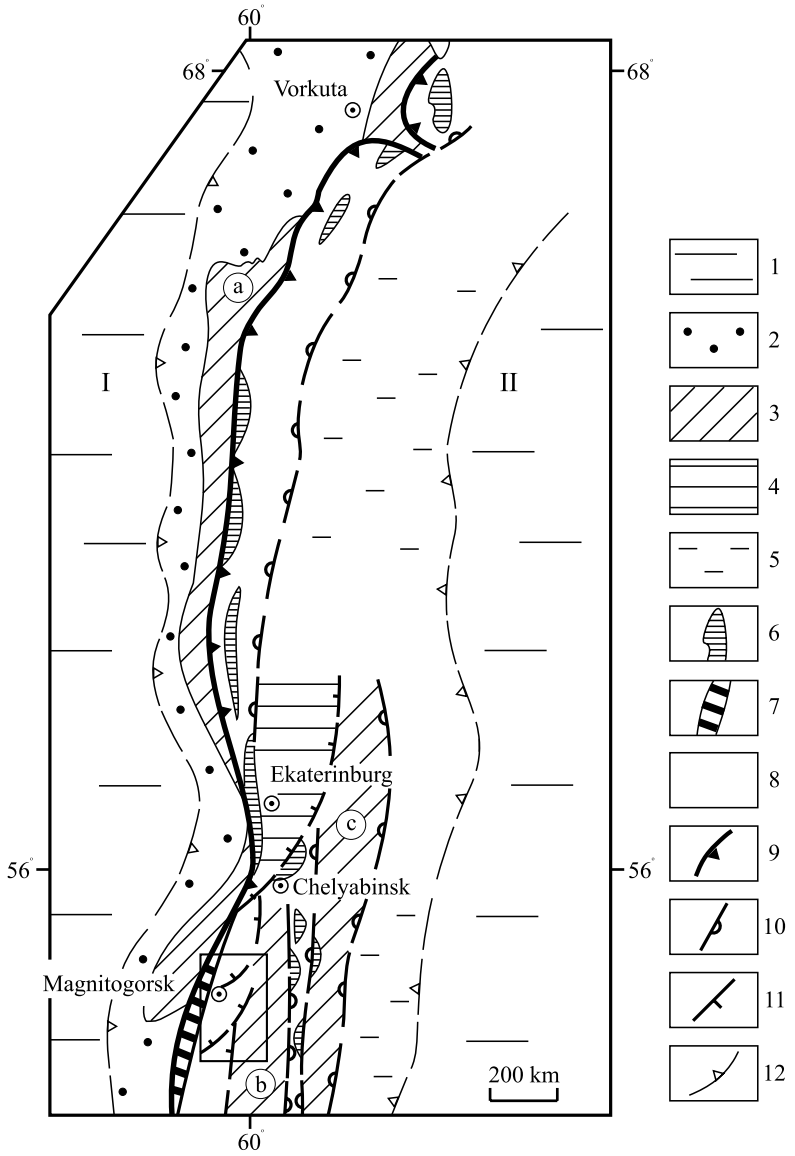

Fig. 2. Geological location of the Magnitogorsk area within the structure of the Urals foldbelt (contoured by heavy lines)

1 - East European (I) and Kazakhstan-Tyan-Shanian (II) continental plates; 2 - sedimentary complexes of the Palaeozoic passive margin and Foreuralian trough; 3 - microcontinents: Central Uralian (a), East Uralian (b) and Transuralian (c); 4 - East Uralian microcontinent covered by allochthons of Devonian island arc complexes; 5 - destructed margin of Kazakhstanides below units of marginal volcano-plutonic belt (C_{1-2}); 6 - largest terranes of the mature Silurian island arc; 7 - relics of the Devonian exterior island arc (Irendyk Complex, D_2ef_1); 8 - accreted volcano-sedimentary complexes of backarc basins; 9 - Main Uralian suture between active and passive palaeomargins; 10 - suture zones of Early Devonian arc - microcontinents collision; 11 - suture zones of Late Visean arc - microcontinents collision; 12 - boundaries of the Uralian foldbelt.

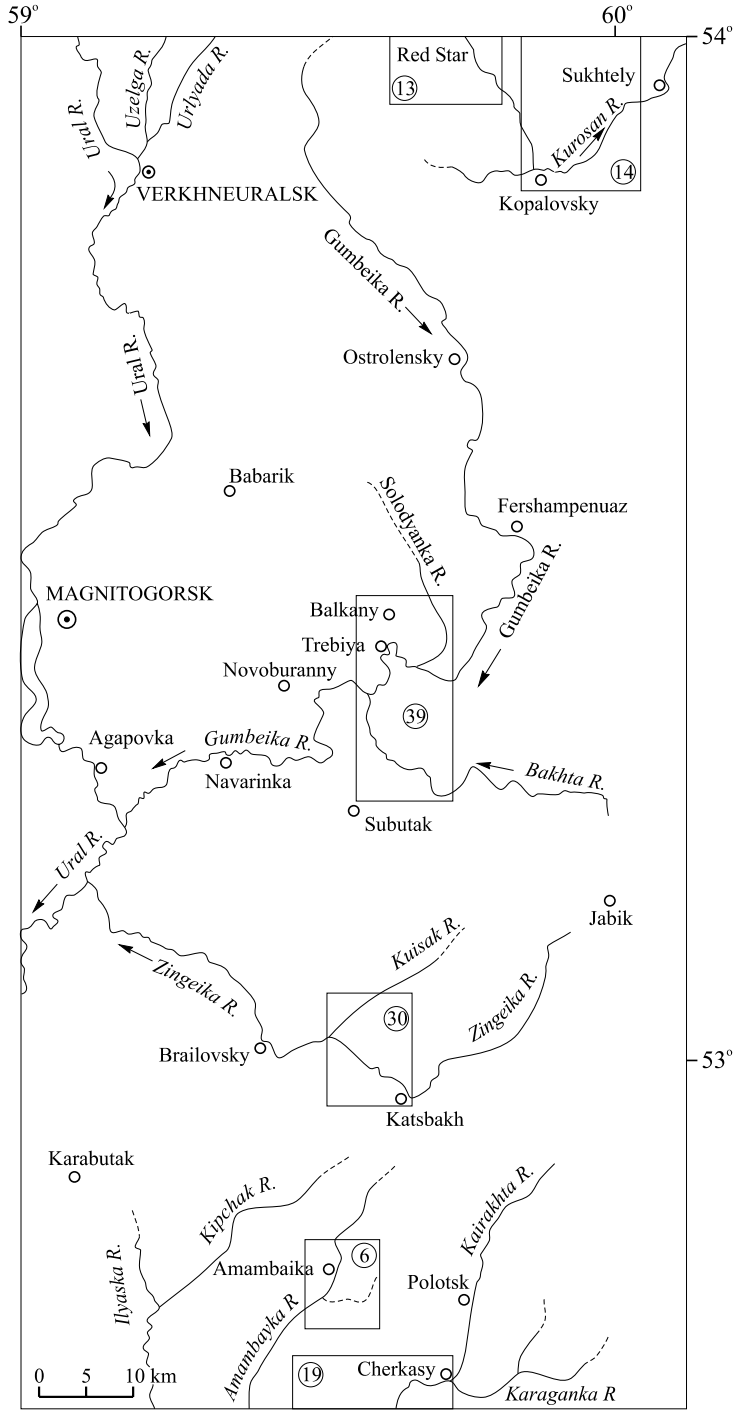

Fig. 3. Map of the study area (Appendix 1) showing detail research locations (discussed in the paper).
Numbers in contours correspond to Figures in the text.