
PETROLOGICAL PROBLEMS DURING REGIONAL GEOLOGICAL STUDIES

Building Metamorphic Maps or Schemes with Regard to Results of Thermodynamic Modeling of Mineral Assemblages

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Abstract—An approach to constructing metamorphic maps and schemes is considered, whose key element is the integration of traditional geological methods with results of thermodynamic modeling of mineral assemblages. Traditionally applied mapping methods, based on field studies, often lead to ambiguous interpretations. The use of modern software packages for thermodynamic modeling helps in elucidating and avoiding these discrepancies by making it possible to verify and refine metamorphic zone boundaries and to solve problems of stratigraphic and lithological correlation for metamorphosed sequences. A combination of traditional mapping and numerical modeling enhances the reliability and plausibility of the results, ensuring a more accurate geodynamic and petrological interpretation of geological data.

Keywords: metamorphism, mapping, metamorphic zones, thermodynamic modeling, mineral assemblage

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Metamorphic maps and diagrams graphically display the conditions of metamorphism (temperature, pressure, and mineral assemblages), as well as the nature and direction of metamorphic transformations in the rocks. Such data visualization in the form of metamorphic maps or diagrams is necessary for reconstructing the geological history of regions, analyzing tectonic processes and, in particular, predicting mineral resources and reserves in these areas. In the practice of geological research, facies maps have become widespread. These maps show the distribution of metamorphic facies (for example, greenschist, amphibolite, and granulite ones). At the same time, so-called *isograd maps* are often used, which show temperature or pressure isograds and the occurrence (or absence) of index minerals at the current erosion surfaces of metamorphic complexes. Accordingly, mineralogical and facies schemes illustrate the distributions of metamorphic mineral assemblages in space and in relation to the variations in the P – T conditions. Recall that principles of mapping metamorphic complexes by constructing mineral isograds were proposed and applied in practice as far back as 1893 (Barrow, 1893).

The starting point for building technique of such maps and/or diagrams is field research and rock sampling for the further petrographic analysis of the min-

eral associations and the identification of the mineral assemblages and reaction relationships of minerals.

Recent progress in methods for the thermodynamic modeling of mineral-forming processes makes it possible to confirm or refute a particular scheme (map) of metamorphism built on the basis of the aforementioned traditional approaches.

A region highly suitable for demonstrating the capabilities (and even an arbitration role!) of thermodynamic modeling of mineral-forming processes is the Early Proterozoic zonal metamorphic complex in the northern Ladoga area. The boundaries of the staurolite metamorphic zone in this area have long been a matter of discussions, and various researchers almost simultaneously proposed schemes that were basically different, especially in what concerns interpretations of the northern boundary of this zone (Fig. 1).

The ambiguities in interpretation of the location of the staurolite isograd are likely explained by certain features that controlled the stability of staurolite in rocks: in addition to P – T parameters needed for staurolite to form, the protolithic rocks should have a suitable chemical composition. If staurolite was not found in a rock, this has been explained (Nagaytsev, 1965; Velikoslavinsky, 1972) by that this rock occurred in a zone of lower-temperature metamorphism, in which the temperature was too low for staurolite stability.

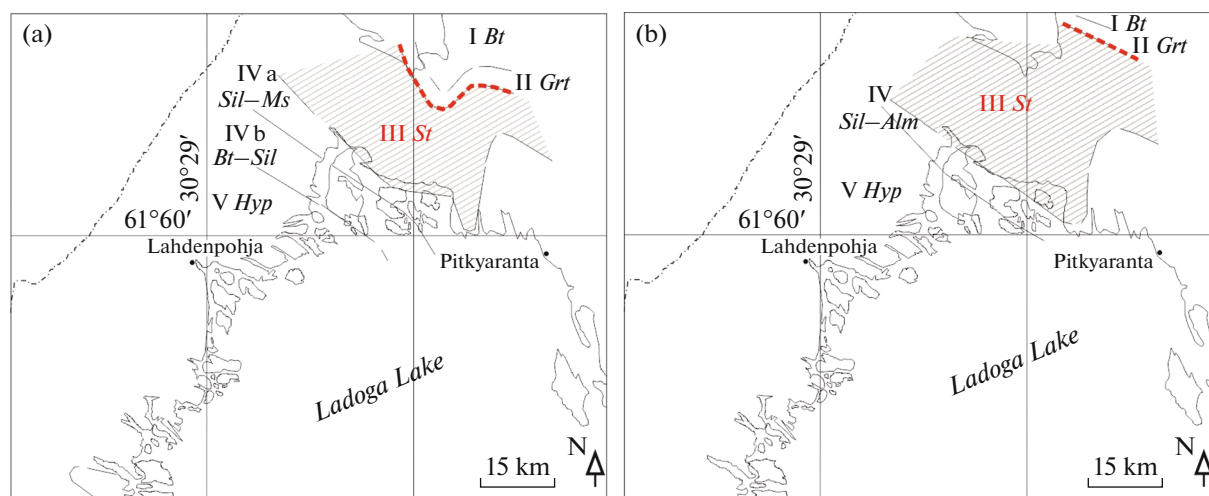


Fig. 1. Schematic map of metamorphic zoning in the northern Ladoga area, showing different interpretations of the boundaries of the staurolite zone: (a) (Nagaytsev, 1965; Velikoslavinsky, 1972) and (b) (Predovsky et al., 1967).

Thermodynamic modeling now allows the researcher to determine the range of P – T parameters for rocks of any initial chemical composition, which makes it possible to more reliably identify the facies affiliation of rocks in the absence of informative mineral assemblages in them. Petrological tools, such as *Perple_X* (Connolly, 1990, updated in 2025), *Theriak-Domino* (de Capitani and Petrakakis, 2010, updated in 2022), *MAGEMin* (Riel et al., 2022, updated in 2025), and *Thermocalc* (Holland and Powell, 2011, updated in 2025) can simulate the formation parameters of most metamorphic minerals, which is useful for verifying metamorphic schemes or maps.

In addition to refining the boundaries of metamorphic zones, modeling can be instrumental in solving the problem of the lithological homogeneity of strata that have experienced metamorphic transformations to different grades, i.e. in drawing stratigraphic–lithological correlations. An example is the Belogorsk metamorphic complex in the Urals, which is characterized, from east to west, by sharply different mineral assemblages: from chloritoid and chlorite to staurolite and kyanite, located tens of kilometers apart from one another (Petrov et al., 2015). Thermodynamic analysis of the mineral-forming processes revealed that these rocks, which now greatly differ from one another in metamorphic grade and mineral composition, had a common protolith.

CONCLUSIONS

The current capabilities of modeling the parameters of metamorphic mineral-forming processes facilitate a higher quality solution of problems in practical geology and are particularly useful for geological map-

ping and conducting regional or interregional correlations of metamorphic strata.

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CONFLICT OF INTEREST

The authors of this work declare that they have no conflicts of interest.

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