METHODS FOR GENERALIZING GEOLOGICAL INFORMATION WHEN COMPILING VARIOUS GEOLOGIC MAPS FOR THE TERRITORY OF YAKUTIA

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ABSTRACT

The 1:500,000 - scale geological map of Yakutia is a compilation of geologic structure data covering a large area of the earth's crust including the Siberian platform and fragments of several mobile belts. The rock formations mapped cover an extremely wide stratigraphic range, and a large variety of magmatic and metamorphic rock types. The geologic map has been compiled using the results of detailed geological investigations, including the State geological survey 1:200,000 and 1:50,000 scale mapping carried out during the last few decades. These complex and diverse data were compiled using the following principles: The map is composed of several local stratigraphic regions (blocks). Eleven blocks, each comprising several of the total (81) map sheets, were completed. These include general geologic structure maps divided into geo-economical regions, and other charts which are interrelated with those of adjacent blocks. Suites - the local stratigraphic units - have been selected as the basis of the stratification, so the details of the geological structure are depicted prior to (?) deformation. References 21.

INTRODUCTION

The Yakutian State Prospect-and-Survey Expedition of the Sakha (Yakutia) Republic's State Committee of Geology and Natural Resources is issuing 1:500,000 scale colored geologic map sheets of Yakutia (81 sheets). The maps demonstrate the structure of over 3.1 million sq. km. of the Earth's crust embracing an ancient stable core of continental crust (eastern Siberian platform) and the fragments of its surrounding mobile belts (Verkhoyansk-Chukotka, Baikal-Patom, and Djugdjur-Stanovoy foldbelts). The map is based on the results of 1:200,000 and 1:50,000 scale surveys, regional geophysical studies, deep drilling, and special investigations and scientific research.

The map is highly informative with a detailed subdivision of different-aged series. It can be compared to 1:200,000 scale geologic maps but covers a larger area. For the sake of convenience both in publication and use, the map is divided into 11 composite blocks: Lower Olenek, Botuobiya, Markoka, West Verkhoyansk, Central Yakutian, South Yakutian, Novosibirsk, Upper Indigirka, Lower Yana, South Verkhoyansk, and Indigirka-Kolyma, each consisting of 4 to 11 sheets. Each map block combines areas with similar geological structure which belong to the same geological-economical region. The map blocks are supplemented with tectonic and geophysical schemes (scale 1:1,500,000), correlation diagrams between stratigraphic sequences and paleontological and palynological data, chemical composition tables for the primary magmatic rock types, and indexes to the data sources. These supplements are in many aspects equivalent to and even more informative than traditional explanatory notes.

The authors conducted a large body of research and solved the complex problem of generalizing the variety of geological data available for the enormous territory of the Sakha (Yakutia) Republic. It is obvious that only a well-thought-out legend could complete a map covering such a great territory. In designing the legend, we tried to use most fully the results of the production geomapping and, at the same time, take into account the results of special investigations and scientific research with a due regard to the earlier mapping experience.

PECULIARITIES OF STRATIGRAPHIC AND MAGMATIC ZONATION

Subdividing and correlating many kilometers of stratified sequences mapped on a few thousand independent geologic maps compiled over the last 20-25 years was the most difficult problems to solve. We found it appropriate to retain the earlier approach of survey geologists who used, as a rule, local stratigraphic schemes. These diverse schemes were ordered through stratigraphic zonation. The main stratigraphic principles were worked out for the Ordovician of the Siberian platform (Tesacov et al., 1975). Sratigraphic zonation of Triassic deposits of the Vilyui syneclise, Preverkhoyansk, and Lena-Anabar basins (Golovin, Slatenov, 1991), as well as those for the Permian deposits of the Verkhoyanye were used also (Grinenko, 1992).

What are the advantages of the stratigraphic zonation over the structural-facies one? It is well known that in preparing the 1:200,000 scale States Geologic Map, zonation schemes based on structural, structural-formational, and lithologic principles are used. A structural-zone is therefore a volume-area unit. As a result of the increased body of geological information and detailed 1:50,000 scale mapping of the areas, the facies zonation within the limits of structural-facies zones no longer meet the demands of large-scale investigations. This follows, on the one hand, from stratigraphic analysis of the structural-facies zone in which it is impossible to delineate with certainty the territory where one or another local scheme was used and, on the other hand, from subsequent paleo-reconstruction in which the structural boundaries, normally changing in time and space, generally do not coincide with the boundaries of the mapped lithological formations. The authors (Grinenko et al., 1994) determined the areal distribution of local stratigraphic divisions as a basis for stratigraphic zonation of Yakutia.

The primary stratigraphic division of the legends and geologic map blocks is the local unit, "formation". In addition, lithostratigraphic units such as "series" and "layers" are also used. They were established locally from drilling, mapping, and special investigations. The authors use the term "stratigraphic territory" to describe a site of local litho- and stratigraphic formations. "A stratigraphic area" is a lateral distribution area of a packet of similar-aged formations. "A stratigraphic subregion" combines several areas where one or more formations occur under the same name. "A stratigraphic region" is a group of subregions that contain formations that developed during the same geological stages and have common fauna and flora peculiar to this stage.

The above clearly shows the advantage of the stratigraphic zonation over a structural-facies one. This is especially true with regard to the concepts "stratigraphic area" and "stratigraphic subregion" which are delineated irrespective of the structures modern(?) spacial boundaries. Additionally, the stratigraphic zonation is more objective in delineating existing and naturally separated boundaries of specific paleobasins and their depositional settings. Further correlation of local schemes subdividing the Phanerozoic series is performed by ranking a number of stratigraphic territories (from large to small): region-subregion-area-territory. Through these classifications, similar-aged stratigraphic subdivisions are successively correlated.

We followed a more complex path when compiling the Geologic Map and legend of the Aldan Shield (South Yakutian block). This was caused by both a confusion in the classification and nomenclature of various magmatic rocks the region, and by the necessity of dividing infra- and supracrustal Archean formations, reconstructing their initial nature, and their classification. When solving these problems, attention was centered on the petrochemical characteristics of the rocks. A map was compiled which showed the distribution of sampling sites at the same scale as the geologic map. The maps of the South Yakutian block are supplemented by an array of approximately 20,000 chemical analyses data points. We reconstructed the initial nature of the metamorphic series by V.A. Kudryavtsev's method (Kudryavtsev, 1985, 1987). The method is based on empirical laws regulating the distribution of the primary rock-forming oxides and not on various transformed petrochemical coefficients. We selected this method after comparing the reconstruction results obtained using many well-known methods. A few thousand analyses of weakly metamorphosed Upper Archean and Lower Proterozoic rocks of western Aldan Shield with well-preserved relics of sedimentary, volcanogenic, and intrusive rocks, as well as relics of metamorphosed Riphean-Phanerozoic sediments and magmatic rocks were used as controls. Normative mineral compositions for all the rock types were calculated. Sedimentary rocks were categorized by the method of O.M. Rozen and others (1982), and magmatic rocks by the method of A. Ritman (1975). Finally, the rocks were classified and nomenclature worked out, geological bodies indexed, compositions of magmatic complexes and stratigraphic subdivisions of all ranks refined, and the region was divided into zones. Magmatic rocks were classified using the scheme in the book "Magmatic rocks" (Gol'shakova, 1983).

ZONATION OF FOLD STRUCTURES IN EASTERN YAKUTIA

At present, the prevailing understanding of the geological structure and development of northeast Russia is mobilistic (Pushcharovskiy, 1987). At the same time, the terminology and systematic of the main structural elements within the framework of mobilistic paradigm are yet to be solved. The predominant version of mobilistic understanding of the tectonics of the greater part of northeast Russia is, without doubt, debatable. Nevertheless, it permits us to systematize the available material from a single point of view, and to give a brief historical and geodynamic interpretation.

Following L. M. Natapov and others (1977) and L. M. Parfenov (1984), the authors singled out the main structural elements of northeast Russia: a passive margin of the Siberian continent, the Okhotsk and Omolon continental massifs, Ilin-Tas (Uyandina-Yasachnaya) island arc, Uda-Murgal island arc, Priokhotsk continental margin, and Alazeya and Anyui (Novosibirsk-Chukotka) "oceanic" blocks. In the late Mesozoic, oceanic basins compressed and shortened causing island arcs and continental blocks to collide, producing the Verkhoyansk-Kolyma, Novosibirsk-Chukotka, and Priokhotsk fold belts. The 1:1,500,000 scale tectonic schemes supplementing the map sheets focus attention on the fact that large geologic bodies which existed in the Mesozoic rocks prior the collision (island arcs, a continental slope with a thick sediment cover, forearc basins filled with deposits, Precambrian continental blocks, and continental blocks formed during the previous folding stages) are preserved in the Mesozoic fold belts both as formational bodies with their own sets of formations, and as structural complexes with characteristic deformational associations. The boundaries between the bodies (faults, flexures, and deep sutures) are also preserved in a transformed form.

In order to underline the formational-genetic content of the elements established in a fold structure, such as in the Mesozoic rocks of northeast Russia, we suggest that their restored contents be added to the rank names of the structural elements. Thus island-arc, forearc, near-continental, and other folded zones are established in the folded systems. Stable associations of these zones can be united into megazones. Zonation at the folding level (anticlinoria, synclinoria, etc.) does not always reflect the fold structure of the Mesozoic rocks since this might be a derivative of neotectonics.

The Verkhoyansk-Kolyma fold system includes three megazones: Outer, Central, and Inner. The outer megazone is located on the site of the Late Paleozoic-Mesozoic lowered eastern margin of the Siberian continent and its continental slope representing a passive continental margin. Within the outer zone are established near-continental and near-ocean zones. The first is seen in the Mesozoic structure as a belt of marginal anticlinoria (Kharaulakh, Orulgan, Sette-Daban). Cores sampling these rocks, indicate Riphean and Lower-to-Middle Paleozoic rocks and those of the oldest carboniferous parts of the Verkhoyansk terrigenous complex. Magmatic formations are dominated here by basalt and alkali-ultra basic formations. Sedimentary and magmatic complexes are similar to contemporaneous platform (unfolded) formations. Some researchers (Parfenov, 1984) note that the Verkhoyansk terrigenous complex is detached from the Paleozoic and older basement. The zone is separated from the Siberian platform by a system of thrusts and strike-slip faults (Prokopiev et al., 1994) It is separated from the near-ocean zone by subvertical faults of unclear kinematics (East Verkhoyansk and Minorsk) (Tectonic map..., 1973). A belt of medium-high ranges (Kharaulakh, Orulgan, Sette-Daban, etc.) is the modern expression of these structures.

The continental margin folded zone formed on the continental slope. In the Mezozoides it corresponds to a vast anticlinorium dislocated and complicated by longitudinal and transverse faults. In this zone, the Verkhoyansk terrigenous complex is characterized by a rapid ten-fold increase in thickness to the east, and the presence of a section of turbidites and underwater slump structures. Granites here include sodium varieties. To the east of the near-ocean zone, Triassic and Jurassic sandy siltstones fine, becoming siltier. The boundary between the near-ocean and forearc zones is drawn along a thrust, probably, coinciding with the paleo-Benioff zone and a transform fault (Baky-Bytyntay). In modern expression of the near-ocean zone is the Yana-Indigirka intermontane.

The central megazone consists of combined forearc, accretionary, and island-arc zones. The forearc zone is expressed by the Polousnyy and In'jali-Debin synclinoria. Its fore-arc origin is indicated by its association with contemporaneous island arc deposits, and by the composition of the graywacke which was deposited in the forearc by erosion of the island-arc and the adjacent accretionary wedge deposits with a long and multistage folding history. Jurassic deposits (Middle and Upper Series) which make up the forearc zone form a "peak" overhanging the near-ocean zone. Simple folds of the "peak" differ markedly from the complex folds of the Triassic series underlying the "peak". Medium-high ranges and the plateaus overlain by the massifs made of the Main batholithic belt granites are the modern expressions of the forearc zone.

The accretionary zone forms a discontinuous structural step between the forearc and island-arc zone. It is made of Triassic rocks dislocated into imbricated packets. Fragments of Triassic schists with faunal remains occur in Middle Jurassic deposits of the forearc basin, Based on this evidence, one can assume that the zone formed on the site of a non-volcanic island arc. Some of the massifs of the Main batholithic belt are located along this zone.

The island-arc zone of Ilin-Tas is expressed by a complex chain of anticlinal structures overthrusting the forearc and accretionary zones. The cores of the anticlinoria contain Precambrian and Paleozoic rocks. In many places there are protrusions of Early Proterozoic gabbros and hyperbasites possibly representing a basite basement block upon which the arc was built. On the flanks of anticlinoria, there are Upper Jurassic volcanics of calc-alkaline composition and comagmatic subvolcanic bodies. The zone is characterized by a block structure with abundant longitudinal thrusts and strike-slip faults. The modern expression of the zone is the highest ranges of the Chersky system.

The inner megazone is poorly investigated. It probably represents an area with unworked oceanic-type crust which include early consolidation massifs with superimposed Mesozoic structures. The early consolidation massifs include the Alazeya blocks which represents a Middle Paleozoic island arc (L.M.Parfenov, 1984). The superposed structures include the Moma-Zuryanka backarc basin of Late Mesozoic age. Granitoids are practically absent in the megazone, while Late Mesozoic and, possibly, Cenozoic basalts are widespread here. A large depression is the modern expression of the megazone. Geophysically, the megazone is defined by a distinct banded structure of the gravity and magnetic fields and a relatively high gravity field strength. In the Alazeya block there are exposures of the Precambrian basite basement metamorphosed to a glaucophane-schist facies.

The Novosibirsk-Chukotka fold system is represented within eastern Yakutia by a small fragment which is almost completely overlain by a Cenozoic cover of the Primorsk lowland and is concealed by the waters of the East-Siberian sea. According to geophysical data it consists of the outer island-arc zone and inner residual oceanic megazone (Spector, 1987). Island-arc volcanics of Late Mesozoic age are found in the Svyatoy Nos Cape where they form extensive fields in the Nenkan and Vukvaam basins (Parfenov, 1984). Volcanics belong to the Anyui segment of the Novosibirsk-Chukotka system, while gabbros and hyperbasites belong to the basement system. The latter crop out on the surface in the Anyui segment on Bolshoy Lyakhov Island, while on the rest of the inner megazone they arc inferred from geophysical data.

The Okhotsk and Omolon continental massifs are located at the boundary of the Verktoyansk-Kolyma and Priokhotsk fold systems. Due to such features as a block structure, an incomplete and discontinuous Phanerozoic section, the presence of the proved Archean basement, and Mesozoic folding, the massifs may serve as tectonotypes of Precambrian median massifs.

ZONATION OF GEOPHYSICAL FIELDS (EAST YAKUTIA)

Information about geophysical fields of east Yakutia is given briefly here as this area of knowledge is beyond the limits of geological mapping. It is worthwhile to have a grasp of the structure of fields, to compare it to the mapped fold structure, and to have an idea of the deep structure of the region. The information about the magnetic and gravitational fields is general and ranked. Generalization was made possible due to recognition of structural types indicated by the gravity and magnetic fields and the analysis of correlations between them.

Within northeast Yakutia, three structural types of geophysical fields are observed: homogeneous weakly differentiated, mosaic, and banded. In most cases, over large areas, a positive correlation between structural types and the gravity and magnetic fields was observed. Thus correlated anomalous geophysical fields were used as the basis for ranking. The highest rank is "a region" to which the territory of the Verkhoyansk - Chykotka fold area corresponds. Other ranks are in descending order as follows: megasystem anomaly, system anomaly, zone anomaly, and local anomaly. This approach to zonation was worked out by V.M.Mishnin (1988) for the Siberian platform and was used by the authors with some modifications in compiling geophysical maps for the Verkhojansk-Chukotka area. Of all the above mentioned ranks only "region" is based on geological features. A "region" is a territory of a large geological structure in the rank of a platform or a fold-belt. In this case the territory of Mesozoides in northeast Russia can be called a region. Further subdivision is based mainly on geophysical data.

"Megasystem anomaly" is a part of a region which is characterized by a homogeneous structure and differs from adjacent megasystems by the averaged strength of the gravity and magnetic anomaly fields. Based on these features, parts of the Verkhoyansk-Kolyma, Svyatoy Nos-Kolyma, Okhotsk, and Chukotka megasystems have been established within east Yakutia.

The Verkhoyansk-Kolyma megasystem which corresponds to the fold system under the same name and the distribution zone of the Verkhoyansk terrigenous complex, is characterized by homogeneous weakly differentiated gravity and magnetic fields with local sections of mosaic (in the distribution zones of granite massifs) and banded anomaly field structures. The Verkhoyansk-Kolyma megasystem includes the following anomaly systems: West Verkhoyansk, East Verkhoyansk, Polousnyy, and Laptev. In plan they have the form of bands elongated along the strike. The bands are rather large in size: hundreds of kilometers in one direction.

The West Verkhoyansk anomaly system, previously known as the Preverkhoyansk anomaly belt (Sitnikov, Spector, 1978), is characterized by on ill-defined mosaic-banded anomaly field structure. Local anomalies of this system are elongated parallel to the strike of the folds and obliquely crosscut banded anomalies typical of the Siberian platform fields.

The East Verkhoyansk is the type system of the megasystem. Here large isometric anomalies are widespread. They are complicated by high-intensity anomalies related to granite batholiths and their contact margins. The general structure of the anomaly field is homogeneous and weakly differentiated. The Polousnyy system is characterized by a mosaic structure, while the Laptev system by an ill-defined banded gravity field structure and non-differentiated magnetic field structure.

The Svyatoy Nos-Kolyma megasystem includes the Svyatoy Nos-Anyui system of northwest striking banded anomalies and the Alazeya-Oloy system of concentrically banded anomalies with the Alazeya block as its center. In the Alazeya-Oloy system, formations of the "granitic" layer are practically absent and at a depth of about 10 km the rock density value is 3.0. The Anyui system has similar characteristics. These data, along with the above mentioned geological materials permit us to suggest that relics of the ocean-type or transition-type crust has preserved in the inner zones of the Novosibirsk-Chukotka and Verkhoyansk-Kolyma fold systems.

Alongside the banded anomaly systems, the megasystems under consideration contains mosaic anomalies. The largest of them is the Omolon anomaly corresponding to the median massif under the same name. It is characterized by a normal thickness (up to 40 km) of the Earth's crust and the presence of "a granitic" layer. Anomaly systems consist of zones which unite several similar anomalies. An anomaly zone might include anomalies of different correlation type, but show similar form, strike, intensity, etc.

ZONATION OF THE PRE-RIPHEAN BASEMENT (CENTRAL YAKUTIA)

Zonation is based on the concept of a discrete structure of the Earth's lithosphere (Krasnyy, Sadovskiy, 1986). As applied to the consolidated crust of ancient platforms, the concept assumes that similarly ranked units of tectonic divisions (Kosygin, 1964; Soolovyev, 1975); isometric (Archean cratons, crystalline clumps, metamorphic blocks) and linear (Early Proterozoic foldbelts, interclump zones, interblock faults), combined in groups of twos to form a closed structural cell (Mishin, 1988). With such grouping, isometric units always fill the inner part of cells to form the cores, while linear ones form outer limits (walls) of the cells. A basic structural unit of the lithosphere of ancient platforms is a "Staisy cell" (Steisy, 1972). Structurally similar subordinate cells occur in a basic cell in accordance with the geometric type (orthogonal, diagonal, concentric-radial) of crustal tectonic divisions prevailing in the given region.

Cartographic presentation rank units.

In accordance with the generally accepted systematics, linear units in the study area (intercratonic belts, interclump zones, interblock faults) are not only large geologic bodies of a particular size but categories of tectonic divisions too. That's why in the legend they are assigned to appropriate fault classes. Faults of a smaller rank divide Precambrian stratified structural-formational complexes of the continents (SFC after Kosygin, 1964). Reference complexes in the exposed part of the Aldan Shield are metamorphic series given in the legend: Udokan (protoplatform), Ulcan (protoorogenic), Iyengra (beyond the limits of the study area), and others.

Rock composition of structural-formational complexes.

Sutam and Timton-Djeltula complexes and their analogues are leuco- and mesocratic hypersthene, two-pyroxene, amphibole, and biotite gneisses. Iyengra and Nimnyr complexes and their analogues are quartzites and quartzite-gneisses interbedded with biotite, sillimanite, and cordierite schists. Olekma and Stanovoy complexes and their analogues are biotite-garnet, biotite-amphibole, and biotite gneisses. Subgan and Tasmiela complexes and their analogues are metaextrusives of basic composition; mica, garnet-mica, mica-sillimanite schists, metaandesites, metadacites, and metarhyolites. Udokan complex and its analogues are phyllites, quartzites, metasandstones, and metasiltstones. Crosscutting bodies are represented by stratified basite-hyperbasite intrusions (Yakutsk-Zhigansk magnetic anomaly - a local analogue of the Great Dike of Rhodesia). Udocan and Chiney complexes and their analogues within the Central-Yakutsk region are represented only by intrusive bodies. These are solitary dikes, dike swarms, injection basite domes, as well as massifs of the central-type alkali-ultra basic rocks. Distribution of these bodies and comagmatic granitic complexes (beyond the limits of the Central Yakutian region) is controlled by spacial polarization: Archean cratons are specialized for acid magma differentiates, while intercratonal belts for basic and ultra basic magma differentiates. The latter are concentrated in the intercratonal belts but along the lateral apophyses they spread into the neighboring cratons.

CONCLUSIONS

In compiling the 1:500,000 scale Geologic Map of Yakutia and the graphic supplements, the authors were guided by consideration of unified requirements. They used standard conventional symbols worked out by themselves. All map sheets are well-coordinated. The materials used were approved by the "Roskomnedra" scientific-editorial council attached to VSEGEI (St.Petersburg). All these are top quality and provide a high level of knowledge on the geology of Yakutia. The map can be used as a reliable base for compiling special maps such as information, tectonic, geodynamic, geochemical, mineralogical, geologic-ecological, etc. It should be of interest for a wide circle of specialists and can be used for training purposes at higher and secondary educational institutions.

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