Geoscience Canada

The Anabar Shield Field Conference, Siberia 1990

David Bridgewater, Garth Jackson et Hewitt Bostock

Volume 18, numéro 1, march 1991

URI : https://id.erudit.org/iderudit/geocan18_1con06

Aller au sommaire du numéro

Éditeur(s)

The Geological Association of Canada

ISSN

0315-0941 (imprimé)
1911-4850 (numérique)

Découvrir la revue

Citer cet article

Bridgewater, D., Jackson, G. & Bostock, H. (1991). The Anabar Shield Field Conference, Siberia 1990. *Geoscience Canada*, *18*(1), 28–32.

The Anabar Shield Field Conference, Siberia 1990 [1]

David Bridgwater
Geological Museum
Østervoldgade 5-7
Copenhagen
Denmark DK 1350

Garth Jackson and Hewitt Bostock
Continental Geoscience Division
Geological Survey of Canada
601 Booth Street
Ottawa, Ontario K1A 0E8

INTRODUCTION

Under the auspices of International Geological Correlation Programmes 217, 247 and 280 and International Lithosphere Programmes, Working Groups 2a and 2c, 7 foreign and 17 Soviet geologists visited the Anabar shield in northern Siberia (Figure 1), which until recently has been one of the Precambrian areas in the world least known to geologists outside the Soviet Union. To the best of our knowledge, the 7 noted above are the first foreign geologists to visit the shield in many years. The field excursions and workshop, held 17-27 July 1990, were led and organized by Professor O.M. Rosen, whose institute (Institute of the Lithosphere, USSR Academy of Sciences, Moscow) contributed the major part of the very considerable expenses involved. A comprehensive guide book prepared for the workshop (Rosen, 1990) includes many chemical and isotopic results. More complete details are available in Rosen (1989) and in Rosen *et al.* (1988). These papers are used freely in the following report.

Approximately half the time was spent in lectures and discussions in a field camp set up by the Institute of the Lithosphere, and half in visiting outcrops either by helicopter or tracked vehicle. The 24 hours of daylight in this part of Siberia during July were utilized to the full, even if the helicopters at times arrived at 18:15 h to begin a day's work.

Most of the foreign guests were essentially field geologists with many years of regional experience in shield areas in Canada, Greenland, southern Africa and China. We immediately found ourselves at home among our Soviet counterparts. The workshop was designed so that Soviet geologists could present ideas and information from their work on the Anabar shield, virtually all of which was new to the foreigners and a large part of which was probably new to many of the other Soviet geologists present. Both the results and their interpretations were discussed while actually looking at the rocks. The foreigners presented summaries of their own work, either as up-to-date reviews of areas of which they had detailed knowledge, or as reviews of their particular fields of expertise which bear on the interpretation of Precambrian shields. As visitors, we hope that our Soviet colleagues got as much stimulation from us as we did from them.

The Anabar shield is a *ca.* 50,000 km^2 area of complexly folded, granulite- to amphibolite-facies, Archean and Proterozoic gneisses, with a regional NNW-SSE structural trend (Figure 2). Middle Proterozoic to Cenozoic diabase dykes intrude the gneisses and trend chiefly E-W. Gently dipping, Middle Proterozoic and Early Paleozoic, sedimentary rocks rim the triangular shield. Kimberlite and carbonatite pipes (chiefly Silurian-Devonian) occur around the shield and in its easternmost parts.

ANABAR COMPLEX

About 80% of the Anabar shield is complexly folded gneisses of the Anabar complex, which itself is chiefly Archean granulites. These high-grade rocks have been subdivided stratigraphically from bottom to top into the Daldyn series, Upper Anabar series and Hapschan series ("series" as used by Rosen (1989, 1990) corresponds to "group" in western stratigraphic nomenclature). The regional model used as a basis for discussion during the conference (Rosen, 1990) considered that all three series have been derived chiefly from supracrustal rocks. The two lower series form most of the Anabar complex and crop out throughout the shield area. They have been interpreted as being mostly mid-Archean felsic metavolcanics with variable amounts of paragneisses and mafic metavolcanics: the lowermost Daldyn series contains a significant proportion of paragneisses and mafic rocks, while the overlying (suggested), slightly younger, Upper Anabar series contains more homogeneous, hypersthene-bearing plagioclase gneisses of general tonalitic composition. Tonalites in the Daldyn and Upper Anabar series have been interpreted as recrystallized volcanics, and the abundant orthopyroxene-bearing plagiogneisses in turn as granulite facies products from tonalitic parents.

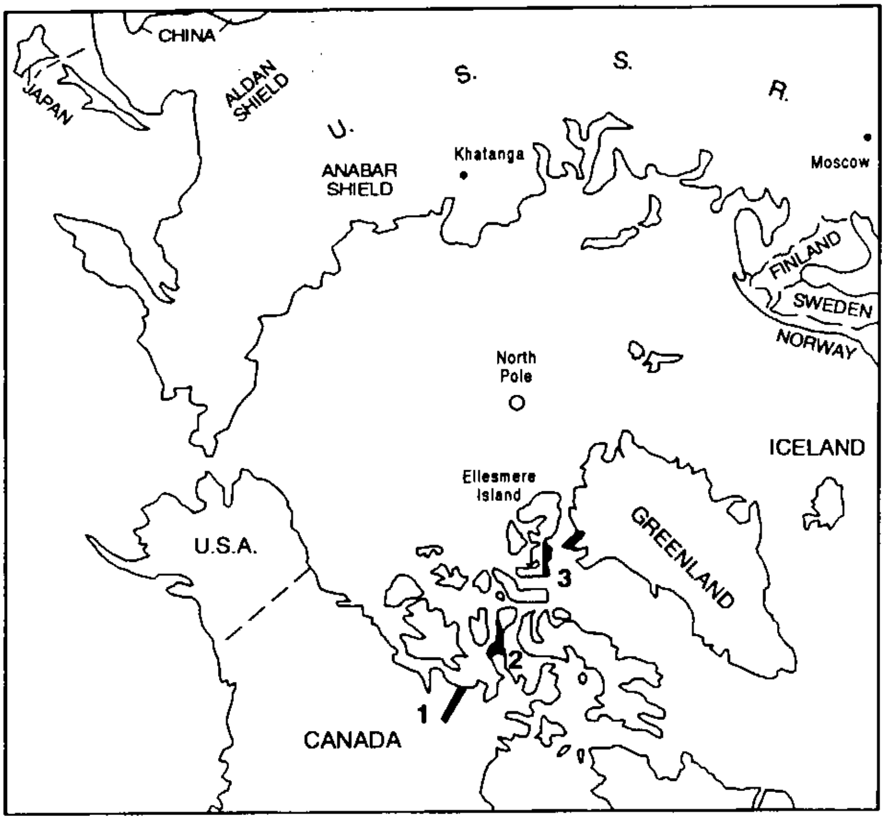

Figure 1 *Location of Anabar shield in relation to Aldan shield, Thelon Tectonic Zone (1), Boothia Peninsula - Somerset Island (2), SE Ellesmere Island - NW Greenland (3).*

---

[1] Geological Survey of Canada Contribution No 56490

The uppermost Hapschan series crops out in three major belts (Figure 2). It comprises mostly metasediments, such as garnet gneisses, marbles and calc-silicate rocks, and minor hypersthene plagiogneisses (recrystallized felsic volcanics?) and mafic rocks. The metasediments shown to us in the field seemed to be in the amphibolite metamorphic facies. Also, mineral assemblages noted in the literature are not diagnostic of the granulite facies, although locally developed granulite-facies assemblages are known. Neither way-up criteria nor unconformities between the three series are reported, but outcrop pattern, metamorphic grade and available isotopic data (see below) have suggested to several Soviet workers that the Hapschan series should be treated as a separate younger unit, a policy followed in this report and in Figure 2.

The main structures seen in the granulite-facies gneisses follow the NNW-SSE regional trend. There are local fold closures with clear repetition of units on a scale of hundreds of metres. From the helicopter traverses made during the field excursions and from maps in Rosen *et al.* (1988), several of us gained the impression that the regional strike could represent a late regional strain impressed on earlier complex folds, the hinge zones of which are preserved in "eyes" of low deformation. The regional structural pattern resembles that of granulite terranes elsewhere which have been affected by one or more periods of later, inhomogeneous, high-strain deformation.

The high-grade gneisses are divided geographically into major tectonic blocks by three major and two minor shear zones of intense deformation that trend parallel to the NNW-SSE regional structural trend. These deformation zones may have been initiated in the Late Archean, but their present features developed chiefly in the latter part of the Early Proterozoic. They contain amphibolite-facies tectonites, called the Lamuyka complex, that are considered to comprise mostly tectonically reworked Anabar complex. The shear zones seem to some degree to have controlled the distribution of an anorthosite-bearing suite and late Early Proterozoic granitic plutons that are restricted chiefly to the three major shear zones.

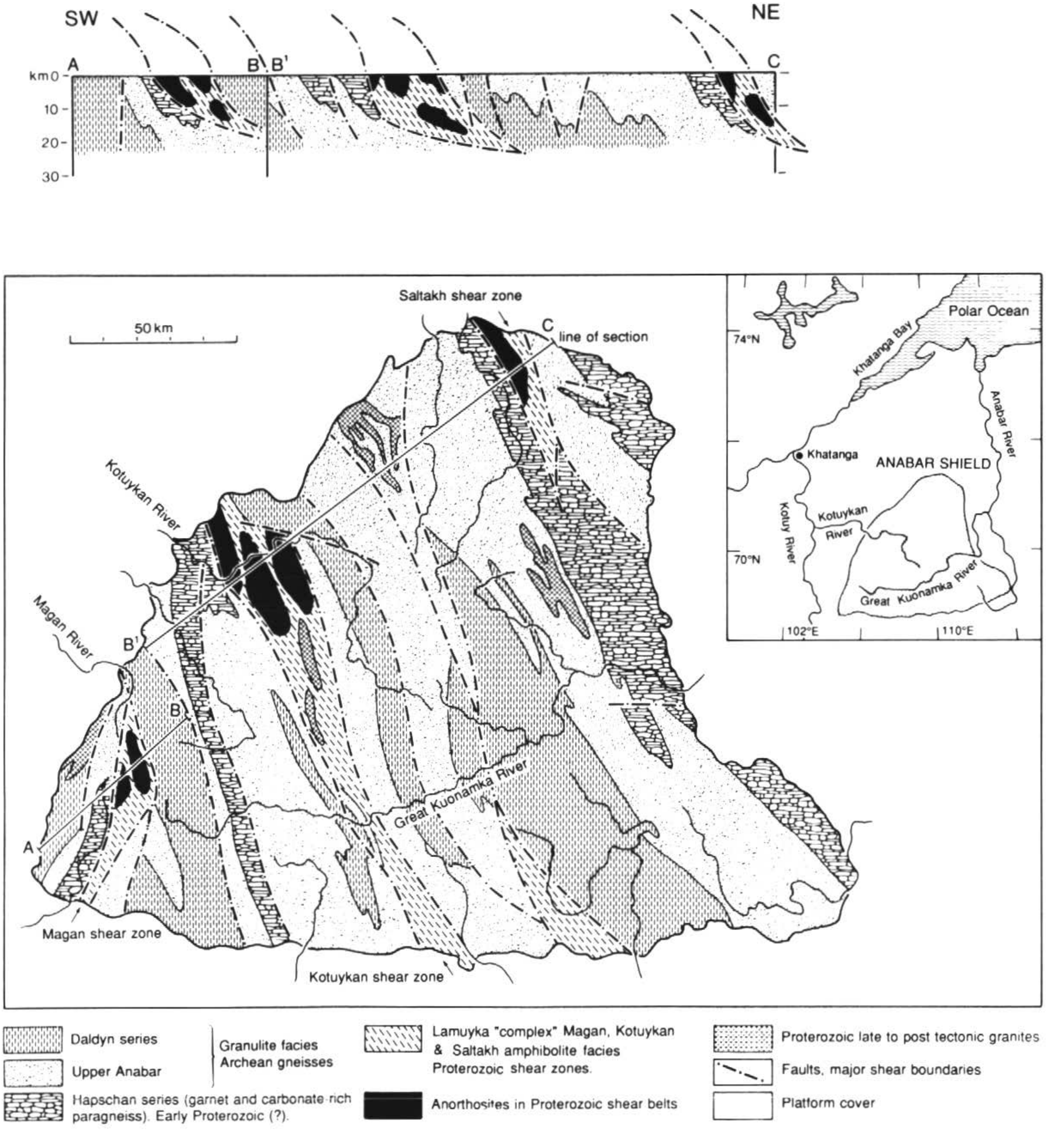

Figure 2 *Geology of the Anabar shield. (Modified from Rosen, 1990).*

The oldest materials so far dated from the Anabar shield are zircons from the granulite-facies plagiogneisses of the Daldyn series, which yield a concordia intercept age of 3.32 Ga (SHRIMP ion probe data by E.V. Bibikova in Rosen *et al.*, 1988). Both conventional U-Pb multigrain zircon discordia ages and Nd depleted mantle model ages fall between 3.0 and 3.4 Ga for the Daldyn and Anabar series, but show no significant difference between the two groups. The limited number of outcrops which could be visited during an excursion of this kind confirmed that metasedimentary and metavolcanic rocks in various stages of migmatisation and partial melting are a conspicuous component of many outcrops. Both the supracrustal enclaves and their host plagioclase gneisses were partially melted and remobilized during a Late Archean granulite-facies metamorphism. The apparent abundance of supracrustal remnants gives rise to the fundamental question of whether the Anabar shield differs in proportions of paragneiss to orthogneiss in comparison with areas such as the North Atlantic craton, where gneisses of demonstrable metasedimentary or metavolcanic origin form less than 10% of the total outcrop. Alternatively, the abundance (or dearth) of paragneiss may reflect an artifact of the exposure, and a third possibility is that part of the paragneisses seen in the Anabar complex may reflect younger supracrustal material interlayered tectonically with older basement gneisses. Certainly, at this stage in the regional mapping, most of the foreign visitors would perhaps be cautious about erecting a stratigraphy across large areas of complexly folded, high-grade gneisses using subtle distinctions in the abundance of key lithologies of paragneiss and metavolcanic remnants surrounded by tonalitic gneisses. If the lithological distinction between the Daldyn and Upper Anabar series is valid, a possible explanation of their wide regional distribution may be that each series of plagiogneisses and associated supracrustal remnants represents different tectonic slices (terranes) juxtaposed during a Late Archean tectonic event which culminated in the regional development of granulite facies. In many shield areas, the pre-3.0 Ga history seems to be one of small continental masses of different ages welded together during the Late Archean. If over 70% of the gneisses of the Anabar shield (and by inference a large proportion of the hidden Siberian basement) formed directly from pre-3.0 Ga metasedimentary or metavolcanic parents, then we are going to have to revise our ideas of Archean evolution between 3.6 and 3.0 Ga. Regional whole-rock dating methods, such as Pb-Pb or Sm-Nd model-age work, may be able to give at least an indication of whether or not the Archean units in each structural block are approximately the same age, and whether or not they had a major metasedimentary component. For finer correlations, we may not know the answers until single crystal dating of zircon becomes more commonplace than at present.

The regional granulite-facies metamorphism which affected the Daldyn and Upper Anabar gneisses was associated with a high degree of partial melting during which small enderbitic and charnockitic bodies were formed. There is at least local evidence that this took place *in situ*. Fluid inclusion data suggest CO_2 flux was associated with the formation of some of the more massive hypersthene-bearing bodies. Low-U zircons from some of the granulite-facies gneisses give concordia upper intercept ages of 2.7-2.8 Ga, but it is uncertain whether this represents the only granulite-facies event affecting the Anabar complex, since other results include an upper intercept age at 2.3 Ga and a Sm-Nd mineral isochron age of 1.9 Ga.

A Nd-depleted mantle model age of 2.4 Ga has been obtained from four samples of the Hapschan series. The data form a tight group on a Sm-Nd isochron plot, suggesting that this model age is unlikely to be the result of metamorphic disturbance of an appreciably older sequence. While the model age does not give a precise age of deposition, it clearly separates the Hapschan series from the Daldyn and Upper Anabar series. Furthermore, although a minor clastic component derived from a *ca.* 3.2 Ga basement may be present, the Nd model age strongly suggests a major Proterozoic component from a juvenile source and also that this series was deposited later than 2.4 Ga. Sm-Nd mineral ages for the Hapschan series and zircon ages for the Lamuyka complex and associated plutons (1.8-2.0 Ga) are taken to indicate a minimum age of 1.9 Ga for deposition of the Hapschan series. Detailed geochemistry and stable isotope studies (with a major contribution from one of our guides, Dr. Valery Zlobin of the Institute of the Lithosphere) point to a marine environment with some sialic detritus. The low Nd model age may indicate a 2.0 to 2.4 Ga volcanic component from a mantle-like source.

LAMUYKA COMPLEX

The tectonites of the Lamuyka complex occur in the five shear zones mentioned above (Figure 2), and include a variety of rocks that can be related to those of the Anabar complex. These range from rafts or tectonic augen of slightly retrogressed granulite-facies gneisses to thoroughly reworked and recrystallized gneisses. There are, however, rock assemblages within the shear belts which may be absent, less abundant, or just not seen by us in the adjacent granulite-facies Archean gneiss complex. These include a supracrustal sequence associated with major units of amphibolite and anatectite, and major anorthositic and granitic intrusions. Chemical compositions of Lamuyka complex and Anabar complex gneisses differ markedly, in that there is a higher concentration of LIL elements in the Proterozoic shear belts (Rosen, 1989). This may reflect different primary assemblages, the results of chemical changes during retrogression, or, most probably, a combination of both factors.

Rounded, relatively uranium-rich zircon fractions from biotite gneisses in the Lamuyka complex have given U-Pb intercept ages of *ca.* 1.97 Ga, which has been interpreted as the age of amphibolite-facies metamorphism.

INTRUSIVE ROCKS

The Lamuyka complex within the three major shear zones seems to form the host rock for several meta-igneous complexes, the most important of which contain anorthosites associated with monzodiorites and jotunites. The anorthosites are complex bodies, ranging from pyroxenite layers through coarse-grained olivine-orthopyroxene-bearing leucogabbros to true anorthosites with the mafic minerals concentrated in faint layers. The anorthosite complexes are at least locally strongly deformed, and the Proterozoic deformation impressed on these meta-igneous rocks varies markedly. In general, outcrops in the centres of the bodies locally preserve original igneous textures and minerals; those near the margins are strongly foliated and their original orthopyroxene-olivine-clinopyroxene-plagioclase igneous assemblages have recrystallized under amphibolite-facies conditions.

One outcrop of massive white anorthosite in the centre of the Kotuykan shear belt attracted considerable interest. It consists of medium-grained anorthosite with rather ill-defined, irregular and folded layers of hornblende leucogabbro. The layering is cut by irregular sheets and dykes of hornblende-rich material with a high content of accessory minerals such as zircon and apatite (V. Zlobin, written communication, 1990). Zones of alteration contain zoisite, which is also found as intergrowths within the anorthosite. Garnet-epidote rock forms irregular masses several metres across within the anorthosite mass. Corundum crystals occur locally, in possible association with zoisite veins. The main feature which gave rise to considerable discussion (even among the present writers) was an apparent discrepancy between the comparatively low strain seen over a large part of the outcrop and the lack of high-temperature igneous minerals such as orthopyroxene, relics of which are abundant in other, more noticeably deformed parts of the complex. Textures over much of the outcrop resemble those seen in undeformed cumulate igneous rocks, with hornblende crystals filling the interstices between plagioclase. The late mafic dykes, which we interpret as late differentiates, cut the layering in the anorthosites, but are themselves irregular and boudined. In general, they are massive to weakly foliated, with locally aligned hornblende, indicating that the mineralogy is at least partly metamorphic. A working hypothesis put forward by two of the visitors (B.F. Windley and D. Bridgwater) suggested that many of the features could be those of a wet primary magmatic body, possibly near the roof of the original anorthositic intrusion, the lower parts of which crystallized from a drier magma as plagioclase-olivine-pyroxene rocks. However, subsequent thin-section study has verified that the anorthosite at this outcrop is strongly recrystallized. Scattered primary plagioclase cores are rimmed by granular material, the hornblende is metamorphic and at least two generations of zircons have been identified. The origin of the water in the upper part of the body, therefore, is still uncertain.

Age data from the anorthosites are inconclusive. One Pb-Pb age of 2.7 Ga and a few ages between 1.8 and 1.9 Ga have been obtained using the thermo ion evaporation technique on zircons. A Sm-Nd mineral isochron yielded 2.2 Ga. Thus, it is uncertain whether the anorthosites are older bodies caught up in the shear zones or are Early Proterozoic intrusions possibly emplaced during the deformation that formed the shear zones.

The youngest rocks forming the Anabar shield are biotite granites. These occur within both Archean gneisses and the Proterozoic shear belts (Figure 2). Outcrops visited during the excursion suggested that although these bodies were emplaced after the main deformation in the shear zones they recrystallized during the final stages of metamorphic and tectonic activity. The granites have yielded U-Pb zircon discordia ages between 1.84 and 1.87 Ga. Pb-Pb ion evaporation ages for charnockites outside the shear zones are younger than 2.0 Ga.

METAMORPHIC AND TECTONIC HISTORY

Mineral assemblages and geothermobarometry in the Anabar complex indicate that pressures of about 8 kb at temperatures of about 800°C were common. The highest values (11 kb at 950°C) were obtained from the central part of the shield. Values for the Lamuyka complex average about 6.5 kb at 700°C and show a retrogression to greenschist facies (6-4 kb, 650-480°C). Fluid inclusion P-T determinations for both complexes agree well with the mineral-based estimates.

Aeromagnetic and other geophysical studies presented at the field conference (see also Rosen *et al.*, 1988) suggest that the overall linear structural pattern of the Anabar shield and its related regional differences in metamorphic grade extend south-southeast some 1500 km to the Aldan shield (Figure 1). Similarities in regional trends and recently determined U-Pb zircon ages suggest a more tentative correlation with Archean and early Proterozoic rocks of SE Ellesmere Island, Boothia Peninsula and the Thelon Tectonic Zone in northern Canada, now separated from Siberia by the Arctic Ocean (Figure 1).

To summarize, the Daldyn and Upper Anabar series appear to represent the most important components in a large shield area that formed at or prior to 3.3 Ga and was deformed and metamorphosed to granulite facies at 2.8 Ga. Several of the Soviet geologists and many of the foreigners considered that the Hapschan series is Early Proterozoic in age rather than Archean and that the present outcrop pattern is the result of tectonic interlayering between an Archean basement and cover rocks. The geochronology presented to us and the presence of orthopyroxene-bearing intrusions which postdate regional high-strain structures gave some support to this model. It seems possible that much of the Anabar shield may have reached upper amphibolite-facies conditions at about 1.9 Ga and that granulite-facies conditions were reached locally in association with the intrusion of charnockitic bodies also at about 1.9 Ga, an hypothesis also advocated by several Soviet geologists.

As in complex shield areas worldwide, there is considerable scope for detailed U-Pb work on single zircons, particularly where a detailed local field chronology has been established. Many of us were very pleased to see that the art of exact field observation and deduction flourishes in the Soviet Union. Olga Syschina, a graduate student from the Institute of the Lithosphere, showed the visitors a classic example of how she had used structure, differences in metamorphism and dyke chronology to unravel a sequence of events on the margin of a charnockite body within the Archean, granulite-facies gneisses. If this detailed field work can be followed up by U-Pb studies on well-controlled field samples, it should be possible to demonstrate conclusively whether there was more than one period of granulite-facies metamorphism in the high-grade gneiss complex. Pb-Pb ion evaporation ages of 1.9 Ga reported from granulite-facies basic dykes at this site suggest that there was Proterozoic activity within the older gneisses.

A problem complementary to the metamorphic history of the high-grade area is the origin and history of the major shear zones. If most of the deformation in the shear zones occurred at about 1.9 Ga, their size and spacing suggest that the parallelism of the structures in the Archean complex might, at least in part, be due to a Proterozoic imprint. The major shear zones may represent possibly long-lasting fractures along which contiguous parts of the same sialic crustal block moved against one another and along which large grabens were formed. Alternatively, they may represent major thrust zones, possibly ramps, related to the docking of previously unrelated (exotic) terranes. According to Rosen (1990), strain indicators are consistent with thrust movements toward the WSW (Figure 2). Left-lateral slip movements are recorded by rotated feldspars in the Kotuykan shear belt. However, from regional mapping, one Soviet geologist considers most of the movements in the shear zone to have a major right-lateral strike slip component. Nearly all the rocks within the shear belts contain amphibolite-facies assemblages, with locally preserved relics of an older granulite-facies assemblage. Observations during the excursion suggested a complex history of early granulite-facies metamorphism, followed by retrogression during deformation and then by late, essentially static, local growth of orthopyroxene associated with granite veining. As with the high-grade complex outside the shear zone, there is scope for U-Pb zircon geochronological studies on samples selected as time markers in the shear belts.

EPILOGUE

In conclusion, the Anabar shield provides an important window on a major part of the Precambrian crust and fully justifies the research efforts being made in it. The workshop and field excursions were stimulating scientifically and, at the same time, a very enjoyable personal experience. The visitors came away with a great deal to think about and a very positive impression of Soviet geological science. In 1990, the western media have been full of adverse comments on standards of management in the Soviet Union. Oleg Rosen showed that under any system, a mixture of enthusiasm, leadership, humour and, on occasion, a little show of controlled temper over the radio can work wonders. Anyone who has worked with helicopters hundreds of kilometres from base in the remote Arctic knows that intelligent planning, while often for naught, is essential. To get 24 visitors through many bureaucratic hurdles, into the field on time, house them, feed them with fresh vegetables, fish, meat and vodka, show them all the outcrops in the guidebook, persuade them to hold lectures, and then get them back to Moscow on schedule needs management abilities out of the ordinary. To ensure good weather and a mosquito-free summer in northern Siberia suggests powers which most of us do not have. In fact, the only serious hold-up was with baggage collection at Moscow airport — a phenomenon not exactly unknown in Heathrow or Toronto and certainly needing higher powers to solve. We only hope that the visitors gave some value in return, even if only to encourage Rosen and his colleagues to refute some of the more uncontrolled ideas put forward. In this, the geologist who knows the area will always have the last word. Rosen and his co-workers certainly know the Anabar shield!

ACKNOWLEDGEMENTS

We are grateful to T. Frisch for reading the manuscript and suggesting several improvements. Figure 1 was drawn by Jay Pratt and Figure 2, by Ragna Larsen.

REFERENCES

Rosen, O.M., 1989, Two geochemically different types of Precambrian crust in the Anabar shield, North Siberia: Precambrian Research, v. 45, p. 129-142.

Rosen, O.M., 1990, compiler, Metamorphic rocks of the Anabar shield, Workshop guide: Academy of Sciences of the USSR, Institute of the Lithosphere, 102 p.

Rosen, O.M., Andreev, V.P., Belov, A.N., Bibikova, E.V., Zlobin, V.L., Lyapunov, S.M., Milanovski, S.Yu., Nozshkin, A.D., Rachkov, V.S., Sonyuschkin, V.E., Sukhanov, M.K. and Shakhotko, L.I., 1988, The Archaean of the Anabar shield and the problems of the early evolution of the Earth: Nauka, Moscow, 253 p. [In Russian].

Accepted, as revised,
28 February 1991.

Geoscience canada

**CANADA'S
BEST
KEPT
SECRET**

Everyone knows about *Facies Models*, the book.
It started life as a series in *Geoscience Canada*.
Why wait for the book?
Get a head start on your colleagues —
read it in *Geoscience Canada* first!

Established in 1974

Geoscience Canada, published quarterly in March, June, September and December by the Geological Association of Canada, covers all fields in the geological sciences. The journal is received worldwide by more than 3600 professional geoscientists working in industry, universities, government departments, and consulting, and by libraries and students.

In general, contributors provide reviews of topics of current interest in their field of specialization in a style that will interest and inform both specialists in other fields of geoscience and non-specialist earth science readers. These include topical series of invited reviews suitable for reference or teaching purposes (see list below). Also published are conference reports, book reviews, discussions of previously published articles, letters to the editor and other regular features.

The following series of topical review articles have been revised and published as:

- Facies Models
- Dating Methods of Pleistocene Deposits
- Ore Deposit Models
- Diagenesis
- Methods in Quaternary Ecology

Geoscience Canada Reprint Series 1, 2, 3, 4 and 5, respectively.

Order your subscription today!
Only $40 * (Canadian) per year!
* (Canadian orders add 7% GST)

Orders and requests for information should be sent to:
Geological Association of Canada, Publications — GC181,
Department of Earth Sciences, Memorial University of Newfoundland,
St. John's, Newfoundland A1B 3X5