INTERPRETATION OF AIRVIEWS AND SATELLITE IMAGES: MORE POTENTIALITIES FOUND

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ABSTRACT:

The authors have revealed a new solution in the field of plotting aerial and remote survey data, which enables to visualize crystalline formations deep beneath the Earth's surface. That lithological/facial features of deep-seated geological bodies turn out to become visible makes us to admit that we are facing natural phenomena still unknown and independent in terms of time and space. Such ability to discern the results of these phenomena offers many prospects in various fields of geoscience. This presentation demonstrates how successfully a practical utilization of the said ability comes off in geological industry.

This presentation is intended to inform an audience and geological community on abilities the remote sensing data conceals. One of such "secret" powers consists in that a pattern of deep-seated crystalline formations can be recognized (invention covered by Author's Certificate #1393026, registered January 3, 1988, in the former USSR). This, to a great extent, facilitates a procedure of constructing geological maps showing a top surface of a basement overlain by a "sandwich" of sedimentary strata. The pattern can be produced to view in a scale range from 1/10,000 to 1/1,000,000. Geological plotting of compound multilayer sections is known to be a toilsome job requiring expensive methods in the field of geophysics, geochemistry, drilling, aerogeology, remote sensing, etc. And yet, sometimes even such a multidisciplinary study fails to yield a complete picture, be it a top surface of a buried basement or some deep-seated structural level of unconformity. As for the commonly applied conventional airborne survey methods, these all are known, as it is admitted in the manuals, to possess a low efficiency in case of deep mapping. What makes their application fairly limited is a sedimentary cover's thickness, lithified rocks in the cover sequence, geological setting of an area in question, its geographic localtion, how well the area is economically developed, and many other factors as well.

True, what we suggest as a method of constructing the geological maps for various depth intervals on the basis of airviews and satellite images may sound rather uncommon, and yet the Earth pictures are such that they enable to reconstruct the lithological/facial mode of a plate basement and the surfaces of regional unconformities in the very deeply seated crystalline rocks varying in composition. To acquire indispensable data, one needs nothing but airphotos and satellite flown images, and topographic base maps to make the latter's geolocation. To avoid any predisposition when constructing geological maps based on airborne-satellite-flown survey data, we abstain from examining any geological information already available for the area in scrutiny.

As far as well-exposed areas are concerned, to recognize and plot geological objects there by dint of natural indicators is known to have been a long-time practice. Specialists can easily interpret the patterns on the basis of airborne and satellite data: indeed, they are quite confident in plotting linear and planar elements, as well as such rock features as a texture, structure and composition, a shape of a geological body, its boundaries, strike and dip of layers, etc.

Thanks to natural indicators, plotting of very deeply seated crystalline formations is possible, too; here the indicators are put together in the form of lines reproducing similar landscape components which one identifies on remote survey photos. Field work experience has proved each such line to correspond to particular sets of arranged in persistently repeated rows ultimate groups of unambiguous landscape components. The latter comprise minute and microtopographic features, nano- and mesocombinations of plant communities and water-impregnated areas, these being arranged in nonrandomly oriented linear or curvilinear forms. No study has been made yet as to how texture and structure of the crystalline rocks are translated vertically up to the surface, whereupon they give shape to the abovesaid landscape complexes.

Thus, a spatial combination of landscape components that form up an array of the lines, or "symbols", unmistakenly reproduces a composition of deep-seated crystalline formations as an imprint on a surface of the sedimentary rocks. Geological mapping, prospecting and detail exploration in various landscape- and geozones have established and proved this phenomenon quite definitely. The lines, as an outcoming information, are pinpointed on a photo and then plotted on a topographic map where these are called the lines with "preferred orientation" (LPO). Borrowed from F.H.Lahee's "Field geology", NY, 1961, this definition has been reserved to the authors since 1978. Normally, the lines with resemblant patterns make up persistent "cartographic images" (CI) - a definition borrowed from A.M.Berliand's "An image of a space: a map and information"(Moscow, "Mysl" Publishing House, 1986, in Russian). As it shows up from the LPO's, a particular CI corresponds to particular features of a particular deep-seated rock. Provided a specialist knows by appearances the structural/textural features of a rock type, its composition and genesis, he can easily recognize and translate such CI into the said rock type. A so to speak read-out of CI's is known to be most reliable in case of generally classified, or undivided, geological sequences, like granitoids, gabbroids, effusives, metamorphites, etc. Using an "image" language, one can read from sedimentation strata a rock composition and geometry of crystalline formations, their fabric, relative age and other particulars, zones of plastic strain and metasomatism included. In other words, one can create a "lay-out" of a geological map; moreover, the lay-out of an aerophotogeological map can be made for any area overlain by a cover of unconsolidated sediments, whatever the physiographic conditions of this area are. Besides, the CI gives means to construct, when needed, geological maps for the surfaces of regional unconformities within the basement, at its various depth intervals, in the crystalline rocks varying in composition.

An example of a 1/200,000-scale map showing the LPO's and results of structural interpretation thereof is given in Figure 1 (Q-cover thickness up to 50 m). Where the LPO's strike in a nearly latitudinal direction one can trace a distinctly pronounced CI of an anticlinal fold with a trend close to meridional. The fold is discontinuous because of longitudinal faults that cut the fold's closure into three segments resembling a trident. A central structural high is accompanied in the W and E by narrow and parallel minor inverted folds, of which the western one is nearly asymmetric, while the eastern fold is just cut off along the fault. The anticline has resulted most likely from vertical movements in the process of magma intrusion, as one may judge from a series of sills developed within the anticline. Host rocks responded to folding by forming medium-size fault blocks, or mesoblocks, varying in height. In the south, trains of lakes have enabled a concealed fault, that marks off the confines of megablocks, to be identified running normal to the fold's lineation and axes. As it follows from the CI's geometry, a group of rocks constituting a territory may be regarded as granitoids and their varieties.

Figure 2 shows another case of reading out, in the same scale, the lithological/facial mode of the crystalline formations under the sedimentary cover as thick as 60 m. Plotted in the drawing is an outcrop area of a jaspilite formation containing iron hornfels (in the middle). The fabric of the hornfel strata is marked by a nearly parallel course of LPO's, whereas the hornfel-bearing host rocks constitute a gneiss complex, displaying their typical CI in the form of extended and very slightly undulating LPO's which not infrequently close up at acute angles.

In 1984 a really unexpected result was obtained in the north of the Fennoscandian Shield (Kola peninsula, Lovozero area). While examining a 1/500,000-scale satellite image, it turned out that the Khibiny massif (size 45km x 36km, area 1300 sq.km, relative elevation up to 800 m, absolute elevation range 1,100-1,200 m), which is subsiding gradually eastwards, and the Lovozero mountainous terrain (5 km to the west, size 25km x 27.5km, area 680 sq.km) were originally nothing else than a single intrusion. One may consider the Khibiny massif of to-day to be a basis, while the Lovozero massif is understood to be a former apex that slipped off a previously single construction eastwards. The satellite image pretty clearly betrays on the Khibiny massif's surface a space which, as our experience in photointerpretation suggests, reminds us of a cut-off that corresponds by its area to the basement of the Lovozero massif. Being projected on to the Khibiny massif, hypsometric, landscape and structural contours of the Lovozero coincide completely with the Khibiny's contours in plan view. Nor do the massifs differ in their inner structure. It should be noted that ever since the very beginning of research activities in the Khibiny intrusion area (1840) and Lovozero massif (1887) those two have been treated by all researchers as two separate alkaline multiple intrusion bodies which possessed a complex structure and primary layering.

In a period 1990-1992 that hypothesis was checked by interpretation aimed to spot an emplacement channel of the Lovozero massif. Results of interpreting the Archean-Proterozoic basement rocks at a depth interval of 1,000-800 m beneath the Lovozero alkaline rock complex are presented in Figure 3 (a,b). Plotted in Figure 3a are the LPO's, while their interpretation in terms of lithology and facies is shown in Figure 3b. Basing then upon the already available geological map of the Lovozero massif's surround (1981) overlain by the Lovozero formations, and looking at the CI's, we succeeded in reconstructing the following stratigraphic sequence of the basement complex: (a) Archean rocks - granites and gneiss-granites, (b) granodiorites and gneiss-granodiorites, (c) Archean-Proterozoic rocks - gneiss-diorites and gneiss-gabbro-diorites, (d) inferred iron-ore formation, (e) gneisses,(f) rocks with their composition not defined yet. As for the intrusive formations, we managed to plot (g) granites, (h) intrusive bodies filling the faults, (i) dikes and dike-like bodies varying in composition and age. We also identified those faults that betrayed unconformity in rocks, in particular (k) thrust faults, (l) normal faults, and (m) shifts.

We have not revealed, however, any feeder, nor any sign of it. On the other hand, as it can be perceived from the CI's, the rock complex related to a bottom of the Lovozero strata that slipped off the Khibiny massif can be described as far from being simple. Some of its parts appear to be deformed rocks that formed while the Lovozero strata were sliding off and down. Good indicators of that are plates of foliation and echelon-like displacement along the planes of sliding off the massif's bottom, as well as the thrust-fault crush zones which attain a thickness of 3 m, as is known from drill log data of 3 boreholes.

Integrated geological-geophysical surveys that the "Petersburg Geophysical Expedition" State Enterprise (PGE) carried out in the area in scrutiny in 1990-1992 were aimed to provide a basis for detail exploration. The specialists involved in the project pointed out a certain genetic affinity between the geological sections of the Khibiny and Lovozero massifs in terms of lithology and structural/textural features. Thus, a poikilitic nepheline syenite complex at the bottom section of the Lovozero strata correlates well with a ristschorrite at an errosion cut plane of the Khibiny intrusive rock formations. Deep layers of foyaites, as a differentiated rock complex in the middle of the Lovozero formations, are similar to the

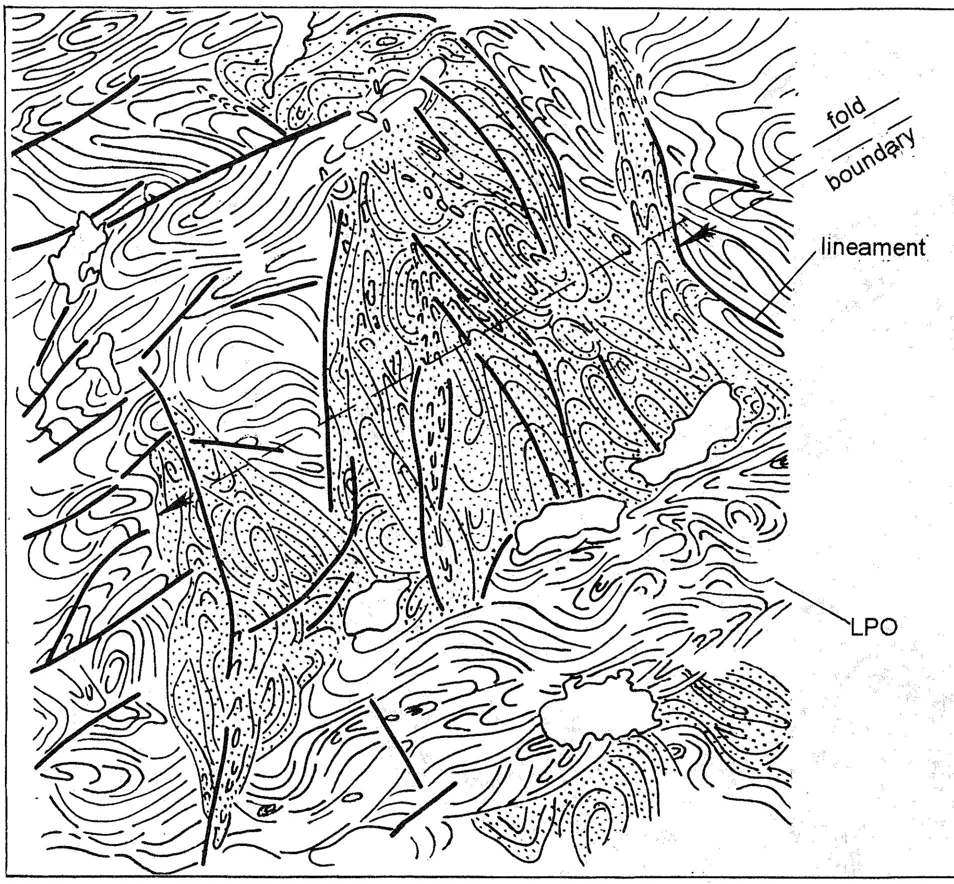

Figure 1. Structural map of Archean-Proterozoic basement, based on LPO's. Q-cover thickness 50 m. Scale 1/200,000. Explanations in the text.

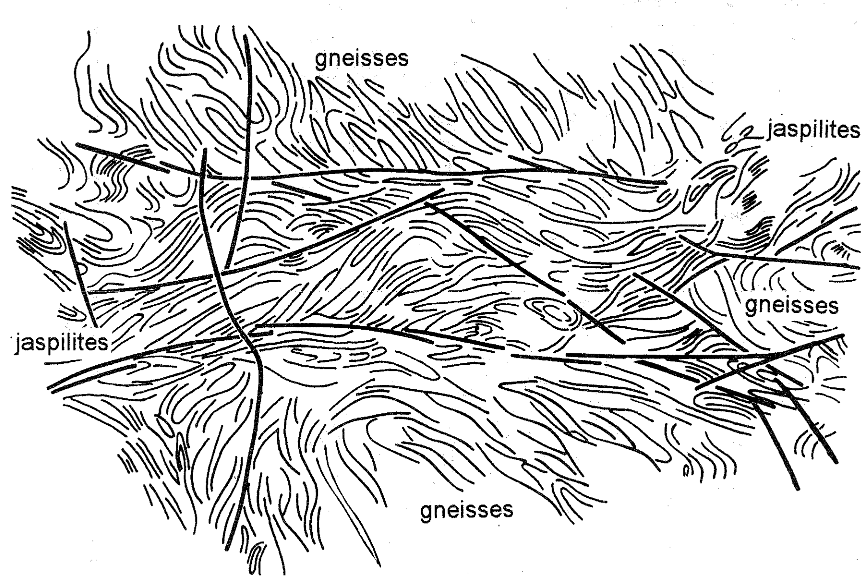

Figure 2. Map of Archean-Proterozoic basement complexes in terms of their lithology and facies, as based on LPO's. Q-cover thickness 40 m. Scale 1/50,000. Explanations in the text.

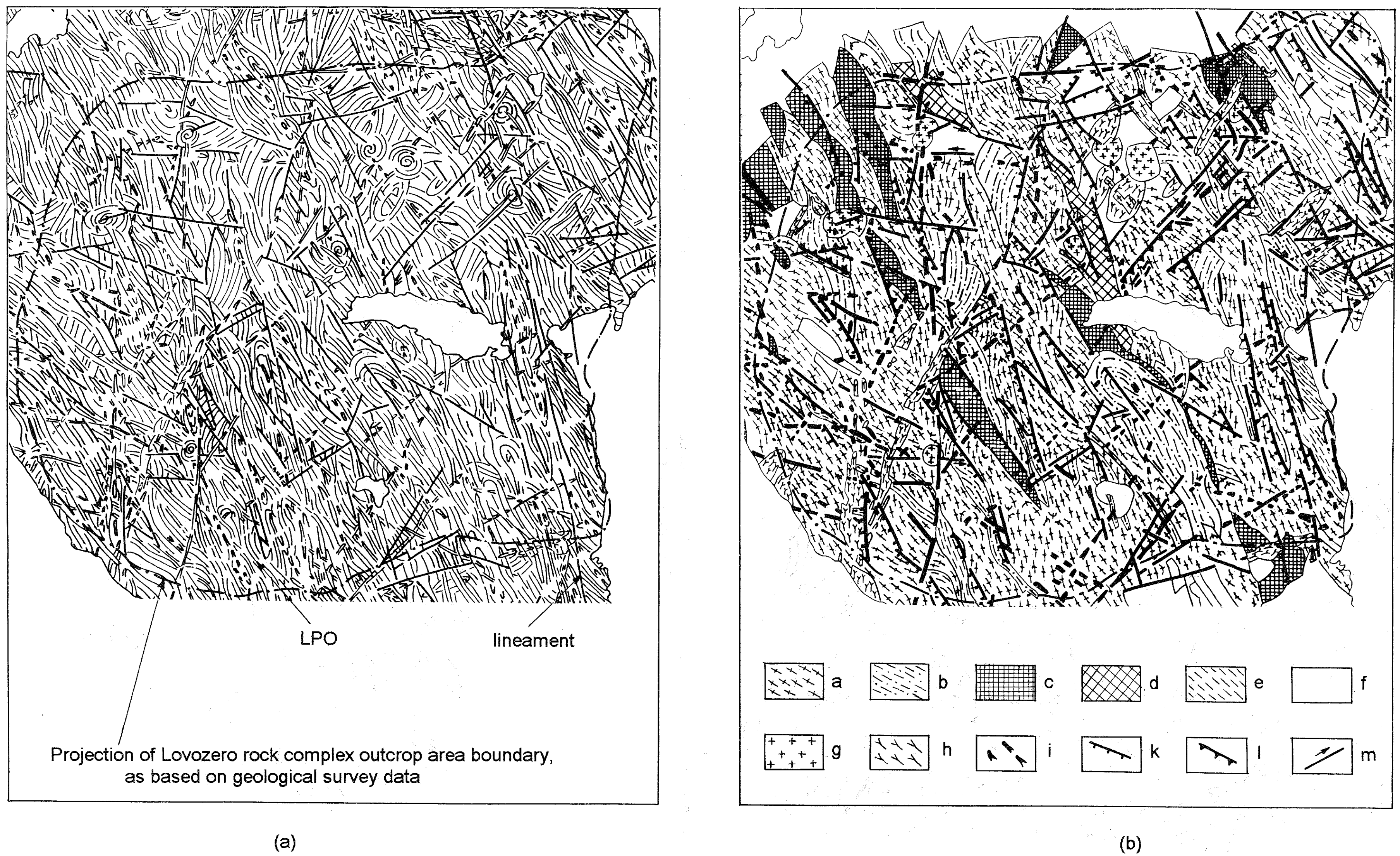

Figure 3. Lines with preferred orientation (LPO) and lineaments, as they are plotted at the Archean-Proterozoic basement level using the images in the scale of about 1/50,000. Thickness of alkaline intrusive rocks, through which mental mapping of the basement is done, ranges 800-1,000 m. Scale around 1/300,000 (a). Geological map based on PLO (b). Explanations in the text.

Khibiny foyaites. Same similarity is observed in a pattern of this or that field of these two massifs. In particular, their magnetic properties are close to each other and so are their outlines. As for gas and chemical state parameters in minerals, they vary, proceeding from Khibiny to Lovozero. Airborne gamma-spectrometry data proved a 3D position of K-Th anomalous concentration zones to be the same in the Khibiny and Lovozero formations.

A gravity survey of the Lovozero rock complex detected a thick horizontal fault zone at a depth of 800-1,000 m. As it was said above, this zone comprises the intervals where rocks are heavily crushed and fractured, these intervals being drilled through by boreholes across the western boundary of the Lovozero massif within the mined areas. Seismic data prove this zone to occur at a depth around 800 m. In the long run the authors came unanimously to a notion that the Lovozero structure could result from shift-slip seismic-tectonic shocks and that, provided the transported Lovozero segment was likely to displace within a distance of 30-40 km from the Khibiny mountains, a slip plane should then be expected to slant eastwards at 20-30°. And indeed, drilling did prove a western contact of the Lovozero massif's bottom to tilt eastwards at 30-35°.

The interpretation technique we have mastered enabled us to be the first in establishing a spatial and genetic relation between the Khibiny and Lovozero alkaline formations. Looking, in parallel, at the geological maps of the Khibiny and Lovozero massifs, based on geological survey and airborne/satellite-flown survey data respectively, we picked eventually out those formations which coincide spatially with each other in plan view and defined the Lovozero formations as a block detached from the apex of the Khibiny massif.

But the most important thing about that is that now we have a prerequisite for creating an utterly new historical-genetic approach to the analytical treatment of airborne and satellite-flown survey data. As a new guideline, this approach yields new potentialities of better looking into the depths of the ore-producing upper terrestrial shell and directing effectively a search for mineral deposits in a basement overlain by a sedimentary cover varying in thickness.