TECHNOLOGIES FOR GEOLOGICAL AND ENVIRONMENT PROTECTION PROJECTS USING REMOTE SENSING DATA AND FIELD SPECTROMETRIC MEASUREMENTS.

Alexei V. Pertsov, Director and Svetlana G. Slutskaya, Secretary for Science

Institute of Remote Sensing Methods for Geology (VNIIKAM),
Birzhevoy proyezd 6, Saint-Petersburg, 199034, Russia
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ABSTRACT: A review of unpublished results by Russian remote sensing institution VNIIKAM is presented. Spectral curves in 1.2-2.4 and 8-14μm regions are obtained by field spectrometry for crystalline rocks of Karelia and Transbaikalia. They are used as a basic data for multispectral surveys. First radar images in the one meter region are obtained by a new SLAR system 'IMARK'. These images provide important information for subsurface mapping. An advance in processing of remotely sensed data is related to 'Data-Knowledge Transformation' project.

KEY WORDS: Remote Sensing, Multispectral, Radar, Expert System, Image Interpretation.

INTRODUCTION

For many years VNIIKAM has been developing various methods of acquisition, processing and interpretation of remotely sensed data, and implementing them as integrated technologies of geological and ecological mapping. The resultant technologies are based on knowledge of physical properties of mapped objects and phenomena, on varying techniques of remote sensing in the visible, infrared and radio ranges, on the data processing both by simple analogue transformations and by digital geoinformation expert systems.

The cornerstone of a remote sensing technology is empirical knowledge of spectral features of the surveyed natural objects.

SPECTROMETRY

Remote Sensing technologies in geology need information on reflection and emission characteristics of natural objects in the range of 0,4-14,0μm. Widerange field spectrometry gives the most accurate estimates as compared to aerial measurements. The following tasks of geological and ecological applications of multispectral remote sensing can be field spectrometry: distinquishing rocks of various composition, detection of man-induced change of environment, selection of wavelength channels for remote sensors and of survey conditions, photometric calibration of remote sensors, radiation correction. In spectrometric investigation of VNIIKAM, supervised by Dr. Surin the following spectrometers are involved: SRP 8/14 - in the thermal infrared range 8-14 μm (Surin 1992), SP-U - in visible and nearinfrared ranges 0,4-2,5 μm (Kuvaldin E.V. et al. 1992), FM - in range 1,2-2,4 μm. The quantities to be measured are spectral reflectance (ρ) in the range of 0,4-2,5 m and spectral emittance (ε) in the range of 8-14 μm.

The SRP - 8/14 is calibrated in laboratory by the standard energy brightness-absolutely black body with regulated temperature. Then the calibration is checked and corrected in field by a special radiator. SP-U and FM are supplied with two standards (measuring and controlling) made of $BaSO_4$ and of Al_2O_3 ceramics. This allows to test the devices in field. Here are the results of field spectral measurements of some Precambrian rocks of the southern margin of the Baltic Shield performed by SRP - 8/14 in Karelia, June 1991. The measured rock varieties show specific sets of spectral bands which are registered as minima of emissivity (Fig. 1a, b, c, d, e, f, g, h). The most characteristic feature of silicate rocks spectra is the wide minimum around 9μm which depends on silica content. This feature has been used for estimation of SiO_2 content in these rocks. The accuracy of discerning is first percents as for the pink pegmatoid in Fig. 1a. If the rocks are weathered (Fig. 1b,c,d) the basic silicate band widens, its intensity changes, and it shifts toward the longer wavelengths. Similar effects have been registered for greisenization, epidotization and other rock alterations (Fig. 1e,f,g). Rocks with dusty surface show another spectra modification: widening of the silicate band along with a shift towards shorter wavelengths as opposed to the long-wave shift caused by mineral content and weathering. In addition there is an increase of emittance around 8,4μm wavelength. A similar effect was previonsly registered by American colleagues in laboratory (Salisbury, 1989). On the whole emission spectra in the thermal infrared region provide apportunity of identifying certain rocks and registering alterations of their surface, induced by whethering and disting. A more detailed analysis of rock spectra (Fig. 1c,d,f,h) has revealed several pairs of objects with intersecting spectral curves. Such spectra have also been obtained from Transbaikalian granites in the region of 1,2-2,4 μm (Fig. 2). In accordance with the conditions of contrast accumulation (Slutskaya, 1986) the two spectral zones neighbouring the intersection of reflection or emission spectral curves are recommended as optimum channals of multispectral scanners. The ration of images obtaned in these two channels amplifies the contrast between the objects of the pair. Simultaneously the contrast between the pair and a background increases. This transformation

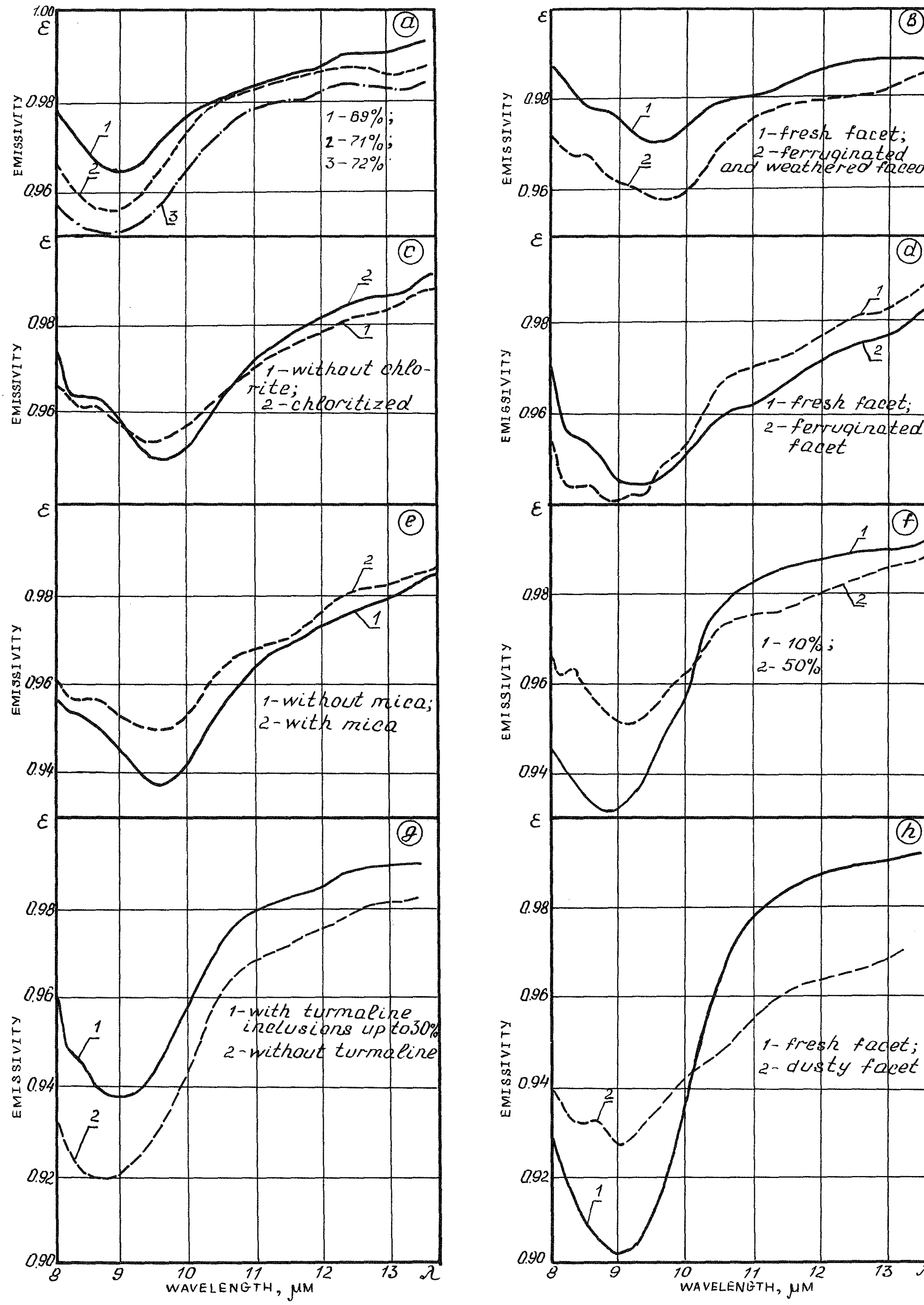


Fig. 1. Spectral emittance of Precambrian rocks of Karelia. (a) pink pegmatoid massif with spectrometrically estimated silica content of its different portions, (b) amphibole-biotite schist, (c) pink gneiss-granite, (d) pink pegmatite, (e) chloritized gneiss-granite, (f) pegmatoid with different content of epidote, (g) rare-metal pink pegmatite, (h) pink gneiss-granite.

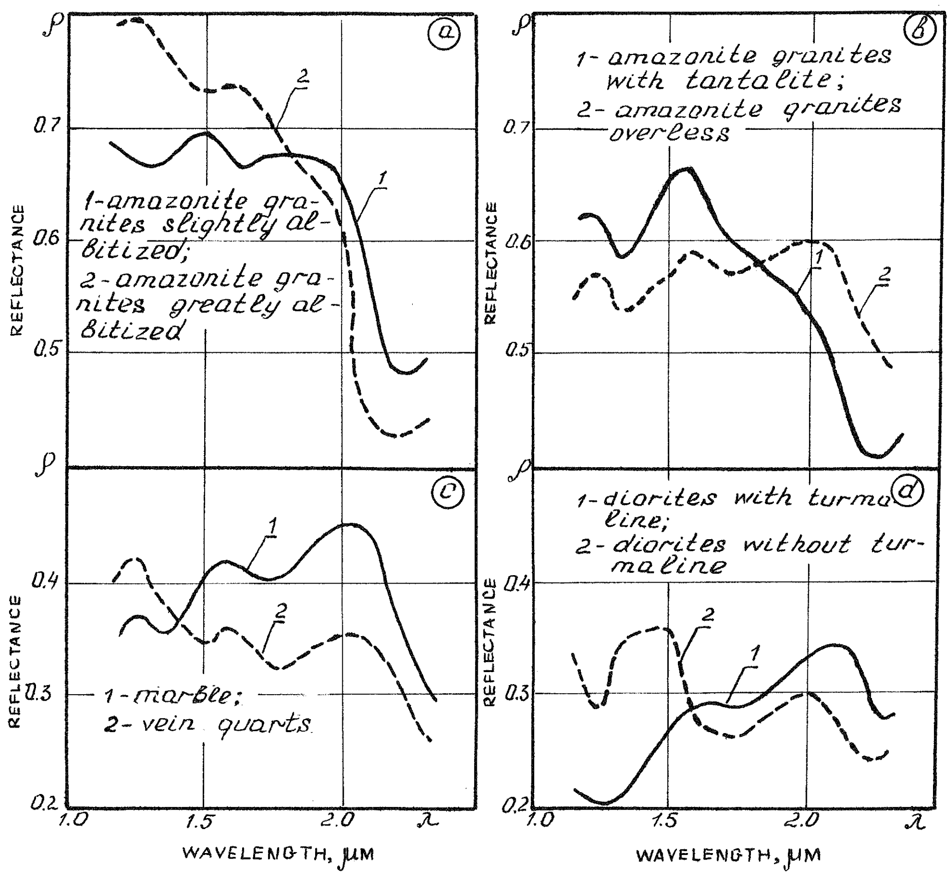
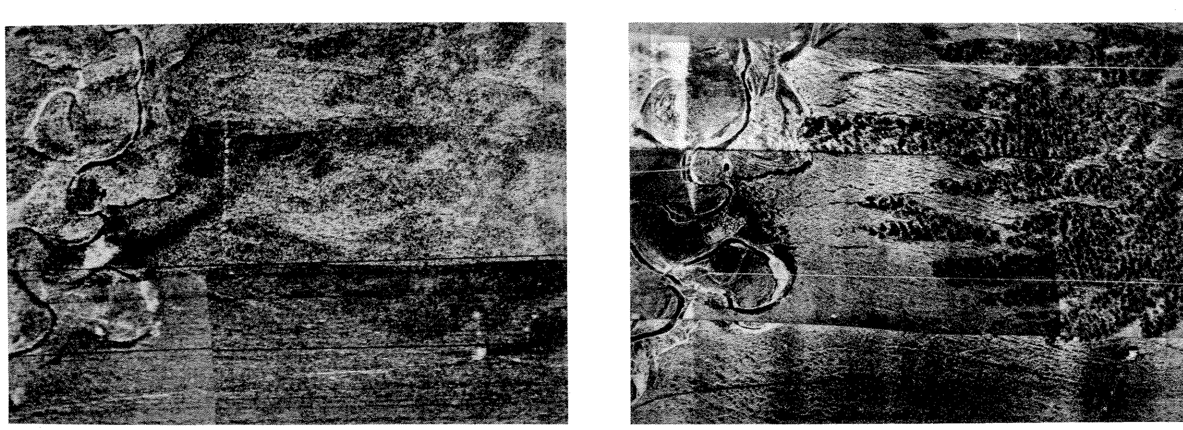


Fig. 2. Spectral reflectance of Transbaikalian rocks.



a b

Fig. 3. Radar pictures of an area in Turkmenistan: (a) one meter range, (b) 4 centimeter range.

provides an isolation of each of these two objects from a population of any other objects not having intersecting spectral curves. Thus, field spectrometry helps to select informative survey channels and efficient algoritmous of remote sensed data.

RADAR

The new multi-frequency SLAR "IMARK" is the result of a special study in the field of remote sensing. The "IMARK" was originally created in 1989 in the Russian concern "VEGA". The "IMARK" reflects four centimeter and two and an half meter ranges of radiowaves; its resolution being five and twenty five up to thirty meters, accordingly. The system operates with horizontal and vertical radiowave polarizations (both linear and cross); it works at additional ranges of twenty five centimetres and one meters (long-wave ranges). "IMARK" is capable of radiowave digital analysis, produced in the course or immediately after the process of surveying. The results of the research fulfilled jointly by VNIIKAM and the "VEGA" concern (Starostin, 1991) can be applied to geoecological tasks. The research resulted in the following. Penetrating power of radiowaves of the first meters range is increased up to several dozens meters. The intensity of penetration is dependent upon such factors as: composition of a bedrock; depth of the first stratum capable of absorbing/reflecting radiowaves. The depth level is determined by the level of ground waters; presence or absence of aquic faults; big deposits of electro-conductive ores; patches of permafrost. The materials supplied by the long-wave radar survey contain important information concerning different subsurface characteristics (especially in the regions covered by soft sediments. The system is intended for ore deposits, diamond tubes, lens, pure and mineral waters exploration. The "IMARK" radar pictures of an area in Turkmenistan serve as an illustration (Fig. 3a and b). Fig. 3a shows the inner structure of barkhans, the "roots" of wich are buried in the Neogene relief. Comparing it to the Fig. 3b of the same area, one can see that in the Fig. 3a taken in the long-wave range information about sand ridges, interridge troughs, takyrs, drainage system and vegetation is eliminated. As a result, mapping of ground waters at depths of 30 to 50 m is possible, which is veri fied by drilling data. Multi-frequency radar surveys of West Siberia (the city of Surgut) discovered local patches of buried permafrost.

Thus, data obtained by the new multi-frequency radar system "IMARK" and used jointly with conventional geologic-geographic information leads to better geological, hydrogeological and geoecological maps and charts.

EXPERT SYSTEM

One of the most promising projects by VNIIKAM on remote sensed data processing is "Data-Knowledge Transformation" (DKT) which is headed by Dr. Naidenova. The goal of the DKT Project is the creation of computer tool for the integrative interpretation of geoscience spatial data and the recognition of such natural objects as ore deposits, rocks, vegetation and so on combining remote sensed data, and expert knowledge. The DKT project encompasses the results of long-term researches on logical classification and pattern recognition methods. The main idea which was an incitement to us consists in using algebraic lattice for data representation and simulation of classification and pattern recognition processes. The idea that classification is a lattice arose from practical tasks of developing information retrieval and pattern recognition systems. In (Boldyrev, 1974) advanced the formalization of pattern recognition system as an algebra with two binary operations of refinement and generalization defined by an axiom system including lattice axioms (Gretzer, 1982). Within this mathematical model we have modified the traditional notion of diagnostic test and have introduced a new concept of the "good diagnostic test" for a given classification (Naidenova, 1982, 1986). The problem of finding all good diagnostic tests for a given classification and a given set of training exemples have been first formulated and algorithms for inferring good classification tests have been proposed in (Naidenova, 1991; Megretskaya 1988). The unique role of the good test concept is explained by the equivalence of the following relationships (Naidenova, 1982; Spyratos, 1986): (a) identifying/distinguishing relation between object descriptions, (b) functional dependency between attributes, (c) patition dependency between classifications generated by attributes on a set of a given objects descriptions. The decision of the problem of finding all good classification tests allows to infer a structure of interrelated classifications hidden in a given set of data, to discover constraints of the three types of knowledge (a), (b), (c) simultaneously. Implementation of the indictive mechanism for inferring the three types of knowledge allows to integrate data and knowledge in one intellectual system using a uniform management process.

The test inference algorithm mentioned above has been implemented in SIZIF - the System of Knowledge Acquisition from Know Facts. SIZIF is developed in C for IBM PC/AT or compatible computers in the MS DOS environment. The system provides an easy way of studying experts' data, constructing a database and its deductive extension to a knowledge base with the mechanisms of logical inference over the constraints obtained from data analysis. SIZIF supports in particular the following database models:

- embedding independence-reducible scheme based on key-equivalent partition of a set of database schemes proposed by (Ke Wang, 1990);
- canonical database scheme proposed by N. Spyratos (Spyratos, 1986; Lecluse, 1988).

SIZIF supports the majority of machine learning problems having already been formulated, in particular, concepts, production rules, decision trees inductive inference by examples.

The universal user interface is currently being developed.

TECHNOLOGIES

VNIIKAM is a research institute specializing in acquisition and use of remote sensing data for various fields of geology and environmental studies. Specialists from VNIIKAM have developed the following technologies:

1. Integrated use of remote sensing, landscape, geologic and geophysical data to study tectonics in oil - and gas - bearing basins to prognosticate oil and gas traps.

2. Use of remote sensing data to prognosticate reefs and other heterogeneities in sedimentary basins.

3. Use of remote srnsing data for studies of thrust tectonics in oil and gas prospecting.

4. Acquisition, processing and use of data from specialized aerial photographic surveys to study the geology of sea-floor in shallow areas.

5. Integrated use of remote sensing, landscape and geophysical data for geological mapping at scales 1:200 000 and 1:50 000.

6. Use of remote sensing, landscape, geological and geophysical data for modelling major ore objects, compilation of prognostic-metallogenic maps, and ore prospecting.

7. Use of remote sensing and landscape data to prognosticate orebearing structures in areas with alpinotype tectonics.

8. Acquisition and use of data from multifrequency radar aerial survey for underground water prospecting.

9. Use of remote sensing data to compile maps of the enviromen state, study its dynamics and predict unfavourable changes.

10. Use of data from thermal aerial survey to study regions of active volcanism, including submarine one.

11. Acquisition and use of data from thermal aerial survey to detect hidden fires in industrial and household waste dumps, colliery heaps, peat deposits and other combustible rocks.

12. Acquisition and use of thermal satellite and aerial data to detect pollution of water reservoirs with oil products and waste waters from nuclear electric power plants.

13. Acquisition and use of thermal aerial data for trouble-shooting the ubran heating pipelines and control of energetic losses from dwelling-houses and industrial buildings.

14. Acquisition and use of thermal aerial data to detect and monitor forest fires.

15. Acquisition and use of data from thermal aerial survey for monitoring major oil and gas pipelines, to detect leaks from irrigation systems.

Booklets with the technologies described are available from the authors.

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