ECOLOGICALLY NONHAZARDOUS PROCEDURE INCORPORATING STRUCTURAL PHOTOINTERPRETATION TECHNIQUES AND PRECEDING DEEP-SEATED RESOURCES PROSPECTING

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ABSTRACT

A new ecologically nonhazardous technique of deep geological mapping has been invented in compliance with standing rules and accuracy limits. This in-office technique, which hardly incurs any noticeable expenses, enables geological and paleomorphologic setting of the Earth crust's structural stages to be mapped. Again, this technique is a good adviser, in terms of theory, in a general scientific study of the Earth, as well as in finding and explaining an origin of this or that geological process within the crust. As for its practical use, this procedure, when incorporated in geological prospecting, makes it possible to trace mineral formations far down to deeper intervals of a stratigraphic section, and to construct multipurpose geological maps of deep-seated horizons drawn in a scale range from 1/10,000 to 1/500,000. Photointerpretation procedure suggested here is based merely upon two universal interpretation indicators, or guides, that are identified on airphotos and are common for all regions, regardless of their landscape features, and are good enough for producing geological maps.

1 INTRODUCTION

This paper deals with a nontraditional approach in handling airborne and satellite data when producing geological maps of crystalline basement occurring at various depth intervals. The said approach is based on results of work that the author has done on a contract basis for geological reconnaissance and prospecting field teams which have taken up all the costs.

As far as promising areas are concerned, seismic survey data is still traditionally employed there for interpretation of geological setting's features. Seismic data processing eventually results in a construction of a combined geoseismic section that shows confines of structural units within sedimentary strata and those peculiar features in a setting of structural stages which are crucial in terms of prediction and exploration in each particular area. Three-dimensional transformation of seismic parameters enlarges to a great extent an overall output information and thus enables a three-dimensional model of platform mantle formations to be constructed (Telegin, 1991). There is one problem, however, and this is a too high cost of seismic prospecting.

It is just in order to have a money-saving solution for such kind of assignment that we have been elaborating for thirty years a nontraditional procedure of airviews and satellite images interpretation resulting in a three-dimensional visualizing of deep-seated structures' pattern. In doing this we base upon two universal interpretation indicators, or guides, which can easily be recognized on airviews. They are the same for any region, whatever its landscape features are, and they are quite sufficient for geological mapping. One of these guides is a so-called line of preferred orientation, i.e. a pattern of structural and textural features of a deep-seated target body, as it is imprinted onto a recent surface. Another guide is some widely known lineament corresponding to a fault. Interpretation procedure is remarkable for its simplicity, and yet it provides great capabilities in construction of special-purpose maps. This procedure will surely be of interest to those field geologists who needs to have a preliminary assessing look in depth at geological and structural position of a poorly explored area. Our basic ideas of deep mapping technique have been publicized constantly in various field reports and put across in published works, over 50 altogether, of which two are listed in References (Sokolova, 1996; Sokolova, Proskuryakov, 1996).

As far as a buried crystalline basement is concerned, repeatability of results obtained consists in, firstly, persistent visualizing of geological bodies varying in composition and genesis, and, secondly, in recognizing fold and fault structures that vary in order and include those where mineral resources are localized. There are no other targets for mapping in sedimentary rock complexes but morphology of vastly present regional unconformities in the form of wash-outs that separate structural stages and jointing which makes those stages complex. A follow-up check of the author's geostructural models under various physiographic conditions proved the models to tally quite well enough. Thus, it comes to 50-80% in case of determining rock complexes and morphology of geological bodies in the crystalline basement, whereas veracity of defining structural and tectonic components of the basement and sedimentary cover not infrequently is as high as 80-90%. Let us consider, in particular, some field cases.

2 FIELD CASES

Case I. In 1978 nontraditional photointerpretation was made in Rybozero area (SE Karelian Republic, Russian Federation) in connection with a commencement of preliminary geological prospecting for noble metals. Interpretation enabled to define a general structural lay-out of the area, its morphology, size of mineral occurrings, and standards of judgement to be applied in prospecting. Thickness of Quarternary formations there attained 30 meters and there were no bedrock outcrops whatsoever.

By the time the prospecting in Rybozero area was launched, two explorers of the said region, namely V. Oushkov and A. Goroshko, had a feeling that one should not expect evident relationship between metal ore potentiality and stratigraphic particularities of rocks. The former, they thought, was more closely related to such tectonic elements as less coherent zones of schistosity where mineral-forming processes were likely to happen due to metasomatism. This was why tectonics turned out to be a main target of photointerpretation.

Owing to photointerpretation we managed to find out numerous faults in the area in question, and these, varying in magnitude, were for the most part thrust faults (Figure 1). Thorough examination of drill core samples established the fact that displacement amplitudes in the thrust faults of the first and second order were as large as 100-200 m. Such thrusts formed along those layers of talc-chlorite and talc-tremolite rocks that had been most vulnerable to shifting. Their frontal sections comprised zones of schistosity 400-500 m wide, which are known to be good for metal enrichment. Minor imbricated thrust faults of 3rd-4th order were recorded in drill core samples as crush zones varying in thickness from 100 to 800 meters. Rocks there are severely fractured, and both rupture and shear joints are equally well developed. Rupture joints run at 70-90° to rock strike and most of the joints dip at 5-20°. As it follows from geochemical survey data such crush zones generally agree with expected ore-controlling faults.

Photointerpretation resulted in plotting of Archean-Proterozoic faults and geofractures. The former could well be feeders for emplacement of intrusions and these are definitely intepreted as domes some 5-8 km in diameter. As for geofractures, these are accompanied by traces of effluent lava flows and plastic strain; furthermore, they divide crystalline formations into three blocks, of which the northern block has its rocks striking north and northwest, the southern one has a nearly meridional trend, whereas the central block is tectonically complex and is, therefore, regarded as a main target of research. That the southern and central blocks are separated by the geofracture was proved by geological prospecting in the area.

Right under the upper structural stage's crystalline formations an anticline, something about 3 km wide, was very surely identified and mapped. It has a northeastern strike and represents the lower structural stage. Core samples from the holes drilled within the anticline's core area betray an utmost denundation section of the upper structural rock complex; also the lower complex's rocks appear there too.

As a result of nontraditional photointerpretation of the Rybozero area, established was the fact that, whatever favourable tectonic framework was, an outcome was negative, i.e. no areas potential for metals were found. By the time geological prospecting and core drilling (altogether 57 holes) were completed, no metallization zones good for further development had been discovered either.

Case II. In 1989, while prospecting within the then unexplored Uzbekskoye deposit (Shaimsky oil-bearing area, West Siberia) was effected, a suggestion was made to the author to construct a map of the basement underlying Cenozoic-Mesozoic sedimentary strata something around 1,600 meters thick. Photointerpretation enabled the author to identify volcanogenic formations in the west, to locate a basic rock body within a central part (even to trace periods in its development and recognize step-like pattern which is typical of trap rocks), and, finally to plot metamorphic rock complex in the east (Fig. 2a). Furthermore, plotted throughout the whole research area were the bodies that filled faults, geofracture zones and dikes. Alongside with photointerpretation, drilling of 18 holes was effected in the said area on the customer's request. When plotted on a prototype aerial survey map, the drill data did not make different the meaning of the map (Fig. 2b). Again, no essential corrections were made to our plotted elements after adding seismic survey data which depicted geometry of interface between structural stages. What is also important is that nontraditional photointerpretation technique can easily read tectonic pattern of the area from the lines of preferred orientation. In particular, established is the fact that the basement comprises the blocks with reverse movements, whereas the eastern portion of the area plunges as a wedge-like underthrust fault under the intrusion formations.

Case III. Similar work was performed in Vyngapurovsky oil and gas deposit (Lower Vartovsky oil and gas bearing area, West Siberia) in 1990. Overall thickness of a sedimentary cover exceeds there 3,100 meters. Plotted through

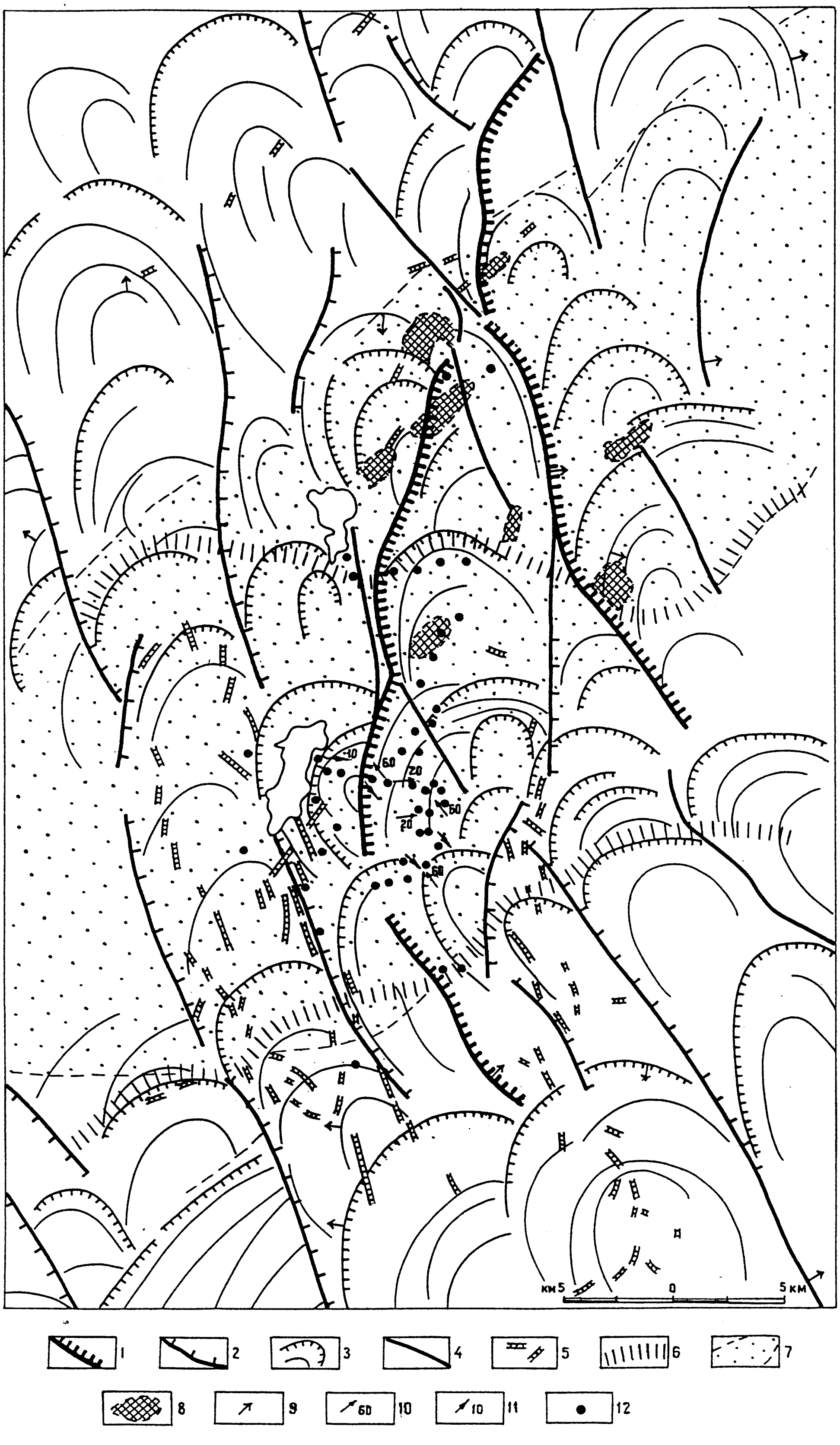

Figure 1. Structural map based on photointerpretation results (photo scale 1/25,000)
1 - overthrust faults, 1st order; 2 - overthrust faults, 2nd order; 3 – imbricated overhtrust faults, 3rd and 4th order, in some areas manifested in landscape features; 4 - faults; 5 - dikes; 6 – crush zones, neotectonic (?); 7 – anticline of the lower structural stage; 8 – inliers of rocks of the lower structural stage. Rock movements, proved: 9 – in landscape; in boreholes, according to measured angles of inclination to the earth's surface; 10 – block's uprise; 11 – block's subsidence; 12 – boreholes.

(a)

(b)

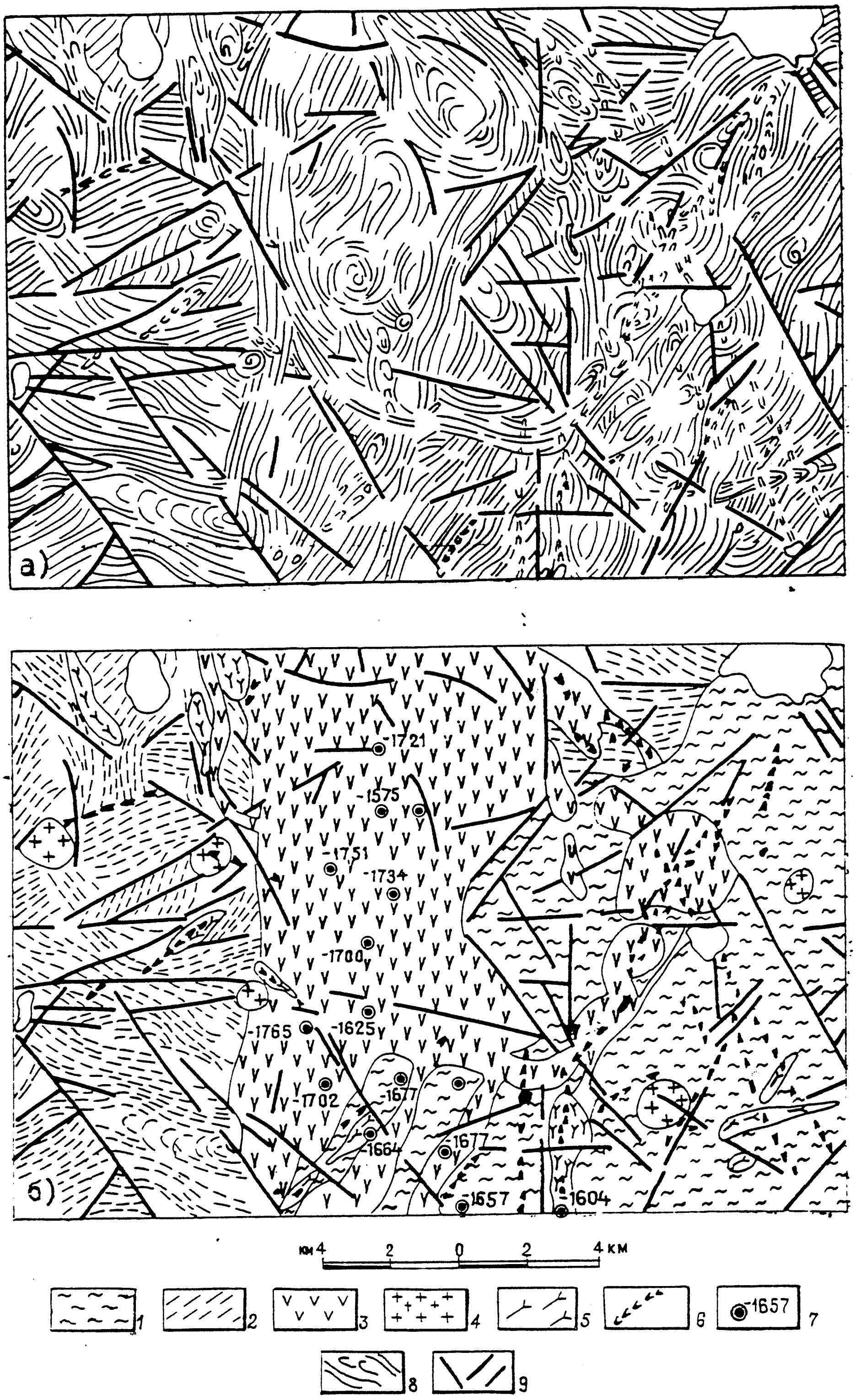

Figure 2. Map showing lines of preferred orientation in geological formations, as read from scale 1/35,000 airviews (a), geological map drawn with reference to the lines of preferred orientation and proved by drill data (b).
1 – metamorphosed rock complex; 2 – volcanogenic rocks; 3 – basic rocks; 4 – granites; 5 – ultrabasic rocks; 6 – dikes; 7 – boreholes, absolute depth marks of the basement. Airview and satellite image interpretation data: 8 – lines of preferred orientation, actual and when read from the photos and plotted, as they correspond to geometric and morphological features of deeply seated geological bodies; 9 – lineament.

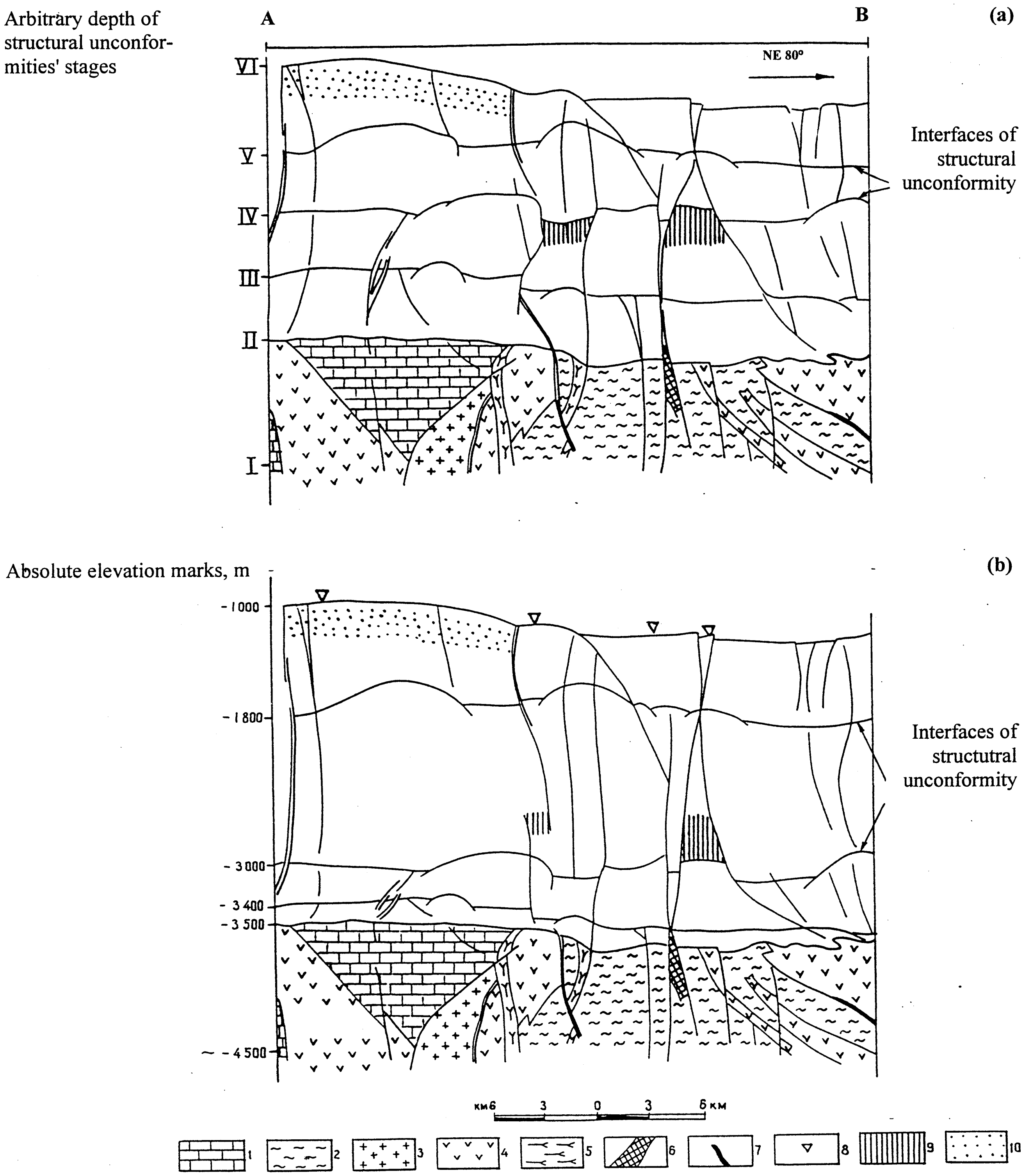

Figure 3. Geostructural sections through line A-B, drawn after photointerpretation data (a) and verified according to seismic survey and drilling data (b).
1 – limestone; 2 – metamorphosed rocks; 3 – granites; 4 – basic rocks; 5 – ultrabasic rocks; 6 – zones of tension; 7 – dikes; 8 – boreholes; 9 – oil; 10 – gas.

photointerpretation there were 4 levels of wash-outs in sedimentary rocks and 2 such levels in crystalline formations. These are drawn on a latitudinal geostructural section depicting a central portion of Vyngapurovsky structure (Fig. 3a). Shown vertically are most probable depths of levels (I through IV) of unconformity stages, whereas horizontal axis bears information as to all peculiar features of these stages. The lower part of the section, plotted wherein are 2 levels of unconformity, is nothing else than an ordinary geological profile. It turned out possible, basing on the said structural stages, to reconstruct the topography's setting and one block which, being most unstable in terms of tectonics, is capable of holding hydrocarbon accumulations. On completion of work a customer handed over actual geological and geophysical field data. Subject to correction were, for the most part - and it stands to reason, - the predicted depths of unconformity surfaces, namely Jurassic-Triassic and Aptian formations, their vertical thickness being actually less than interpreted (Fig. 3b).

Case IV. Another target area to be mentioned here is North Variegansky oil deposit (Lower Vartovsky oil and gas field area, West Siberia) where in 1992 verified and assessed were the joints which had been revealed through nontraditional interpretation procedure. Research was aimed at main features of the jointing's pattern in Upper Paleozoic-Jurassic formations within a depth interval of 3,300-3,400 meters, since those features are very important for hydrocarbon reservoirs. The joints were compared with oil development well drilling data and time cross-sections based on a nonstandard FOTON program developed by Tyumenneftegeofizika Oil Industry Organization. FOTON program consists in reinterpretation of time cross-sections by giving a gray-scale image showing there positive and negative in-phase axes. An advantage this technique possesses over the ordinary procedures is in that it enables to recognize far more surely in the section's plane the peculiarities of a wave field and its horizontal and vertical dissection (Trousov, 1990). It was proved through comparison that the faults in Prejurassic rocks (A-A_I), as they were reconstructed according to the FOTON time cross-section and on the basis of airviews on the scale of 1/50,000, irrespective of the technique applied to pinpoint them, occupy more or less the same position at those points where they crop out onto horizon-A_I surface.

3 CONCLUSIONS

It should be concluded now that a very serious thing about the nontraditional photointerpretation procedure is to get adequate and veracious data, both positive and negative. Referring to the results of the contract-based work, it would be reasonable, when conducting geological and geophysical survey within the platform cover of plates, to combine nontraditional airborne and satellite image interpretation technique with seismic prospecting. Saying so we mean that it is necessary to perform photostructural study in advance, using nontraditional photointerpretation technique. Such succession in research methods makes it possible to choose deliberately target areas for seismic survey and drilling, thus cutting down expenses greatly.

Finally, a computer-assisted procedure of nontraditional photointerpretation becomes a bare necessity: by putting it in practice we could do without any ground work, but just construct in office, and very quickly indeed, multipurpose maps with reference to washout planes at great depth intervals and on the scale of 1/10,000 and down.

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