EIGHTH INTERNATIONAL CARTOGRAPHIC CONFERENCE
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Remote sensing data obtained from aircraft and space systems are known to be highly important to compose various thematic geological maps such as lithological-stratigraphic, lithological-formation, tectonic, structure reference-horizon maps as well as mineralogenic (including metallogenic), geomorphological, hydrogeological, engineering geology maps etc.

At present, airborne and space photographs, including narrow-bend multispectral ones taken by photo, TV cameras and scanners in the electromagnetic spectrum are used on a broad scale to compile such maps. Aerial side-looking radar data obtained through the use of an active method in the microwave (cantimeter) spectrum are applied on a smaller scale, thermal infrared data being used experimentally.

Aerial and space images are of special value because of broad ground coverage, natural integration and generalization of topographic features, one component of which is a geological pattern. One photo shows simultaneously several geological bodies and structures of any class what makes it possible to see their relationship. The integration effect on the photoes showing minor details of the country build-up separated or complicated by other features makes it possible to observe the whole structures against the background of minor features that may escape one's notice or may not be identified in the course of ground observations. Features of low classes come out generalized on the photoes, owing to the fact major features of the country topography become obvious. The degree of ground coverage, integration and of generalization is dependent upon the type of studies and is proportinal to the denominator of their scales.

The above mentioned characteristics of aerial and space photographs enable us to construct more precise geological models than thematic geological maps compiled without remotely sensed data. The natural generalization of a geological pattern on aerial and space photographs presents a methodological basis of the geological mapping based upon remote sensing data. Mapping of the earth's surface is always based on generalization of features photographed without which one cannot create a model incorporating physical features, i.e. any geological map. In case the remote sensing data are not avaliable, the generalization becomes, to a certain extent, subjective and the degree of the subjectiveness cannot be predicted. In case of the remote sensing applications, the generalization of geological structures, linear features and their relationship is made on a true basis and may be easily checked up.

The compilation of geological maps based on remote sensing data falls into a number of consecutive processes.

Tht first one is a transformation of images into a given projection, otherwise serious errors may be made. The transformation problems are solved to a considerable extent as far as the aerial and space photographs, taken in a projection close to the central one, are concerned. Geometric distortions complying, in this case, with certain regularities may be removed. The algorithms of transformation of such images of the earth's surface are elaborated, which enable us to carry

out geometric transformation of photographs in practice. High altitude aerial photoes taken by long-focus objectives may be used without preliminary transformation as these remain orthogonal even in the case of highly rugged topography. This is quite an advantage of such photographs.

The transformation of photoes taken by the scanner and radar methods is more complicated. The geometric distortions are in this case due to accidental reasons such as advertence of the aircraft carrying the shooting camera from its heading, change in the flight velocity and that of the scanning, which do not comply with certain laws. Therefore, it is difficult both to construct a stereomodel based on the images of such a type and transform such photoes in a certain projection. The problem of transformation of these images may best be solved by introducing, on board the craft, the required corrections for alterations of photographic conditions. It is less desirable that images be transformed by reducing these to a selected standard model through the use of electronic scanning transformers and computers.

The next stage in production of geological maps following the transformation is interpretation of remote sensing data, i.e. identification of geological bodies and structures, drawing them as areal contours and linear elements as well as finding out indications of any features produced by geological processes. The interpretation is necessarily performed by means of appropriate instruments through the use of stereoimpression. In case overlapping photographs are lacking, a pair of identical photographs is studies. Orbital images, whether original or enlarged, are liable to identification. When selecting aerial photoes for interpretation, one uses not only photoprints but also mosaics and photomaps yielding a better coverage. The same photoes are being studied at least by two interpreters working independently so that the identification should be more comprehensive and true. In some circumstances, original images undergo optical and/or electronic filtration and decomposition according to their densities by means of TV systems. It helps obtain additional information and makes identification more certain. Means and methods of automation of the interpretation process are being elaborated, computers are used to convert images into digital charts. However, automatic methods of identification and interpretation, in particular, are not completely developed in the case of complex geological features.

Identification results are plotted on photoplans or photomaps what makes it possible to interprete separate geological features observed on the photographs in total. The procedure of geological interpretation of remotely sensed data is based on the theory of detecting natural geological features from photographic (radar, thermal-infrared) images and, practically, on elaborating and applying interpretation criteria found in the course of identification of geological features. Although there are some difficulties in forming a uniform theory of natural indicators, methods through which geological information may be obtained from remote sensing are being successfully developed and applied in practice. A contrast-analogue principle of detecting and identifying geological features is highly important since it is absolutely impossible to interprete geological information derived from remote sensing without application of the said principle. Practically, interpretation and identification become one process.

The interpretation of the identified data is a most complicated stage of operations. In the first instance, an interpreter applies his experience, who, on the basis of recognition indicators, may assume a type of the geological feature he deals with at the moment. Certain criteria for interpretations of geological features are worked out. In some cases, the criteria are good for large areas, for example, in the case of granitic intrusions belonging to the same stage of geologic history. Then, to disclose the substance of recognozed features, one makes use of available geological, tectonic, geomorphological and other maps (according to the subject of interpretation) as well as of field geological and geophysical information obtained from the region. All the uncertain features newly disclosed that had not been plotted on maps drafted before and those which interpretation on the basis of identification indications does not match with the known data are to be born in mind. All such features require additional studies.

Identification and interpretation help reveal some bedding features and dislocation planes, dips of peneplane relics, steepness of slopes, local differences in elevations, thickness of series and rock bodies, as well as help obtain rhythmograms, plot geomorphological profiles and geological cross-sections, locate key horizons and compile structural maps by photogrammetric instruments. Sometimes, thickness of Quaternary valley sediments may be estimated by aerial photographs.

The interpretation and classification of recognized features result in drafting up descriptive reports to the maps which contents may vary due to amounts of information available from remote sensing records used and to predetermined aspects within which interpretation was undertaken.

Then comes a stage at which the results of both identification and interpretation are checked up on the basis of known geological information. One of the steps of information checks is matching of remotely sensed data with geological data from the available geological maps. However, it occurs infrequently because the identification usually yields a lot of new geological information not plotted on geological, tectonic and other available maps. Remote sensing applications are primarily aimed at obtaining new information. So, it is quite a task to control, prove and define it concretly by other data. It is very important to select optimum means and meatods at the control stage.

Controlling of the geological features obtained from remote sensing data is a time consuming and expensive work, particularly, in case there is a necessity of controlling the data derived from the identification of space and other small-scaled photographs covering vast areas. Therefore, not all the recognized features are controlled by field geological, geophysical and other investigations. It is only representative features of each type that are controlled in the field, data obtained being extrapolated to other features of the same type. So, when compiling maps, both the deductive (from the general to the particular) and inductive (from the particular to the general) principles are used. The identification of remote sensing data is also performed during the field operations.

After the office studies of field data are completed, photographs are reidentified and reinterpreted on the basis of new data. Final classification of geological features based on images are made and the description to the map is specified.

The final stage in compilation of a geological map is the transfer of all collected data from photographs (photoplans, photomaps) onto a map in a selected projection. If the photographs have already been transformed, the transfer does not make a problem and is practically performed by means of photogrammetric instruments and by eye. The transfer by eye cannot always be usable as it cannot provide for required accuracy for the areas that are scarce of landmarks; errors in the eye transfer may bring to the misinterpretation of geological features what may cause errors in trends and targets of geological exploration.

Remote sensing data of various types and scales present qualitatively different information what is due, firstly, to a part of electromagnetic spectrum used and recording instruments and, secondly, to degree of generalization of terrain details on photographs. Due to these factors geological features of various orders are identified on various scaled photographic images. Maps of different contents are, accordingly, made on the basis of photographs of various types and scales.

On the basis of identification of TV pictures on a scale of less than 1:5 000 000 'space' tectonic maps are compiled. The East European Platform Map (Fig.1) is an example of such a map. In such a case, major blocks of the earth's crust are taken as a basis of mapping, which are separated by faults and differ in origin and structures.

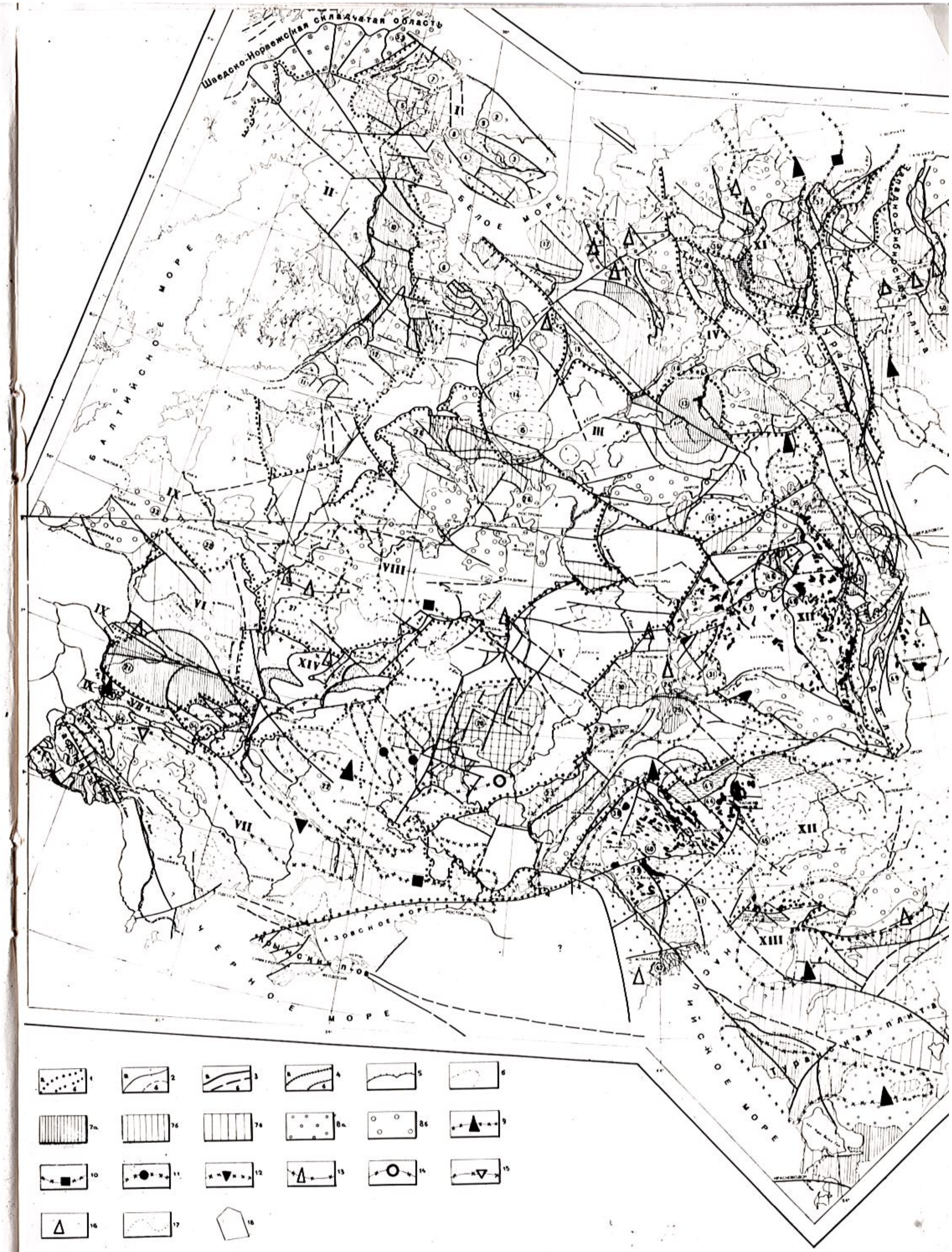
Scanner satellite photographs which on the same scales have higher acutance help compile maps of structural-tectonic region divisions. The map of regional division of the Turan Plate (Fig.2) may serve as an example. Alongside with structure-forming faults (including the so-called 'translucent' ones which have not been found by ground geological survey), the map reveals regions different in tectonic features, thicknesses and compositions of rocks building up the platform mantle. Important data on the origin of minerals in the area are associated with these features.

The satellite photoes on a scale of 1:1 000 000 or close to it (for example, photoes shot from the "Soyuz-12" and multi-spectral scanner images taken from the "ERTS") are characterized by somewhat better acutance, lower degree of generalization of the terrain details providing at the same time the synoptic (summary, wide-covering) nature of information. It permits to compile more detailed maps of major regions what may be illustrated by structural geological maps for the Mangyshlak Peninsula (Fig.3) and for Lake Balkhash (Fig.4). The aforesaid photographs made it possible to mark on the above maps not only structure-formation zones and a network of various faults but also some lithological and stratigraphic units and complexes of intrusive formations.

It is long ago since aerial photographs have successfully been used in compilation of medium-scaled and large-scaled photogeological, geological, geomorphological, engineering geology, hydrogeological and other maps. At the same time, all the bulk of space different-scaled photographs is applied for the purpose. When mapping a concrete area, aerial photographs on various scales are applied, i.e. all the photoes available for the area, differing in scales three and more times as much. It is worth mentioning that the pictures taken by converntional cameras, conventional films, varying in scales not less than three times, contain appreciably different geological information. For the past time, small-scaled aerial photographs taken at altitudes of 7.5 to 12 km have been applied. Thus, when carrying out geological mapping, aerial photographs of not less than a pair of scales are being studied, for example, pictures on scales of 1:150 000 and 1:50 000 and/or of 1:100 000 and 1:25 000. The horizontal photographing on scales of 1:5 000 000 to 1:15 000 by a small dimension camera built in a light aircraft commences as early as during the geological investigations devoted to bridging of pits and holes in most complex sites. Perspective airborne and ground stereoscopic photographying is underken over highly rugged terrain.

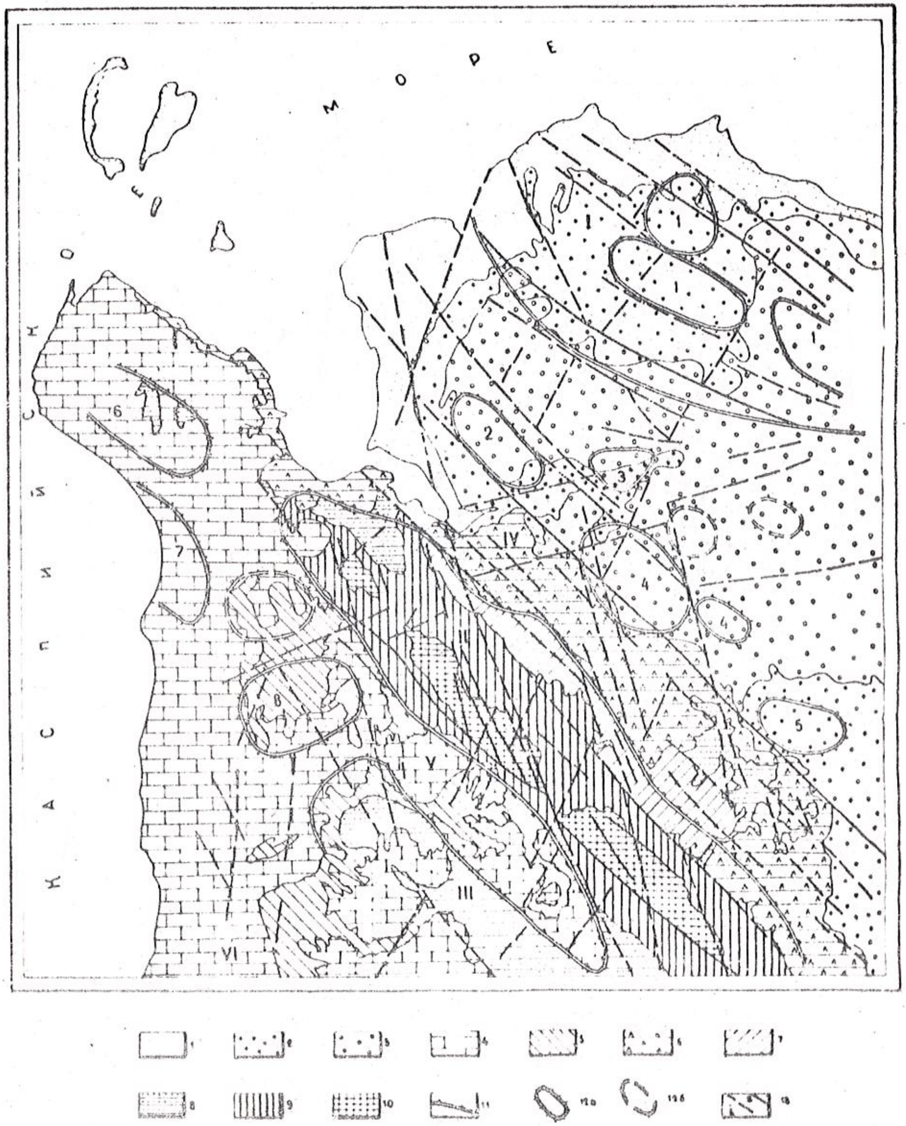
Well known geological maps on medium and large scales based on annotated aerial data have been compiled for various areas of the Soviet Union. Therefore, we are not discussing and not giving examples of such maps. What is more important to mention is that the aerial data applications have essentially changed the procedure and organization of regional surveys. At present, a geological party carries out studies over vast areas covering a whole of the geological structure or its major portion and in case of surveying on a series of topographic sheets. The selection of targets of field work is based on the recognized aerial photograph data. The investigations are concentrated on complex sites for which there are plenty of data available as well as on sites which are most promising for exploration. The mapping is performed from the general to the particular, as a rule, through gradual extention of observation points over the whole of the territory, repeated interpretation of remotely sensed data and compilation of advance sheets of the territory under mapping at all the intermediate stages. Field observation and office study data are plotted on photoplans since the interpretation of photographic images of the terrain presents a basis of the compilation of geological and other maps drafted in the course of regional survey.

In conclusion it is worth emphasing that obviousness of remote sensing data make maps based on the above data reproducible. Recognition of natural features and their interpretation remain subjective to some extent but photographic images of the natural objects are true.




КАСПИЙСКОЕ МОРЕ
БАРСАКЕЛЬМЕССКИЙ ПРОГИБ
АРАЛЬСКОЕ МОРЕ
ЧУЙСКАЯ ВПАДИНА
ЦЕНТРАЛЬНОКЫЗЫЛКУМСКИЙ СВОД
ЗАКАСПИЙСКАЯ ВПАДИНА
ВОСТОЧНО-ТУРКМЕНСКАЯ ВПАДИНА
СКЛАДЧАТАЯ ЗОНА
ЮЖНО-АФГАНСКАЯ ВПАДИНА

Фиг. 2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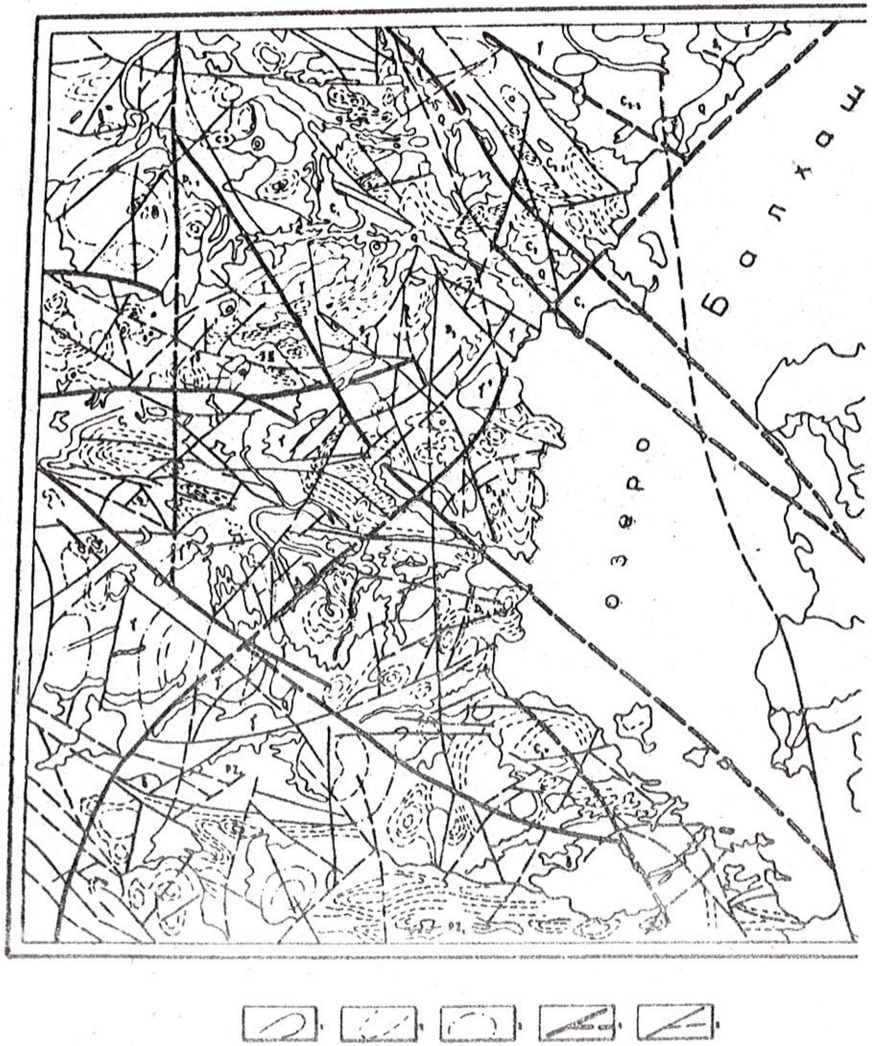
Фиг. 3



Фиг. 4

Fig.1. Satellite Tectonic Map of the East European Platform compiled by I.I.Bashilova on the basis of TV pictures taken from satellites of the 'Meteor' type.

1-major block boundaries, 'a' being for distinct and 'b' for probable ones; 2 - boundaries of structure zones and individual structures that are well (a) and poorly (b) recognized; 3 - regional high angled faults, 'a' for obvious and 'b' for less obvious ones; 4 - thrusts, 'a' for regional and 'b'for local ones; 5 - probable imbricate structures; 6 - various structural lines; 7 - uplifts, arches, swells, horsts, 'a' for larger, 'b' for medium and 'c' for small amplitude ones; 8 - troughs, depressions, grabens,deep (a) and shallow (b); boundaries of known basins; '9' for oil and gas, '10'for coal, '11' for iron ore, '12' for Dneprovsky basin (iron ore, nickel, boxite, coal etc.); boundaries of areas promising, according to identified records, for : 13 - oil and gas, 14 - iron ores, 15 - nickel, iron ore, boxite, coal.; 16 - expected oil and gas fields; 17 - the upper cloud-limit; 18 -the area lacking photographs good enough for geological and tectonic interpretation. Other indices (solid coloring, dotting) stand for structural zones and structural forms, different in structure and setting within major blocks suggested by various TV images. Major blocks of the East European Platform: I - Kola-Karelsky Block, II - Sweedish-Finland Block, III - Onega-Kamsky Block, IV -Dvina-Vychegodsky Block, V - Voronezhsky Block, VI - Belorussian Block, VII - Ukranian Block, VIII - Moscow Syneclise, IX - Pribaltic Block, X -Sredneuralsky Block, XI - Pechorsky Block, XII - Uralo-Caspian Block, XIII - Gurievsky

Arch, XIV - Kiev-Bobruisky Block; Structure zones : 1 - Onega Rise, 2 - Murmansky Massif, 3 - Keyvsky Synclinorium, 4 - Imandra-Varguza Synclinorium, 5 - Inarsky Massif, 6 - Belomorsky Massif, 7 - Pechengskaya Depression, 8 - Khibinsky Pluton, 9 - Lovozersky Pluton, 10 - Karelsky Massif, 11 - Vyborgsky rapakivi Massif, 12 - Salminsky rapakivi Massif, 13 - Syktyvkarsky Horst-Arch, 14 - Nyandomsky Massif, 15 - Vologda Massif, 16 -Kirovskaya Graben-Syneclise, 17 - Dvina-Mezensk Rise, 18 - Vychegda Graben-like Trough, 19 - North Dvina Graben, 20 - Central Uplift of the Voronezhsky Block, 21 - Brestsky Horst-Arch, 22 - Dnieper-Donetzsky Trough, 23 - Don-Medveditzky Horst-Arch, 24- Zhyguli Arch, 25 - Zhguli-Pugachevsky Arch, 26 - Kostroma Uplift, 27 - Krestzovsky Trough, 28 -Tykhvinsk Dislocations, 29 - Saratovsky Dislocations, 30 - Saransky Pluton, 31 - Kuybyshevsky intrusive (?) Massif, 32 - Daugavpils Massif, 33 - Pribaltiyskaya Syneclise, 34 - Bashkirsky Horst, 35 - Permskaya Zone, 36 -Srednepechorsky Massif, 37 - Intinsky Massif, 38 - Privolzhskaya Zone, 39 - Baskunchak Zone, 40 - Elton Zone, 41 - Pricaspian Zone, 42 - Astrokhanskaya Zone, 43 - Uralskaya Zone, 44 - Chapaevskaya Zone, 45 - Inzerskaya Zone, 46 - Sarapulskaya Zone, 47 -Kazanskaya Zone, 48 - Ufimskaya Zone, 49 - Magnitogorskaya Zone, 50 - Lower Ob Graben, 51 - Chetlass Scarp, 52 - Vymsky Horst-Arch, 53 - Varager and Rybachy Peninsulas sparagmite, 54 - Lvov-Zhytomyrskaya Zone of imbricated thrusts.

Fig. 2. The Map of Structural-Tectonic Division of the Turan Plate. It is compiled on the basis of the scanner photograph taken from the man-made satellite "Meteor-18". Boundaries of major structural forms : 1 - well identified, 2 - doubtful, 3 - configurations of ring structures; faults : 4 - deep faults (sometimes accompanied by sutural troughs), 5 - regional faults; arched uplifts: 6 - higher ones, 7 - lower ones; depressions, troughs : 8 - deeper ones, 9 - shallower ones.

Fig. 3. The Structural Geological Map for the Mangyshlak Peninsula compiled by S.M.Bogorodsky, I.K.Abrosimov, E.A.Vostokova and L.I.Solovyeva on the basis of the picture taken from "Soyuz-12". 1 - lower novocaspian sands; 2 - upper novocaspian sands; 3 -khvalynsk sands with pebble; 4 - Middle Miocene-Lower Pliocene limestones and marls; 5 - Oligocene - Lower Miocene clays; 6 - Paleogene clays, marls and sands; 7 - Danian - Paleogene limestones, marls and sands; 8 - Cretaceous sands and clays; 9 - Jurassic - Cretaceous sandstones, siltstones and shales; 10 - Permian - Triassic sandstones, argillites and siltstones; 11 - boundaries of regional uplifts and troughs; 12 - configurations of local uplifts recognized well (a) and probable (b); 13 - lineaments proved by geological and geophysical records (a) and assumed ones (b); regional uplifts : I - Buzachinsk Uplift, II - Mangyshlak-Central Ustyurtsk Ulift, III - Beke-Bashkudunsk Uplift. Regional troughs: IV - South Buzachinsky Trough, V - Chakyrgansky Trough, VI - South Mangyshlaksky Trough. Local uplifts : 1 - Uplift belonging to Djaman-Orlinskaya group, 2 - Ashysorsky Uplift, 3 - Taschekunduksky Uplift, 4 - Uplift of the Koshkanskaya group, 5 - Koshnar -Kiskunduksky Uplift, 6 - Uplift of the Tyubedjinskaya group, 7 - Uplift of the Zholospanskaya group, 8 - Karaimansky Uplift.

Fig. 4 .The Structural Geological Map for Lak Balkhash based on multispectral scanner pictures from "ERTS".
1 - boundaries between lithological and structural complexes

-liable to identification (indeces standing for some lithological- and-stratigraphic units and intrusive formations); 2 - structural lines, marker folds; 3 - configurations of ring structures; 4 - major faults separating structural blocks; 5 - other major faults.