THE ANALYSIS OF SPACE IMAGES WITH THE PURPOSE OF REVEALING THE RING STRUCTURES OF IMPACT TYPE

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Space pictures in geology have been applied from the early sixties. Remote sounding has given an opportunity to look at the terrestrial surface in a new fashion, having given a birth to new regional researches in the field of geology, geomorphology, tectonics, soil science, and opening of new deposits of minerals.

At remote sounding various wave bands are used: ultra-violet, visible infra-red, thermal, microwave. Thus the image varies depending on time of day and season. Using various filters and a combination of above-listed ranges the experts with the help of hardware methods achieve the best visibility of structures, processes and covers.

Then the information from space pictures is obtained with the help of images interpretation. Usually there are four kinds of objects in space pictures: linear, area, dot and ring.

Linear objects or lineaments are linear heterogeneities of the earth's crust in space pictures of different size and various genetic belonging. Lineaments can be caused by presence of geological breaks, flexure folds, dikes, anthropogenesis activity.

Area objects in space pictures have broken outlines and are submitted by structural, material complexes of rocks having an influence on genesis of soil and vegetative covers, and they, in their turn, are the indicators of materially-genetic belonging of tectonic infringements.

Dot objects are of various nature: sources of underground waters, single plants, man-caused objects. Frequently they are not considered as a separate kind of objects, but their presence in space pictures is without controversy figure1.

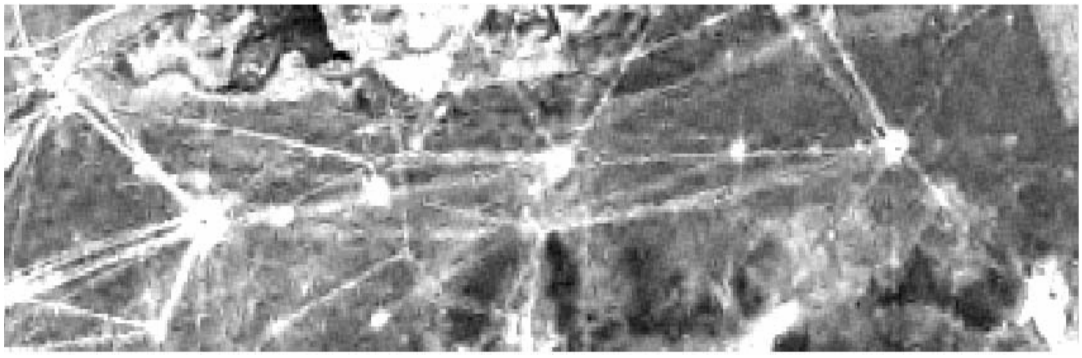

Figure 1. Chain of dot objects connected by linear ones (wells with potable water and a road network).

Ring structures are in special group. Part of them can be attributed to Area heterogeneities of the earth's crust, the other part to linear objects. The former are shown in pictures as color (continuous-tone) or morphological heterogeneity, the last are limited only by lines. Frequently their combination can be observed (Fig. 2).

In other words, ring structures in space pictures are expressed by spectrometer anomalies and quite often emphasized by system of concentric and arc linear objects.

Ring structures have been known for a long time, but with occurrence of space pictures an interest to them has increased. Also due to the fact that about 70 % of deposits are connected with them (Korchuganova N. I., 1998).

Ring structures are classified by genetic attributes, the sizes, geomorphologic attributes and expressiveness in space pictures

Monogenic structures are divided into endogenous, exogenous, man-caused and impact.

Endogenous structures can be tectonic i.e. formed as a result of tectonic movements, magmatogene - their source is the magmatic activity, and metamorphogene i.e. formed as a result of changes in rocks.

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Figure 2. Ring structure. A combination of color (continuous-tone), morphological and linear heterogeneities (Kentish massif, the Central Kazakhstan).

Endogenous ring structures

Tectonic structures as a result of tectonic movements are connected with anticlines, salt domes, anticline folds (positive structures). Negative structures are connected with buried depression of the base, synclinal folds. Rotational structures are connected with horizontal turn of blocks and can be both positive and negative, or at all not expressed in a relief.

Magmatogene structures are widespread on platforms and in folded areas and make more than half of all ring structures revealed in space pictures. Formation of massifs of alkaline- ultrabasic composition and also small intrusives (including kimberlite, advanced on platforms) is connected with mantle magmatism.

Volcanic and volcanoplutonic structures of small diameter dated for zones of deep breaks are characteristic for trap fields of ancient platforms.

Plutonic structures are connected with crust magmatism, and they are widespread in folded belts. These structures are formed by granitoid plutonic rocks and represented by large batholite, with big vertical capacity, isometric rods, ring and conic intrusions.

Volcanic and volcanoplutonic structures are connected with crust magmatism and distributed in continental volcanic belts. They are represented by positive extensive raisings of the base of belts or by negative structures that is more often. The most typical among them are volcanic depressions of round or oval form; internal parts of such volcanic structures bear passive sag above devastated magmatic centers, and external ones are emphasized by the system of radial dumps.

Vulcanotectonic structures have large sizes up to 400-600 km across diameter and are formed by tectonic depressions filled with volcanic and vulcanosedimentary rocks.

Metamorphogene ring structures are divided into gneissic folded ovals and granitogneiss domes.

Exogenous ring structures

Superficial geological processes result in formation of karstic, suffosion, thermokarstic craters, failures of seismic character.

Man-caused ring structures.

In space pictures the ring structures coming out of industrial, agricultural, military, scientific or other activity of man (Figure 3) are observed. Approximately in 10-20 % of cases it is impossible to reveal their genetic

belonging. Therefore they should be ascribed to an independent class of structures of unrevealed genesis. As a rule, this class includes the structures there is no data at the initial analysis to identify.

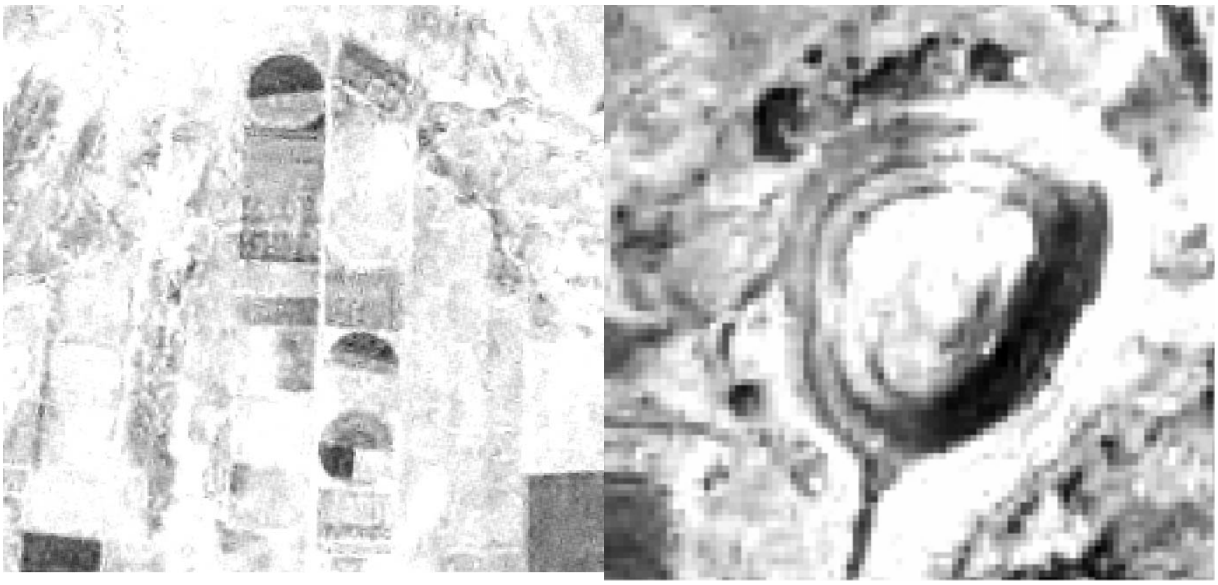

Figure 3. Ring man-caused ring structures: a. result of agricultural activity of man; b. result of development of deposits of minerals.

Impact ring structures.

In space pictures there are ring structures of impact or space origin, differently called astroblems. They appear as a result of falling of space bodies onto the Earth.

Impact craters or astroblems have always been attractive for researchers. There was not systematic character in astroblems studying till 1960, only several largest meteoric craters were known. Within the last forty years our vision of the Earth and its place in Solar system has appreciably changed.

The view on influence the impact phenomena have on terrestrial processes has also changed: from the exotic phenomenon to the strongest factor at geological and biological development of the Earth.

In the past of the Earth the impact phenomena more than once cardinally changed the composition and structure of biosphere, resulted in global dispositions of the earth's crust, generated global outpourings of magmatic rocks, formed large ore deposits and once at the least caused global extinction of kinds (French B. M. 1998). It happened about sixty five million years ago. Some researchers consider Chicxulub crater on Yucatan peninsula, in Mexico, about 170 kilometers in diameter to be the result of a terrible meeting with a heavenly body. Thus three quarters of living beings populated the Earth were lost at this accident. From cold and starvation the dinosaurs have died out; in the seas countless numbers of fishes and mollusks have disappeared.

Studying the Moon, and then other objects of Solar system the experts became firmly convinced that meteorites of the various sizes to some extent influence on planetary processes.

Thus on surface of all solid planets of Solar system it can be found traces of bombardment, even gas giants have traces of space impacts. The rings of Saturn can be considered to be the result of catastrophic bombardment of its satellite. Even fine asteroids have characteristic "wounds".

The best example of such catastrophic phenomena became a series of explosions in the atmosphere of Jupiter, caused by falling on it the fragments of comet Shumeiker-Levi 9 in July, 1994. The nucleus of the comet in July, 1992 as a result of approach to Jupiter broke up into fragments which subsequently collided with a planet - giant. In connection with the fact that collisions occurred on the night side of the Jupiter, terrestrial researchers could observe only the flashes reflected by satellites of the planet and impressing consequences on the surface of the planet. The analysis has shown that diameter of fragments of the comet is from one up to several kilometers. 20 splinters have fallen onto Jupiter.

Now on the Earth a little more than 170 meteoric craters are authentically confirmed. The majority of them were recognized in the fifties after studying space pictures, thus several impact craters are diagnosed and confirmed every year (Earth Impact Database, 2003.).

Comparison of the surface of the Earth with space pictures of the Moon or Mercury without effort allows to see, that there are a lot more ring impact structures on them. It is considered that the cause of it is an early

(3,8-3,9 billion years ago) termination of active development of these planets, absence at them the atmosphere and the hydrosphere, connected with them exogenous geological processes resulting to eroding or burying the impact structures. It is supposed that the Earth at the beginning of existence (4,5-3,9 billion years ago) was similar to the Moon or Mercury. Therefore studying the astroblems and comparing the results of these researches with planetary data allow to understand the history of our planet (Feldman V.I. 1999) better.

Comparing the number of known astroblems on the Earth and Venus (172 and 967 respectively), excepting the area of world ocean, ice sheet and lakes of the Earth, it turns out that a terrestrial astroblem accounts for the area of active surface of 760 thousand km2 and 380 thousand km2 on Venus. Thus, it is twice as more craters per area unit on Venus than on the Earth. The difference can be explained well by active erosive processes on the Earth.

Comparing the number of astroblems with planets without any atmosphere or their satellites it is necessary to remember that dense atmosphere brakes a space body the more strongly, the more its diameter as it moves gas ahead of itself, compressing it and gradually slowing down. If condensed mass of gas (M) is great enough (at M of gas > 10M of a meteorite the speed of movement falls by 90 % and more) then the speed of impact approaches to zero. There is the iron meteorite Hoba about 60 тонн by weight in Namibia (Southern Africa). Its falling has resulted in neither a crater nor even a hole. The meteorite has landed as though on an air pillow, with practically zero speed of impact (Feldman V.I, 1999).

The age of known astroblems is within the limits of 750 million years and for more than 60 % of them is within the limits of 250 million years. The size of 85 % of astroblems is up to 30 km (Figure 4). And about 15 % of astroblems concern to young formations, their age is up to 1 million years. Why do researchers take an active interest in impact ring structures?

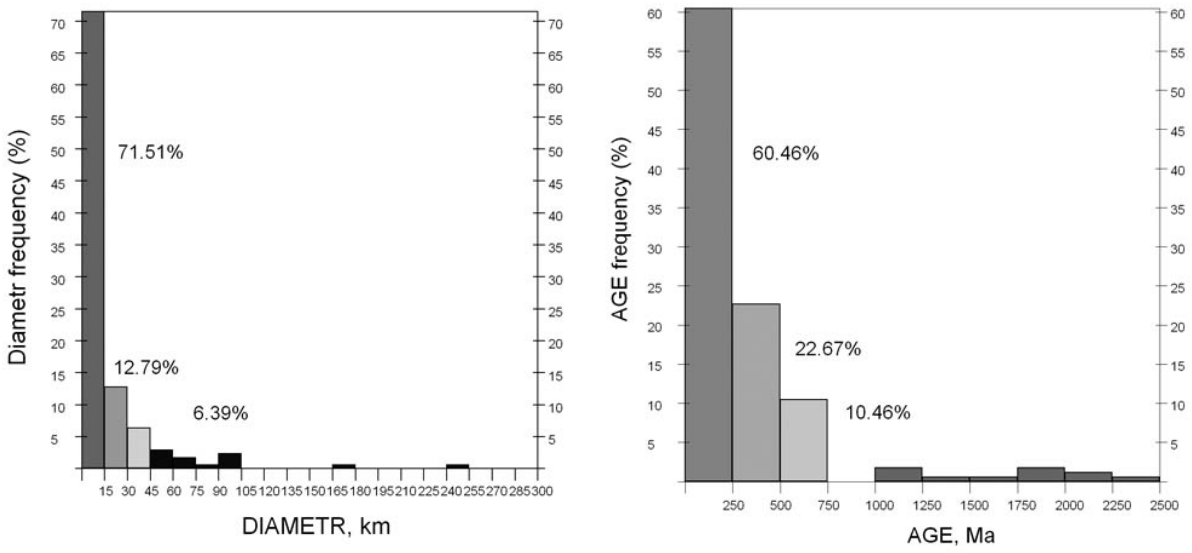

Figure 4. Frequency of distribution of known ring structures by age and sizes in percentage.

This is a practical question. There is a connection between these remarkable objects and minerals. Impact processes are catalysts, and the zones weakened by impact influence are the tank for accumulation of minerals. Presence of such kinds of minerals as building stone, diamonds and uranium is connected with them. Petroleum and gas are the basic products of impact structures (Donofrio, 1997; Johnsonand Campbell, 1997). Impact breccias under astroblems (Ames (Oklahoma); Red Wing Creek (North Dakota) are traps for petroleum and gas. An impact breccias inside and around astroblems [Ries Crater (Germany) represents an excellent building stone, oil shale [Boltysh (Ukraine)], diamonds diatomite [Ragozinka (Russia)], gypsum [Lake St. Martin (Canada)], and lead-zinc ores [Crooked Creek (Missouri)].

Only studying the impacts ring structures it is possible to reveal cyclicity, regularity of space impacts. In other words an opportunity to predict, when, as frequently and how big space bodies will meet the Earth. The example of bombardment of Jupiter by Shumeiker-Levi 9 comet proves that similar catastrophic processes have not stopped yet, and studying of these processes is a key to understanding and predicting the danger of space bombardment.

Studying of consequences of impact explosions gives invaluable scientific information. Any terrestrial process is not similar to impact one. The reasons of explosion are hard braking of space body at collision and

transition of kinetic energy of moving body partially to mechanical, partially to thermal energy. The total energy implemented during an impact can exceed 1019-1023 joule. Comparison of this value with energy of catastrophic volcanic eruptions (1,44*1020 joule at eruption of Tambora volcano in 1815 or 1,81*1019 joule for Krakatau volcano in 1883), shows that it is of about the same order. However the results of volcanic explosion and impact event are completely non-comparable. It is connected with the fact that in volcanic process the energy spends not at once, but in a series of the following one by one emanations within 10^3-10^5 s. At impact process the realization of kinetic energy of a space body lasts from several milliard fractions of a second up to the first seconds (the longer the more the total energy). Such high density of energy determines the enormous gradients of parameters (pressure and temperature) and as a consequence -very high speeds of mechanical and thermal processes passing. For example, the speed of mechanical deformation of rocks in endogen geological processes makes 10^{-16}-10^{-13} s^{-1}, and at impacts 10^{-3}-10^{-4} s^{-1}, that is by 17-20 orders more. (Feldman V.I., 1999)

Morphology of impact craters

Meteoric craters are the circular depression, surrounded by a ring height i.e. swell. The morphology of impact craters depends on their sizes. Craters in diameter up to 3-5 km have the concave bottom. Bottom of larger craters is flat. There is quite often a height in its central part, the so-called central uplift, formed as a result of elastic reaction of rocks after impact of a meteorite. There are one more or several ring uplifts in craters in diameter more than 20-25 km, but they are lower than an external swell. Both in the crater and outside of it at the distance of radius the rocks are crushed and intermixed by explosion of a meteorite. At the bottom of swell, under crater emissions, a little bit raised bedrocks are deposited. It is so-called structural rise. Craters are surrounded with a system of radial-concentric breaks. Their sizes depend on diameter of the crater, conditioned in its turn on energy of explosion.

This energy is enormous. For formation of a crater of 25 - 35 kilometer it should be ten times more the energy of the severest earthquakes. And at formation of 100-kilometer Popigay crater in Eastern Siberia 50 - 60 million years ago the energy released was thousands times more the energy of the severest earthquakes called the world disasters.

Traces of falling on the ground

The problem of ascertainment of ring structures belonging to impact ones is that many ring structures with age of more than 10 million years have lost geomorphological outlines of circular depressions surrounded by a swell from emissions of rocks (Korchuganova N. I., 1998). And large meteoric craters appeared about 100 million of years ago and earlier have almost or completely lost their initial morphology. Traces of active impact influence have been transferred by terrestrial superficial processes to other places. Active exogenous and endogenous processes have erased all geological consequences of powerful explosions.

As a result of active geological processes impact structures are so deeply eroded that sometimes even have no ring form and can be identified only by presence of chaotic spots of an unusual breccias or strange "volcanic" formation (French B.M., 1998).

And the deeper erosion will result in only poorly appreciable signs as a ring system of breaks - the inherited ring form of relief on the ground surface. But in this case it is practically impossible to prove impact origin.

Technique of revealing the impact craters

Methodically works on revealing the new ring structures can be divided into the following basic parts:

1. Interpretation of space pictures to reveal the ring structures;
   - Interpretation of ring structures independently of their genetic class;
   - Determination of their morphological class with use of the topographical information;
   - Division of the revealed ring structures into genetic classes with use of the geological information;
   - The choice of the most perspective (conditional impact) ring structures to transfer them to the following stage of processing.
2. Field and laboratory researches.

Only field observations and laboratory analyses can confirm the impact nature of ring structures.

In field conditions it is necessary to search for traces of shock-metamorphism, in some cases finds of meteoric substance or its traces as an overabundance of iridium are possible. Many of well-known now structures have been found out as a result of regional geophysical researches.

Geological signs

First of all, at studying the area of ring structure it should contain the bed rocks sharply differing from geological environment. In the area it should be precisely determined the presence of deformations and breccia

of rocks. The area should contain unusually looking igneous or intrusive rocks (sometimes such rocks look as quite usual magmatic rocks) (French B. M., 1998).

During explosion of a meteorite the bed rocks are exposed to influence of very high temperatures and pressure and consequently collapse, melt, evaporate, and in the centre of explosion even turn into plasma. Naturally, the changes occurring to rocks and minerals composing them have zonality i.e. the further from the centre of explosion, the less the changes. There, where the temperature is lower than melting point, but pressure is high, in minerals the changes occur, that allow determining the fact that the rocks have undergone an impact-explosive influence. For example, at pressure of 100-450 kilobar (that is 100-450 thousand atmospheres) and temperature of 100-900 °C quartz is squeezed, in its crystal lattice such qualitative changes occur (planar structures), that it turns into new minerals - stishovit and koesit, and graphite turns into peculiar diamonds not found in usual for the Earth kimberlite deposits. (Polocukhin V., 1981)

Shock-metamorphism in rocks results in formation of a system of cracks i.e. impact cones. These macrostructures in rocks are the result of only the influence of enormous pressure of more than 10 GPa Such structures are formed in all rocks, but most clearly traced in fine-grained rocks, and especially in limestones. There are frequently planar structures in impact cones rocks.

Geophysical signs

Shock - metamorphism results also in a change of physical properties of rocks.

Many impact ring structures show as a negative gravitational anomaly, but such anomalies are not a cogent feature and are absent of many known structures.

The magnetic field measured around impact ring structures is not noted for specific values but, nevertheless, in result of an impact process the natural anomalies get some characteristic features (Fig.5).

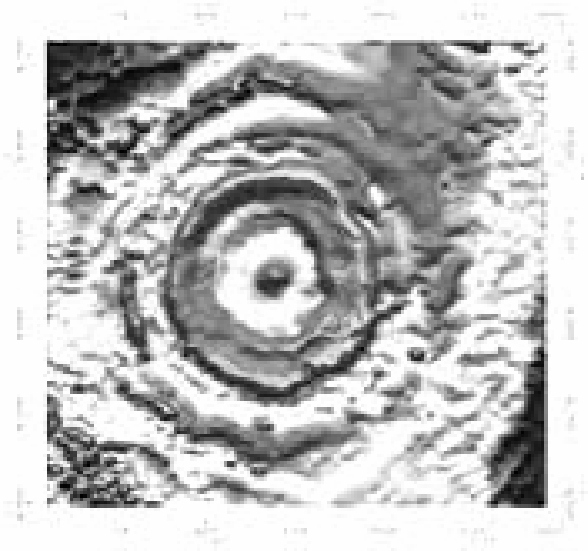

Figure 5. Yalali astroblem (Australia, diameter of 12 km), data of magnetic survey.

Seismic prospecting is the most effective way of determination of impact nature of structures, even the structures being under cover of younger rocks. With the help of seismic prospecting the following large and very important impact structures have been determined: Puchezh-Katunki (Russia) (D = 80 km), Chicxulub (Mexico) (D > 180 km), the Chesapeake Bay Crater (USA) (D = 90 km), and Morokweng (South Africa) (D > 70 km?), M'olnir astroblem (Norway, diameter of 40 km) (Figure 6)

Now the number of known impact structures makes about 25 % from total number of known structures on the surface of the Earth (Trefil and Raup, 1990; Grieve, 1991). To increase the number of recently found structures it is necessary to analyze the modern data. In this respect the territory of Central Kazakhstan is very promising.

Initially it is reasonable to use the materials on the most exposed and geologically-studied territory of Central Kazakhstan. Absence of forest cover, fine rock exposure gives a good opportunity to interpret geological and morphological conditions on space pictures. And space pictures of new generation have higher resolution.

Frequently at search for impact structures it was found out, that the nature of impact rocks was interpreted

by various researchers from the position of terrestrial processes, as for example, Unusual volcanic activity or "cryptovolcanic" events. (French B. M., 1998). Among such structures, initially incorrectly identified, are well-known now as impact structures: Ries Crater (Germany), Sudbury (Canada), and Vredefort (South Africa). Probability to reveal a cosmogeneous structure is not very low. It is necessary to look at the territory under study, but now from the position of revealing the impact ring structures.

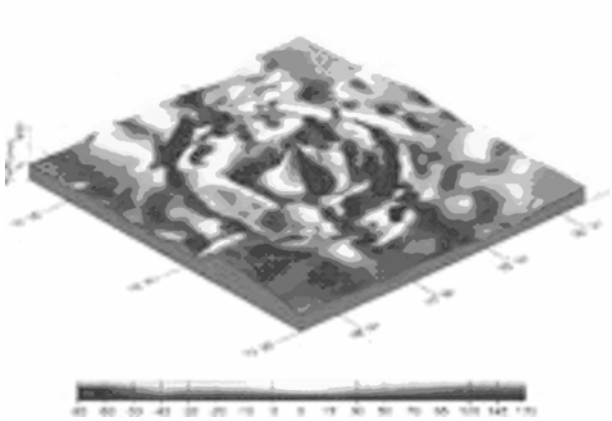

Figure 6. M'olnir astroblem (Norway, diameter of 40 km), the seismic data.

Thus on the territory of Kazakhstan it has been documentary revealed four astroblems. All of them are of different age and size (Tabl. 1), (Fig. 7, 8, 9, 10).

Table 1. Documentary revealed astroblems in Kazakhstan

CRATER NAME	Age (Ma)	DIAMETER (km)
Zhamanshin	0.9 ± 0.1	14
Bigach	5 ± 3	8
Chiyli	46 ± 7	5,5
Shunak	45 ± 10	2,8

Figure 7. Site of proved impact craters on the territory of Kazakhstan

Results of interpretation of M43-G map sheet

As a result of interpretation of space pictures it has been revealed 108 ring structures (Fig.12). By geomorphological signs 51 % of them are positive and 49 % negative and not expressed in relief. Just among these 49 % can be impact structures.

Figure 8. Impact craters Bigach, Age 5±3 Ma, Diameter 8 km.

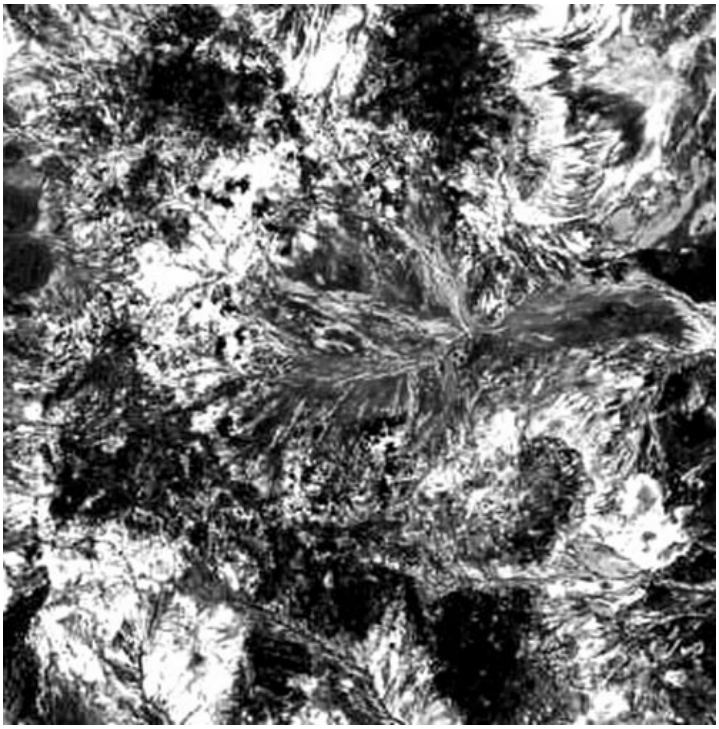

Figure 9. Impact craters Zhamanshin Age 0.9 ± 0.1 Ma, Diameter 2.8 km.

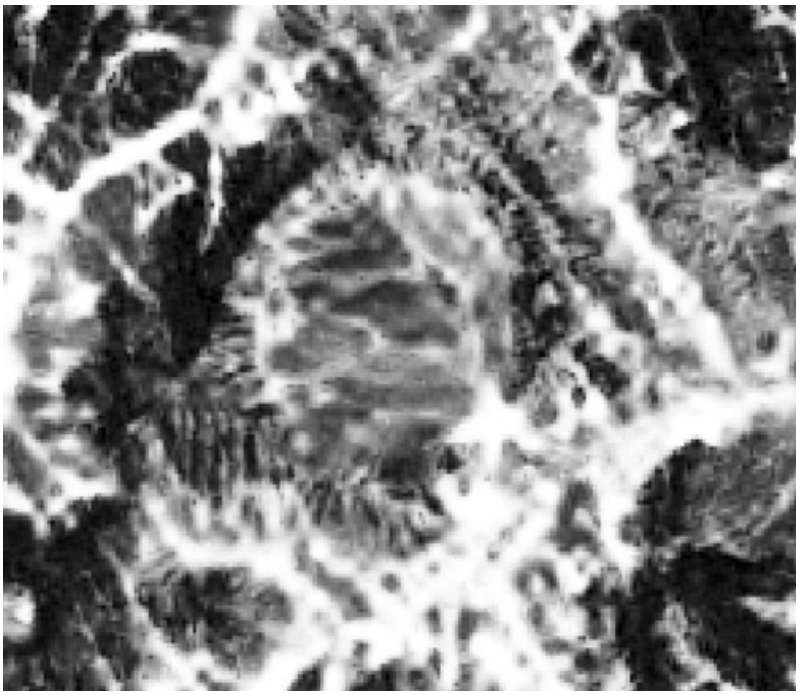

Figure10. Impact craters Shunak Age 45 ± 10Ma, Diameter 8 km

The genetic analysis of ring structures has shown that 8 % of them are conditional impact and about 5 % of unexplained nature (Fig. 11). Ring structures similar to described above by morphological signs have been placed among conditional impact structures. An example of such structures is given on Figure13. The sizes vary from 25 km up to 500 meters. The bottom of structures is rather flat. Central uplifts are not observed, this fact can be connected with active erosive processes. In most cases it is observed an edge uplift and a system of radial concentric breaks.

But as it was mentioned above, impact nature of the revealed structures can be proved only by field and laboratory researches.

Structures of unexplained nature can also be potentially impact ones, but they are not expressed morphologically, and it is impossible to identify them on a geological map.

The fact of revealing high rate (more than 15 %) of man-caused ring structures is of great interest (Fig. 13).

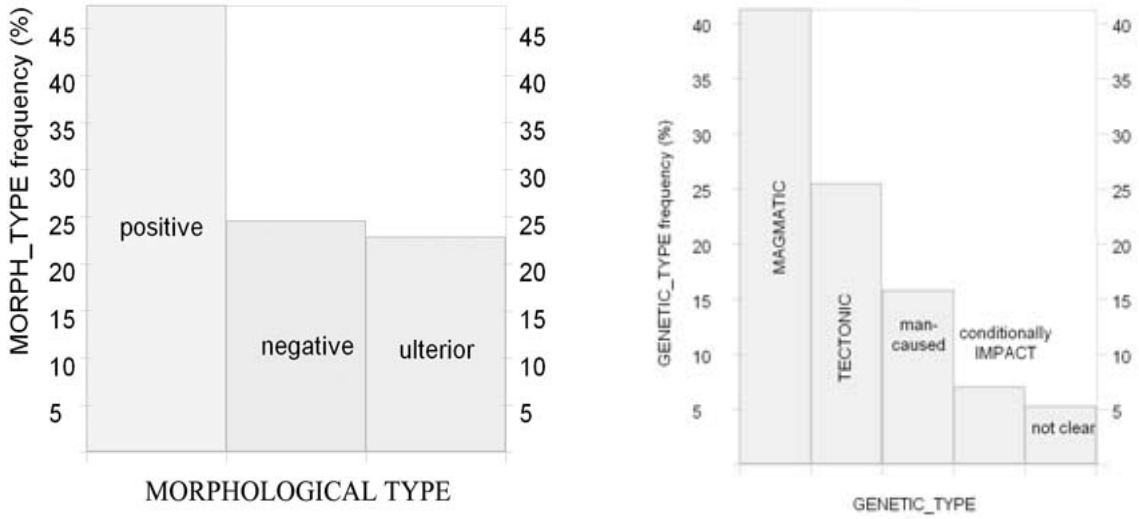

Figure 11. Frequency of ring structures distribution by morphological and genetic types.

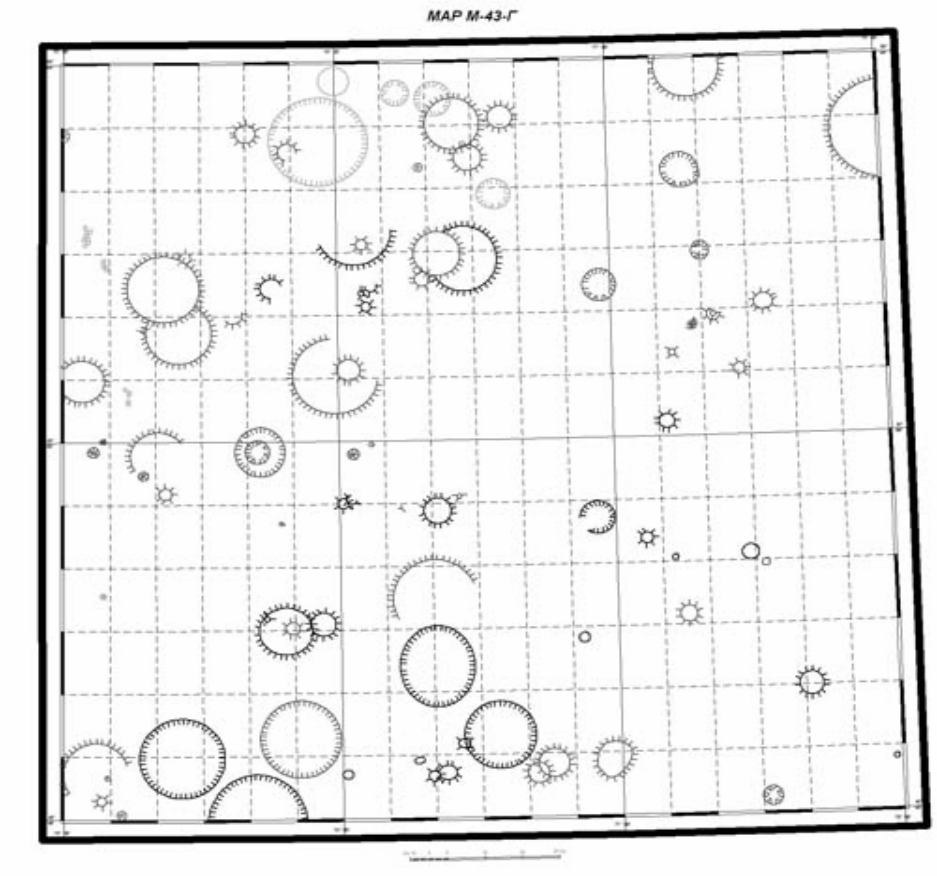

Figure 12. Map of revealed ring structures sheet M-43-G.

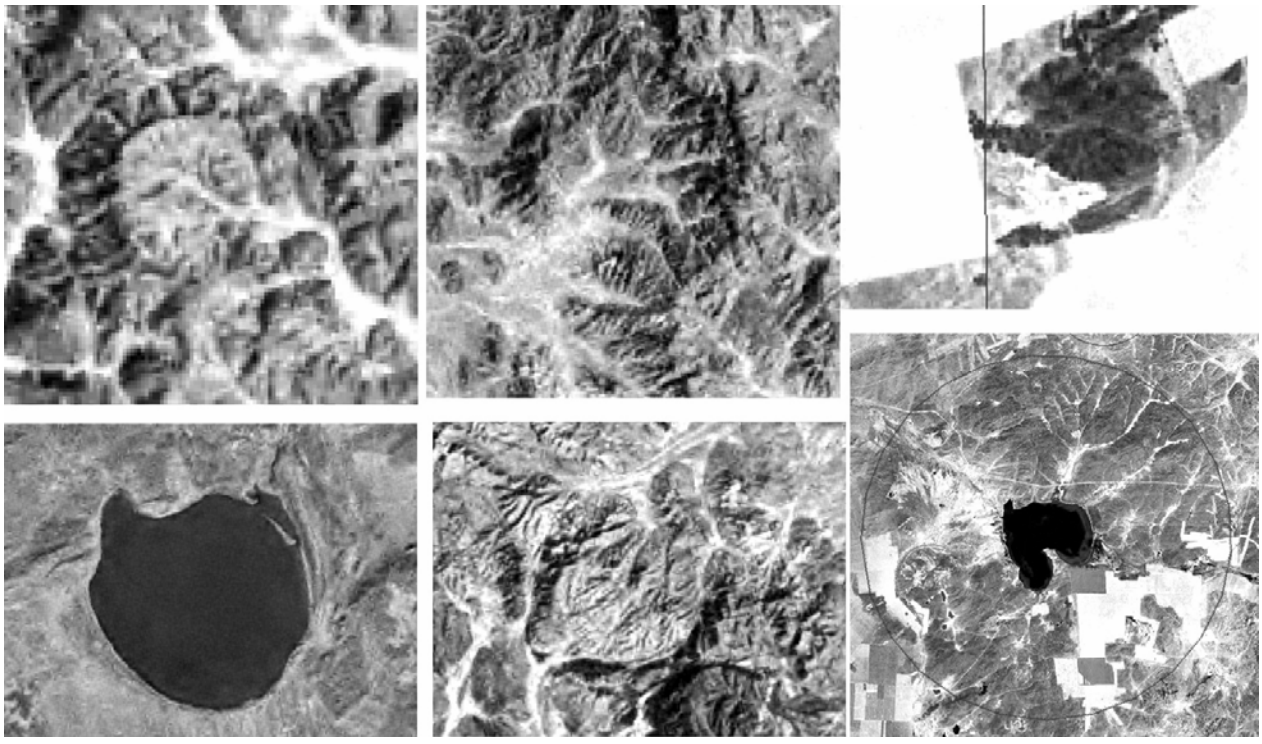

Figure 13. Chosen conditionally impact ring structures by results of interpretation of space images.

Resume

Space bodies of the various sizes reaching the solid surfaces of planets leave there some traces i.e. ring impact structures. These traces remind us of an opportunity of falling onto the Earth a space wanderer.

Falling the space bodies onto the Earth resulted in irreversible changes in the climate and biological diversity, and, only having compared paleoenvironmental, paleomagnetic and paleogeochemical data we can with full confidence say where and when it had taken place. Studying the astroblems we can say about the influence space bodies have on the Earth.

Experts find genetic connection between astroblems and various kinds of mineral resources: petroleum, gas, condensate, uranium, building stone, bitumen slate, diamonds, plaster, lead-zinc ores. Falling of space bodies is a catalyst of terrestrial processes. We can not consider the connection of deposits with impact structures to be implicit, in each individual case everything depends on degree of influence a space object has on the earth's crust and presence of favorable conditions on the Earth.

There is a difficult problem of discovering craters on the seabed for scientists to solve in the future. For that it is necessary to work out new techniques and technologies. For example, a sea astroblem, 11,5 km in diameter, was found out in 1987, not far off the coast of Nova Scotia (Canada).

Till now it has been poorly determined the scales and consequences of influence of early bombardments on the Earth.

Only one crater of more than 2 billion years age and sizes up to 300 km is known on the Earth. While in Venus, Moon and other planets it was discovered the craters of more than 4 billion years age and sizes exceeding 1000 km. The Earth was not an exception. Pre-geological stage of development of the Earth in more detail was studied and described by Soviet researchers Markov M.S. and Fedorovskii B.C., who assumed that the early Earth should have been exposed to meteoric bombardment, especially intensive to a boundary of 3,9 billion years ago. If to proceed from the density of meteoric stream uniform for system the Earth - the Moon then in first 600 million years of existence of our planet on its surface it should have been formed about 25 large craters with diameter of about 1000 kilometers and 2500-3000 craters with diameter of 100 kilometers.

Similar ancient huge astroblems are nuclears. Nuclears laid at initial stages of formation of the earth's crust and developed during all continental stage of its evolution (1600-1900 million years) (Katc Ya. G., Poletaev A.I., Sulidi-Kondrat'ev E.D.)

Impact space processes deserve more steadfast studying, and their influence on planetary processes is not limited by impact craters. During consolidation of the earth's crust the influence of space bodies was much more appreciable because of its low power and resulted in mass of magma flows and migration of substance.

Studying of impact ring structures and its connection with inherited relief is expected to give a key to understanding the geodynamic processes in the Earth's crust, to make a significant contribution on theoretical, regional, and applied geology.

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Резюме

Селенко О. **Анализ космических изображений с целью выявления кольцевых структур импактного типа.**

Приводится классификация объектов на космических снимках: линеаменты, площадные, точечные и кольцевые. Обсуждаются механизмы выявлении кольцевых структур и в частности импактного типа. Раскрывается связь импактных кольцевых структур (астроблем) с полезными ископаемыми. Приводится методика выявления астроблем и пример обработки части территории Центрального Казахстана ─ листа карты масштаба 1:500000 с целью подготовки условно импактных структур к дальнейшим исследованиям.

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Figures. Drawings and graphics are submitted in one copy (printed or ink hand-made). They are numbered on an order of the mention in the text. Tone pictures are not acceptable. The black-and-white photos are submitted in one copy by a size no more 290x210 mm (format A4) and are included in a joint account of Figures. On the back of each Figure or Photo name of the author, title of the article, number of the Figure should be indicated by a pencil, and also the arrow designates the upper side of figure. It is desirable to specify a location of the figures in the text on fields of the manuscript.

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The authors received 20 gratis reprints.

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Язык. Статьи подаются на русском или английском языках. Для поддержания усилий по распространению научной информации среди широкого круга ученых всего мира рекомендуется подавать статьи на английском языке (с адекватным переводом на русском языке). Перевод рукописи с русского языка на английский может быть осуществлен в редакции сборника за сравнительно невысокую плату. Правила транслитерации кириллицы в латиницу:е.э - e; ж - zh; й - y; х - kh; ц - ts; ч - ch; ш - sh; щ - shch; ь, ъ - '; ы - y; ю - yu; я - ya.

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Название статьи
Фамилии и адреса авторов
Учреждение, в котором работает автор и его адрес
Основной текст статьи
Литература
Иллюстрации (рисунки и фотографии)
Подписи к иллюстрациям

Резюме, раскрывающее основное содержание статьи приводится на русском для англоязычных статей и на английском языке для русскоязычных работ..

Иллюстрации. Выполненные черной тушью штриховые и точечные рисунки подаются в одном экземпляре, они нумеруются по порядку упоминания в тексте. Черно-белые фотографии представляются в одном экземпляре размером не более 29x21 см (формат А4) и включаются в общий счет рисунков. На обороте каждого рисунка или фотографии тонким карандашом должны быть указаны фамилия автора, название статьи, номер рисунка, а также стрелкой обозначена верхняя сторона иллюстрации. На полях рукописи желательно указать местоположение иллюстраций в тексте.

Литература. Ссылки приводятся в круглых скобках на языке публикации в хронологическом порядке, например (Holman, 1980; Кадырбеков, 1993). Если статья опубликована не в кириллическом или латинизированном алфавите и не содержит резюме на кириллице или латинице (например, публикации на японском, китайском, грузинском и т.п. языках), то в тексте ссылка на фамилию автора публикации необходимо приводить латинскими буквами. В списке литературы название такой публикации дается в переводе на английский язык, а источник транслитерируется в латиницу, в конце в скобках указывается язык оригинала. В списке литературы сначала приводятся публикации на кириллице, а затем на латинице в алфавитном порядке. Список литературы не нумеруется.

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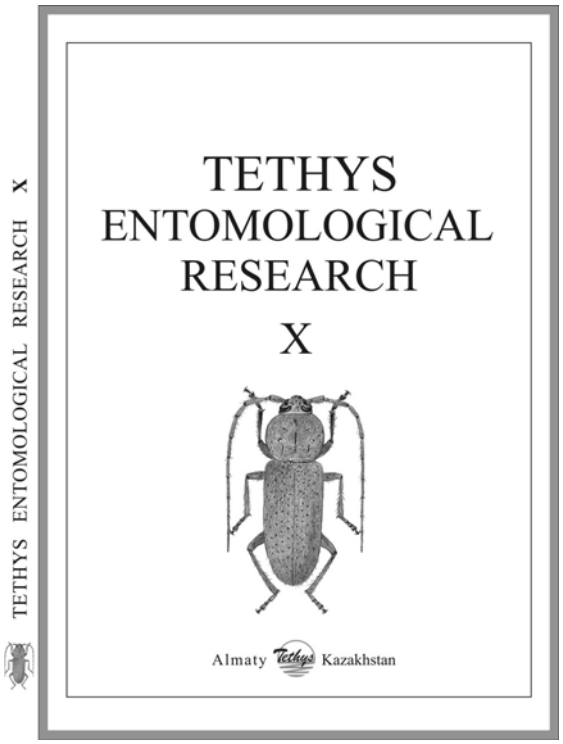

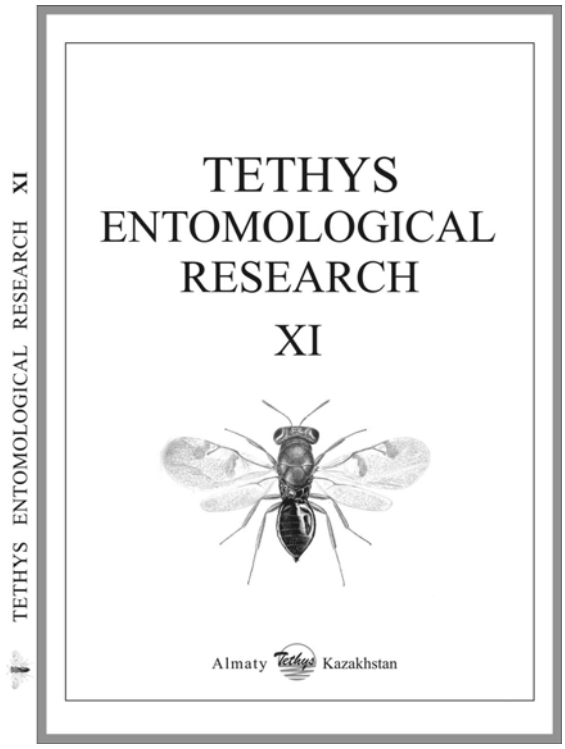

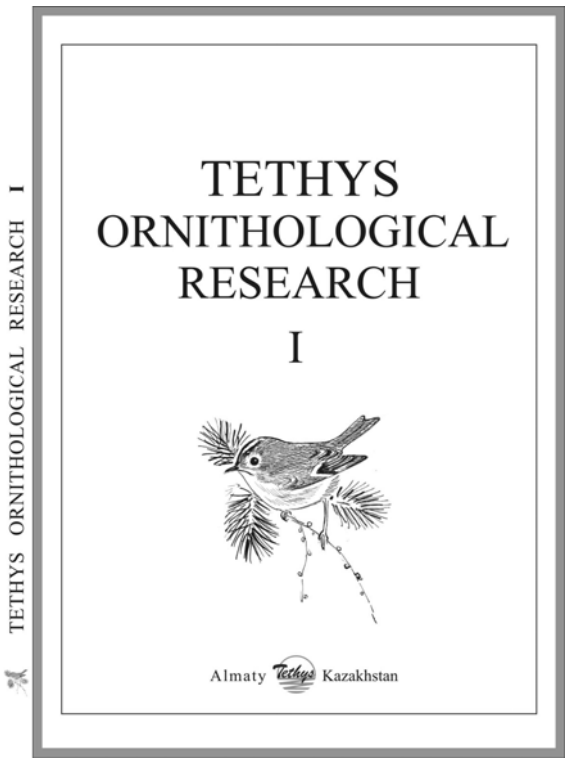

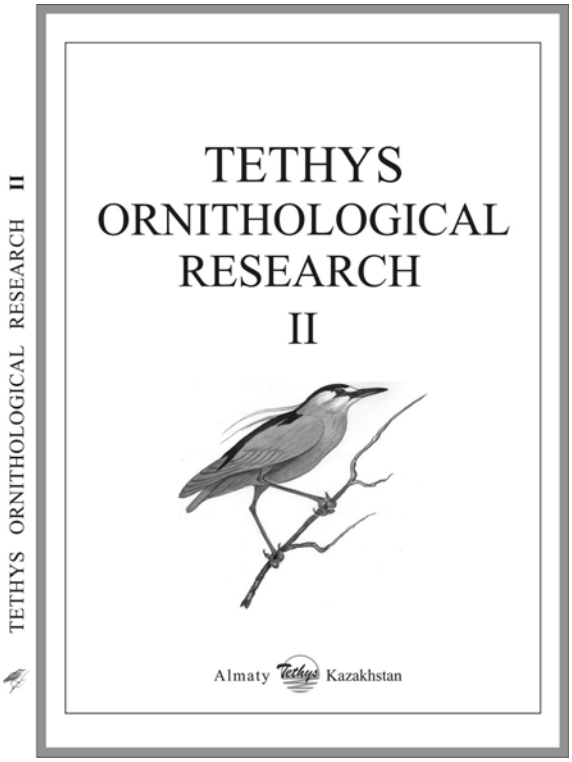

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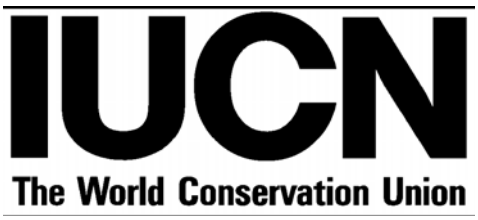

Tethys Geographical Research I

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