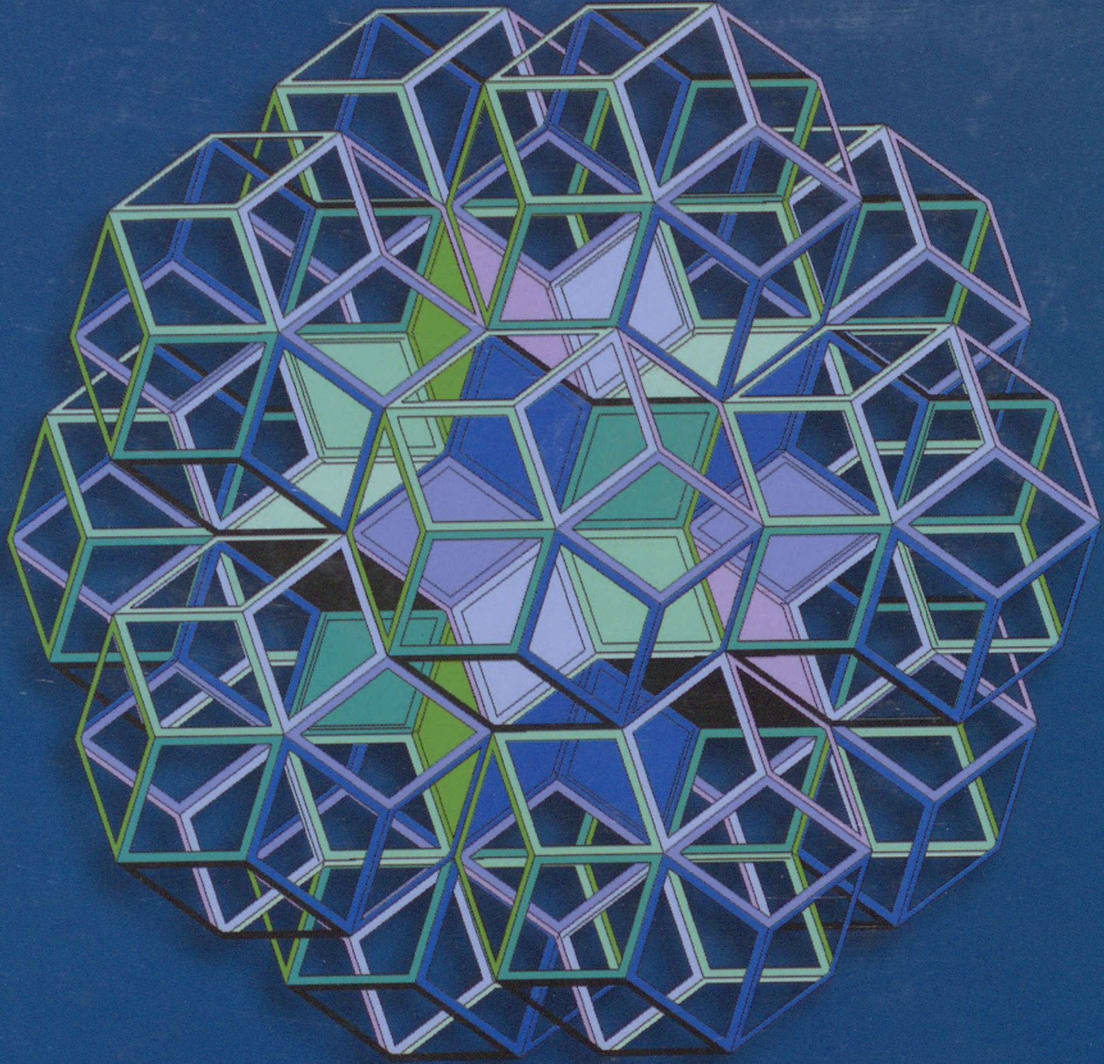

GEONOMY

The Synthesizing Geoscience for the 21st Century

Hungarian Academy of Sciences
Subcommission on Geonomy

Budapest

GEONOMY:

the Synthesizing Geoscience
for the 21st Century

CONTENTS

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PREFACE

In the year 2005 the Geochemical Research Institute of the Hungarian Academy of Sciences celebrates its 50[th] anniversary. We feel appropriate to pay tribute on this occasion also to Professor **E. Szádeczky-Kardoss**, who founded it as a Laboratory for Geochemical Research in 1955 (located initially in the premises of the Department of Petrology and Geochemistry of L. Eötvös University in Budapest) and was its first Director, until his retirement in 1974.

The present collection of papers is an abridged English-language version of the 200-page Hungarian-language book "*Geonomy after the Turn of Millennium*" published in 2003, on the occasion of the centenary of **E. Szádeczky-Kardoss**' birth. Its aim is to make the non-Hungarian readers familiar with his scientific achievements, in particular with his most ambitious (and also most controversial) concepts.

These were intended to set up an all-embracing synthesis of the Earth Sciences he named *Geonomy*, and even more, to create a fair approximation of understanding the Universe as a whole, by means of what he called the *Universal Cycle Relation*.

Thanks are due to the multidisciplinary team of the Subcommission on Geonomy of the Hungarian Academy of Sciences for their valuable contributions and to the X. Section of Earth Sciences of the Hungarian Academy of Sciences for kindly financing and publishing them.

Budapest, 2 May 2005

György Pantó

Full Member of the Hungarian Academy of Sciences

President of the X. Section of Earth Sciences of HAS

INTRODUCTION

After several centuries of highly successful analytical science, from the mid-20th century the need for integration has been growing in the world scientific community. With the boom of space and planetary science, the approach of considering the Earth as a holistic unit, a peculiar planet, became more and more widely accepted. One must not be a prophet, not even a professional futurologist, to predict that the 21st century will bring forth a fundamentally new, all-embracing synthesis of human knowledge, simultaneously anthropocentric and universal, objective and humane, – indispensable to save humankind from self-made nuclear or ecological apocalypse, to have "doomsday cancelled."

The aim of the present publication is to make the Reader acquainted with an outstanding pioneer of this trend, a geoscientist who was at the same time a renaissance-type personality and a synthesizer of scientific knowledge, and who has come too early to be properly understood and appreciated in his lifetime, except for a relatively restricted group of fascinated disciples (including the undersigned) and enthusiastic admirers.

Elemér Szádeczky-Kardoss was born in Kolozsvár/Klausenburg/Cluj in Transylvania, Hungary, on September 10, 1903, in a distinguished family of intellectuals. He attended primary and secondary school in his native town, and it was there that his first paper dealing with geology was printed, at the age of 20. However, he soon left his home. Namely, as a consequence of the Trianon Peace Treaty (1920), the whole Transylvania became annexed by Romania.

In 1926 **E. Szádeczky-Kardoss** graduated at the University of Budapest in Natural History and Chemistry. He became Assistant of Professor **Miklós Vendel** at the Department of Geology and Mineral Deposits, Faculty of Mining Engineering, in the Academy (later University) of Sopron in Western Hungary. He studied the young sediments of the Little Hungarian Plain (filling the NW subbasin of the Pannonian Basin), and eventually developed the **CPV** (Concave-Plane-Convex) technique for the statistical morphometric investigation of gravels.

During a scholarship in Berlin (1929-1930) **E. Szádeczky-Kardoss** studied coal petrography, and back home he began laboratory investigations and publishing in this field. (In 1936 he was appointed Professor.) His pioneering work "*Coal Petrology*" was published in 1952.

In the year 1951 **E. Szádeczky-Kardoss** was charged to chair the Department of Petrology and Geochemistry of the L.Eötvös University (ELTE) in Budapest, and also the Department of Geology and Mineral Deposits of the newly established University of Heavy Industries in Miskolc. He introduced *Geochemistry* as an independent subject of study at the University of Budapest, and published its first Hungarian -language textbook and comprehensive treatise (1955). He paid much attention to the grouping of the chemical elements (further developing **Goldschmidt's** system) and to the various aspects of ionic potentials, the cycles of elements across the geospheres, the role of the biosphere, etc. Dealing with Igneous Petrology, too, he coined and applied the term "trans-vaporization" and elaborated a new, genetic classification of igneous rocks.

Giving up his posts held in Sopron and Miskolc, he concentrated his activities on the ELTE inBudapest, and on the Hungarian Academy of Sciences, of which he was elected Full Member in 1951. 1965-1976 he was Chairman of the Department of Earth and Mining Sciences (sic!), and Editor-in-chief of the two professional journals of the Department, a Hungarian language one and the present English-language one, the "Acta geologica".

Already in 1955 he founded the *Laboratory for Geochemical Research* of the Hungarian Academy of Sciences, and was its Director until his retirement in 1974. He was particularly interested in metamorphism. It was according the concept and under the personal supervision of E. **Szádeczky-Kardoss** that the Map of Metamorphites of the **CBGA** (Carpatho-Balkan Geological Association) territory was produced by an international team of experts. He wa s one of the pioneers of plate tectonics in Hungary.

He was awarded twice the Kossuth Prize (the highest scientific distinction in Hungary), and the Leopold Buch Medal. He was elected Member of the World Academy of Arts and Sciences, and Honorary Member of the Hungarian, Czecho-Slovak and Finnish Geological Societies, and Corresponding Member of the Austrian Academy of Sciences

From mostly analytical research **E. Szádeczky-Kardoss** consciously switched over to synthesizing. His ultimate goal was to create an all-embracing synthesis of the Earth Sciences. This ambition gave birth to his fundamental work entitled "*Geonomy*" in 1974 (3). He organized a series of interdisciplinary symposia at the Hungarian Academy of Sciences under the umbrella title "*Material and Energy Flows of the Earth*". (1) Also information exchange was dealt with. He has set up the multidisciplinary *Commission on Geonomy* of the Hungarian Academy of Sciences, which is still active.

E.Szádeczky-Kardoss himself considered as his greatest achievement the discovery and inter-pretation of what he called the *Universal Cycle Relation*. He plotted the various cyclic motions in a double logarithmic Time versus Space diagram. He was fascinated by the fact that these turned out to be arranged in four distinct stripes (A: electromagnetic motions, B: mechanical motions, C: chemical and biological motions, D: subatomic motions). He kept on working stubbornly on this topic until his death (August 23, 1984) in Budapest. He was buried in the Farkasrét Cemetery in Budapest. An English-language obituary was published in the INHIGEO NEWSLETTER in 1987 (2).

E. Szádeczky-Kardoss' synthetic world concept was published in several postumus works in Hungarian (7, 8) and in English (9). As it had been expected, his attempt to interpret the entire Universe by means of two basic parameters (Time and Space) generated animated, in some cases passionate debates.

On the 100th anniversary of **E. Szádeczky-Kardoss'** birth two scientific sessions held at the ELTE and the Hungarian Academy of Sciences, respectively, and a bust of **E. Szádeczky-Kardoss** was unveiled in the Aula (central hall) of the new campus of ELTE's Faculty of Sciences.

In 2003, a ten-member team of the Subcommission on Geonomy of the Hungarian Academy of Sciences published a critical review of his daring ideas, in Hungarian (3). The *Acta geologica* dedicated a special issue to selected papers of his disciples, with an introductory paper sketching his life and oeuvre. (4). A more detailed study, including pertinent quotations from his works, is in press in *Episodes* of IUGS (5).

The present volume can do nothing more than to provide the Reader with a taste of **E.Szádecz-ky-Kardoss** intellectual universe by means of a collection of papers presenting several aspects of his ideas and assessing their afterlife up to the present day – as well as their possible importance for and message to the 21st century.

Endre Dudich

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GEONOMIES AND GEONOMY

GEONOMY – PAST AND PRESENT
A HISTORICAL APPROACH

by
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1. Historical background

In the second half of the 20th century the (second) scientific and technical revolution attained its climax beside the fields of energetics, automatisation and informatics, in the Bio- and Geo-sciences. First of all the research into the objects of extremely big and extremely small dimensions (the micro- and mega-world, respectively) resulted in a change of paradigm. The achievements interfered with each other positively, further advancing our methodological and theoretical knowledge.

Space research and deep sea exploration, including high-precision measurements of the ocean floor spreading, led to the revision of such traditional theses as the permanence of the oceans and the predominance of vertical movements of the crust.

The novel dynamic approach affected all disciplines of the earth sciences. It became evident that the individual geospheres must not be explored any more separately, and the advances in space exploration and planetology required in-depth comparison of the Earth as a system with the other celestial bodies of the Solar System.

Particularly important was the development and application of system theory, providing a key to understand the dynamism of material structures, mainly in the Bio- and Geo-sciences.

The trend towards integration elevated the existing theories to a higher level. The internal structure of the individual disciplines went on changing at an accelerated pace.

Progress, of course, was not uniform and smooth everywhere. E.g. in the former USSR the introduction of global or plate tectonics by the "mobilists" met the fierce resistance of the "fixists" who enjoyed the support of the Communist authorities. (This is rather remarkable, since on the basis of the official ideology, dialectic materialism, logically the opposite position should have been preferred.) Although Hungary at that time was one of the Soviet block countries, in this respect (and not only in this respect) she was an exception. As early as in the late sixties, the revision of the ideas about the structural evolution of the Carpatho-Pannonian region was started, under the aegis of the Hungarian Academy of Sciences, upon the initiative and under the personal guidance of **E. Szádeczky-Kardoss**. He organized and chaired a series of workshops on the *"Matter and Energy Flows of the Earth"*. These became forums of the geonomic approach he had conceived.

The changes occurring in the system of scientific disciplines reflect, as a rule, the process of cognition, and are followed by modifications in the institutional organisation of science. In some cases it is possible, however, that in a given stage of development some scientsts of broad outlook and solid tehoretical background, with adequate knowledge of the prevailing trends, can forecast the contours of the given discipline, in this way accelerating the progress of science. This was the case in Hungary in the sixties and seventies, when the GEONOMY was about to mature.

2. History of Geonomy as a discipline and its coeval interpretation from the point of view of the philosophy of science.

It was generally believed that the term "geonomy" appeared in the late sixties without antecedents (WILSON J.T., 1968). **E. Szádeczky-Kardoss** himself quoted WILSON who considered Geonomy as the integration of earth sciences – in particular structural geology and geophysics -- looking for causal interpretation in view of the moving and colliding continents.

However, during my studies in the philosophy of science I came across a paper published in the Soviet Union by **B.P. Visotzky** in 1972, entitled *"On the Concept Geonomy"*. According to this paper, a Russian natural philosopher, **N. Yak. Grot** coined the term "geonomy" as far back in time as 1884, to designate a geoscience to be born in the 20th centrury, aiming at generalization. In his view, *Geography* is a descriptive discipline, *Geology* is of historical (genetic) approach, and *Geonomy* should establish "laws" concerning the evolution of the Earth. In the USSR this idea was rather popular in the seventies. In (Soviet) Armenia A.T.**Aslanian** (1974) even proposed to introduce Geonomy as an independent subject of the university curricula of Earth Sciences.

In an earlier study (PÓKA T. 1975) I pointed out that **Wilson's** definition would require some slight modification. One should emphasize that beside integrating all geoscientific knowledge, Geonomy also elevates it to a higher level and can establish general laws concerning the Earth as a whole, as a complex system.

As **E. Szádeczky-Kardoss** put it in his GEONOMY: *"the main task of Geonomy is to systematize the interrelations of scientific phenomena detected by various disciplines using different methods."* Furthermore, he was probably the first to point out that this integration should comprise the living world as well, the biosphere being one of the subsystems of the Earth. He wrote: *"The Earth differs from the other planets mainly in that respect, that in its development beside the initial inorganic factors later an ever increasing role has been played by the organic, (palaeo),biological factors. Accordingly, Geonomy is not only a geoscience seeking causes, but it embraces inseparably the basically biological themes of the origins and inorganic background of life, too.."*

As a matter of fact, this approach became widespread in the last two decades of the 20[th] century, but without the formal acceptance / adoption of a specific theoretical discipline called Geonomy. In the field of the biological sciences, Theoretical Biology played its pertinent part.

In Hungary, this trend became institutionalized by the aforementioned workshops on the Matter and Energy Flows of the Earth, and by the establishment of the interdisciplinary **Commission on Geonomy of the Hungarian Academy of Sciences in 1976.**

It was soon realized that this high-level synthesis may have a conscience-forming effect on the society as a whole. For this reason, considerable efforts were made to introduce Geonomy in the secondary schools. The author of the present paper was member of the competent Commission on Public Education of the Hungarian Academy of Sciences. Experimental instruction of Geonomy was started in twenty grammar schools of Hungary, in the 1[st] class (age 15), replacing General Geography. Both the teachers involved and the pupils concerned reacted rather positively. But the counter-attack of the opponents of the idea was successful, and the experiment was cancelled.

In 1975 I gave the following definition of Geonomy: ***"Geonomy is a theoretical discipline which processes and transmits information obtained by other geosciences. Its aim is to discover structural and functional interrelations characterizing the Earth as a relatively closed system and as the bearer of Life."*** *Geonomy has* ***"to study and interpret the dynamism and evolution history of the system Earth, to forecast its short-, medium- and long-term changes, to transform this knowledge for the use by other sciences, and, finally, to establish a humanistic scientific concept of the world."***

3. The afterlife of Geonomy

In the progress of science, just like in other domains of evolution, trends have not always a smooth and straigth way. For some time the ideas of geonomy were not duly understood and appreciated. Nonetheless the growing need for integration could not be ignored. In the late seventies the *Gaia hypothesis* was launched which considers the planet Earth as a vulnerable living being, capable (within certain limits) of self-regulation / homeostasis and regeneration. From the eighties on, Earth Systems Science has developed, with treatises, textbooks, chairs at universities, independent subject in the curriculum. E.g. the book *"Earth Systems. Processes and Issues"* (ed. by ERNST, W.G) published in 2000 shows remarkable similarities to **E. Szádeczky-Kardoss'** Geonomy of 1974, both in terms of the topics discussed and the conclusions drawn.

4. Conclusion

It can be stated that with his "Geonomy" concept **E. Szádeczky-Kardoss** was ahead of his time by two or three decades. Although it was known and appreciated by a certain (however rather restricted) group of scientists, it had to face also serious misundertanding and incomprehension, so it has not exerted the impact it would have merited. It is a pity that the GEONOMY has not been edited definitively and printed, not even in Hungarian, and even less in English. Otherwise it might have acquired worldwide reputation to its author and honour to Hungarian science. Nonetheless it triggered and stimulated closer cooperation between the disciplines of earth sciences, and contributed to the better understanding of Hungary's geological past and to the modernization of the conscience of society.

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THE UNIVERSAL CYCLE RELATION

by
Ferenc Benkő *[*]

Introduction

During the last ten years of his life (1975-1984) **E. Szádeczky-Kardoss** made a remarkable attempt to create a coherent, all-embracing and quantitative view of the Universe, which eventually might become the basis for a new pedagogy. The starting point was his discovery of what he baptized the Universal Cycle Relation (UCR). Included as Chapter C/12 in his GEONOMY of 1974, it was elaborated later in much detail (1978), but still remained unfinished, and was published posthumously in several versions (1986, 1989, 1992).

1. What is the Universal Cycle Relation?

All enduring motions in the Universe are cyclic or quasi-cyclic: oscillation, rotation, circulation, revolving. Plotting them according to ther space versus time parameters in a 10-based double logarithmic system of coordinates, several important statements can be made.

- The dots are not distributed at random, but they appear arranged in four stripes oriented at 45° to the axers X and Y. The stripes correspond to domains of the velocities of the pertinent motions.
- The four velocity stripes represent the four fundamental forms of motion in the Universe:
  - Stripe A – electromagnetic (maxwellian) motions;
  - Stripe B – mechanical (newtonian) motions;
  - Stripe C – chemical, geological and biological motions going on in complex disperse systems;
  - Stripe D: motions controlled by the nuclear/subatomic (heisenbergian) interactions.
- Stripes A-B and B-C are interconnected by "bridges", i.e. privilegized transitional velocities.

E. Szádeczky-Kardoss proceeded to formulate a number of important statements.

- Each cycle is characterized by six external and six internal parameters.
- New cycles are generated by phase transformation due to **p,t,c** (pressure, temperature, concentration) changes, by fission, or collision.
- There are space and time resonance phenomena between the stripes. These keep the motions going and render possible interactions.
- The natural (but also the artificial) systems are created by (quasi)cyclic motions. These are of hierarchic structure.
- **E. Szádeczky-Kardoss** distinguished altogether 15 hierarchic organization levels from the (hypothetic) space quantum to the Universe as a whole.

2. What had already been known – and what was new?

The cyclic nature of geological processes has been known and admitted for three centuries. (**N. Steno** 1666: sedimentation; **J. Hutton** 1795: magmatism; **Ch. Lyell**: the "geological year"; **E. de Beaumont** 1856: orogeny.) These recognized cycles, however, were qualitative categories only. **L. Glangeaud** (1962) might have been the first to represent them in an X-Y coordinate system, and he wondered how to apply the system of hierarchies to the geological phenomena. Considerable advance was made by **R.W. Bemmelen**. Even the title of is study is rather instructive: "The importance of the geonomic dimension for geodynamic concepts "(1967).

Comparing these pioneering works with those written by **E. Szádeczky-Kardoss,** two decisive differences have to be pointed out.

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[*] Abridged and translated by E. Dudich from F.Benkő's study published in 2003 (after the author's death in June 2003).

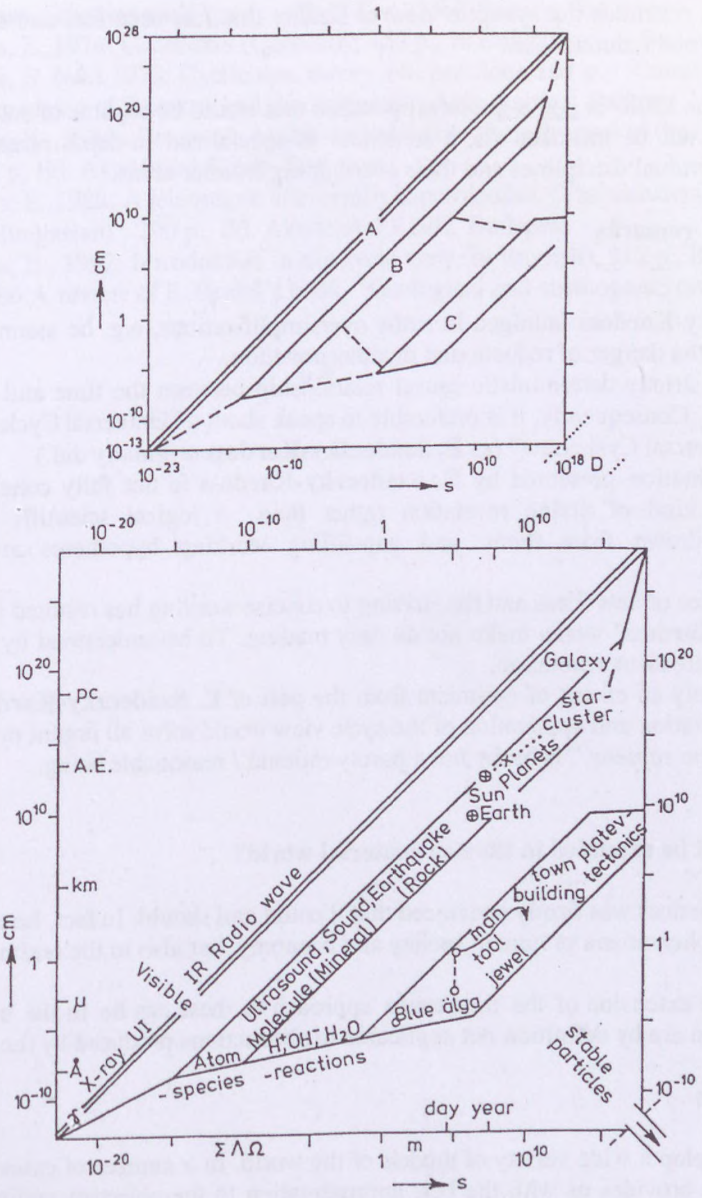

Fig. 1 The time / space diagram

- The diagrams plotted by his predecessors comprised 6 to 23 orders of magnitude of space and time, while **E. Szádeczky-Kardoss'** one embraced 41 (virtually, and by his very intention, the entire Universe).
- The interpretation given by **E. Szádeczky-Kardoss** (see the previous item 1) was completely unknown to his predecessors. Namely they represented both the cyclic and the non-cyclic motions, so that the four stripes could not be – and, in fact, were not – recognized.

3. Why is the UCR important?

- Due to the close connection between the time and space parameters, the UCR is heuristic.
- In finite space only cylic motion can be durable.
- The quasi-cyclic (imperfectly reiterated) motions provide the possibility of evolution (in a "spiral").
- The full hierarchic superposition of cycles can be deduced from it.
- It renders possible to deal with all motion phenomena of the Universe in a uniform, visualized and clearly understandable manner, disclosing their commensurable essences and their quantified interrelations.

- The UCR restitutes the synoptic view of Reality that has been lost due to excessive abstraction and short-viewed reductionism.

Nevertheless, the UCR is not a universal panacea that would be capable of solving all enigmas of the world. It must not be mistaken for a substitute of specialized in-depth research in the historically established individual dsiciplines and their overlapping frontier areas.

4. Five critical remarks

- **E. Szádeczky-Kardoss** indulged in some oversimplifications, e.g. he assumed uniform velocities. This implies the danger of reductionist misinterpretation.
- There is no strictly deterministic causal relationship between the time and space parameters of a given motion. Consequently, it is preferable to speak about a "Universal Cycle Relation" rather than about a "Universal Cycle Law" (as **E. Szádeczky-Kardoss** originally did.)
- The argumentation presented by **E. Szádeczky-Kardoss** is not fully coherent. In some cases is resembles a kind of divine revelation rather than a logical scientific argumentation. Facts, conclusions drawn from them, and gap-filling working hypotheses are not always clearly distinguished.
- The abundance of new ideas and the striving to concise wording has resulted in relative obscurity. **E. Szádeczky-Kardoss'** works make not an easy reading. To be understood by the larger public, they require competent interpretation.
- It was certainly an excess of optimism from the part of **E. Szádeczky-Kardoss** to assume that the general acceptation and application of the cycle view would solve all urgent problems of Humankind. Namely "*Homo sapiens* " is by far not a purely rational / reasonable being.

5. Can the UCR be extended to the non-material world?

E. **Szádeczky-Kardoss** was firmly convinced that it could and should. In fact, he endeavoured extending it not only to all phenomena of human society and economy, but also to the realm of arts, emotions, and even religion.

However, the extension of the time/space approach to these can be in the best case virtual. Real time/space relation are by definition not applicable to abstractions produced by the human mind.

Closing remarks

One can develop a wide variety of models of the world. In a number of cases it is rather difficult to decide which one provides us with the best approximation to the objective reality. Namely this would require full and reliable knowledge of the reality, the Truth as **St.Thomas Aquinas** defined it: "*Adaequatio rei et intellectus*", correspondence of the Mind with the Thing, of the Subject with the Object. But in this ideal case no model whatsoever would be needed any more.

At any rate, it is never admissible to regard a model as a really existing ontological reality; even less to overestimate or reject it on this subjective basis.

By now it is obvious that **E. Szádeczky-Kardoss'** Universal Cycle Relation is a challenging new paradigm (**A.F. Trendall** 1986), created by a daring scientist who set out to comprehend the ordered complexity of the Universe denoted by the ancient Greek "philosophers", or Lovers of Wisdom, "Cosmos".

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A. THE EARTH AND THE OTHER PLANETS

FORMATION OF THE MINERAL BELTS AROUND THE SUN

by
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INTRODUCTION

The material structure of the planetary systems which occur around stars can be understood in the context of a joint evolution process of the star and planets. For the Solar System this common origin of the star and its planets can be deduced from a galactic nebula. We focus on the main events which determined the mineral composition of the planets.

The first event is the contraction of the nebula triggered by the effect of a supernova blown up in the vicinity of the star.

The next event is the heating up of the central portion of the nebula. The thermal gradient from this central hot region out to the peripheries of the nebula differentiates the materials. This results in hot gas and some melt in the central regions where outburst of the early sun (flares) may cause chondrule formation and early solar wind transports this material to the cooler outer regions. In a wide band of transitional thermal regions the heated up gas crystallizes. However, a large amount of previous dust material remains cool during the events. Mixing of the chondrules with this cooler primitive matter results in a primitive initial material for chondrites. This may explain the overall chemical similarity of the solar and the planetary material expressed in the relative abundances of elements. The similarity of the calculated ages of the chondrites, the Earth and the Moon is also in accordance with this common origin.

The main features of the materials in the Solar System was understood by developing the condensation model. It starts from the chemical abundances as initial conditions. It uses chemical equilibria estimations and the condensing crystal assemblages explain the main characteristics of the planets: e.g. the average density at a given solar distance. Such equilibrium condensation models of the Solar System were developed by **Larimer** (1967); **Grossmann** (1972); **Barshay** and **Lewis** (1974) and others. They have deduced the main mineral components of belts around the Sun with decreasing temperature and pressure. The characteristical mineralogy of the belts around the early Sun can be summarized by a sequence of mineral belts calculated from the intersection of the main gas/crystal phase boundaries by the Cameron-type solar adiabat. These calculations were fitted to the known planetary densities (**Lewis**, 1975).

The places of appropriate mineral belts were estimated on the basis of the recently occupied orbital positions of the planets. But a comparison of the condensation temperatures given by the Cameron adiabat on the Lewis-Barshay sequence of mineral phases, and the recent equilibrium temperatures of the planets with their main mineral compositions at their recent orbital distance gave the following results (**Bérczi**, **Lukács**, 1994). As an average, the condensation temperatures of Lewis-Barshay minerals are two times higher than their recently measurable equilibrium temperature at that distances from the Sun. So the results of the equilibrium condensation models on Solar System formation inherently contained references to the changing solar activity. Changing luminosity of the central star modified the distance of the mineral belts. However, the Lewis-Barshay model integrated the mineral assemblages collected by the planets during the whole period of condensation. Therefore we focus our attention to the Lewis-Barshay model, according to **Barshay** and **Lewis** (1975).

THE LEWIS-BARSHAY SEQUENCE OF MINERALS AROUND THE SUN

Barshay and **Lewis** (1975) calculated the sequence of chemical equilibria of selected main mineral components in the gas nebula around the Sun. The solar nebula had cosmic (solar) elementary abundances. This model allows precipitation of minerals in this gas nebula when temperature decreases according to the adiabat of Cameron. In their summarizing map of the p-T diagram of solar gas the phase boundaries of solid phases (which were in equilibrium with solar p-T conditions) were used in deducing condensation temperatures by crossing these boundaries with the adiabat of Cameron. The Lewis-Barshay map shows that decreasing temperature differentiated the solar nebula. The temperature is the function of both solar distance and time. Decreasing temperature with solar distance produces mineral belts around the Sun. Slow changes in the local temperature result in a time-dependent precipitation sequence in the belts.

The sequence of minerals is the following:

Table I

Temp. °K	**Elements, reactions**	**Mineral**
1600	CaO, Al_2O_3, REE oxides	Oxides (ie. perovskite)
1300	Fe, Ni alloy metal	Fe-Ni
1200	$MgO + SiO_2 \rightarrow MgSiO_3$	Enstatite (pyroxene)
1000	Alkaline oxides+Al_2O_3+SiO_2	Feldspar
1200-490	Fe+O-->FeO, FeO+$MgSiO_3$	Olivine
680	H_2S+Fe-->FeS	Troilite
550	Ca-minerals+H_2O	Tremolite
425	Olivine+H_2O	Serpentinite
175	H_2O ice crystallizes	Water-ice
150	gas NH_3+ice H_2O --->$NH_3.H_2O$	Ammonia-hydrate
120	gas CH_4+ice H_2O --->$CH_4.7H_2O$	Methane-hydrate
65	Methane, argone crystallizes	Methane, argone ices

Let us compare this sequence of precipitating minerals to the material make-up of the planets.

The mineral sequence can be divided into 3 different groups. The sequence can also be grouped according to the presence of H_2O. This divides the belts into two groups (without or with ice) that are "separated" by the troilite belt.

The model can be checked by astronomy and space science. We know (1) stony planets, (2) stony-ice comets and (3) icy satellites of giant planets; and many various types of mineral assemblages occur in meteorite collections. The meteorites are leftovers of both the primordial condensation, and thermal evolution of asteroidal sized bodies, all are fragments of planetary bodies of various sizes.

From the point of view of the meteorite classification three main belts can be recognized: *metal*, *silicate* and *ice* belts. To these belts correspond the iron, stony and icy meteorites. For the missing icy meteorites we suggested a search on Antarctica (**Bérczi** & **Lukács**, 1994a).

There are two intermediate types between these three types: the stony-irons and icy-stones. In some respects the icy-stones could be considered to be present in collections with the carbonaceous chondrites, which contain volatile elements and structural water in their minerals. Obviously ices landed on Earth's surface tend to evaporate before being collected.

According to the model, near the Sun one can find those planets which are composed of iron as core and refractory silicates as mantle and crust. This seems to be the case for **Mercury**.

Going outward one finds more and more FeS or FeO instead of metallic Fe in the core, and silicates of decreasing order in melting points as crust. This seems to be true for **Venus**, **Earth** and **Mars**.

According to the condensation theories the hydrated silicates were already abundant in the region of the proto-Mars.

Farther outwards one expects much structural water, and also water-ice precipitation. We know from carbonaceous chondrites that such materials are rather fragile. Farther out from the Sun water ice is solid and forms the main mineral component of the planetary assemblages. Since H_2O is expected to be the most abundant mineral, the planetary masses can be much bigger from the distance of water condensation. Then the protoplanet consisting of ice may serve as a secondary accumulation centre, thus it is capable of collecting great quantities of gases. Therefore this is the mineral belt where the biggest planets of the Solar System are expected. This region is just out of the distance of water-ice condensation.

Considering the timescale, it is in this icy belt that the first planet accumulation is expected to have occurred. This belt was just outer from the asteroid belt, and the forming **Jupiter's** gravitational perturbations contributed to the fragmentation in what is the asteroid belt existing even at present.

In the local system of the planet Jupiter the composition of the larger (Galilean) satellites of Jupiter, Io, Europa, Ganymedes and Callisto indicates that proto-Jupiter was a secondary centre of material differentiation. There the high-temperature inner belts are surrounded by the low-temperature condensation belts.

Still farther outwards the density of the fragmented matter is continually decreasing. Today the **Kuiper belt** is inhabited by comet-like asteroid-sized bodies. These smaller planets are composed mainly of various ices. In this second asteroidal belt the **Chiron** and the **Pluto-Charon** systems are representative.

SUMMARY

The main mineral components were deduced in a model of the solar nebula where chemical condensation occurred during the formation of the Sun. The mineral belt structure theory of the Solar System first determines the sequence of most abundant characteristic minerals. In the model the boundaries of these mineral phase change were intersected by the Cameron adiabat of the solar nebula. Intersections on the condensation T(p) curves gave the condensation temperatures of the respective minerals. The most characteristic fitting was "Mercury" which was found near to the iron point, the "Asteroid Belt" which was found between the serpentine and ice curves, and "Jupiter" which was found at the maximum accumulation of the water ice component.

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THE EARTH AS A PECULIAR PLANET
GEOSPHERES OF THE EARTH - "SOLID" AND "FLUID"

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(1) Peculiarities of the Planet Earth

According to **E. Szádeczky-Kardoss**, geonomical knowledge has four sources: observation, experimentation, direct comparison of the Earth with other celestial bodies, and theoretical research.

"Geonomy, summarizing the complex characteristics of the Earth, is not a chapter of Planetology or Cosmology, but, in accordance with its object and methodology, it synthesizes a particular group of disciplines, namely the Earth Sciences, into a higher unit, in search for the causes." **(E. Szádeczky-Kardoss** . Geonomy, 1974, p.6).

This corresponds perfectly to the definition of science given by **St.Thomas Aquinas:** "*Scientia est cognito rerum per causas.*"

"The most significant peculiarities of the Earth are:
1. *predominance of a poorly dissipating fluid phase (H_2O_{liquid}) in the outer fluid sphere;*
2. *highest average density, only slightly oscillating surface temperature, high free oxygen content of the atmosphere, and a complicated oxidation-reduction system;*
3. *formation of particularly OH-rich minerels (phyllosilicates) near the surface, a thick sedimentary cover;*
4. *development of a double lubrication system (argillaceous-serpentinitic materials near the surfce, volatile-rich melt in the depth), resulting in an extraordinary mobility of the outer zone of the planet's compact interior, characterized by specific rock formation, orogenies, and a Sialic continental crust;*
5. *as a result of the combined effects of all these, the most essential, decisive feature of the Earth has been developed: high-level Life, attaining the organization level of the Noosphere."* (ibid. p.17-18).

Referring to **Gy. Marx** (1971), **E. Szádeczky-Kardoss** assumed that "*this organization level of life may appear in each second Galaxy. On the other hand, one fixed star out of ten thousand has the probability to reach the level of life as it was on the Earth in the Cambrian (some 570 My ago)*" (ibid. p. 18)

Astronomers calculated that the number of fixed stars in our Galaxy is 2.10^{11}. Accordingly, a Cambrian-level biosphere may be present on 2.10^{7} (= twenty million) planets.

2. Geospheres of the Earth –"Solid" and Fluid

In the pertinent chapters of his work (**E. Szádeczky-Kardoss** 1974, A/2 and A/3) the well-known "shells" of the Earth are discussed: crust, upper and lower mantle, outer and inner core. Special attention is paid to the astenosphere, where the thermal convection currents are supposed to occur, producing the entire dynamics of plate tectonism.

The external fluid zone can be subdivided as follows (inwards): magnetosphere, atmosphere (ionosphere, mesosphere, stratosphere, troposphere) and the hydrosphere. Particular emphasis is laid on the life-protecting role of the "ozone shield." Since 1974, this problem has become much more dramatic.

Exceptional importance is attributed to the hydrosphere.

"The hydrosphere provides the solid materials, the chemical elements of our Earth with a peculiar chemical and mechanical mobility, which is absent or rather subordinate on other planets: element mobilization in the form of aqueous solutions. This represents a fine example of how can the conclusions deduced from a wealth of meteorological, hydrological and geographical data on one hand, and petrological, geochemical and geophysical data on the other, be checked and integrated in the framework of the global dynamics of the Earth. The multiple control extended to all disciplines of the geosciences, and other branches of science, provides the geonomical synthesis with a certainty, unambiguity and accuracy hitherto unknown in geology and in the other "historical sciences."" (ibid. p. 45)

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UPDATING THE TOPICS SOLAR ACTIVITY, MAGNETIC POLE REVERSALS AND TIDAL PHENOMENA

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1. Solar activity and its effects on the Earth

E. Szádeczky-Kardoss wrote: *"To study the multilateral, considerable effect of the activity of the Sun on the terrestrial processess...and on the living matter, including Man, is one of the high-priority tasks of modern science... In the stratification of some sedimentary rocks...solar activity induces an easily perceptible cyclicity that could be traced back in time to 2.10^9 years"* (Geonómia, p.48)

Almost all observations concerning the solar activity cycle in the Earth's history roughly correspond with the recent 11-year cycle. The only known exception is represented by the yearrings of **Pinuxylon tarnocziense,** a conifer from the Early Miocene, at Ipolytarnóc, Hungary (protected site). Namely it shows a cyclicity of 7 years. For the time being the causes responsible for this are unkown.

Quite a number of effects on terrestrial phenomena have been suggested: mean temperature, precipitation, biological and historical events, etc. Virtually all are still controversial. Reliable data indicate positive correlation, but statistics are either not sufficiently large or not homogeneous enough, and the mechanism is controversial.

2. Magnetic pole reversals

E. Szadeczky-Kardoss wrote: *"We have good reasons to assume that the initially higher hydrogen content of the outer fluid sphere of the Earth played a role in the origins of its iron core, reducing some part of the iron silicates of the solid rocks to metallic iron. With the development of the iron core, and in particular of its external liquid belt, could appear the magnetohydrodynamic effect which at present is held responsible for the phenomena of geomagnetism, and even for the come into being of the Earth's magnetosphere*" (Geonómia, p.46). *"The geomagnetic field affects the entire Earth. It creates the outmost sphere of the Earth, the magnetosphere, the remanent magnetism in the rocks of the Earth's crust, and the magnetism of the solution flowing in the astenosphere..."* (ibid., p. 50). *"The geomagnetic field, beside several periodic changes, probably has also been changing unidirectionally: backwards in time its intensity is found to be decreasing. The most important type of change is the reversal of the geomagnetic field, when the N and S magnetic poles interchange places. This...happens at irregular intervals, but according to the available evidence on the average about each 200.000 years.. In the past four million years occurred at least 20 such reversals, for the last time some 20 thousand years ago. We still do not know reliably the causes. Processes going on at the core / mantle boundary, exchange of matter may play a role in it."* (Ibid., p.51)—*"In the rocks after each reversal the remanent magnetism is graduually accumulating in accordance with the new position of the poles. Basalt is rich in iron. Geomagnetism during the crystallization of the oceanic crust of basaltic composition induces a new remanent magnetism of opposite orientation,. The magnetism developing in the rocks with parallel isolines but opposite polairty diminishes the intensity of the earth's magnetic field, and at last, beyond a certain limit, concurrently with other factors, may lead to a reversal."* --

The sequence of reversals has been established for the past few million years. The last full reversal occurred some 720.000 years ago. This is the Matuyama / Brunhes boundary. This seems to correspond with the Southern Pacific tectite field, i.e. with a major meteorite impact event. Some of the tectites are of unusual composition **(Li & Ouyang, 1991; Fáy & Lukács, 1997).**They are particularly enriched in magnesium (above the average of the mantle), while they are rather poor in iron, aluminium and calcium.
Since the mechanism of pole reversal has not been clarified yet, and the genesis of spherules is controversial. The same age of the pole reversal and of the Southern Pacific spherules may be, for the time being, nothing more than an intriguing coincidence.

Beside the Matuyama / Brunhes reversal a number of events are also known to have occurred during the past one million years, in terms of "aborted" (started but unaccomplished) reversals. Such are e.g.

Event	Date, ky BP	Duration, years
Jaramilo	900	100
Zone V.	350	40
Blake	140	10
Mungo	30	5
Laschamp	12	2

The causes are unknown. At any rate, the last, Laschamp-Gothenburg event coincides with the Würm III/Flandria transition, i.e. with the end of the last glacial (commonly called the end of the Ice Age), and according to some authors, with an anomaly preserved in the region of Hawaii.

As far as we know, the Würm III/Flandria transition might have been due to the quasiperiodic changes in the Earth's orbit and rotation axis inclination. Other factors also may have contributed.

E. Szádeczky-Kardoss wrote: "*The date of the next reversal can be predicted, although with a considerable marge of error, by extrapolating the present-day slow decrease of the magnetic intensity values to zero. On this basis the next reversal would occur in 2230 ± 20 years. (Malin and Clarke 1974).*". – "*There is remarkable correlation between the regional anomalies of the horizontal component of the geomagnetic field.. and the total ozone content of the atmosphere. These two are approximately coinciding. The atmospheric ozone concentration depends above all upon the temperature... Ozone derives from the partial decomposition of the atmospheric* O_2 *due to the UV components of solar radiation. The ozone content correlates with the heat centres occurring between 10 and 30 km above the Earth's surface. However, the ozone content is influenced also by the oxidation process related with the crystallization of basalt: some part of the oxygen molecules re-converted from ozone are used up. Thus the concentration decreases, showing a zone of minimum values bound to the most intensive ongoing volcanism, i.e. along the rifting lines of the mid-oceanic ridges.... In this way, complex interrelation may be suspected between the plate tectonic rifts of the global dynamism, the basaltic volcanism, and some atmospheric paremeters (temperature and ozone concentration). These may have changed concomitantly also during the past of the Earth*". (Op. cit.., p.54).

3. Tide friction, slow-down of the Earth's rotation

E. Szádeczky-Kardoss wrote: "*During the evolution of the Earth the most important changes of composition volume etc. may occur in the atmosphere of the planet. It is an important problem, which for the time being can not be unambiguously solved, how did this affect the speed of rotation and the orbiting time of the Earth. Theoretically, the... dilatational contraction would result in higher velocity of rotation, preserving the angular momentum. Due to the expansion of the Earth, flattening increases, but this is compensated by the tidal friction. Consequently, the speed of rotation of the Earth decreases, at an estimated annual rate of* $20.\ 10^{-15}$ *sec. Some palaeontological evidence (growth phenomena of Silurian corals) suggest that the orbiting time, i.e. the duration of terrestrial year, in the Silurian was about 400 days*" (Ibid., 54-55).

The dilatation (expansion) of the Earth, assumed by **E. Szádeczky-Kardoss**, has not been proved, but the tidal friction certainly has. The value given by him is still correct. It is interesting, however, that in historical times the process of deceleration has been disturbed. There is no explication available at present.Extrapolating the present decelration rate before cca. 1000 AD problems arise about historical exlipses (**newton, 1972, Fomenko, 1981),** and at the Peloponnesian War (431 BC) the historic dating would contradict to the astronomical one so much that Fomenko had to bring up the event until 1039 AD (!). Also, inclusion of the present rate to the dating of the "eclipse of King Sulgi" (**Gurzadyan, 2000**) would result in problems about the Middle Assyrian and Hittite King Lists. Until we understand this anomaly, it is better to take the standpoint that eclipse dating is still unstable before the Middle Ages; which is surprising indeed.

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ACCRETION OF THE PLANETARY BODIES IN THE SOLAR SYSTEM: THE "GRAVITATIONAL CLUMPING"

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All the Earth-type planets and the cores of the giant planets of the Solar System have been accreted from cold dust of the size of smoke particles. At the beginning of the accretion showers of fluffy, tiny clumps came into being by sticking as the particles, driven by the motion of the gas within the solar nebula, collided with small velocities. These clumps became more and more bulky and increasingly harder with the collisions of increasing relative velocities as those few, quickly growing, dominant planetary embryos perturbed their trajectories. The result of a hit was assembling (accretion) in the case of not too high relative velocities but destruction and mass loss in the case of too high relative velocities.

The Kepler motion, inherited from the rotation of the solar nebula, gave a rotation of simil ar direction to these growing planetesimals through the collisions.

The drag of the extensive atmosphere of the infant Sun decreased the size of the orbits of the bodies moving within it, consequently, they were spiraling inward and getting nearer to the Sun. When, however, somewhere a planetary embryo came into being they were locked by two-body resonance on an outer resonant orbit, and could not be broken further. That is why the larger planetary embryos on their outer resonant places assured on the one hand the larger density of planetesimals leading to collision, and on the other hand holding them on a similar orbit that made the collisions of small relative velocities possible. As a consequence, another planetary embryo has not only started to grow, but a quick growing of it was assisted. That is, planets starting from **Venus** and **Jupiter** came into being by gravitational clumping sequentially in a much shorter time interval than it was calculated earlier by the models without gas drag and without outer resonance. This resonant origin explains the **Titius Bode law**.

With the perfection of the **computer simulations** of the accretion process of the planetary bodies became possible for more and more points – as gravitationally attracting, extended bodies – and also taking into consideration their real orbit variations.

One can see from these simulations that independently of the initial conditions always several hundred planetary embryos are emerging on the territory of the Earth-type as well as of the giant planets, and to the end of the accretion period they are always accreting into 4-5 planets for example in the inner part of the planetary system. This means – and it is supported by the observations that a lot of giant craters are existing on the solid crusts of the planetary bodies – that at the end of the accretion period very many giant impacts took place. At that time the breaking into fragments and the disintegration became important, and the role of the chance was very significant. The resonant situation of the growing planetary system could have been substantially modified by the last largest collisions in particular, the consequence of which might be the deviation from the Titius Bode law. In the case of non-central collisions large obliquities might arise or it could slow down or speed up the spin of a body or even splash down a part of its crust (from which a satellite could have been accreted – see for example our **Moon**) or from the residual material a planet with a large core could be left behind (see for example **Mercury**).

The simulations also demonstrate that *during the accretion period ten times more material was ejected from the territory of the planetary system than that was accreted into the planets.* This can explain on the one hand the different distribution of comets in the nearest reservoir from the disk distribution. On the other hand it explains how the giant planets could drift away from their feeding zones as a reaction to this material ejection. **Jupiter** – for example – could get nearer to the Sun. This harmonizes with two observational facts. On the one hand many of the giant exoplanets are orbiting much nearer to their star, than it could have been expected on the basis of the earlier theory of our Solar System's origin. On the other hand the Galileo probe descending into the atmosphere of **Jupiter** measured 2-2.5 times higher inert-gas content than it could be expected, if **Jupiter** would have been accreted at the present distance from the Sun.

The resonant capture together with the gas drag theory is also advantageous, because shortens the core accretion period of the giant planets. By the running accretion these planets can collect large core-masses in shorter time periods, consequently they could accrete the surrounding gas by gravitational attraction before the solar wind and the radiation pressure would blow it out.

From the flattening disk of the solar nebula finally **the four terrestrial and the four giant planets** came into existence. The disk, however, came not to an abrupt end at 40 Astronomical Units – that is, at the **Neptune's** orbit – but continued with diminishing surface density, as it was postulated by **Edgeworth** and later by **Kuiper**.

There the density was not enough for the accretion of giant planets but several bodies with diameters over one thousand km-s and a large number of objects with diameters of several hundred km-s still could come into being (*Kuiper belt objects: KBO-s*). **Pluto** and **Triton** could belong to these bodies. Neptune could capture the former one for a resonant orbit, while the latter one became a Neptunian satellite.

In 1992 the perfection of the telescopes made the first discovery of a KBO possible (92QB1). Today – ten years later – the number of the discovered KBOs is over 400, that makes already statistical considerations possible. The result is that **Neptune** controls the inner part of the Kuiper belt in a similar manner as Jupiter does the asteroid belt. Consequently, the inner part of the Kuiper belt has a resonant structure and among the KBOs only those can remain on their orbits that are protected by a resonance with**Neptune**. Namely the perturbation of **Neptune** removes the other bodies from their orbits in a short time – like Jupiter removes the asteroids from the asteroid belt.

Among the newly discovered KBOs there are some orbiting on a 3:2 resonant orbit with **Neptune** – like **Pluto**. They are called *plutinos*. The ones that were thrown inward from the Kuiper belt into the territory of the giant planets are called *centaurs*, as the first one, discovered in 1977, was named after Chiron, a centaur. From the inward perturbed KBOs more could be captured by the giant planets, especially by the outer three. So the *outer smaller moons moving on irregular orbits*, originate very probably from the Kuiper belt. Some of the smaller bodies, however, expelled from the Kuiper belt inwards into the inner part of the planetary system, become *short-period comets* since the heating of the near-by Sun launches the release of their volatile material. From the larger objects of the Kuiper belt besides **Pluto** and **Triton** (the moon of **Neptune**) **Charon** (the moon of **Pluto**, discovered in 1978) could originate as well. The fact, however, that on the surface of **Charon** only water ice has been observed – to the contrary of Pluto, where methane ice was announced by the spectroscopic observations – raised the possibility, that similarly to the origin of our **Moon**, a giant impact gave birth also to **Charon**. At that large distance from the Sun, however, H_2O is already the "dry" material that builds **Charon**; while in the case of our **Moon** – being much nearer to the Sun – H_2O is the "volatile" material that disappeared as a consequence of the impact heat.

The increase of the spin rate of the contracting bodies caused – not only at the Sun but also in the case of the giant planets – the detachment of the equatorial belt of material that made the accretion of moon-systems in the vicinity of the giant planets possible. These moons are called *regular moons*. All the regular moon-systems show up a resonant structure, only the constant differs at the different planets. In the case of the Jupiter system one can even think that the infant-**Jupiter's** temperature had an effect on the composition of its forming moons (as their density is lower if they are orbiting further from **Jupiter**). This, however, can be the consequence of a later effect as well, as in the satellite systems the tidal heating suffered by the moons caused the loss of a part of the volatile material, and so the drying up of the moons. The two components have not been separated up till now.

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COMPARATIVE PLANETOLOGY

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The Solar System, like a real laboratory, offers the possibility to investigate the planetary bodies under different conditions. Mercury has a magnetic field but no atmosphere, Venus has no magnetic field but has a thick atmosphere, the Earth has both of them, Mars has neither of them. The Table, containing 26 planetary bodies of diameter larger than about 400 km and having a solid crust, represents this "virtual laboratory".

1. THE THERMAL HISTORY OF A PLANETARY BODY

1.1. Heating and cooling of planetary bodies

Planetary bodies being accreted from cold dust particles are *heated by the thermalisation of the kinetic energy* as they impacted each other. The temperature reached depends on the fact how rapid the accretion was. If it was fast then there was no time to radiate away the heat generated by the previous impact. That is why the heat reserve of a planetary body is strongly dependent on the circumstances: the frequency of impacts, the number, mass and the impact direction of the impactors during this time period. The result was influenced mostly by the latest large impacts during the last intensive bombardments.

After the decline of the accretion process the planetary bodies were *heated mostly by the decay of the radioactive elements*, proportional to their silicate content. Consequently, in case of the icy moons of the giant planets a spherical shape is expected only over diameter of 2000 km. But, on the contrary, the observations reveal that all but one satellite (**Hyperion**) of diameter over 400 km have a spherical form and even several surfaces preserved traces of geological activity. The explanation of this surprising phenomenon may be the **tidal heating** because of the resonant structure of the satellite systems of the giant planets. So if the maximal heating was not enough for melting, an irregular shape remained; if it was just enough, a spherical shape came into being; if it was more than enough, then in addition to making the shape spherical, traces of geological activity are visible on the surface.

The *heat can flow out* from the planet's interior mainly by conduction or by material flow. The material flow can either be mantle convection or volcanism (material outflow through the crust). This latter – since it brings hot matter directly to the surface – is able to cool very effectively.

The *surface* can transfer the heat with radiation and – in the case of liquidosphere or atmosphere – with conduction as well. Cooling is faster on a smaller body, because of its larger surface-to-volume ratio. Therefore the crust of smaller bodies becomes thicker in a shorter time period, which at a critical thickness stops the volcanism and the tectonic movements as well.

The *liquidosphere* looses its heat by conduction, by circulation, by radiation and by evaporation. The *atmosphere* transfers the heat to space by radiation and by particle escape. If some atmospheric constituents absorb in the infrared, then *greenhouse effect* is working in the atmosphere that will slow down the cooling by retaining a part of the heat radiated by the surface. A solid state greenhouse effect may also exist as it has been suggested in connection with the nitrogen ice on the surface of **Triton** and probably with CO_2 ice on the surface of **Mars**.

Heating causes generally *expansion*, *cooling* generally *contraction*, *except the special case of water* which is densest at 4°C. So the freezing of the interior of a certain body containing a large amount of water can produce long fracture of the crust encircling almost their whole surface e.g. the valley on **Tethys**, on **Titania** and on **Ariel** respectively. *Phase transitions* can cause expansion or contraction as well depending on the crystallisation process, which may cause either increase or decrease of the volume.

1.2. How is a planetary body working?

If a planetary body is molten then an inhomogenity in its temperature and/or composition may initiate **convection** in its core, mantle, liquidosphere and atmosphere. The convection in the core and/or in the mantle can produce a **magnetic field** by dynamo action. We attribute the existence of the magnetic field on **Mercury**, on the **Earth**, on **Ganymede**, on the **proto-Moon** and on the **proto-Mars** to their molten iron core. In the case of Jupiter and Saturn mostly the metallic hydrogen mantle, in the case of **Uranus** and **Neptune** mostly the metallic behaviour of the water mantle is responsible for the magnetic field. The consequences of mantle circulation on crusty planetary bodies are **volcanism and tectonism**. The consequences of the circulation in the liquidosphere and/or in the atmosphere are the redistribution of energy (and the erosion on the surface). In the terrestrial oceans we can mention the Broecker conveyor – constituent of which are the Gulf and Humbold streams. In the atmosphere global wind-systems arise, precipitation starts and the electrostatic conditions can change (lightning, recombination etc.)

2. THE CRUST

2.1. Three kinds of crust may exist on planetary bodies.

1.) The quick accretion produced a magma ocean that made the differentiation possible (the heavier elements could sink down). Because of the differentiation, as the bodies were cooling, the first formed crystals of the lightest material were floating on the surface of the magma ocean: this first crust is called the ***primordial crust***. If circulation was initiated in the mantle because of temperature or density inhomogenities, then these light crystals were carried together by the circulation and were collected.

THE SOLAR SYSTEM AS A LABORATORY

		DOES EXIST?					
The name of the planetary body	**Diameter (km)**	**proper magnetic field**	**atmosphere**	**surface pressure (atm)**	**liquidosphere**	**polar cap**	**continent**
Earth	12756	yes	yes, (N_2,O_2,H_2O)	1	yes, H_2O	yes, H_2O	yes
Venus	12104	no	yes, very dense (CO_2)	90	no	no	yes
Mars	6787	is? was?	yes, thin (CO_2)	10^{-3}	was, H_2O	yes, H_2O, CO_2	?
Ganymede	5276	yes	very thin (O_2)	10^{-11}	under icecrust H_2O	whole surface H_2O	
Titan	5150	?	yes,dense(N_2,Ar,CH_4)	1,6	may be, hydrocarbon	?	
Mercury	4878	yes	very thin(He,H,O,Na,K)	10^{-15}	no	yes, only in craters H_2O	
Callisto	4820	no	no		under icecrust H_2O	whole surface H_2O	
Io	3632	?	yes, patchy very thin (SO_2,S,Na)	$<<10^{-9}$	no	no	
Moon	3476	was	yes, very thin (Ne,Ar,Na,K)	10^{-12}	no	yes, only in craters H_2O	?
Europa	3138	?	yes, very thin, (O_2)	$2,5 \times 10^{-11}$	yes, under icecrust H_2O	whole surface H_2O	
Triton	2705		yes, thin(N_2,CH_4)	$1,4 \times 10^{-5}$	?, N_2	yes, N_2	
Pluto	2302		now yes thin (N_2,CO,CH_4,Ar)	5×10^{-5}		yes, N_2	
Titania	1610					whole surface H_2O	
Oberon	1550					whole surface H_2O	
Rhea	1530					whole surface H_2O	
Japetus	1460					?	
Umbriel	1190					?	
Charon	1186					whole surface H_2O	
Ariel	1160					whole surface H_2O	
Dione	1120					whole surface H_2O	
Tethys	1060					whole surface H_2O	
Enceladus	502					whole surface H_2O	
Miranda	484					whole surface H_2O	
Proteus	416					whole surface H_2O	
Hyperion	410					whole surface H_2O	
Mimas	394					whole surface H_2O	

Consequently on some places of the body crust pieces were piling up and the crust became thicker. On the basis of the Archimedean rule of floating this crust was floating on the magma underneath, that is, it was isostatically compensated. If the circulation of the mantle had a one-cell circulation then the collected pieces of the crust were concentrated on one side of the planetary body (as in the case of the **Moon** and **Mars**). In such cases the centre of the shape strongly differs from the centre of mass (this difference is 1,6 km at the **Moon** and 3 km in the case of **Mars**). If the mantle had not a one-cell circulation, then this offset is much smaller.

2.) When all of the light crystals were carried away by mantle circulation from the site of the upwelling, and the remaining part of the melt was crystallised, then a ***secondary crust*** came into being. Such a secondary crust could arise also when the melt from the mantle is uplifted by volcanic activity either on top of, or into the lows of the primordial crust. This happened in case of the "mare regions" on the **Moon**.

3.) If, however, **plate tectonism** is in action on a planetary body, then in subduction zones the secondary crust can carry with itself some broken pieces of the primordial crust as well as the sediment formed from the primordial crust by atmospheric (eolian) or fluidal erosion. This mixed primordial and secondary crust material will be worked into the mantle and a new crust material is formed which is called ***tertiary crust.*** It is a necessary condition for the formation of a tertiary crust that plate tectonism should act continuously through several cycles. According to our present knowledge such tertiary crust exists only on our **Earth**.

2.2. Impact craters

The accretion of planetary bodies happened by a series of impacts. As the bodies became larger and larger, the consequences of these impacts became more and more catastrophic. Impact energy was converted into heat, acoustic energy and into shock wave energy, that ground the surface material down to dust (see the Tunguz event on **Earth** and many cases on **Venus**).

Space probes proved that *impact craters are the most common surface feature on planetary bodies.* Although they originated everywhere by the same procedure and the mechanism of their origin is well known, nevertheless, surprisingly, they have different appearances on different planetary bodies. The result of the impact can be changed considerably by the properties of the impacting as well as of the target bodies.

As regards the *impacting body* the impact velocity is a decisive factor. An impactor coming from a heliocentric orbit will create a larger crater (giant, double wall crater or multiring basin) than coming from a planetocentric orbit. The shape of an impact crater depends on the impact angle. A central impact creates a ring like crater with a ring-like ejecta blanket (or the target body might be completely destroyed). In the case of a highly inclined trajectory the result will be an impact crater of elliptic shape, and/or a "butterfly"-shaped ejecta blanket (or the outer part of the target body will be splashed down). The jet stream, which is the result of the sudden evaporation of the surface matter, can pick up stones from the surface and accelerate them to escape velocity (see meteorites on the **Earth's** surface coming from **Moon** and **Mars**).

Non-central giant impacts can splash the crust down (in the case of **Earth**, **Mercury**, **Pluto**). In such a case a moon can or cannot be the result of the accumulation of the condensed material placed into orbit around the target body (in the case of **Moon** or **Charon**). If the non-central impact is in the equatorial plane of the target body then its rotation rate, if out of the equatorial plane then its rotation rate and its orbital obliquity will change.

As regards the *target body* there are several factors that can change the shape of an impact crater. On smaller bodies the wall and also the central peak can be higher. On bodies of softer material no central peak will occur, and/or the mountains of multiring basins may relax and sink into the crust leaving only an albedo pattern at the place (like Valhalla on **Callisto**). On frozen bodies with thicker crusts there is no possibility for relaxation (see *Herschel crater* on **Mimas** versus *Odysseus crater* on **Tethys**). If the crust of the target body has more than one layer and if the impact is deep enough, than a halo or a ray system with a different albedo might indicate the ejected material.

If the crust of the target body contains a lot of volatile material then a lobate crater will arise (see **Mars**). Even a "negative" crater can come into being in such cases, if the environment was flooded by harder material (lava flow or sediment) and later the ring mountain of the impact was eroded (see **Mars**). In the case of a very dense atmosphere of the target body there are no small craters at all, because the smaller incoming bodies are burned in the atmosphere (cut off limit at about 3 km on **Venus**). Even larger incoming bodies are exploding before reaching the surface and they impact simultaneously (craters with diameters smaller than 10-20 km on **Venus**). In some cases the explosion of larger impactors already at high altitudes in the dense atmosphere can produce a shock wave which reaching the surface is grinding the soil down to dust. The result will be a large *"radar-dark" region* of several crater diameters around the impact crater, or in the case of a total explosion of the impacting body only a "radar dark" region remains without a crater. In case of an oblique impact the ejecta blanket becomes asymmetric because of the turbulent motion of the dense atmosphere, which does not allow the spreading of the debris into the direction of the arrival. The form of the ejecta blanket is similar to a petal because the form of the ejecta blanket is a map of the turbulent mushroom cloud itself. The ejecta blanket may be larger than expected, because the turbulent motion of the hot air may pick up dust particles and bring them further away.

What are the consequences of an impact? The impact crater is a scar which can be seen in large numbers on every crusty planetary body. Sometimes traces of ancient giant impacts can be inferred only by the surface topography (South Pole - Aitken and other basins on the **Moon**) because they are overwritten by many new, smaller craters. An impact can be also the centre of a fracture system or volcanic activity. At the antipode of a large impact the crust can be fractured because of focusing the seismic waves (see Caloris antipode on **Mercury**). After a non-central impact a relatively larger core may remain (in the case of the**proto-Mercury**), or a big moon (the cases of **Earth** and **Pluto**), or some gravitational anomaly in connection with mascons (when the denser mantle material intrudes into the place of the rebound crust, like in the case of the**Moon**). As another consequence of the impact an atmosphere may be blown off, as for example in the case of the *Argyre basin* impact on **Mars**.

The material of the impactors can be implanted into the crust and/or into the atmosphere: the material of cometary nuclei and/or of asteroids are contributing to the volatile content of Earth-like planets. For example the water of the oceans of the **Earth** may have arrived in such a way. The disintegrated material of the impactor can be spread throughout the atmosphere by winds, causing the so called *"nuclear winter"* phenomenon.

2.3. What kinds of deformation are caused by the different processes on a crusty planetary body and where it was observed in the Solar System?

On the most passive planetary bodies there is *no trace of any geological activity,* surface changes occuring only as a consequence of impacts. All the satellites smaller than about 400 km and **Callisto** belong to this category.

Cracks in the crust can take their origin from curvature changes because of tidal deformation (see the lineament system on **Europa**) or because of dome formation over upwellings of the mantle (see the East-African *Great Rift Valley* on **Earth**, or the radial fracture systems of the *coronae* on **Venus**). Traces of expansion, like valleys of global dimension, can be formed by heating of the whole body, or because of the total freeze of the whole body containing large amount of H_2O (see **Tethys, Titania, Ariel, Dione**?). *Global thrust-fault systems* can develop because of outdrying and contraction of the core (see **Mercury**).

More active is a planetary body if traces of *differentiation* can be seen on its surface in the form of rays or halo around the impact craters (see **Mercury, Moon, Ganymede, Callisto, Ariel, Titania, Oberon**) or in the form of mare (like on the **Moon**, on **Europa** and on **Triton**) or as other kinds of volcanic outflow (volcanic plane: **Venus, Io, Ganymede**; volcanic edifice: **Mars, Venus, Earth**). A linear albedo pattern connected to fracture system also refers to differentiation (see the light and dark lineaments on **Europa**).

Global fracture systems or traces of dilatation at one place and traces of compression on others refers to *circulation within the mantle* (only polygonal features of the ancient crust: see on **Umbriel**; fracture system: see on **Ganymede**, on **Ariel**, on **Triton**; rift valley network connected with plate tectonics: see on **Earth**; traces of local dilatation: see on **Enceladus** and the weakness zone between *Beta* and *Artemis Chasma* on **Venus**, *Valles Marineris* on **Mars**; the traces of local compression: see ovoids on **Miranda**, the *Freya*, *Akna*, *Danu* and *Maxwell* chain mountains around *Lakshmi Planum* on **Venus** and chain mountains on **Earth**. Bending occurs also on **Europa**, but it relaxes and does not remain as mountains for a long time).

Local ridge-groove systems can arise from local heating (see **Enceladus**). The raising up of crust material is considered as a trace of local compression: for example lift off of rigid blocks of crust (see *Tibet* on **Earth**, *Lakshmi Planum* on **Venus** or the lifting off on **Miranda**). Compression can arise when crust material is slipping down along the slope of a mountain or dome (see circular ridges around the *giant volcanoes* on **Mars**, or the *annuli* around *coronae* on **Venus**). The gravitational slipping down can also play a role in the origin of *tesserae* on **Venus**.

We may speak about *subduction zones* if a piece of crust is moved below another, down into the astenosphere (see *deep oceanic trenches* on **Earth**, certain *corona arches* or *chasms* on **Venus**, the half craters on **Ganymede** and **Enceladus**?).

Plateau is defined as a piece of crust that has been thickened by volcanism above an upwelling of the mantle. After leaving off its hot spot the piece of crust becomes an isostatically compensated mini-continent (see *Ovda*, *Alpha*, *Thetis*, *Tellus* on **Venus** and *Iceland* on **Earth**). A *continent* is a thickened piece of crust that was carried together and accreted by mantle circulation, and is isostatically compensated. It shows no gravity anomaly since continents have their "roots" extending downwards into the mantle as well (see continents on **Earth**, *Ishtar Terra* on **Venus** and a piece of crust north from *Korolev crater* on the **Moon**).

Global rigid-plate tectonism exists only on **Earth**, where the oceanic crust is rigid enough to transfer the tension from the spreading centres (at mid-oceanic ridges) to great distances, i.e. to the deep oceanic trenches, meanwhile it deforms only at the plate edges. On **Venus** some kind of soft-plate tectonics may be at work, where the plates are plastic, therefore they deform in a diffuse manner everywhere inside the plate, like the continental crust on **Earth**, but they are not rigid enough to transfer the tension to great distances.

Impacts can alter every kind of deformation.

2. 4 Volcanism

The feature on the crust is called *volcano* when molten material is flowing out from the interior of a planetary body to the surface. There is observational evidence that volcanic activity *was* going on on **Venus**, on **Mars**, on the **Moon**, on **Ganymede**, on **Ariel** and on **Europa**, and *is* going on on **Earth**, on **Io** and on **Triton**. We are speaking about a *geyser* when such a component is flowing out from the interior which is considered volatile at the surface temperature of that planetary body (water on **Earth**, sulphur and sulphur dioxid on **Io**, nitrogen on **Triton**, water on **Europa** ? and water on **Enceladus**?).

The volcanic outflow can take its origin from a *hot spot volcanism* (see *Hawaii volcanoes* on **Earth**, giant volcanoes on **Mars**, coronae and volcanic edifices on **Venus**, volcanoes on **Io**), or by *volcanism along fractures* (mid-oceanic ridges on **Earth**, fractures on **Europa**, **Ganymede**, **Ariel**, **Triton**) and also by *explosive volcanism* at the subduction zones where the intruded an melted volatile material causes the explosion (only on **Earth** in connection with deep oceanic trenches).

The *material of the lava* is molten material of the mantle or molten material of the crust. It is silicate on **Mercury**, on **Venus**, on **Earth**, on the **Moon** and on **Mars** and partly on **Io**, but mostly sulphur or sulphur dioxide on **Io**, water on **Europa**, ice on **Ariel** and nitrogen on **Triton**. The very high (1600-1700 K) temperature of some lavas on **Io** reveals that a magma ocean exists under the crust even today. The Venusian lava was extremely fluid, very probably because of its high salt content. Several hundred or even several thousand km long and similarly broad valleys were carved out. The lava is also very fluid on the satellites of **Jupiter** and **Saturn**, where its composition is mainly a mixture of water and ammonia. On the satellites of **Uranus** and **Neptune**, however, some methanol is mixed to the water and ammonia, therefore the lava becomes more viscous there.

In the case of fluid lava *maria* arise, when the *low viscosity lava* fills the low lying parts of the surface (**Moon**, **Europa**, **Triton**). In the case of *dense lava flows* the flow fronts are characterised by rims (see the **Earth**, **Venus**, **Mars** and the satellites of **Uranus** and **Neptune**). In the case of *repeated outflow* volcanic edifice is constructed (**Mars**, **Venus**, **Earth**). The existence of *Olympus Mons*, the largest volcano in the Solar System (its height is 25 km, the diameter of its base is 600 km) hints at the following conclusions: (1) the Martian crust has to be very thick if it can support such a big construction, (2) the volcanism on **Mars** was active for a long time, (3) there is no plate tectonism transporting the plates which could have produced a series of islands instead of one big edifice.

The *height of volcanic eruptions* depends on many aspects. It is increasing with the outflow velocity through the chimney, it decreases with surface gravity and also with the pressure of the atmosphere or liquidosphere. So it is understandable that, because of the lack of an atmosphere/liquidosphere on **Io**, the eruptions of the volcanic material can reach 800 km height.

The volcanic activity is connected with *resurfacing*. The lack of giant craters on a planetary body means that resurfacing has to happen after the large bombardment (see **Ariel**, **Titania**). On **Venus** a huge quantity of viscous lava has filled up all lows of the surface, as a consequence, 65% of the surface is covered by rolling planes. The surface of **Venus** is very young. The very few impact craters (about 800) are distributed uniformly on the whole surface indicating that the volcanic flood very probably happened at the same time on the whole surface by overturn of the crust. The bulk of the surface of **Io** consists also of volcanic planes, regenerated locally on a time scale of 10 years. All maria on the **Moon** are basaltic plains, which have been filled similarly. But a similar type of mare exists also on **Triton** (filled by nitrogen) and on **Europa** (filled by water).

The role of volcanism is very important in supplying atmospheres by the emission of volatiles. The volatile recycling between the mantle and the atmosphere is guaranteed, however, only in the case of a working plate tectonism (as far as we know it, it is only on the **Earth**).

3. VOLATILES

3.1. The *volatile content* came into the planetary bodies absorbed on the dust particles. Computer simulations indicate that in the inner part of the Solar System the too high temperature prevented the incorporation of volatiles with dust particles into planetary bodies, therefore only later cometary nuclei and asteroids (containing 20 – 30% H_2O) could transport water from the outer part of the planetary system to them. Giant planets later, during their accretion, when their core was large enough, could accumulate by gravitational attraction some of the surrounding gas as well.

3.2. Atmospheres

The first atmospheres are called *primordial atmospheres.* On the one hand, the first atmospheres of the crusty planetary bodies came into being after the accumulation period by outgassing of the impact heated bodies.

All these atmospheres, however, were blown off by giant impacts because of the small escape velocities. On the other hand, the atmospheres of the giant planets, because of the large escape velocities, remain during the whole lifetime of the Solar System. So the giant planets all have primordial atmospheres.

The *secondary atmospheres* also originated by outgassing of solid crusts. This process has been accelerated by volcanism, if it was working on a planet. The volatile content of the impacting bodies, as well as the implanted atoms from the solar wind, became part of the atmosphere of the target planet. The solar wind component is negligible in the case of large mass atmospheres, but is essential if the atmosphere is thin (e.g. 98% of the atmosphere of **Mercury** is helium, originating from the solar wind).

In connection with **Io** and **Mercury** we have coined a new name: *patchy atmosphere*. We are using this name when an atmosphere is not covering the whole planet, but only local atmospheric patches are arising for short time periods. On **Mercury** this happens above the "hot poles", on **Io** above active volcanoes. In the latter case a gas cloud exists for 15 – 20 hours before Jupiter picks it up.

An *atmosphere can disappear* in several ways. A large impact can blow it off suddenly. Slow escape is possible due to heat motion. Since this mechanism is making a difference between isotopes, one can estimate for example how many water disappeared from a planet. Solar wind erosion can contribute also to the disappearance of the atmosphere of a planetary body without a magnetosphere. If, however, a magnetosphere exists in the vicinity of a planetary body, either its own or that of its planet nearby, then it can divert solar wind particles.

In the case of a proper magnetosphere, its electric field can accelerate ions over the escape velocity, i.e. the planetary atmosphere loses a part of its gas-content by polar wind. After neutralisation even quick ions transformed into *energetic neutral atoms* (ENA) can escape, if the direction of their velocity vector points away from the planet. Part of the atmosphere can also freeze out to the surface, or can precipitate into the polar caps (see **Earth**, **Mars**, **Triton**, **Pluto**, **Mercury**, **Moon**) or into glaciers (we know only terrestrial examples) or into the regolith with the dust during dust storms (see **Mars**). Some constituents of the atmosphere may become bound into the soil: the released oxygen can oxidize, the CO_2 can bound into carbonates in the presence of water, the H_2O can bound into hydrated silicates (**Earth, Mars, asteroids**) or can compose clathrates with CO_2, NH_3, CH_4, N_2 or Ar on the low temperature of the icy moons.

If on a planetary body there is no constituent absorbing the ultraviolet radiation of the Sun – like the ozone on **Earth** – there the UV radiation gets down to the surface (as for example on **Mars**), and immediately dissociates the subliming H_2O. The hydrogen migrates up into the hydrogen corona and escapes, the oxygen either oxidizes or accumulates in the atmosphere.

To *retrieve* some component of the atmosphere it is necessary to have a specific temperature interval for rain, dew (sulphuric or hydrochloric acid on **Venus**, water or acid rain on **Earth**), or for snow/frost (H_2O snow/frost on **Earth**, H_2O frost and CO_2 frost on **Mars**, sulphur or SO_2 frost on **Io**, CH_4 rain or hydrocarbon aerosols on **Titan**, nitrogen and methane frost on **Triton**). *Recycling* is possible between the atmosphere and the reservoirs (polar caps, glaciers, ocean, regolith) when the temperature changes make it possible (**Earth**, **Mars**, **Titan**, **Triton**), as well as between the mantle and the atmosphere, if the plate tectonism is active on a planetary body (only on **Earth**).

Among the moons only **Titan** has a dense atmosphere in spite of the fact that the Galilean moons have about the same dimension. The reason may be fourfold. **Titan** has a large enough mass with a high enough escape velocity to retain its atmosphere and it is cold enough, that the molecules are moving with smaller heat motion, so only a few can reach the escape velocity. Since also **Saturn** has smaller mass and weaker magnetic field than **Jupiter**, it picks up less of the molecules of the satellite's atmosphere.

3.3. Neutral and ionised components

Neutral atmospheres

The density of an atmosphere decreases exponentially with height. The distance, on which a component decreases by a factor of *e*, is inversely proportional to the molecular weight. Consequently, a constituent of larger molecular weight will decrease with height at smaller altitude than the light ones, and so a layered atmosphere will appear over a given height, where the mixing is not strong enough (*heterosphere*). Under this given height is the *homosphere*, where the free path is small, the molecules collide frequently, and so here the atmosphere is well mixed. The molecular weight in the layers in the heterosphere is decreasing with height, so in every atmospheres the external layer is dominated by the lightest element, the hydrogen: this is the *hydrogen corona*. That height, over which the free path of the atmospheric constituents is large enough to escape is called *exobase*. The part of the atmosphere over the exobase is the exosphere. In very thin atmospheres the *exosphere* can reach the surface (**Europa, Ganymede, Io, Mercury, Moon**).

The *atmospheres rotate* together with the planetary bodies, but not rigidly. If the atmosphere rotates slower or faster, then it as a zonal wind may be observed on the surface. We speak about *superrotation*, if the atmosphere rotates faster than the surface (superrotation of Venus is very strong, 4 versus 243 days). The atmospheres of the giant planets and the Sun rotate slower with increasing latitude: this phenomenon is called *differential rotation*.

Heating of the atmospheres.

The atmospheres receive heat from inside (from the interior of the planetary body) and from outside (electromagnetic and corpuscular radiation from the Sun). The angular distribution of the internal heating is uniform, but that of the external heating is asymmetric. The heating of the electromagnetic radiation from the Sun has a maximum at the subsolar point, while the corpuscular heating is maximal around the magnetic poles. (This heating is particularly strong during geomagnetic storms. If there is no proper magnetic field, the corpuscular radiation can heat anywhere (**Venus**).

The *heating medium* is generally the surface material or the dust in the atmosphere (strong on **Mars** at the time of dust storms). The surface heats the neighbouring atmosphere, consequently, the temperature of the atmosphere will decrease with height (*troposphere*). The other heating medium in an atmosphere is called the *thermosphere*. This is the upper part of the atmosphere, where the ultraviolet and the extreme ultraviolet radiation is absorbed and cause the dissociation of the molecules, the consequence of which is the increasing of the temperature. But the temperature increases only until a certain limit (*exospheric temperature*) because from here the fastest molecules can already escape.

If an intermediate heating medium is present (like ozone on **Earth**) then the rate of the temperature decrease will change, on **Earth** it becomes even increasing (*stratosphere*). Not every planetary atmosphere has a stratosphere.

If any of the atmospheric constituents absorbs in infrared, then the infrared part of the heated surface will be captured (*greenhouse effect;* very strong on **Venus**).

Diurnal temperature changes

In the case of electromagnetic radiation the maximal heating is at the subsolar point. Depending on the heat capacity of the surface material the maximum of the atmospheric temperature will have a delay with respect to the local noon. Because of the increased temperature the air expands, that is, the iso-temperature surface will have a bulge. Because of the increased pressure on the place of maximal heating winds will arise into all directions. This winds will be deviated by the Coriolis force on a rotating planetary body. By these winds, interacting with the rotation of the atmosphere, circulation cells (temperature zones) will arise. The faster a planet rotates the more circulation cells come into being along the latitudinal circles (**Venus** has one, **Jupiter** about eight, **Saturn** more than twenty zones). In the case of a proper magnetic field this regular zonal flow will be disturbed by the heat coming in in the vicinity of the magnetic poles during magnetospheric storms.

Seasonal changes

If the *spin axis* of a planetary body is not normal to the orbital plane, then the latitude of the *place of the maximal heating* will change during the orbital motion (during the "year" of that body). The heating will change accordingly on a moon of such a planet because the moons are moving in their planet's equatorial plane. If the moon of such a planet is moving on an oblique orbit, then combination of the two obliquities results in a very complicated seasonal change (see **Triton**). If the orbit of a planet is *eccentric*, then the *intensity of the heating* is changing along the orbit (during the "year" of that planet). The heating will change accordingly on a moon of such a planet. The obliquity is larger than 20° at the case of the **Earth**, **Mars**, **Saturn**, **Uranus**, **Neptune** and **Pluto**. The eccentricity is larger than 0,09 at**Mercury**, **Mars** and **Pluto**. On **Mars** because of the obliquity of the spin axis and the large eccentricity the seasonal changes are quite complicated.

Ionospheres

The ultraviolet radiation of the Sun will ionise every gas near by, even in the outer part of the planetary atmospheres. In the denser part of the atmospheres the ions colliding recombinate, but where the free path is longer, the movement of the ionised component is divided, depending on their charge. They can be accelerated by the electric fields of the magnetosphere. As they gyrate around the magnetic field lines, they can reach larger height around the magnetic equator, and fill a belt-like zone, the *plasmasphere*. Depending on the ionisation of the different constituents of the atmosphere different ionospheric layers can arise (D, E, F layers on **Earth**).

3. 4. Liquidospheres

If on the surface of a planetary body the atmospheric temperature and pressure falls in such a range that one or more components of the volatile inventory can remain in fluid state, then a "liquidosphere" (on **Earth** hydrosphere) will arise on the surface. To liquidosphere *rivers, lakes, inland seas* and *ocean* are classed. Traces of flowing water are present on **Earth** and on **Mars**, at present continuously fluid water is only on the surface of the **Earth**. Global ocean is only on **Europa** (closed with a thin ice crust to space). Non-global ocean exists on **Earth** (water) and probably on **Titan** (hydrocarbons).

3. 5. Ice spheres

Global ice crust is present on **Europa**.

Polar caps exist if volatile material is transported by atmospheric motion, and it precipitates on the cooler parts of a planetary body (**Earth**: H_2O, **Mars**: H_2O and CO_2, **Triton**: N_2, **Pluto**: N_2). On airless body outgassing volatile material or impacting cometary volatile material covers the surface and in permanent shadows can remain for a longer time (**Moon** and **Mercury**).
The condition of strong seasonal changes is the existence of icy and non-icy regions on the surface of a planetary body.

Glaciers

We are speaking about glaciers if solid precipitation accumulates and changes its position by rigid flow. We know glaciers up till now only on **Earth**.

Ice bounded in regolith

On **Mars** after dust storms the atmospheric H_2O aggregates on the dust particles and will settle together with the dust. This is a larger H_2O reservoir on **Mars** than the polar caps. Its capacity is changing with the variation of the orbital elements of **Mars** on a timescale of 100 thousand years.

4. MAGNETIC FIELDS, MAGNETOSPHERES

4.1. **The magnetic field** around a planetary body can be caused by an intrinsic magnetic field, by an induced magnetic field or by a frozen-in magnetic field. The measured magnetic field will be the resultant of all of them.

In case of an *intrinsic magnetic field* the circulation of an inner molten and electrically conducting material produces the magnetic field by dynamo mechanism. If the dynamo is operated by an axisymmetric circulation in the core then the dipol term will dominate, the centre of which coincides with the centre of mass, its axis with the rotation axis of the body (**Saturn**). If the circulation is not symmetric then an obliquity of the magnetic axis will arise (**Earth, Mercury, Jupiter, Ganymede**) and/or the higher terms are important (**Jupiter**). If, however, the source of the magnetic field is the circulation of the mantle then the offset of the centre and the obliquity of the axis will be even larger (**Uranus, Neptune**).

In case of an *induced magnetic field* the planetary body ought to have a global, electrically conducting layer *and* a changing (in strength and/or in direction) magnetic field in the vicinity. For example in response to changes in the interplanetary magnetic field the ionospheric electric currents vary in the **Earth's** atmosphere; in response to **Jupiter's** magnetic field differences in the changing actual position of its moons, induced magnetic fields will arise in them (in the **Jupiter** system it was proven already in **Europa**, **Callisto** and **Ganymede**, but surely it exists in **Io** as well). While in case of an intrinsic magnetic field the magnetic axis is more or less fixed to the planetary body as long as the circulation remains unchanged, in case of an induced magnetic field the direction of the magnetic axis is changing together with the change of the driving magnetic field.

Frozen in magnetic field will arise when molten ferromagnetic material cools below the Curie point in the presence of any magnetic field (**Moon, Mars,** surface layers on **Earth**, asteroids **Gaspra** and **Ida**).

4.2. Magnetospheres

The magnetic field of a planetary body will be compressed into a drop-shaped space by the surrounding magnetic field (by the magnetic field of the solar wind in the case of planets, or by the planet's magnetic field in the case of a moon; until now we know that out of the moons only **Ganymede** has an own, intrinsic magnetic field). So the magnetic field lines of the planet will be deformed: they will be compressed from the direction of the Sun and will lengthen on the anti-sunward side (*tail of the magnetosphere*). The magnetic tail of a moon will point to the forward direction of its motion, because the magnetic field lines of the planet will overtake the moon as the planet's magnetosphere is corotating with the planet itself and is moving faster at the distance of the moon than the Kepler motion.

The *dimension of a magnetosphere* depends on the strength of the planet's magnetic dipol moment and on the dynamical compression of the solar wind (velocity times number density). As the solar wind is highly variable the dimension of a planet's magnetosphere is changing accordingly (between 40-100 Jupiter-radii in the case of **Jupiter** in the sunward direction).

A magnetosphere can protect the atmosphere of a "resident" planetary body from the solar wind erosion. So the planet's magnetosphere protects the moon's atmosphere as well, if the moon is orbiting inside the planet's magnetosphere (giant planet's regular moons) but at the same time the moon is exposed to the magnetospheric erosion of the planet. In lack of a magnetosphere there is no protection against the solar wind erosion; in such cases the atmospheres extend further in the anti-sunward direction (tails of comets, **Venus, Moon**).

The structure of the magnetospheres. The field lines near to the planet remain *closed* but will be compressed and deformed. At low and mid-latitudes, at the footprints of the field lines, the fast ions of the ionosphere can reach larger heights along the field lines: the torus-like space populated by them is called *plasmasphere*. Particles of certain energy populate certain beams of field lines: these are called *radiation belts* (Van Allen belts around the **Earth**).

The field lines that are further from the planet are *open* because of merging with the magnetic field lines of the solar wind. They are pulled back by the motion of the solar wind and so a tail of the magnetosphere will be formed. Here the particles of the solar wind can enter into the magnetosphere. The energy feeded by the solar wind into the magnetosphere is stored in the tail in the form of particle motion and/or in magnetic energy.

The tail has two lobes with proper current systems flowing into opposite directions, where the collective motion of the protons, originating from the solar wind, forms the electric current. In the plane of the magnetic equator, at the boundary of the two lobes, the larger density of protons appears like a current sheet. If there are too many particles stored already in the tail, or some disturbance is arriving from the interplanetary space, then field lines merging back will follow: this is called a substorm. At such a time particles from the current sheet will be injected towards the auroral oval and the magnetic equator where a ring current will arise (such particle injections have been observed at **Earth** and at **Mercury**).

In the vicinity of the aurora regions the atmosphere will be heated by the Joule heating of the electric current (that is represented by the movement of charged particles) and by the impact of precipitating particles. At the vicinity of the equator the atmosphere will be heated by ENAs (**E**nergetic **N**eutral **A**toms – which are the neutralized ions of the ring current by charge exchange with the neutral atoms of the hydrogen corona), and also by ion impacts because of wave-particle interaction (SAR arc – **S**table **A**uroral **R**ed arc, that was observed until now only at **Earth**).

On the sunward side of the magnetosphere a shock wave will be formed, on the inner side of which is the magnetopause. The charged particles of the solar wind cause magneto-hydrodynamic waves at the boundary of the magnetosphere. Some field lines can resonate to them and the oscillation of these field lines can be recorded in the magnetic observatories as telluric magnetic oscillations.

Radio waves were observed by space probes at the **Earth** and at the **giant planets**. On special places of the planetary magnetospheres electron acceleration is occurring, and the synchrotron radiation of the electrons accelerated to relativistic velocities, generates the planetary radio waves. As radio waves do not arise in every place in the magnetospheres the variation of the strength of the radio signal with the rotation of the planet makes possible the determination of the rotation period of the interior, to which the magnetic field is linked,. This phenomenon is important in the determination of the rotation of the giant planets, as they have differential rotation. In case of **Jupiter** the coordinate system linked to the magnetic field is called system III (I is linked to the rotation of the equator, II is to mid-latitudes).

CONCLUSION

As we can see, all but one (plate tectonism) of the **"geophenomena"** occur on some other planetary bodies as well. But their form of appearance and their importance are not the same as in the case of the **Earth** – because of the different initial and/or environmental conditions.

There are, however, some phenomena that appear somewhere on other planetary bodies but not on **Earth**, or only simply we did not recognize its importance up till now on **Earth**.

To explain some phenomena on other planetary bodies the "ground truth" helps, that is, direct terrestrial investigation is needed. But the contrary is true as well. To recognize some negligible components of a phenomenon on **Earth**, other planetary bodies are of great help, where the given component is important and conspicuous; even that is why we could recognize it there. After this recognition we can build it into our terrestrial models, and hence the *real role of the other components* will be clearer. As a consequence our model will be better, and later at the extrapolation with this model the usefulness of the forecast will be more convincing. Nowadays, for example, as the problem of global warming and the role of anthropogenic influences in it became so depressing, it is of great importance if our atmospheric model worked well also under conditions different from the present ones.

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EXTRATERRESTRIAL MATERIALS OF THE SOLAR SYSTEM

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There are various sources where one can study SolarSystem materials. Lunar materials were collected by Apollo manned missions, and Luna 16, 20 and 24 robotics. Martian materials were collected as meteorites. Other meteorites have come mostly from asteroidal bodies. Moon, Mars and asteroids (mainly chondritic ones) are the bodies of the Solar System which are represented in rock collections on the Earth.

Terrestrial rocks were used to make a model of the thermal history of Earth. This is also a useful viewpoint when one compares Solar System bodies according to their rock samples. The thermal evolution of a rocky celestial body strongly depends on its size (and so its mass). The active period with products of layers on the surface could last ca. 100 Ma on an asteroidal sized body with ca. 100-200 kms in diameter, while for the Moon this interval lasted for more than 2 Ga, and on Earth it is still going on.

METEORITES

Meteorites are fragments of different asteroid-sized bodies. The mineralogical and textural characteristics of various meteorites reveal processes, which help to arrange them into genetic types and classes. Many important processes can be fitted into a global evolutionary picture if we assume that larger bodies suffered thermal metamorphism during their early lifetime, when radioactive heating warmed up them. This thermal heating affected the chondritic meteorites which give 85 % of the meteorites. The mineralogy and chemistry of those types transformed mainly by chondritic processes seemed most initial. Early classifications to types by **Prior**, then **Urey** and **Craig**, further developed by **Wiik, Keil** and **Fredriksson**, and to petrologic class definitions of **Van Schmus** and **Wood** refined the global picture till the recognition of the role of aqueous alteration (**McSween, Zolensky**). In this short overview we use the thin section set of the National Institute of Ploar Research, Tokyo, Japan. This set was compiled on the basis of almost 20000 pieces of meteorites collected by Japanese expeditions on Antarctica. (**Yanai, Kojima**, 1987)

THERMAL HISTORY OF A CHONDRITIC PARENT BODY: THIN SECTIONS OF THE NIPR ANTARCTIC METEORITE SAMPLES

The chondritic texture consists of two main components: **chondrules** and **matrix** (hand specimen of ALHA 761 and thin section of CO3 Yamato 791717). The first remarkable thermal transformational sequence shown is the metamorphism throughout the van Schmus -Wood petrologic classes, where we can use H3 (Yamato 791428), H4 (ALHA 77233), H5 (Yamato 74079) and H6 (Yamato 74014). Through this thermal metamorphic sequence (1) equilibration of chondrules and matrix, (2) chondrule fading and obscuring, and (3) changes in iron grain size distribution can be observed. Parallel thermal metamorphic sequence can be observed on those chondrites with other initial total iron vs. oxidized iron content ratio. Their five chondrite groups can be recognized on the Fe+FeS vs. Fe-oxides field introduced by **Urey** and **Craig**: H and L, the E, LL and C groups. The diagram is drawn from the database of the Catalog of Antarctic Meteorites (**Yanai, Kojima, Haramura**, 1995).

Projecting the corresponding Fe compound ratios of the H and L, the E, LL and C groups to the metallurgic field, the petrologic classes (numbers) show evolutionary paths (**Lukács, Bérczi,** 1997). These evolutionary paths result from the data of the Fe compounds of the Fe+FeS vs. Fe -oxides field.

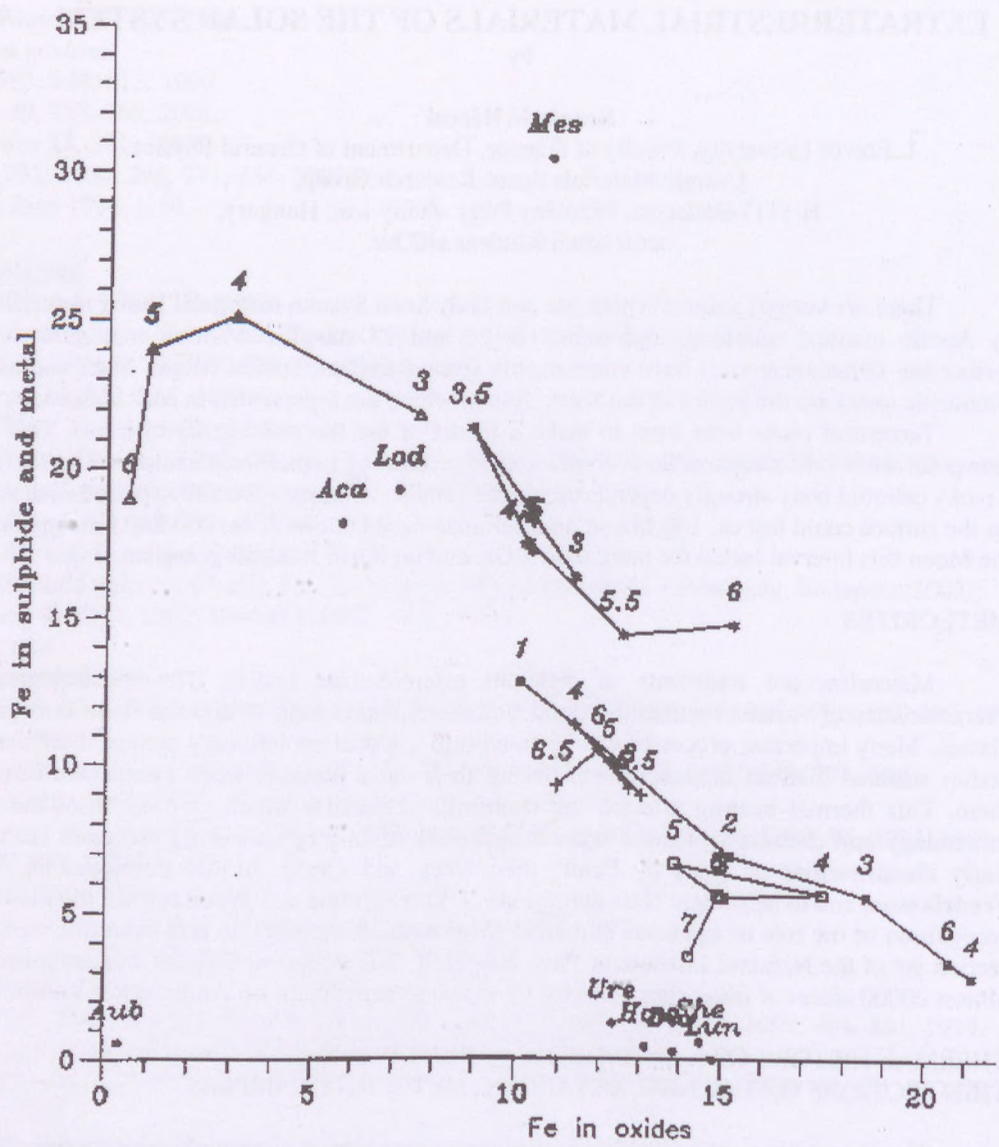
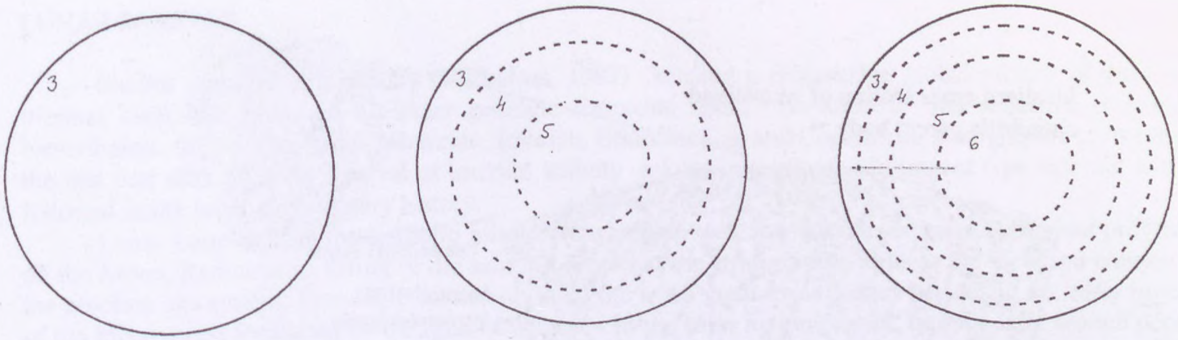


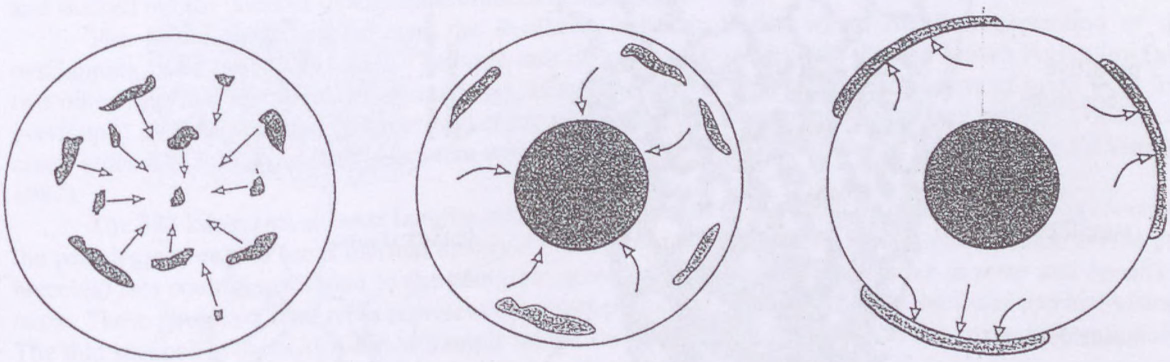
Fig. 1. Evolutionary paths of the H and L, the E, LL and C chondrite groups' types when we project the corresponding Fe compounds to the Urey-Craig field (the petrologic type numbers are shown, **Lukács, Bérczi**, 1997).

We can see the main trends of first reduction, then oxidation and the transformation of this sequence to a layered structure of the chondritic parent body.

The second great period of an asteroidal sized body consists of two main events: migration of molten iron to the core and extrusion of mantle partial melts to the surface forming there the parent rocks of basaltic achondrites. (**Takeda et al.** 1997, **Ykeda et al.** 1996.) The process of iron accumulation into the core is illustrated by a sequence of increasing Fe-Ni metal containing meteorites: mesosiderite (ALHA 77219), pallasite (Yamato 8451), and a large metallic clast containing late petrologic class chondrite sample (L6 of Yamato 790126, from the NIPR volume of **Yanai et al.** 1987.), and finally an iron (Yamato 791076, from the NIPR volume of **Yanai et al.** 1987.). The achondrites are represented by eucrites, first crystalline (hand specimen of Yamato 793169, and its thin section from NIPR volume of **Yanai et al**. 1987., and set thin section of Yamato 791195), and brecciated (Yamato 82009 from the NIPR volume of **Yanai et al.** 1987, and set thin section of Yamato 74450). The residual achondrites are represented by a lodranite (thin section of Yamato 791493 of NIPR volume of **Yanai et al**. 1987.) and by ureilites (thin section of ALHA 78262 of NIPR volume of **Yanai et al**. 1987, and set thin section of ALHA 77257).



Overview of the full timescale layering and *metamorphism,*
differentiation in a chondritic parent body: cross sections with a characteristic onion-shell layering.



iron core and basaltic achondritic layers differentiating.

Fig. 2. Cross sections of the chondritic parent body during the two main periods of the thermal evolution. In the first part thermal metamorphism forms onion-shell layers according to the vSW types (upper row). Int he second part differentiation occurs: first iron migrates to the central regions, later basaltic partial melts migrate toward the surface (lower row).

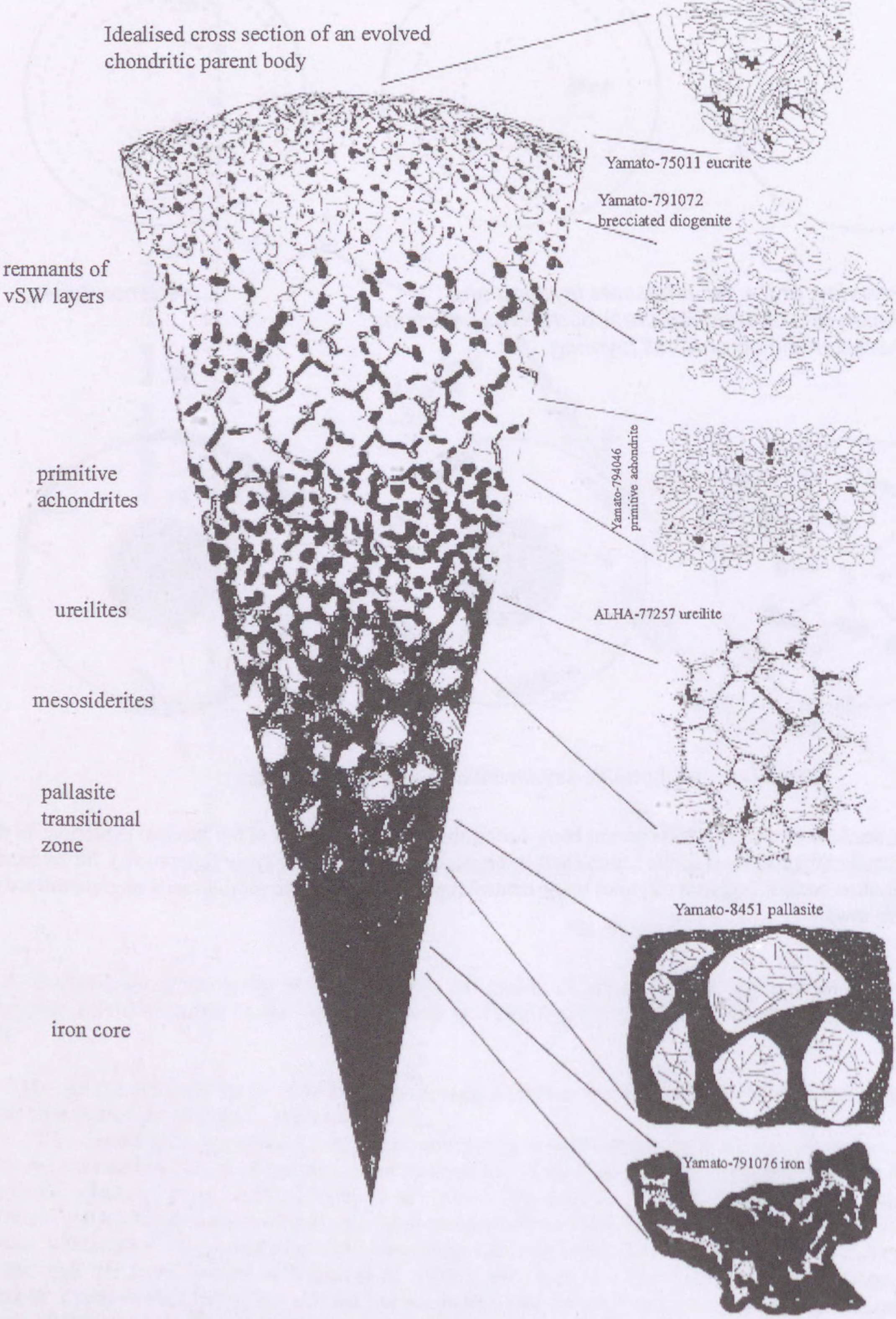


Fig. 3. Layers of a differentiated chondritic parent body. From centrum toward the crust we can find the following meteorite types. Irons and pallasites form the core. Then mesosiderites and ureilites, together with some lodranites and other primitive achondrites form the mantle. Lower crust may contain olivine bearing diogenites like ALH-77256. Basaltic achondrites form the crust but in many cases regoliths are the outer layers with hydrated silicates.

LUNAR SAMPLES

Studies of lunar stratigraphy (**Wilhelms**, 1987) sketched a remarkable global picture of the lunar thermal evolution, although no exact geologic timescale could be fitted to this sequence of events. Nevertheless, the pre-Nectarian, Nectarian, Imbrian, Eratosthenian and Copernican stratigraphic units reflect the fact that after an early interval of internal activity a later interval of only impact type external events followed in the lunar evolutionary history.

Lunar samples from the 6 Apollo mission first ranged rock types to the principal geological provinces on the Moon. Radiometric dating of the samples projected the stratigraphic units to the idealised column of the absolute age system. Petrologic studies revealed the main great evolutionary periods in the early history of the Moon: crust formation by flotation of feldspars in the early magma ocean, and the later second period of extrusion of partial melts from the lunar mantle to the surface, filling large impact basins and forming lunar maria.

THERMAL EVOLUTION OF THE LUNAR BODY

Lunar stratigraphy first determined the two main geologic provinces of **terra** and **mare** on the Moon and worked out the detailed stratigraphic column of basic units.

The initial target region was the Southern Imbrium Basin, where the best exposition of the overlapping basic units was found. The basic unit of lunar stratigraphy was the Fra Mauro Formation (and two other Imbrium ejecta-related formations). Late Imbrian (earlier Procellarian) layers of mare were first overlapped by Eratosthenian (without ray) crater units, then later the younger (with ray system) Copernican crater units. The initial pre-Imbrian system was later subdivided into Nectarian and pre-Nectarian (**Wilhelms**, 1987).

The 384 kilograms of lunar samples collected and brought to the Earth by Apollo expeditions revealed the petrologic events of lunar thermal history. Of the three main rock types found (anorthosites, basalts and breccias) two could correspond to the two great geological provinces: *anorthosites to terra* and *basalts to mare*. These two main rock types represent two great periods of differentiation in the lunar thermal history. The thin sections of the NASA Lunar Sample set are shown in this sequence of the two main differentiational periods (**Meyer**, 1987).

Two thin sections represent lunar terra. The **60025 anorthosite** exhibits all important and nice characteristics of the shocked and brecciated ancient rocks which once had cumulate texture but impacts transformed it. The three main shock phenomena of (1) undulatory extinction, (2) kink banding and (3) twinning are all well represented in textural regions of the 60025 anorthosite sample. The largest shock effect of diaplectic glass formation is visible on the **8235 norite** sample. It represents the other terra rock type, the intrusive ANT suite, and its plagioclase feldspar was mostly transformed to maskelynite. The summary of these first differentiational period suggests a magma ocean in which the flotating plagioclase feldspars accumulated to an anorthositic crust, into which ANT suite rocks later intruded.

The great basin forming impacts continue the lunar history.

Basins contain those layers which form the other great lunar geologic province rocks: basalts. They are represented with three very nice thin sections of samples 12002, 12005 and 70017. They exhibit somewhat different texture corresponding to the depth of crystallisation in some 10 m thick lava flows. **12002** shows porphyritic texture with variolitic matrix, **70017** is extremely rich in sector zoned pyroxenes embedded poikilitically to large feldspars, while **12005** has the most slowly crystallized texture.

The **74220** orange glass sample can also be connected with this second part of lunar volcanism: it represents the orange pyroclastic soil. The 40-60 micrometer sized orange-coloured spherules are primary liquid compositions from lunar mantle spread around a lava-fountain in the Taurus-Littrow landing site of Apollo 17.

Finally, brecciated rocks represent the final common fate of rocks from any kind of thermal history periods. The **14305 breccia** contains a large anorthositic recrystallized fragment and a poikilitic grain, while sample **72275** displays a breccia-in-breccia hierarchic texture. This proves that repeated impacts fragmented and cemented together surface and near-surface rocks during the last 3 Ga.

From studies of thin sections of cosmic materials we reconstructed an (in many aspects hypothetical) succession of the main events in the thermal history of a small (chondritic, evolved asteroidal) and a larger (the lunar) rocky celestial body. Thanks to the richness of the two collections such events were well represented and could give an appropriate idea of both types of rocky bodies.

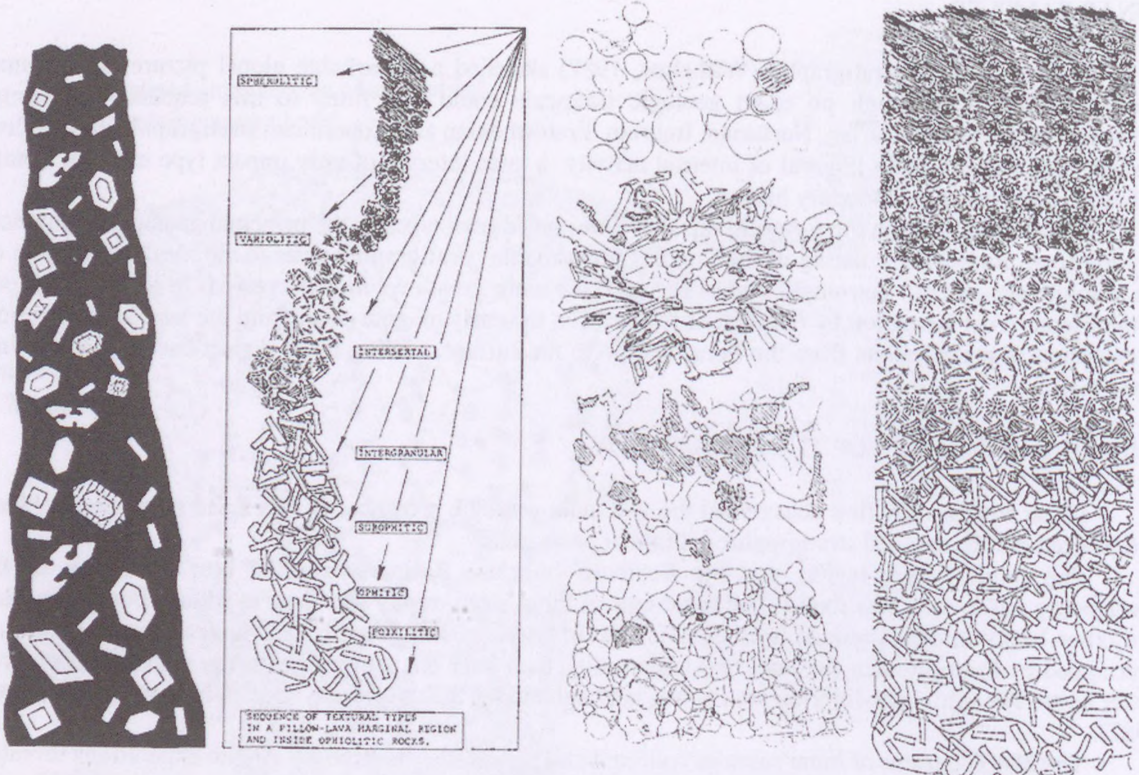


Fig. 4. Cross section of a lunar lava flow with the corresponding position in the lava pile of the basaltic samples from the NASA lunar educational thin section set. Up is the place of the **74220** orange glass sample, then **12002** sfollows with a porphyritic texture with variolitic matrix. In the middle regions is **70017** which contains sector zoned pyroxenes embedded poikiliticallly into the large feldspars. Finally **12005** has the most slowly crystallized texture at the lower position int he lava pile.

ACKNOWLEDGEMENTS

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B. PRESENT-DAY GLOBAL DYNAMICS

GLOBAL DYNAMICS -- GLOBAL TECTONICS

by
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The consistent theory of plate tectonics was born in 1968, unifying disparate pioneering ideas and linking together seemingly independent facts.

E. Szádeczky-Kardoss promptly recognized its extraordinary significance, and became one of its first adherents and promoters in Hungary. In his GEONOMY (1974) he presented and discussed it in not less than six chapters: B/3-6, B/10-11.

According to our current knowledge the moving mechanism of plate tectonism is the thermal convection in the upper mantle (**Peltier** 1989, **Schubert et al**. 2001).

Convection currents are active from the ocean bottom down to the mantle/core boundary, due to differences in density resulting from differences in temperature. Their effects include, along with the "conveyor belt type" movement of the lithospheric plates, also gravitational downsliding on the gentle slopes of mid-ocean ridges, and the generation of "hot spots".

E.Szádeczky-Kardoss added a factor of its own, developing the model of "*vapour pillow*". Namely he realized that huge amounts of water-bearing sediments get into the astenosphere by the process of subduction. He assumed that this water, being liberated, migrates by diffusion in the partially melted asthenosphere, building up a "vapour pillow" that functions as a lubricant, facilitating plate downsliding.

This idea, alas, has to be abandoned. In fact, the lithospheric plates are moving not on, but with the materials of the mantle, "dragged" by them. We also have learnt that some effects of subduction may reach down to the very core (but in the lower mantle they are aseismic), and not only to 700 km depth, as **E. Szádeczky-Kardoss** assumed (for the Circumpacific type subduction).

The plastic (quasi-fluid) behaviour of the otherwise solid mantle material can be explained in terms of deformation mechanisms (creep due to dislocational flow, diffusional flow), caused by defects in the lattices of crystals (**Gordon** 1967).

E. Szádeczky-Kardoss was in favour of the "expanding Earth" theory developed by **L. Egyed,** in a modified form he called "*the model of contractional dilatation*." Nowadays this model is regarded as rather unlikely.

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* Abridged and translated by E. Dudich from his study published in 2003 (after the Author's death in December 2002).

REGIONAL TYPES OF IGNEOUS PETROGENESIS

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Introduction

In the GEONOMY (1974) professor **E. Szádeczky-Kardoss** summarized his views on igneous petrogenesis basically on the new approach provided by plate tectonics, with an introductory chapter on phase diagrams. This proved to be an idea that many authors followed later on, and it is adopted in our current overview as well.

The importance of phase diagrams in modeling igneous processes goes back to roughly a hundred years, and is still considered one of its most important bases.

As this summary, however, puts emphasis on the regional types of igneous petrogenesis, phase diagrams are not treated in the followings.

#

Igneous processes occur along divergent and convergent plate margins as well as in plate interiors.

1. Magmatism along divergent plate margins

This kind of magmatism – the most voluminous on Earth – has been active along mid-ocean ridges (and beneath) since at least 140 million years. The present ridge system has a total length of about 65000 km, and the tholeiitic basalts erupted there (Mid-Ocean Ridge Basalt = MORB) cover ~ 70 % of the Earth' surface (**Hess**, 1989). As compared to their enormous volume and spatial extent they are chemically and petrologically rather homogeneous (**Yoder**, 1976). These magmas are the products of partial anatexis in the upper mantle (more precisely the upper astenosphere), caused by decompression of rising mantle rocks along large scale convective cells (**Fig. 1**).

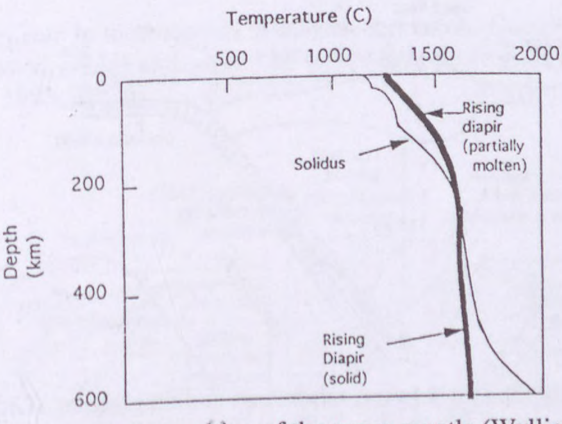

Fig. 1: Decompression melting of the upper mantle (Wyllie, 1981)

About 20 to 30 % partial melting of these basically lherzolitic rocks can produce the MORB-type magmas (**Green** and **Ringwood**, 1967). In spite of the homogeneity mentioned before, there are differences both in their incompatible trace element content (**Wood**, 1979), and $^{87}Sr/^{86}Sr$ as well as $^{143}Nd/^{144}Nd$ isotopic ratio (**LeRoex et al.**, 1983), on the basis of which normal MORB (N-MORB) and enriched MORB (E-MORB) varieties can be distinguished. These differences point to the geochemical heterogeneity of the source region and/or variations in the degree of anatexis (**Langmuir et al.**, 1992).

The product of MORB-type magmatism is the oceanic crust itself with different rocks as a function of crystallization depth (**Fig. 2**).

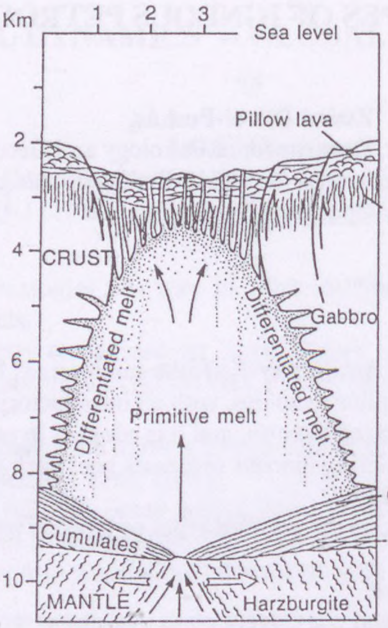

Fig. 2: Formation of rock-types in the oceanic crust (after Bryan and Moore 1977, in Raymond 1995)

Fractional crystallization may locally lead to the formation of intermediate or even acidic rocks in small volume (**Raymond** 1995, and references therein).

2. Magmatism in subduction zones

Subduction of the oceanic lithosphere is spatially related to the formation of magmas **(Fig. 3).**

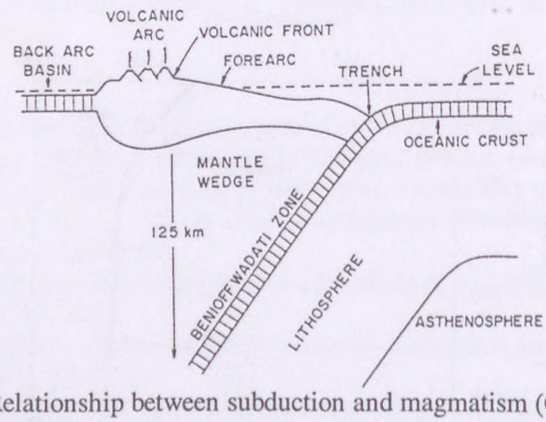

Fig. 3: Relationship between subduction and magmatism (Gill, 1981)

Igneous activity at convergent plate margins occurs along island arcs and active continental margins. The intrusive and extrusive rocks there rank second in terms of volume after those of the mid-ocean ridges. Island arc magmatism is dominated by extrusive rocks of the basalt – andesite – dacite – rhyolite series, while that of the continental margins by batholite-forming plutonic rocks of the gabbro – diorite – tonalite – granodiorite – quartz monzonite – granite association, with predominance of tonalite and granodiorite. A minor percentage of plutonic rocks forms smaller mafic – ultramafic bodies, the Alaska-type complexes.

Volcanic rocks occurring above subduction zones can be divided into four geochemical series on the basis of their potassium content:

- low-K
- calc-alkaline
- high-K
- shoshonite (**Ewart**, 1982).

Island arcs without mature continental crust are characterized by tholeiitic basalts and basaltic andesites (e.g. Mariana, Tonga, South Sandwich, Northern Lesser Antilles), while those with well-developed continental crust (e.g. Japan, SW-Indonesia) as well as active continental margins by calc-alkaline andesites, which is the predominant volcanic rock above subduction zones.

In the Central Andean region, which is characterized by extremely thick continental crust of about 70 km, the predominant volcanic rocks are SiO_2-enriched andesites, dacites and rhyolites, with only subordinate basalt and basaltic andesite. This points to the influence of the thickened continental crust on volcanism at convergent plate margins.

The petrogenesis of volcanites above subduction zones is still not clarified in all details, but is generally considered a complex process. One of the most important factors is the vertical distribution of geotherms along subduction zones which determines metamorphism – and related fluid release – of the subducting slab (**Fig. 4**).

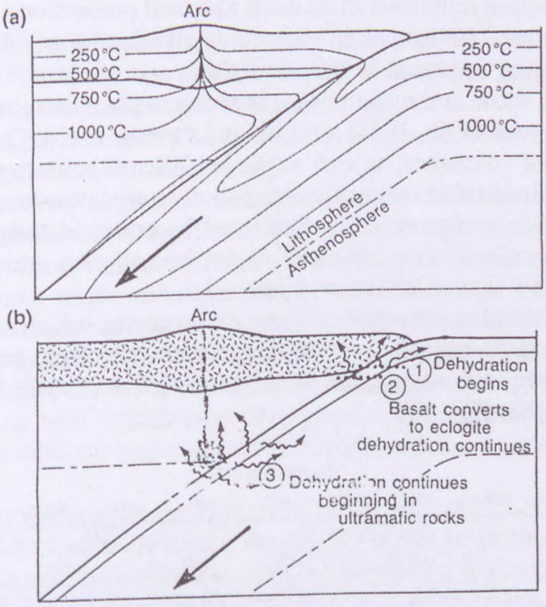

Fig. 4: Geotherms (a), and dehydration (b) in subduction zones (Raymond, 1995)

H_2O-rich fluids play a key role in most models of magma formation. One of the most widely accepted one has been elaborated by **Ringwood** (1974) and refined by others later on (e.g. **Myers** and **Marsh** 1987, **Morris** and **Tera** 1989; in **Raymond** 1995; **Fig. 5**).

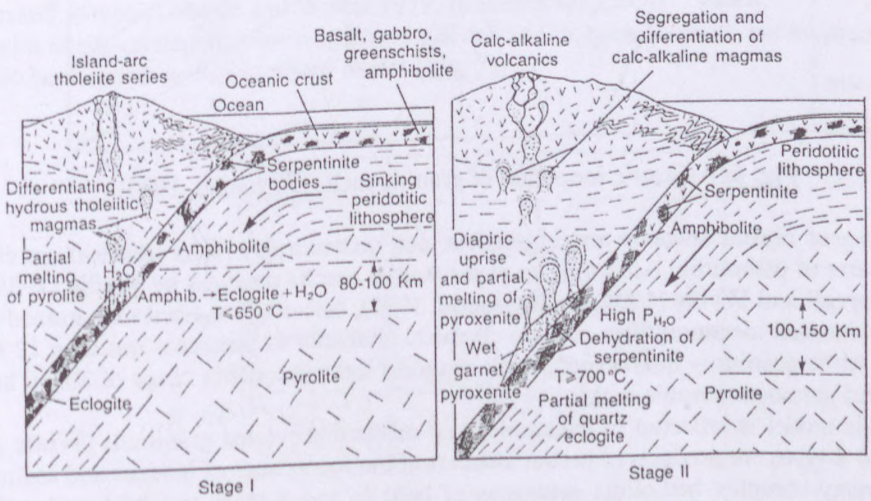

Fig. 5: Formation of tholeiitic (Stage I) and calc-alkaline (Stage II) magmas related to subduction (Ringwood, 1974)

According to this model, formation of tholeiitic magmas characteristic of immature island arcs, is triggered by H_2O-rich fluids released in the course of progressive metamorphism of the subducting oceanic crust. These fluids result in a decrease of solidus temperature in the mantle wedge above, leading to magma formation.

The formation of calc-alkaline magmas may be more complicated. Dehydration of serpentinized upper mantle of the subducting oceanic lithosphere also plays a key role, resulting in complex interaction between fluids, the overlying metamorphosed oceanic crust and the mantle wedge above.

These processes yield predominantly andesitic lavas, however basaltic, dacitic and rhyolitic melts also erupt in considerable quantity. In regions where rhyolitic lavas predominate the anatexis of lower continental crust is presumed. This may be the result of rising high-temperature mafic melts, leading to assimilation of SiO_2-rich crustal rocks and the concomitant fractional crystallization of the contaminated magmas (AFC-process).

To sum it up, calc-alkaline volcanism in the subduction zones is conceived as a result of many interacting processes (mantle and crustal anatexis, mantle metasomatism, assimilation, fractional crystallization, magma mixing, etc.), which is reflected e.g. in the MASH-model of **Hildreth** and **Moorbath** (1988).

The contribution of subducting sediments in anatexis and melt production can now well be constrained by precise measurement of radioactive ^{10}Be isotope in recent calc-alkaline lavas. ^{10}Be, with a half-life of only 1.5 million years, is continuously being produced in the atmosphere as a result of cosmic ray bombardment. After deposition on the Earth' surface, those at the appropriate convergent plate margins are being subducted, and re-appear again in recent lavas (**Brown et al.,** 1983; **Arculus** and **Powell**, 1986). Considering the ^{10}Be-contents of both the recent sediments and the volcanites, as well as the half-life of the isotope, and an average 10 cm/year subduction rate, it has been concluded that sediment contribution in arc lavas does not exceed 5%.

Intrusive magmatism in subduction zones is dominated by granitoid batholiths. They are composed of different rock types of basically calc-alkaline character, but chemically, on average, are more acidic than the extrusive rocks, and show only few signs of differentiation.

Their magmas are probably also the result of complex processes, which is reflected in various models. Anatectic ones seem to be the most reliable, in accordance with petrology, geochemistry and experimental petrology. The most abundant granitoid magmas are minimum temperature melts formed in the PT-regime of the high-temperature amphibolite facies (**Fig. 6**).

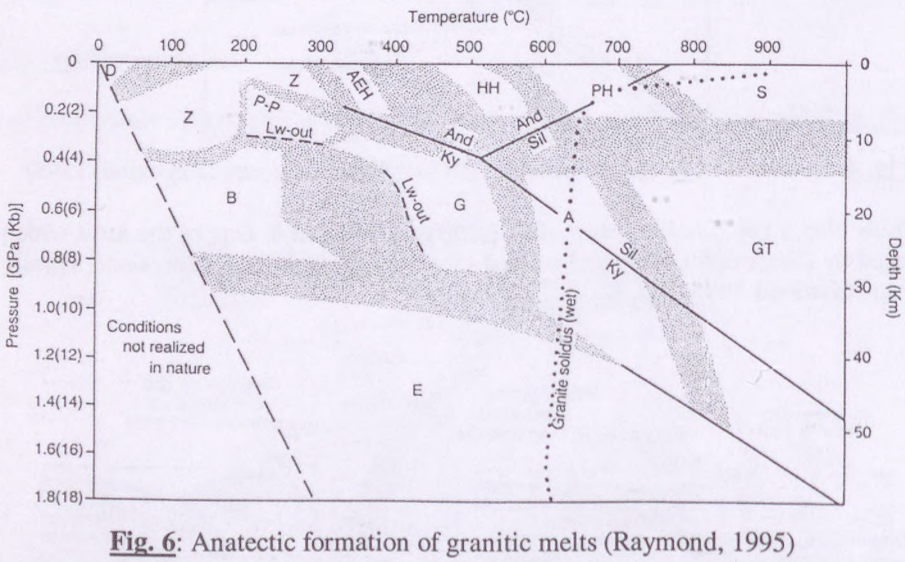

Fig. 6: Anatectic formation of granitic melts (Raymond, 1995)

Field evidence of crustal anatexis are migmatites, and metamorphic rocks (restites) are common in the upper marginal parts of batholiths. According to experimental results obtained by **Wyllie** (1984), **Huang** and **Wyllie** (1986), **Carroll** and **Wyllie** (1990) (in **Raymond**, 1995), calc-alkaline tonalitic – granodioritic magmas form from water-saturated metamorphites of basic chemical character in pressures less than 12 kbar (i.e. up to depth of 40 km), while granitic – quartz monzonitic magmas form in a depth range of 30±10 km from water-saturated ortho- and parametamorphic rocks.

The anatectic model is reflected in the typology of subduction related granitoids (**White** and **Chappell**, 1983): I-types, and S-types are products of partial anatexis of metamorphites of igneous and sedimentary origin, respectively. In many complex batholiths evidences of both I- and S-types can be found, pointing to their complex origin.

More mafic rocks (gabbro, diorite) occurring in batholiths in about 10 % are considered as products of mantle melts, mixed with the acidic crustal magmas in the course of their evolution.

K-metasomatism was earlier considered to be of paramount importance in the genesis of granites (**Read**, 1948). In recent views it may only have local influence in shaping their petrological and geochemical character.

Alaska-type complexes are minor, irregularly zoned plutons with igneous layering, cumulate texture, and mafic to ultramafic composition. On the basis of geochemical reconstruction their tholeiitic parental magmas were derived by partial fusion of mantle rocks. Based on their plate tectonic position as well as petrological and geochemical character, they are considered as plutons differentiated in magma chambers under the volcanic edifice in island arcs.

3. Magmatism inside continental plates

Magmatism in the continental interiors is highly heterogeneous, due to either hot spot activity, or different stages of rifting coupled occasionally with crustal thinning and mantle diapirism.

Heterogeneity of subcontinental mantle, degree of its anatexis, contamination of primary magmas by the continental crust, differentiation and magma mixing further contribute to the formation of very different rock types. Geochemically they are mainly tholeiitic and alkaline, while petrographically range from ultrabasic to acidic.

The best studied continental *hot spot* region is the Yellowstone National Park in the USA, characterized by bimodal basalt – rhyolite volcanism: the tholeiitic basalt is of mantle origin, while rhyolite derives from lower crustal anatexis (**Christiansen** and **Blank**, 1972).

Plateau basalts, various rift volcanites, kimberlites – lamproites, lopoliths, anorthosites and komatiites have all been developed in extensional tectonic settings.

Plateau basalts may have very large areal extension (0.05 – 1.5 million km^2), with an average thickness of 1 – 2 km. They are mainly Phanerozoic in age. Well-known examples are the Deccan in India, Central Siberia in Russia, Karroo in Southern Africa, Paraná in Brasil, and Columbia in the western USA. The rock types are mainly tholeiitic basalts of mantle origin with different degree of crustal contamination. Fractional crystallization may lead to the development of intermediate, or even acidic rocks (**Hess**, 1989).

Continental rifts are elongated narrow structures inside the continental lithosphere, occasionally with axial rift valley (**Williams**, 1982). Their development may reach different stages, and in its most advanced form a new oceanic crust begins to develop with MORB-type magmatism. Numerous rifts have aborted, however, but the igneous activity related to the different stages of rifting is quite common and unique to the area. Many of them have alkaline character.

The best-known recent examples are the East and Central African rift (6500 km in legth), the Rio Grande rift in the border region of the USA and Mexico, the Rhine Graben in Germany, the Baikal rift (2500 km in length), while the Oslo Graben and the Kola peninsula are well-studied examples of inactive rifts.

Very different, sometimes curious extrusive and intrusive rocks belong to the rifts. E.g. the most common rock types in the East African rift are basalt, basanite, nephelinite, phonolite, carbonatite, trachyte, and rhyolite (**Williams**, 1978).

Inactive, deeply eroded rifts are characterized by similarly very different intrusive rocks. E.g. on the Kola peninsula alkaline ultramafics, ijolite, melteigite, nepheline syenite and carbonatite (**Gerasimovsky** et al., 1974), while along the Cameroun rift (on the Jos Plateau, Nigeria) peralkaline and peraluminous granite, as well as syenite and nepheline syenite appear (**Bowden** and **Turner**, 1974). Granitoids in such anorogenic tectonic settings are termed A-type (**Loiselle** and **Wones** 1979; in **Raymond** 1995).

The origins of rift-related alkaline magmas is still debated in many respects, but anatexis of heterogeneous mantle seems to be the most widely accepted model (Fig. 7).

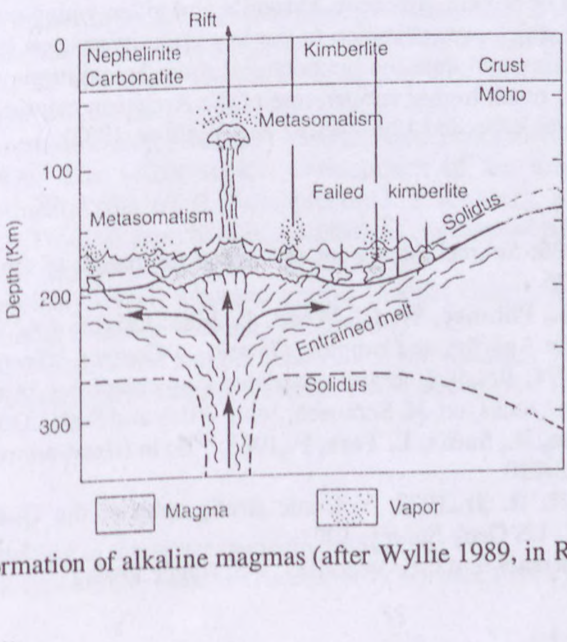

Fig. 7: The formation of alkaline magmas (after Wyllie 1989, in Raymond, 1995)

Small volume *kimberlitic and lamproitic* magmatites occur inside and marginal cratonic settings, respectively.

Kimberlites are high-K ultrabasic rocks rich in mantle-derived xenoliths (peridotites, eclogites), as well as xeno-, mega-, and phenocrysts, with H_2O- and CO_2-containing minerals in the groundmass (serpentine, chlorite, carbonates; **Dawson**, 1980).

K-rich lamproites can be devided into ultrabasic (olivine lamproite) and basic (leucite lamproite) subtypes. They are also rich in xenoliths, but lack CO_2-containing minerals in the groundmass (**Jacques et al**., 1984).

Both kimberlites and lamproites may contain diamond, and are rich in incompatible trace elements.

On the basis of stability analysis of xenoliths and xenocrysts, these magmas derive from the greatest depth in the Earth mantle, of about 150 to 200 km. Their small volume points to incipient anatexis in an enriched source region. This is also in accordance with their high concentration in incompatible trace elements and volatiles. These small-volume, high fluid-pressure magmas must have been ascended from the deep source region very quickly (35 to 100 km/h; **Mercier** 1979, **Artyushkov** and **Sobolev** 1984; in **Raymond** 1995), as evidenced by the almost complete lack of re-equilibration on their xenoliths and xenocrysts.

Lopoliths are intrusive bodies filling crustal depressions, having generally considerable volume and surface area, and consisting predominantly of layered mafic and ultramafic rocks. The most notable examples are the Bushveld in South Africa, Great Dike in Zimbabwe, Stillwater and Duluth in the USA, Muskox in Canada, and Skaergaard in Greenland. Their areal extension is generally between 1000 and 5000 km^2 (but Bushveld, the largest of all crops out on about 66000 km^2, while Skaergaard on 100 km^2 only). Their thickness varies from 2500 m (Skaergaard) to 9000 m (Bushveld).

Detailed studies were performed mainly on Skaergaard and Stillwater by **Hess** (1960), **Jackson** (1961, 1970), and **Wager** and **Brown** (1968). The notions of cumulates, rhythmic, uniform and cryptic layering as well as in-depth understanding of petrological and geochemical processes governing the fractional crystallization of a large-volume basaltic melt all have been developed from the studies of lopoliths.

Anorthosite plutons are mainly Archaean and Proterozoic in age, but the youngest ones formed in the early Palaeozoic (**Morse**, 1982). Those of Archaean age are found in greenstone belts of cratons, and are generally metamorphosed (greenschist and amphibolite facies). They are very coarse-grained, An-rich (An=80-95%) without mineral zoning (**Phinney**, 1982). Proterozoic anorthosites are situated in high-grade metamorphic terrains, often associated with charnockites (**Hess**, 1989). Their areal extension is about 1000 to 20000 km^2. They can be metamorphosed to various degree, but unmetamorphosed examples are also known (e.g. in the Labrador peninsula).

Coarse grain size, lower An-content (An=40-65%), and crystal zoning are characteristic. Based on their structure and texture, they are cumulates, crystallized from mafic melts of mantle origin, though complementary mafic rocks are not known as yet. This may hint to the possibility of the formation of primary mantle melts with anorthositic composition in the Precambrian (**Wiebe**, 1979), an idea supported by Sr- and Nd-isotopic evidences (**Ashwal et a1.,** 1983).

Komatiites are ultramafic volcanites, discovered only in 1969 in the Archaean greenstone belts of the Transvaal Craton (**Viljoen** and **Viljoen**, 1969). Since then komatiites have become known in most continents in similar geological settings. Their surface area may reach 10^5 km^2, with length of some hundred km and thickness of about 1 km (**Nisbet**, 1982), resembling plateau basalts of younger age. They are extremely MgO-rich (18 to 35%), with igneous assemblage of olivine, pyroxene, chromite and glass, which are characteristically replaced by metamorphic minerals. Very quick crystallization of the low-viscosity magma is evidenced by their specific spinifex texture. Based on experimental data the temperature of the komatiitic lava might have been between 1500 and 1800 °C. This implies much higher temperature of the Archaean mantle, in which conditions partial melting may have reached, or even exceeded 50% (**Nisbet** and **Walker**, 1982).

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Figure captions

Fig. 1: Decompression melting of the upper mantle (Wyllie, 1981)

Fig. 2: Formation of rock-types in the oceanic crust (after Bryan and Moore 1977, in

EROSION AND SEDIMENTATION

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Erosion (removal) and sedimentation (deposition) are two complementary sections of the global dynamism. In 1974, **E. Szádeczky-Kardoss** attempted to make a quantitative approach, relying upon data published by **Clarke** (1924) and **Corel** (1959).

The most probable average rate of erosion turned out to be 0,2 to 0,3 mm/year. This would mean the removal of 30 to 45 cubic kilometres per year for the entire continental surface of the Earth, i.e. 150 million square km.

The rate of sediments from 0,67 to 0,002 mm/year (from the lagoons to the abyssal trenches). **E. Szádeczky-Kardoss** considered 0,1 mm/year as an acceptable average value.

Some part of the resedimented erosion products, as well as of the biogenic and chemogenic deposits, are gradually absorbed by the ongoing process of subduction:

$$S = (E + B + C) - Mr$$

where

S = subducted total mass
E = erosion products
B = biogenic (organogenic) deposits
C = chemogenic deposits (precipitates and evaporites)
Mr = marine residue

As a matter of fact, **E. Szádeczky-Kardoss** disregarded B and C. In this way, he obtained as S for the past 180 million years (post-Jurassic period) $6{,}4.10^9$ km^3. This means 33,7 km^3/year of "disappearing" sediments.

Adding a rough estimate of $B + C = 6{,}3$ km^3/year, one arrives at a value of 40 km^3/year.

This seems to be the order of magnitude of the destruction of the solid crust ("from above") compensated – at least on the long run – by its growth ("from below").

It is an open question whether this is a homeostatic self-regulation process of "Gaia" or not.

Accumulated new data, obtained by regions, computerized processing and alternative multifactorial simulation tests most probably could produce better approximations.

This would be particularly relevant in case of the oxygen, carbon and sulfur geochemical cycles.

The results obviously would shed new light onto the active role played by the biosphere in the global dynamism, which seems to be much more important than **E. Szádeczky-Kardoss** assumed.

E. Szádeczky-Kardoss forwarded the idea of getting rid of all kinds of anthropogenic waste by introducing them it into the zones of active subduction. However, this can hardly be a viable solution to the problem, because the rate of subduction is too (s)low: some 1 to 3 cm/year.

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GEOCHEMISTRY OF THE SUBDUCTION ZONES

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E. Szádeczky-Kardoss in his Geonomy (1974) stated that

- *"the CaOo and CO_2 contents of the sediments are much higher than those of the crust...This enigma of geochemistry can be solved by means of the new global tectonics: the difference is due to the mainly argillaceous, less carbonatic nature of the subducted sediments."* (Op. cit. p. 190).
- *"Starting from the new global tectonics, the main items and basic features of the Earth's metabolism can be calculated."* (Ibid., p. 197.)
- *"The movements of the lithospheric plates control the emplacement and type of ore mineralization."* (Ibid., p. 201).
- *"As a rule, three stages can be distinguished: mobilization, recrystallization of the mobilized elements in tha main minerals of the igneous rocks,* [according to te sequence of decreasing ionic potentials], *and the segregation / concentration leading to the formation of specific ore deposits."* (Ibid., p.203).

His assumptions have been fully confirmed by subsequent research.

The most important ore provinces are in fact bound to the main subduction zones.

1. Most of the post-magmatic (i.e., pegmatitic, pneumatolytic and hydrothermal) vein-type or disseminated ore deposits are related to the volcanic edifices and subvolcanic bodies of active or relatively young subduction zones. Examples are the porphyry copper deposits in the Andes and the Au-Cu-Mo mineralizations of the Rocky Mountains, as well as the copper ore deposits of the Carpathian-Balkan region (Medet in Bulgaria, Majdanpek in Serbia, Rosia Poeni and Deva in Romania, Recsk in Hungary, Banská Štiavnica in Slovakia, to mention only a few.)
2. Other ore mineralizations are related to accretional sutures (ophiolitic, liquid magmatic deposits etc.)
3. A third group is to be found in consolidated plate interiors that used to be called "cratons".

4. **E.Szádeczky-Kardoss** even extended his interpretation to the sedimentary deposits.

"The polyvalent elements become concentrated to sedimentary ore deposits by Eh (redoxi potential) changes. With increasing oxydation degree on the ancient tables itabirite-jasplitie ores are developed, while in younger formations – oolitic iron, manganese and uranium...ores. Dissolution residues of chemically simpler composition may be generated from rocks of more complex chemical composition by diagenetic or metamorphic liberation of violatiles /solutions. Such are e.g. the coal and bauxite deposits. Finally, the diagenetically mobilized and conveniently trapped substances may form industrially utilizable deposits. Such are the hydrocarbon deposits." *(Ibid., p.208.)*

According to our present-day knowledge, these generalizations are somewhat exaggerated, although the fundamental idea is reasonable. They would merit a global statistical assessment – a task for the future.

METASOMATISM AND METAMORPHISM IN SUBDUCTION ZONES

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According to **E. Szádeczky-Kardoss,** during recrystallization the chemical composition of rocks is modified: recrystallization is usually an allochemical process. Beside migration of some substances it often involves partial exchange: removal of matter and its substitution by an other, of different composition but equal volume ("substitutional metasomatism"). The processes of metasomatism and metamorphism depend on pressure, temperature, depth and the initial material.

In Hungary, rocks generated by potassium metasomatism are known in considerable areal extension in the Mátra and the Tokaj Mountains. In the past decades we had the opportunity to perform in-depth research on the physico-chemical processes of potassium metamorphism, in the framework of project T.026410 of OTKA (National Scientific Research Foundation) entitled "*Investigation of the mineralogical-petrogaphical composition and genesis of the K-rich rocks of Mátra Mountains.*"

It has been established that the potassium metasomatism affected the andesite complex of Middle Miocene (Badenian) age that makes up the bulk of the mountains produced by island arc volcanism related to subduction.

The transformation of the predominant plagioclases to sanidine and orthoclase might have occurred at p = 1 Bar and t = 20 °C. Only adequate quantities of K^+ cations and SiO_2 are required.

Consequently, the metasomatism was going on near the surface, due to low-temperature hydrothermal solutions. This would explain why no potassium-rich rocks are known to occcur in the Mátra Mountains in deeper position than 110 m below the surface.

The potassium enrichments associated to the hydrothermal veins of the polymetallic ore mineralization at Gyöngyösoroszi are not due to potassium feldspars but to illitic argillization.

The source of the great amount of potassium has not been cleared yet. It can be assumed, however, that the potassium content of the huge mass of potassium-rich rocks (3,5 cubic km, on > 100 square km) have been leached from the underlying lithosphere plate and transported upwards, near the surface, while temperature was gradually decreasing.

PLATE TECTONICS - A NEW PARADIGM

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By now, plate tectonics has become a generally accepted theory in Earth Sciences. It has penetrated virtually everywhere, including the curricula of primary and secondary schools, the science vulgarization papers, the media, and even the science fiction. (As early as 1973 **Sake Komatsu** published a novel under the title "*Death of the Dragon*". This describes the apocalyptic destruction of Japan caused by an unexpected acceleration of the subduction process.) It has nearly become a commonplace, replacing completely **Dana's** geosyncline theory.

When **E. Szádeczky-Kardoss** wrote his Geonomy (1974), the situation in Hungary was very different from the present-day one. The Big Brother's grisp and pressure was very serious in all fields of life, including science. The model to imitate and the example to follow was Soviet science. Now, in Soviet geology fixism had great traditions and enthusiastic supporters (**Belousov** 19870, **Pushcharovsky** 1972), and the **Mayerhoff** brothers. For this reason **E. Szádeczky-Kardoss** regarded it indispensable to discuss and assess their objections against plate tectonics in a 4,5-page chapter entitled "Criticism of the Criticisms". His final conclusion was:

"*The study of the arguments set forth by these three prominent adversaries of the new global tectonics has shown that the fixist position cannot maintain itself any more, confronted with the new global tectonics that is supported by a high number of convergent proofs.*" (**E. Szádeczky-Kardoss** 1974, p. 239.)

We are in full agreement with this statement.

Recently it is much more important to avoid that plate tectonics as the new paradigm of Earth Sciences on its turn become a rigid and unquestionable dogm.

C. INTERACTIONS OF THE FLUID AND „SOLID" GEOSPHERES AND THE BIOSPHERE

A CRUCIAL GEOSPHERIC INTERACTION: CLAY MINERALS AND LIFE

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One of the basic principles of the geonomic concept developed by **E. Szádeckzy-Kardoss** is the permanent interaction of the geospheres as relatively individualized integral components of the planet Earth, producing and maintaining the global dynamism. Scientific research in this respect is focused on the interactions between the solid Earth (lithosphere) and the fluid spheres (hydrosphere and atmosphere), as well as the biosphere.

Studying the processes of these interactions, **E. Szádeczky-Kardoss** attributed a prominent role to the genesis of clay minerals, a process going on on (and near to) the surface of the Earth, because he recognized their importance for the interaction of the non-living and the living matter. He considered the clay minerals as a mineral phase specific for the Earth, one of the factors that make it unique in the solar system. At present one admits the possibility of existence of planets and moons on which clay minerals may have existed, i.e. of the generation of silicate phases resembling the terrestrial clay minerals, under **p-t** conditions permitting the existence of liquid H_2O.

Clay minerals are formed on the surface of the solid Earth, or near the surface in the lithosphere, as a result of interaction with the hydrosphere, atmosphere and biosphere.

This interactive process called chemical weathering is characterized by the specific composition of the interacting solid, liquid and gaseous phases and the redoxi potential and pH values. The chemical weathering selectively mobilizes the chemical elements, while the solid phase is transformed, and new, transitory mineral phases come into being, with high water content in the crystal structure. As a result, layered silicates are formed. The crystal strucutres of these have rather peculiar features that have a considerable influence on the terrestrial processes and are indispensable for the living beings. These minerals display remarkable concentrations in sediments and soils, while in the deeper parts of the lithosphere, while they undergo step-by-step changes, play a fundamental role in the processes of tectonic movements and complex rock genesis.

According to E. **Szádeczky-Kardoss,** the anthropogenic pollutions taken as a whole are insignificant with respect to the global dynamism, but the rapid and locally concentrated contaminations may represent a serious danger for the living world. He thought that humankind can feed back the accumulated hazardous waste, bound mainly to clay minerals, into the large global circulation (in the deep sea troughs, i.e. in the subduction zones), and no natural disaster would occur. Unfortunately this view has been refuted during the past 30 years. Global environmental pollution has attained such a degree (mainly as far as the hydrosphere, atmosphere and biosphere are concerned) that it has exceeded the correction capacity of the global dynamism.

At the same time we have to agree unconditionally with the view of **E. Szádeczky-Kardoss,** namely that the solution of these problems requires the geonomic approach. This is true already for the realistic estimate of the imminent danger. Namely, the other sciences are too static to be able to handle these issues with success.

The formation of phyllosilicates has global effects, due mainly to the role they are playing in geochemical mobility.

The peculiar structure of micas, serpentines and clay minerals (very strong bonds in the planes of they SiO_4 layers, but loose bonds connecting the layers with each other) render possible rather ionic and molecular binding, in some cases considerable swelling, while along the crystal planes micromovements (translations) go on easily. On this basis, **E. Szádeczky–Kardoss** ascribed an exceptional importance to the role as a lubricant of the layered silicates in the processes of global plate tectonism. It is beyond doubt that this phenomenon exists on the microtectonic scale. It is also true that the structurally bound water of the great masses of clay minerals during subduction may get into **p-t** conditions that would bring about its liberation, resulting in a sudden increase of volatile concentration. In the global plate movements, however, according to our present knowledge, they can not play a triggering role.

The ion-binding and exchanging capacity and high volatile content of the phyllosilicates beyond doubt play an important part in the matter and energy flows within the lithosphere, in the processes of melting and rock neoformation (anatexis). Most clay minerals are the stablest under surficial conditions. During diagenesis and metamorphism they suffer transformations in the following way:

→ degradation →

mica structure, chlorite → illite → vermiculite → smectite

← aggradation ←

On the Earth's surface beside the composition of the soil the climate, the topography and the biological (and human) activities are the main factors that determine the development of various soil types which are characterized by different mica structures. This, on its turn, affects the composition and quality of the vegetation.

It should be noted that mica structures may develop also in the lithosphere, due to the influence of magmatiogenic solutions (hydrothermal transformation) from other mineral phases. From this one may conclude that clay minerals may have formed even before the start of chemical weathering of the Earth's surface. Even more: such peculiar layered silicates may have developed which do not exist any more. Consequently the idea forwarded in the mid-20th century that the polymerizing role of clay minerals might have played a significant part is not excluded, but has not been proved so far.

E. Szádeczky-Kardoss ascribed great importance to the fact that these mineral structures contain 4 to 10 percent of the total water reserves of the Earth. About 60 percent of this amount can be liberated from the crystal lattice at temperatures over 500-600 centigrade. This assures the conservation of water and its lithospheric cycle.

30 years ago there were only some speculative ideas about the possible existence of organic matter bound to particular clay mineral structures (*organo-complexes*). At present, this is a fact proved by instrumental analysis. They play an important part in the binding and preservation of the organic substances of the soil. Research has proved also the catalytic role of clay minerals in the polymerisation processes of oil generation.

Summing up:

E. Szádeczky-Kardoss made the following main statements concerning the clay minerals.

1. They represent transitory phases between the solid and fluid states.
2. They represent a transition between the non-living and the living matter.
3. They are specific forms of matter characteristic for the planet Earth.
4. Their presence was indispensable for the genesis and persistence of life on Earth, as well as for the global dynamism of the lithosphere.

According to our present-day knowledge these theoretical generalisations are acceptable and would merit further research. The great theoretical and practical significance of this topic is supported by the methodological and theoretical progress of science in these particular fields during the past decades. Human practice, in particular the demand for a revolutionary transformation of agriculture and the environmental problems require in-depth research. Such disciplines like environmental geochemistry and environmental mineralogy elevated clay minerals research to its proper place. For the multilateral utilisation of the scientific achievements, as well as to its feedback to the better knowledge of the generation of the global dynamism and life, the global, integrated geoscientific concept, called "Geonomy" by **E. Szádeczky-Kardoss** and left over to us as his scientific heritage in his work "Geonomy" (the very first one of its kind), is absolutely indispensable.

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THE DARING IDEAS OF E. SZÁDECZKY-KARDOSS ABOUT THE APPEARANCE OF LIFE AND THE EXOSPHERE

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1. Introduction

The origin of life as well as its ancient environment and early development belong to the most difficult problems of scientific thought.

The Hungarian scientific community recognized the outstanding importance of this topic, and has contributed to it with inventive results. The contribution of biology has been particularly essential such as **Tibor Gánti's** "chemoton concept" (**Gánti**, 1979). Works of **Mihály István Szabó** and **Gábor Vida** also have to be mentioned (**Szabó**, 1988; **Vida**, 1981). Emphasizing the unity of biological and earth sciences their works introduce the results of the worldwide scientific studies on the origin and early evolution of life. This paper does not attempt to review the widely ramifying biochemical, molecular and theoretical biological results concerning the origin of life and the evolution, however, draws the attention to works of **Eörs Szathmáry** represented by two books by him and his co-author (**Maynard Smith** and **Szathmáry**, 1995, 1999).

Theoretical physics, mainly works of **György Marx,** are interested in the origins of life and its early evolution in several contexts (e.g. **Marx**, 1960, 1979, 1985, 2000). Pioneer experiments of **Sándor Szalay** to determinate the composition of the Precambrian atmosphere (**Szalay**, 1977) are also well-known to the international scientific community. Thinking about the chance of the extraterrestrial life, or even the "extraterrestrial intelligent life, civilization" is in close connection with the enigma of the origins of life. The works, observations and epistemological theoretical achievements of Hungarian researchers in astronautics, astrophysics, cosmochemistry, bioastronomy also confirm this statement (e.g. **Almár** 1995, 1999; **Székely**, 1997; **Végh**, 2000, etc.).

E. Szádeczky-Kardoss dealt with this problem in a whole chapter in his "Geonomy" published in 1974, and further relevant ideas can be found in other parts of the text (**Szádeczky-Kardoss**, 1974). The principal aim of this study is to draw the attention to statements of **E. Szádeczky-Kardoss**, to introduce his original and sometime daring thoughts, and to emphasize their scientific value. The interpretation of the pertinent ideas of **E. Szádeczky-Kardoss,** however, requires the knowledge of his two books on the "Cycle view" and "Universal connections of phenomena" (**Szádeczky-Kardoss,** 1986, 1989) that followed his "Geonomy". The latter one has been published also in English (1992).

Research on the origin of life must not be separated from the geological study of the formation and early changes of the ancient environment. What was the early evolution of the Earth like? When and how was the Earth-Moon system developed? When did plate tectonic processes and Precambrian orogeny begin, and what dynamics did they continue with? How was the composition of hydrosphere and atmosphere formed and changed? What were the early climatic changes? How were the systems of sedimentary rocks modified as consequence of the modifying hydrosphere and atmosphere? Answers to these questions have been taking shape through debates, influence simulation experiments, models and theories concerning the origins of life.

Knowledge of the nature and the changes of the ancient environment is even more important for understanding the early formation and evolution of life. In this case this concept is modified and widened because the biosphere has exerted influence on the lithosphere, hydrosphere and atmosphere through a feed-back mechanism since its birth. Living and non-living systems exist in close interaction as factors determining each other. Regarding the ancient atmosphere, for instance, it is generally accepted that extra oxygen beyond the relatively small amounts deriving from photodissociation of water is due to the photosynthetic activity of bluish green algae (**Urey**, 1952; **Rutten**, 1970; **Schidlowsky**, 1971; **Kasting**, 1982, 1987, 1993). Atmospheric free oxygen essentially influences both the environmental changes (processes of weathering, soil formation) as well as the differentiation and adaptive radiation of living structures (change from fermentation to breathing, the development of organs etc.)

The "Geonomy" of **E. Szádeczky-Kardoss** did not only reproduce the knowledge of his time but, performing several simulation experiments and model calculations, interpreted the 4,5 billion (10^9) year history of the Earth and the evolution of the exospheres by a particular approach.

The evolution of life and the Earth is characterized by "cycles" (orogenic and plate tectonic ones) and "big leaps" (events). **E. Szádeczky-Kardoss** distinguished the Prearchaean (4,5-3,5 Bya), Archaean-Proterozoic (3,5-0,57 Bya) and Phanerozoic (>0,57 Bya) Eons.

Beside field work (collecting fossils and sampling rocks) and simulation model experiments, theoretical approach is basically important for understanding the problem of formation and early evolution of the exospheres of the Earth from the point of view of the Prearchaean events. The keys are the evolution models, i.e., "stationary" or "dilatational" models of the Earth should be taken into consideration. It was **E. Szádeczky-Kardoss** who proposed the so-called "contractional-dilatational" model of the Earth, and approached the formation of the Prearchaean ancient atmosphere, hydrosphere and lithosphere in a quite new manner.

Opinions about the origin of life and its ancient environment have been extremely varied. There are several options for the site of birth of life: in the tidal zone of the ancient seas, in kind of a "clay mineral soup", in mud-volcanoes or near the conduits ("smokers") of the mid-oceanic ridges on pyrite crystals, or life on the Earth may be even a result of "panspermia", seeds or germs having been transported by comets and meteorites.

2. Definition of Life

Every theoretic scientist interested in the origin of life has to face the question: "what is life?" Many of them pointed out that it is impossible to answer this question because of the complexity of the problem. Others answered the question, but the presentation of these definitive answers would require another paper, since they would have to be reviewed also from the historical point of view.

E. Szádeczky-Kardoss emphasized that the definition of life must start "from the side connecting it to inorganic world and not from that which separates them": "Accordingly, *life on the Earth is a self-maintaining operation of super-crystallized macro-molecules which is adaptable to the surficial changes; these macro-molecules formed by connection of at least 3 types of basic molecules progressively crystallized to larger molecules having definite structure in the ancient high-pressure as well as* CH_4*- and* NH_3*-rich atmosphere of the Earth, and finally they became to be unambiguously coded by partly inorganic cyclic processes.*"

This definition contains the basic concept being present from **Aristotle** to our days in scientific thought: material systems differ from each other only by the respective level and organization quality. His individual approach consists in his "geonomic view", the concept of bilateral unity of life determined by the inorganic nature and its "laws".

The chemical composition of living organisms preserves the features of the ancient environment. This marker can be traced from the elementary level of abiotic organization, through the formation of polymers, to the evolutionary process producing the first living cell. Therefore, the question "how and when was life formed?" can be answered, and features of the ancient environment, the exospheres, can be characterized by consequent experiments and calculations.

The other part of the definition concerns the interpretation of the organizational process that leads from the inorganic matter to the organic one. **E. Szádeczky-Kardoss** analyses the connection system of the counter-points ("the analogies") rather than the "extreme differences of counter-points". The main aim of his interdisciplinary and original statements was to establish relationships between several features of the counter-points "inorganic starting point and organic result".

E. Szádeczky-Kardoss made the following epistemological statement that may seem too optimistic even nowadays: *"We are able to modify the parameter corresponding to the geonomical factors at relatively short intervals of time according to the geonomic succession. In this manner it becomes, in principle, possible to synthesize living molecules and to simulate the life processes experimentally*" (Geonomy, 1974, pp. 322- 323.)

3. Hope of life in the Cosmos

Obviously, there is a deterministic relationship between the origin of life and exceptional and particular conditions characteristic for our planet, the Earth. **E. Szádeczky-Kardoss** recognized that *"mainly the exceptional accumulation of* H_2O *in the form of water led to special global dynamics in the Earth, which is absent in the other planets, and it made the development of unique features of the Earth possible. Accordingly, water accumulation in the Earth leads to the principal characteristics of the Earth, such as the clay-based evolution of rocks, global dynamics and evolution of life."* He added: *"Hypothetically, it is possible, however, that some planet characterized by high-level life similar to the Earth has formed in other solar systems, but it requires extremely strict conditions of the mass and surface temperature of the planet, see chapter A/1"* (Geonomy, 1974. p. 71 and 73).

Using the **Drake's** formula and modified functions **E. Szádeczky-Kardoss** attempted to calculate the frequency of life in the Cosmos. According to his calculations, *"occurrence of intelligent organisms might be expected in every second galaxy, only."* These problems can be found in his later works. He declared that intelligent life is much rarer than it had been assumed, and there is no life in the Galaxy but on the Earth, though there might be *"some beginning of life at very low level"* on Mars (Geonomy, 1974, p.18; 1986, .p. 82; 1992, p. 107).

Thinking about the existence of cosmic civilizations, or even the hope of making connection with them, began simultaneously with the start of astronomical research (**Cocconi** et **Morrison**, 1959; **Morrison**, 1962; **Cameron**, 1963). The first special radio telescope was built for the signals expected from the direction of the τ Ceti (**Drake**, 1962).

The reaction of **E. Szádeczky-Kardoss** was sceptical, or even revealed some antipathy to it: *"As an extreme consequence of the Copernican aspect.... interstellar communication (Cameron, 1963) was dreamed about. This concept induced a series of pseudo-scientific hypotheses resulted in fashion of sci-fi literature..."* (Geonomy, 1974, p. 381). The epistemological approach of **Gy. Marx** is absolutely different: *"Perhaps, we will receive answer from the direction of the τ Ceti 21 years later ... This needs fortunate coincidence of events of quite low probability. According to our recent knowledge in physics, however, we cannot make more for it, and, after all, it is not impossible physically as a matter of course"* (**Marx**, 1960, p. 337).

Since then, research of the assumed extraterrestrial intelligence (SETI – Search for Extraterrestrial Intelligence) has developed to be an independent, multiplied and ramifying scientific method (**Almár**, 1999), there is no doubt about its role and importance.

The extraterrestrial origin of life, "panspermia hypothesis" of **Svante Arrhenius**, was renewed by Sir **Fred Hoyle** and **N. Chandra Wickramasinghe.** Their works based on analysis of galactic infra-red radiation sources and on investigation of interstellar dust. These authors detected not only simple organic compounds but "polyformaldehyde molecules and cellulose-like complex polymers", and even "hibernated dry bacteria" was also assumed by them. Although the scientific public has received their theory on the origin of life with scpticism, they undoubtedly explored new research fields (**Hoyle**, 1982, 1983, 1994; **Hoyle** et **Wickramashinge**, 1979, 1982).

Research of the extraterrestrial material organization is timely. Newer and newer groups of compounds have been identified in the organic molecules of the carbonaceous chondrites. For example, **Cooper et al.** (2001) identified polyols, sugars, sugar-alcohol, sugar-acids, compounds essential for RNA, DNA, cell membrane and for energy donors during the reanalysis of the Murchison and Murray meteorites. This result is important not only for as a novelty of identification of these compounds, but it draws the attention to the fact that photolysis and formaldehyde chemistry may play a role in the extraterrestrial molecular organizational processes.

A paper of **Marcano** et al. (2001) offers a good example for novelties of the simulation experiments. Assuming thermostable n-alcane ($\geq$ n-C_{18}) primordial atmosphere for the beginning of the formation of the Earth-like planets, they were able to form peptide-like components, aromatic and non-aromatic alcohol, non-water soluble synthesis products. This way, they present a possible way of water-free polymer formation and molecule stability.

Micrometeorites has been also studied. **Maurette** (1998) discussed that these carbonaceous objects of less than 1 μm in size may act as independent "microscopic chemical reactors" in the process of the prebiotic molecular synthesis 4 billion years BP.

The "modern panspermia" theory (**Melosh**, 1988) may not ignored, either, because presence of not only abiotic polymer structures but so-called Nanobacteria is supposed to be identified in meteorites. First, trace of extraterrestrial life were supposed to be in a Martian meteorite collected in the Antarctic (**McKay** et al., 1996), and then in other famous meteorites, such as Murchinson (**Hoover**, 1997), Allende (**Folk** et **Lynch**, 1997) and Tatahouine (**Gillet** et al., 2000), moreover, Siderococcus- and Sulfolobus-like Coccoids were supposed to be determined in Lunar regoliths (**Zhmur** et **Gerasimenko**, 1999). These are debated by several researchers. Some of them regard the identified biomarkers as terrestrial contamination, and suppose the structures to be results of impact events, i.e. "shock metamorphic products", and others debate the existence of Nanobacteria or do not accept the arguments for their identifications (e.g. **Becker** et al., 1997; **Jull** et al., 1998; **Steel** et al., 2000; **Pósfai**, 2003).

Research of the so-called "habitable zones" is in search for other possible site, environmental conditions and forms of the formation of life, mainly in our solar system, but in some cases in other galaxies (e.g. **Kasting**, 1997; **William** et al., 1997; **Doyle** et al, 1998; **Franck** et al., 2000, 2001; **Gonzalez** et al., 2001).

Planned astronomical research of our solar system may reveal whether life may form, is existing, has not begun or come to an evolutionary deadlock on Mars and Europa (**Illés-Almár** et al., 1997; **Brack**, 1999; **Mischna** et al., 2000; **Westall**, 2000), perhaps on Titan and Triton (see **Almár**, 1999, pp. 52-58 for more details), or on Venus (**Cockell**, 1999).

Interpretation of the photos on the southern polar region of the Mars taken by "Mars Global Surveyor" is also worth of interest. Seasonal changes of the so-called Dark Dune Spots (DDSs) may suggest biological activity on that planet (**Gánti** et al., 2002a,b; **Horváth** et al., 2001; **Horváth** et al., 2002a, b).

Terrestrial analogues may also help to search the possibilities of cosmic life. Study of the so-called "extremophyles" and their habitats is important. For example, the "hyperthermophile and/or methanogene" Archeas live in ocenanic fault systems and hydrothermal fluids of over 85 C°, and in even one km depth of 110-120 C° and high pressure (**Chapelle**, 2002; **Reysenbach** et **Cady**, 2001; **Reysenbach** et **Shock**, 2002; **Newmann** et **Banfield**, 2002). Community of Antractic and Greenland ice, and that of the lakes under the ice represents another group (**Price**, 2000; **Siegert** et al., 2000). Maybe, the subsurface "lithoautotrophic life" (**Stevens**, 1997) is more common than it was believed.

4. "Szádeczky-Kardoss's Earth model" and the origins of life

Ideas on the origin, formation and early evolution of life are significantly influenced by the knowledge of the "laws" governing the cosmic organization of matter, planetary evolution and, as a part of it, the structure and formation of the Earth.

Assessing **E. Szádeczky-Kardoss's** works concerning this issue, it can be stated that all of his ideas on the origin of life were basically inspired by the so-called *"complex or geonomic evolution model of the Earth"* elaborated by him previously. This "*contractional-dilatational model of the Earth*" assumes that volatiles played a significant role in the accretion of the inner planets, and the character of the Earth was similar to that of the Jupiter-type planets because of the abundance and extension of the volatiles. The volatiles were released very slowly (by "*restrained dissipation*" as **Szádeczky-Kardoss**, 1968 called it), and "*the alkali-silicates dissolved in them*" accumulated as crust-forming materials. Therefore, the total volume of the Earth decreased (contraction) but, simultaneously, the volume of "*inner parts which had had an approximately constant mass*" began to increase (dilatation) because of the decreasing pressure, the forming thermal convection, and the magmatic deep currents. This theory was based on several detailed model calculations, and provided a new interpretation of the formation of the ancient exospheres, their relationship, and origins of life.

The statements of **E. Szádeczky-Kardoss** on the first one billion years of the Earth are the following.

The initial, so-called maximum temperature (possibly not higher than 200-300 °C) is characteristic for the history of the Earth from 4,5 to 4,2 billion years. By 3,5 billion years B.P. the average temperature has dropped to 50-80 °C. Initially, the atmospheric pressure was $2{,}64\text{-}6{,}73 \times 10^6$ atm, later it fell to 100-176 atm. After cooling the total volume of the separated atmosphere and hydrosphere was higher by three orders of magnitude (!) than it is now. The ratio of fluid and gas phases was 65 (ancient hydrosphere) : 34 (ancient atmosphere) in the outer fluid zone of the 3,5 billion years old Earth according to experiments of **László Pesthy, Csanád Sajgó, Ottó Tomschey** and **Elemér Tomor** (in GEONOMY, 1974, p. 260). That time the total mass of the ancient atmosphere was 113 times more while that of the ancient hydrosphere was less than at present. In spite of its smaller mass, the proto-ocean covering the Earth was deeper since the Earth had a much shorter diameter (**Hilgenberg's** model).

The immense system of dispersed aerosol that had surrounded the Earth was transformed into an atmosphere by physical (gravitation, dissipation) processes. At first, the separated gas phase was reductive, then neutral. On the basis of model calculation (m) and simulation experiments (s), the author supposed that 3,5 billion years ago the Earth's atmosphere had the following mass ratios for gases:

CO_2 40%(m), 57%(s) : H_2O 40%(m), 28%(s) : NH_3 14%(m), 11%(s) : CH_4 6%(m,s).

The extraterrestrial material served as source for the ancient crust (SiAl), the so-called *"sublimite"*, became hydrated in the ancient atmosphere, and after accumulation it might have been similar to the montmorillonite-serpentinite-hydrous mica - Mg, Fe-rich carbonate paragenesis of the recent hypo-magmatic phase. This ancient alkali-alumo-silicate system had a multifunctional and prominent role in the origin of life.

The ancient ocean became separated from the ancient atmosphere as early as 4,4 billion years ago. It was deeper and more extent than recently. Three billion years ago it was acidic and, in some places, "oxidative". It is remarkable that **E. Szádeczky-Kardoss** did not accept the common opinion of that time that the ocean basement was uniformly reductive, anoxic. According to him the reductive facies character of the oldest sediments is a consequence of advanced diagenesis and low-grade metamorphism that resulted in regular decrease of the oxidation degree rather than of the anoxic character of the ancient ocean. He said that "*...seawater dissolves the oxygen released by metamorphism, thus it locally becomes oxidative. Partial melting of the ultra-basic rocks in the mantle may represent an important oxygen source. It can reach sea-water mainly through the deep sea trenches.*" (Geonomy, 1974, p. 274). The author regards the whole ocean environment to have been oxidative from 3 billion years B.P.

The author characterizes the 3,5 billion years old ancient environment and its reproductibility in an individual way: "*according to our model the real ancient substrate was formed at the boundary of the fluid and solid zones of the Earth surface which basically differed from the present ones, therefore its composition could also differ from that of the present sediments. This volatile-rich and, consequently, sensitive environment dominated by inorganic mineral substances, which were necessarily transformed during the billions of years and it can not be found in its original form any more, is the real substrate of formation of the living matter; its knowledge is a prerequisite of a more precise determination of life and of its synthesizing.*""

There are several arguments both against and for **E. Szádeczky-Kardoss's** model of the evolution of the Earth.

One of the most important counter-arguments is that the Earth was formed by dry meteorite dust and planetesimals; the temperature concerning the Earth-Sun distance (1 Astronomic Unit) exceeded 1000 °K that obviously precludes the existence of fluid water on the surface of our planet.

However, it can be considered that **Szádeczky-Kardoss's** hypothesis is proved by the theory of **Oró** et **Lazcano** (1996) and **Owen** (1997), that water got to the Earth by impact of extraterrestrial objects, mainly comets. This theory is proved by the mathematical model of **Delsemme** (1996), which suggests impact events of comets affecting the Earth as a result of orbit modification effect of the formation of Jupiter and Saturn, and supposes that the mass of the water captured by this way exceeded that of the present-day oceans.

The author of this paper believes that the immense outer "aerosol disperse system" of **E. Szádeczky-Kardoss's** Earth model can be explained by this planetary event. Moreover, the hypothesis that the impact-accretion events of the Earth-Moon system (**Canup** et **Esposito**, 1996), or the ensuing Hadean and Archaean asteroid and meteorite events (**Arrhenius** et **Lepland**, 2000), might have made the outer volatile zone disappear just because of the immense exosphere proposed by the geonomic Earth model could be reconsidered. It is possible that the Earth was covered by water as early as 4,4 billion years ago (**Delsemme**, 1996) as it was assumed by **E. Szádeczky-Kardoss,** too. Moreover, **MccCendon** (1999) suggests that the extraterrestrial objects impacted during the above mentioned cosmic event could have a significant influence on the structure of exospheres, such as the ion-content of the ancient ocean, and it might have produced even clayey suspensions. **E. Szádeczky-Kardoss's** ancient ocean, the so-called "*sublimite*", is identical with a "*clayey soup*".

Another importance of the geonomic model of the Earth is that it shed new light on the role of geological time, i.e. the dynamics of the chemical evolution.

According to **E. Szádeczky-Kardoss,** the process of molecular evolution to the formation of the simple abiogenic organic molecules required quite a long geological time. This can be explained by "very low activity" of the Earth during the first one billion years. In contrast to this, he interpreted the structural polymer stage of the molecular evolution as a quite rapid event (just a moment in the geological time-scale), a key-point that can be connected to the beginning of formation and operation of the global dynamics (plate tectonism, volcanism, exogenous processes) as a limit event.

As a consequence of the geonomic model of the Earth it is supposed that the first self-reproductive macro-molecules were formed on the basement of the oceans in deeper regions and not in different environments. This may be the only one explanation for the uniform code system of life and formation of the first cellular living organism (the first common ancestor). However, the different environments and sediments played the main role in the further diversification of living beings.

This thought does not preclude the possibility of a polyphyletic origin. *"More or less isometric structures of living forms associated with siliceous rocks could be also formed in warm water lakes of ancient volcanic rocks, in particular"* (Geonomy, 1974, p. 324).

The geonomic model of the Earth does not preclude absolutely the option of extraterrestrial origin of life, either. According to the author: "... *an extraterrestrial seed could be multiplied only in the early stage of the Earth, that was extremely favourable for the formation of life, and when the autochthonous terrestrial life did not cover the surface. However, it could not survive in the struggle against the life that has come to being on the Earth.*" (Geonomy, 1974, p. 363).

5. Determining role of mineral phases

Bernal (1951, 1967) was the first to propose the possibility of polymer formation by clay minerals adsorption in subvital environment, i.e. that a clay mineral might have been responsible for the first replication. Later, **Cairn-Smith** (1982) as well as **Cairn-Smith** et **Hartman** (1986) published that mineral surface can catalyze the formation of several compounds that are essential for life, chirality, and even that the dominance of the catalytic clay mineral surface worked as primary genetic mechanism, and the special RNA and/or protein connection was to develop later (**Nussinov** et al., 1997).

One of the crucial points of the origin of life is the question how the instructional polymers were organized. Now, it is generally accepted that nucleic acids might have been preceded by simpler instructional polymers, and since the knowledge of the basic features of clay mineral-organic material systems (**Theng**, 1974) the hypothesis that clays were these primary polymers has been more and more accepted.

Much ahead of the present ideas and hypotheses **E. Szádecky-Kardoss** regarded the "*prevital organic – inorganic complexes*" as a transition between living and non-living structures, and indicated the way of the evolution of matter as the "*inorganic crystal → complex inorganic molecule charaterized by several types of bond energy (e.g. OH containing silicates) → complex inorganic –organic molecule → organic polymer → macro-molecule mainly characterized by protein – sugar – phosphate → living molecule organized as cell*" (Geonomy, 1974, p.350).

The chapter on "Bilateral organic-inorganic chemistry" (Geonomy, 1974, p. 331-349) deals with an informative connection between the element composition ratios of living organisms and the chemistry of the ancient exosphere. Accordingly,

- calculations prove that element ratios concerning the average composition of living organisms (H, C, N, Ca, P, Cl, S) may be in connection with *"the composition of the ancient hydrous carbon-dioxide hydrosphere of high concentration and pressure"*, but not with the element composition of the ancient atmosphere;
- element ratios of the organic macro-molecules – and their constituent compounds: the amino acids and the nucleic bases – building up living organisms (H, C, N, S) could be related to the chemistry of the methane and ammonia rich, still *"undifferentiated"* ancient atmosphere; sulphur and phosphorus can be linked to troilite (FeS) and schreibersite ($[Fe, Ni, Co]_3P$), respectively, which are characteristic minerals of the ultrabasic lithosphere of that time;
- the *other essential elements of living organisms might be in genetic relationship with the micro and trace elements of low and medium ion potential enriched in pelitic sediments.*

Assessing the knowledge of his time on lattice constants, coordinations, bond energies and structures of phyllosilicates, **E. Szádeczky-Kardoss** concluded that

- the phase transition of mixed-structure clay minerals can be characterized by alternating exo- or endothermic processes, hence they serve as *"thermostats"* during temperature changes of the environment, therefore, they could protect thermally sensitive organic molecules building into the lattice even at higher temperatures, and could provide the moisture necessary for chemical reactions;
- besides kaolinite and montmorillonite, the compatibility of lattice constants can be also extended to serpentine minerals (antigorite), hydro-micas and muscovite. Phyllosilicate templates are necessary for the formation of not only proteins but also for that of fatty acids;
- beside the structures of chain polymers, the compatibility of lattice parameters and the characteristic electrostatic effects of phyllosilicates create their spiral structures, and it can be also assumed that it is phyllosilicate code that brings about amino acid sequences and chirality;
- the DNA molecule *"directly reflects the (hydro-)mica structure"*. The uniform formation of life is proved by the triplet code. *"It is also in connection with the hexagonal structure containing three parallel pairs of faces. Since 1,5 base pairs belong to each hexagon, two mica layers lying on two sides of the DNA spiral link three base pairs, i.e. triplets."* (Geonomy, 1974, p.345).
- Energy to the process is provided by the Sun, *"the regular daily, monthly, annual, etc. changes of solar energy getting to the surface of the Earth result in material exchange and, as a consequence, create micro-levels inside the macro-molecules.., at the same time, the separation of the specialized molecule groups results in the development of rhythmic metabolic-automatism."* (Geonomy, 1974, p.346).

Summary

I tried to compare the statements made by **E. Szádeczky-Kardoss** to the antecedents and our recent knowledge. As a matter of fact, a good many of his conclusions are relevant even today, and are in accordance with the latest achievements of researc h. Which are these?

(1) Living structures might eventually have come from another planet or solar system to the Earth. However, every record indicates that chemical composition of the primitive Earth as well as physico-chemical conditions characteristic for the Earth at the time of the formation of life could be the most favorable for the generation of life in the solar system.

(2) The energy necessary for chemical reactions, directly or indirectly, derived from sunlight.

(3) Many simple compounds essential for life might be formed in the atmosphere where gas compounds serving as precursor might have been present, and where also sunlight and electric charge enough for chemical reaction were present. Compounds formed in the atmosphere might have been transferred to the ocean by rain. Concentration of the essential compounds in the ocean might have been too low for further chemical reactions. This means that these compounds had to be concentrated; one of the possible places of concentration was the solid-liquid boundary layers, such as clay.

(4) The first organisms had to be products of an extended process of several stages. Each step had to lead to a progress that offered a kinetically more advantageous situation for the synthesis of mixtures of the products, and somehow they were stable enough to subsist to make the next step.

(5) Once instructional polymers had been formed, the following evolutionary steps were inevitable. Namely the instructional polymer has the ability of the self-reproduction, and it is able to store the information that is necessary for the evolution.

(6) The key problem of the origin of life is to identify the evolutionary events which led to the first polymers of this kind. Since nucleic acids are the only polymers we know, the primary question is whether

simpler instructional polymers existed before nucleic acids. Clays are regarded as possible polymers of this kind.

Science dealing with the origin of life is basically theoretical, but the experimental approach is also important. **E. Szádeczky-Kardoss's** "Geonomy" repeatedly refers to simulation experiments performed in the Geochemical Research Laboratory of the Hungarian Academy of Sciences. Unfortunately, details of these experiments as well as experimental methods and procedures are not known to the author ofthe present paper. It would be exciting to trace these experiments, and to know how far this excellent scientist reached during the experimental study of the chemical evolution of "geonomic view". Moreover, it would be interesting very much since several monomers have already been produced by synthetic organic chemical simulations; however, the production of nucleic acid type polymers has failed. Perhaps the evolutionary process leading from the simple monomers to the RNA could be more easily reached by knowing the experiments made by the team of **E. Szádeczky-Kardoss.**

Considering the physico-chemical conditions proposed by **E. Szádeczky-Kardoss's** contractional-dilatational model of the Earth, the possible mineral carriers, and the experimental results concerning abiotic synthesis of organic compounds, the author of this paper supposes that this simulation experiments were performed in alternating high-pressure vapour and liquid phases.

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BILATERALISM OF ORGANIC-INORGANIC CHEMICAL PROCESSES

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The three aims of the present paper are: i) to give a short summary of the two relevant chapters, ii) to outline the recent developments in the concerned fields, and iii) to demonstrate the extraordinary role of life and her products in the inorganic world..

I) In this section I disregard the questions that are discussed by **Gy. Szőőr** or **T. Póka** (in this volume), although they were dealt with basically in the chapters C 9 and C 10 of Szádeczky-Kardoss's Geonómia (1974)

Szádeczky-Kardoss (1974) in those chapters set up a hypothetical synthesis of inorganic and organic processes on the surface of the early Earth after the appearance of proto-oceans involving ancient reductive atmosphere. In a first step, the ultramafics of Earth' surface were weathered producing phyllosilicates to be catalysts of the prebiotic synthesis of organic molecules (**Oparin**, 1938, 1959, 1961, 1968; **Haldane**, 1928, 1954; **Bernal**, 1951, 1959a, 1959b, 1961, 1967; **Rutten**, 1971).

He calculated the average elementary composition of living organisms, and concluded that the C/O and H/O ratios in the molecules of the recent biota have preserved the original ratios of the high-pressure ancient hydrosphere rich in CO_2,. Later the ratios were maintained by photosynthesis (**Szádeczky-Kardoss**, 1955, **Bowen**, 1966, **Vinogradov**, 1953, 1963).

Szádeczky-Kardoss suggested that the high phosphorus content due to schreibersite provided the base for ATP and its related compounds (**Matheja** and **Degens**, 1971). He compared the trace and rare element concentrations in living matter with those in shales (clay rich rocks), and found correlations between 25 of them, except theorganophilic and argillaceous elements (C, O, H, N and Si, Al, Ti, Fe, respectively). The common ions of clays became physiologic or catalytic ions in the living matter (e.g. Mg, Ca, Cl, and Fe, Mn, Zn, Co, Ni, Cu, respectively). Other trace elements (Mo, V, and J) are also enriched in both kingdoms (e.g.: **Bertrand**, 1950; **Szádeczky-Kardoss**, 1955, **Bowen**, 1966, **Vinogradov**, 1953, 1962, 1963, **Turekian** and **Wedepohl**, 1961).

The presence of clay minerals was considered to be a prerequisite for prebiotic organic processes by **Szádeczky**-Kardoss: at first, the diluted organic molecules (the "thin soup") were concentrated on the surface of clay minerals, than their polymerization took place, catalysed by clay mineral matrix (physical adsorption, then chemisorptions: polymerization are the steps in the synthesis; as suggested: by **Bernal**, 1951, 1961; **Vernadskii**, 1924, 1926, 1930, 1997). The protecting role of clay minerals was also important for large molecules, molecular aggregates; meanwhile their crystal structure had a decisive control on the structure of organic products. He found strict relationship between the lattice constants of phyllosilicates and the sizes of many different basic building blocks (prevital essential organic molecules).

Szádeczky-Kardoss recognized the importance of Le Châtelier's principle in synthesis of the living matter (e.g. the size of organic units growing with decreasing pressure, or beings ensure their own co-ordinated structure by increasing the degree of disorder of their surroundings, i.e. increase in entropy around themselves, and the phenomenon of "aperiodic crystals" (**Schrödinger**, 1945), as well as the way of how they build the structure of macromolecules. The parameters of the helix structure of fibroid proteins and the lattice constants of antigorite and smectite coincide. According to **Szádeczky-Kardoss's** calculations there is a similar correspondence between the double helix of DNA involving the sizes of pairing nucleic acid bases and deoxyribose, and the hydromicaceous silicates; the PO_4 / SiO_4 and SiO_4 / K ratios are identical, i.e. the mica imprints its structure to the DNA. The mononucleotide units in DNA and RNA may be regarded as genetic code words (each triplet is termed a codon), and codons are universal for each beings (from bacteria to human). He suggested that the codon formation is controlled by two micaceous layer units binding three base pairs i.e. triplets and the predominance of C_{16} and C_{18} fatty acids is also determined by micaceous layer silicates (C_0 = 20 Å). On the epitaxial generation of prebiotic essential first complex compounds on phyllosilicates, the living organisms inherited the inorganic-organic complex basic codes.

Szádeczky-Kardoss accepted the extraterrestrial origin of life as a parallel phenomenon, but he had strong doubts about the competitiveness of the panspermia with the autochthonous life on Earth during the intensive development and general propagation of life on the whole Earth.

Szádeczky-Kardoss (1974) synthesized his knowledge about our solar system, the history of the Earth, the crystal structure of minerals and the primitive building blocks of living matter to sketch the birth of life in our planet. His idea was partially demonstrated by our experiments (**Szőőr**, in this volume).

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II) Developments in the aforementioned topic after Szádeczky-Kardoss's Geonomy was published.

Advances and developments on the horizon of the topic: for or against [questions that are discussed by **Gy. Szöőr** or T. **Póka** (in this volume: the questions of new ideas about ancient atmosphere, definition of life, hope of life in Cosmos: e.g.: **Almár**, 1995, **Folk** and **Lynch**, 1997, **Gánti**, 1979, **Maynard Smith** and **Szathmáry**, 1999) are omitted].

Ideas about the origin of life on the early Earth have evolved considerably over the last 30 years, but many uncertainties still remain. Many parts of possible synthesis have been provided by new results and finds, more mysteries. Old ideas are still alive, but several new ones have arisen.

On half way, **Degens** (1989) summarized the advances and evaluated the prospects. As the accumulated data could not bridge the gap between mineral / chemical evolution and the biological one, the theories gave birth to new rival ones.

Lovelock (1979, 1988) introduced the *Gaia*, "a new look at life on Earth" This concept was earlier recognized by **Vernardskii** (life as "Lord of Planet Earth") i.e. a self-regulating planetary system. **Lovelock** claims that there is strong evidence to suggest an overall systemic control of the earth's surface temperature, atmospheric composition and ocean salinity. Lovelock made "*The Daisyworld*", a computer model of a hypothetical planet with characteristics similar to Earth including a rising input of solar heat, to refute most of criticisms: the theory is not scientific because it is impossible to test it by controlled experiment. He points out that, in this model, the effects beneficial to life are obtained by means of natural selection only - there is no need for purpose, altruism, teleology or anything beyond normal genetic process.

Cairns-Smith (1982) envisaged irregularities in the structure of a clay - for example, an irregular distribution of cations - as the repository of genetic information. His basic statement is identical to **Szádeczky-Kardoss's** (1974) opinion: "I think that the process most likely to be responsible for the origin of life is the process of crystallization". He proposed that life on Earth evolved through natural selection from inorganic crystals. Organic compounds became stepped later into a living entity that already existed in the form of clay organism. Selection could be achieved if the distribution of cations in a layer determined how efficiently that layer would be copied. **Cairns-Smith** and **Hartman** (1986) published the proceedings of Glasgow conference in 1983, concentrating on "clay hypothesis" ("to what extent might clay minerals have been suitable as bio-materials, to make such things as genes, the catalysts, and the membranes of the very first organisms?"). They thought they had identified the mechanism by which genetic systems composed of organic polymers are most likely to have formed, but "in any competition between organic and inorganic control systems, the organic ones would be almost bound to win in the end - because metastable structures can be engineered more finely with the use of organic molecules". This statement explains **Szádeczky-Kardoss's** suggestions (1974): the pivotal clay minerals in the synthesis of the first living beings had been destroyed during the changes of conditions on the early Earth, and the increase in size of the organic molecules withinthe strcture of the phyllosilicates was limited, consequently the inorganic-organic symbiosis had to come to an end. **Cairns-Smith's** hypothesis seems to have been neglected in recent times. Up to now no one has tested this daring hypothesis in the laboratory.

The universality of the genetic code has been denied, but the number of the exceptions is very limited, and they are accepted as aberrations, i.e. the consequences of defective replications as a result of a series of nondisruptive changes (e.g. **Osawa et al.** 1982)

Research on the origin of life seems to be unique in that the conclusion has already been accepted. The task is to find the life-making reaction vessel and to describe the detailed mechanisms and processes by which this happened.

Woese (1979, 1980) suggested that the most primitive forms of life were generated in the outer atmosphere of the early Earth where the temperature was lower than water boiling temperature. Storms carried dust to this sphere where water drops were formed and the first cells generated in drop phase. Later the atmospheric life moved to the oceans. Recently **Tuck** (2002) proposed that atmospheric aerosols might have been the prebiotic chemical reactors of the early stages of life.

The occurrence of certain microorganisms at deep-sea vents suggests that life could have arisen in a submarine hydrothermal vent (e.g. **Jannasch** and **Mottl**, 1985, **Nisbet** and **Fowler**, 1996). They suggest that hydrothermal systems on ridge sediments may have been pivotal in providing environment to sustain the first communities of life. Their hypothesis claims that the hydrothermal-world had been the first and its imprint has burned in all organic life.

Wächtershäuser (1992): introduced the Iron-Sulfur World as the life-making box, instead of clay minerals. The "prebiotic pizza" hypothesis was successful in experiments. It requires higher temperature and pressure than other surface models.

Sugisaki and **Mimura** (1994) emphasized the role of mantle hydrocarbons as prebiological organic matter in the primitive Earth i.e. as a first step in the chemical evolution of life.

Ponds, not oceans, as the cradle of life were suggested by **Apel** (2002). He and his co-workers were able to create stable vesicles using freshwater solutions of ingredients found on the early Earth, but not salty solutions. The first step was the formation of a spherical membrane according to the present theories on the origin of cellular life. The self-replicating chemical chains were enclosed by vesicle. The hypothesis is that the necessary ingredients for primitive membranes were all available on the early Earth, and once formed vesicles spontaneously in water. When salt or ions of Mg or Ca were added the vesicles came apart. Nevertheless, the problem of when multicellular life appeared on Earth is unsolved. However, the newest results have shown the possibility of the presence of a 4,300 Myr old liquid hydrosphere, i.e. oceans on the early Earth as one of the fundamental requirements of life, supposing an earlier emergence of primitive life (**Mojzsis** et al, 2003 or **Bada**. 2004.

The theories on origin of life could not bridge the gap between chemical and biological evolution and several unsolved problem remained. These uncertainties introduced the criticism of current models. **Aw Swee-Eng** (1996) concluded: "The available evidence from the field and laboratory is not amicable to the theory that life began with the accidental assembly of a self-replicating molecule. It is now accepted with so many qualifications that its scientific integrity, even as a heuristic device, is questionable". This statement proves that the current theories on the origin of life on Earth are still far from answering the problems of prebiological and biological evolution.

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III) Reverse effect ("feed-back"): living organisms and biologic matter control on inorganic kingdom and processes on and in Earth

Vernadskii (1934) stated: "On the surface of the Earth, there is no chemical force that would act more constantly and therefore more powerfully in its final consequences, than living organisms taken as a whole. The chemical phenomena of the biosphere have lasted throughout the course of all geologic history".

The main remains of life in the stratigraphic record are phosphatic, calcareous and silicified tissues, thus calcium, silicon, carbonate and phosphate are the main elements/ions in the process of mineralization of biological tissues. A rather considerable part of sedimentary rocks has not been produced originally by chemical sedimentation.

Carbonate sediments which accumulated in seawater are usually made up partly by rock forming shells or tests composed by high-magnesium calcite or aragonite. The rarity of these minerals in older sediments suggests that these minerals are easily transformed into more stable calcite. The primary calcite is more resistant against diagenetic recrystallization (e. g. foraminifera shell). From this reason, the percentage of organic deposits in carbonates (deposits formed by organism or their remains) is seriously underestimated.

Cherts (silica: quartz, opal, α–cristobalite) are rather common silica-rich sedimentary rocks. The origin of silica from either radiolaria, diatomaceous or sponge residues, or from chemical precipitation cannot be easily determined in cherts. The solubility of silica is rather high so that many of the thin-walled shells and needles of siliceous organisms are lost through recrystallization, consequently the proportion of biogenic silica may also be underestimated.

Phosphate rocks (often of complex composition) may have biogenetic origin (remnants of guano, coprolites, major element of teeth and bones; for a long while the only source to manufacture phosphorus was urine) or an unknown inorganic origin (often interbedded with dark shales).

The sulfur emission to the atmosphere from combustion is a crucial problem, but it turned out that volatile biogenic sulfur species contribute similar quantity of sulfur to the atmosphere as humans do ($103 * 10^{12}$ g S a^{-1} and $104 * 10^{12}$ g S a^{-1}, respectively (**Andrea**, 1986; **Cullis** and **Hirschler**, 1980). The most considerable part is released by planktonic algae, as dimethylsulfide (~50%). Microorganisms can do the other way, to precipitate sulphates in pyrite form by changing the chemical conditions in the environment. The cycling of sulfur, besides acting of organisms, can be linked to cycles of other elements (C, O, Fe, and Ca). Understanding of the interaction of biogeochemical cycles is the real task for scientists.

The considerable amounts of subsurface bacteria were recognized recently (**Parks** et al., 2000). The bacterial biomass (in the upper 500 m ocean sediments) is equivalent to ~ 10% of the total surface biosphere. The population is significantly correlated with depth/temperature until about 4 km. The role of bacteria in methane generation is much more important, than earlier was supposed (**Martini** et al., 1996 and **Vető et al.,** 2004). Biodegradation of oils occur in reservoirs below 80° C temperatures, but if palaeosterilization had taken place in subsequently uplifted reservoirs filled with oil to much cooler regions, degradation does not occur, suggesting that sterilized reservoirs are not decolonised by hydrocarbon-degrading bacteria (**Wilhelms** et al., 2001). In fine-grained sediments acetogenic bacteria, and other organic-acid-producing microorganisms can produce organic acids from CO_2 as by-product at low temperatures (below 40°C during diagenesis) causing e.g. secondary porosity (**Chapelle** and **Bradley**, 1996). Bacteria and other primitive organisms can secrete a great variety of minerals in diverse aquatic environments including e.g. iron, manganese, and sulfur containing ones. Magnetotactic bacteria synthesize intracellular, nanometer-scale minerals. The product of the biologically controlled mineralization can be iron oxide or sulphide (e.g. magnetite, mackinawite, greigite) within the bacteria (**Pósfai** et al., 1998, **Pósfai** and **Arató**, 2000, **Pósfai** et al., 2001.). On the basis of crystal size and shape, the biogenic minerals are distinct from non-biogenic ones. It is important to make distinction between biologically induced and biologically controlled mineralization. The first one is owing to the metabolism of bacteria to produce amorphous precipitates which can be converted to crystals.

Another important phenomenon of enrichme nt of elements by post-mortem (fossil) organic matter is the cation exchange in insoluble humic acids of peats. The geochemical enrichment factor for U and some other cations is about 10000. Some microelements which were present as anions (e.g. V and Mo, as VO_3^- and MoO_4^{2-}) are reduced by humic acids to cations in a first step, and then the cations are fixed (VO^{2+} and MoO^+_2, Mo^{4+} or Mo^{5+}). As and Se are fixed under anaerobic condition as volatile hydrogen compounds, they are reduced to arsenopyrite and selenopyrite during sulphidizaton of the ironhumate content in peat (**Szalay**, 1964, **Szalay**, 1969, **Szalay** and **Szilágyi**, 1969). During sulphide precipitation other elements are also enriched (Cu, Pb, Zn, Co, Ni, etc. besides Fe). The effect of complexation by humic acids is a relevant environmental factor in the interaction of clay mineral and metal oxide particles. Aggregation and dispersion of the mineral particles in question are considerably controlled by humic acids bonding to the most reactive surface sites of the particles, i.e. to Al-OH mainly at the edges of clay lamellae, and to Fe-OH on iron oxides (**Johnston** and **Tombácz**, 2002, **Tombácz**, 2003, **Tombácz** et al., 2004). The particle network in soils and fate of mineral components in natural waters are determined by polyanionic organic substances as complexants, consequently the retardation or release of colloidal particles, and their mobility and transport are inherently affected by post-mortem organic matter.

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D. GEONOMY AND SOCIETY

GEONOMY AND SOCIETY

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1. Introductory Remarks

The present paper is a condensed version of E. Szádeczky-Kardoss's pertinent texts.

The effects of geonomic factors, however active they might have been since the very appearance of Life on the Earth, have stayed below the level of the natural "noise", so as they were hidden for direct, spontaneous perception. Man and his Society had to attain a high level of (scientific) reflection to be able to recognize (and admit) the geobases of his own existence, functioning and evolution.

The superimposed and constantly changing "geonomic fields" could not be measured. Even now we are living on the Earth like unconscious children, although we are striving hard to modify it dramatically.

Our culture is yet an immature greenhouse product built on a rather insecure foundation.. It has been repeatedly endangered rather seriously both by its own actions and by inadequately known geonomic factors.

It is quite understandable that the geonomic changes were ignored, since even the largest-scale geonomic phenomena, the horizontal displacements of the lithospheric plates, could not be proved and traced by measurements. In the past decades this became possible, and the rates turned out to be in the order of magnitude of **cm/year.**

The vertical movements, uplifts and subsidences, can be measured with much less difficulty and much higher accuracy. Their velocity is by an order of magnitude lower than that of the horizontal ones.

The motions of the solid lithosphere need to overcome certain tensions. Accordingly, they take place in discrete "jumps", in more or less disjunct successive phases. The velocity of these "jumps" is by several orders of magnitude higher than the average ones. Some of them are disastrous for the environment.

The recurrent destructive earthquakes, volcanic eruptions, tsunamis, as well as some necessarily high-intensity meteorological phenomena occur primarily in the active subduction zones, first of all at the deep oceanic troughs.

Along the Tertiary subduction zones, due to the rather slow process of great-depth thermal transformation, the movements reaching up to the surface are going on even now. Activity has completely died away only in the Mesozoic (or even more ancient) subduction zones.

2. Geonomic Factors in the Development of Civilizations

"The discovery (and recognition) of the fact that the genetically determined accumulation of utilizable mineral resources occurred preferentially in subduction zones, particularly in the – geologically not too old – semiactive ones, was very important even from the practical point of view." (**E. Szádeczky-Kardoss** 1974, p. 419)

Each of the three stages of subduction is – to a certain degree – related to one of the development stages of human culture.

- The moderately warm-climate regions of the active subduction zones, rich in copper, lead and tin ores, correspond to the areas of the early civilizations: the Mediterranean and the Circum-Pacific realms, complemented by the extensional rift zone of the Red Sea and the Jordan Valley.
- At a higher stage of development, iron ores and fossil fuels (coal first, and later on oil and gas) became decisive factors. These occur mainly in the semi-active zones of Eurasia and America.
- Recently, uranium ores and rare elements have gained prominent importance. These occur mostly in the heavily eroded, inactive, ancient subduction zones of the oldest parts of the continental lithosphere.
  It has to be stressed that **E. Szádeczky-Kardoss** firmly rejected all forms of simplistic geographic determinism and one-sided (unifactorial) approach, calling them "enormous blunders" and "nice examples of pseudo-scientific vulgarization."

Geonomy implies the prolongation and extrapolation of the historical view to the more ancient epochs of the Earth's history, where the correlations were less complex and more unambiguous. In this manner, it contributes to the further development of historicism.

"A virtually virgin, unexploited field is the realm of relationships of geonomy with the arts". This statement made by **E. Szádeczky-Kardoss** in 1974 is, alas!, still in force.

3. Geonomy and the Geocentrism(s) of Science

Beside direct observation, science is based on measurements. Very likely every decisive momentum of measuring starts from a basis related to the Earth. The established units of various types of measurements derive, probably without exception, from the macro-world dealt with by the earth sciences. It occurred only very recently that some units were based on selected phenomena of the micro-world, e.g. on the frequency of oscillation of an electrically excited quartz crystal. However, even such units are not "absolute" in the proper sense of this term.

The units used in practice are not only "geocentric", but even anthropocentric: they have been defined intentionally so that they be most convenient to the dimensions of the human being.

"One can conclude that the accumulation and progress of human knowledge is a phenomenon determined by geonomic processes." **(E. Szádeczky-Kardoss** 1974, p.426).

The geocentricity of human thinking is not only an unavoidable necessity, but also a fundamental feature of the cognitive process. Therefore it is a high-priority task to eliminate the errors generated by the previous, spontaneous (naive) geocentrism, with the help of the new, basically revised and consciously adopted geonomic geocentrism.

The conclusion is that genuine, realistic and useful science can be built on a solid geoscientific basis only.

"The geonomic approach provides us also with a possibility to get rid of the general phenomenon of fear and anxiety. At the human level, the biological struggle for life becomes step by step replaced by the confrontation of ideas. The better we recognize the factors and geonomic relations of the human being's natural situation, the better we approach the level of existence that can assure human harmony". **(E. Szádeczky-Kardoss,** 1974, p. 427).

This is the Creed of Geonomic Humanism.

4. Impact of the Geoelectromagnetic Field on Human Beings

The matter and energy flows incessantly ongoing in the geospheres generate electromagnetic fields. These exert influence on the bioshpere, and as far as the human beings are concerned, on their health and their behaviour.

The impact of geomagnetism on the human organism – rather poorly known so far --, may eventually exceed that of the climatic factors.

The liquid water and vapour, respectively, contained in the lithosphere and the astenosphere are mineralized, i.e. electrically conductive. Affected by the electromagnetism of the Earth, in these solutions electromagnetic motions, electric currents may be generated. This effect may be particularly strong in the haloes of ore deposits, due to the higher ion content of the solutions. At least some of the "divining rod" phenomena– often discredited and discarded, because investigated without success – may be related to this.

It would be very timely to study the biological effects of the reversals of geomagnetic polarity: the next one is expected to occur around 2230 A.D.

Beside endogenic factors, **E. Szádeczky-Kardoss** dealt also with the exogenic (cosmic) ones, such as the interaction of planets, solar activity, and the cycloidal motion of the Earth in the Galaxy.

He did not mention the possible effects of meteorite impacts and of the cosmic dust.

"Under the changing effects of geonomic factors the life processes tend to maintain an equilibrium, the genetic code of the living matter. The higher is the organization level of a living being, the more indirect are the ways of keeping this equilibrium; in the case of Man, it is often governed by the nervous systems.– The tolerance limits of living change with geological time, as a function of the duration and rate of the changes occurring in the geonomic factors. Long-term oscillation of parameters may result in an adaptation of the organism to extreme conditions. However, very short-term extreme conditions may be well tolerated even without previous adaptation." **(E. Szádeczky-Kardoss** 1974, p. 434).

E. Szádeczky-Kardoss discussed one by one the effects of pressure and temperature changes, frontal passages, electricity (AC electric field in particular), and radioactive gases (e.g. radon). In this manner in fact he dealt with environmental contamination by electromagnetism and natural radioactivity, without employing these terms.

The physical factors of the solid Earth – gravity, rotation, precession etc. – have a much lesser impact on the individual organism.They can even be "switched off" for some time, without doing any harm (e.g. the state of weightlessness). But in the long run even these may influence considerably the fate of the species.

5. Human Feedback to the Global Dynamics

"During the last third of the 20th century Man became a geonomical factor, as a consequence of the scientific and technical revolution. For a radical therapy of the well-known dangers brought up by the 'human factor' an in-depth analysis of the global dynamics is indispensable." **(E. Szádeczky-Kardoss** 1974, p. 441).

At present, the most important feeadback effects are the following.

1. Partial destruction of the 'ozone shield' by released "greenhouse" gases.
2. Increase of the carbon dioxide content of the troposphere. This is liable to produce a greenhouse effect, i.e. global warming.

"However, at least part of the excess heat generated near the Earth's surface escapes into the outer space by dissipation, which becomes intensified with the increase of temperature. Moreover, the higher CO_2 content promotes the reflection of the IR (heat) rays. Consequently, a slight anthropogenic increase in the CO_2 content of the atmosphere does not necessarily result in a genuine and long-term increase of temperature." **(E. Szádeczky-Kardoss 1974,** p.441).

3. Along with the increased amount of clay minerals due to more intensive weathering, the quantity of anion forming elements extracted from the air and the water, and bound by adsorption on the surface of clay minerals, compensates the excess of volatiles brought about by the also intensified volcanism.
4. The anthropogenic increase of the overall quantity of terrestrial biomass increases, while that of the marine one decreases. Consequently, the biological equilibrium is destroyed.
5. Several anthropogenic effects enhance the mobillity of the Earth's surface: intensified chemical weathering and soil erosion, higher rate of sedimentation. **E. Szádeczky-Kardoss** even assumed that the anthropogenic factors contributed to the acceleration of the subduction process, and of the global dynamics in general. This idea obviously has to be revised.

6. Geonomy for the Bright Future of Humankind

The main statements made by **E. Szádeczky-Kardoss** are as follows.

- A basic problem is long-term energy supply, with special regard to the "demographic explosion" in the developing countries.
- The exploitation of almost all other kinds of mineral resources are going to increase, in spite of the proposed economy measurements and recycling.
- Great attention has to be paid to the forthcoming reversal of the geomagnetic field.
- Realistic and reasonable long-term planning must be based on advanced knowledge of the global dynamics and the cyclic evolution.
- On the basis of geonomical knowledge, the problem of transformation of Nature is enriched with essential new aspects. Since Man has become a considerable geological, even geonomical factor, its Nature-transforming activity can direct the evolution of the Earth as a whole to a direction most convenient for him, as soon as this direction can be identified with the help of in-depth geonomic knowledge. The "transformation of Nature" is not only a static technological task, but to a great extent also a dynamic geonomic problem. (NB. this may be even interpreted as a rather cautiously formulated criticism of the over-ambitious Soviet plans aiming at the "transformation of Nature".)
- The problem of environmental protection has to be dealt with primarily in the context of water management.
- The anthropogenic pollution of the atmosphere does not result in a substantial greenhouse effect. (This is a rather controversial statement.)
- The problems caused by contamination of the Earth's surface with harmful / toxic by-products and wastes of human civilization, and environmental protection in general, have to be solved on the basis of a global geonomic approach.
- By the recently obtained new information, **J. A. Comenius'** concept about the integration of the entire human knowledge into a coherent system, which in the 20th century was regarded as an utopy, has obtained support and a new outlook: there must be some logical connections between things that have become into being together. In the '40-ies **J. Huxley** proposed and propagated a "*world scientific humanism*". The geonomic approach has contributed to this intellectual integration with its achievements, promoting "border sciences" --e.g. biogeochemistry – in a remarkable, maybe even decisive manner, filling in with specific relationships the gap between "matter" and "psyche".
- The development of an integrated world view helps also Man to become psychically more well-balanced and to get rid of all kinds of pessimistic philosophies. This should not mean, however, the adoption of some general, light-hearted and static intellectual conformism. Theestablishment of a static world science is hardly possible, and it is even less desirable.

- With the help of technological, biological and above all geonomical knowledge, human society can more and more master Time, in the sense of **H. Bergson's** "*durée réelle*" (real duration). With the help of science we can extend our Present, we can take part in the activities of future times, in the form of a "quasi-survival".

7.- Final Conclusion

The activity performed by Science for the welfare and harmony of Humankind as a basic feature is revealed by the humanistically integrating role of Geonomy. **It is by studying our Mother Planet that the responsibility of scientists for Humankind becomes a central scientific problem**.

The development of science, in particular of the rather expensive systematic geonomical research, and the establishment of a global monitoring and "early warning" network gathering information from the Earth's interior and from the outer space as well, offers a reasonable alternative to arms development for the high-tech and the heavy industry.

The capital, having produced an escalating armament race in the 20th century, can be invested into even commercially profitable large-scale international projects, with the aim of assuring a better life to Humankind.

The various scientific programs, in particular the large-scale and long-term geonomic ones, resulting in a "qualitative jump", would also provide us with a guarantee for universal peace.

One can only hope that **E. Szádeczky-Kardoss'** apparently too optimistic forecast was in fact a realistic prophecy.

* * *

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EPILOGUE AND CHALLENGE

You may feel that this large spectrum of studies is after all rather uneven and incomplete, and you are right. Even our multidisciplinary team was not capable of fully revising, updating and improving all aspects of **E. Szádeczky-Kardoss's** *Geonomy* concept.

You may have questions and objections, and very likely most of these are reasonable and justified. We do not pretend to have solved all problems encountered, to have found the right answer to every question; not even to have identified all the questions to be asked.

Our aim was only to instigate the distinguished Readers to further mental efforts in search for the Truth. This was, very explicitly, also the intention of **E. Szádeczky-Kardoss.**

Please feel free, even requested, to correct, to improve, to achieve further progress on the tortuous and virtually endless road of ever-improving understanding of the Universe in general and our mother-planet Earth in particular.

With the best wishes of patience, endurance and success,
we remain
very truly yours,

Endre Dudich
and his co-authors

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3000,-

In the year 2005 the Geochemical Research Institute of the Hungarian Academy of Sciences celebrates its 50th anniversary. We feel appropriate to pay tribute on this occasion also to Professor E. Szádeczky-Kardoss, who founded it as a Laboratory for Geochemical Research in 1955 (located initially in the premises of the Department of Petrology and Geochemistry of L. Eötvös University in Budapest) and was its first Director, until his retirement in 1974.

The present collection of papers is an abridged English-language version of the 200-page Hungarian-language book *"Geonomy after the Turn of Millennium"* published in 2003, on the occasion of the centenary of E. Szádeczky-Kardoss' birth. Its aim is to make the non-Hungarian readers familiar with his scientific achievements, in particular with his most ambitious (and also most controversial) concepts.

These were intended to set up an all-embracing synthesis of the Earth Sciences he named *Geonomy,* and even more, to create a fair approximation of understanding the Universe as a whole, by means of what he called the *Universal Cycle Relation.*

Thanks are due to the multidisciplinary team of the Subcommission on Geonomy of the Hungarian Academy of Sciences for their valuable contributions and to the X. Section of Earth Sciences of the Hungarian Academy of Sciences for kindly financing and publishing them.

Budapest, 2 May 2005

György Pantó
Full Member of the Hungarian Academy of Sciences
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