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Geological Catastrophes: Essential Stage in Formation of Endogenic Fields

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***Abstract*—The nature of ore metallization, energetics of ore-formation and its stimulating motives have always taken one of the central parts in the formation of endogenic fields. It has been indicated that the motive, i.e. the initial stage of field formation (especially of those of large and unique scale), is geological catastrophes – short-lived events originating mostly in the Universe (near and deep space as an undulatory source of energy) and consequently stirring up the entrails of the Earth to its very core and leading to the formation of the productive fluid-magmatic ore-forming system.**

Keywords—geological catastrophe; energetics of ore-formation; ore-magmatic system; field prediction

I. INTRODUCTION

One of the central parts in the existing theories of endogenic ore-formation has always been taken by the nature of ore metallization, energetics of ore-formation and motives that stimulate the process of ore-formation and develop the ore-forming system: what underlies the birth of the multi-component endogenic ore-forming system which includes a generation zone (source of the ore body), transit zone and an ore localization zone?

The present work, being an empirical summarizing which relies on inner peculiarities of ore-formation processes, indicates that the initial step in the birth and development of the ore-forming system is a geological catastrophe – a short-lived event which originates mostly in the Universe (near and deep space as an undulatory source of energy) and consequently stirs up the entrails of the Earth to its very core. The scale of the ore-forming system determines the scale of endogenic ore metallization. In the course of its development and formation, the ore-fluid-magmatic system born by catastrophism was leading to the formation of a more perfect ore field at different structural stages of the Earth crust, along with the incoming substance and energy from outside with cooperation of many factors involved. Even under small-scale disturbances, the ore-forming system is subject to saltatory alterations which may give birth to a new geological and industrial ore metallization type.

The paper presents examples of large and unique fields of the world (mainly of the most prominent geological and industrial field types) which illustrate their connection to regional geological events of catastrophic nature associated with geological and structural reorganization of the earth surface.

II. PROBLEM DEFINITION

Scientific views on the main components of the ore-forming process, causes of increased and high concentrations of elements in rather limited space are traditionally ambiguous: these are the sources of ore material, ways of its transportation and conditions and peculiarities of its concentration in ore-localization areas. There is a wide range of views on the causes of industrial (anomalous) concentrations of the material in small areas and on their depths.

The nature of large and unique fields is disputable: do they develop under special laws and a rare combination of favorable factors or do they always follow existing schemes of ore-formation being different only in quantitative measures. Do unique fields occur and do they recur in the history of the Earth or are they few in number?

Analysis of geo-structural and genetic peculiarities of fields and of large sites of the world especially allows us to contend that catastrophism phases of terrestrial or non-terrestrial origin are crucial in their formation, which are to a different degree revealed in the chronicles of the field. At least under systematic analysis, a field is treated as an object-scheme, and catastrophism is viewed as a component and indispensable part of the self-organizing ore-magmatic system [10].

Geological catastrophes exist in different scales. They range from global and more notable ones (reflected in geological chronicle) to local ones of interlayer type in sheeted series which are treated as "jumps" in sedimentary process. Thereby, it is worth noting that widely spread horizontal bedding which is usually viewed as a characteristic of mild sedimentation in sedimentary basins does not correspond to the present state, as bedding would not develop at all under mild sedimentation, while there would be smooth transitions between component parts of the rock (e.g. sandstone or siltstone). In this case, interlayers in horizontal bedding correspond to the "jump" caused by an occasional hydrodynamic pulse (an explosive event including atmosphere) after which occurs an instantaneous precipitation of weighed material with the formation of a layer. This kind of texture can be observed in the mass of fresh condensed snow in city boundaries. A different situation is marked in

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conditions of an active hydrodynamic regime which leads to the formation of various types of cross bedding.

As is known, catastrophes are saltatory changes ("spasms", "episodes", "events") which occur as a sudden response (reaction) of the system to the smooth changes (qualitative and quantitative) of external conditions [1]. It is a transition from one stable condition to another, a new balanced state irrelative of the scale of the event. At the same time both qualitative and quantitative changes occur, and big saltatory changes may occur under little influence. Common understanding of catastrophes associated with natural disasters which cause people's deaths (hurricanes, floods, etc.) is not considered here [9].

Processes, earlier considered linear and ordered, have turned out to be nonlinear and unordered with occasional fluctuations. Nonlinearity is viewed as the largest achievement of natural sciences which is yet to take the role of the most general paradigm in the XXI century [8].

In geological history of the Earth development, a differently ordered and established cyclicity is rather important, i.e. quasi-periodical (nonlinear) repetition of development stages, where order of events and transitions occur in discontinuous manner. V.Ye. Khain grounded larger tectonic cycles under the name of Wilson cycle, Bertrand cycle and Stille cycle [13].

P.I. Gretener proposed such interpretation of this notion: "event" is a process taking not more than one hundredth of total duration of the geological period in question, because a segment on any diagram, which is equal to one hundredth of the time scale, is no thicker than a pencil line. And, consequently, the event will look like a jump [4], i.e. fixation of a catastrophe is viewed as possible. Duration of a catastrophic event in geological processes may vary (initial minutes of earthquakes up to millions of years in tectonic epochs, in quantum processes duration is estimated at a nanolevel).

The origin of large-scale cyclicity is associated not only with depth geodynamic processes occurring in tectonosphere of the Earth, but also with processes occurring in the Galaxy.

In natural ore-forming systems of various hierarchical levels, there is evident interaction and interchange of two differently developing processes in the course of evolution: when moving away from balanced state (self-organization) and when approaching such state – degradation that is an indispensable part of the development process itself.

Saltatory (discontinuous) flow of fluid-magmatic systems is defined by the faltering of changes in thermo-dynamic parameters (apart from changes of the environment), and primarily depends on the main fluid component – water, whose structure (as shown by multiple works of physicists and experimenting geochemists) changes in a saltatory way when the temperature goes up from 0 to 500 ˚C, and consequently changes metal solubility, dissociation constants of different electrolits, the character and the course of interaction between hydrothermal solution and enclosing medium, etc. Such (discontinuous) flow of the ore-forming system occurs also when the pressure changes and leads to periodical explosive "reboiling" of solutions and mass precipitation of ore material, in the feedback mode and attaining self-regulating criticality, i.e. such state in the system when its governing parameter reaches its critical point, after which an avalanche-like process begins (instantaneous displacement of excess energy). Emergence of an anomalously strong event (catastrophe) is conditioned by synergic effect (a cooperative action of many factors in a dynamic system).

Features of catastrophic events are recorded at a sedimentation level (catastrophites – tempestites, turbidite, "black" shale, etc.), a biotic level (large and small extinction), geochemical (iridium anomaly, isotope ratio of sulphur, oxygen and carbon, rare-earth elements and their isotopy), tectonic (orogeny phases, top-discordance, regional breaks in deposition), cosmic (oval structures, impactites, planar structures, "shocked twins", etc.), eustatic (world transgressions and regressions, Weile's curve [18]). These make possible wide stratigraphic correlatability (together with seismic stratigraphy), specify and detail stratigraphic correlatability.

Catastrophism features are indicated in the formation of a unique Udokan copper site. They are recorded in the ore-bearing horizon in the form of mass formation of "seismogene" sandstone (lime conglobreccia) which is mostly absent prior to and after the formation of ore ledge [11], and are also indicated by a regional factor of non-terrestrial origin. Characteristic are foreshock and aftershocks (Fig. 1).

One of the most vivid features of the saltatory development (according to the catastrophism theory) of geological processes of a higher level is breaks, especially angular ones. This served as a basis for an outstanding German tectonist H. Stille to define the main orogenic phases (Stille's Table/Zyklentheorie) in pharenozioc section of continents (1924).

Global statistics of breaks (A.A. Pronin, 1969) proves validity of pointing out such phases in Pharenozoic [7]. It was shown that tectogenesis process is continuous but uneven; besides there are evident quality jumps (tectogenesis phases) and other endogenous processes (magmatism, metamorphism) have discontinuously broken, pulsating character [17].

As for the consequence of catastrophic events occurring mostly in the stratified shell of the Earth, it was a new scientific branch called event stratigraphy which operates with material results of relatively short-termed events: biotic (large and small extinction), sedimentalogical (catastrophites – tempestites, turbidite, "black" shale, etc.), geochemical (iridium anomaly, isotope ratio of sulphur, oxygen and carbon), tectonic (orogeny phases, top-discordance), cosmic (impactites, planar structures, etc.), eustatic (world transgressions and regressions, Weile's curve [18]), which make possible wide stratigraphic correlatability (together with seismic stratigraphy), specifying and detailing of stratigraphic correlatability [2], along with ore-formation processes.

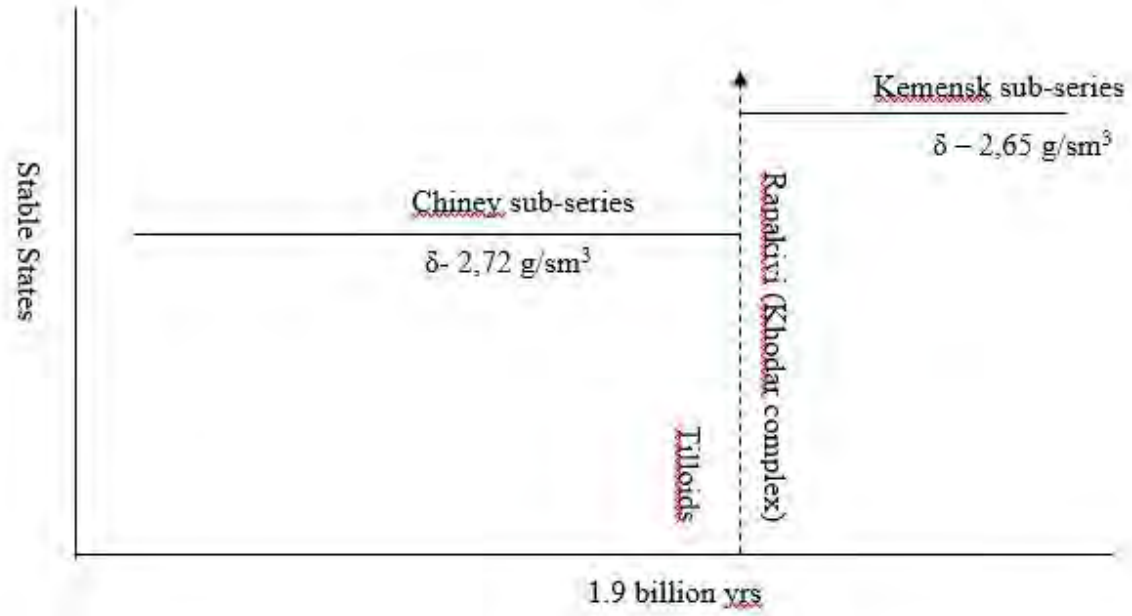

Fig.1. Changes of states of Udokan series and on the boundary of Udokan field formation (triangle – Udokan field, dots – "trail" of forming copper)

Black shale formations as typical of regional geological events serve as an indicator of periods of catastrophic development of the Earth [6]. Their formation is associated with stages of catastrophic growth of degassing of the Earth's core, its losing considerable carbon plums and surfacing of high-temperature carbon-containing fluids, whose cooling stimulates the development of disproportioning of reactions followed by free carbon discharge. Black shale formation is associated with a large complex of ore and non-ore elements including unique fields, especially ones with noble metals. Emergence of such formations occurs periodically, once in 220 million years (galaxy year), with quite accurate time lapse of 30 million years (the main periodicity according to N.L. Dobretsov) [3].

III. Conclusion

1. Catastrophic event is just as normal form of natural processes as its evolutional branch (gradual change); moreover, revolutionary and evolutional branches of geological development exist in dialectical unity, thus proving one of the most important laws of dialectics – transition of quantity changes into quality ones, as well as the law of unity and struggle of opposites.
2. Formation of fields does not usually occur during the peak of a catastrophic geological event, but follows it. At the same time, as a rule, anomalous objects are followed by a "trail" of smaller ore-assemblages, preceding the main epoch or following it. Catastrophism is a moving force of the ore-formation process.
3. Reasons of natural catastrophes are complex: internal, conditioned by pallial heterogeneities, different weight and openness of geological systems with a high-energy current leading to self-reorganization, as well as external factors – cosmogenic [16, 17].
4. Geological catastrophes are closely associated with biogenic catastrophes (extinctions), which can be large and small in scale. On the other hand, there is abiogenesis as a result of catastrophic

Catastrophism effect is more pronounced when there is a combination of high pressure and shifting deformations, when there is an abrupt speeding of diffusion processes, an abrupt decrease of the pressure barrier of phase transitions and formation of thermodynamically incompatible phases (Bridgeman effect). When critical points in thermodynamic parameters are reached, there is an *instantaneous* transition of mechanical energy into thermal one, which leads to "rheological eruption" (Ph.A. Letnikov, Yu.N. Avsyuk, 2008). Periodical change of dynamic strain leads to *saltatory* (and instantaneous) sedimentation of ore substance, especially in resonance areas, taking into account undulatory nature of the strain.

In the course of its development, the ore-fluid-magmatic system produced by catastrophism led to the formation of a more perfect ore field at different geo-structural levels of the Earth's crust in the process of cooperative interaction of multiple factors along with a substance and energy incoming from outside.

Scientific importance of the catastrophism idea is in the further development of the theory of endogenous ore-formation and acquiring further knowledge of complex self-organizing natural fluid-ore-magmatic systems, where catastrophism is the basis, the initial phase (stage) of ore-formation.

Practical relevance of the catastrophism idea is in its application under long-term evaluation and forecasting of endogenous ore metallization of territories on the basis of regional and local geological, geophysical and geochemical search criteria and features of catastrophic nature. They can

also be applied at the functioning sites for increasing their prospects.

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