Genetic Classification of ore-forming processes

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Abstract The absence of a genetic classification of ore-forming processes is the result of a rather slow-paced accumulation of knowledge in ore-forming processes, which, in its turn, could be explained by objective conditions such as the fact that during the last few decades the genetic classification included only the description of mineral deposits. The existing genetic mineral deposit classifications has developed and embraced the genetic classification of ore-forming processes in accordance with system theory, structured taxons revealing the nature of the processes and the basis- information source of these processes. The base involved the developed model system of ore mineralization- ore formations (geological formations with syngenetic mineralization) within poly-component and mono-component subformations; for convergent mineralization- geological types of deposits. The latter, as well as non-convergent subformations has accumulated all data about initiating and conditioning ore formation within wide-scaled geological processes. The geological mineralization types within ore formations and subformations are included in the genetic classification of ore-forming processes. This, in its turn, makes it possible to forecast the functions and provide a regular transition into the geological-genetic classification of ore-forming processes in accordance to above-mentioned matrix-structure, and, simultaneously, further the development of the existing geological-genetic theory of ore formation.

1. Introduction

The classification of natural processes (phenomena) based on fundamental information and the structure and principles of which have been developed within the framework of contemporary theory system reflects the maturity of the existing theory. In the absence of a theory, a classification has been developed to describe either genetically natural objects and ore mineral deposits if it concerns ore geology. However, on this case, such precise and accurate classifications would completely depend on the information (data) of ore formation conditions.

In the first half of the 20th century such geologists as V Lindgren [8] and V Obruchev [4] considered that mineral deposits should be genetically-based classified and according to the geological processes. Nevertheless, they understood that it was impossible to put forward such an “ideal” genetic classification of ore-forming processes, due to the fact that there is no justifying theory to prove this.

This, all in all, is the result of a rather slow-paced accumulation of knowledge in ore-forming processes, which, in its turn, could be explained by objective conditions such as the fact that during the last few decades the genetic classification included only the description of mineral deposits.

The authors proposed a transformation of existing genetic mineral deposit classification into a more sophisticated genetic classification involving the ore-forming processes. This classification could be based on an updated ore-formation theory and include the application of system theory approach in describing the natural objects and processes. This proposed classification will be described further.

2. Genetic classification of mineral deposit structure and composition

V Lindgren, the author of the earliest mineral deposit classification, wrote ”....the only reasonable classification of deposits into classes could be the following: 1) deposits formed from pre-existing minerals by mechanical concentration or 2) deposits formed as a result of some reaction in solutions”, while “.......the present classification describing the complex formation of ore deposits is the only possible one” [8]. It was this fact that became the basis of Lindgren classification:

Deposit I includes clastic rocks, clays and placer. **Deposit II** embraces the existing Russian classification i.e. exogenous (weathered **rocks**, sedimentary) and endogenous.

Simultaneously, another genetic classification of mineral deposits was developed by V Obruchev (Mining Department, Tomsk Technological Institute- 1901-1912) [4].

Genetic classification of mineral deposits
(Obruchev [4])

GROUP A. ABYSSAL DEPOSITS (ENDOGENOUS)

Category 1. Magmatic

Class 1. Evamagmatic

Type a.. Segregated

Type b. Liquated

Class 2. **Injection**

Class 3. Pegmatitic

Category 2. Emanation

Class 1. Contact

Class 2. Pneumatolytic

Class 3. Exudates and sublimates

Category 3. Hydrothermal

Class 1. Hypothermal

Class 2. Mesothermal

Class 3. Epithermal

Type a. Packed void

Type b. Metasomatic

GROUP B. SURFACE DEPOSITS *(EXOGENOUS)*

Class 1. Sedimentary

Class 2. Infiltration

Class 3. Residual

Class 4. Clastics or placers

GROUP C. ALTERED DEPOSITS (METAMORPHIC)

Class 1. Pyrometamorphic

Class 2. Dynamometamorphic

Class 3. Hydatometamorphic

Class 4. Complex genesis (proto-magmatic, proto-contact, metamorphised proto-sedimentary, for example, ferruginous quartzites)

It should be noted that V Obruchev considered metamorphic (metamorphogenic) deposits as deposits of different origin and minerals, existing before metamorphism and transformed differently during the metamorphism itself, but preserving the initial minerals. Although the genetic classifications of deposits by Lindgren and Obruchev include authentic data information revealing the ore-forming processes, they are different in form and content.

According to Obruchev classification, clastic and placer deposits conforming with the concentration behavior of commercial minerals in deposits are comparable to Lindgren classification "the mechanically- formed concentrations." And, according, to Lindgren classification the chemically-concentrated deposits are described as taxons in Obruchev classification. It should be stated that in the first and second cases both classifications are rather distinct and comparable. Obruchev borrowed from Lindgren classification the concept of differentiated hydrothermal deposits as hypo-, mezo- and epithermal. The latter two terms are applicable even today.

The basic difference between these two classification is the description sequence of deposit formation processes, i.e by Lindgren- from exogenous to endogenous and visa versa from endogenous to exogenous by Obruchev. This difference is expressed as prioritization in evaluating the relevant factors determining ore-forming processes and mechanism of mineral concentration within Lindgren classification, while energy source needed for deposit formation within Obruchev classification.

All the ensuing numerous domestic genetic mineral deposit classifications only extended Obruchev classification, but this included insignificant and or significant alterations or additions. This could be due to either the accumulation of advanced data or even be motivated by the desire of some authors to make one's own contribution in upgrading the base classification.

The first significant alteration in above-mentioned Obruchev classification was notable after the publication of the following classification [1]: in Group B "altered deposits" have been renamed into "metamorphogenous" in Group C which included metamorphic deposits formed during metamorphism and being the result of metamorphism itself. Thus, two associated deposits in the upper level third taxon were combined: metamorphosed (metamorphic, metamorphogenic, altered, consequently existing before metamorphism, according to Obruchev) and metamorphic, not existing before metamorphism, but formed by metamorphism itself. This addition is extant only in all classifications developed during the last few decades [6]. The existing base classification involves another insignificant alteration: hydrothermal taxon is divided into hydrothemal deposit categories- carbonate, skarn, albite and greisen.

3. Results and discussion

This brief descriptive history of the development and design of the genetic mineral deposit classification reflects the evidence of its periodicity in the research of generation-to-generation geologists. It is well-known that the results characterizing the ore-forming processes prove their reliability and relevant scenario which reflect how nature influenced this or that deposit.

The 100-year accumulated direct knowledge could be sufficient enough to build the backbone of the theory – genetic ore-forming deposit theory – which would describe the processes occurring within the developing deposits [5–7]. One should also mention the considerable achievements in developing the ore-forming theory from the fundamental geological (metallogenic) aspect so as to reconstruct and describe (decipher) rather wide-scaled geological processes in the earth crust and/or mantle trriggering and conditioning ore-formation.

The geological basis of this theory, concerning exogenous and endogenous processes which are aggravated by multiple-diversified geological (magmatic, metamorphic) processes within one and the same genetic deposit type and in one specific deposit and which, in its turn, stipulates ore formation. The major problem arises in reconstructing the geological factors involved in the formation of hydrothermal deposits, due to limited accessibility in investigating the sources of energy, fluids and ore matter being located in significant hypothetical depths.

In this case, these achievements in developing the genetically ore-formation theory determine the practicability and completeness of transforming the genetic mineral deposit classification into a more sophisticated classification of ore-forming processes, the structure of which would compile to the requirements of system theory [2]. Obruchev classification is the basis in the development of this updated classification. According to the system theory the classification should include subdominant taxons which differentiate the processes and direct foundation, i.e. information source which, in its turn, is the basis in detecting these processes.

The classification is designed in accordance to: 1) transferability principle, providing the transition from the immediate base to the processes and reversely; 2) entity principle identifying the processes as internal dissected units; 3) use-principle of one feature by autonomy of each peer-to-peer taxon; 4) hierarchical principle of leveled process structure as system constituents, defining distinct taxonomy level hierarchically interconnected so as one taxon is the basis for the next one; 5) principle of taxon discreteness.

Genetic classification of ore-forming processes

ENDOGENOUS GROUP
- **Category** Magmatic
  - **Class** Liquation
  - **Class** Crystallization
    - ***Subclass*** Early crystallization
    - ***Subclass*** Late crystallization
- **Category** Fluid-magmatic
  - **Class Plutonogenous**
    - ***Ore formation Rare-metal****-ornamental* ***granite*** *pegmatite*
      - *Ore subformation Rare-metal*
      - *Ore subformation* Ornamental stones
  - **Class Ultra-metamorphogenous**
- **Category** Hydrothermal
  - **Class Magmatogenous**
    - ***Subclass*** Plutonogenous
      - ***Ore formation*** *Ferrum-phosphous- rare metal* ***carbonates***
        - ***Ore subformation Ferrum-phorsphous***
        - ***Ore subformation*** *Rare-metal- rare earth*
        - ***Ore subformation*** *Polymetallic*
      - ***Ore formation*** *Gold-uranium-polymetallic* ***beresite***
        - ***Ore subformation*** *Gold*
          - ***Geological type***
        - ***Ore subformation*** *Uranium*
          - ***Geological type***
        - ***Ore subformation*** *Antimonite*
          - ***Geological type***
        - ***Ore subformation*** *Polymetallic*
    - ***Subclass*** **Volcanogenous**
  - **Class Metamorphogenous**
    - ***Subclass*** Greenschist
    - ***Subclass*** Epidote-amphibolite (amphibolite)
    - ***Subclass*** Granulite

EXOGENOUS GROUP
- **Category Hydragenous**
  - **Class** Residual
    - ***Subclass*** Siallites
    - ***Subclass*** Laterites
  - **Class Infiltrated**
- **Category** Sedimentary
  - **Class** Mechanical substance sedimentation
    - ***Subclass*** Continental

Subclass Marine
Class Chemical substance sedimentation
Subclass Continental
Subclass Marine
Ore formation *Ferrum-manganese-carbonate-sandy-**argillaceous***
Ore subformation *Iron ore*
Ore subformation *Manganese*
Class Biochemical substance sedimentation
Subclass Continental
Subclass Marine
POLYGENOUS GROUP
Category Hydrothermal-sedimentary (kuroko type)
Category Metamorphised
Category Unconformity type

According to this classification the metamorphogenic group is replaced by polygenic group when subjected to exogenous and endogenous processes. Carbonate, skarn, albite and greenschist deposits were formed as a result of hydrothermal processes, consequently, these constituents represent all hydrothermal associations, including fenite, beresite, argillite, alkaline metasomatites, propylite, and others. Gold, uranium, antimonite and other minerals in metamorphogenic deposits are displaced from earlier metamorphogenic group to endogenous hydrothermal group.

Accumulating type- models (repeating in numerous features) for each genetic feature type are preferable to stand-alone deposits with their specific features. These models are ore formations providing that the system of ore formations is not based on fragmentary metal mineral ore composition only (as earlier stated), but based on both geological and ore-forming processes of the substance within the geological formation itself [3]. In this case, ore formation is the geological formation with syngenetic mineralization.

Endogenous (magmatic, metasomatic) and sedimentary formations are classified on the composition-genetic basis excluding the geodynamic formation regimes, while metasomatic formations – without correlation with magmatism. It is advisable to detect geodynamic formation regimes, which, in its turn, proves their correlation with wide-scaled geological processes not at the stage of segregation, but within the segregated geological formations. In this case, the geological formation processes coupled with their composition-genetic basis are intended to characterize the earth crust formation regularities This approach minimized and / or excluded all possible discussion concerning the autonomous formation typification of rock associations and being applied in the formation classification of mineral deposits could eliminate all insuperable difficulties in implementing the metal-ore-mineral approach [3].

To define the nature laws that form this or that type of mineral deposit it is proposed to differentiate the poly-component ore formations into mono-component subformations.

Following observations, in some cases the geological conditions (geodynamic regimes, conditioned by the priming ore formation of more wide-scaled geological processes) in ore formation convergence embraces geological types, the number of which equals the number of convergence conditions. The geological mineralization types within ore formations and subformations are included in the genetic classification of ore-forming processes. This, in its turn, makes it possible to forecast the functions and provide a regular transition into the geological-genetic classification of ore-forming processes in accordance to above-mentioned matrix-structure [3], and, simultaneously, further the development of the existing geological-genetic theory of ore formation.

4. Conclusion

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In the first quarter of the XX century geologists from different countries remodeled practically all well-known mineral formation processes. The obtained information was adequate enough to classify the deposits terming their formation processes. Most described terms, except for outdated ones, are still used in the modern classification. However, each term embraces incomparably more deeper and extensive knowledge which was accumulated in the past decades.

The first mineral deposit classifications developed by such well-known geologists as V. Lindgren, V. Obruchev, Matthew Emmons, Paul Niggli and Hanz Schneiderhöln were conceptually different. The above-described genetic mineral deposit classification by Obruchev more or less conforms with the classification principles of scientific units and phenomena being based on the existing system theory. In this case it is appropriate as a classification base.

But contemporary classifications could be exceptions to the rules. For example, endogenous metamorphic deposits are not included in the endogenous group, but are included in the metamorphogenic group. Some complexes of hydrothermal deposits are excluded from the hydrothermal category, but still possess equal taxon status with the latter (distributed in one-rank level taxon).

To convert the deposit classification into the classification of processes it is necessary to introduce corresponding alterations in the base classification structure itself, i.e. ranking within three taxons of the base where “geological types” taxon could accumulate new data of geological processes conditioning ore formations and revealing the principles of distribution and formation of mineralization.

Thus, the genetic mineral deposit classification transforms naturally into the genetic ore-forming process classification, while the latter- into geological-genetic classification reflecting the ore-forming theory completely.

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