

**Russian Academy of Sciences
Ural Branch
Mining Institute**

**Tatyana Kalinina
Olga Kadebskaya**

**Cryomineragenic processes on an example
of caves of the Urals**

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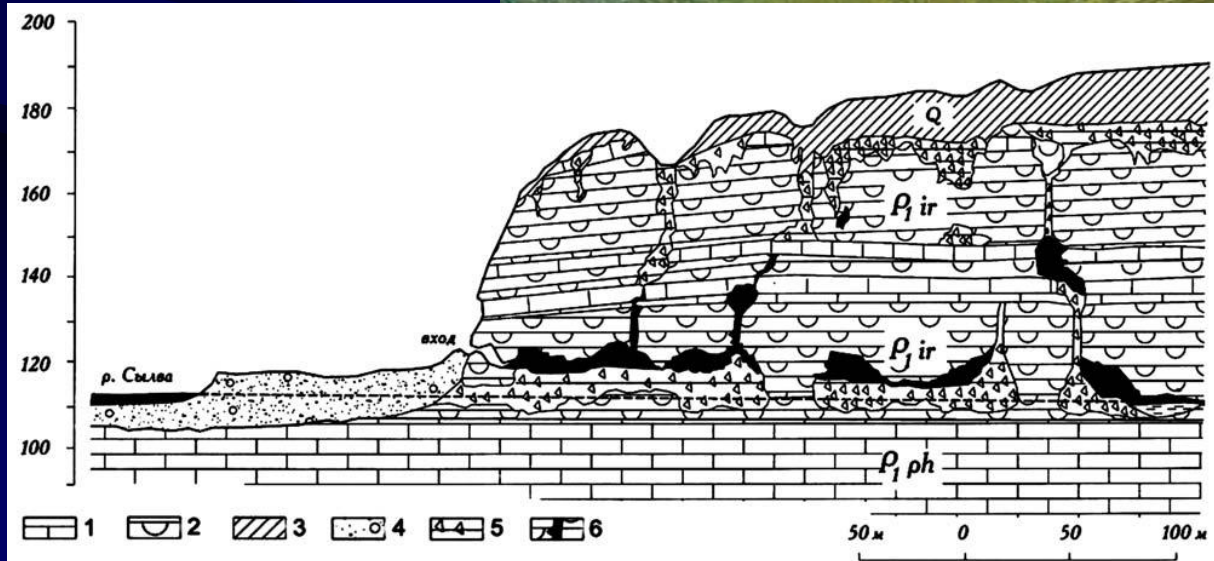


We haven't general classification of cryomineragenic processes (conditions, types etc.)



The cryochemical processes are connected with surface glaciers and underground ice

The latter covers the regions with *perennial permafrost* and also the regions, located more to the south, where underground ice forms in *underground cavities – caves*



History of investigation of cryomineral formations of caves

There are some special works concerning mainly glaciers and naled ice, where investigation of their chemical contents gave some important data on their chemical components and also cryochemical processes connected with them

Alexeyev, 1987, Alexeyev, Ivanov, 1976,

Ivanov, 1981, 1983, Shumskiy, 1955,

Bukowska-Jania, Pulina, 1984, 1990,

Bukowska-Jania, 1998, Clark, Lauriol, 1992,

Courty, Marlin, Dever, Tremblay,

Vachier 1994, Drozdowski, 1982, Fairchild, Bradby, Spiro, 1993,

Fairchild, Bradby, Spiro, 1994,

Fairchild, Killawee, Sharp, Spiro, Hubbard, Lorrain, Tison, 1999,

Fairchild, Killawee, Spiro, Tison, 1996, Faure, Hoefs, Jones, Curtis, Pride, 1988,

Ford, Fuller, Drake, 1970, Galuskin, Bukowska-Jania, 1999,

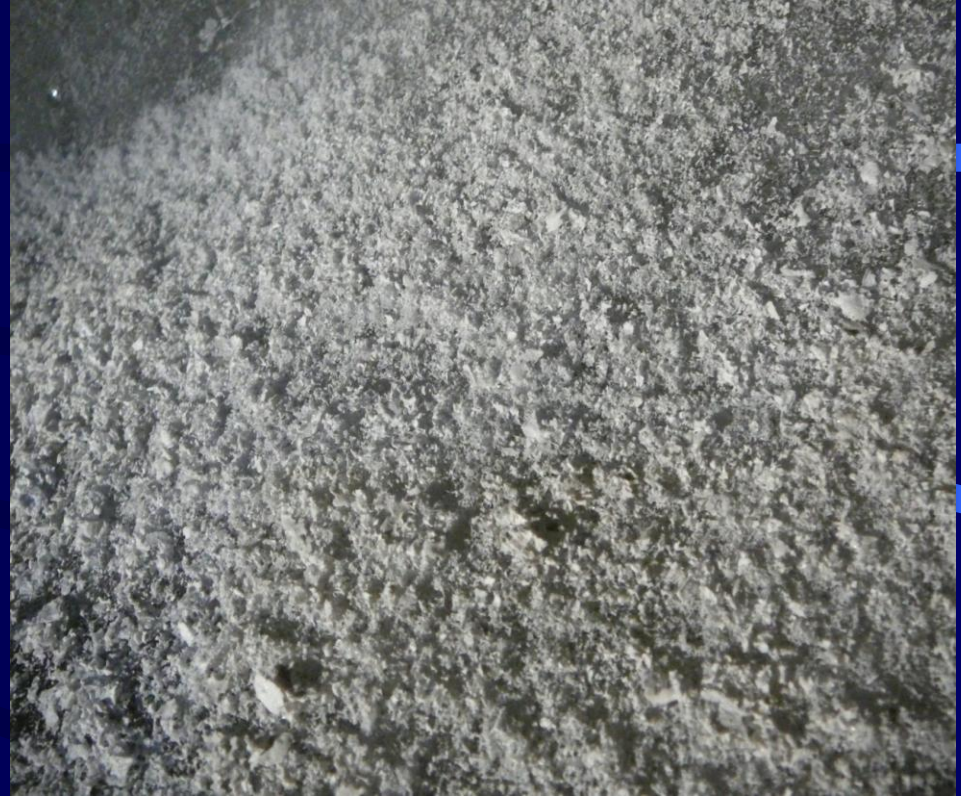
Gokhman, 1997, Grasby, 2003, Griselin, Marlin, 1998,

Hallet, 1979, Jazuel, Sauchez, 1982,

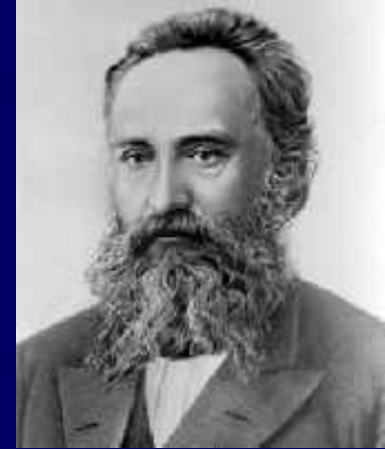
Killawee, Fairchild, Tison, Janssens, Lorrain, 1998, Souchez, Lemmens, 1985,

Vogt, T., Corte A.E., 1996, et.al.

The main process of mineral formation in caves is isolation of mineral aggregates at ice evaporation



It is possible that Kungur Ice Cave is the place where cryogenic minerals were found for the first time. In 1880 I.Polyakov got interested in the “gypsum powder”



He had connected its appearance with freezing of mineralized water, followed by ice melting. Four years later E.Fjodorov, who made mineralogical survey in the cave, has repeated Polyakov's conclusions, but he has connected depositing of gypsum microfractions by ice evaporation without "liquid" phase.

Various similarities and differences in the mechanism of the cryomineragenic processes can be observed in all the mentioned cases

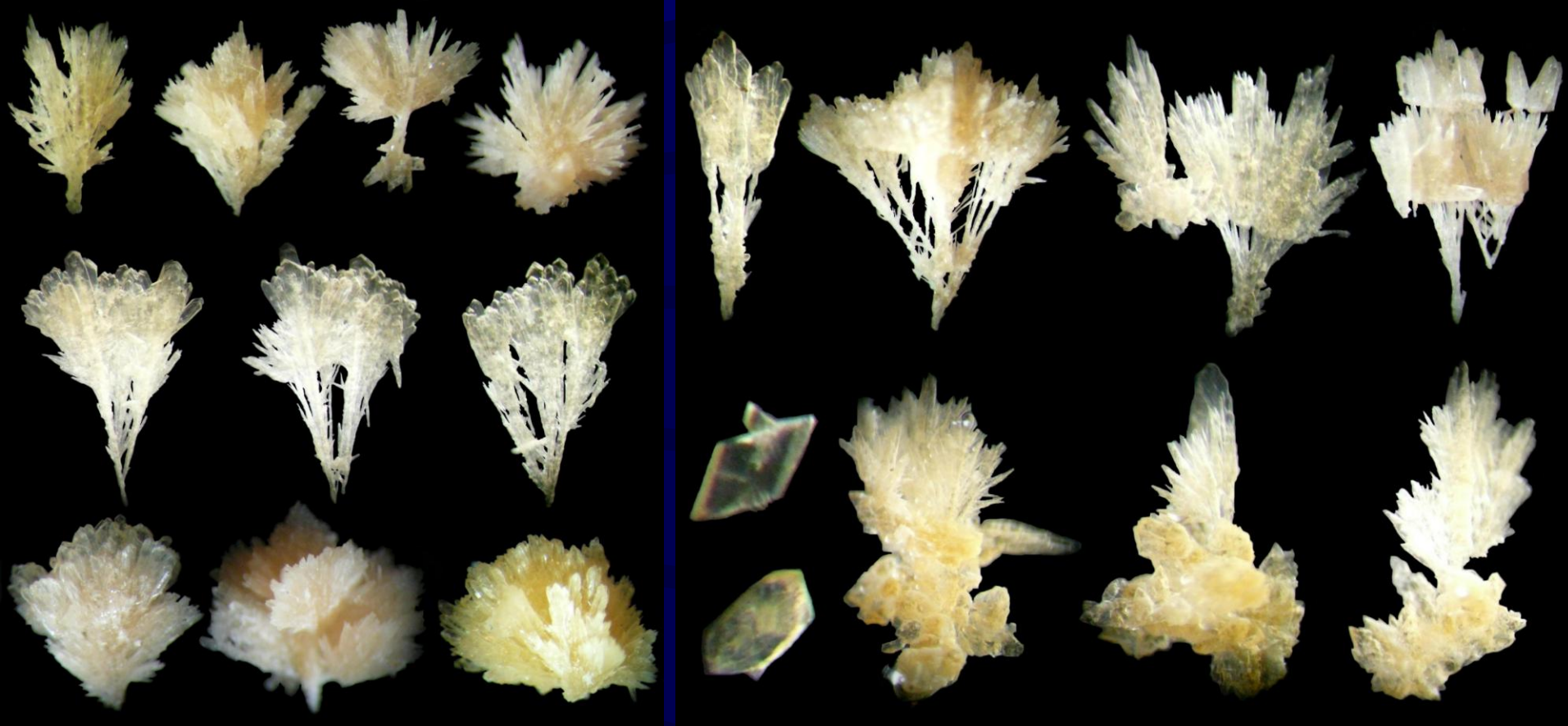


It is not possible to characterize all the mentioned conditions, but in all cases formation of a large amount of cryomineral powder take place. The particles of cryomineral powder are usually dispersed in the whole mass of the rocks, however, after melting of ice bodies they can accumulate in various forms and sizes.



“Cryochemical factories” were especially active in production of dispersed carbonate material in Pleistocene

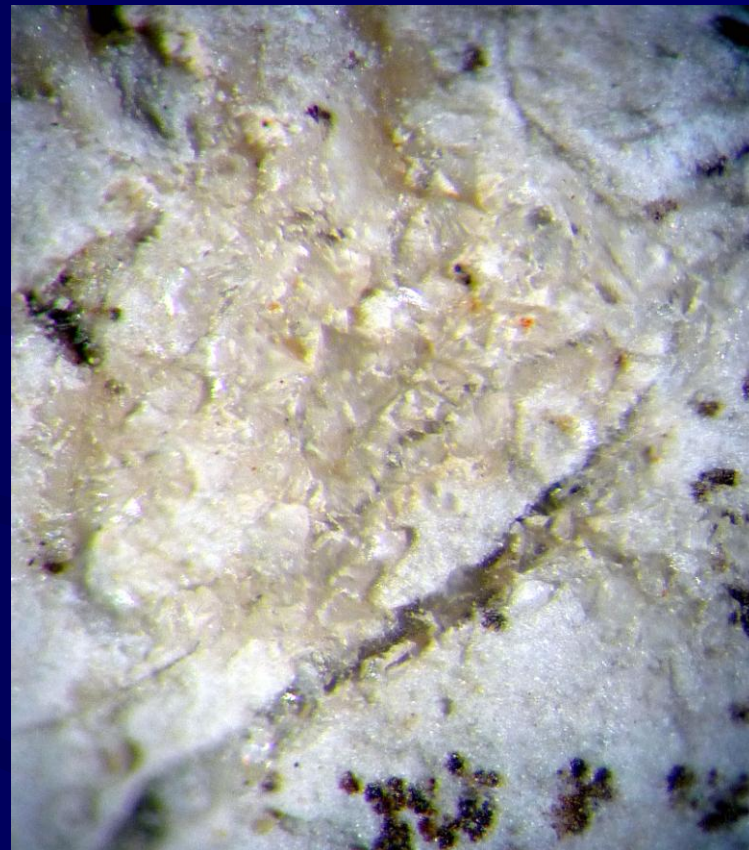




The separated pine-skeletal dendrites in different stages of regeneration (at the left), zonal aggregates and separated crystals with new formed on them split crystals. Pervyj Grotto, Kungur Ice Cave

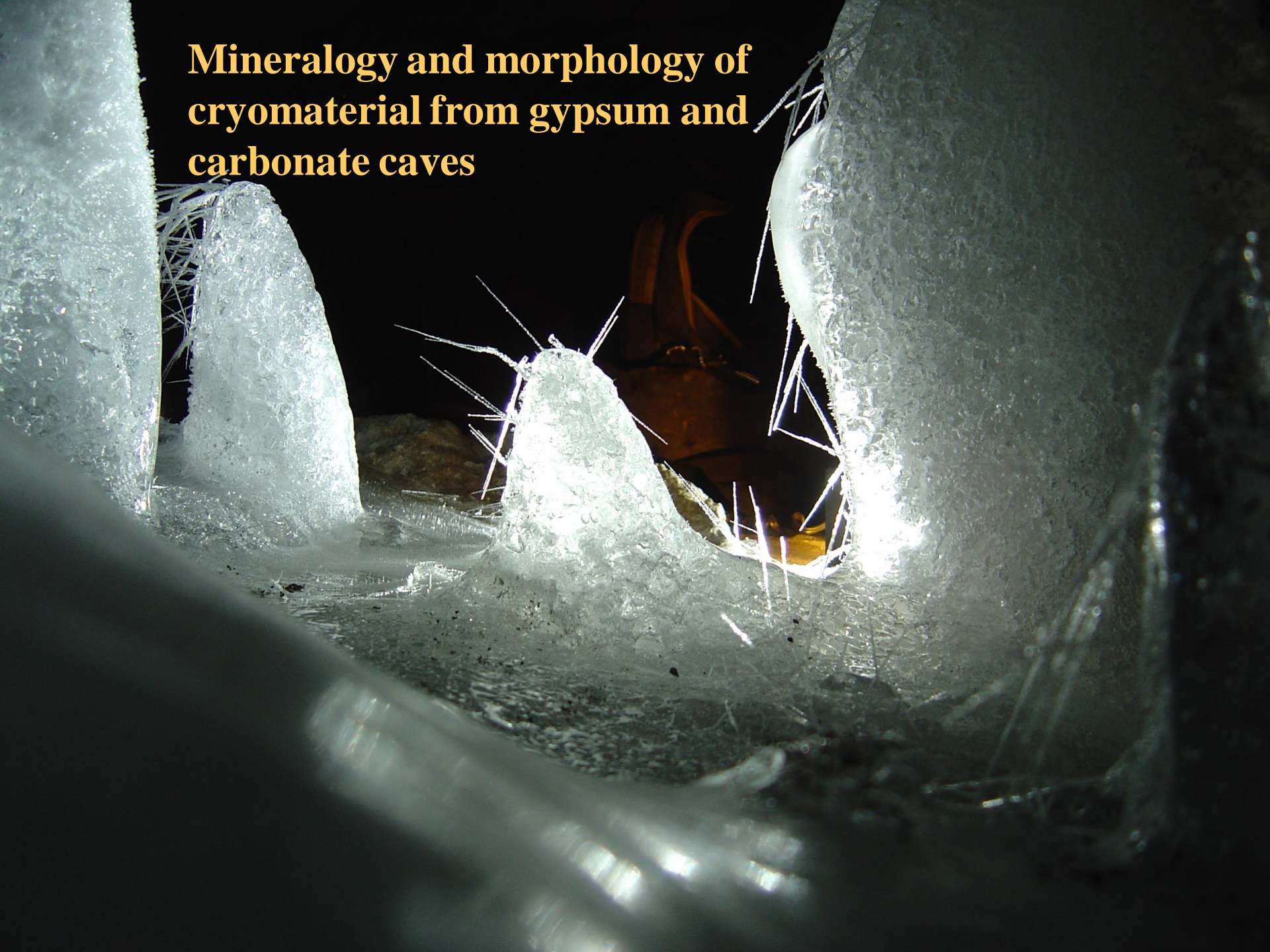
Such aggregates show cyclicity of stages of supersaturation and dissolution, and the changing of ice boundary location relatively to the forming minerals

**General view and morphology of neogenic breccias
(debris of 1 to 5 cm in size) cemented and covered with calcite
crystals from the transition zone, Kungur Ice Cave**



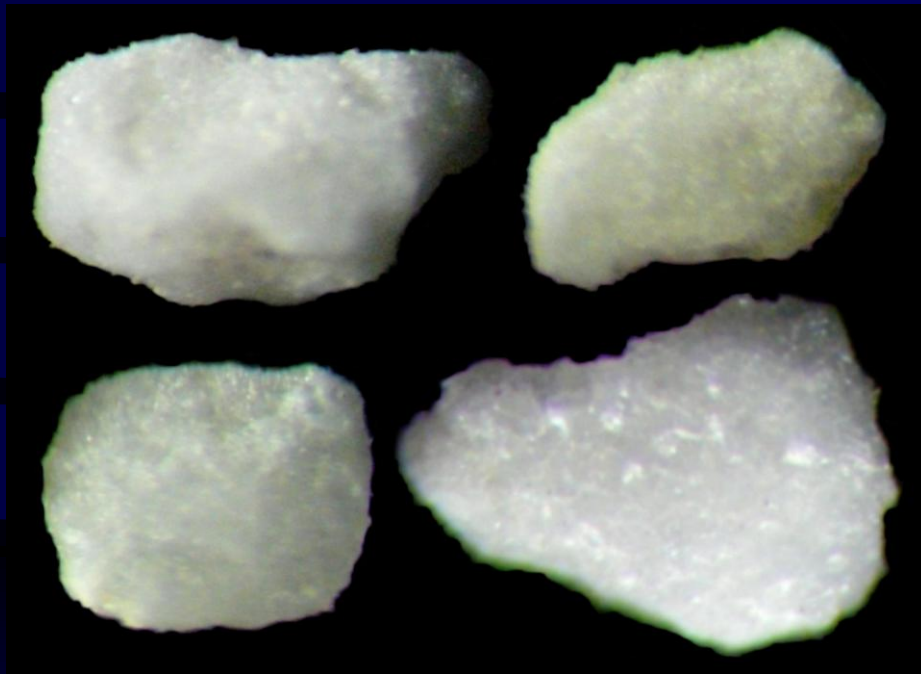
In the cold zone the amount of neogenic calcite is minimal and there are also solitary individuals with split surface. In the warm zone, besides separate crystals and concretions, more complex concretionary aggregates are observed and in the transition one – lithified parts of slide rock (breccias) cemented with calcite cement.

Mineralogy and morphology of cryomaterial from gypsum and carbonate caves

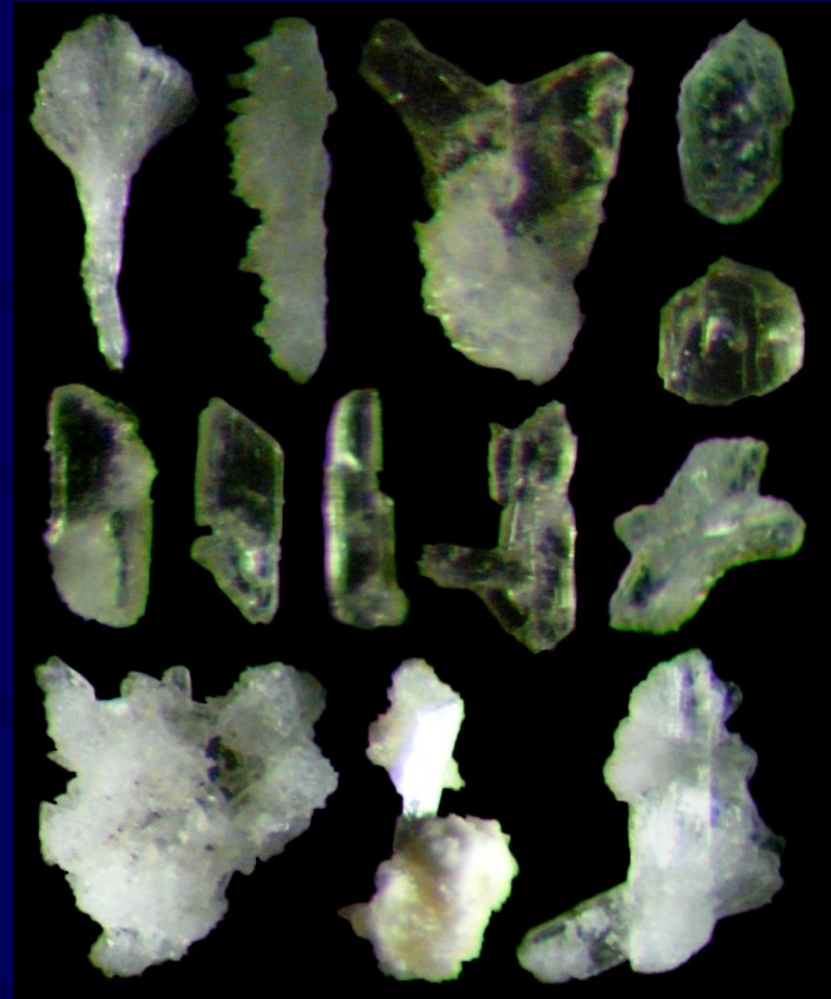


Original alabaster debris and cryogenic gypsum

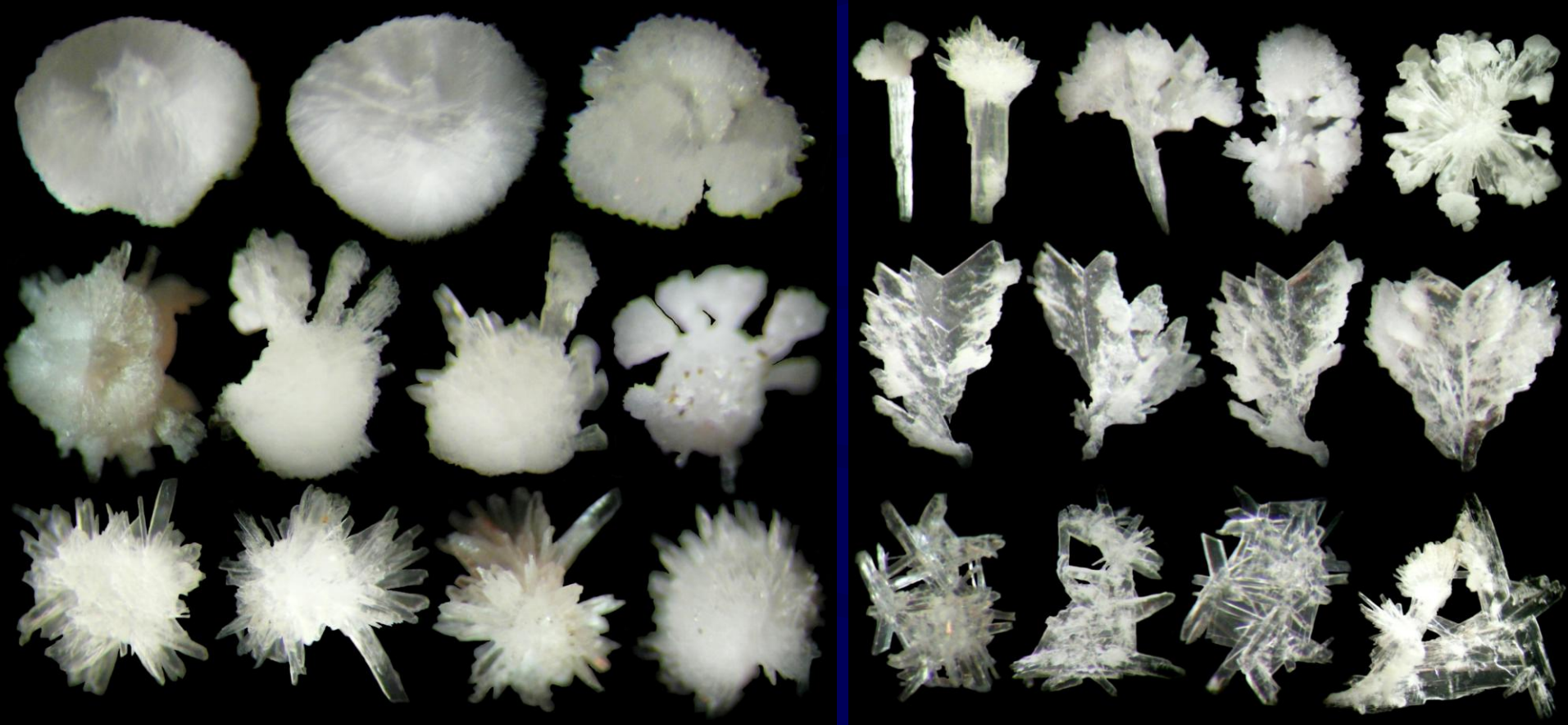
formations from the cold zone slide rock, Orda Cave



0.1 to 1 mm in size



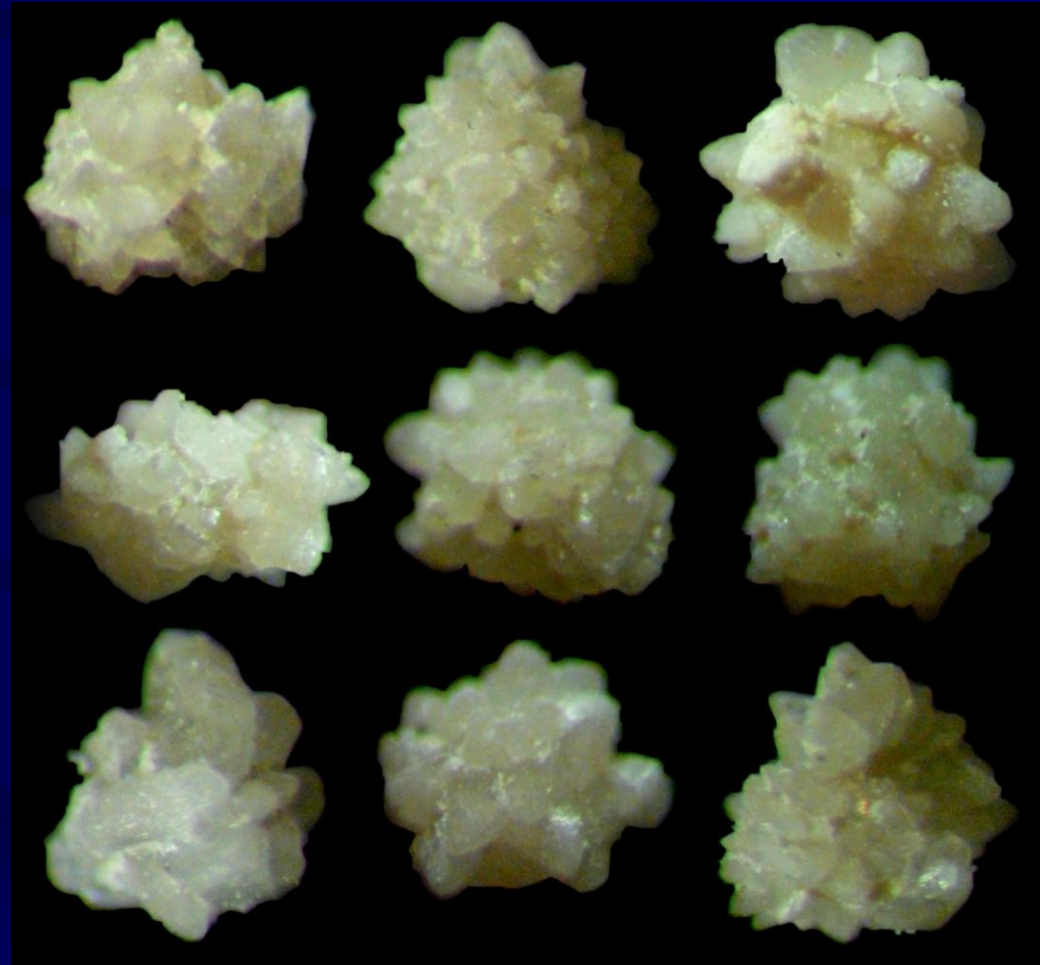
0.1 to 0.5 mm in size

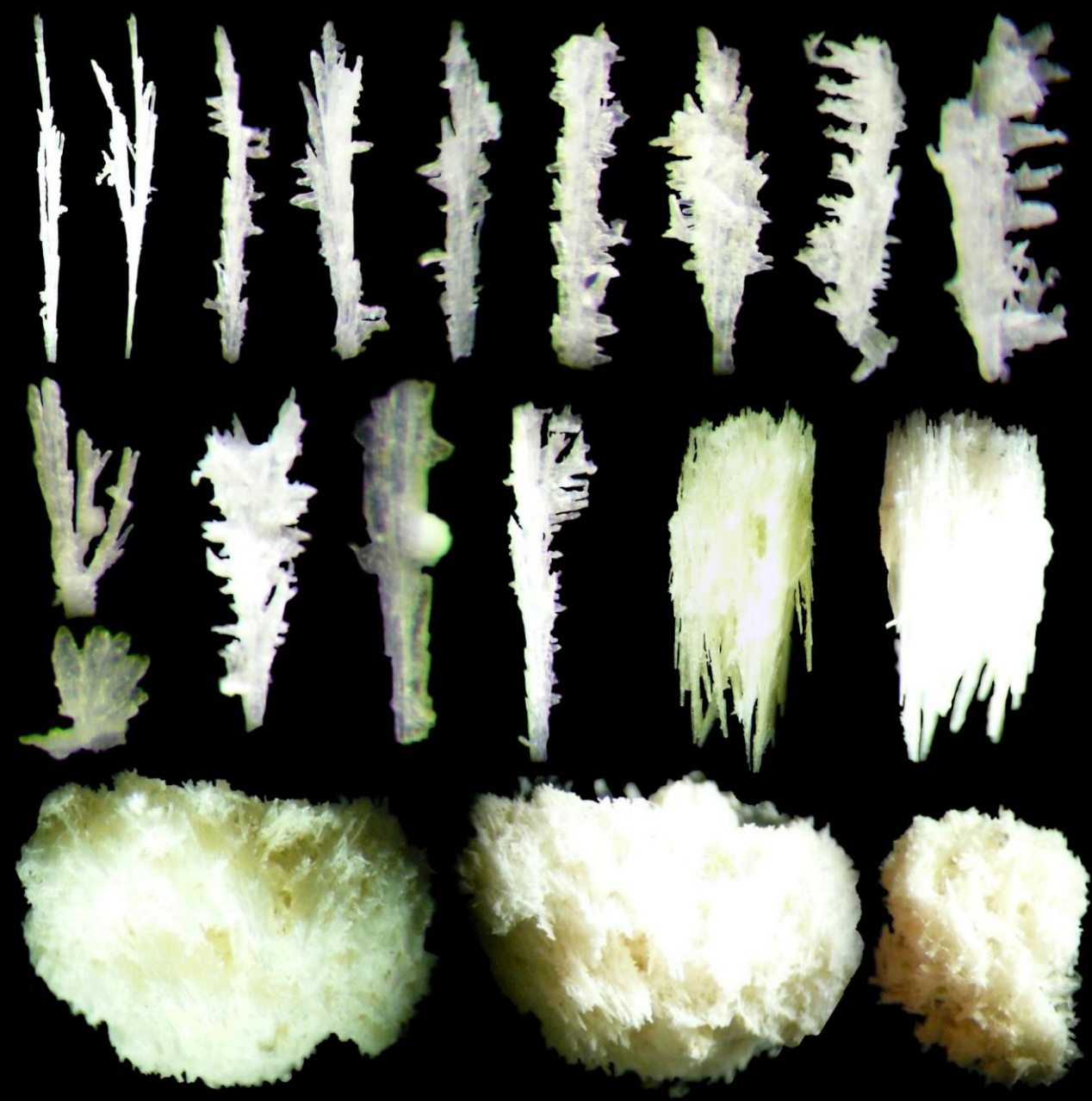


Regenerated (in different degree) spherulites, sometimes with the signs of 2 stages of splitting (at the left). Split crystals of gypsum and flat aggregates (twins and joints). Scandinavskj Grotto, Kungur Ice Cave

All of them are characterized by normal growth followed by split
one and on the contrary

Gypsum debris (0.1 to 1mm in size) and products of their partial or complete recrystallisation from the transition zone talus, Kungur Ice Cave

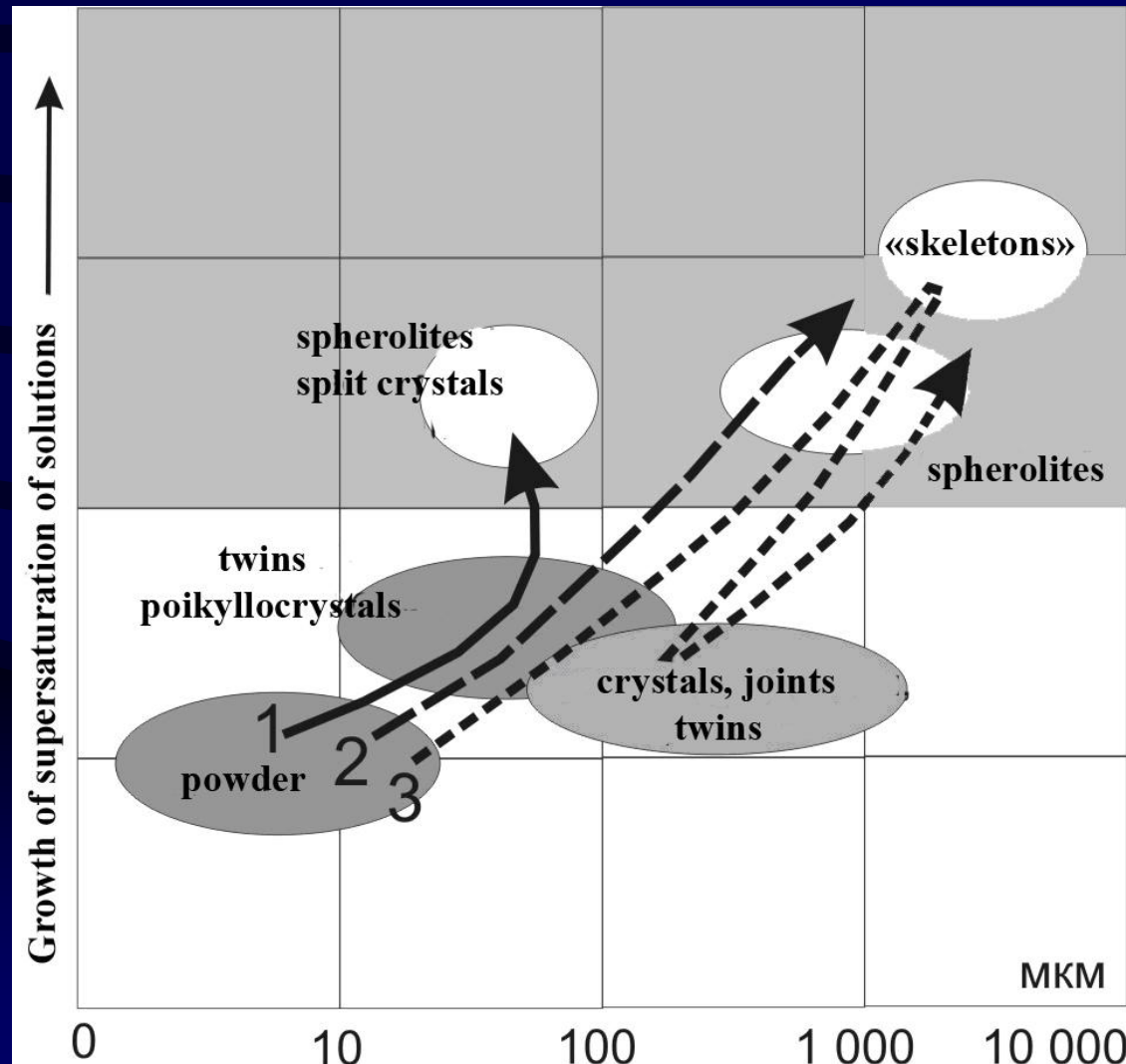




This sample was taken off from niche. It contains fragments of loose crystal crust with small thickness (1.5-6 mm) and skeletal sub-parallel or confused sub-individuals. It is considered that they formed in water on clay surface in conditions of significant evaporation, maintaining water in the supersaturated conditions

Separated skeletal sub-individuals and fragments of loose crystals crust.
Scandinavskij Grotto, Kungur Ice Cave

Summarizing the morphological features of crystals we can mention that the absence of gypsum of micron size (1-30 mkm) most likely shows his considerable transformation (recrystallization)

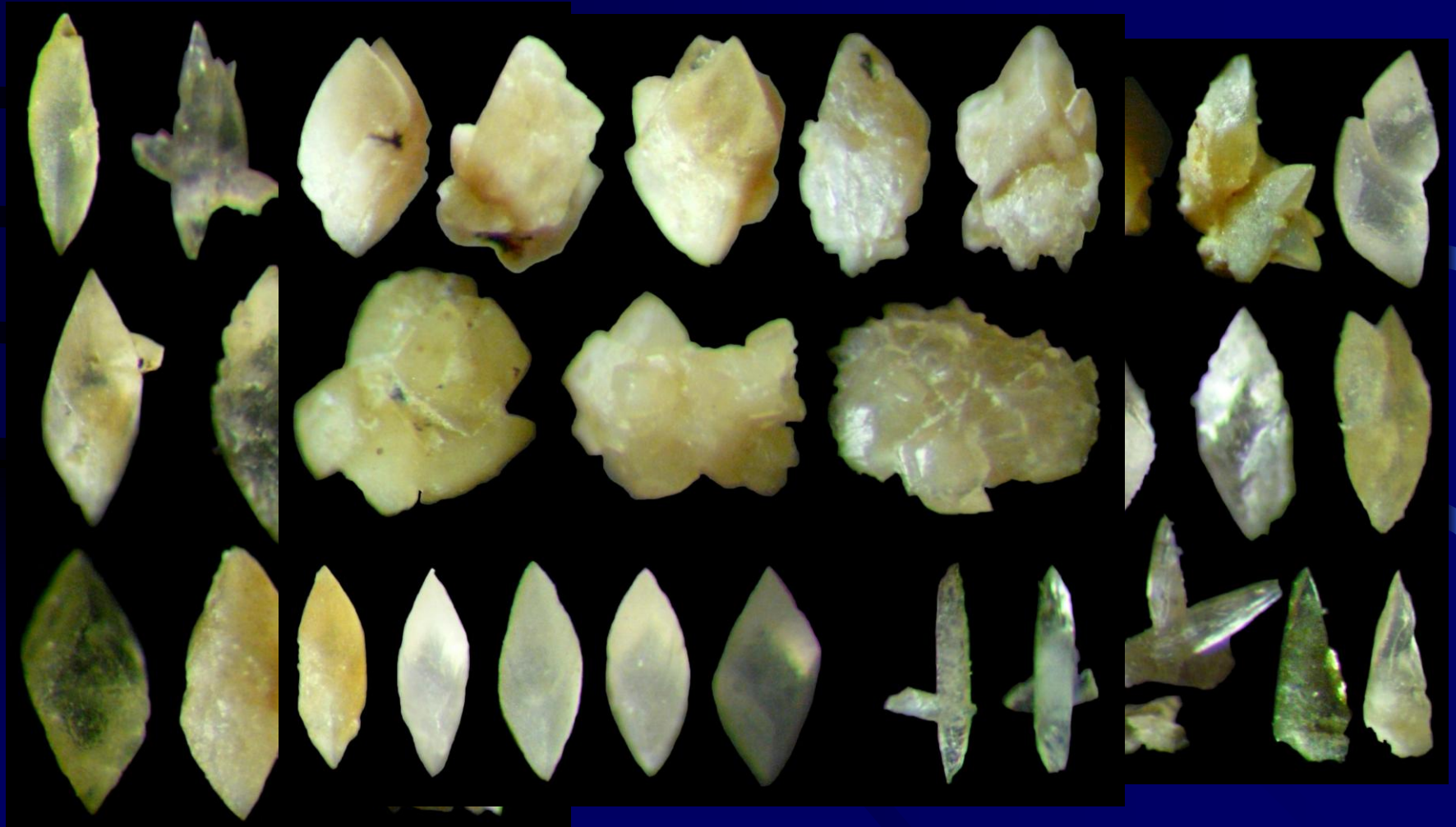


Morphologic variety of cryominerals in carbonate caves

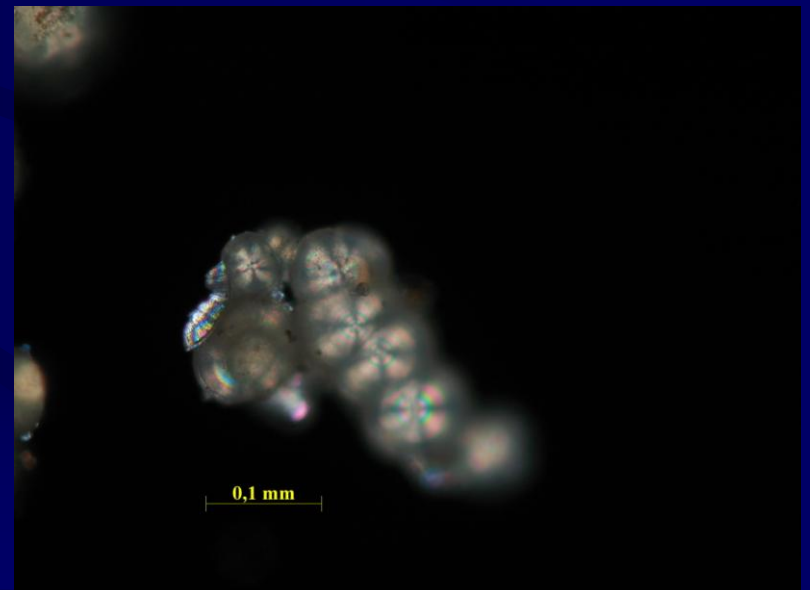
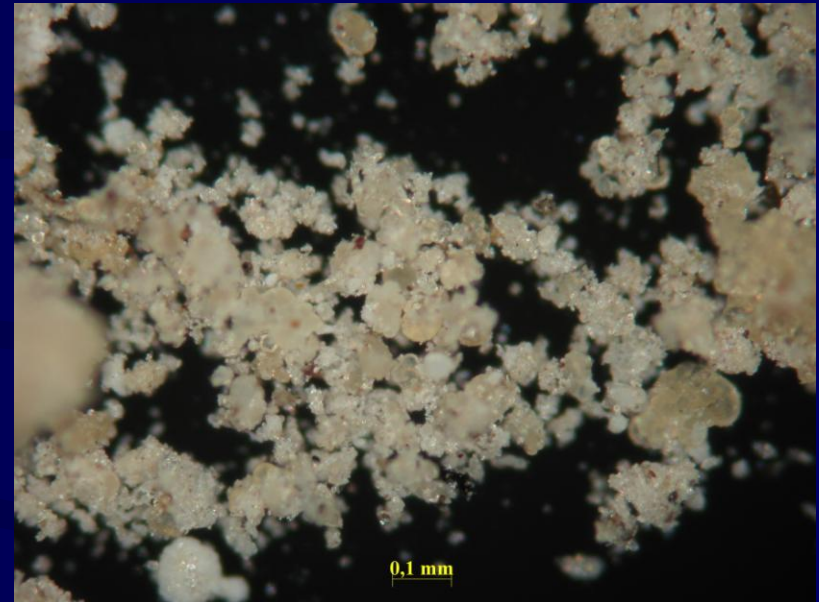
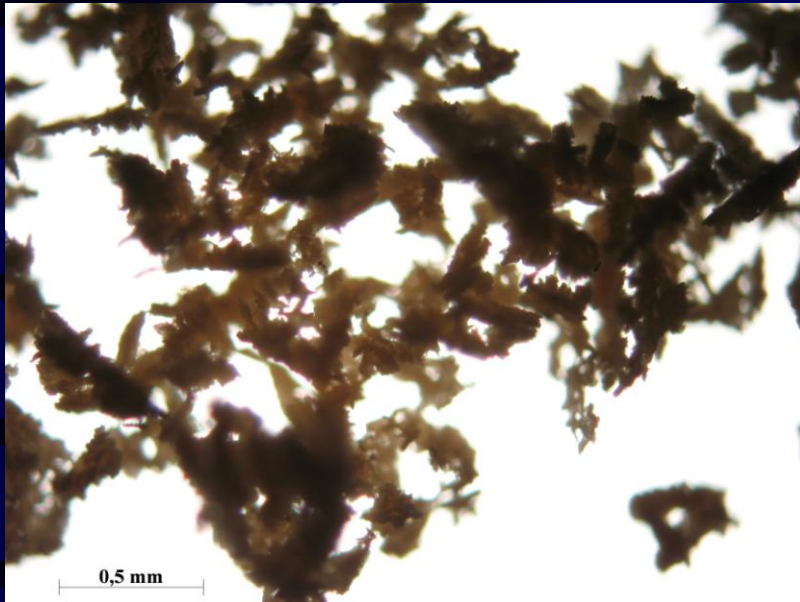


In all samples three types of rhombohedral crystals were registered: relatively isometric opaque off-white, sharper tintless-yellowish and sharp tintless ones

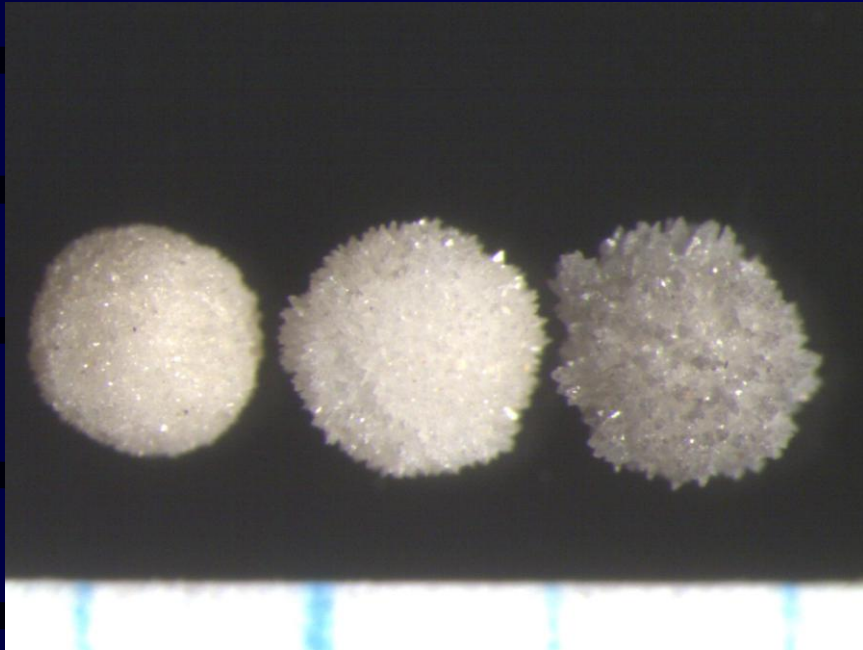
**Calcite morphology (0.1 to 1mm in size) from cold,
transition zones, Kungur Ice Cave**



Recrystallisation of carbonate cryogenic powder, Mariinskaya Cave, Perm Region



Cryogenic pearls (Pobeda Cave, Bashkortostan)



Research methods

- electronic microscope
- x-ray structural analysis
- geochemical analysis (isotope analysis (isotope ratios of oxygen and carbon))

Identification of cryomineral formations of caves

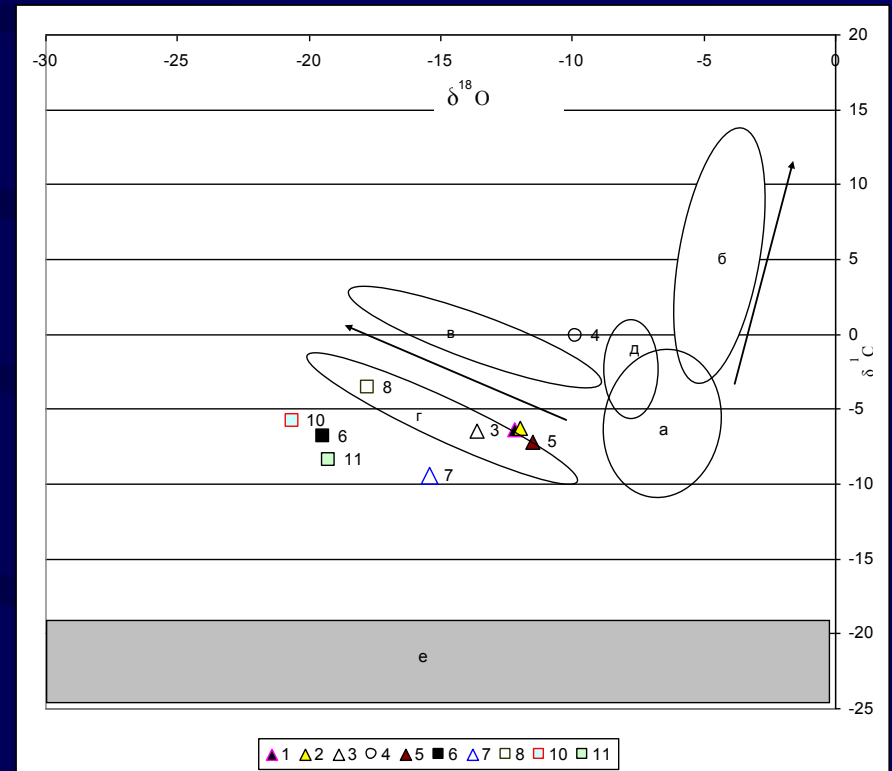


Unfortunately, it is impossible to find features definitely determining cryogenic origin of minerals at this stage of research. It is necessary to examine bigger number of samples, possibly to carry on their statistic analysis, to study their morphology and to make an attempt to find “isotopic support” for the morphological features etc. Currently, the investigation can be based only on results of underground observations, few experimental data and also on the number of morphological features always accompanying cryocrystals

Importance of "speleocryomineralogical" researches

- Age of cryomineral formations is also very interesting for investigation. Their dating could distinctly show the growth of underground ice, so the cryominerals could serve as age markers much more stable than ice which can melt, recrystallise, etc.
- Aerosol material, including particles are transported by air from outside, is preserved in cryomaterial growing layer by layer in underground naled ice. It can also be the source of information about pelaeoclimatic conditions of the past.

Cave material varies greatly in its content and morphology, reflecting, not only different formation mechanisms, but also varied factors of unbalanced conditions of the solution and changing environmental conditions in the cave



Detailed mineralogical investigations, applying the latest research methods, including isotopic analysis, will undoubtedly explain unknown effects and consequences accompanying cold mineral origin

Successive stages of mineral crystallisation, tempo of the process, cryomorphic transformation of crystals in the surrounding ice, inclusions in cryocrystals (for example water or other minerals), phase transformation of the mineral matter, its aggregation, structure of crystals (growth zones etc.) and many other problems also are very interesting



Thank you for attention!

