

# Change of fine gold properties for industrial application

S Sitkevich<sup>1</sup>, L A Gömze<sup>2</sup>, T Mayorova<sup>1</sup>

<sup>1</sup>Institute of Geology Komi SC UB RAS, 167982 Syktyvkar, Russia

<sup>2</sup>University of Miskolc, Hungary

E-mail: [sitx0113@yandex.ru](mailto:sitx0113@yandex.ru)

**Abstract.** At present we face the problem of cost-effective and efficient method for the enrichment of fine and small fractions of gold and its industrial application. New extraction technologies are required (sometimes more than a third of valuable raw are wasted). One of the trends to solve this problem is the change of magnetic susceptibility of gold.

## 1. Introduction

With the development of economy and science-based industries the demand for gold is increasing. This leads to a gradual involvement of poor and rebellious ores with rebellious, small and fine gold and also old tailings of processing plants. It is known that in certain objects main gold reserves are represented by small and fine fractions (up to 85% in some places in Chukotka). This significantly affects the results of enrichment: sometimes 40% of valuable raw go to the dumps. Loss is conditioned by both small dimension and morphology of gold particles.

One of the trends to solve the problem of gold recovery of specified classes is to change its natural properties, particularly magnetic susceptibility, for subsequent enrichment by a magnetic (electromagnetic) method. Detailed researches were conducted in the area of imparting magnetic properties to gold [1], taking into account the surface properties [2]. For example, according to one of the methods, the ore is treated with gaseous Fe (Ni, Co) carbonyl without changing the magnetic susceptibility of waste rock, i.e. based on chemical processes of interaction between gold surface and magnetic material [3]. However, these methods are still quite expensive. In addition to the problem of low-dimensional gold enrichment, there are certain difficulties with the extraction of a useful component from the concentrate and recleaning products.

The aim of the paper is to study the process of change of magnetic properties of fine and small gold to improve the efficiency of its extraction at the enrichment process.

## 2. Subjects and Methods

The objects of study were samples (collection) of gold from the Devonian paleoplacers of Timan. Dispersed gold content is characteristic for the whole producing horizon with higher concentrations in pebble conglomerates of bedrock-adjacent part of Devonian system.

In the experiments we used gold particles of flattened shape with grain size 0.1–0.4 mm from the nonmagnetic fraction. We added magnetic material to quartz sand and subjected the sample to impact test. The extraction into the magnetic fraction was carried out by magnetic separation using SIM-1 device in a weak magnetic field (less than 0.5 Tesla) at current 0,01–0,4 Å.

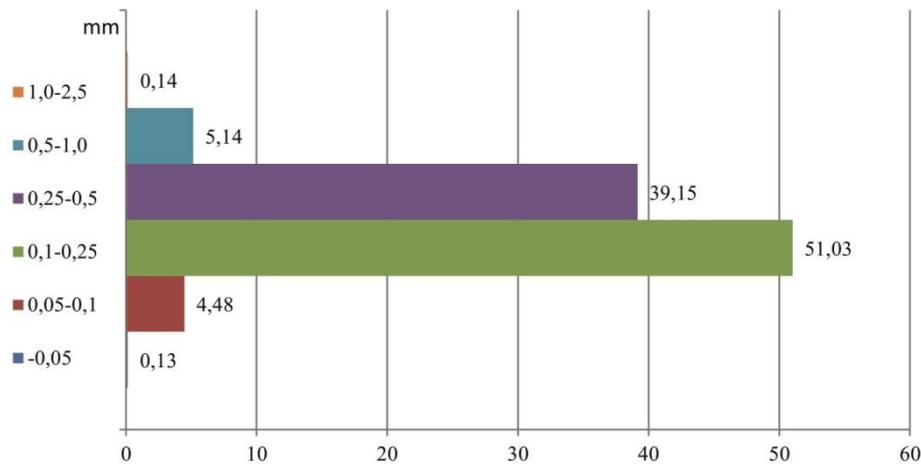
We used a range of modern physical and physical-chemical methods of research: optical-mineralogical (stereomicroscope MBS-10, polarizing microscope POLAM L-311), a computerized optical microscopy in translucent and reflection mode (Polam 3-312 and OLYMPUS BX51);



analytical scanning electron microscopy (JSM-64000, Jeol); X-ray fluorescence analysis (MESA-500W, Horiba) ICP-MS (ELAN 9000, Perkin Elmer); X-ray diffraction (XRD-6000, Shimadzu); IR spectroscopy (Fourier spectrometer FT-02 Intralum, Lumex), magnetometry; ferromagnetic and nuclear magnetic resonance.

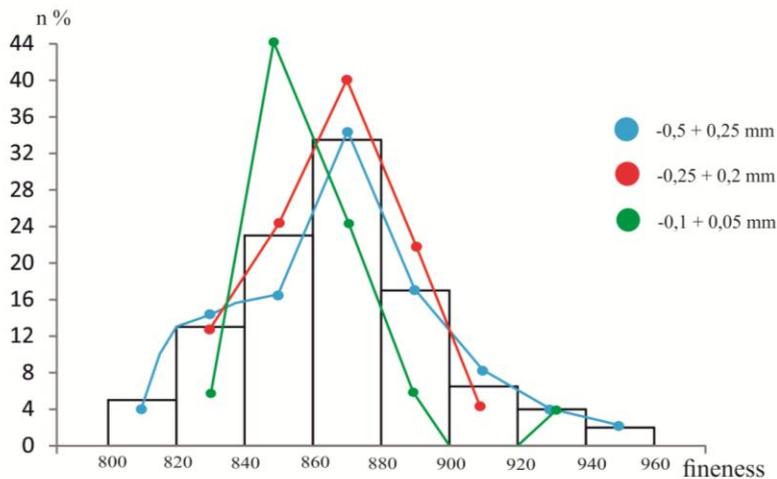
**3. Results and discussion**

Gold occurs in association with tantaloniobates (columbite, ilmenorutile), rare earth minerals (cularite, monazite, torite), osmirides, titaniferous minerals (leucoxene, ilmenite, rutile, anatase, brookite), sulphides (pyrite, pyrrhotite), Cr-spinels, pyrope. In the form of aggregates with gold we detected: quartz, feldspars, columbite, ilmenorutile, monazite, zircon, siderite, limonite, goethite.



**Figure 1.** Histogram of the class distribution of gold

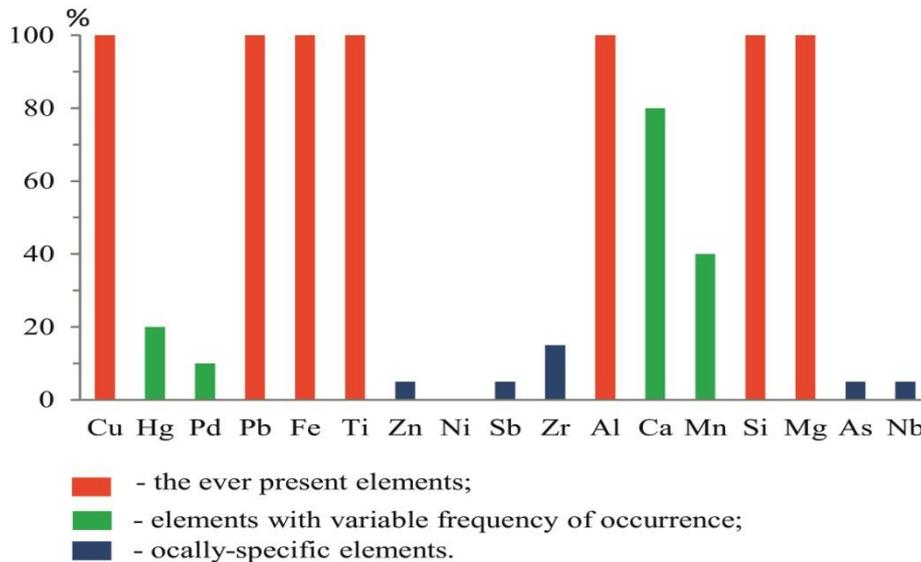
The gold is small, very small and fine (Fig. 1). It is characterized by high sorting, composition uniformity, high fineness. It is represented mostly by flattened low elongated forms. The coefficient of elongation of gold particles varies between 1.0-3.0. The modal value of grain length - 0.22 mm, width - 0.13 mm. The ratio of the modal values of gold particles of length to width defines elongation factor 1.69.



**Figure 2.** Histogram of gold fineness and fineness curves depending on the particle size

Figure 2 shows the curves of distribution of gold fineness into classes. Perhaps the lowest fineness values are a local feature and do not apply to all gold-bearing Devonian formations of Timan.

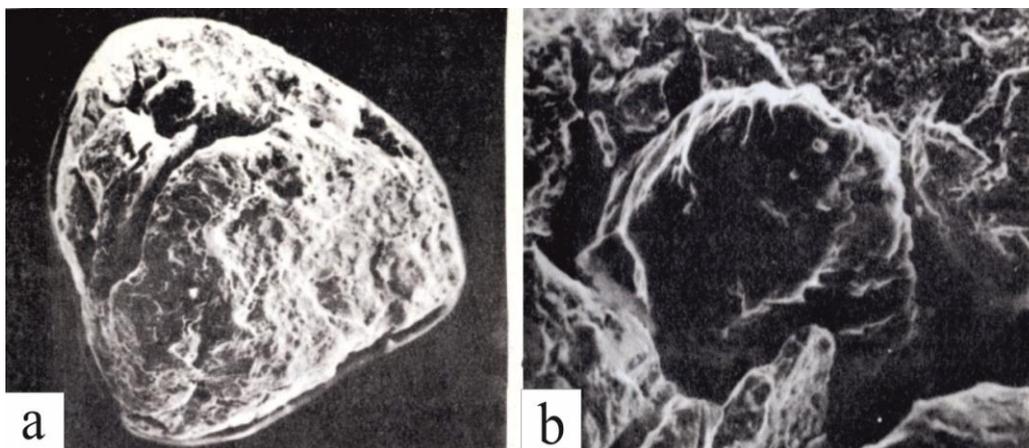
The permanent impurities in gold are silver, iron, copper, lead, titanium. Less common - bismuth, palladium, zirconium, mercury, arsenic, manganese, antimony, zinc (Fig. 3). The copper content ranges from 0.05 to 0.15, mercury from 0.04 to 0.15, palladium – thousandths to hundredths of a percent. Petrogenous elements: aluminum, silicon and others are always present, but their presence may be explained by inclusions.



**Figure 3.** Frequency of occurrence of impurity elements in gold from Devonian paleoplacers of Timan

From 70 to 90% of the gold belong to subrounded (roundness factor by Powers is 40), 5-15% are subangular individuals (roundness factor – 30) and 8 to 10% are represented by angular gold with roundness factor equal to 21, and particles with size 0.2 mm or more have a better roundness [1].

The surface of the gold particles is often microscaly, low porous. However, particles of -0.5; +0.2 class are characterized by a coarse foveolar, lumpy surface. The morphology of the gold from the paleoplacer is quite diverse: from nodular and plate to spherical. After processing the gold particles are mostly lumpy (Fig.4).

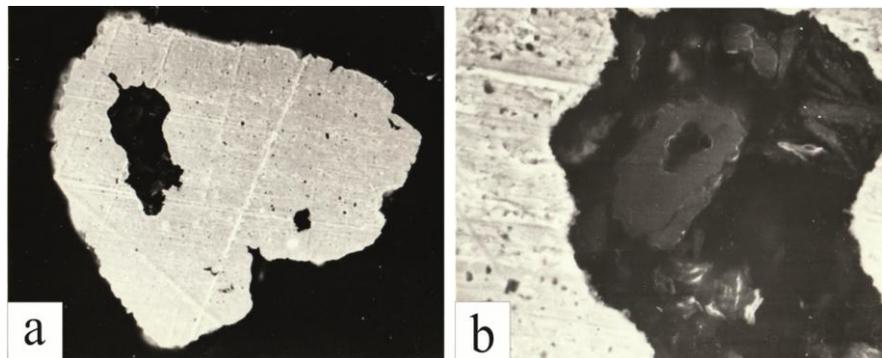


**Figure 4.** Gold particles after processing: a – general view of gold particle, magnified 400x; b – fragment of capture of mineral with electromagnetic properties by the gold particle, 1500x [1]

From the above characteristics it should be followed that paleoplacer gold of Timan belongs to the rebellious category, which requires application of new methods of metal extraction.

The application of high-gradient magnetic separation allows extracting up to 60% of gold to a hard fraction. Such an effect is conditioned by the following factors: 1) riveting of dispersed iron on gold particles during grinding process; 2) deposition of iron hydroxides, formed during pyrite oxidation, on gold in heaps; 3) close association of gold with magnetic minerals; 4) iron impurities in the gold. Studies of the influence of the material dimension to extraction gave the following results: 1) optimal dimension of enriched material ranges from  $106 + 30$   $\mu\text{m}$ ; 2) separation efficiency decreases with sizes from 15 to 100  $\mu\text{m}$ , finer grains have relatively less magnetic susceptibility.

The analysis of processed gold revealed that the magnetic material got lumpy inside particles or captured by the edges of particles at the moment of deformation. Microscopic examinations with an electron microscope allow diagnosing the observed microinclusions as iron-containing minerals (Fig.5).



**Figure 5.** Entering of magnetic fraction into gold (polished section): a – general view 50x; b – fragment of the area of entering 250x

It should be noted that the iron-containing material (in this case - magnetite) should be added to the sample in the range 0.07–0.08 %. As a result, from 92–95 % to 100 % of gold can be extracted into the electromagnetic fraction from the concentrate.

#### 4. Conclusion

Thus, changes of the magnetic properties of gold can be carried out at the stage of disintegration of rocks fast and without additional operations that will enhance the efficiency of extraction of gold of very small and fine classes. However, we must emphasize the laboratory level of researches. The solution of industrial problems requires some technical improvements of industrial installations in the technological scheme of enrichment of specific deposits of fine and small gold.

#### References

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