# THE INTERMETALLIC COMPOUNDS OF GOLD WITH LEAD

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## ABSTRACT

The article presents information about the intermetallic compounds of gold and lead. These compounds have been previously obtained by scientist in their experimental studies. The authors who have found Novodneprite in Kazakhstan, in the study used the polarizing microscope for reflected of light, ultrasonic needle to extract spheroidal gold from the polished section for X-ray diffractive study in the Debye-Scherrer camera, microprobe JCXA-733.

**Keywords**: intermetallic compounds, deposit, gold, lead

## INTRODUCTION

The experimental data of Japanese scientists conducted in 1958, to study the system Au - Pb pointed to the possibility of finding intermetallic Au-Pb in nature. They have a fairly high of temperature stability. Intermetallic compound - $AuPb_3$ was also published in the magazine [1]. As of today three intermetallic compounds are discovered: 1) Anyuit – $AuPb_2$ (Russia, 1989), 2) Hunchunite - $Au_2Pb$ (China, 1992), 3) Novodneprite – $AuPb_3$ (Kazakhstan, 2002). All intermetallic compounds got names in a location where they were found. Anyuit was found on the Anyui river, Hunchunite on the Hunchun river, Novodneprit at the Novodneprovskoe gold deposit. Novodneprite was found on microscopic examination of gold concentrate from the limonite zone of Novodneprovskoe deposit and it is in close association with Anyuit. G. Anisimova and other researchers have found in the sediment spheroidal native gold and spherical formations consisting of galena and sulfide Pb, Cu and Ag that fall out after dissolving of concentrate in aqua regia [2]. The composition of the low-melting material, which goes into the ingot during smelting concentrate consists of intermetallic Au and Pb with varying concentrations of Sb and As. This once again shows the influence of lead in the formation of gold. According to Anisimova in the remainder of sediment after processing gold of concentrate by dilute nitric acid, fused with caustic soda in a muffle furnace (T 550°C) and melting in water, were found visible membrane fractal cluster gold and three intermetallic compounds – $AuPb_2$; $Au_2Pb$; $AuPb_3$.

## RESEARCH

### *Novodneprovskoe deposit*

The reason for the study of the gold concentrate there is lead in the gold alloy. Gold particles in the concentrate have an unusual spheroidal shapes and consist of both pure

gold spheroids and polymineral spheroids. Novodneprite in intergrowths with Anyuit fills the free spaces between the crystals of gold inside the spheroidal aggregates. In another polymineral spheroidal formations gold crystals in intergrowths with fine grains auricuprid are allocated in the mass, which consists of native lead, novodneprite with anyuit.

The spheroid gold aggregates have been found in a gravity gold concentrate from limonite loose zone Novodneprovskoe deposit. It relates to the gold-arsenic-polymetallic type with the combined of vein and veinlet-disseminated mineralizeation. The deposit is composed of Precambrian gneiss-terrigenous-carbonate rocks of the sharyksry and kokshetausky suites which intersected by small granitoid bodies of zerenda complex. Enclosing rocks crumpled into steep folds and subject to shearing and mylonitization. The zone of oxidation is presented weathered rock - gravel, clay, with frequent formation of pockets and cavities that are filled with limonite and manganese sypuchka, with relict of sulfides. The depth distribution of the oxidation zone is significant - 70-350m.

The spheroid gold aggregates are located in the jacobsite-kampylite mass (Figures 1 and 2). The mineral association is native gold, intermetallic compounds of Au and Pb, native lead. The size of the spheroids of gold is from 0.01 to 0.35 mm. There are three types of spheroid formation of gold: 1) monosferoids, consisting only of gold with a perfect round shape, and 2) spheroids of gold, consisting of small crystals of gold, the space between them is filled with intermetallic compounds of gold and lead (Figure 3), and 3) spheroids of gold, in which crystals of gold in intergrown with grains of auricuprid, the space between them are filled with intermetallic compounds of gold and lead (Figure 4).

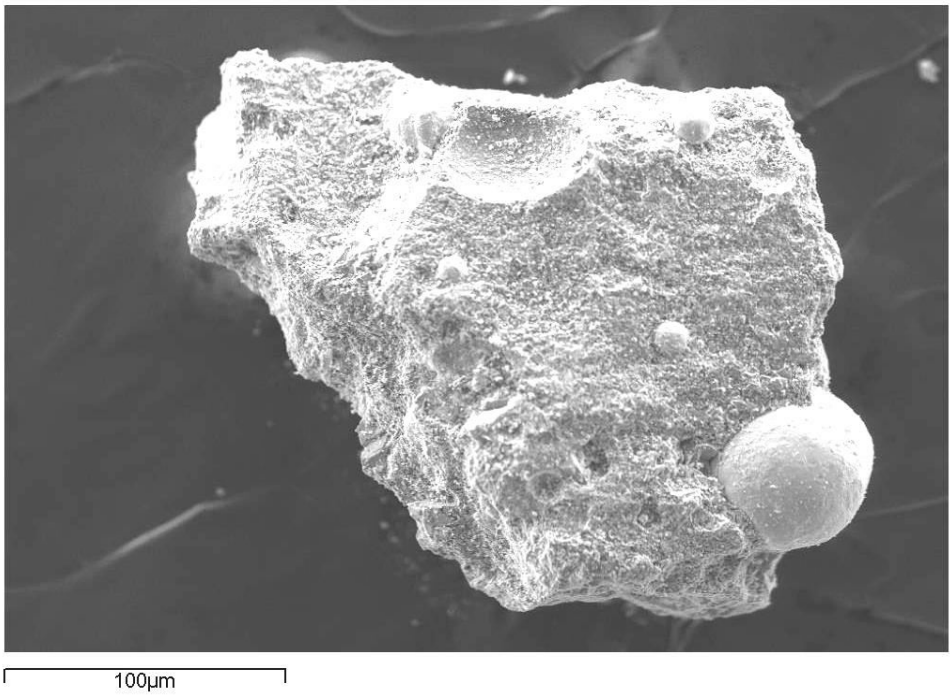


Figure 1 – Spheroids of gold in the jacobsite-kampylite aggregate.

Image is in the secondary electrons

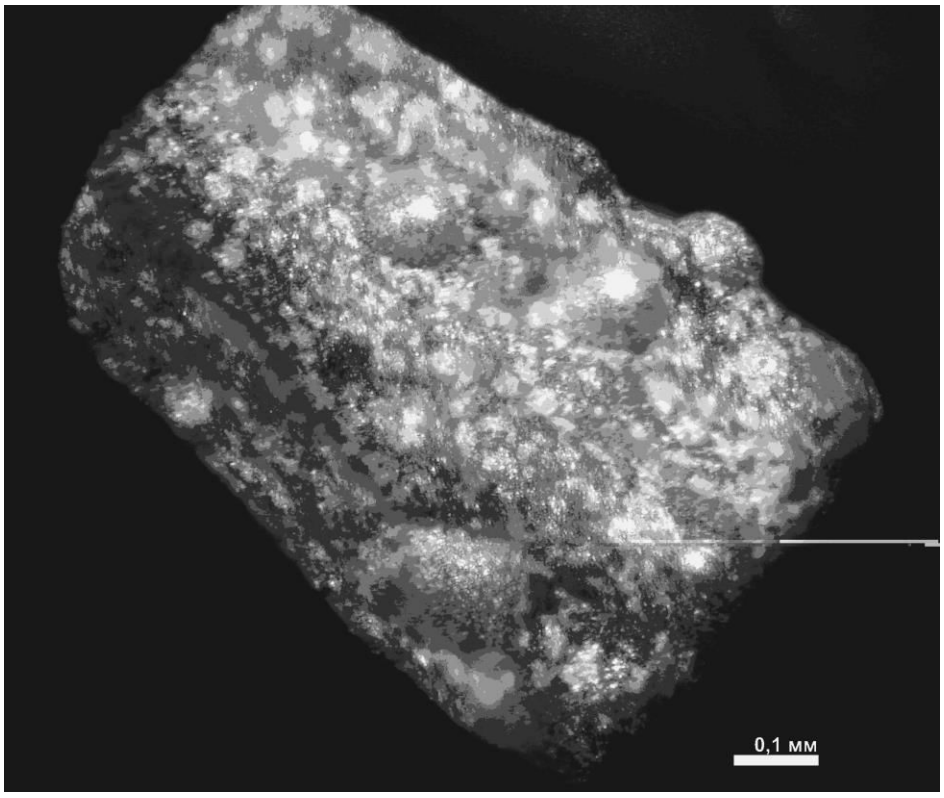


Figure 2 – Spheroids of gold in the jacobsite-kampylite aggregate

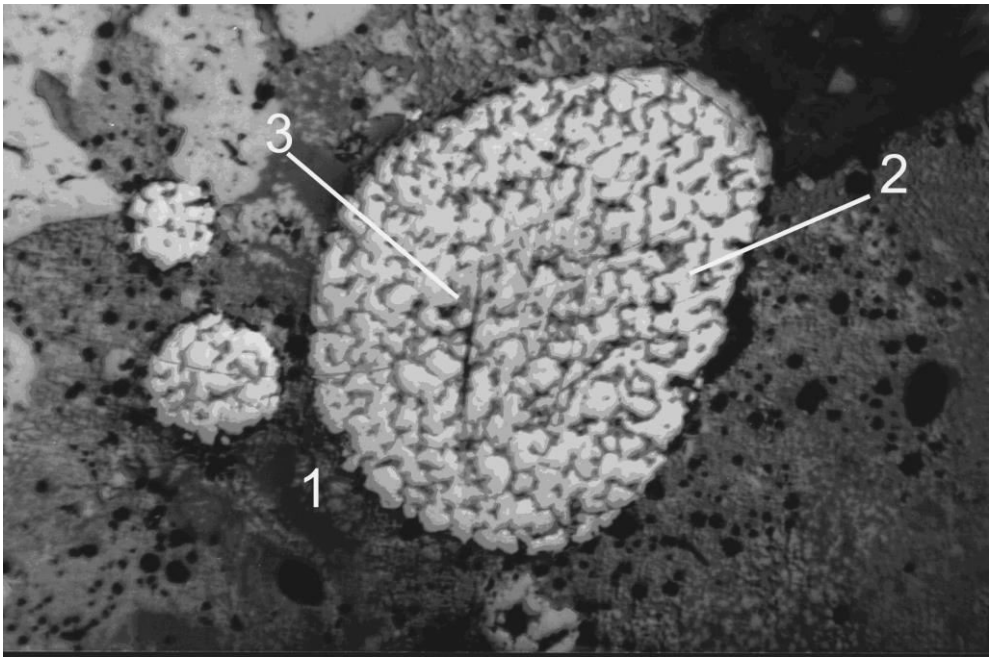


Figure 3 – Polymineral spheroids of gold in the jacobsite-kampylite aggregate (1).
Grains of native gold (2) are cemented by novodneprite with anyuit (3).
Polished section. The increase in 250

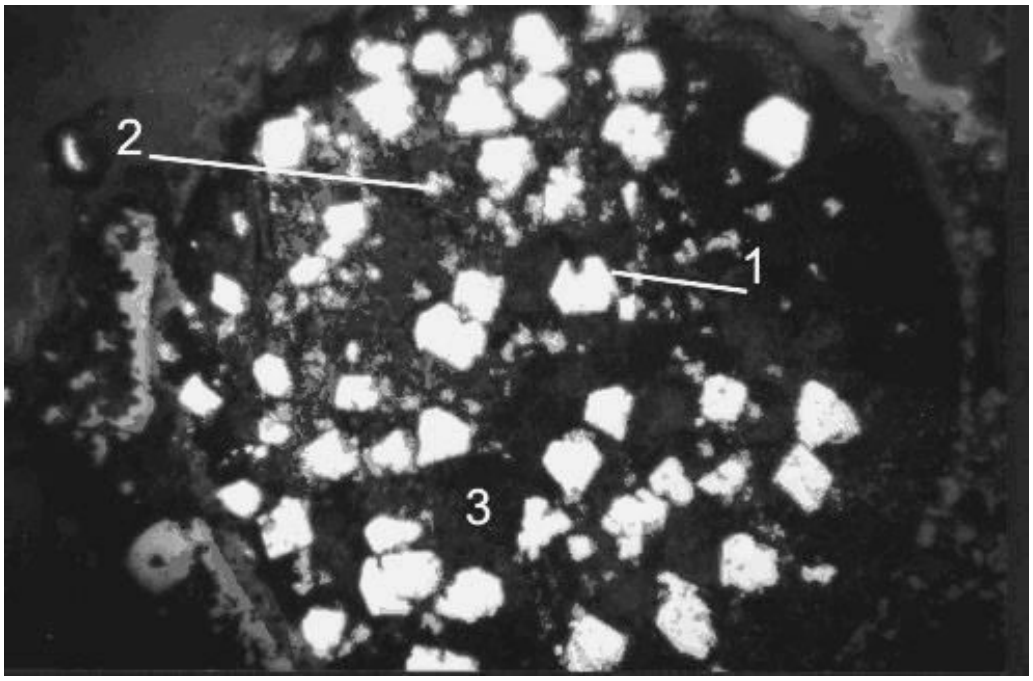


Figure 4 – Polymineral spheroids. Crystals of gold (1) in intergrowths with small grains of auricuprid (2), native lead, novodneprite and anyuit (3). The increase in 250

Novodneprite was discovered by the author and colleagues and have been approved by the International Mineralogical Association Commission on new minerals and mineral names in 2005. The mineral is invisible. You can see it only under microscope. The size of the new mineral is 7 mkm.

The chemical composition of the new mineral has been studied in microanalyzer JCXA-733 (Table 1). Analysis conditions: accelerating voltage of 25 kV, probe current 25 nA. The measurement time of peaks and background - 30 and 5, respectively (analyst P. Kotelnikov). The average empirical formula is $(Au_{1,00}Cu_{0,01}Ag_{0,01})_{1,02}Pb_{2,98}$. The ideal formula is $AuPb_3$. New mineral contains small number isomorphic impurities Cu and Ag. Novodneprite prevails over the anyuit in polymineral spheroidal formations. Comparison of novodneprite and anyuit is in Table. 2.

Table 1 - Chemical composition (wt%) of novodneprite (9 analyzes) in the polymineral spheroidal formations

| Components | The average value | The range of values | Standard deviation | Standard used |
|---|---|---|---|---|
| Au | 24,15 | 20,73-25,29 | 1,32 | Au – 100% |
| Cu | 0,11 | 0-0,18 | 0,05 | Cu – 100% |
| Ag | 0,11 | 0-0,13 | 0,06 | Ag – 100% |
| Pb | 76,00 | 73,74-77,33 | 1,13 | PbS |

Table 2 - Comparative characteristic of novodneprite ($AuPb_3$) and anyuit ($AuPb_2$)

| Components (wt.%), the unit cell parameters | Novodneprovskoe deposit, North Kazakhstan | | Placer River Big Anyui, Russia (1989) |
|---|---|---|---|
| | Novodneprite | Anyuit | Anyuit |
| | (average of the 7 analyzes) | (average of the 3 analyzes) | (average of the 3 analyzes) |
| Au | 23,60 | 29,70 | 32,6 |
| Cu | 0,10 | 0,43 | - |
| Pb | 75,55 | 65,99 | 64,8 |
| Ag | 0,06 | 0,45 | 0,35 |
| Sb | 0,00 | 0,00 | 0,30 |
| Total | 99,31 | 96,57 | 98,05 |
| Microhardness, kgs/mm$^2$ | | | from 124 to 146 |
| ***a***, Å | 11,954(3) | | 7,39(2) |
| ***c***, Å | 5,890(5) | | 5,61(3) |
| ***V***, Å$^3$ | 842(1) | | 306,37 |
| Pr. g. | $I\bar{4}2m$ | | $I4/mcm$ |
| Z | 8 | | 4 |

Spheroidal aggregates of gold were extracted from polished sections by ultrasonic needle for X-ray studies. Powder patterns of spheroidal aggregates contain a line of three minerals: native gold, anyuit and novodneprite. Reflexes of novodneprite identical with the reflexes of synthetic phase $AuPb_3$. Novodneprite belongs to the tetragonal system similar to the synthetic phase $AuPb_3$. The unit cell parameters: a 11,954 (3) Å; c 5,890 (5) Å; V 842 (1) Å3, Z = 8. Space Group: $I\bar{4}2m$.

Structural study of single crystals of novodneprite currently not possible because of small grain size and its intergrowth with anyuit.

The formation of spheroidal golds that are composed of native gold and gold in association with other minerals (native lead, novodneprite, anyuit, auricuprid) is difficult to explain. No doubt the spheroidal golds are located in the jacobsite-kampylite aggregate.

Perhaps jacobsite played a role of the precipitant. Intermetallic compounds in which there are the main elements of Au, Pb, Cu, Ag, probably formed as a result of the decay of high-temperature solid solutions with decreasing temperature. In spite of the fact that the minerals were found in the oxidation zone their composition, structural features, a

close relationship with jacobsite confirm of the hypogene formation. Kampylite, which is intimately intergrowth with yakobsite, formed under the influence of surface water containing phosphoric acid that had an influence on the lead minerals (galena, cerussite), whose presence is noted in the oxidation zone. The source of the arsenic is a process of oxidation of arsenopyrite and possibly tetrahedrite.

This association with native lead, intermetallic Au and Pb and native gold was cited in L. Razin and G. Sidorenko [3] when describing anyuit $AuPb_2$ - a new mineral, found by them on the river Anyui. The authors believe that such intergrowth of anyuit with native lead is possible at decomposition of solid solution.

There is a point of view on the conditions of formation of gold spheroids [4]. The gold spheroids according to this theory is the result of filling of the gas-liquid cavities with gold and other minerals in quartz**.** Then quartz weathered. The authors of these studies was dissolved quartz-vein matrix to extract the pure gold grains with preservation of their natural forms. A lot of gold spheroids (more than one thousand of 7 deposits) among the various forms of gold were revealed. Their chemical composition, surface morphology and internal structure (several hundred of gold spheroids) were studied by microprobe microanalysis.

## CONCLUSION

In conclusion, mineralogical and experimental studies indicate a close relationship of gold and lead, which play an important role in the formation of deposits of noble metals.

In the study of many gold-pyrite-polymetallic deposits in Kazakhstan galena plays an important role for the deposition of gold in the late stages of mineralization. Later associations in these deposits very often contains galena, which is intimately intergrown with gold and tellurides.

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