Making a Silk Purse on the Silk Road
Cleangold Report on Artminer's Project in Xinjiang, China
October, 2013

Introduction:

This project was in the making for a couple of years with the destination changing as political climates in various countries changed. With the projects that we have done in the past our work was focused on small scale and artesanal gold mining and intervention of the use of mercury in these groups through demonstration of the Cleangold technology and methods. However, for this project we shifted course upon arrival to that of a large scale mine. This mine uses a variety of methods including flotation, centrifugation (reportedly), as well as cyanide extraction of the concentrates generated by these processes. With the support of various government and industry groups we were able to visit the lab at the mine site and secure samples of process materials to evaluate the gold being lost as well as the gold that was being recovered.

Securing a Source of Magnetite

The Cleangold technology and methodology are dependent on a source of magnetite, Fe3O4, a magnetic iron oxide. Sometimes magnetite is present in the ore being run as with placer and alluvial deposits. As we learned more about the mine ore we discovered that considered opinion had it that there was no magnetite in the ore. At our first meeting with one of the partners in this project, Dr. Ma Hua Dong, a senior geologist and assistant Chief of the Xinjiang National 305 Project, we raised this question and Dr. Ma pointed us to a magnetite mining and crushing operation that was feeding a steel mill in the region where the gold mine we were to visit was located. So we loaded up the next day and headed through the agricultural lands outside of Urumqi towards the Tian Shan Mountains. It was quite a trip to see this area of western China unfold its geological and ethnic history. The agriculturalists in the region are the Uyghurs while the grazing and pastoralists are the Kazaks. Not nearly as forested as the mountain ranges that I grew up with, the Tian Shan Mountains have grass lands and alpine meadows, which reach almost to the glaciers that feed powerful rivers out onto the arid grasslands below. These high areas are the summer herding grounds for the Kazaks and we saw their herds of sheep, camels, horses and cows throughout the hillsides, as well as the honey stands by the road supported by their extensive beekeeping operations.

When we arrived at the magnetite operation we were shown to piles of what appeared to be hematite and testing the fines of this material showed no significant presence of magnetite. We experimented with a small pile of black material which contained a small amount of magnetite. Finally we flagged down a truck hauling crushed ore from

the crushing operation higher up and found it was just what we were looking for. The material we first looked at that had come off of the reddish chunks was hematite but the material inside the large red chunks was magnetite. Later at the mine lab we would find that the material could be engineered to create a good adsorbing matrix for our process.

Visiting the Mine

With a bucket of crushed magnetite we drove to the mine site where we were led to the mine's laboratory. There, a sample of the flotation process tailings had been collected for our work. The magnetite was processed into a useable material and then the sample was run on a Prospector's Sluice that was precharged with the engineered magnetite. We did not have an opportunity to see the mining and processing operations but with the help of our interpreters, and some English skills exhibited by one of the laboratory chemists, we were able to ask the lab personnel about the processes and learn of several other sampling points in the process that could provide insights into the routine losses experienced.

With what we learned at the mine combined with what we later learned from people associated with the Gold Institute my understanding of the gold recovery process currently in use is as follows:

1) The ore (averaging 40-50 grams of gold/ton or 20-30 grams per ton depending on the source referenced) is crushed to minus 200 mesh and is then subjected to centrifugal recovery using Knelson concentrators on the whole ore. The concentrates of this process are sent to cyanide extraction for final recovery.

2) The gold in this ore is mostly less than 200 mesh in size and coatings with pyrite are common.

3) Tailings of the Knelson concentrators are then sent to the flotation circuit where the bulk of the gold from the operation is concentrated prior to final recovery by cyanide extraction. The tailings of the flotation process generally run about 0.5 grams/ton. Given that the mine is running 1000 tons per day, this loss would be estimated at about $20,000 per day.

4) The concentrates of the Knelson concentrators and the flotation concentrates are subjected to closed circuit cyanide extraction. The tailings of this process shows losses of about 5 grams per ton, but the radically reduced amount of material being extracted in comparison to the amount of raw ore being processed makes these losses less important than those seen in the flotation tails.

With respect to the Knelson concentrators in use, we had an interesting conversation at the mine lab. Testing had been done on the use of Knelson concentrators for the fraction of gold that was smaller than 200 mesh and the result was poor. We will come back to this point later.

5) Previously at this mine a biological system had been tested on the whole ore with the intention of replacing the large scale cyanide leaching which was the original method used on this ore. The biological recovery was found to be too slow. Environmental issues with cyanide led to the present day system of centrifuges and flotation with concentrates being processed by closed system cyanide extraction.

We were able to complete the extraction and collect high density samples for microscopical examination on the flotation tailings sample provided by the laboratory personnel and time was short that day. It was suggested that we could stay on at the mine and do additional testing the next day. Unfortunately, our project partners said we were expected to return to Yili that day. So, with one sample in hand and a promise of three additional samples that the mine lab would prepare and send to us in Urumqi we departed.

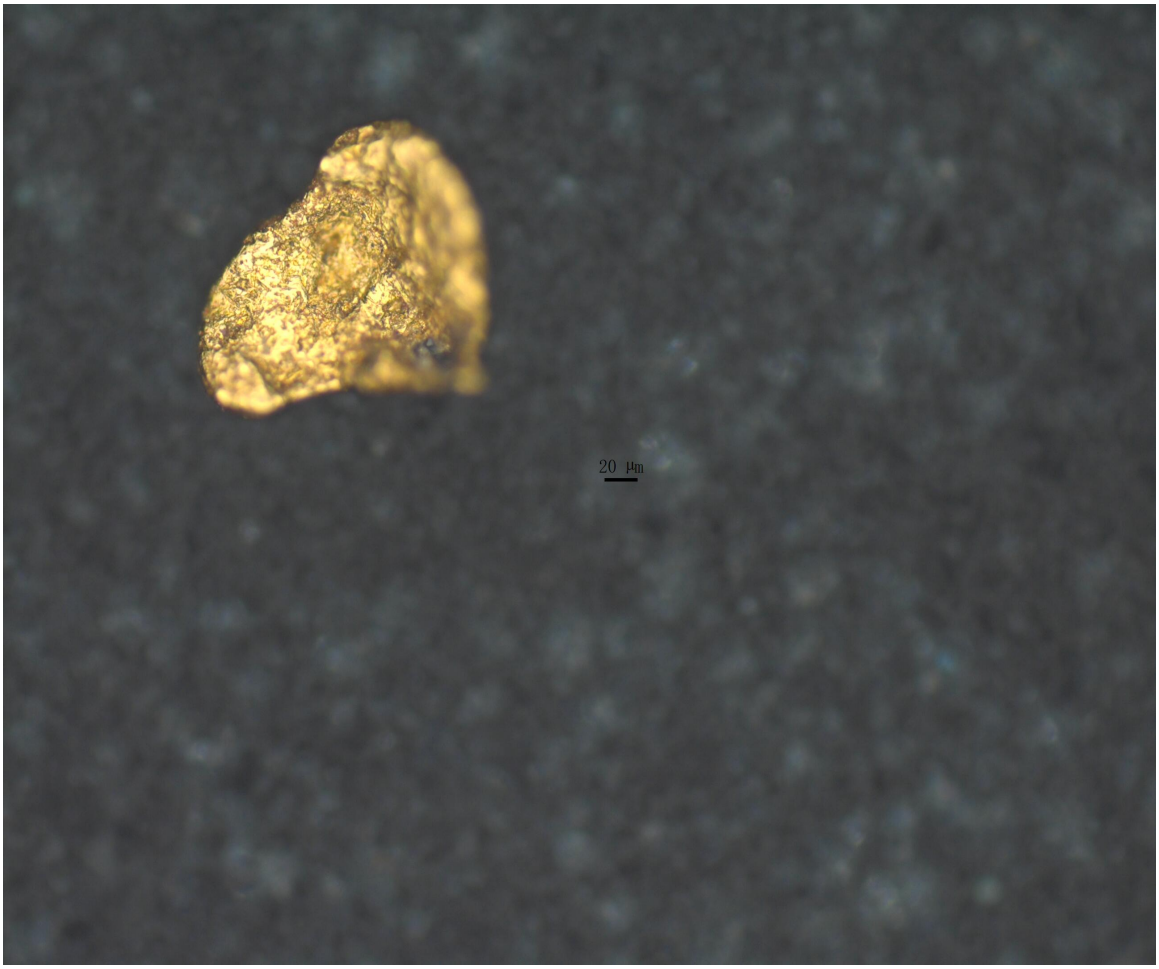
Testing in Urumqi

In Urumqi we had a number of tasks to complete. First was the more complete processing of the unused magnetite that we had brought back. This entailed sieving the sample. A significant amount of the crushed magnetite was larger than 6 mesh and this fraction along with the fraction that was larger than 100 mesh was collected and dried for recrushing. This was where our host partners really shined on this project. With their contacts outside the Institute they were able to take us to a milling operation and get our oversized material recrushed so that we could secure sufficient material for running the samples that were yet to come from the mine, as well as for demonstrations that we were anticipating.

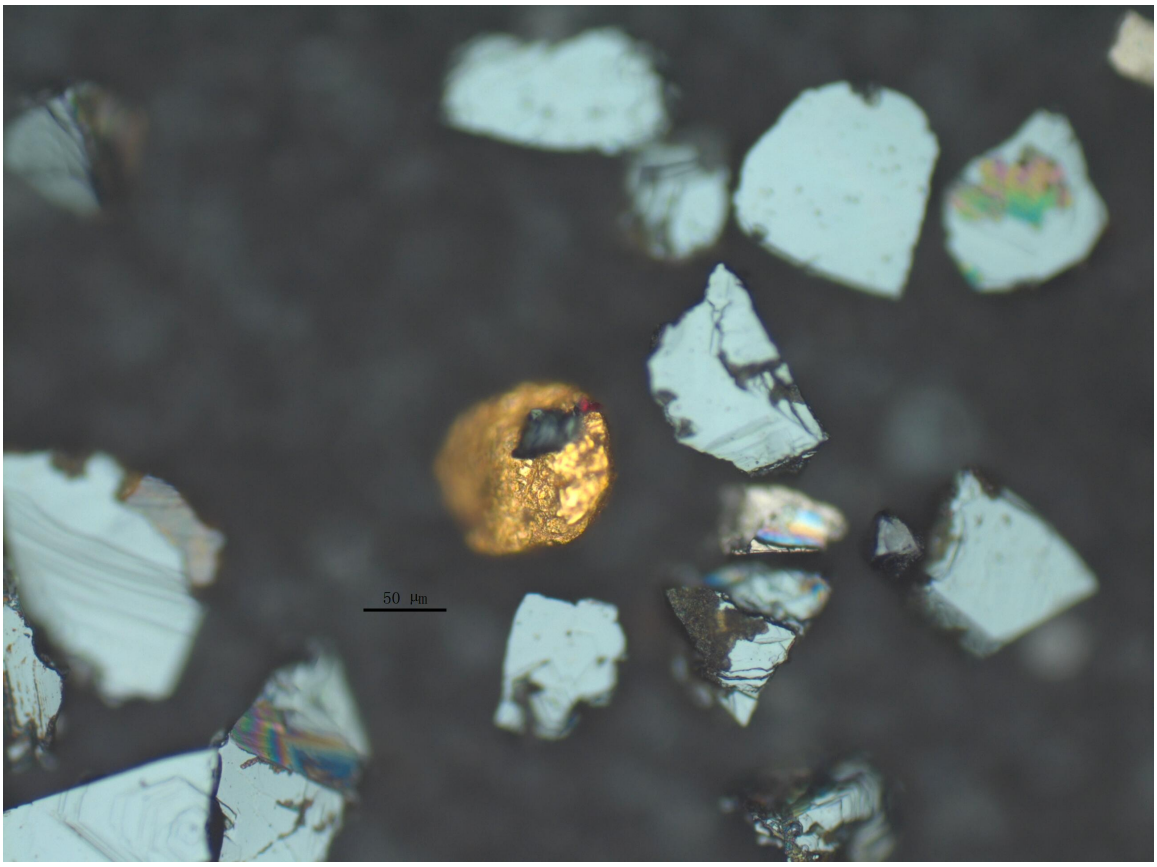
In addition, tools such as sieves and pipettes were found or bought to keep the work rolling along. But, most importantly and unique in my field experience, was that through the contacts that Dr. Li's group had with other groups in the Institute we were able to get time on a high quality microscope so that while I was working with the samples I would get to examine the gold grains being concentrated and recovered. Often this work is done many weeks after returning from field work. In this case, we were working on a project that we had not imagined before we arrived and this one tool allowed us to answer some questions as they arose which helped make the most of our time in China.

Flotation Tails Sample from Mine Lab

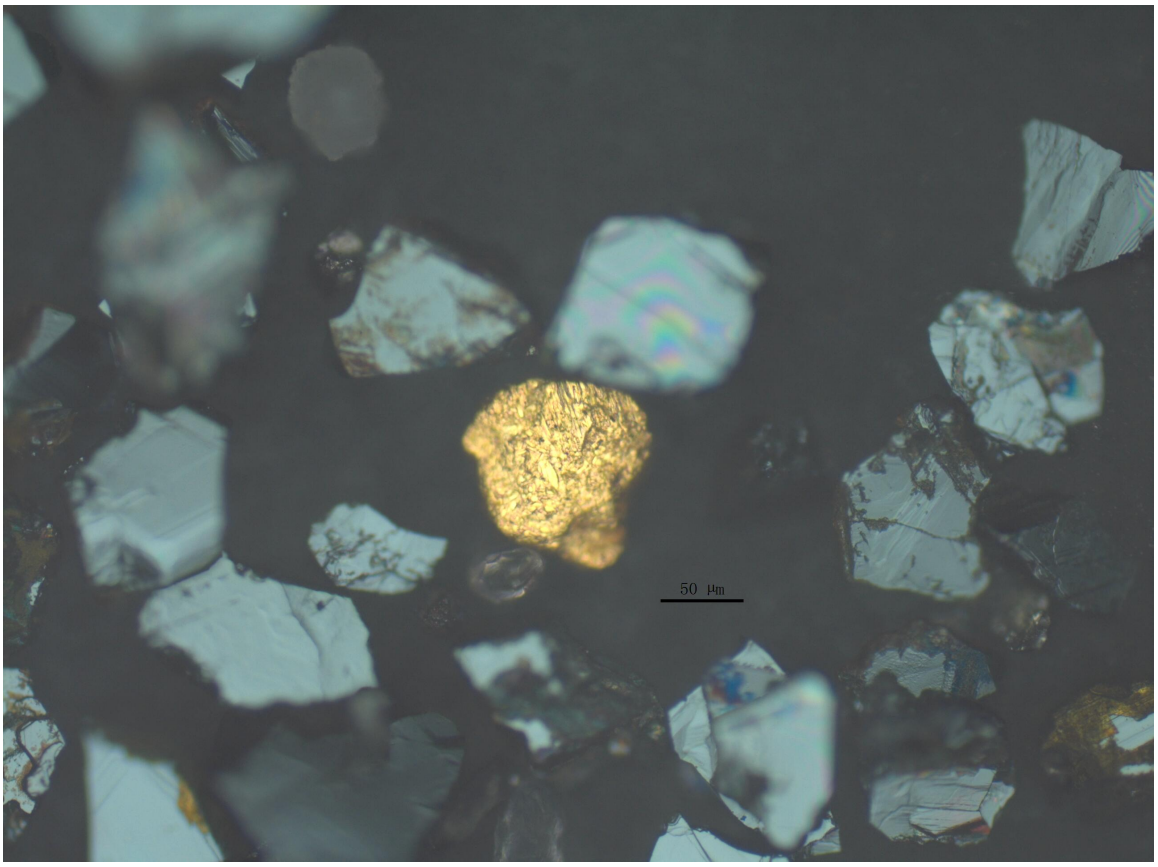
The concentration of the sample on a prepared bed of magnetite using a Prospector's Sluice was performed and the high density fraction of this concentrate was panned, collected, and taken back to Urumqi. Then microscopy was done on this sample as well as on a second run of the sample tailings that were collected at the mine when the first run was performed. It was noted that there was significantly more sulfide and gold recovered in the first test than in the second test run on the tailings of the first test indicating a good recovery of fine gold in the first pass. This was confirmed microscopical examinations of slides made of each test.



Photomicrograph 1-200X nominal magnification. This was some of the first gold that was recovered from the Flotation Tailings sample that was run at the mine's lab.

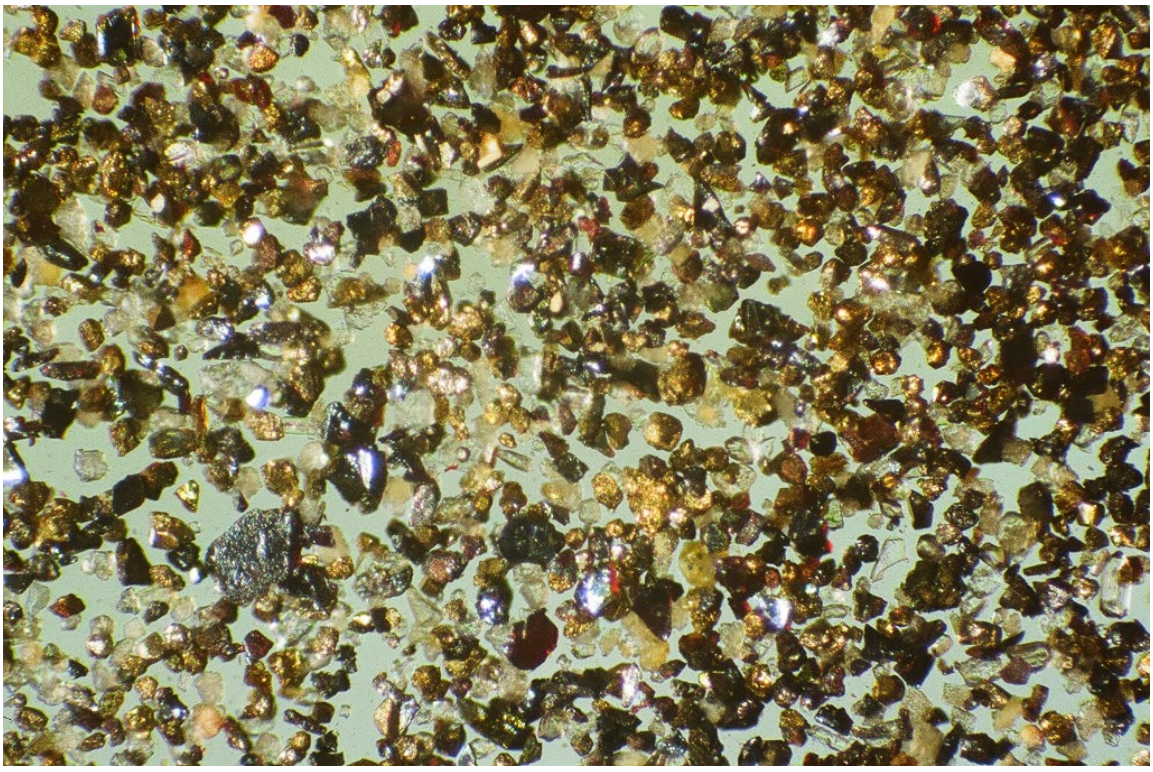


Photomicrograph 2- 200X nominal magnification. Gold particle with gangue material still attached. Surrounding particles are high density suspected sulfides.



Photomicrograph 3-200X nom.mag. Another gold particle showing a unique "ropey" surface character.

These first three images show the type of photomicrographs which I was able to make using the materials at hand. I was only able to make scatter slides without mounting media and view the dry particles using only top lighting. Photomicrograph 4 was taken, in my lab, of a permanently mounted specimen that was inverted such that all of the particles are par focal.



Photomicrograph 4- 100X nom.mag. Taken with Nikon Optiphot-Pol using unidirectional top lighting and transmitted light. This sample is of the -200 mesh fraction of the Flotation Tailings concentrate generated at the mine lab with the first test run.

One thing that stands out when viewing this photomicrograph is that there is gold of various sizes and appearance represented in this sample. That we are able to concentrate and examine this gold from a sample that had been subjected to both centrifugation and flotation indicates a strong case for inclusion of Cleangold technology in the concentration and recovery processes used with this ore.

Subsequent Samples Received in Urumqi from the Mine Lab

A few days after returning from Yili we received three samples from the laboratory we visited at the mine. Relabeled as M1, M2, and M3 these samples were each half a kilogram of dried ore. Descriptions of the ore as they were received are as follows;

M1- Cyanide Tails- very fine, light in color.

M2- Flotation Tails- light color, dried sample with clumps of ore. (Note- this should be a new sample of the material that we ran while we were at the mine laboratory.)

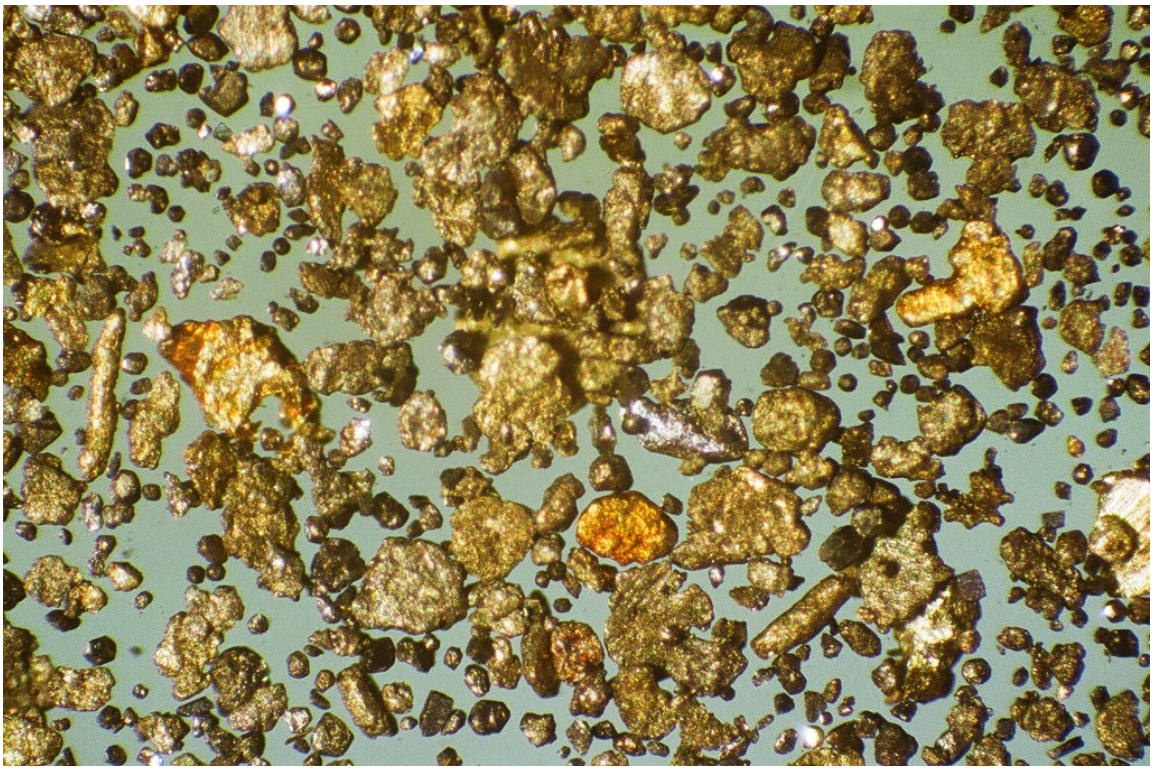
M3- Flotation Cons- darker colored dried material with clumps. Upon working with it in water a slight sulfide odor was noted. (Note- this sample is assumed to be

concentrates based on the amount of gold seen once the sample was analyzed.)

There was some confusion as to the identification of the samples based on their markings, in Chinese. Our translators were not familiar with mining terminology or processes. Given that at the time the samples were received I had not yet secured an adequate supply of clean, processed magnetite, I might have chosen to run the samples in a different order.

At the lab in Urumqi the samples were run in the following order:

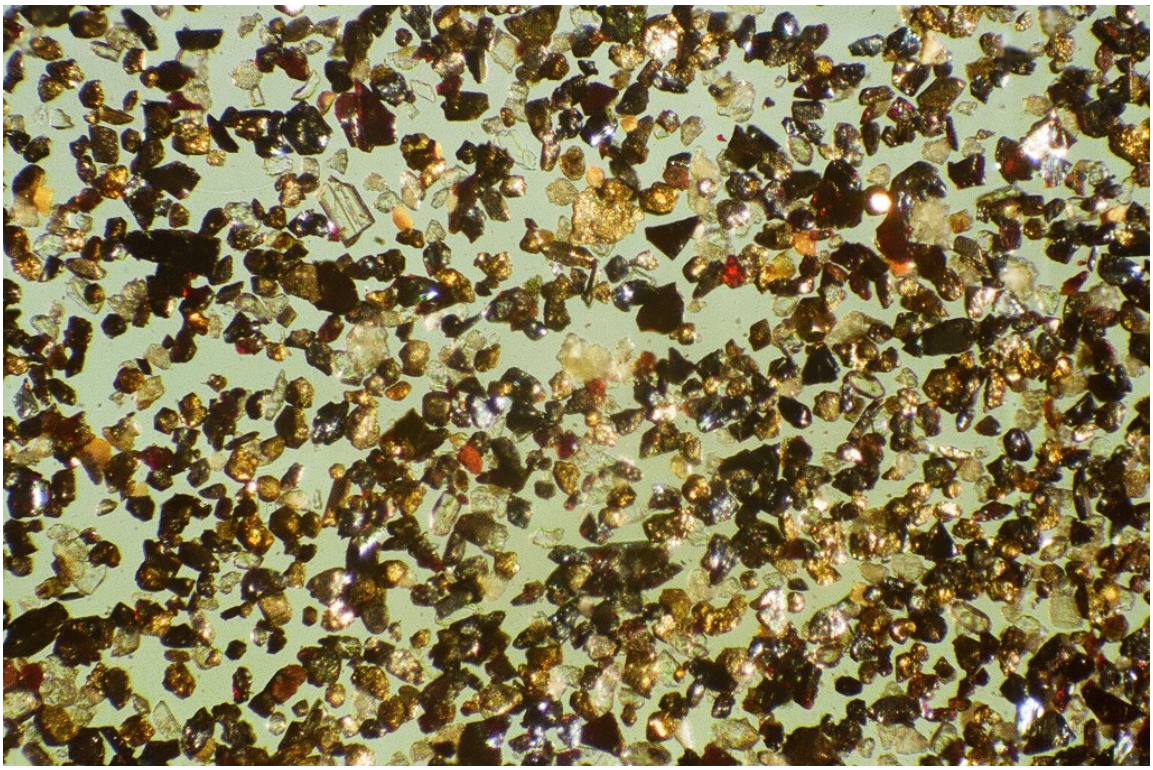
8/27/2013 Sample M3 (Flotation Concentrates) . This sample was the darkest. There was some difficulty rehydrating the dried sample and the large amounts of sulfides in the sample created some problems using static Cleangold methods (ie sample preparation from Prospector's Sluice concentrates). Two runs were made of the material with overnight soaking of the ore, between runs, as well as additional wet sieving to further break up the ore.



Photomicrograph 5-100X nom.mag. Sample M3 (Flotation Cons) This sample is nearly all gold and shows the variety of coatings on gold being recovered by flotation.

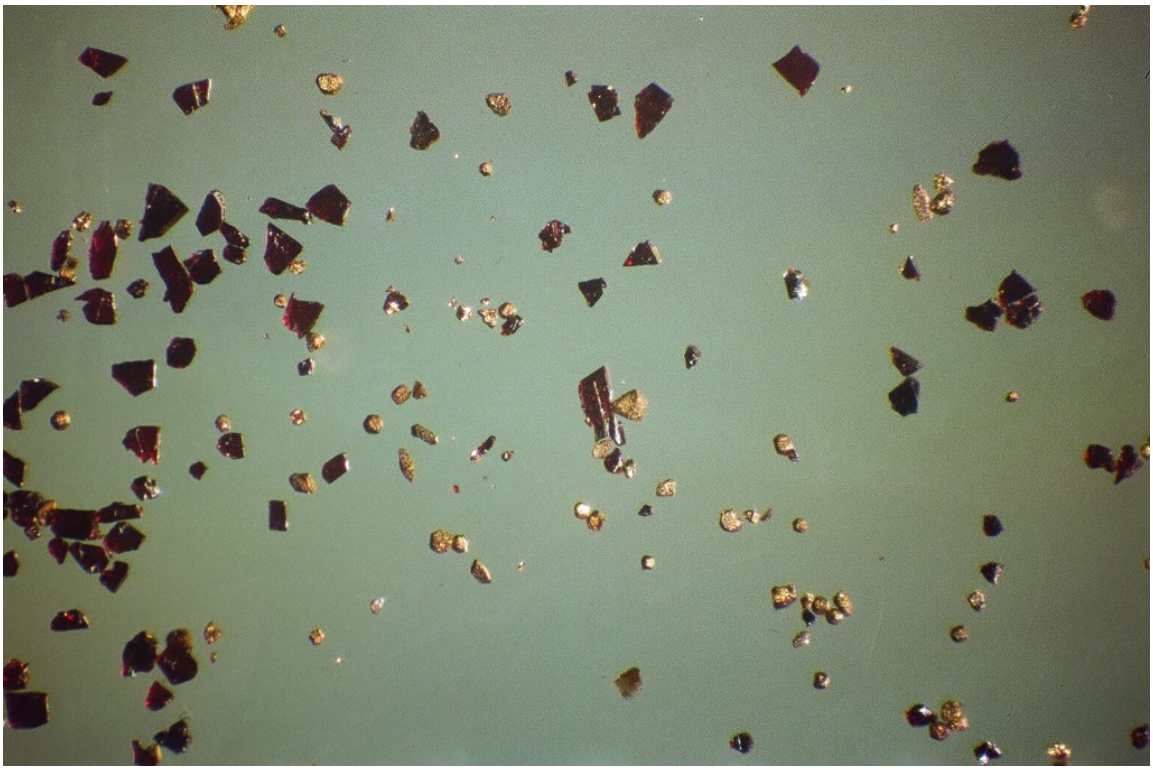
8/28/2013 The next sample run was M2 (the Flotation tailings). Unfortunately, the work done on this sample was done using the magnetite previously used on sample M3 so cross contamination prevents many conclusions from being drawn. Fortunately, the work done and samples taken during the original Flotation Tailings run at the mine

lab were brought back and better slides were made of the gold recovered from the tailings. Photomicrograph 4 and the following give the best representation of gold that is currently being lost from the flotation process.

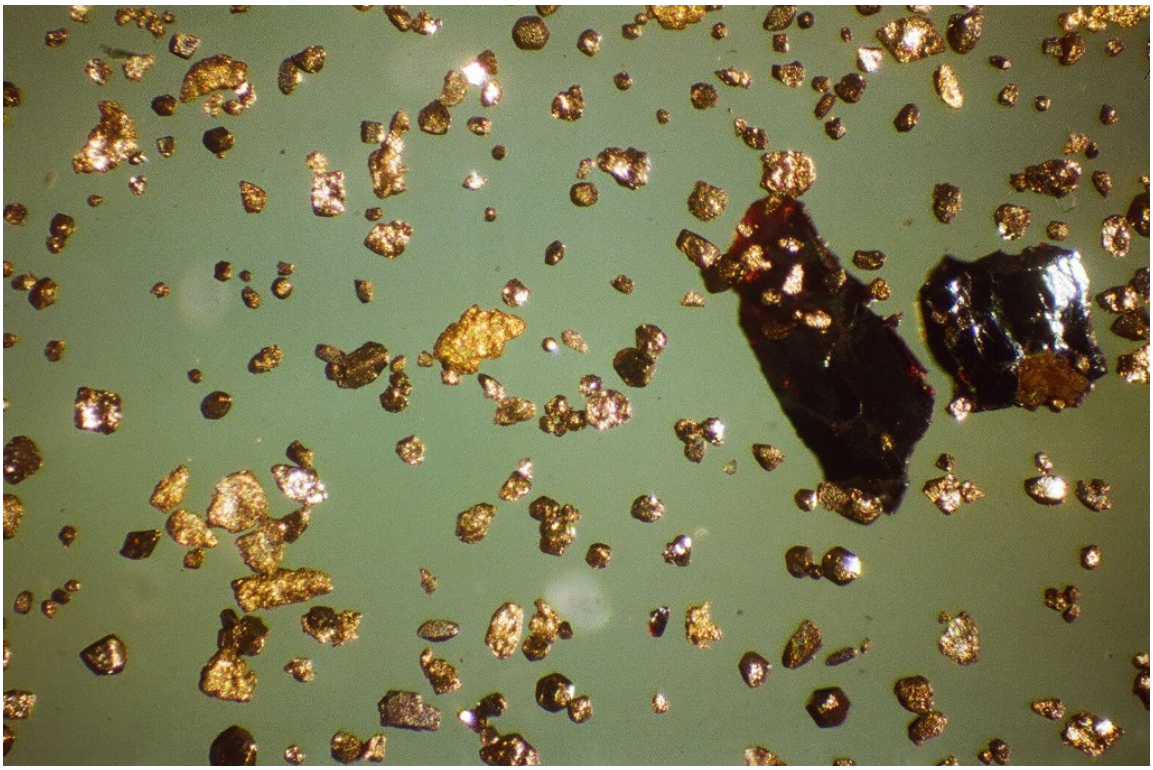


Photomicrograph 6-100X nom.mag. Flotation Tails (Mine Lab test) This sample is of gold and high density minerals from the -100+200 mesh fraction

8/30/2013 Sample M-1 (Cyanide Tailings) was run using new magnetite processed from the materials that were sent out for milling in Urumqi. This sample had a strong odor even though it had been washed and dried before being sent to the lab in Urumqi.

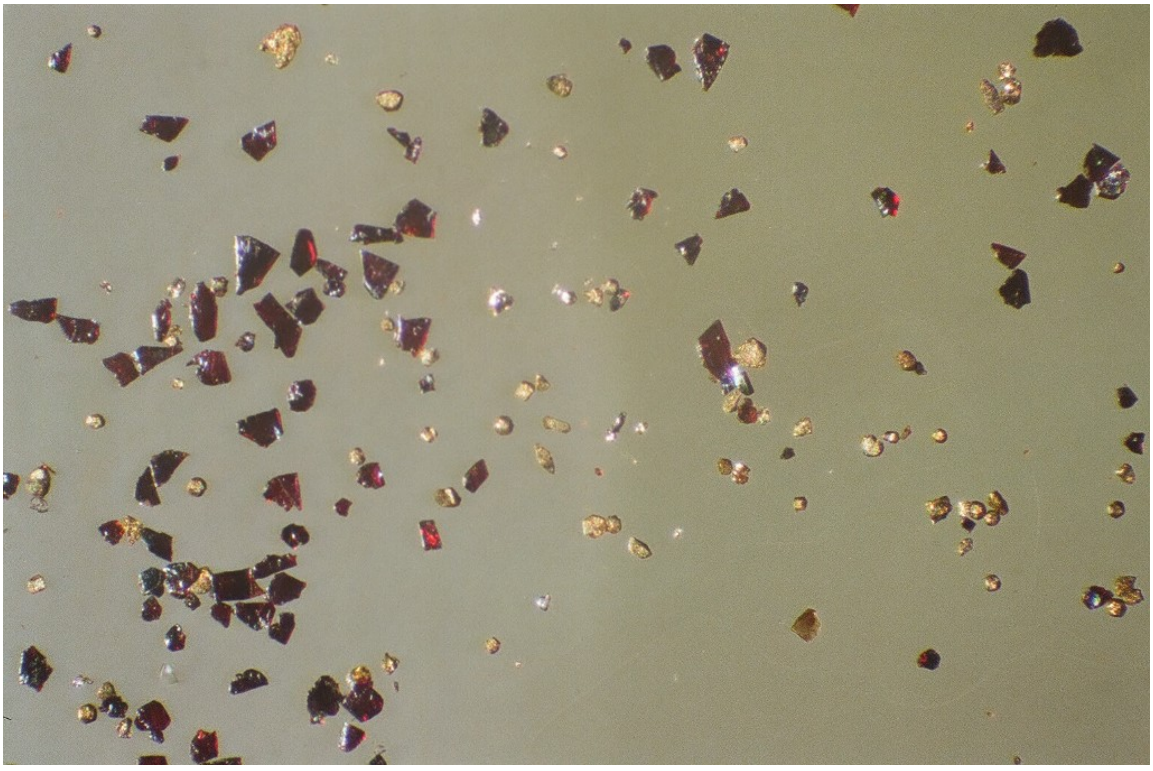


Photomicrograph 7-100X nom.mag. Sample M1 (cyanide tailings). As with most of the fine gold seen in the ore from this mine, the gold smaller than 200 mesh is mostly equant. It is interesting that this assemblage of fine gold was seen with little in the way of coatings.



Photomicrograph 8-100Xnom.mag. Sample M1 (cyanide tailings) Another assemblage of gold some showing coatings but on the whole looking cleaner than the gold seen in other samples.

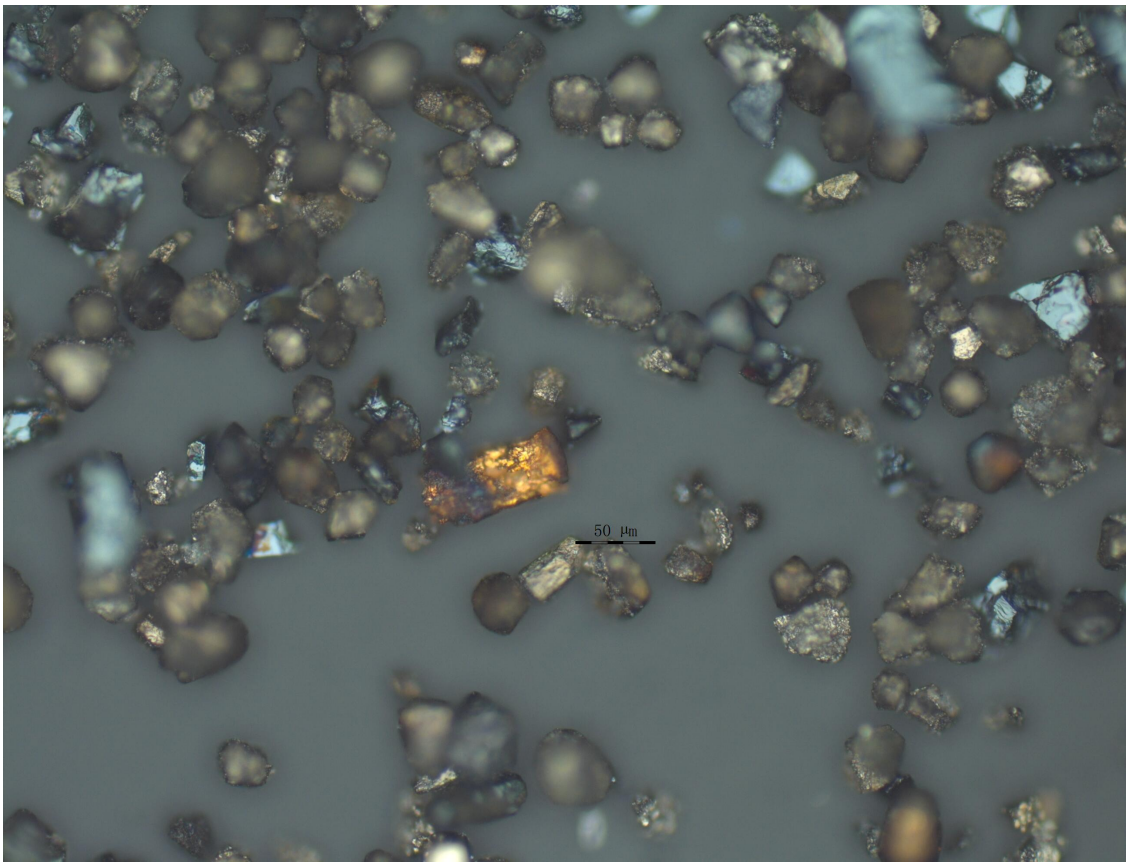
Photomicrograph 9-100X nom.mag. Sample M1 (cyanide tailings)



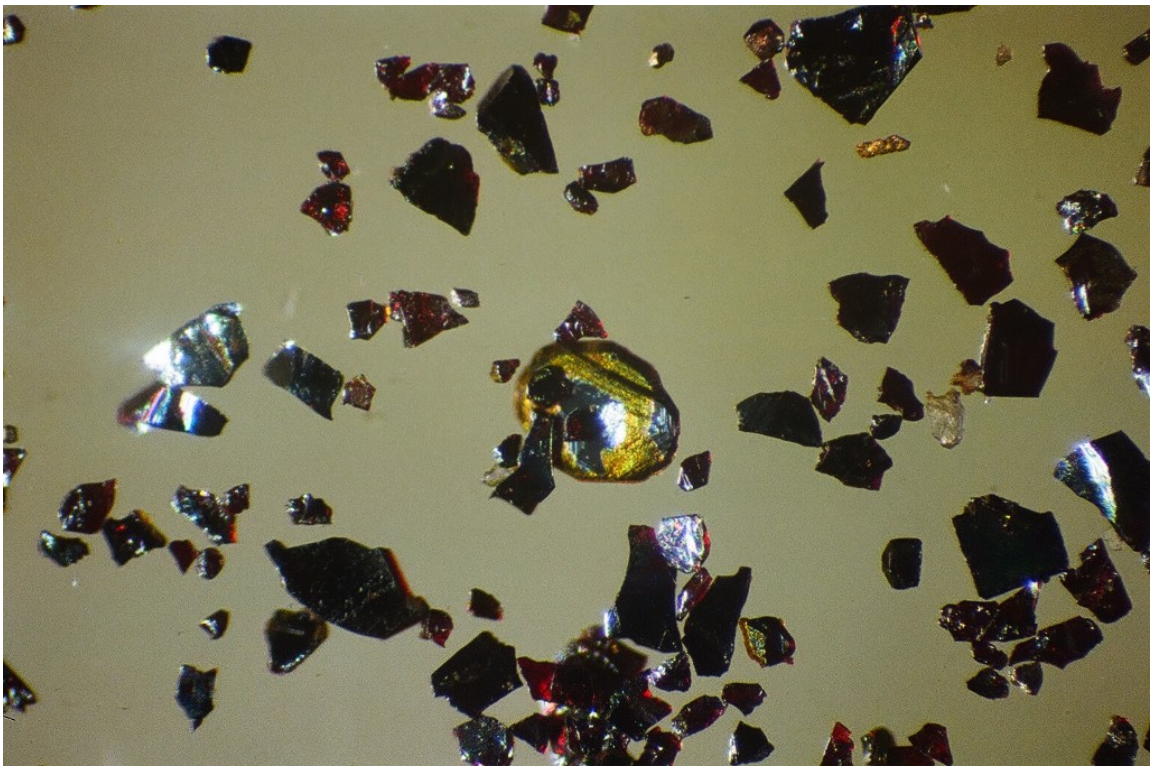
Photomicrograph 10- 100X nom.mag. Sample M1 (cyanide tailings) Other groupings

of fine gold seen in the cyanide tailings.

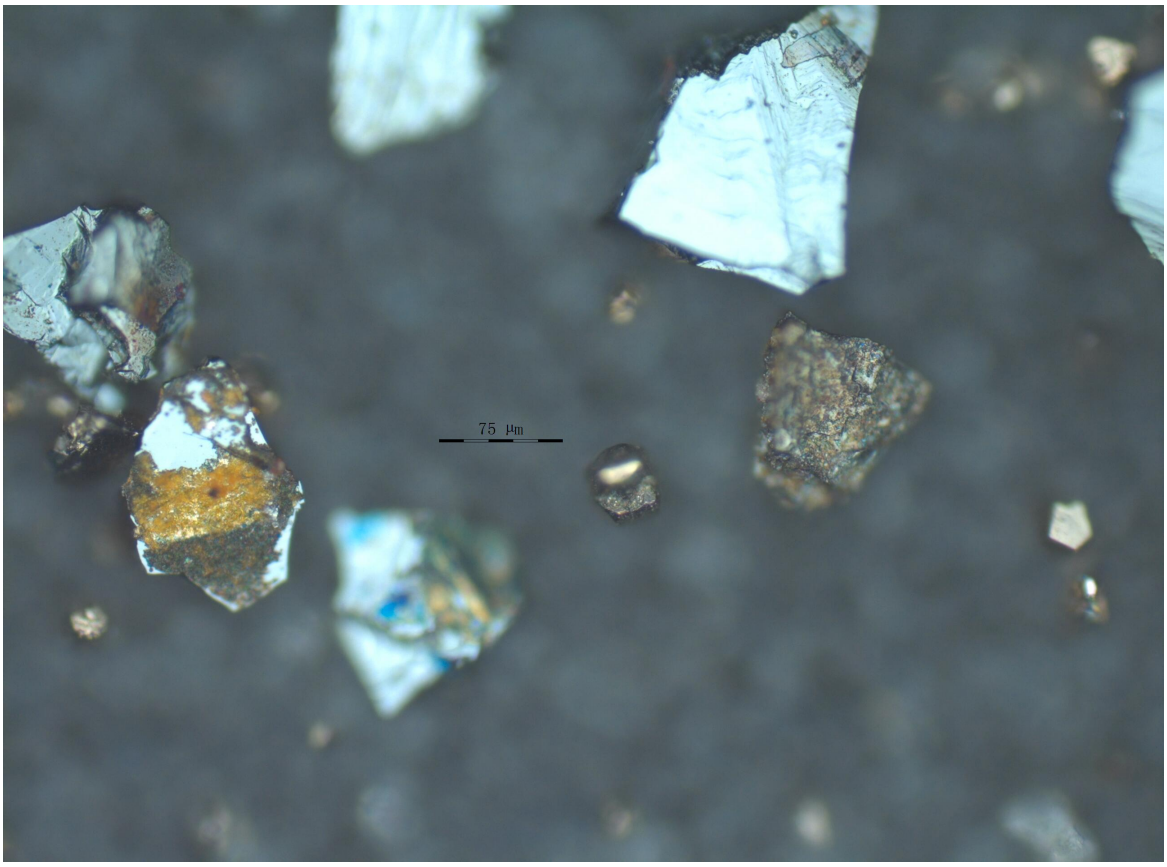
What follows now is a group of photomicrographs illustrating what I think are key points about the gold in this mine's ore.



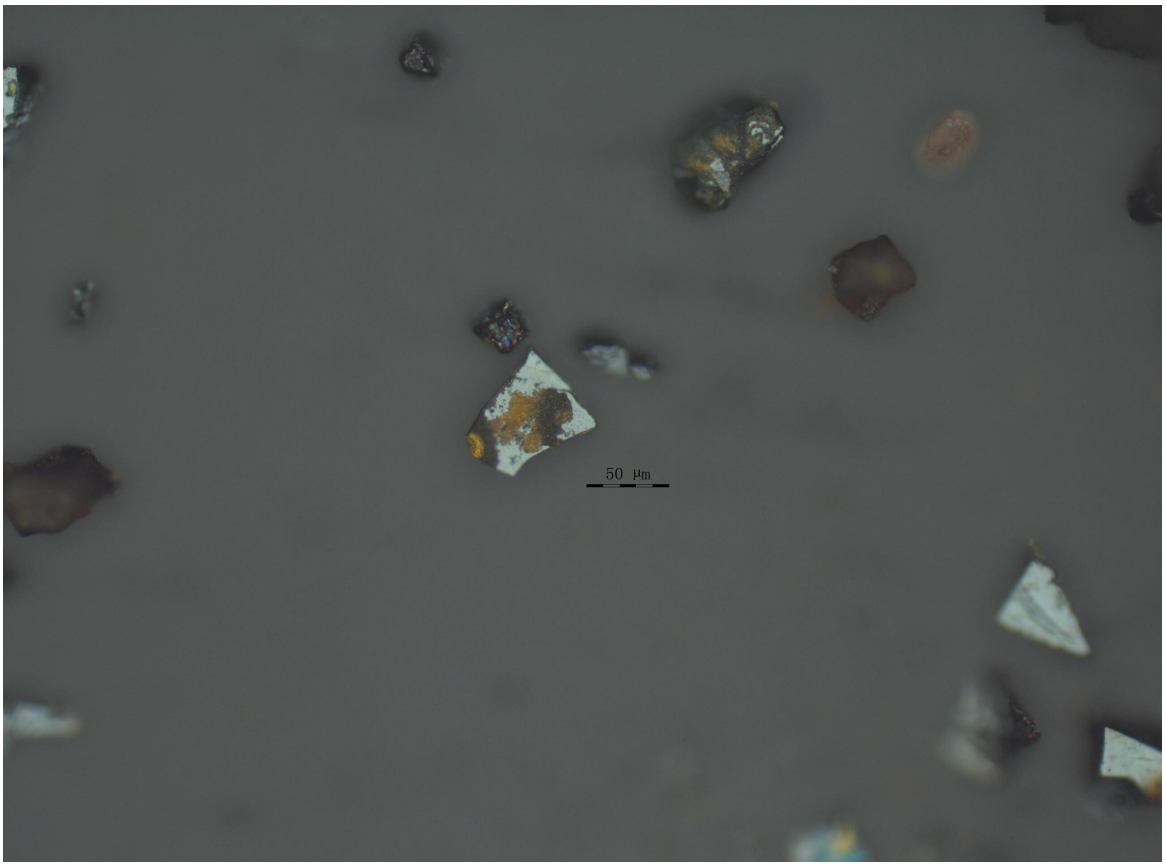
Photomicrograph 11-200X nom.mag. Sample M1 (cyanide tails) A variety of coatings are seen on this one gold particle.



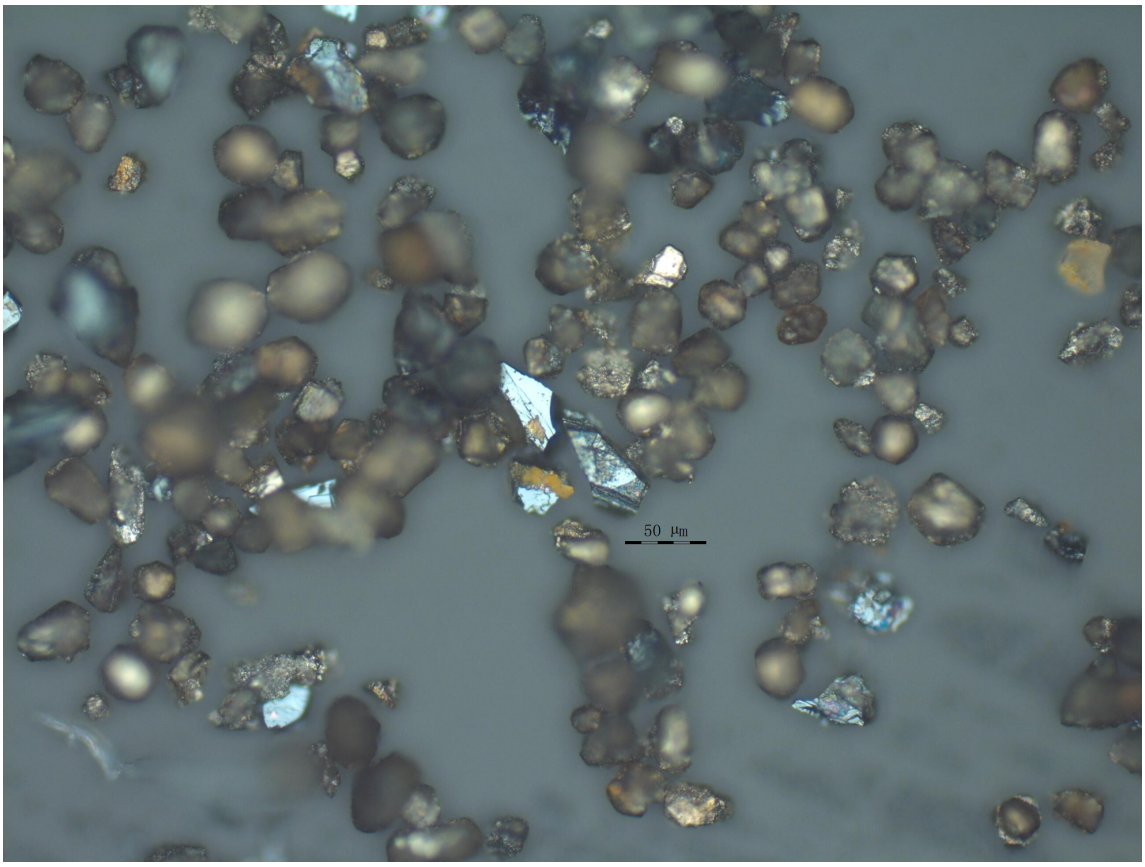
Photomicrograph 12- 100X nom.mag. This sulfide particle is coated with a thin yellow layer that is suspected of being gold. Numerous examples of this were seen where grinding had broken a particle along the crack into which this suspected gold was deposited.



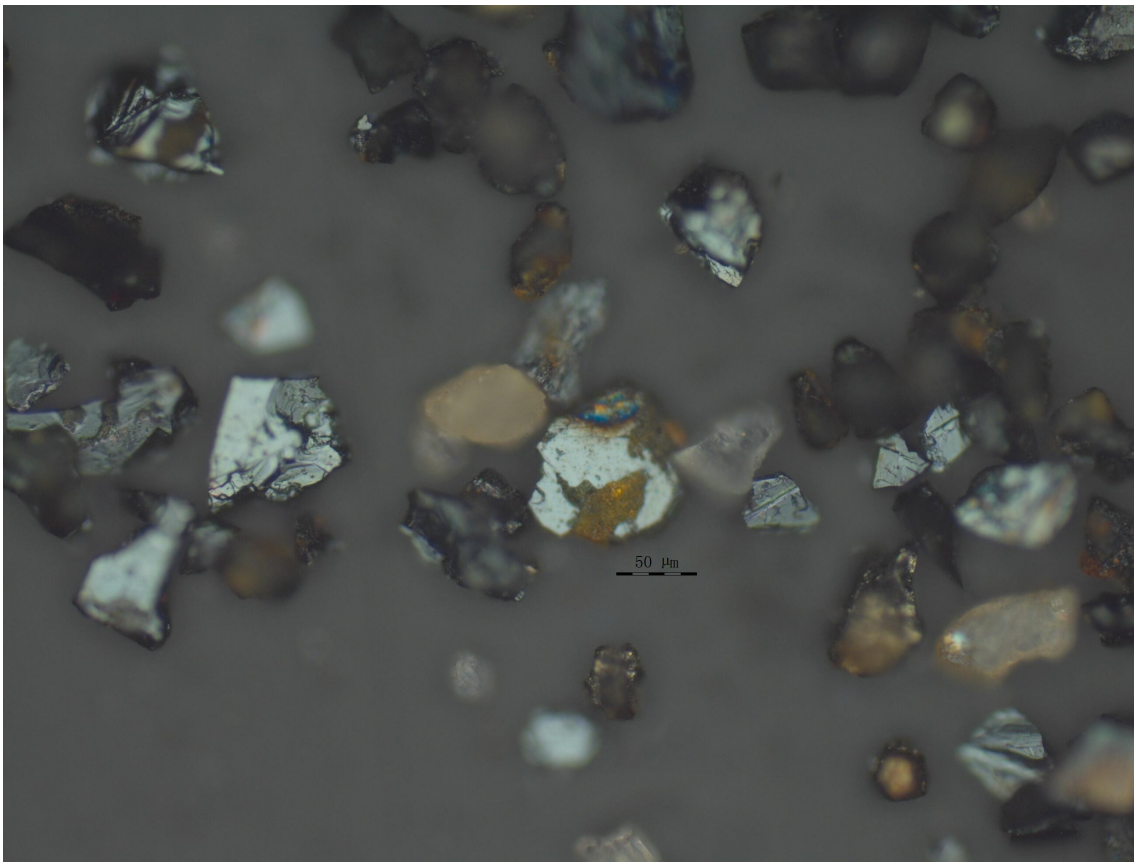
Photomicrograph 13- 200X nom.mag. The sulfide on the left has a layer of yellow material that is suspected of being gold.



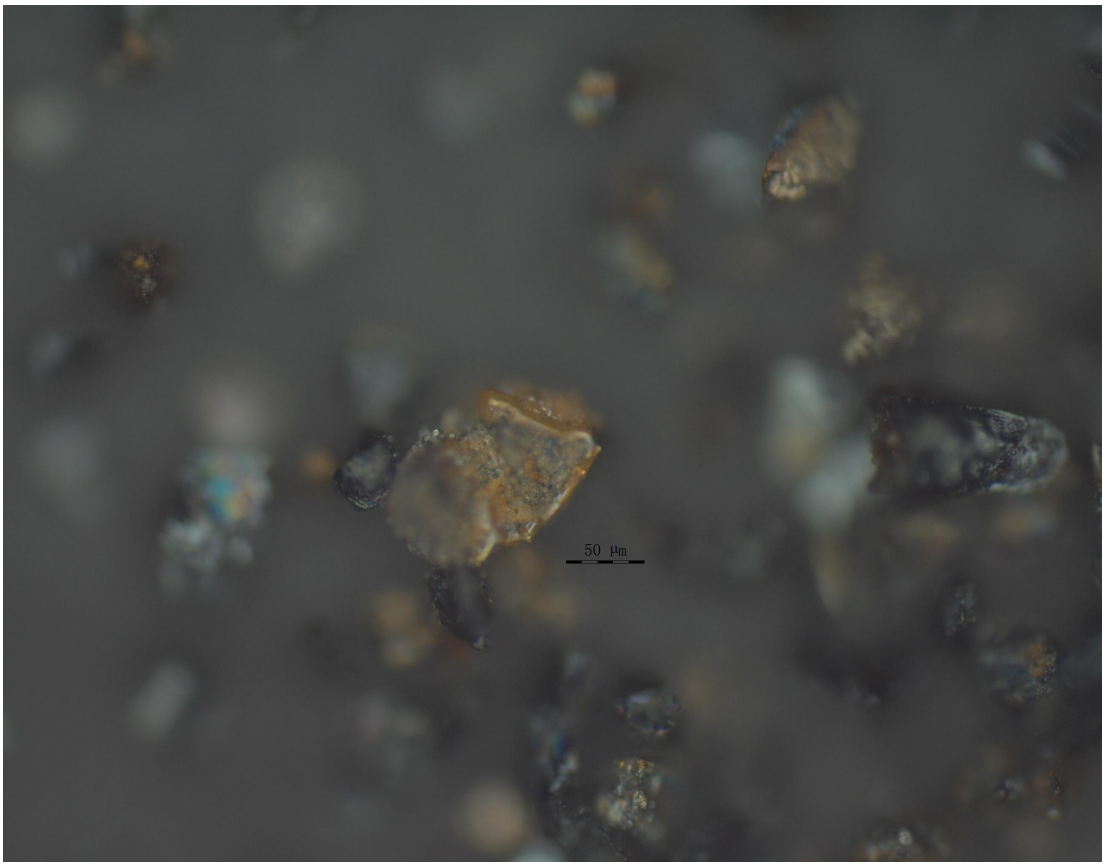
Photomicrograph 14-200X nom.mag. A nice example showing a black coating on the cleaved surface as well as a thin yellow coating with a void, that is suspected of being gold.



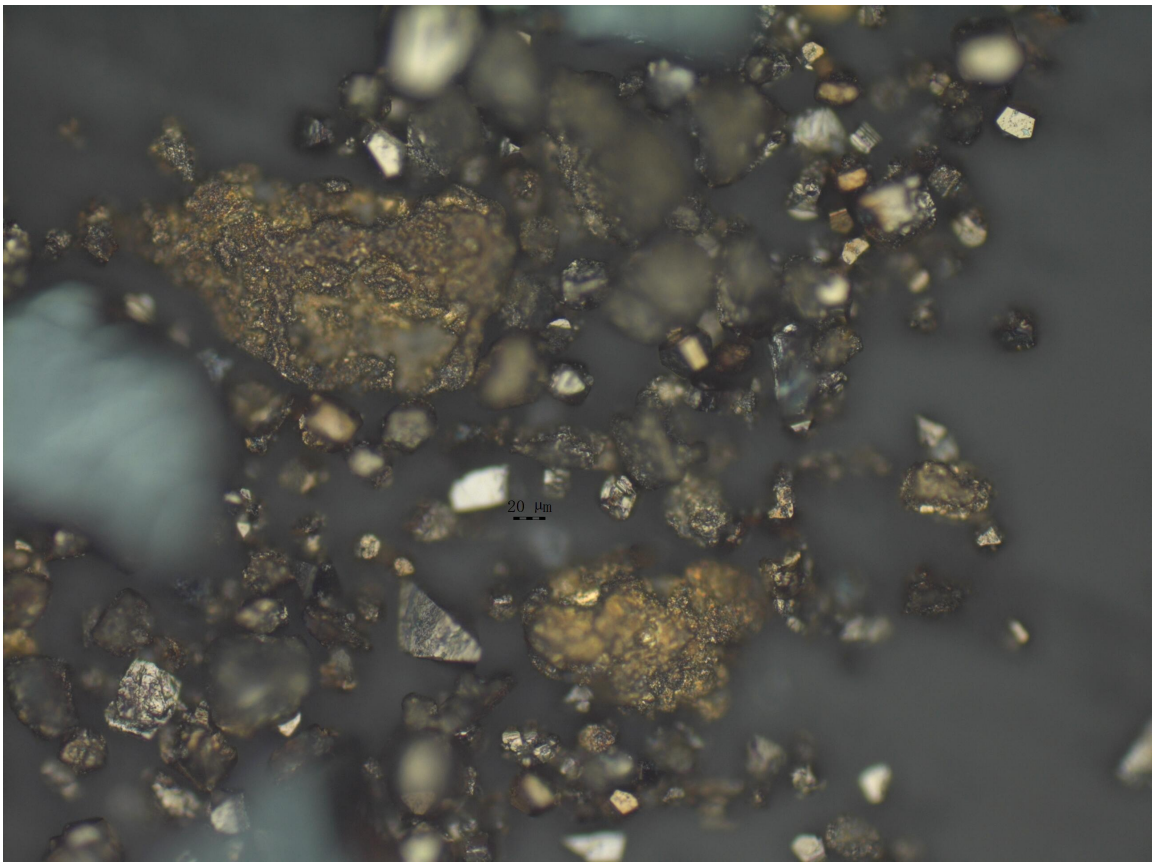
Photomicrograph 15-200X nom.mag. Two pieces of cleaved sulfide showing yellow deposits, suspected of being gold.



Photomicrograph 16-200X nom.mag. Layer of yellow material, suspected of being gold, on a cleaved piece of sulfide.



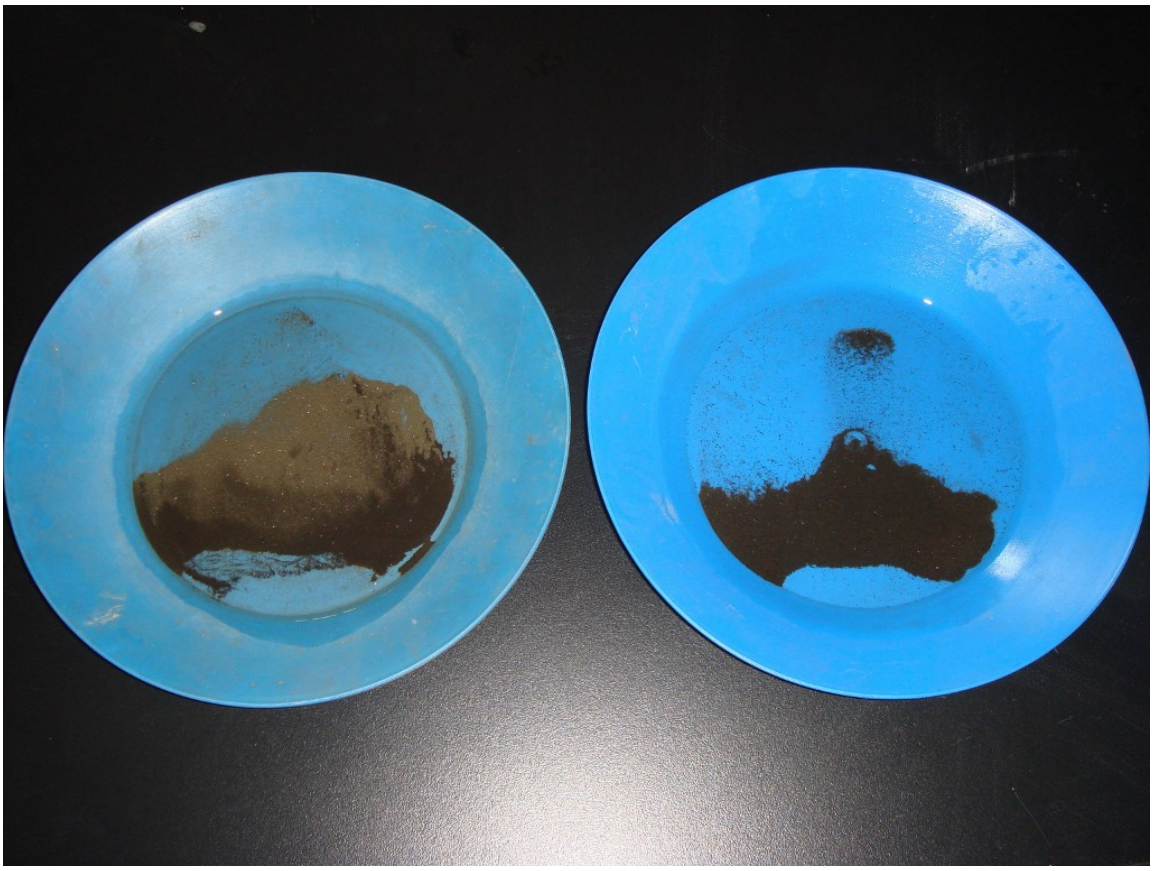
Photomicrograph 17- 200X nom.mag. A thick piece of gold with a layer of silvery colored sulfide.



Photomicrograph 18-200X nom.mag. Sample M3 (flotation concentrates) . Compared to the gold that is being recovered from the flotation tails this gold all shows considerable coatings. Also note the presence of gangue material on the lower right corner of the largest particle above.

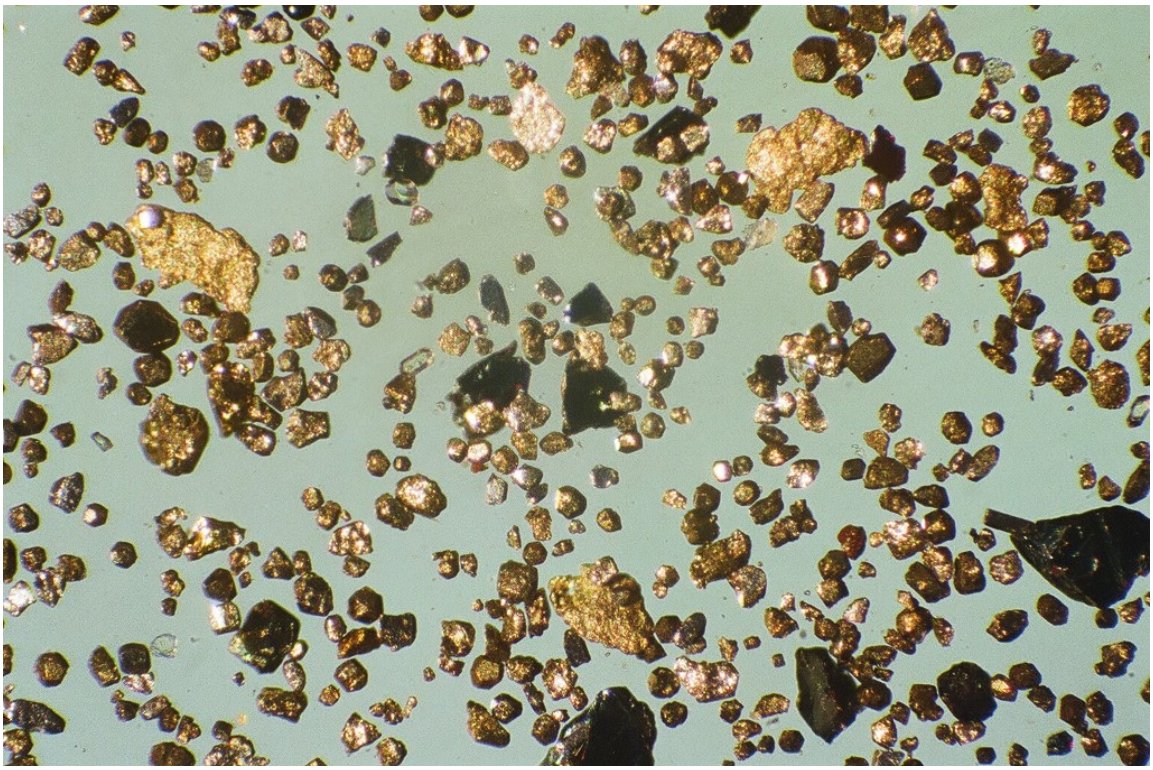
The final test that was run at Urumqi was to combine the tailings of the three samples tested (M1,2, and 3) and run this material using a flow regime more characteristic of how one would implement a Cleangold system in a mine of this size. A Cleanup Trough was precharged with new, engineered magnetite and then a slurry of the tailings was processed.

Photograph A Test apparatus for the dynamic flow test of combined tailings of the three M samples.

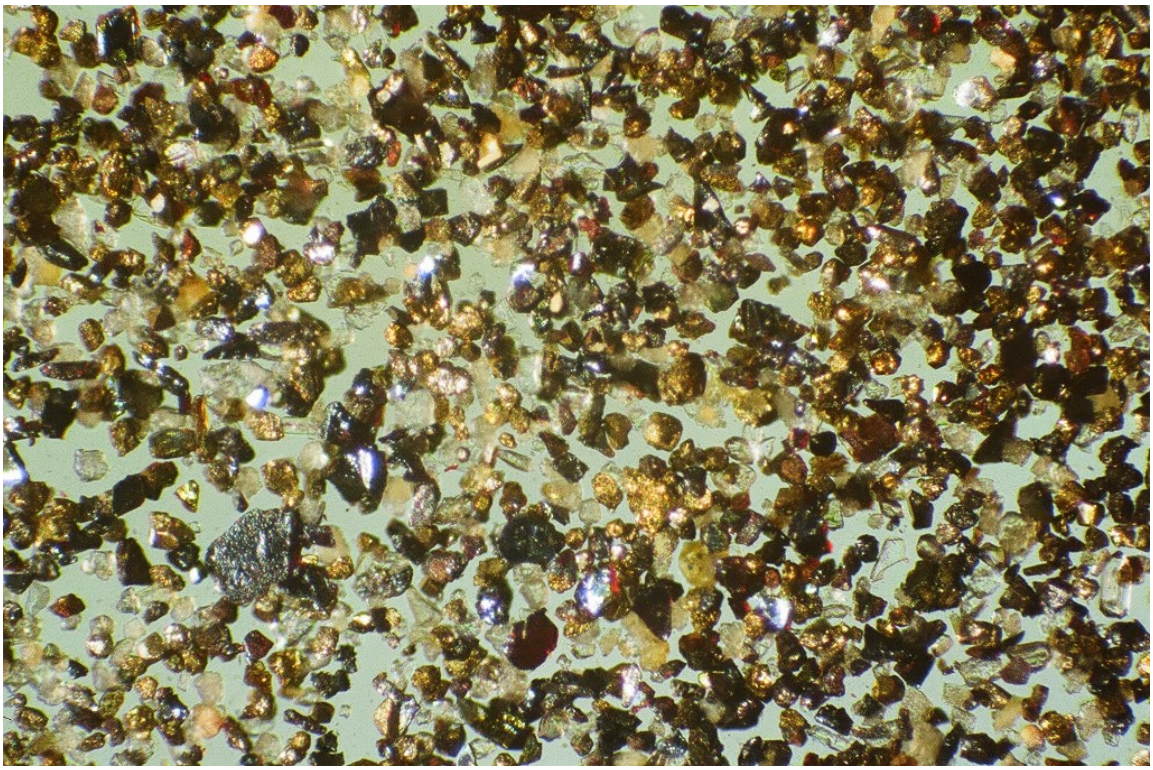


Photograph B Concentrated and separated into two distinct fractions. A sample of the yellowish brown sulfide was submitted for assaying. This ore contained two distinct suspected sulfides, one a golden color and the other a silvery color. In the dynamic concentration the less dense silvery sulfide was excluded by the more dense golden colored sulfide as well as high density minerals and gold.

As with all the other tests, a high density fraction of this test was collected for microscopy. It was thought that this test, looking at what less efficient static testing methods had lost, would give insights into which processes would be most needed in a modified mine operation.



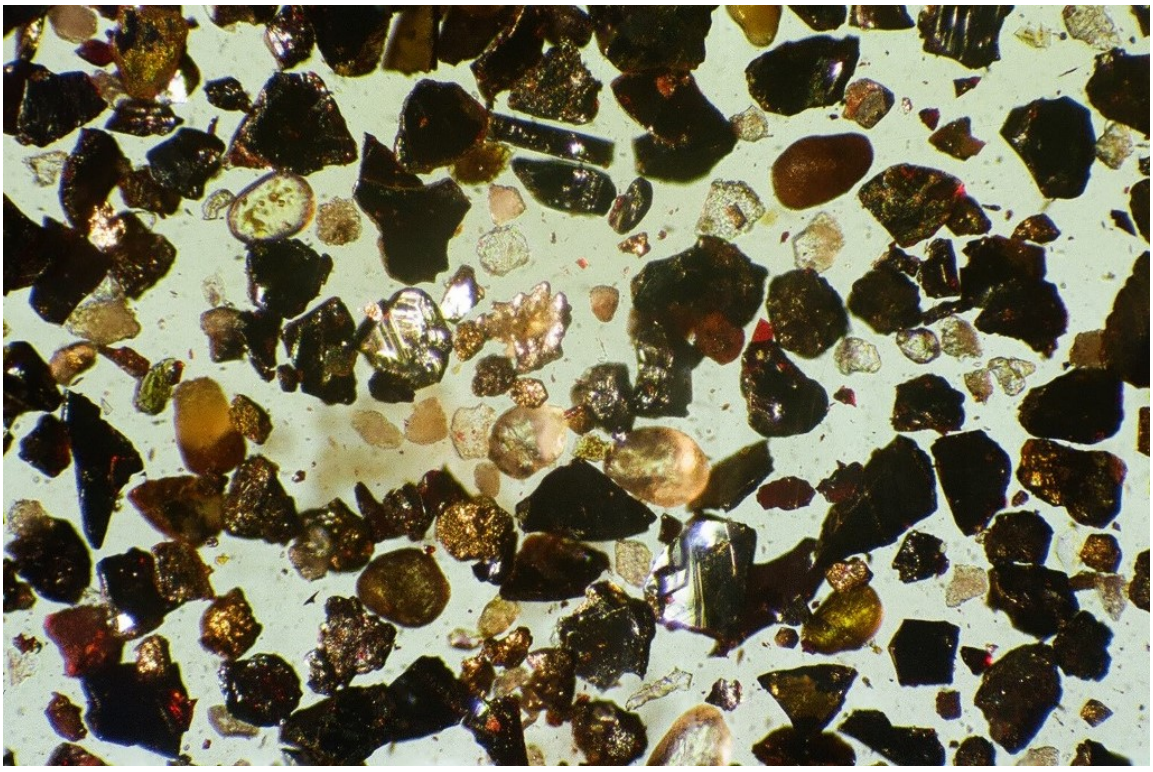
Photomicrograph 19-100X nom.mag. CT Test (dynamic run) of tailings from M1,M2, and M3 samples on fresh magnetite (-100mesh +200 mesh fraction). This would be a mix of the gold types that are being recovered by flotation and those that are being lost by Knelson concentrators, flotation, and cyanide. This would represent all the gold types in the ore except that portion that is being recovered by the Knelson concentrators.



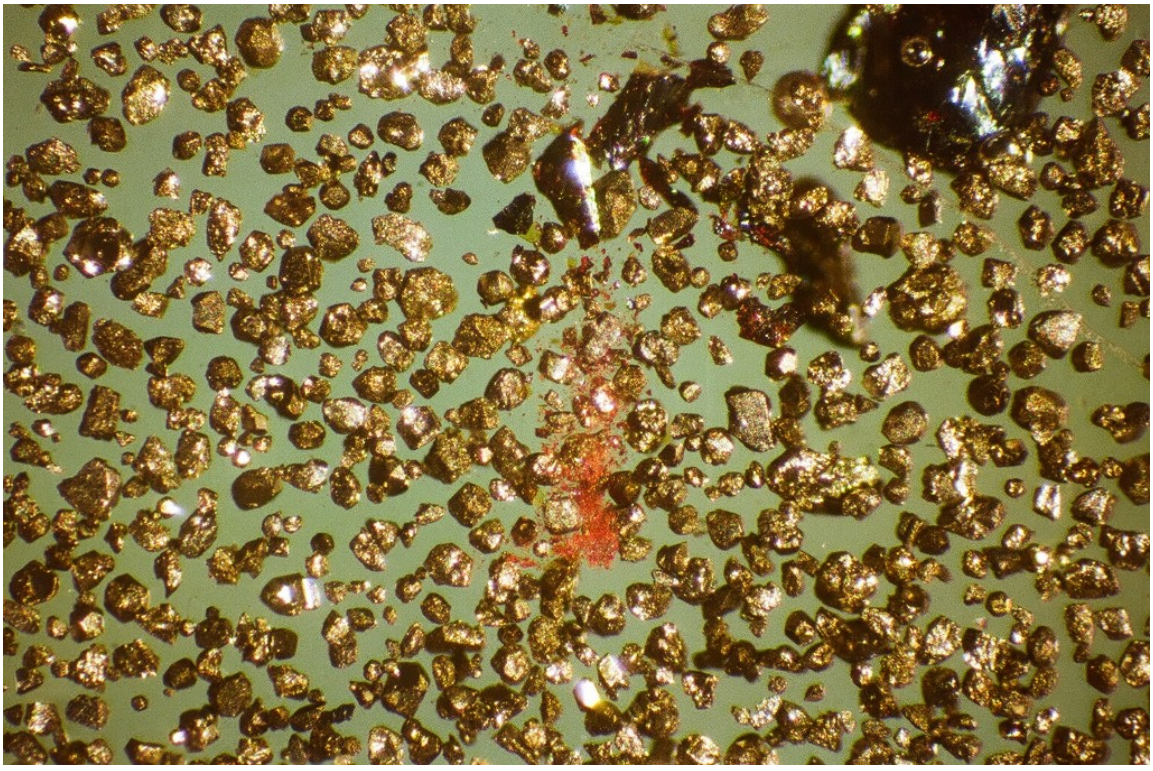
Photomicrograph 20- 100X nom.mag. CT Test of tailings from M1,M2,and M3 photomicrograph of the -200 mesh fraction.

Notes on Mercury

There are a number of gold particles seen in this project that showed coatings that might be mercury. In addition, one of the high density minerals seen shows a red color in its thinner portions and a crushing color that is red to orange and vibrant. If this sulfide is mercury (II) sulfide then heat generated during crushing might be sufficient to release free mercury and create a free mercury amalgam on the surface of previously uncoated particles.



Photomicrograph 21 100X nom.mag. The irregular silvery white particle above, left of center, is suspected of being coated in mercury. The central part is still showing gold color.



Photomicrograph 22 100X nom.mag. The crushed mineral in the lower central area shows the mineral suspected as being mercury (II)sulfide (cinnabar)

Notes on Centrifuge and Flotation Losses

In looking at the concentrates and the tailings of the flotation process it would appear that flotation is focused on the sulfides and coated gold. The flotation concentrates show considerable large flat gold particles but mostly they are heavily coated in sulfides. The flotation tailings showed small gold with a variety of coatings but the larger particles were mostly flat and uncoated. This would suggest that as with most flowing gravity methods (except Cleangold) fine, dense sulfides will create a recovery problem. We know that centrifuges also have a lower limit of recovery and often start to lose efficiency below 200-300 mesh. So in addition to the small gold being lost by the centrifuges, large flat particles are also a problem due to the presence of the fine sulfides. While the flotation can cover for loss of large, flat particles it has poor efficiency for the recovery of uncoated particles. Hence, the larger gold particles seen in the flotation tailings show less coatings. Many flotation processes are available and they are chosen based on the highest recovery for the bulk of the gold present. In this case, most of the gold is heavily coated. It was suggested that the bulk of the gold recovered from this mine is recovered in the flotation circuit.

Notes on Gold from Cyanide Tailings

It was surprising that some of the gold that was being lost by the cyanide extraction of concentrates appeared to be devoid of coatings. At first thought it would seem that uncoated gold would be the most reactive to cyanide. However, the possibility exists that the appearance of these particles is a result of incomplete extraction, or that these particles have a thin unidentified coating that is not reactive to cyanide. Other particles seen in the tailings of the flotation tailings were clearly encapsulated or intimately in contact with sulfides.

Conclusions

The work done on the samples taken from different stages of the operation show gold, mostly less than 200 mesh, with a variety of coatings. Gold particles as fine as 1250 mesh were concentrated and recovered using Cleangold methods. The larger gold being recovered by the flotation method are mostly flakes, some as large as 40 mesh. Gold smaller than 200 mesh is mostly equant. The size range of gold being recovered by Knelson concentrators is unknown. But, as previously mentioned the presence of large amounts of sulfide in the ore can result in considerable losses by centrifuges of the smaller gold with the same problem exacerbating losses of large flat gold.

All of the gold seen in this study was amenable to recovery using Cleangold technology. The coatings seen on gold particles in the study do not effect recovery using Cleangold technology.

One particular type of suspected gold, the thin layers seen that were on cleavage planes of some sulfide particles may present a more difficult recovery problem. First, we do not know the prevalence of this, again, suspected gold and what portion is not liberated into easily viewed or chemically labile layers by crushing. If subsequent testing showed that this was gold, then recrushing the flotation concentrates would be necessary to access this gold.

Further testing would best be done at the mine. A 10 ton per hour test apparatus could be built and tested at various locations in the process. Laboratory support with assaying capabilities will help determine the recovery statistics on gold that is currently being lost by centrifuges and flotation. It will also allow us to look at methods that are currently in use that would become unnecessary due to the addition of environmentally benign Cleangold methods. For instance, Cleangold concentrates often have high enough gold values that direct smelting could be substituted for the closed system cyanide extraction that is currently being used for final recovery. This would solve both the problem of coatings and potential environmental contamination in a single step.

Cleangold technology is also effective at concentrating other high density minerals of commerce. For instance, in the high density fractions collected during this study, zircon was often noted.

The title of this report “Making a Silk Purse on the Silk Road” refers to the challenges that were encountered throughout the project. Through the help of our translators and technical support of the members of Dr. Li’s team and others at the Xinjiang Institute of Ecology and Geography we were able to overcome many of the challenges that we faced and develop information that will be significant for large scale mining in Xinjiang as well as small scale miners throughout the world who are considering replacing their use of mercury with more environmentally sustainable methods. Special thanks are extended to Dr. Ma HuaDong of the Xinjiang National 305 Project which made it possible for us to visit the mine in Yili as well as ensuring our success through his local knowledge of the mines in Xinjiang and the processes used therein.

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