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Geoforensic Passport of Mined Gold

Speakers:
Dr Stewart Murray, GDL Consultant, LBMA/ Speaker 1
Dr Barbara Beck, University of Lausanne, UNIL/ Speaker 2:
Dr Johnathan J. Jodry, Head of Laboratories and New Business Development, Metalor/ Speaker 3

Summary:
For those of you that missed LBMA's Ninth Assaying and Refining Digital Conference 2021, one of the headlining sessions was undoubtedly the joint announcement by the University of Lausanne and Swiss refiner, Metalor, that they have developed a "Geoforensic Passport" – a breakthrough scientific approach that validates the origin of doré received by refineries. This project was co-funded by the Swiss Government through Innosuisse, together with Metalor Technologies.

Speaker 1:
Good morning or good afternoon, everyone. What a pity it is that I can't begin by thanking the sponsors of last night's dinner on your behalf. What a pity it is that I cannot hope that none of you has a hangover after all the late-night networking, following the dinner. So, instead, I will thank the five LBMA referees, not just for all the work that they do in support of the good delivery system, but also for the commitment of their representatives to the development of the programme for this conference. As has been mentioned several times yesterday, there are some real benefits to having a virtual event, but there was a time, or perhaps there were times during the past year when it was by no means certain that we should go ahead. So, all credit to the referees on the conference committee, which has actually met fourteen times since our last conference, and especially to its chairman, Mike Hinds, and above all, to the LBMA team for having the courage and the ability to put on this digital conference.

Now, to our first session, which includes one presentation, a long one, but two speakers. One Dr Jodry needs no introduction for this audience, so I'm not going to give him one. The other is Dr Barbara Beck, and she's speaking here for the first time. Barbara is an Earth Sciences graduate, and her Ph.D. was in the field of archaeometry. You'll note I had some difficulty pronouncing that. I confess I had never heard of this term before. I'm a bit familiar with Archaeometallurgy, which begins with the Bronze Age, but I now understand from Barbara's bio, that archaeometry can go much further back in time, based on studies of the minerals and the geological structures to shed light on historical developments. The title of their presentation is intriguing: The Origin of Gold, Geoforensic Passport. Well, in this country, in the recent past, there are lots of discussions about a new type of passport – a COVID passport. Well, forensic science seems to be the basis for much of what's on television recently, mostly in the form of drama. We had papers on fingerprinting of gold bullion at this conference in 2013 and 2015, but there was no geo involved in either of them. And, as for the origin of gold, well, I mentioned yesterday, the Supernova Cassiopeia A, but I suspect that Jon and Barbara won't be looking just that far back, but who knows? Anyway, we will very soon find out, and I'm looking forward very much to hearing what is going to come out of this mix of these very interesting ideas. So over to you, Jon and Barbara.

Speaker 2:
Good morning.

Speaker 3:
Good afternoon Asia, it is our pleasure today to present for the first time an academic work which started already in 2016 on the origin of gold and specifically the geoforensic passport. We all know about the compliance problem dealing with Doré coming from mines and we believe that for the first time, we are able to provide scientific tools allowing refiners to have a very high level of confidence with the material they are receiving.

Speaker 2:
Our study focuses on the production of gold in an industrial context. Each year, Metalor receives several thousand Doré. The origin of this Doré is declared by the supplier. We want to ensure that this declaration of origin is reliable. For this reason, we developed a scientific tool, with the aim to confirm the declared origin of the gold. However, we were confronted with a few challenges. Firstly, for a very long time, the gold supply chain was considered extremely complex to the point that gold traceability was considered impossible. The first question was, therefore, whether it is technically possible to trace the gold's origin in a scientifically reliable way. Secondly, gold supply involves a very large number of players around the world. It was therefore impossible to systematically collect samples from gold mines. And, finally, a solution had to be found that could be carried out in a systematic way and could be integrated into the refining process at Metalor. Our solution is the geoforensic passport that we are going to present to you today.

Speaker 3:
The presentation will have three main parts. We will quickly go through the state of the art and discuss a little bit what has been done so far. We will then explain about the creation and the validation of the geoforensic passport and, finally, we will focus on applications, explaining how this geoforensic passport can help refiners. You are all aware, or many of you at least, of the Conference given at the Assaying and Refining Seminar in 2013 by Colonel Dixon. Colonel Dixon, unfortunately, passed away last year. His work is really central in the determination of the origin of gold. During his Ph.D. studies, he started to develop tools to prove the origin of gold in criminal cases, and later this was extended to supply chain problems. His work is mostly based on detailed chemical composition by LA-ICP-MS.

Speaker 2:
The pioneering study is that of the BGR which developed the analytical fingerprint methods to monitor the supply of tin, tungsten, and tantalum ore and gold in the Great Lakes region of Central Africa. Their method has been developed since 2006 as a contribution caused by the UN for a scheme to verify the origin of conflict minerals. They set up a reference database, including all artisanal and small-scale mines in this region, to finally compare transboundary mineral shipments to this reference. This scientific tool is based on a combination of chemical and mineralogical analysis. For gold, BGR commissioned a feasibility study but did not develop a tool. And, finally, the study of the BRGM aimed at controlling the supply of gold in Guyana and Suriname. This study was carried out on the initiative of the WWF. Their approach is based on the collection of Doré from artisanal and small-scale mines, followed by a complex mineralogical and metallographic study. And the last two studies were not conclusive.

The implementation, in particular the collection of samples in the field, and the laboratory work proved to be very complex, expensive, and time-consuming. Understanding the shortcomings of these studies was decisive for the approach we took. First of all, it was important to avoid extensive fieldwork but intervene at the bottleneck of the gold supply chain: the refineries. We have therefore developed a geoforensic passport, which is a complex concept that integrates chemical, isotopic, geological, and supply chain information. This graph shows the geoforensic passport of one single customer. We can see dots in a three-dimensional coordinate system. The axis of this graph here does not represent one single chemical element, but a combination of chemical elements arranged in such a way as to be as discriminating as possible. These are the principal components of the passport and based on statistical evaluation. In this graph, I have represented only the first three principal components on the first three axes, but our analysis is carried out in a multidimensional space. In our case, up to 15 dimensions. You'll get a clearer picture of how it works in the following slide. Each dot represents the signature of one Doré from this specific customer. We can see that group dots, as the red, the green, and the orange subgroups. Each subgroup has a well-defined chemical composition. Then we can see isolated dots, the outliers marked in yellow in this graph, they do not have a common chemical composition with another dot. Furthermore, if you look, for example, at the red subgroup and the medium green subgroup in this graph, we can see that they are relatively far apart.

This graph represents exactly the same datasets as in the previous graph but according to three other of the fifteen possible dimensions. The red subgroup and the middle green subgroup are much closer than in the previous graph. If we imagine this data in an even larger space with fifteen dimensions, we can see the discriminating power of this evaluation. How does the geoforensic passport work? If we insert a new Doré into the data set, and if we can attribute it to one of the subgroups, its declared origin is confirmed. If this is not the case, the Doré is attributed to a new yellow dot. This is an outlier. If the Cloud origin cannot be confirmed, then further investigations are necessary. Depending on the supplier, normally, more than 90% of its production is confirmed, but obviously, the geoforensic passport evolves over time. This change can be influenced, according to the evolution of the ore deposits, but also according to metalogical changes. For example, in this specific case, no Doré could be attributed to this orange group two years ago. It was necessary to wait several months before seeing one Doré with the signature. We have therefore classified it as an outlier. And a few more months later, we had other Doré with the same signature that initially we declared outlier, had to be considered as the starting point of a new subgroup, thus leaving each outlier status. Let us also mention that these signatures are not necessarily unique. Two different suppliers both exporting the same ore deposits can have close signatures.

Speaker 3:

So, this is the level one analysis for our investigation. We are relying on ED-XRF, but we have, if we get an inconclusive result, the ability to go to a higher level of investigation. Level two will be based on an isotropic-lead analysis, and even if at this stage there is an inconclusive result, we are able to go to further investigation to validate the origin of the Doré. The main interest of using the multilevel process is to be able to start with ED-XRF analysis. ED-XRF instruments are relatively inexpensive, they have improved a lot over the last ten years. The samples do not require a significant preparation time. You still need to calibrate the equipment properly and, for this project, we calibrated twenty different elements using one hundred and twenty homemade standards at Metalor. Still, this approach is much more affordable than what was done in the past, using especially MC-ICP-MS, which we use for level two analysis. You can simply see with the size of the equipment and the place it's taking in a lab, and it’s not something refiners will be able to afford anytime soon. So, for this project, we provided to Barbara ED-XRF historical data, a lot of them, several thousands of results with mines from all around the world, and then Barbara used those data to build the first model.

Speaker 2:

Using this level one data, we moved on to a series of statistical evaluations based on unsupervised learning. On this graphic, you can see the results of a principal component analysis. The results of this first statistical approach give a detailed analysis of the chosen data set, such as supplier, a supplier group, a region, a continent, and so on. Then, we need to validate this data. This validation helps us to understand why the Doré from the supplier is attributed to a certain subgroup, and not to another one. Here, for example, that red subgroup is characterized by the presence of element X, and the absence of the element Y. The grey group contains both the upper and lower elements and so on, with 20 elements initially measured by ED-XRF, this step validates the subgroups and outliers of each data set. Next, the results need to be put into a more general context. For example, we want to understand statistically, what are the similarities and the differences between two suppliers. Is it possible that two suppliers have subgroups with almost the same signature? Can this be related to geological conditions? And so on. Once all this data has been integrated to be carried out, and other statistical analysis, this time under supervised learning, it is, therefore, a Discriminant analysis that results on a Confusion matrix. This Confusion matrix allows us to control the allocation of a sample to a data set. When the sample is correctly allocated, then it lies on the green diagonal. This evaluation, therefore, leads to calibrated subgroups, and these calibrated subgroups constitute the first level of the geoforensic passport.

Speaker 3:

Once we have this geoforensic passport in our hand, we do analyse every single Doré received at the refinery and through multivariate statistics, we are going to be able to do a classification of those materials. We have explained that for any given mine, we create a number of subgroups. Those subgroups are created statistically. We do not need to ask any information from the supplier, and this is very important. We can create the whole model without getting any details from the way the gold was mined. We only need to know the country of origin and the customer. Once we have this, for every single sample we tested for all the subgroups of the supplier, and as you can see in most of the cases, we can confirm that this is part of one of the subgroups of the given supplier. When we have a problem, when the assignation is not clear or only partially clear, we then can move to the level two analysis. So, let us show you a little bit how we validated this model. And one of the tests we have done is using one hundred Doré samples received at Metalor in late 2020 from South America. For those one hundred samples, we only provided to Barbara, the country of origin, and the customer's name, and we only used the ED-XRF to confirm the origin of the Doré. And to make things a little bit more interesting, we performed a small trick on one of the samples which was manipulated. On the left column here, you can see a typical sample that we had from South America, and we replaced it with a very similar sample coming from Asia, and those data were provided to Barbara for analysis.

Speaker 2:
And the two samples were immediately detected as problematic.

Speaker 3:
And then we realized that's the first problem because I only manipulated one sample, so, at that stage, I started to be quite worried.

Speaker 2:
In the graph on the left, you can see the geoforensic passport of the declared supplier of this manipulated sample. It can be seen that the sample of the Asian origin differs very clearly from other Doré from the same declared supplier. As for the second sample identified as problematic, P19, its output classification highlighted in red in this table to the right, also shows that the allocation is wrong. The allocation of the sample P19 is not constant unlike the other samples of the same data set.

Speaker 3:
So, to understand what was happening, we went back to the receiving process at Metalor and extracted the pictures of the four ingots received the same day from the same supplier. As Barbara said, the three others were confirmed and had no problem whatsoever, and they looked exactly like that relatively large, melted ingot, but the ingot that was creating a problem is seen here on the right. And, as you can see, it has a very different appearance. What we did is, we went to the customer and asked more information about that specific material and learned later on that this was the remelt of samples kept at the mine, explaining why the analysis was so off. So, it's very interesting to see that this geoforensic passport not only allows us to understand and monitor differences when the origin changes, but also allows us to identify significant changes in the metallurgical processes.

As many of you are aware, in June 2019 Metalor announced that it would stop sourcing gold from mine collectors. There are many reasons that were put upfront to explain this decision. Some of them are that it is difficult to rely on local authorities, that the compliance risk is relatively high dealing with collectors, and that there is significant challenging traceability, in general. With this project in our hands, we were interested to understand how the geoforensic passport could help understand better the mine collector's business, and especially we wanted to understand whether it is possible to distinguish the different sources from where a collector is receiving his gold.

Speaker 2:
On this slide, we see photos that were taken in a semi-artisanal mine that was in the process of being formalized.

Speaker 3:
Those are typically mines that are providing material to the collectors.

Here you see the geoforensic passport on a Peruvian collector. The data were collected until June 2019. What we see is that there are different types of groups. There are very, very specific groups like the green one or the pink one, and those are likely industrial mines or relatively large mines that are very well defined. Then we see some larger clouds here in yellow, which we believe are artisanal mines. It's slightly more heterogenous but it still has a signature which is quite clear. And then we have a very large number of orange signatures here, and those are complete outliers. This is typically the kind of sourcing that we do not understand, and which for us at Metalor is a compliance risk.

Speaker 2:
The second case study is an example of a more complex case. The geoforensic passport shows a very homogeneous green subgroup. Another subgroup, the orange one shows a very atypical chemical composition, as shown in this table on the right. The green group shows relatively high silver and gold contents, while the orange subgroup is characterized by high nickel and copper contents. We were therefore almost certain that these two subgroups did not come from the same operation. It is for this reason that we carried out additional investigations as proposed by level two of our approach. And as the top analysis clearly showed that the two groups, which are chemically very distinct, had an identical lead isotopic composition, as can be seen on this graph. Obviously, the samples of these two groups are from the same supplier.

Speaker 3:
So, this is a typical example where even if you have an inconclusive result in level one analysis, you can move to level two analysis and get a confirmation that the origin, which was declared is indeed genuine.

If there is one name that all gold refiners know is that of La Rinconada. La Rinconada is the highest city in the world. It is a shanty town at more than 5000 metres in Peru, where more than 60,000 people live and work in extremely difficult social and climatic conditions. Obviously, no serious refiner wants to source gold from there.

Speaker 2:
In La Rinconada, the ore body is very special because it is exploited when it comes from this particular region but very small as shown in this picture. These dimensions are so small that industrial exploitation can never be envisaged. It will therefore be a huge artisanal mines until complete exploitation of the ore body.

Speaker 3:
This project did not limit itself to laboratory work, and we had the incredible opportunity of having Barbara going to Peru and collect first-hand samples from areas where no refiner could go. This includes especially material collected in La Rinconada, which is here at the border with Bolivia, and also the ability to go directly to Comptoir where gold is traded in smaller and larger cities in Peru and buy a gold nugget. This gold nugget, bought in Juliaca, which is next to the Titicaca Lake, was proven through its geoforensic passport to come in fact, from the La Rinconada area.

What we can see at Metalor is that several thousands of Doré were analysed from Peru, many of them have a very clear signature, but what we can learn with this project is that the gold coming from La Rinconada represented here in red, has a very significantly different signature from the rest of the official suppliers. But, of course, there is one question that stays. We can say that no shipment from La Rinconada was received at Metalor since the beginning of the project. We are really sure of that. But what is happening if we get mixtures? If you imagine that a supplier for example is taking some gold from a specific area which is declared and is adding gold from La Rinconada, we would like to know whether the geoforensic passport can help us to trace these kinds of manipulations.

Speaker 2:
This graph represents the 2D geoforensic passport of all Doré from Peru we've had for two years at Metalor. And here, in the same graph, are the first samples collected at La Rinconada and Juliaca. We can see right away that the signature of these four samples is completely incompatible with the signature of the Doré from other Peruvian mines. We then tried to see what would happen if we mixed gold from La Rinconada in green, with gold from a manufacturer, also located in Southern Peru in red. We, therefore, created artificial mixtures. Here you can see the results. In green, the gold of La Rinconada. In red, supplies of gold from Southern Peru and the purple stars are the bogus mixtures. It can be seen that even the addition of only 10% of La Rinconada gold can be detected by statistical analysis.

Speaker 3:
And keep in mind that this is performed on two dimensions. You can see only two dimensions of the screen, while in reality, the system is still working on multidimensions [inaudible 28:05] for more segregation.

Speaker 2:
Our study shows extremely promising results that are likely to have a major impact on the gold supply chain. Confirmation of origin is, therefore, possible using the scientific multistep methods. We would like to point out that we will not make a determination of origin, but a confirmation of the declared origin of the gold. Our approach is based on the equation of the geoforensic passport established for each customer, the relevant groups of customers, regions, and so on, and even a small percentage of mixtures can be detected. We don't need large-scale field studies, our investigations take place at the bottleneck of the gold supply chain on arrival at the refineries.

Speaker 3:
For the refiners, this is a very interesting game-changer approach. We are using an equipment which is inexpensive, readily available at most refineries, and we are able to do systematic analysis without stopping the flow of the precious metal. It's easy to integrate the data in the analysis in existing flows, so, we believe that this is really a game-changer for the refiners and that over the next years, this will receive more and more interest from many of the people working with gold. It is the first time that we have a scientific tool, which is readily available, will be fully described, will be published in scientific publications, and brings an answer to one of the fundamental questions for the refiners; can I be sure that the gold for mine is coming from where the supplier is announcing?

Speaker 2:
And, finally, our method has to be improved. For the next steps, we need to automate the first level of indications to facilitate the selection of outlier Doré as soon as they arrive at the refinery. And then we need a better understanding of the Doré outliers through well-targeted field studies.

Speaker 3:
This project is really a long project, and a lot of people from the University of Lausanne were involved. We would like to thank them very, very warmly, as well as colleagues from Metalor that helped a lot as for the whole project. But we also would like to thank the Swiss Embassy in Peru, which really provided some insights and helped when Barbara visited the country, as well as the University of Geneva for multiple analysis, together with Thomas Hentschel from the Better Gold Initiative and Diana Culillas from SBGA. This project was co-funded by InnoSuisse, Swiss governmental agency, together with Metalor Technologies. Thank you all for listening.

Speaker 2:
Thank you.

Speaker 1:
Well, what can I say? That was a most amazing and mind-boggling presentation, and I would like to thank you both, and your institutions, for having undertaken this work and for coming here and presenting it to us today. My mind is still struggling to get around the fifteen different dimensions that you mentioned. Personally, I still struggle a bit to understand the basic nature of these multi-dimensional charts that you were demonstrating to us. We have, not surprisingly, a number of questions from the audience, and I'd like to start by taking the one from Madeline Theron who asks how you got the samples. “Did you drill the incoming Doré, or did you melt and take a dip sample from it?”

Speaker 3:
Yeah, I think that's a very good point, thank you, Madeline. All the samples taken were drilled on the bars as received, and that was a very, very clear requirement from Barbara.

Speaker 2:
So, effectively, we didn't want to make an additional step of the metallurgical procedure and so–

Speaker 3:
Of course, you can take the sample after melting, but any melting is kind of a refining process, so you are basically changing a little bit the signature of the material. And while the material is relatively insensible to those operations, you’ll still lose a little bit of information. So, everything was done on the material as received. And, of course, you can imagine all of your Doré received at a refinery, they are not always completely homogeneous especially at the surface, because this is where we have the more deleterious elements, but even the local homogeneity we could have were not impacting negatively on the geoforensic signature.

Speaker 2:
And the most important is to take the sample always on the same step of the processing.

Speaker 3:
Which is easier if you do it at the first step.

Speaker 1:
Okay. Another question here from Edward Stefanescu. “Did Metalor engage with the Peruvian mining authorities to exchange knowledge regarding the composition of the deposits?”

Speaker 3:
So, I think one really added value of this project is a lot of work was done in Peru, which was that as a test country where Barbara travelled extensively. So, I think this is really for you the question.

Speaker 2:
Actually, we were working with the local NGOs, and they, sort of, relied on the Peruvian authorities but the most information was really by working with these NGOs [inaudible 34:40] work on the formalization of the artisanal mines.

Speaker 3:
And, in general, to build this system, we were using only the basic information. So, all the analysis we're doing here, as well as the name of the supplier, the name of the mine, and nothing else. We were not asking for any detail from the suppliers, because we didn't want to introduce data in the system that might not be very robust, so everything was done with a minimum of information required. But as you were showed in the presentation, Barbara spent also a lot of time to understand why you could find differences or similarities in some signatures, and this is done, of course, using more information on the geological aspect of the Doré.

Speaker 1:
Fine, thank you. If you were to be a new refiner, looking at your presentation and saying that’s a jolly good idea, but you didn't have all that data taken from previous XRF analysis, and maybe you weren't in close connection with Barbara. What would you have to do to start up this project?

Speaker 2:
Actually, our approach is a multivariate statistical approach. For this, we need quite a lot of data, so, the more data you get, the more precise are the results of this statistical interpretation. Actually, you can start with quite less data, between ten and twenty data, but then the result is not very fixed, not stable, and you get more outliers than when you have a huge database.

Speaker 3:
This project is really based on its big data and statistics, it's really the two things that render that project possible. For big data, you need data – there were several years of data collected for this project, and this is what made everything possible. If you start from scratch, you would need a certain number of samples for every customer you have probably gathered over a couple of months. Basically, the more data you have, as Barbara said, the [more] stable your system is, and the less you need to go to level two or higher analysis. So, you will need to spend a little bit of time gathering data, that's kind of important.

Speaker 1:
Okay, now, what would happen if let's say two or three years from now, ten or twenty refiners have followed your pioneering lead here and have set up their own databases and have done all the XRF analysis and put it into this computer system, looking at the big data. So, you've then got lots of data sets. Is it possible somehow to – for these datasets – called to be compatible and to, kind of, work with each other to make this more global rather than a single refiner-based project?

Speaker 3:
Now, that would be cool. I mean from the scientific point of view, that would be absolutely fantastic. You would need to ensure that the data are entered in the system with the same level of precision. So, we spent all sorts of time developing an XRF method that was reliable, with good calibration but provided that the refiner has a good analytical method, that would be really interesting. You can imagine you have

a lot of data. There's a problem of confidentiality. You need to say which customer that material is coming from. I don't know how many refiners would be ready to provide even anonymously the name of their suppliers. Could be a little bit tricky, but from the scientific point of view, the amount of information you would get would be absolutely incredible, and the system would be significantly more robust.

Speaker 1:
Just looking at the questions that have come in. There are so many. We're not going to be able to address them all. One is here about the homogeneity of the bars that come in. You know, every bar from the same supplier is going to be slightly different. I also wondered during your presentation, I mean, how much does the variability of, you know, one particular trace element affect whether, you know, that particular Doré is put in with all the other ones?

Speaker 3:
I think it's a good question. It's true, I mean every refiner knows, even when you see the bars, they don't look that homogeneous, and that is technically an issue, but remember the dimensions. It's not one dimension for copper, one dimension for selenium, and one dimension for arsenic. The dimensions are built by the system through statistical tools and, overall, those dimensions are relatively insensitive – they are rendered insensitive to variation, typically surface variations. So, of course, if the supplier pre-melts or pre-refines a little bit more one Doré, you will have less impurities, but specific ratios will be kept, and the system is basing itself on those ratios. So, over time, you have to imagine that this system, it's kind of dynamic, and over time, it's reaching a state where it's relatively stable, or sometimes even quite stable, we can say. And this is really what allows variations in the composition, which will be almost always the same. If you pre-refine more, you will lose more of the impurities and you will lose them at a specific ratio that is more or less coherent. And everything put in the system allows for variations of the surface, or variation super refining relatively insensitive to a system.

Speaker 1:
Okay, well, I'm very sorry but we are running out of time. Can you just tell the audience how they can find out more? Where you're going to publish this work? Whether you're going to be available later today in the networking area to discuss other questions that people might have?

Speaker 3:
We are happy to join the networking; to go to the networking session. I think I just saw a message saying that the networking access has been fixed. So, I think if everyone wants to try again. Sorry I think it was a bit difficult to connect yesterday but if everyone tries again, we will be there at the end of the next session, and we are happy to answer questions and to follow up. And, for publication, this depends mostly on Barbara.

Speaker 2:
I'm working on it

Speaker 3:
So, we are working on a scientific publication and peer reviews and we hope it will be out soon, but it takes some time.

Speaker 1:
Okay, well thank you, again, both of you. A very big round of applause can be assumed, and for everyone, would you please rate this session before moving on immediately to the next one. Thank you all very much

Speaker 3:
Thank you.

Speaker 2:
Thank you.

For more information, please contact:

Tayler Birch
Events Coordinator
events@lbma.org.uk
Tel: 07388 798 992

1-2 Royal Exchange Buildings, Royal Exchange, London EC3V 3LF
Tel: +44 (0)20 7796 3067 www.lbma.org.uk

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