COMPARING SAMPLING TECHNIQUES FOR GOLD BULLION EVALUATION

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RAND REFINERY

AGENDA

1 Introduction & Theory Review

2 Methodology

3 Results

4 Conclusion

5 Acknowledgement

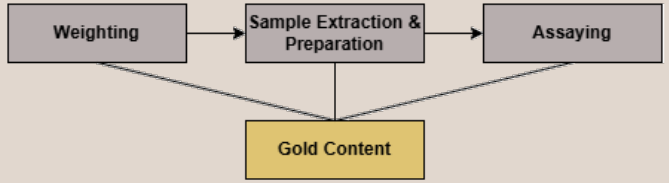
INTRODUCTION & THEORY REVIEW

INTRODUCTION: GOLD BULLION EVALUATION

Gold Bullion Composition

- 🏭 Complex compositions (gold, silver, copper)
- 🟡 Varies across different deposits

Evaluation Process



Importance of Accurate Sampling

- 💰 Fair financial settlements
- ⚖️ Avoid financial losses due to biased sampling

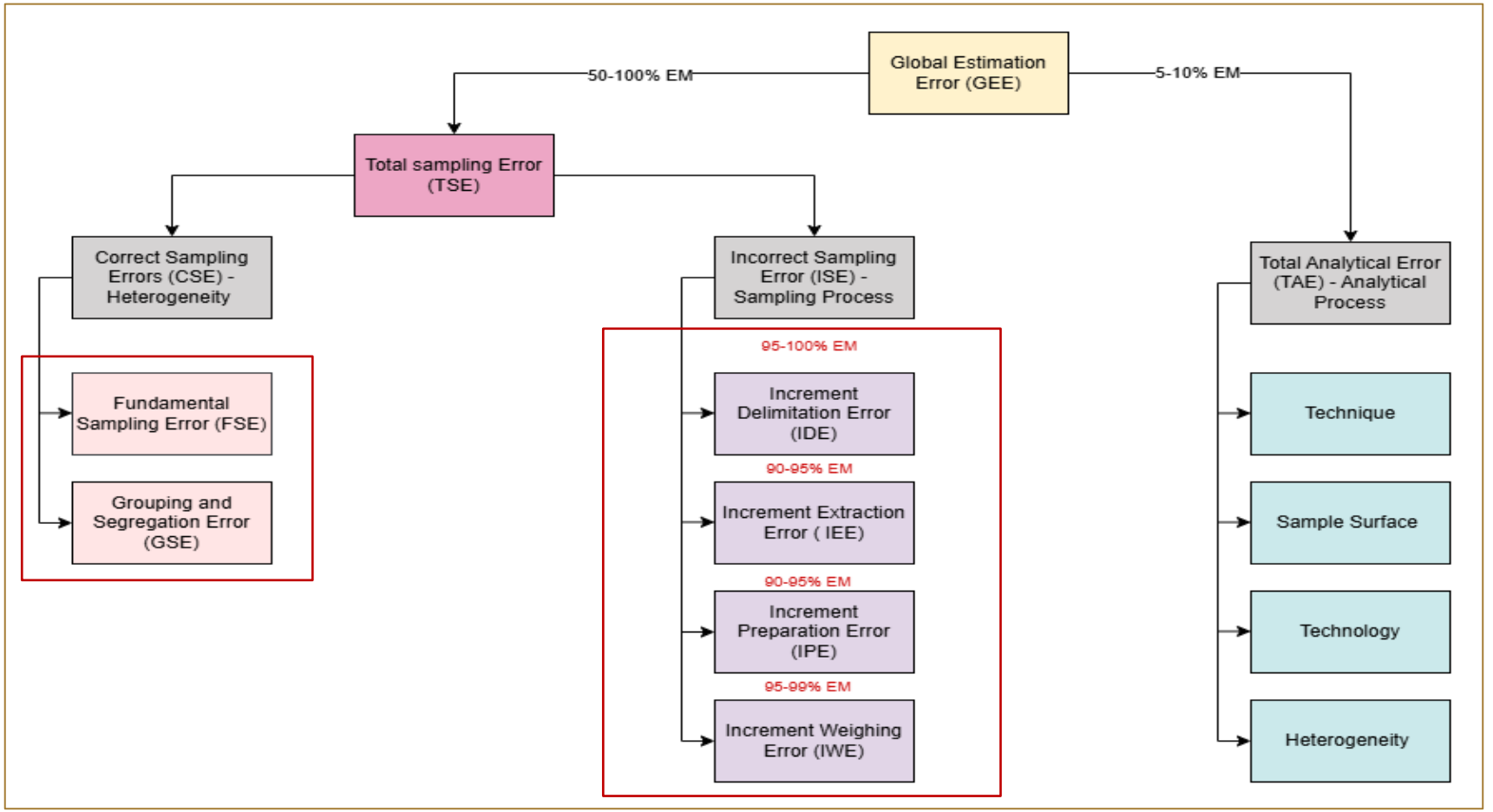
Financial & Reputational Impact

- 🚨 Inaccurate sampling damages reputation
- 🔬 Maintaining transparency is key

THEORY REVIEW

THEORY OF SAMPLING (TOS) & SAMPLING ERRORS IN BULLION EVALUATION

Pierre Gy's Theory of sampling (TOS) | Sampling accuracy | Heterogeneity in sampling | Sampling errors: source and types | Sampling errors in gold bullion



GOLD BULLION SAMPLING: A REFINERY CASE STUDY

Impact of sampling on assay and grades

- 🧪 Sampling affects grade and assaying accuracy
- 🚫 Errors accumulate if not addressed

Essential quality standards and controls

- 📏 Quality standards minimize errors
- 📊 Standards for sample extraction, preparation, and laboratory analysis

Case study: A test for assay variance

- 🎯 Investigation of the effectiveness and validity of different sampling techniques
- 📊 Comparing Dip vs Drill sampling technique
- 🔍 Identifying the most accurate method for gold content determination

Purpose of the study and relevance

- 🏭 Conducted at Rand Refinery, a gold leading refinery
- 🔬 Improving efficiency and ensuring compliance
- 💰 More than accuracy — financial integrity and efficiency

METHODOLOGY

METHODOLOGY: SAMPLING

SAMPLING TECHNIQUES FOR GOLD BULLION EVALUATION

Dips Sampling

Molten gold extracted using dipping iron sampler

Discs Sampling

Graphite crucible used to extract molten and pour molten gold into disc moulds

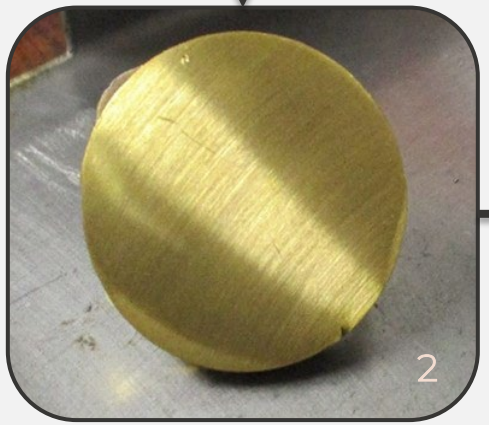
Pin Tube Sampling

Pin tubes dipped into molten and extract molten samples using vacuum suction

METHODOLOGY: SAMPLING

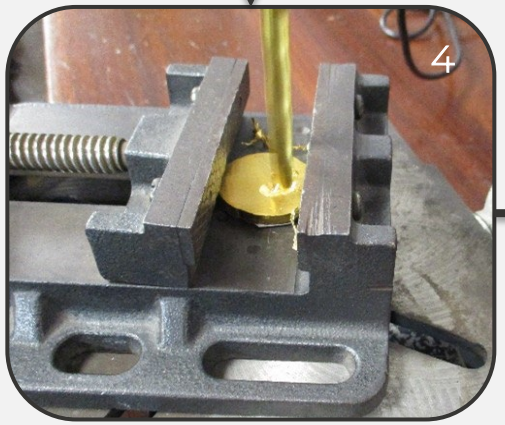
PREPARATION OF DISCS DRILLINGS

Milling

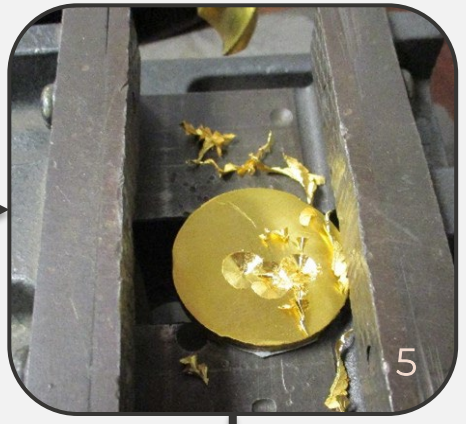


Prepped disc

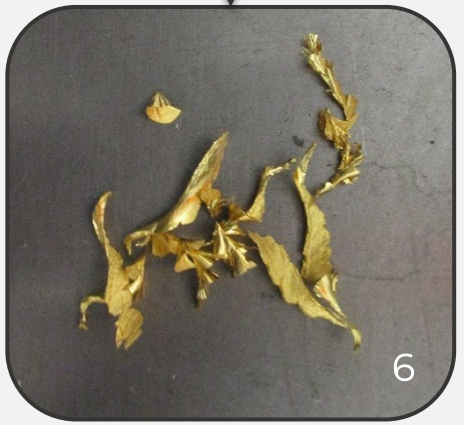
Drill bit: Tungsten



Drilling of disc



Drilled disc

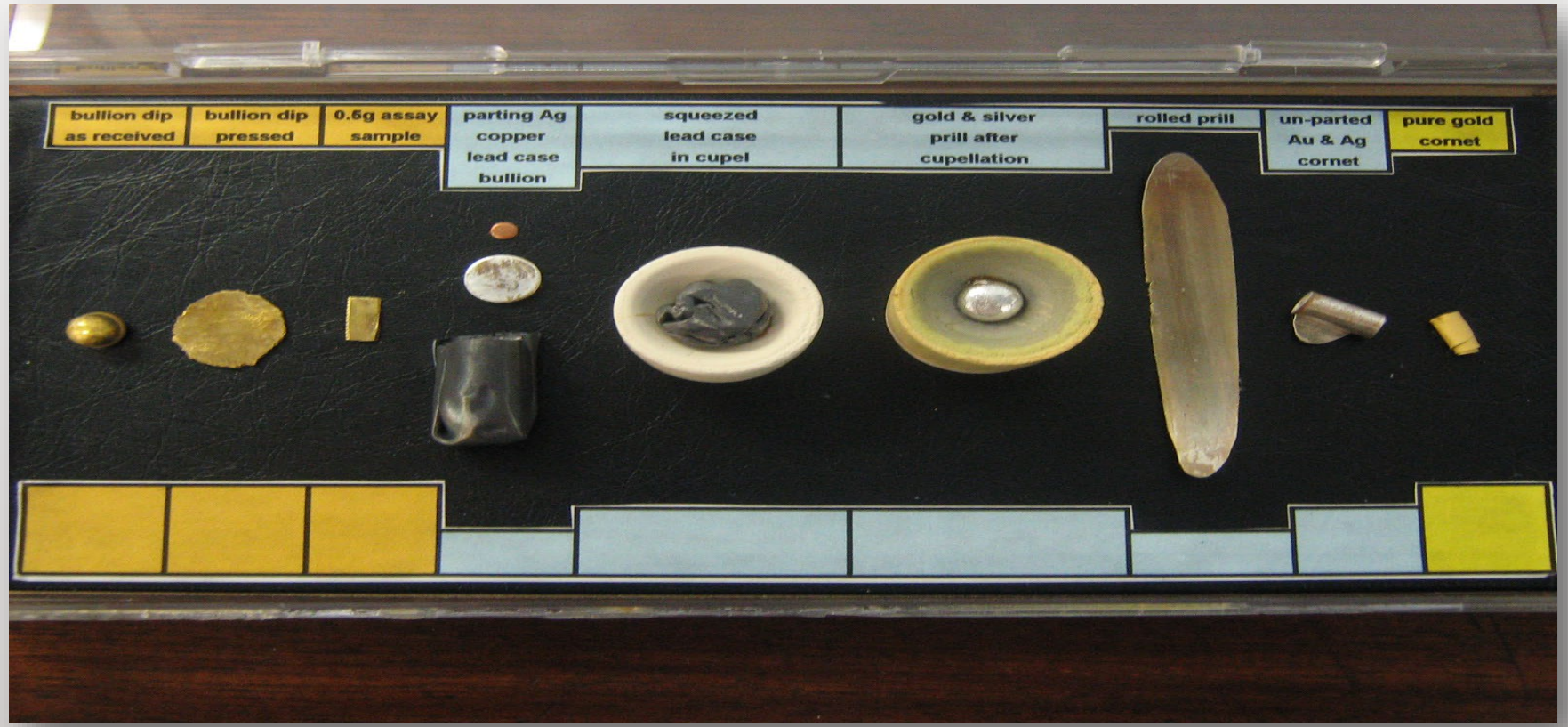


Disc drillings

METHODOLOGY: ANALYSIS

BULLION ASSAY – FIRE ASSAY BY CUPELLATION PROCESS

- Sample Receiving
- Sample Preparation
- Sample Weighing
- Addition of Lead, Silver and Copper
- Cupellation Process
- Parting Process
- Final Weighing
- Quality Control and Reporting



RESULTS

RESULTS

Only deposits with **80% gold content** or higher were included in the analysis

47 deposits with 80% Au content and above, contributed by **21 depositors**

Five replicates per sample were assayed for accuracy

Average and **Standard Deviation** were calculated for each method after assay

Outliers are excluded: **Grubbs' Test** for Outliers and **physical** outliers

Batch Number	Dips (%)	Pin Tube (%)	Discs drilling (%)
00001	89.709	89.899	89.724
	89.691	89.704	89.683
	89.708	89.694	89.705
	89.736	89.719	89.691
	89.541	89.708	89.730
Standard Dev.	0.019	0.010	0.020
Average	89.711	89.706	89.707

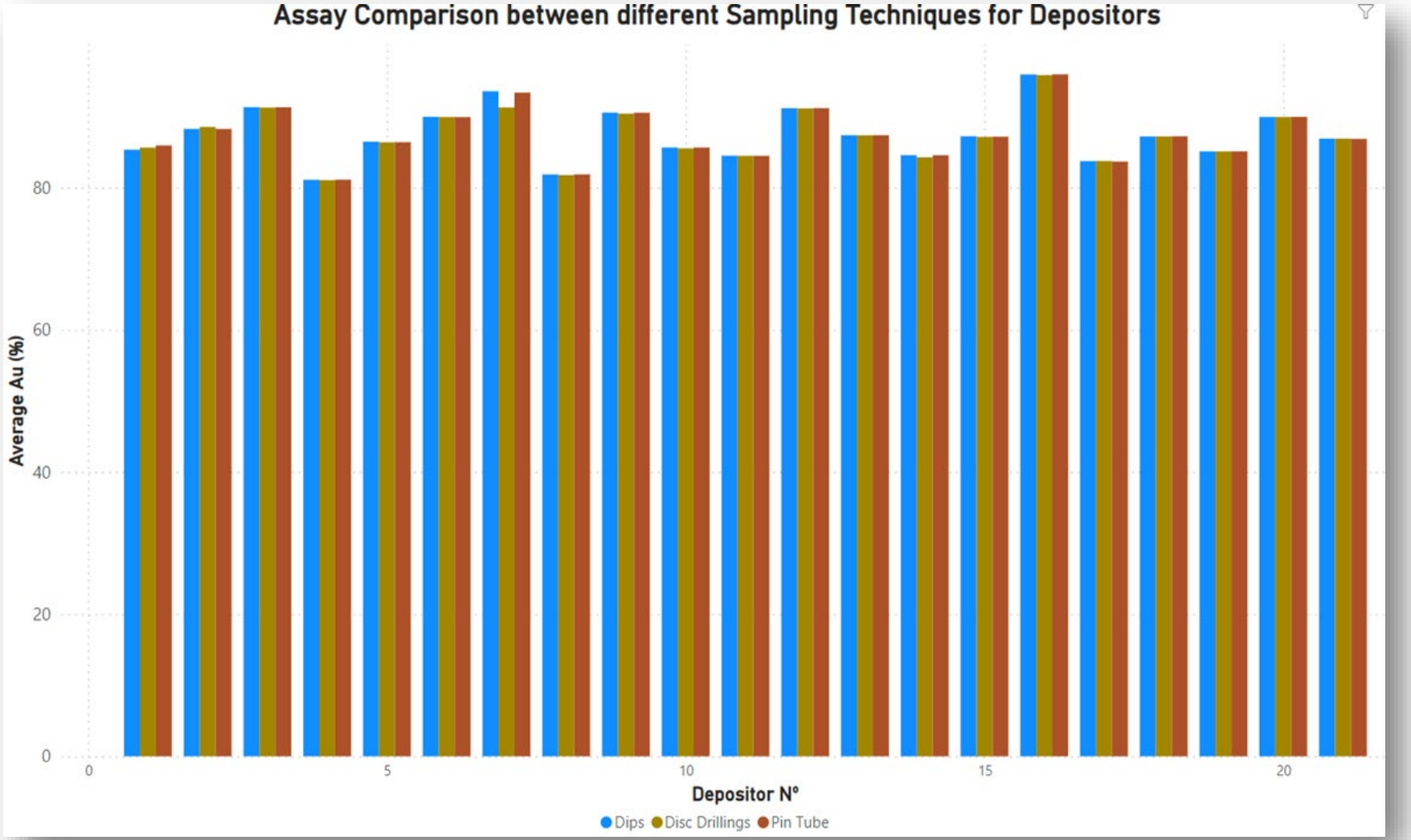
RESULTS

COMPARISON OF AVERAGE ASSAY RESULTS

Objective 🎯 : Compare the average assay results for each sampling method

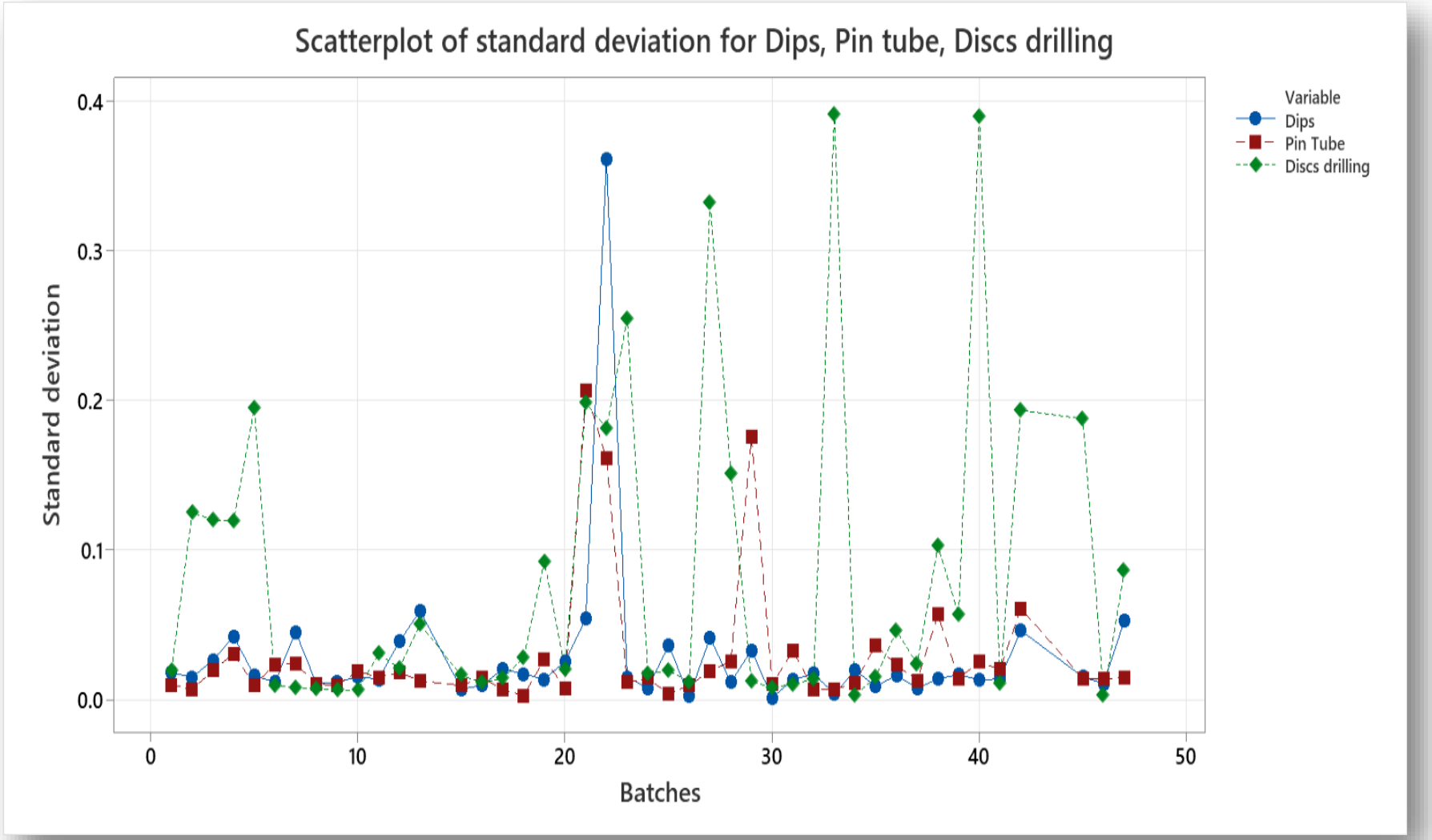
Focus: deposits from the **same depositors**

No significant differences in average assay results across all methods



RESULTS

STANDARD DEVIATION COMPARISON



Notable variance in the standard deviations ≠

Pin tube and dip samples results indicated lower standard deviation

Average of standard deviation for the disc drilling : 3X higher

Observed variance, but cannot confirm statistical significance of it

RESULTS

TEST FOR EQUAL VARIANCES: STANDARD DEVIATION

The ANOVA techniques used was the Levene's test and multiple comparison methods

+

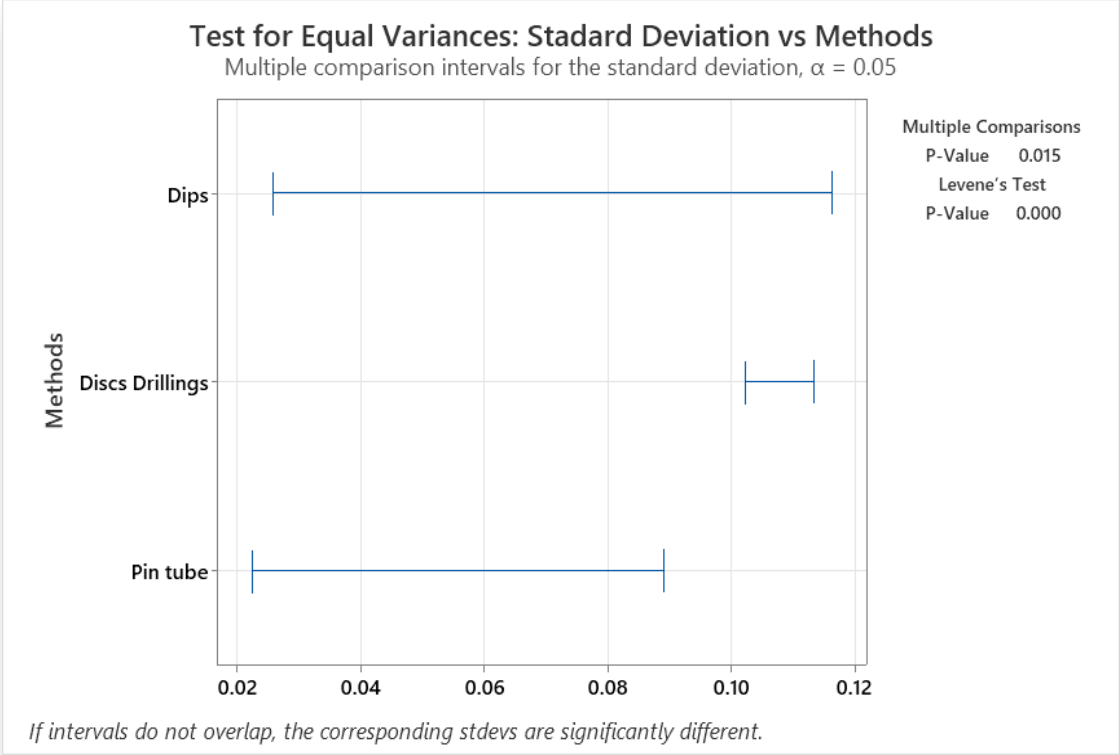
Assumption is that equal variance is expected between the three sampling methods

+

If P-value ≤ α the reject equal variance but if P-value > α , accept equal variance

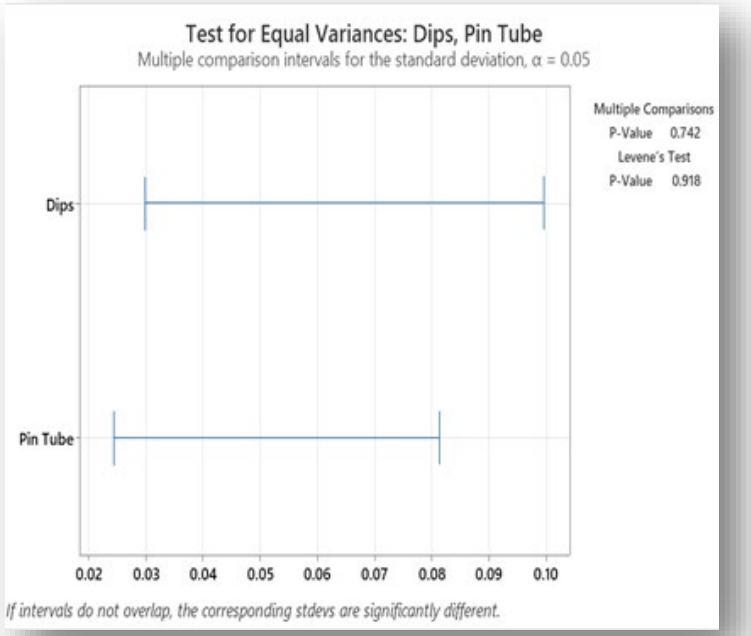
=

Variance is statistically significant, suggesting that one or more methods have inconsistent assay results



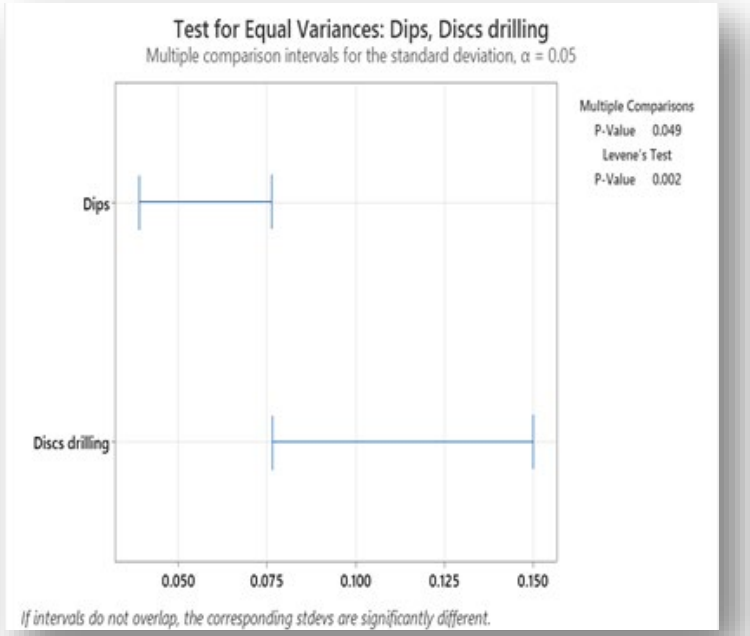
RESULTS

BILATERAL COMPARISON OF SAMPLING METHODS



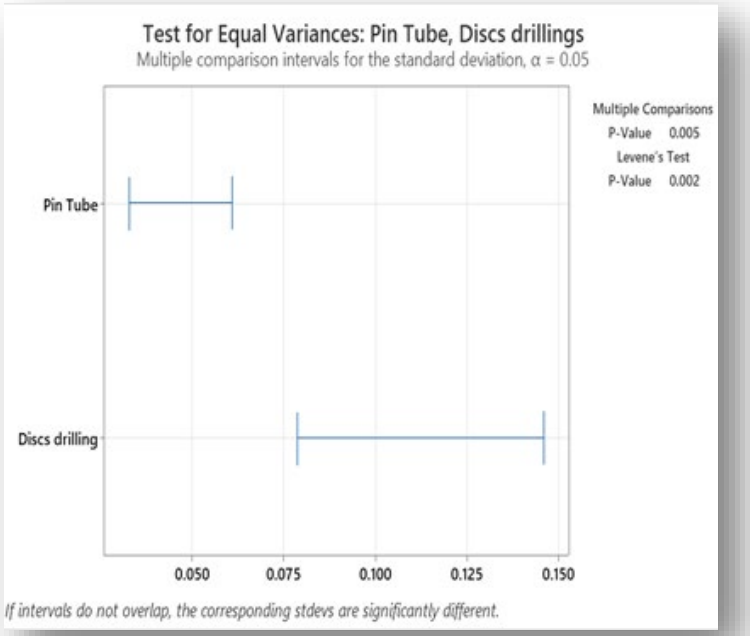
Multiple Comparison Test P-value: 0.742
Levene's Test P-value: 0.918

✅ **No** significant difference in standard deviation between Dips and Pin Tubes, indicating similar variability



Multiple Comparison Test P-value: 0.049
Levene's Test P-value: 0.002

🔴 **Significant difference** in standard deviations, with **Disc Drillings** showing higher variability than **Dips**



Multiple Comparison Test P-value: 0.005
Levene's Test P-value: 0.002

🔴 **Significant difference** in standard deviations, with **Disc Drillings** showing **greater** variability than **Pin Tubes**

RESULTS

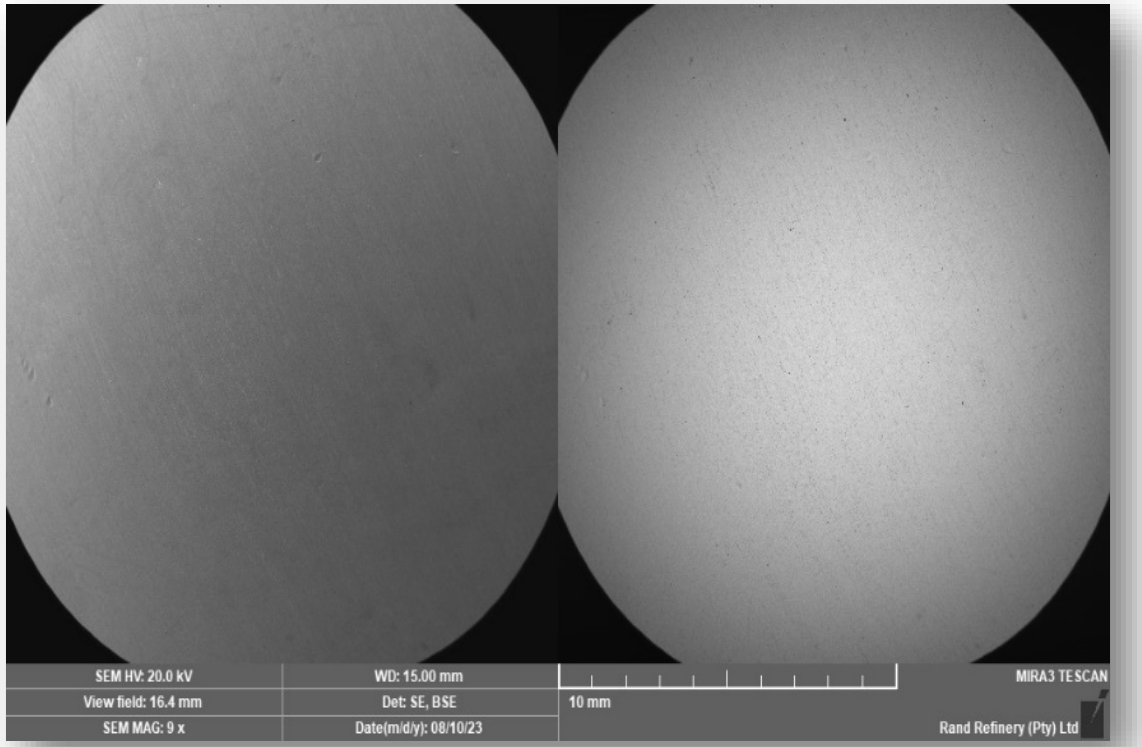
FURTHER METALLURGICAL ANALYSIS OF DISC DRILLINGS

The discs samples with the **highest SD** were analyzed using **XRF**

The XRF analysis revealed traces of deleterious metals, such as **Ni** and **Fe**

These elements can cause **segregation and heterogeneity**

The disc samples underwent further analysis using **SEM-EDX analysis at 9X**



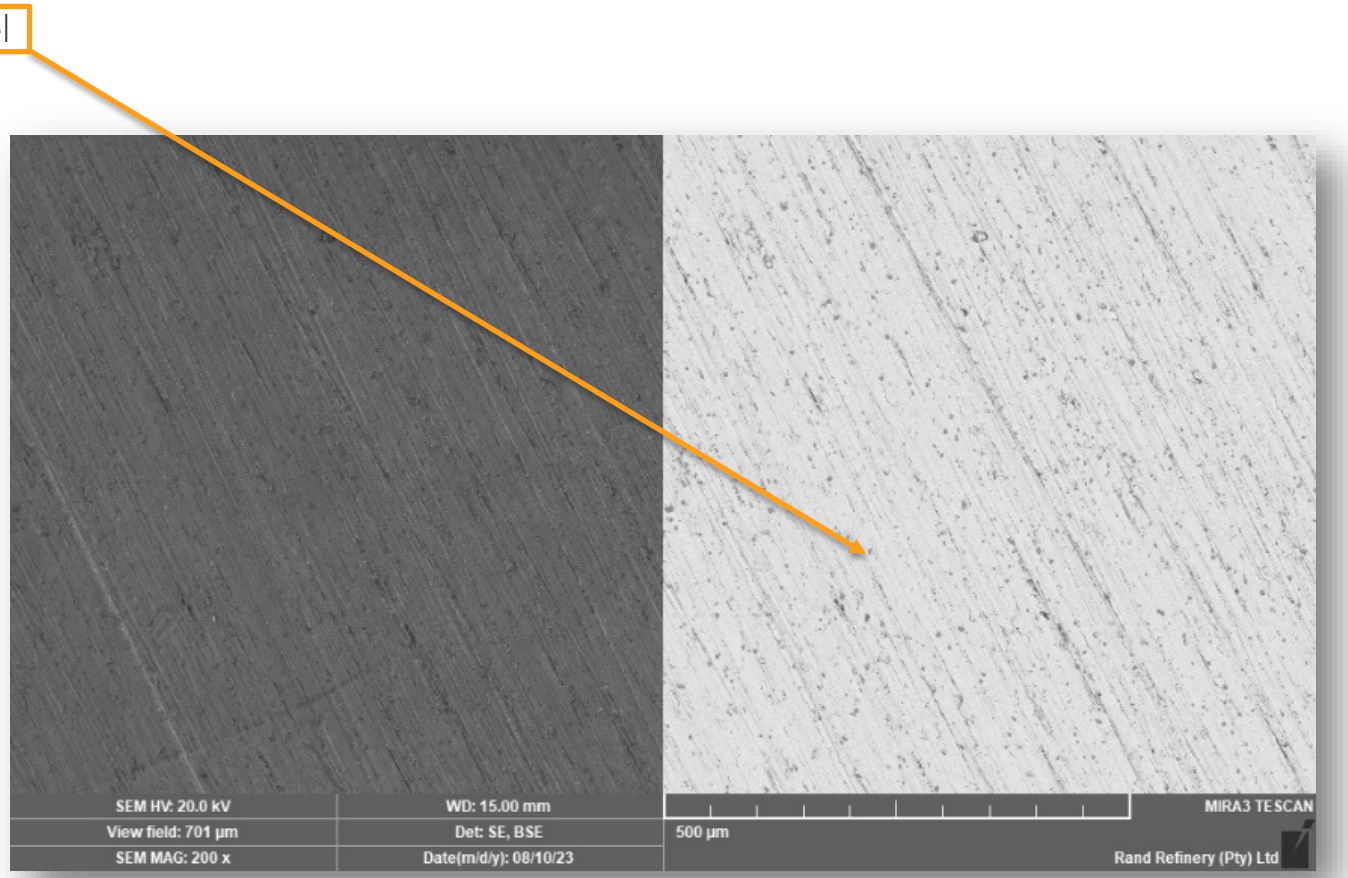
DISC SAMPLE UNDER SEM MICROSCOPE

RESULTS

FURTHER METALLURGICAL ANALYSIS OF DISC DRILLINGS

While **no clear** heterogeneity was initially detected at magnitude of **9x**

SEM analysis at **200x** revealed **micro-heterogeneity** on the disc samples



SECONDARY ELECTRON AND BACK SCATTERED IMAGES OF THE BULLION DISC AT A MAGNIFICATION OF 200X

RESULTS

FURTHER METALLURGICAL ANALYSIS OF DISC DRILLINGS

Furthermore, **EDX analysis** detected concentrations of **nickel (4.4%)** and **iron (0.7%)**

Contributed to the observed **heterogeneity**

EDX CHEMICAL MAP OF THE BULLION DISC AT A MAGNIFICATION OF 200X

RESULTS

KEY FINDINGS

Cause of Heterogeneity!!!

⚠️ Correct sampling errors: Fundamental sampling errors and grouping & segregation errors

🔥 Nickel and iron do not effectively alloy with precious metals

🔄 As the molten bullion cools, segregation occurs, leading to variations

Why Nickel & Iron Affect Disc Drilling More?

🧬 Disc moulds have larger surface areas, promoting more segregation of nickel and iron during cooling.

🔴 Drilling into locations rich in nickel and iron, resulting in higher standard deviations and variability in assay results

CONCLUSION

CONCLUSION

KEY FINDINGS & RECOMMENDED SAMPLING METHOD

Recommended Sampling Method

❌ Disc Drilling is less reliable due to its increased susceptibility to segregation compared to Dip Sampling and Pin Tube Sampling

✅ Dip Sampling and Pin Tube Sampling are more consistent and reliable

⚖️ These methods exhibit lower variability in results compared to Disc Drilling

Importance of Accurate Sampling:

⚖️ Accurate sampling ensures fair financial settlements and consistent gold evaluation

👨‍🔬 Quality control and standardization in sampling methods are crucial to minimize sampling errors

Further Research Needed

🔍 Further investigation into nickel and iron's impact on gold bullion sampling

📊 Focus on understanding how these metals affect sample accuracy and refining processes

Disclaimer

🚨 Study based on mined gold bullion deposits

📜 Conclusions apply to this type of gold material only

ACKNOWLEDGEMENTS

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(OPERATIONS MANAGER)

Amanda Hefer
(Senior Manager: Met-Services)

"EVERY MILLIGRAM COUNTS FOR ME"

-RAND REFINERY

THANK YOU!!!

RAND REFINERY