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### ► To cite this version:

Thomas Dewez, Sébastien Linares, Silvain Yart, Florian Masson, Marie Collignon, et al.. Mapping gold mines under the French Guiana rainforest: return of experience with different mobile lidar systems. EGU 2024, EGU, Apr 2024, Vienne (AUT), Austria. hal-04508900

**HAL Id: hal-04508900**

**<https://hal.science/hal-04508900>**

Submitted on 18 Mar 2024

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Géosciences pour une Terre durable

brgm



Dorlin, October 2022, heliborne photo © T. Dewez – BRGM

# Mapping gold mines under the French Guiana rainforest: return of experience with different mobile lidar systems

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EGU2024-GM 3.2 - Vienna - 15 April 2024



BY

## Context

# Where is gold exploited? How?

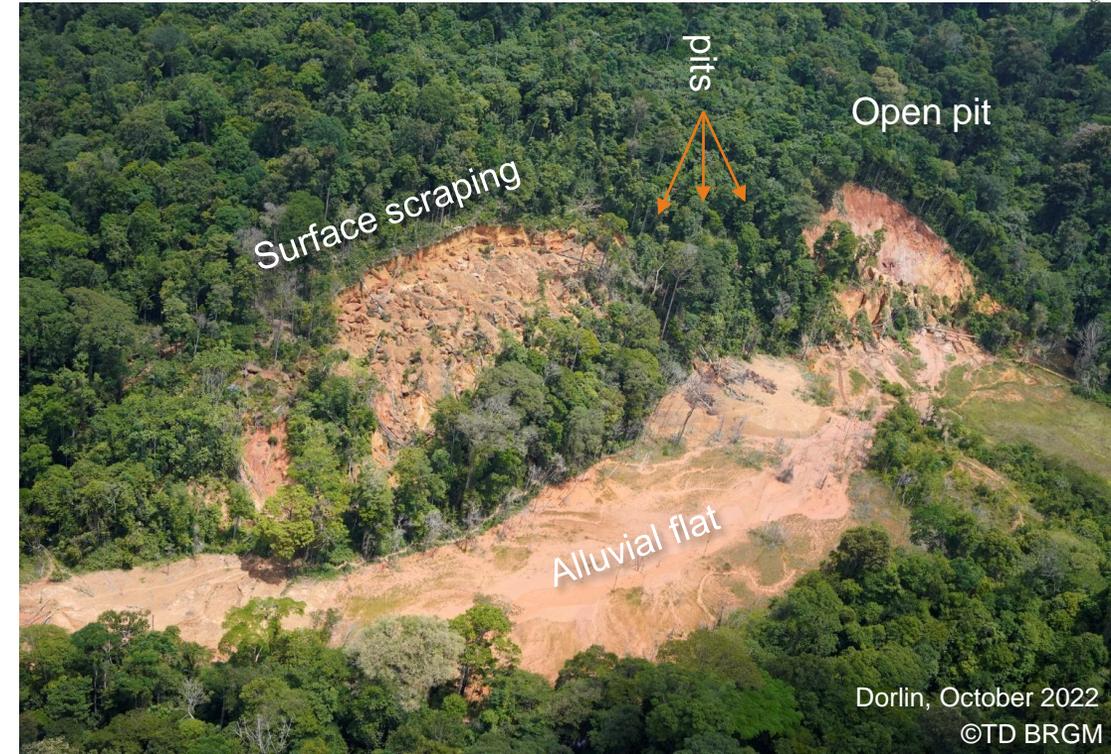
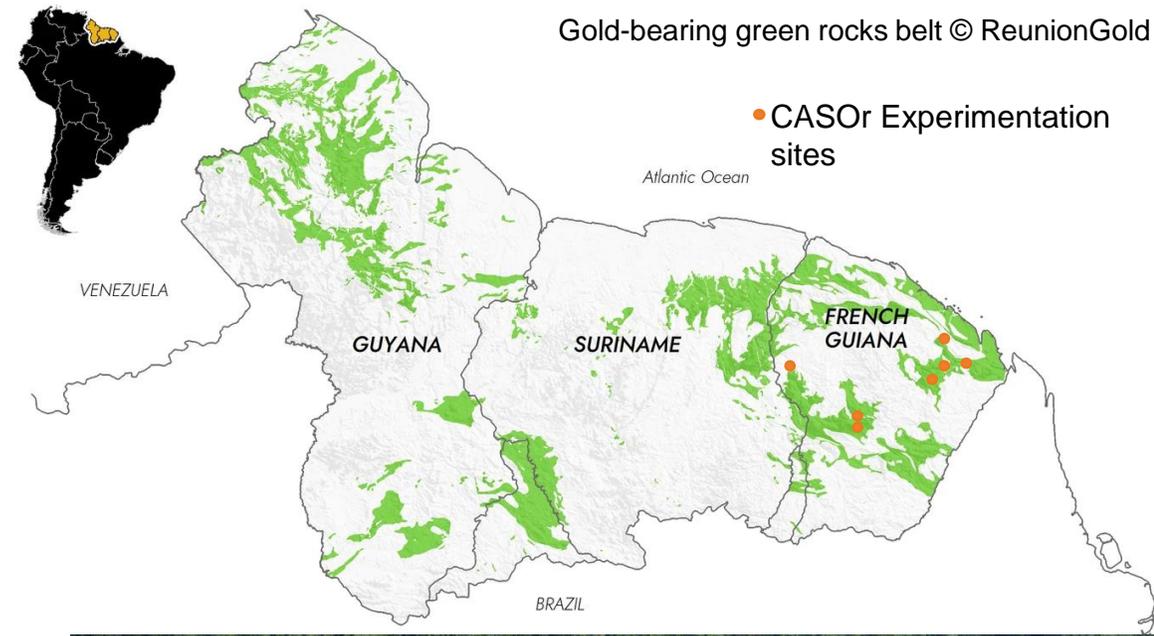
In northern South-America gold is found in the green rocks belt of the Guiana shield (~2 bn years old)

## Mining targets two gold sources

- **Secondary gold** in rivers (downstream from the source)
  - The most common type of extraction
  - Cut down the forest, scrape the sediments, sieve them, recover the gold
- **Primary gold** in bedrock
  - Cut the trees, scrape the surface and dig open pits
  - Drive shafts down in the rock and drill galleries (no need to cut down the forest)

Each target has specific associated shape and objects

Primary gold extracted from pits and galleries is the most difficult to spot for airborne law enforcement patrols





## Overarching aim

# How much gold is extracted illegally in French Guiana?

Go find, count and map gold mines in the rainforest !

And by the way, use lidar, it sees through the vegetation

Right, but here is the context :

- Highest above-ground biomass in the world (Amazonian forest)
- Remote regions of interest (walk, drive, sail, fly)
- Sudden localized thunderstorms (no internet to know in advance)
- Dark wet soils

To design a lidar acquisition scheme, you need to optimize :

- Desired information contents (what do you need to see?)
- Fitness for purpose (will you see? isn't it overkill?)
- Costs (won't it cost an arm?)

## Primary gold extraction sites

# Open-sky mining structures

## Geometric objects linked to the mine

### Objects linked to **ore extraction** typical dimensions

- Access features (shafts and galleries)  $\sim 1\text{m}^2$
- Extracted material (stock piles and platforms from spoils)  $1\text{-}30\text{ m}^2$
- Hoisting devices  $< 1\text{m}^2$
- Woodcraft equipment (boards)  $< 1\text{m}^2$

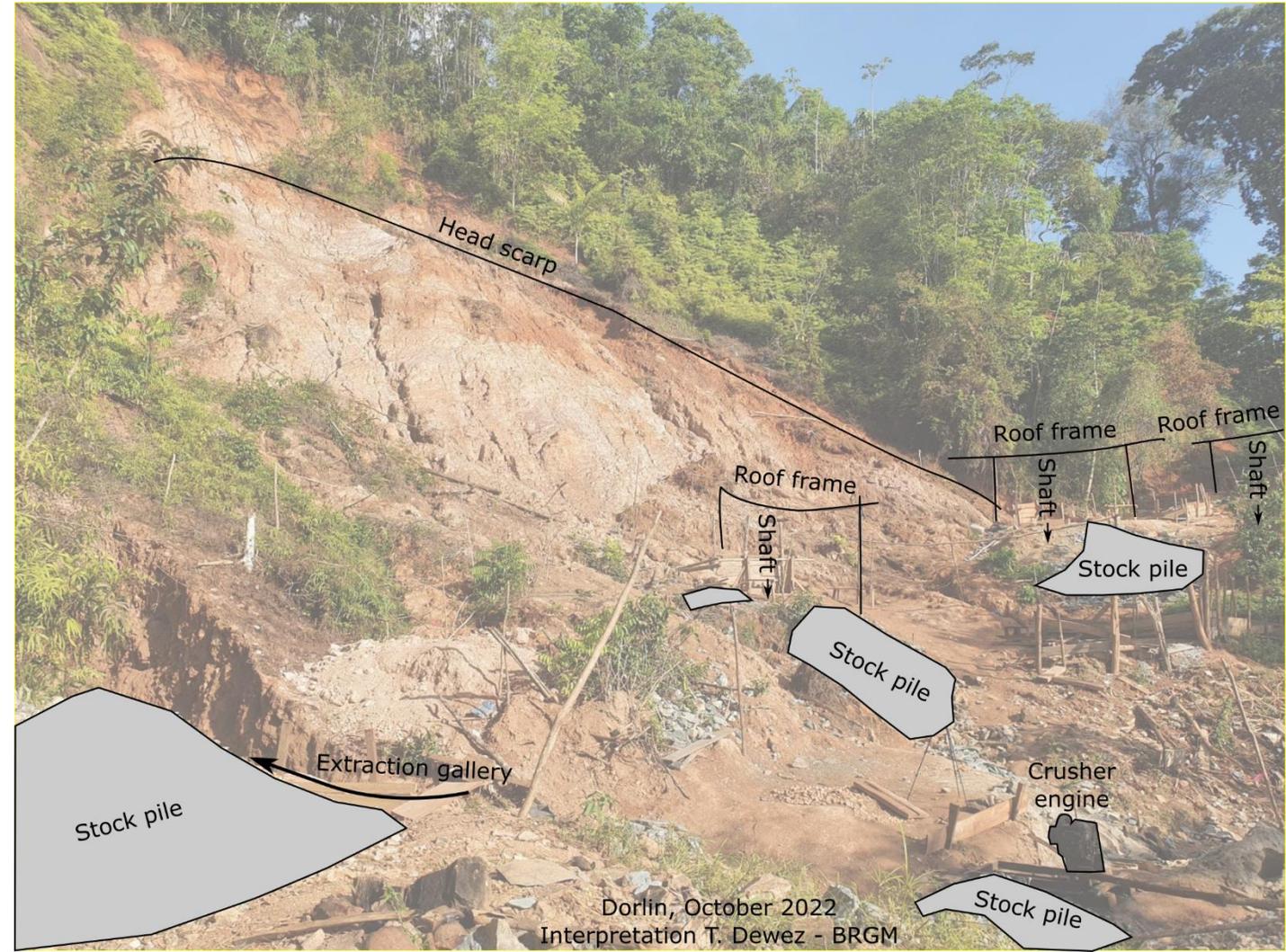
### Objects linked to **gold recovery**

- Rock processing units (crusher engines and support)  $0.25\text{-}0.5\text{m}^2$
- Sluice with downstream sand cones  $1\text{ m}^2$

### Objects linked to workers

- « Comfort » structures (benches, roof frames)  $1\text{m}^2$

Overall feature lengths in the range 1 cm to 10 m



## Primary gold extraction sites

# ...and under the canopy

### Extraction sites

- Platforms, shafts and sheltering structure

### Logistics infrastructures

- Dirt tracks and narrow foot paths to reach working sites and living bases
- Accommodation (groups of rectangular cabin frames, possibly with tarpaulin)
- Furnitures (wooden benches, tables...)

Can these features be detected, counted and characterized ?



## Detection and mapping tools

# Tested carriers and sensors



Carrier	Plane	Helicopter	UAV VTOL Quantum Trinity F90+	UAV DJI M300 Quadcopter	UAV Flyability Elios3 Quadcopter	Zeb_Horizon
Carrier coverage	10 <sup>6-8</sup> m <sup>2</sup> (10s km <sup>2</sup> )	10 <sup>6-7</sup> m <sup>2</sup> (10 km <sup>2</sup> )	10 <sup>6</sup> m <sup>2</sup> (1km <sup>2</sup> )	10 <sup>5</sup> m <sup>2</sup> (0.1km <sup>2</sup> )	10 <sup>4</sup> m <sup>2</sup> (1 ha)	10 <sup>4</sup> m <sup>2</sup> (1ha)
Payload	100+ kg	10-100 kg	1 kg	1-2 kg	< 500 g	1.5 kg
Acquisition autonomy	Hours	Hours	Up to 90 min	20-40 min	9 min	20-30 min
Autonomous Terrain following capability	Yes, inhabited aircraft	Yes, inhabited aircraft	Yes poor	Yes poor, better if RTK works	No manual flight	Yes, operator driven
<b>Lidar</b>						
System	Dual Riegl VQ780(+Ili)	Riegl VUX-1LR	Qube240	DJI L1	Ouster Rev-6/Rev-7	Velodyne Puck VLP-16
Range	> 1km	< 1km	Optimal 50m	Optimal 50m	100 m	100 m
GNSS RTK dependance	No, uses PPK	No, uses PPK	No, uses PPK	Yes, but PPK possible	No, SLAM-based	No, SLAM-based
	<b>Phase 1 : Site Detection</b>				<b>Phase 2 : Site Mapping</b>	



## Results

# Phase 1 : Site detection - Airborne lidar survey

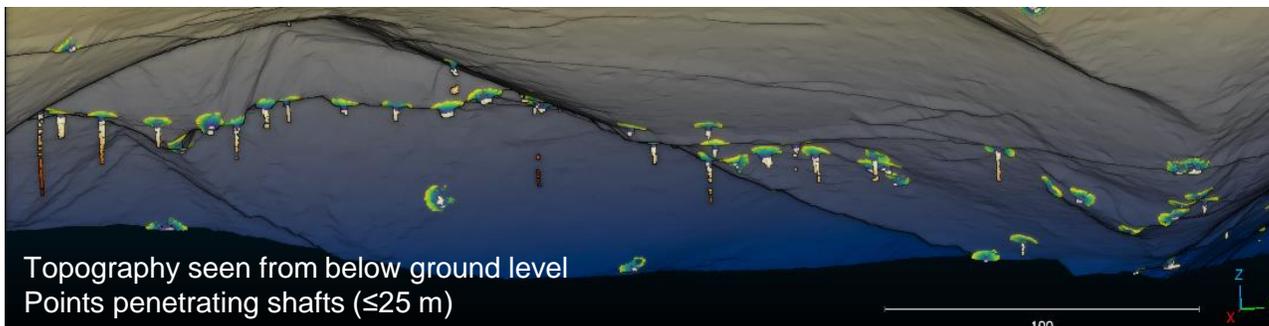
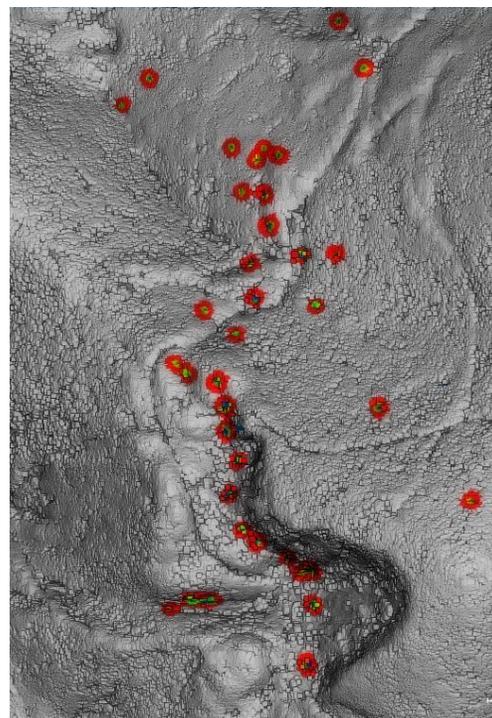
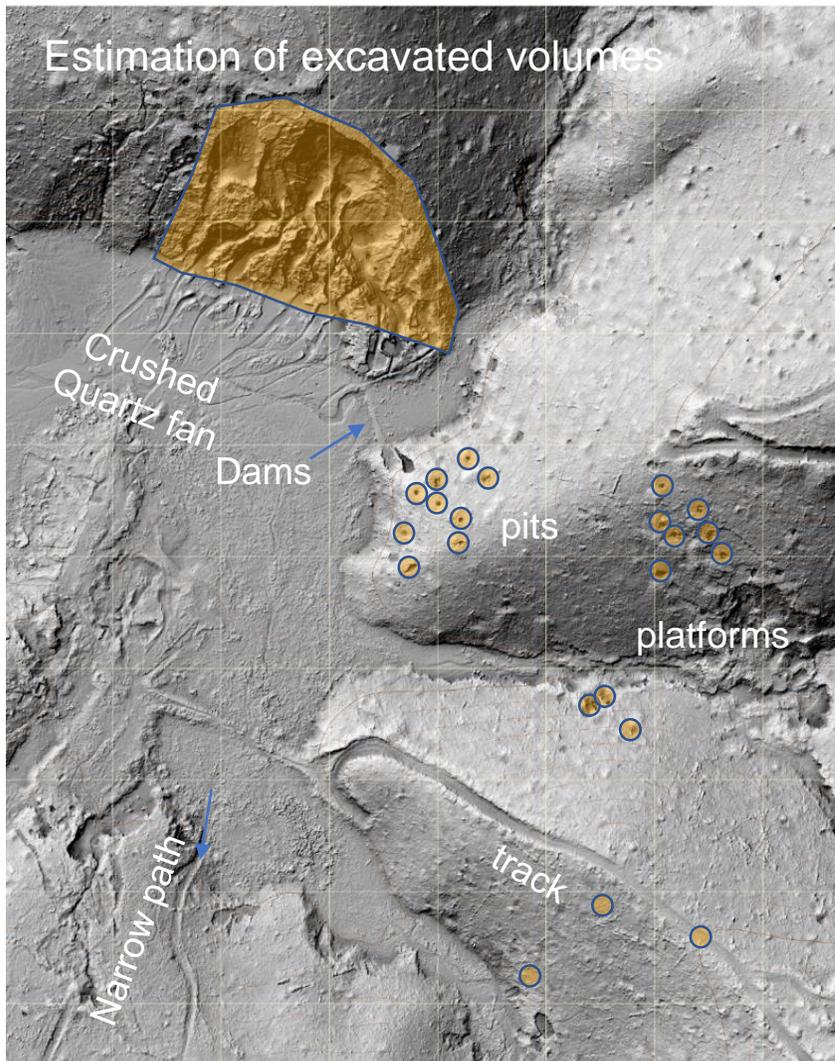
Point density target : > 400 pts/m<sup>2</sup>

Performed : min 403 pts/m<sup>2</sup>, median 630 pts/m<sup>2</sup>; max 948 pts/m<sup>2</sup>

25cm/pix DTM  
(60% pixels with lidar point)

Points penetrated ~1m<sup>2</sup> pit  
shafts aperture (36 pits)

Base camp structures with and w/o tarpaulin  
Contained in ≤4m AGL





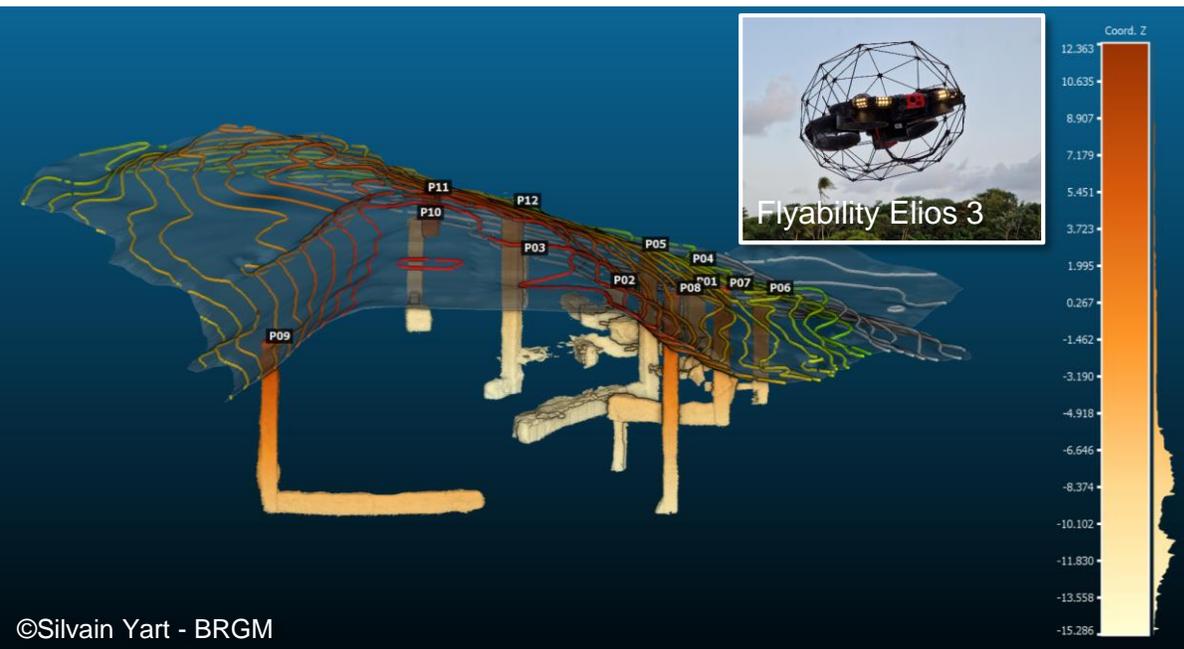
## Results

### Phase 2 : Site mapping – Close range lidar

dGNSS acquisition fails under the canopy, the SNR is too high

**BUT SLAM-based lidars keep working** without GNSS signal

- Handheld mobile scanner Zeb Horizon
  - Mapping stock piles
    - ➔ ore volume
- UAV Flyability Elios 3 (live video, lidar, thermal IR)
  - Mapping shafts and gallery network
    - ➔ quartz veins thickness and density



## Lidar mapping of illegal gold mines under the rainforest canopy

# Conclusions

Even the Amazonian rainforest is somewhat transparent to lidar

Inhabited carriers (**planes, helicopters**) are best suited (cost 30-35 €/ha)

- To **fly just clear** of rugged tree-covered topography
- To **adapt** to changing aerological conditions

Airborne lidar systems **detect mining sites** (including 1m<sup>2</sup> pit shaft conduits)

Ground-based systems successfully **map active exploitation features** (including stock piles and galleries)

Observed penetration was better than **1 ground point for 50 lidar shots** in Dorlin (but only 1 in 200 in St Jean)

→ Canopy-top density > 400 pts/m<sup>2</sup> achieved 0.25 m/pix DTM (largest data gap < 8m radius)



Gold-bearing quartz - Dorlin

And because all wouldn't happened without them

# Acknowledgements

This work was financially supported by

- French Ministry of Environment (MTES/DGALN)
- Préfecture de Guyane – EMOPI
- BRGM

Fieldwork was conducted under the protection of Gendarmerie Nationale, 9<sup>e</sup> RIMA and 3<sup>e</sup> REI





### **This presentation**

**Dewez, T.J.B., Linares, S., Yart, S., Masson, F., Collignon, M., Rivera, L., Bedeau, C., Chevillard, M.**, 2024. Mapping gold mines under the French Guiana rainforest: return of experience with different mobile lidar systems, in: EGU General Assembly Conference Abstracts. Presented at the EGU General Assembly 2024, Vienna, Austria, pp. EGU24-15904. <https://meetingorganizer.copernicus.org/EGU24/EGU24-15904.html?pdf>

### **Reference**

**Dewez, T.J.B., Chevillard, M., Le Maire, P., François, B., Aertgeerts, G., Roux, B., Plaetvoet, J., Houllès, M.**, 2022. Méthodologie d'acquisition de données LiDAR par drone et perspectives de couplages géophysiques. Application à l'exploration aurifère alluvionnaire en Guyane ( BRGM/RP-72082-FR). BRGM, Orléans, France. <https://infoterre.brgm.fr/rapports/RP-72082-FR.pdf>