



FRAME

FORECASTING AND ASSESSING EUROPE'S
STRATEGIC RAW MATERIALS NEEDS

WP7 Historic Mine Sites revisited

Case Study

The Avoca Mine, Ireland

Authors: Eoin McGrath (GSI)



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731166





FRAME

FORECASTING AND ASSESSING EUROPE'S
STRATEGIC RAW MATERIALS NEEDS



FRAME

FORECASTING AND ASSESSING EUROPE'S
STRATEGIC RAW MATERIALS NEEDS

Disclaimer

The contents of this document are the copyright of the FRAME consortium and shall not be copied in whole, in part, or otherwise reproduced (whether by photographic, reprographic or any other method), and the contents thereof shall not be divulged to any other person or organization without prior written permission. Such consent is hereby automatically given to all members who have entered into the FRAME Consortium Agreement, dated 01.07.2018, and to the European Commission to use and disseminate this information.

This information and content of this report is the sole responsibility of the FRAME consortium members and does not necessarily represent the views expressed by the European Commission or its services. Whilst the information contained in the documents and webpages of the project is believed to be accurate, the author(s) or any other participant in the FRAME consortium makes no warranty of any kind with regard to this material.



FRAME

FORECASTING AND ASSESSING EUROPE'S
STRATEGIC RAW MATERIALS NEEDS

Table of Contents

1	Introduction	4
1.1	Avoca location	4
2	Avoca Mine history	5
3	Geology of the Avoca Deposit	7
4	Tailings and Spoil Heaps at Avoca	9
4.1	Base and precious metal mineralisation at the Avoca spoil heaps.....	10
4.2	CRM potential.....	11



FRAME

FORECASTING AND ASSESSING EUROPE'S
STRATEGIC RAW MATERIALS NEEDS

1 Introduction

The Avoca Mine was in operation from the early 18th century, with a final phase of open pit mining during the 1970s and into the early 1980s. The deposit is a volcanogenic massive sulphide (VMS) style and mining extracted Cu, Pb and minor Zn, with uneconomic levels of Au and Ag present. Following the cessation of mining operations in 1982 several spoil heaps near the mine were abandoned that, alongside causing ongoing environmental hazards, represent a potential source of suture mineable resources. The spoil heaps at Avoca have been the subject of ongoing investigation to determine the concentration of base and precious metals as well as critical raw materials within the spoil, and the possible impacts and benefits that may be obtained from processing this material.

1.1 Avoca location

The Avoca mining area is located in the eastern foothills of the Wicklow Mountains some 55 km south of Dublin. The Vale of Avoca divides the mine sites into East and West Avoca. These mine sites cover approximately 0.34 km² and 0.29 km² respectively, extending from the river onto the higher ground on either side of the valley to the north east and south west. A 2019 Mineral Resource estimate focused upon the Cronebane, Mt Platt and Tigroney East spoil heaps. Fig. 1 shows the location of the Project and the spoil heaps.



FRAME

FORECASTING AND ASSESSING EUROPE'S
STRATEGIC RAW MATERIALS NEEDS

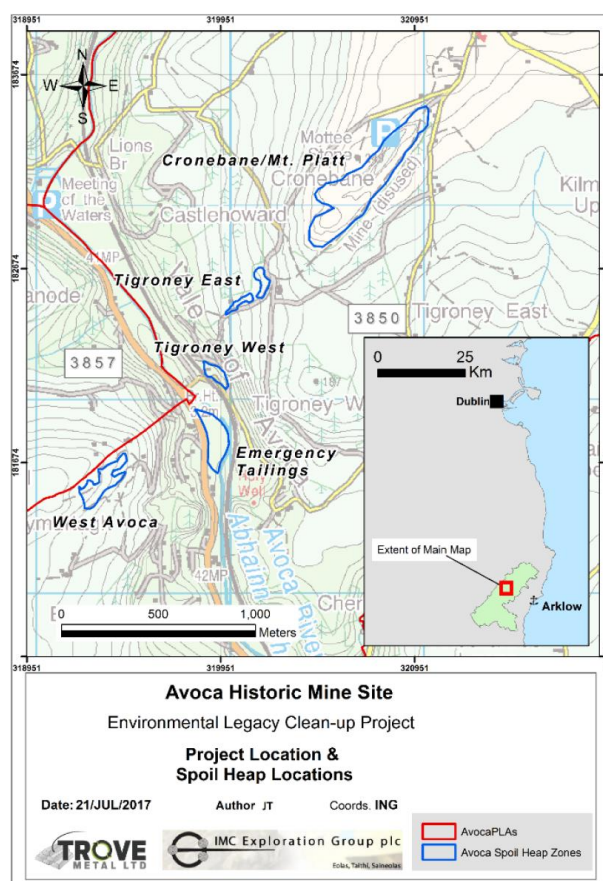


Figure 1: Location of the Avoca historic mine site and associated spoil heaps courtesy of Trove Metal Ltd. (2017).

2 Avoca Mine history

There is evidence to suggest that Avoca was worked for copper as long ago as the Bronze Age (c.2500-600 BC) and possibly through medieval times. From the 12th century, the site was mainly producing iron, but this had been exhausted by the end of the 17th century. The earliest documented activity at East Avoca was in 1752 when 500 miners were reported to be at work at “Crone Bawn” (Cronebane) most likely producing lead. Up to the 1850s copper was the most important mineral produced. After this date, iron pyrites was the dominant mineral being mined. Sulphur, from the pyrites, was produced from 1840-1865 and intermittently until 1949, especially during the two World Wars. Minor amounts of gold, silver and zinc have also been extracted over the life of the deposit, but these were never significant.



FRAME

FORECASTING AND ASSESSING EUROPE'S
STRATEGIC RAW MATERIALS NEEDS



Figure 2: The East Avoca open pit from Stanley et al. (2009)

Low grades and low metal prices during the latter part of the 20th century ensured that mining at Avoca was a marginal proposition. Mining at Avoca was from both underground and open pit mining methods, with the open pits observed today mined in the latter part of the 20th century. Following the Avoca Mine Site ceasing production in 1982, the mine site and spoil heaps have been largely undisturbed. There was an unsuccessful attempt to recover the gold in the spoil heaps in the early 1990s by Feltrim Mining/Connary Minerals. The main technical obstacle seems to have been that much of the gold was too fine to be processed by existing methods, including heap leach, which was the intended processing method (Trove Metal Ltd. 2017).



FRAME

FORECASTING AND ASSESSING EUROPE'S
STRATEGIC RAW MATERIALS NEEDS



Figure 3: The Cronebane open pit with the Mount Platt spoil heaps in the background from Gallagher and Connor (1999)

3 Geology of the Avoca Deposit

The Avoca deposit is a Kuroko-type Volcanogenic Massive Sulphide deposit occurring within the Caradocian volcanic belt of the Leinster Massif, Co. Wicklow. The deposit is hosted within an extrusive succession of the Lower Ordovician age Duncannon Group consisting of intermediate and felsic lavas and tuffs (Units 3 & 4), overlain by basic to intermediate lavas that have been folded forming an isoclinal syncline that plunges 30° SW (McConnell et al. 1991; Figure 4).

Three main ore types were described at Avoca by Gallagher and Connor (1999), namely:

1. **Pyritic zones:** Bands of pyritic ore alternating with bands of sphalerite rich ore and bands of chlorite and sericite. Pyrite is the dominant mineral, either banded or as massive lenticles with or without interstitial chalcopyrite, sphalerite and galena in a chloritic matrix. Magnetite, hematite, arsenopyrite, pyrrhotite, bismuthinite and native bismuth are minor constituents. Gold is rare. This ore was observed in the Main Lode in East Avoca.



FRAME

FORECASTING AND ASSESSING EUROPE'S
STRATEGIC RAW MATERIALS NEEDS

2. **Siliceous zones or stringer ore:** Major pyrite, chalcopyrite, sphalerite and lesser galena occur within a siliceous matrix. Arsenopyrite, pyrrhotite, bismuthinite, native bismuth, tetrahedrite and bournonite are minor constituents with cobaltite and lillianite as trace occurrences. These zones were observed in the hanging wall of East Avoca.
3. **Pb-Zn ore:** Banded sphalerite, galena and pyrite occur with minor arsenopyrite and chalcopyrite in a chloritic matrix, with rare tetrahedrite and Bournonite. This ore was observed in the "kilmacooite" zone at Cronebane-Connary.

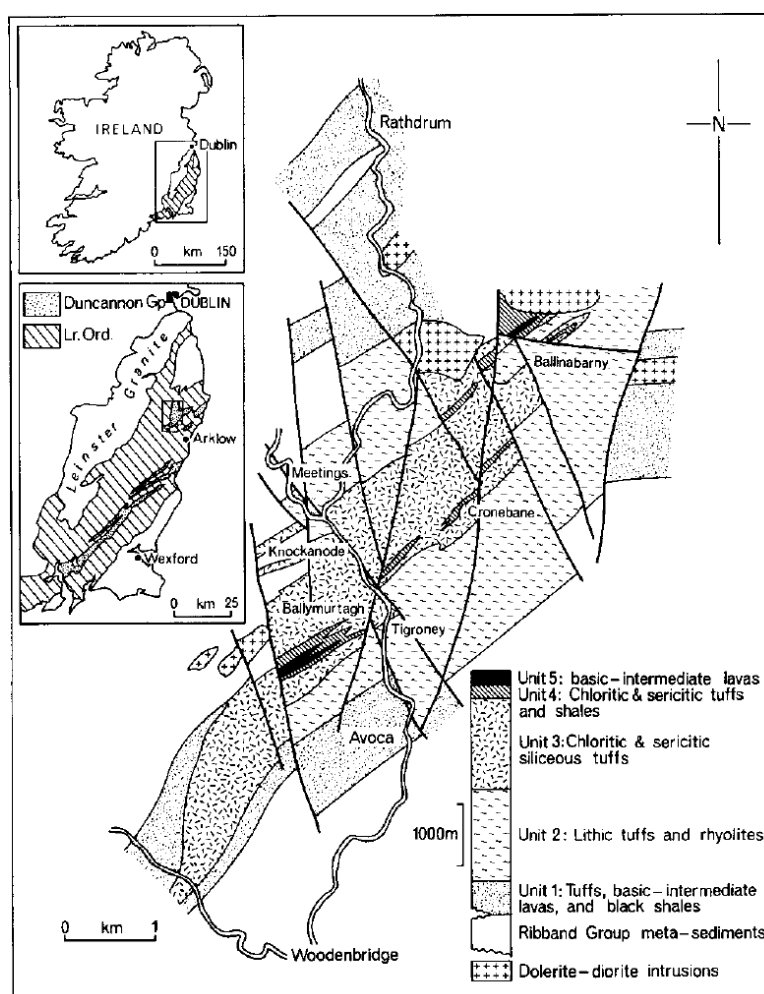


Figure 4: Geological map from McConnell et al. (1991) illustrating the distribution of the Avoca volcanic rocks in the region surrounding the deposit. The distribution of the Duncannon Group is shown in the insert.



FRAME

FORECASTING AND ASSESSING EUROPE'S
STRATEGIC RAW MATERIALS NEEDS

4 Tailings and Spoil Heaps at Avoca

There are numerous occurrences of mine waste at Avoca (Fig. 5) with the most prominent of these being the waste rock from the Cronebane pit. The Cronebane and Mt Platt spoil pile is located at the mine site whilst several smaller spoil piles are located to the west including the Tigroney East and West piles, the Emergency Tailings and West Avoca. A former tailings facility is located at Shelton Abbey, south of the mine.

The Mt Platt and Cronebane spoil heaps were predominantly sourced from the Cronebane open pit mined in the 1970s . Much of the mine spoils were built up to form the Cronebane Waste Pile, partly because of lack of space, but also as part of a policy by Avoca Mines Ltd to rehabilitate the site. The source of the smaller spoil heaps at Tigroney East is unclear, although the larger spoil heap at Tigroney North is likely to have originated from material excavated from the adjacent East Avoca open pit. The Forest of Gold spoil heap is comprised of fine-grained material and may have been sourced from milled ore (CSA Global 2019).

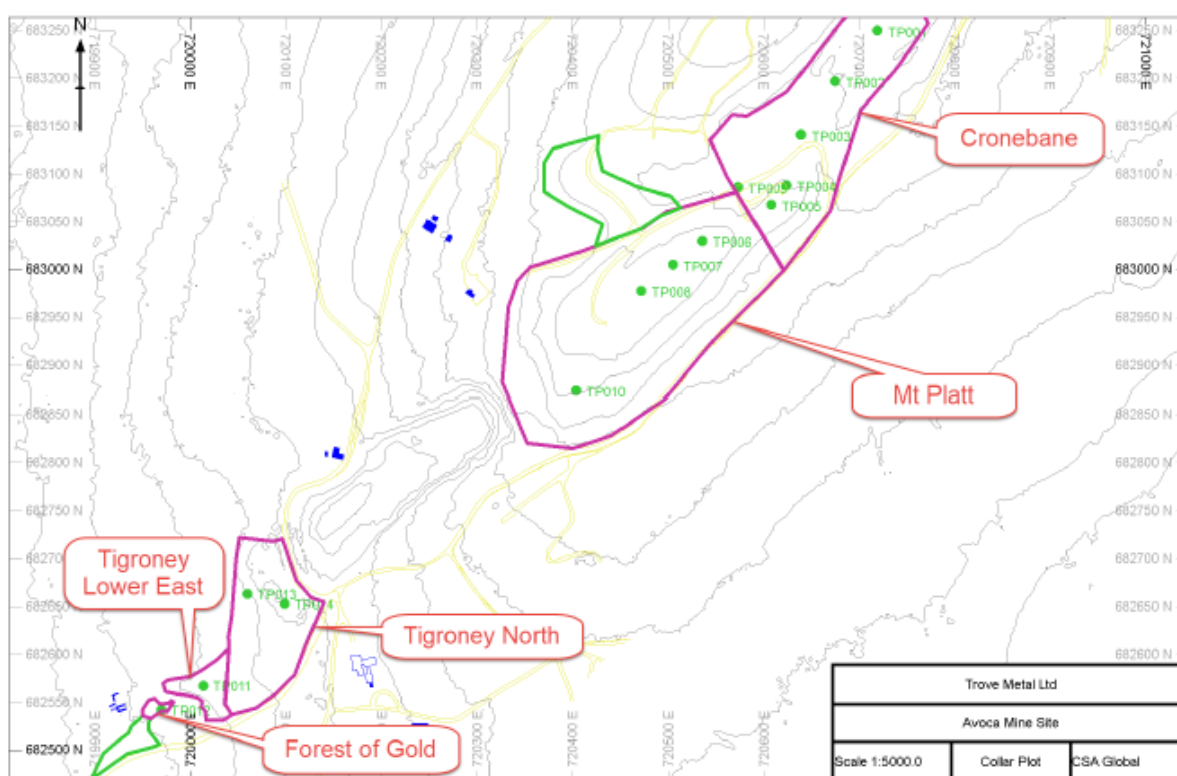


Figure 5: Plan of the mineral resource surfaces used in the mineral resource estimates of CSA Global (2019)



FRAME

FORECASTING AND ASSESSING EUROPE'S
STRATEGIC RAW MATERIALS NEEDS

4.1 Base and precious metal mineralisation at the Avoca spoil heaps

A JORC compliant inferred mineral resource estimate of the Forest of Gold, Tigroney East, Mt Platt and Cronebane spoil heaps was conducted by CSA Global in 2019 to assess the economic potential of the spoil piles. The estimates were based upon representative samples taken from 14 test pits across the study area (e.g. Figure 670) and recent survey data used to calculate the volume of each spoil heap. Samples were assayed for elements of interest by ALS Laboratory, Loughrea, Co. Galway. The results are presented in

Table 1 and indicated that there were reasonable prospects for the eventual economic extraction of the Mineral resources in the Spoil Heaps at Avoca.

Table 1: Inferred Mineral Resource estimate (all tonnages reported with no cut-off grade applied)

Spoil Heap	Tonnes (kt)	Cu (%)	Pb (%)	Zn (%)	Au (g/t)	Ag (ppm)
Forest of Gold	2	0.57	4.31	0.83	5.2	64
Tigroney Lower East	19	0.44	0.68	0.37	0.6	13
Tigroney North	158	0.18	0.12	0.04	0.1	3
Subtotal (Tigroney East)	178	0.29	0.62	0.20	0.7	11
Mt Platt	852	0.13	0.37	0.12	0.2	7
Cronebane	841	0.13	0.43	0.16	0.4	10
Total	1871	0.14	0.42	0.14	0.3	9



FRAME

FORECASTING AND ASSESSING EUROPE'S
STRATEGIC RAW MATERIALS NEEDS



Figure 6: Example trial pit through the spoil heaps at Avoca. The measuring stick on the right-hand photo is 4 m long.

4.2 CRM potential

In 2016 Geological Survey Ireland funded a research project to preliminarily assess the economic potential of Ireland's mining waste stockpile (McGrath 2016). This included work on both spoil and tailings piles at Avoca to assess the Critical Raw Materials (CRMs) content for potential future economic extraction. Within the district there is a very clear difference between the mine waste in the former tailings facilities and the spoil heaps. For most elements, the spoil heaps have much higher values, frequently an order of magnitude greater. For example copper values in the spoil heaps over 0.5% have been noted, with the most elevated tailings Cu content 0.06% (Figure 71). Exceptions to this include cobalt and chromium where the values are elevated in the



FRAME

FORECASTING AND ASSESSING EUROPE'S
STRATEGIC RAW MATERIALS NEEDS

tailings relative to the spoil. It has been suggested that these values are elevated due to contamination from metals used in the milling process.

There are several groups of significantly correlated elements ($R^2 > 0.9$) within the Avoca waste material. Of these, silver, lead and antimony are closely linked, with high values of each element associated with the other two (Figure 8 & 73). Similarly linked groups include K, Cs & Rb; Ta, Hf, Nb, Th & Y; Zn & Cd. There is also a broad correlation between gold and silver (Figure 1074).

Of greatest economic importance at Avoca are the high levels of REEs and gold. Alongside the JORC report, this study illustrated that the grades of gold within the spoil heaps at Avoca are comparable to mined grades at operations worldwide with values up to 9.8 ppm and a mean spoil value of 1.57ppm Au. The distribution of gold, silver and base metals are heterogeneous both within and between spoil heaps, with Tigroney West and Tigroney East typically exhibiting higher values than Conebane and West Avoca. Variability within individual spoil heaps such as Tigroney East highlights the importance of detailed resource definition for accurately quantifying the resources, but also offers the opportunity to target high-grade spoil heaps to yield early returns on investment when mining.

Rare Earth Element (REE) values are also highly elevated within the spoil heaps, with values of up to 0.238% TREO recorded and a mean value of 0.116% TREO (Figure 11:). Grades for economic deposits of REEs currently under development are around 0.5% (Nora Karr, Strange Lake) although lower grade deposits are known in the Murmansk region (Kalashnikov et al. 2016). Although beyond the scope of this study, the data gathered may be of use to conduct more detailed analyses of the Avoca mineralising system.



FRAME

FORECASTING AND ASSESSING EUROPE'S
STRATEGIC RAW MATERIALS NEEDS

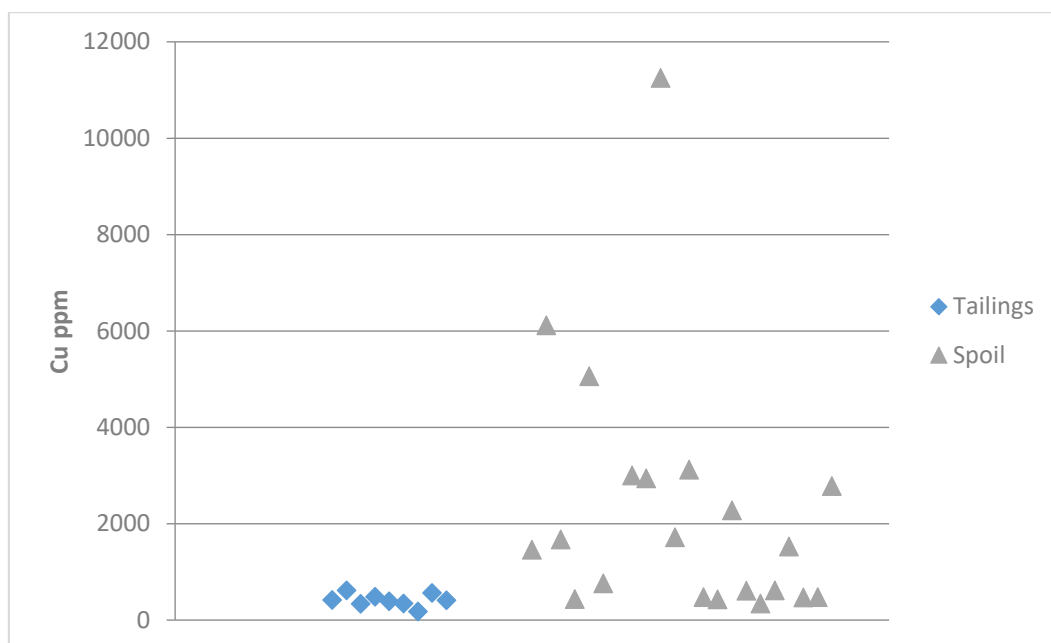


Figure 7: Cu (ppm) in tailings piles at Avoca vs. in spoil heaps at Avoca.

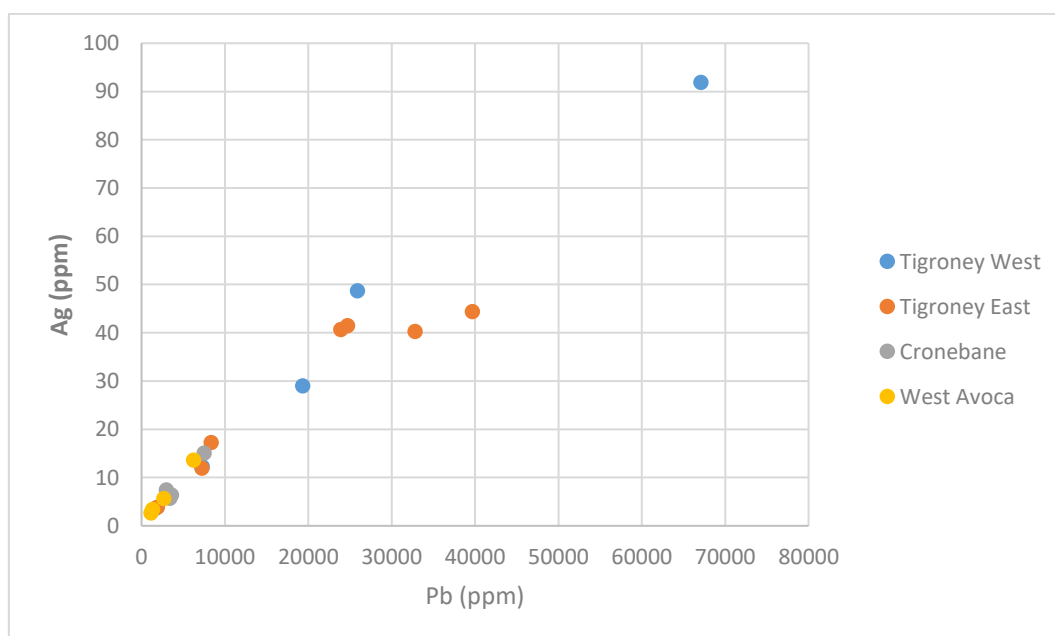


Figure 8: Lead vs. silver plot for bulk samples from the spoil heaps at Avoca



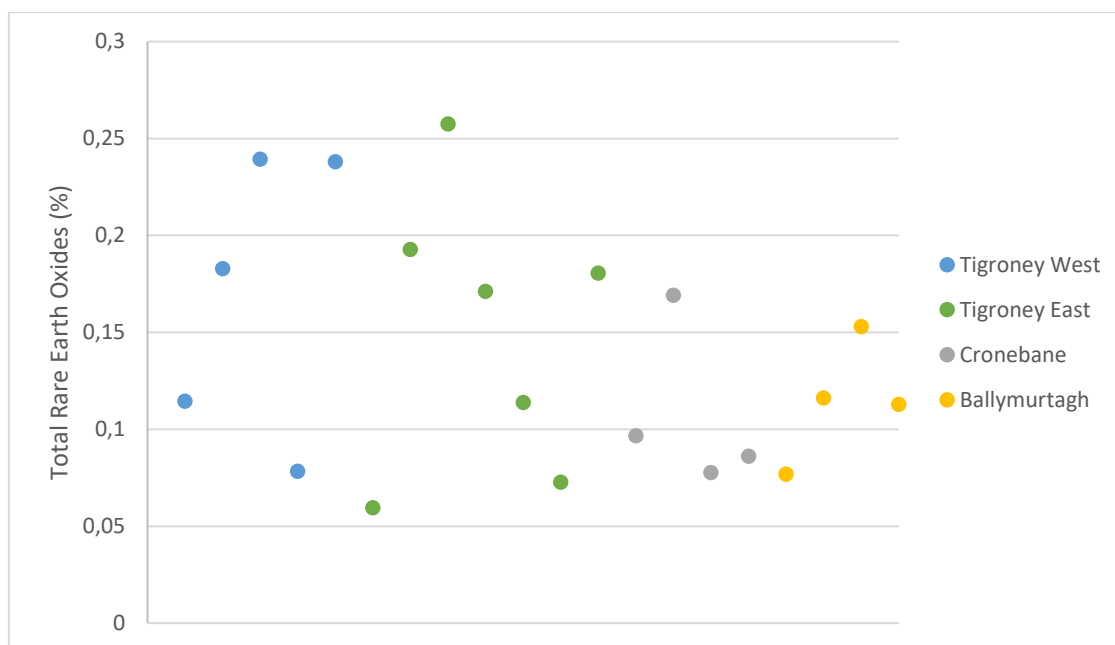


Figure 11: Total Rare Earth Oxides in Avoca waste material

References

- CSA Global 2019. *MINERAL RESOURCE ESTIMATE – AVOCA HISTORIC MINE SITE PROJECT*.
- Gallagher, V. and Connor, P.O. 1999. THE AVOCA MINE SITE. *Biology and Environment: Proceedings of the Royal Irish Academy* 99B(1), pp. 43–57.
- Kalashnikov, A.O. et al. 2016. Rare Earth Deposits of the Murmansk Region, Russia - A Review. *Economic Geology* 111(7), pp. 1529–1560.
- McConnell, B.J. et al. 1991. An Ordovician basalt to peralkaline rhyolite fractionation series from Avoca, Ireland. *Journal of the Geological Society* 148(4), pp. 711–718. doi: 10.1144/gsjgs.148.4.0711.
- McGrath, E. 2016. *An Economic Assessment of Irish Mining Waste*.
- Stanley, G. et al. 2009. *Historic Mine Sites – Inventory and Risk Classification*.
- Trove Metal Ltd. 2017. *Outline report on Avoca Historic Mine Site, Environmental Cleanup Project*.



FRAME

FORECASTING AND ASSESSING EUROPE'S
STRATEGIC RAW MATERIALS NEEDS