Domaining of Downhole Geochemical Data: An Automated Approach Applied to The Northern Limb of the Bushveld Complex

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1. Introduction

The Northern Limb of the Bushveld Complex is host to some of the largest platinum-group element (PGE) deposits in the world; however, there is limited understanding of the precise controls on the style and spatial distribution of mineralisation.

Geochemical domains can be used as an initial step to help understand magmatic processes and for generating 3D orebody models, however the interpretation of domains and where boundaries should be placed can be subjective and time consuming when interpreting many drillholes.

This study looks at using an automated approach to finding and classifying domains from downhole bulk geochemistry

2. Aim

Can manually interpreted domains be identified using an automated approach?

It has been shown [1] that the CIPW normative mineralogy can be used to identify downhole domains in the Critical Zone of the Northern Limb. Can the process of manually interpreting these domains be repeated using automated approaches?

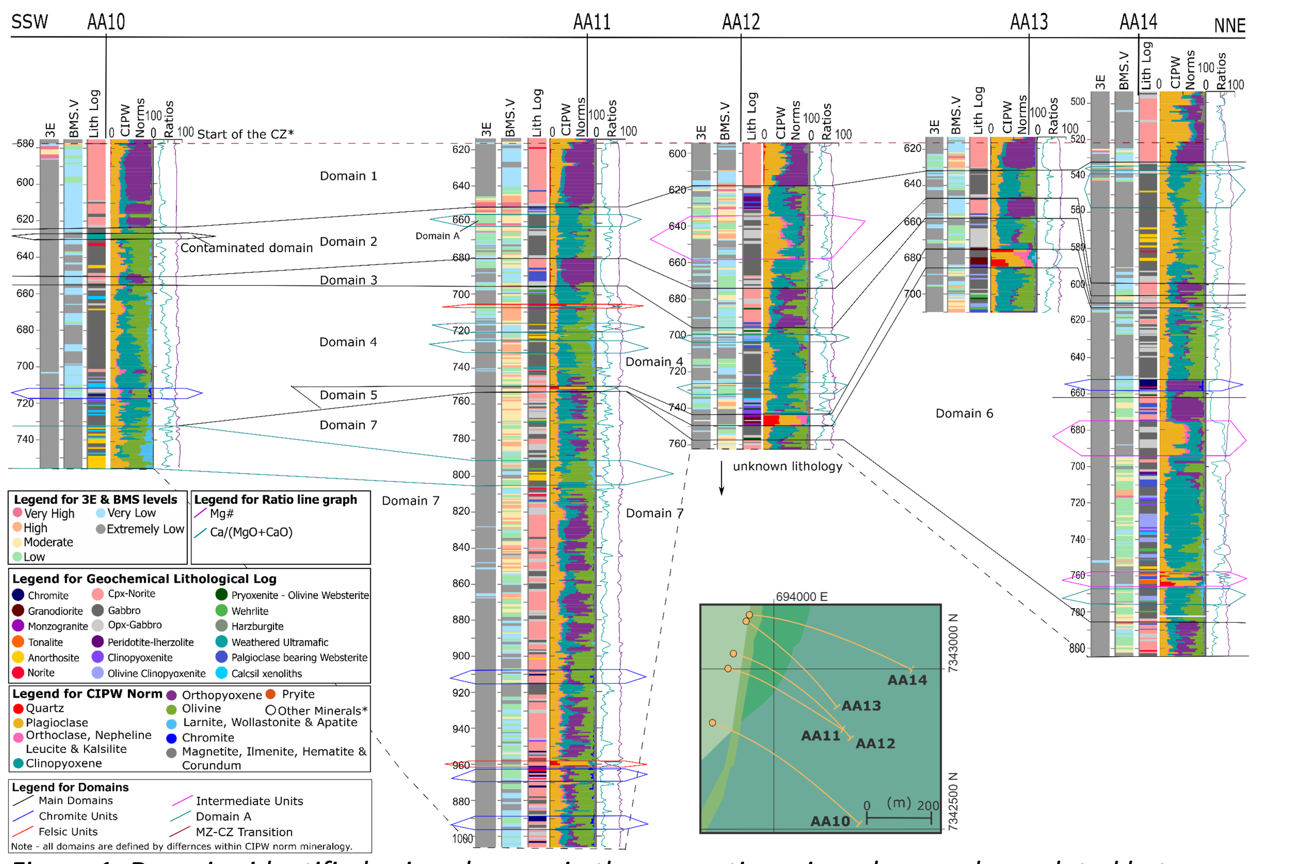


Figure 1: Domains identified using changes in the normative mineralogy and correlated between a series of holes in the Northern Limb of the Bushveld Complex (from [1])

Why Automate This?

Data Volume

- *Time consuming to manually interpret the holes*
- *Reluctance to implement an alternative interpretation*

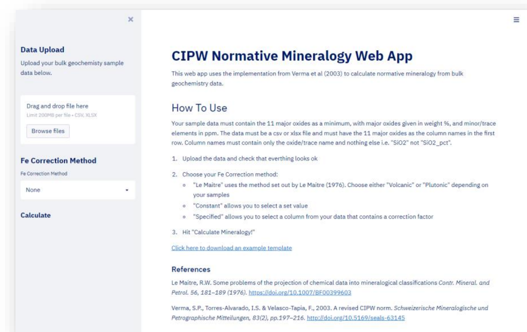
Subjectivity and Bias

- *Any subjective choice given to multiple geologists will result in a slightly different answer*
- *Easy to get stuck or attached to one interpretation based on your starting point (anchoring bias)*

3. Method

CIPW Normative Mineralogy - A Python Implementation

- The normative mineralogy gives and idealised assemblage of minerals for a given bulk rock sample from major oxide content in weight %.
- Existing methods to calculate the normative mineralogy were limited
- Therefore, a Python function was developed and is available for use through the Python package 'Pyrolite' [2] or as a web app:

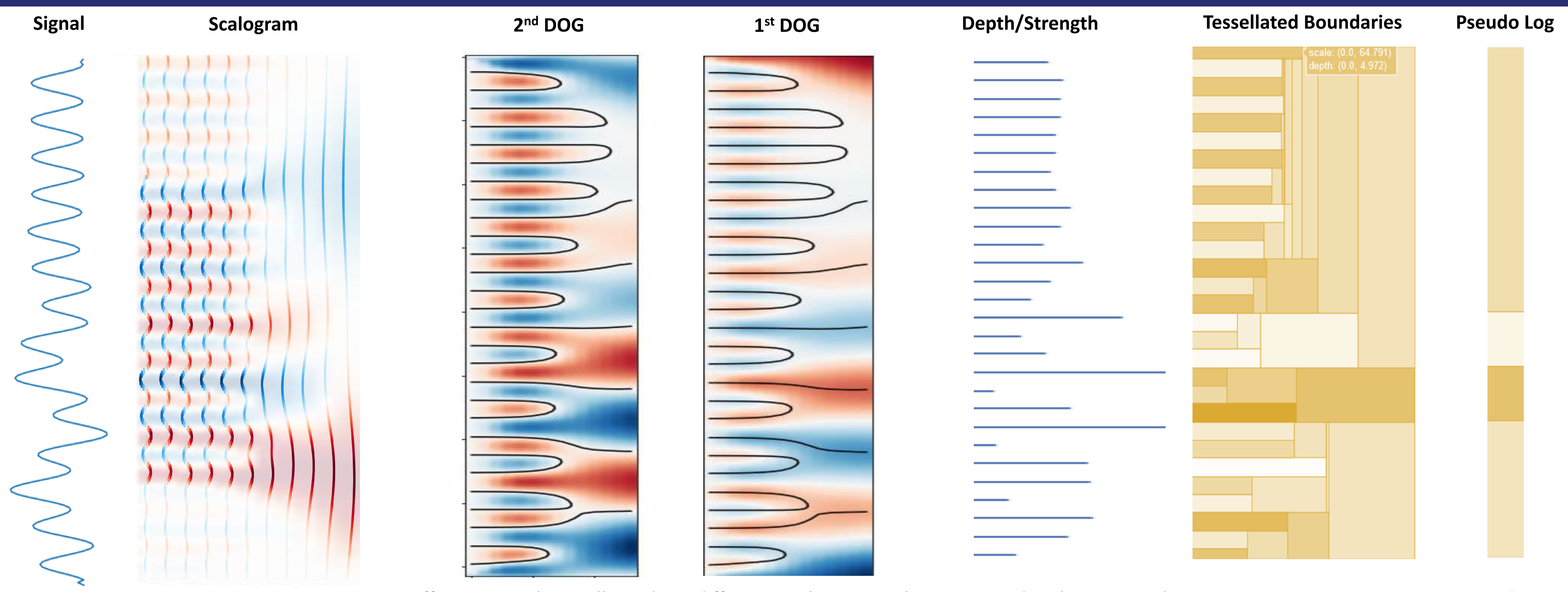


share.streamlit.io/bomtuckle/cipw_norm_web_app/app.py

4. Method

Continuous Wavelet Transformation Boundary Detection

- The continuous wavelet transform (CWT) method has been used as an edge detection method for images, and to identify inflection points (i.e. boundaries) in down hole geophysical data [3]
- The method allows for the detection of boundaries at multiple scales, which is particularly useful for geoscience applications
- Tessellation of the resulting multiscale boundary data allows for more intuitive interpretation of domains in a hierarchical fashion [4]



A regularly sampled downhole signal is convoluted using a wavelet across a continuous range of wavelet scales to generate the scalogram

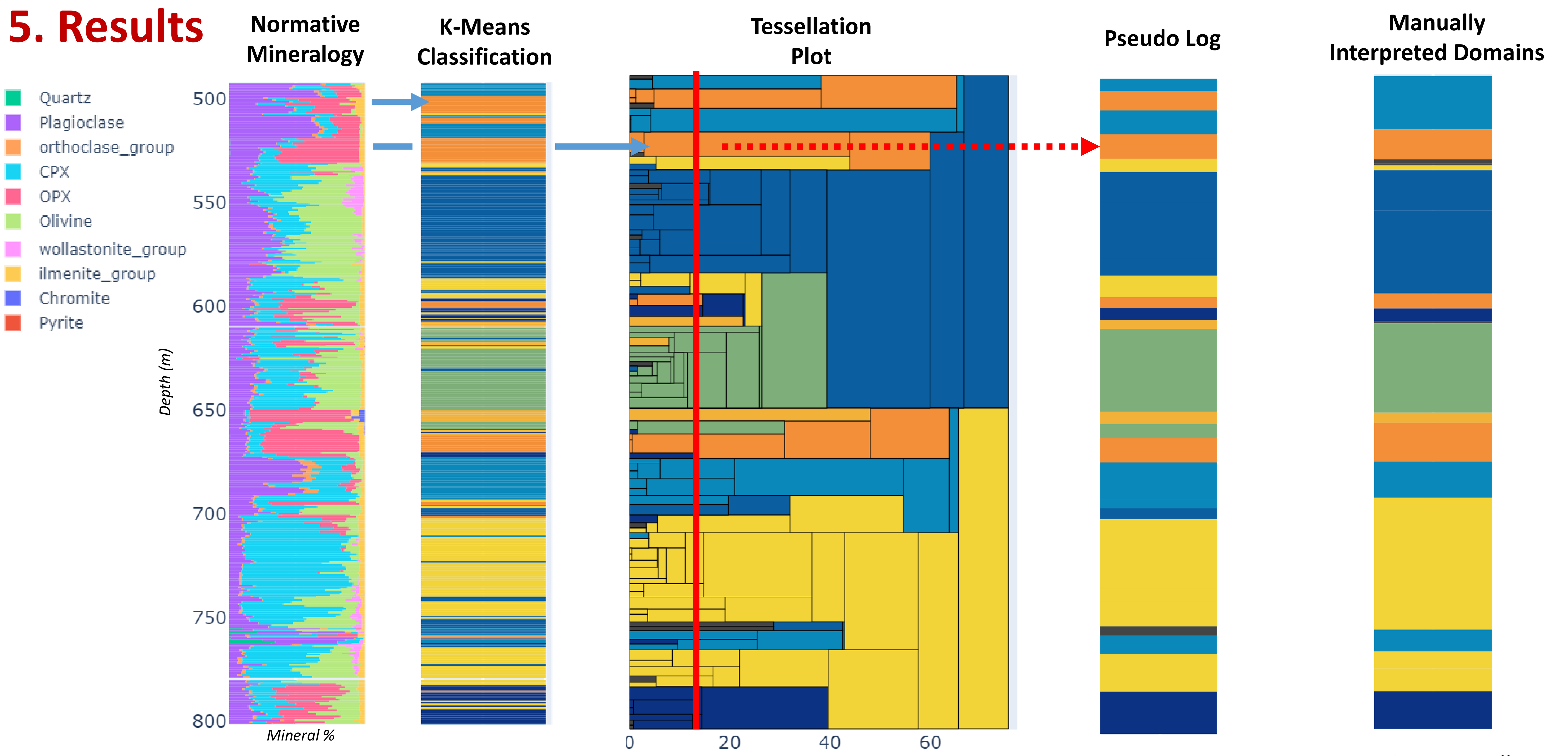
Different wavelets will produce different scalograms. The 2nd derivative of gaussian wavelet (DOG) scalogram finds boundary locations at the 0 crossings (as contoured above). The most accurate location is found at the smallest scale. Strength can be found using the maximum value along the same contour overlayed on the 1st DOG scalogram.

Boundary location and strength data can be combined to visualise the different boundaries downhole.

The locations and strength data can also be presented in a tessellated fashion to show multiscale domains

Boundaries can be extracted at a given strength to create a 'pseudo log'

5. Results



Normative mineralogy is calculated for every sample downhole. K-Means clusters are determined using the log ratio transform of the mineralogy

Tessellation plot derived from multivariate CWT boundary detection. Domains are coloured by the modal K-Means cluster across that interval

Pseudo Log Extracted at scale 17

Domains manually interpreted, coloured by the modal K-Means cluster within each domain

6. Conclusions

- The continuous wavelet transform (CWT) boundary detection method finds boundaries that are comparable to those identified manually
- The method is fast and repeatable, allowing for easy reinterpretation of many holes using different input variables. This opens the possibility for rapid modelling of different domains at a variety of scales for various purposes, for example less detailed long term planning models, high detail geological models to aid orebody understanding or geometallurgical models.

7. Next Steps

- As the CWT method relies on relative changes rather than absolute values, can similar boundaries be found when using pXRF as an input vs lab XRF, despite the errors associated with pXRF?
- Are there better ways to classify the domains than upscaling the sample classification?

References:

[1] Brooksby, K. 2020. Litho-and Chemo-Stratigraphy of the Critical Zone at Sandsloot, Northern Limb of the Bushveld Complex. *CSM MSc Thesis.*
[2] Williams et al., 2020. Pyrolite: Python for geochemistry. *Journal of Open Source Software, 5(50), 2314.*
[3] Cooper, G.R.J., Cowan, D.R., 2009. Blocking geophysical borehole log data using the continuous wavelet transform. *Exploration Geophysics 40, 233–236.*
[4] Hill, E.J., Pearce, M.A., Stromberg, J.M., 2021. Improving Automated Geological Logging of Drill Holes by Incorporating Multiscale Spatial Methods. *Mathematical Geosciences 53, 21–53.*

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