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INTRODUCTION

High toxicity levels in the natural environment lead to degradative effects to the ecosystem and human health. Heavy metal toxicity increases the risk of neurological disorders and cancer related disease in humans, and abnormal growth in plants. Land and marine industrialization, road development, agricultural and farming practices, runoff, waste treatment, together with natural activity including geological erosion and metallic evaporation from land are all linked to the rise of heavy metal toxicity levels on beaches. These concentrations increase by accumulation over time and by variations in seasons due to the changes in human activities and due to weather effects. Other studies in the Mediterranean region have established that the studied area is highly affected by human activities which vary according to the seasons and concluded that heavy metal concentration studies should be included in environmental monitoring programs.

METHODOLOGY

Sand samples were collected at the end of summer from 5 different beaches in Malta and Gozo. Sampling points were planned along linear transects orthogonal to the shoreline mapping most of each beach surface. A total of 3 samples were gathered at different depths at each sampling point – at the surface, at 10 cm depth and at 20 cm depth. Each of the 160 samples were dried at 70 °C for approximately 24 hours until constant mass was achieved. Sand was sieved to retain granules up to 2 mm in size. Some 25 ± 0.1 g of each sample in loose powder form was levelled in the respective plastic cups lined with mylar thin-film spectro-membrane and analysed using Bruker S2 Ranger EDXRF.

RESULTS

Analysis of samples showed presence of 41 heavy metals, of which elements presented in Table 1 have a concentration > 0.01 wt.%.

Element	Mean Concentration (wt.%)	Standard Deviation
CaCO ₃ [*]	94.176 ^{b, c}	4.310
Fe ₂ O ₃	1.413 ^{b, c}	1.348
SiO ₂	1.329 ^{b, c}	0.588
Na ₂ O	0.660 ^{a, b, c}	3.071
Cl	0.515	0.406
MgO	0.514 ^{a, b, c}	1.050
SO ₃	0.437	0.237
P ₂ O ₅	0.418 ^{b, c}	0.259
Al ₂ O ₃	0.183 ^{a, b, c}	0.337
K ₂ O	0.182 ^{b, c}	0.082
SrO	0.089 ^{b, c}	0.042
SnO ₂	0.016 ^{b, c}	0.001
MnO	0.013 ^b	0.007
TiO ₂	0.012 ^{b, c}	0.018

Table 1: Elemental concentrations in wt.% and respective standard deviation. Element marked * chosen as matrix component. Superscript letter ‘a’ represents retaining hypothesis of concentration distribution being same across all categories of Location; Superscript letter ‘b’ represents retaining hypothesis of concentration distribution being same across all categories of Depth; Superscript letter ‘c’ represents retaining hypothesis of concentration distribution being same across all categories of Distance away from shoreline – as determined by Independent Samples Kruskal-Wallis Hypothesis Test.

Assessment of heavy metal content in sand beaches in the Maltese Islands using EDXRF spectrometry.

Figure 1: Principal component analysis showing clustering of different heavy metal concentrations according to the beaches sampled proving strong relationships among groups of elements proving common possible sources.

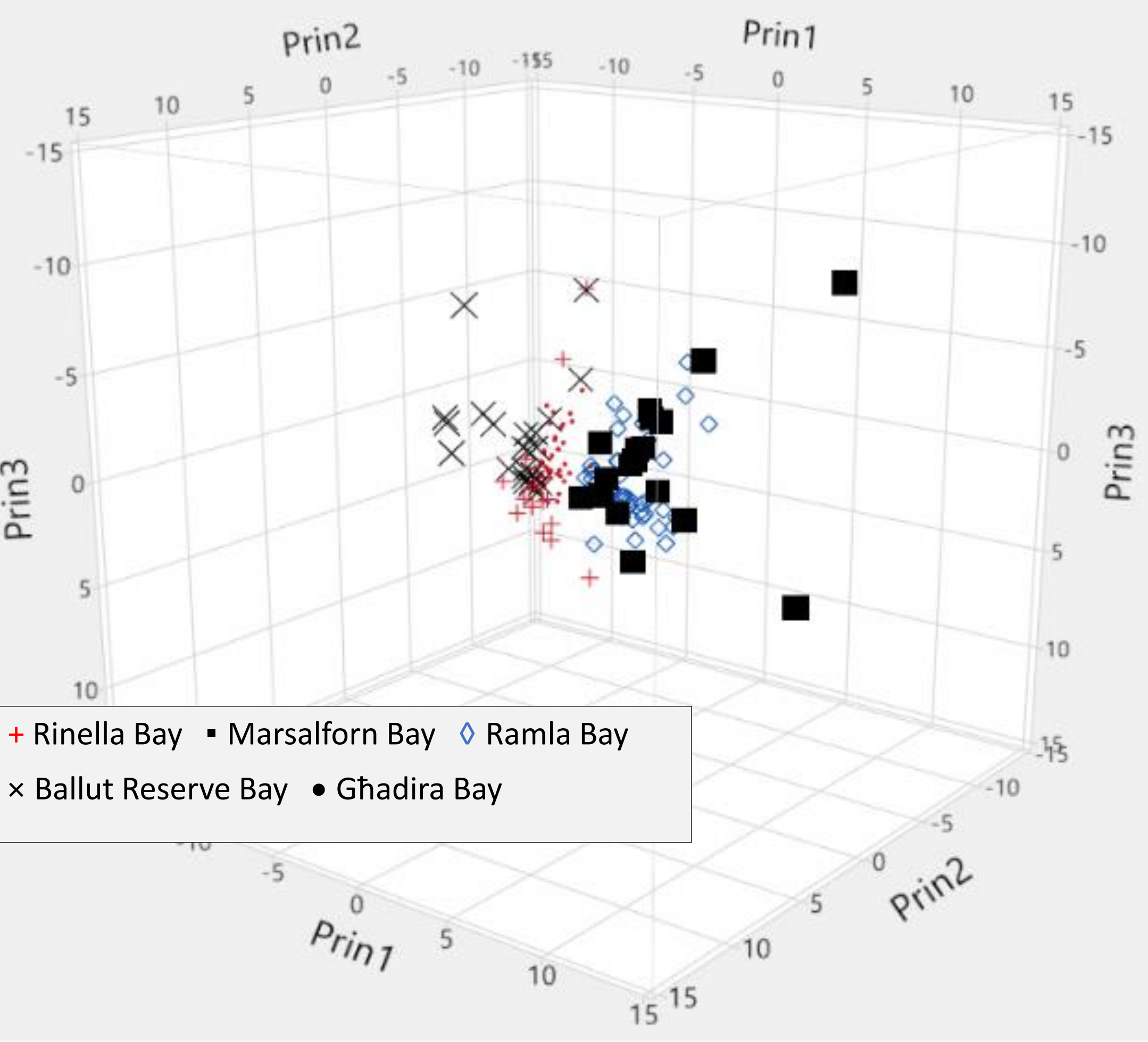


Figure 2: Hierarchical Diagram and Heat Map showing Two-Way Cluster Analysis of Depth vs. Elemental Concentrations for Distance away from the Shoreline less than 10m sorted by Location.

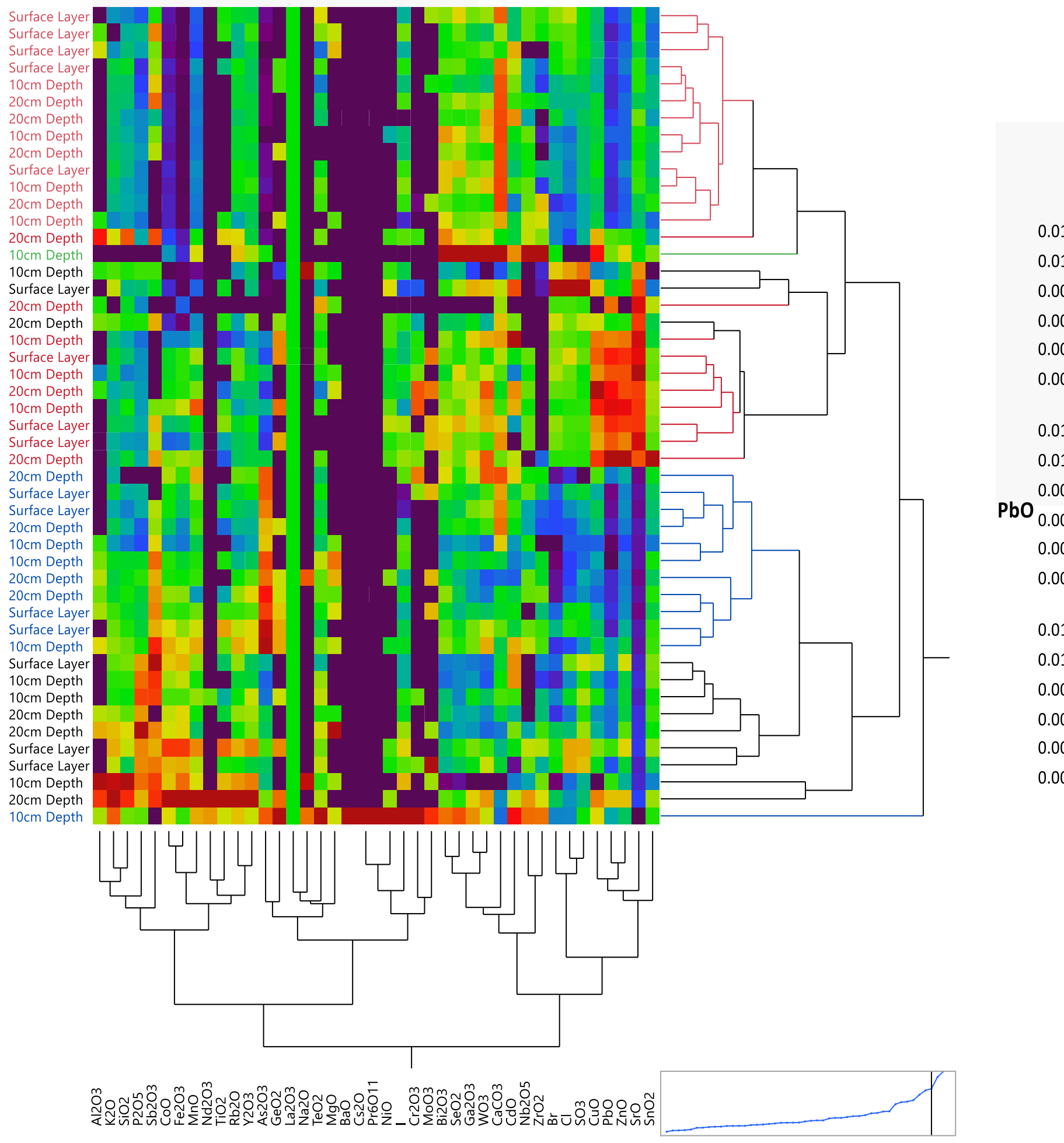
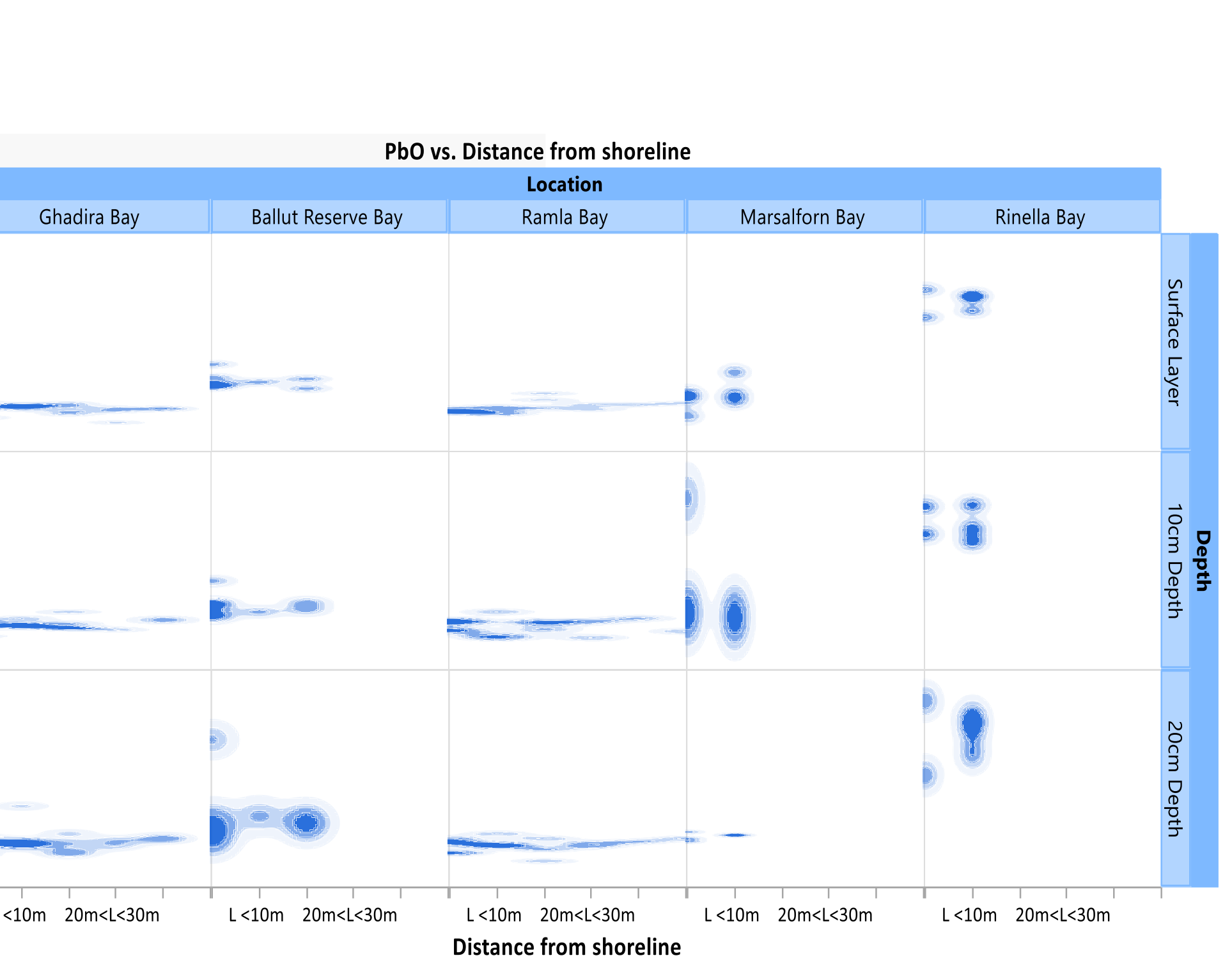


Figure 3: Graph of PbO depicting Concentration variation with Location, Depth and Distance from Shoreline.



Correlations analysis tests showed strong relationships ($r > 0.7$) between Br, Cl and SO₃; CoO, Fe₂O₃ and MnO; PbO, SrO and ZnO. Principal Components Analysis, and Two-Way Clustering hinted at lithogenic sources of Fe₂O₃, CoO, MnO, CuO, SrO, and ZnO; and at anthropogenic sources of PbO, SO₃, Br and Cl.

CONCLUSIONS

- Sources of heavy metals under study vary depending on the sampling location due to variation in presence and concentration at different depths and distance away from the shoreline.
- Results obtained prove higher heavy metal concentrations present in bays close to port zones and in proximity to major roads, while lower concentrations in bays located in valleys surrounded by agricultural fields.
- Temporal variation studies are needed to consolidate the relationships found in this research work; and outline new possibilities. Further work is required to help find mitigation measures to limit toxicity levels on beaches reducing health risks and environmental pollution, thus working in-line with sustainable development goals.

REFERENCES

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ACKNOWLEDGEMENTS

The research work presented has been undergone at the University of Malta Faculty of Science Department of Chemistry, with support from faculty laboratory officers.