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Contact Profile Analysis of Resource Estimation Domains: a Case Study on a Laterite Nickel Deposit †

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Abstract: Resource estimation is commonly performed in separate domains, defined using different criteria depending on the type and geometry of the deposit, the mining method used, and the estimation method applied. The validity of estimation domains can be critical to the quality of produced resource estimates as they control various steps of the estimation process, including sample and block selection. Estimation domains also affect the statistical and geostatistical analysis as they define what estimation practitioners will consider as statistically separate distributions of data. Sometimes samples that are at different estimation domains share similar grade properties close to the contact between the domains, a situation known as a soft boundary. In such cases, it can be useful to include samples from a different domain at short distances from the boundary. Contact profile analysis is a technique that allows measuring the relationship between grades either side of the contact between two estimation domains. As it will be discussed in the study presented in this paper, contact profile analysis can help validate the defined estimation domains and control the application depth of any soft boundaries found between domains.

Keywords: contact profile analysis; soft boundaries; estimation domains; resource estimation; geostatistics

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1. Introduction

Resource estimation of mineral deposits is based on three-dimensional models of geology, the success of which depends on the quality of the relational database used. The estimation approach is always stepwise and can be based on explicit or implicit modelling of geology. Regardless of the method used to produce it, the geological model will control, to a large extent, the quantities reported as Resources and Reserves, as it will define the volumes that are considered to potentially host ore and thus get estimated using a geomathematical method such as ordinary kriging. In certain deposits, ore can exist across multiple zones or domains of lithological or grade-controlled character, and in some cases, these domains can be in contact with each other and not separated by totally sterile material. Identifying these domains and modelling their boundaries is a time-consuming process and the estimation practitioner needs to be able to validate them before moving on to their estimation.

Modelling of multi-domain deposits and analysis of statistical and geostatistical behaviour of samples across domain boundaries has been the subject of extensive research in the past [1-5]. The Contact Profile Analysis (CPA) technique, discussed in this paper, is a useful tool to investigate the behaviour of the transition from one geological unit to another and can be used to improve the use of samples from neighbouring units to estimate the grades of a given geological unit. Allowing the exchange of samples between neighbouring domains when supported by CPA can help increase the confidence of estimates near their boundary, improve the Resource classification, and guarantee a smoother transition of estimated grades across their boundary.

2. Geological Background

The nickeliferous mineralization in Greece is related to the geotectonic zones of Almopia, Pelagonian and Sub-Pelagonian, - the main metalliferous regions are situated in Locris, Euboea and Kastoria. In Central Euboea – the location of the Tsouka laterite nickel deposit of our study (Figure 1) – iron and nickel ores of Cretaceous age occur, which are of sedimentary type and consist of stratified lenses and layers, overlain by Upper Cretaceous limestones and underlain by ophiolites (and in exceptional cases by Jurassic limestones). The mineralization is either pissolitic or compact with silcretes developed within the ore, the development of lenticular intercalations or siliceous layers is also common, while silcretes are also found in the bedrock. Many significant deposits exist in the Psachnon area, the Akres, Katsikiza, Isomata and the Katavolo-Fterada in the Kimi's area [6].

Figure 1. Location of Tsouka deposit in central Greece.

In the area of Agios Ioannis, there are large laterite deposits developed and mined by LARCO GMMSA and belong to the Sub-Pelagonian zone. The Tsouka Ni-laterite deposit is characterized by a saprolite zone, 1 m thick, followed by a pelitic-pisolitic horizon, 4 m thick, the upper part of which is comprised of transported material. Lower Cretaceous limestone layers alternating with Ni-laterite ore are conformably overlying the mineralized horizon [6-11]. Mining of the Tsouka deposit started before WWI using an underground room and pillar process. LARCO started surface mining of the deposit in the 90s.

The resource estimation procedure applied in all Fe-Ni deposits of LARCO has been described by Kapageridis et al. [12]. Modelling and estimation of the Tsouka deposit was based on a dataset consisting of 218 drillholes providing a total of 12,473 1m composite samples (Figure 2). Samples have been assigned to different domains based on lithology, and Fe-Ni grades. The boundaries between domains have been modelled using a mostly stratigraphic approach and have been used to flag blocks in the model before Resource estimation. Figure 3 shows a typical section through the deposit and the relative location of the estimation domains.

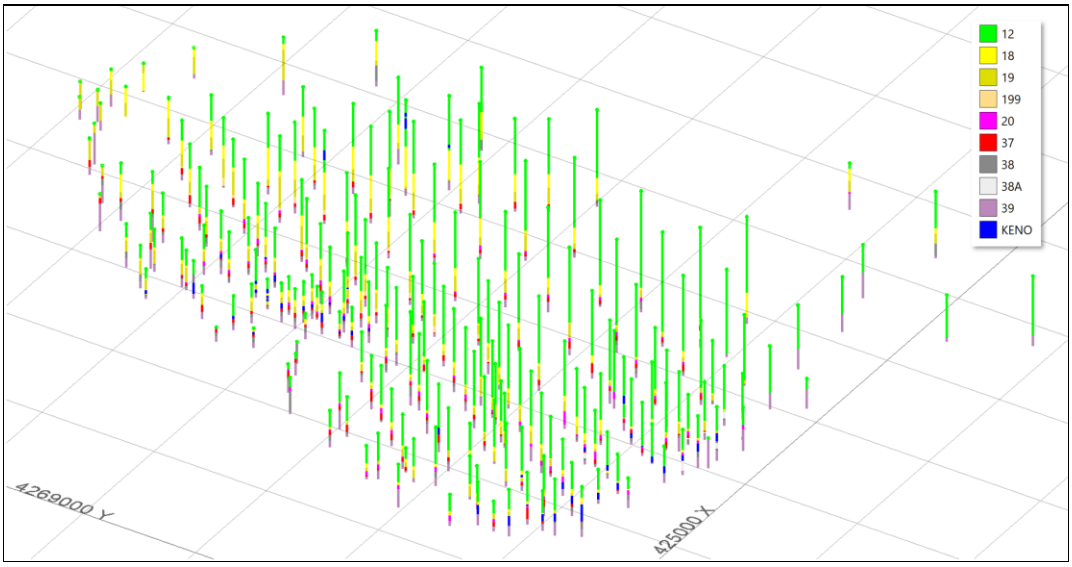

Figure 2. Drillholes from the Tsouka deposit coloured by domains with a 100x100m grid overlay.

The following domains have been identified and modelled in the Tsouka deposit according to the domain naming system used by LARCO:

- 12 (Roof): overburden – limestone
- 18: conglomerate
- 19: poor clay horizon
- 199: poor mineralisation with slightly higher Fe concentration than 19
- 20: poor mineralisation with high Fe content
- 37 (Ore): main mineralisation
- 38: red ophiolite with some rich spots
- 39: green ophiolite (bedrock)
- KENO (Void): old underground workings (room and pillar)

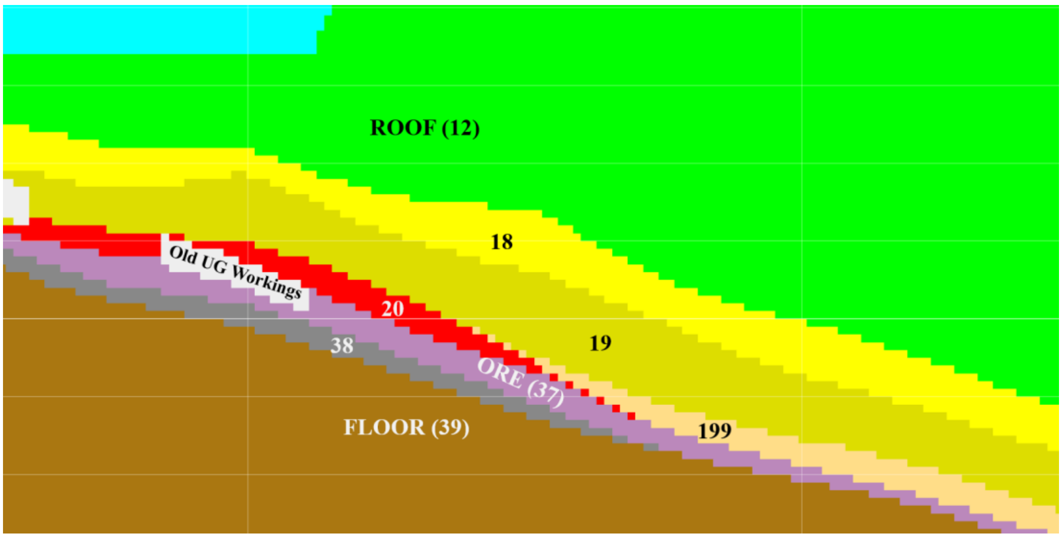

Figure 3. Cross section through Tsouka block model colour coded using modelled domains.

3. Contact Profile Analysis

The Contact Profile Analysis (CPA) tool, included in Maptek Vulcan™ mine planning software, was used to investigate the relationship between grades when moving from one estimation domain to another to validate the domains and possibly justify and control the use of samples from neighbouring domains during estimation. Samples from each domain were paired with samples from a neighbouring domain based on a separation distance. The pairs were constructed over an increasing separation distance. For each separation distance, the average grade of the first domain was plotted against the average grade of the second. Average grades from the first domain were plotted on negative distances so the differences could be observed within the graph (Figure 4). Careful examination of the produced graphs allowed the determination of the type of boundary (soft or hard) and a safe distance or width in the case of a soft boundary between estimation domains for sharing samples. The different scale of each of the contact profile graphs should be considered when comparing them.

Starting from the top, the contact profile between overburden material (12) and the conglomerate layer (18) was constructed (Figure 4a). The values near the interface between the two domains were considerably different, producing a sudden jump in Ni grade when moving from domain 12 to 18 - more than Ni 0.25% and a similar change in Fe grade (more than 10%) in less than a meter of distance. This was considered a hard boundary and no samples from 12 were used to estimate domain 18. Basic sample statistics shown in Table 1 and 2 (first two rows) also supported the exclusion of any domain 12 samples from estimating domain 18. The clear difference between samples from the two domains near their interface and the produced contact profile graph were considered as evidence of validity of the modelled boundary between them.

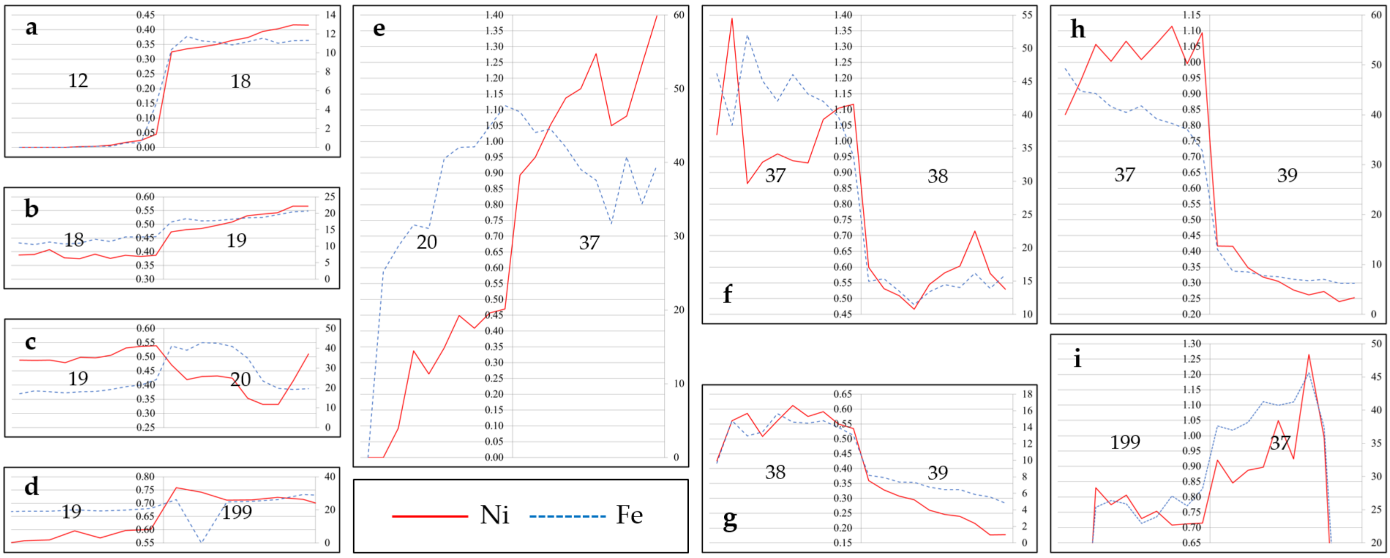

Figure 4. Contact profile graphs between various domains of the Tsouka deposit. Middle vertical axis shows mean Ni% grades of distance intervals either side of the contact, while right vertical axis shows corresponding Fe% mean grades. Horizontal axis starts and ends 10m before and after the boundary between the two domains.

A different contact profile was presented between domain 18 and 19 (Figure 4b). A jump in the Ni grade is still present, but the difference was less than 0.1% in less than a meter of distance. Fe presents a similar behaviour across this boundary and thus a choice was made to allow exchanging of samples between these two domains during estimation of both Ni and Fe. The contact profile between domain 19 and 20 confirmed the lower Fe content of the first and the higher Fe content of the second. The opposite behaviour is present in Ni grades, with domain 19 having a more constant and overall higher Ni grade than domain 20. As there is a rapid change at the boundary between the two domains in both elements, the boundary was considered valid, and no samples were exchanged between the two domains during estimation of Fe and Ni.

In Figure 4d, Ni and Fe grades seem to be similar either side of the boundary between domain 19 and 199. Unlike the boundaries seen so far, this was considered to be a soft boundary and samples were exchanged between the two domains during estimation up to 6m from the boundary. The boundary between domains 20 and 37 presented a smooth transition of Fe grades, with a peak at the boundary, while Ni grades seemed to constantly increase moving from domain 20 to 37 (Figure 4e). Thus, the contact between these two domains was considered a soft boundary for both Fe and Ni grades, but with a different range of sample exchange – 6m for Fe and 4m for Ni. The same choice was made for the boundary between domains 199 and 37 shown in Figure 4i.

The contact profile between domains 37 and 38 (Figure 4f), and 37 and 39 (Figure 4h) led to considering their boundary as a hard one and no exchange of samples was allowed during their estimation. The statistics and first interval correlation value for the two domains in Table 1 and 2, also supported this choice. The same applied to the contact between domains 38 and 39 (Figure 4g).

Table 1. Basic statistics of Ni samples near the interface between neighbouring domains and first interval correlation.

Domain	Domain total samples count	Mean of totals	Domain intervals samples count	Mean of intervals	First interval correlation	Type of boundary
12	7116	0.00	1727	0.01	0.00	hard
18	1140	0.38	865	0.36		
18	1140	0.38	833	0.38	0.31	soft
19	1436	0.53	1101	0.52		
19	1436	0.53	472	0.51	0.11	hard
20	311	0.41	246	0.43		
19	1436	0.53	288	0.56	0.02	soft
199	82	0.73	82	0.73		
20	311	0.41	198	0.42	0.03	soft
37	455	1.04	269	1.07		
37	455	1.04	296	1.04	0.08	hard
38	376	0.56	230	0.54		
37	455	1.04	437	1.04	0.03	hard
39	1323	0.28	587	0.30		
199	82	0.73	72	0.73	0.00	soft
37	455	1.04	92	0.95		

4. Conclusions

Contact Profile Analysis is a technique that can be used to investigate the relationship between grades either side of the boundary between neighbouring domains. The results of CPA can be used to increase confidence in the boundaries themselves and how efficiently they separate sample distributions, decide as to the type of the boundary (soft or hard), and in the case of soft boundaries, control the depth of sample exchange between domains. The study presented in the paper demonstrated the practice and benefits of CPA when applied to a laterite Fe-Ni deposit consisting of multiple domains.

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Table 2. Basic statistics of Fe samples near the interface between neighbouring domains and first interval correlation.

Domain	Domain total samples count	Mean of totals	Domain intervals samples count	Mean of intervals	First interval correlation	Type of boundary
12	7116	0.07	1727	0.21	0.31	hard
18	1140	11.46	865	11.26		
18	1140	11.46	833	12.03	0.43	soft
19	1436	18.36	1101	18.55		
19	1436	18.36	472	19.91	0.07	hard
20	311	36.42	246	39.92		
19	1436	18.36	288	19.24	0.06	soft
199	82	25.92	82	25.92		
20	312	36.42	200	42.64	0.39	soft
37	456	39.91	270	42.34		
37	456	39.91	297	40.28	0.13	hard
38	376	13.98	230	13.92		
37	456	39.91	442	39.79	0.03	hard
39	1323	6.71	581	7.69		
199	82	25.92	72	26.12	0.22	soft
37	456	39.91	92	39.79		

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