NICKEL RESOURCE ESTIMATION AND RECONCILIATION AT TÜRKMENÇARDAĞI LATERITE DEPOSITS

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NICKEL RESOURCE ESTIMATION AND RECONCILIATION AT TÜRKMENÇARDAĞI LATERITE DEPOSITS

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ABSTRACT

NICKEL RESOURCE ESTIMATION AND RECONCILIATION AT TÜRKMENÇARDAĞI LATERITE DEPOSITS

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In recent years nickel is mostly produced from lateritic ore deposits such as nontronite, limonite, etc. Resource estimation is difficult for laterite deposits as they have a weak and heterogeneous form. 3D modeling software are rather suitable for deposits having tabular or vein type ores. In this study the most appropriate estimation technique for resource estimation of nickel laterite deposits was investigated.

One of the known nickel laterite deposits in Turkey is located at Türkmençardağı - Gördes region. Since the nickel (Ni) grade recovered from drilling studies seem to be very low, a reconciliation pit having dimensions of 40 m x 40 m x 15 m in x-y-z directions was planned by Meta Nikel Kobalt Mining Company (META), the license owner of the mine, to produce nickel ore.

13 core drilling and 13 reverse circulation drilling (RC) and 26 column samplings adjacent to each drillholes were located in this area. Those three sampling results

were compared to each other and as well as the actual production values obtained from reconciliation pit. On the other side 3D computer modeling was also used to model the nickel resource in Türkmençardağı - Gördes laterites. The results obtained from both inverse distance weighting and kriging methods were compared to the results of actual production to find out the applicability of 3D modeling to laterite deposits.

Modeling results showed that Ni grade of the reconciliation pit in Türkmençardağı - Gördes, considering 0.5% Ni cut-off value, by using drillholes data, inverse distance weighting method estimates 622 tonnes with 0.553% Ni and kriging method estimates 749 tonnes with 0.527% Ni. The actual production pit results provided 4,882 tonnes of nickel ore with 0.649% Ni grade. These results show that grade values seem to be acceptable but in terms of tonnage, there are significant differences between theoretical estimated values and production values.

Keywords: Türkmençardağı - Gördes Laterites, Resource Estimation, Reconciliation, Inverse Distance Weighting Method, Kriging Method

ÖZ

TÜRKMENÇARDAĞI LATERİT YATAKLARINDA NİKEL KAYNAK KESTİRİMİ VE DOĞRULAMA ÇALIŞMALARI

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Eylül 2012, 122 sayfa

Son yıllarda nikel genellikle nontronite, limonit vb. gibi laterit yataklarda üretilmektedir. Lateritik yataklar zayıf ve heterojen yapıda olduklarından kaynak kestirimi bu tür yapılar için çok zordur. Üç boyutlu maden modelleme programları tabular veya damar tipi yapıları olan yataklar için daha uygundur. Bu çalışmada bu tip yapıdaki nikel laterit yatakları için en uygun olan modelleme tekniği araştırılmıştır.

Türkiye'deki nikel laterit yataklarından bilinen bir tanesi Türkmençardağı – Gördes alanında bulunmaktadır. Sondaj çalışmalarından alınan nikel (Ni) tenörü çok düşük göründüğünden dolayı, nikel cevherini üretmek için x-y-z yönünde 40 m x 40 m x 15 m boyutlarında bir test ocağı açılması madenin lisans sahibi Meta Nikel Kobalt Madencilik A.Ş. (META) tarafından planlandı.

Alandan 13 karotlu sondaj ve 13 ters sirkülasyon sondaj ve her sondaj kuyusu için 26 kolon numunesi alınmıştır. Bu 3 sonuç birbirleriyle karşılaştırılmış ilaveten bu

test ocağının gerçek üretim değerleri elde edilmiştir. Diğer yandan Türkmençardağı - Gördes lateritlerindeki nikel kaynağını modellemek için üç boyutlu modelleme kullanılmıştır. Üç boyutlu modellemenin laterit yataklarına uygulanabilirliğini bulmak için uzaklığın tersi metodu ve krigleme metodu sonuçları gerçek üretim değerleriyle karşılaştırılmıştır.

Analiz sonuçları gösteriyor ki; % 0,5 sınır değeri alındığında sondaj datalarını kullanarak test ocak alanının % Ni tenor değeri uzaklığın tersi metodu ile 622 ton % 0.553, krigleme metodu ile 749 ton % 0.527 olarak bulunmuştur. Gerçek üretim değerlerinde % 0.649 Ni tenörü ile birlikte 4,882 ton nikel cevheri bulunmuştur. Bu sonuçlar gösteriyor ki; tenör değerleri kabul edilebilir görünüyor fakat tonaja bakılırsa teorik değerler ile üretim değerleri arasında önemli farklar vardır.

Anahtar Kelimeler: Türkmençardağı - Gördes Lateritleri, Kaynak Kestirimi, Doğrulama Çalışmaları, Uzaklığın Tersi Metodu, Krigleme Metodu

To My Mother and Wife

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CHAPTER 1

INTRODUCTION

1.1 General Remarks

Nickel is a metal with major importance as it has various utilization fields in modern life. There are over 300,000 applications of nickel contributing to innovation and technology. Most commonly used areas of nickel are stainless steel and resistant alloy production as it is resistant to corrosion, oxidation, and heat. Nickel is declared as a critical raw material by the European Union (EU) in 2010 as its high economic importance and supply risk (European Commission Enterprise and Industry, 2010). Official price of nickel concentrate published daily by the London Metal Exchange (LME) is approximately 18,000 $/ton (LME, 2012). Low substitutability of nickel also makes it a critical raw material for EU as stainless steel industry has a major importance in the economy.

Majority source of world nickel production has been sulphide deposits. However, decreasing amount in this type of deposits gives way to lateritic type deposits, which also house a great amount of cobalt reserves. One of the known nickel laterite deposits in the country is located at Türkmençardağı - Gördes region and in this study Türkmençardağı laterite deposit is evaluated as a case study.

Non-uniform and dispersed ophiolitic melange structure of Türkmençardağı nickel laterites makes it difficult to estimate the grade, as well as the tonnage of the resource. On the other side, resource estimation methods need homogeneous zones. Moreover, 3D mine modeling software such as Micromine, Surpac, Vulcan, etc. is more suitable for tabular or vein type deposits. Therefore, in this study it is

investigated whether this type of ophiolitic melange can be modeled with these software and if it can be which estimation method is appropriate for this type of deposit.

1.2 Statement of the Problem

Laterite deposits are commonly found in a loose and soil like form so that a certain reserve type can not be assigned. There are no easily observed reserve limits with surrounding rock. Also, the heterogeneous form and uneven distribution of grade of such deposits makes close grade control during production essential; therefore, modeling stage is very challenging. This also makes chemical analysis essential as the grade distribution is easily varying even in a meter.

1.3 Objectives and Scope of the Study

The aim is to find out the difficulties in such heterogeneous deposits like complex structure of Türkmençardağı - Gördes nickel laterites during resource estimation analysis. In this study, 3D computer modeling results are compared with the actual results in order to find out the most appropriate estimation method.

This study focuses on nickel resource estimation in laterites in Manisa-Gördes region by kriging and inverse distance weighting methods. The elements of the main objective are:

i. Comparison of drill hole data with column sampling data,
ii. Calculation of actual production values,
iii. Resource estimation by 3D modeling using kriging method,
iv. Resource estimation by 3D modeling using inverse distance weighting method,

v. Comparison of estimation results with actual production figures of reconciliation pit.

The importance of this study is that there is not enough information related to nickel laterite modeling methods. Therefore, this study is thought to be a good source for future studies on nickel resource estimation.

1.4 Research Methodology

A reconciliation pit was exploited by META in Türkmençardağı - Gördes mine field. The drillhole data was supplied to Hacettepe University to provide nickel resource estimation using kriging method in the study area (Tercan, 2012). Also the reconciliation pit was modeled by using Micromine software with inverse distance weighting method (META, 2010) in order to determine which method is most appropriate. The results of the modeling were compared with the actual production results and finally the suitability of these methods for this type of nickel deposits was discussed.

1.5 Outline of the Thesis

This thesis is composed of five chapters. In the first chapter, general information is given about the thesis and problem. In the second chapter, basic concepts about nickel and resource estimation are given. In the third chapter, general information is given about the Gördes region and Türkmençardağı laterite deposits. In the fourth chapter, the results of the estimation methods and actual production results are discussed. In the last chapter, conclusions and recommendations are given.

CHAPTER 2

BASIC CONCEPTS ABOUT NICKEL AND RESOURCE ESTIMATION

2.1 General Information about Nickel

Similar hardness and strength to iron, nickel is a transition element composed of ferrous and nonferrous metal properties. This silvery-white metal is hard yet still bendable and easy to work with in comparison to iron. When alloyed with several other elements, nickel imparts toughness, strength, and resistance to corrosion. Also, it shows various other electrical, magnetic, and heat resistant properties (Blainey *et al.,* 2003).

Some important physical properties of nickel are as follows (Bailey *et al.,* 2002):

- Melting point : 1453 ^{o}C
- Boiling point : 2730 ^{o}C
- Specific gravity (25 ^{o}C) : 8.9
- Volume increase on melting : 4.5 %

2.1.1 Production and Consumption of Nickel

Although nickel is one of the most common elements in the composition of the earth, the fact that it is thinly spread in the earth's crust raises many questions. Most of these resources occur in minerals such as nickeliferrous limonite – poorly crystalline to non-crystalline nickel-bearing ferric oxides in laterite deposits - and garnierite - a principle constituent of nickel bearing limonite (Blainey *et al.,* 2003).

Today, more than 80% of the world's nickel production is used in alloys as at least 3000 nickel alloys were brought to light so far. About 69% of the nickel output was reserved for the production of the stainless steel (Dalvi *et al.*, 2004).

The approximate nickel consumption ratios in different fields are given in Figure 2.1.

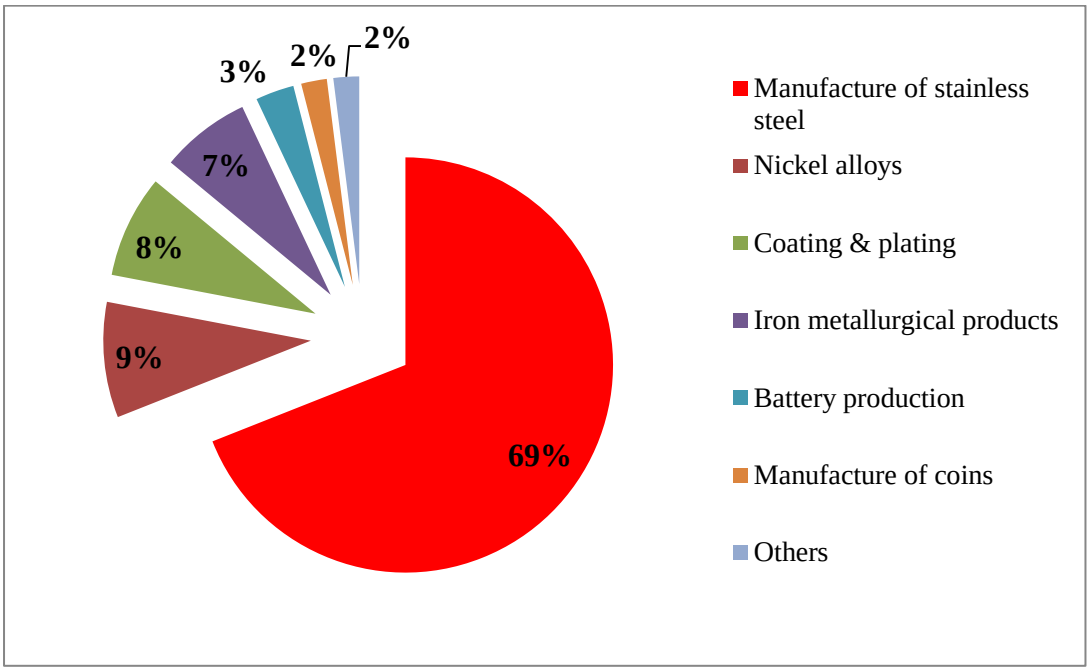


Figure 2.1 Nickel consumption ratios (Dalvi *et al.*, 2004)

As it can be seen from the Figure 2.1 the major utilization of nickel is stainless steel production, one of the very important construction materials, needs nickel in its composition to increase its corrosion resistance and strength.

World nickel production was at 1.416 million tonnes in 2007. However, between 2008 and 2009 nickel production decreased to 1.32 million tonnes due to economic crisis. But in 2010 it became sharply to 1.446 million tonnes and increased further to 1.589 million tonnes in 2011 (INSG, 2012).

2.1.2 Trend of Nickel Price in Recent Years

The nickel price in 2012 is changing between 15,000 and 22,000 USD/ton. Also the prices are increasing towards the end of the year. The trend of nickel price in 2012 can be seen from Figure 2.2.

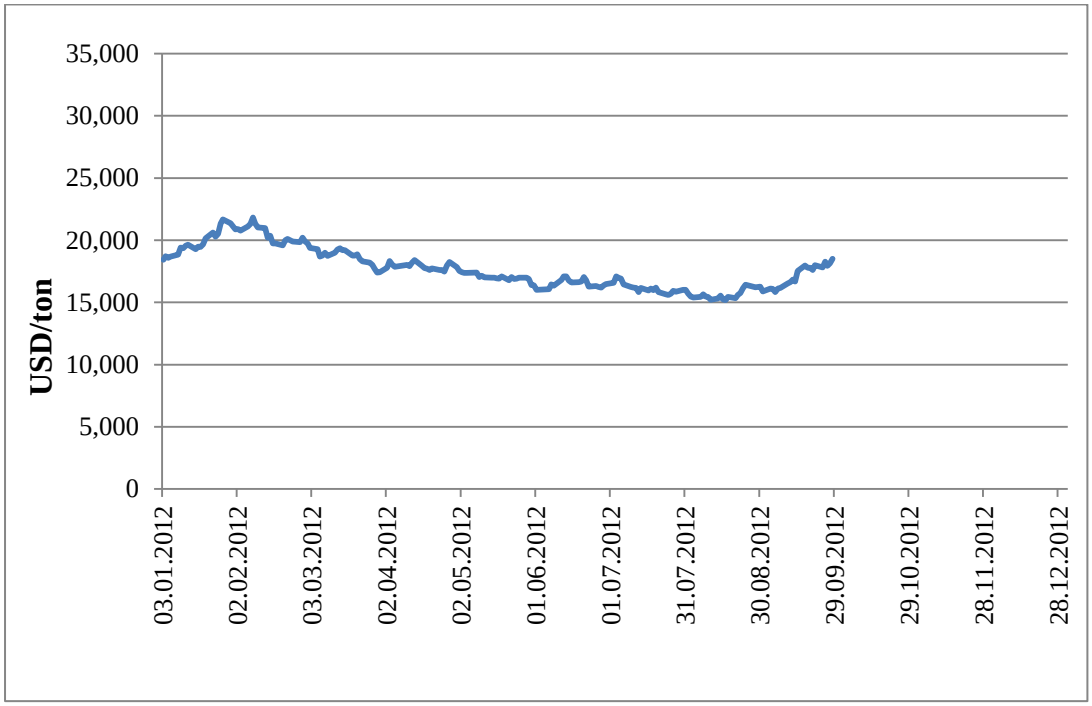


Figure 2.2 Trend of nickel price in 2012

From Figure 2.2 it is concluded that maximum price of nickel reaches around $21,800 and minimum price is around $15,200 in 2012 so far. Additionally the mean price is around $17,700.

2.2 General Information about Laterite Deposits

Today the bulk of the nickel comes from two types of ore deposits: the first being the laterites with the principal minerals of nickeliferrous limonite and garnierite and

the second being the magnetic sulfide deposits with the principle minerals of pentlandite (Blainey *et al.*, 2003).

The production of the nickel from laterite ores, however, is hardly a new option. It started about 100 years ago with the processing of the garnieritic ores from New Caledonia. Today, it presents itself as a new opportunity to expand the production capacity. That is, the lower capital and operating costs of the new laterite projects will affect the nickel supply considerably and, therefore, lower the prices immediately.

Nickel laterite deposits are formed from the weathering of nickel-bearing rocks. Typically, nickel laterites are composed of an upper limonite zone and a lower saprolite zone. These two zones must be treated differently to recover the nickel efficiently, due to the different proportions of iron, magnesium, and silica in each zone (Dalvi *et al.*, 2004).

The world nickel resources and production ratios can be seen in the Figure 2.3.

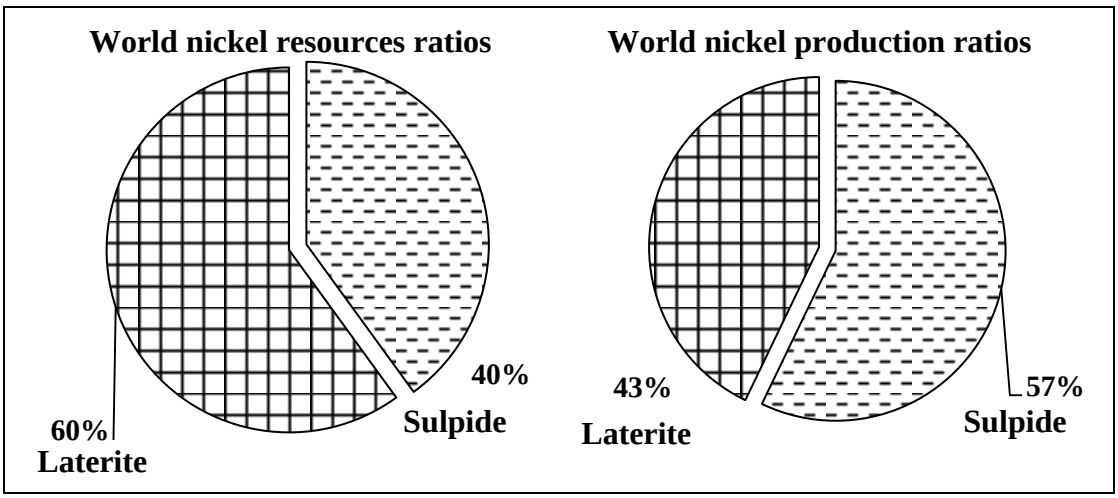


Figure 2.3 World nickel resources and production ratios (Dalvi *et al.*, 2004)

As given in the Figure 2.3, according to year 2004, nickel laterite deposits contained the majority of the world's known nickel reserves – i.e. 60% of the world's known nickel resources as the rest is sulphide ores. On the other hand, 40% of Ni production is done from laterite deposits and the rest is produced from sulphide deposits.

Nickel is produced from both nickel sulphide and nickel laterite deposits. However sulphide deposits have been the main source for the world's nickel supply due to economic reasons (Dalvi *et al.*, 2004). World's nickel laterite resources distributions are given in Figure 2.4. Major nickel mining countries are Australia, New Caledonia, Madagascar, and Cuba (META, 2010).

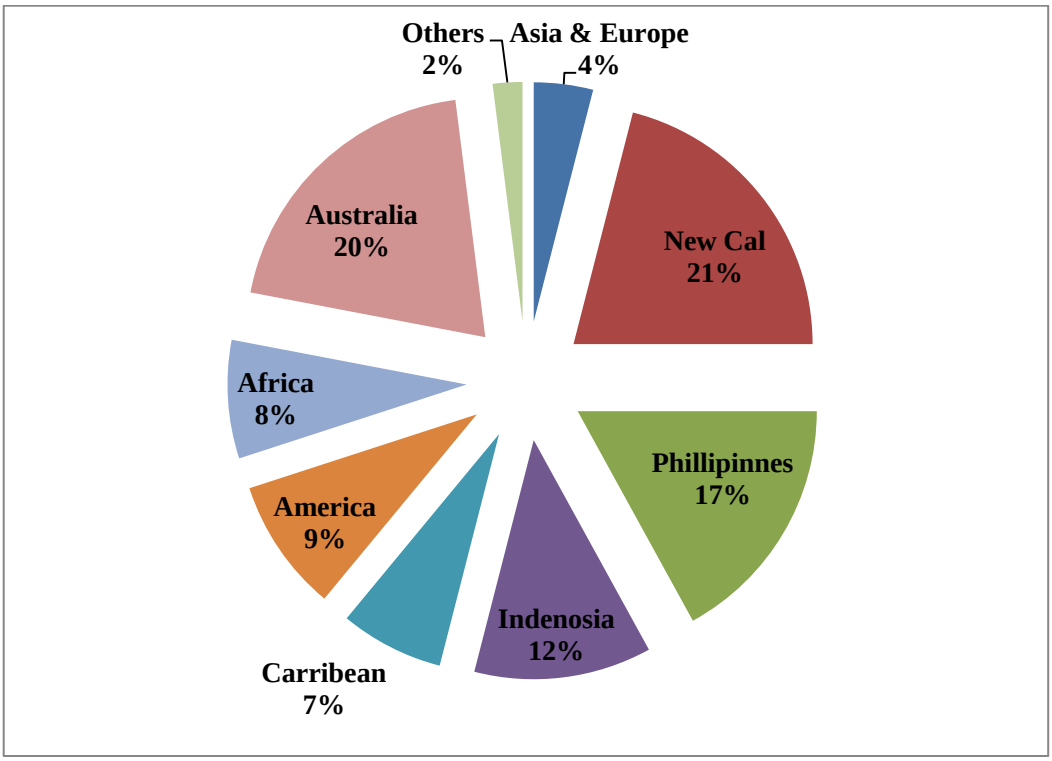


Figure 2.4 Distribution of world's known nickel laterite resources (Dalvi *et al.*, 2004)

As given in Figure 2.4 New Caledonia has the largest laterite deposits with 21% share. The second major rate belongs to Australia.

Magnetic sulphide deposits are primary nickel deposits and they are formed by magnetic processes. These processes are mostly happens in Canada, the former Soviet Union, the Republic of South Africa, Australia, Zimbabwe, and Finland (Reimann *et al.*, 1999).

The laterite deposits have a complicated geological history. They are formed by the ultramafic rocks outcropped over a huge area. These rocks are olivine-bearing, mainly dunite and olivine-pyroxene peridotite, and their serpentinized equivalents (Brand *et al.*, 1998).

Peridotite, in fact, consists mainly of olivine, a magnesium iron silicate containing up to 0.3% nickel. In most of the rocks, the peridotite has been altered to serpentine, a hydrated magnesium silicate, before exposed to weathering. In time, groundwater containing carbon dioxide dissolves olivine and serpentine to form soluble magnesium, iron, nickel, and colloidal silica. When exposed to air, the iron rapidly oxidizes and precipitates by hydrolysis to form goethite and hematite. This layer stays near the surface of the deposit.

The decomposed nickel and magnesium, and the colloidal silica, on the other hand, penetrate downwards in the laterite deposit. This composition stays in solution so long as the solution is acidic. When the solution is neutralized by reaction with rock and soil, however, the nickel, silica, and some of the magnesium precipitate as hydrated silicates (Roorda and Queneau, 1973).

The following Figure 2.5 demonstrates a typical cross-section of a laterite deposit.

Depth of meter	Idealized Laterite	Approximation Analysis %			
0	Overburden	Ni	Co	Fe	MgO
1		≤ 0.8	≤ 0.1		
2	Limonite	0.8 to 1.5	0.1 to 1.2	40 to 50	0.5 to 5.0
3					
4					
5					
6	Transition Zone	1.5 to 1.8	0.02 to 0.1	2.5 to 40	5 to 15
7					
8	Saprolite	1.8 to 3	≤ 0.02	10 to 25	15 to 35
9					
10					
11	Unaltered Bedrock	0.25	≤ 0.02	5	≥ 35

Figure 2.5 An idealized section through laterite deposit (Roorda and Queneau, 1973)

As given in Figure 2.5, a typical laterite deposit demonstrates a variety of chemical components with depth. Typically, they have two zones, an upper limonite zone and a lower saprolite zone. The former has a reddish color distinctly fading to brown on depth. The cobalt stays with the iron but tends to concentrate with depth. The lower level is the saprolite that has the highest nickel grades while being deficient in cobalt. Harder than the upper level, the saprolite is less weathered (Reimann *et al.*, 1999).

Each of these zones has different proportions of magnesium, iron, and silica. Thus, it is necessary to treat each level separately, especially if an efficient recovery of nickel is needed (Dalvi *et al.*, 2004).

As such, the weathering of these nickel-bearing rocks forms nickels laterite deposits in time. Conversely, they contain economically usable reserves of nickel and usually cobalt.

Nickeliferrous limonite is a term used in referring to poorly crystalline to non-crystalline nickel-bearing ferric oxides in laterite deposits developed from ultrabasic rocks. Goethite is a principle constituent of nickel bearing limonite. The water content of limonite varies widely (Boldt, 1967).

Both type of nickel mineralization - laterite and sulphide - are found in Turkey. The main laterite resources in Turkey are in Manisa-Turgutlu-Çaldağ, Manisa-Gördes, Uşak-Banaz, Eskişehir-Mihalıççık-Yunusemre and sulphide resources are in Bitlis-Pancarlı, Bursa-Orhaneli-Yapköydere and Sivas-Divriği-Gümüş (DPT, 2006).

2.3 Resource Estimation Methods

Resource estimation methods are practically divided into two groups, which are geometrical methods and geostatistical methods. The shape, dimension, and the complexity of the deposit affect the method selection as well as the type, dimension, and pattern of spacing of the sampling. According to Horton (2008) in resource estimation there are three basic parameters; grade, density and volume. Because nickel laterites are partially sensitive to estimates, resource volume estimates are important. The inverse distance weighting and kriging methods are the main interest of this study.

2.3.1 Polygonal Methods

Polygonal resource estimation method is a geometrical method. This method is based on the polygons areas, which is established around each drillhole. In this method, an area of influence is assigned to whole area. The polygon construction

procedure based on the theory that the influence of a hole extends halfway to the next adjacent hole is illustrated in Figure 2.6. Areas are then measured by planimeter or calculated analytically and subsequent calculations used for finding tonnage and grade (Hartman, 1987).

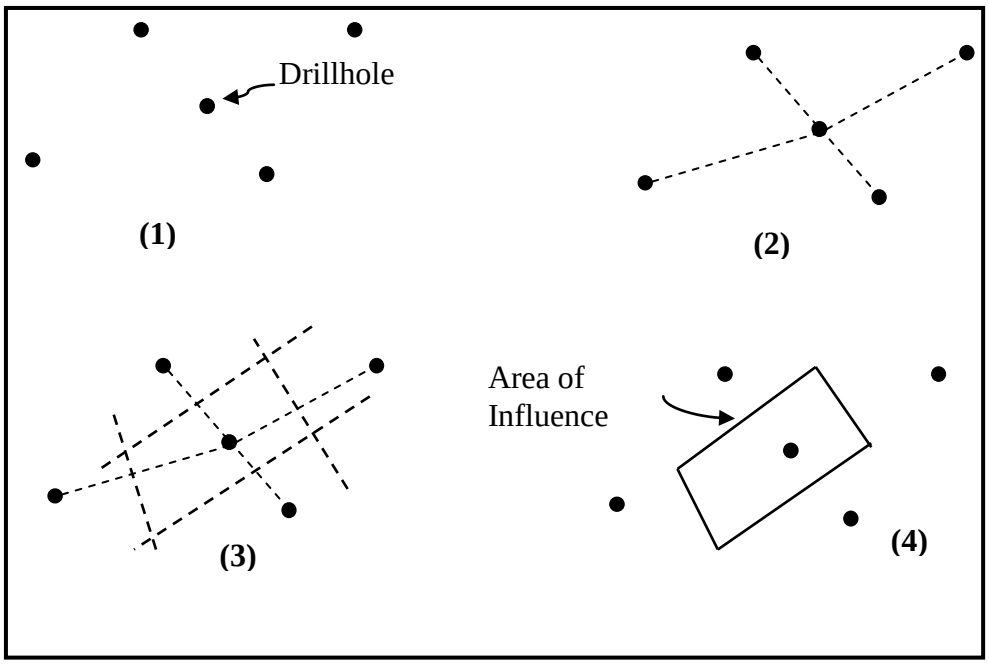


Figure 2.6 Steps of a polygon construction (Hartman, 1987)

Drillholes define the polygon and they should be selected, whereas, the orientation and configuration of the polygons are selected arbitrarily. The reason is to obtain the central drill hole with as uniform radius as possible (Güyagüler, 2007).

2.3.2 Triangular Methods

The triangular method can be said that it is a kind of polygonal methods with some modifications. The difference between triangular method and polygonal method is that three drillholes are used for constructing each triangle. The most important point of this method is that there is a gradual, linear, and continuous change between the sample points.

The advantage of the triangular method is that the data from three vertices are used to estimate the grade and thickness for the triangular prism (Hartman, 1987). Calculation procedure is the same with the polygonal method. Also the triangular method procedure can be seen in Figure 2.7.

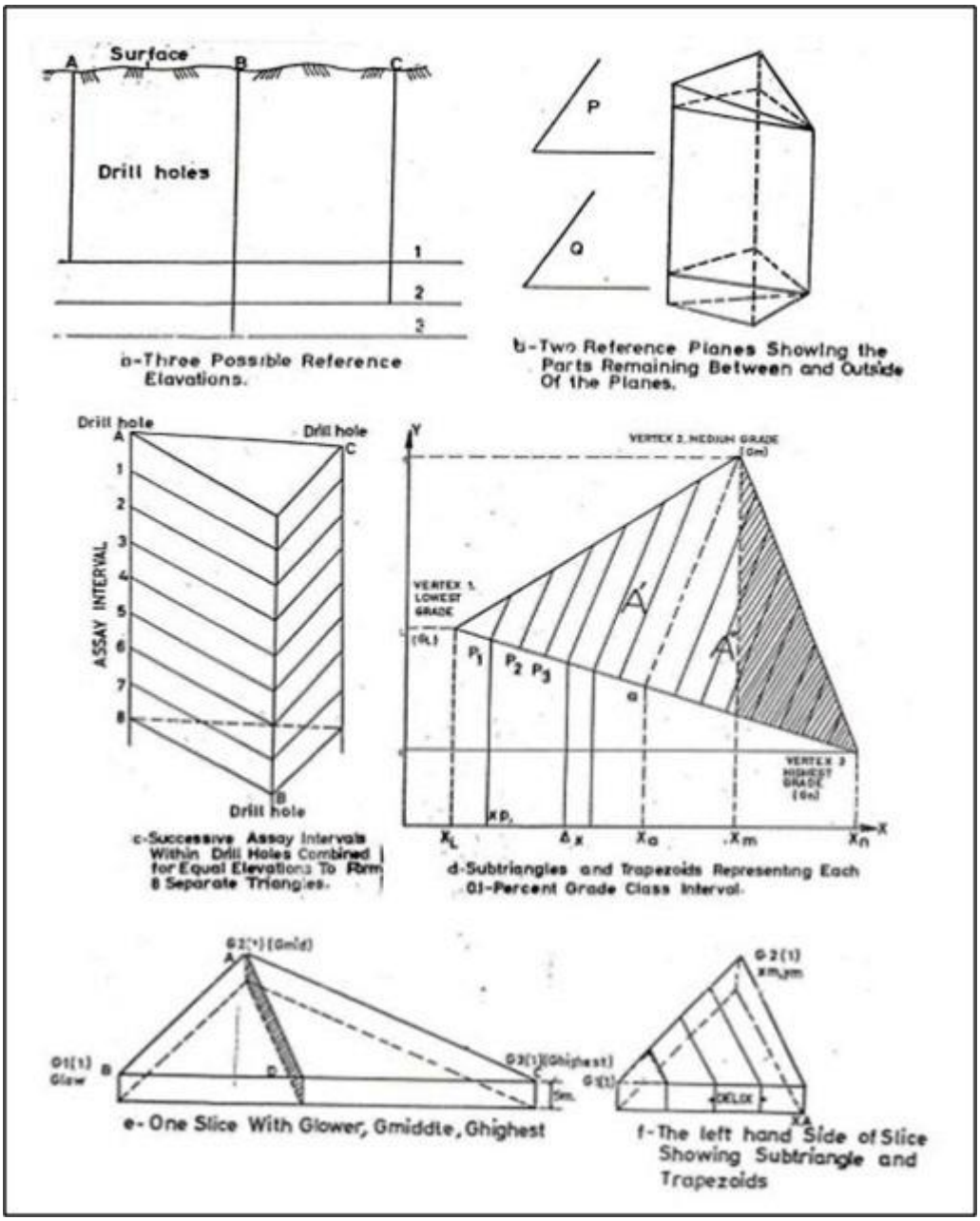


Figure 2.7 Triangular method procedures (Hartman, 1987)

In a global estimation, if the triangles are equilateral, the average grade of ore for the triangle is the average of the grades in the three holes. If these triangles are not equilateral, weighted averages of the holes are considered (Güyagüler, 2007).

2.3.3 Cross-sectional Method

The suggested method requires one to prepare several different sections of the ore body. The holes for these sections should be more or less on coordinates. A set of sections crossing the major axis, for example, would be the most useful one. The boundary of the ore body, on the other hand, should be determined in view of the thickness and the grade of the ore.

The sum of the parallel or nonparallel sections dissecting the ore body forms the cross-sectional method. All of these sections with known grade and physical properties demonstrate the geologic data of the deposit. To build a model, they should be combined to one another by linear interpolation. To do that, either a gradual change could be assumed from one section to the next, or each section could be extended halfway to the next, suggesting a sudden change in the deposit (Badiozamani, 1992). Cross sectional methods calculation procedures can be seen from Figure 2.8.

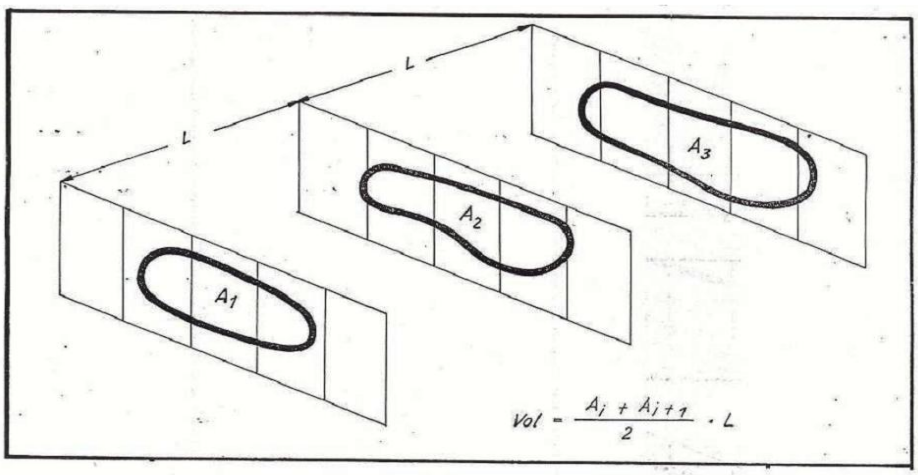


Figure 2.8 Cross section calculation procedures (Hartman, 1987)

2.3.4 Inverse Distance Weighting Method

One of the most used practical methods in mine resource estimation methods is inverse distance weighting method. The inverse distance weighting method procedure is multidirectional, user-friendly, easy to understand, and is fairly accurate under a wide range of conditions (Lam, 1983). This method is some kind of deterministic method, which is used for multivariate interpolation. With this method values of unknown points are calculated and assigned by using the values of known points. To use this strategy, the weighted average of the data is used.

In this method it is expected that when two samples get closer, the values also get similar. The similarity in sample values will decrease when distance between them increases. Contrary, the difference between sample values will increase when distance increases. So there is a spatial relation in sample values. This relation depends on the distance.

2.3.5 Kriging Method

Geostatistics may be defined as the application of the theory of regionalized variables to the problems of earth sciences. The regionalized variable is a variable that at least has one coordinate and specific to a certain region such as a mineral deposit (Tercan, 2010).

Geostatistical methods were conducted either to get samples' relationship in the deposit or find out the error in the calculations (Güyagüler, 2007).

As formulated by Isaaks and Srivastava (1989), the basic idea behind the geostatistics is verify quantitatively the possible relation in space of the data within an area, to approximate the ore reserve together with the calculation of the possible estimation error.

In kriging method the aim is to assign a best estimated value to unknown points at some location within an ore deposit. Best estimated value would be mostly the grade of the ore. In other words kriging is a set of linear regression routines, which minimize estimation variance from a predefined covariance model (Tercan, 2010).

There are some parameters that should be discussed when explaining kriging methods. These parameters are variogram (variogram function), range of influence, sill, and nugget effect. Any variogram model can be defined by three parameters: range 'a', nugget effect 'C_0', and sill 'C'. Basically, variogram includes all of them. It shows a certain range of influence, sill and nugget effect.

In geostatistics, the spatial relation is determined by using variogram function. Variogram function is used in determining the basic features of the regionalized variable. In other words, the difference between the values of two random variables is a function of the distance between them. The parameters of a typical variogram function can be seen on Figure 2.9.

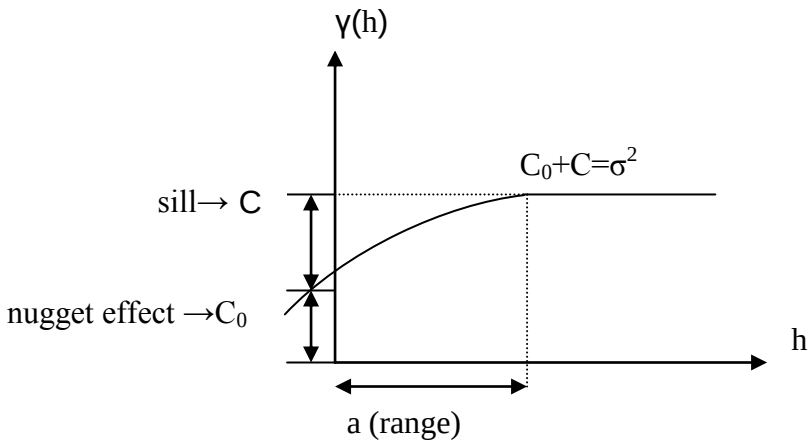


Figure 2.9 The parameters of a typical variogram (Tercan, 2010)

Range of influence means that if any other sampling points, which lie in a certain distance from the special point wanted to calculate, have influences to the

calculation. Sill is the variance of the sample used in estimation. In addition, nugget effect gives the measurement errors made by sampling, analyzing, and calculating, or a structure, which is smaller than the sampling grid.

There are three basic types of variogram model with sill, which are spherical, gaussian and exponential. Figure 2.10 shows these three types of variograms.

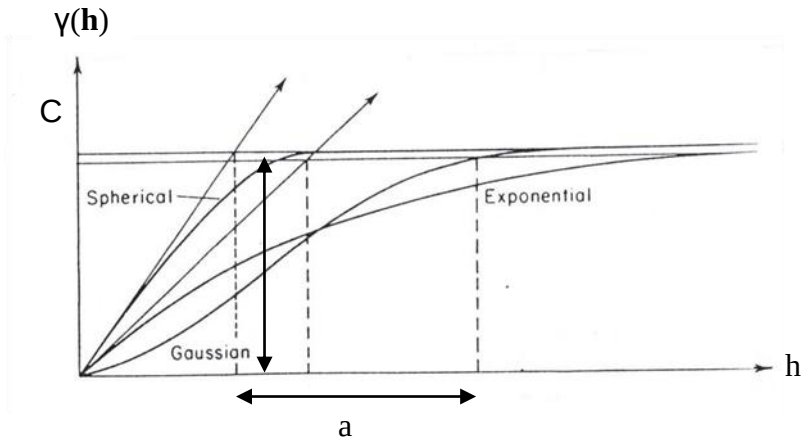


Figure 2.10 Basic variogram models (Tercan, 2010)

Isaaks and Srivastava (1989) argue that the value at a given location can be estimated by all interpolation algorithms as a weighted sum of data values at surrounding locations. Yet this would be still a result of an interpolation algorithm, which could lead similar results for particular other cases. For instance (Bohling, 2005),

- For a case where the data were uniformly distributed throughout the study area, a very good estimation would be possible no matter what the interpolation algorithm.

- For a case where the data were fall in a few clusters with large gaps in between, the result could lead to unreliable estimates no matter what the interpolation algorithm.

According to Belous *et al.* (2000), the resource estimation by using software has some steps and benefits. The steps are database validation, exploratory data analysis, geological interpretation, geostatistical analysis, grade and specific gravity interpolation, estimation of waste, modeling results and resource reporting, and categorization. The followings, on the other hand, are the benefits: rapid project evaluation, reproducibility of estimates, ease of sensitivity analyses and cost savings.

CHAPTER 3

GENERAL CHARACTERISTICS OF GÖRDES LATERITES

3.1 General Information about Türkmençardağı Laterite Deposits

3.1.1 Location

The Türkmençardağı laterite deposits lies in the west part of Turkey, between Akhisar and Gördes, and close to the villages of Fundacık, Kalemoğlu and Çiçekli in Manisa province (Figure 3.1).

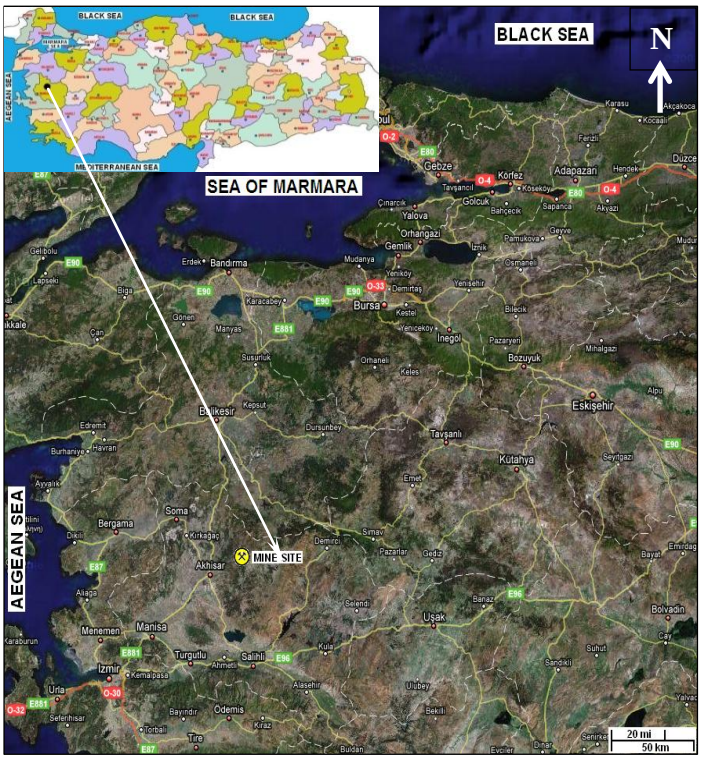


Figure 3.1 Location map of Türkmençardağı Mine Site (META, 2010)

Türkmençardağı pit is located at about 13 km away from Gördes county and 38 km away from Akhisar. The topography of the area nearby the pit is rather smooth and elevation changes between 950 m and 1050 m.

Continental climate is effective in Gördes where the summer is cool and dry; winters are cold and snowy. The average temperature of the area is 12°C where the coldest temperature recorded was -17.5^{o}C and the hottest 44.2 ^{o}C.

The town of Gördes, with some 11,000 inhabitants, is connected by asphalt-paved road to Akhisar some 70 km to the west, then on to Manisa (115 km), and ultimately to the coast at Izmir (160 km). The project area is about 20 km from the center of Gördes and 45 km from Akhisar.

The connection from the main Gördes highway, which lies to the south of the site, to the project area is provided by a 2 km access road, 1.5 km of which is part of the old Gördes highway, and is, therefore, structurally sound. Numerous forest trails provide further access into the interior of the area. The nearest railway access is at Akhisar.

The study area is characterized by generally moderate relief with gentle hills dissected by numerous streams. Elevations generally rise from the north to the south across the area with the most important high points being Görenez Mountain (1,280 m), Seyhan Mountain (1,356 m), Kireçocağı Hill (1,091 m), Demir Hill (1,141 m), Demiroluk Hill (1,126 m), and Sümbüllükır Hill (1,036 m). The Gördes and Simav rivers form the principal water courses in the region, whilst other minor streams also occur.

The Gördes area was identified as prospective for nickel laterites following a regional mapping programme undertaken by the Aegean Directory of the General Directorate of Mineral Research and Exploration (MTA) in 1987.

Lateritic occurrences were mapped over an area of 500 km^2. Trenches up to 4 m deep were excavated over areas of lateralized serpentine and samples showed anomalous nickel grades, mostly less than 1% Ni but with some values in excess of 2% Ni. It was found that the laterites tended to occur on the hilltops, having been eroded away in the valley areas (META, 2010).

In 2001, META acquired exploration licenses over the Gördes area. In 2003 further trenching and RC drilling was carried out. Eight trenches were excavated in the vicinity of Türkmençardağı Hill with positive results, with a number of samples containing up to 2% Ni.

3.1.2 Geology of the Site

Up to date geological study related to the site and environs has been carried out by Konak *et al.* (1980). A summary of this study is presented in this section and a generalized stratigraphic column of the region suggested by Konak *et al.* (1980) is given in Figure 3.2.

Different geological units starting with Paleozoic age are observed in the area. These units are summarized below according to principal geological times. Additionally, the regional geology is complex. The Gördes nickel laterite deposits originate from the weathering of peridotites, mainly dunite and harzburgite, belonging to the Eydemirçay mesozoic formation, a complex ophiolitic unit.

Also intense tectonic activity in the region has resulted in ophiolites and limestones/sandstones/siltstones being strongly intermingled in a complex ophiolitic melange.

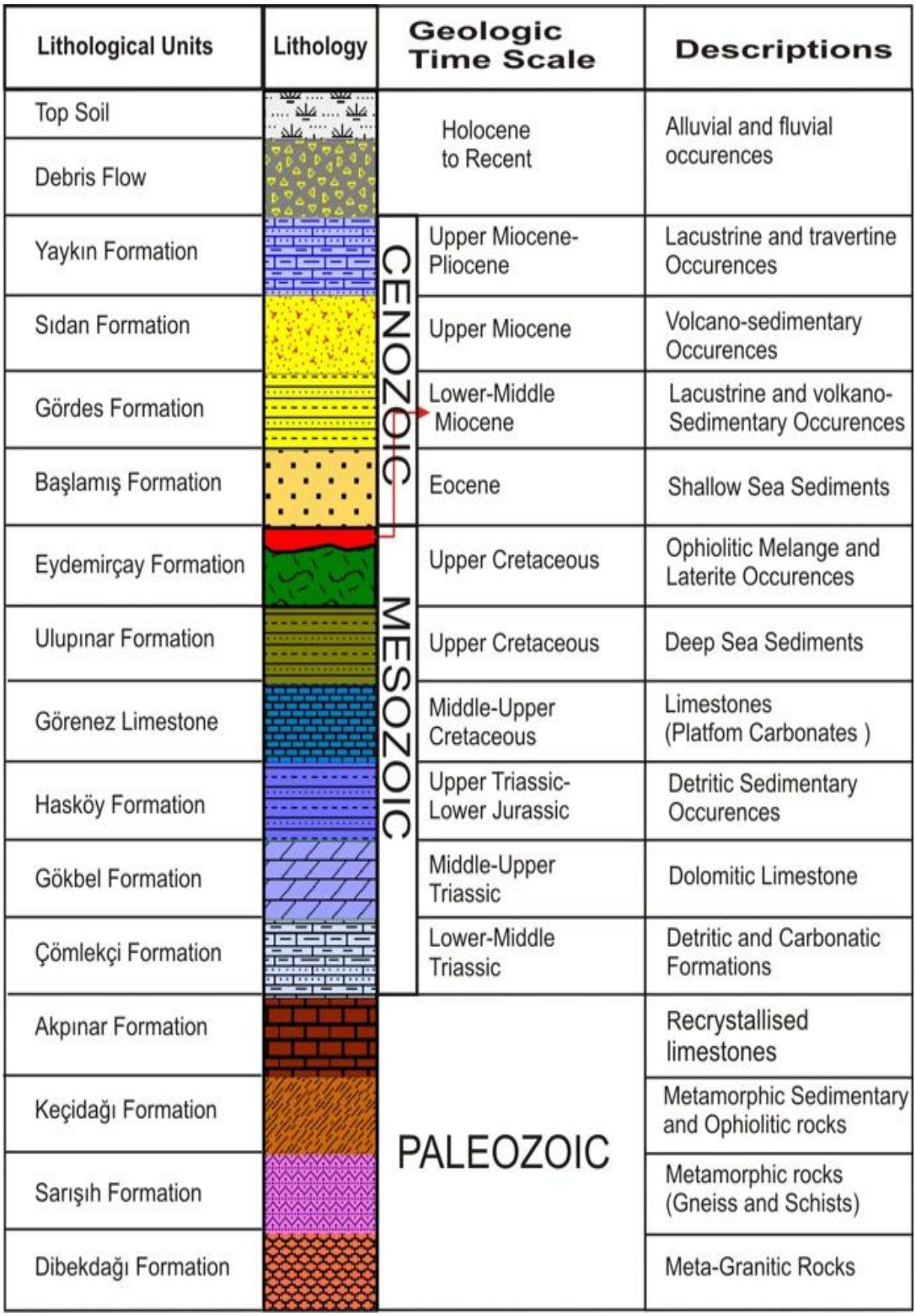


Figure 3.2 A generalized stratigraphic column observed in the region (Konak *et al.* 1980)

Locally, limestone both bound the lateritic formation at Türkmençardağı Hill north and south. The same limestone unit is observed under the laterite; it was intercepted at the end of the most of the drill holes completed on the deposit. General view of the study area can be seen on Figure 3.3.

Figure 3.3 General view of the study area from the SE direction

3.1.3 General Characteristics of Gördes Laterites

General characteristics of Gördes laterite formations are given below (META, 2010):

Fresh Serpentine Zone: Hostrock of serpentine is generally harzburgite. Fresh rock is generally dark green and black in colour but it can be seen as yellowish and brown levels in altered zones and its nickel (Ni) content is about 0.1-0.2%.

Altered Serpentine Zone: It is situated under the laterite formation. There are partially altered gossan textured serpentine zones defined as “saprock” and completely altered zones called as “saprolite. There is also garnierite formation with a Ni grade upto 0.6% in the altered serpentine zone. In some places of this zone very-high Ni content is determined locally.

Saprock Zone: It is on the fresh serpentine zone and has an average thickness changing from 1-2 cm to a few ten meters. In general it has yellow – green colour but in silicified zone it can be seen as brown and reddish brown in colour. The clayey zone is widespread along the fractured zone, and garnierite plastering and nickel Ni – silicate formations can be seen very often on the fresh rock surface.

Saprolite Zone: It has an average thickness changing from centimeters to 10 – 15 m. It is yellow, greenish yellow, and bluish yellow in colour and generally comprised magnesite veins.

Garnierite is seen very often and sometimes blue and green clay (especially talc) can not be distinguished from the garnierite unit. It has an average Ni grade differing from 0.4% to 6% and it is characterized by low iron (Fe) content (5-10 %). There are zones with an average grade of 4% Ni and have an average thickness changing from 3 – 4 m and their Magnesium (Mg) content varies between 2 -10%.

Nontronite Zone: Thickness of this zone varies between 1 – 20 m. It is green and brown in colour and generally located at the upper part of the altered serpentine zone. This zone is partly or completely clayey and comprised lens forms. Garnierite deposition is widespread in the interm zones and less at the lower zones.

This zone has an average Ni grade changing from 1.3% to 2.5% and it is very important for Ni deposition. Its Fe content varies between 15 - 20% generally. It was determined in the mineralogical studies that nickel - serpentine and nickel - simectite are the main minerals in this zone.

There are completely clayey interim zone and plastic clay above the nontronite zone. Their Ni content varies between 0.3 - 1% Ni and their Fe content varies between 8 -15%.

Limonite Zone: It has an average thickness differing from 1 m to 30 m. It has clay and altered serpentine layers. This zone is dark red or brown in colour and it has Fe coloured altered serpentine in its interim zones.

The main mineralizations in this zone are goethite and hematite and they can have low or high amount of clay (smectite). Garnierite is seen very often but sometimes laminated green clay (especially talc and halloysite) can not be distinguished from the garnierite.

In general, Ni content varies between 0.3 - 2% in this zone but in some cases, garnierite zones cause rises in Ni values up to 20%. Fe content is much more than 20% and generally it varies between 25 - 50%.

Especially, in Türkmençardağı, where the most of the limonite mineralization is located, while being approached to fault zone as content varies between 0.3 – 2.5%. As because of the secondary hydrothermal effects and even in some places it can be much more than the Ni content. Mg average grade is around 2% in this zone. A typical formation of laterites can be seen from Figure 3.4.

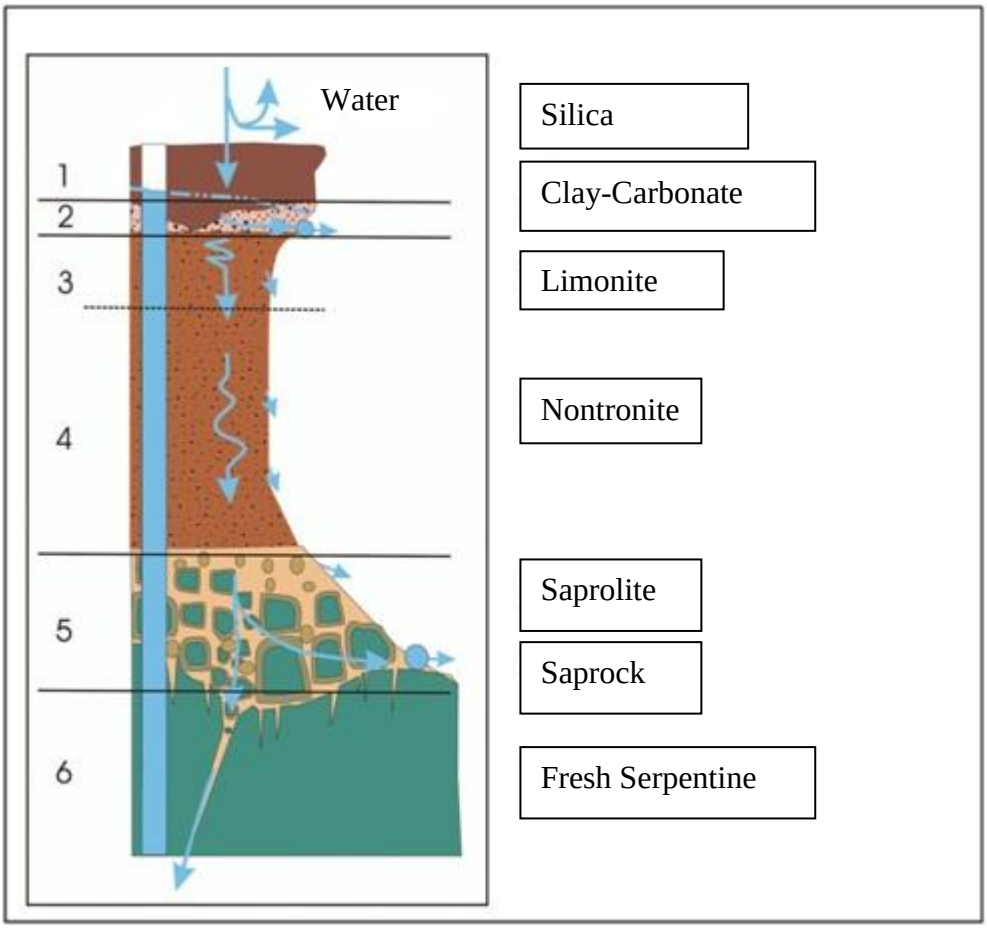


Figure 3.4 Typical formations of laterites (META, 2010)

3.1.4 General Characteristics of Türkmençardağı Laterites

Laterite formation at Türkmençardağı Hill is bounded with limestone unit both the north and the south direction. It is also observed under the laterite zone in the most of the drillholes except that are ended before cutting the base formation because of the technical reasons. The typical NW-SE direction profile observed at Türkmençardağı Hill is given in Figure 3.5.

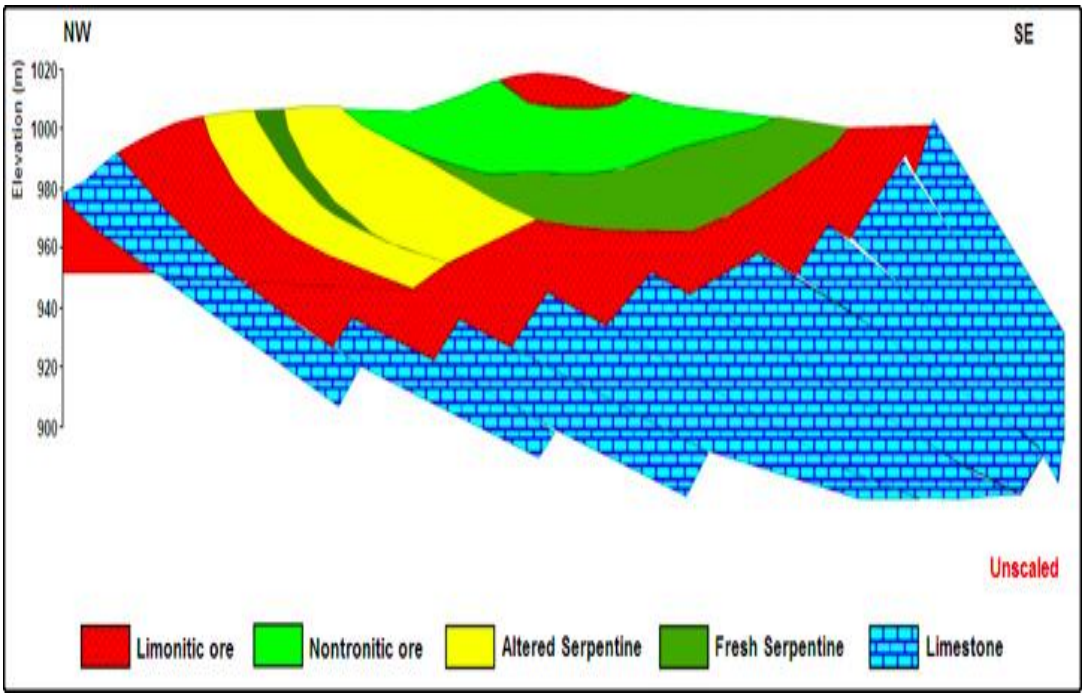


Figure 3.5 Typical cross-section of Türkmençardağı hill (META, 2010)

A main fault with a strike of NE-SW direction exists and it divides the hill into two parts (Figure 3.6). Ore packages show lithological differences at eastern and western sides of this fault.

At the eastern part of Türkmençardağı Hill, profile starts with serpentine unit at the bottom and it is followed by saprolite, nontronitic laterite and the profile ends with silica containing limonitic laterite at the top.

Türkmençardağı laterite formation presents typical ophiolitic melange, sandstone, and siltstone lenses are observed in the patches. At the north - west part of Türkmençardağı Hill, neogene units cover laterite zones.

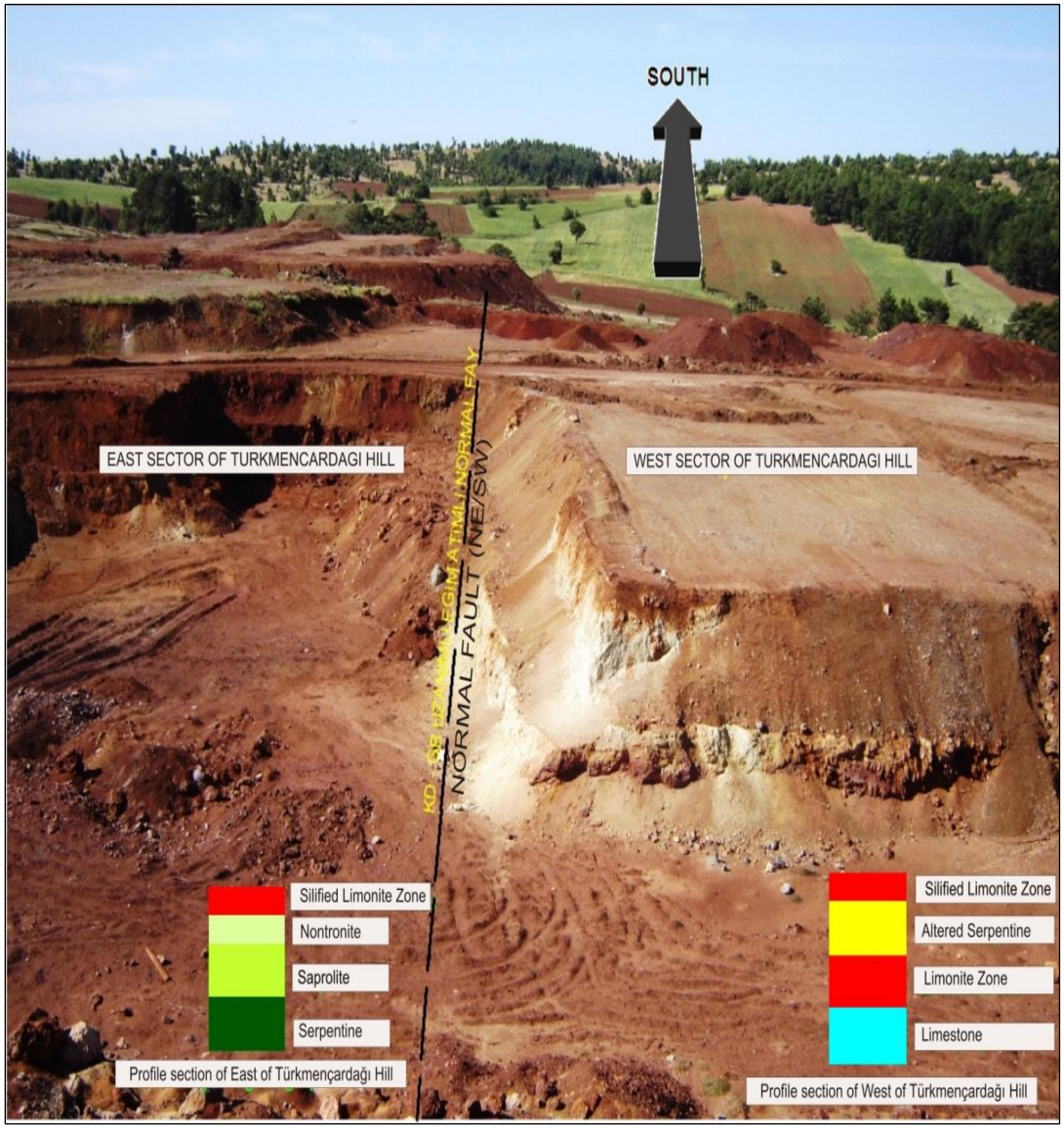


Figure 3.6 Typical profiles observed in eastern and western sectors of Türkmençardağı hill (META, 2010)

In the western sector of Türkmençardağı hill, limonite and/or siliceous limonite unit is overlaid by the base unit limestone. Section is followed by altered serpentine and again limonite and/or siliceous limonite unit is located at the top of this section. Limonite unit has a thickness of 5 – 20 m and has an average grade of 1% Ni and 20 - 40% Fe. This unit consists of silica and clay bands. Garnierite mineral can be seen at the contact zones of the limonite with the siliceous material. Ni content at these

contact zones increases up to 3 – 4%. Light green colour altered serpentine is located over the limonite and it has a mesh structure.

Kidney shaped magnesite occurances can be seen in these mesh structures. Ni and Fe grades increase at the contact zones of the altered serpentine unit. Altered serpentine at these contacts can be seen as light brown in colour because of iron staining. Although altered serpentine is mostly clayish, silification and carbonation effects can be seen in the patches.

The more regular profile is observed at the eastern sector of Türkmençardağı Hill compared with the western sector. Limonite unit with silica and clay bands is located at the top. Below the limonite, nontronitic laterite unit is situated. Nickel content of this unit is higher than that of limonite unit. Average Ni grade of it is about 1.5% and its thickness varies from 5 m to 10 m. It is green in colour.

A saprolitic unit which has a lighter green colour is located below the nontronitic unit. The saprolitic unit is totally altered (clay content is over 20%). Saprolite has 0.3 - 0.5% Ni which is less when compared with the Ni content of the other units in the area.

Fresh serpentine is commonly located below the saprolitic units. Serpentine zone has 0.1-0.3% Ni and common rock type is harzburgite. Limonitic unit is again observed under the serpentine zone. Below the limonitic unit, rich ore lenses are observed especially at the contact zones of serpentine and limestone units.

In Türkmençardağı sector 202 test pits, 111 core and 84 RC drillholes were evaluated based on assay values for nickel, arsenic, iron and chromium and field observations and 8 limonite (Limonite-1, Limonite-2, Limonite-3, Limonite-4, Limonite-5, Limonite-6, Limonite-7 and Limonite-8) and 2 nontronite (Nontronite-1 and Nontronite-2) lenses were designed (Tercan *et al.*, 2009).

According to cross-sections in north – south direction it was assessed that there was a basin like limonitic mineralization. The top view of Türkmençardağı deposit from Micromine software is represented in Figure 3.7.

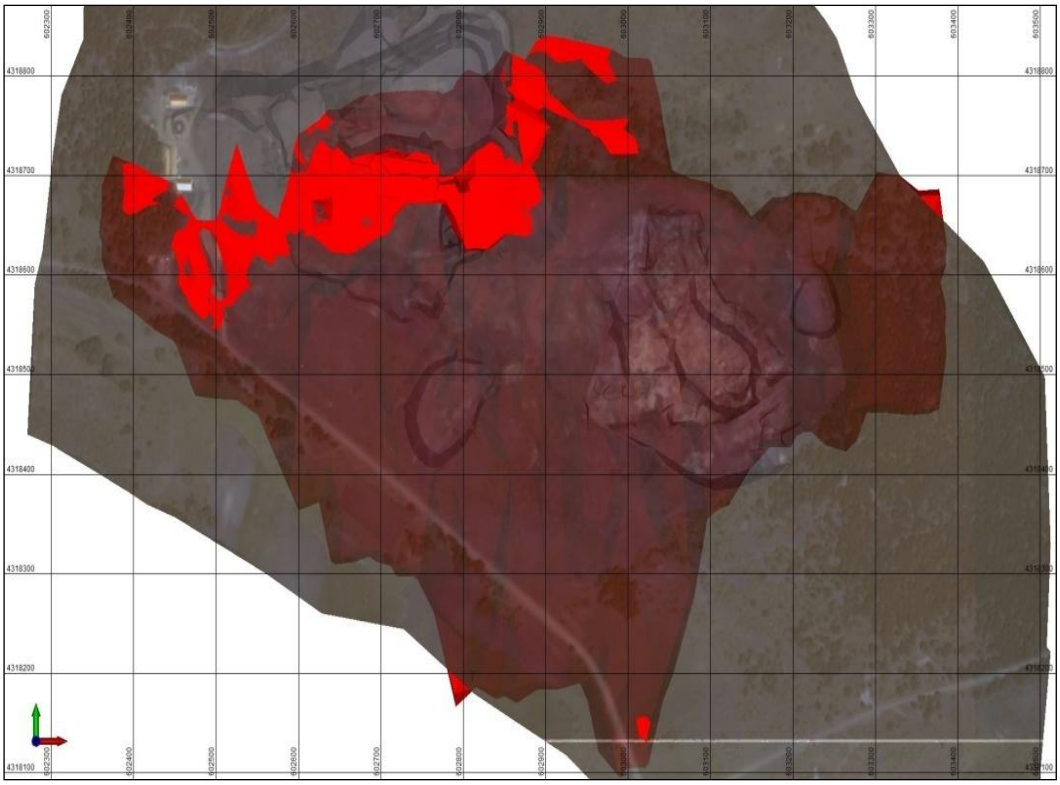


Figure 3.7 Top view of Türkmençardağı deposit (META, 2010)

A view of identified 8 limonite and 2 nontronite lenses modeled in Türkmençardağı sector are given below (Figure 3.8). Limonite bodies were shown as red and nontronite ones were shown green in colour below the surface topography.

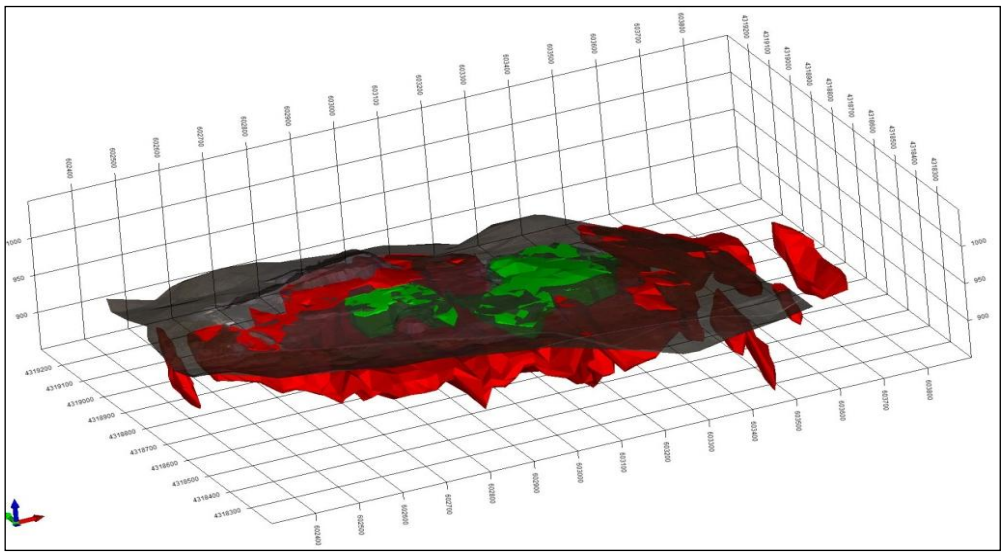


Figure 3.8 Ore bodies below topography in Gördes - Türkmençardağı deposit (META, 2010)

3D solid model of nickel ore lenses in Türkmençardağı area can be seen in Figure 3.9 (Tercan et al., 2009).

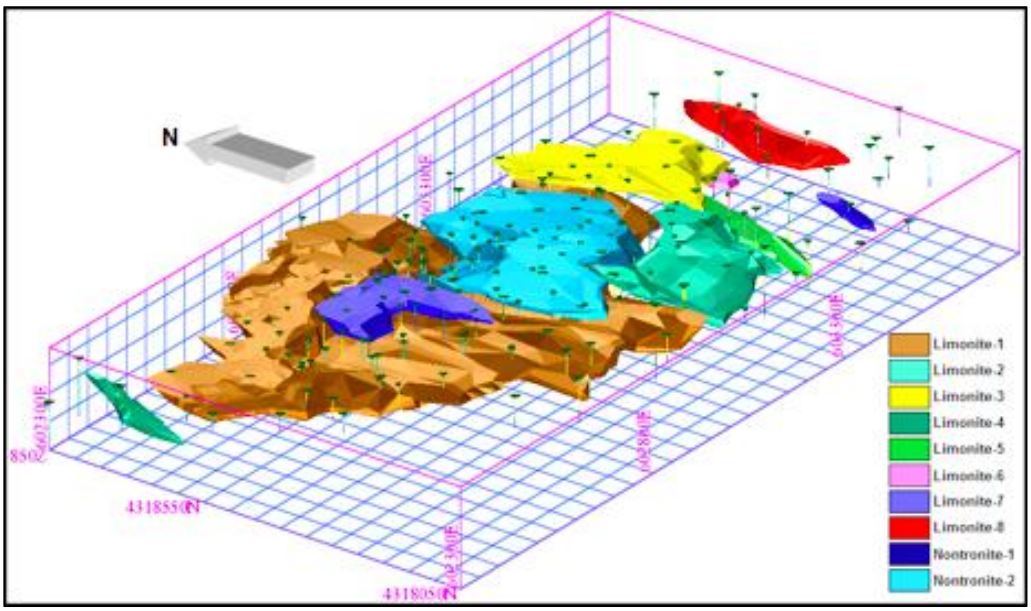


Figure 3.9 3D solid model of nickel ore lenses in Türkmençardağı area (Tercan *et al.*, 2009)

As given in Figure 3.9, the dominant type in the Türkmençardağı deposit is Limonite-1 lens. Since the area mostly consists of Limonite-1 (nearly 70% of estimated), in resource estimation analysis Limonite-1 type is used.

Plan and section view of nickel ore lenses in Türkmençardağı area is represented in Figure 3.10 (Tercan *et al.*, 2009).

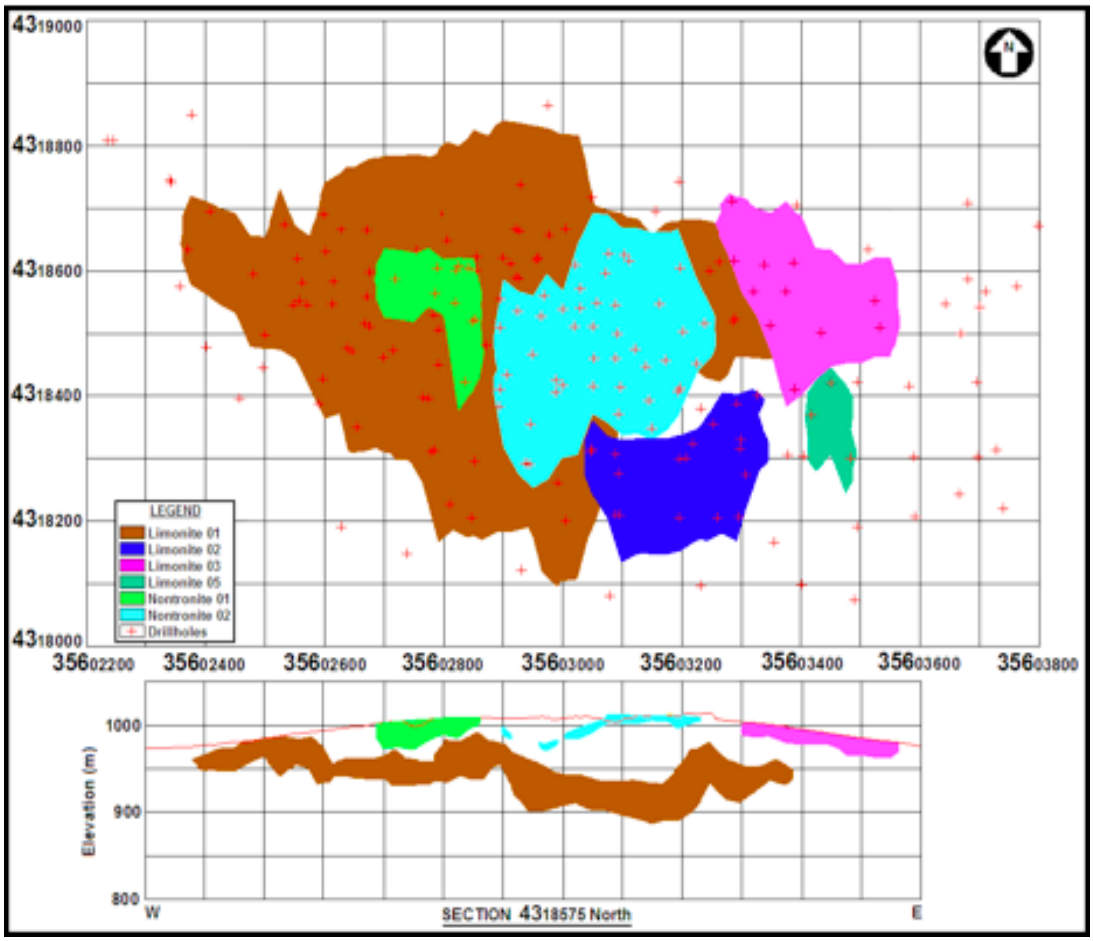


Figure 3.10 Plan and section view of nickel ore lenses in Türkmençardağı area (Tercan *et al.*, 2009)

The Limonite-1 lenses lie below Nontronite lenses and Limonite-3 lenses as it can be seen from the section view of the Figure 3.10. Also it is clearly seen that the

dominant type of the study area is Limonite-1 lenses with brown colour in the figure above.

3.2 Previous Geological Studies Related to the Area

General Directorate of Mineral Research and Exploration (MTA) and foreign researchers had completed geological studies at various times. Most recent study for the general geology of MTA was done by Konak *et al.* (1980) between Gördes – Akhisar.

3.2.1. MTA Work

The first geological study in Gördes and the surrounding belongs to Tchihatcheff (1850). He explored Azimdağ ebonite in the western part of Gördes and metamorphic around Marmara Lake. In 1913, during his study around Marmara Lake, Philippson classified metamorphic formations in the region and named the age as Palaeozoic. According to Canet and Jaoul (1946), who have done the exploration at the same region, the age of this formation is Permo-Carbonifer.

Arpat and Norman (1961) have explored the Hasköy formation in the eastern part of Akhisar as metamorphic schists and classified two marble levels transitive with schists. They named marbles and schists as Palaeozoic aged and classified Jura-Creatase limestone above them as discordant. They also named serpentine gabbros and diabase inside sandstone, gray sandstone, marl and radiolarite group in the upper levels as intrusive.

Canik (1962) classified two type of limestone, one on the other with discordance, and named the lower one using fossils as Upper Jura-Lower Cretaceous and named the upper one as Upper Cretaceous. Upper Cretaceous Mixed Series which contains ophiolites is transgressive over limestone and layered on as discordance by Upper

Cretaceous-Paleocene flysch. The researcher named three discordance and accepted peridotite and serpentine were injected into the Upper Cretaceous mélange.

Ürgüp (1966), in his studies in southern part of Çaldağ and northern part of Turgutlu, thought that dunite, peridotite and serpentine cut both schist and Mesozoic aged limestone.

According to Oğuz (1967) fillat, sandstone, marble, dolomotic limestone and dolomite in Çaldağ are Paleozoic age. Below these rocks, radiolarite, diabase, serpentine and amphibolites belongs to Upper Cretaceous eugeosinclane and major tectonic phase should be end Upper Cretaceous – before Neogene.

According to Karamanderesi (1972), Mesozoic sediments were layered on Paleozoic aged metamorphic rocks and peridotit, dunit, and serpentine were settled as intrusive.

According to Dubertret and Kalafatçıoğlu (1973), in Gördes River, conglomerate and Permian-Mesozoic limestones layered on Precambrian Paleozoic aged metamorphic. Ultrabasic rocks are located on Maestristien limestones.

3.2.2. DAMA Engineering Work

In 2007 META assigned Dama Engineering to make the geological map of the area and both META and DAMA have used the geological map of Konak *et al.* (1980) for the geological studies. The Dama Engineering work is summarized below.

The study for general geology and mining geology for northern and western part of Gördes nickel basin was done by Dama Engineering. In this scope, DAMA prepared a geological map of 21,368 Ha in northern and western part of the basin (Figure 3.11).

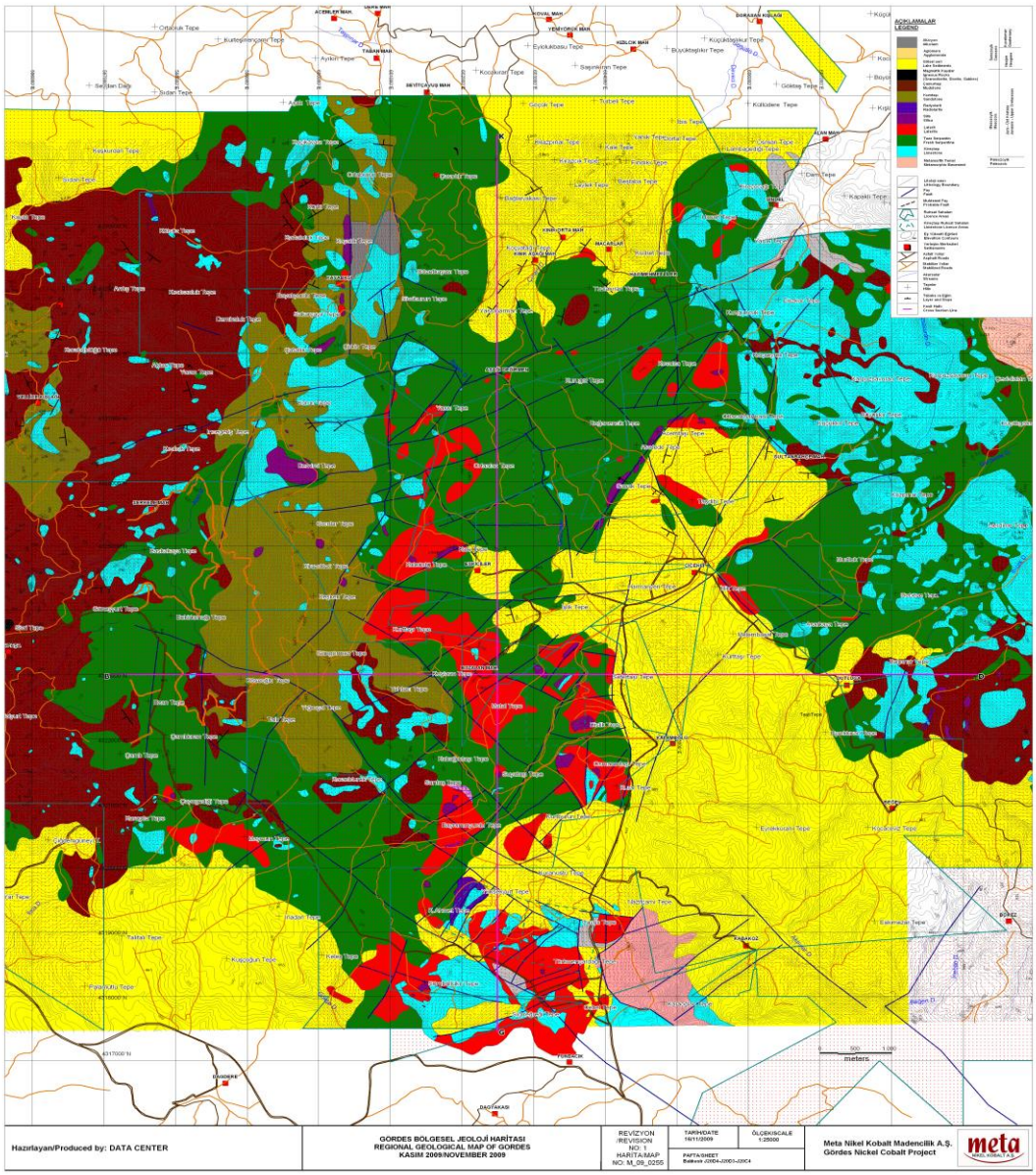


Figure 3.11 Gördes geological map showing META and DAMA study zones (META, 2010)

The classification of geological units was done according to dominant lithologies but not formations. For example, limestone, sandstone, mudstone etc. laterite zones and silica were labelled in the map separately. Faults and structural components (layer direction etc.) determined during the study were labelled in the map.

3.2.3. META Work

The first geological studies for the southern part of Gördes nickel basin was done by META in 2004. In this study, geological units and lateritic zones of the southern part of Balıkesir J20-d3 sheet were mapped. Geological units were named as lithological. For this reason, different aged limestones were named as the same unit. As there was no sufficient structural visual data in lateritic zones, limestones related with those lateritic zones were mapped in details with structural components.

Gördes lateritic nickel deposits are densely seen at the northern part of Fundacık village on Akhisar-Gördes highway in an area of 10 km x 20 km. The area identified as ophiolitic melange as given on the regional geological map presented in Figure 3.12.

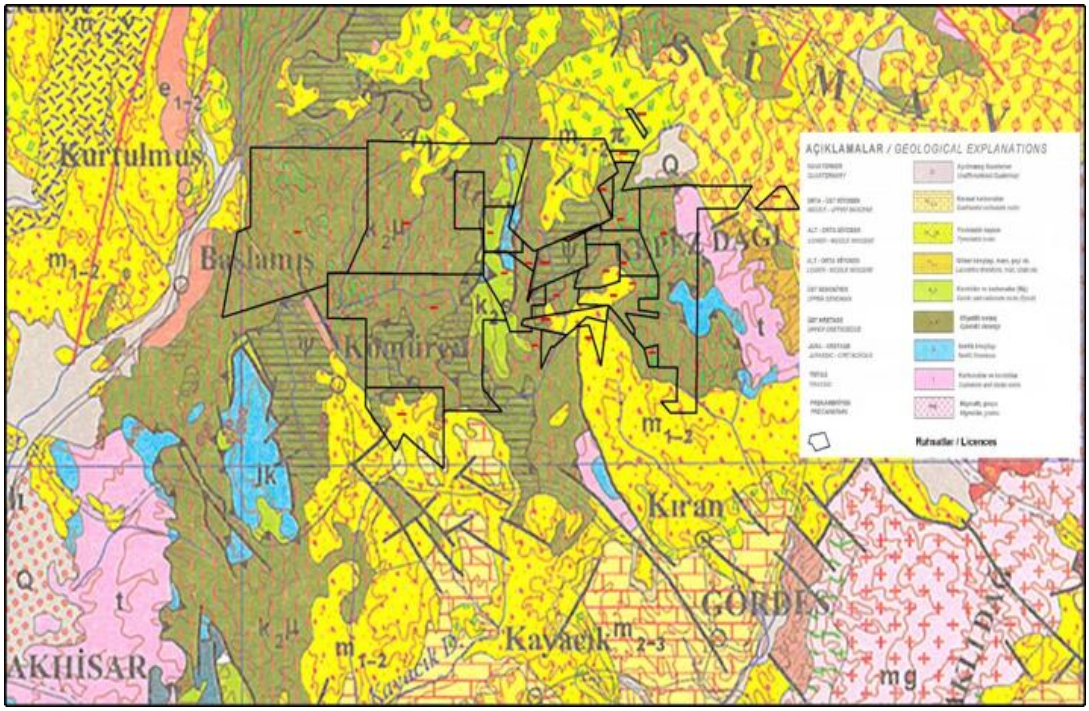
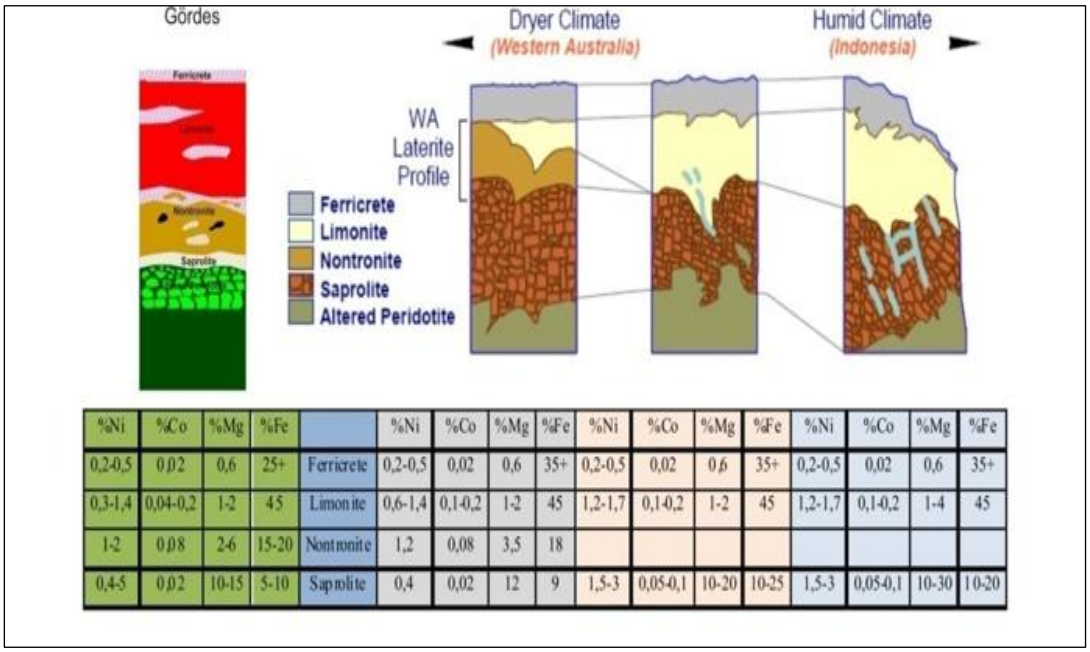


Figure 3.12 Regional geological map (META, 2010)

Gördes laterite formations present different profiles at different parts in the area from north towards south. The figure includes the areas where nickel mineralization (limonite or nontronite) has been discovered after exploration studies were undertaken in the region. Comparisons of Gördes laterite formations with other formations in the world can be seen in the Figure 3.13.



%Ni	%Co	%Mg	%Fe		%Ni	%Co	%Mg	%Fe	%Ni	%Co	%Mg	%Fe	%Ni	%Co	%Mg	%Fe
0,2-0,5	0,02	0,6	25+	Ferricrete	0,2-0,5	0,02	0,6	35+	0,2-0,5	0,02	0,6	35+	0,2-0,5	0,02	0,6	35+
0,3-1,4	0,04-0,2	1-2	45	Limonite	0,6-1,4	0,1-0,2	1-2	45	1,2-1,7	0,1-0,2	1-2	45	1,2-1,7	0,1-0,2	1-4	45
1-2	0,08	2-6	15-20	Nontronite	1,2	0,08	3,5	18								
0,4-5	0,02	10-15	5-10	Saprolite	0,4	0,02	12	9	1,5-3	0,05-0,1	10-20	10-25	1,5-3	0,05-0,1	10-30	10-20

Figure 3.13 Comparisons of Gördes laterite formations with other formations in the world (META, 2010)

As given in, Figure 3.13 Gördes nickel formation is a typical arid climate lateritization due to its chemical contents and profile characteristics.

3.3 Exploration Drilling at Türkmençardağı Laterite Deposit

As mentioned earlier in Türkmençardağı deposit both core drilling (TC) and reverse circulation drilling (RC) operations are done.

3.3.1 Core (TC) Drilling

Craelius D 260, Wirth and Levent 2002 brand hydraulic, rotary drilling machines had been used as drilling equipment till today. While taking cores, at hard floors T 76 type of 1.5 m core drills on the other hand at clayey grounds 1.5 m BW drill bits were used. Especially in silica zones rockbit drills (76 mm or 98 mm) were used because there was no penetration in drilling. Due to the presence of fractured and cracked units in the holes water circulation could not be provided and so there was a risk of collapse or subsidence. Since this type of problem was exist, in order to ensure progress in the drillhole, regulator cover NW was used (META, 2010).

In core drilling, because of problems arising from the floor average amount of daily drilling progress was around 10 meters. Not to disturb the core samples in clayey zones, water swivel was attached on BW regulator cover by an adaptor and hence samples were removed easily by water pressure (META, 2010).

3.3.2 Reverse Circulation (RC) Drilling

Up to date in RC drilling, Gemrot 500, Wirth 350 and RC 500 pneumatic drilling machines had been used. At RC drilling machines, bits in different diameters were used. Gemrot 500 pneumatic drilling machine used 5.5" RC bit, Wirth 350 pneumatic drilling machine used 4.5" and 4” RC bits and RC 500 pneumatic drilling machine used 5" RC bit. Drillholes located on hard rock units could be completed by using small diameter drilling bits.

Specified each drilling system maximum and minimum volumes of drillholes were calculated separately and volumetric percentage of drillholes have been evaluated. During RC drilling organic drilling fluids were used to help the progress. RC drilling had between 25-30 meters progress by day (META, 2010).

3.3.3 Locations of Drillholes

In 2003, META drilled 5 RC holes in the vicinity of Türkmençardağı Hill. In 2004, 42 RC holes were drilled in the vicinity of the open pit at Türkmençardağı Hill. In 2006, 8 wire-line core drilling have been carried out in the vicinity of the open pit on Türkmençardağı Hill. Main drilling program started in April 2007 and finished at the end of 2008 in Türkmençardağı area. Two views of this exploration drilling works are given in Figure 3.14.

Figure 3.14 RC drilling in 2004 (left) and wire-line core drilling in 2006 (right)

A total of 192 drill holes, 111 core drill (TC) and 81 reverse circulation drill (RC), were opened in the area since 2006. Annual distribution of these drill holes is such that 5 (all TC) in 2006, 105 (102 TC and 3 RC) in 2007, 80 (4 TC and 76 RC) in 2008 and 2 (all RC) in 2009. These drill holes in Türkmençardağı area are located on a map according to their coordinates given by META (Figure 3.15).

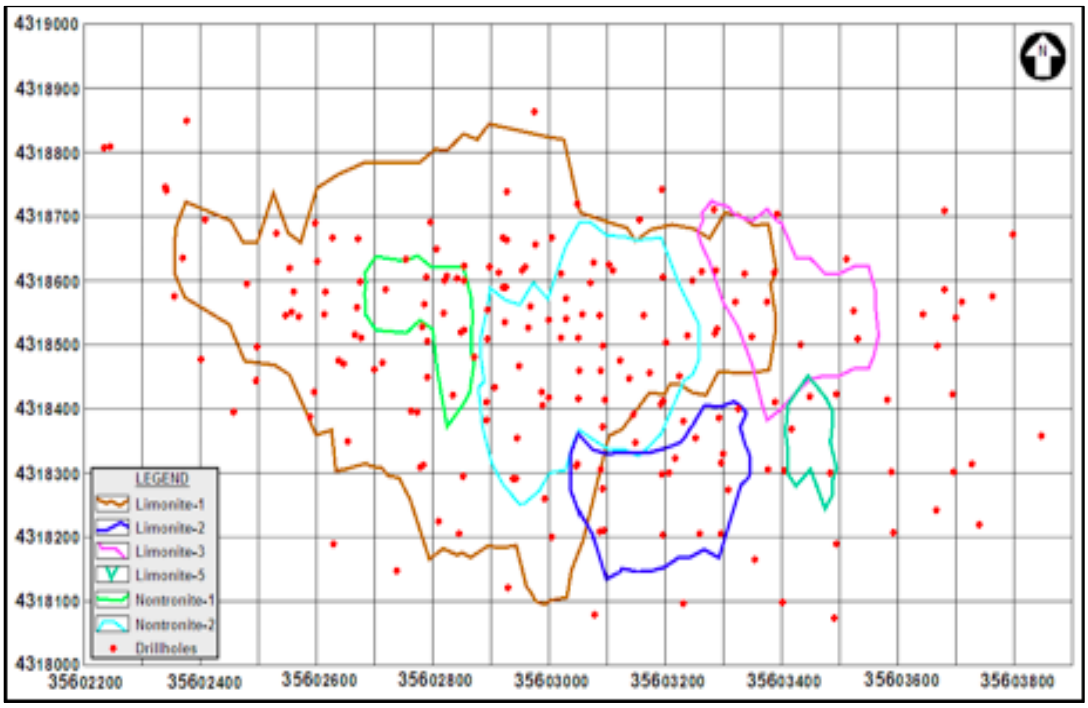


Figure 3.15 Drill hole locations at the Türkmençardağı open pit

By the end of 2008, a total length of 11,432.1 m drillholes have been opened in the Türkmençardağı open pit. 5,163.1 m of it is made by core drill while the rest (6,169 m) is made by reverse circulation drilling method.

The minimum and the maximum spacings between the drillholes are 35 m and 190 m, respectively where the average distance is 60 m. According to the lenses defined by META, the individual surface (map) areas of the lenses and the number of drillholes within each lens are determined.

During drilling process some problems were observed. Due to these problems, the core recoveries from these holes were affected negatively and this caused problems in resource estimation. Ore recovery problems associated with core drilling are as follows;

i. **<u>Heterogeneous structure of rock:</u>** In some places, the limonitic ore contains silica layers or boulders in different sizes (Figure 3.16). Generally the nickel is in fine grain within the limonitic ore, when the drill bit hits high strength silica, it is possible that some of the fine grained Ni is washed away by the drilling fluid hence lowering the grade of the core sample.

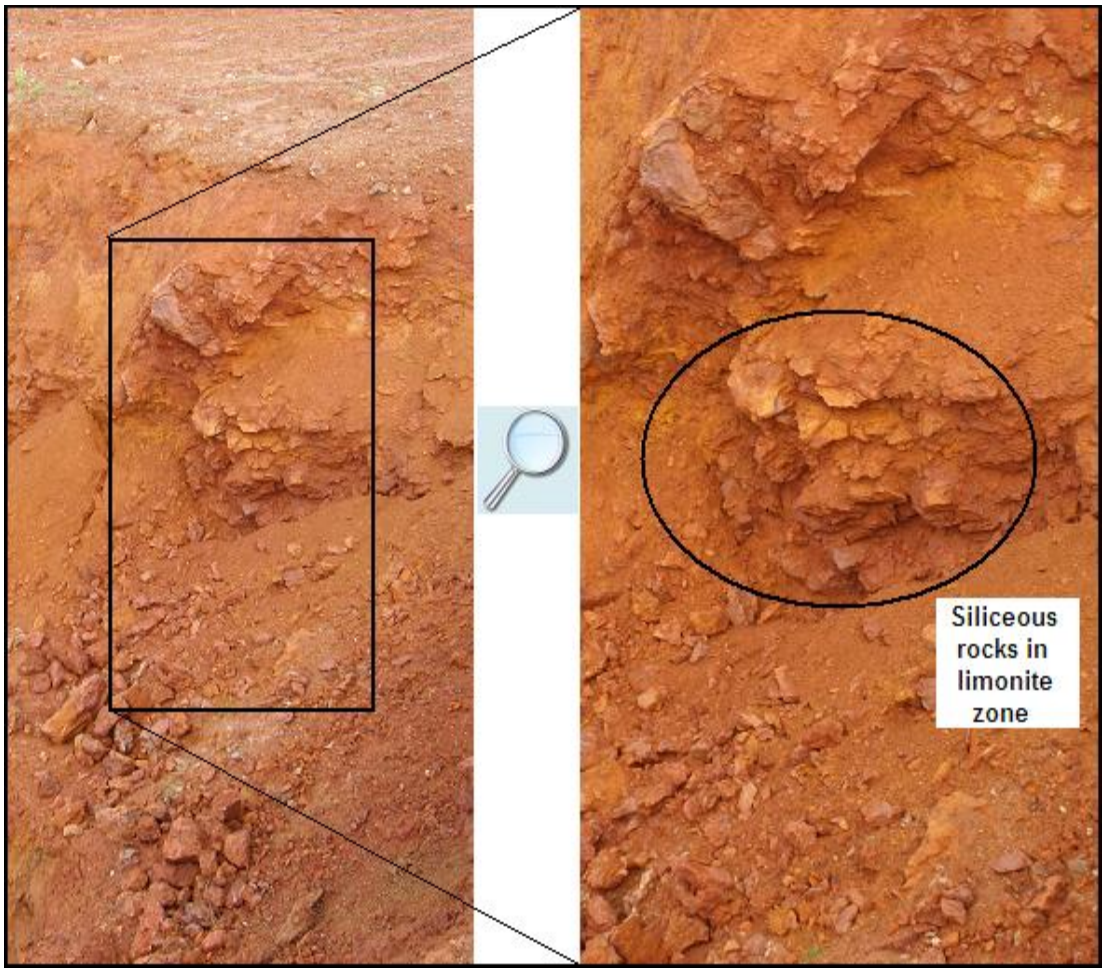


Figure 3.16 View of siliceous rocks in limonite zone

ii. **<u>Use of different bit types:</u>** Often clayey and high graded Ni mineralization zones underlying the hard and siliceous levels. When thick, hard and strong siliceous layers met, these siliceous levels were drilled by rock bits instead of diamond bits. At these types of transition

zones there is loss of Ni because rock bits could not take samples. In addition to that if the rock bit passed into soft zones beneath the silica, the thicknesses of mineralization zones could not be taken accurately.

Recovery problems associated with RC drilling that may also lead to underestimation of Ni grades are as follows;

i. **Ore loss in the cyclone:** Especially in high grade limonitic rock, the Ni grade is in very fine particles in situ. During the drilling process some of the dust materials escape from the top of the cyclone and this could reduce the Ni grade estimation (Figure 3.17).

Figure 3.17 Dust like particles in limonite parts in siliceous zones RC drilling

ii. **Less recovery due to wall squeeze:** Another potential problem occurred in soft clayey zones where the RC drill crushed the ground instead of cutting. Crushed material was pushed and compressed to the wall of the drillhole and less material was taken from drilling.

iii. **Contamination due to drillhole wall collapse:** At siliceous limonitic mineralization regions, if moisture content of material is low, the circulation of air became more difficult and air blew into gaps increasing its velocity and samples could be contaminated from the upper parts of the bore walls.

3.3.4 Test Pit Column Sampling

In order to determine drilling losses, META excavated test pits at surface area covering 12 drillholes where surface mineralization was determined in 2008. Vertical channel samples are taken to replicate drill holes at the same place as the drill holes. To reveal the probable drilling losses and adequate comparison, sampling was done from the same meters with the drillholes. This study was carried out on 7 core drilling and 5 RC drilling.

First of all, sampling units and interval(s) were defined. Then face of test pits was cleaned by a hammer or a trowel until the fresh (uncovered) surface appeared. After that, channels with the same geometry were excavated (5 cm in depth and 15 cm in width) by a hammer or a trowel and sample was taken by the trowel below. Great attentions paid to have sufficient amount of representative samples of excavated surface. Hence each wall of the pit clearly (carefully) defined before taking sample.

Stratigraphical changes in the wall were assessed to determine where samples had to be taken within lithological types. Test channels (column) opened in lithological units with no defined orientation or bedding like laterites were oriented in the N – S

direction. In sampling hard-wearing plastic or fabric bags were used. Labels were used while sampling on field, also notes were recorded on every sample.

An example of this column sampling is shown in Figure 3.18 and detail is in Figure 3.19. Some representative column sampling visuals are given in Appendix – A.

Figure 3.18 Column sampling view at face

Figure 3.19 Close view of column sampling

CHAPTER 4

NICKEL RESOURCE ESTIMATION IN TÜRKMENÇARDAĞI LATERITE DEPOSITS BY KRIGING AND INVERSE DISTANCE WEIGHTING METHODS

4.1 Resource Estimation and Evaluation of Türkmençardağı Laterite Deposits

Nickel bearing rocks has a variable structure. It shows abrupt changes over short distances. In polygonal methods it is assumed that grade value does not change in the polygonal area. But this approach can not fit the nonhomogeneous deposits like nickel laterites. In order to apply this method the deposit should have tabular or vein type structure.

As explained before triangular method approach is a modification of polygonal method. As it is expected the logic behind this approach is similar with polygonal method. In triangular methods it is assumed that grade does not change in the triangular area. Because of the non-homogeneity this method is not suitable for nickel laterites either.

The same situation is also valid for the cross-sectional method. According to cross-sectional method approach grade value in the cross-sectional area does not change. But in reality nickel laterites have such a structure that grade value can be change even in 1 meter distance. Therefore this method is also not suitable for Türkmençardağı nickel laterites.

Based on the fact that explained above deposits having irregular and non-homogeneous structures can not be estimated by using polygonal, triangular, and cross-sectional methods.

Hence, in this study inverse distance weighting and kriging methods are investigated to find out which one is more suitable for nickel laterites.

4.1.1 Reconciliation Work Plan

To analyze which resource estimation method is more suitable for the study area, a reconciliation pit was excavated. Reconciliation pit area was determined according to location and previous drillholes analysis results. An area of 130 m in EW direction (between 35602450E - 35602580E) and 100 m in NS direction (between 4318550N - 4318650N) was defined as the most suitable location for reconciliation work.

The importance of this area is that Limonite-1 lenses are very near to topographic surface in its west of outside of the pit. As mentioned earlier 70% of Türkmençardağı deposit consists of Limonite-1 lenses.

As it is mentioned before core drilling of siliceous levels causes a systematic fall in nickel grade of limonite since soft limonite ore in siliceous zones were washed up by drilling liquid. On the other hand, in RC drilling, limonitic material between siliceous zones were removed just like dust particles.

In clayish zones, being relatively soft and damp, RC drilling causes the material to perfuse on the wall of drillholes. Generally in this type of ground, hard particles such as serpentine could be carried out by air and finally removed.

Therefore, in the reconciliation pit, twin drilling (RC drilling + core drilling) holes and sampling channels were applied at the same location. For this study total of 13

twin drilling work was done. The locations of reconciliation pit area can be seen from Figure 4.1.

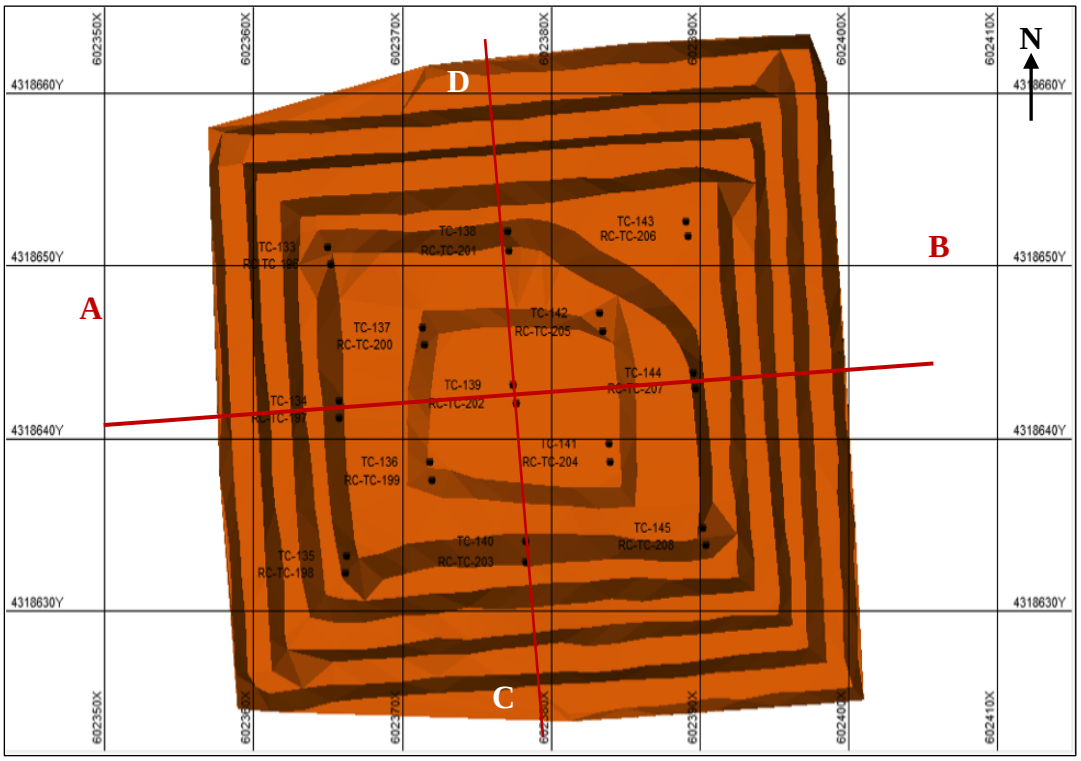


Figure 4.1 The top view of the reconciliation pit and drillholes location

The dimension of 40 m x 40 m x 15 m in x-y-z directions was defined for test pit production. 13 RC drilling totally 230 m were completed in reconciliation pit area. After RC drilling work, 13 core drilling holes which were located 1 m north of RC drilling were done. Core drilling was totally 225 m.

The spacing between twin drillings was 10 m in the EW direction and 12 m in the NS direction. To see the benches, bench heights and bench numbers the AB (EW) section view of the reconciliation pit area is given on Figure 4.2. Additionally CD (NS) section can be seen on Figure 4.3.

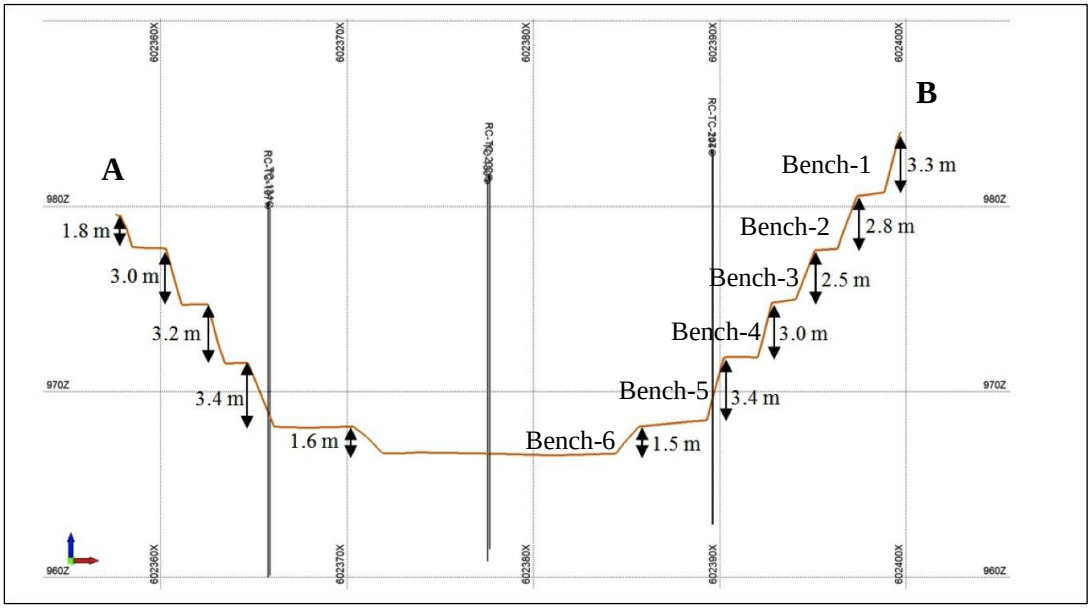


Figure 4.2 Section view of reconciliation area in EW direction (AB section)

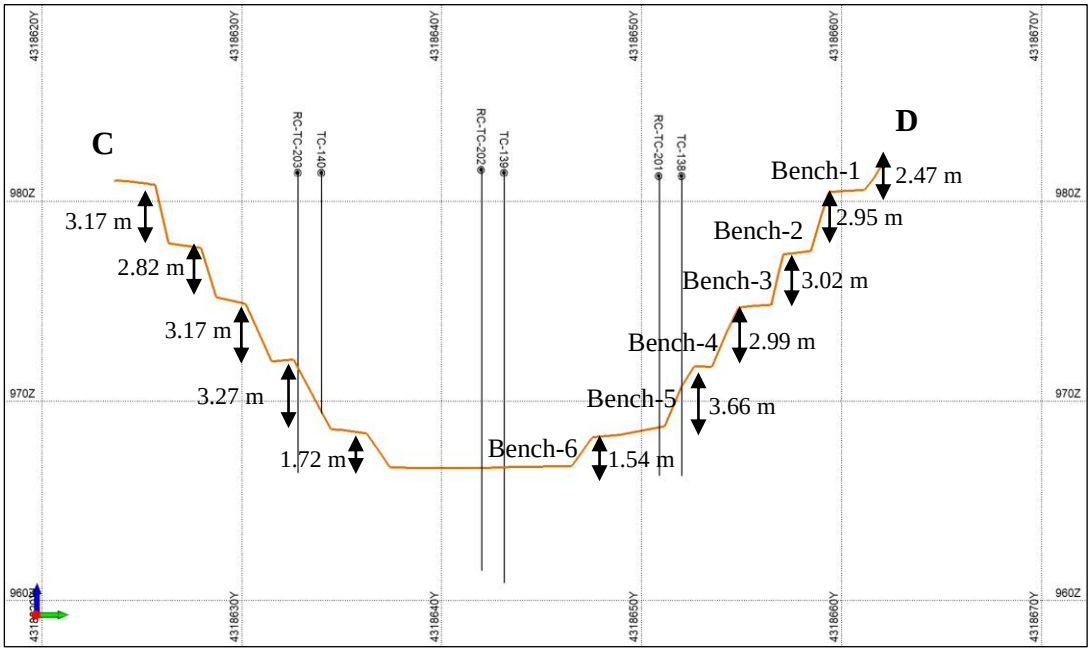


Figure 4.3 Section view of reconciliation area in NS direction (CD section)

Reconciliation work in the test pit was carried out as follows;

1. Drilling of RC holes and sampling at 1 m interval from these holes and analyze the cores for Ni contents,
2. Recording the lithology along with drillholes,
3. Examining the assay values and the lithology,
4. Suggesting a core drilling nearby each RC hole where appropriate,
5. Repeat the same procedure in part 1,
6. Estimating the mean Ni values of the blocks by inverse distance squared method and ordinary kriging method using Ni assay data,
7. Producing the ore and take the representative bulk samples and analyze them for Ni contents,
8. Comparing the production data with block model data.

The RC and core drilling locations in the reconciliation area presented in Figure 4.4.

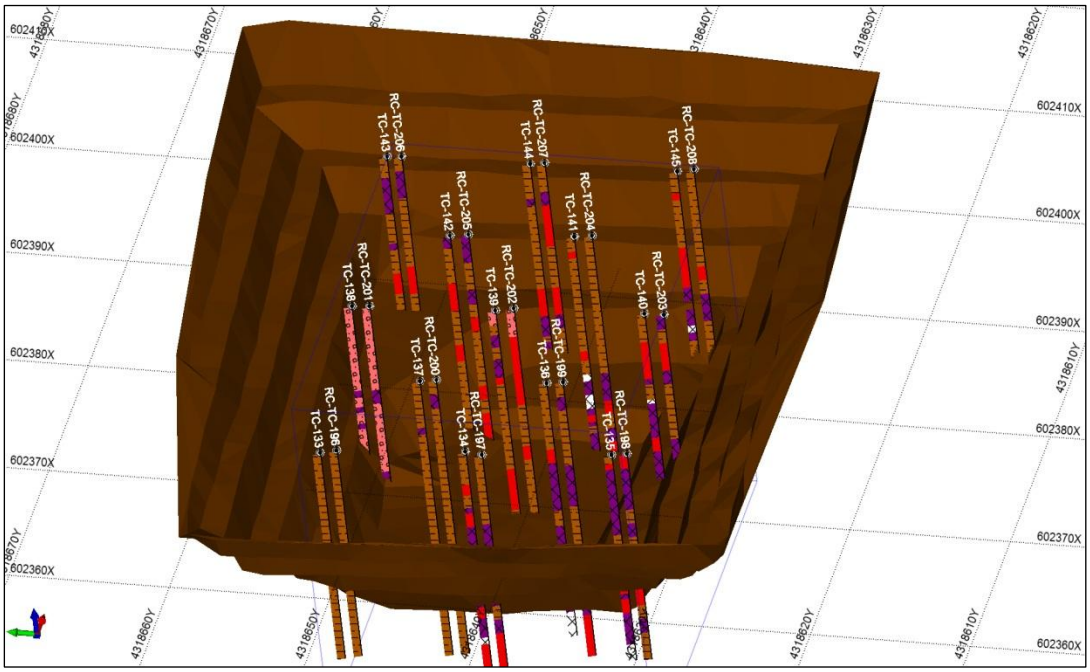


Figure 4.4 The RC and core drilling locations

The cross-section and model cut-off visuals are represented in Appendix-B.

4.1.1.1 Comparison of Core Drilling with Reconciliation Pit Column Sampling Data

A representative comparison graph of column sampling results and core drilling results are given in the Figure 4.5.

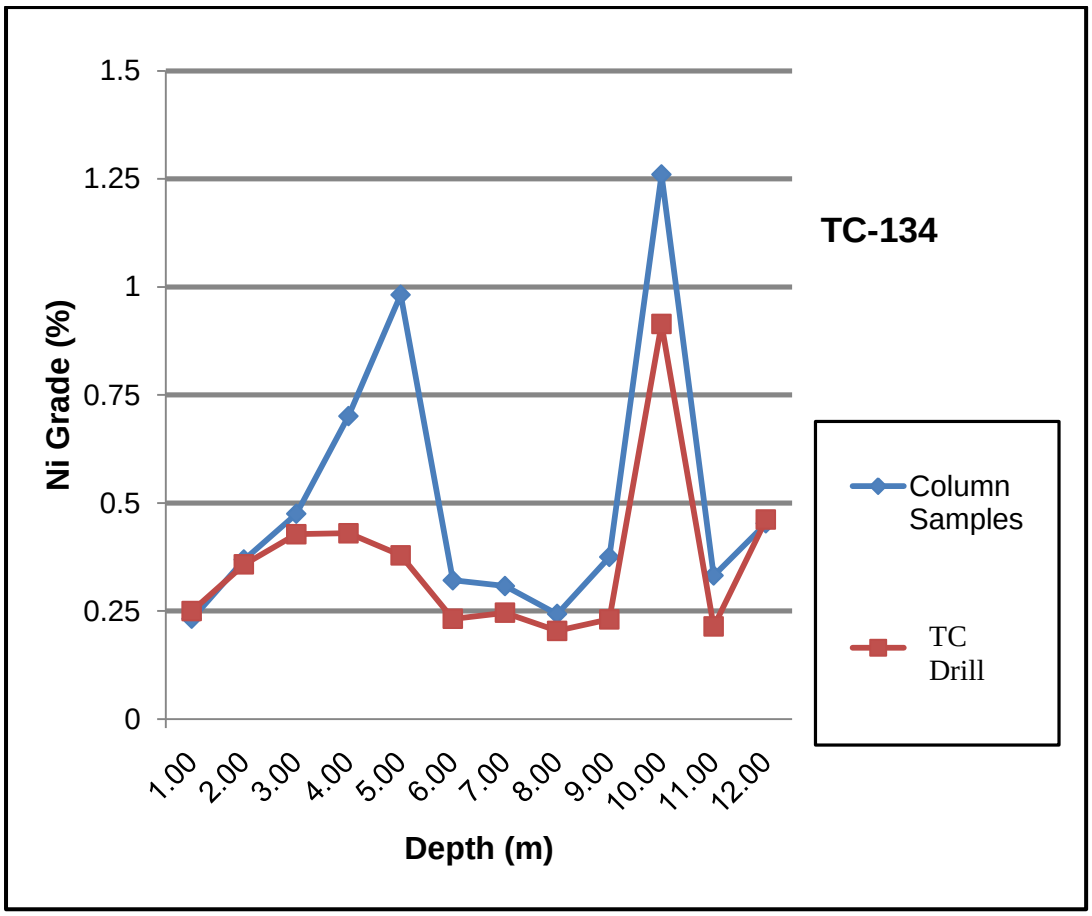


Figure 4.5 Comparison of TC-134 core drilling data with related column sampling data in the reconciliation pit

As it can be seen from the graph; in the drillhole coded TC-134 column sample analysis results approximately 22% higher in average nickel grade. The effect of

22% difference between these two data can be seen while comparing modeling results with the actual production data. In addition, generally column sampling grades are higher.

The rest of the study results of TC-133, TC-135, TC-136, TC-137, TC-138, TC-139, TC-140, TC-141, TC-142, TC-143, TC-144 and TC-145 drillholes are shown in the Appendix-C.

4.1.1.2 Comparison of Reverse Circulation Drilling with Reconciliation pit Column Sampling Data

A representative comparison graph of column sampling results and reverse circulation drilling results is given in the Figure 4.6.

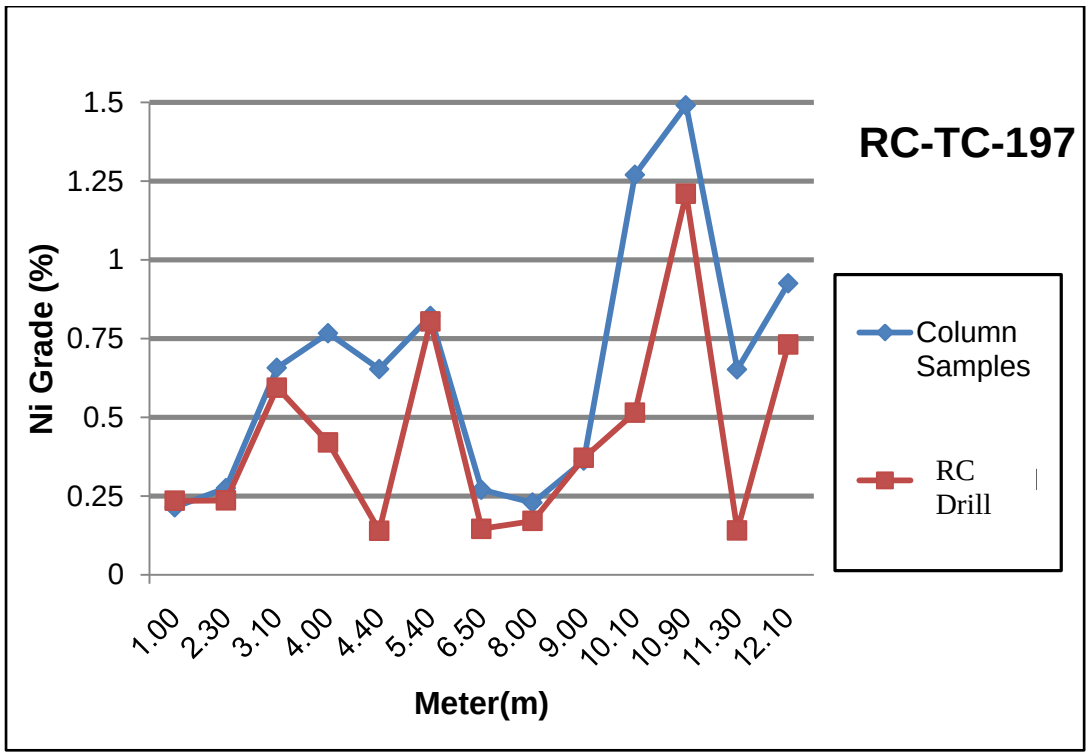


Figure 4.6 Comparison of RC-TC-197 RC drilling data with related column sampling data in the reconciliation pit

As it can be seen from the Figure 4.6, in the drillhole coded RC-TC-197 column sample analysis results are approximately 30% higher in average nickel grade. The effect of 30% difference between these two data can be seen while comparing modeling results with the actual production data.

The rest of the study results of RC-TC-196, RC-TC-197, RC-TC-198, RC-TC-199, RC-TC-200, RC-TC-201, RC-TC-202, RC-TC-203, RC-TC-204, RC-TC-205, RC-TC-206, RC-TC-207 and RC-TC-208 drillholes are shown in Appendix-D.

All 26 drilling logs belonging to reconciliation pit area are shown in Appendix-E.

4.1.2 Actual Production Results of Reconciliation Pit

Actual production was done by applying selective mining methods with trucks and shovels. The reconciliation pit area had 6 benches in east direction and 5 benches in west direction having approximately 2.75 meter depth. Each truck was numbered and material carried out stocked separately. From these stocks representative samples were taken by sampling method and analyzed to calculate the actual production figures. According to the analysis results stocks were combined based on their Ni grade values.

Based on these analysis 11,865 m^3 and 23,689 tonnes with 0.367 % Ni grade ore were produced in Türkmençardağı - Gördes reconciliation pit. When the cut-off grade was taken into account as 0.5 %, the produced amount was 4,882 tonnes with 0.649 % Ni grade.

The actual production values of each bench are also calculated, and the results are tabulated in Table 4.1.

Table 4.1 Actual production results of each bench

Bench No		1	2	3	4	5	6
Cut-Off (-)	Tonnage	3301	7052	5637	4212	2913	574
	%Ni	0,234	0,312	0,382	0,423	0,517	0,485
Cut-Off Ni ≥ 0.1%	Tonnage	3,301	7,052	5,612	4,212	2,913	547
	%Ni	0.234	0.312	0.384	0.423	0.517	0.508
Cut-Off Ni ≥ 0.2%	Tonnage	3,075	6,972	5,612	4,212	2,913	547
	%Ni	0.236	0.313	0.384	0.423	0.517	0.508
Cut-Off Ni ≥ 0.3%	Tonnage	62	2,966	3,209	3,054	2,2	526
	%Ni	0.333	0.418	0.491	0.491	0.602	0.518
Cut-Off Ni ≥ 0.4%	Tonnage		1,304	2,181	2,111	1,92	362
	%Ni		0.514	0.557	0.557	0.640	0.588
Cut-Off Ni ≥ 0.5%	Tonnage		716	1,387	1,163	1,43	187
	%Ni		0.572	0.618	0.651	0.704	0.738
Cut-Off Ni ≥ 0.6%	Tonnage		232	641	703	1,047	128
	%Ni		0.651	0.701	0.729	0.764	0.827

Additionally the total actual production values are tabulated in Table 4.2.

Table 4.2 Actual production results

Cut-off Grade (%)	Tonnage (tonnes)	Ni Grade (%)
0.0	23,689	0.367
0.1	23,638	0.368
0.2	23,332	0.370
0.3	12,017	0.494
0.4	7,877	0.572
0.5	**4,882**	**0.649**
0.6	2,751	0.734
0.7	1,485	0.809

The production results are shown on Table 4.2 at 0.5 Nickel cut-off grade tonnage and grade are 4,882 and 0.649 respectively. The cut-off Ni grade for determination of the economic limits of mining has been set at 0.5% by META and the modeling results evaluated according to this cut-off grade.

4.1.3 Resource Estimation of Türkmençardağı Laterite Deposits by Kriging Method

The experimental variograms in the downhole and main horizontal directions were calculated and interpretable results were obtained for the reconciliation pit area. The variogram model parameters determined by Tercan (2012) are listed in Table 4.3 where C_0 is nugget effect, C_1 is sill and C_2 is $sill_2$, a_1 is $range_1$ and a_2 is $range_2$.

Table 4.3 Variogram model parameters (Tercan, 2012)

Reconciliation Pit	
C_0	0.006
C_1	0.025
C_2	0.030
a_1 (m)	1.4 (down hole)
	1.6 (horizontal)
a_2 (m)	14 (down hole)
	18 (horizontal)

Composite length was taken as 1 m. Moreover, both variograms are spherical. Weighted average procedure was applied for composite left overs. Figure 4.7 and Figure 4.8 shows the experimental horizontal and vertical variograms.

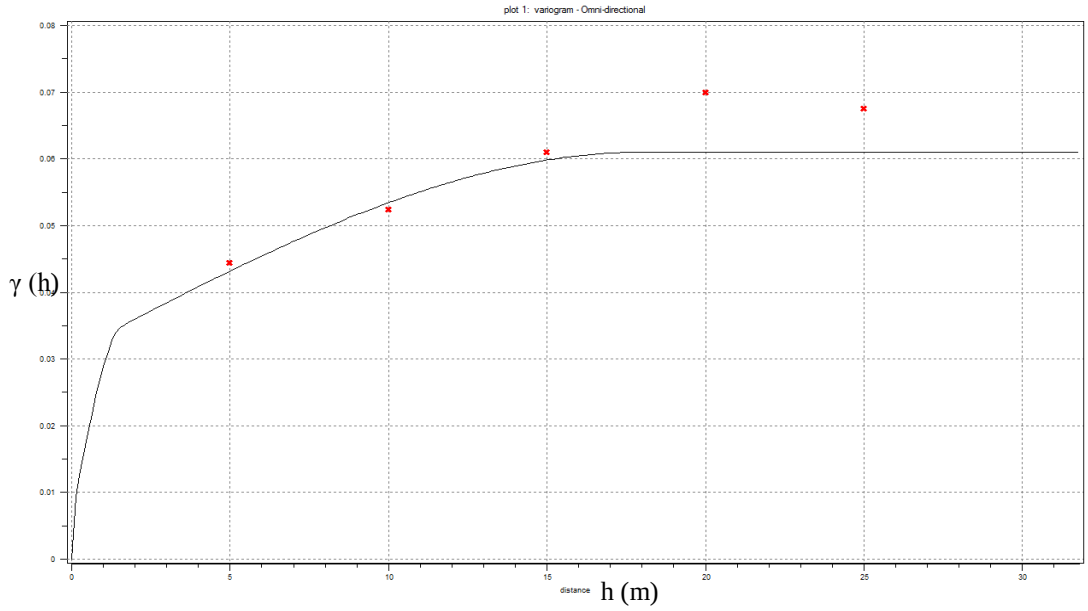


Figure 4.7 The omni-directional variogram of data in the reconciliation pit (Tercan, 2012)

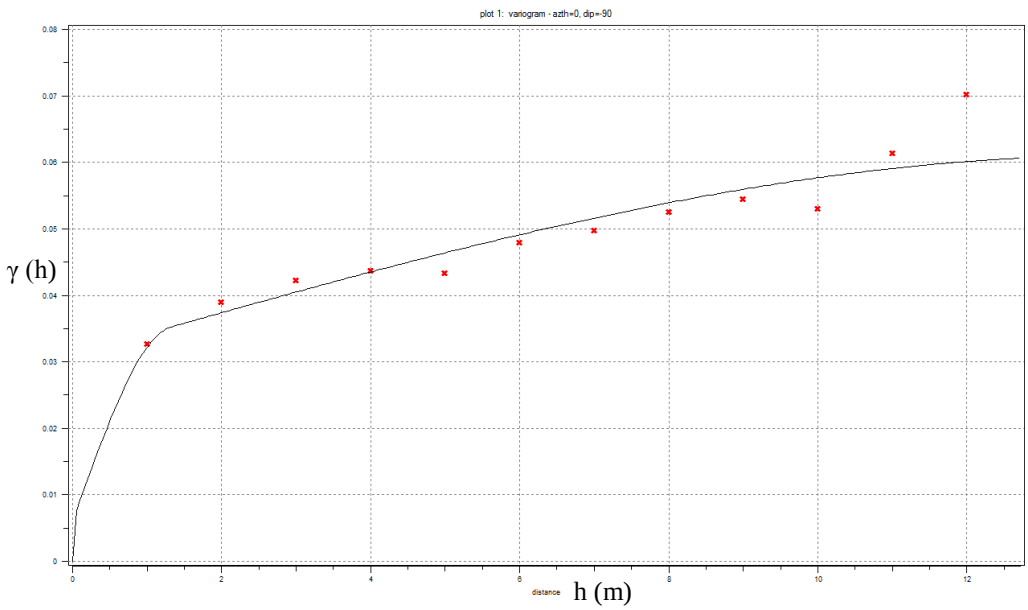


Figure 4.8 The vertical variogram of data in the reconciliation pit (Tercan, 2012)

In order to test that the whether variogram models were not grossly incorrect or not, cross validation test was carried out. Table 4.4 shows cross validation results. The mean value was near to zero, the variance and mean kriging variance values were almost the same and additionally, the error value was close to 95%, so the results indicate that the variogram models were not inconsistent.

Table 4.4 Cross validation statistics (Tercan, 2012)

Reconciliation pit	
Mean	0.0001
Variance	0.0368
Number of data	454
Mean kriging variance	0.0363
Error % in ± 2σ	96

Block sizes were 5 m by 5 m horizontal by 3 m in vertical direction. Sub-blocking with sizes of 2.5 m by 2.5 m horizontal by 1.5 m in vertical elevation was also considered. Average block grades were estimated using ordinary kriging which is practical assumption in mining industry. The search strategy used to determine which nearby drill holes and which composites used for estimation is given in Table 4.5 (Tercan, 2012). These values were chosen based on the variogram parameters.

Table 4.5 The search strategy parameters

Minimum number of samples	3
Maximum number of samples	20
Azimuth of major axis	0
Search distance of major axis (m)	20
Search distance of minor axis (m)	20
Search distance of vertical axis (m)	15

At first for modeling the reconciliation pit area drillholes data were used therefore the density was taken as 1.7 t/m^3. The grade tonnage change with respect to benches based on both drilling and column data can be seen from Table 4.6.

Table 4.6 Grade tonnage change with respect to benches based on both drilling and column data (density: 1.7 t/m^3)

		RC-DD DATA			AP		COLUMN DATA		
		Volume	Tonnage	% Ni	Tonnage	% Ni	Volume	Tonnage	% Ni
BENCH-1	Cut-Off (-)	1528	2598	0.251	3301	0.234	1528	2598	0.257
	Cut-Off Ni ≥ 0.1%	1528	2598	0.251	3301	0.234	1528	2598	0.257
	Cut-Off Ni ≥ 0.2%	1238	2104	0.264	3075	0.236	1528	2598	0.257
	Cut-Off Ni ≥ 0.3%	225	383	0.342	62	0.333	225	383	0.339
	Cut-Off Ni ≥ 0.4%								
	Cut-Off Ni ≥ 0.5%								
	Cut-Off Ni ≥ 0.6%								
BENCH-2	Cut-Off (-)	3750	6375	0.295	7052	0.312	3750	6375	0.301
	Cut-Off Ni ≥ 0.1%	3750	6375	0.295	7052	0.312	3750	6375	0.301
	Cut-Off Ni ≥ 0.2%	3525	5993	0.301	6972	0.313	3750	6375	0.301
	Cut-Off Ni ≥ 0.3%	1584	2693	0.377	2966	0.418	1716	2917	0.369
	Cut-Off Ni ≥ 0.4%	347	590	0.439	1304	0.514	328	558	0.419
	Cut-Off Ni ≥ 0.5%	75	128	0.504	716	0.572			
	Cut-Off Ni ≥ 0.6%				232	0.651			
BENCH-3	Cut-Off (-)	2962	5036	0.326	5637	0.382	2962	5036	0.378
	Cut-Off Ni ≥ 0.1%	2962	5036	0.326	5612	0.384	2962	5036	0.378
	Cut-Off Ni ≥ 0.2%	2700	4590	0.338	5612	0.384	2962	5036	0.378
	Cut-Off Ni ≥ 0.3%	1603	2725	0.396	3209	0.491	2156	3666	0.431
	Cut-Off Ni ≥ 0.4%	881	1498	0.434	2181	0.557	1491	2534	0.476
	Cut-Off Ni ≥ 0.5%	28	48	0.504	1387	0.618	366	622	0.521
	Cut-Off Ni ≥ 0.6%				641	0.701			
BENCH-4	Cut-Off (-)	2100	3570	0.346	4212	0.423	2100	3570	0.424
	Cut-Off Ni ≥ 0.1%	2100	3570	0.346	4212	0.423	2100	3570	0.424
	Cut-Off Ni ≥ 0.2%	2025	3443	0.352	4212	0.423	2100	3570	0.424
	Cut-Off Ni ≥ 0.3%	1481	2518	0.399	3054	0.491	1481	2518	0.500
	Cut-Off Ni ≥ 0.4%	703	1195	0.452	2111	0.557	1256	2136	0.524
	Cut-Off Ni ≥ 0.5%	16	27	0.524	1163	0.651	741	1259	0.568
	Cut-Off Ni ≥ 0.6%				703	0.729	234	398	0.645
BENCH-5	Cut-Off (-)	1341	2279	0.353	2913	0.517	1341	2279	0.475
	Cut-Off Ni ≥ 0.1%	1341	2279	0.353	2913	0.517	1341	2279	0.475
	Cut-Off Ni ≥ 0.2%	1341	2279	0.353	2913	0.517	1341	2279	0.475
	Cut-Off Ni ≥ 0.3%	994	1689	0.392	2200	0.602	1097	1865	0.526
	Cut-Off Ni ≥ 0.4%	300	510	0.487	1920	0.640	947	1610	0.551
	Cut-Off Ni ≥ 0.5%	112	191	0.547	1430	0.704	600	1020	0.620
	Cut-Off Ni ≥ 0.6%	19	32	0.605	1047	0.764	356	606	0.650
BENCH-6	Cut-Off (-)	450	765	0.395	574	0.485	450	765	0.514
	Cut-Off Ni ≥ 0.1%	450	765	0.395	547	0.508	450	765	0.514
	Cut-Off Ni ≥ 0.2%	450	765	0.395	547	0.508	450	765	0.514
	Cut-Off Ni ≥ 0.3%	338	574	0.439	526	0.518	412	701	0.536
	Cut-Off Ni ≥ 0.4%	244	414	0.478	362	0.588	366	622	0.555
	Cut-Off Ni ≥ 0.5%	103	175	0.534	187	0.738	262	446	0.604
	Cut-Off Ni ≥ 0.6%	19	32	0.613	128	0.827	178	303	0.637

By using drillholes data at 0.5 nickel cut-off grade tonnage and grade are 749 and 0.527 respectively. By using column sampling data at 0.5 nickel cut-off grade tonnage and grade are 3,347 and 0.580 respectively. The total results of kriging method are tabulated in Table 4.7

Table 4.7 Kriging method results (density: 1.7 t/m^3)

		RC-DD DATA			AP		COLUMN DATA		
		Volume	Tonnage	% Ni	Tonnage	% Ni	Volume	Tonnage	% Ni
TOTAL	Cut-Off (-)	12131	20623	0.316	23689	0.367	12131	20623	0.363
	Cut-Off Ni ≥ 0.1%	12131	20623	0.316	23638	0.368	12131	20623	0.363
	Cut-Off Ni ≥ 0.2%	11278	19173	0.325	23332	0.370	12131	20623	0.363
	Cut-Off Ni ≥ 0.3%	6225	10583	0.391	12017	0.494	7088	12049	0.448
	Cut-Off Ni ≥ 0.4%	2475	4208	0.451	7877	0.572	4388	7459	0.508
	Cut-Off Ni ≥ 0.5%	441	749	0.527	4882	0.649	1969	3347	0.580
	Cut-Off Ni ≥ 0.6%	38	64	0.609	2751	0.734	769	1307	0.645

In fact after production, i.e. after calculating the actual production volume and tonnage, it was seen that the density should be 1.99 t/m^3. For this reason the analysis should revised by changing density.

The revised grade tonnage change (density: 1.99 t/m^3) based on both drilling and column data can be seen from Table 4.8.

Table 4.8 Kriging method results (density: 1.99 t/m^3)

		RC-DD DATA			AP		COLUMN DATA		
		Volume	Tonnage	% Ni	Tonnage	% Ni	Volume	Tonnage	% Ni
TOTAL	Cut-Off (-)	12131	24226	0.316	23689	0.367	12131	24226	0.363
	Cut-Off Ni ≥ 0.1%	12131	24226	0.316	23638	0.368	12131	24226	0.363
	Cut-Off Ni ≥ 0.2%	11278	22523	0.325	23332	0.370	12131	24226	0.363
	Cut-Off Ni ≥ 0.3%	6225	12432	0.391	12017	0.494	7088	14154	0.448
	Cut-Off Ni ≥ 0.4%	2475	4943	0.451	7877	0.572	4388	8762	0.508
	Cut-Off Ni ≥ 0.5%	441	880	0.527	4882	0.649	1969	3932	0.580
	Cut-Off Ni ≥ 0.6%	38	75	0.609	2751	0.734	769	1535	0.645

The revised grade tonnage change with respect to benches based on both drilling and column data can be seen from Table 4.9.

Table 4.9 Grade tonnage change with respect to benches based on both drilling and column data (density: 1.99 t/m^3)

		RC-DD DATA			AP		COLUMN DATA		
		Volume	Tonnage	% Ni	Tonnage	% Ni	Volume	Tonnage	% Ni
BENCH-1	Cut-Off (-)	1528	3052	0.251	3301	0.234	1528	3052	0.257
	Cut-Off Ni ≥ 0.1%	1528	3052	0.251	3301	0.234	1528	3052	0.257
	Cut-Off Ni ≥ 0.2%	1238	2472	0.264	3075	0.236	1528	3052	0.257
	Cut-Off Ni ≥ 0.3%	225	450	0.342	62	0.333	225	450	0.339
	Cut-Off Ni ≥ 0.4%								
	Cut-Off Ni ≥ 0.5%								
	Cut-Off Ni ≥ 0.6%								
BENCH-2	Cut-Off (-)	3750	7489	0.295	7052	0.312	3750	7489	0.301
	Cut-Off Ni ≥ 0.1%	3750	7489	0.295	7052	0.312	3750	7489	0.301
	Cut-Off Ni ≥ 0.2%	3525	7040	0.301	6972	0.313	3750	7489	0.301
	Cut-Off Ni ≥ 0.3%	1584	3163	0.377	2966	0.418	1716	3427	0.369
	Cut-Off Ni ≥ 0.4%	347	693	0.439	1304	0.514	328	655	0.419
	Cut-Off Ni ≥ 0.5%	75	150	0.504	716	0.572			
	Cut-Off Ni ≥ 0.6%				232	0.651			
BENCH-3	Cut-Off (-)	2962	5916	0.326	5637	0.382	2962	5916	0.378
	Cut-Off Ni ≥ 0.1%	2962	5916	0.326	5612	0.384	2962	5916	0.378
	Cut-Off Ni ≥ 0.2%	2700	5392	0.338	5612	0.384	2962	5916	0.378
	Cut-Off Ni ≥ 0.3%	1603	3201	0.396	3209	0.491	2156	4306	0.431
	Cut-Off Ni ≥ 0.4%	881	1760	0.434	2181	0.557	1491	2977	0.476
	Cut-Off Ni ≥ 0.5%	28	56	0.504	1387	0.618	366	731	0.521
	Cut-Off Ni ≥ 0.6%				641	0.701			
BENCH-4	Cut-Off (-)	2100	4194	0.346	4212	0.423	2100	4194	0.424
	Cut-Off Ni ≥ 0.1%	2100	4194	0.346	4212	0.423	2100	4194	0.424
	Cut-Off Ni ≥ 0.2%	2025	4045	0.352	4212	0.423	2100	4194	0.424
	Cut-Off Ni ≥ 0.3%	1481	2958	0.399	3054	0.491	1481	2958	0.500
	Cut-Off Ni ≥ 0.4%	703	1404	0.452	2111	0.557	1256	2509	0.524
	Cut-Off Ni ≥ 0.5%	16	32	0.524	1163	0.651	741	1479	0.568
	Cut-Off Ni ≥ 0.6%				703	0.729	234	468	0.645
BENCH-5	Cut-Off (-)	1341	2677	0.353	2913	0.517	1341	2677	0.475
	Cut-Off Ni ≥ 0.1%	1341	2677	0.353	2913	0.517	1341	2677	0.475
	Cut-Off Ni ≥ 0.2%	1341	2677	0.353	2913	0.517	1341	2677	0.475
	Cut-Off Ni ≥ 0.3%	994	1984	0.392	2200	0.602	1097	2191	0.526
	Cut-Off Ni ≥ 0.4%	300	599	0.487	1920	0.640	947	1891	0.551
	Cut-Off Ni ≥ 0.5%	112	224	0.547	1430	0.704	600	1198	0.620
	Cut-Off Ni ≥ 0.6%	19	38	0.605	1047	0.764	356	712	0.650
BENCH-6	Cut-Off (-)	450	899	0.395	574	0.485	450	899	0.514
	Cut-Off Ni ≥ 0.1%	450	899	0.395	547	0.508	450	899	0.514
	Cut-Off Ni ≥ 0.2%	450	899	0.395	547	0.508	450	899	0.514
	Cut-Off Ni ≥ 0.3%	338	674	0.439	526	0.518	412	823	0.536
	Cut-Off Ni ≥ 0.4%	244	486	0.478	362	0.588	366	731	0.555
	Cut-Off Ni ≥ 0.5%	103	206	0.534	187	0.738	262	524	0.604
	Cut-Off Ni ≥ 0.6%	19	38	0.613	128	0.827	178	356	0.637

4.1.4 Resource Estimation of Türkmençardağı Laterite Deposits by Inverse Distance Weighting Method

META has tried to obtain the most reliable geological model to predict tonnage and grade data of the ore body. The consistency between assay, coordinate, and lithology data were checked with 13 core drilling and 13 RC drilling data. The statistical properties of Ni in assay data are summarized in Table 4.10.

Table 4.10 Descriptive statistics of Ni assay data

Minimum	0.09
Maximum	1.98
No. of Points	454
Mean	0.37
Variance	0.0611
Standard Deviation	0.2471

When the histogram related to assay data was reviewed, it could be concluded as grade distribution is normal distribution. The grade distribution is given in Figure 4.9.

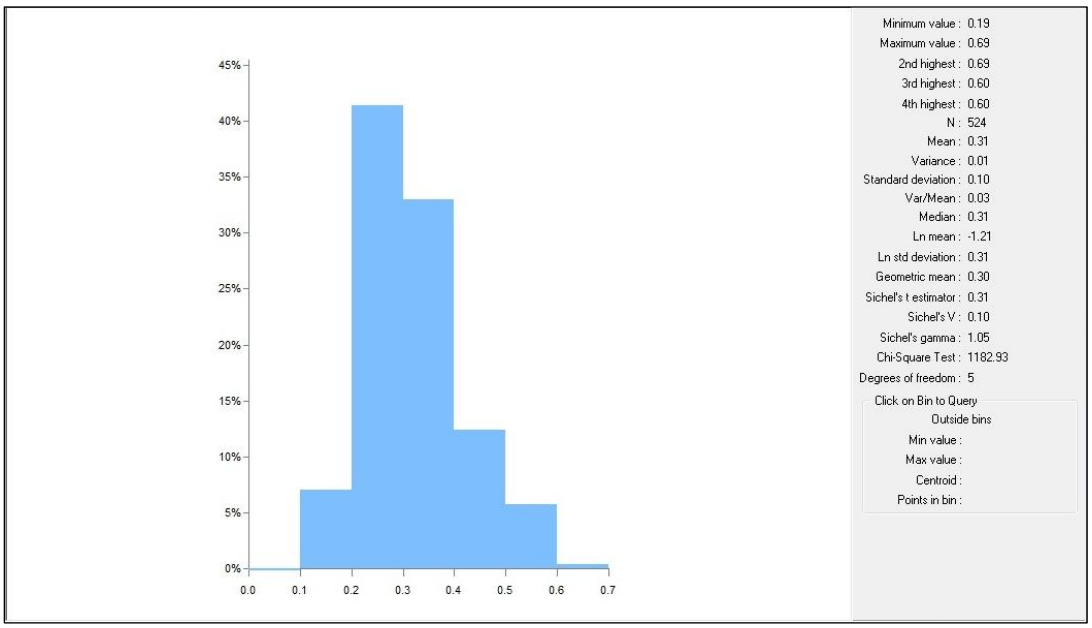


Figure 4.9 The grade distribution of Ni

The consistency between data was controlled as mentioned above and these data input to Micromine in order to check the accuracy again. After prepared drillhole data, the units considered as ore were visualized.

At first by taking sections from drillholes 3D solid model was generated and blocks were fitted to solid model. After that main block model was restrained by pit solid model in order to obtain reconciliation pit block model. Additionally, the compatibility with reconciliation pit had been checked.

The figure of the block model can be seen in the following figure (Figure 4.10).

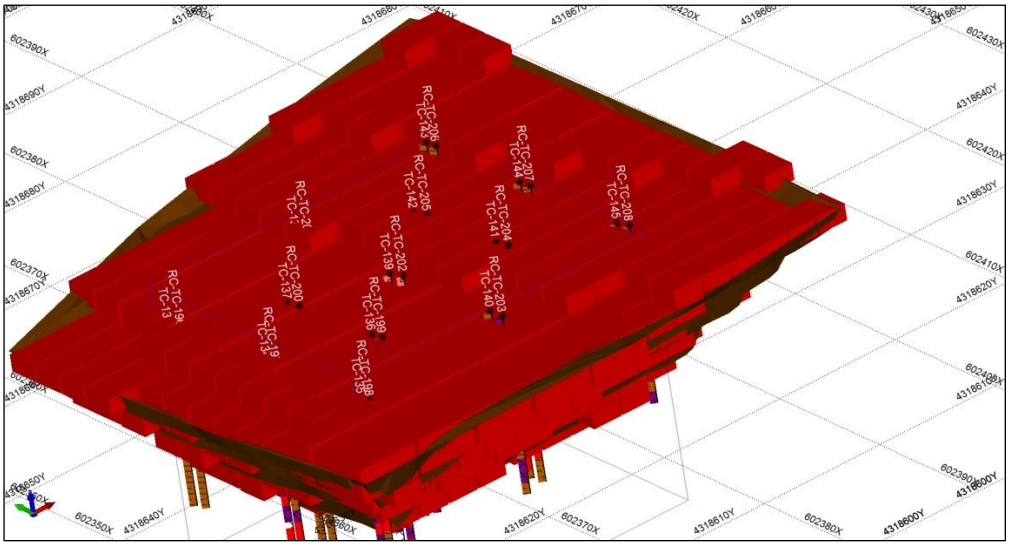


Figure 4.10 Block model view

The production volume was divided into main blocks and sub-blocks with equal shape and size. The size of main blocks are 5mx5mx3m and the number of them is 110 similarly the total number of sub-blocks having size 2.5mx2.5mx1.5m is 414. At first, again Ni grade values and 1.7 t/m^3 density were assigned to the obtained reconciliation pit block model. To assign the composite assay data to the Ni grade values inverse distance weighting method was used. In this method inverse distance weighting power factor was assumed as 2 because of the practical reasons in mining

industry. Also during this assigning procedure to the reconciliation pit block model a search ellipsoid was used. The properties of this search ellipsoid are tabulated in Table 4.11.

Table 4.11 Properties of search ellipsoid

Azimuth	0
Plunge	0
Azimuth factor	20
Dip	0
Dip Factor	20
Thick Factor	15

The data of search ellipsoid were chosen according to the data used in kriging method conducted by Tercan (2012). Additionally the view of the ellipsoid can be seen in Figure 4.11.

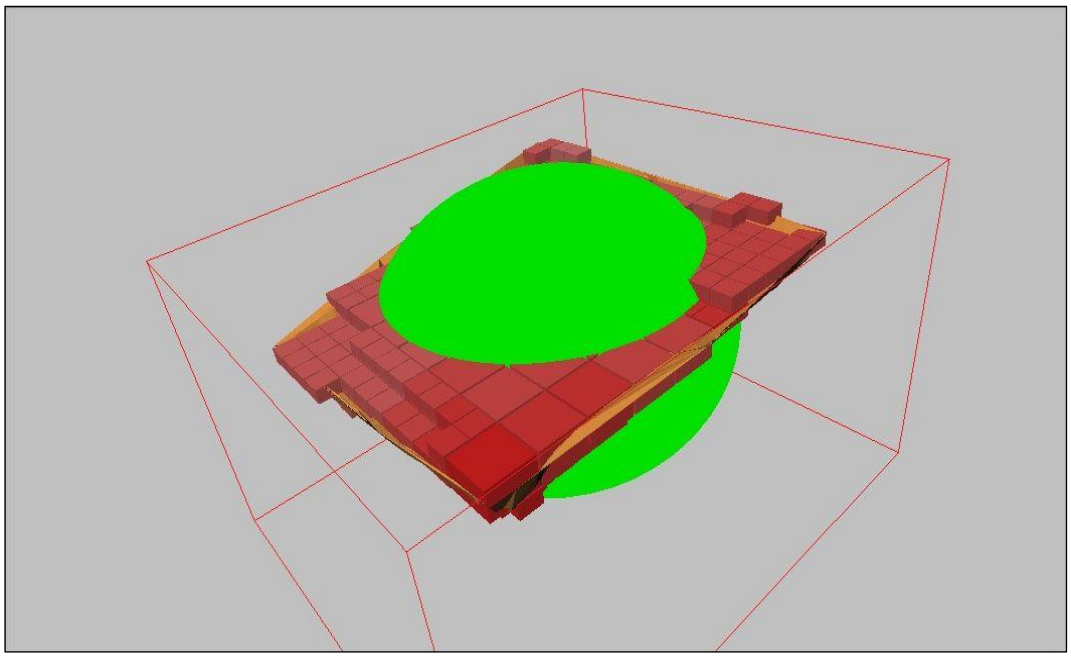


Figure 4.11 View of the search ellipsoid and solid model

After assigning the grades by inverse distance weighting method again the statistical properties were checked. The statistical properties of Ni in block model are summarized in Table 4.12.

Table 4.12 Descriptive statistics of Ni block data

Minimum	0.17
Maximum	1.72
No. of Points	614
Mean	0.32
Variance	0.0099
Standard Deviation	0.0993

When the histogram related to block data was plotted, it can be seen that the grade distribution shows normal distribution. The grade distribution is given in Figure 4.12.

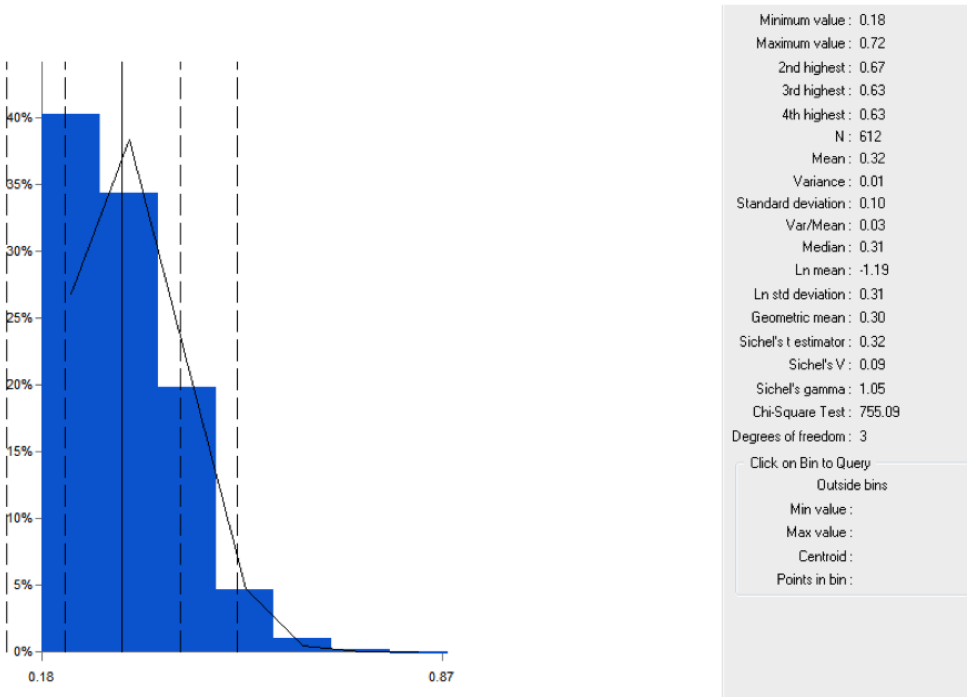


Figure 4.12 The grade distribution of Ni in blocks

Created block model by using composite assay data was visualized with drillholes and controlled. The same colour codes were assigned for the same grade intervals to observe the consistency between block model and drillhole. The view of this situation is given in the Figure 4.13.

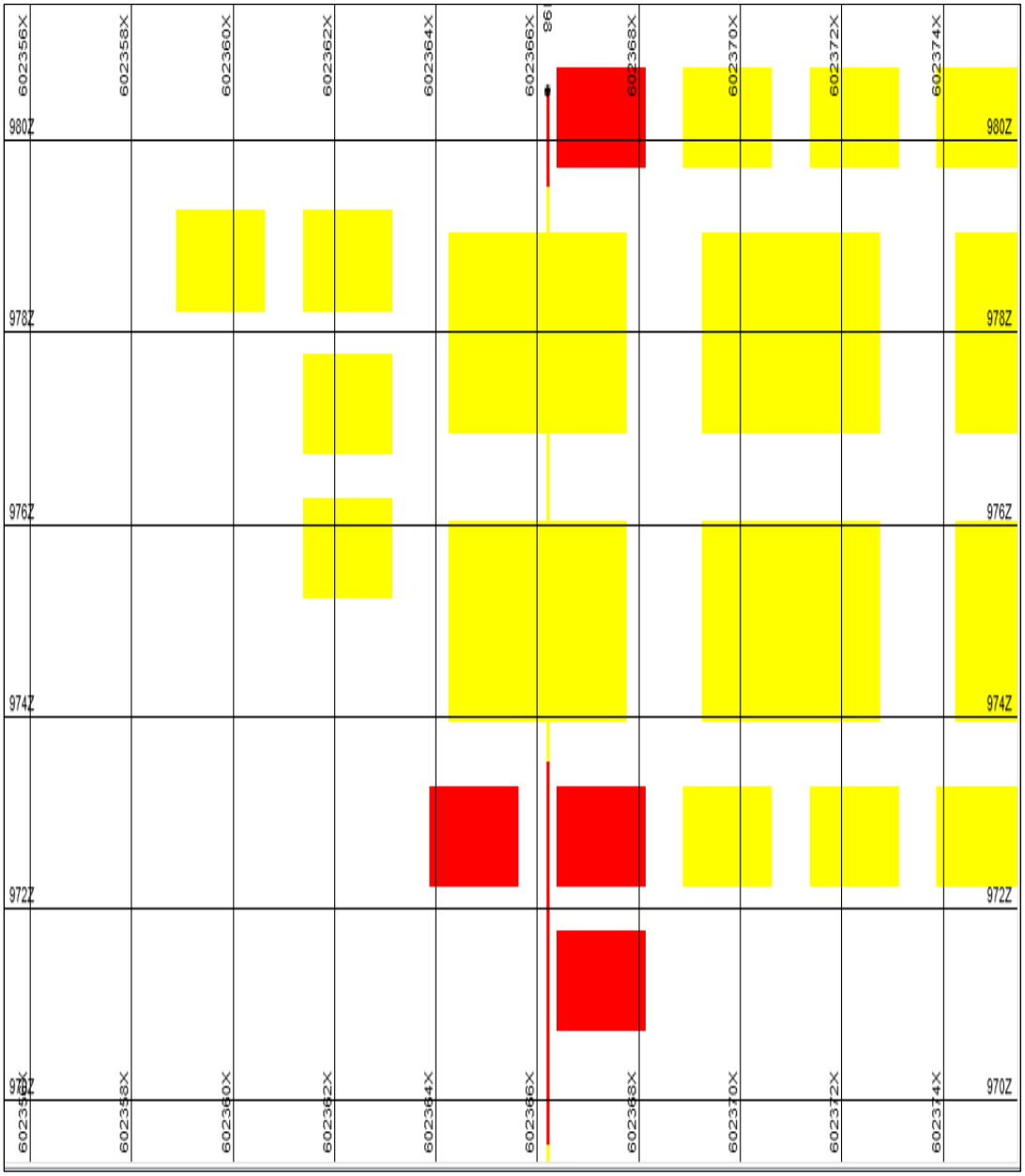


Figure 4.13 A view of block model with drillhole

The inverse distance weighting method grade and tonnage results based on both drilling and column data benches (density: 1.7 t/m^3) are tabulated in Table 4.13.

Table 4.13 The inverse distance weighting method results based on benches (density: 1.7 t/m^3)

		RC-DD DATA			AP		COLUMN DATA		
		Volume	**Tonnage**	**% Ni**	**Tonnage**	**% Ni**	**Volume**	**Tonnage**	**% Ni**
BENCH-1	Cut-Off (-)	1528	2598	0.243	3301	0.234	1528	2598	0.262
	Cut-Off Ni ≥ 0.1%	1528	2598	0.243	3301	0.234	1528	2598	0.262
	Cut-Off Ni ≥ 0.2%	975	1658	0.269	3075	0.236	1528	2598	0.262
	Cut-Off Ni ≥ 0.3%	262	446	0.350	62	0.333	225	383	0.366
	Cut-Off Ni ≥ 0.4%						9	16	0.412
	Cut-Off Ni ≥ 0.5%								
	Cut-Off Ni ≥ 0.6%								
BENCH-2	Cut-Off (-)	3750	6375	0.286	7052	0.312	3750	6375	0.305
	Cut-Off Ni ≥ 0.1%	3750	6375	0.286	7052	0.312	3750	6375	0.305
	Cut-Off Ni ≥ 0.2%	3525	5993	0.292	6972	0.313	3750	6375	0.305
	Cut-Off Ni ≥ 0.3%	1603	2725	0.366	2966	0.418	1791	3044	0.375
	Cut-Off Ni ≥ 0.4%	300	510	0.432	1304	0.514	609	1036	0.429
	Cut-Off Ni ≥ 0.5%				716	0.572			
	Cut-Off Ni ≥ 0.6%				232	0.651			
BENCH-3	Cut-Off (-)	2962	5036	0.327	5637	0.382	2962	5036	0.386
	Cut-Off Ni ≥ 0.1%	2962	5036	0.327	5612	0.384	2962	5036	0.386
	Cut-Off Ni ≥ 0.2%	2700	4590	0.339	5612	0.384	2962	5036	0.386
	Cut-Off Ni ≥ 0.3%	1716	2917	0.393	3209	0.491	2157	3667	0.442
	Cut-Off Ni ≥ 0.4%	816	1387	0.444	2181	0.557	1491	2534	0.494
	Cut-Off Ni ≥ 0.5%				1387	0.618	703	1195	0.534
	Cut-Off Ni ≥ 0.6%				641	0.701			
BENCH-4	Cut-Off (-)	2100	3570	0.344	4212	0.423	2100	3570	0.425
	Cut-Off Ni ≥ 0.1%	2100	3570	0.344	4212	0.423	2100	3570	0.425
	Cut-Off Ni ≥ 0.2%	2100	3570	0.344	4212	0.423	2100	3570	0.425
	Cut-Off Ni ≥ 0.3%	1331	2263	0.404	3054	0.491	1556	2646	0.486
	Cut-Off Ni ≥ 0.4%	497	845	0.475	2111	0.557	1331	2263	0.511
	Cut-Off Ni ≥ 0.5%	159	271	0.546	1163	0.651	591	1004	0.586
	Cut-Off Ni ≥ 0.6%				703	0.729	234	398	0.678
BENCH-5	Cut-Off (-)	1341	2279	0.349	2913	0.517	1341	2279	0.472
	Cut-Off Ni ≥ 0.1%	1341	2279	0.349	2913	0.517	1341	2279	0.472
	Cut-Off Ni ≥ 0.2%	1341	2279	0.349	2913	0.517	1341	2279	0.472
	Cut-Off Ni ≥ 0.3%	919	1562	0.391	2200	0.602	1097	1865	0.521
	Cut-Off Ni ≥ 0.4%	300	510	0.487	1920	0.640	947	1610	0.547
	Cut-Off Ni ≥ 0.5%	103	175	0.552	1430	0.704	478	813	0.639
	Cut-Off Ni ≥ 0.6%	19	32	0.693	1047	0.764	281	478	0.686
BENCH-6	Cut-Off (-)	450	765	0.397	574	0.485	450	765	0.504
	Cut-Off Ni ≥ 0.1%	450	765	0.397	547	0.508	450	765	0.504
	Cut-Off Ni ≥ 0.2%	450	765	0.397	547	0.508	450	765	0.504
	Cut-Off Ni ≥ 0.3%	375	638	0.425	526	0.518	441	749	0.509
	Cut-Off Ni ≥ 0.4%	244	414	0.487	362	0.588	366	622	0.539
	Cut-Off Ni ≥ 0.5%	103	175	0.566	187	0.738	253	430	0.584
	Cut-Off Ni ≥ 0.6%				128	0.827	141	239	0.622

By using drillholes data at 0.5 nickel cut-off grade tonnage and grade are 622 and 0.553 respectively. By using column sampling data at 0.5 nickel cut-off grade tonnage and grade are 3,443 and 0.580 respectively.

The total results of inverse distance weighting method are tabulated in Table 4.14.

Table 4.14 Total inverse distance weighting method results (density: 1.7 t/m^3)

		RC-DD DATA			AP		COLUMN DATA		
		Volume	Tonnage	% Ni	Tonnage	% Ni	Volume	Tonnage	% Ni
TOTAL	Cut-Off (-)	12131	20623	0.312	23689	0.367	12131	20623	0.366
	Cut-Off Ni ≥ 0.1%	12131	20623	0.312	23638	0.368	12131	20623	0.366
	Cut-Off Ni ≥ 0.2%	11091	18854	0.322	23332	0.370	12131	20623	0.366
	Cut-Off Ni ≥ 0.3%	6206	10551	0.388	12017	0.494	7266	12352	0.449
	Cut-Off Ni ≥ 0.4%	2156	3666	0.460	7877	0.572	4753	8080	0.504
	Cut-Off Ni ≥ 0.5%	366	622	0.553	4882	0.649	2025	3443	0.580
	Cut-Off Ni ≥ 0.6%	19	32	0.693	2751	0.734	656	1116	0.669

Likewise, after production the analysis should be revised due to the change of the density. The revised total results (density: 1.99 t/m^3) can be seen on Table 4.15.

Table 4.15 Total inverse distance weighting method results (density: 1.99 t/m^3)

		RC-DD DATA			AP		COLUMN DATA		
		Volume	Tonnage	% Ni	Tonnage	% Ni	Volume	Tonnage	% Ni
TOTAL	Cut-Off (-)	12131	24226	0.312	23689	0.367	12131	24226	0.366
	Cut-Off Ni ≥ 0.1%	12131	24226	0.312	23638	0.368	12131	24226	0.366
	Cut-Off Ni ≥ 0.2%	11091	22148	0.322	23332	0.370	12131	24226	0.366
	Cut-Off Ni ≥ 0.3%	6206	12394	0.388	12017	0.494	7266	14510	0.449
	Cut-Off Ni ≥ 0.4%	2156	4306	0.460	7877	0.572	4753	9492	0.504
	Cut-Off Ni ≥ 0.5%	366	731	0.553	4882	0.649	2025	4045	0.580
	Cut-Off Ni ≥ 0.6%	19	38	0.693	2751	0.734	656	1311	0.669

The results of inverse distance weighting method based on benches (density: 1.99 t/m^3) are tabulated in Table 4.16.

Table 4.16 The inverse distance weighting method results based on benches (density: 1.99 t/m^3)

		RC-DD DATA			AP		COLUMN DATA		
		Volume	Tonnage	% Ni	Tonnage	% Ni	Volume	Tonnage	% Ni
BENCH-1	Cut-Off (-)	1528	3052	0.243	3301	0.234	1528	3052	0.262
	Cut-Off Ni≥ 0.1%	1528	3052	0.243	3301	0.234	1528	3052	0.262
	Cut-Off Ni ≥ 0.2%	975	1948	0.269	3075	0.236	1528	3052	0.262
	Cut-Off Ni ≥ 0.3%	262	524	0.350	62	0.333	225	450	0.366
	Cut-Off Ni ≥ 0.4%						9	19	0.412
	Cut-Off Ni ≥ 0.5%								
	Cut-Off Ni ≥ 0.6%								
BENCH-2	Cut-Off (-)	3750	7489	0.286	7052	0.312	3750	7489	0.305
	Cut-Off Ni≥ 0.1%	3750	7489	0.286	7052	0.312	3750	7489	0.305
	Cut-Off Ni ≥ 0.2%	3525	7040	0.292	6972	0.313	3750	7489	0.305
	Cut-Off Ni ≥ 0.3%	1603	3201	0.366	2966	0.418	1791	3576	0.375
	Cut-Off Ni ≥ 0.4%	300	599	0.432	1304	0.514	609	1217	0.429
	Cut-Off Ni ≥ 0.5%				716	0.572			
	Cut-Off Ni ≥ 0.6%				232	0.651			
BENCH-3	Cut-Off (-)	2962	5916	0.327	5637	0.382	2962	5916	0.386
	Cut-Off Ni≥ 0.1%	2962	5916	0.327	5612	0.384	2962	5916	0.386
	Cut-Off Ni ≥ 0.2%	2700	5392	0.339	5612	0.384	2962	5916	0.386
	Cut-Off Ni ≥ 0.3%	1716	3427	0.393	3209	0.491	2157	4308	0.442
	Cut-Off Ni ≥ 0.4%	816	1629	0.444	2181	0.557	1491	2977	0.494
	Cut-Off Ni ≥ 0.5%				1387	0.618	703	1404	0.534
	Cut-Off Ni ≥ 0.6%				641	0.701			
BENCH-4	Cut-Off (-)	2100	4194	0.344	4212	0.423	2100	4194	0.425
	Cut-Off Ni≥ 0.1%	2100	4194	0.344	4212	0.423	2100	4194	0.425
	Cut-Off Ni ≥ 0.2%	2100	4194	0.344	4212	0.423	2100	4194	0.425
	Cut-Off Ni ≥ 0.3%	1331	2658	0.404	3054	0.491	1556	3108	0.486
	Cut-Off Ni ≥ 0.4%	497	993	0.475	2111	0.557	1331	2658	0.511
	Cut-Off Ni ≥ 0.5%	159	318	0.546	1163	0.651	591	1179	0.586
	Cut-Off Ni ≥ 0.6%				703	0.729	234	468	0.678
BENCH-5	Cut-Off (-)	1341	2677	0.349	2913	0.517	1341	2677	0.472
	Cut-Off Ni≥ 0.1%	1341	2677	0.349	2913	0.517	1341	2677	0.472
	Cut-Off Ni ≥ 0.2%	1341	2677	0.349	2913	0.517	1341	2677	0.472
	Cut-Off Ni ≥ 0.3%	919	1835	0.391	2200	0.602	1097	2191	0.521
	Cut-Off Ni ≥ 0.4%	300	599	0.487	1920	0.640	947	1891	0.547
	Cut-Off Ni ≥ 0.5%	103	206	0.552	1430	0.704	478	955	0.639
	Cut-Off Ni ≥ 0.6%	19	38	0.693	1047	0.764	281	562	0.686
BENCH-6	Cut-Off (-)	450	899	0.397	574	0.485	450	899	0.504
	Cut-Off Ni≥ 0.1%	450	899	0.397	547	0.508	450	899	0.504
	Cut-Off Ni ≥ 0.2%	450	899	0.397	547	0.508	450	899	0.504
	Cut-Off Ni ≥ 0.3%	375	749	0.425	526	0.518	441	880	0.509
	Cut-Off Ni ≥ 0.4%	244	486	0.487	362	0.588	366	731	0.539
	Cut-Off Ni ≥ 0.5%	103	206	0.566	187	0.738	253	505	0.584
	Cut-Off Ni ≥ 0.6%				128	0.827	141	281	0.622

4.2 Comparison of Applied Estimation Methods with Actual Production Results

Analyzing the above results it can be said that both resource estimation methods quite compatible each other in terms of grade, but it is not the same for tonnage.

When the cut-off grade increases, the tonnage difference between the actual production and estimation method results also increases.

There is a huge difference that can not be ignored. In order to specify the difference between these values a difference table is created and shown in Table 4.17.

Table 4.17 Difference between the reconciliation pit production results and estimation methods results according to drillholes data

According to Tonnage (tonnes)					
Cut-off Grade	**Kriging results (KM)**	**Inverse distance weighting results (IDM)**	**Actual production results (AP)**	**Difference**	
				AP / KM	**AP / IDM**
0.0	20,622	20,622	23,689	1.15	1.15
0.1	20,622	20,622	23,638	1.15	1.15
0.2	19,173	18,854	23,332	1.22	1.24
0.3	10,582	10,281	12,017	1.14	1.17
0.4	4,206	3,665	7,877	1.87	2.15
0.5	**749**	**622**	**4,882**	**6.52**	**7.85**
0.6	64	32	2,751	42.98	85.97
According to Ni Grades (%)					
Cut-off Grade	**Kriging results (KM)**	**Inverse distance weighting results (IDM)**	**Actual production results (AP)**	**Difference**	
				AP / KM	**AP / IDM**
0.0	0.316	0.312	0.367	1.16	1.18
0.1	0.316	0.312	0.368	1.16	1.18
0.2	0.325	0.322	0.37	1.14	1.15
0.3	0.391	0.389	0.494	1.26	1.27
0.4	0.451	0.460	0.572	1.27	1.24
0.5	**0.527**	**0.553**	**0.649**	**1.23**	**1.17**
0.6	0.609	0.693	0.734	1.21	1.06

Without considering cut-off grades both for inverse distance weighting method and kriging method results were compared to actual production results. There exists

14.9% difference in tonnage values. This difference comes from siliceous rocks in the production stage. If the geologic solid model includes heterogeneous minerals such as ore and siliceous bed rock, then no estimation method can give reasonable results. So whether estimation method produces good results depends on goodness or representativeness of the solid model. If solid model includes heterogeneous zone, one never expect that estimation techniques produce current results.

The comparison of kriging and inverse distance weighting methods based on both drilling and column data with actual production figures based on tonnage values is given in Figure 4.14.

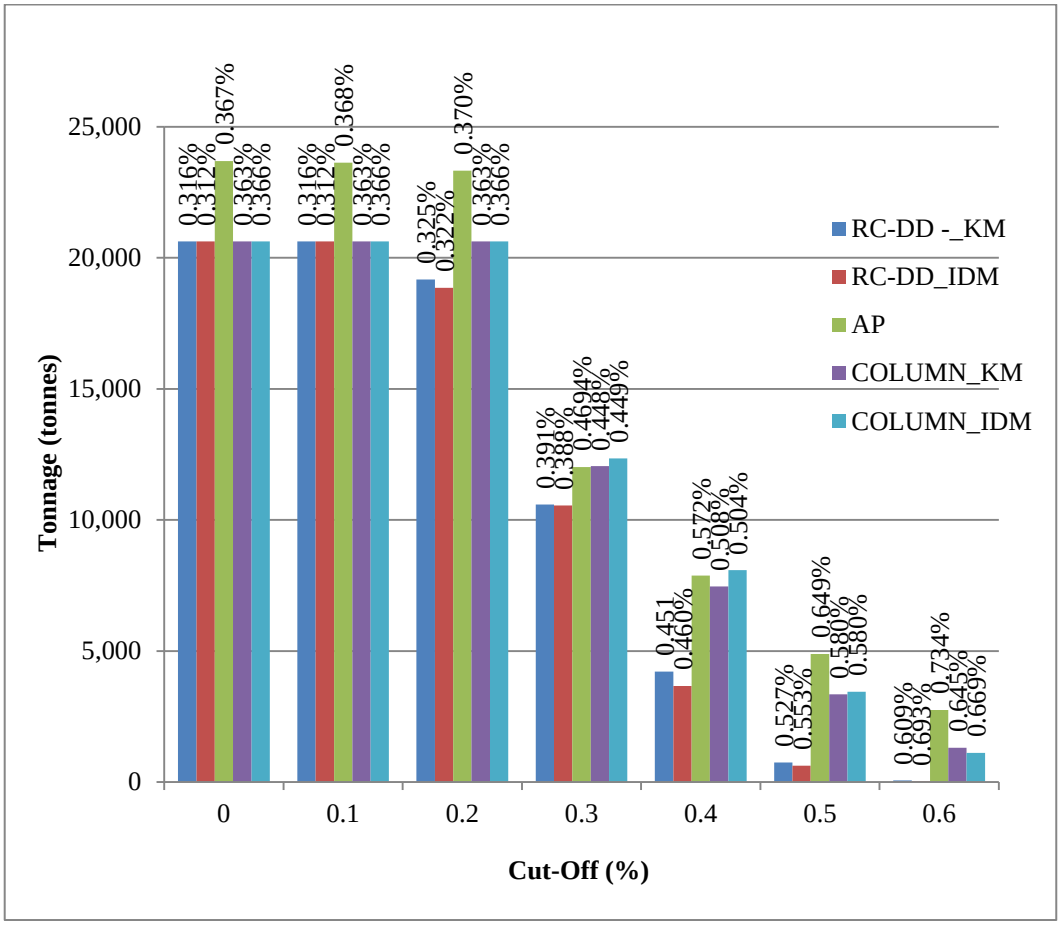


Figure 4.14 The comparison of applied estimation methods based on tonnage values (5x5x3 block sizes)

When 0.5% cut-off grade, which is the grade considered in the project, was applied the tonnage difference between kriging method results and actual production results becomes approximately 6.52 times. On the other hand the same case for the inverse distance weighting method results is 7.85 times.

The block sizes were created as 5x5x3 sizes. The above results are based on these analyses. But a revised analysis was done by changing the block sizes as 1x1x1 dimensions. The smaller block sizes analysis comparison graph also can be seen in Figure 4.15. It is seen that there is not a noticeable difference by decreasing block sizes.

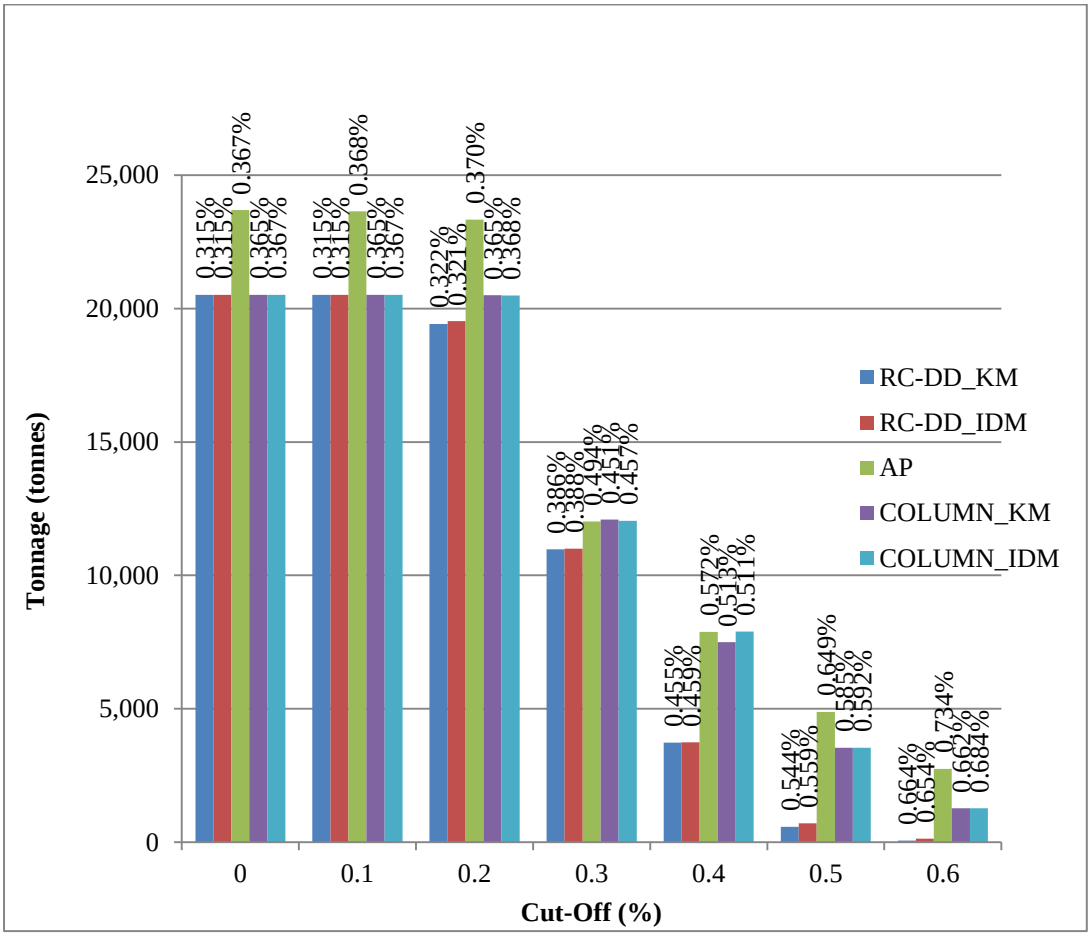


Figure 4.15 The comparison of applied estimation methods based on tonnage values (1x1x1 block sizes)

When the evaluation was also made according to each bench, depending on the drillholes data both resource estimation methods can not reach the actual production values when a cut-off grade was applied. Like the total production and estimation method results when the cut-off grade increases, the tonnage difference between the actual production and estimation method results also increases.

Using estimation methods and a set block size there appears to be a tendency to reduce the predicted grade in the block. Many field and drilling samples show higher grade levels than block models in same locations. The smaller grade in the blocks could be a result of:

- Core samples can be underestimated,
- Blocks within the ore body are generally rigid in size and they do not correspond to changes in grades or lithology. Therefore lower grade ore, such as silica layers, and other low nickel layers reduce the overall grade predicted in blocks,
- Unless there are similar or higher grades between 2 boreholes the method rapidly reduces the grade away from the holes.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

The main conclusions derived from this study are:

1. Since the geometrical methods do not represent the nonhomogeneous deposit like nickel laterites, they did not applied in this study.

2. The presence of siliceous layers in laterites, at about 20% according to drillhole logs in area decreased nickel grades both for RC and core drilling studies. Although the theoretical density was calculated as 1.7 t/m^3 according to drillholes data, in the production the actual density was calculated as 1.99 t/m^3.

3. The nickel grades determined from column sampling results in reconciliation pit were greater than both RC drilling and core drilling, as expected.

4. In reconciliation pit area, assuming 0.5% Ni cut-off value, by using core drilling and RC drilling data inverse distance weighting method gave 0.553% Ni grade, while kriging method results was 0.527% Ni grade. In addition by using column sampling data both inverse distance weighting and kriging method results gave 0.580% Ni grade. However actual production result was 0.649% Ni grade.

5. In reconciliation pit area, assuming 0.5% Ni cut-off value, by using core drilling and RC drilling data inverse distance weighting method gave 622 tonnes Ni, while kriging method results was 749 tonnes Ni. In addition by using column sampling data inverse distance weighting method gave 3,443 tonnes Ni, while kriging method results was 3,347 tonnes Ni. However actual production result was 4,882 tonnes Ni.

6. When using the column samplings data, inverse distance weighting methods gave 42% and kriging method gave 46% difference on tonnage values and both methods gave 12% difference on grade values.

7. Whatever the method for assessing grades changes between cores, the presence of silica boulders within the limonite in particular meant that mining within the blocks will generally achieve higher grades as these silica blocks, that are likely to lower block grade, can be easily separated during mining to increase mined grade.

8. When the blocks sizes reduced to 1x1x1 dimensions, the results show not a noticeable difference.

9. Although the general pattern of spacing between drillholes in Türkmençardağı nickel laterites 60 m x 60 m, in reconciliation pit area 12 m x 10 m drillhole spacing was used. Therefore decreasing the spacing between drillholes gave similar results to larger spacing.

10. As a result, this reconciliation study has showed the trends of the average Ni grade and tonnage during mining is higher than what would have been predicted from 3D modeling.

The main recommendations related to this study are:

1. The inconsistency between 3D model results and actual production results started with the applied cut-off grades. Without considering cut-off grade, inverse distance weighting and kriging methods can be used for total tonnage and average grade calculations. Geostatistical conditional simulations can probably better represent even considering 0.5% cut-off grade.

2. Considering the ophilotic melange structure of Türkmençardağı Gördes nickel laterites, indicator kriging can be tried.

3. Increasing the depth of reconciliation pit area and also choosing an arbitrarily area may give more representative results.

4. This study need be done for all limonite and nontronite lenses in the area in order to associate the results.

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APPENDIX A

COLUMN SAMPLING VISUALS

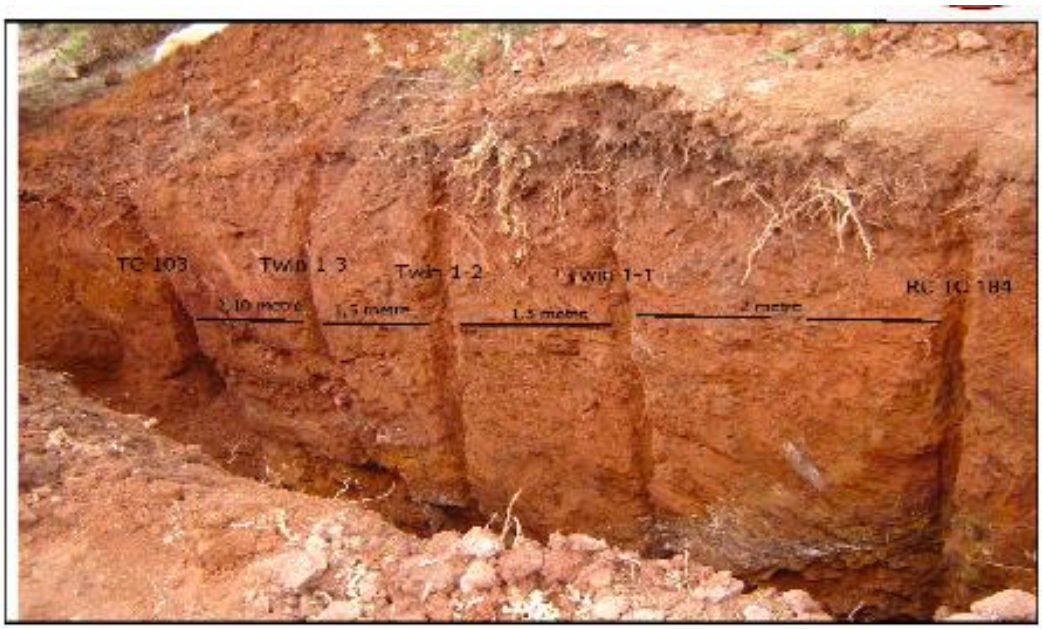


Figure A.1 A view of column sampling

Figure A.2 Column sampling view

APPENDIX B

RECONCILIATION PIT VISUALS

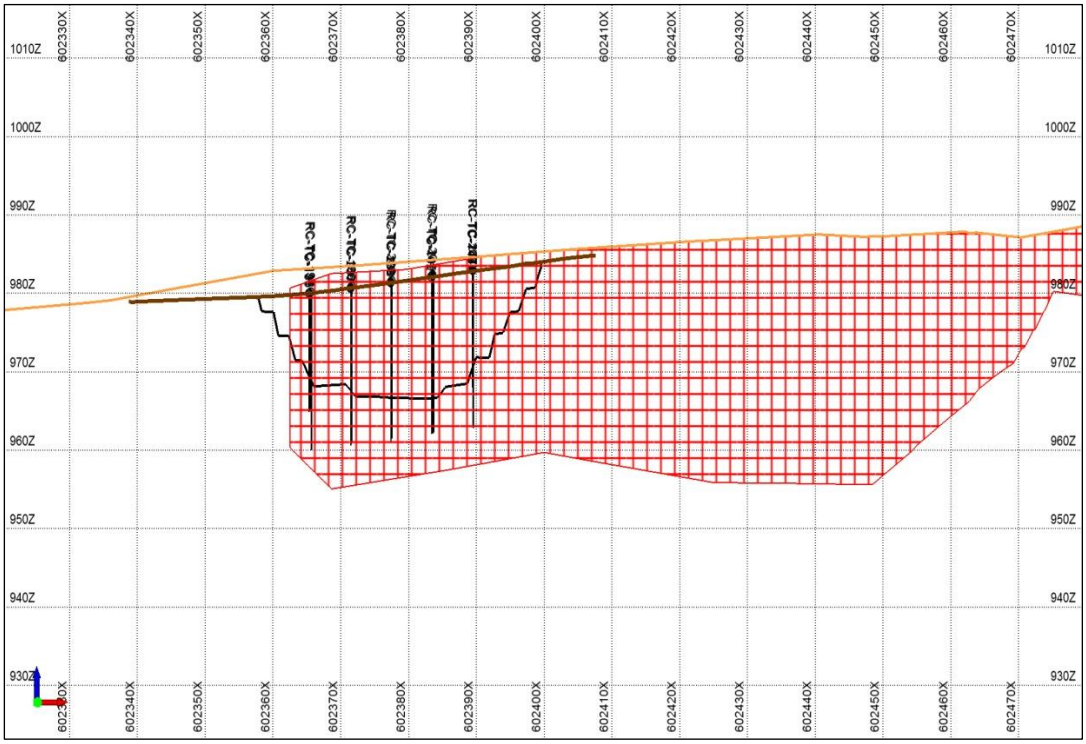


Figure B.1 E-W section of reconciliation pit and twin drills

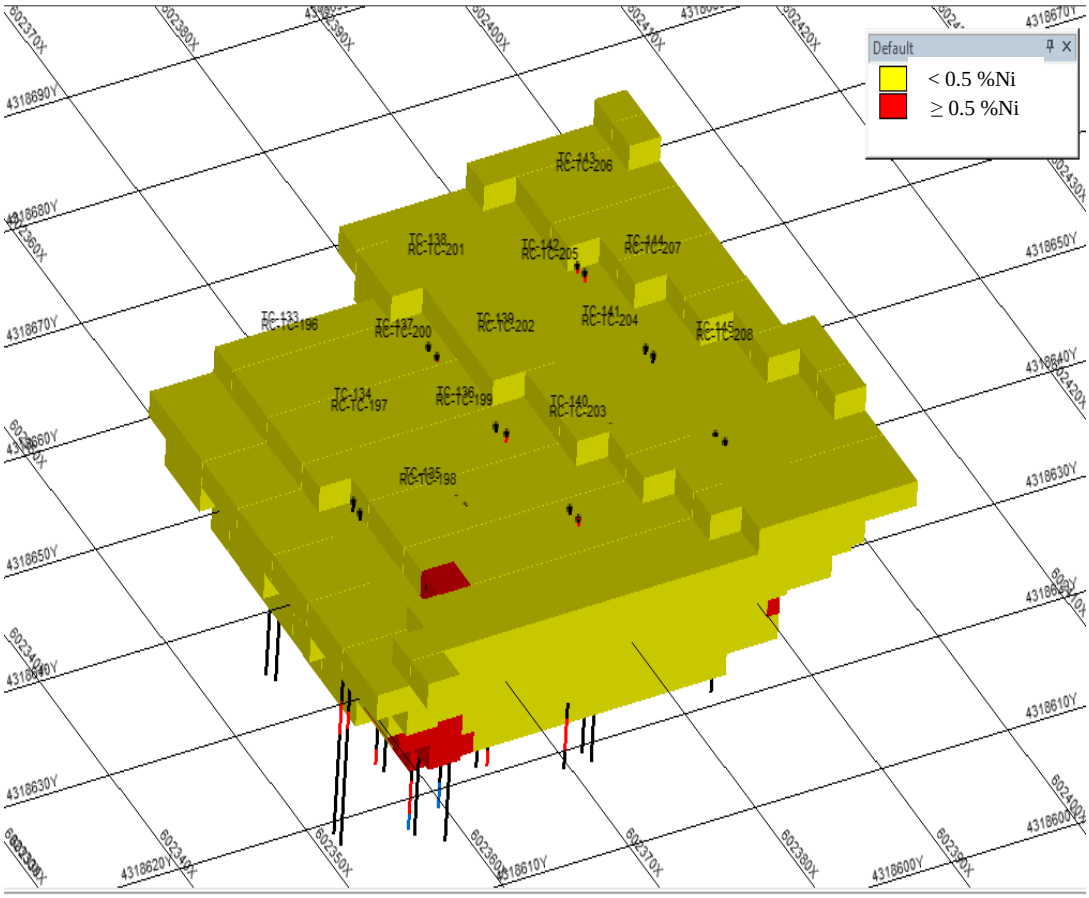


Figure B.2 3D isometric view of solid model

APPENDIX C

COMPARISON OF CORE DRILLING WITH RECONCILIATION PIT COLUMN SAMPLING DATA

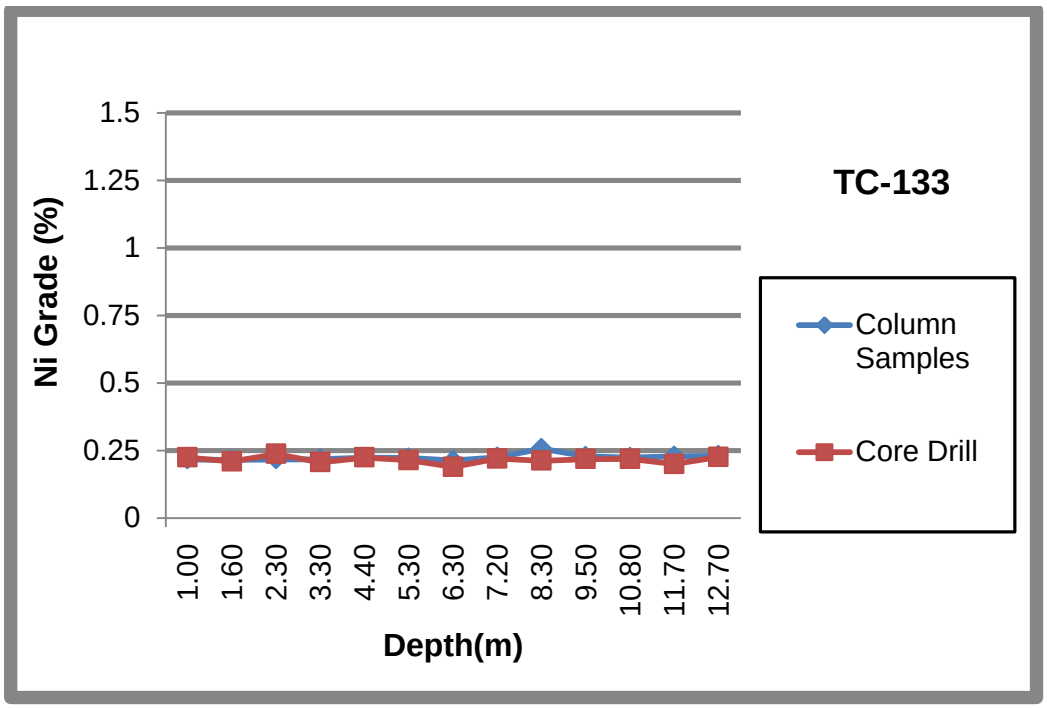


Figure C.1 Comparison of TC-133 core drilling data with related column sampling data in the reconciliation pit

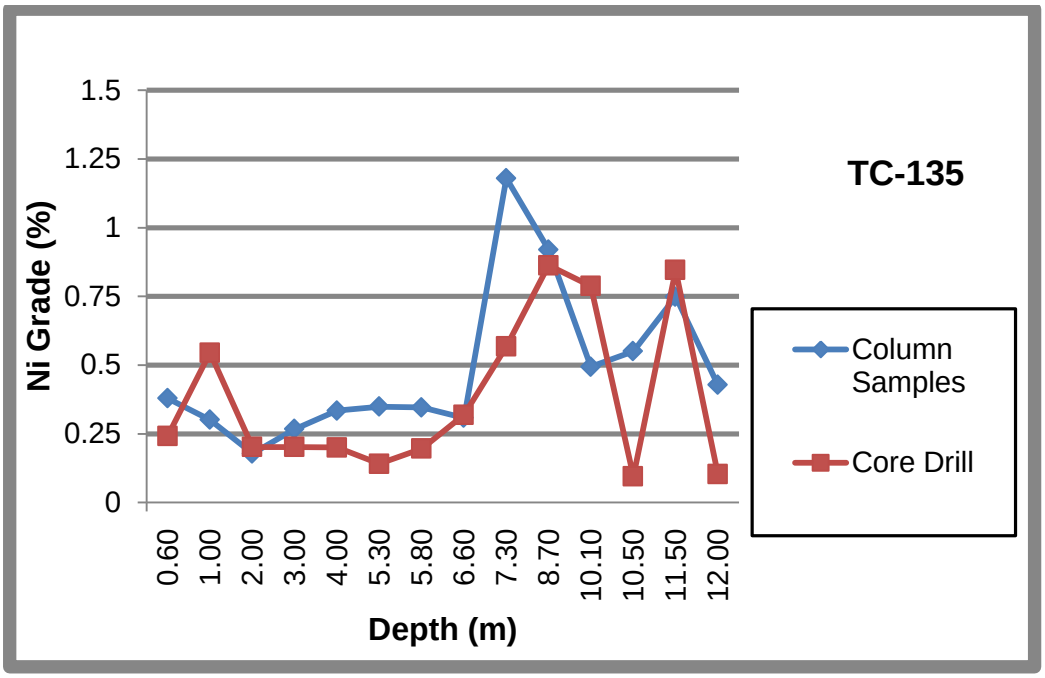


Figure C.2 Comparison of TC-135 core drilling data with related column sampling data in the reconciliation pit

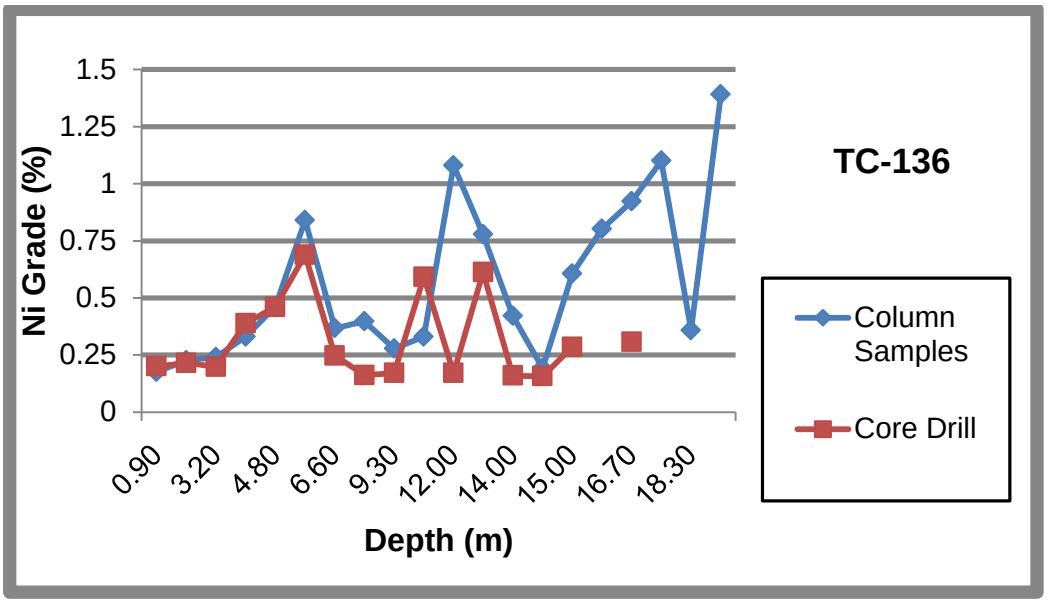


Figure C.3 Comparison of TC-136 core drilling data with related column sampling data in the reconciliation pit

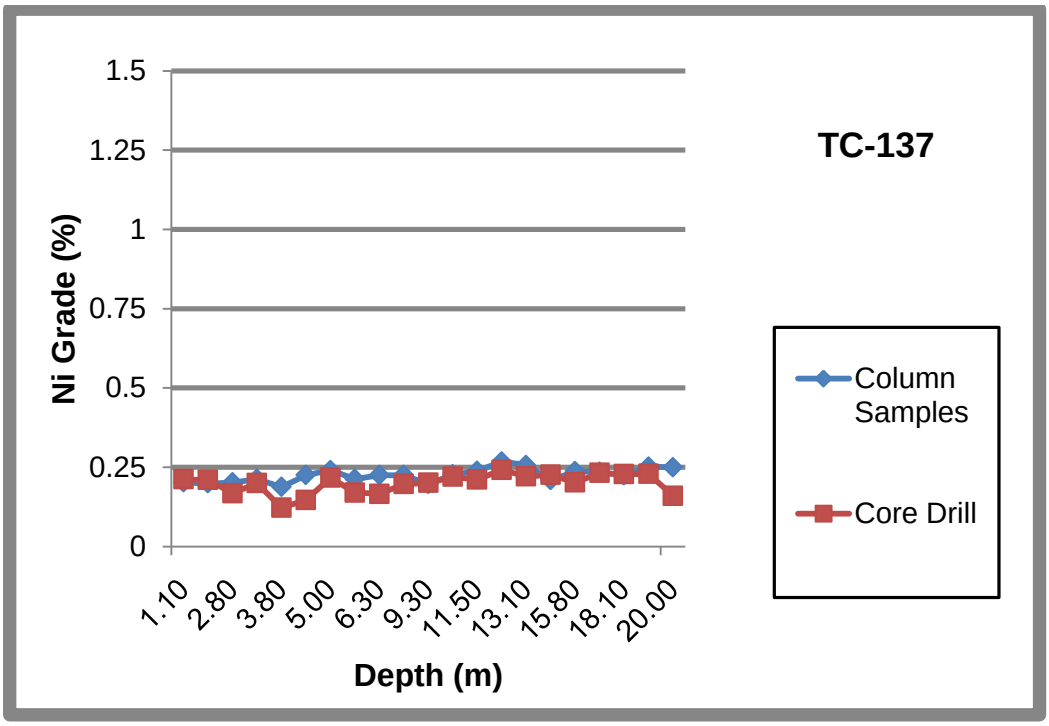


Figure C.4 Comparison of TC-137 core drilling data with related column sampling data in the reconciliation pit

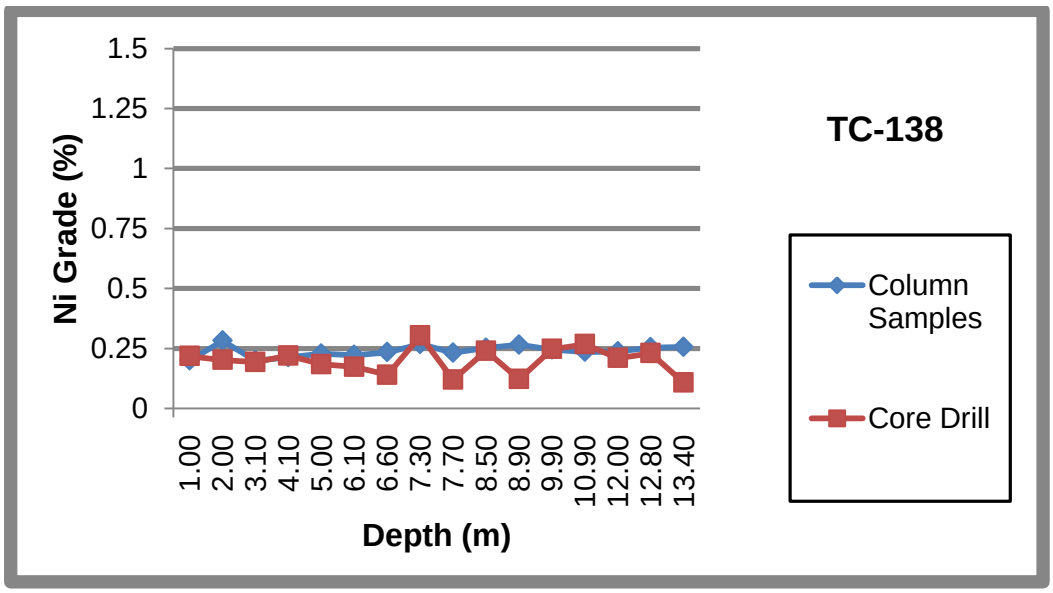


Figure C.5 Comparison of TC-138 core drilling data with related column sampling data in the reconciliation pit

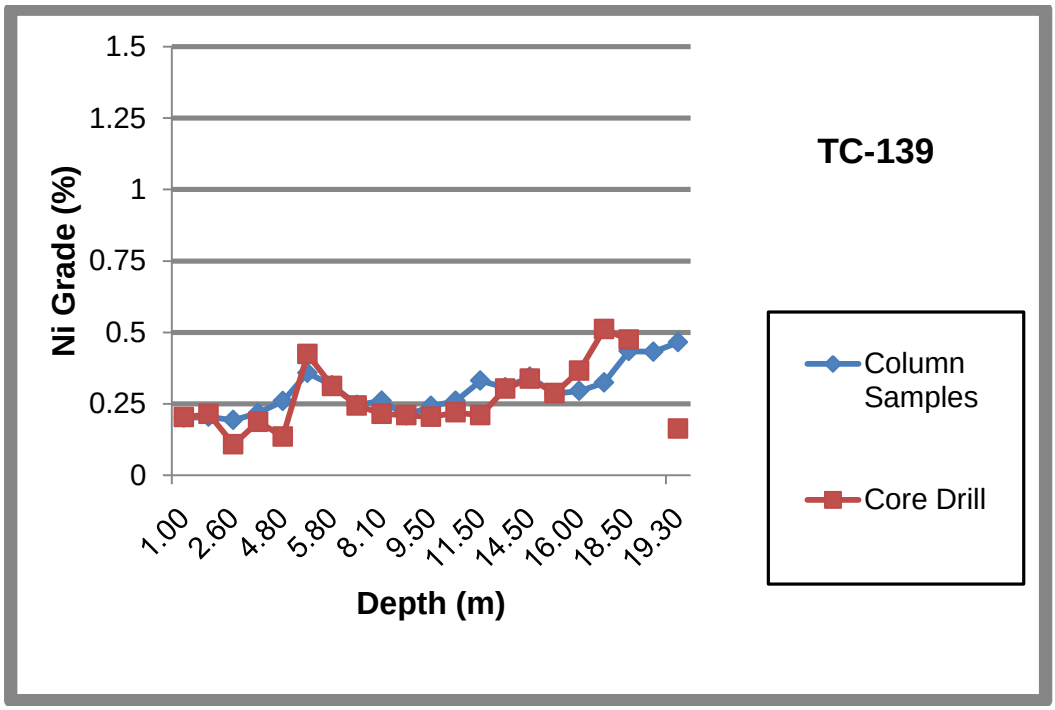


Figure C.6 Comparison of TC-139 core drilling data with related column sampling data in the reconciliation pit

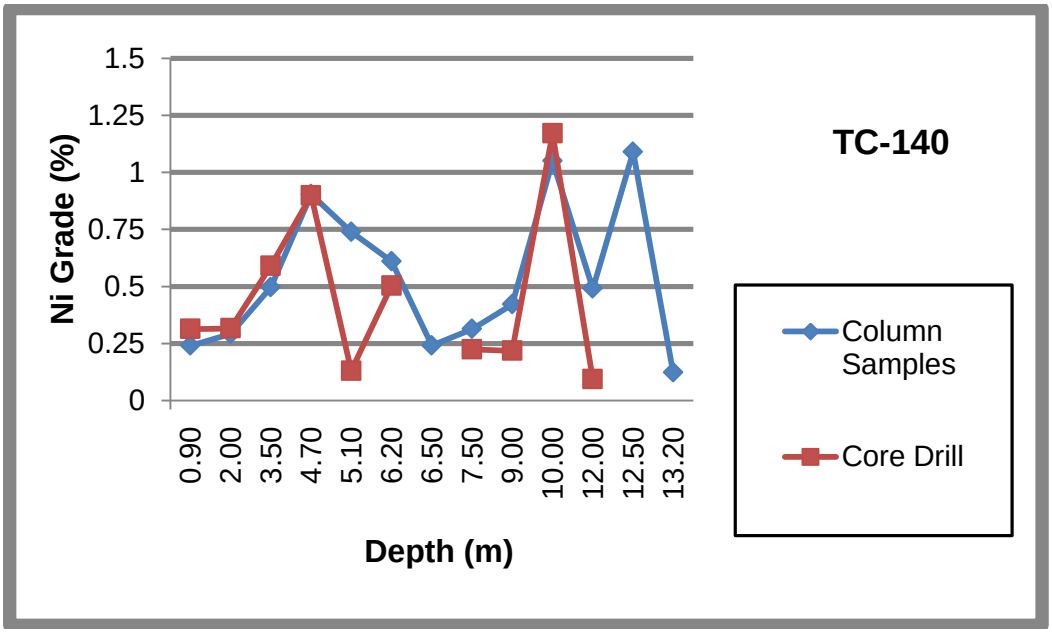


Figure C.7 Comparison of TC-140 core drilling data with related column sampling data in the reconciliation pit

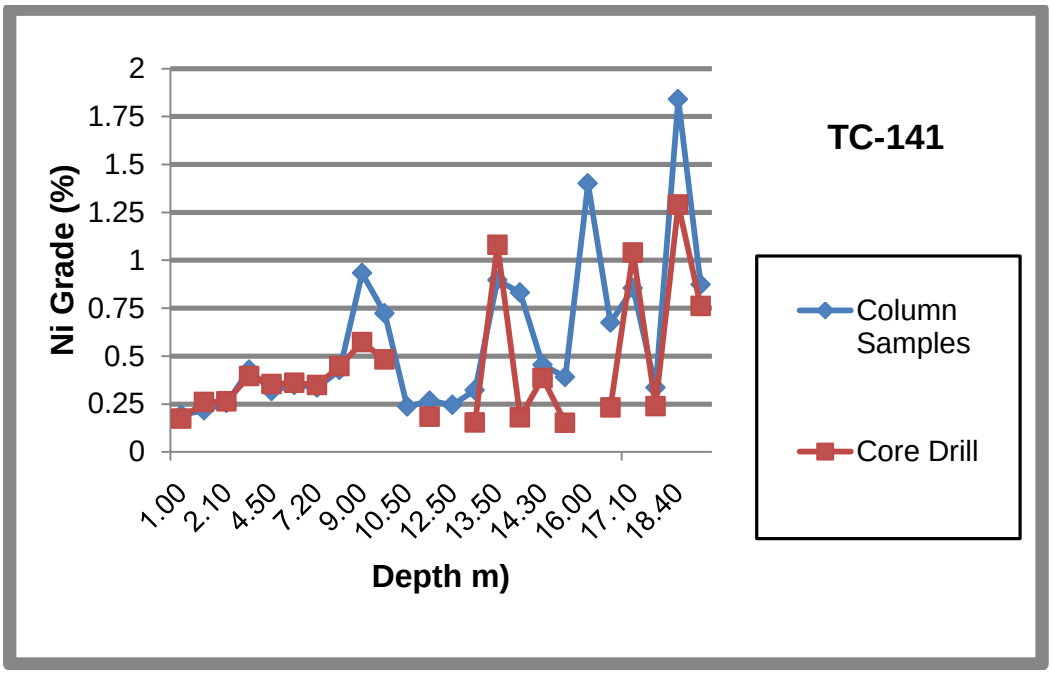


Figure C.8 Comparison of TC-141 core drilling data with related column sampling data in the reconciliation pit

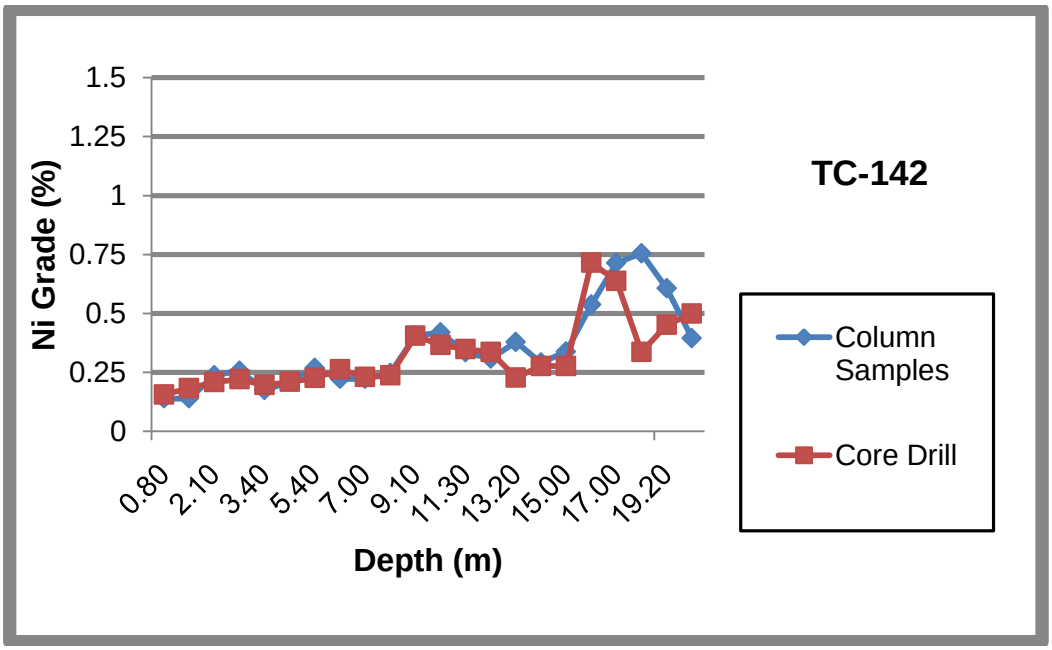


Figure C.9 Comparison of TC-142 core drilling data with related column sampling data in the reconciliation pit

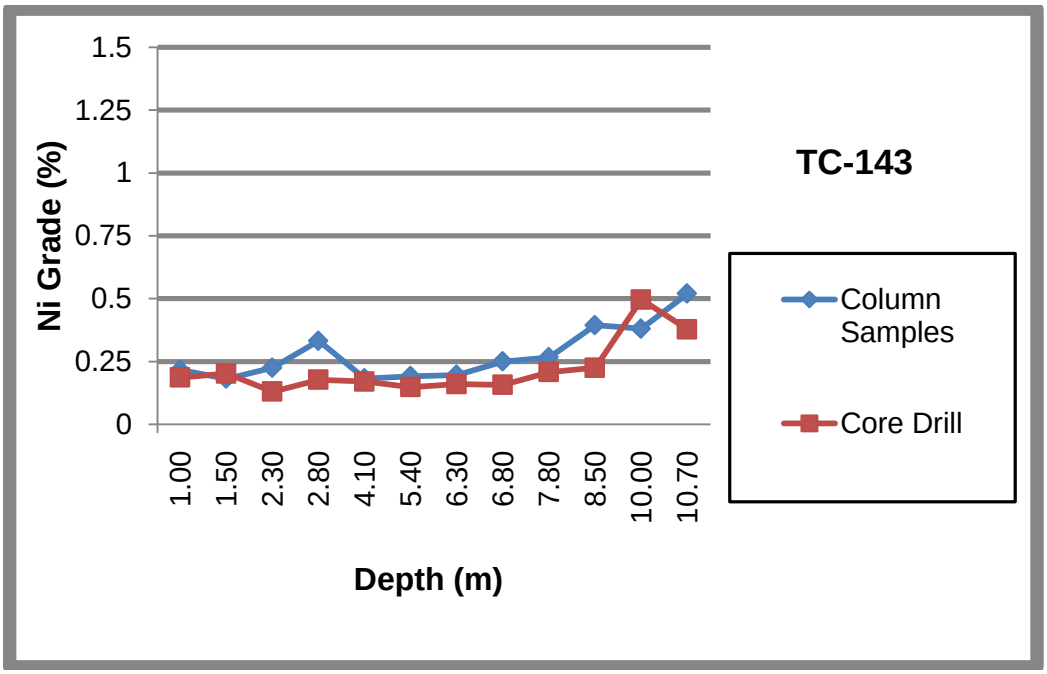


Figure C.10 Comparison of TC-143 core drilling data with related column sampling data in the reconciliation pit

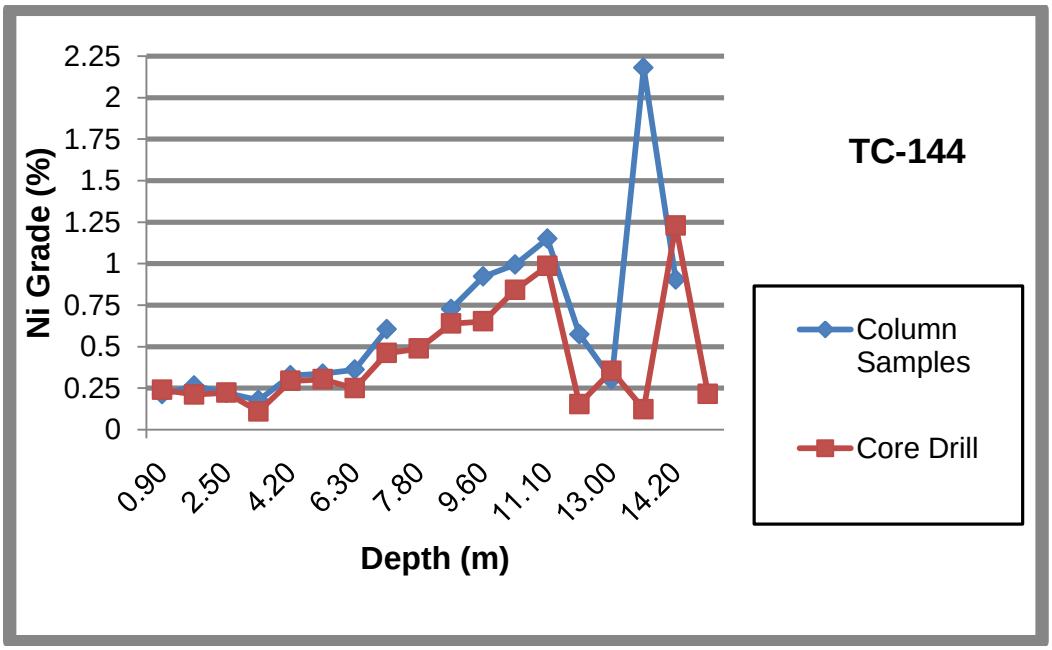


Figure C.11 Comparison of TC-144 core drilling data with related column sampling data in the reconciliation pit

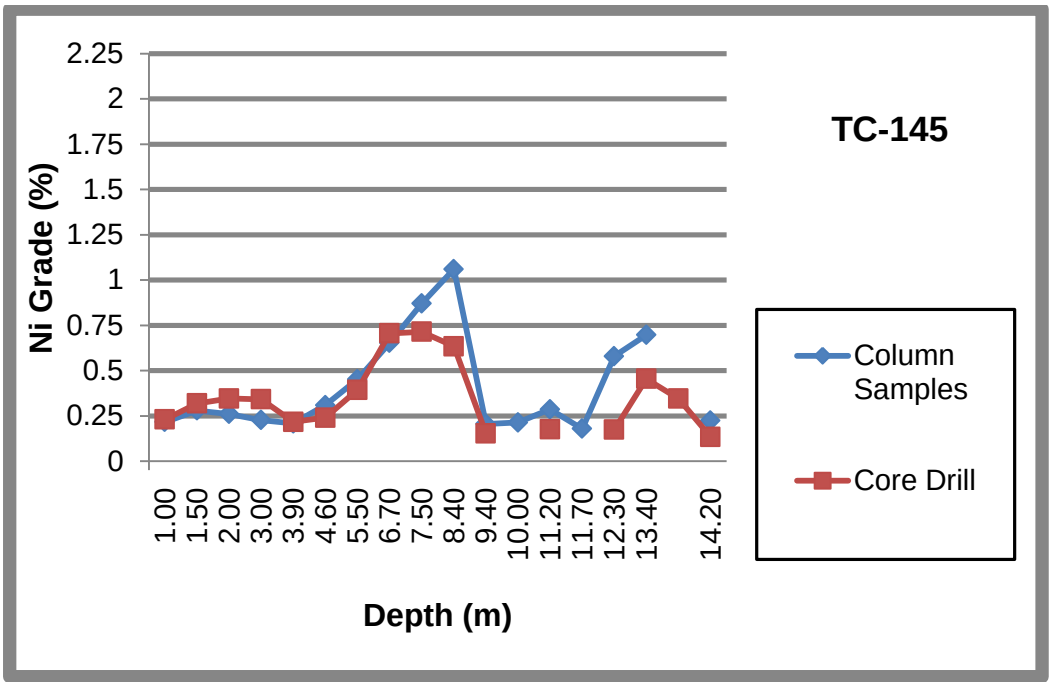


Figure C.12 Comparison of TC-145 core drilling data with related column sampling data in the reconciliation pit

APPENDIX D

COMPARISON OF RC DRILLING WITH RECONCILIATION PIT COLUMN SAMPLING DATA

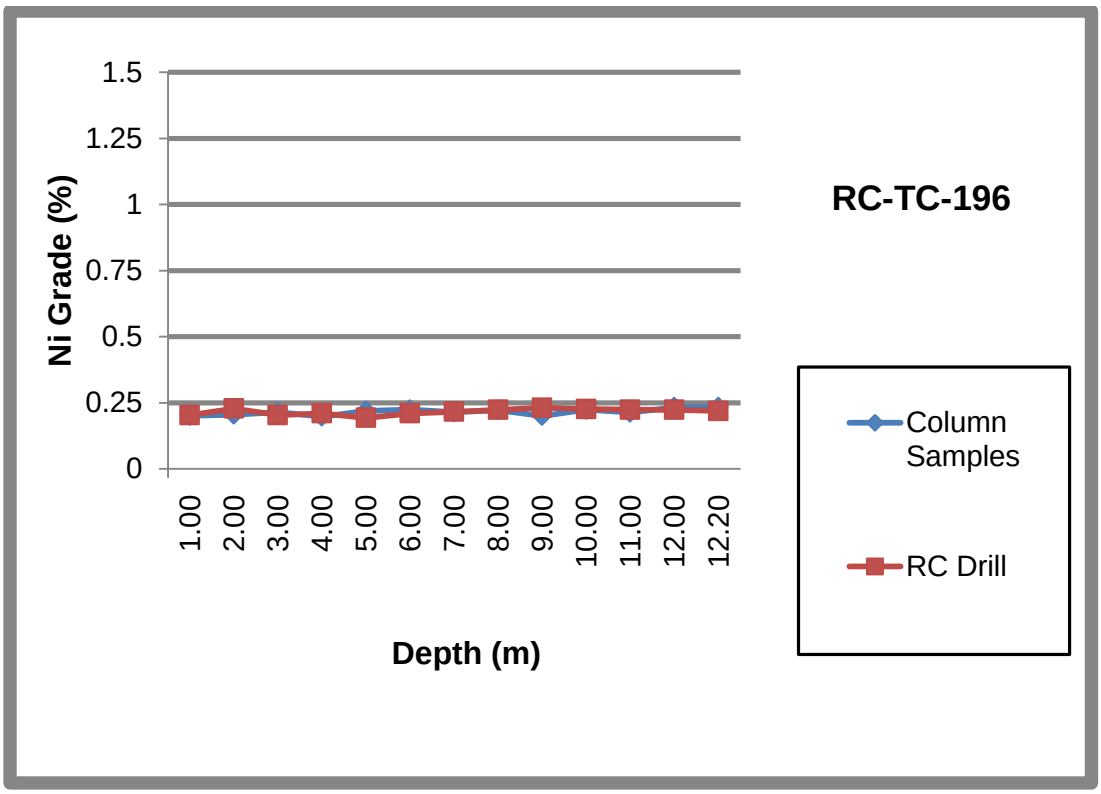


Figure D.1 Comparison of RC-TC-196 RC drilling data with related column sampling data in the reconciliation pit

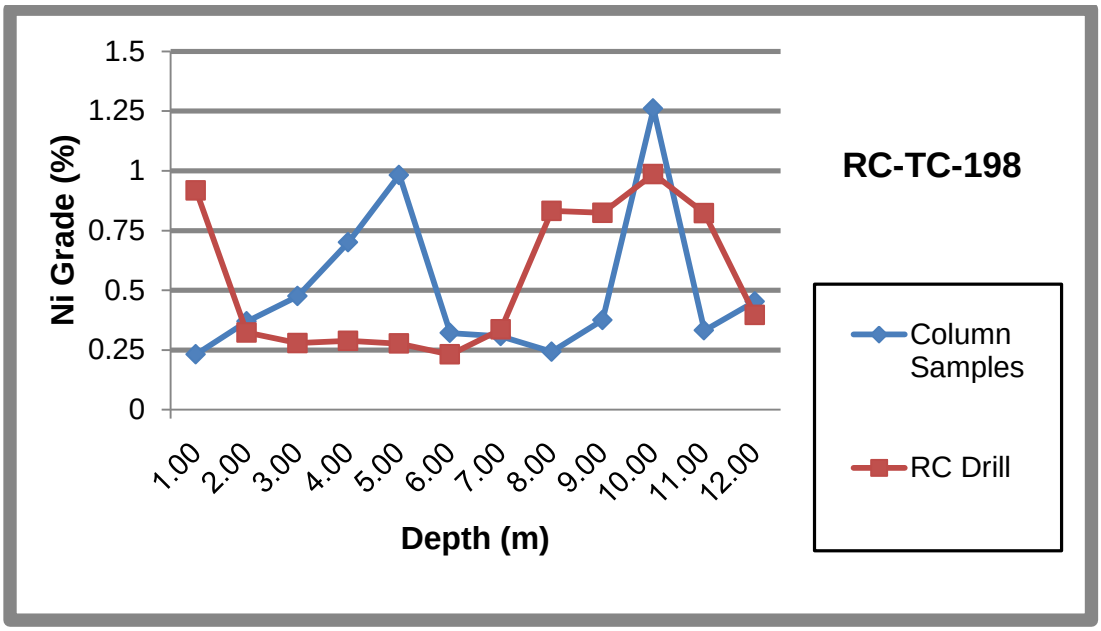


Figure D.2 Comparison of RC-TC-198 RC drilling data with related column sampling data in the reconciliation pit

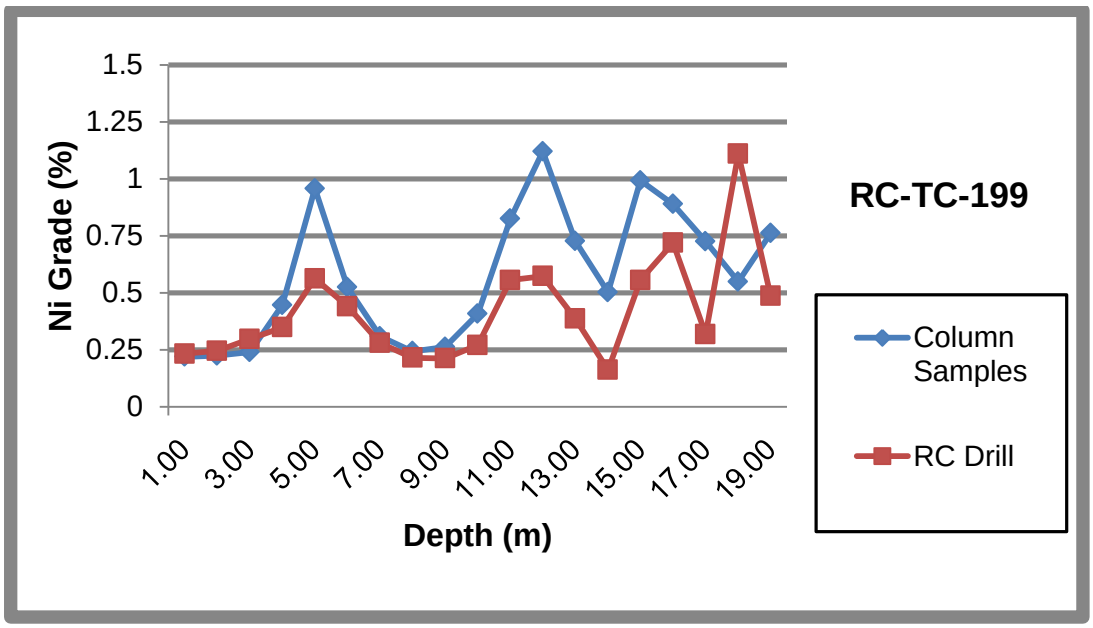


Figure D.3 Comparison of RC-TC-199 RC drilling data with related column sampling data in the reconciliation pit

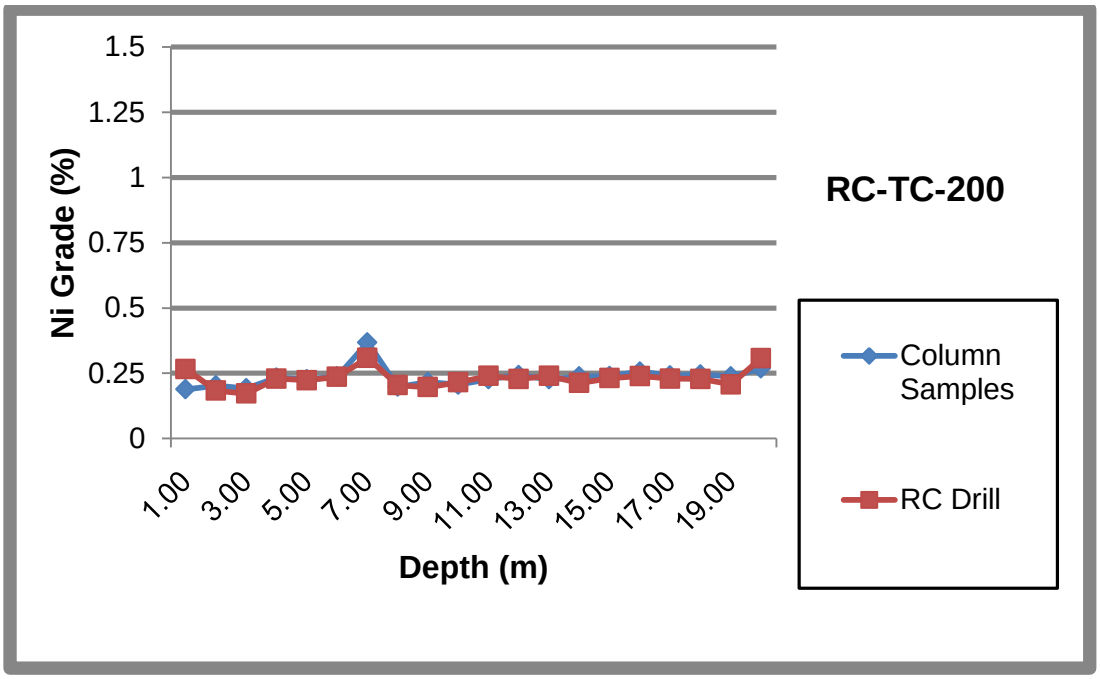


Figure D.4 Comparison of RC-TC-200 RC drilling data with related column sampling data in the reconciliation pit

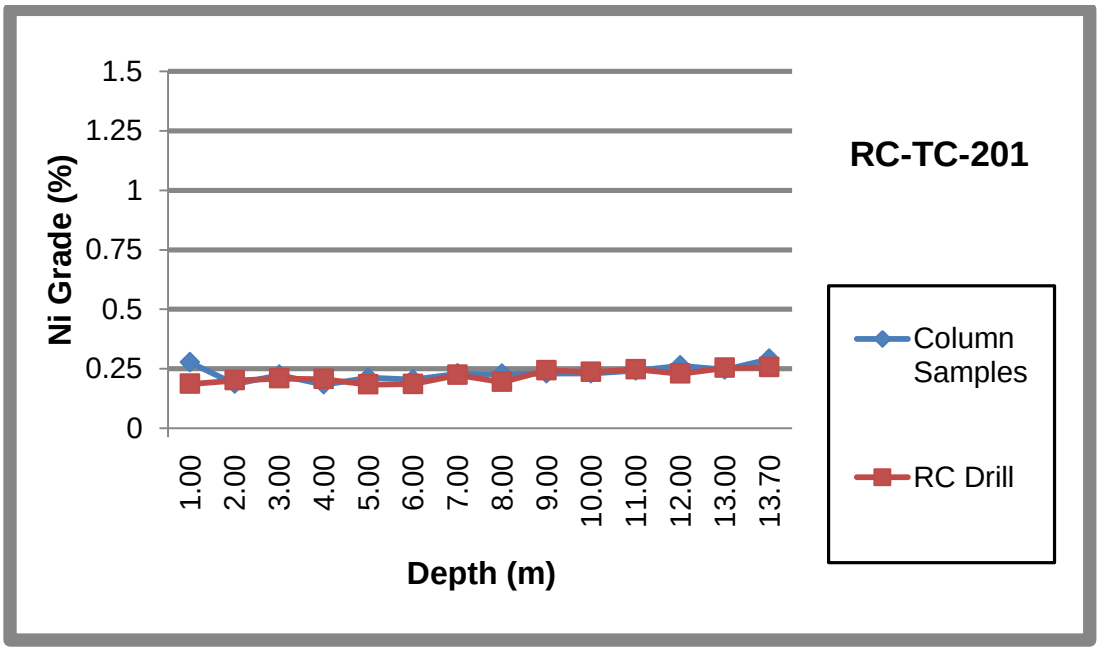


Figure D.5 Comparison of RC-TC-201 RC drilling data with related column sampling data in the reconciliation pit

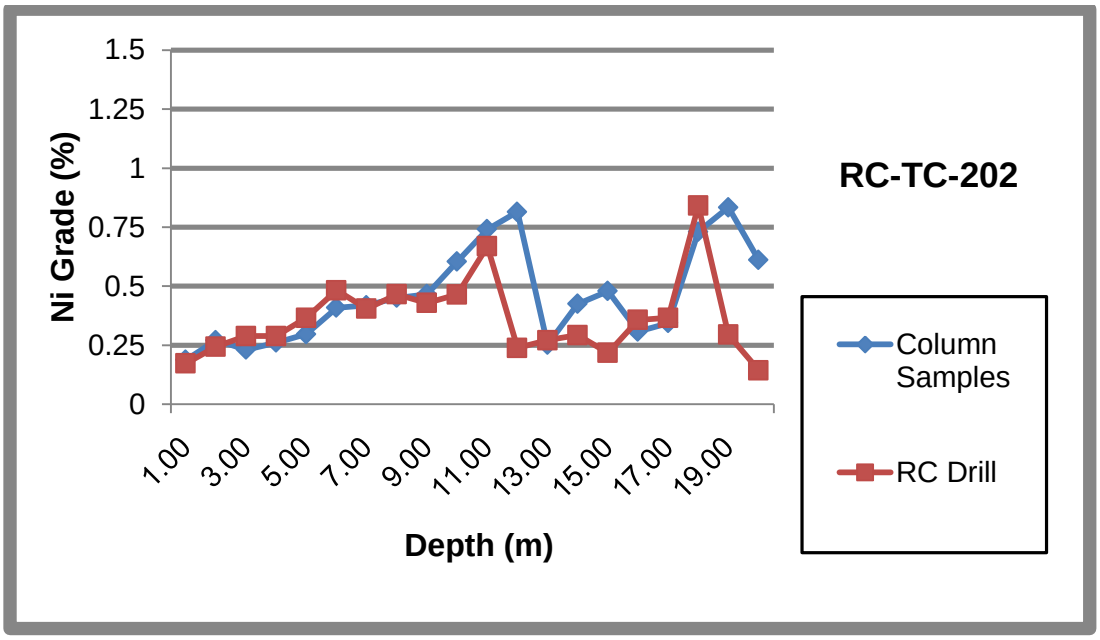


Figure D.6 Comparison of RC-TC-202 RC drilling data with related column sampling data in the reconciliation pit

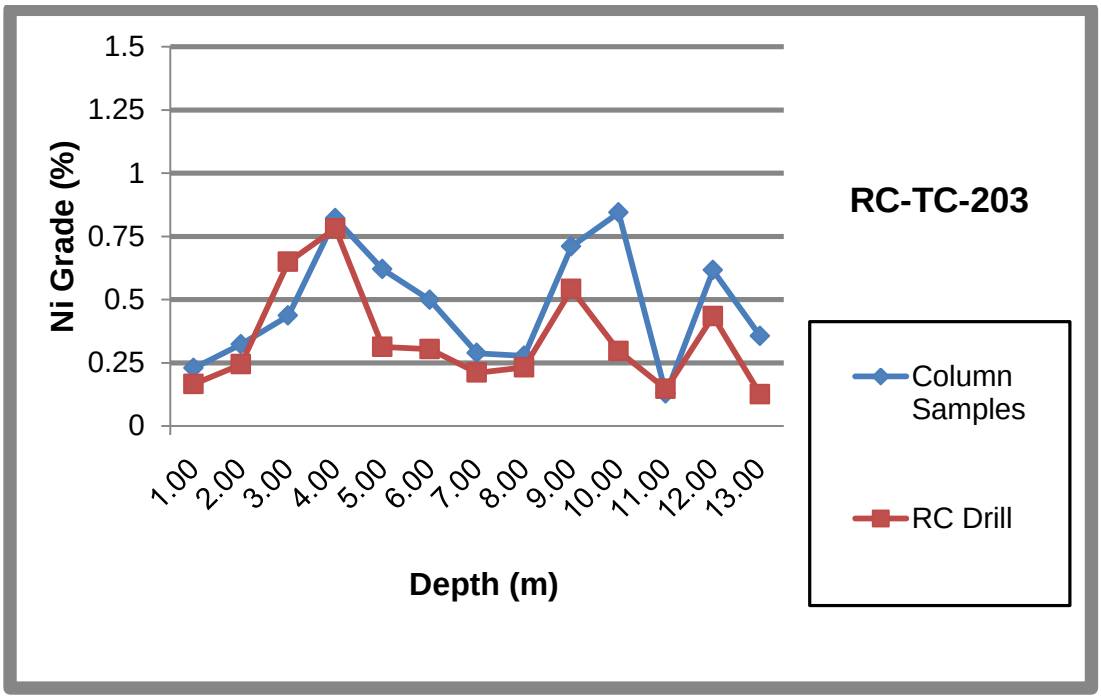


Figure D.7 Comparison of RC-TC-203 RC drilling data with related column sampling data in the reconciliation pit

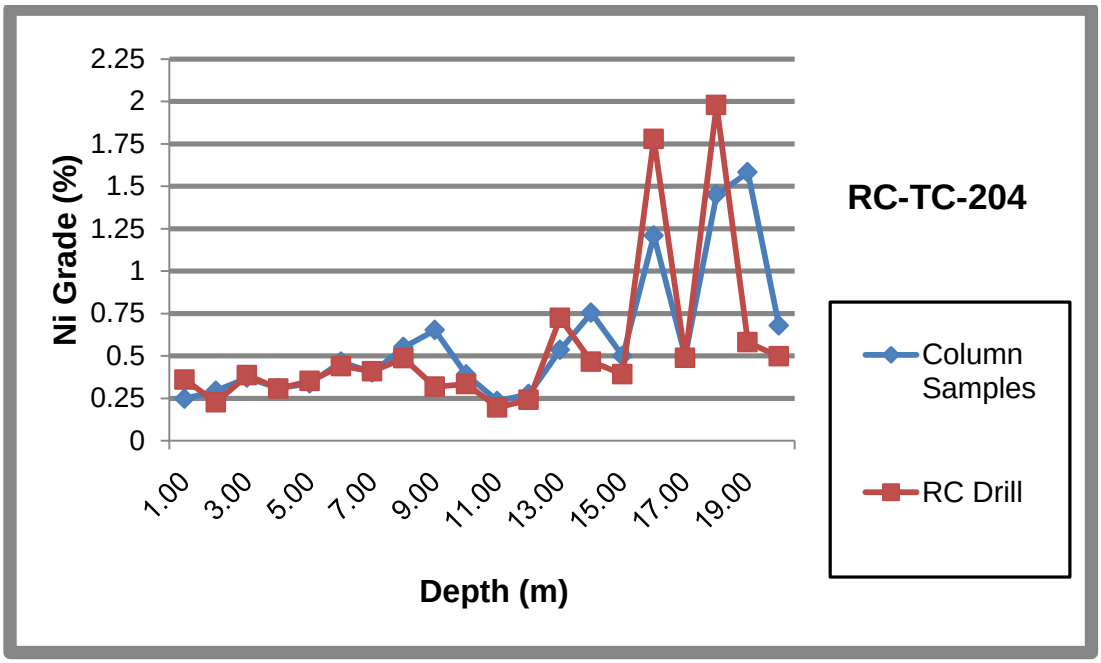


Figure D.8 Comparison of RC-TC-204 RC drilling data with related column sampling data in the reconciliation pit

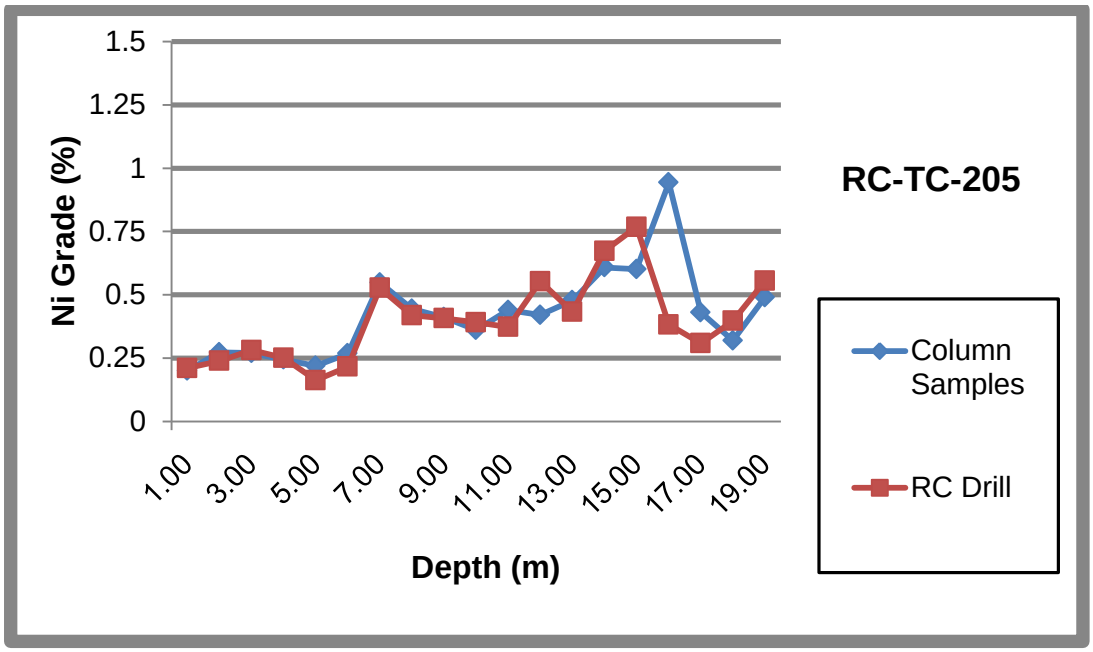


Figure D.9 Comparison of RC-TC-205 RC drilling data with related column sampling data in the reconciliation pit

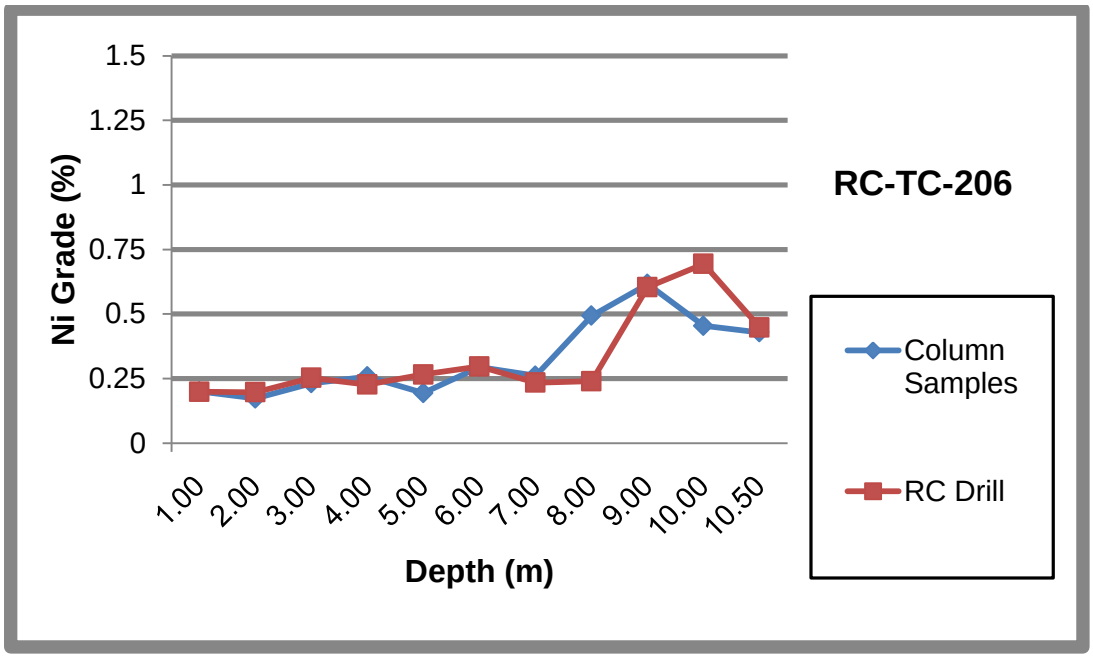


Figure D.10 Comparison of RC-TC-198 RC drilling data with related column sampling data in the reconciliation pit

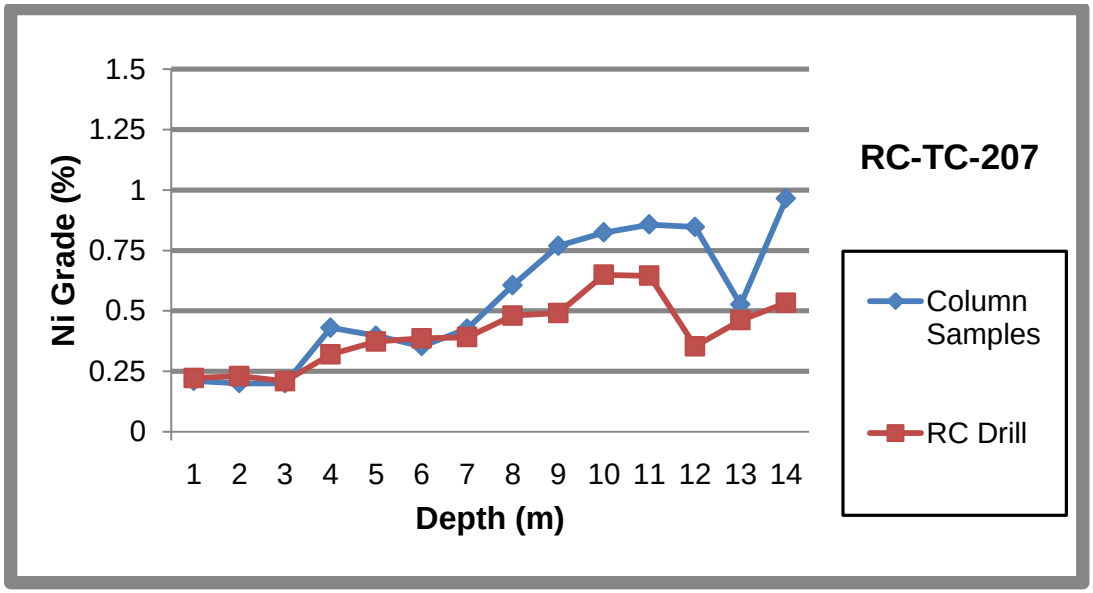


Figure D.11 Comparison of RC-TC-207 RC drilling data with related column sampling data in the reconciliation pit

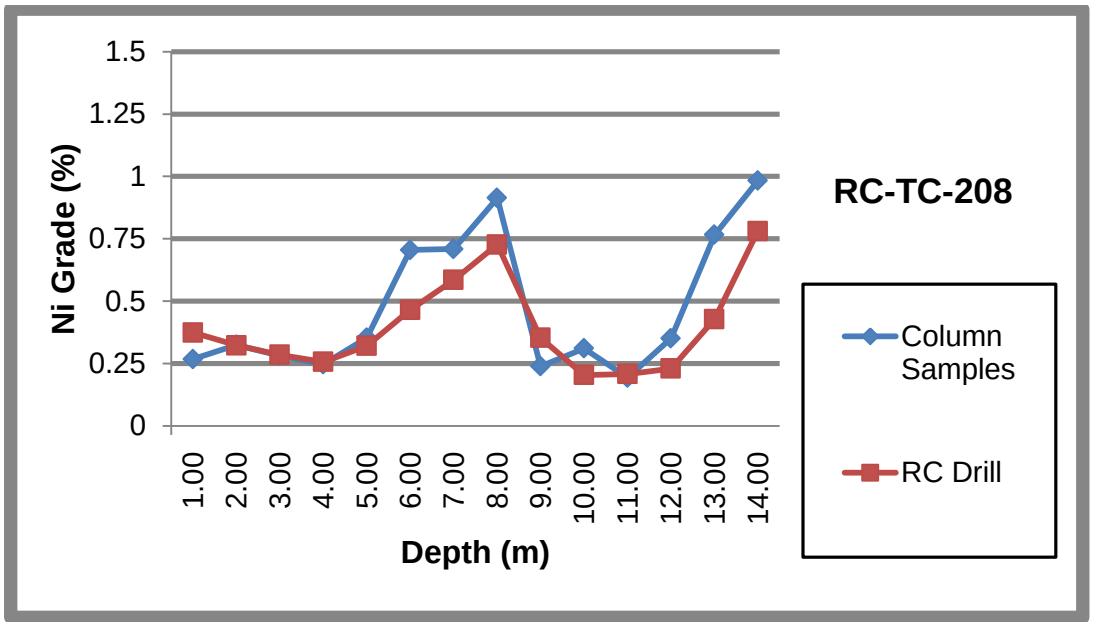


Figure D.12 Comparison of RC-TC-208 RC drilling data with related column sampling data in the reconciliation pit

APPENDIX E

DRILLHOLE LOGS

Location : Türkmençardağı	**Start Date :** 16.08.2010	meta NİKEL KOBALT A.Ş.	**Depth of Hole** (m) : 15,00
Drill Hole No: RC-TC-196	**End Date :** 17.08.2010	Gordes Nickel - Cobalt Project	**Dip of Hole** (degree) : 90
			Azimuth (degree) : 0

Map : Balıkesir J20-D3
E : 602365,204
N : 4318650,131
RL : 979,975

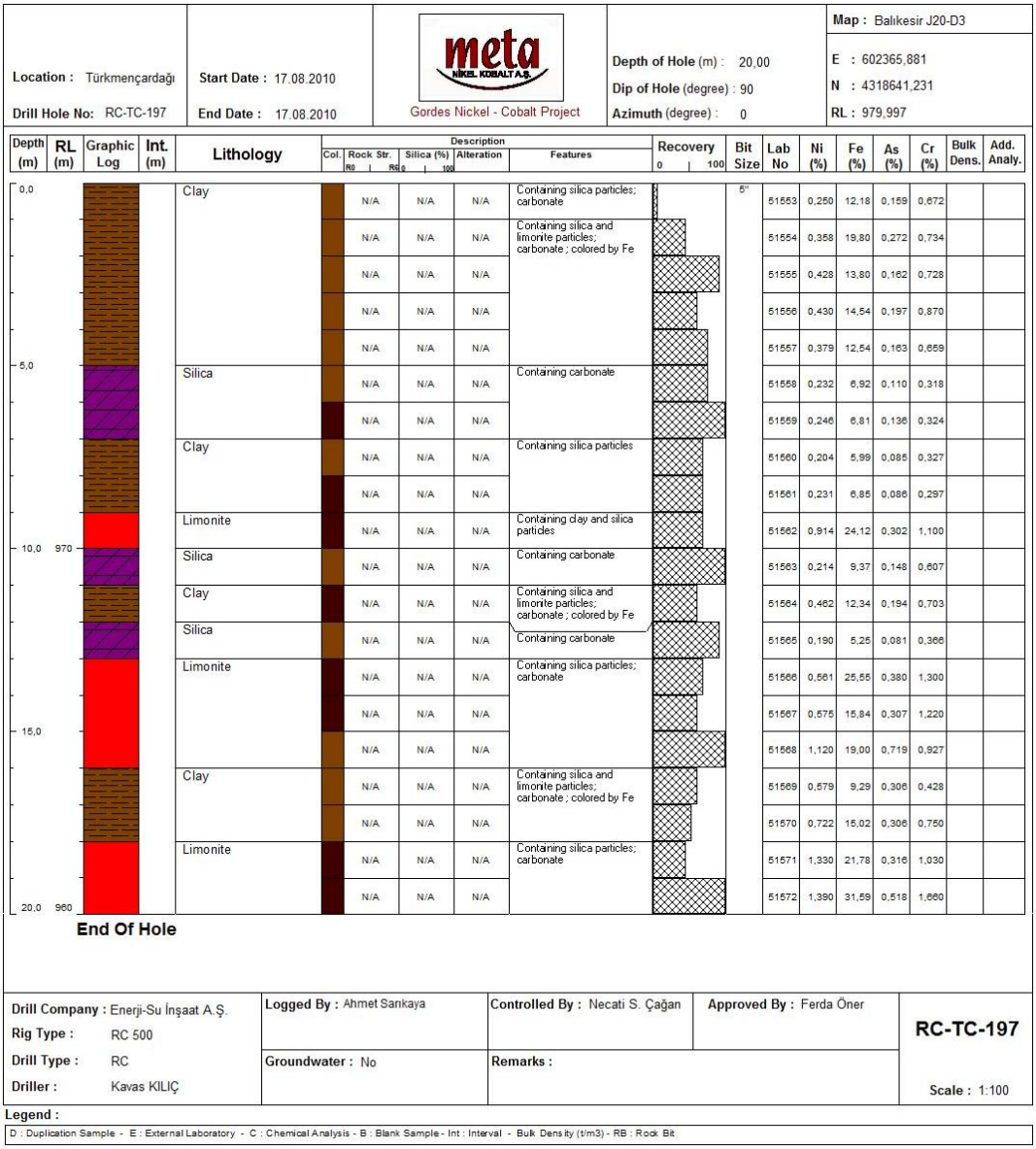
Depth (m)	RL (m)	Graphic Log	Int. (m)	Lithology	Description: Col.	Rock Str. (R0 – R6)	Silica (%) (0 – 100)	Alteration	Features	Recovery (0 – 100)	Bit Size	Lab No	Ni (%)	Fe (%)	As (%)	Cr (%)	Bulk Dens.	Add. Analy.
0,0				Clay		N/A	N/A	N/A	Containing silica particles		5"	51538	0,203	11,71	0,167	0,629		
						N/A	N/A	N/A	Containing silica particles; colored by Fe			51539	0,228	13,06	0,161	0,687		
						N/A	N/A	N/A	Containing silica particles; carbonate; colored by Fe			51540	0,203	12,60	0,172	0,692		
						N/A	N/A	N/A				51541	0,210	11,90	0,163	0,742		
						N/A	N/A	N/A				51542	0,193	12,12	0,161	0,563		
5,0						N/A	N/A	N/A				51543	0,210	12,45	0,169	0,663		
						N/A	N/A	N/A				51544	0,216	12,98	0,196	0,804		
						N/A	N/A	N/A				51545	0,223	12,99	0,188	0,858		
						N/A	N/A	N/A				51546	0,231	13,23	0,188	0,746		
						N/A	N/A	N/A				51547	0,226	13,08	0,174	0,705		
10,0	970					N/A	N/A	N/A				51548	0,224	13,05	0,176	0,653		
						N/A	N/A	N/A				51549	0,223	13,15	0,178	0,659		
						N/A	N/A	N/A				51550	0,219	12,63	0,152	0,568		
						N/A	N/A	N/A				51551	0,214	13,44	0,160	0,563		
15,0						N/A	N/A	N/A				51552	0,222	13,43	0,170	0,579		

End Of Hole

Drill Company : Enerji-Su İnşaat A.Ş.	**Logged By :** Ahmet Sarıkaya	**Controlled By :** Necati S. Çağan	**Approved By :** Ferda Öner
Rig Type : RC 500			**RC-TC-196**
Drill Type : RC	**Groundwater :** No	**Remarks :**	
Driller : Kavas KILIÇ			**Scale :** 1:100

Legend :
D : Duplication Sample - E : External Laboratory - C : Chemical Analysis - B : Blank Sample - Int : Interval - Bulk Density (t/m3) - RB : Rock Bit

Figure E.1 Drillhole log of RC-TC-196



Location : Türkmençardağı	Start Date : 17.08.2010	meta NİKEL KOBALT A.Ş.	Map : Balıkesir J20-D3
Drill Hole No: RC-TC-197	End Date : 17.08.2010	Gordes Nickel - Cobalt Project	Depth of Hole (m) : 20,00
			Dip of Hole (degree) : 90
			Azimuth (degree) : 0
			E : 602365,881
			N : 4318641,231
			RL : 979,997

Depth (m)	RL (m)	Lithology	Col.	Rock Str. (R0 – R6)	Silica (%) (0 – 100)	Alteration	Features	Recovery (0 – 100)	Bit Size	Lab No	Ni (%)	Fe (%)	As (%)	Cr (%)	Bulk Dens.	Add. Analy.
0,0		Clay		N/A	N/A	N/A	Containing silica particles; carbonate		5"	51553	0,250	12,18	0,159	0,672		
				N/A	N/A	N/A	Containing silica and limonite particles; carbonate ; colored by Fe			51554	0,358	19,80	0,272	0,734		
				N/A	N/A	N/A				51555	0,428	13,80	0,162	0,728		
				N/A	N/A	N/A				51556	0,430	14,54	0,197	0,870		
				N/A	N/A	N/A				51557	0,379	12,54	0,163	0,659		
5,0		Silica		N/A	N/A	N/A	Containing carbonate			51558	0,232	6,92	0,110	0,318		
				N/A	N/A	N/A				51559	0,246	6,81	0,136	0,324		
		Clay		N/A	N/A	N/A	Containing silica particles			51560	0,204	5,99	0,085	0,327		
				N/A	N/A	N/A				51561	0,231	6,85	0,086	0,297		
		Limonite		N/A	N/A	N/A	Containing clay and silica particles			51562	0,914	24,12	0,302	1,100		
10,0	970	Silica		N/A	N/A	N/A	Containing carbonate			51563	0,214	9,37	0,148	0,607		
		Clay		N/A	N/A	N/A	Containing silica and limonite particles; carbonate ; colored by Fe			51564	0,462	12,34	0,194	0,703		
		Silica		N/A	N/A	N/A	Containing carbonate			51565	0,190	5,25	0,081	0,366		
		Limonite		N/A	N/A	N/A	Containing silica particles; carbonate			51566	0,561	25,55	0,380	1,300		
				N/A	N/A	N/A				51567	0,575	15,84	0,307	1,220		
15,0				N/A	N/A	N/A				51568	1,120	19,00	0,719	0,927		
		Clay		N/A	N/A	N/A	Containing silica and limonite particles; carbonate ; colored by Fe			51569	0,579	9,29	0,306	0,428		
				N/A	N/A	N/A				51570	0,722	15,02	0,306	0,750		
		Limonite		N/A	N/A	N/A	Containing silica particles; carbonate			51571	1,330	21,78	0,316	1,030		
20,0	960			N/A	N/A	N/A				51572	1,390	31,59	0,518	1,660		

End Of Hole

Drill Company : Enerji-Su İnşaat A.Ş.	Logged By : Ahmet Sarıkaya	Controlled By : Necati S. Çağan	Approved By : Ferda Öner
Rig Type : RC 500			RC-TC-197
Drill Type : RC	Groundwater : No	Remarks :	
Driller : Kavas KILIÇ			Scale : 1:100

Legend :

D : Duplication Sample - E : External Laboratory - C : Chemical Analysis - B : Blank Sample - Int : Interval - Bulk Density (t/m3) - RB : Rock Bit

Figure E.2 Drillhole log of RC-TC-197

Location : Türkmençardağı	Start Date : 16.08.2010	meta NİKEL KOBALT A.Ş.	Depth of Hole (m) : 15,00	Map : Balıkesir J20-D3
Drill Hole No: RC-TC-198	End Date : 17.08.2010	Gordes Nickel - Cobalt Project	Dip of Hole (degree) : 90	E : 602366,267
			Azimuth (degree) : 0	N : 4318632,250
				RL : 980,524

Depth (m)	RL (m)	Graphic Log	Int. (m)	Lithology	Description: Col.	Rock Str. (R0 – R6)	Silica (%) (0 – 100)	Alteration	Features	Recovery (0 – 100)	Bit Size	Lab No	Ni (%)	Fe (%)	As (%)	Cr (%)	Bulk Dens.	Add. Analy.
0,0	980			Limonite		N/A	N/A	N/A	Containing silica particles; carbonate		5"	51573	0,917	24,02	0,442	1,250		
				Silica		N/A	N/A	N/A	Containing clay layers; carbonate			51574	0,323	9,32	0,143	0,509		
						N/A	N/A	N/A				51575	0,279	8,69	0,135	0,402		
						N/A	N/A	N/A				51576	0,288	8,27	0,147	0,393		
				Clay		N/A	N/A	N/A	Containing carbonate			51577	0,277	7,50	0,121	0,413		
5,0				Silica		N/A	N/A	N/A				51578	0,231	6,18	0,089	0,268		
				Clay		N/A	N/A	N/A				51579	0,336	10,43	0,131	0,523		
				Limonite		N/A	N/A	N/A	Containing clay and silica particles; carbonate			51580	0,832	26,00	0,260	1,670		
						N/A	N/A	N/A				51581	0,824	24,99	0,282	1,300		
						N/A	N/A	N/A				51582	0,986	24,48	0,228	1,050		
10,0	970					N/A	N/A	N/A				51583	0,823	21,67	0,242	1,090		
				Clay		N/A	N/A	N/A	Containing silica and limonite particles; carbonate; colored by Fe			51584	0,396	14,77	0,218	1,160		
				Silica		N/A	N/A	N/A	Containing carbonate; colored by Fe			51585	0,308	12,37	0,155	0,900		
				Clay		N/A	N/A	N/A	Containing silica and limonite particles; carbonate; colored by Fe			51586	0,370	14,63	0,221	0,928		
15,0						N/A	N/A	N/A				51587	0,324	13,79	0,212	1,120		

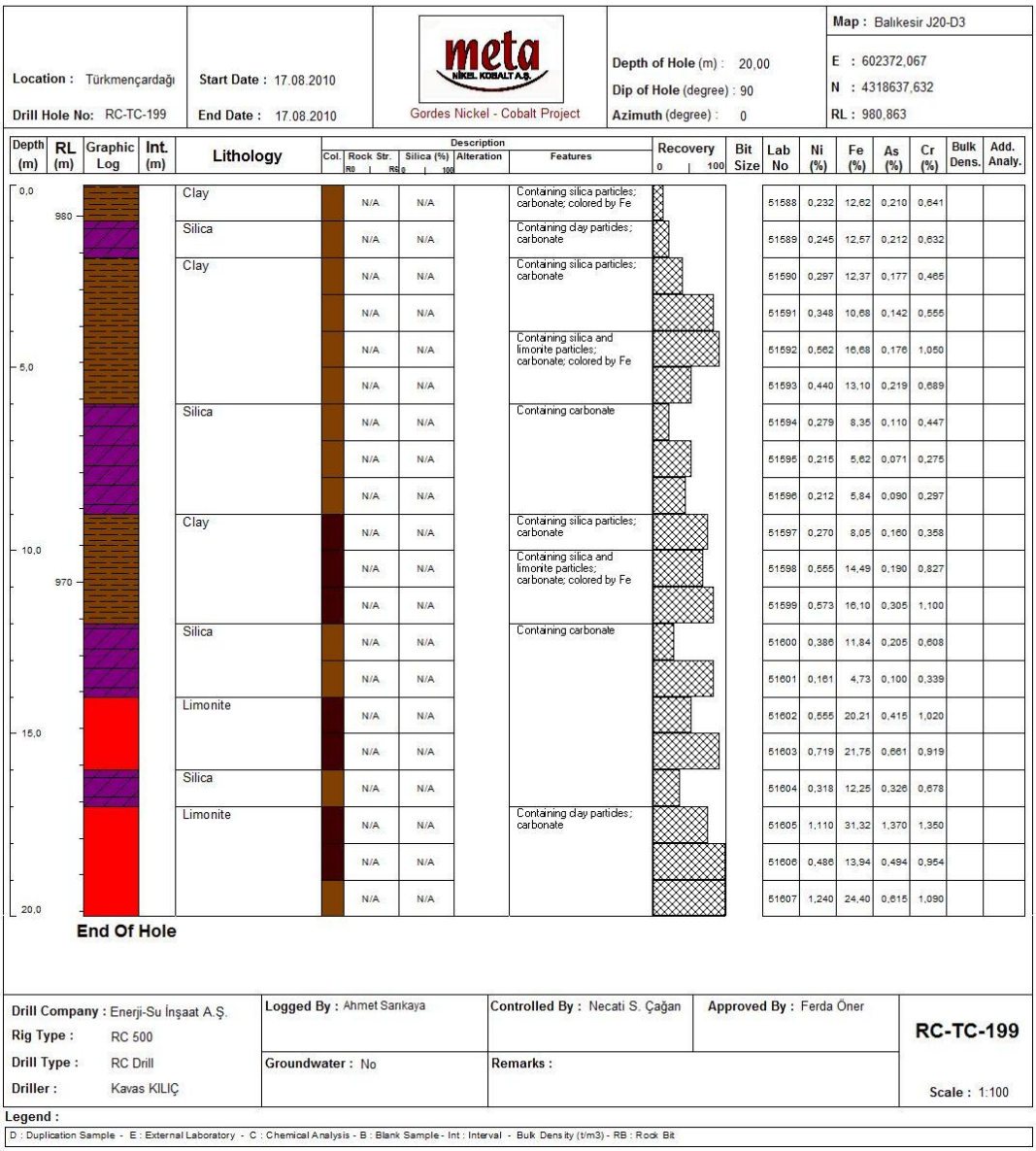
End Of Hole

Drill Company : Enerji-Su İnşaat A.Ş.	Logged By : Ahmet Sarıkaya	Controlled By : Necati S. Çağan	Approved By : Ferda Öner	RC-TC-198
Rig Type : RC 500				
Drill Type : RC Drill	Groundwater : No	Remarks :		
Driller : Kavas KILIÇ				Scale : 1:100

Legend :

D : Duplication Sample - E : External Laboratory - C : Chemical Analysis - B : Blank Sample - Int : Interval - Bulk Density (t/m3) - RB : Rock Bit

Figure E.3 Drillhole log of RC-TC-198



Location : Türkmençardağı	Start Date : 17.08.2010	meta NİKEL KOBALT A.Ş.	Depth of Hole (m) : 20,00	Map : Balıkesir J20-D3
Drill Hole No: RC-TC-199	End Date : 17.08.2010	Gordes Nickel - Cobalt Project	Dip of Hole (degree) : 90	E : 602372,067
			Azimuth (degree) : 0	N : 4318637,632
				RL : 980,863

Depth (m)	RL (m)	Graphic Log	Int. (m)	Lithology	Col.	Rock Str. (RB 1 – RB 9)	Silica (%) (0 – 100)	Alteration	Features	Recovery (0 – 100)	Bit Size	Lab No	Ni (%)	Fe (%)	As (%)	Cr (%)	Bulk Dens.	Add. Analy.
0,0	980			Clay		N/A	N/A		Containing silica particles; carbonate; colored by Fe			51588	0,232	12,62	0,210	0,641		
				Silica		N/A	N/A		Containing clay particles; carbonate			51589	0,245	12,57	0,212	0,632		
				Clay		N/A	N/A		Containing silica particles; carbonate			51590	0,297	12,37	0,177	0,465		
						N/A	N/A					51591	0,348	10,68	0,142	0,555		
						N/A	N/A		Containing silica and limonite particles; carbonate; colored by Fe			51592	0,562	16,68	0,176	1,050		
5,0						N/A	N/A					51593	0,440	13,10	0,219	0,689		
				Silica		N/A	N/A		Containing carbonate			51594	0,279	8,35	0,110	0,447		
						N/A	N/A					51595	0,215	5,62	0,071	0,275		
						N/A	N/A					51596	0,212	5,84	0,090	0,297		
				Clay		N/A	N/A		Containing silica particles; carbonate			51597	0,270	8,05	0,160	0,358		
10,0	970					N/A	N/A		Containing silica and limonite particles; carbonate; colored by Fe			51598	0,555	14,49	0,190	0,827		
						N/A	N/A					51599	0,573	16,10	0,305	1,100		
				Silica		N/A	N/A		Containing carbonate			51600	0,386	11,84	0,205	0,608		
						N/A	N/A					51601	0,161	4,73	0,100	0,339		
				Limonite		N/A	N/A					51602	0,555	20,21	0,415	1,020		
15,0						N/A	N/A					51603	0,719	21,75	0,661	0,919		
				Silica		N/A	N/A					51604	0,318	12,25	0,326	0,678		
				Limonite		N/A	N/A		Containing clay particles; carbonate			51605	1,110	31,32	1,370	1,350		
						N/A	N/A					51606	0,486	13,94	0,494	0,954		
20,0						N/A	N/A					51607	1,240	24,40	0,615	1,090		

End Of Hole

Drill Company : Enerji-Su İnşaat A.Ş.	Logged By : Ahmet Sankaya	Controlled By : Necati S. Çağan	Approved By : Ferda Öner
Rig Type : RC 500			RC-TC-199
Drill Type : RC Drill	Groundwater : No	Remarks :	
Driller : Kavas KILIÇ			Scale : 1:100

Legend :

D : Duplication Sample - E : External Laboratory - C : Chemical Analysis - B : Blank Sample - Int : Interval - Bulk Density (t/m3) - RB : Rock Bit

Figure E.4 Drillhole log of RC-TC-199

Location : Türkmençardağı	Start Date : 17.08.2010	meta NİKEL KOBALT A.Ş.	Depth of Hole (m) : 20,00	Map : Balıkesir J20-D3
Drill Hole No: RC-TC-200	End Date : 17.08.2010	Gordes Nickel - Cobalt Project	Dip of Hole (degree) : 90	E : 602371,520
			Azimuth (degree) : 0	N : 4318645,421
				RL : 980,722

Depth (m)	RL (m)	Graphic Log	Int. (m)	Lithology	Description: Col.	Rock Str. (RB 1 RS 0)	Silica (%) (0 100)	Alteration	Features	Recovery (0 100)	Bit Size	Lab No	Ni (%)	Fe (%)	As (%)	Cr (%)	Bulk Dens.	Add. Analy.
0,0	980			Clay		N/A	N/A	N/A	Containing silica particles; carbonate		5"	51608	0,266	12,51	0,219	0,693		
				Silica		N/A	N/A	N/A	Containing clay particles			51609	0,183	8,48	0,156	0,587		
				Clay		N/A	N/A	N/A	Containing silica particles; carbonate			51610	0,172	11,79	0,195	0,671		
						N/A	N/A	N/A				51611	0,229	14,60	0,216	0,796		
						N/A	N/A	N/A				51612	0,223	14,95	0,217	0,877		
5,0						N/A	N/A	N/A	Containing carbonate			51613	0,236	16,15	0,246	0,991		
						N/A	N/A	N/A	Containing limonite particles; colored by Fe			51614	0,309	23,35	0,374	1,050		
						N/A	N/A	N/A	Containing carbonate; colored by Fe			51615	0,204	12,93	0,216	0,742		
						N/A	N/A	N/A	Containing carbonate			51616	0,197	11,37	0,181	0,656		
						N/A	N/A	N/A	Containing silica particles; carbonate			51617	0,215	13,59	0,210	0,700		
10,0	970					N/A	N/A	N/A	Containing silica particles; carbonate; colored by Fe			51618	0,240	14,64	0,208	0,719		
						N/A	N/A	N/A				51619	0,228	14,09	0,222	0,786		
						N/A	N/A	N/A				51620	0,240	15,08	0,230	0,797		
						N/A	N/A	N/A	Containing carbonate; colored by Fe			51621	0,213	13,94	0,202	0,756		
						N/A	N/A	N/A				51622	0,231	14,54	0,215	0,800		
15,0						N/A	N/A	N/A				51623	0,239	13,98	0,200	0,996		
						N/A	N/A	N/A				51624	0,229	12,95	0,191	0,726		
						N/A	N/A	N/A				51625	0,228	12,84	0,200	0,731		
						N/A	N/A	N/A				51626	0,207	12,22	0,217	0,606		
20,0						N/A	N/A	N/A				51627	0,308	19,37	0,348	0,757		

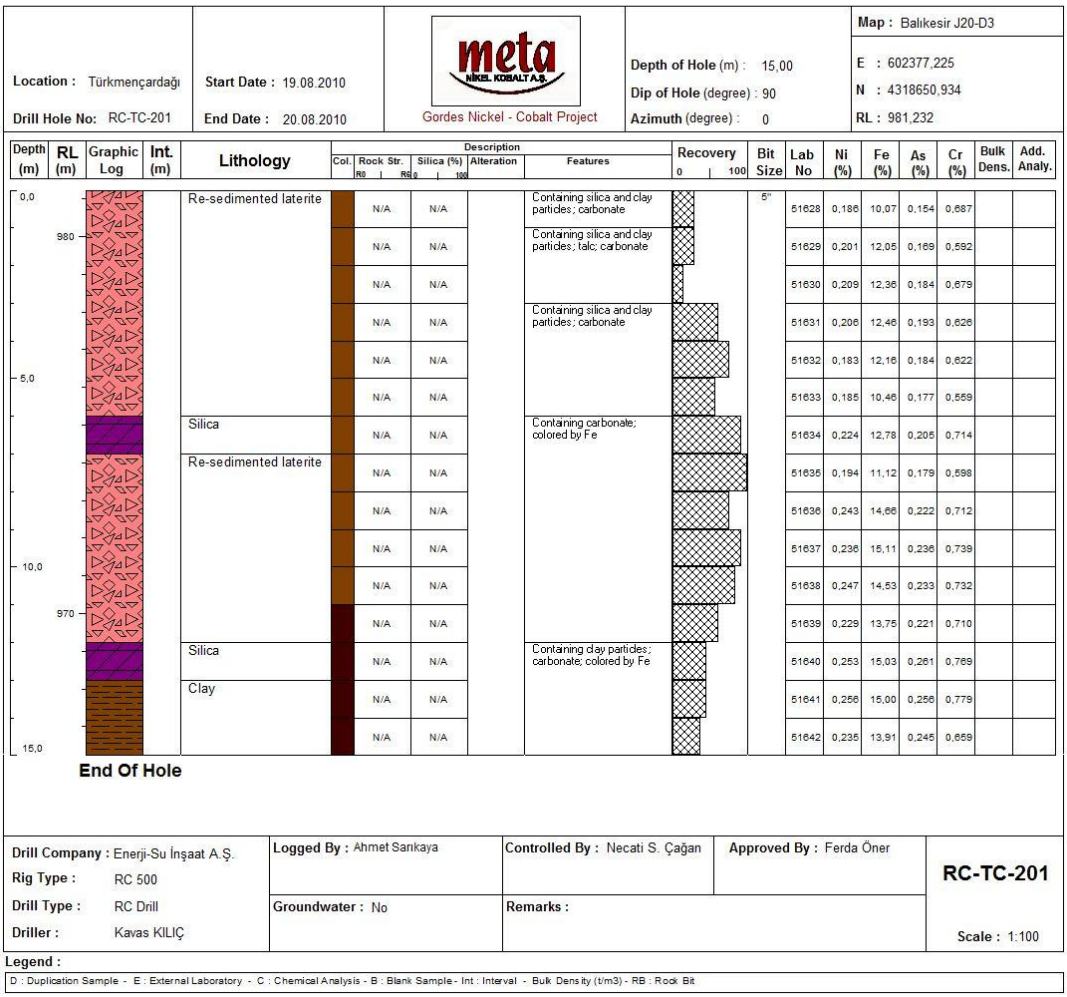
End Of Hole

Drill Company : Enerji-Su İnşaat A.Ş.	Logged By : Ahmet Sarıkaya	Controlled By : Necati S. Çağan	Approved By : Ferda Öner	RC-TC-200
Rig Type : RC 500				
Drill Type : RC Drill	Groundwater : No	Remarks :		
Driller : Kavas KILIÇ				Scale : 1:100

Legend :

D : Duplication Sample - E : External Laboratory - C : Chemical Analysis - B : Blank Sample - Int : Interval - Bulk Density (t/m3) - RB : Rock Bit

Figure E.5 Drillhole log of RC-TC-200



Location : Türkmençardağı	Start Date : 19.08.2010	meta NİKEL KOBALT A.Ş.	Depth of Hole (m) : 15,00	Map : Balıkesir J20-D3
Drill Hole No: RC-TC-201	End Date : 20.08.2010	Gordes Nickel - Cobalt Project	Dip of Hole (degree) : 90	E : 602377,225
			Azimuth (degree) : 0	N : 4318650,934
				RL : 981,232

Depth (m)	RL (m)	Graphic Log	Int. (m)	Lithology	Description: Col.	Rock Str. (R0 – R6)	Silica (%) (0 – 100)	Alteration	Features	Recovery (0 – 100)	Bit Size	Lab No	Ni (%)	Fe (%)	As (%)	Cr (%)	Bulk Dens.	Add. Analy.
0,0				Re-sedimented laterite		N/A	N/A		Containing silica and clay particles; carbonate		5"	51628	0,186	10,07	0,154	0,687		
	980					N/A	N/A		Containing silica and clay particles; talc; carbonate			51629	0,201	12,05	0,169	0,592		
						N/A	N/A					51630	0,209	12,36	0,184	0,679		
						N/A	N/A		Containing silica and clay particles; carbonate			51631	0,206	12,46	0,193	0,626		
						N/A	N/A					51632	0,183	12,16	0,184	0,622		
5,0						N/A	N/A					51633	0,185	10,46	0,177	0,559		
				Silica		N/A	N/A		Containing carbonate; colored by Fe			51634	0,224	12,78	0,205	0,714		
				Re-sedimented laterite		N/A	N/A					51635	0,194	11,12	0,179	0,598		
						N/A	N/A					51636	0,243	14,66	0,222	0,712		
						N/A	N/A					51637	0,236	15,11	0,236	0,739		
10,0						N/A	N/A					51638	0,247	14,53	0,233	0,732		
	970					N/A	N/A					51639	0,229	13,75	0,221	0,710		
				Silica		N/A	N/A		Containing clay particles; carbonate; colored by Fe			51640	0,253	15,03	0,261	0,769		
				Clay		N/A	N/A					51641	0,256	15,00	0,256	0,779		
15,0						N/A	N/A					51642	0,235	13,91	0,245	0,659		

End Of Hole

Drill Company : Enerji-Su İnşaat A.Ş.	Logged By : Ahmet Sarıkaya	Controlled By : Necati S. Çağan	Approved By : Ferda Öner	RC-TC-201
Rig Type : RC 500				
Drill Type : RC Drill	Groundwater : No	Remarks :		
Driller : Kavas KILIÇ				Scale : 1:100

Legend :

D : Duplication Sample - E : External Laboratory - C : Chemical Analysis - B : Blank Sample - Int : Interval - Bulk Density (t/m3) - RB : Rock Bit

Figure E.6 Drillhole log of RC-TC-201

Location : Türkmençardağı	Start Date : 17.08.2010	meta NİKEL KOBALT A.Ş.	Depth of Hole (m) : 20,00	Map : Balıkesir J20-D3
Drill Hole No: RC-TC-202	End Date : 17.08.2010	Gordes Nickel - Cobalt Project	Dip of Hole (degree) : 90	E : 602377,780
			Azimuth (degree) : 0	N : 4318642,028
				RL : 981,514

Depth (m)	RL (m)	Graphic Log	Int. (m)	Lithology	Description: Col.	Rock Str. (RB 1 – RS 0)	Silica (%) (0 – 100)	Alteration	Features	Recovery (0 – 100)	Bit Size	Lab No	Ni (%)	Fe (%)	As (%)	Cr (%)	Bulk Dens.	Add. Analy.
0,0				Re-sedimented laterite		N/A	N/A	N/A	Containing silica and clay particles; carbonate		5"	51643	0,173	9,79	0,203	0,529		
	980					N/A	N/A	N/A				51644	0,244	12,92	0,320	0,570		
				Limonite		N/A	N/A	N/A	Containing clay and silica particles; carbonate			51645	0,289	23,93	0,498	0,782		
						N/A	N/A	N/A				51646	0,289	22,08	0,473	0,972		
						N/A	N/A	N/A				51647	0,366	22,38	0,438	0,934		
5,0						N/A	N/A	N/A				51648	0,483	20,86	0,342	1,130		
						N/A	N/A	N/A				51649	0,405	20,55	0,320	1,150		
				Clay		N/A	N/A	N/A	Containing limonite particles; carbonate			51650	0,466	16,11	0,316	0,969		
						N/A	N/A	N/A				51651	0,429	13,57	0,214	0,614		
						N/A	N/A	N/A				51652	0,465	14,18	0,189	0,808		
10,0				Limonite		N/A	N/A	N/A	Containing silica particles; carbonate			51653	0,669	25,04	0,363	1,140		
	970			Clay		N/A	N/A	N/A				51654	0,239	8,69	0,168	0,316		
						N/A	N/A	N/A				51655	0,271	9,67	0,188	0,468		
						N/A	N/A	N/A				51656	0,293	9,55	0,164	0,494		
						N/A	N/A	N/A				51657	0,218	6,16	0,103	0,298		
15,0						N/A	N/A	N/A	Containing limonite particles; carbonate			51658	0,357	12,16	0,220	0,411		
						N/A	N/A	N/A				51659	0,366	10,81	0,220	0,573		
				Limonite		N/A	N/A	N/A	Containing clay particles; carbonate			51660	0,841	25,59	0,576	1,350		
				Silica		N/A	N/A	N/A	Containing carbonate			51661	0,295	9,61	0,211	0,668		
20,0						N/A	N/A	N/A				51662	0,144	4,60	0,099	0,344		

End Of Hole

Drill Company : Enerji-Su İnşaat A.Ş.	Logged By : Ahmet Sarıkaya	Controlled By : Necati S. Çağan	Approved By : Ferda Öner	RC-TC-202
Rig Type : RC 500				
Drill Type : RC Drill	Groundwater : No	Remarks :		
Driller : Kavas KILIÇ				Scale : 1:100

Legend :

D : Duplication Sample - E : External Laboratory - C : Chemical Analysis - B : Blank Sample - Int : Interval - Bulk Density (t/m3) - RB : Rock Bit

Figure E.7 Drillhole log of RC-TC-202

Location : Türkmençardağı	Start Date : 20.08.2010	meta NİKEL KOBALT A.Ş.	Depth of Hole (m) : 15,00	Map : Balıkesir J20-D3
Drill Hole No: RC-TC-203	End Date : 21.08.2010	Gordes Nickel - Cobalt Project	Dip of Hole (degree) : 90	E : 602378,351
			Azimuth (degree) : 0	N : 4318632,861
				RL : 981,384

Depth (m)	RL (m)	Graphic Log	Int. (m)	Lithology	Description: Col.	Rock Str. (R0 – R6)	Silica (%) (0 – 100)	Alteration	Features	Recovery (0 – 100)	Bit Size	Lab No	Ni (%)	Fe (%)	As (%)	Cr (%)	Bulk Dens.	Add. Analy.
0,0				Silica		N/A	N/A		Containing carbonate		5"	51663	0,166	6,76	0,123	0,440		
	980			Clay		N/A	N/A		Containing silica particles; carbonate; colored by Fe			51664	0,244	12,51	0,203	0,577		
				Limonite		N/A	N/A		Containing clay and silica particles			51665	0,649	23,83	0,260	1,150		
						N/A	N/A					51666	0,781	25,71	0,193	1,690		
				Silica		N/A	N/A		Containing carbonate			51667	0,313	10,83	0,128	0,556		
5,0				Clay		N/A	N/A		Containing silica particles; carbonate			51668	0,304	8,06	0,188	0,412		
						N/A	N/A					51669	0,211	6,48	0,083	0,314		
						N/A	N/A					51670	0,232	7,04	0,118	0,338		
						N/A	N/A		Containing silica and limonite particles; carbonate; colored by Fe			51671	0,541	16,20	0,204	0,873		
				Silica		N/A	N/A		Containing carbonate			51672	0,296	8,24	0,111	0,473		
10,0						N/A	N/A					51673	0,146	4,61	0,057	0,445		
	970			Clay		N/A	N/A		Containing silica and limonite particles; carbonate; colored by Fe			51674	0,434	11,03	0,225	0,645		
				Silica		N/A	N/A		Containing carbonate			51675	0,125	4,09	0,076	0,266		
						N/A	N/A					51676	0,115	3,96	0,089	0,221		
				Clay		N/A	N/A		Containing limonite particles; colored by Fe			51677	0,405	11,90	0,297	0,494		
15,0																		

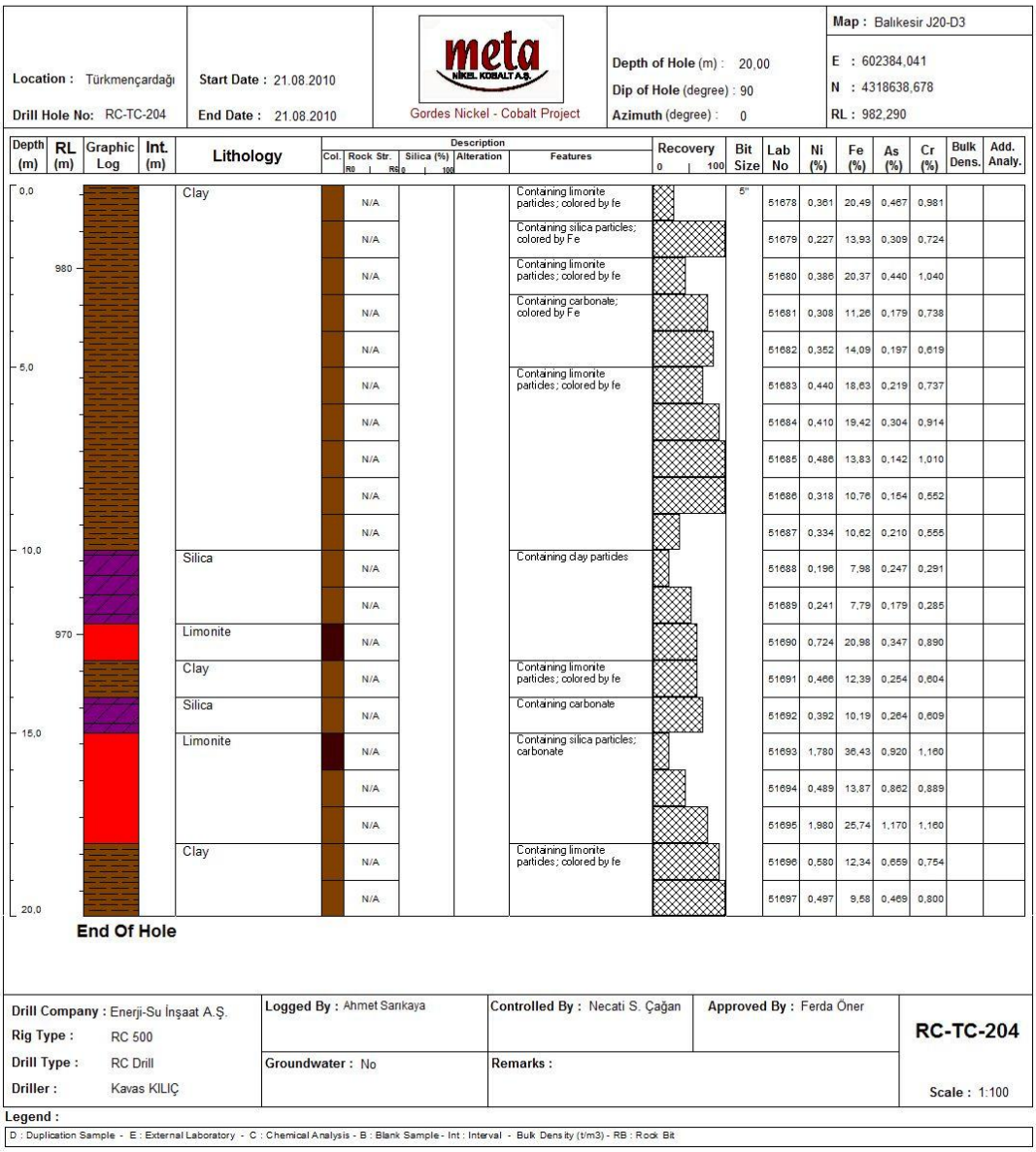
End Of Hole

Drill Company : Enerji-Su İnşaat A.Ş.	Logged By : Ahmet Sarıkaya	Controlled By : Necati S. Çağan	Approved By : Ferda Öner
Rig Type : RC 500			**RC-TC-203**
Drill Type : RC Drill	Groundwater : No	Remarks :	
Driller : Kavas KILIÇ			Scale : 1:100

Legend :

D : Duplication Sample - E : External Laboratory - C : Chemical Analysis - B : Blank Sample - Int : Interval - Bulk Density (t/m3) - RB : Rock Bit

Figure E.8 Drillhole log of RC-TC-203



Location : Türkmençardağı	Start Date : 21.08.2010	meta NİKEL KOBALT A.Ş.	Depth of Hole (m) : 20,00	Map : Balıkesir J20-D3
Drill Hole No: RC-TC-204	End Date : 21.08.2010	Gordes Nickel - Cobalt Project	Dip of Hole (degree) : 90	E : 602384,041
			Azimuth (degree) : 0	N : 4318638,678
				RL : 982,290

Depth (m)	RL (m)	Graphic Log	Int. (m)	Lithology	Col.	Rock Str. (RB – RS)	Silica (%) (0 – 100)	Alteration	Features	Recovery (0 – 100)	Bit Size	Lab No	Ni (%)	Fe (%)	As (%)	Cr (%)	Bulk Dens.	Add. Analy.
0,0				Clay		N/A			Containing limonite particles; colored by fe		5"	51678	0,361	20,49	0,467	0,981		
						N/A			Containing silica particles; colored by Fe			51679	0,227	13,93	0,309	0,724		
	980					N/A			Containing limonite particles; colored by fe			51680	0,386	20,37	0,440	1,040		
						N/A			Containing carbonate; colored by Fe			51681	0,308	11,26	0,179	0,738		
						N/A						51682	0,352	14,09	0,197	0,619		
5,0						N/A			Containing limonite particles; colored by fe			51683	0,440	18,63	0,219	0,737		
						N/A						51684	0,410	19,42	0,304	0,914		
						N/A						51685	0,486	13,83	0,142	1,010		
						N/A						51686	0,318	10,76	0,154	0,552		
						N/A						51687	0,334	10,62	0,210	0,555		
10,0				Silica		N/A			Containing clay particles			51688	0,196	7,98	0,247	0,291		
						N/A						51689	0,241	7,79	0,179	0,285		
	970			Limonite		N/A						51690	0,724	20,98	0,347	0,890		
				Clay		N/A			Containing limonite particles; colored by fe			51691	0,466	12,39	0,254	0,604		
				Silica		N/A			Containing carbonate			51692	0,392	10,19	0,264	0,609		
15,0				Limonite		N/A			Containing silica particles; carbonate			51693	1,780	36,43	0,920	1,160		
						N/A						51694	0,489	13,87	0,862	0,889		
						N/A						51695	1,980	25,74	1,170	1,160		
				Clay		N/A			Containing limonite particles; colored by fe			51696	0,580	12,34	0,659	0,754		
20,0						N/A						51697	0,497	9,58	0,469	0,800		

End Of Hole

Drill Company : Enerji-Su İnşaat A.Ş.	Logged By : Ahmet Sankaya	Controlled By : Necati S. Çağan	Approved By : Ferda Öner	RC-TC-204
Rig Type : RC 500				
Drill Type : RC Drill	Groundwater : No	Remarks :		
Driller : Kavas KILIÇ				Scale : 1:100

Legend :

D : Duplication Sample - E : External Laboratory - C : Chemical Analysis - B : Blank Sample - Int : Interval - Bulk Density (t/m3) - RB : Rock Bit

Figure E.9 Drillhole log of RC-TC-204

Location : Türkmençardağı Drill Hole No: RC-TC-205	Start Date : 21.08.2010 End Date : 23.08.2010	meta NİKEL KOBALT A.Ş. Gordes Nickel - Cobalt Project	Depth of Hole (m) : 20,00 Dip of Hole (degree) : 90 Azimuth (degree) : 0	Map : Balıkesir J20-D3 E : 602383,564 N : 4318646,295 RL : 982,105

Depth (m)	RL (m)	Graphic Log	Int. (m)	Lithology	Description: Col.	Rock Str. (RB – RS)	Silica (%) (0 – 100)	Alteration	Features	Recovery (0 – 100)	Bit Size	Lab No	Ni (%)	Fe (%)	As (%)	Cr (%)	Bulk Dens.	Add. Analy.
0,0				Silica					Containing carbonate		5"	51744	0,210	8,06	0,215	0,669		
									Containing clay particles; carbonate; colored by Fe			51745	0,239	19,85	0,468	0,881		
	980			Clay					Containing silica particles; carbonate; colored by Fe			51746	0,281	21,95	0,581	0,628		
												51747	0,251	13,67	0,448	0,712		
				Silica					Containing carbonate			51748	0,162	7,73	0,213	0,413		
5,0				Clay					Containing carbonate; colored by Fe			51749	0,216	12,29	0,315	0,874		
				Limonite					Containing clay particles; carbonate			51750	0,527	28,23	1,040	1,170		
				Clay					Containing limonite particles; carbonate			51751	0,419	15,68	0,306	0,757		
									Containing limonite and silica particles; carbonate			51752	0,407	14,27	0,333	0,640		
									Containing limonite particles; carbonate			51753	0,391	14,87	0,333	0,758		
10,0												51754	0,373	14,06	0,279	0,771		
				Limonite					Containing clay particles; carbonate			51755	0,553	19,13	0,248	1,170		
	970			Clay					Containing limonite particles; carbonate			51756	0,433	14,16	0,206	0,709		
				Limonite					Containing clay particles; carbonate			51757	0,673	19,18	0,238	0,952		
												51758	0,768	23,81	0,284	1,080		
15,0				Clay					Containing silica particles; carbonate; colored by Fe			51759	0,382	14,95	0,243	0,953		
									Containing silica particles; carbonate			51760	0,308	11,35	0,229	0,429		
												51761	0,397	13,94	0,281	0,668		
				Limonite								51762	0,555	21,43	0,563	0,906		
				Clay					Containing limonite and silica particles; carbonate			51763	0,427	15,52	0,406	0,735		
20,0																		

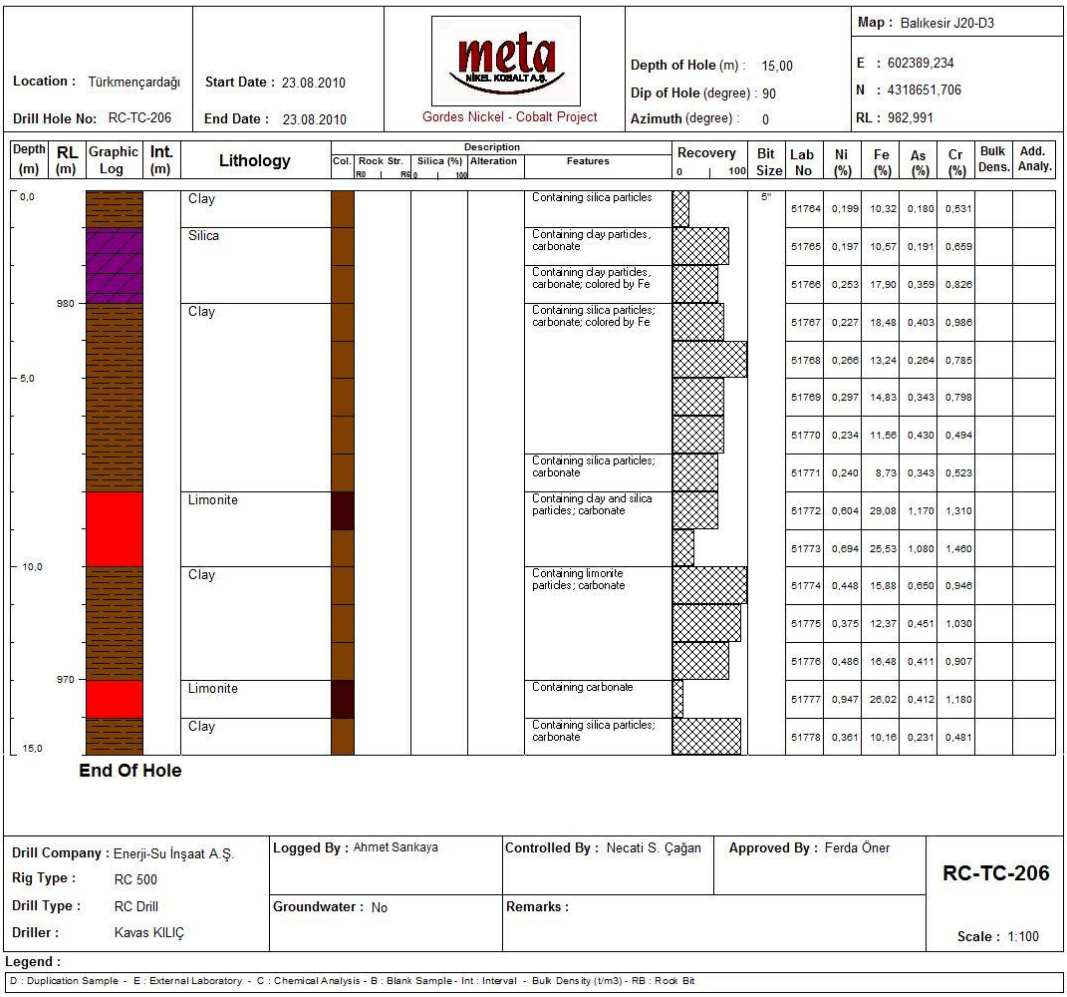
End Of Hole

Drill Company : Enerji-Su İnşaat A.Ş. Rig Type : RC 500 Drill Type : RC Drill Driller : Kavas KILIÇ	Logged By : Ahmet Sankaya Groundwater : No	Controlled By : Necati S. Çağan Remarks :	Approved By : Ferda Öner	RC-TC-205 Scale : 1:100

Legend :

D : Duplication Sample - E : External Laboratory - C : Chemical Analysis - B : Blank Sample - Int : Interval - Bulk Density (t/m3) - RB : Rock Bit

Figure E.10 Drillhole log of RC-TC-205



Location : Türkmençardağı	Start Date : 23.08.2010	meta NİKEL KOBALT A.Ş.	Depth of Hole (m) : 15,00	Map : Balıkesir J20-D3
Drill Hole No: RC-TC-206	End Date : 23.08.2010	Gordes Nickel - Cobalt Project	Dip of Hole (degree) : 90	E : 602389,234
			Azimuth (degree) : 0	N : 4318651,706
				RL : 982,991

Depth (m)	RL (m)	Graphic Log	Int. (m)	Lithology	Description: Col.	Rock Str. (RS 0 – RS 10)	Silica (%) (0 – 100)	Alteration	Features	Recovery (0 – 100)	Bit Size	Lab No	Ni (%)	Fe (%)	As (%)	Cr (%)	Bulk Dens.	Add. Analy.
0,0				Clay					Containing silica particles		5"	51764	0,199	10,32	0,180	0,531		
				Silica					Containing clay particles, carbonate			51765	0,197	10,57	0,191	0,659		
									Containing clay particles, carbonate; colored by Fe			51766	0,253	17,90	0,359	0,826		
	980			Clay					Containing silica particles; carbonate; colored by Fe			51767	0,227	18,48	0,403	0,986		
												51768	0,266	13,24	0,264	0,785		
5,0												51769	0,297	14,83	0,343	0,798		
												51770	0,234	11,56	0,430	0,494		
									Containing silica particles; carbonate			51771	0,240	8,73	0,343	0,523		
				Limonite					Containing clay and silica particles; carbonate			51772	0,604	29,08	1,170	1,310		
												51773	0,694	25,53	1,080	1,460		
10,0				Clay					Containing limonite particles; carbonate			51774	0,448	15,88	0,650	0,946		
												51775	0,375	12,37	0,451	1,030		
												51776	0,486	16,48	0,411	0,907		
	970			Limonite					Containing carbonate			51777	0,947	26,02	0,412	1,180		
				Clay					Containing silica particles; carbonate			51778	0,361	10,16	0,231	0,481		
15,0																		

End Of Hole

Drill Company : Enerji-Su İnşaat A.Ş.	Logged By : Ahmet Sarıkaya	Controlled By : Necati S. Çağan	Approved By : Ferda Öner
Rig Type : RC 500			
Drill Type : RC Drill	Groundwater : No	Remarks :	
Driller : Kavas KILIÇ			

RC-TC-206

Scale : 1:100

Legend :

D : Duplication Sample - E : External Laboratory - C : Chemical Analysis - B : Blank Sample - Int : Interval - Bulk Density (t/m3) - RB : Rock Bit

Figure E.11 Drillhole log of RC-TC-206

Location : Türkmençardağı Drill Hole No: RC-TC-207	Start Date : 23.08.2010 End Date : 24.08.2010	meta NİKEL KOBALT A.Ş. Gordes Nickel - Cobalt Project	Depth of Hole (m) : 20,00 Dip of Hole (degree) : 90 Azimuth (degree) : 0	Map : Balıkesir J20-D3 E : 602389,770 N : 4318642,924 RL : 982,850

Depth (m)	RL (m)	Graphic Log	Int. (m)	Lithology	Description: Col.	Rock Str. (RB – RS)	Silica (%) (0 – 100)	Alteration	Features	Recovery (0 – 100)	Bit Size	Lab No	Ni (%)	Fe (%)	As (%)	Cr (%)	Bulk Dens.	Add. Analy.
0,0				Clay				N/A	Containig silica particles; carbonate		5"	51779	0,222	9,56	0,235	0,724		
								N/A				51780	0,230	13,76	0,338	0,767		
				Silica				N/A	Containing carbonate			51781	0,209	13,10	0,246	0,683		
	980			Limonite				N/A	Containing clay and silica particles; carbonate			51782	0,320	20,28	0,685	0,926		
								N/A				51783	0,373	25,52	0,569	1,180		
5,0								N/A				51784	0,386	21,00	0,484	1,270		
				Clay				N/A	Containing limonite particles; carbonate; colored by Fe			51785	0,391	15,29	0,282	1,020		
								N/A				51786	0,480	16,07	0,279	0,888		
								N/A				51787	0,491	13,42	0,145	0,705		
				Limonite				N/A	Containing clay particles; carbonate			51788	0,649	18,54	0,171	1,050		
10,0								N/A				51789	0,645	19,26	0,301	1,160		
				Silica				N/A	Containing carbonate			51790	0,353	10,79	0,248	0,551		
				Clay				N/A	Containing limonite particles; carbonate; colored by Fe			51791	0,461	13,06	0,423	0,698		
	970							N/A				51792	0,533	13,04	0,551	0,766		
								N/A				51793	0,433	15,43	0,989	0,854		
15,0								N/A				51794	0,505	14,87	1,020	0,711		
				Limonite				N/A	Containig silica particles; carbonate			51795	1,370	21,26	1,020	1,160		
								N/A				51796	0,908	22,48	1,920	1,700		
				Clay				N/A	Containing clay and limonite particles; carbonate			51797	0,504	13,70	1,690	0,779		
				Limonite				N/A	Containig silica particles; carbonate			51798	0,821	24,27	2,520	1,280		
20,0																		

End Of Hole

Drill Company : Enerji-Su İnşaat A.Ş. Rig Type : RC 500 Drill Type : RC Drill Driller : Kavas KILIÇ	Logged By : Ahmet Sarıkaya Groundwater : No	Controlled By : Necati S. Çağan Remarks :	Approved By : Ferda Öner RC-TC-207 Scale : 1:100

Legend :

D : Duplication Sample - E : External Laboratory - C : Chemical Analysis - B : Blank Sample - Int : Interval - Bulk Density (t/m3) - RB : Rock Bit

Figure E.12 Drillhole log of RC-TC-207

Location : Türkmençardağı	Start Date : 24.08.2010	meta NİKEL KOBALT A.Ş.	Depth of Hole (m) : 15,00	Map : Balıkesir J20-D3
Drill Hole No: RC-TC-208	End Date : 24.08.2010	Gordes Nickel - Cobalt Project	Dip of Hole (degree) : 90	E : 602390,445
			Azimuth (degree) : 0	N : 4318633,823
				RL : 982,637

Depth (m)	RL (m)	Graphic Log	Int. (m)	Lithology	Description: Col.	Rock Str. (R0 – R6)	Silica (%) (0 – 100)	Alteration	Features	Recovery (0 – 100)	Bit Size	Lab No	Ni (%)	Fe (%)	As (%)	Cr (%)	Bulk Dens.	Add. Analy.
0,0				Clay		N/A			Containin silica particles; carbonate; colored by Fe		5"	51799	0,374	18,20	0,570	1,050		
						N/A						51800	0,323	13,61	0,263	0,768		
	980					N/A						51801	0,285	19,80	0,311	0,821		
						N/A						51802	0,257	14,65	0,287	0,741		
						N/A						51803	0,321	13,36	0,257	0,768		
5,0						N/A			Containing limonite and silica particles; carbonate			51804	0,465	13,86	0,241	0,835		
						N/A						51805	0,585	16,55	0,213	0,820		
				Limonite		N/A			Containing clay and silica particles; carbonate			51806	0,727	23,15	0,239	1,270		
				Clay		N/A						51807	0,353	9,89	0,149	0,604		
				Silica		N/A			Containing carbonate			51808	0,204	6,11	0,100	0,270		
10,0						N/A						51809	0,208	6,53	0,123	0,408		
				Clay		N/A			Containing silica particles; carbonate			51810	0,230	10,76	0,186	1,150		
	970					N/A			Containing limonite and silica particles; carbonate			51811	0,428	10,62	0,223	0,705		
						N/A						51812	0,781	11,08	0,419	1,270		
				Silica		N/A			Containing carbonate			51813	0,264	8,66	0,318	0,401		
15,0																		

End Of Hole

Drill Company : Enerji-Su İnşaat A.Ş.	Logged By : Ahmet Sarıkaya	Controlled By : Necati S. Çağan	Approved By : Ferda Öner	RC-TC-208
Rig Type : RC 500				
Drill Type : RC Drill	Groundwater : No	Remarks :		
Driller : Kavas KILIÇ				Scale : 1:100

Legend :

D : Duplication Sample - E : External Laboratory - C : Chemical Analysis - B : Blank Sample - Int : Interval - Bulk Density (t/m3) - RB : Rock Bit

Figure E.13 Drillhole log of RC-TC-208

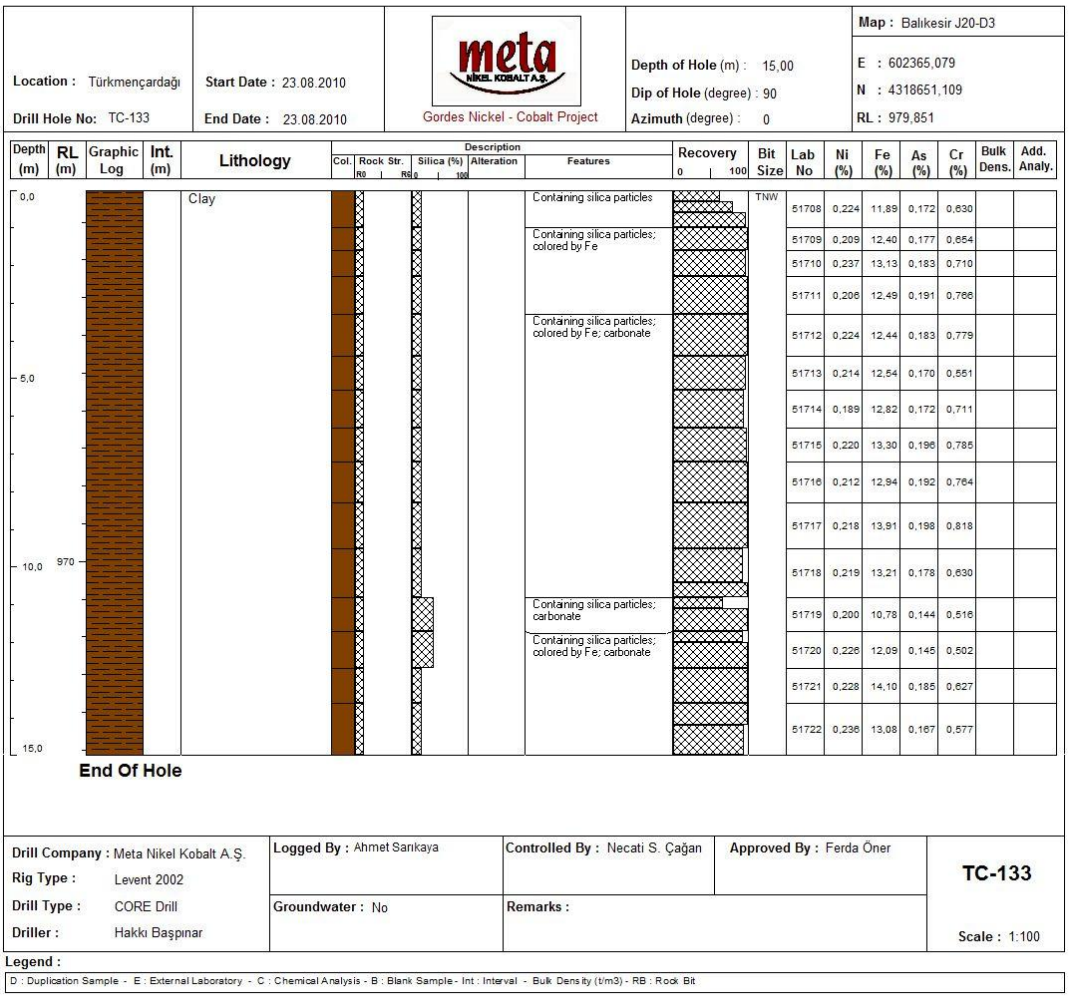


Figure E.14 Drillhole log of TC-133

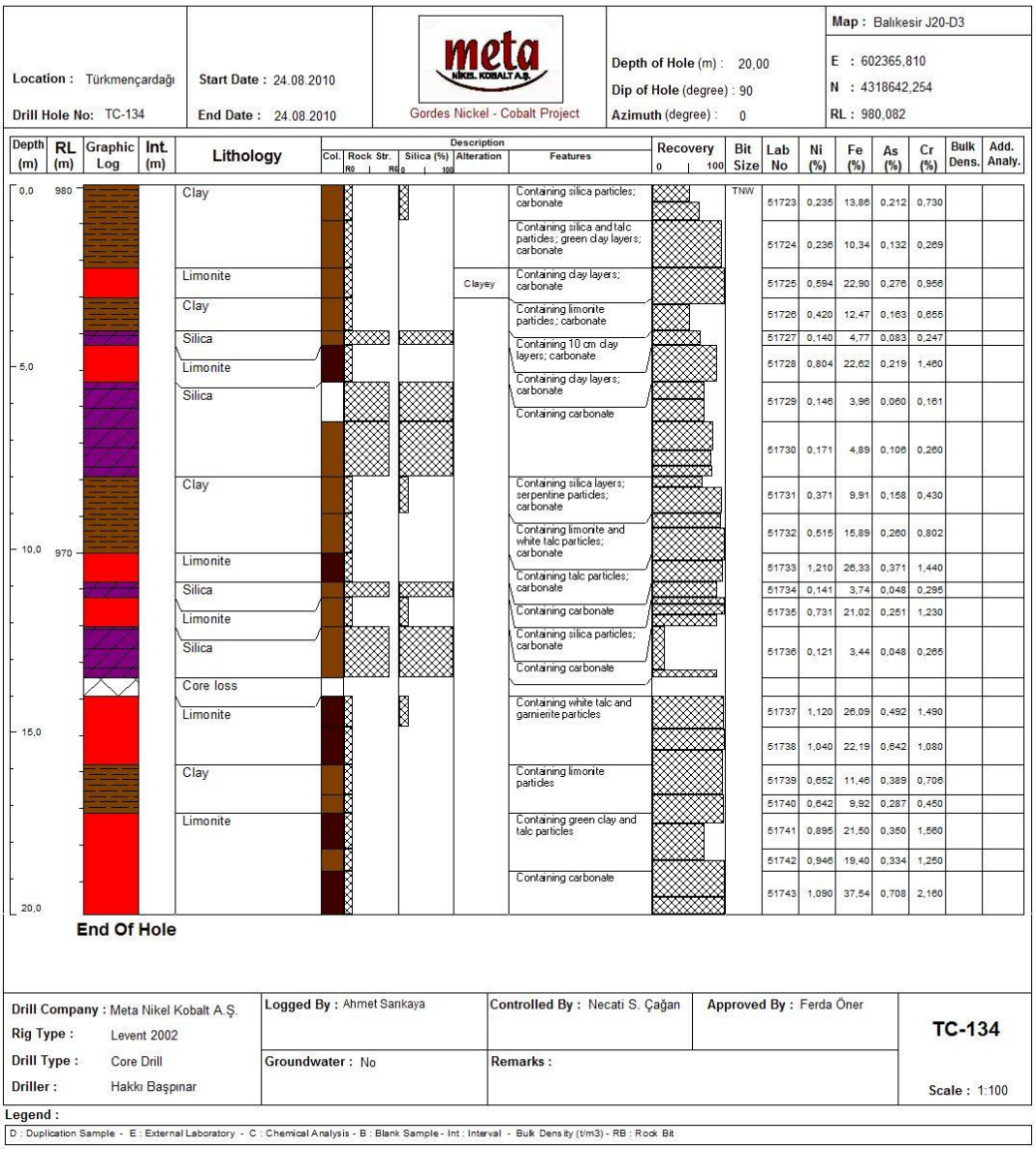


Figure E.15 Drillhole log of TC-134

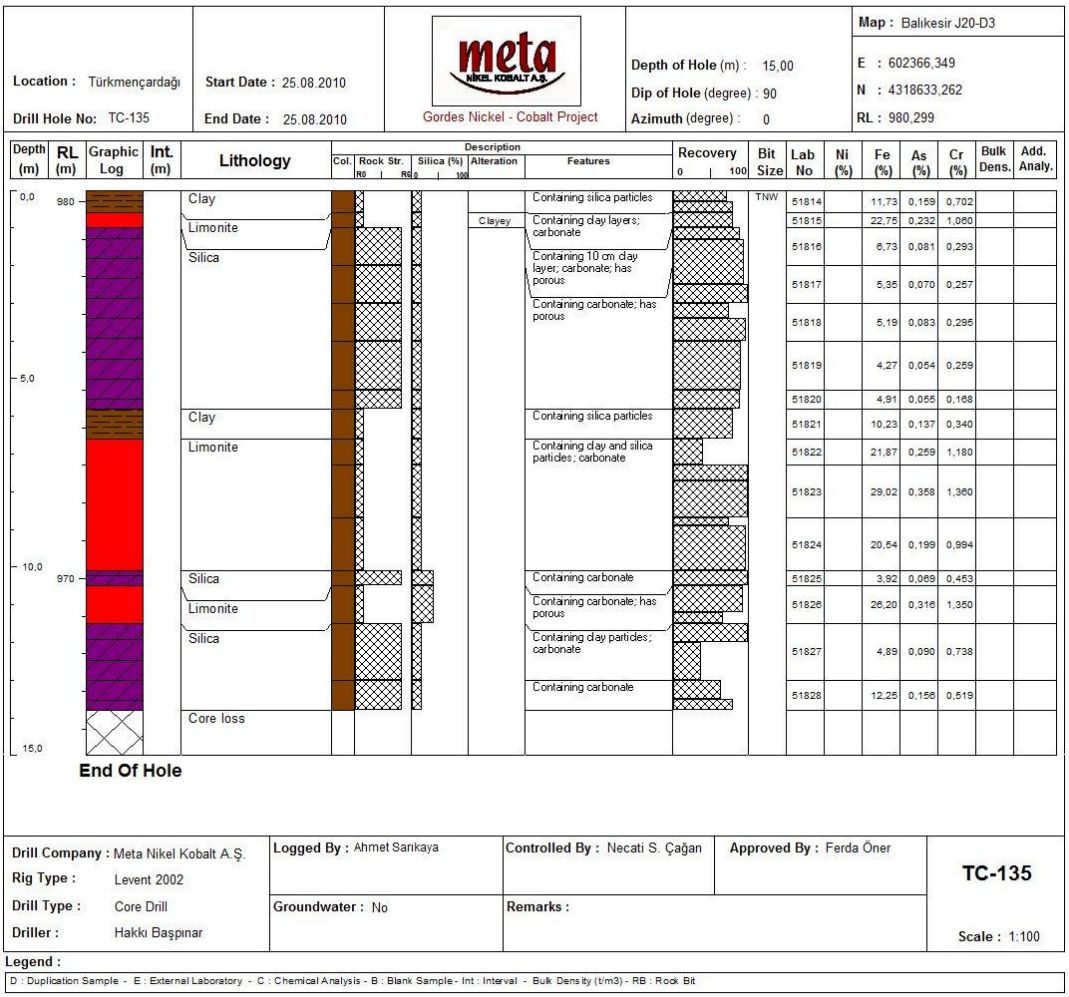


Figure E.16 Drillhole log of TC-135

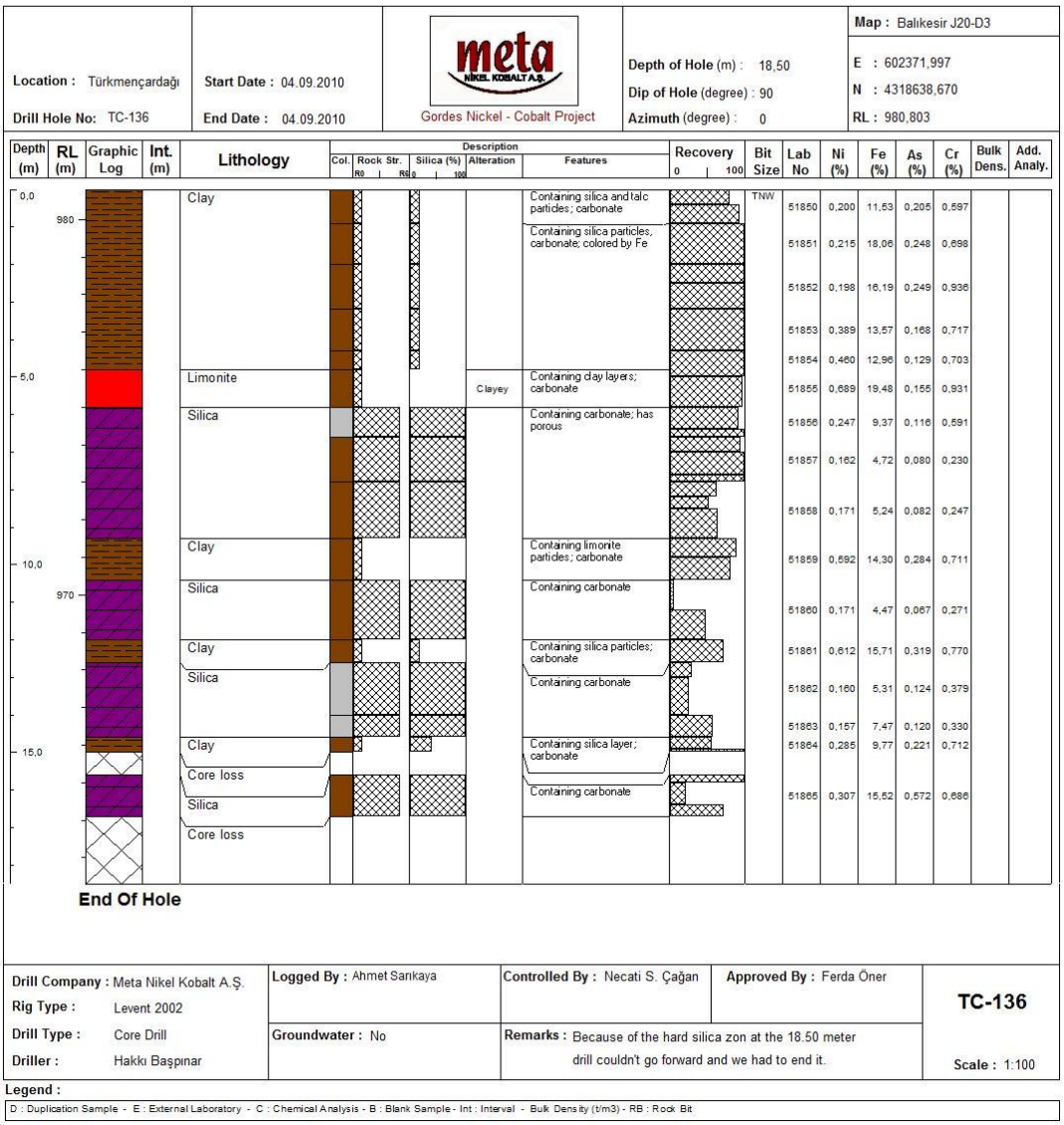


Figure E.17 Drillhole log of TC-136

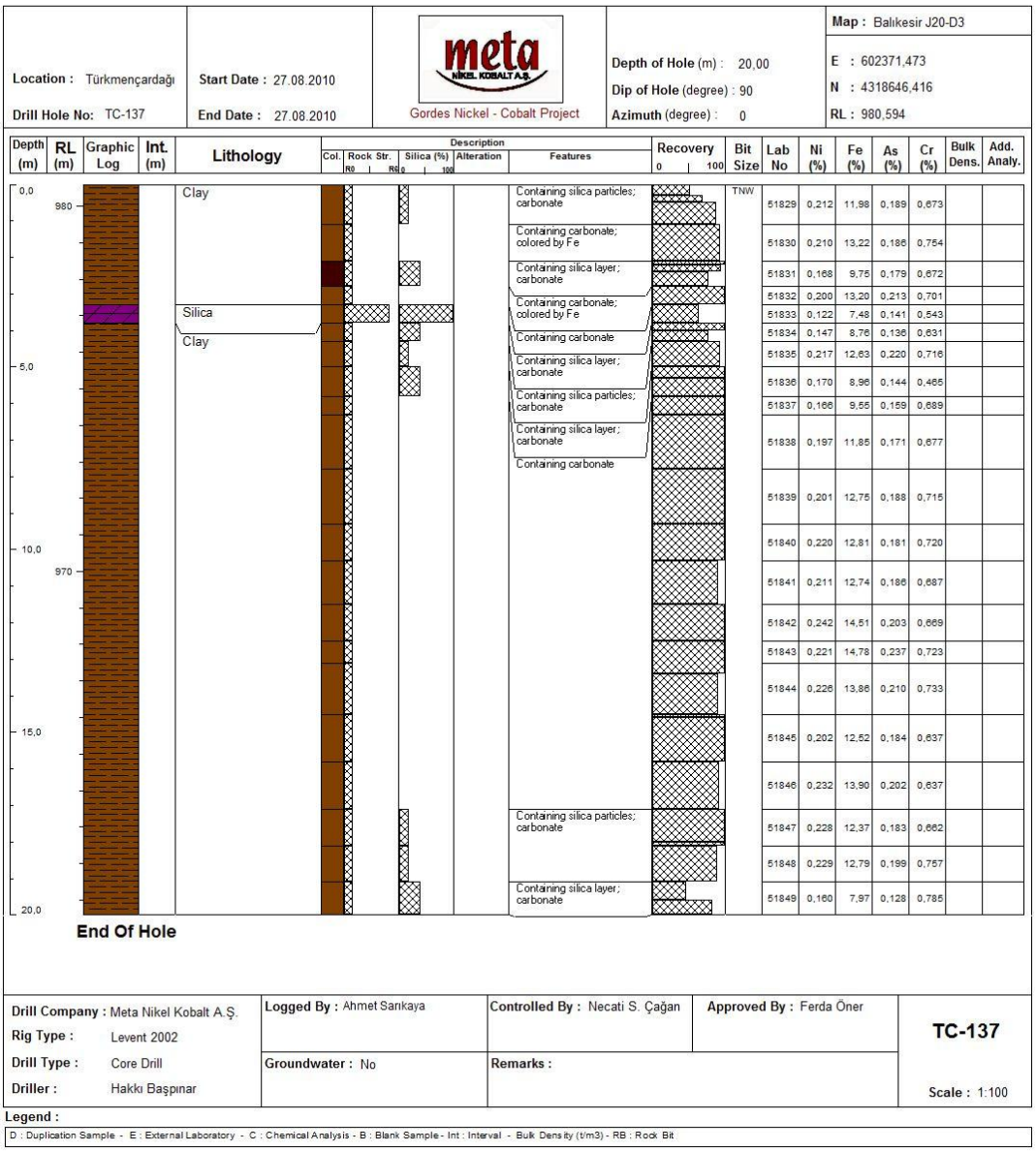


Figure E.18 Drillhole log of TC-137

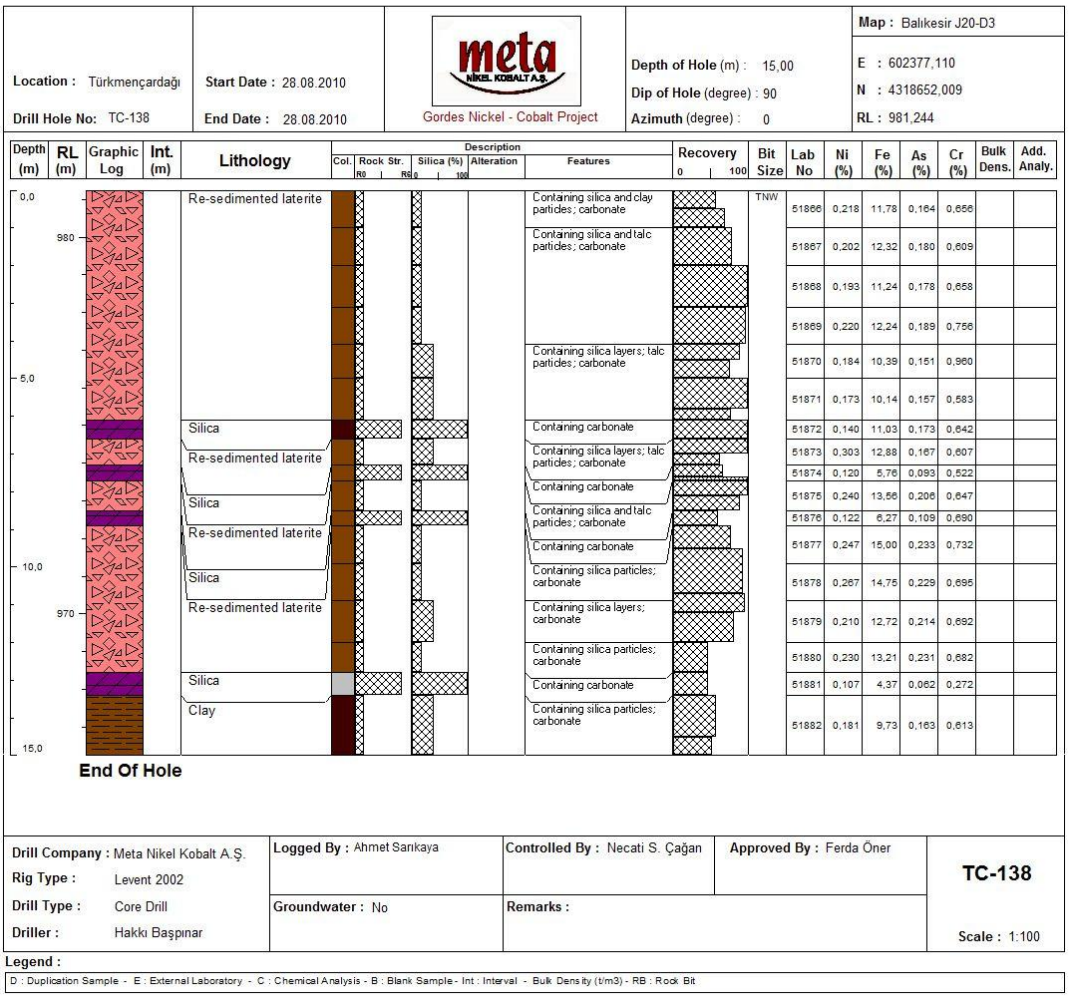


Figure E.19 Drillhole log of TC-138

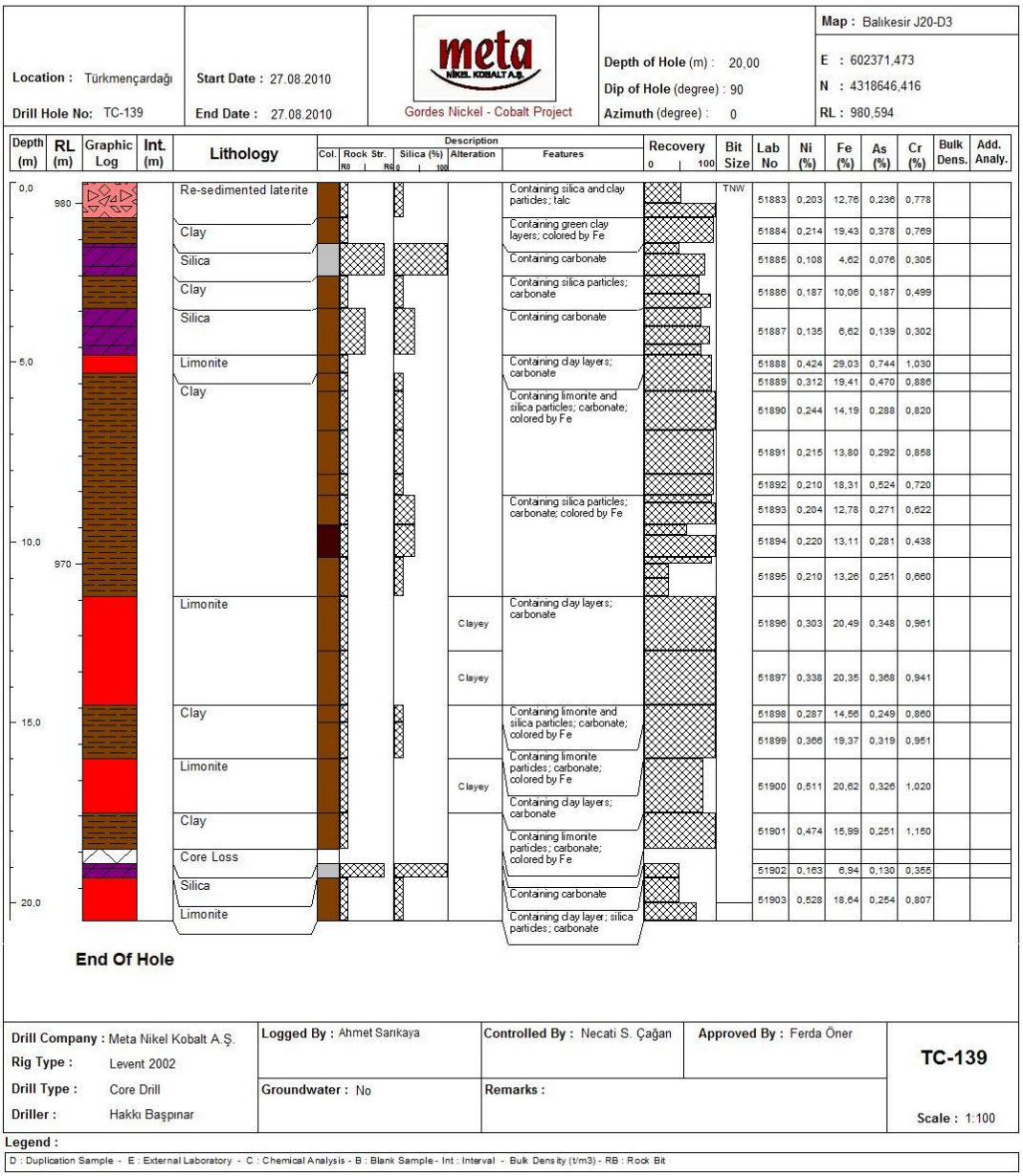


Figure E.20 Drillhole log of TC-139

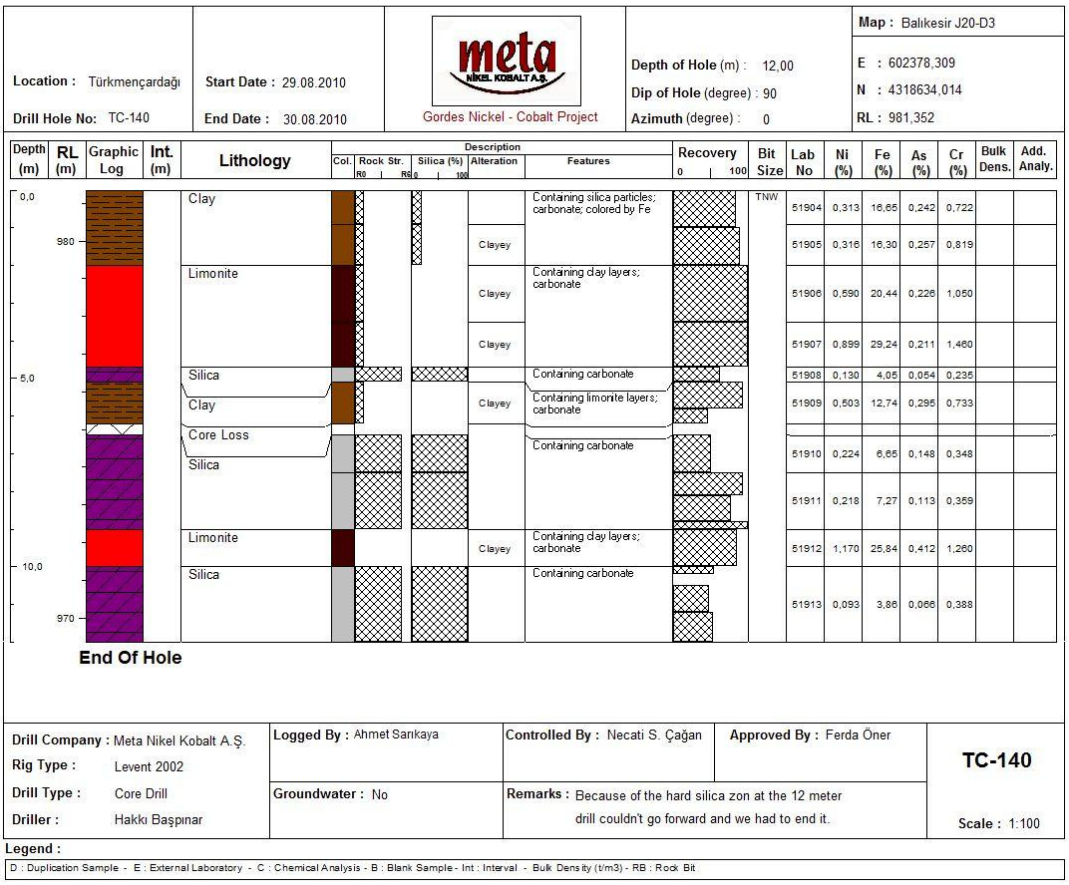


Figure E.21 Drillhole log of TC-140

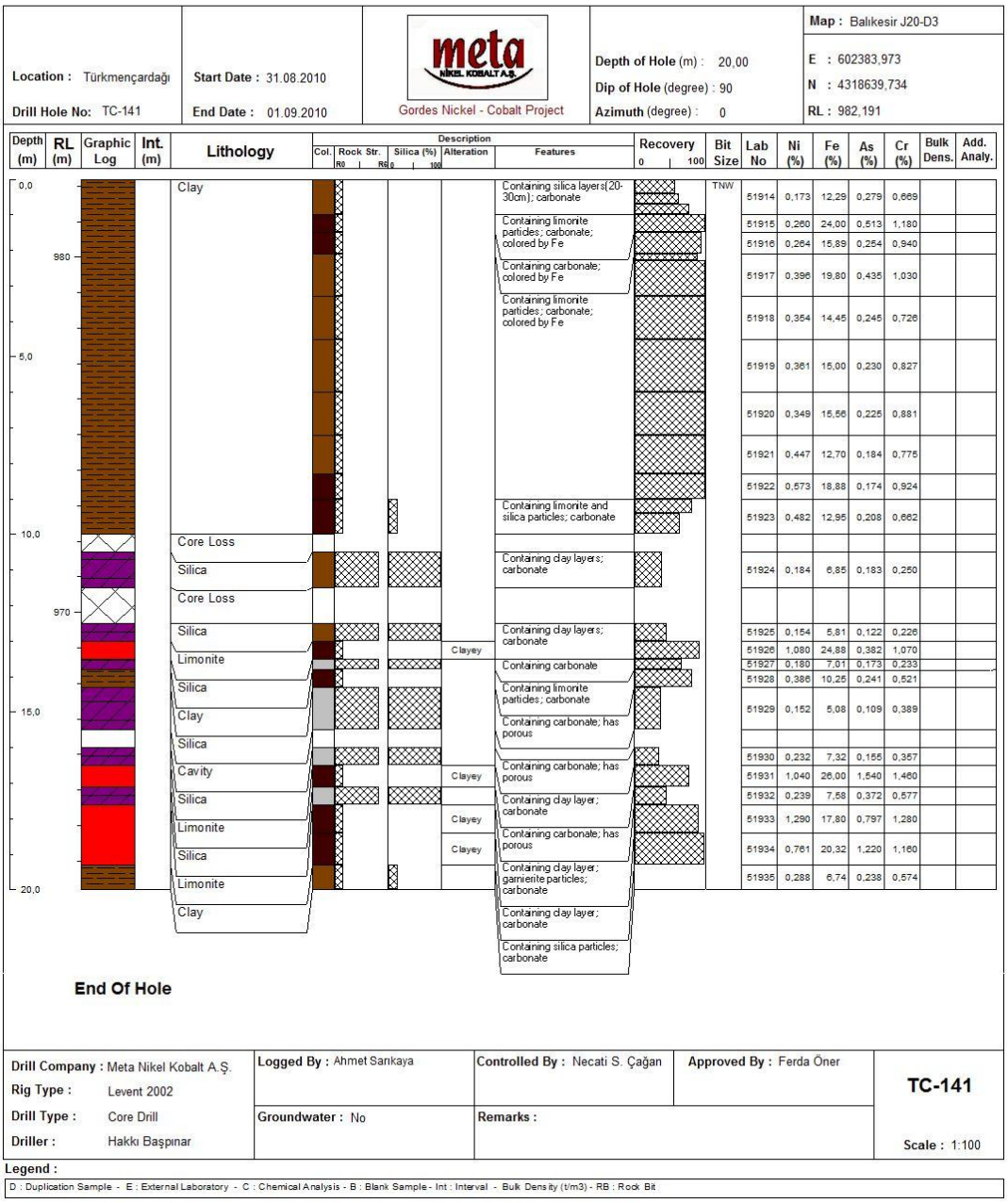


Figure E.22 Drillhole log of TC-141

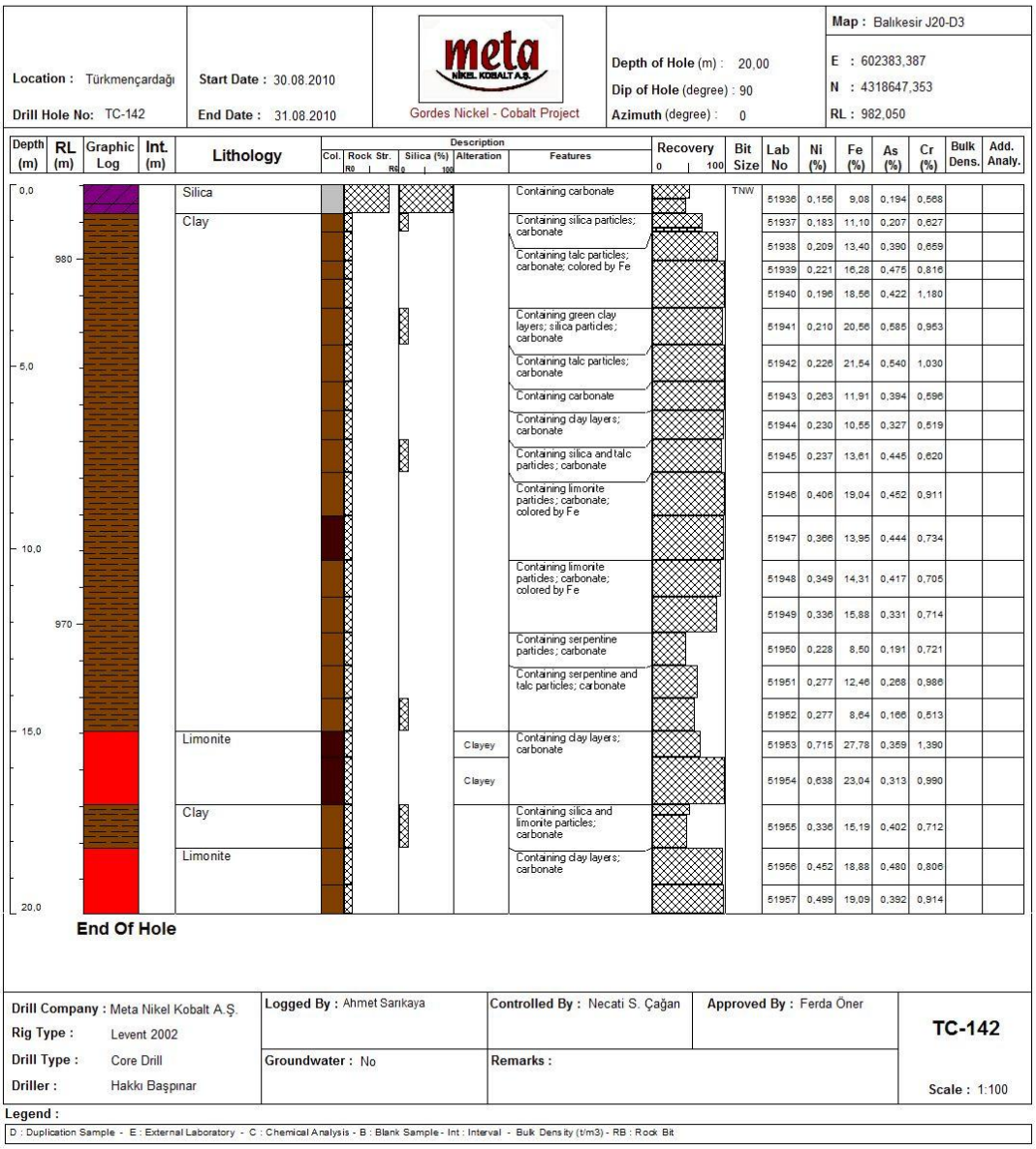


Figure E.23 Drillhole log of TC-142

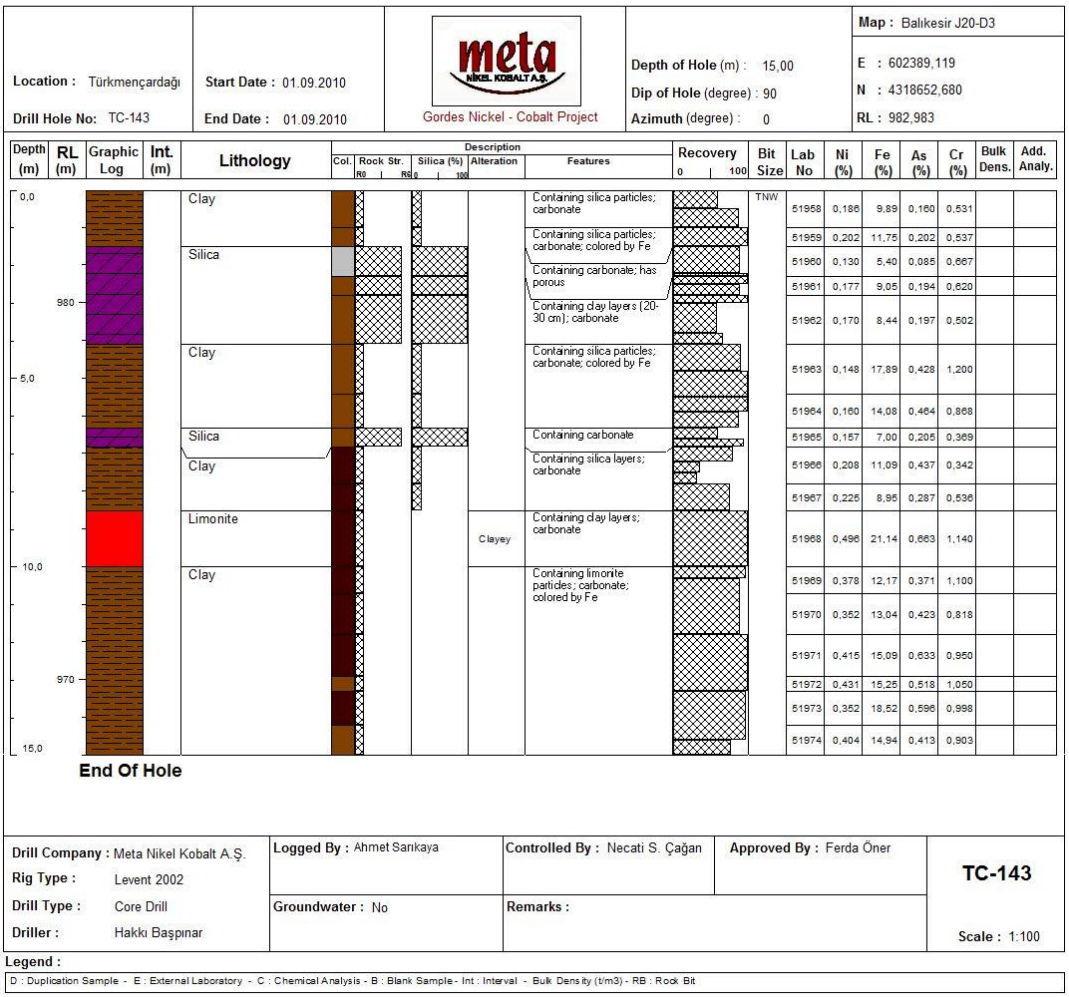


Figure E.24 Drillhole log of TC-143

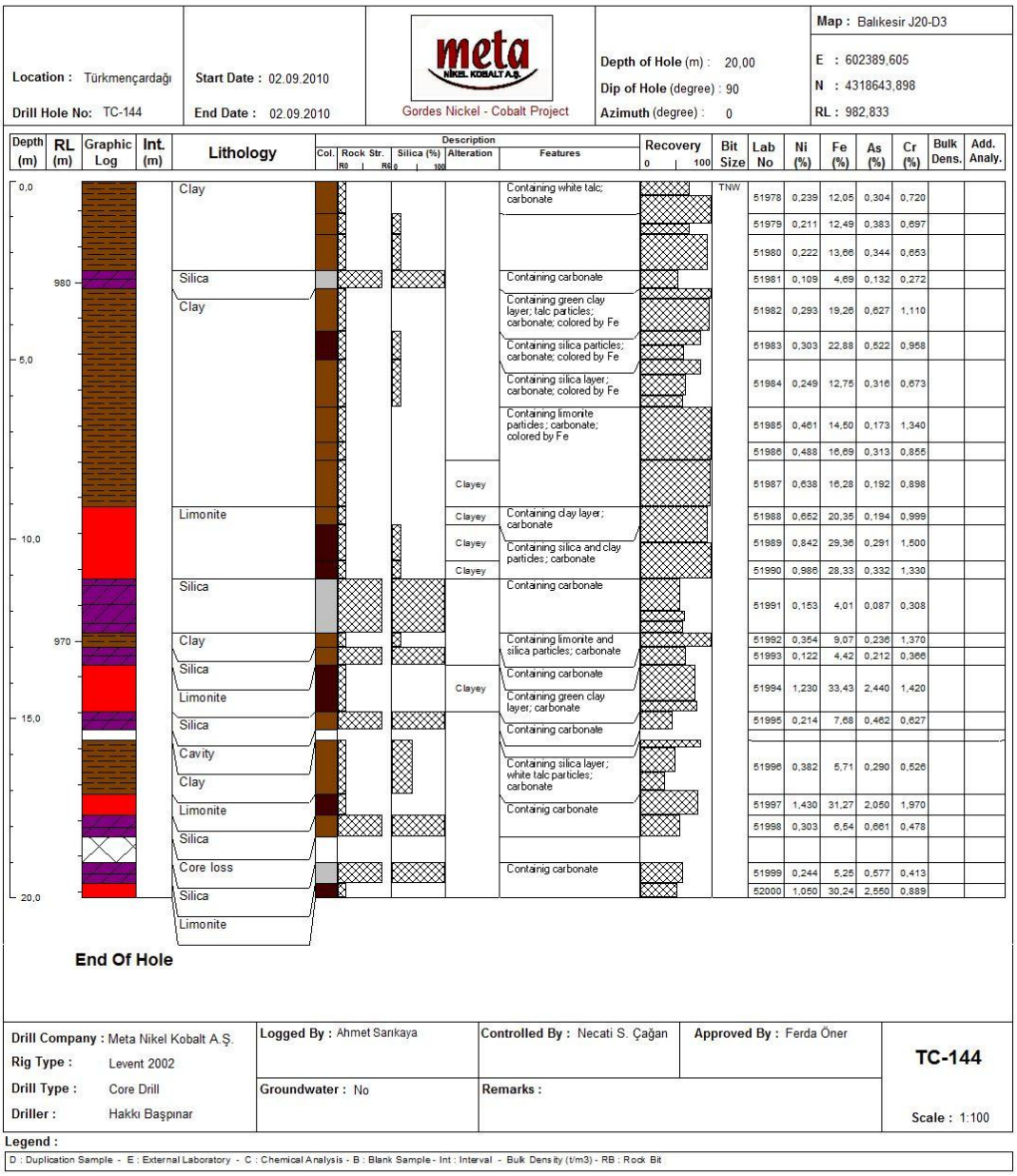


Figure E.25 Drillhole log of TC-144

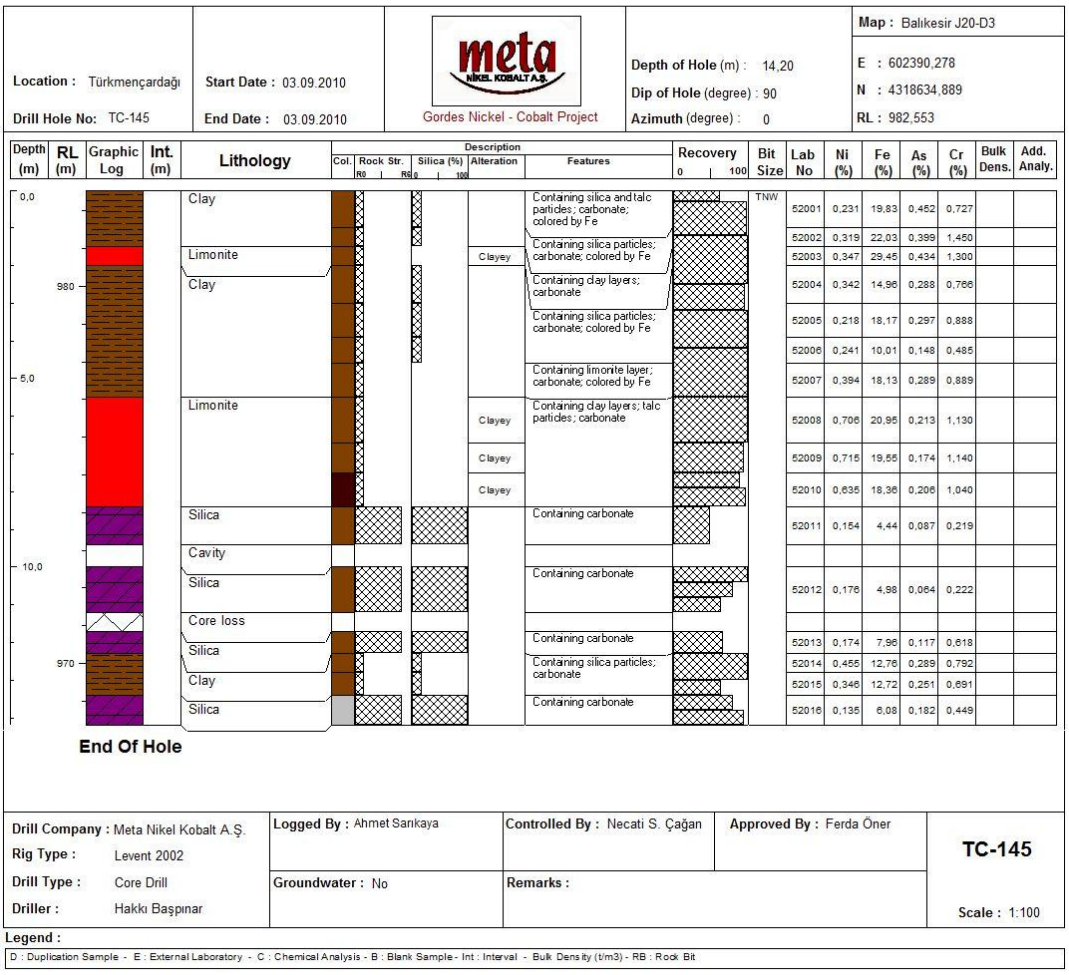


Figure E.26 Drillhole log of TC-145