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RESEARCH ARTICLE

Causes of Drillhole Deviation during Exploratory Drilling for Gold: A Case Study from Geita Gold Mine-Star and Comet Deposit, Tanzania

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Abstract

Bore hole deviation is one of the most significant problems in drilling applications. It occurs because of various reasons. In the present study for the determination of drill hole deviation, two methods are used: (i) downhole surveying and (ii) geological logging of core and chips. Down hole survey monitoring of the hole is done by an instrument called Gyro, which will be run inside the casing tube/drill pipe to record dip amount and azimuth at a particular depth to record direction and angle of the hole at that particular depth. Geological logging of the core and chips involve study of the samples of the drilled area so as to determine the lithology and structures of the area to know how they influence deviation of the drill hole. As per this study it is observed that much of the deviation is observed along weak zones and near the contact between two lithologies. Also structures like folds and fractures has greater influence on drill hole deviation.

Keywords: Gold Mining; Bore Hole Deviation; Lithology and Structures

Introduction

Drilling is a very important phase and also very expensive stage in mineral exploration and mining activity [1]. During drilling, deviation of bore holes occur for various reasons [2]. Because of this drilling costs are increasing and target is missing. So, by knowing the reasons for drill hole deviation may help in solving the problem and hence reducing drilling cost there in targeting of the ore body.

To determine the causes of drill holes deviation in gold exploration, Geita Gold Mine (GGM) has been selected. Geita Gold Mine is both an open pit and underground Gold mine located approximately 90Km Northwest of Mwanza and 5Km west of Geita town (formerly a part of Mwanza region) of Northern Tanzania [3]. It is situated 02050'S 0320 18'E about 25Km from southern shores of Lake Victoria (Figure 1). The Geita Gold mine can be accessed via road originating from Mwanza town through Sengerema and connect to the Biharamuro district. It is located within Greenstone belt in the northern portion of Sukumaland Greenstone belt along with other Lake Victoria gold fields [4].

The main drilling programs for exploration at GGM are Diamond drilling (DD) and Reverse Circulation (RC) drilling. Under these drilling programs there is a problem of drill hole deviation. So, this research work has been carried out to address causes of drill hole deviation and provide possible solution and precautions while doing drilling.

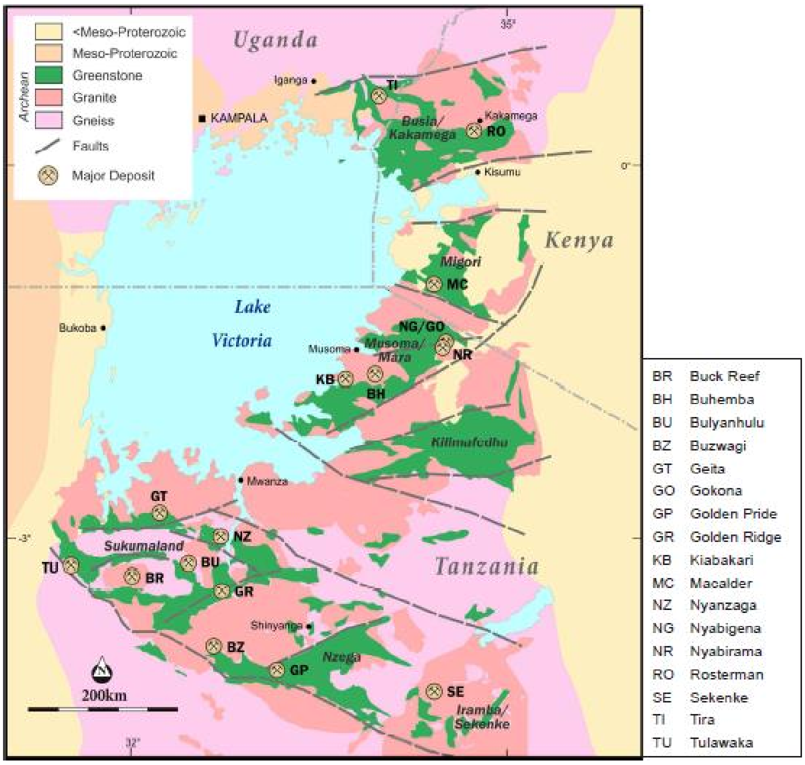

Figure 1: Nyanzian greenstone belts of the Lake Victoria Goldfields and locations of major gold deposits [4]

Geology of the Study Area

Geita Gold Mine is situated within Geita Greenstone belt in the northern portion of Sukumaland Greenstone belt within lake-Victoria Gold Fields. Other Gold mines located in Lake Victoria Gold fields are Bulyanhulu, STAMIGOLD (formerly Tulawaka), North Mara, Buswagi and Golden pride. See figure 1.

The Sukumaland Greenstone belt is the largest greenstone belt and most productive Gold field in Tanzania [5]. The greenstone belt is within an Archean granite-greenstone terrain developed as a part of the Tanzania craton between 2.8-2.5Ga [6]. Sukumaland greenstone belt is Neoarchean age and has world class Gold deposit [7].

Geita gold mine is an Archean mesothermal ore body which lies within E-W trending of Geita greenstone belt. It is dominated by Banded iron formation intercalated with younger intermediate to felsic intrusions (diorite, quartz porphyry and feldspar porphyry), sedimentary sequences (shale, mudstone, siltstone and sandstone) and mafic dykes (lamprophyre and dolerite) along reactivated faults [8].

According to Sanislav, I.V., et al., [5], mineralization is mainly structurally controlled (faults, folds and shear) and lithological favoured in which most cases higher grades found in BIF, Tuffaceous sediments and brecciated zones. Gold mineralization is also associated with quartz veins, disseminated sulphides and in quartz- carbonate- chlorite shear zones replacing and crosscutting magnetite rich BIF. Mineralization is associated also with disseminated sulfide bodies on the contact between felsic tuff and BIF. The principal sulfide present in the shear and vein hosted deposit are pyrite, pyrrhotite and arsenopyrite. Carbonate minerals that are present in the sequence are dominated by calcite which occurs as fine grained in altered BIF and as coarser grain calcite in veins [5].

The mineralization within the Geita greenstone belt is hosted by a sequence of thrusted and folded metasediments and BIF that defines three distinct geological trend from W-E [9]. They are:

(i) Kukuluma trend: contain five major gold deposits distributed along and approximately E- W mineralized trend. These are from east to west; Area 3 west, Area 3 south, Area 3 central, Kukuluma and Matandani. The mineralization is steeply dipping along the contacts of intermediate finegrained intrusion and magnetite rich chert and ironstone. Gold is associated with secondary pyrite, arsenopyrite and minor pyrrhotite.

(ii)Geita central trend: contain three largest gold deposits occurring along NE-SW mineralization trend. These are from NE to SW; Geita hill, Lone cone and Nyankanga. Other small mines in this trend are Chipaka, Pit 30 and Mgusu. Mineralization is mainly related to diorite-ironstone contacts exploited by the shear system. The alteration is restricted within the ore zone and consists of secondary sulphides (mainly pyrite), silica, carbonate and moderate hematite alteration.

(iii)Nyamulilima trend: contain three major Gold deposits on an approximately NW-SE mineralized trend. From SE to NW are Ridge 8, Star and comet and Robert. Mineralization is preferentially localized along the fault zone where they cut the ironstone granitoid contact. Gold mineralization is associated with secondary pyrite and minor pyrrhotite, silica, carbonate and actinolite alteration

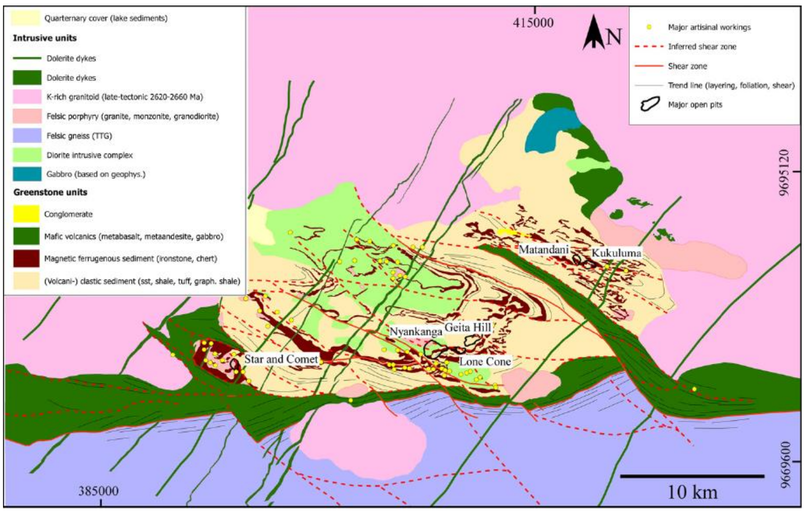

Figure 2: Geological map of the Geita Greenstone belt showing the location of the gold deposits and the main geological units and structures [5].

Drill Hole Deviation

According to Deshpande [10], hole deviation is one of the most significant problems in drilling applications. Deviated holes result in inefficient blasting and have severe economic impacts due to increased equipment consumption and partial intersection of the ore body. Conversely, straighter holes help in increasing production scales and reduce operational costs.

Drill hole deviation is the unintentional departure of the drill bit from a preselected drill hole trajectory [11]. Whether it involves drilling a straight or curved-hole section, the tendency of the bit to walk away from the desired path can lead to drilling problems such as higher drilling costs and also partial intersection of the ore body. The down hole survey may help to determine to what extent the hole deviates and logging of the core and chips samples from drilling area may help in determining the geological causes of drill hole deviation.

Deshpande [10]stated that, the reason for hole deviations could range from anisotropic behavior of the rocks being drilled to the behavior of the drill string under the action of imposed forces. Deviations caused due to rock anisotropy are complex in nature and non-controllable to some extent but deviations due to mechanics of drill strings can be controlled as they lie in the operator's area of influence [10]

Khashaba[12] in his theory stated that the factors such as cutting parameters, tool geometries, tool type and sand materials greatly influence the drilling of laminates and quality of the drilled hole. Therefore, it is necessary to select appropriate cutting parameters, tool geometries, tool type and materials due to the fact that an unsuitable choice could lead to unacceptable work material degradation [12].

Methods of Study

In the present study, for the determination of drill hole deviation, two methods are used: (i) downhole surveying and (ii) geological logging of core and chips. The geological logging of the core and chips will help to identify the lithologies and the structures at the study area that will enable the plotting of the sections and to determine their influences in drill hole deviation. The down hole survey will be used to obtain the drill hole survey data that will help to determine to what extent the hole deviated from the planned path. The combination of both geological data from geological logging and the survey data from down hole survey will help in the determination of the geological causes of the drill hole deviation at the study area. When deviation occur drilling cost increases and target is missing.

So by knowing the reasons for drill hole deviation may help in solving the problem and hence reducing drilling cost and missing intersection of the ore body.

Down Hole Surveying

This is done by an instrument called Gyro which will be run inside the casing tube/drill pipe to record dip amount and azimuth at a particular depth. According to GGM protocol down hole survey is done after every 50m for DD and 35m for RC drilling

Down hole survey is done so as to ensure if the hole is passed through the desired path /trajectory. Monitoring of the hole is done by controlling parameters which are dip and azimuth. Monitoring is done through the survey instrument which is lowered down hole to record direction and angle of the hole at that particular depth.

The instrument by now used for down hole survey is called **North Seeking Gyro** in which measurement is taken on reference to north. The Gyro instrument is a highly accurate, extremely reliable downhole directional survey and orientation tool [13]. Unlike other downhole survey or magnetic tools, the **Gyro Tracera** is not affected by magnetic interference. It can be run inside casing, tubing, drill pipe and magnetically disturbed ground.[13]

Prior performing downhole survey, the North seeking Gyro is calibrated and used with winch system, a wire line cable and a computer system for data aquisation, recording and analysis of the survey data. The Gyro Tracera is then attached to the wire line cable and then lowered down to the drill hole to the desired depth. When the desired depth is reched, the instumnt is initiated by rotation it or moving to align it with the north direction as the measurement are taken in reference to North direction. The downhole survey will start by activating data acquisition system in the computer, and dip amount and azimuth will be recorded and a particular depth. The instrument will be lowered at a regular interval and the data will be captured continuously until the desired depth is reached. When the survey is complete, the instrument will be retrieved by winch system and the data obtained will be analyzed and interpretated the the deviation zote will be determine. The deviation zone pointed from downhole survey will be linked with the geological logging data and the reason for deviation will be determined.

Geological Logging of the Core and Chips

Involve study of the samples of the drilled area so as to determine the lithology and structures of the area so as to know how they influence deviation of the drill hole. There is two kind of logging that has been done so as to collect data. There is chips logging and core logging whereby I was able to identify different lithology and structure in core logging.

The data obtained from logging were used in drawing of different sections by combining with survey data so as to determine reasons for drill hole deviation.

Results and Discussion

Logging was done for fifteen holes in core and chips where by four lithologies were encountered which include; Banded iron formation (BIF), Volcanogenic sediment, Lamprophyre and tonalite as well as few felsite dykes and massive sulfides. BIF`s and volcanogenic sediments were observed almost in all drilled holes. Structures encountered during core logging are bedding, contacts, brecciated zones, folds, fractures as well as joints. Data obtained from logging enable in plotting cross-sections where by three section were generated. In every section, one hole was surveyed and interpreted and the reason of deviation was determined.

Three sections and profiles were prepared respectively, showing the lithology of the area. (Sections - 5250E, 5272E and 5010E.) All sections are in Local coordinates.

Section 5272E

Section contains 5 holes which are SCRD0389, SCRD0395, SCRD0145, SCRD0003 and SCRD0959 where by interpretation was done and survey data was investigated for hole number SCRD0959 that shows up-dip deviation (uplift) because is the longest hole with much deviation.

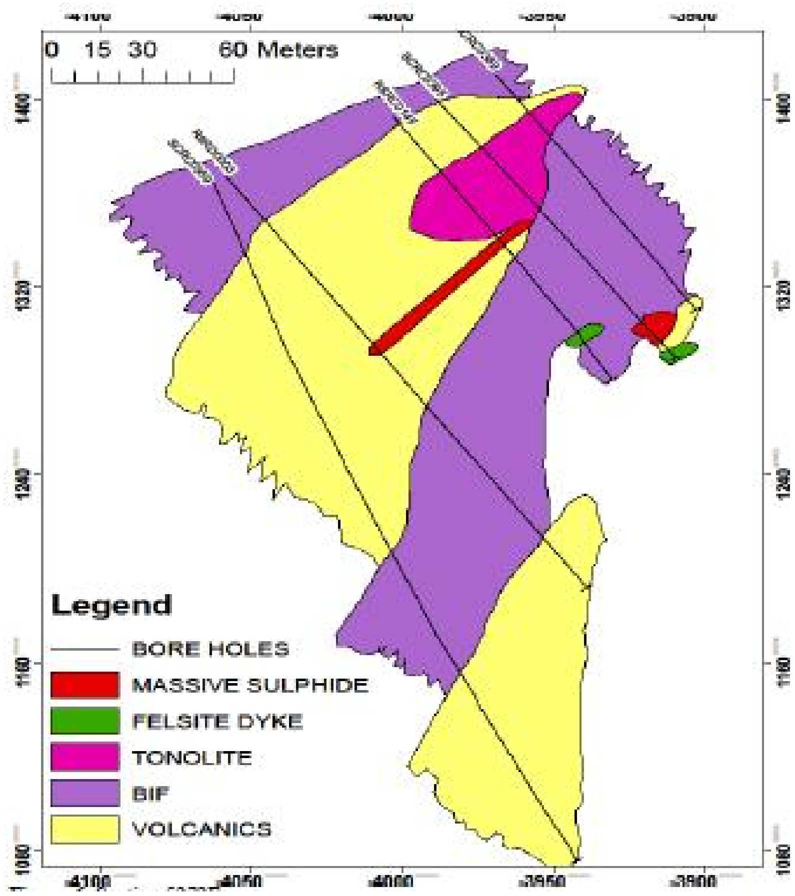

Figure 3: Section 5272E

Interpretation of the Logged Drill Hole (SCRD0059)

This hole was logged and it shows that at the zone of brecciation is where deviation started to develop (see point B below)

The hole was planned with a dip of (71) at zero depth. The drill hole trajectory maintained it's tangential and from the depth of (150.00-190.00) m the big changes started to develop. About 5degrees was lost and the hole started building up at 200.00m is where the Kick - Off Point (KOP) started to generate a significant inclination angle.

The survey data was observed and linked with the lithology of the area of deflection. The deflection was revealed to originate in the zone of brecciation in BIFC. See point B (Figure 4). This might be the cause of the hole deviation (drill hole uplifting). Due to this observation the chances of partial intersection of the ore body might have been encountered.

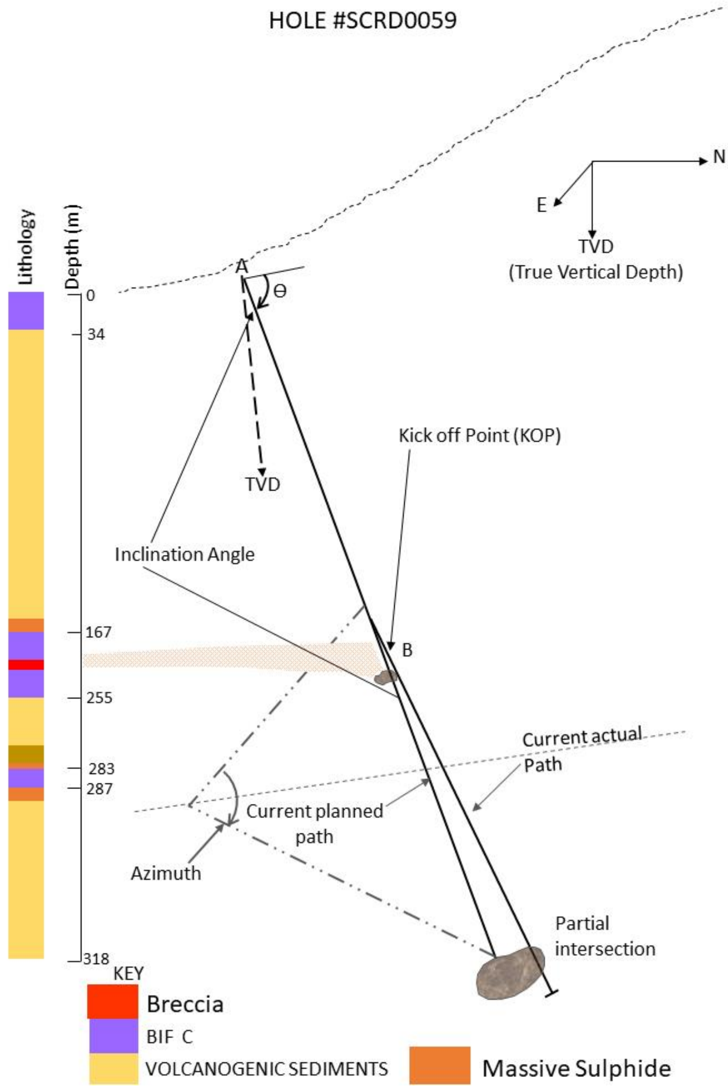

Figure 4: Interpretation of hole SCRD0059 with up-dip deviation

Figure 5: Brecciation zone at BIFC lithology

Section 5010E

A section 5010E with the longest hole SCRD0027 in which interpretation was made and turning (Lifting) of the drill hole SCRD0027 was observed.

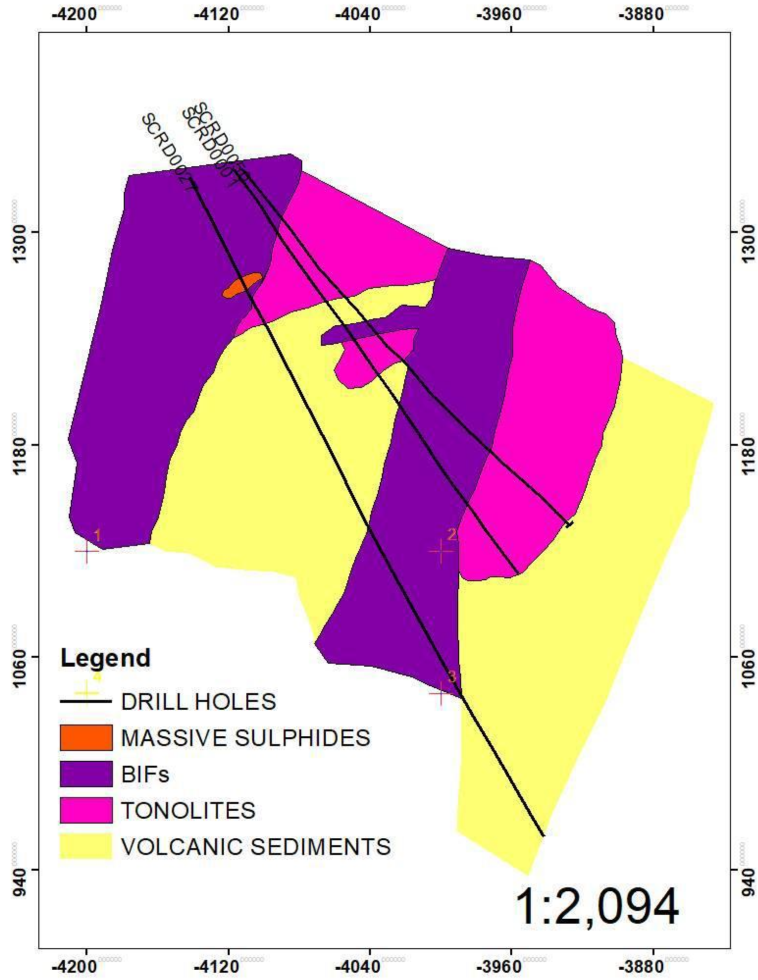

Figure 6: Section 5010E

Interpritation of the Sketch 5010E, Bore Hole SCRD0027

The hole was planned with a dip of (65) at zero depth. The drill hole trajectory maintained its tangential and at the depth of (216.00) m the changes of degrees began from (62-61degrees) and the hole started to building up.

The kick off point start to be generated at the contacts of two lithologies where the hole started lifting up. The transformation from soft to hard lithology with unchanged penetration rate of about less than 2000rpm might be the reason of deviation. The contact between two lithologies which were from soft to hard with unchanged drilling force is the one thought to be reason of hole deviation. (Figure 7).

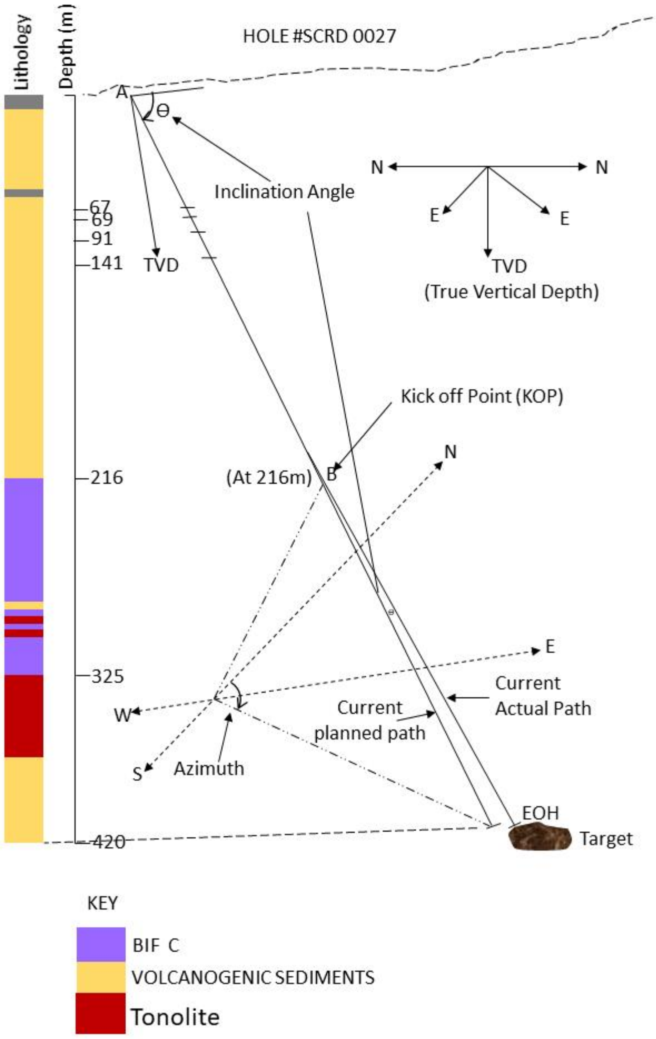

Figure 7: Interpretation of hole SCRD0027 with up-dip deviation

Section 5250E

A section 5250E with dropping deviation of hole SCRC0392

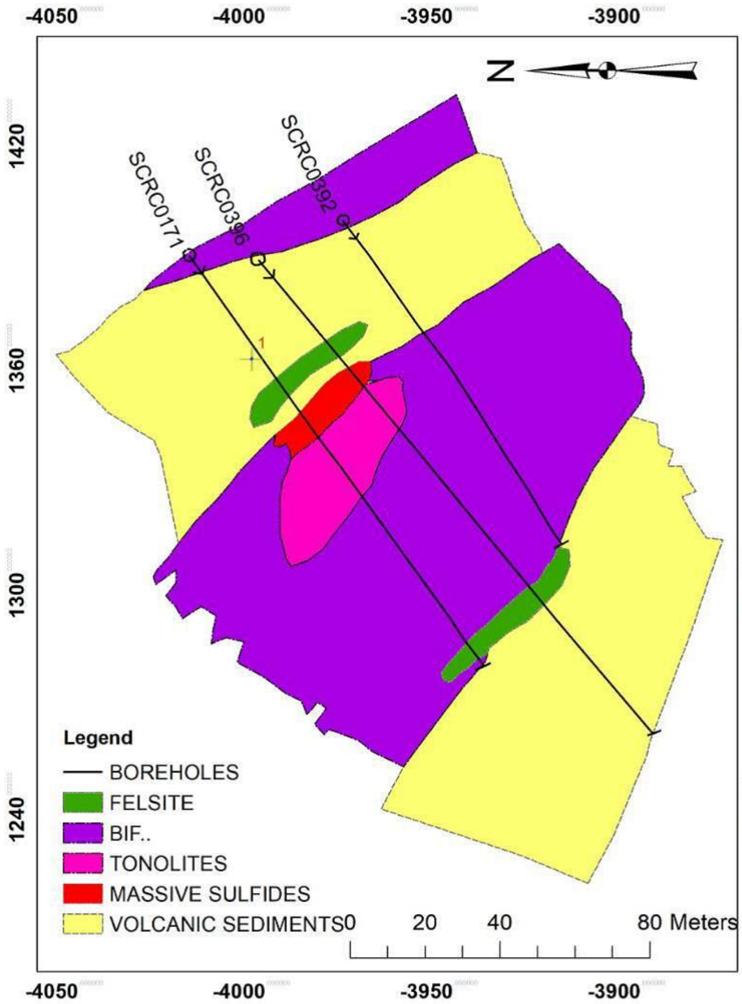

Figure 8: section 5250E

Interpretation of Hole Number SCRD0392

Data from this drill hole indicate a possible upper and lower saprolites in the weathered profile and BIFC, TUFFs then a massive sulphide zones.

The drilled holes show dropping effect from planned path. The drill hole is straight until the KOP where it is kicked off and an angle is built at folded zone (Fig 13) due to ground condition. The presence of folds was thought to be one of the reasons for hole deviation. When the deviation starts the inclination angle is reached, the drill hole path is kept tangent or curved away from the desired target, hence the target is missed. (Figure 9)

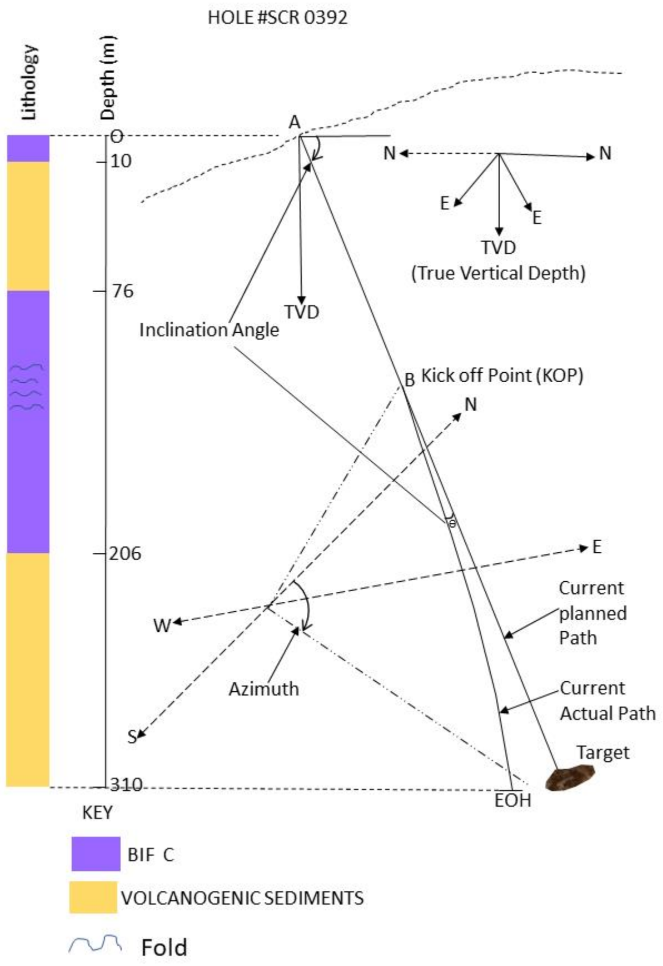

Figure 9: Interpretation hole SCRC0392 with down-dip deviation

Figure 10: Folds in BIF lithology

Conclusion and Recomendation

Conclusion

In the present study, structures encountered during core logging are bedding, contacts between the two rock types, brecciated zones, folds and fractures as well as joints.

In Bore hole number SCRD0059 of section 5272E, the deflection was revealed to originate in the zone of brecciation in BIFC. In Bore hole SCRD0027 of section 5010E, the contact between two lithologies which were from soft to hard with unchanged drilling force is the one thought to be reason of hole deviation. In Bore hole number SCRD0392 of section 5250E, the presence of folds was thought to be one of the reasons for hole deviation.

The data obtained from logging assist is much on understanding the lithology of the area and determine reasons for drilling hole deviation. Much deviation observed along weak zone and at and near the contact between two lithologies. Due to that, during drilling much care must be kept when meeting the contact between lithologies and weak zones so as to make correction early. Also structures like folds and fractures has greater influence on drill hole deviation.

Bore hole deviation is common in drilling applications, even though care has been taken to select appropriate cutting parameters, tool geometries, tool type and materials. When deviation occurs drilling cost increases and target is missing. So, as in this study, identifying the reasons for drill hole deviation will help in solving the problem.

Recomendation

Based on the results of this study it is recommended that the effects of the formation and profile observed could be controlled easily by controlled drilling with low penetration rate /rotation in the weathered profile, when drilling a weak zone with geological structures like folds, fault and shear zones. Also, when drilling near contact between lithologies the penetration rate should be lowered so as to avoid shifting of the drill bit and missing the target. The down hole survey need to be done in a small interval so as to adjust the measurements before hole deviated gets so far.

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