Report on the Geological Mapping of the Graphite Occurrences around the Selected Grid Unit in Maduragoda within Rideegama Divisional Secretariat Division

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May 2017

Contents

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1. INTRODUCTION

Due to increment of the high grade graphite demand in the world market, numerous companies interested on Graphite exploration in Sri Lanka in recently since the Sri Lankan graphite is well known for its high grade and purity.

The geological survey was carried out on the request made by management of RS Mines (PVT) Ltd to evaluate and exploration to identifying existing mined locations of the Graphite resources within as area covering 1 grid unit ($1km^2$) around Maduragoda within Rideegama divisional secretariat division.

The presence of several abandoned pits, collapsed adits & shafts indicates that the area has been mined for Graphite in earlier time. Most of these shafts and adits are collapsed. There are sort of mucks of quarts which consisting crystalline graphite evident that those areas have been operated for mining activities. According to inhabitants, considerable reserves of graphite may still exist in these places and as most of them are abandoned due to dramatic price drops after World War II or due to difficulties in talking the inherent ground water and ventilation problems.

The objective of the present survey was to look into the possibility to revive the graphite industry in the area with economic exploitation. The survey was carried out by geologists in April 2016 and this report presents the outcomes of the corresponding geological survey.

2. GENERAL PROPERTIES OF GRAPHITE

Graphite receives its name from "Graphein" the Greek word meaning to write. Once mistaken for Lead, it was also called "Black Lead" and pencils made from Graphite are still called "Lead Pencils". The name "Plumbago" is a commercial name used for Graphite. Graphite is the mineralogical name for one of the naturally occurring crystalline forms of carbon, the other varieties being diamond and charcoal. Although these materials are chemically identical, they differ largely in physical properties and this is mainly due to their different atomic arrangements. Graphite conducts electricity and heat well but is extremely refractory. It is, consequently, useful in such applications as arc lamp electrodes. Other major properties are chemical inertness and very low hardness varies between 1and 2 in the Mohr's scale.

There are three principal types of natural Graphite, each occurring in different types of ore deposits i.e.

a) Flake Graphite

Flake graphite is found in metamorphic rocks uniformly distributed through the body of the ore or in concentrated lens shaped pockets. Carbon concentrations vary between 5% and 40%. Graphite flake occurs as a scaly or lamella form in certain metamorphic rocks such as limestone, gneisses and schists.

b) Amorphous Graphite

Amorphous graphite is the least graphitic of the natural graphite. However, the term "amorphous" is a misnomer since the material is still crystalline. This is formed as fine particles and is the result of thermal metamorphism of coal. Amorphous graphite is found as minute particles in beds of metamorphic rocks such as coal, slate or shale deposits. The graphite content ranges from 25% to 85% dependent on the geological conditions.

c) Crystalline Vein Graphite (Lump Graphite)

Crystalline vein graphite is believed to originate from crude oil deposits that through time, temperature and pressure have converted to graphite. This form is occurred in fissure veins or fractures and appears as massive platy intergrowths of fibrous or acicular crystalline aggregates, and is probably hydrothermal in origin. Vein graphite fissures are typically between 1cm and 1 m thick, and are typically >90 % pure. Although this form of graphite

is found all over the world, it is only commercially mined in Sri Lanka by conventional shaft or surface mining techniques.

- **Applications of Graphite**

1. Refractory Materials

   Due to its high temperature stability and chemical inertness graphite is a good candidate for a refractory material. It is used in the production of refractory bricks and in the production of "Mag-Carbon| refractory bricks (Mg-C). Graphite is also used to manufacture crucibles, ladles and molds for containing molten metals. Additionally graphite is one of the most common materials used in the production of functional refractors for the continuous casting of steel. In this application graphite flake is mixed with alumina and zirconia and the isostatically pressed to form components flow of molten steel and protecting against oxidation. This type of material may also be used as shielding for pyrometers.

2. Chemical Industry

   There are many high temperature uses for graphite in the chemical industry such as in the production of phosphorous and calcium carbide in arc furnaces. Graphite is used as anodes in some aqueous electrolytic processes such as in the production of halogens (chlorine and fluorine).

3. Electrical Applications

   The main application for graphite as an electrical material is in the manufacture of carbon brushes in electric motors. In this application the performance and lifetime of the component is very dependent on grade and structure.

4. Mechanical Applications

   Graphite is used widely as an engineering material over a variety of applications.

Apart from above applications Amorphous Graphite has applications in Metallurgy, Pencil Production, Refractories, Coatings, Lubricants, Paint Production and Crystalline Graphite is used in Batteries, Lubricants, Grinding wheels & Powder metallurgy. Flake Graphite is used predominantly in refractory applications mainly in secondary steel making; in addition to this it may also be used in lubricants, powder metallurgy, pencils and coatings.

3. GRAPHITE OCCURRENCES IN SRI LANKA

Graphite occurs in the island in veins, pegmatite and disseminated flakes in the country rocks. The vein type graphite is mainly confined to fracture or joint systems in the folded meta-sedimentary rocks. Only the vein type deposits are exploited. The reserves of graphite in the island are estimated to be very large, but due to the nature of the deposits (vein type), it is not possible to estimate the quantities available. The veins normally follow a structural pattern, and major veins tend to follow one or two directions. East-West trending graphite veins are common with off-shoots following the joints and minor fractures in the surrounding rocks. The graphite deposits of the island are mainly concentrated in anticlinal structures generally trending in a north-south direction.

a) Historical Background of Graphite Mining In Sri Lanka

Graphite appeared in the international trade since the 16th century after which time the mining industry was present mainly in Germany and Siberia. Subsequently, more and more countries began producing Graphite and the occurrence of Graphite in Sri Lanka was first reported in 1675 by the Dutch Governor Rycloff Van Goens. However, this became known to Sri Lanka as a mining industry as well as an important export commodity during the British colonial period. But their engagement in Graphite mining was extremely limited, although the British were in possession of all the required facilities and technology. It is quite strange however, that while the British had the complete control in the plantation industry and export trade, they were unable to gain a similar position in Graphite mining though there is evidence to suggest that they made serious efforts to do so. According to British Mining Engineer G.A. Stonier, there were only 3 mines owned by the British miners in 1903. It was also believed that the local miners did not like the British entering into the Graphite industry so that they did not provide any assistance to them in this trade.

Graphite was the most important mineral product in Sri Lanka and its export began before 1830. It has been an important export commodity similar to Tea, Rubber and Coconut. But Sri Lanka produces only a few thousand tons of Graphite annually and its contribution to national economy is negligible. Current annual production is around 4,200 tones though it had been 20.000-30.000 tones during the boom times i.e. 1st three decades of the 20th century. The highest ever Graphite export was 33,411 ton reported in 1916, at a value of Rs.22 million.

During the first two decades of the 20th century, the local industry was at its peak level owing mainly to the heavy demand created by World War 1 and also because most parts of the world had yet to know about this strategic industrial mineral. This situation was triggered by the civil war in America making high demand for high quality Graphite from Sri Lanka. The world wars made the industry to grow and to be matured during the period of 1870 and 1917 and the discovery of similar quality Graphite from Madagascar made the industry to be declined in 70's. For instance, the highest ever export tonnage was reported in 1916 which was 35% of the world consumption. During this period, there had been about 3000 pits and mines in operation in all over the southwest and central parts of Sri Lanka.

Among the factors contributing to the expansion of the Graphite industry at this stage were the ability to export without processing due to the extremely high purity, low mining cost, large production from shallow pits and the high demand. Because of the high purity, the local Graphite does not need to go through expensive and time consuming upgrading process. It could be directly exported to the consumers from the mines. The Graphite grade of the other producing countries was around 40% C but Sri Lankan Graphite has more than 90% C. The Graphite producing areas of Sri Lanka during this boom time were Bogala, Kahatagaha/Kolongaha, Madawachchiya, Vavuniya, Kurunegala, Kegalle, Ratnapura, Ruwanwella, Dompe, Mirigama, Kirindiwela, Padukka, Matugama, Ingiriya, Bulathsinhala, Agalawatta, Meegahathanne, Dumbara, Dodanduwa etc.

Most of the mining methods adopted were very primitive and the majority were pit mining operated entirely by manual means. Therefore, the miners were unable to tackle the inherent problems of ground water, ventilation, side wall fixing, bringing of mined Graphite from deeper mines and drilling and blasting etc.

Sri Lanka had been one of the leading suppliers of Graphite to the world until 1920 and approximately Sri Lanka's share had been 20-35% of the total world production. However, discovery of many low grade (about 40%C) surface Graphite deposits in worldwide, created an unexpected crisis into Sri Lankan Graphite industry. As a result, Sri Lanka supply had fallen to less than 2% in 1980. Since then, only two Graphite mines namely Kahatagaha-Kolongaha and Bogala mines remained in operation and both mines were operated by the State Mining and Mineral Development Cooperation until they were privatized.

4. OBJECTIVES OF THE PRESENT SURVEY

- To locate the existing adits/shafts to identify potential areas for graphite occurrences and graphite vein pattern within surveyed area.

- To study the geology and structures in relation to graphite mineralization of the potential areas which identified in preliminary survey.

- To make visual geological observations that would indicate any graphite mineralization in the selected potential areas.

- To prepare a detailed geological map with 1: 5,000 scale, locations with promising graphite occurrences based on the field observations, existing geological information and aerial photograph analysis.

- To demarcate areas for further study (Geophysical Survey and drilling Investigations)

5. SURVEY AREA

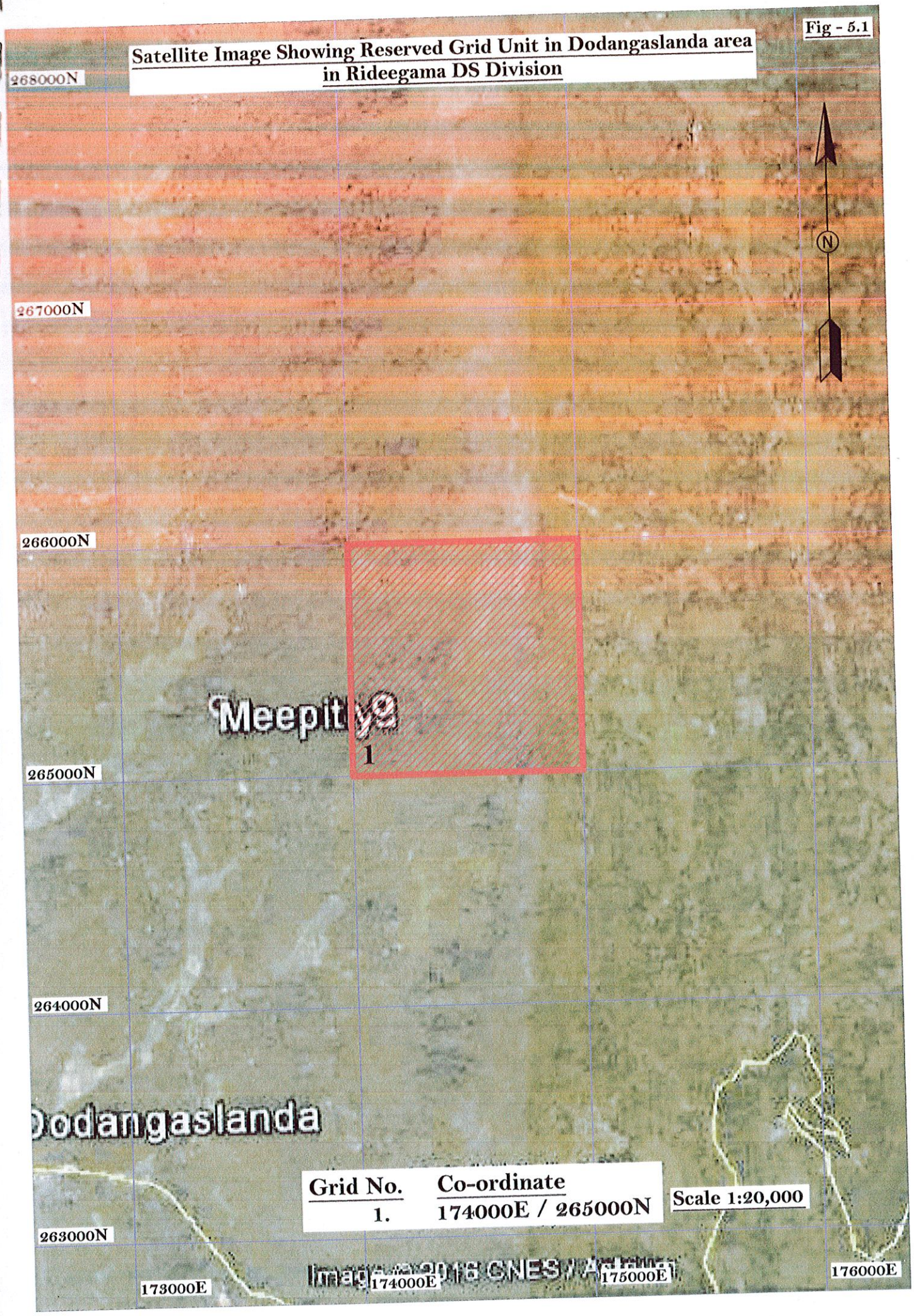
Initially the surveyed area is consisting 01 metric grid unit with a total extent of 1 km^2. Satellite image of this initial survey area is shown in Figure - 5.1 in 1:20,000 scale and the topographical map of the initial survey area is shown in Figure - 5.2 in 1:50,000 scale.

Preliminary survey was conducted throughout this grid unit and extend the survey for detailed geological mapping. During the preliminary survey it was observed several abandoned adits & shafts since the area was focused for above mapping. The selected grid unit for detailed geological mapping and for preliminary survey is as bellows,

- Grid No. 01 - 174000E / 265000N

Fig - 5.1

Satellite Image Showing Reserved Grid Unit in Dodangaslanda area in Rideegama DS Division

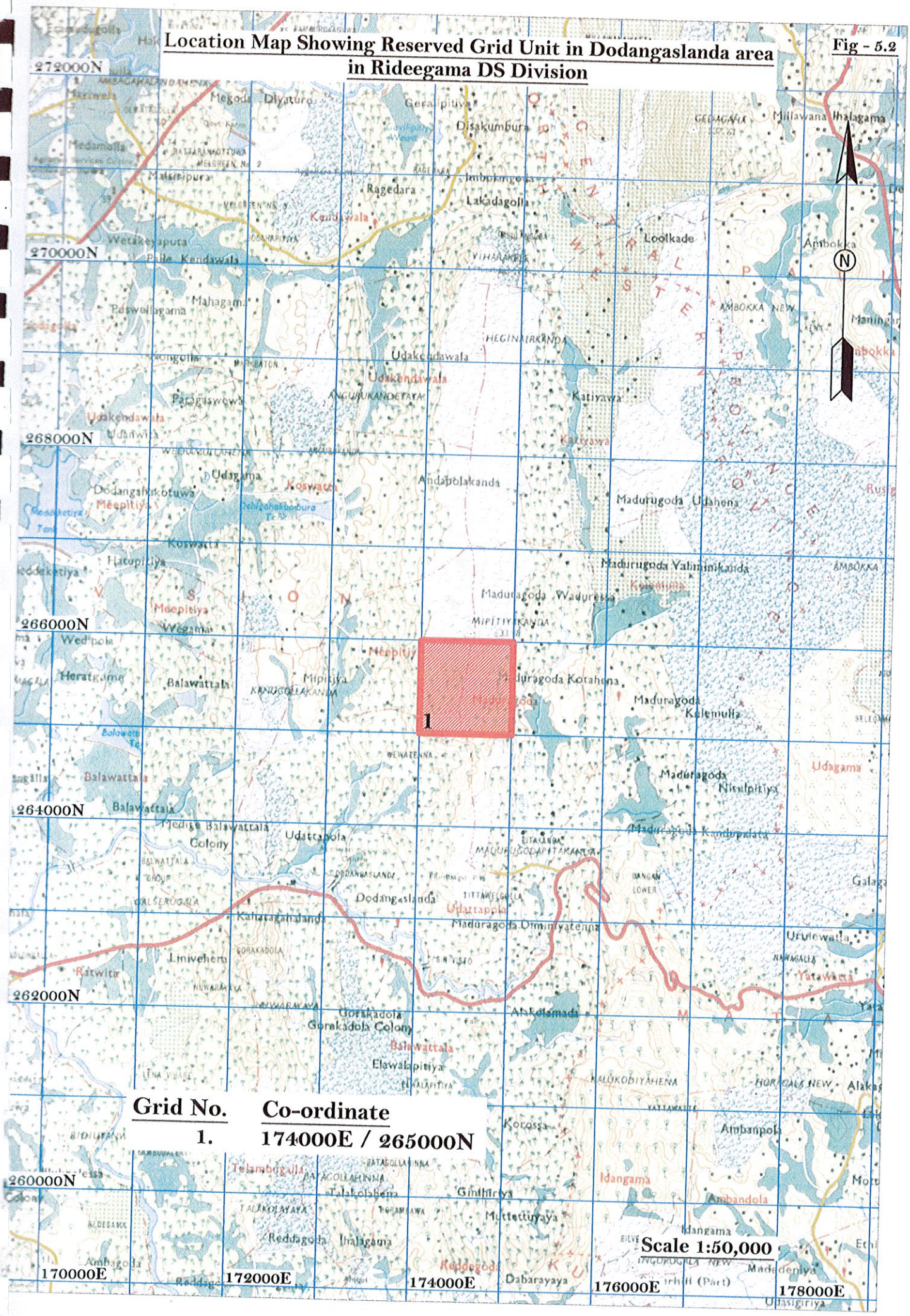


Grid No.	Co-ordinate
1.	174000E / 265000N

Scale 1:20,000

Location Map Showing Reserved Grid Unit in Dodangaslanda area in Rideegama DS Division

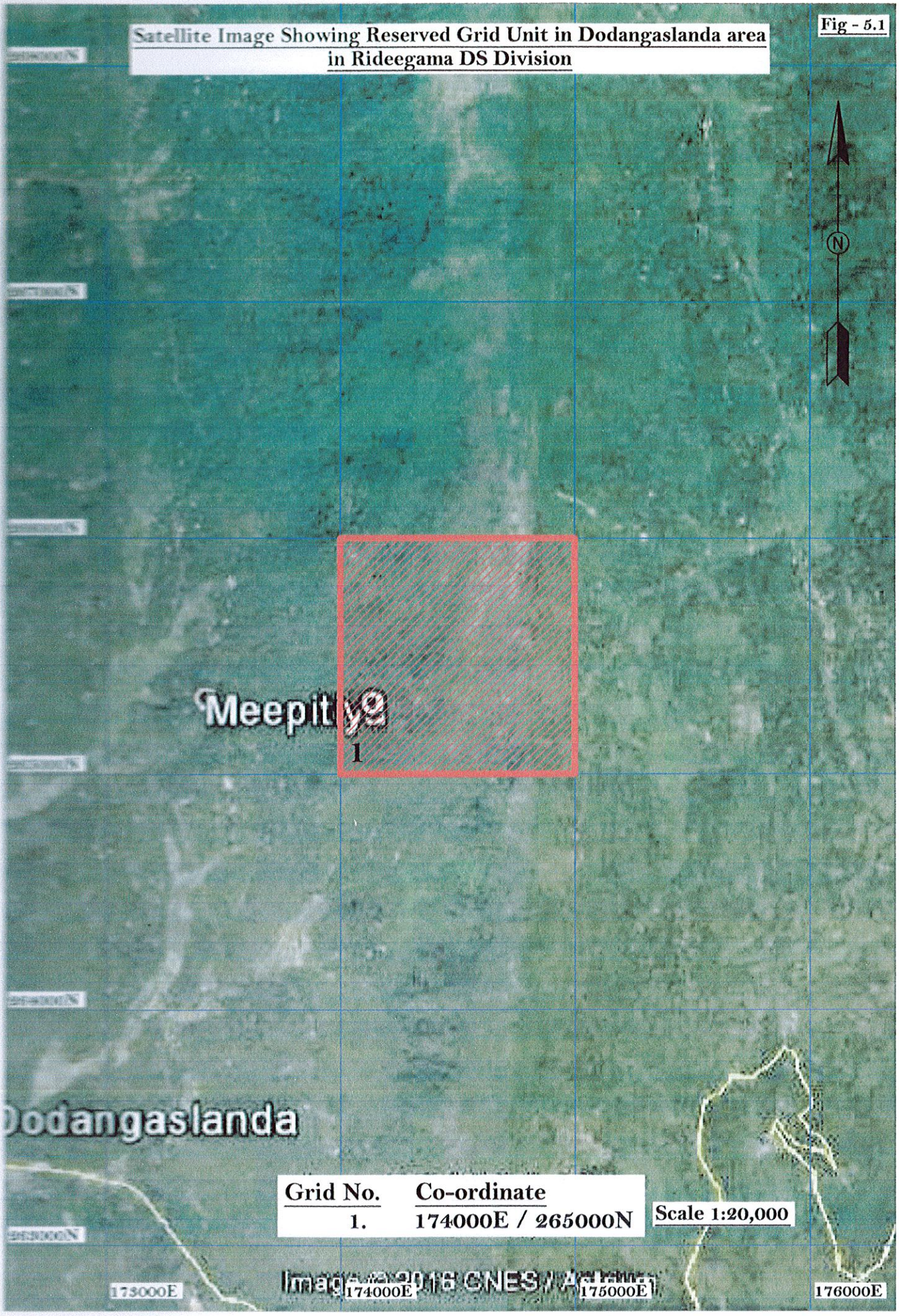
Fig - 5.2



Grid No.	Co-ordinate
1.	174000E / 265000N

Fig - 5.1

Satellite Image Showing Reserved Grid Unit in Dodangaslanda area in Rideegama DS Division



Grid No.	Co-ordinate
1.	174000E / 265000N

Scale 1:20,000

6. METHODOLOGY

The desk study and initial social survey was carried out in order to collect information on previous mining activities and abandoned graphite mines as well as reasons to termination of their mining activities. Social survey was carried out with focusing old villagers who were living around the area and information was gathered and locations were found with the aids of themselves. Apart from that available research papers, lithological maps which were processed with covering the suspecting area in order to collect information of Graphite occurrences as well as mining activities.

GPS locations of all abandoned Graphite mines and pits were marked on the 1:50,000 scale topographic sheets obtained from the Department of Survey of Sri Lanka. These maps were used as base maps for geological mapping of the area covered by the selected grid unit. Located mine structures are shown in Figure - 6.1 in 1:10,000 scale.

All the relevant details were recorded throughout all foot paths to roads & traverses which were perpendicular to the general strike of the rock layers. Historical data and data interpreted using satellite images were also consumed in the map preparation.

8. GENERAL GEOLOGICAL CONDITIONS

Sri Lanka is underlying by high grade Proterozoic gneisses consisting of a variety of Ortho-Gneisses and Meta-Sediments, Metamorphosed to Amphibolite to Granulite facies at about 610-550 Ma, with Phanerozoic sediments being restricted to the coastal regions.

Ninety present of Sri Lanka is underlying by high grade Proterozoic Gneiss consisting of a variety of ortho-gneises and meta-sediments, metamorphosed to amphibolite to granulite facies at about 610-550 Ma, with Phanerozoic sediments being restricted to the coastal regions. Recent Nd model ages, high precision U-Pb zircon ages and new Rb-Sr age dates indicate that Sri Lanka's evolution during the Proterozoic was occurred by two separate tectonic collisions of three distinctive crustal units , which are currently known as Highland Complex (HC), Wanni Complex (WC), Vijayan Complex (VC), in to one package, during the Pan-African orogeny at 610-550 Ma. The survey area belongs to Highland Complex which is located centrally in Sri Lanka comprises mainly granulite grade Charnokitic rocks, and Meta-Sedimentary rocks are Quartzite, Marble, Calc Silicates, Felsic Gneisses and Khondalite (Garnet Silliminite Graphite Gneisses).

Figure 8.1 : Geological Setting of Sri Lanka

a) **GENERAL GEOLOGICAL SETTING OF THE WANNI COMPLEX**

The Wanni Complex is characterized by thick sequences of orthogneisses comprising amphibolite-grade migmatitic granitic and granodioritic gneisses and, at lower structural levels dioritic orthogneisses with minor gabbros. In the northeast, granulite-grade variants are common. In the westernmost part of the Wanni Complex, common late-stage events include the pervasive introduction of pink potash-feldspar-rich crustal melts and syenites, locally occurring as discrete syn- to post-techtonic bodies. The structurally lowest levels of the Wanni Complex - those juxtaposed with the Highland Complex - are considerably more mafic and lithologically similar to gneisses described below. It is possible that there is an intrusive relationship between these mafic orthogneisses and the migmatitic paragneisses of the structurally uppermost Highland Complex, though the zone is extensively modified by late-stage tectonism.

The Wanni Complex *sensu lato* tends to be poorly exposed but is potentially of economic importance due to the large number of undersaturated peralkaline and alkaline rocks of different ages within it. At least some of those must represent late-stage continental extensional-type magmatism linked to uplift and cooling. Locally, rocks of unusual compositions are present. These include the carbonatite at Eppawala with economic quantities of phosphate in the form of very large *apatite* crystals. Ages for the Wanni Complex are *ca* 1080 Ma, the maximum age of sedimentation, with a cluster of Neoproterozoic intrusive ages for orthogneisses around 770 Ma.

b) **GENRAL GEOLOGICAL SETTING AROUND THE SURVEYED AREA**

As per the geological setting of the area, the study area belongs to the Wanni Complex of Sri Lanka and entirely consists of granulite grade Proterozoic metamorphic rocks. According to the 1:100,000 Dambulla-Pallegama Geological map (Sheet No. 11) published by the Geological Survey and Mines Bureau of Sri Lanka, the rocks encountered in and around the surveyed area on regional scale are,

1. Garnetiferous Quartzofeldspathic Gneiss
2. Quartzofeldspathic Gneiss
3. Quartzite
4. Garnet Sillimanite Biotite Gneiss +/- Graphite
5. Biotite-Hornblende Gneiss

However the area is in the western limb of Maduragoda antiform running North-South. General geological setting of the study area is shown in Figure - 8.2 in 1:50,000 scale.

9. FIELD OBSERVATIONS

a) Occurrences of Graphite Mines within Surveyed Area

During the survey, it has observed 13 numbers of abandoned graphite mine structures which had been operated at single mining site (Figure 6.1). They consists 5 number of adits and 8 number of shafts; details of them are given in the table 02. Huge muck of mined out materials around these abandoned mine sites may indicates that, they have been mined down to a deeper depth. As per the villagers information most of sites has been shut down due to unavailability for technique on dewatering.

Also several unreachable mine structures are at abandoned state on the top of the ridge structure within this study area. These structures are unreachable due to thick forest cover & less access paths. As per villagers information these mines were operated at well manner & they have to be shut down due to lowering of market price and difficulty of advancing these mines without updated technologies.

However there were three most prominent joint systems which takes N-S, N20⁰W and N30⁰W directions. In addition to that another minor joint systems could be observed along N35⁰W & N70⁰W directions. All of these joint systems have interfered on the morphology of the outcrops presence.

All the noted down joint orientations were added to a database to generate a rose diagram to identify most prominent joint pattern. Generated rose diagram is shown in Figure – 9.1.

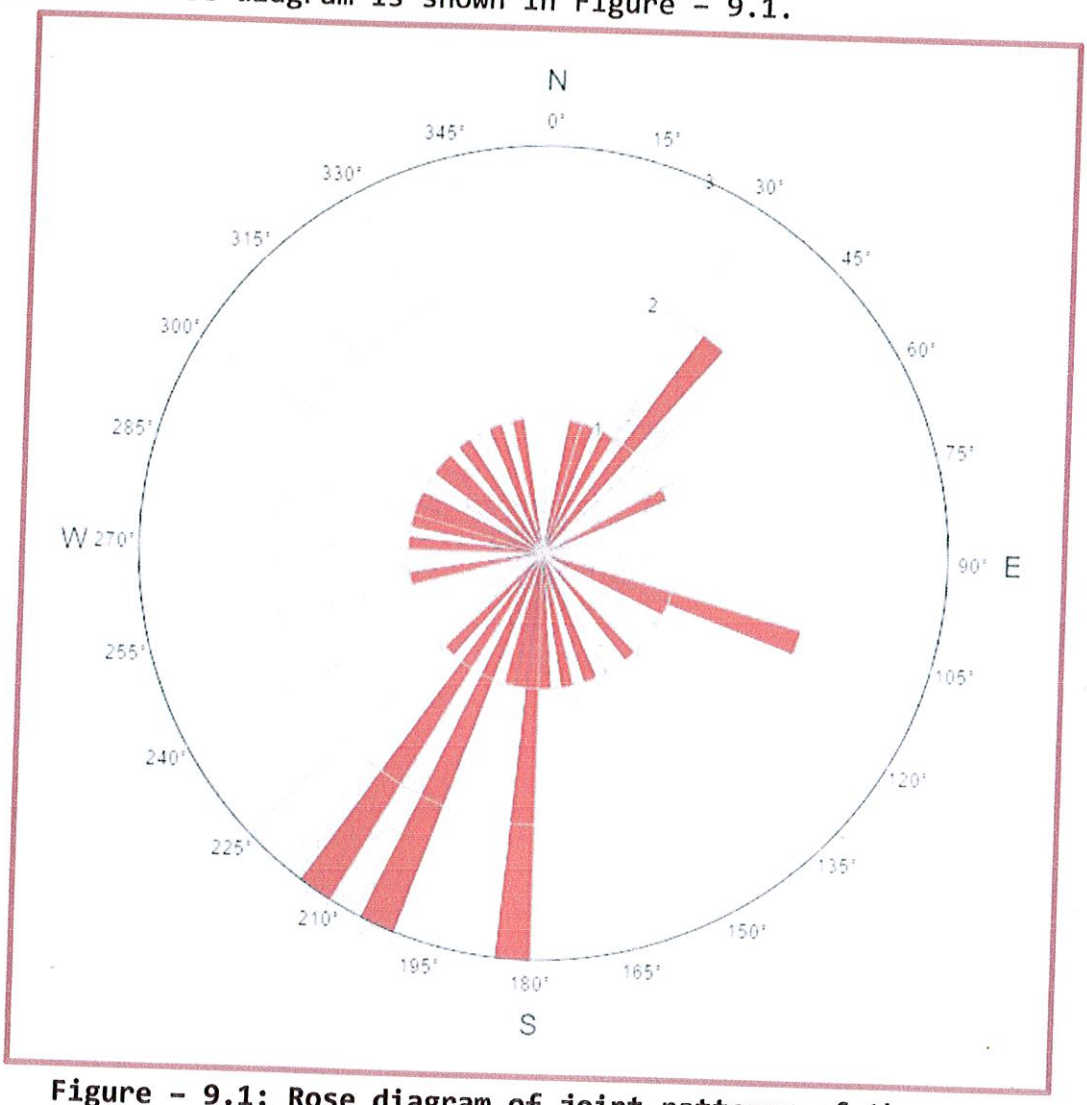
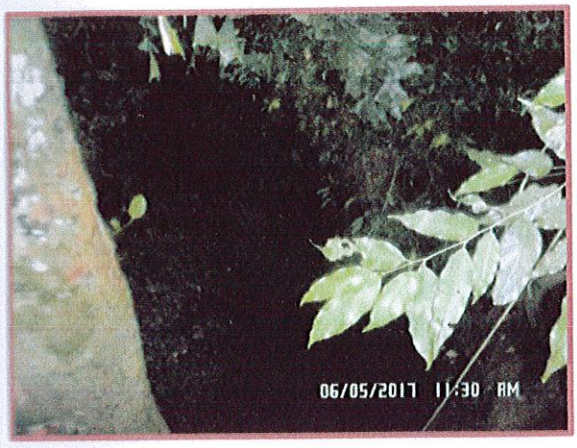


Figure – 9.1: Rose diagram of joint patterns of the area

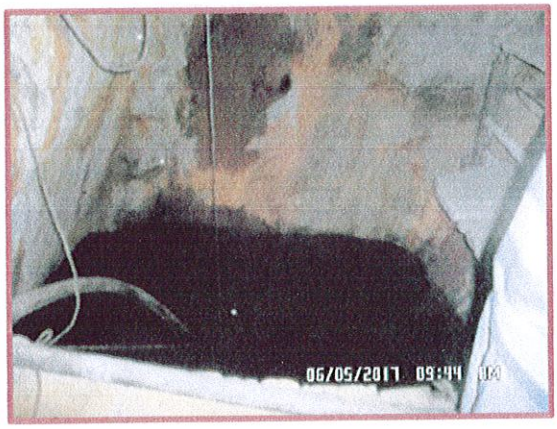
Plate 09.01 – 09.08: Abandoned Graphite Mined Locations and their characteristics



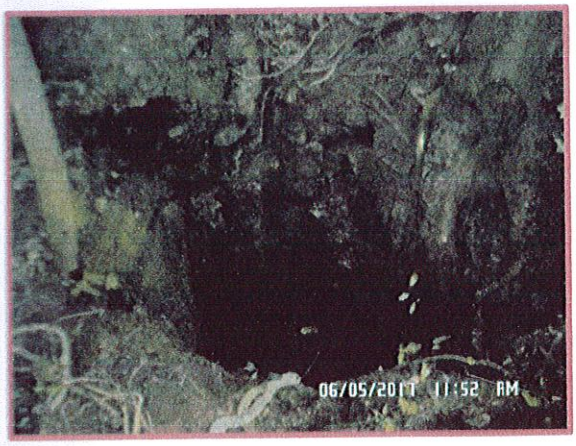
01. Abandoned pit

02. Graphite bearing rock fragments

03. Graphite Bearing Quartz fragments

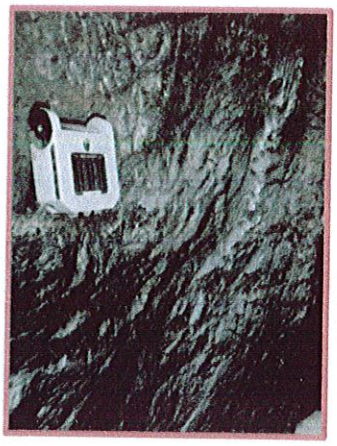


04. Water logged shaft inside of the adit

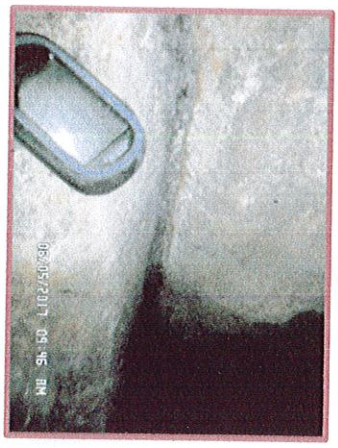


05. Partially collapsed shaft

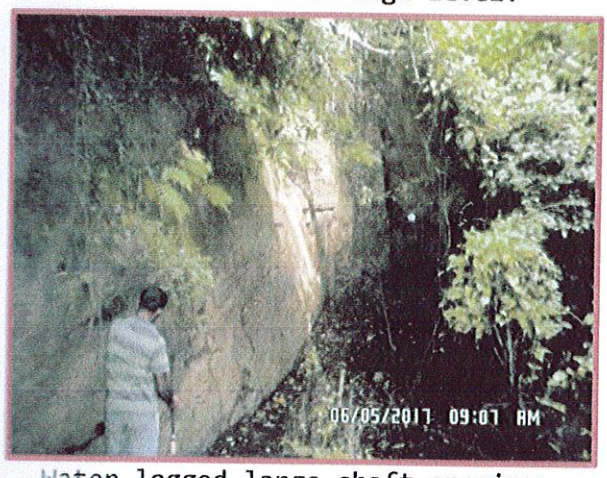
06. Collapsed Shaft



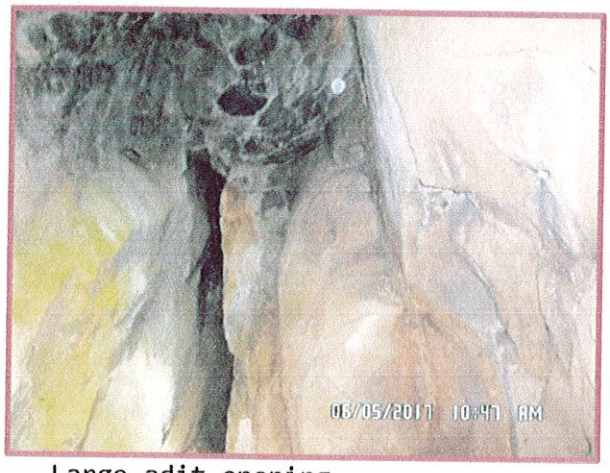
07. Crystalline graphite can be seen in the hanging wall, these are indicate the purity of the graphite which were consists should be in high level.



08. The vein has developed through the fracture system of the base rock & seems that the quality of graphite is high.



09. Water logged large shaft opening



10. Large adit opening

It can be seen most of adits running direction takes generally same bearings mean there could be tunnel system inside of the hill. Once these adits are correlated with available shafts.

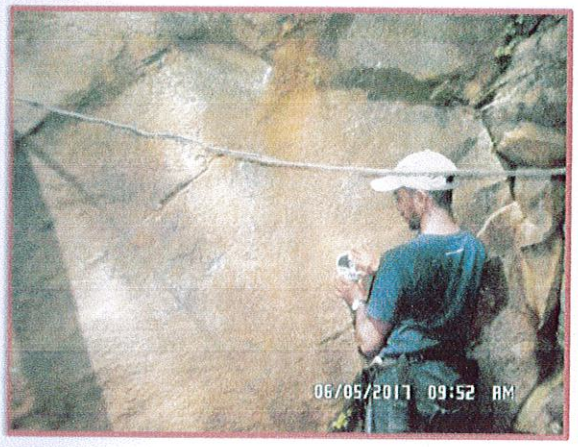
b) **Lithology of Surveyed Area**

According to the data gathered during the survey throughout mentioned grids, it has been identified single lithological structure as follows,

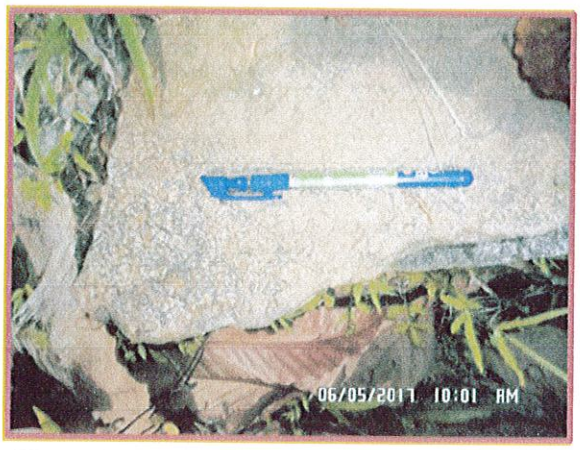
1. Garnetiferous Quartzofeldspathic Gneiss

It has been observed that the local variation of compositions such as Garnet & Quartz content variation and biotite appearance can be seen in the similar parent rock material, partially separated between Gneissic and Granitic compositions during metamorphic process.

Usually Ridge-forming weather resistant quartz rich Gneissic rocks can be found in hilly area and weather favoring rocks such as Biotite gneiss form negative features and usually very poorly exposed in the valley bottoms (Plate 9.11 – 9.12).



11. Garnetiferous Quartzofeldspathic Gneiss rock outcrop



12. Quartz with Graphite

Apart from that it has been observed quartz veins within the parent rock throughout the area. It has been suspected that the graphite mineralization has happen with the formation of these veins.

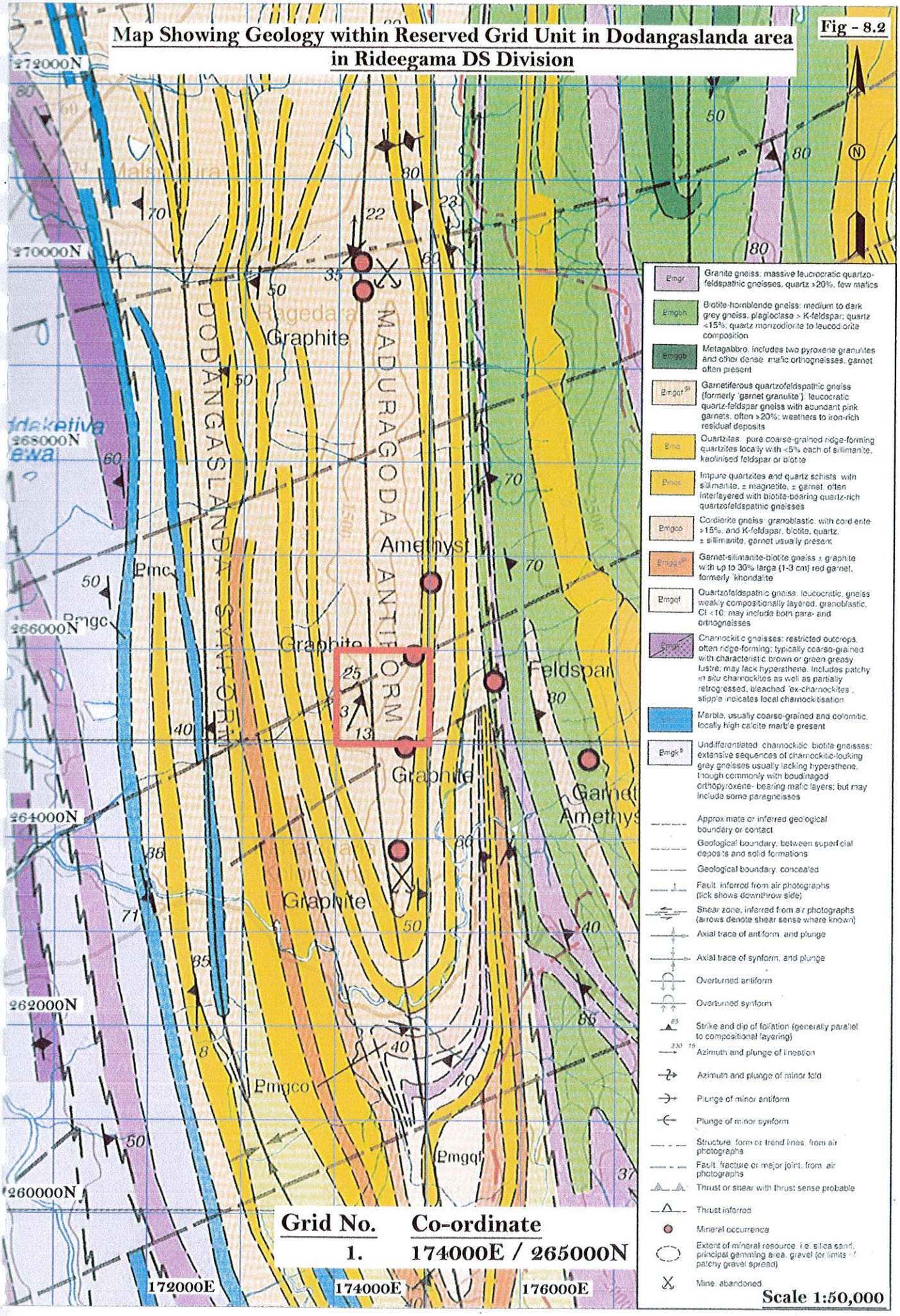
c) Geological Structures of the Surveyed Area

Geological structures observed are the results of early stage deformations happened to the Precambrian metamorphic rocks in the area. Both ductile and brittle type deformational structures could be observed in the surveyed area both regional and local scale.

Joint systems observed on rock outcrops are the major brittle type local structures of the area. Usually several joint systems were observed and their general orientations are as bellows;

Map Showing Geology within Reserved Grid Unit in Dodangaslanda area in Rideegama DS Division

Fig - 8.2



Grid No.	Co-ordinate
1.	174000E / 265000N

Table 9.1: Geographic units and details of the abandoned Graphite Mines in the area

Location	Easting	Northing	Grid No	Structure	Details	Bearings
01	174312	265485	01	Adit	2 x 3 m^2	N-S
02	174346	265722	01	Shaft	Deep about 15m, partially collapsed, mined beyond fresh rock	-
03	174344	265706	01	Shaft	Deep about 20m, partially collapsed, mined beyond weathered rock	-
04	174318	265734	01	Shaft	partially collapsed, mined up to fresh rock	-
05	174162	265472	01	Shaft / Adit	Vein direction is very similar to adit direction, mined beyond fresh rock	N-S
06	174530	265050	01	Shaft	Vein direction observed as 290⁰ and deep about 5m at current conditions	-
07	174499	265220	01	Adit / Shaft	13m long adit and then a shaft opening	290⁰
08	174467	265300	01	Shaft	Totally filled by debris depth cannot identified. present depth is about 5m	-
09	174507	265459	01	Adit	minimum vein thickness identified is 0.3m	-
10	174504	265434	01	Shaft	Large shaft opening filled with water approx. dimensions are 4mx15mx10m (w*l*d)	-
11	174486	265356	01	Adit	Probably a ventilation adit	-
12	174426	265359	01	Shaft	Deep about 10m, partially collapsed, mined beyond fresh rock	-
13	174430	265292	01	Shaft	Deep about 18m, partially collapsed, mined beyond weathered rock	-

The captures of the above adits & shaft has shown with brief description in Plate 9.01 – 9.10.

10. Discussion and conclusions

Two abandoned graphite mining sites could be found within surveyed area. The deposit may form with quartz intrusions to the fissures of the brittle & ductile deformed country rock during. As per the observation the fluid graphite should have high purity and mineralization has happen throughout the structural discontinuities in the country rock. Metamorphism itself also can be interface on the segregation of different minerals in to different layers due to changes happening in pressure and temperature which may reason to increase the purity of the deposit. Apart from that this may be the reason to local variation of composition in Quartzofeldspathic Gneisses in the area. There are several locations which has Garnet & Biotite with considerable mineral percentage, however regionally area has same country rock. The quartz intrusions & pegmatitic intrusions have been taken place through the joints and fracture system of the country rock as well as graphite mineralization has happen with quartz intrusion. It has been observed mineralized graphite in side of quartz clearly evident for the occurrences of graphite has happen with the intrusions of quartz. Therefore the graphite deposit may extend deeper throughout the well-developed deep seated fracture system of the country rock.

According to the evidences gathered during field surveys, can assume the mining has not taken deeper because of unavailability of method to dewatering. These structures can be seen at certain elevation of the ridge indicate the apparent elevation of the bottom which has operated at the time. This is indicating that very primitive methods has been used in these mines during the peak period of graphite mining due to lack of technology and mining professionals. The majority were pit mining, operated entirely by manual means. Therefore, miners were unable to tackle the problems of ventilation, side wall fixing, and haulage of mined graphite from deeper locations of the mines and drilling & blasting etc. in addition to that, these mines also may have been abandoned because the miners were unable to solve the inherent ground water problems.

The available adits & shafts can be developed since it won't cost much to develop the mine. There can be more deposits beneath the certain height of the mountain which has formed through the fracture system.

11. Recommendations

a) It is recommended to carry out a detailed geophysical survey followed by a drilling survey for further evaluation of a lateral and vertical distribution pattern of the Graphite veins in the surveyed areas

b) During the field study and map works it was identified the geophysical study will be very effective if it is conduct on identified positive zone of graphite mineralization and that area is shown in Fig 11.1 in 1:10,000 scale.

c) It can be seen correlation between all structures which has been operated to excavate graphite deposit running in the Maduragoda antiform axis, since it is recommended to carry out a geophysical survey as follows.

d) It is also recommended to opening up old working sites (shafts and adits). This will enable to study the vertical and lateral distribution of the vein and its economic viability.

e) It is better to check the air quality and air availability inside those mine structures before conducting additional surveys inside of them to avoid injuries by mine gasses and lack of oxygen.

f) Also those mine structures should support by better tunnel support system such as iron bars, rock anchors, timber planks, ventilation ducts, etc., to avoid injuries by mine structural failures.

g) The mineralization has happen with formation of vein system throughout the antiform axis and distributed joint system, since it is recommended to carry out stereographic projection analysis on fracture system & joint patterns in order to identify the graphite source distribution.

h) Prior to the commencement of the mining operation it is recommended to obtain mining licenses and approval from the GSMB.

12. Acknowledgements

The author would like to convey their sincere gratitude to 'Grama Niladhari' of Maduragoda village, villagers in survey area and Management of RS Mines (Pvt) Ltd, for providing support in various ways. Also would like to thanks the land owners within the study area who helped to continue this mapping programme without any objection.

A special thanks would like to give for Mr. K. D. A. Samaraweera who helped in mapping programme by providing expertise knowledge in geology.

13. References

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