

# Beneficiation of Ilmenite from Ultramafic Lamprophyres of Mithapukur, Rangpur District of Bangladesh

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**Abstract** In the present study, the main objective is the beneficiation of ilmenite from ultramafic lamprophyres of Mithapukur, Rangpur District of Bangladesh. Mineralogical studies performed by XRF, optical microscopy and Electron Probe Micro Analyzer (EPMA) studies indicated that ilmenite and apatite are main valuable minerals. The gangue minerals consist of the silicate minerals such as pyroxene, olivine and some secondary minerals. Ilmenite in ultramafic lamprophyre ore occurs in various forms such as Ilmenite grains, exsolved Ilmenite lamellae in phlogophyte and Ilmenite particles disseminated in silicate minerals. The feasibility of physical separation has been performed for mineral beneficiation. The grain forms liberated in 63 $\mu$ m-1000 $\mu$ m are recoverable by physical methods. The maximum content of TiO<sub>2</sub> in Ilmenite lattice is determined 54.62% by EPMA. Although the ore has 6.37% average grade of TiO<sub>2</sub>, the recoverable TiO<sub>2</sub> is only about 4.55%, the studied sample contained 11.10% Ilmenite and the amount of recoverable Ilmenite is only about 9.09% (4.55% TiO<sub>2</sub>). This is due to the Ilmenite exsolutions and inclusions in phlogophyte and silicate minerals, and the TiO<sub>2</sub> in solid solution in the lattices of these minerals. In fact, about 81% of whole Ilmenite content of the ore will be recoverable.

**Keywords** Lamprophyre, Ilmenite, Apatite, Physical Separation

## 1. Introduction

Titanium is widely used as titanium dioxide (TiO<sub>2</sub>) for production of white pigment[1]. Ilmenite (FeTiO<sub>3</sub>, 52.6% TiO<sub>2</sub> and 47.4% FeO) is the most common source of titanium dioxide[2]. The term Ilmenite, as used in the titanium industry, commonly covers the entire range from unweathered Ilmenite with TiO<sub>2</sub> contents below 50% to altered Ilmenite containing more than 60% TiO<sub>2</sub>[3]. All economically exploitable Ilmenite occur as hard rock resources and beach sands. The hard rock titanium deposits have complicated mineralogical characteristics whose identification is the most important from processing viewpoint. The amenability of various iron-titanium deposits to beneficiation is controlled by mineralogical and textural characteristics. In the evaluation of the mineralization and in the design of procedures of mineral dressing, the distribution of the valuable material is a matter of immediate importance. It is necessary to determine whether a given element is occurring in one mineral or several[3].

The Ultramafic lamprophyres hard rock deposits has been

located at Mithapukur, Rangpur District of Bangladesh. The lamprophyres are alkaline potassic intrusives with affinities towards aillikites, lamproites and kimberlites and may be diamondiferous. Ultramafic lamprophyres of Mithapukur, Rangpur District of Bangladesh are extremely silica under saturated consists of olivine, phlogopite, pyroxene, biotite with apatite, rutile, leucite, spinel and some opaque minerals. The lamprophyres are essentially ultrapotassic (K<sub>2</sub>O/Na<sub>2</sub>O: 8-13) and ultramafic (MgO: 12.83-22.99wt %). High TiO<sub>2</sub> (5.39-9.25wt %) as well as high P<sub>2</sub>O<sub>5</sub> (1.99-3.15wt %) contents are key features of these rocks owing to high modal rutile + ilmenite and apatite respectively which is higher than beach sand or river sand. The identified ultramafic lamprophyre rock is discovered in the bore hole GDH-52 which was drilled by Geological Survey of Bangladesh (GSB). The higher contents of TiO<sub>2</sub>, P<sub>2</sub>O<sub>5</sub> was found from the depth 722' to 992' of this borehole. The main objective of this study is to separate the TiO<sub>2</sub>, P<sub>2</sub>O<sub>5</sub> bearing minerals from the Ultramafic lamprophyre hard rock. For this purpose the drill core sample has been collected from the core sample library of GSB. The objectives of the study are given below

- The quality and quantity of the liberated mineral and trace element of the rock.
- The estimation of the liberated mineral and trace element of the area.

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c. The up gradation of the liberated mineral into industrial grade.

d. Whether it is economically viable or not, mineral beneficiation from the Ultramafic lamprophyre hard rock of Mithapukur.

by X-ray fluorescence (XRF) and Electron probe micro analyzer (EPMA). The corresponding polished thin sections were studied for ore and rock forming minerals and their textural relationships by reflected and transmitted light microscopy.

## 2. Materials and Methods

The drill core samples from the borehole GDH-52 with overall length about 220' (from the depth 722' to 992') were collected from core sample library of Geological Survey of Bangladesh, Bogra office. The crushing of the samples less than 2mm was done by laboratory jaw crusher. The disc mill was used for grinding of samples. The chemical and mineralogical composition of different samples carried out

### 2.1. Chemical Analysis by XRF

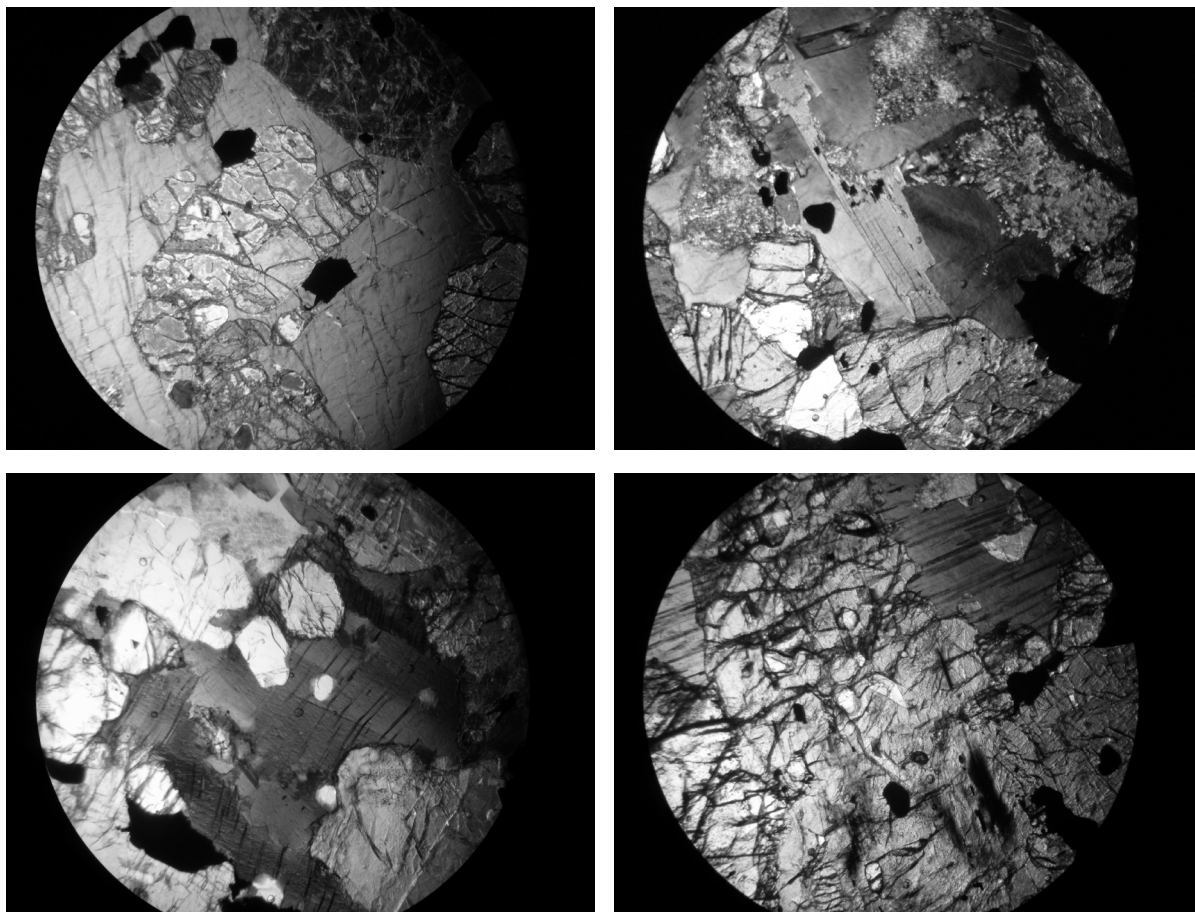
The collected drill core 13 (thirteen) samples depth from 722' to 992' were analyzed and the chemical composition of the samples is shown in Table 1. In the samples SiO<sub>2</sub> ranges from 38.29 to 42.45%, Al<sub>2</sub>O<sub>3</sub> 4.71 to 8.11%, TiO<sub>2</sub> 5.56 to 8.09%, Fe<sub>2</sub>O<sub>3</sub> 10.86 to 15.28%, MgO 9.82 to 20.13%, CaO 7.41 to 11.41%, Na<sub>2</sub>O 0.39 to 1.37%, K<sub>2</sub>O 3.07 to 9.72% and P<sub>2</sub>O<sub>5</sub> 1.01% to 2.90% (Table-1).

**Table 1.** showing the chemical analysis of the collected drill core samples

Elements	Depth in Feet												
	722	774	815.2	849.1	852.1	883	894	939	962.1	969	981.4	989	992
F	0.31	0.37	0.31	0.34		0.15	0.25	0.39	0.22	0.23	0.19		0.14
Na <sub>2</sub> O	0.84	0.71	0.89	1.34	0.95	0.39	1.37	1.03	0.76	0.52	0.75	0.95	0.47
MgO	15.83	17.66	17.10	9.82	16.86	15.45	12.32	9.86	14.31	20.13	14.09	13.32	13.10
Al <sub>2</sub> O <sub>3</sub>	6.19	7.01	4.71	6.27	7.62	6.47	5.98	7.95	6.69	5.50	6.66	8.11	6.90
SiO <sub>2</sub>	40.54	40.10	39.09	39.43	38.29	39.11	39.30	41.45	40.43	38.45	40.63	42.45	41.22
P <sub>2</sub> O <sub>5</sub>	1.45	1.62	1.86	2.19	2.10	1.72	2.90	1.97	1.63	1.01	1.54	1.45	1.42
SO <sub>3</sub>	0.12	0.07	0.08	0.10	0.05	0.06	0.17	0.05	0.05	0.15	0.04	0.04	0.08
Cl	0.03	0.02	0.02	0.04	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
K <sub>2</sub> O	4.62	4.97	3.08	7.95	4.53	4.55	8.17	9.72	4.36	3.29	4.64	5.43	5.39
CaO	10.28	9.41	11.41	10.09	7.42	10.94	8.55	7.86	10.47	9.47	9.87	9.23	10.01
TiO <sub>2</sub>	5.76	6.11	5.66	8.09	5.56	6.16	6.95	7.46	6.13	5.82	6.05	5.59	5.73
Cr <sub>2</sub> O <sub>3</sub>	0.32	0.23	0.36	0.09	0.29	0.31	0.12	0.14	0.31	0.25	0.33	0.30	0.31
MnO	0.19	0.15	0.21	0.20	0.22	0.19	0.12	0.14	0.20	0.23	0.20	0.17	0.18
Fe <sub>2</sub> O <sub>3</sub>	12.79	10.99	14.74	12.14	15.28	13.84	12.53	10.86	13.86	14.48	14.39	12.27	14.33
Co <sub>2</sub> O <sub>3</sub>	0.01		0.01	0.01	0.01	0.01							
NiO	0.09	0.07	0.09	0.02	0.11	0.08	0.04	0.03	0.09	0.08	0.10	0.09	0.10
CuO	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
ZnO	0.03	0.02	0.03	0.04	0.02	0.03	0.03	0.02	0.03	0.03	0.06	0.02	0.03
Rb <sub>2</sub> O	0.01	0.01	0.01	0.02	0.02	0.01	0.03	0.03	0.01	0.01	0.01	0.01	0.01
SrO	0.20	0.19	0.16	0.46	0.19	0.18	0.38	0.38	0.19	0.19	0.18	0.20	0.21
Y <sub>2</sub> O <sub>3</sub>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ZrO <sub>2</sub>	0.05	0.02	0.05	0.37		0.03	0.27	0.24	0.03	0.02	0.05	0.02	0.03
Nb <sub>2</sub> O <sub>5</sub>	0.01	0.01	0.01	0.05	0.01	0.01	0.04	0.03	0.01	0.02	0.01	0.01	0.01
BaO	0.32	0.24	0.11	0.65	0.43	0.22	0.17	0.19	0.20	0.11	0.17	0.33	0.29
La <sub>2</sub> O <sub>3</sub>				0.09									
CeO <sub>2</sub>				0.10		0.06	0.16	0.09					
Nd <sub>2</sub> O <sub>3</sub>				0.06			0.05	0.05					
PbO				0.01			0.05						
ThO <sub>2</sub>				0.01			0.01						

## 2.2. Ore Microscopy

Based on the results obtained from transmitted-light microscopy studies, these rocks have the mineralogy typical of highly-K plutonic ‘lamprophyre’ contains olivine, phlogopite, pyroxenes, biotite, feldspar, leucite, apatite, spinel, rutile, chlorite and some opaque minerals. The dominant phenocryst is set in golden-yellowish in color of phlogopite, olivine and pyroxene (Fig. 4). Some of them with carbonate veins. Olivine, phlogopite and pyroxenes are the predominant phases with apatite and rutile. The phenocrysts are made up essentially of ferromagnesian minerals, an important characteristic of lamprophyres[10]. The porphyritic nature is highlighted by presence of hexagonal and pseudo-hexagonal clinopyroxenes and euhedral mafic minerals like olivine showing a panidiomorphic habit (Fig. 1).



**Figure 1.** Photomicrograph of lamprophyres a) euhedral grains of olivine and pyroxene (plane polarized  $\times 4.0$ ) b) panidiomorphic granular texture (plane polarized  $\times 4.0$ ) c) pyroxene-phlogopite-olivine nodule in lamprophyre consisting of large phlogopite plates with opaque oxides and apatite inclusions (cross nicols  $\times 4.0$ ) d) zircon inclusion in pyroxene (cross nicols  $\times 4.0$ ). Pyx-Pyroxene, Ol-Olivine, Chl-Chlorite, Bt-Biotite, Ap-Apatite, Opq-Opaque, Phl-Phlogopite, Zr-Zircon

Subhedral and euhedral olivines (not rounded, as in kimberlite) and phlogopite occurs as phenocrysts (in some sections olivine grains are  $>1.5\text{mm}$ ) as well as groundmass microphenocrysts of both. Quartz and amphibole/hornblende grains are almost absent in the studied rocks. Phlogopite usually occurs as lath-shaped and orangish to golden yellowish in color with a tinge of red. The phlogopite grains are also observed in hand specimen with golden teen in color which is a characteristic feature of titanium-rich micas[11]. Both fresh and with euhedral apatite inclusions phlogopite grains are also observed in some thin sections. Some of the grains are twisted or bent probably due to some pressure. Some pyroxenes and phlogopite also alters to chlorite along the rim. The

prismatic and euhedral apatite grains are abundant in all the samples of Mithapukur alkaline rocks; their abundance is also proved by high content of  $\text{P}_2\text{O}_5$ .

## 2.3. Electron Probe Microscopy Analysis (EPMA)

The studies of samples by EPMA were performed for two main purposes: 1) Study of exsolution and inclusion texture in ilmenite minerals, 2) to determine the minor element constituents in ilmenite and to distinguish the type of different lamellae inside them. Average analysis of different phases of samples performed by EPMA is given in Table 2. The  $\text{TiO}_2$  content of ilmenite is 54.44 to 54.62%. The  $\text{MgO}$  content of ilmenite is 5.91 to 6.03% which is relatively high.

**Table 2.** showing the selected Electron Probe Microscopy Analysis (EPMA) of Ilmenite phase

DataSet/Point	Na <sub>2</sub> O	MgO	Al <sub>2</sub> O <sub>3</sub>	K <sub>2</sub> O	TiO <sub>2</sub>	FeO	CaO	MnO	SiO <sub>2</sub>	Cr <sub>2</sub> O <sub>3</sub>	NiO	P <sub>2</sub> O <sub>5</sub>	Total	Comment
773 / 1 .	0.00	6.01	0.00	0.01	54.62	38.79	0.02	0.32	0.00	0.48	0.08	0.00	100.33	Ilmenite
774 / 1 .	0.00	5.91	0.00	0.00	54.52	38.78	0.02	0.34	0.02	0.47	0.06	0.03	100.15	Ilmenite
775 / 1 .	0.04	6.01	0.00	0.00	54.62	38.83	0.00	0.38	0.04	0.51	0.11	0.00	100.54	Ilmenite
784 / 1 .	0.01	6.03	0.00	0.00	54.40	38.77	0.00	0.38	0.02	0.45	0.06	0.03	100.15	Ilmenite
785 / 1 .	0.01	5.94	0.00	0.00	54.44	38.44	0.01	0.38	0.00	0.45	0.12	0.00	99.78	Ilmenite

### 3. Feasibility of Physical Separation

The crushing of the samples less than 2mm was done by laboratory jaw crusher. The disc mill was used for grinding of samples. The grinding samples were then oven dried over night at 110°C and 100gm of each sample was sieved for 15 minutes on Fritsch Vibratory Sieve Shaker using mesh 45 $\mu$ m, 63 $\mu$ m, 500 $\mu$ m and 1000  $\mu$ m sieving interval. The separation tests were performed on the head samples 500-1000 $\mu$ m size and 63-500  $\mu$ m size fractions. The Ilmenite liberation degree was determined by using grain counting method by reflected microscope[7] (Table 3). The separation tests were performed by three methods such as hand panning method, gravitational separation by shaking table method and magnetic separation method.

**Table 3.** showing Ilmenite percentage of the collected drill core samples

Depth	Ilmenite (%)
722' /	10.12
774' /	10.84
815'2'' /	9.91
849'10'' /	14.94
852'10'' /	9.7
883' /	10.95
894' /	12.58
939' /	13.64
962'10'' /	10.88
969' /	10.24
981'4'' /	10.72
989' /	9.77
992' /	10.06
Average	11.10

#### 3.1. Hand Panning Method

The hand panning test was performed for 9 (nine) samples to separate the heavy and light part. The average grading TiO<sub>2</sub> of the nine samples is 6.37% which implies about 11.10% Ilmenite (Table 3). The two size fractions (500 $\mu$ m-1000 $\mu$ m and 63 $\mu$ m-500 $\mu$ m) have been taken for this test. The result shows that in the size fraction 500 $\mu$ m-1000 $\mu$ m, the concentration of heavy part is on an average 60.04% and in the size fraction 63 $\mu$ m-500 $\mu$ m is 20.75% (Table 4). The chemical analysis of heavy part was done by XRF. The heavy part contains 9.98% of TiO<sub>2</sub> (Table 5). The recovery of TiO<sub>2</sub> in heavy part of the size fraction 500 $\mu$ m-1000 $\mu$ m is 68.46% and in the size fraction 63 $\mu$ m-500 $\mu$ m is 27.45%. So in the hand panning method,

the recovery of TiO<sub>2</sub> in the size fraction 500 $\mu$ m-1000 $\mu$ m is better than the size fraction 63 $\mu$ m-500 $\mu$ m. In this experiment, though the TiO<sub>2</sub> can be recovered in the heavy part but the bulk amount of the concentration is high. As a result, the extraction of TiO<sub>2</sub> from heavy part will be more costly.

**Table 4.** showing the heavy and light part separation by hand panning method

Depth	500 $\mu$ m-1000 $\mu$ m		63 $\mu$ m-500 $\mu$ m	
	Heavy Part (%)	Light Part (%)	Heavy Part (%)	Light Part (%)
774' /	39.73	60.27	12.82	87.18
815'2'' /	78.13	21.88	37.80	62.20
849'10'' /	68.42	31.58	36.84	63.16
852'10'' /	46.15	53.85	10.87	89.13
883' /	74.36	25.64	13.93	86.07
894' /	41.03	58.97	16.22	83.78
939' /	68.97	31.03	15.69	84.31
989' /	59.74	40.26	32.89	67.11
992' /	63.83	36.17	9.68	90.32
Average	60.04	39.96	20.75	79.25

**Table 5.** showing the chemical analysis of heavy and light part separated by hand panning method

Elemental Composition (% mass)	Heavy part	Light Part
F	0.2089	0.1468
Na <sub>2</sub> O	0.8643	0.7852
MgO	12.6282	10.9897
Al <sub>2</sub> O <sub>3</sub>	5.302	7.4286
SiO <sub>2</sub>	37.6134	40.9141
P <sub>2</sub> O <sub>5</sub>	1.721	2.0771
SO <sub>3</sub>	0.0655	0.065
Cl	0.0154	0.0185
K <sub>2</sub> O	4.8462	6.7973
CaO	8.8063	8.655
TiO <sub>2</sub>	9.9802	6.9048
Cr <sub>2</sub> O <sub>3</sub>	0.234	0.2121
MnO	0.2635	0.2177
Fe <sub>2</sub> O <sub>3</sub>	16.6529	13.751
Co <sub>2</sub> O <sub>3</sub>	0.0151	0.0114
NiO	0.0746	0.0629
CuO	0.0091	0.0075
ZnO	0.0229	0.0222
Rb <sub>2</sub> O	0.0122	0.018
SrO	0.2356	0.281
Y <sub>2</sub> O <sub>3</sub>	0.0029	0.0028
ZrO <sub>2</sub>	0.1303	0.1306
Nb <sub>2</sub> O <sub>5</sub>	0.0276	0.0232
BaO	0.2134	0.4265
CeO <sub>2</sub>	0.0543	0.0509

### 3.2. Gravitational separation by Shaking Table

The gravitational separation test by shaking table was performed for 3 (three) samples to separate the heavy and light part. The average grading of  $\text{TiO}_2$  of the 3 (three) samples is 5.90%. The result shows that the concentration of heavy part of three samples is 22.70 to 24.46% (Table 6).

**Table 6.** showing the heavy and light part separation by shaking table

Depth	Heavy Part (gm)	Heavy Part (%)	Light Part (gm)	Light Part (%)
969'	124	23.89	395	76.11
962'10"	42	22.70	143	77.30
722'	90	24.46	340	75.54
Average		23.68		76.32

After separation the concentration of heavy part of the three samples is mixed and the chemical analysis of heavy part was performed by XRF. The  $\text{TiO}_2$  contain in the mixed heavy part is 16.26% (Table 7). The recovery of  $\text{TiO}_2$  in the heavy part of mixed sample is 51.46%. Compare to hand panning method, this method is better to extract  $\text{TiO}_2$  economically but this concentrate should be run at magnetic separator.

**Table 7.** showing the chemical analysis of heavy and light part separated by shaking table

Elemental Composition (% mass)	Heavy Part	Light Part
F	0.123	0.1416
$\text{Na}_2\text{O}$	0.4583	0.7376
$\text{MgO}$	15.0301	12.9014
$\text{Al}_2\text{O}_3$	2.9822	8.0855
$\text{SiO}_2$	29.1054	42.7315
$\text{P}_2\text{O}_5$	1.9398	1.4752
$\text{SO}_3$	0.0431	0.042
Cl	0.0222	0.0272
$\text{K}_2\text{O}$	1.5728	5.3962
$\text{CaO}$	9.3153	10.0792
$\text{TiO}_2$	16.2588	4.8118
$\text{Cr}_2\text{O}_3$	0.3721	0.2516
$\text{MnO}$	0.3093	0.1847
$\text{Fe}_2\text{O}_3$	21.9377	12.4902
$\text{Co}_2\text{O}_3$	0.017	
$\text{NiO}$	0.0998	0.0789
$\text{CuO}$		0.0063
$\text{ZnO}$	0.0308	0.019
$\text{Rb}_2\text{O}$	0.0035	0.0146
$\text{SrO}$	0.15	0.1979
$\text{Y}_2\text{O}_3$	0.0024	0.0016
$\text{ZrO}_2$	0.0448	0.0151
$\text{Nb}_2\text{O}_5$	0.0253	0.0058
$\text{BaO}$	0.1562	0.3053

### 3.3. Magnetic separation by Induced Roll Magnetic Separator (IRMS)

The magnetic separation test by induced roll magnetic separator of the samples was done to separate the magnetic and non-magnetic part. The two size fractions

(500 $\mu\text{m}$ -1000 $\mu\text{m}$  and 63 $\mu\text{m}$ -500 $\mu\text{m}$ ) of 9(nine) samples have been taken for this test and run at 3 amps current to the induced roll magnetic separator. The recovery of magnetic fraction is well in the size fraction 63 $\mu\text{m}$ -500 $\mu\text{m}$  (average 61.38%) than the size fraction 500 $\mu\text{m}$ -1000 $\mu\text{m}$  (average 26.28%) (Table 8).

**Table 8.** showing the magnetic separation of the drill core samples by IRMS

Depth	63 $\mu\text{m}$ -500 $\mu\text{m}$		500 $\mu\text{m}$ -1000 $\mu\text{m}$	
	Magnetic Part (%)	Non-Mag Part (%)	Magnetic Part (%)	Non-Mag Part (%)
774'	66.67	33.33	19.18	80.82
815'2"	73.49	26.51	35.42	64.58
849'10"	66.32	33.68	25.00	75.00
852'10"	58.70	41.30	26.92	73.08
883'	56.56	43.44	30.77	69.23
894'	60.81	39.19	30.77	69.23
939'	58.82	41.18	15.52	76.00
989'	54.61	45.39	22.08	77.92
992'	56.41	43.59	30.85	69.15
Average	61.38		26.28	

As the recovery of magnetic fraction in the size fraction 63 $\mu\text{m}$ -500 $\mu\text{m}$  is high, this fraction was taken for further magnetic separation. The sieve analysis was done for this fraction of 8(eight) samples. After sieving, the three size fractions 63 $\mu\text{m}$ -125 $\mu\text{m}$ , 125 $\mu\text{m}$ -250 $\mu\text{m}$  and 250 $\mu\text{m}$ -500 $\mu\text{m}$  were obtained from eight samples (Table 9).

**Table 9.** showing the grain size analysis of magnetic fraction of eight samples

Depth	Grain size ( $\mu\text{m}$ )		
	63-125	125-250	250-500
774'	29	33	27
815'2"	32	42	45
849'10"	14	23	31
852'10"	19	22	22
883'	22	28	29
894'	12	17	26
989'	26	33	39
992'	28	35	37

Then individual fraction of each samples were mixed to get the head samples of that three size fractions. The samples were run at 0.3 amp current to the induced roll magnetic separator (Table 10) and did XRF analysis of the separated magnetic part (Table 11).

**Table 10.** showing the magnetic separation at 0.3 amp by IRMS of three size fractions

Size ( $\mu\text{m}$ )	Magnetic Part (gm)	Magnetic Part (%)	Non-Mag Part (gm)	Non-Mag Part (%)
63-125	49	30.82	110	69.18
125-250	60	24.59	184	75.41
250-500	42	15.97	221	84.03

The result shows that in the size fraction 63 $\mu\text{m}$ -125 $\mu\text{m}$ , the product is an Ilmenite concentrate with 15.47%  $\text{TiO}_2$

grade by containing 78.45% (Recovery) of titanium dioxide. In the size fraction 125 $\mu$ m-250 $\mu$ m, the product is an Ilmenite concentrate with 21.81% TiO<sub>2</sub> grade by containing 78.93% (Recovery) of titanium dioxide. In the size fraction 250 $\mu$ m-500 $\mu$ m, the product is an Ilmenite concentrate with 28.53% TiO<sub>2</sub> grade by containing 81.87% (Recovery) of titanium dioxide. The beneficiation of Ilmenite in this method is higher than other methods but the recovery is depending on the grain size fractions. It is difficult to keep the grain size in definite size fractions by disc mill or any other grinding mill in commercial operation.

**Table 11.** showing the elemental composition of the separated magnetic part of three size fractions

Elemental Composition (% mass)	63 $\mu$ m-125 $\mu$ m	125 $\mu$ m-250 $\mu$ m	250 $\mu$ m-500 $\mu$ m
F	0.1582		
Na <sub>2</sub> O	0.2892	0.1524	0.1844
MgO	21.9214	21.7961	15.7217
Al <sub>2</sub> O <sub>3</sub>	1.7363	0.9845	1.3416
SiO <sub>2</sub>	27.7766	20.7124	16.8646
P <sub>2</sub> O <sub>5</sub>	0.26	0.3809	0.6752
SO <sub>3</sub>	0.0738	0.0527	0.047
Cl	0.018	0.011	0.0182
K <sub>2</sub> O	0.8996	0.5463	0.6489
CaO	3.9395	1.5812	1.858
TiO <sub>2</sub>	15.4678	21.8097	28.5295
Cr <sub>2</sub> O <sub>3</sub>	0.3975	0.3703	0.4348
MnO	0.3921	0.4069	0.4382
Fe <sub>2</sub> O <sub>3</sub>	26.3913	30.893	32.9198
Co <sub>2</sub> O <sub>3</sub>	0.0174	0.0216	0.0158
NiO	0.1305	0.1401	0.1195
CuO	0.0084		
ZnO	0.0345	0.0368	0.0361
SrO	0.0336	0.0274	0.0472
ZrO <sub>2</sub>	0.0285	0.0389	0.0497
Nb <sub>2</sub> O <sub>5</sub>	0.026	0.0378	0.0499

## 4. Conclusions

According to ore microscopically results, these rocks have the mineralogy typical of highly-K plutonic 'lamprophyre' contains olivine, phlogopite, pyroxenes, biotite, feldspar, leucite, apatite, spinel, rutile, chlorite, ilmenite and some opaque minerals. The dominant phenocryst is set in golden-yellowish in color of phlogopite, olivine and pyroxene. The ultramafic lamprophyre ore by average grading of 6.37% TiO<sub>2</sub> which implies about 11.10% Ilmenite (by considering 48% TiO<sub>2</sub> for Ilmenite, based on EPMA analysis result) is one of the low grade deposits in the world. However the TiO<sub>2</sub> content of Lamprophyre of Mithapukur deposit is lower than Tellnes (upto 18% TiO<sub>2</sub> and 35% Ilmenite) and Otanmaki (upto 14% TiO<sub>2</sub> and 28% Ilmenite) ores but it is comparable with these ores from reserve viewpoint.

The Ilmenite in this ore is in various forms: Ilmenite grains, exsolved Ilmenite lamellae in phlogophyte, Ilmenite fine particles disseminated in silicates. Based on TiO<sub>2</sub> content of Ilmenite concentrate, the amount of lamellae form of Ilmenite is unrecoverable by physical methods. The much of the Ilmenite disseminated in silicate minerals are unrecoverable by physical methods too. So, the TiO<sub>2</sub> content of the ore which is usually determined by chemical analysis is not totally recoverable. Consequently, the recoverable Ilmenite content of the rock is not exceeding 9.09%. Another valuable mineral apatite can not be recovered by physical method. In spite of complicated mineralogical features of studied ore, it is predicted that by combination of gravity methods such as tabling and Humphrey spiral and magnetic separation, the concentration and production of commercial Ilmenite concentrate from ultramafic lamprophyre deposit will be possible. In addition, the P<sub>2</sub>O<sub>5</sub> is obtained from apatite concentrate which can be recovered by floatation of tailings of gravity separation. Ilmenite and apatite are valuable minerals for production of TiO<sub>2</sub>, P<sub>2</sub>O<sub>5</sub> and Fe; the rare earth elements Sr, Rb, Nb, Nd, Ce, Ba can be extracted as a by-product.

The ultramafic lamprophyre which is discovered by IMM scientists is alkaline potassic intrusives with affinities towards aillikites, lamproites and kimberlites and may be diamondiferous. Throughout the world diamond is explored and mined in this type of rock. So this area may be a prospective zone of Bangladesh for valuable minerals and metals. This study is based on the one drill hole done by Geological Survey of Bangladesh, that's why the reserve estimation and extent can not be possible. For this purpose a comprehensive study such as drilling program in systematic pattern and geophysical exploration are needed to estimate the reserve calculation.

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