SHIVA ANALYTICALS INDIA PRIVATE LIMITED

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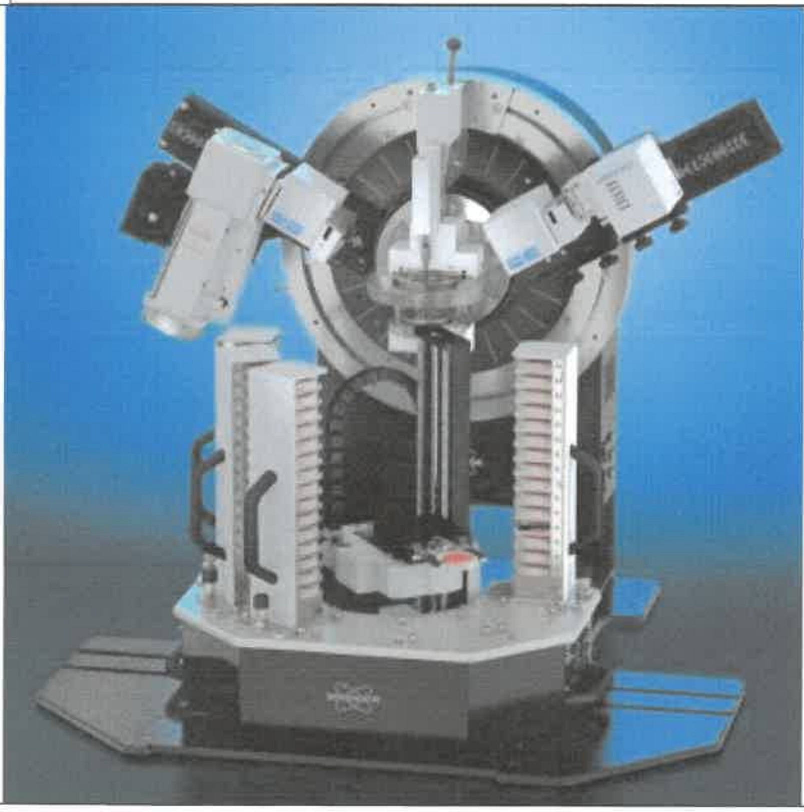
Customer Ref : BRS94/BTB/2025
Lab ID : G2803-5
Date of Sample Analysis :17/10/2025
Date of Reporting :23/10/2025

MINERALOGY TEST REPORT

1.60 KW POWDER X RAY DIFRACTOMETER METHOD



INTRODUCTION: X-ray diffraction (XRD) and petrology studies are both valuable techniques used in geology and materials science for analysing minerals and rocks, but they serve different purposes and offer unique advantages. Here's how XRD is superior to petrology studies in certain aspects. XRD excels in identifying crystalline minerals present in a sample. It provides precise information about the crystal structure and lattice parameters of minerals, which can be challenging to ascertain solely through petrological observations. XRD allows for quantitative analysis of mineral phases present in a sample, providing accurate estimates of mineral composition based on peak intensities. Petrology studies, while descriptive, may not always provide quantitative data on mineral abundance. XRD is highly sensitive and can detect trace amounts of minerals present in a sample, even at concentrations as low as a few percent. Powder Diffraction (XRD) Database, contains a comprehensive collection of more than 6000 diffraction patterns for various materials. Researchers use this resource for identifying unknown substances, confirming crystal structures, and conducting material characterization. Shiva Analyticals team has decades of experience on XRD studies. Accurate chemical assay coupled with reliable mineralogy information is vital in resource characterisation.

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Verified by: Satyanarayana

Sample Code: G2803-5 (BRS94/BTB/2025)

Instruments: WDXRF – Bruker S8 Tiger Series 2 (4 kW); XRD – Bruker D8 Advance (1.6 kW).
2θ Scan Range: 5–80° | Crystallinity: 74.90% | Amorphous: 25.10% |

Bulk Oxides by WDXRF:

Oxide	Wt.%
Al2O3	12.97
BaO	<0.05
CaO	11.54
Cr2O3	0.10
Fe2O3	12.60
K2O	1.08
MgO	9.39
MnO	0.14
Na2O	2.32
P2O5	0.36
SiO2	45.45
SO3	<0.05
SrO	<0.05
TiO2	2.45
V2O5	<0.05
ZrO2	<0.05
HfO2	<0.05
CuO	<0.05
NiO	<0.05
PbO	<0.05
ZnO	<0.05
LOI	1.38

Mineral Phases by XRD:

Sl.no	Mineral Phase	Chemical Formula	XRD Wt.%	XRD Crystalline Wt % (XRD Wt.% ×0.749)	Molecular Weight (g/mol)
1	Augite	$(Ca,Mg,Fe)Si_2O_6$	0.31	0.23	236.35
2	Enstatite	$MgSiO_3$	1.88	1.41	100.39
3	Pigeonite	$(Ca,Mg,Fe)Si_2O_6$	0.71	0.53	219.70
4	Aegirine	$NaFeSi_2O_6$	10.98	8.22	231.00
5	Diopside	$CaMgSi_2O_6$	14.36	10.76	216.55
6	Labradorite	$(Ca,Na)(Al,Si)_4O_8$	12.1	9.06	271.81
7	Andesine An50	$(Na,Ca)(Al,Si)_4O_8$	25.59	19.17	521.21

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Sl.no	Mineral Phase	Chemical Formula	XRD Wt.%	(XRD Wt.% ×0.749)	Molecular Weight (g/mol)
8	Bytownite	$(Ca,Na)(Al,Si)_4O_8$	19.17	14.36	275.01
9	Magnetite	Fe_3O_4	3.18	2.38	231.53
10	Jacobsite	$MnFe_2O_4$	0.06	0.04	227.38
11	Chromite	$FeCr_2O_4$	0.27	0.20	171.84
12	Quartz	SiO_2	1.32	0.99	60.08
13	Dolomite	$CaMg(CO_3)_2$	1.5	1.12	184.4
14	Clintonite-1M	$Ca(Mg,Al)_3(Al_3Si)O_{10}(OH)_2$	0.75	0.56	415.81
15	Hydroxyclino-humite	$(Mg,Fe)_9(SiO_4)_4(OH,F)_2$	1.16	0.87	621.49
16	Cancrinite	$Na_6Ca_2Al_6Si_6O_{24}(CO_3)_2$	0.93	0.70	1052.5
17	Titanite	$CaTiSiO_5$	0.94	0.70	196.04
18	Clinochlore	$(Mg,Fe)_5Al(Si_3Al)O_{10}(OH)_8$	2.11	1.58	595.22
19	Laumontite	$CaAl_2Si_4O_{12}{\cdot}4H_2O$	2.4	1.80	470.44
Total			100	74.90	

Stoichiometric Comparison Table:

Oxides	XRF (wt%)	XRD crystallinity (wt%)	Amorphous (wt%)
SiO2	45.45	38.76	6.69
Al2O3	12.97	12.72	0.25
Fe2O3	12.60	6.47	6.13
MgO	9.39	3.91	5.48
CaO	11.54	9.20	2.34
Na2O	2.32	2.28	0.04
K2O	1.08	0.00	1.08
TiO2	2.45	0.23	2.22
Cr2O3	0.10	0.07	0.03
MnO	0.14	0.01	0.13
F	0.00	0.05	-0.05
CO2	0.00	0.60	-0.60
H2O	0.00	0.59	-0.59
Traces	1.96	0.00	1.96

Interpretation

- The WDXRF analysis shows the sample is dominated by SiO_2 (45.45 wt%), Fe_2O_3 (12.60 wt%), Al_2O_3 (12.97 wt%), CaO (11.54 wt%), and MgO (9.39 wt%), with minor alkali oxides (Na_2O 2.32 wt%, K_2O 1.08 wt%) and trace elements. This composition suggests a silicate-rich matrix with significant mafic (Fe-Mg-Ca) components, consistent with plagioclase-pyroxene dominated lithologies.

- The XRD data identifies 19 crystalline phases, predominantly plagioclase feldspars (Andesine, Bytownite, Labradorite, pyroxenes (Diopside, Enstatite, Augite, Pigeonite, and minor amphiboles/chlorites (Clinochlore, Clintonite, Hydroxyclinohumite), along with accessory magnetite, chromite, titanite, quartz, and dolomite. Notably, aegirine indicates some Na-rich clinopyroxene crystallization.

Suggested minor/Secondary mineral phases

- Silica-rich glass: The largest contributor to the amorphous fraction , likely forming from rapid cooling of silicate melts or fine-grained volcanic glass.
- Fe-rich amorphous oxides: Non-crystalline Fe_2O_3 may occur as nano-magnetite, ferrihydrite, or poorly crystalline iron silicates.
- Mg-silicate glass or amorphous chlorites: MgO could be associated with poorly crystalline Mg-silicates or fine-grained alteration products.
- Ti-bearing amorphous phases: TiO_2 may exist as amorphous Ti-silicates or nanocrystalline titanium oxides.
- K-rich amorphous silicates: K_2O likely occurs in glassy or secondary alteration phases, as no crystalline K-feldspar is observed.
- Minor amorphous Ca- and Na-bearing phases: Small contributions from CaO and Na_2O may arise from partially amorphous plagioclase, calcium silicates, or carbonate glasses.

Potential commercial uses

Component	**Applications**
SiO_2 (amorphous + crystalline)	Glass and ceramics production, refractory materials, silica fillers
Al_2O_3 (plagioclase, minor amorphous)	Refractories, ceramics, abrasives
Fe_2O_3 (magnetite, amorphous Fe oxides)	Pigments, magnetic materials, iron source in steelmaking
MgO (pyroxenes, chlorites, amorphous Mg-silicates)	Refractory bricks, cement additive, lightweight aggregates
CaO (plagioclase, dolomite, amorphous Ca-silicates)	Cement and lime production, soil amendment
K_2O (amorphous K-rich phases)	Potash fertilizers, specialty glass
TiO_2 (titanite, amorphous Ti-phases)	White pigments, ceramics, catalysts
Minor trace elements (Cr, Mn, Ni)	Alloying, pigments, corrosion-resistant coatings

Probable origin assessment

The sample likely originates from a mafic to intermediate volcanic or shallow intrusive source, dominated by plagioclase and pyroxene crystallization. The presence of aegirine, Ti-bearing phases, and significant amorphous content (~25 wt%) indicates rapid cooling or quenching, while minor hydrous silicates suggest low-grade hydrothermal alteration.

Final Results

- Bulk Composition: The sample is silicate-rich, dominated by SiO_2 (45.45 wt%), Fe_2O_3 (12.60 wt%), Al_2O_3 (12.97 wt%), CaO (11.54 wt%), and MgO (9.39 wt%), with minor alkali and trace elements, indicating a mafic to intermediate composition.
- Mineralogy (XRD): Major crystalline phases include plagioclase feldspars (Andesine, Bytownite, Labradorite), pyroxenes (Diopside, Enstatite, Augite), and aegirine, with minor hydrous silicates (Clinochlore, Clintonite, Laumontite), oxides (Magnetite, Chromite, Titanite), carbonates (Dolomite), and quartz.
- Amorphous Phases: Approximately 25 wt% of the sample is amorphous, dominated by SiO_2, Fe_2O_3, MgO, TiO_2, and K_2O, likely representing volcanic glass, poorly crystalline silicates, and secondary alteration products.
- Probable Origin: The rock likely formed from a mafic–intermediate volcanic or shallow intrusive source, with rapid cooling/quenching and minor low-grade hydrothermal alteration, reflecting a combination of magmatic crystallization and secondary processes.

Stoichiometric Oxide Table

Mineral Name	Chemical Formula	XRD wt%	SiO2	Al2O3	Fe2O3	MgO	CaO	Na2O	K2O	TiO2	Cr2O3	MnO	F	CO2	H2O
Augite	$(Ca,Mg,Fe)Si_2O_6$	0.23	0.13	0.00	0.02	0.02	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Enstatite	$MgSiO_3$	1.41	0.85	0.00	0.00	0.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pigeonite	$(Ca,Mg,Fe)Si_2O_6$	0.53	0.29	0.00	0.07	0.09	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aegirine	$NaFeSi_2O_6$	8.22	4.35	0.00	3.56	0.00	0.00	0.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Diopside	$CaMgSi_2O_6$	10.76	5.97	0.00	0.00	2.01	2.78	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Labradorite	$(Ca,Na)(Al,Si)_4O_8$	9.06	5.43	2.65	0.00	0.00	0.54	0.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Andesine An50	$(Na,Ca)(Al,Si)_4O_8$	19.17	11.19	4.90	0.00	0.00	2.03	1.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bytownite	$(Ca,Na)(Al,Si)_4O_8$	14.36	6.84	4.39	0.00	0.00	2.75	0.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Magnetite	Fe_3O_4	2.38	0.00	0.00	2.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jacobsite	$MnFe_2O_4$	0.04	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Chromite	$FeCr_2O_4$	0.20	0.00	0.00	0.13	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.00
Quartz	SiO_2	0.99	0.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dolomite	$CaMg(CO_3)_2$	1.12	0.00	0.00	0.00	0.24	0.31	0.00	0.00	0.00	0.00	0.00	0.00	0.57	0.00
Clintonite 1M	$Ca(Mg,Al)_3(Al_3Si)O_{10}(OH)_2$	0.56	0.29	0.05	0.00	0.11	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05
Hydroxyclinohumite	$(Mg,Fe)_9(SiO_4)_4(OH,F)_2$	0.87	0.31	0.00	0.05	0.39	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.07
Cancrinite	$Na_6Ca_2Al_6Si_6O_{24}(CO_3)_2$	0.70	0.31	0.14	0.00	0.00	0.08	0.09	0.00	0.00	0.00	0.00	0.00	0.03	0.05
Titanite	$CaTiSiO_5$	0.70	0.27	0.00	0.00	0.00	0.20	0.00	0.00	0.23	0.00	0.00	0.00	0.00	0.00
Clinochlore	$(Mg,Fe)_5Al(Si_3Al)O_{10}(OH)_8$	1.58	0.49	0.28	0.18	0.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15
Laumontite	$CaAl_2Si_4O_{12}\cdot 4H_2O$	1.80	0.95	0.31	0.00	0.00	0.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27
Aegirine-augite	$(Na,Ca)(Fe,Mg)Si_2O_6$	0.21	0.10	0.00	0.05	0.01	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total	**74.9**	**38.76**	**12.72**	**6.47**	**3.91**	**9.20**	**2.28**	**0.00**	**0.23**	**0.07**	**0.01**	**0.05**	**0.60**	**0.59**

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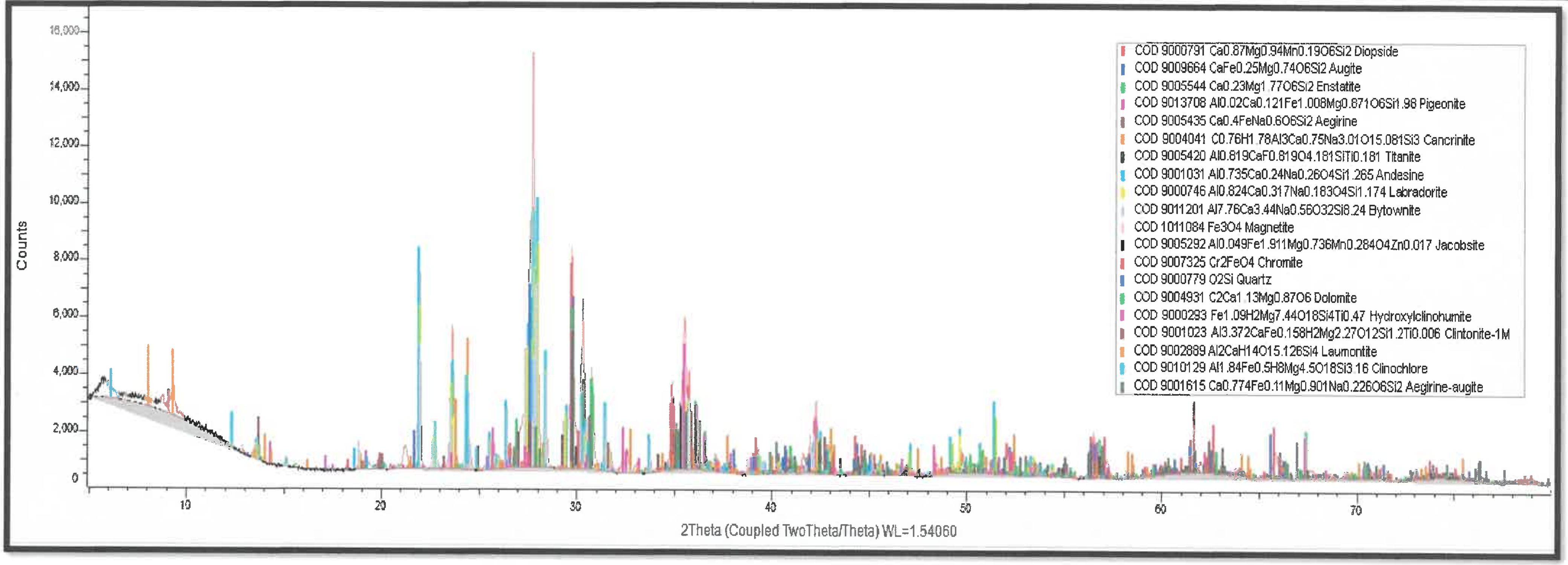
SHIVA ANALYTICALS INDIA PRIVATE LIMITED — BRUKER D8 ADVANCE XRD TEST DATA

G2803-5 — BRS94/BTB/2025 — XRD Scan Report_1 of 2



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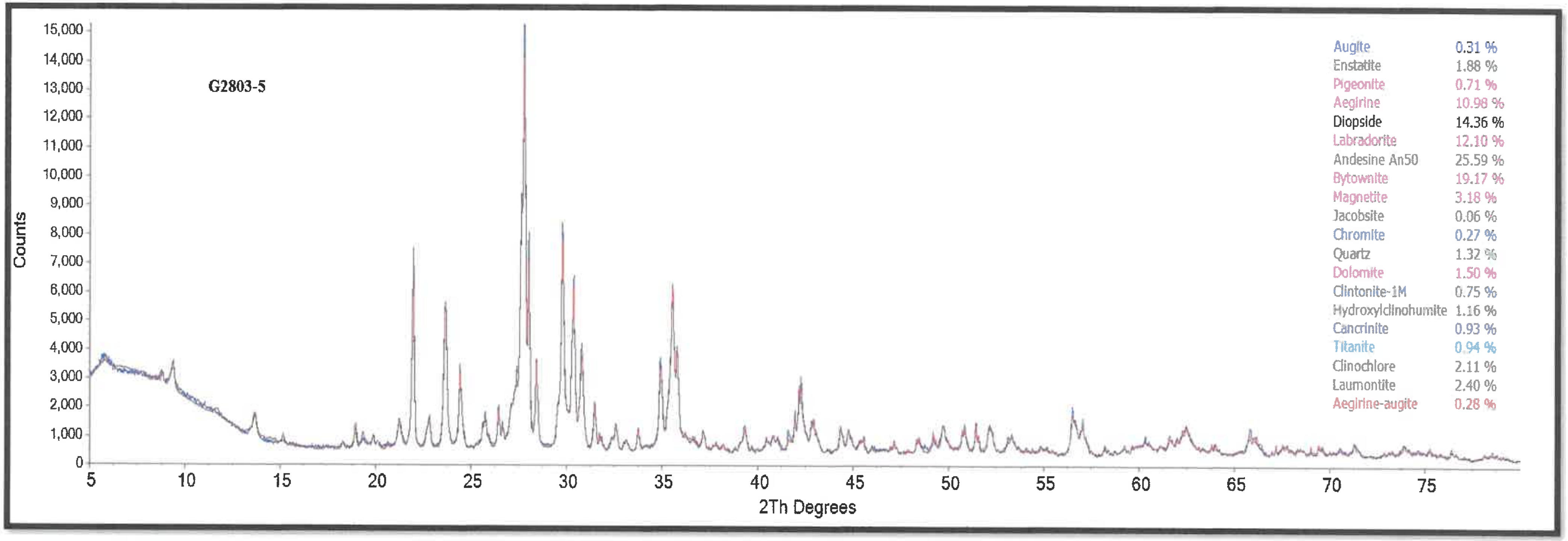
G2803-5 | BRS94/BTB/2025 | XRD Scan Report_2 of 2



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