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Customer Name: Mr. K. Nageswara Rao.
Customer Address: Critical Minerals Trackers, Mineral Exploration and Geo Solution, #Concourse, No 406,7-1-58/CC/406, Opp Lal Bungalow, Greenland's, Hyderabad -500016 India.
Customer Ref : P31/RB/2025
Lab ID : G2296-2

Dates of Sample Analysis :05/09/2025
Date of Reporting :08/09/2025

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

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Sample Code: G2279-2 (P31/RB/2025)

Expert Report for Sample No. G2296-2

WDXRF Data on Elemental Composition

The WDXRF results provide a detailed oxide breakdown of Sample G2296-2

Oxide	% Composition
Al_2O_3	25.78
BaO	<0.05
CaO	1.47
Cr_2O_3	<0.05
Fe_2O_3	20.39
K_2O	0.05
MgO	0.35
MnO	<0.05
Na_2O	0.07
P_2O_5	0.62
SiO_2	31.38
SO_3	0.09
SrO	0.24
TiO_2	5.17
V_2O_5	0.07
ZrO_2	0.05
PbO	<0.05
CuO	<0.05
NiO	<0.05
ZnO	<0.05
LOI (Loss on Ignition)	14.23

These chemical compositions inform the analysis of the mineral phases and offer valuable insights into commercial and geochemical applications.

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Stoichiometric Link between WDXRF and XRD Results

Proportioned Correspondence:

The WDXRF elemental composition was mapped to the major XRD phases to validate the match, as shown below:

Mineral Phase (XRD)	Proportion (%)	Relevant Oxides (WDXRF)	Stoichiometric Match
Kaolinite	39.11	Al_2O_3 (25.78%), SiO_2 (31.38%)	Al-rich aluminosilicates; direct match to Kaolinite ($Al_2Si_2O_5(OH)_4$).
Hematite	8.97	Fe_2O_3 (20.39%)	Iron oxides primarily fit Hematite (Fe_2O_3).
Calcium Carbonate	3.61	CaO (1.47%), LOI (14.23%)	LOI suggests CO_3 volatiles matched to $CaCO_3$.
Ilmenite	5.41	TiO_2 (5.17%), Fe_2O_3 (20.39%)	Fe-Ti phases tie strongly to Ilmenite ($FeTiO_3$).
Amorphous (Unidentified)	42.9	Trace oxides: P_2O_5, MgO, V_2O_5, etc.	Uncrystallized residue and secondary traces.

Key **crystalline content is 57.1%**, while the **remaining 42.9% is amorphous**, likely comprising silica or iron phases.

Crystallinity Distribution

- **Crystalline Phase (57.1%)**: Includes Kaolinite, Hematite, Calcium Carbonate, and Ilmenite.
- **Amorphous Phase (42.9%)**: Represents silicates, secondary oxides, or poorly crystallized material.

Secondary/Minor XRD Mineral Phases

Potential unidentified phases suggested by WDXRF include:

1. **Quartz (SiO_2)**: Excess SiO_2 not accounted for by Kaolinite.
2. **Goethite (FeOOH)**: Iron oxides formed under weathered conditions.
3. **Rutile/Anatase (TiO_2)**: Ti traces could manifest in TiO_2 polymorphs.
4. **Apatite ($Ca_5(PO_4)_3$)**: Suggested by trace P_2O_5.

Probable Origin of Material

Geochemical Indicators

- **Kaolinite & Hematite**: The weathered mineralogy suggests alteration of volcanic rocks under tropical or subtropical environments.
- **Ilmenite**: Strongly indicates a volcanic or igneous (mafic) origin, with potential hydrothermal alteration.
- **Calcium Carbonate**: Inferred as post-depositional precipitation due to interaction with carbonated waters.

Conclusion: The sample most likely originated from a weathered volcanic deposit modified by hydrothermal or tropical processes.

Potential Commercial Applications

Based on mineralogy and composition, similar materials have the following commercial uses:

Mineral Phase	Applications
Kaolinite	Ceramics, rheology modifiers in paper production, and fillers.
Hematite	Raw material for iron, abrasives, pigment manufacturing.
Ilmenite	Titanium dioxide for paints, plastics, and coatings.
Calcium Carbonate	Adhesives, cement additives, limestone derivatives, and fillers.
Amorphous Silica	Reinforcements (e.g., additives in cements, glass production).

Tabulated Summary

WDXRF and XRD Data Combined

Oxides (WDXRF)	% Composition	Major Phases (XRD)	Phase % (XRD)	Interpretation
Al_2O_3	25.78	Kaolinite	39.11	Kaolinite as the dominant aluminosilicate.
SiO_2	31.38	Kaolinite + Quartz (Trace)	39.11 + Trace	Excess SiO_2 forms quartz.
Fe_2O_3	20.39	Hematite, Ilmenite	8.97 + 5.41	Fe_2O_3 matches Hematite and Ilmenite.
TiO_2	5.17	Ilmenite	5.41	Fe-Ti association supports Ilmenite.
CaO	1.47	Calcium Carbonate	3.61	Matches $CaCO_3$ phase with LOI confirming carbonates.
P_2O_5	0.62	Apatite (minor)	Trace	P suggested formation of phosphates.

Other Oxides	Trace	None	Amorphous Sections	Trace oxides add to unclassified amorphous materials.

XRD Mineral Phase and Oxide Assignment for Sample G2296-2

XRD Mineral Phase (with Formula)	XRD Proportion (%)	Oxides (%) Assigned from WDXRF for this Mineral Phase	Balance of Each Oxide (%) Left Over	Suggestions for Amorphous Phase Predicted Minerals
Kaolinite ($Al_2Si_2O_5(OH)_4$)	39.11	Al_2O_3: 20.09%, SiO_2: 20.95%, LOI (H_2O): 7.83%	Al_2O_3: 5.69%, SiO_2: 10.43%, LOI (H_2O): 6.4%	Excess SiO_2 suggests Quartz (SiO_2); LOI points to hydroxide formations like Goethite (FeOOH).
Hematite (Fe_2O_3)	8.97	Fe_2O_3: 8.97%	Fe_2O_3: 11.42%	Excess Fe contributes to Goethite (FeOOH) or other iron hydroxides.
Calcium Carbonate ($CaCO_3$)	3.61	CaO: 1.47%, LOI (CO_2): 2.14%	CaO: 0%, LOI: 4.26%	Remaining LOI may correspond to phases like minor Carbonates (e.g., dolomitic inclusions) or evaporite minerals.
Ilmenite ($FeTiO_3$)	5.41	TiO_2: 5.02%, Fe_2O_3: 3.93%	TiO_2: 0.15%, Fe_2O_3: 7.49%	Residual TiO_2 could form Rutile/Anatase (TiO_2) phases in the amorphous composition.
Amorphous Phases (Remaining Oxides)	42.9	(Residual oxides after assigning crystalline mineral phases):	Al_2O_3: 5.69%, SiO_2: 10.43%, Fe_2O_3: 7.49%, TiO_2: 0.15%, P_2O_5: 0.62%, and trace MgO, V_2O_5, etc.	Quartz (SiO_2), Goethite (FeOOH), Rutile/Anatase (TiO_2), and possible Phosphates (e.g., Apatite, $Ca_5(PO_4)_3$) derive from trace oxides.

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Key Observations

Oxide Assignments for Crystalline Phases:

- **Kaolinite** utilizes most of the available **Al_2O_3 (20.09%)**, **SiO_2 (20.95%)**, and a significant proportion of LOI (7.83%), leaving small balances unassigned.
- **Hematite (8.97%)** fully utilizes part of **Fe_2O_3 (8.97%)**, but **7.49% remains** available for amorphous iron phases like Goethite or ferrihydrite.
- **Calcium Carbonate** accounts for all **CaO (1.47%)** and part of the LOI, pointing to carbonate sources.
- **Ilmenite** effectively incorporates **TiO_2 (5.02%)** with minimal excess (**0.15%**) and partially utilizes **Fe_2O_3**.

Balances and Contributions to Amorphous Phase:

- The **remaining SiO_2 and Al_2O_3** likely form secondary silicate minerals or residual glassy components.
- **Unassigned Fe_2O_3** suggests amorphous Fe-hydroxides such as Goethite.
- **Residual TiO_2** could crystallize as Rutile or Anatase in poorly ordered regions.
- **Adjunct oxides (P_2O_5, V_2O_5, MgO)** might align with minor phosphates or exotic silicates.

Conclusion

- The material predominantly comprises **Kaolinite, Hematite, Ilmenite, and Calcium Carbonate**, with minor contributions from secondary quartz, goethite, and anatase.
- The probable origin points to **volcanic activity**, followed by weathering and deposition in a humid environment.
- Commercially, the material offers applications in **ceramics, pigments, and construction-related fields**.

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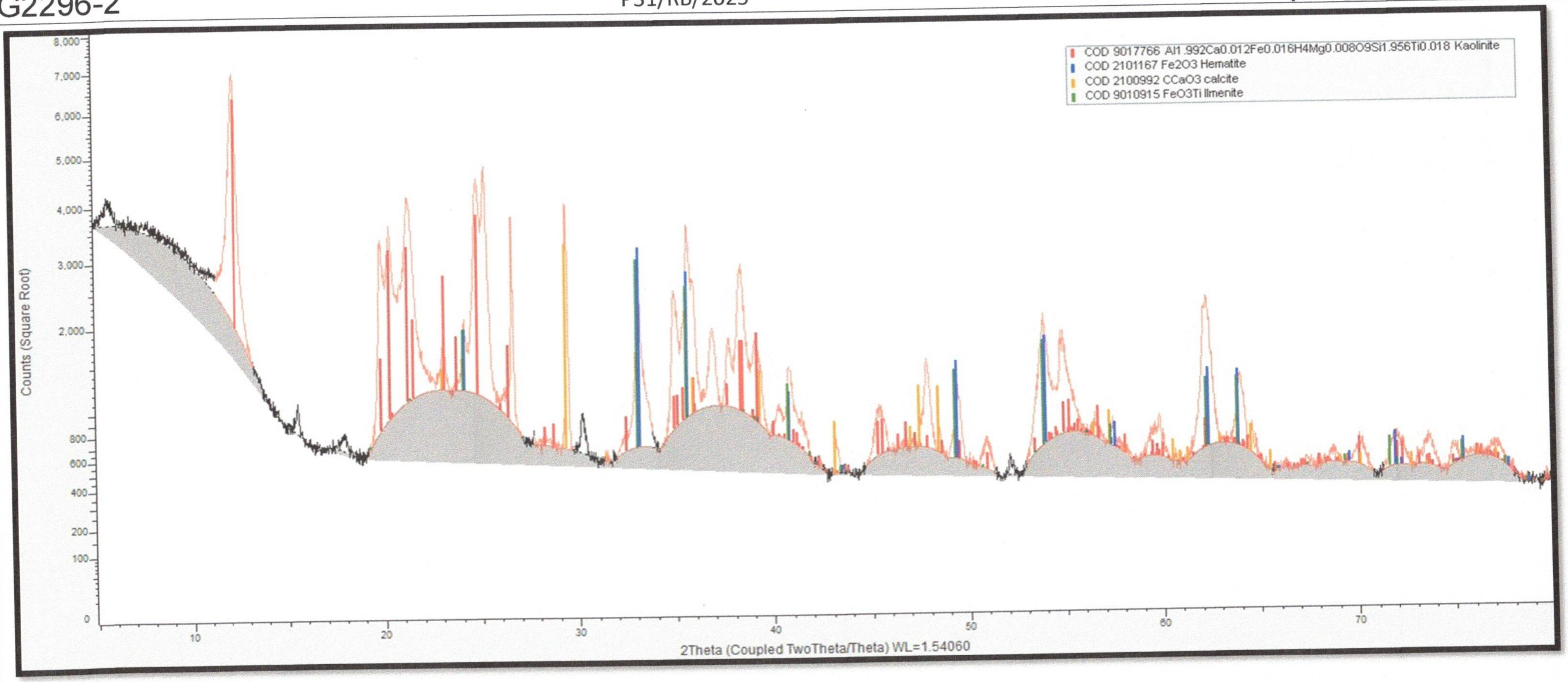
BRUKER D8 ADVANE XRD TEST DATA

G2296-2

P31/RB/2025

XRD Scan Report_1 of 2



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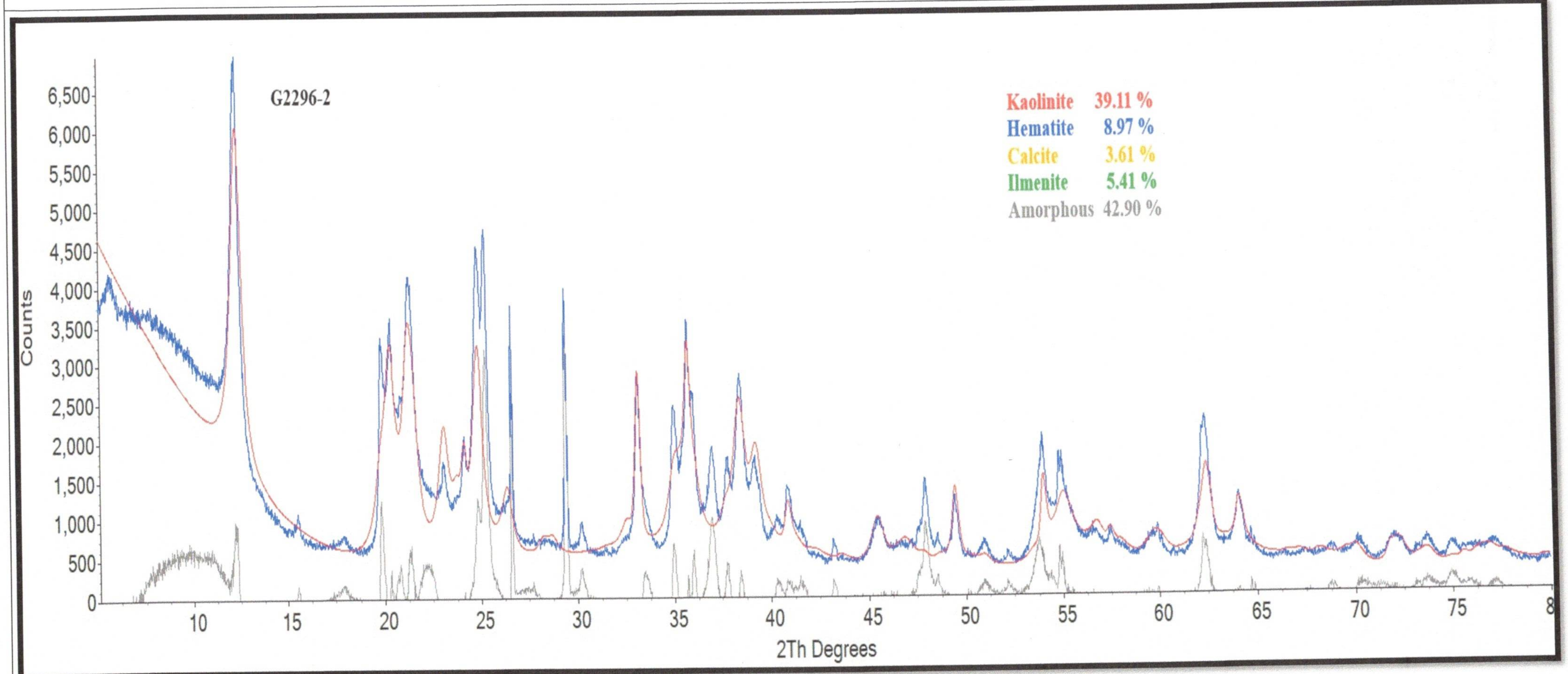
G2296-2 | P31/RB/2025 | XRD Scan Report_2 of 2



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Customer Ref : T21/RB/2025/07
Lab ID : G2296-4

Dates of Sample Analysis :05/09/2025
Date of Reporting :08/09/2025

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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Sample Code: G2279-4 (T21/RB/2025/07)

Expert Report for Sample No. G2296-4

WDXRF Data on Elemental Composition

Oxide	% Composition
Al_2O_3	27.79
BaO	<0.05
CaO	2.65
Cr_2O_3	<0.05
Fe_2O_3	12.29
K_2O	0.12
MgO	0.26
MnO	<0.05
Na_2O	0.08
P_2O_5	0.38
SiO_2	35.18
SO_3	0.22
SrO	0.09
TiO_2	6.19
V_2O_5	0.09
ZrO_2	0.06
PbO	<0.05
CuO	<0.05
NiO	<0.05
ZnO	<0.05
LOI (Loss on Ignition)	14.53

This chemical analysis lays the foundation for stoichiometrically justifying the observed XRD phases.

Correlation between WDXRF and XRD Results

Proportions of Oxides for Identified XRD Phases

The following table aligns the WDXRF oxide data with the major mineral phases detected by XRD and evaluates the stoichiometric relationships:

Phase (XRD)	Proportion (XRD %)	Relevant Oxides (WDXRF)	Stoichiometric Justification
Kaolinite ($Al_2Si_2O_5(OH)_4$)	47.64	Al_2O_3 (27.79%), SiO_2 (35.18%)	Strong match; Kaolinite is aluminosilicate-rich.
Hematite (Fe_2O_3)	3.93	Fe_2O_3 (12.29%)	Trace amounts identified align with iron oxide content.
Calcium Carbonate ($CaCO_3$)	4.24	CaO (2.65%), LOI (14.53%)	CaO aligns with carbonate phases; LOI reflects CO_2 release.
Ilmenite ($FeTiO_3$)	7.58	TiO_2 (6.19%), Fe_2O_3 (12.29%)	Ti-rich phase perfectly aligns with Ilmenite composition.
Amorphous	36.60	Residual oxides (e.g., SiO_2, P_2O_5)	Complex traces suggest amorphous silicates or secondary phases.

Crystallinity and Amorphous Content

- **Crystalline Phase:** 63.4% (Kaolinite, Hematite, Calcium Carbonate, and Ilmenite dominate).
- **Amorphous Content:** 36.6% (unclassified silicates, minor Fe, or Ti inclusions and residual phases from WDXRF).

Possible Minor or Secondary Mineral Phases

Based on WDXRF data, several **secondary or minor phases** can be proposed beyond the major mineral phases detected:

1. **Quartz (SiO_2):** High SiO_2 content (35.18%) not fully allocated to Kaolinite likely forms minor Quartz inclusions.
2. **Goethite (FeO(OH)):** Fe_2O_3 surplus suggests minor hydrated iron oxides under weathering conditions.
3. **Anatase or Rutile (TiO_2):** Excess TiO_2 might result in the formation of minor TiO_2 polymorphs.
4. **Phosphates:** Limited P_2O_5 (0.38%) could form trace phosphate phases like Apatite ($Ca_5(PO_4)_3F$).

Probable Origin of Material

Geochemical Indicators

- **Kaolinite and Hematite:** Weathered tropical settings with strong chemical alteration of volcanic or sedimentary deposits.
- **Ilmenite ($FeTiO_3$):** Suggests a volcanic or mafic igneous origin, possibly residual titanium minerals post-igneous crystallization.

- **Calcium Carbonate:** Likely precipitated from secondary processes, potentially during weathering or diagenesis.

Conclusion:

The origin of this sample is likely **volcanic**, with subsequent hydrothermal and weathering modifications in a tropical-subtropical environment.

Commercial Applications

This material's mineralogical composition and properties suggest various **commercial applications**:

Mineral Phase	Applications
Kaolinite	Ceramics, paper-coating pigments, polymer fillers, refractories.
Hematite	Source of iron for steelmaking, pigments, abrasives.
Ilmenite	Titanium dioxide production for pigments and coatings.
Calcium Carbonate	Concrete, lime production, filler for construction materials.
Quartz (Secondary)	Glassmaking, silicon manufacturing for electronics.

Tabulated Results Summary

WDXRF Data with Proportioned XRD Results

Oxides (WDXRF)	% Composition	Major Phases (XRD)	Phase % (XRD)	Stoichiometric Justification
Al_2O_3	27.79	Kaolinite	47.64	Al-rich phase directly matches aluminosilicate structures.
SiO_2	35.18	Kaolinite, Quartz	47.64 + Trace	Residual SiO_2 contributes to potential Quartz phase.
Fe_2O_3	12.29	Hematite, Ilmenite	3.93 + 7.58	Fe oxides split between Hematite and titaniferous Ilmenite.
TiO_2	6.19	Ilmenite	7.58	Ti strongly supports titaniferous phases like Ilmenite.
CaO	2.65	Calcium Carbonate	4.24	Carbonates align well with CaO and LOI contributions.
P_2O_5	0.38	Minor/Secondary Phase	Trace	May contribute to minor phosphate minerals (e.g., Apatite).
Others	Trace amounts	Amorphous Materials	36.60	Likely residual silicates or poorly crystallized material.

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Crystallinity

Crystalline Content	% Contribution
Crystalline Phases	63.4%
Amorphous Phases	36.6%

XRD Mineral Phase Analysis with Chemical Formula and Remaining Oxides

XRD Mineral Phase (% with Chemical Formula)	% of Each Oxide Assigned for this Mineral Phase (WDXRF)	Amount of Each Oxide (%) Balance Left After Assignments	Amorphous Phase Predicted Minerals and Remaining Oxides Assignment (%)
Kaolinite (47.64%; $Al_2Si_2O_5(OH)_4$)	Al_2O_3 (22.55%) and SiO_2 (22.00%)	Al_2O_3 Balance: 5.24%; SiO_2 Balance: 13.18%	Remaining SiO_2 likely contributes to Quartz (SiO_2) in the amorphous phase.
	H_2O (derived from LOI; 6.28%)	LOI Balance: 8.25%	LOI remainder may form hydroxides like Goethite (FeOOH) in the amorphous phases.
Hematite (3.93%; Fe_2O_3)	Fe_2O_3 (3.93%)	Balance Fe_2O_3 left: 8.36%	Excess Fe likely contributes to Goethite (FeOOH, hydrous Fe oxides) in amorphous phase.
Calcium Carbonate (4.24%; $CaCO_3$)	CaO (2.65%) and CO_2 (from LOI; 1.59%)**	Balance CaO: 0.00%	Contribution fully accounted; no residual CaO remains.
Ilmenite (7.58%; $FeTiO_3$)	Fe_2O_3 (4.93%) and TiO_2 (5.17%)	Balance TiO_2: 1.02%; Fe_2O_3: 3.43%	Residual TiO_2 possibly forms Rutile/Anatase (TiO_2 polymorphs) in amorphous phase.
Amorphous Phases (36.60%) Predicted As...	Trace oxides, LOI residuals:		Contribution from V_2O_5, MgO, P_2O_5, Na_2O, forming Phosphates or Silicates in amorphous phase.

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Breakdown of Unallocated/Remaining Oxides and Amorphous Predictions

- **SiO_2 (Remaining 13.18%)**:
  Likely contributes to **Quartz (SiO_2)** or secondary glassy silicates in the amorphous content.
- **Fe_2O_3 (Remaining 3.43%)**:
  Likely forms **Goethite (FeOOH)** alongside residual hydroxides or trace hematite in amorphous phases.
- **TiO_2 (Remaining 1.02%)**:
  Residual Ti would crystallize as trace **Rutile/Anatase polymorphs (TiO_2)**.
- **P_2O_5, CaO, MgO, and LOI Residuals**:
  These key inputs (e.g., **LOI: 8.25%**) likely feed **phosphate or hydroxide phases** (e.g., minor Apatite or other silicates) in amorphous material.

Conclusion

- **Mineralogy (Major Phases):** The sample consists primarily of **Kaolinite (47.64%)**, followed by **Hematite (3.93%)**, **Calcium Carbonate (4.24%)**, and **Ilmenite (7.58%)**.
- **Secondary/Minor Phases:** Potential includes **Quartz, Goethite, Anatase/Rutile**, and trace **Phosphates**.
- **Probable Origin: Volcanic material** subjected to weathering and hydrothermal alteration in tropical-subtropical environments.
- **Economic Potential:** Suitable for **ceramic, pigment, refractory, and construction industries**.

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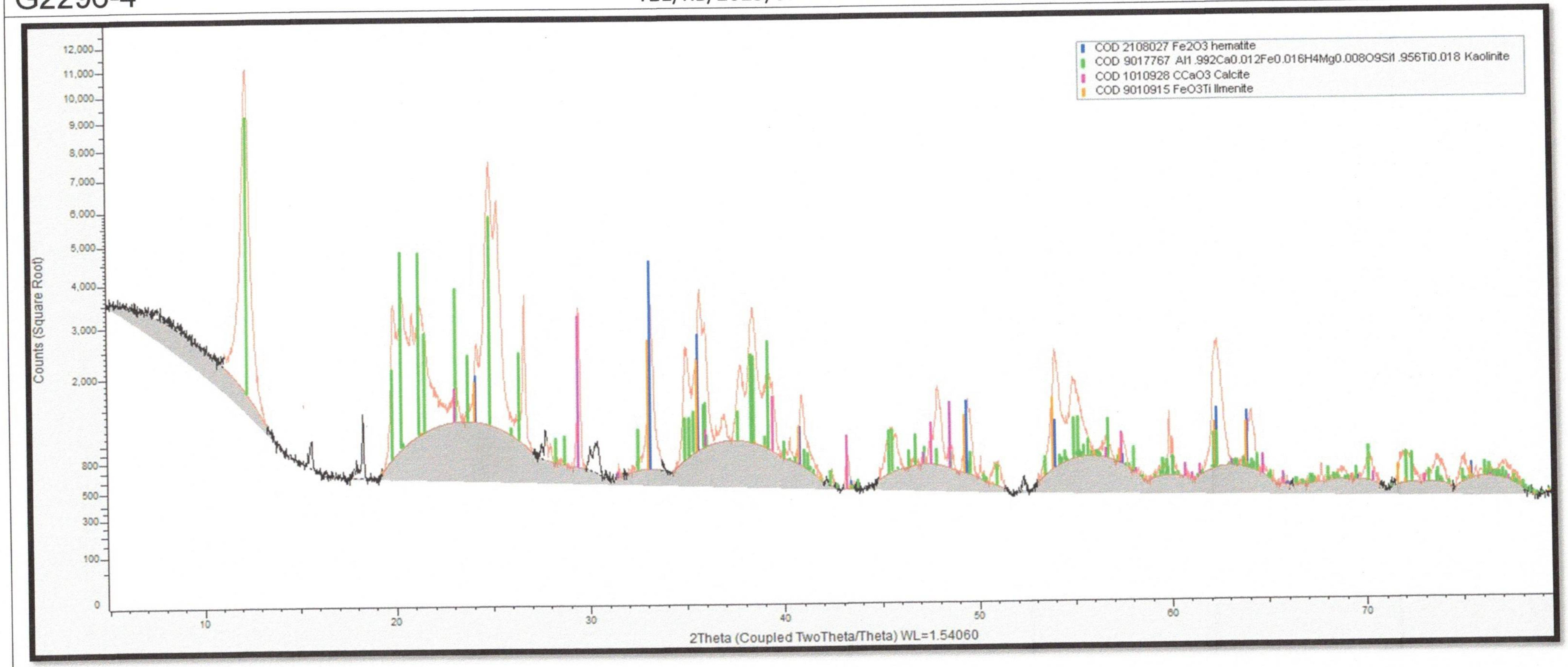
BRUKER D8 ADVANE XRD TEST DATA

G2296-4

T21/RB/2025/07

XRD Scan Report_1 of 2



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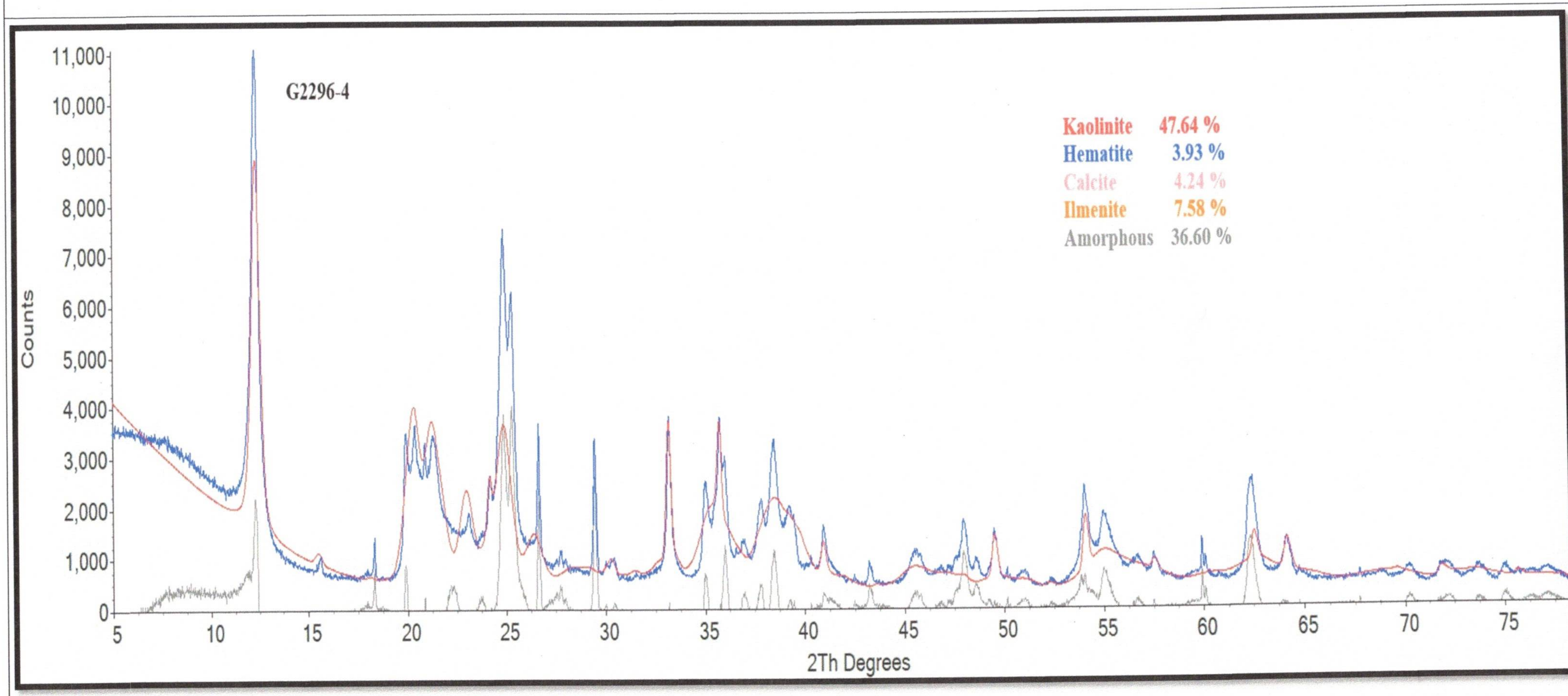
G2296-4 | T21/RB/2025/07 | XRD Scan Report_2 of 2



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Customer Ref : T23/RB/2025/01
Lab ID : G2296-6

Dates of Sample Analysis :05/09/2025
Date of Reporting :08/09/2025

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Summary

Sample G2296-6 (T23/RB/2025/01)

Sample G2296-6 was analysed by WDXRF (Bruker S8 Tiger Series) and XRD (Bruker D8 Advance). WDXRF bulk oxide results (wt%) and XRD major phase quantification (weight %) are reconciled below. XRD reports 70% crystalline phases (Kaolinite, Gibbsite, Mg?Calcite, Ilmenite) and 30% amorphous.

Analytical data

WDXRF (Bruker S8 Tiger Series) — Oxide results (wt%):

Oxide	Wt %
Al2O3	31.59
SiO2	33.71
CaO	2.94
MgO	0.49
Fe2O3	5.70
TiO2	5.96
K2O	0.40
Na2O	0.37
P2O5	0.15
SO3	1.04
LOI	17.37

XRD phases

Mineral phase	Wt % (sample)
Kaolinite	46.20
Gibbsite	8.65
Mg-Calcite	8.15
Ilmenite	7.00

Crystallinity (sum of identified phases) = 70.0 % ; Amorphous = 30.0 %.
XRD scan: 2θ = 5–80°.

Stoichiometric conversion — mineral ↔ oxide equivalents

Key calculated oxide composition (wt%) for each mineral (per 100 g of mineral):

Mineral	Formula (approx.)	Molecular mass (g/mol)	Major oxide wt% (representative)	LOI / CO2 (wt%)
Kaolinite	Al2Si2O5(OH)4	258.157	Al2O3: 39.495 SiO2: 46.548	H2O: 13.957
Gibbsite	Al(OH)3	78.002	Al2O3: 65.357	H2O: 34.643

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Mg?substituted Calcite (avg)	$(Ca,Mg)CO_3$ (Mg frac from bulk MgO/CaO)	97.117	CaO: 46.873 MgO: 7.812	CO_2: 45.315
Ilmenite	$FeTiO_3$	151.709	FeO: 47.356 (=> Fe_2O_3 equiv for XRF), TiO_2: 52.644	—

Proportionation: oxide contributions from identified crystalline phases

The table below shows oxide contributions (wt% of sample) predicted from the XRD-identified crystalline phases using stoichiometric conversions:

Oxide	Measured (WDXRF)	From Kaolinite	From Gibbsite	From Mg?Calcite	From Ilmenite (Fe_2O_3 equiv / TiO_2)
Al_2O_3	31.59	18.24	5.65	0.00	0.00
SiO_2	33.71	21.50	0.00	0.00	0.00
CaO	2.94	0.00	0.00	3.82	0.00
MgO	0.49	0.00	0.00	0.63	0.00
Fe_2O_3	5.70	0.00	0.00	0.00	7.36
TiO_2	5.96	0.00	0.00	0.00	3.68
LOI	17.37	0.00	0.00	0.00	0.00

Predicted totals from crystalline phases and residual (measured − predicted = amorphous + mismatch):

Oxide	Measured (wt%)	Predicted from crystalline (wt%)	Residual = Meas − Pred (wt%)
Al_2O_3	31.59	23.90	7.68
SiO_2	33.71	21.50	12.20
CaO	2.94	3.82	-0.88
MgO	0.49	0.63	-0.14
Fe_2O_3	5.70	7.36	-1.66
TiO_2	5.96	3.68	2.27
LOI	17.37	13.13	4.23

Amorphous fraction (30%) — inferred composition

Residual oxides (measured − crystalline) are attributed primarily to the amorphous fraction. Values below are normalized to 100% of the amorphous fraction (i.e., % of the 30% amorphous mass). Negative residuals indicate a mismatch (XRD vs XRF) and are discussed in the interpretation section.

Oxide	Residual (wt% of sample)	Inferred % of amorphous fraction (residual/30 *100)
SiO_2	12.20	40.68
Al_2O_3	7.68	25.63
LOI	4.23	14.10
TiO_2	2.27	7.58

SO_3	1.0	3.46
K_2O	0.40	1.33
Na_2O	0.37	1.23
P_2O_5	0.15	0.50
ZrO_2	0.08	0.26
SrO	0.06	0.20
Cr_2O_3	0.04	0.13
V_2O_5	0.04	0.13
PbO	0.04	0.13
MnO	0.01	0.03
NiO	0.01	0.03
MgO	-0.14	-0.48
CaO	-0.88	-2.93
Fe_2O_3	-1.66	-5.56

Interpretation & expert justification

• The four XRD-identified crystalline phases (sum = 70%) explain most of the Al_2O_3 and a significant portion of SiO_2, TiO_2 and the structural H_2O/CO_2 (LOI). Predicted LOI from crystalline phases ≈ 13.138 wt% compared with measured LOI 17.370 wt% — residual LOI ≈ 4.232 wt% (allocated to amorphous).

• The amorphous fraction is inferred to be rich in SiO_2 (~40.68% of amorphous), Al_2O_3 (~25.63%), with appreciable TiO_2 (~7.58%) and structural H_2O/CO_2 (LOI ≈ 14.11% of amorphous). This composition is consistent with amorphous aluminosilicates (allophane/opal), poorly crystalline clays, and fine Ti⍰oxide phases (anatase/ferrihydrite/opaline Ti phases).

• A notable mismatch: predicted CaO from the Mg⍰calcite amount (from XRD) is 3.820 wt% while measured CaO is 2.940 wt%. Predicted > measured suggests one or more of: (a) XRD overestimate of the Mg⍰calcite concentration, (b) carbonate occurs with variable Mg/Ca not captured by the bulk proxy, (c) analytical uncertainty/errors (preferred orientation, Rietveld fit, or WDXRF calibration), or (d) Ca partly present in phases below XRF detection or lost during LOI. Such mismatch warrants follow⍰up (see recommendations).

Minor / secondary phases likely present (not in major XRD list)

Based on residual oxides and trace elements, plausible minor/secondary phases include:
- Amorphous silica (opal-A / opal-CT) or microcrystalline quartz (accounts for extra SiO_2)
- Poorly crystalline aluminosilicates (allophane, proto⍰imogolite), smectite (if present)
- Fine Ti⍰oxide phases (anatase, rutile) and leucoxene derived from ilmenite weathering
- Iron (oxy)hydroxides (goethite/ferrihydrite) as coatings — may be in amorphous fraction
- Apatite or fluorapatite (trace P_2O_5 = 0.15%)
- Gypsum/anhydrite (trace SO_3 = 1.04%) or adsorbed sulfate
- Trace zircon (ZrO_2), accessory Pb⍰bearing phases, Ni, V traces

Probable origin of the material

The mineral assemblage (dominant kaolinite + gibbsite + significant LOI + some ilmenite) strongly suggests intense chemical weathering in a tropical/subtropical environment — a residual soil / lateritic horizon or bauxitic/weathered regolith. High Al_2O_3 (31.6%) with substantial structural water and kaolinite/gibbsite indicates leaching of mobile elements and enrichment of Al and Ti. The presence of ilmenite indicates an igneous/mafic heavy⍰mineral source (detrital or residual concentration).

Commercial evaluation & potential uses

- Kaolinite uses: paper/coating fillers, ceramics, refractories, filler for rubber/paint. Usable if impurities (Fe, Ti) are low — current TiO_2 (~6%) and Fe_2O_3 (~5.7%) may limit some high⍰brightness uses.
- Gibbsite / Al⍰bearing phases: indicates potential aluminum resource (bauxite precursor) but with Al_2O_3 ~31.6% the sample is lower grade for direct Al production; beneficiation and silica reduction would be required.
- Ilmenite/TiO_2: ilmenite is a Ti resource for pigment (TiO_2) or Ti metal feed — but economic viability depends on ilmenite abundance and grain size; here ilmenite = 7% (XRD) and TiO_2 = 5.96% (XRF) suggesting low⍰to⍰moderate potential.
- Mg⍰calcite: limited commercial value (<10%) — can be used as filler or soil amendment.

Overall: material is more suitable as industrial mineral feedstock (ceramics, filler, construction) or possibly as a low⍰grade bauxite/ilmenite deposit after beneficiation rather than as a primary metallurgical ore without processing.

Final Results (concise)

- XRD major phases (wt%): Kaolinite 46.20, Gibbsite 8.65, Mg⍰Calcite 8.15, Ilmenite 7.00 (sum = 70%). Amorphous = 30%.
- Bulk XRF (wt%): see Table in Section 2.
- Inferred amorphous composition (normalized to amorphous 100%): top components — SiO_2 ~40.7%, Al_2O_3 ~25.6%, LOI ~14.1%, TiO_2 ~7.6%.
- Interpretation: Highly weathered residual (lateritic / bauxitic) material with detrital heavy minerals (ilmenite). Follow⍰up recommended as above.

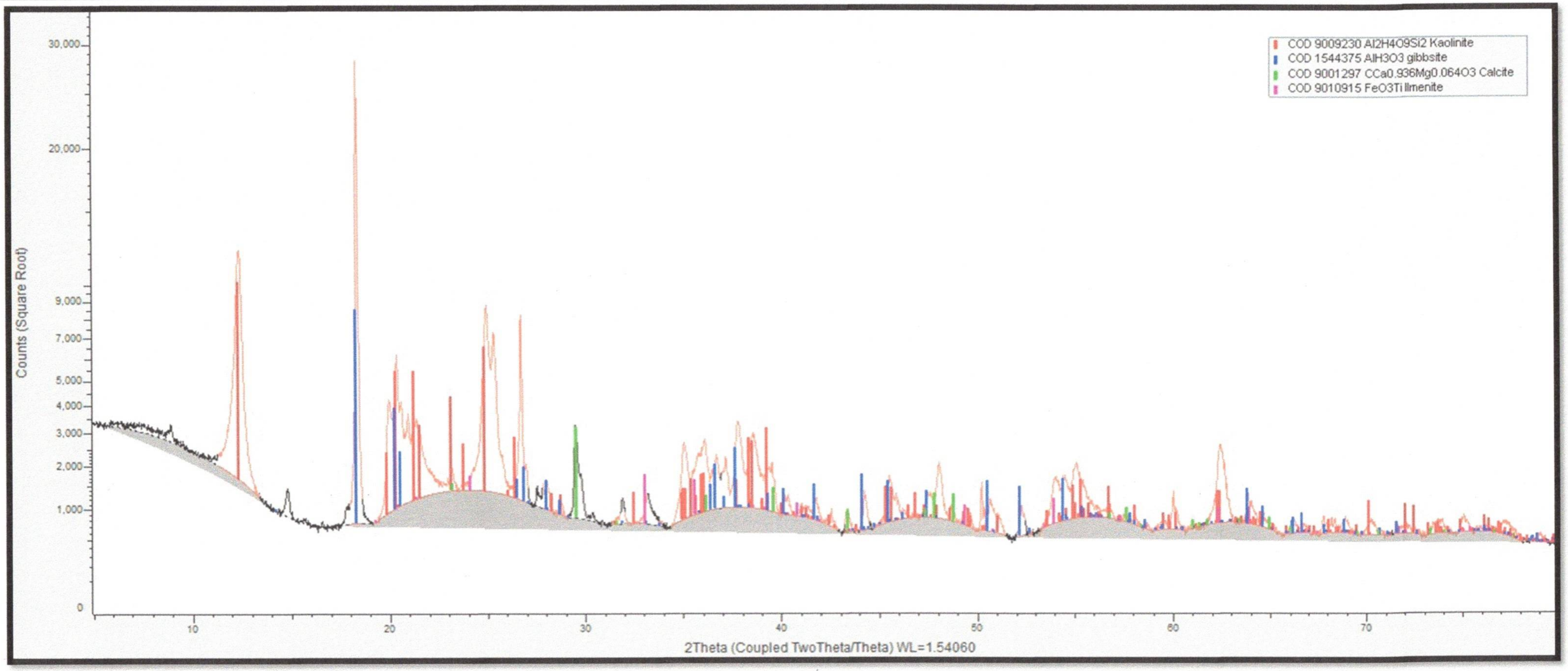
SHIVA ANALYTICALS INDIA PRIVATE LIMITED

BRUKER D8 ADVANE XRD TEST DATA

G2296-6

T23/RB/2025/01

XRD Scan Report_1 of 2



Prepared by: Nagaraj Singh

Verified by: Satyanarayana

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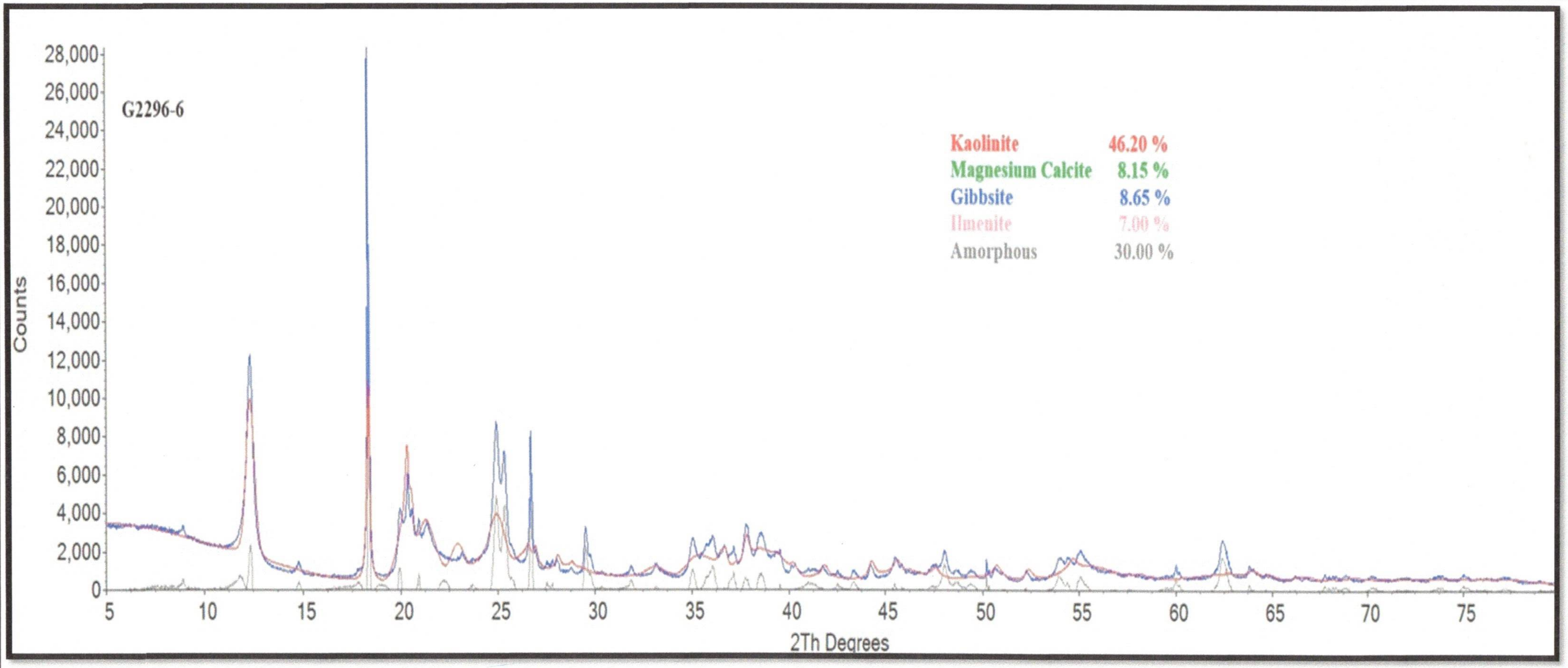

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