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Department of Health

QUANTITATIVE X-RAY DIFFRACTION AND CHEMICAL ANALYSIS OF TSP AND PM_{10} FILTERS COLLECTED FROM HUMMOCK HILL, WALLS STREET AND CIVIC PARK, WHYALLA

GRAHAM OHMSEN
ENVIRONMENTAL HEALTH SERVICE
SOUTH AUSTRALIAN DEPARTMENT OF HEALTH

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EXECUTIVE SUMMARY

Quantitative X-ray diffraction was used to characterise and quantify the mineralogy of the total suspended particulate (TSP) and particulates <10 microns (PM_{10}) filters collected from Hummock Hill representing 13 days of highest filter loading during 2003, all of which exceeded the NEPM 24-hour PM_{10} concentration of 50µg/m^3. These consisted of 12 TSP and 13 PM_{10} filters. The 24-hour average dust concentration (µg/m^3) under Onesteel sector wind conditions ranged between 174-1344µg/m^3 for TSP and 72-440µg/m^3 for PM_{10}. In comparison, filters representing "background" non-Onesteel sector wind conditions contained dust concentrations of 30-40µg/m^3 (TSP) and 16-21µg/m^3 (PM_{10}).

The mineralogy of the filters collected under winds from the Onesteel sector (350-100°) were dominated by hematite (Fe_2O_3), which constituted 48-69% of TSP and 42-66% of PM_{10} dusts, and goethite (FeO_2H) which constituted 2-18% of TSP and 0-19% of PM_{10} dusts. In comparison, filters collected on 3 days when winds did not have a major Onesteel direction component (background) were dominated by background minerals quartz (SiO_2), sea salt ($NaCl$) and kaolin (clay). Hematite and goethite were minor components or absent from the background filters.

The identification of hematite and goethite as the main components in TSP and PM_{10} filters and pellet plant dusts, and their absence from "background" samples strongly indicated that fugitive emissions emanating from the pellet plant were the source of airborne Fe dusts responsible for ongoing environmental contamination.

INTRODUCTION

Characterisation of fugitive dust emissions emanating from the Onesteel pellet plant was undertaken using quantitative X-ray diffraction (XRD) and multi element chemical analysis to identify and quantify the mineralogy and composition of total suspended particulate (TSP) and material less than 10 microns (PM_{10}) collected over the period from 12/1 to 17/11/2003 using high volume air samplers. Quantitative XRD analysis was undertaken on 37 high volume TSP and PM_{10} filters collected from Hummock Hill, Walls Street and Civic Park. The majority of the filters (25) were chosen to represent days with wind direction predominantly from the Onesteel sector (350-100°). The wind conditions and data for these filters are shown in Table 1.

The most heavily loaded filters for 2003 from Hummock Hill were selected for analysis. All exceeded the NEPM 24-hour PM_{10} concentration of 50µg/m^3. These consisted of 12 TSP and 13 PM_{10} filters. The maximum 24-hour average dust concentration (µg/m^3) under Onesteel sector wind conditions was 1343.8µg/m^3 for TSP (range: 174.4-1343.8µg/m^3) and 400.4µg/m^3 for PM_{10} (range: 71.8-400.4µg/m^3).

Two PM_{10} filters from Walls Street were also supplied from Onesteel to provide comparison with filters from Hummock Hill. These filters (18/10/03, 27/10/03) had total dust concentrations of 63.2 and 55.5µg/m^3 respectively. Background filters (TSP, PM_{10}) representing non-Onesteel wind sector conditions were selected by EPA staff based on appropriate meteorological conditions (Figure 1). The background samples from Hummock Hill represented conditions dominated by background and marine influences whilst the samples from Civic Park were intended to represent a distant receptor outside the influence of the pellet plant fall-out. The maximum 24-hour average concentration of dust on non-Onesteel days was 40.4µg/m^3 for TSP (range: 29.7-40.4µg/m^3) and 20.9µg/m^3 for PM_{10} (range: 15.5-20.9µg/m^3). The background filters from Civic Park had maximum concentrations 135.4µg/m^3 for TSP and 60.2µg/m^3 for PM_{10}.

This report is intended to complement the report detailing characterisation and apportionment of air-fall dusts collected from Hummock Hill, Walls Street and the Croquet Club over the period of December 2003 to March 2004.

METHODS

The quantitative XRD analyses of TSP and PM_{10} filters representing Onesteel wind sector (350-100°) and non-Onesteel wind sector (100-350°) were performed at CSIRO Division of Soil and Water located at Urrbrae, Adelaide. The methodology used for QXRD analysis is detailed in the companion report on air-fall and pellet plant dust characterisation (October 2004). The QXRD analysis of TSP and PM_{10} filters was influenced by the amount of dust loading on the filters.

The multi-element chemical analyses of TSP and PM_{10} filters were undertaken by AGAL (Australian Government Analytical Laboratories) in Sydney to provide information on the concentrations of Fe, Al, Ca, Mg, Mn, Na, K, P, S and Ti associated with airborne dusts. Silicon (Si) was excluded from the analysis due to the filters being made of glass fibre. Blank filters were also analysed to allow blank subtraction and determination of elemental concentrations. The filters were digested in HCl, with the analysis obtained using atomic absorption spectroscopy (AAS).

RESULTS

A: ONESTEEL WIND CONDITIONS (350-100°)

The quantitative XRD analysis of TSP and PM_{10} filters from Hummock Hill and Walls Street resulted in the identification of 13 minerals (Table 2). These were hematite, goethite, quartz, kaolin, halite, magnetite, calcite, dolomite, albite, gypsum, augite, talc and mica. The mineralogy of TSP and PM_{10} filters from Hummock Hill were dominated by the Fe-bearing minerals hematite (Fe_2O_3), goethite (FeO_2H) and magnetite (Fe_3O_4). Calcite ($CaCO_3$), and dolomite ($CaMg(CO_3)_2$), fluxing agents added in the pelletising process prior to induration, were also identified as minor components.

Minerals identified on the filters derived from the background were kaolin (Al-clay), quartz (SiO_2) and gypsum ($CaSO_4.2H_2O$). The other widely identified mineral was halite (1-10%), which represented contribution from sea spray. Calcite is also widespread as a background mineral, indicating that its presence on the filters cannot be apportioned solely to fugitive material from the pellet plant. Compositions of the minerals identified by XRD are given in Appendix A-1. The XRD patterns for the filters are presented in Appendix A-2.

TSP, PM_{10} Air Filters (Hummock Hill)

The results from the XRD analysis showed the mineralogy of TSP and PM_{10} filters were dominated by hematite, goethite and kaolin. The main findings from the analysis were;

i). TSP filters (12 filters)

- Hematite was identified as the major phase in all filters, constituting 48-69% of mineralogy
- Goethite was identified on all filters, where it constituted 2-18%
- Magnetite was identified on 8/12 filters, where it constituted 1-12%
- Background minerals quartz (0-6%), calcite (0-11%), gypsum (0-4%) were minor constituents
- Dolomite was identified on 7 filters, where it constituted 1-6% of the mineralogy
- halite (sea salt) was identified on all filters as a minor component, constituting 1-3%

ii). PM_{10} filters (13 filters)

The results for the PM_{10} filters showed increased contribution of calcite, kaolin and halite compared to the corresponding TSP filters. The main findings were;

- Hematite (Fe_2O_3) was identified as the major phase on all filters, constituting 42-66% of mineralogy
- Goethite (FeO_2H) was identified on 12/13 filters, where it constituted 4-19%
- Calcite ($CaCO_3$) was identified on 5/13 filters, where it constituted 12-21%
- Kaolin ($Al_4Si_4O_{10}(OH)_8$) was identified on 12/13 filters, where it constituted 8-26%
- Halite (NaCl) was identified on 12/13 filters, where it constituted 1-10%

B: COMPARISON of WALLS ST. and HUMMOCK HILL PM_{10} FILTERS

The results of the QXRD analysis of PM_{10} filters from Hummock Hill and Walls Street showed the filters from Walls Street contained less hematite, goethite and magnetite, and increased amounts of halite, quartz and calcite. The concentration of dust was also found to be appreciably less at Walls Street compared to Hummock Hill. For the filter collected on 18/10, the dust concentration at Walls Street was 63.2µg/m^3, compared to 200.8µg/m^3 at Hummock Hill (ratio of 1:3), whilst for the filter collected on 27/10, the concentrations were 55.5µg/m^3 compared to 136.6µg/m^3 (ratio of 1:2.5).

The main differences in mineralogy between the Hummock Hill and Walls Street filters were:

- Hematite constituted 28% and 51% in the Walls Street filters for 18/10 and 27/10 respectively compared to 50% and 54% at Hummock Hill

- Goethite constituted 0% and 9% at Walls Street for 18/10 and 27/10 respectively compared to 8% and 16% at Hummock Hill
- Halite constituted 24% and 15% at Walls Street for 18/10 and 27/10 respectively compared to 5% and 7% at Hummock Hill
- Calcite constituted 30% and absent at Walls St. (18/10 and 27/10) compared to 14% and absent at Hummock Hill
- Quartz constituted 19% and 4% at Walls St for 18/10 and 27/10 compared to 4% and 1% at Hummock Hill
- Magnetite and dolomite were absent from both filters at Walls Street, but constituted 0% and 3% (magnetite) and 5% and 3% (dolomite) for 18/10 and 27/10 at Hummock Hill

The decreased percentages of Fe minerals (Fe_2O_3, FeO_2H) in the Walls Street filters may be the result of many factors, including the distance between Walls Street and pellet plant compared to the sampling site at Hummock Hill and prevailing meteorological conditions. Examination of the prevailing wind conditions for the sampling days (Table 1) revealed that wind strength was appreciably greater on 18/10 (max: 18.9m/s) compared to 27/10 (max: 8.9m/s). The stronger winds recorded for 18/10 may have mobilised a greater background dust and sea spray, as evidenced by the greater proportion of quartz, halite and calcite identified on the filters. The variability of emissions from the pellet plant site may also account for the difference in Fe_2O_3 identified on the filters. Other factors which may also have influenced the Fe content and mineralogy of the dusts include the topography and factors in the immediate environment of the sampling point, such as traffic movement.

C: BACKGROUND (Non-Onesteel Wind Sector Days)

In comparison to the TSP and PM_{10} filters collected under winds from the Onesteel sector, the background (non-Onesteel) filters showed marked differences in mineralogy, their relative percentages and overall composition. The background filters showed significant decreases in the percentages of hematite, goethite and magnetite, whilst the contribution from background minerals quartz, calcite, kaolin and sea salt (halite) were substantially increased.

The dust concentration on the non-Onesteel days was noticeably lower than for Onesteel days. The particulate concentrations at Hummock Hill ranged between 10.4-35.0µg/m^3 for TSP and between 15.5-20.9µg/m^3 for PM_{10} under predominantly sea winds. At Civic Park, the recorded dust concentrations were somewhat higher than for the Hummock Hill filters, with concentrations of 71.9-135.4µg/m^3 for TSP and 42.3-60.2µg/m^3 for PM_{10}.

i). Hummock Hill

The mineralogy of the "background" TSP and PM_{10} filters exhibited noticeable differences compared to those collected on Onesteel wind days. The main differences were;

- The mineralogy of the background filters was simpler than identified for Onesteel wind sector days, with only 4 minerals (quartz, halite, hematite, calcite)
- Hematite content was much lower and identified in only 2 filters collected on 8/11 and 11/11/03 (48% and 29% respectively)
- PM_{10} filters dominated by halite (sea salt), which constituted 100% of the mineralogy of all 3 filters
- Halite also constituted 100% of the TSP filter collected on 26/2/03
- Goethite, magnetite and kaolin (clay) were absent from all filters

ii). Civic Park (27/08/02, 12/01/03)

In comparison with Hummock Hill, the TSP and PM_{10} filters from Civic Park reflected mineralogy dominated by crustal components. The main features of the TSP/PM_{10} filters from Civic Park were;

- Hematite, goethite and magnetite were absent from all filters
- Mineralogy was dominated by kaolin (41-67%), quartz (15-22%) and mica (20-29%)
- The halite content (2-8%) much less than background filters from Hummock Hill and Walls Street, reflecting greater distance from the ocean
- The filters from 27/08/02 were the only samples to contain mica (20% and 29%)

D: MULTI ELEMENT CHEMISTRY: TSP and PM_{10} FILTERS

i). TSP Filters

The chemical analyses TSP filters from Hummock Hill collected under winds from the Onesteel sector (Table 3) revealed the Fe loading on the filters ranged between 43,575-221,870µg/filter (blank corrected). The maximum loading occurred on 12/1/2003 under light to moderate wind strength. The results for TSP filters showed Fe constituted 72.89-392.03µg/m^3 of the total measured dust in air, accounting for ~25-51% (ave. 34%) of the total TSP.

Other major elements identified on the filters were Ca and Na, at loadings of 3,762-46,832µg/filter and 2,780-19,160µg/filter respectively. Aluminium and Mg were minor constituents identified on the filters at loadings of 2,740-14,205µg/filter and 1,908-9,647µg/filter respectively. Manganese was also present on the filters at loadings of 764-6,984µg/filter. The presence of Ca, Mg, Al and Na were reflected in the presence of calcite, dolomite, kaolin and halite as minor components of the mineralogy.

ii). PM_{10} Filters

The results for the PM_{10} filters showed the total Fe loadings on the filters ranged between 16,275-107,876µg/filter (blank corrected), with the greatest Fe loading recorded on 12/1/03. The contribution of Fe to the overall dust concentration was 31.27-205.26µg/m^3 Fe, which accounted for 34-59% (ave. 49%) of the measured particulate concentration. Apart from Fe, Ca (1,334-15,100µg/filter) and Na (1,330-17,394µg/filter) were the main elements identified in the PM_{10} filters, with lesser but appreciable amounts of Al (1,380-4,630µg/filter) and Mg (1,005-3,300µg/filter) also present. Manganese was present on the PM_{10} filters at loadings of 284-2,532µg/filter

iii). Background Filters: Chemistry

The Fe loadings on non-Onesteel wind sector TSP and PM_{10} filters were appreciably lower than observed for filters collected from Onesteel sector wind days. At Hummock Hill, the Fe loadings ranged between 649-1,515µg/filter for TSP and 198-222µg/filter for PM_{10}. The main differences between the two wind regimes were markedly decreased Fe loadings and corresponding increased Na loadings. One PM_{10} filter (AB874) had only Fe, Mn and Na above detection limits. The differences in composition were manifested in the relative percentages of hematite (Fe_2O_3) and halite (NaCl) identified by XRD on the filters.

Both TSP and PM_{10} filters collected from Civic Park contained more Fe than the filters from Hummock Hill. The Fe loadings on the TSP filters were 3,555-4,035µg/filter, whilst the Fe loadings for PM_{10} filters were 1,913-2,548µg/filter. The lower Fe loadings corresponded with significantly lower Fe in dust concentrations. At Hummock Hill, the Fe concentrations were 1.38-2.57µg/m^3 for TSP and 0.42-1.06/m^3 for PM_{10} filters, which accounted for 4.6-7.2% of TSP and 2.2-6.8% of PM_{10}. The results for Civic Park were slightly higher, with Fe concentrations of 5.60-6.45µg/m^3 for TSP and 3.74-5.02µg/m^3 for PM_{10} fractions. This accounted for 4.8-7.8% of TSP and 6.2-11.9% of PM_{10} of the total dust concentration of these filters.

The ratio Fe/Ti can be used to allow an assessment of the relative contribution of Fe to the environment. The Fe/Ti for TSP filters ranged between 348-1138 whilst the Fe/Ti ranged between 313-1189 for PM_{10} filters. In comparison, the Fe/Ti of background filters were lower. For non-Onesteel sector winds At Hummock Hill, the Fe/Ti ranged between 130-154 for TSP and 54-99 for PM_{10} filters, whilst for Civic Park, the Fe/Ti ranged between 142-269 for TSP and 102-147 for PM_{10} filters. The Fe/Ti for PM_{10} filters from Walls Street were 195 (18/10) and 613 (27/10), reflecting the greater Fe_2O_3 content of the latter sample.

E: PELLET PLANT SOURCE DUSTS

In order to develop a clearer understanding of the mineralogy of TSP and PM_{10} filters, dusts from 10 locations within and around the pellet plant were also analysed using quantitative XRD. The pellet plant samples were collected from the screening plants, reclaims shed, pre and post-fluxing, post drying, pre and post-grinding, and post induration areas. The results are detailed in the accompanying report (Characterisation and Source Apportionment of Air-Fall Dusts-July 2004).

The pellet plant dusts were dominated by hematite, which constituted 52-89% of the identified mineralogy. Dusts from the pre-induration processes also contained appreciable amounts of goethite (6-18%) and kaolin (6-19%). The dusts from the post-induration areas contained less goethite and greater percent of hematite. Magnetite was restricted to post-induration dusts. The main feature of the pellet plant dusts was the variation in particle size between operations. Of the areas sampled and analysed, the pre-drying, post-drying and post-grinding areas contained the greatest amount of material <10µm in size. Approximately 30% and 20% of dusts from the post-grinding and "black hole" areas were found to be <5µm in size. The number of source areas with dusts containing material <10µm in size indicated that a number of operations within the pellet plant may have been sources of such material.

Discussion

The identification of hematite as the major component of mineralogy on TSP and PM_{10} filters collected under winds from the Onesteel sector (350-100°) indicated that appreciable amounts of fugitive hematite were mobilised from the pellet plant under the prevailing meteorological conditions. The findings were confirmed by the chemical analyses which showed filters collected winds from the Onesteel sector contained much higher concentrations and total percentages of Fe compared to filters collected on background days.

A number of factors and source areas not considered in this investigation may also have influenced the observed mineralogy and chemistry of the filters. One of the main factors was the effect of distance between the pellet plant and receptor. This appeared to be a major influence on the mineralogy and Fe loadings recorded Walls Street and Civic Park. Other source areas around the pellet plant which may have contributed to the fugitive dusts include roadways, horizontal surfaces, stockpiles, railway transportation and unloading, conveyors and handling facilities.

The announcement by Onesteel to spend $10 million to relocate the primary crushing and screening operations to the mine site (April 2004) should result in decreased dust emissions. Goethite was also identified as a lesser, though appreciable component of dusts from the screening plants and reclaims shed. When completed, this change should result in appreciable decreases in the amount of fugitive hematite and goethite in both TSP and PM_{10} size fractions associated with these operations.

Main Findings

The main findings from the QXRD and multi-element analysis of TSP and PM_{10} filters collected under winds from the Onesteel (350-100°) were:

- Mineralogy of TSP and PM_{10} filters under Onesteel wind conditions were dominated by hematite (42-69%), with lesser but appreciable amounts of goethite (4-19%)
- Dust concentrations ranged between 174.4-1343.8µg/m^3 (TSP) and 71.8-400.4µg/m^3 (PM_{10})
- Fe loadings ranged between 25,575-221,870µg/filter (TSP) and 16,275-107,876µg/filter (PM_{10}) on Onesteel wind days
- Background minerals quartz (1-7%) and halite (1-10%) constituted minor/trace component of mineralogy on Onesteel wind days
- The small number (3) of sampling days of non-Onesteel direction conditions were dominated by sea breezes

In comparison, the main findings from the analysis of filters collected under winds from the non-Onesteel sector (100-350°) were:

- Total dust concentrations were much lower, ranging between 29.7-135.4µg/m^3 (TSP) and 15.5-60.2µg/m^3 (PM_{10})
- Fe loadings at Hummock Hill and Civic Park were much lower on non-Onesteel wind days, ranging between 198-1,515µg/filter and 1,913-4,035µg/filter at each location respectively
- Sodium (Na) was the dominant element identified on the filters
- Mineralogy dominated by background minerals quartz (4-22%), kaolin (21-67%) and halite (2-100%)
- Hematite was absent from 8/10 filters and goethite from all filters

Assessment of the dusts from around the pellet plant identified three main areas as potential sources of Fe_2O_3 dust <10µm in size; these were post-drying, black hole and post-grinding areas. The dusts from these areas of the pellet plant also contained appreciable precent of particles <5µm in size. TSP dusts were associated mainly with unloading, screening and crushing operations, although these areas also contained lesser percentages of PM_{10} sized dusts.

Acknowledgements

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APPENDIX A-1. XRD and OPTICAL MINERALOGY/CHEMISTRY

The quantitative XRD analysis of TSP and PM_{10} high volume filters and pellet plant dusts 13 minerals. The chemistry (ideal) of these phases is listed below.

Phase	**Chemistry (ideal)**
Hematite	Fe_2O_3
Goethite	FeO_2H
Quartz	SiO_2
Kaolin (clay)	$Al_4Si_4O_{10}(OH)_8$
Halite	NaCl
Magnetite	Fe_3O_4
Calcite	$CaCO_3$
Dolomite	$CaMg(CO_3)_2$
Gypsum	$CaSO_4.2H_2O$
Augite	$Ca(Fe,Mg)Si_2O_6$
Albite	$NaAlSi_3O_8$
Mica	$KAl_2(Al,Si_3O_{10})(OH)_2$
Talc	$Mg_3Si_4O_{10}(OH)_2$

APPENDIX A-2. X-RAY DIFFRACTION PATTERNS

A) Hummock Hill: Onesteel wind sector (350-100°)

TSP Filters	Coll. Date	PM10 Filters	Coll. Date
AA1872	12/1/03	AA 1879	12/1/03
AA1895	24/1/03	AA 1881	24/1/03
AB 154	9/5/03	AB 160	9/5/03
AB 146	8/6/03	AB 330	8/6/03
AB 258	26/6/03	AB 268	26/6/03
AB 360	11/7/03	AB 473	11/7/03
AB 9	4/8/03	AB 449	4/8/03
AB 21	10/8/03	AB 452	10/8/03
		AB 572	22/8/03
AB 646	30/9/03	AB 582	30/9/03
AB 639	18/10/03	AB 840	18/10/03
AB 844	27/10/03	AB 843	27/10/03
AB 870	17/11/03	AB 876	17/11/03

B) Background: Hummock Hill non-Onesteel wind sector (100-350°)

TSP Filters		PM_{10} Filters	
AA 2190	26/2/03	AA 2219	26/2/03
AB 867	8/11/03	AB 873	8/11/03
AB 868	11/11/03	AB 874	11/11/03

C) Civic Park

TSP Filters		PM_{10} Filters	
AA 1016	27/8/02	AA 1022	27/8/02
AA 1876	12/1/03	AA 1864	12/1/03

D) Walls Street

PM_{10} Filters
18/10/03
27/10/03

FIGURE 1. WIND ROSES FOR "NON-ONESTEEL" WIND SECTOR SAMPLE DAYS

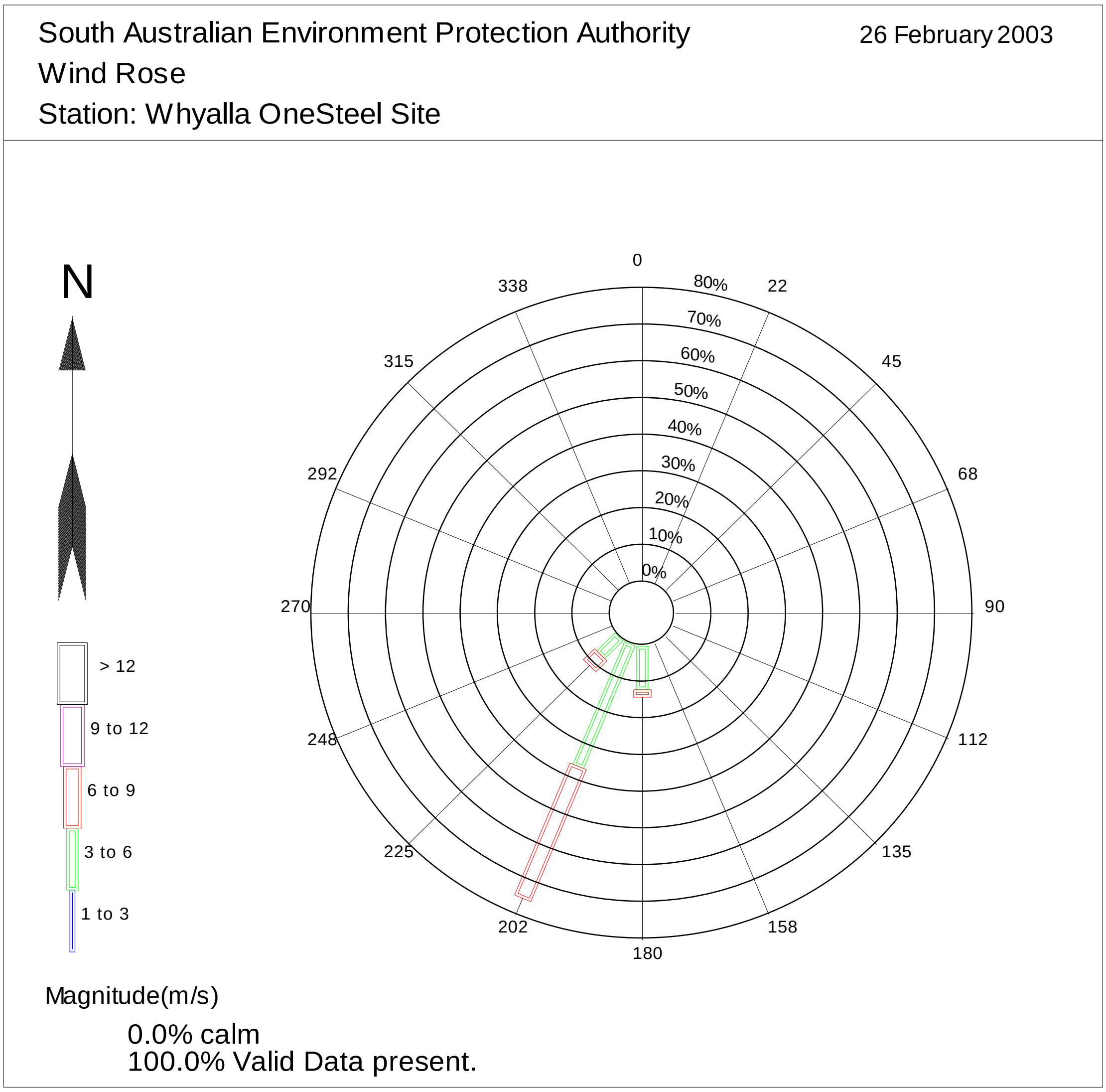


FIGURE 1 (cont.)

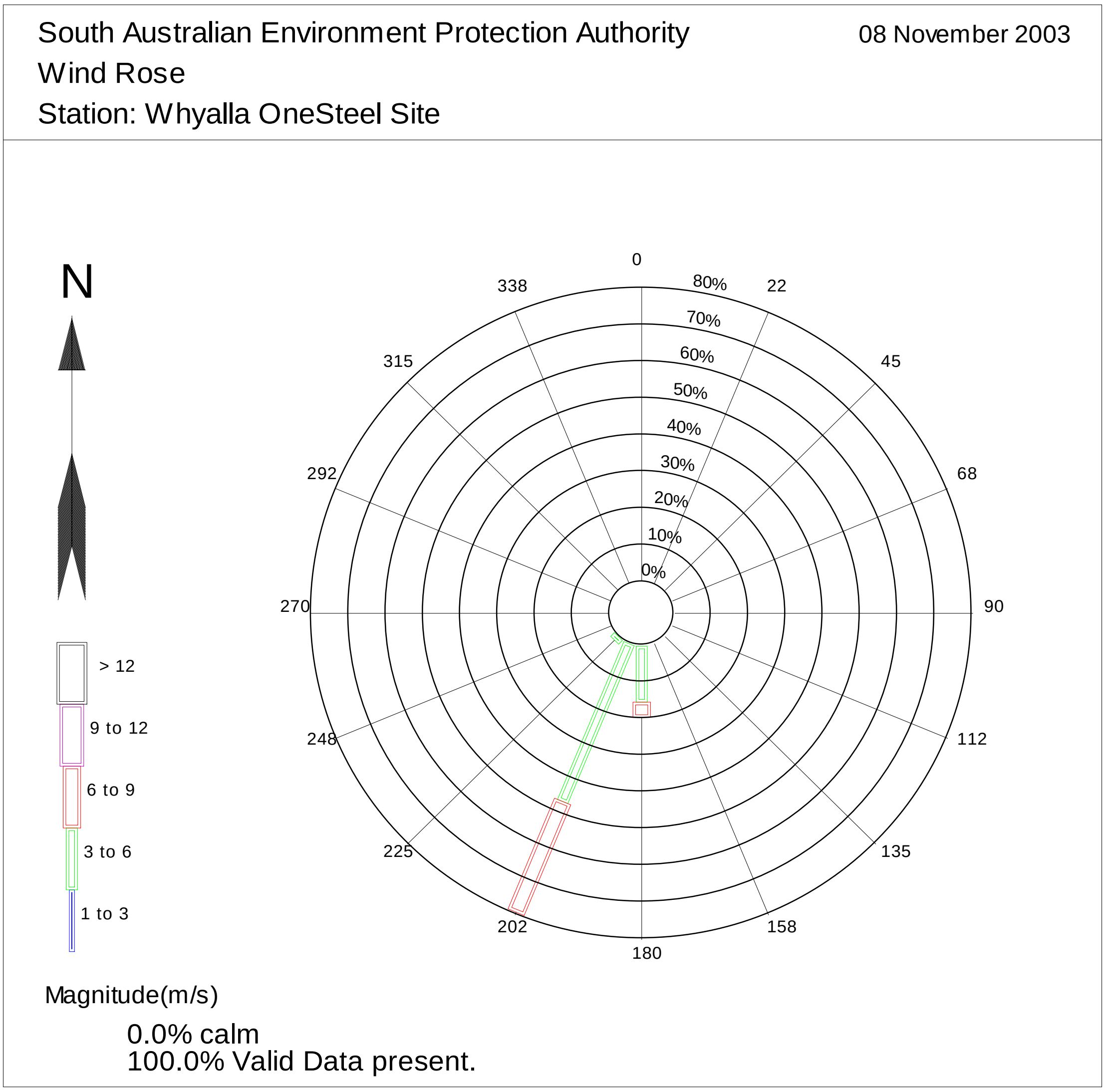


FIGURE 1 (cont.)

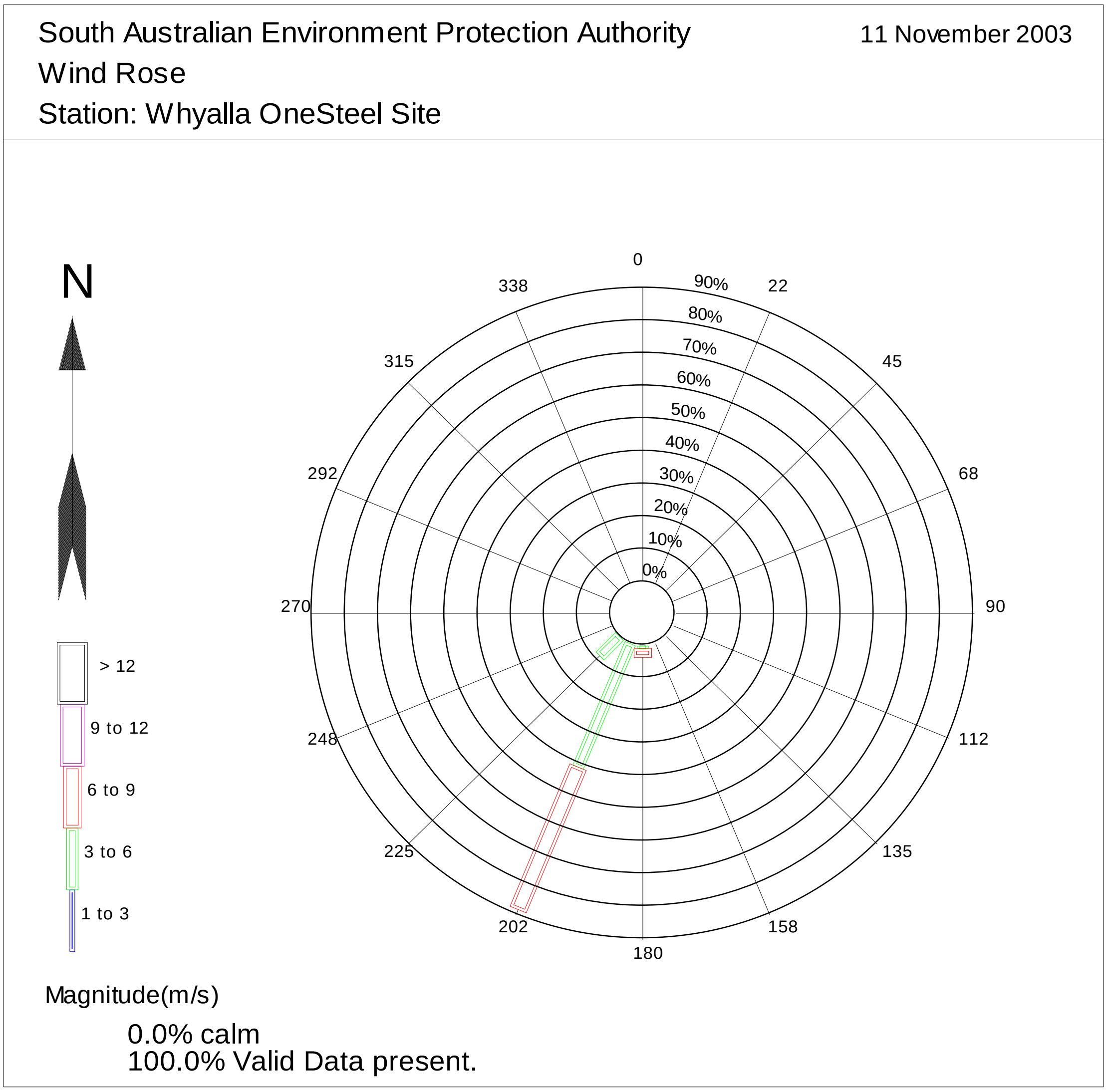


TABLE 1. MASS AND CONCENTRATION DATA FOR XRD FILTERS, HUMMOCK HILL, WALLS STREET AND CIVIC PARK, WHYALLA

TSP DATA: HUMMOCK HILL and CIVIC PARK

Filter No.	Site	Date	TSP µg/m3	Fe loading µg/filter	Fe µg/m3
AA1872	Hummock Hill	12/01/2003	1343.8	221870	392.03
AA1895	Hummock Hill	24/01/2003	214.9	49670	85.07
AB154	Hummock Hill	9/05/2003	174.4	43575	72.89
AB146	Hummock Hill	8/06/2003	276.6	84775	141.79
AB 258	Hummock Hill	26/06/2003	437.1	77972	126.37
AB360	Hummock Hill	11/07/2003	381.9	61190	96.78
AB9	Hummock Hill	4/08/2003	269.1	48575	81.34
AB21	Hummock Hill	10/08/2003	257.1	62374	99.52
AB646	Hummock Hill	30/09/2003	796.4	170882	283.51
AB639	Hummock Hill	18/10/2003	451.7	86376	144.57
AB844	Hummock Hill	27/10/2003	329.2	85785	143.91
AB870	Hummock Hill	17/11/2003	623.1	134875	224.83
AA1016	Civic Park	27/08/2002	135.4	2472	6.45
AA1876	Civic Park	12/01/2003	71.9	3072	5.60
AA2190	Hummock Hill	26/02/2003	29.7	649	1.38
AB867	Hummock Hill	8/11/2003	35.0	1515	2.52
AB868	Hummock Hill	11/11/2003	40.4	1170	2.57

PM10 DATA: HUMMOCK HILL and CIVIC PARK

Filter No.	Site	Date	PM10 µg/m3	Fe loading µg/filter	Fe µg/m3
AA1879	Hummock Hill	12/01/2003	400.4	107876	205.26
AA1881	Hummock Hill	24/01/2003	92.6	25575	48.76
AB160	Hummock Hill	9/05/2003	85.9	16275	31.27
AB330	Hummock Hill	8/06/2003	82.2	25676	48.00
AB268	Hummock Hill	26/06/2003	127.7	23270	44.06
AB473	Hummock Hill	11/07/2003	131.5	29572	56.55
AB449	Hummock Hill	4/08/2003	121.5	32575	63.07
AB452	Hummock Hill	10/08/2003	89.6	23278	45.12
AB572	Hummock Hill	22/08/2003	71.8	25117	43.75
AB582	Hummock Hill	30/09/2003	206.8	66575	122.87
AB840	Hummock Hill	18/10/2003	200.8	39676	75.05
AB843	Hummock Hill	27/10/2003	136.6	41885	78.83
AB876	Hummock Hill	17/11/2003	235.6	53970	120.56
AA1022	Civic Park	27/08/2002	60.2	1913	3.74
AA1864	Civic Park	12/01/2003	42.3	2548	5.02
AA2219	Hummock Hill	26/02/2003	18.1	198	0.42
AB873	Hummock Hill	8/11/2003	15.5	217	1.06
AB874	Hummock Hill	11/11/2003	20.9	222	0.44

TABLE 2. QUANTITATIVE MINERALOGY: TSP/PM10 FILTERS FROM HUMMOCK HILL, WALLS STREET AND CIVIC PARK

	Date	µg/m3	Filter	Location	Hematite	Goethite	Quartz	Kaolin	Halite	Albite	Magnetite	Calcite	Dolomite	Gypsum	Talc	Augite	Mica
AA1872	**12/01/2003**	**1343.8**	**TSP**	**Hummock Hill**	59	15	2	18	<1	1	<1	<1	<1	-	1	2	-
AA1879	**12/01/2003**	**440.4**	**PM10**		51	16	2	26	1	1	<1	-	-	-	2	-	-
AA1895	**24/01/2003**	**214.9**	**TSP**		65	9	2	10	3	-	8	2	-	-	-	-	-
AA1881	**24/01/2003**	**93.6**	**PM10**		59	11	5	19	6	-	-	-	-	-	-	-	-
AB154	**9/05/2003**	**174.4**	**TSP**		48	16	2	21	1	-	-	10	2	1	-	-	-
AB160	**9/05/2003**	**85.9**	**PM10**		42	18	6	22	-	-	-	12	-	-	-	-	-
AB146	**8/06/2003**	**276.6**	**TSP**		55	2	-	-	3	8	12	-	-	3	-	12	-
AB330	**8/06/2003**	**82.2**	**PM10**		65	-	1	-	10	16	7	-	-	-	-	-	-
AB258	**26/06/2003**	**437.1**	**TSP**		57	10	4	9	1	-	-	12	6	-	-	-	-
AB268	**26/06/2003**	**127.7**	**PM10**		51	12	5	8	3	-	-	17	5	-	-	-	-
AB360	**11/07/2003**	**381.9**	**TSP**		60	6	6	9	2	-	<1	11	3	4	-	-	-
AB473	**11/07/2003**	**131.5**	**PM10**		47	4	7	16	5	-	-	21	-	-	-	-	-
AB9	**4/08/2003**	**269.1**	**TSP**		57	8	4	13	1	-	3	8	6	-	-	-	-
AB449	**4/08/2003**	**121.5**	**PM10**		45	5	4	22	5	-	-	13	6	-	-	-	-
AB21	**10/08/2003**	**257.1**	**TSP**		58	13	2	21	2	-	-	-	<1	3	1	-	-
AB452	**10/08/2003**	**89.6**	**PM10**		56	11	2	23	8	-	-	-	-	-	-	-	-
AB572	**22/08/2003**	**71.8**	**PM10**		59	9	5	18	10	-	-	-	-	-	-	-	-
AB646	**30/09/2003**	**769.4**	**TSP**		69	12	3	8	2	<1	1	-	1	2	-	2	-
AB582	**30/09/2003**	**206.8**	**PM10**		66	8	2	16	6	-	2	-	-	-	-	-	-
AB639	**18/10/2003**	**451.7**	**TSP**		62	10	4	10	2	-	<1	6	4	2	-	-	-
AB840	**18/10/2003**	**200.8**	**PM10**		50	8	4	14	5	-	-	14	5	-	-	-	-
AB844	**27/10/2003**	**329.2**	**TSP**		60	12	2	7	3	6	2	1	2	3	-	3	-
AB843	**27/10/2003**	**136.6**	**PM10**		54	16	1	15	7	-	3	-	3	-	-	-	-
AB870	**17/11/2003**	**623.1**	**TSP**		54	18	2	18	2	-	-	<1	<1	2	2	-	-
AB876	**17/11/2003**	**235.6**	**PM10**		46	19	4	24	4	-	-	-	-	4	-	-	-
1665	**18/10/2003**	**63.2**	**PM10**	**Walls Street**	28	-	19	-	24	-	-	30	-	-	-	-	-
1825	**27/10/2003**	**55.5**	**PM10**		51	9	4	21	15	-	-	-	-	-	-	-	-
AA1016	**27/08/2002**	**135.4**	**TSP**	**Civic Park**	<1	-	19	44	2	-	-	5	<1	8	-	-	20
AA1022	**27/08/2002**	**60.2**	**PM10**		<1	-	15	41	3	-	-	7	-	3	-	-	29
AA1876	**12/01/2003**	**71.9**	**TSP**		-	-	22	67	7	-	-	5	-	-	-	-	-
AA1864	**12/01/2003**	**42.3**	**PM10**		-	-	18	65	8	-	-	9	-	-	-	-	-
AA2190	**26/02/2003**	**29.7**	**TSP**	**Hummock Hill**	-	-	-	-	100	-	-	-	-	-	-	-	-
AA2219	**26/02/2003**	**18.1**	**PM10**		-	-	-	-	100	-	-	-	-	-	-	-	-
AB867	**8/11/2003**	**35.0**	**TSP**		48	-	9	-	32	-	-	11	-	-	-	-	-
AB873	**8/11/2003**	**15.5**	**PM10**		-	-	-	-	100	-	-	-	-	-	-	-	-
AB868	**11/11/2003**	**40.4**	**TSP**		29	-	13	-	44	-	-	14	-	-	-	-	-
AB874	**11/11/2003**	**20.9**	**PM10**		-	-	-	-	100	-	-	-	-	-	-	-	-

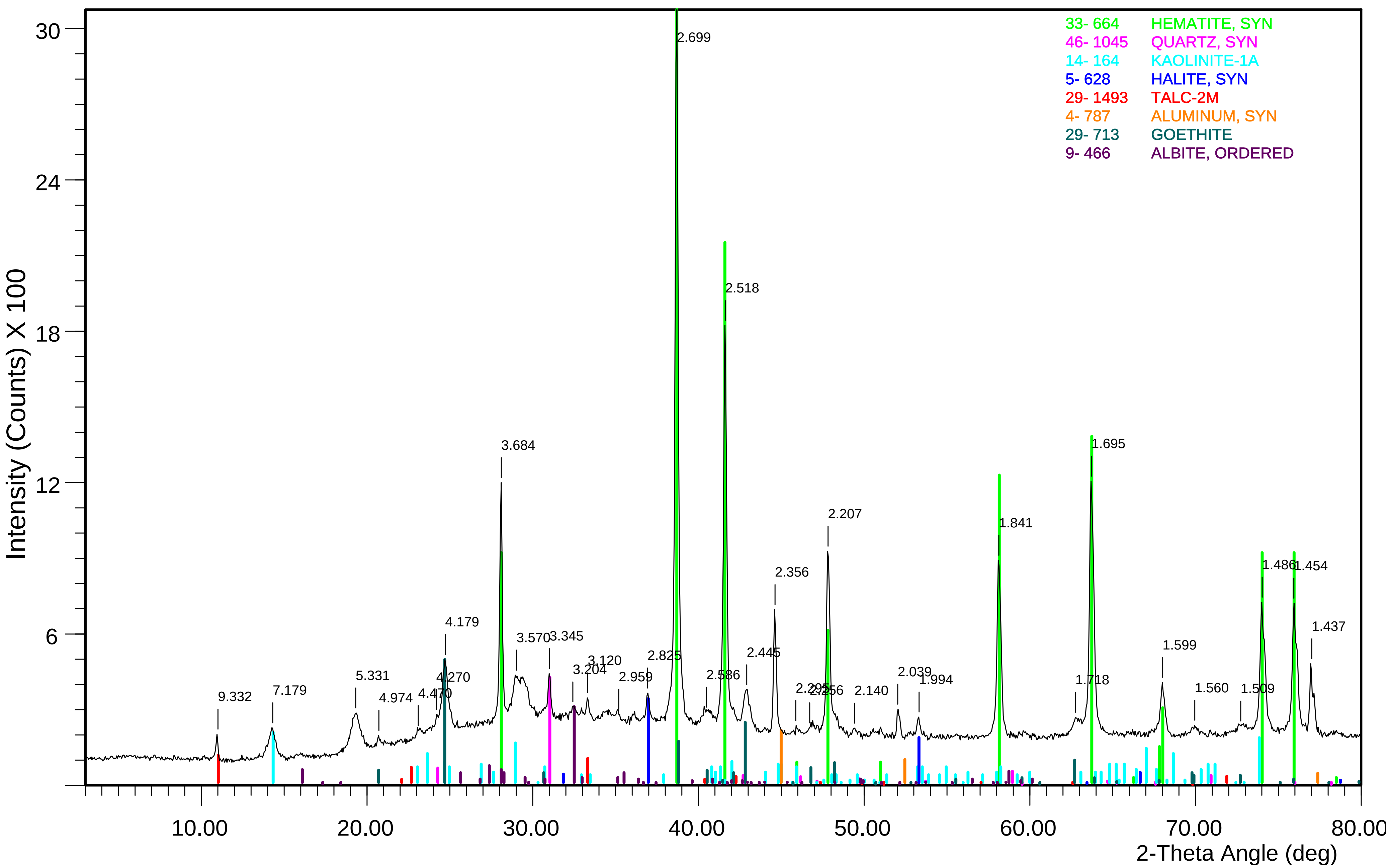
TABLE 3. MULTI ELEMENT CHEMISTRY OF TSP AND PM10 FILTERS FROM HUMMOCK HILL, WALLS STREET AND CIVIC PARK

	BLANK	AA1872	AA1879	AA1895	AA1881	AB154	AB160	AB146	AB330	AB258	AB268	AB360	AB473	AB9	AB449
	ave. (n = 3)	**TSP**	**PM10**	**TSP**	**PM10**	**TSP**	**PM10**	**TSP**	**PM10**	**TSP**	**PM10**	**TSP**	**PM10**	**TSP**	**PM10**
Al	**340**	14205	4630	3405	1939	2740	1380	3352	1665	5264	2394	5836	2575	4007	2392
Ca	**2580**	24325	6970	12865	5882	12002	7152	17380	5219	46832	14880	38970	15100	24080	11780
Fe	**32**	221870	107876	49670	25575	43575	16275	84775	25676	77972	23270	61190	29572	48575	32575
Mg	**940**	9647	2998	3858	1954	2480	1257	5102	2904	9160	2567	8745	3300	5434	2842
Mn	**1.3**	6984	2532	944	420	1232	603	764	284	2646	912	3544	1252	2164	1040
P	**9**	1348	496	224	84	196	104	204	45	528	84	44	184	324	175
K	**460**	2595	792	480	336	372	233	134	101	680	304	1308	304	496	266
Na	**13800**	11440	11455	7086	8082	13185	2740	11405	3015	19160	1330	15348	14210	2780	13505
S	**460**	6775	5352	2840	2005	1452	833	3114	840	7908	744	3660	1824	7555	4006
Ti	**1**	195	80	76	44	96	52	80	44	196	72	176	75	80	80

	AB21	AB452	AB572	AB646	AB582	AB639	AB840	AB844	AB843	AB870	AB876	1665	1825
	TSP	**PM10**	**PM10**	**TSP**	**PM10**	**TSP**	**PM10**	**TSP**	**PM10**	**TSP**	**PM10**	**PM10**	**PM10**
Al	2936	1920	2582	9550	3384	5060	2506	3485	1990	7610	2906	310	330
Ca	3762	1334	3485	18715	5720	28838	11400	13303	5419	10912	4776	1950	1640
Fe	62374	23278	25177	170882	66575	86376	39676	85785	41885	134875	53970	780	1840
Mg	1908	1005	1328	8144	2940	7870	3317	5553	2470	5265	2262	530	580
Mn	1192	443	352	3572	1128	2632	1072	1352	592	3464	1224	45	35
P	224	76	64	876	104	516	204	336	136	676	264	14	9
K	133	540	125	789	323	484	251	303	214	1080	293	210	250
Na	4276	8728	11274	14065	17394	9618	5812	8870	8560	10440	5242	7050	8800
S	12990	3500	1610	3869	1483	3464	2629	3102	1877	5573	3800	500	590
Ti	80	32	35	164	56	136	80	76	44	128	60	4	3

	AA2190	AA2219	AB867	AB873	AB868	AB874	AA1016	AA1022	AA1876	AA1864
	TSP	**PM10**	**TSP**	**PM10**	**TSP**	**PM10**	**TSP**	**PM10**	**TSP**	**PM10**
Al	493	135	428	83	325	b.dl	2311	912	2150	2076
Ca	942	b.dl	3050	1054	3429	b.dl	2472	418	3072	6550
Fe	649	198	1515	217	1170	222	4035	1913	3555	2548
Mg	917	10	266	554	661	b.dl	605	b.dl	1045	2320
Mn	22	1	32	8	32	4	88	38	92	60
P	28	b.dl	8	b.dl	24	b.dl	84	32	84	84
K	1138	339	92	291	309	b.dl	1681	458	1921	2900
Na	28515	7560	8863	11550	2872	1710	10440	8760	20840	51035
S	538	62	243	665	1309	b.dl	2760	2178	480	660
Ti	5	2	10	4	8	b.dl	15	13	25	25

AA1879



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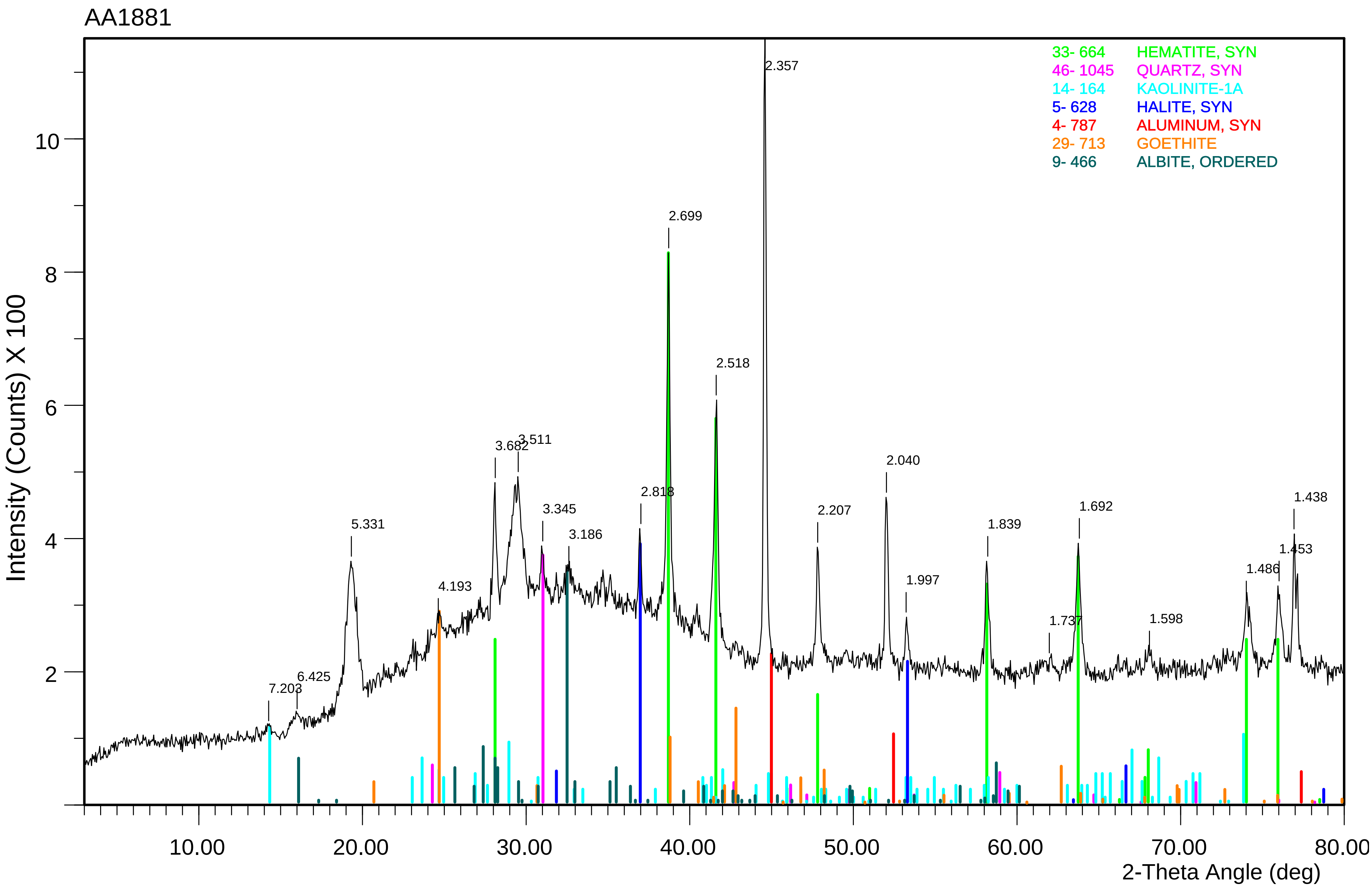
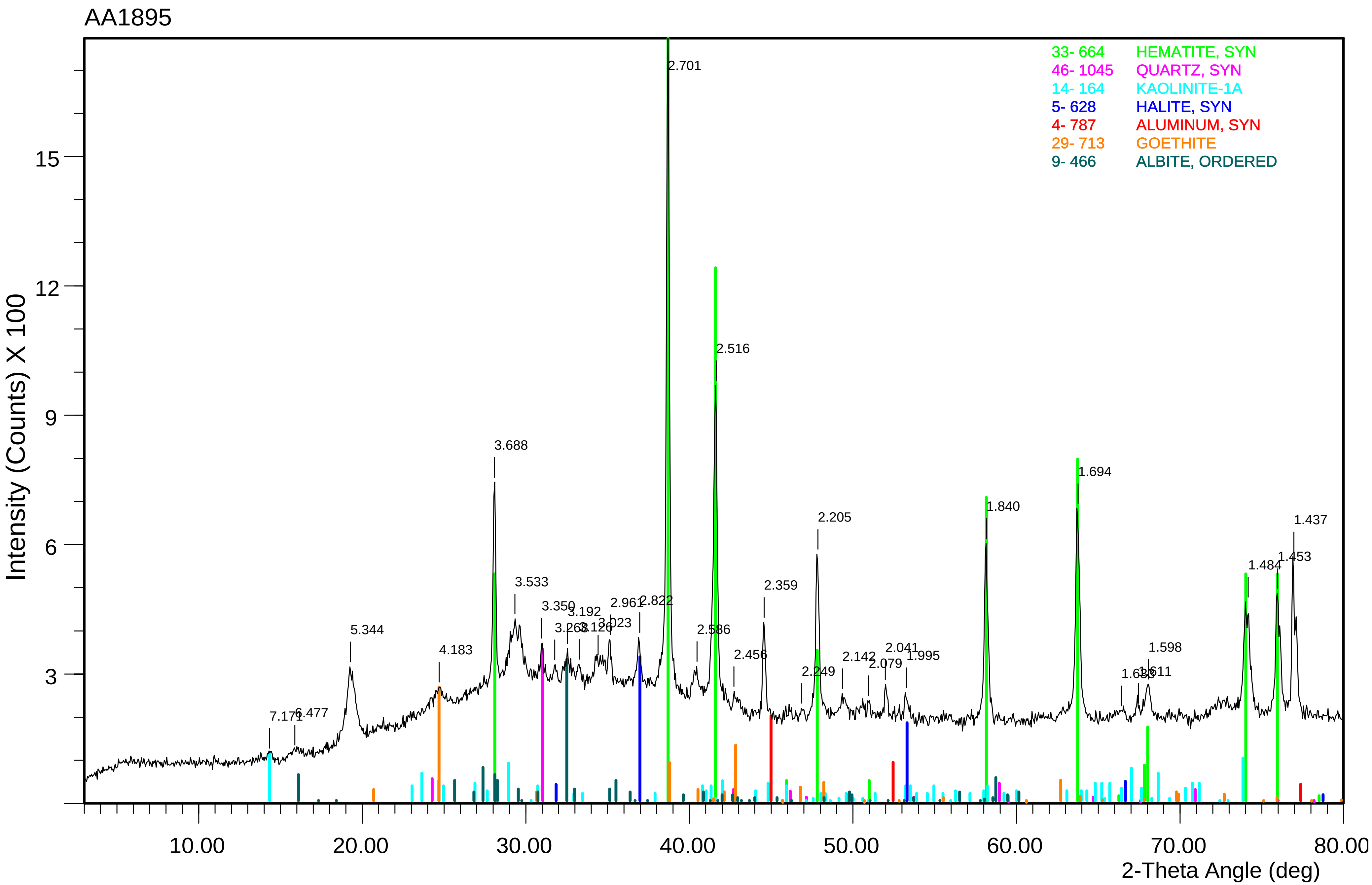
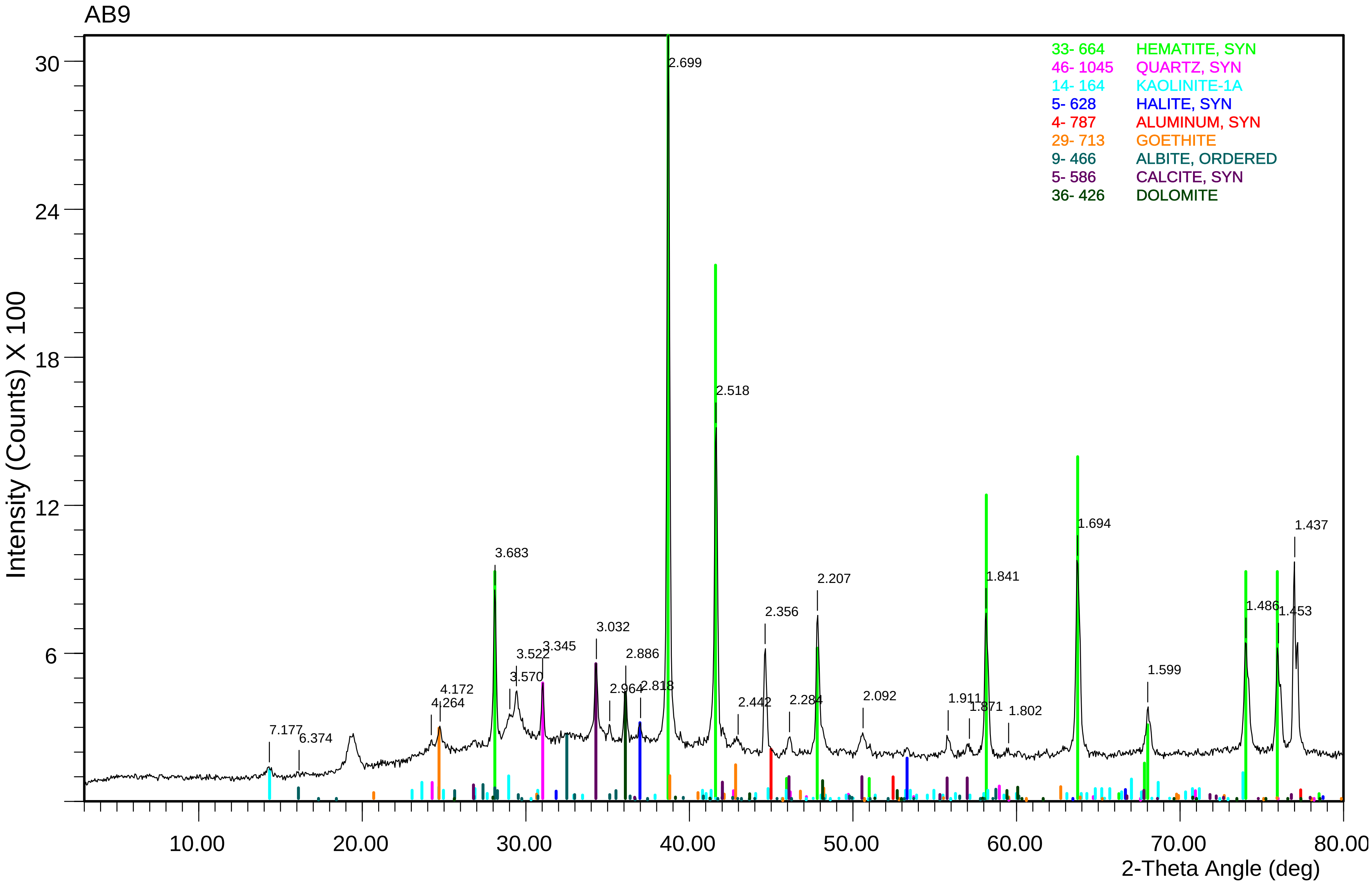


File Name: d:\xrddat~1\11971blk.102

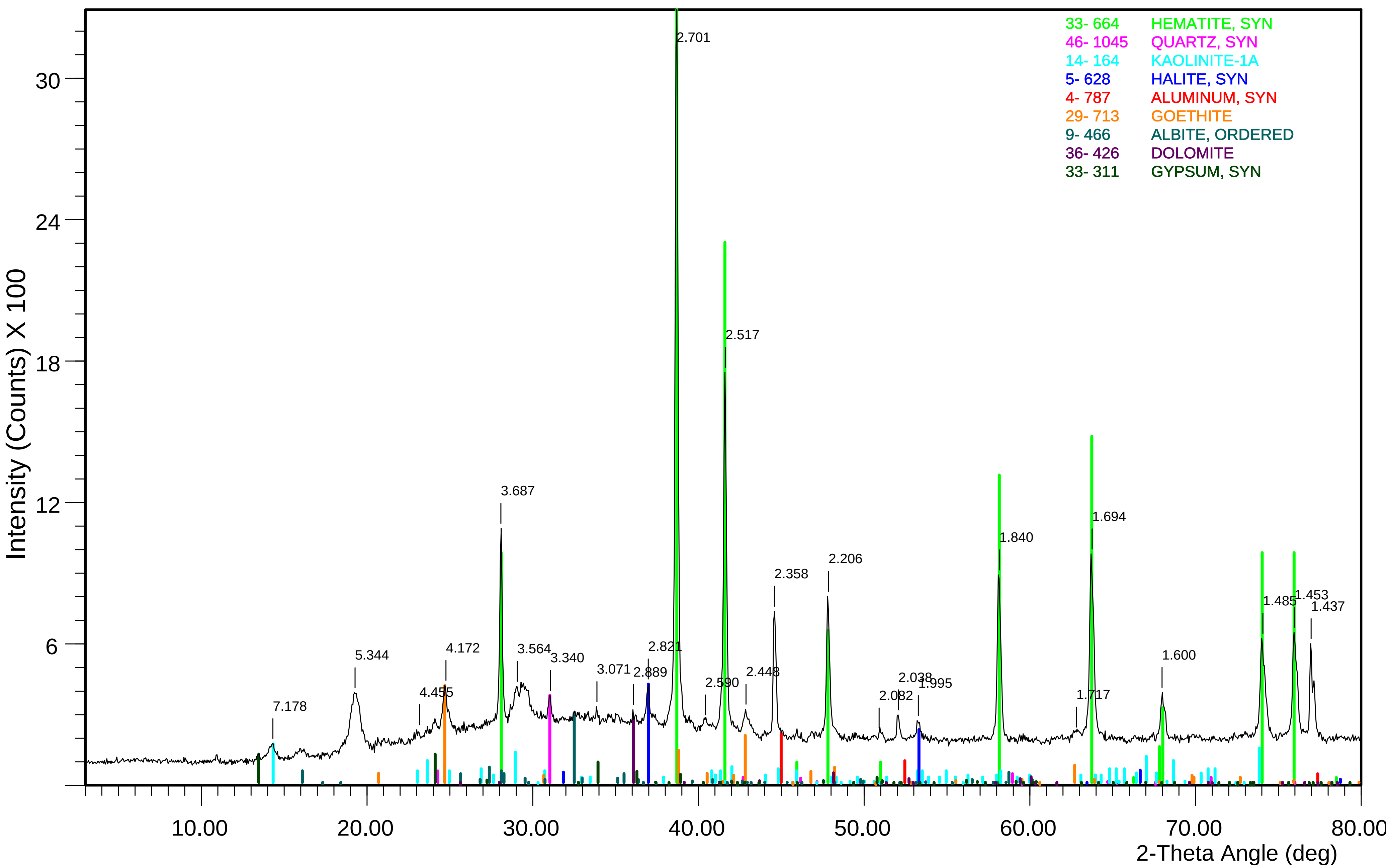


File Name: d:\xrddat~1\11972blk.103



File Name: d:\xrddat~1\11973blk.104

AB21



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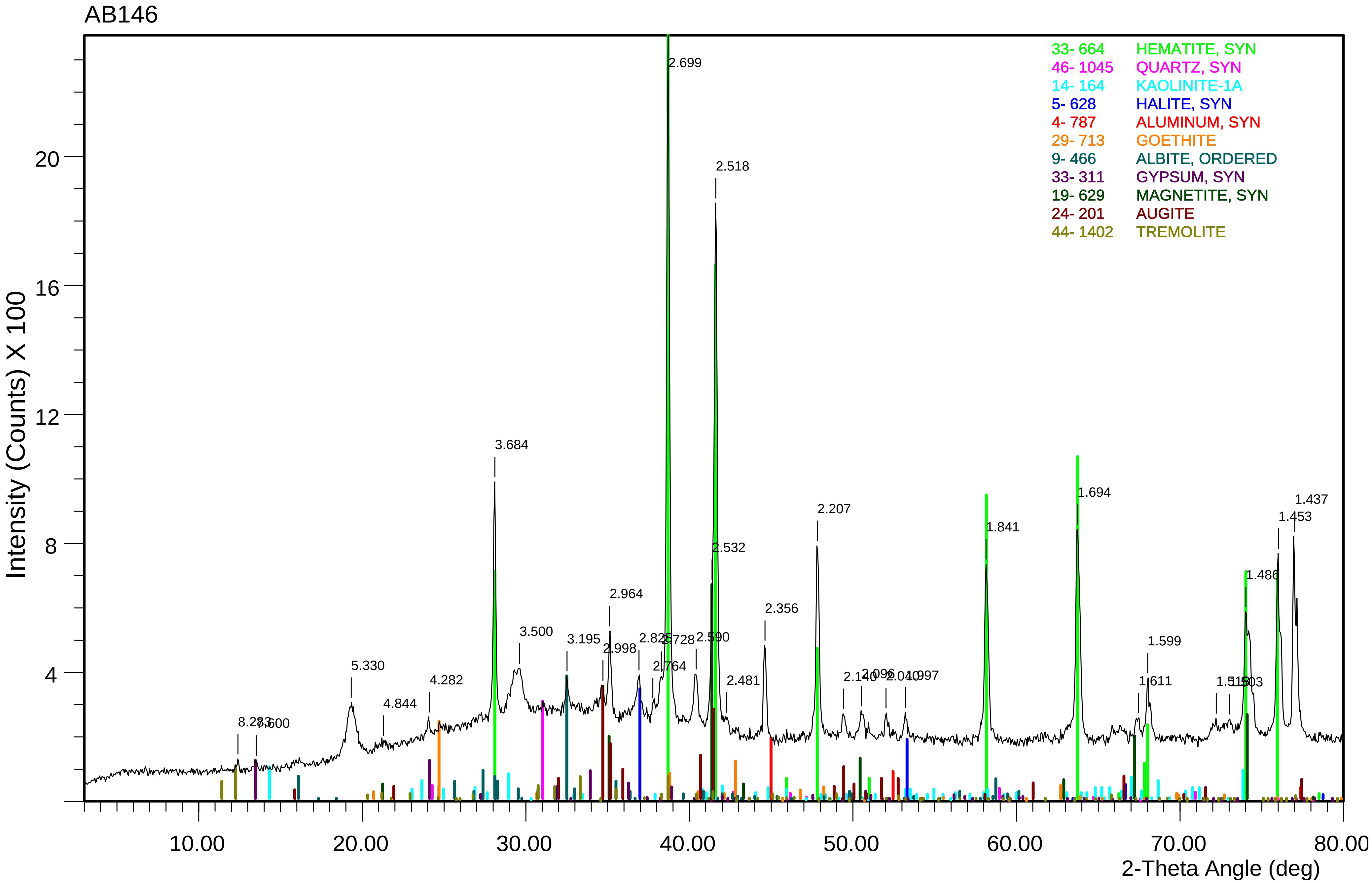
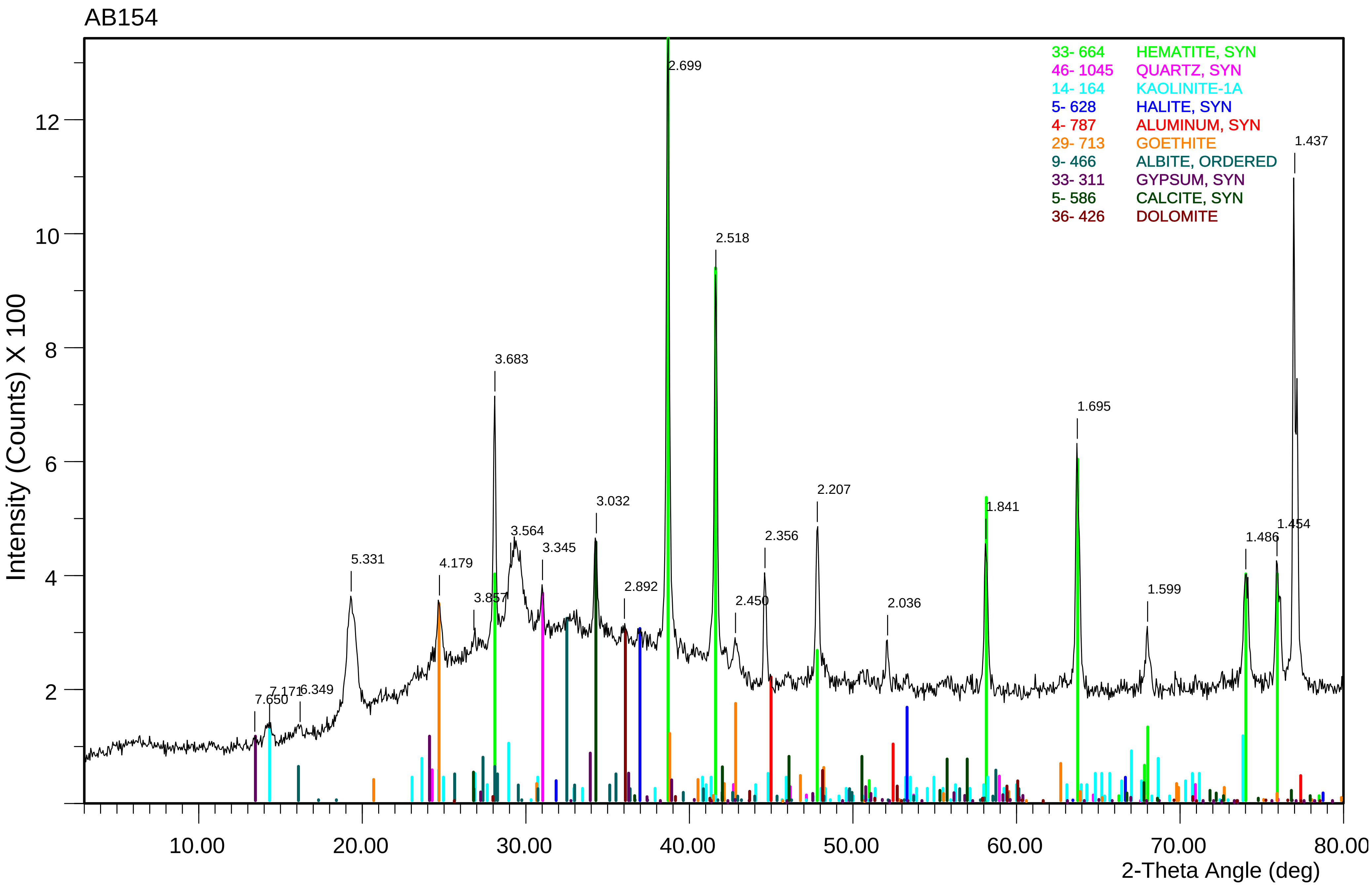
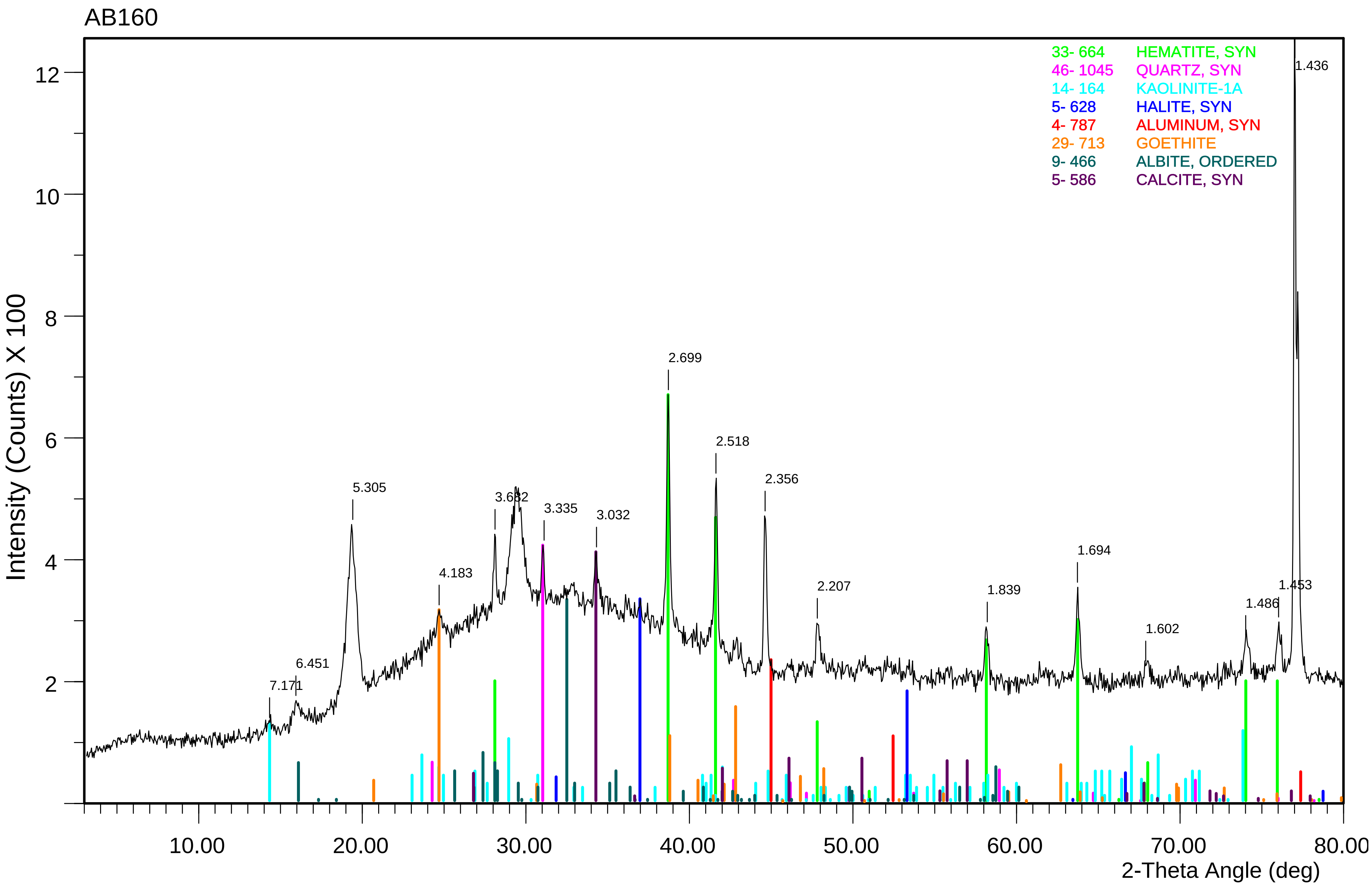


File Name: d:\xrddat~1\11975blk.106



File Name: d:\xrddat~1\11976blk.107



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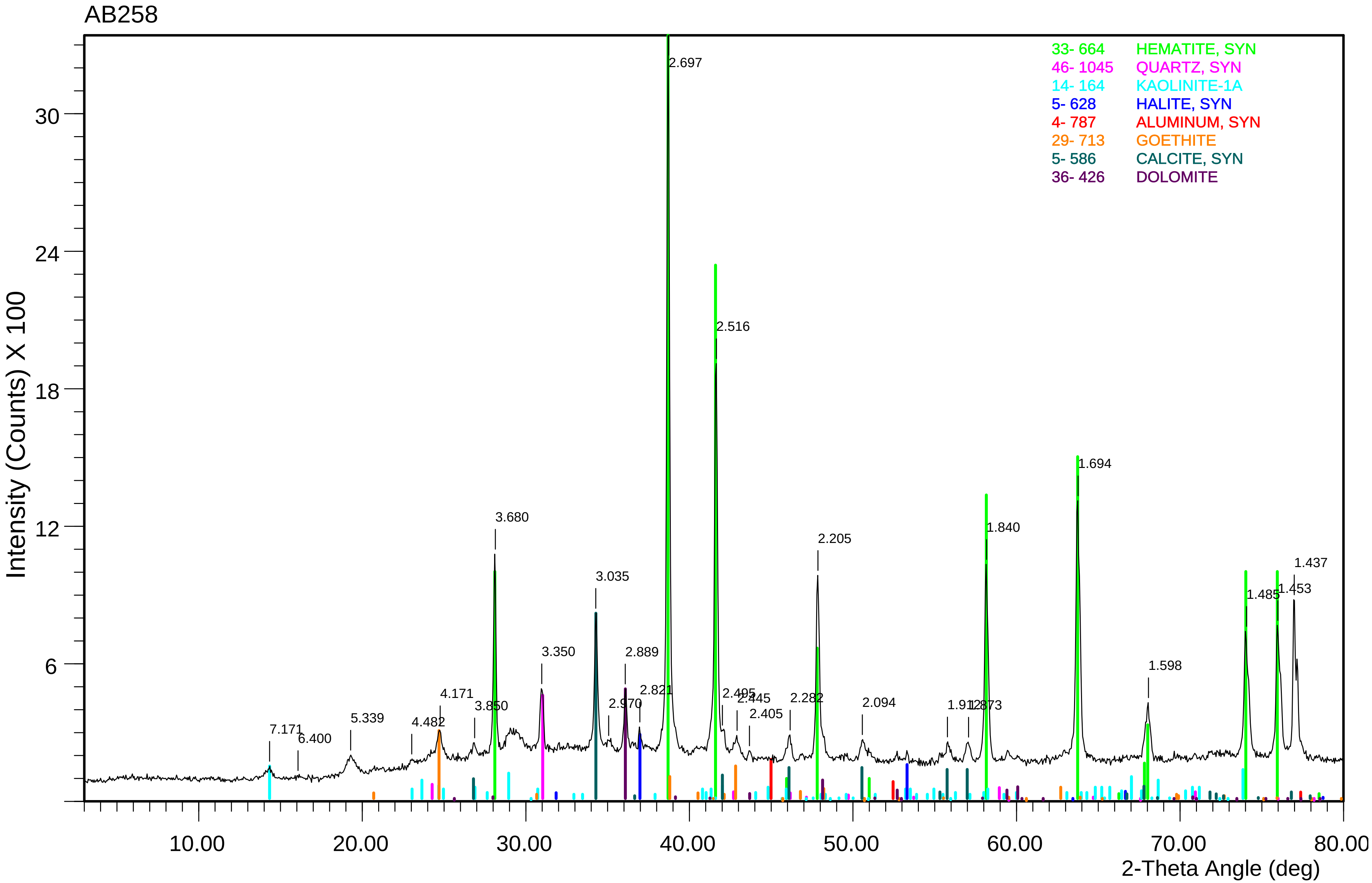
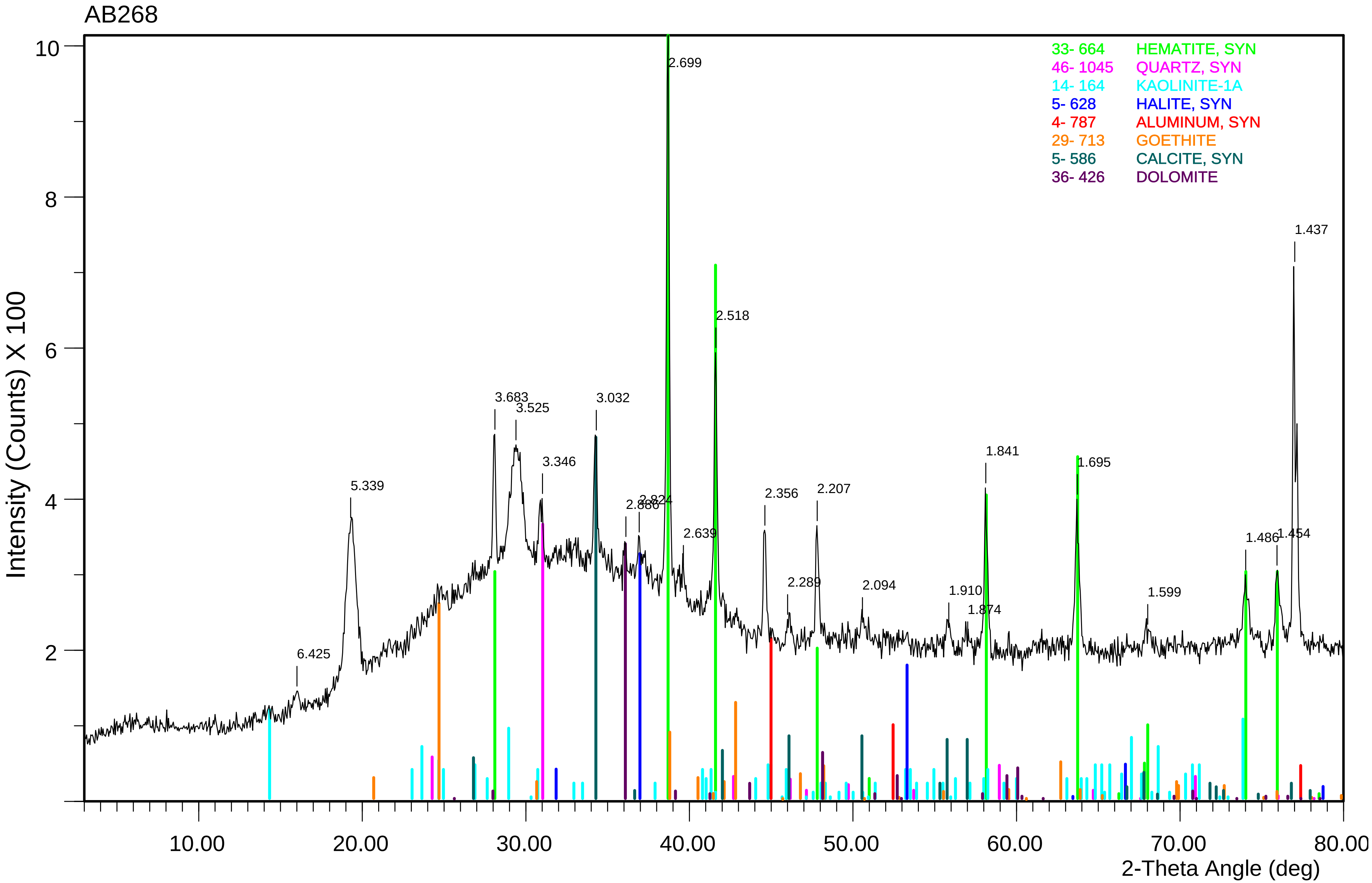
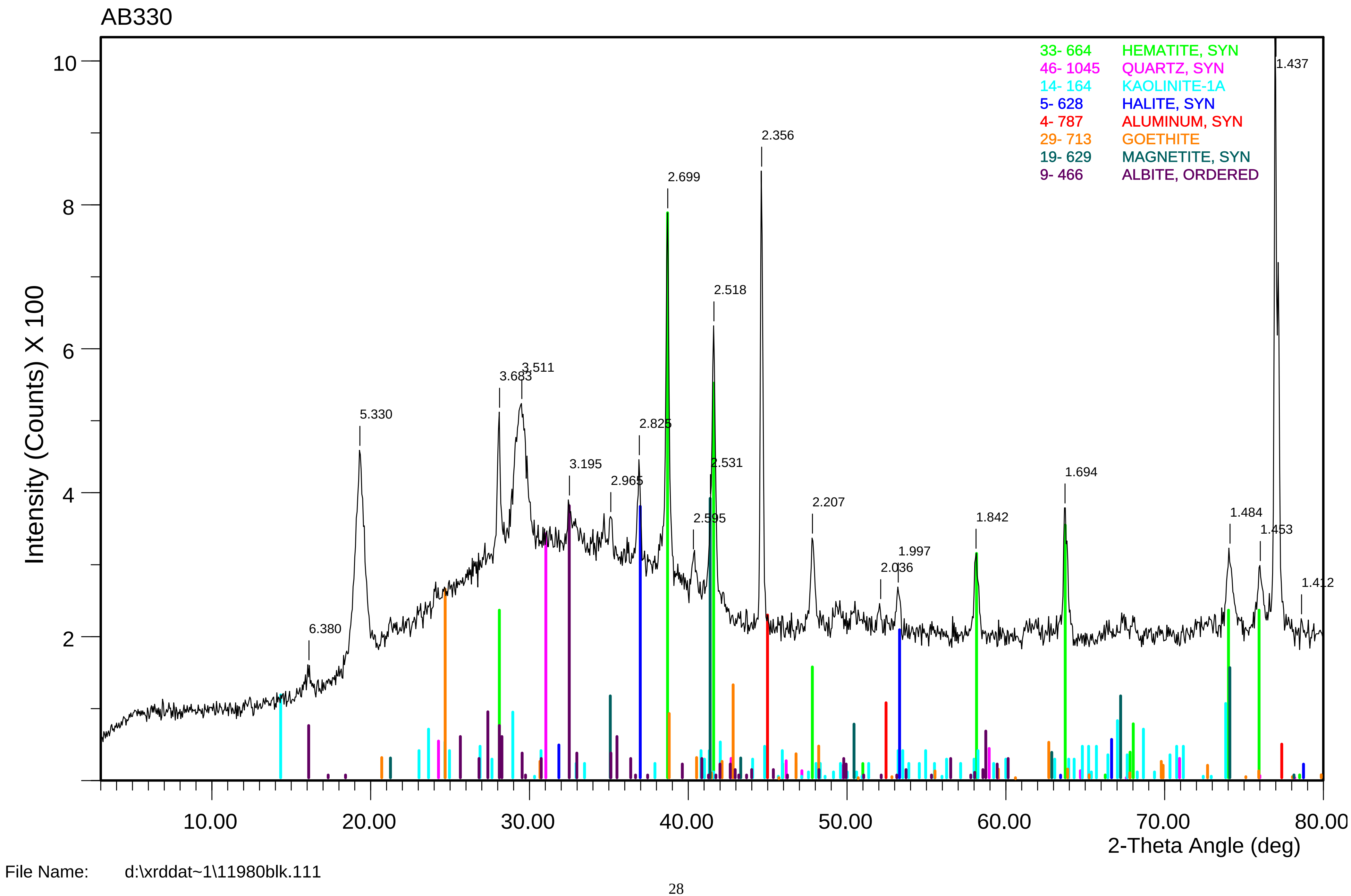
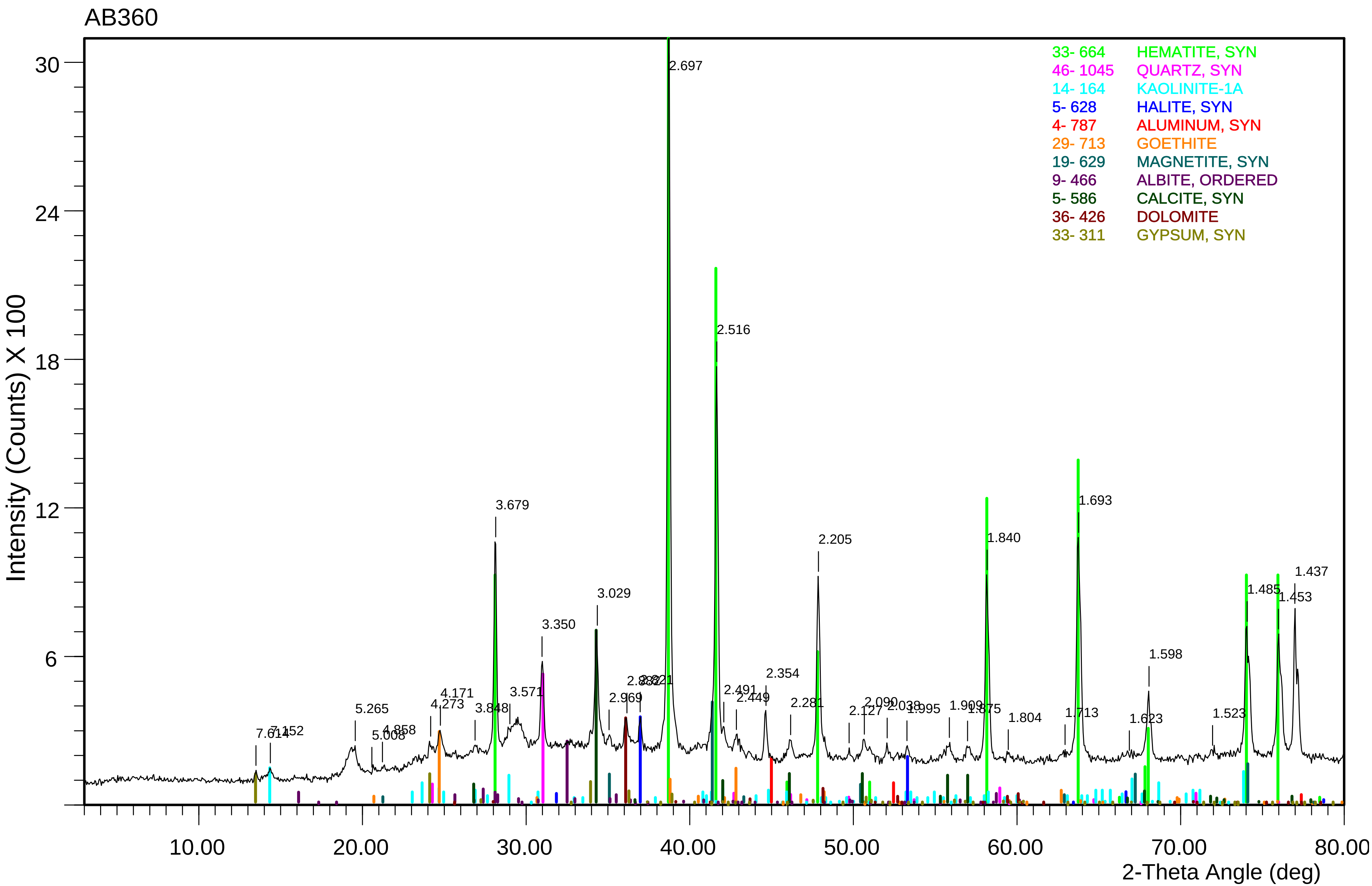


File Name: d:\xrddat~1\11978blk.109

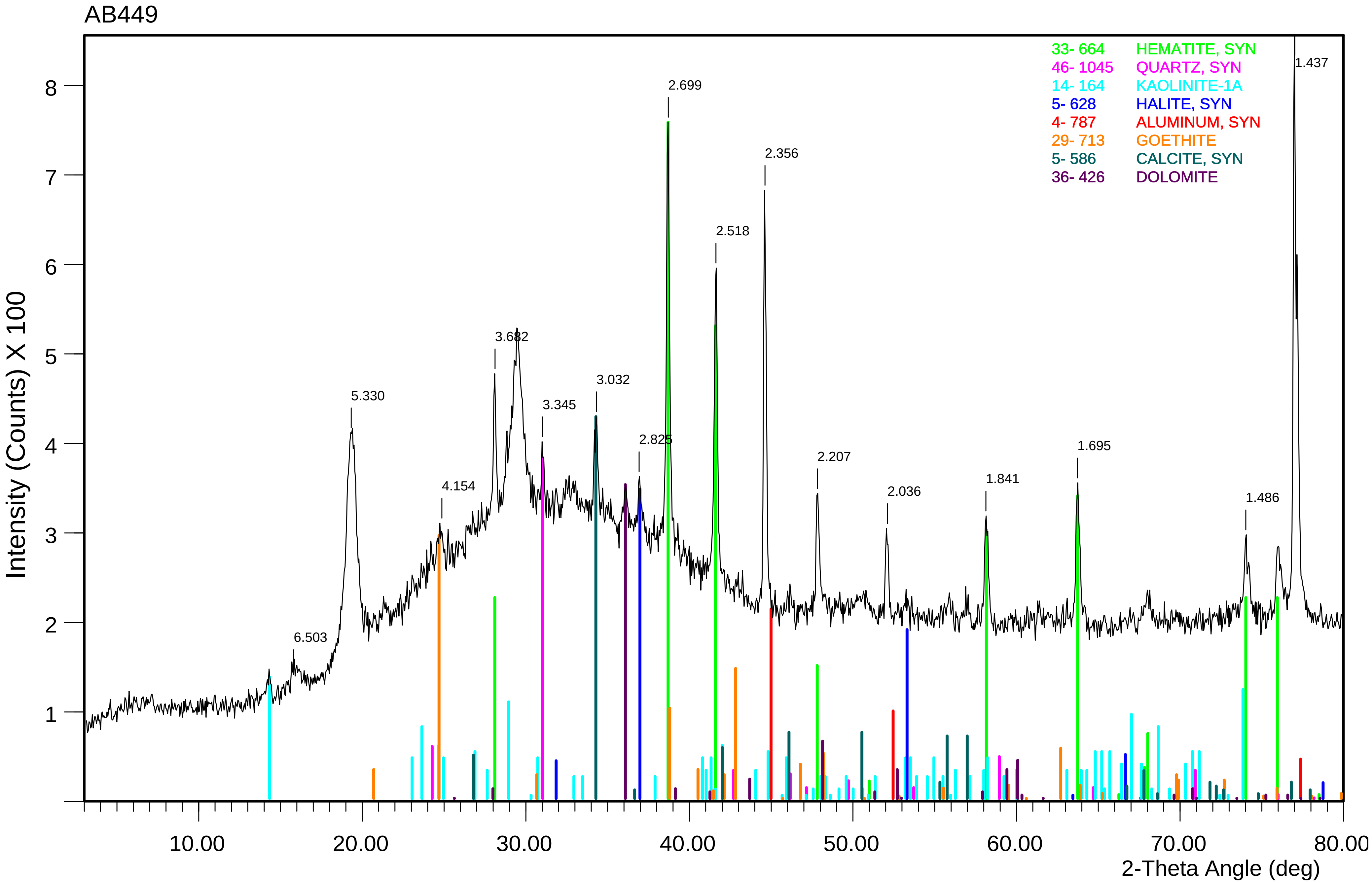


File Name: d:\xrddat~1\11979blk.110

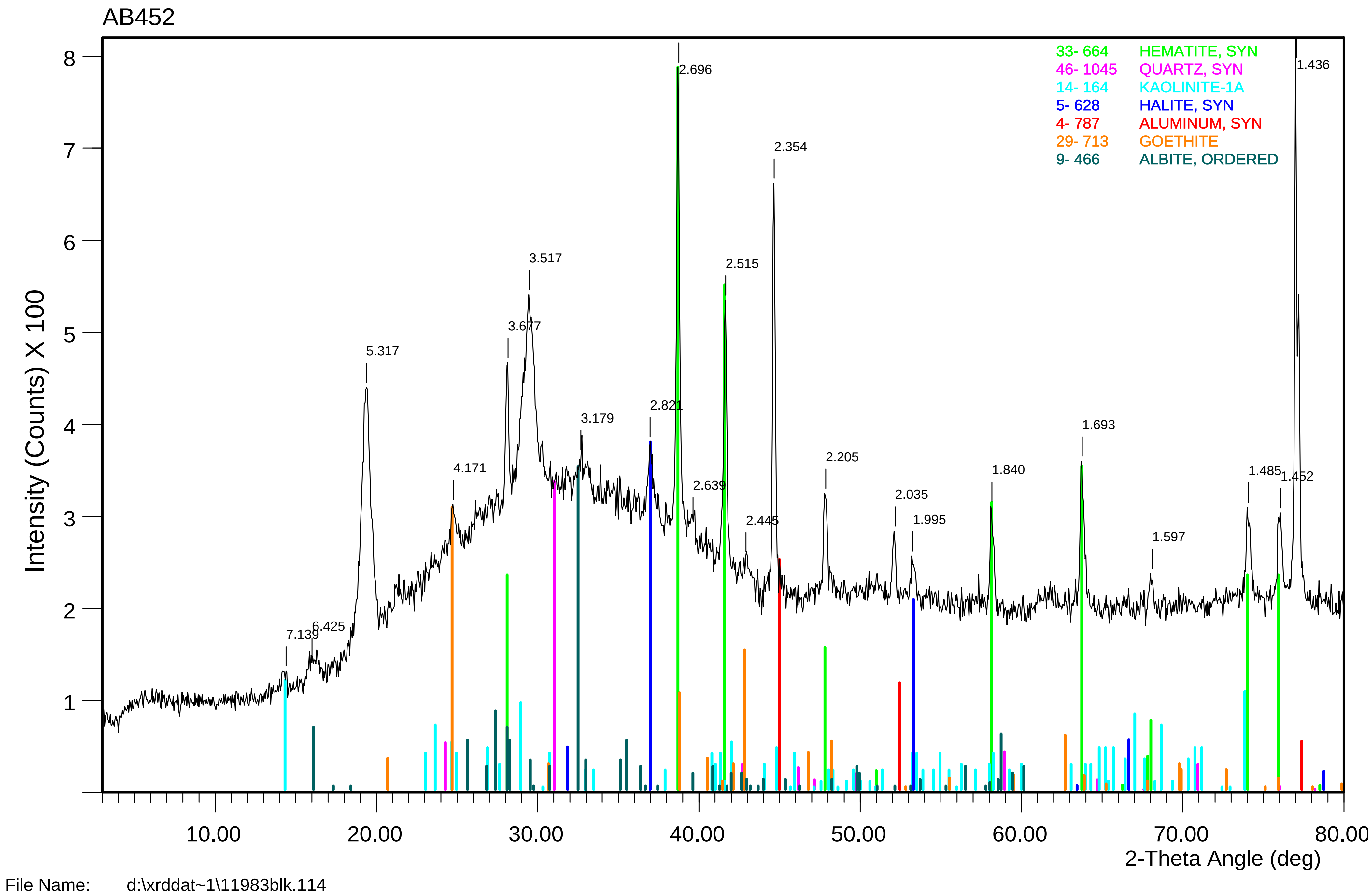

AB330
33- 664 HEMATITE, SYN
46- 1045 QUARTZ, SYN
14- 164 KAOLINITE-1A
5- 628 HALITE, SYN
4- 787 ALUMINUM, SYN
29- 713 GOETHITE
19- 629 MAGNETITE, SYN
9- 466 ALBITE, ORDERED
Intensity (Counts) X 100
2-Theta Angle (deg)
6.380
5.330
3.683
3.511
3.195
2.965
2.825
2.699
2.595
2.531
2.518
2.356
2.207
2.036
1.997
1.842
1.694
1.484
1.453
1.437
1.412
File Name: d:\xrddat~1\11980blk.111

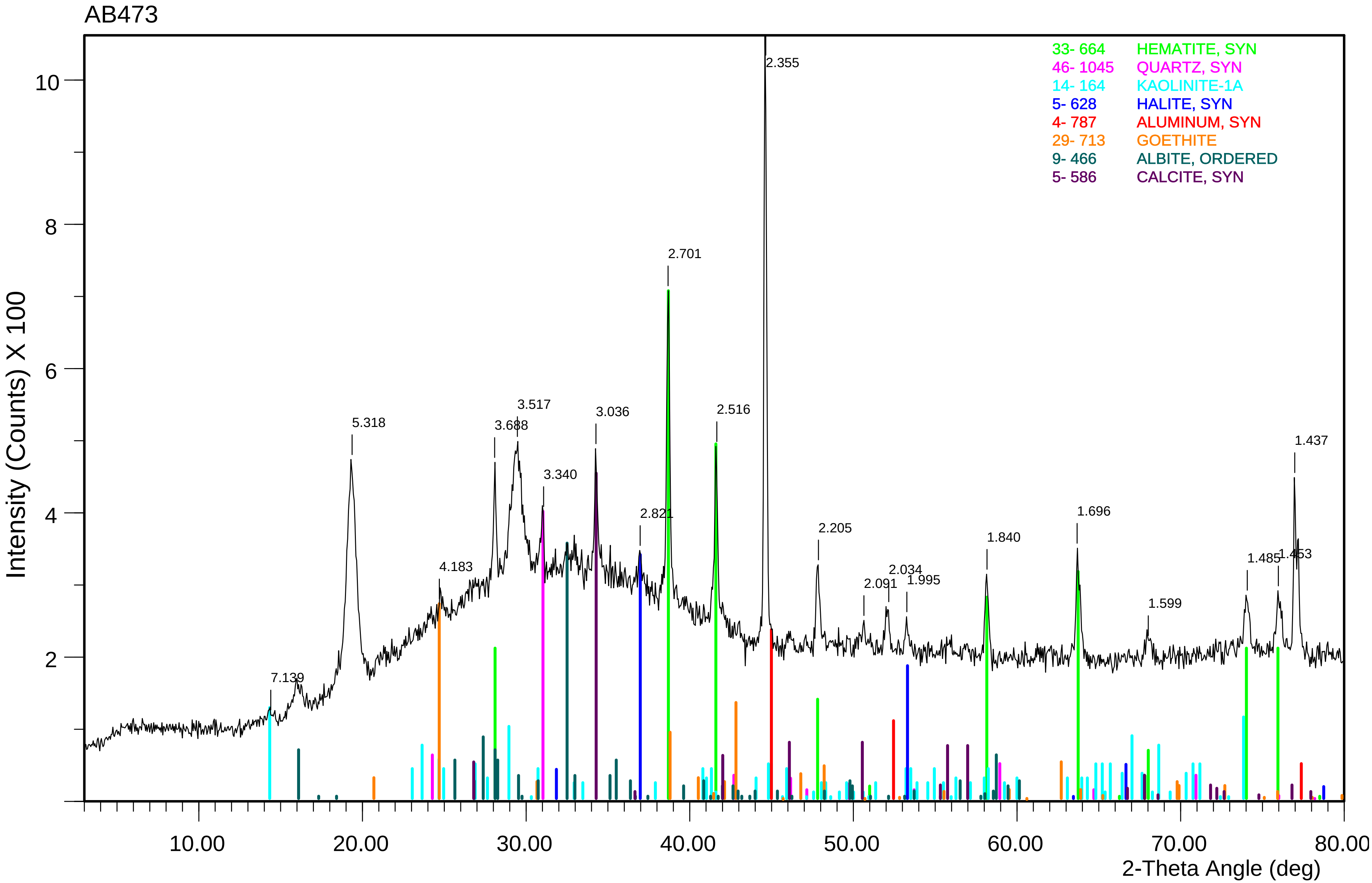


File Name: d:\xrddat~1\11981blk.112

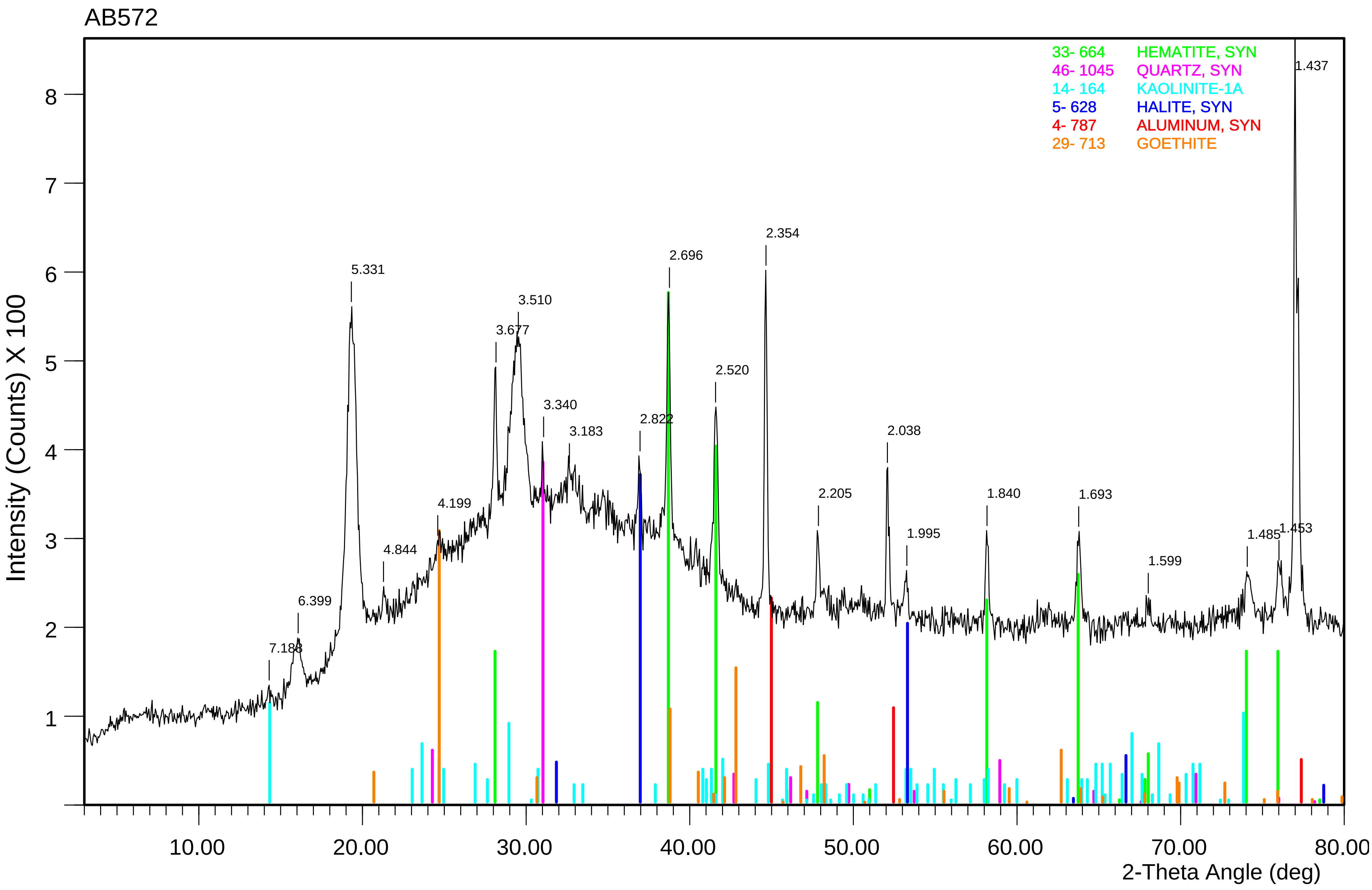


File Name: d:\xrddat~1\11982blk.113


AB452
Intensity (Counts) X 100
2-Theta Angle (deg)
33- 664 HEMATITE, SYN
46- 1045 QUARTZ, SYN
14- 164 KAOLINITE-1A
5- 628 HALITE, SYN
4- 787 ALUMINUM, SYN
29- 713 GOETHITE
9- 466 ALBITE, ORDERED
7.139
6.425
5.317
4.171
3.677
3.517
3.179
2.821
2.696
2.639
2.515
2.445
2.354
2.205
2.035
1.995
1.840
1.693
1.597
1.485
1.452
1.436
File Name: d:\xrddat~1\11983blk.114

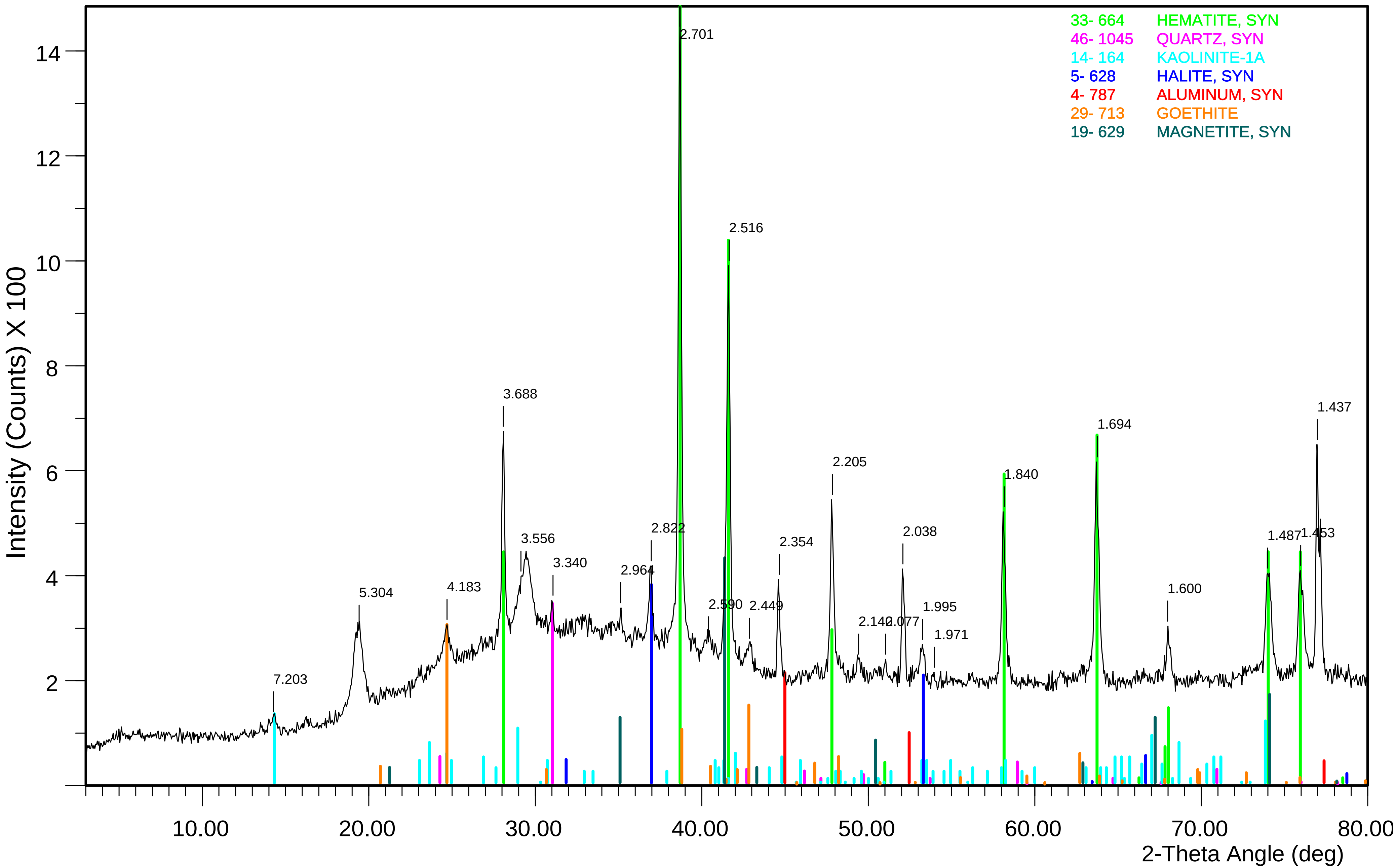


File Name: d:\xrddat~1\11984blk.115

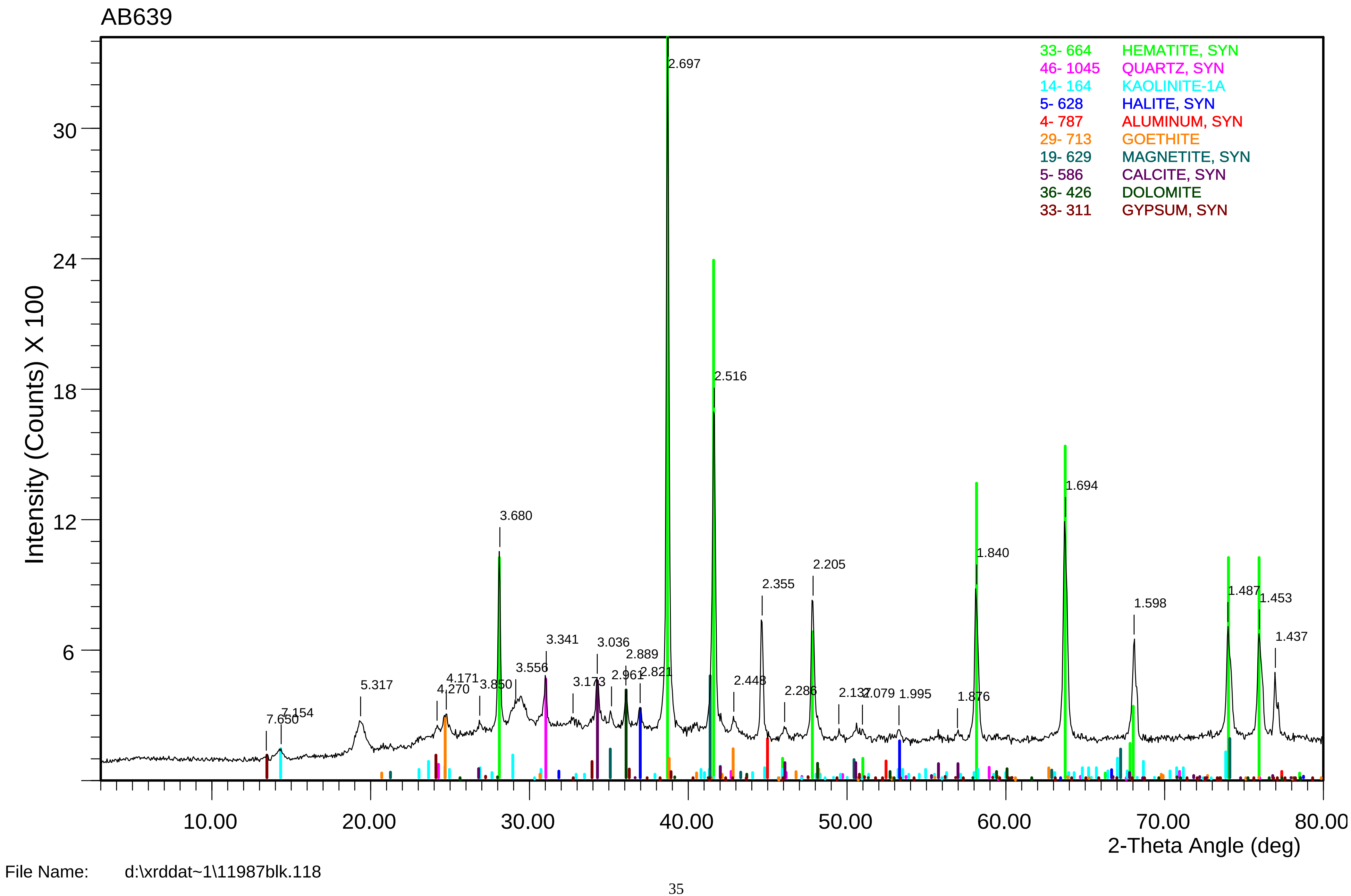


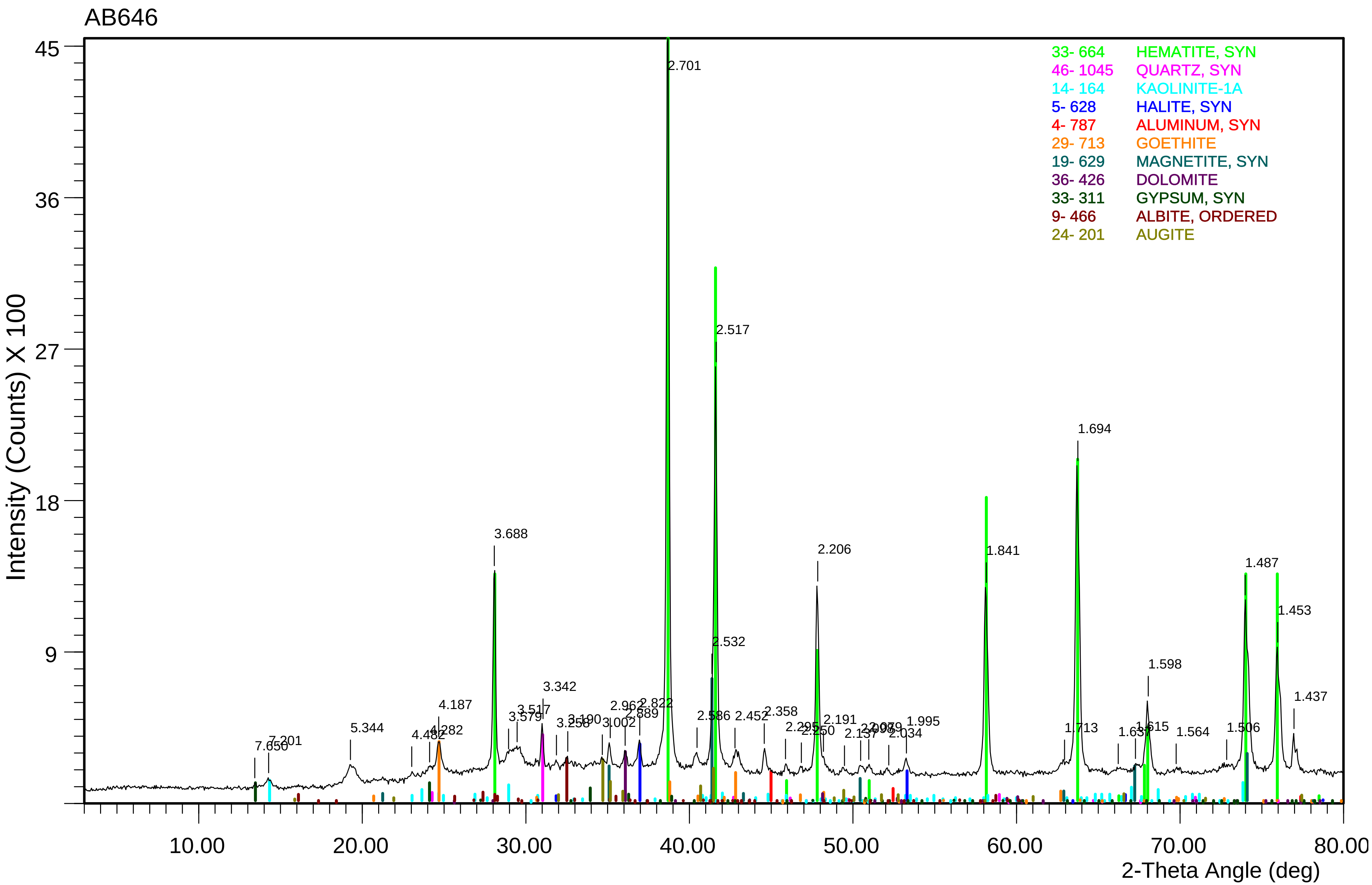
File Name: d:\xrddat~1\11985blk.116

AB582

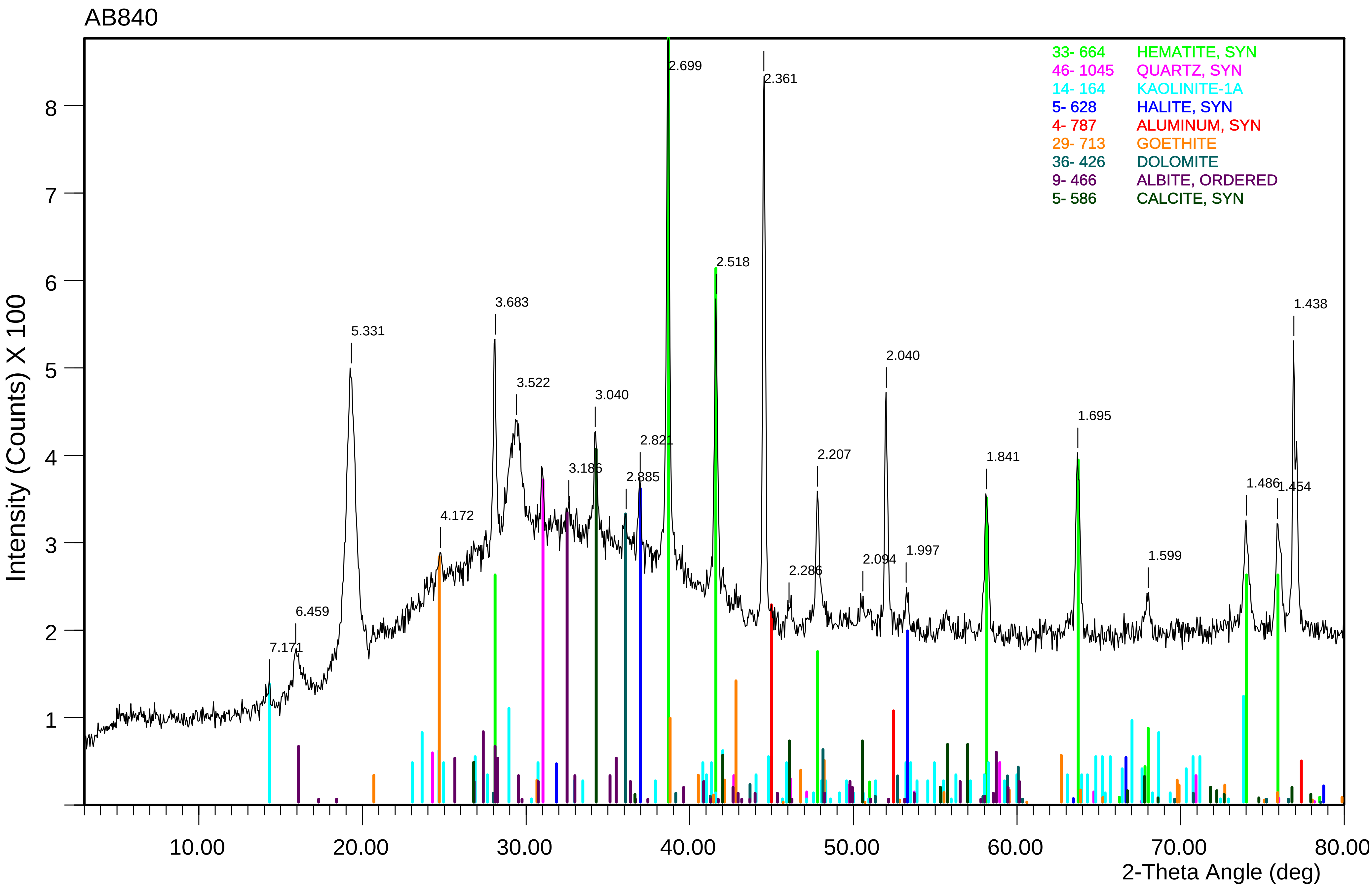


File Name: d:\xrddat~1\11986blk.117

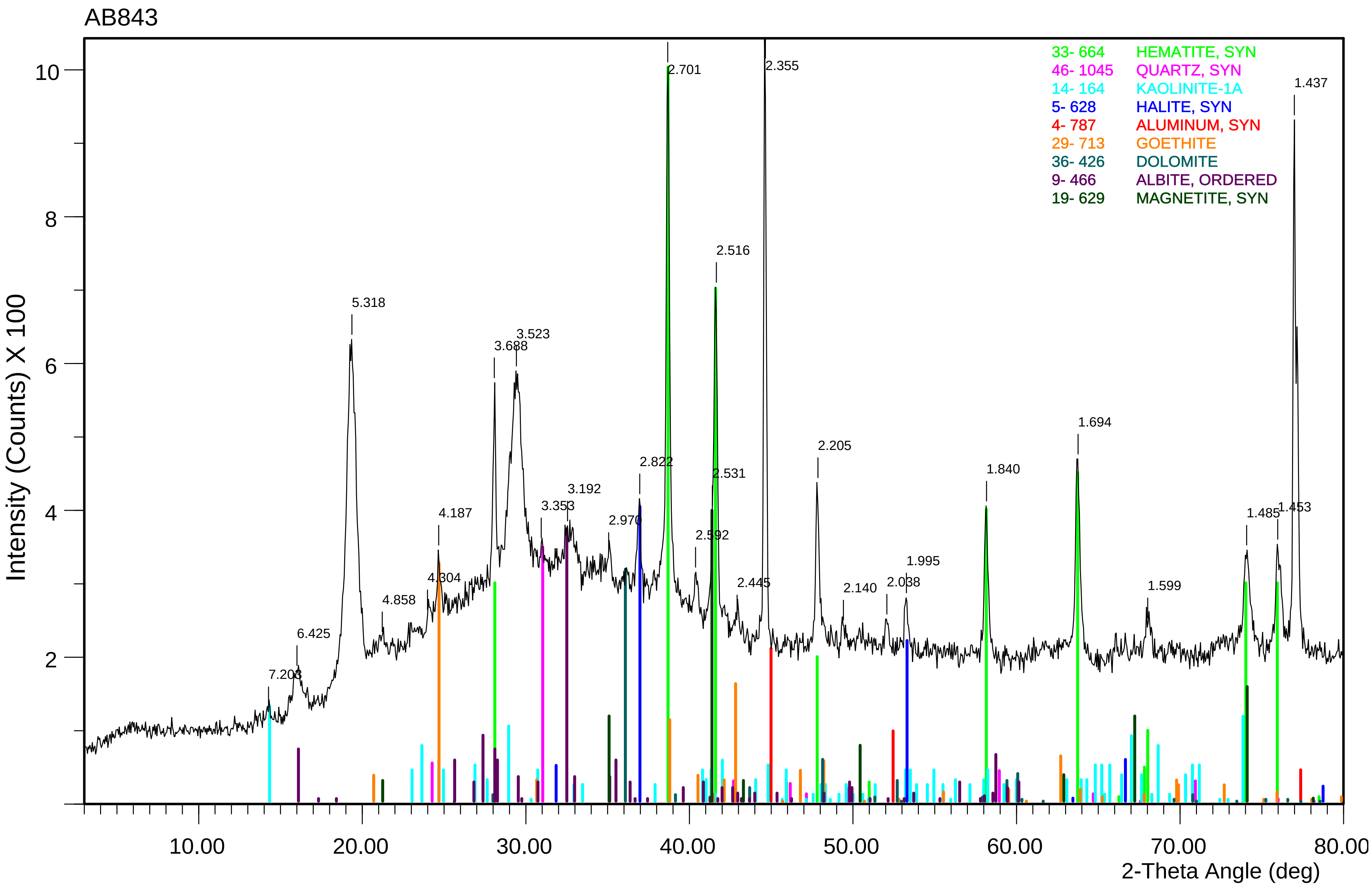

AB639
33- 664 HEMATITE, SYN
46- 1045 QUARTZ, SYN
14- 164 KAOLINITE-1A
5- 628 HALITE, SYN
4- 787 ALUMINUM, SYN
29- 713 GOETHITE
19- 629 MAGNETITE, SYN
5- 586 CALCITE, SYN
36- 426 DOLOMITE
33- 311 GYPSUM, SYN
Intensity (Counts) X 100
2-Theta Angle (deg)
2.697
2.516
1.694
1.840
2.205
2.355
3.680
1.598
1.487
1.453
1.437
3.341
3.036
2.889
2.821
2.961
3.173
3.556
3.850
4.171
4.270
5.317
7.154
7.650
2.448
2.286
2.132
2.079
1.995
1.876
File Name: d:\xrddat~1\11987blk.118



File Name: d:\xrddat~1\11988blk.119

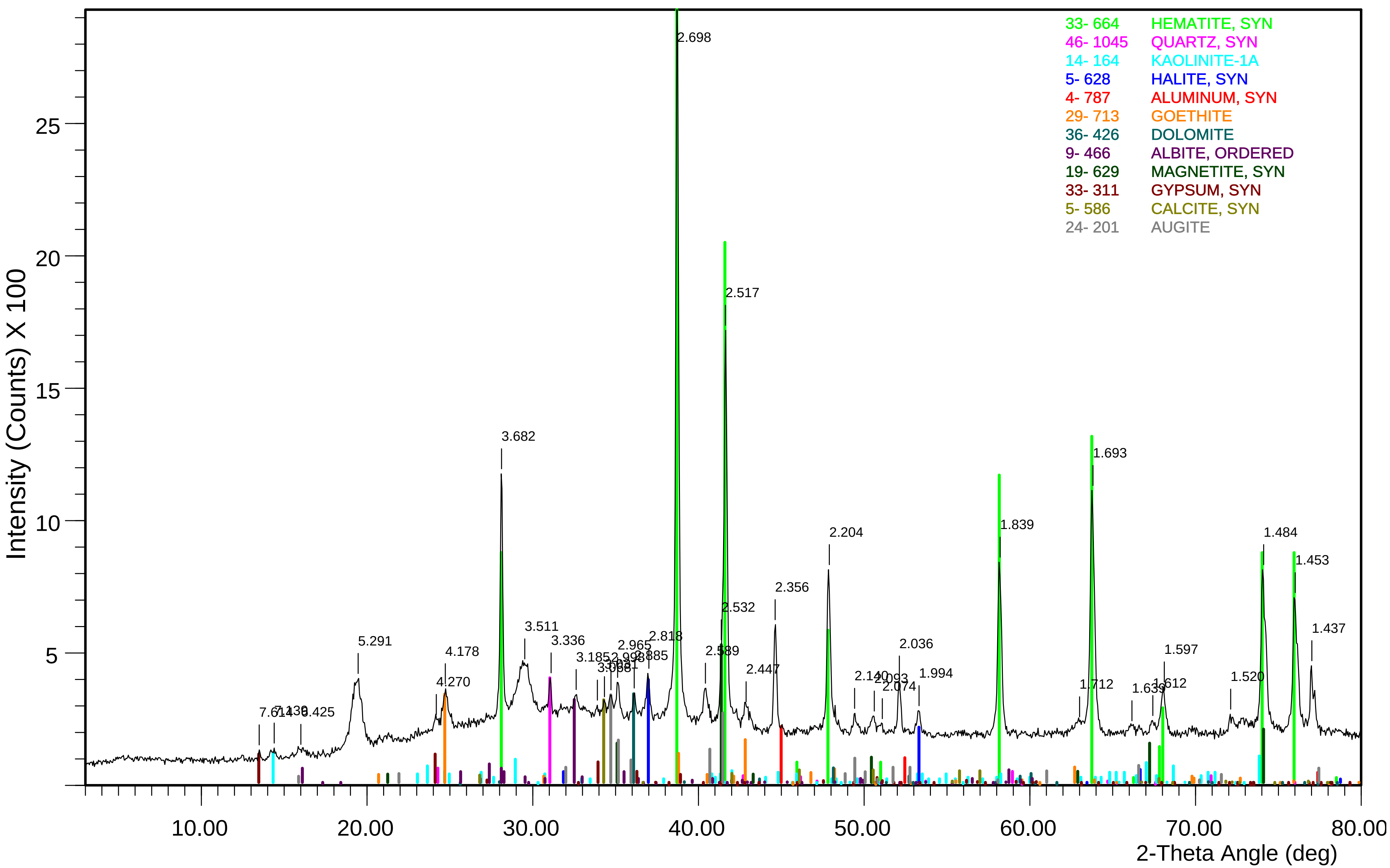


File Name: d:\xrddat~1\11989blk.120

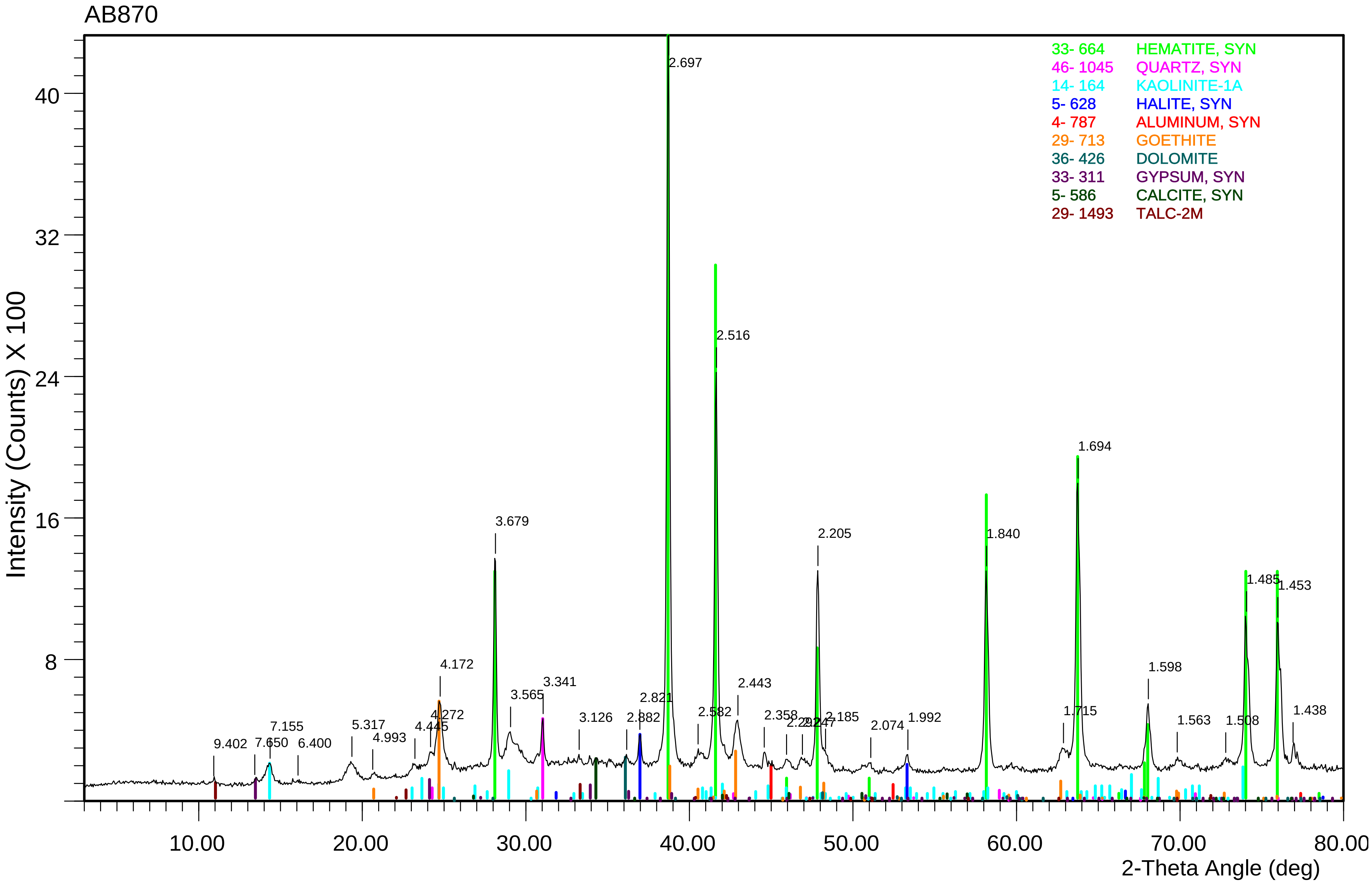


File Name: d:\xrddat~1\11990blk.201

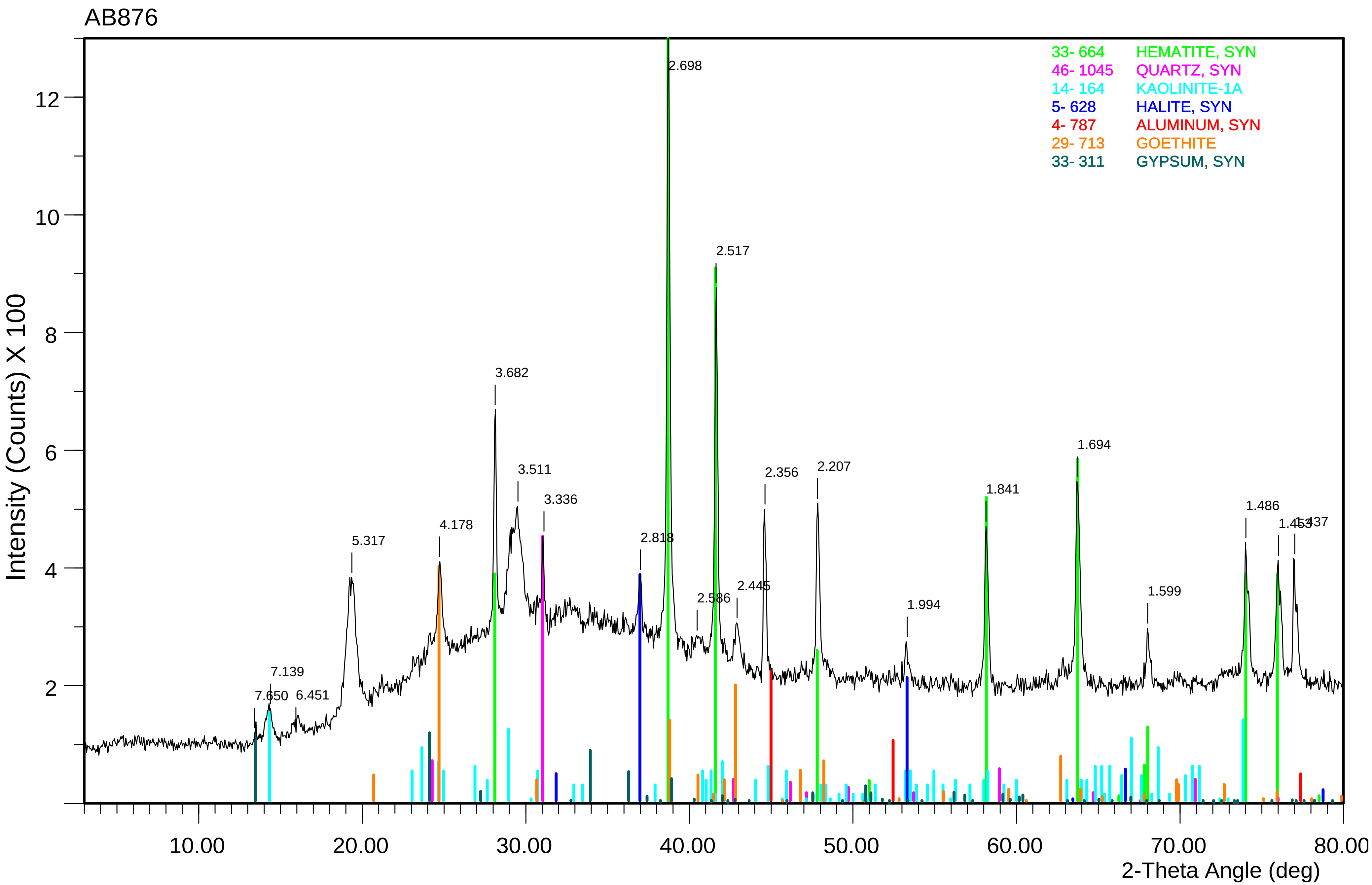
AB844



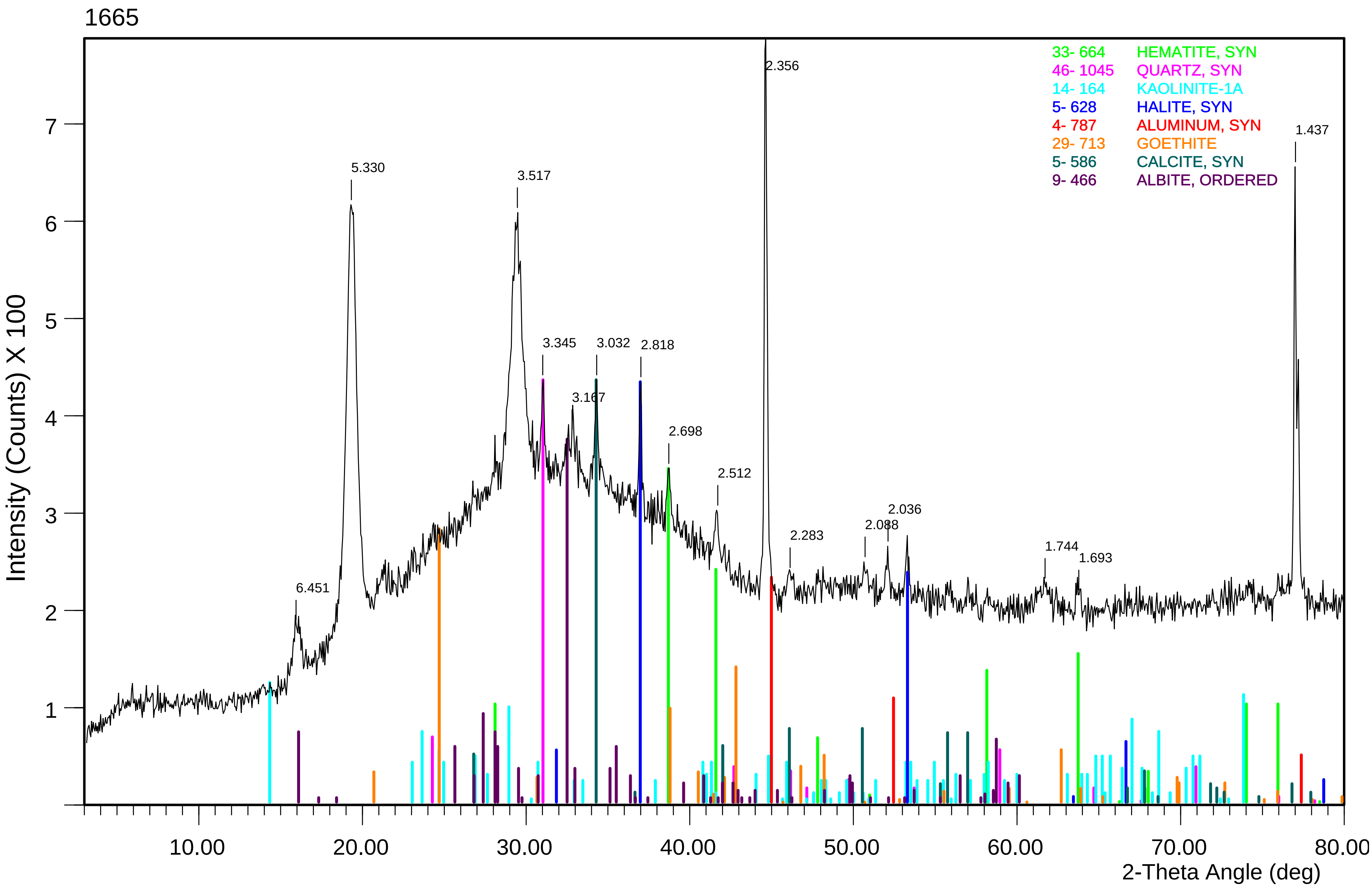
File Name: d:\xrddat~1\11991blk.202



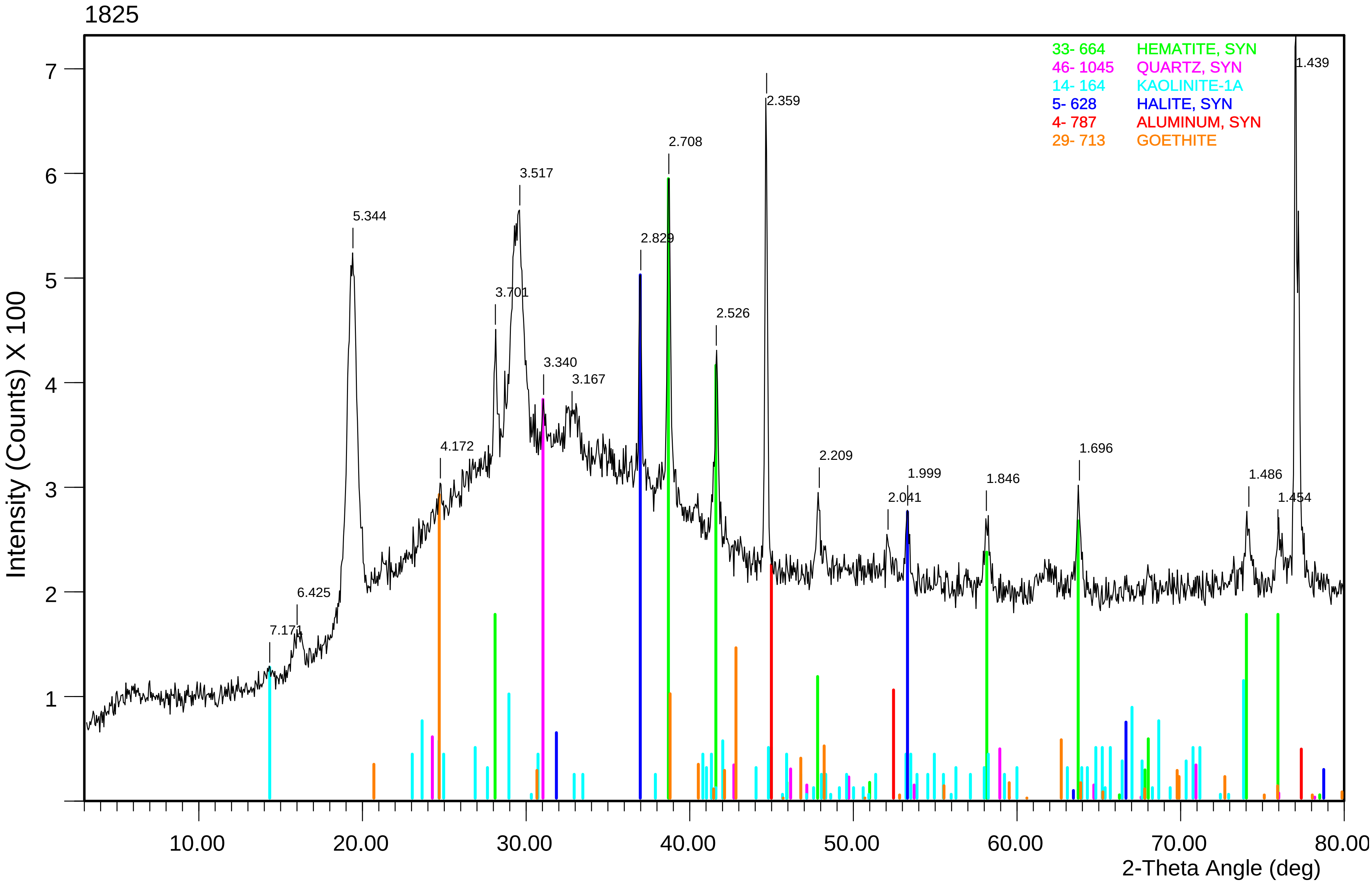
File Name: d:\xrddat~1\11992blk.203



File Name: d:\xrddat~1\11993blk.204

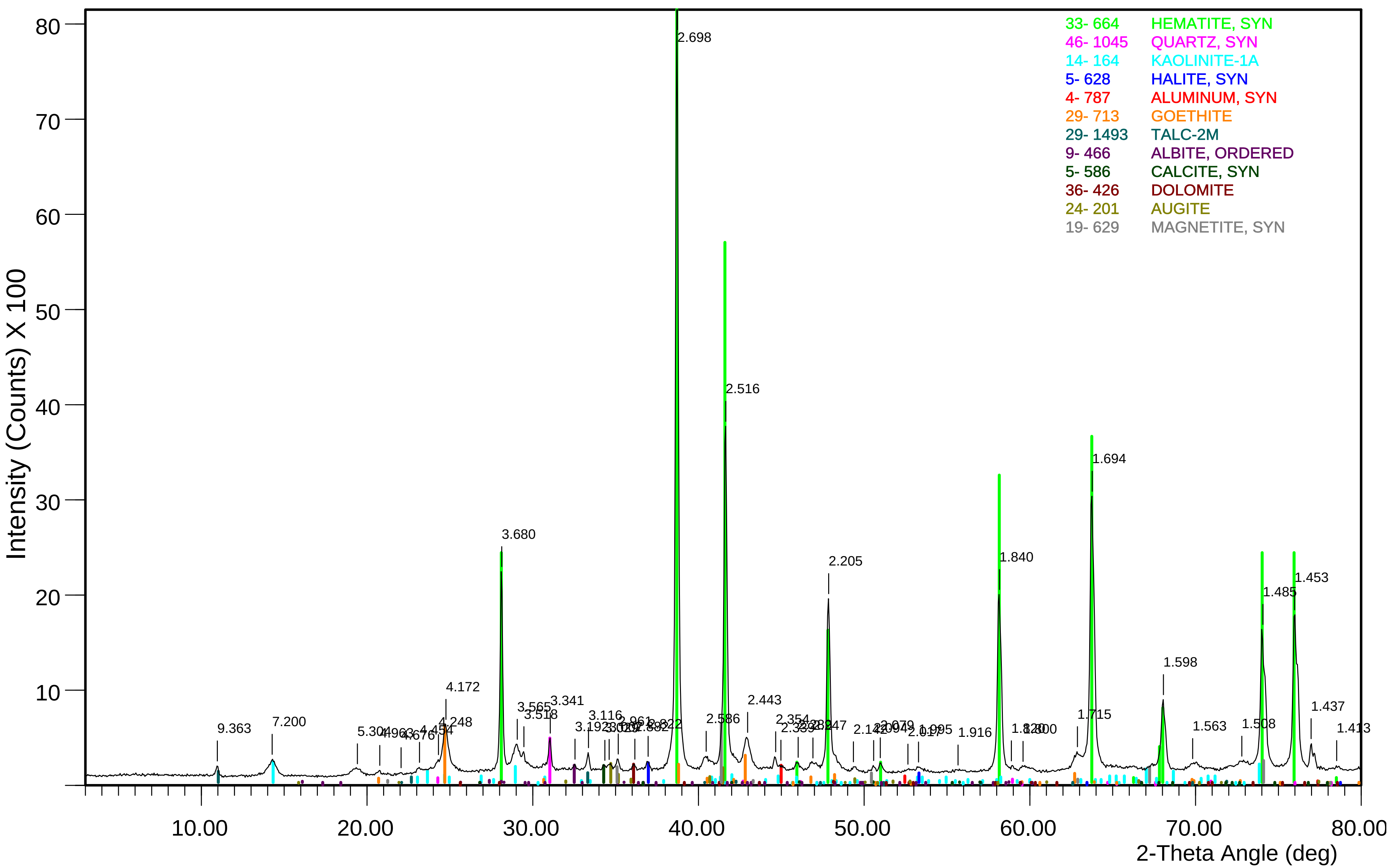


File Name: d:\xrddat~1\11994blk.205

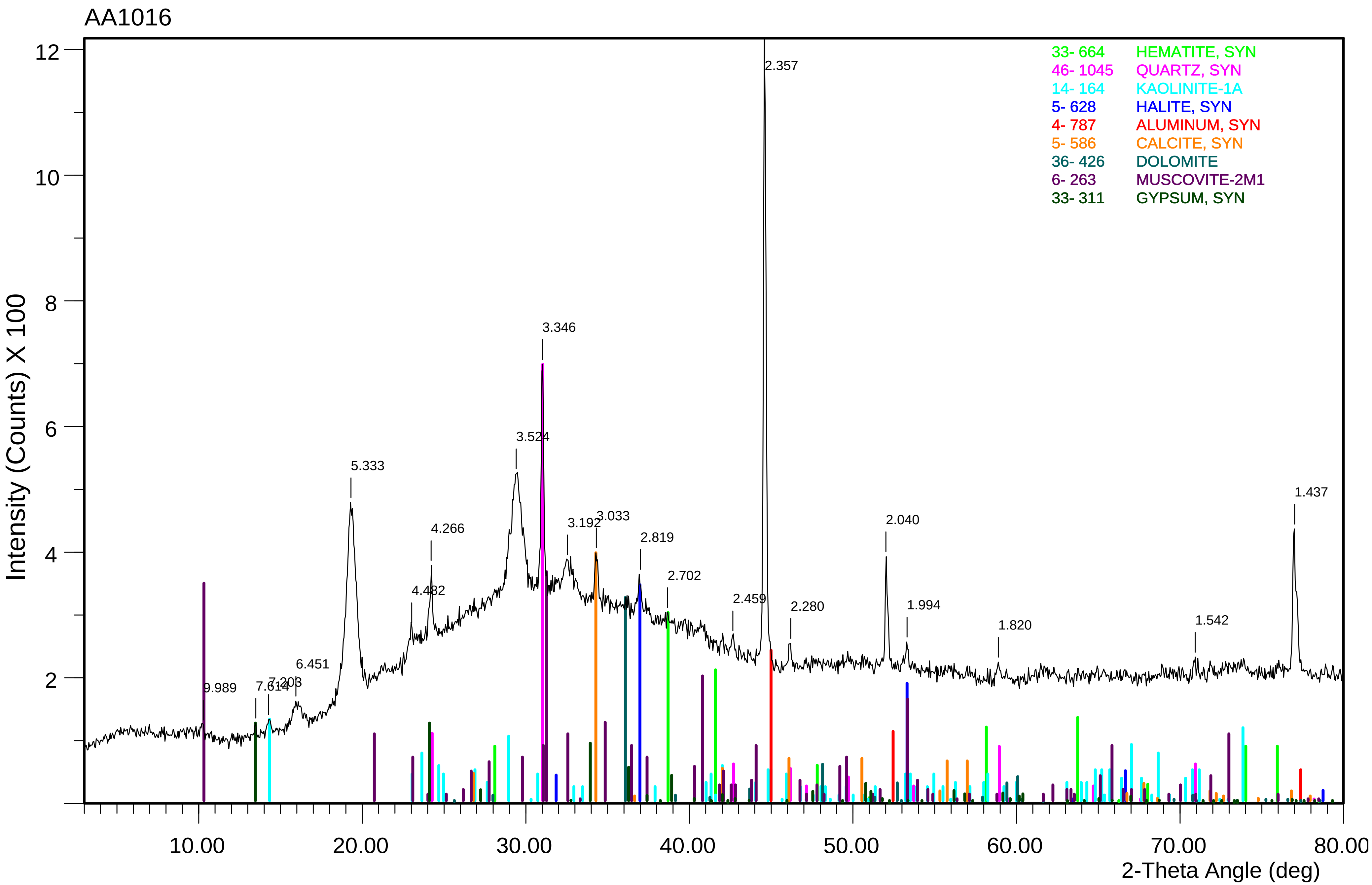


File Name: d:\xrddat~1\11995blk.206

AA1872



File Name: d:\xrddat~1\11996blk.101



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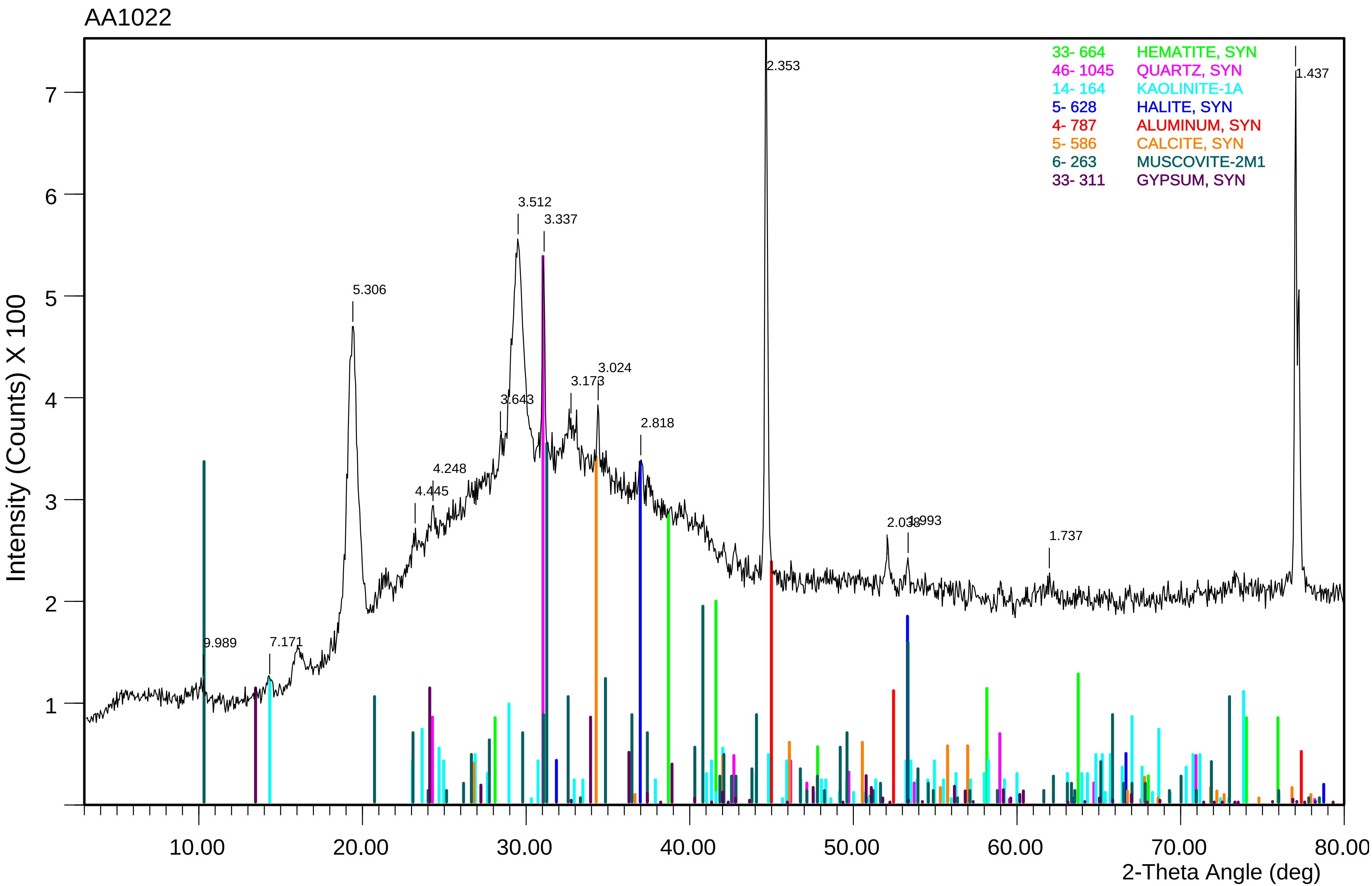
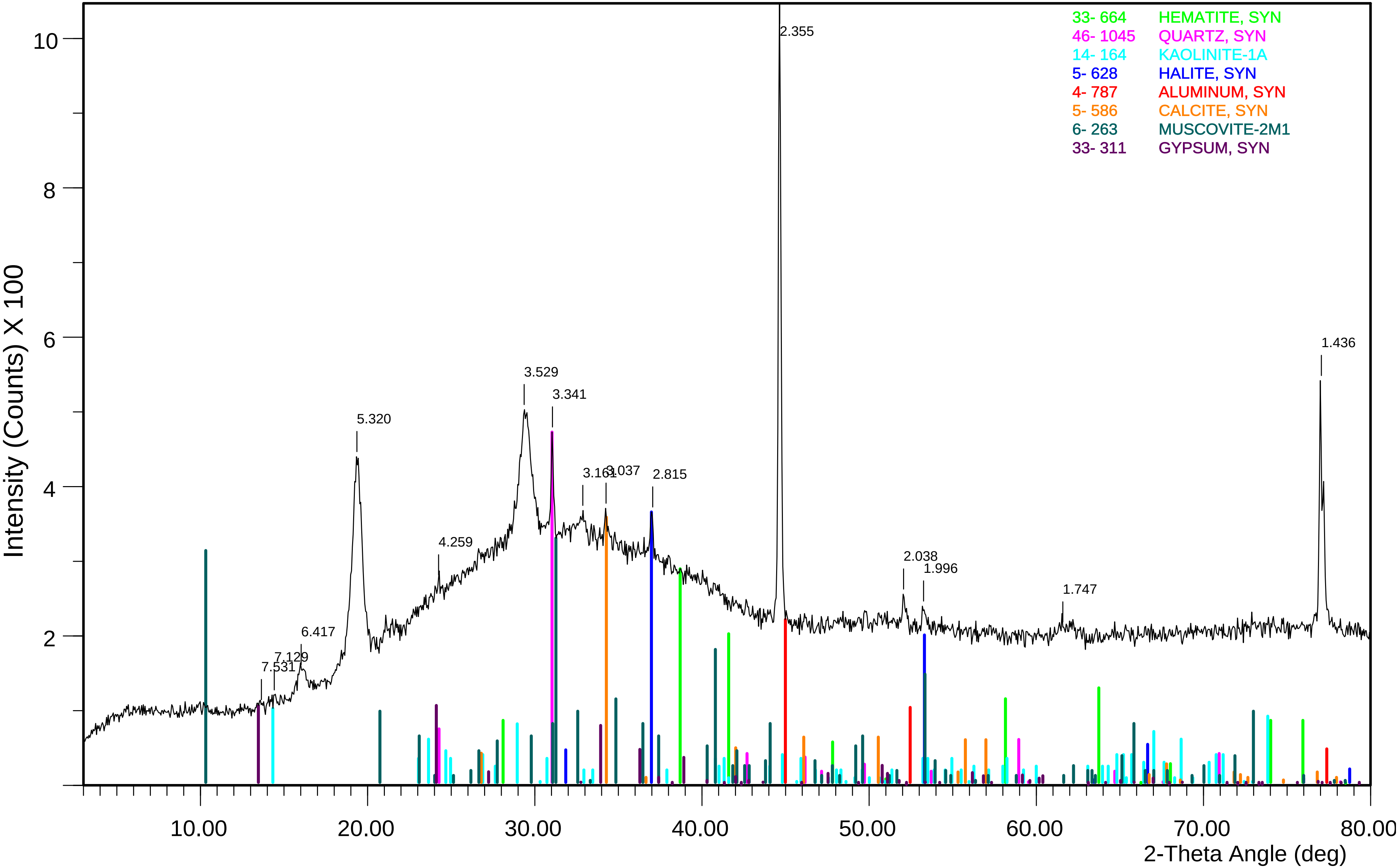


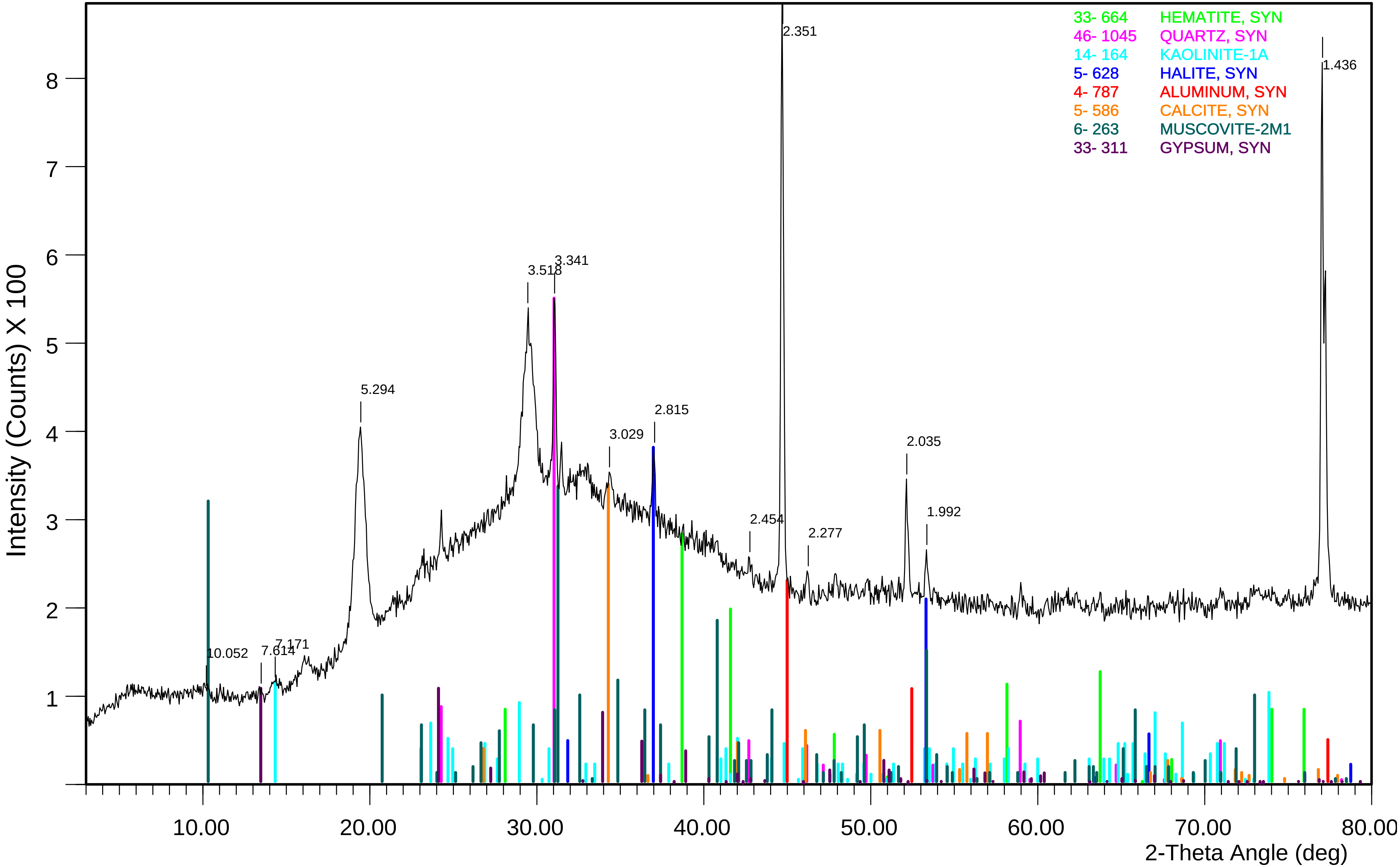
File Name: d:\xrddat~1\11998blk.103

AA1864

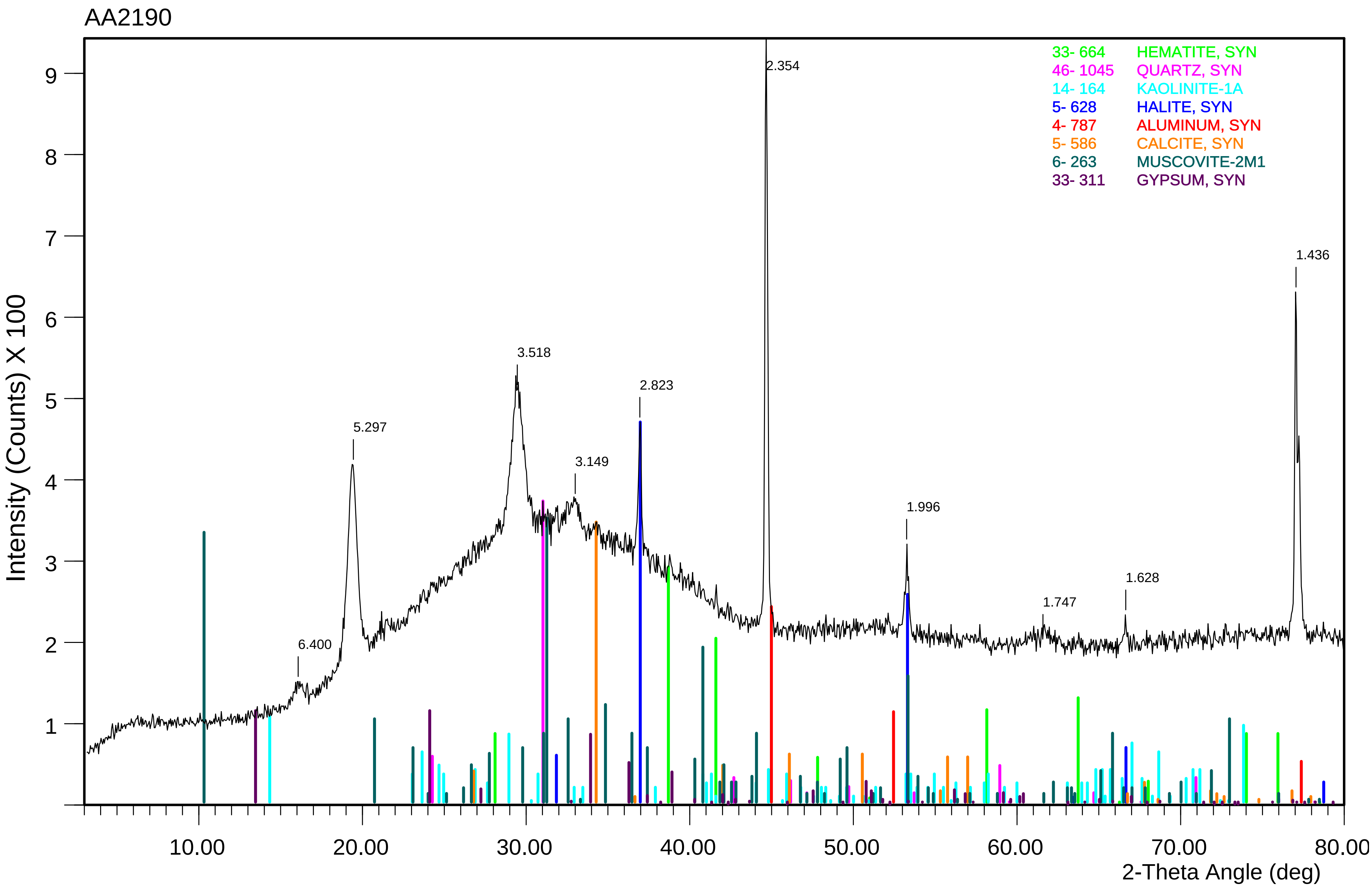


File Name: d:\xrddat~1\11999blk.104

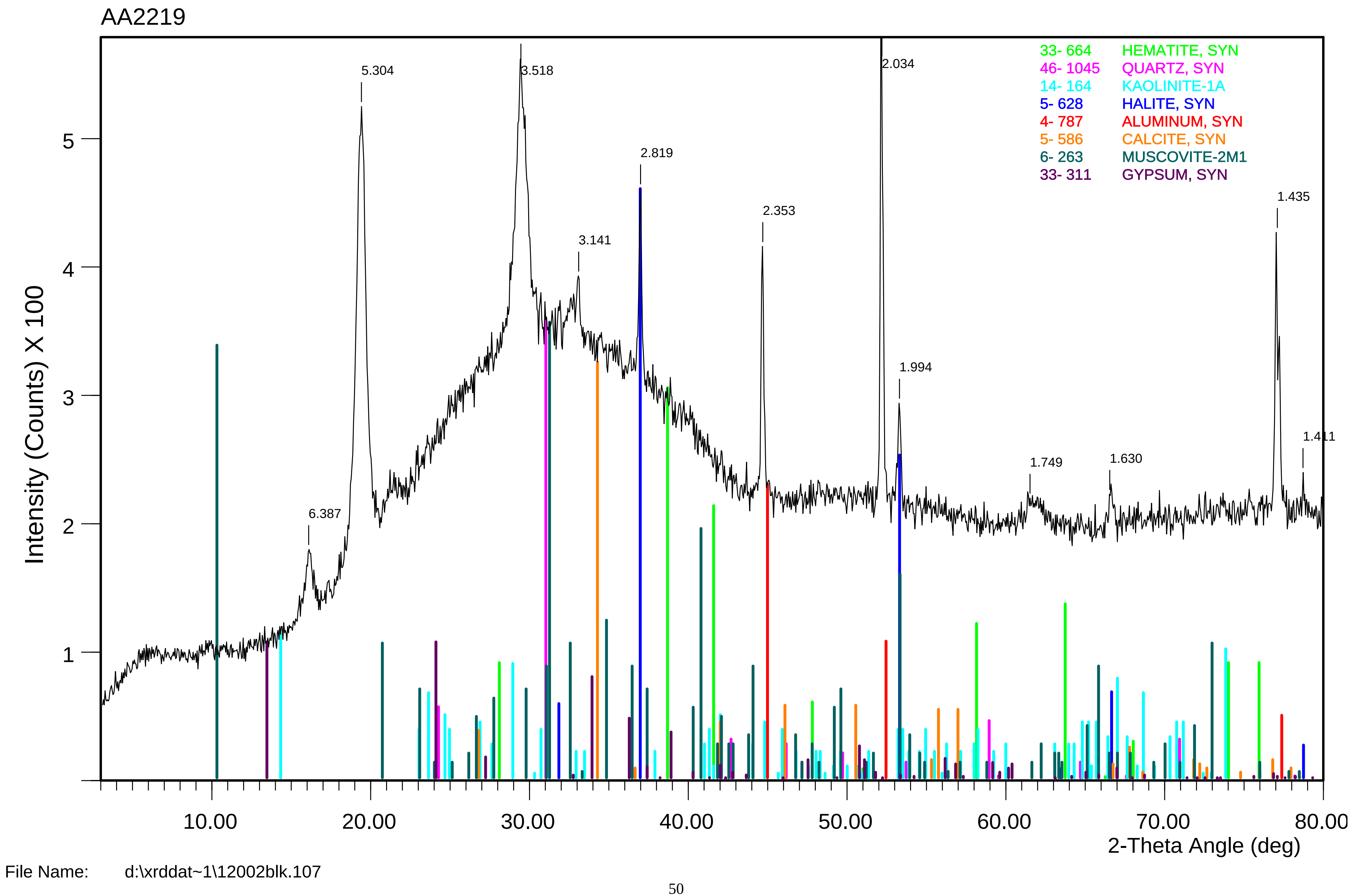
AA1876



File Name: d:\xrddat~1\12000blk.105



File Name: d:\xrddat~1\12001blk.106


AA2219
33- 664 HEMATITE, SYN
46- 1045 QUARTZ, SYN
14- 164 KAOLINITE-1A
5- 628 HALITE, SYN
4- 787 ALUMINUM, SYN
5- 586 CALCITE, SYN
6- 263 MUSCOVITE-2M1
33- 311 GYPSUM, SYN
Intensity (Counts) X 100
1
2
3
4
5
6.387
5.304
3.518
3.141
2.819
2.353
2.034
1.994
1.749
1.630
1.435
1.411
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
2-Theta Angle (deg)
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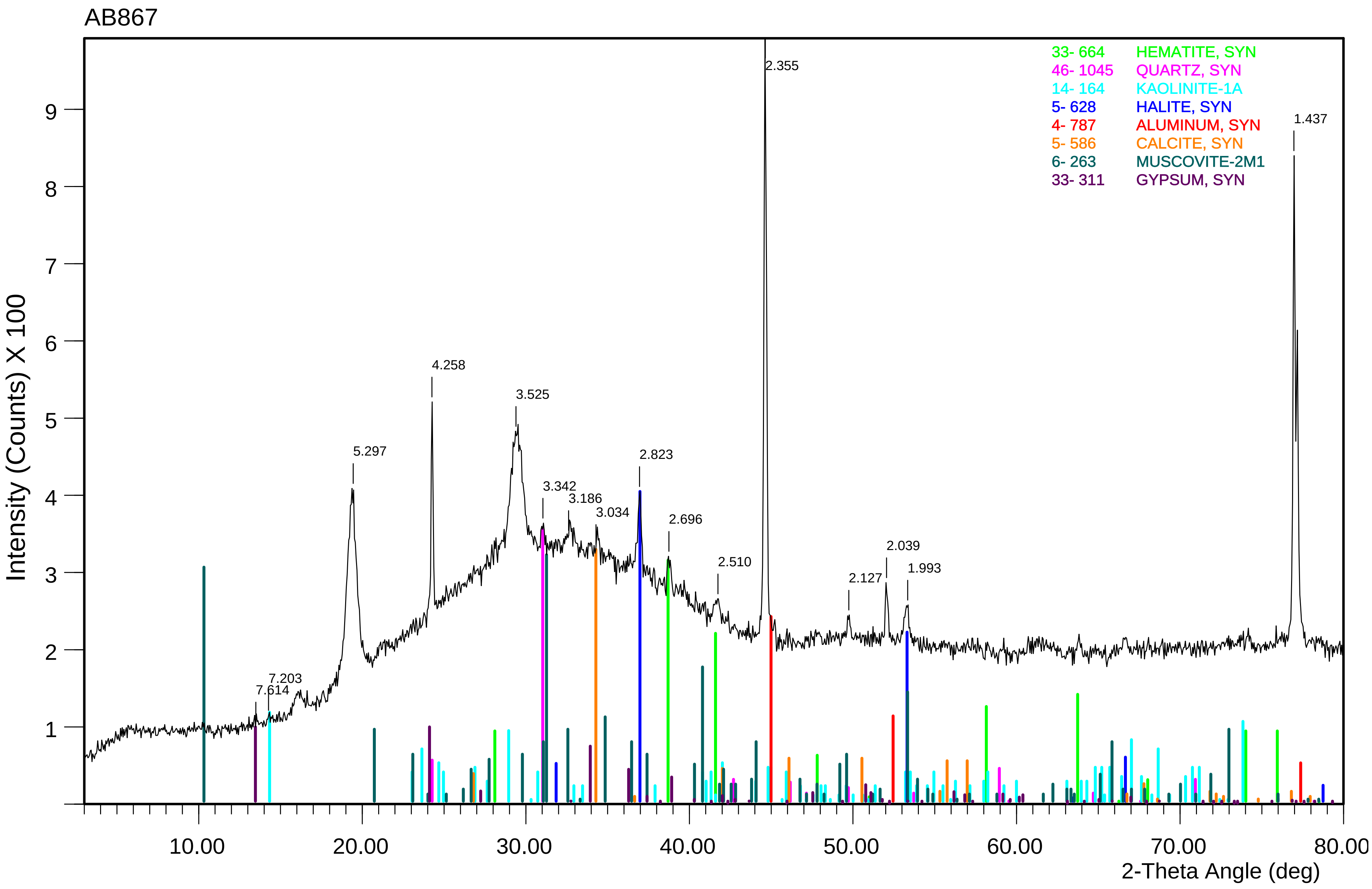

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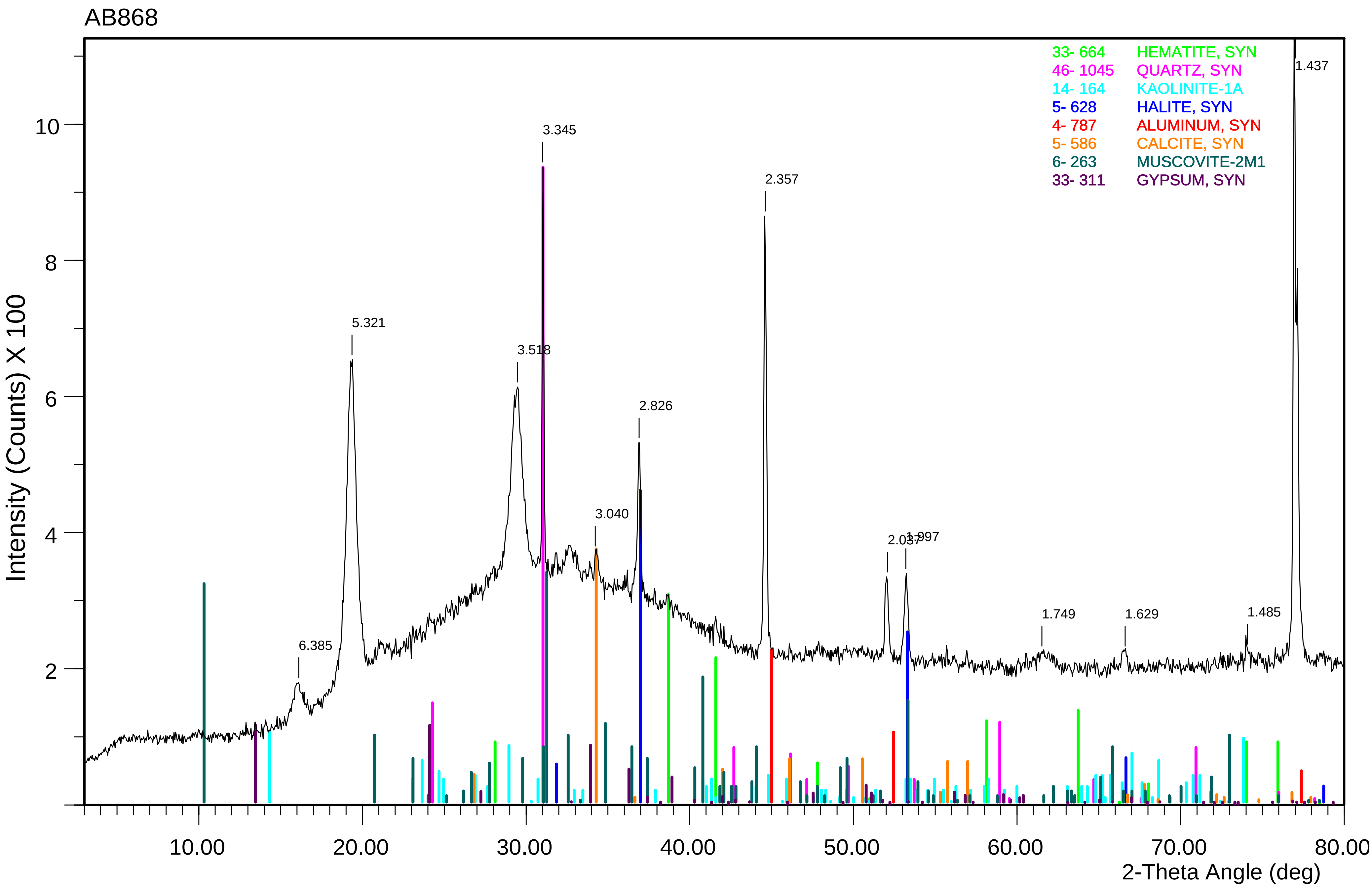

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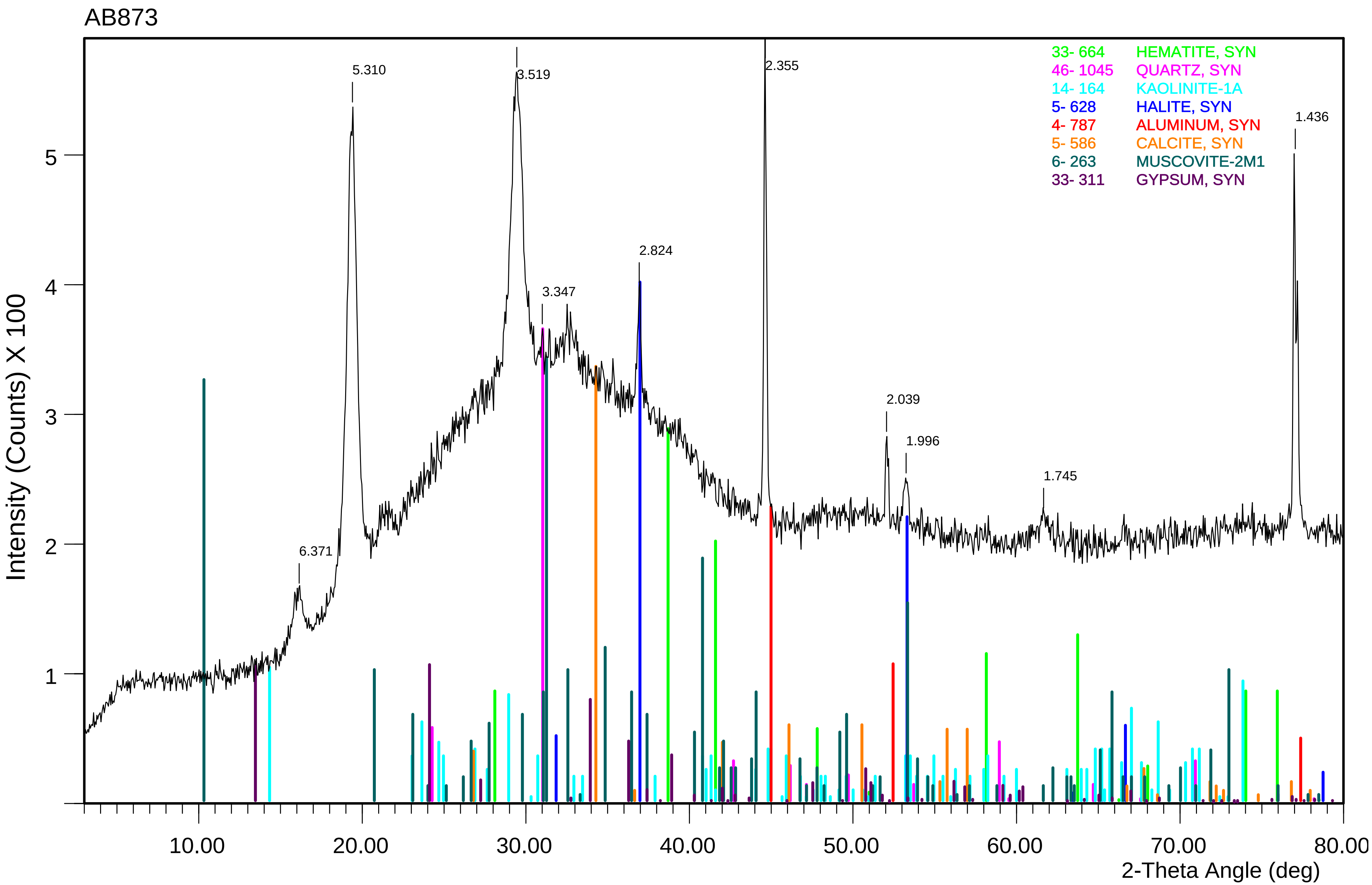

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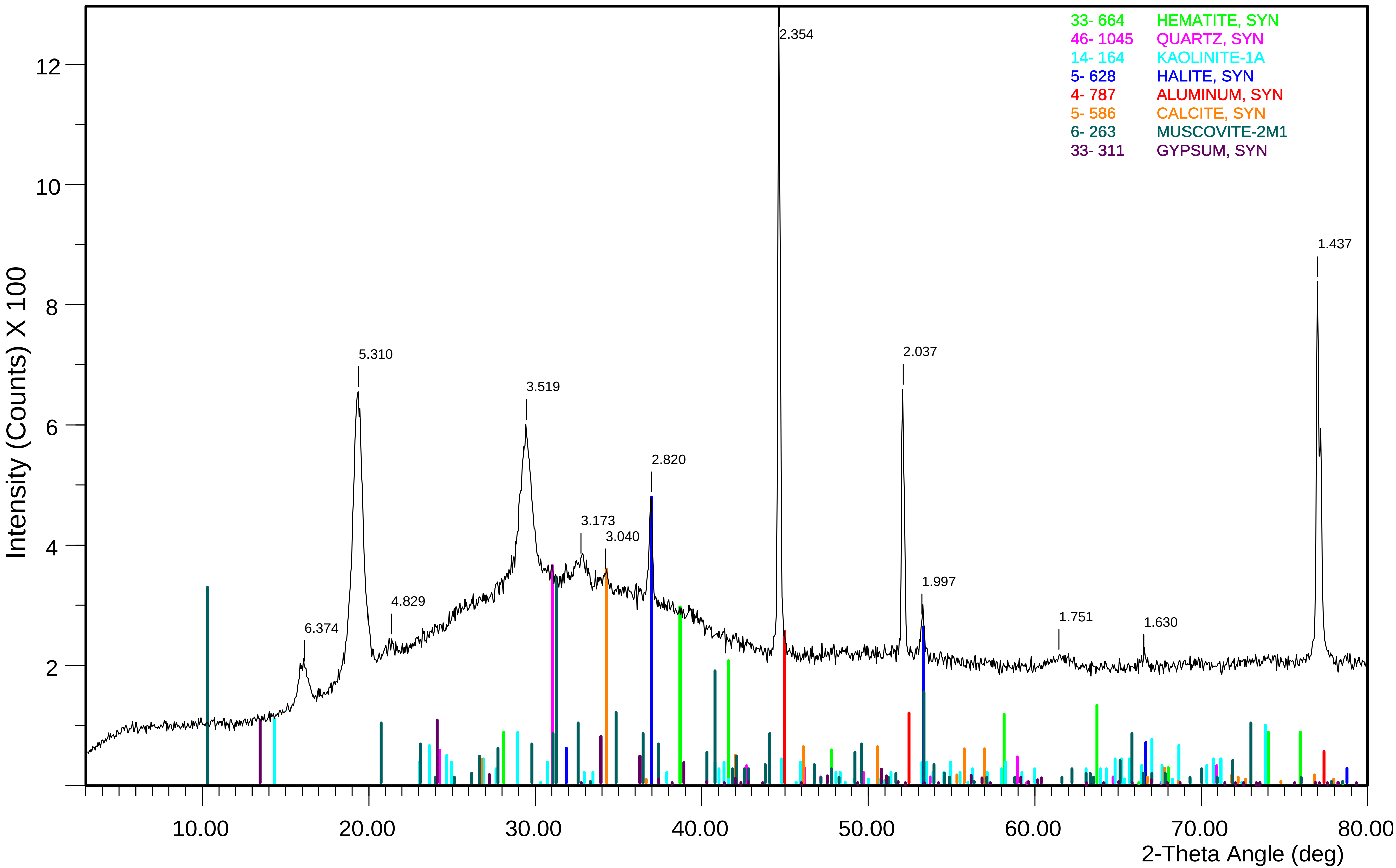
AB874



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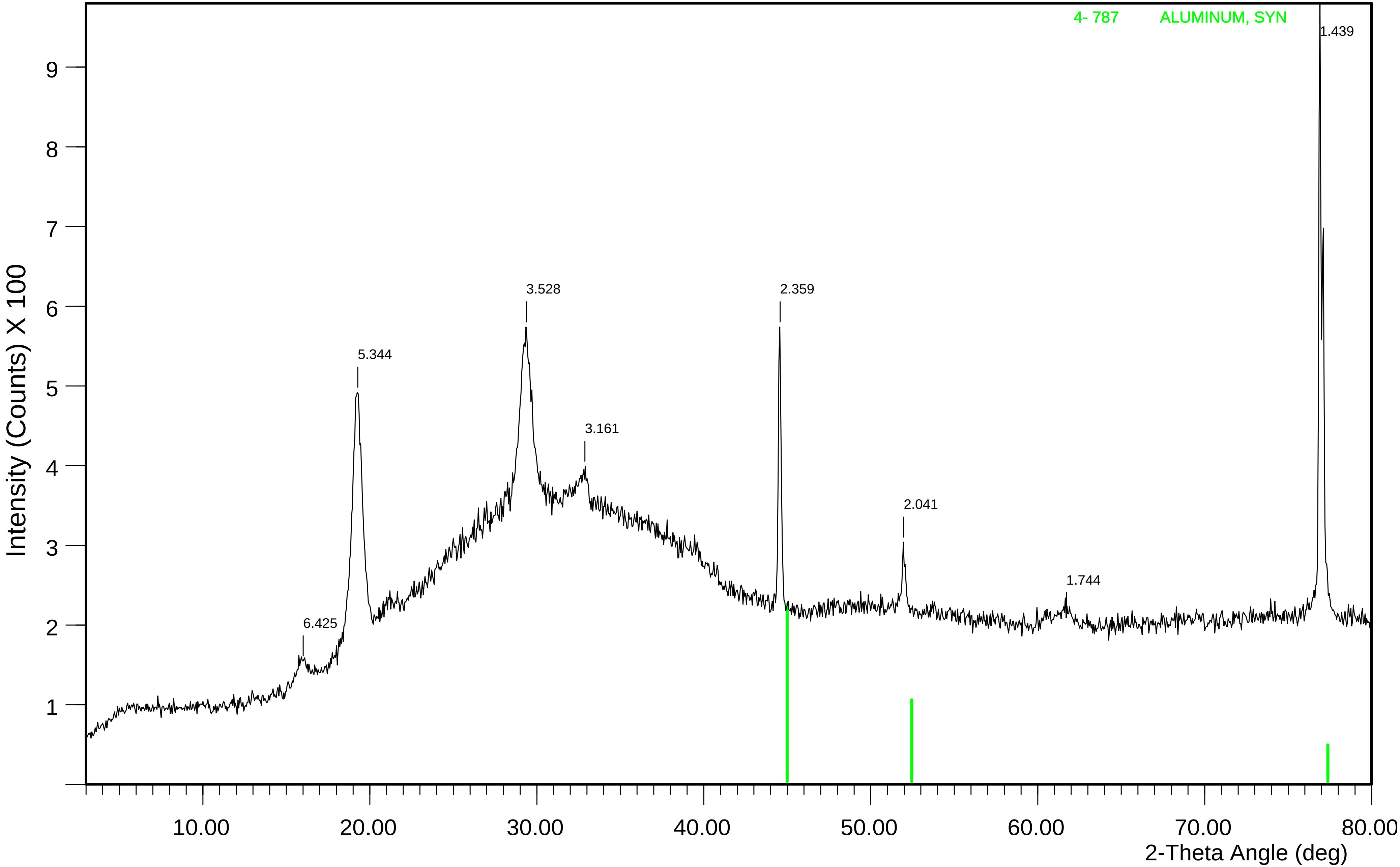

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