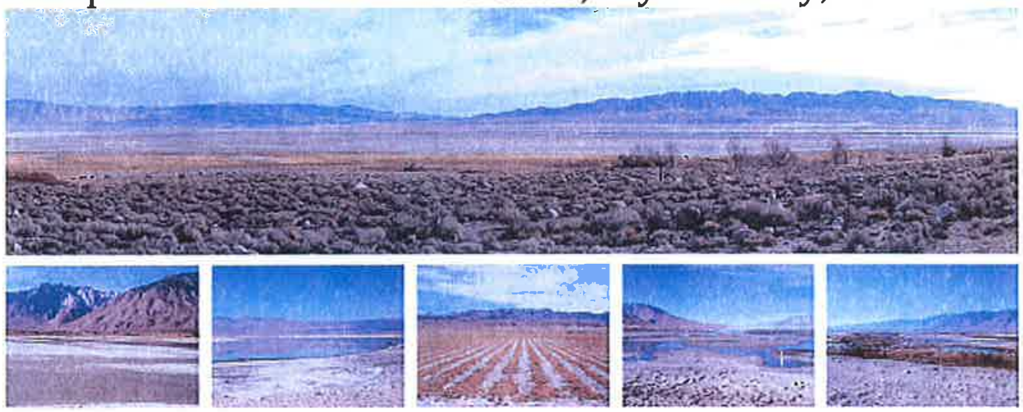
Owens Lake Shoreline Study Technical Services

Preliminary X-Ray Diffraction and Texture Analysis Report, Owens Lake Area, with Emphasis on the Keeler Dunes, Inyo County, California

AECOM

Owens Lake Shoreline Study Technical Services

Preliminary X-Ray Diffraction and Texture Analysis Report, Owens Lake Area, with Emphasis on the Keeler Dunes, Inyo County, California



Prepared for:

City of Los Angeles
Department of Water and Power
111 North Hope Street
Los Angeles, CA 90012

Contact:

Michelle Lyman
Deputy City Attorney
213-367-4530

Prepared by:

Miles Kenney, Ph.D., PG
AECOM
2020 L Street, Suite 400
Sacramento, CA 95811

Contact:

Kevin Coulton
Senior Project Manager
503-227-1042

AECOM

December 11, 2012

60221498

Table of Contents

Plates (attached at end of report)

Appendices

1 INTRODUCTION

1.1 Study Goals

The primary goal of this study was to evaluate potential eolian sand sources (windblown sand) that may have contributed sediments to the Keeler Dunes both during Historical times to the "younger" Keeler Dune system, but also to the "older" Keeler Dune system in pre-Historical periods. A secondary goal of this study was to evaluate sources of fine-grained sediments (silts and clay size grains) in the study area that may have contributed to dust emissions in the Keeler Dune system.

1.2 Potential Eolian Sand Sources for the Keeler Dunes

Potential eolian sand sources for the Keeler Dunes include erosion of sandy deposits on Lone Pine Mesa consisting of older eolian dunes and lacustrine shoreline berms, the Owens River Delta region, Swansea Bay dune systems, from across Swansea Bay, and from washes on the Keeler Fan emanating from Slate Canyon. Based on prevailing wind directions and geomorphic mapping, the component of eolian sands transported from the Swansea Dunes to the Keeler dunes is very low. Sand source evaluation within the younger Keeler Dune system is complicated due to erosion of older Keeler Dune deposits within the system primarily during the past 30 years. The internal erosion of the Keeler Dune system occurred within an older dune mound system (pre-Historical) that likely began to form sometime between 2,700 to 1,700 years Before Present (BP – time before the year 1950 AD).

2 METHODS

2.1 Sampling Number and Locations

X-ray Diffraction (XRD) analysis was performed on ten samples in the northeastern Owens Lake region that included Lone Pine Mesa, the Swansea Bay shoreline including the Swansea Bay Dunes, on the Swansea Bay lake bed, areas of the old North Sand Sheet, Swansea Dunes, active alluvial sediments on the Keeler Fan, the Older Keeler, and the Older Keeler "shoreline" dunes (Plate 1). XRD data acquired by the GBUAPCD (District) have been published (Baker, 2012) in the same general region (Appendix C). These results were also utilized in our analysis. Texture analysis was performed to evaluate the quantity of fine-grained sediments (silts and clay sizes) in local deposits to provide a qualitative evaluation of their emissivity potential.

The XRD analyses were performed by Applied Petrographics Services, Inc. and their report is provided in Appendix A. A texture analysis was performed by IAS Laboratories on four of the XRD samples and these results are provided in Appendix B. Twelve additional texture evaluations by IAS Laboratories were conducted for a sand proportionment study by Air Sciences and these data are also provided in Appendix B.

2.2 Processing the XRD Data

Mineral percent values provided in the Applied Petrographic Report (Appendix A) on 10 samples were normalized such that the results could be plotted on mineral percent ternary diagrams. Ternary diagrams are useful to provide the evaluation of the variation of the composition of different samples in a spatial manner. The XRD analyses identified: quartz; sodium-calcium feldspars, including albite, anorthoclase, anorthite, and labradorite; potassium feldspar, including microcline and orthoclase; carbonate minerals, including calcite (calcium carbonate) and dolomite (magnesium-calcium carbonate); halite (salt); muscovite (mica); chalcopyrite; montmorillonite (clay); glauconite; illite (clay size mica); and, orthopyroxene.

The XRD analysis by Applied Petrographic (Appendix A) was unable to provide relative mineral abundances for every mineral in each sample primarily due to the complexity and number of the mineral assemblages. For this reason, the provided mineral percentages in their report simply combined minerals with similar X-ray diffraction patterns. For example, we were informed verbally by Applied Petrographic Services that the relative percent values provided for albite includes minerals from the sodium-calcium feldspar series. Mica and clay minerals exhibit very similar X-ray diffraction patterns, which leads to difficulties in evaluating which of the two, if not both, actually occur in a sample.

As a result of these types of issues, the XRD mineral percent analysis (Appendix A) identified a total of ten minerals in all the samples that include quartz, albite, microcline (K-spar), Calcite (calcium carbonate), halite (salt), Dolomite (magnesium calcium carbonate, mica (muscovite), clay, orthopyroxene, and orthoclase (K-spar). Lastly, because microcline and orthoclase are both "K-spar" minerals, the percent abundance of these minerals were combined during the analysis.

3 FINDINGS

3.1 Ternary Diagrams – Visualizing the XRD Data

Seven mineral percent ternary diagrams were produced by normalizing their relative percent values (Plates 2 through 8). In all the ternary diagrams, the percent of quartz and "albite" were used for consistency, and the third mineral varied. XRD data provided by the Great Basin Unified Air Pollution Control District (District, 2012; Baker, 2012) were also plotted on the seven ternary diagrams. Each of the ternary diagrams (Plates 2 through 8) are discussed briefly below.

- Plate 2 plots **orthoclase (and microcline)** relative to quartz and albite. This ternary diagram represents comparison of the most abundant minerals in most of the samples and represents a granodiorite "igneous plutonic-granitic" composition. Plate 2 exhibits the same minerals plotted on the ternary diagram provided by the District (2012) on their Figure 4.5-5. Granodiortites rocks are common in the Sierra Nevada Mountains. All three of these minerals are relatively robust in terms of their rate of chemical and mechanical weathering indicating that they can be transported further distances than many of the other minerals analyzed during this study. In general, as sediments are transported by wind or fluvial processes, the percentage of quartz gradually increases over time.

- Plate 3 plots **calcite** relative to quartz and albite. Calcite is a calcium carbonate mineral which is the same composition as marble (metamorphosed calcite). Thus, in the samples, calcite may be a precipitated mineral due to surficial processes in recent times, or could represent eroded sediments from metasedimentary marbles in the local Inyo Mountains. During wind and fluvial transport, calcite chemically and mechanically erodes relatively quickly and thus their relative abundance in these types of deposits typically decreases fairly quickly during transport and weathering processes. Thus, their presence suggests a relatively close source geographically and that the sediments are "immature". However, as discussed earlier, calcite can also form on the surface due to groundwater and fluvial processes.

- Plate 4 plots **dolomite** relative to quartz and albite. Dolomite is a calcium-magnesium carbonate mineral and likely was derived from the local Inyo Mountains. During wind and fluvial transport, dolomite chemically and mechanically erode relatively quickly and thus their relative abundance in these types of deposits decreases fairly quickly during transport and weathering processes. Thus, the presence of dolomite in a sample suggests that its source is likely relatively close geographically and that the sediments are immature.

- Plate 5 plots **halite** relative to quartz and albite. Halite is a sodium-chloride salt and forms due to near surface processes in recent times. Abundant salts are produced on the Owens Lake bed but could also form in other environments as well but to a lesser extent.

- Plate 6 plots **mica** (muscovite) relative to quartz and albite. Mica minerals such as muscovite typically developed in igneous (from magma crystallization) and metamorphic rocks. These types of rocks occur both in the Sierra Nevada and Inyo Mountains. During wind and fluvial transport, mica minerals tend to chemically and mechanically erode relatively quickly and thus their relative abundance in these types of deposits decreases fairly fast during transport and weathering processes. The presence of muscovite in a sample suggests that the mica source is likely relatively close geographically and that the sediments are immature. Difficulties arise in the XRD data in terms of knowing whether or not the muscovite is actually clay minerals and vise versa due to their similar X-ray diffraction patterns.

- Plate 7 plots **clay** relative to quartz and albite. Clay minerals typically develop associated with near surface chemical weathering processes such as soil pedons. Clays are common in the distal flood deposits on the Keeler Fan and as lacustrine (lake) deposits on the Owens Lake bed. The term clay has two meanings in Geology, both as a group of clay minerals with distinct "clay" compositions, and also as a grain size (the smallest of the designated grain sizes. As discussed above for Plate 6, the X-ray diffraction for clays and micas are very similar, thus the percentage of mica provided for samples 15 and 29 (the only samples exhibiting mica, may actually be clay minerals or simply clay size grains. It is interesting to note that the XRD percent mica for sample 15 is 26.4% and the percent clay size grains on the texture analysis (Appendix B) is 26%. For this reason, Plate 7 also provides plotted locations for samples 15 and 29 that incorporate both the XRD percent clay and mica added together. These samples are labeled 15A and 29A.

- Plate 8 plots **orthopyroxene** relative to quartz and albite. Orthopyroxene typically forms in igneous (mafic) and metamorphic rocks. Once exposed to near surface weathering processes the mineral chemically breaks down relatively quickly. Hence, it presence suggest are relatively close source geographically and according, immature sediments in terms of transport distance.

3.2 Texture Analysis

Sixteen texture (sieve and hydrometer) tests were conducted to evaluate the percent of gravel, sand, silt and/or clay size particles occurred in various samples. The texture data is provided in Appendix B and their locations are provided on Plate 1. Most of the samples on Lone Pine Mesa, Owens Lake bed in the Swansea Bay area, dune systems of Swansea Bay, Swansea and Keeler, and the Keeler Fan were dominated by sand and/or gravel. The only samples exhibiting abundant fine-grained sediments (silts and clays) were associated with flood deposits emanating from Slate Canyon and flowing down the Keeler Fan.

4 CONCLUSIONS

Preliminary conclusions of the XRD and Texture analysis include:

- The Keeler Fan wash mineral assemblage and grain sizes are clearly distinct and different than the eolian samples. The Keeler Fan Wash samples exhibit a mineralogy that correlates well with weathering of metamorphic (metasedimentary) rocks, which is consistent with their source within the Inyo Mountains.

- Samples exhibiting relatively abundant fine sediments include active fluvial sediments associated with the Keeler fan, older flood deposits within the older Keeler Dunes exposed by abrasion during the past 30 years, and older lake plain deposits below elevation 3619 feet located on the western edge of the Keeler dunes. These data indicate that the in the region of the Keeler Dunes, numerous local sources of fine grained sediments occur.

- The Lone Pine Mesa, Swansea Bay and Owens Delta eolian sands are very similar to the Keeler Dune sands. This suggests a similar source. The modern Swansea dunes sands also exhibit a similar composition utilizing the District's XRD data (Baker, 2012). Accordingly, the primary eolian sand source for the Keeler dunes is likely from the north to northwest including Owens

Delta, Lone Pine Mesa, the Swansea Bay dunes, and Swansea Bay (lake bed and as a sand transport migration zone).

- The older Swansea Dune deposits (sample XRD-32 which was collected beneath three weak buried soil horizons (paleosols) show a distinct composition based on one sample compared to the actively moving sand in these dunes (District sample OL-11-009). This suggests that the sand source for the older-original Swansea Dunes may have changed compared to recent times. Based on these data, it is possible that the older Swansea dunes (pre-historical) received a relatively strong sand source from the Keeler Wash, thus from the south. However, this conclusion is based on very limited data.

- The District's XRD data exhibits a very high precision that does not seem reasonable for natural deposits in the area, and this may be the result of sample preparation techniques.

- XRD analysis has difficulty distinguishing between clay minerals and micas. The texture data only provides a percent of clay size particles and, thus, it is difficult to ascertain whether or not clay minerals actually exist in the texture samples.

- There is a paucity of halite in all the XRD samples. In fact all samples showed zero halite (XRD) with the exception of XRD sample 9 located on Owens Lake in an area approximately near the contact of the North Sand Sheet and Swansea Bay. The salt likely originates from precipitation occurring on the lake bed.

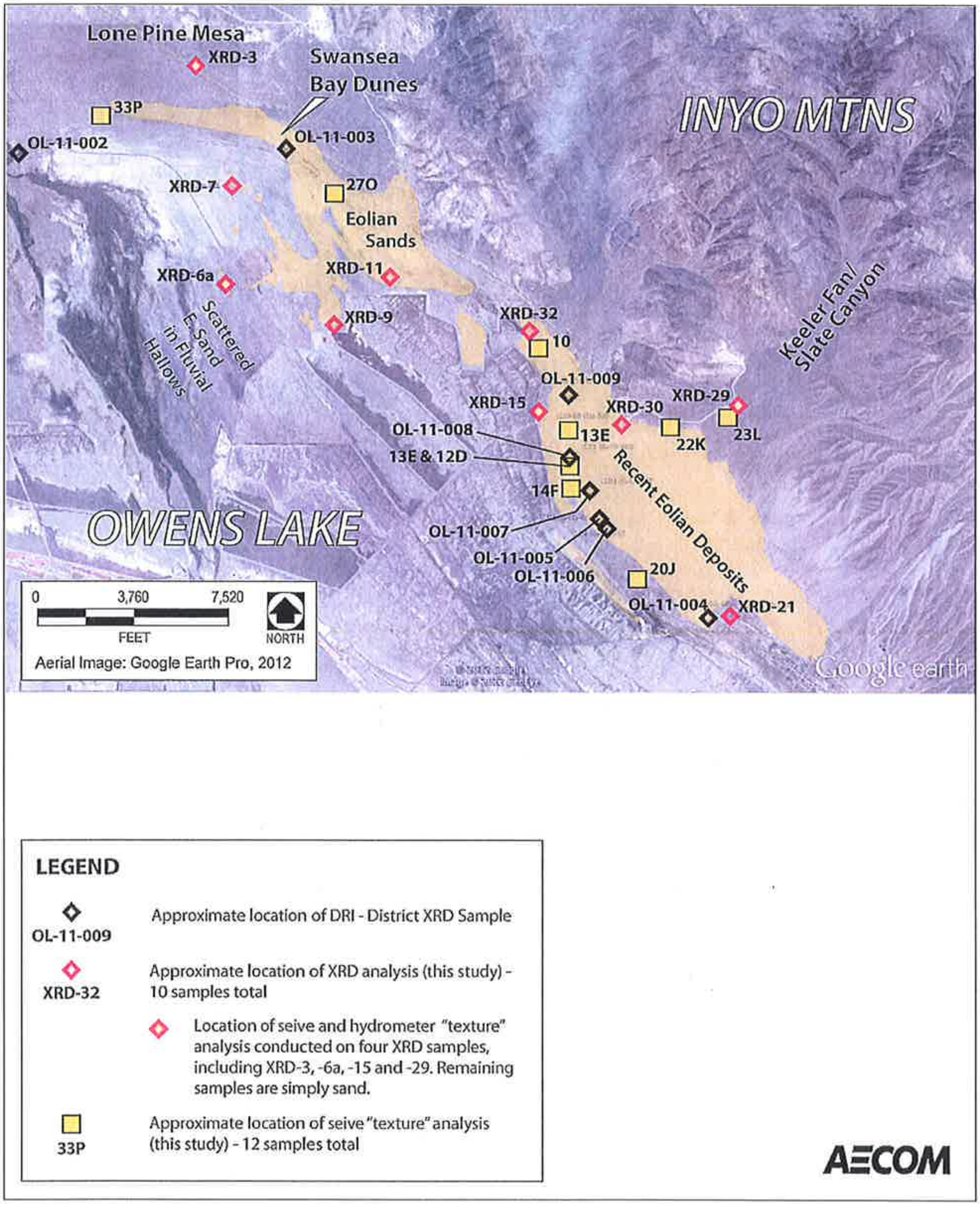
- Calcite, which can behave in many ways as a salt in the near surface, may actually have originated from marbles (metasedimentary) in some samples. The Keeler Fan wash samples exhibited the highest calcite values and it is likely attributed to mechanical weathering of metasedimentary cratonal rocks exposed in the Inyo Mountains.

5 REFERENCES

Baker, S., 2012; Keeler Dunes – Bulk XRD Analysis, February 2012; *in* Great Basin Unified Air Pollution Control District (District), 2012, Final Staff Report on the Origin and Development of the Keeler Dunes; Report dated September 7, 2012 (revised November 16, 2012).

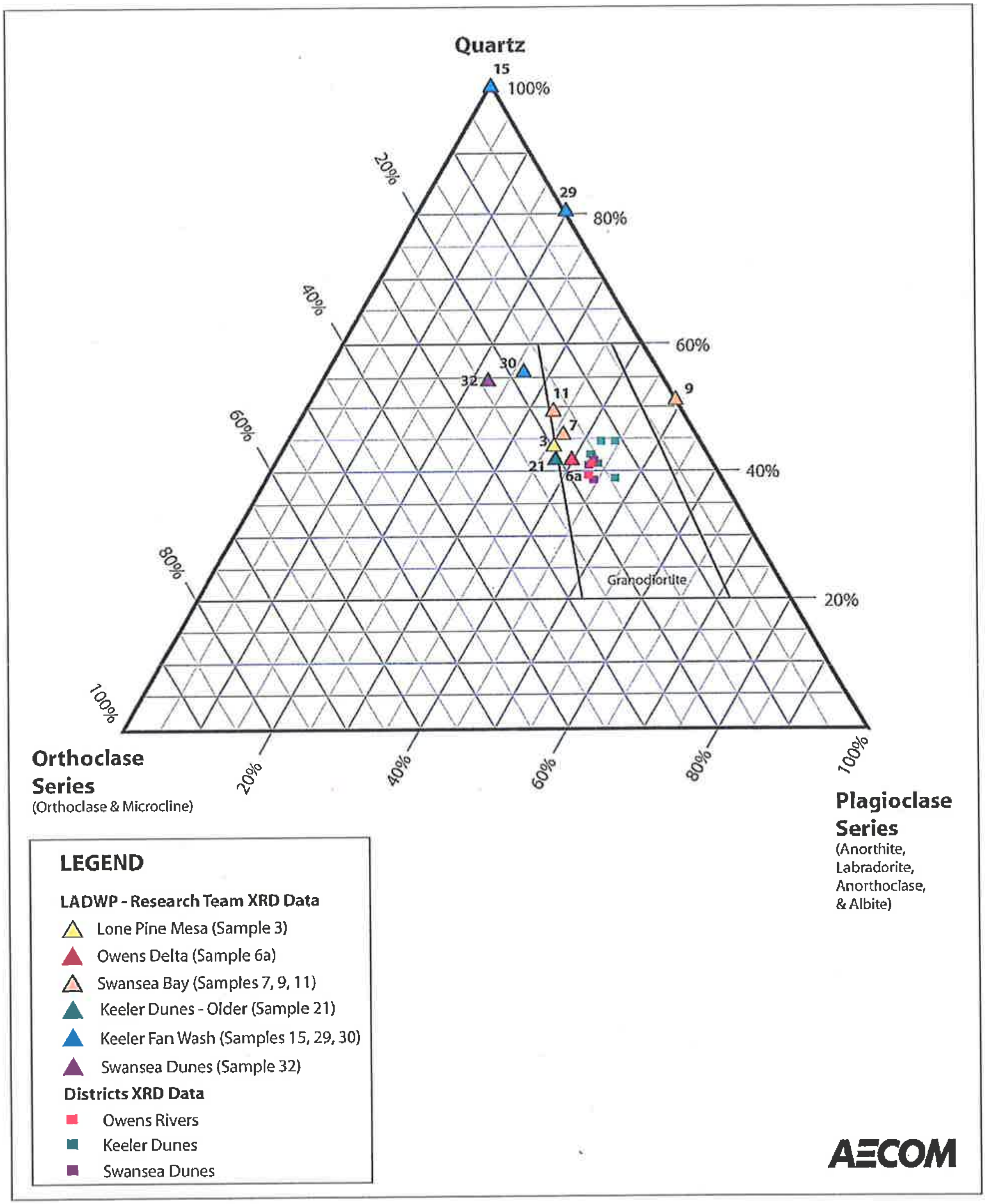
Great Basin Unified Air Pollution Control District (District), 2012, Final Staff Report on the Origin and Development of the Keeler Dunes; Report dated September 7, 2012 (revised November 16, 2012).

PLATES



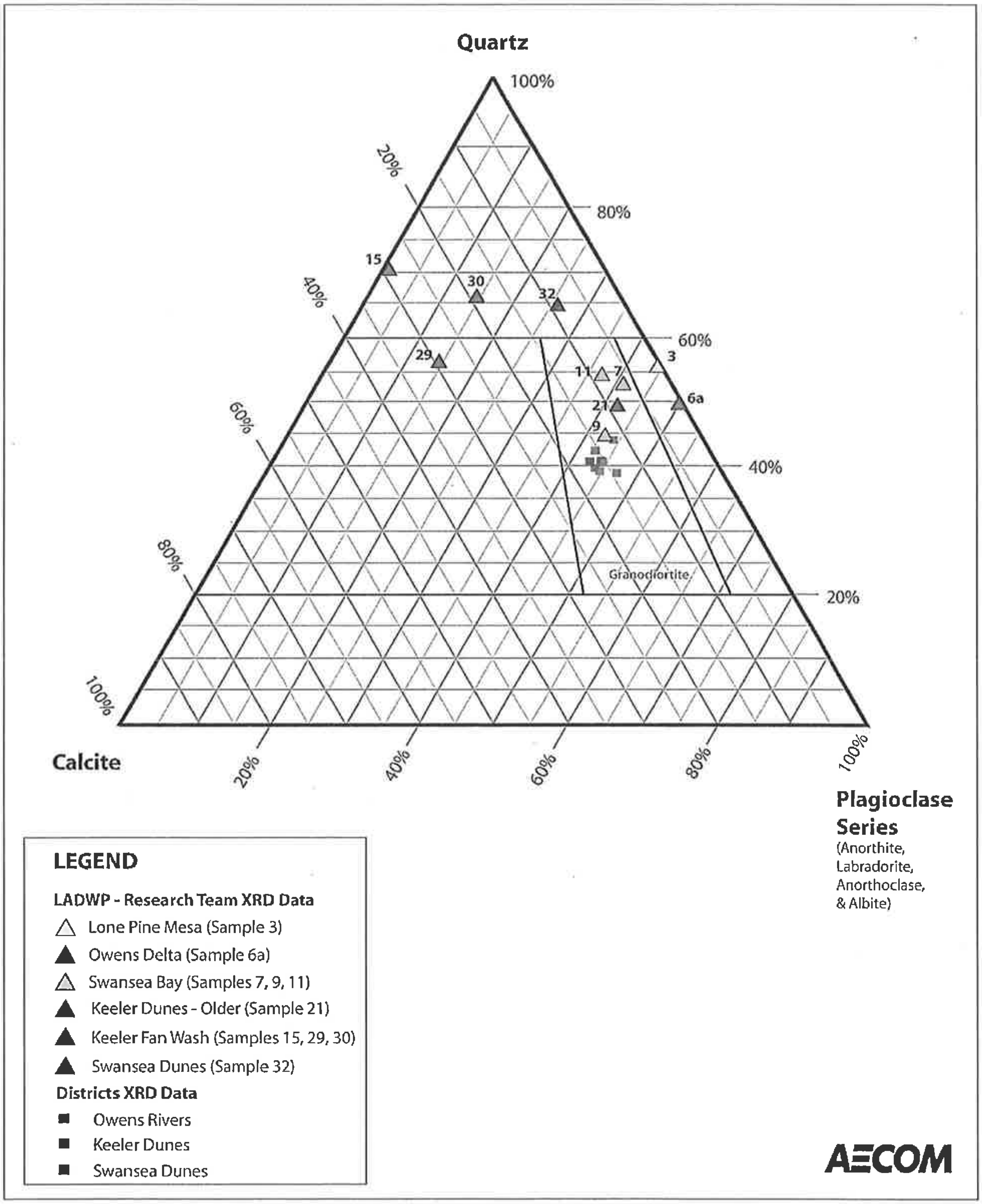
Source: AECOM, December 7, 2012

Plate 1 XRD and Texture Sample Location Map



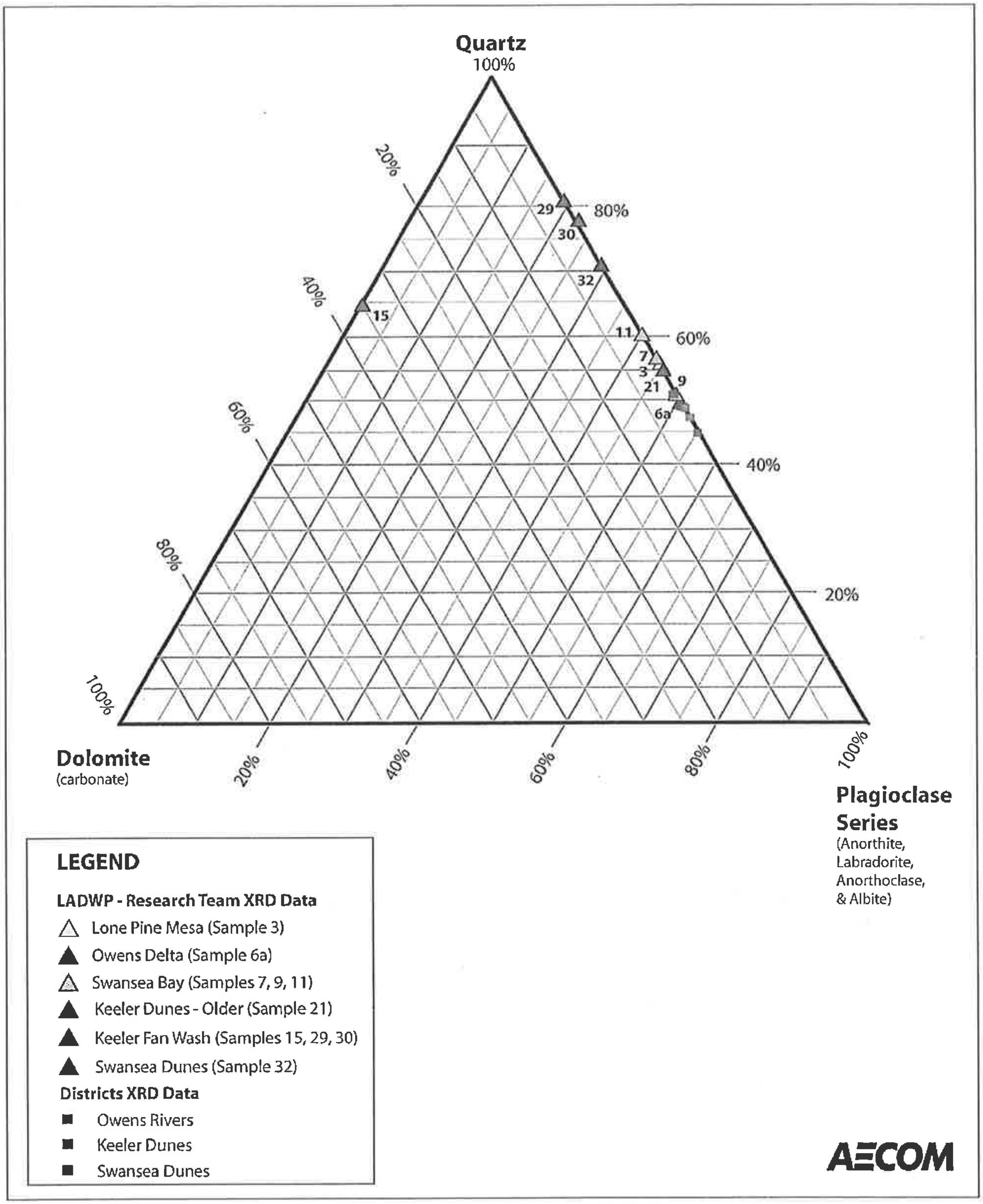
Source: AECOM, December 7, 2012

Plate 2 XRD Ternary Diagram – Quartz, Plagioclase and Microcline



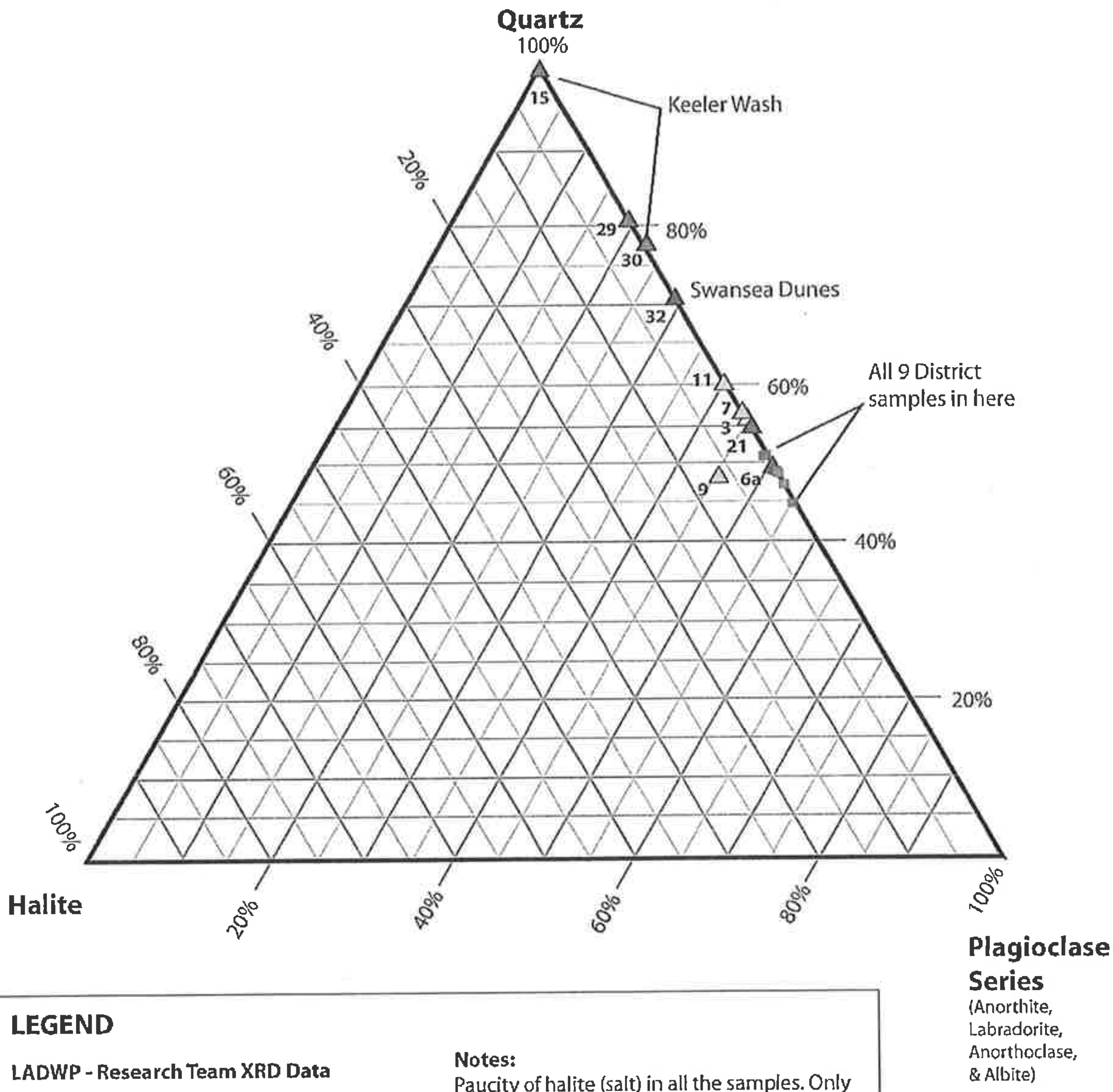
Source: AECOM, December 7, 2012

Plate 3 XRD Ternary Diagram – Quartz, Plagioclase and Calcite



Source: AECOM, December 7, 2012

Plate 4 XRD Ternary Diagram – Quartz, Plagioclase and Dolomite



LEGEND

LADWP - Research Team XRD Data

- △ Lone Pine Mesa (Sample 3)
- ▲ Owens Delta (Sample 6a)
- △ Swansea Bay (Samples 7, 9, 11)
- ▲ Keeler Dunes - Older (Sample 21)
- ▲ Keeler Fan Wash (Samples 15, 29, 30)
- ▲ Swansea Dunes (Sample 32)

Districts XRD Data

- ■ Owens Rivers
- ■ Keeler Dunes
- ■ Swansea Dunes

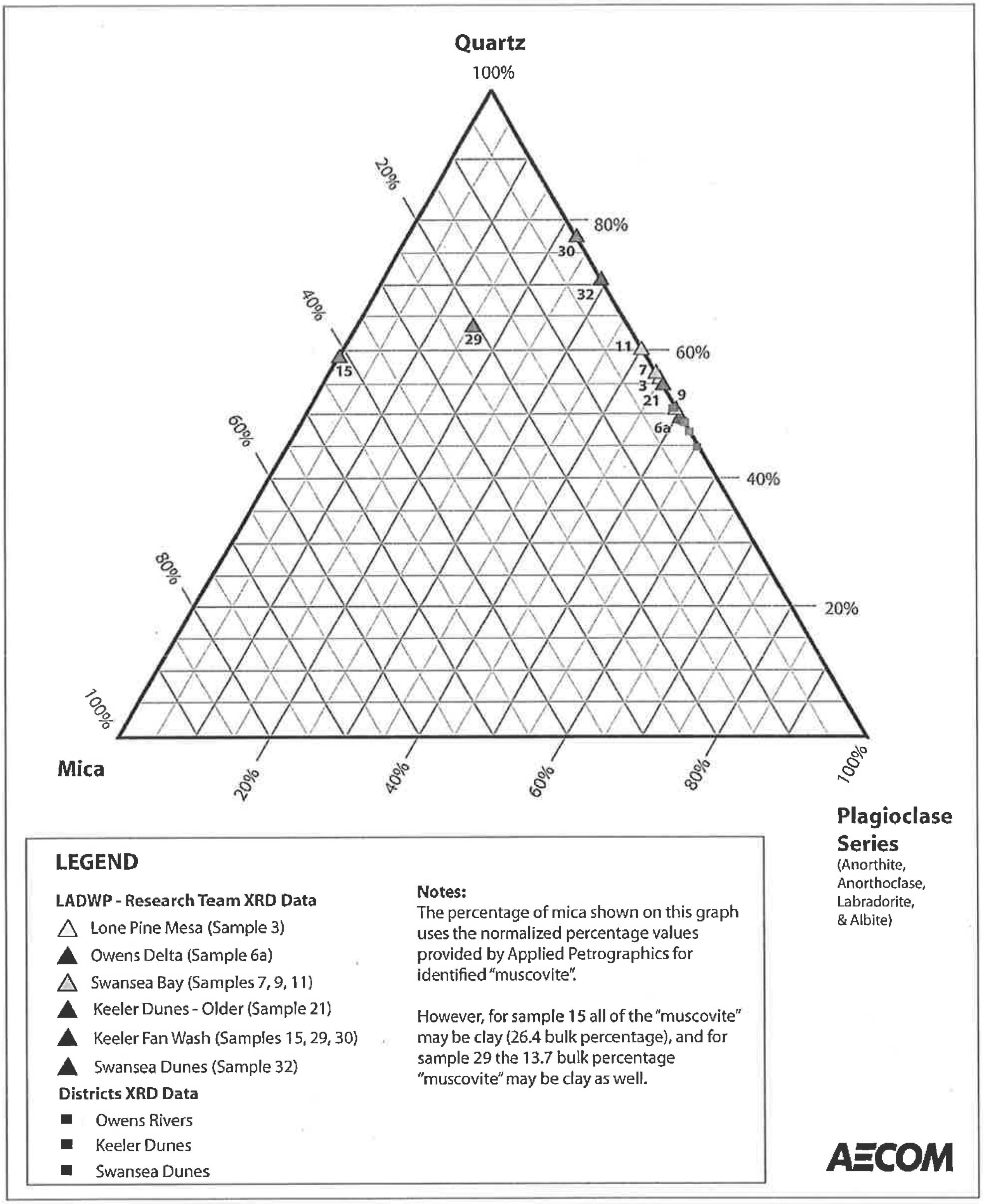
Notes:
Paucity of halite (salt) in all the samples. Only one sample has halite (Sample 9) with 5.5% relative to the total mass. Sample 9 is on the Owens Lake bed near the transition of the North Sand Sheet and Swansea Bay.

Lone Pine Mesa, Swansea Bay, and Keeler Dunes have similar Quartz, Orthoclase compositions, which are major constituents.

AECOM

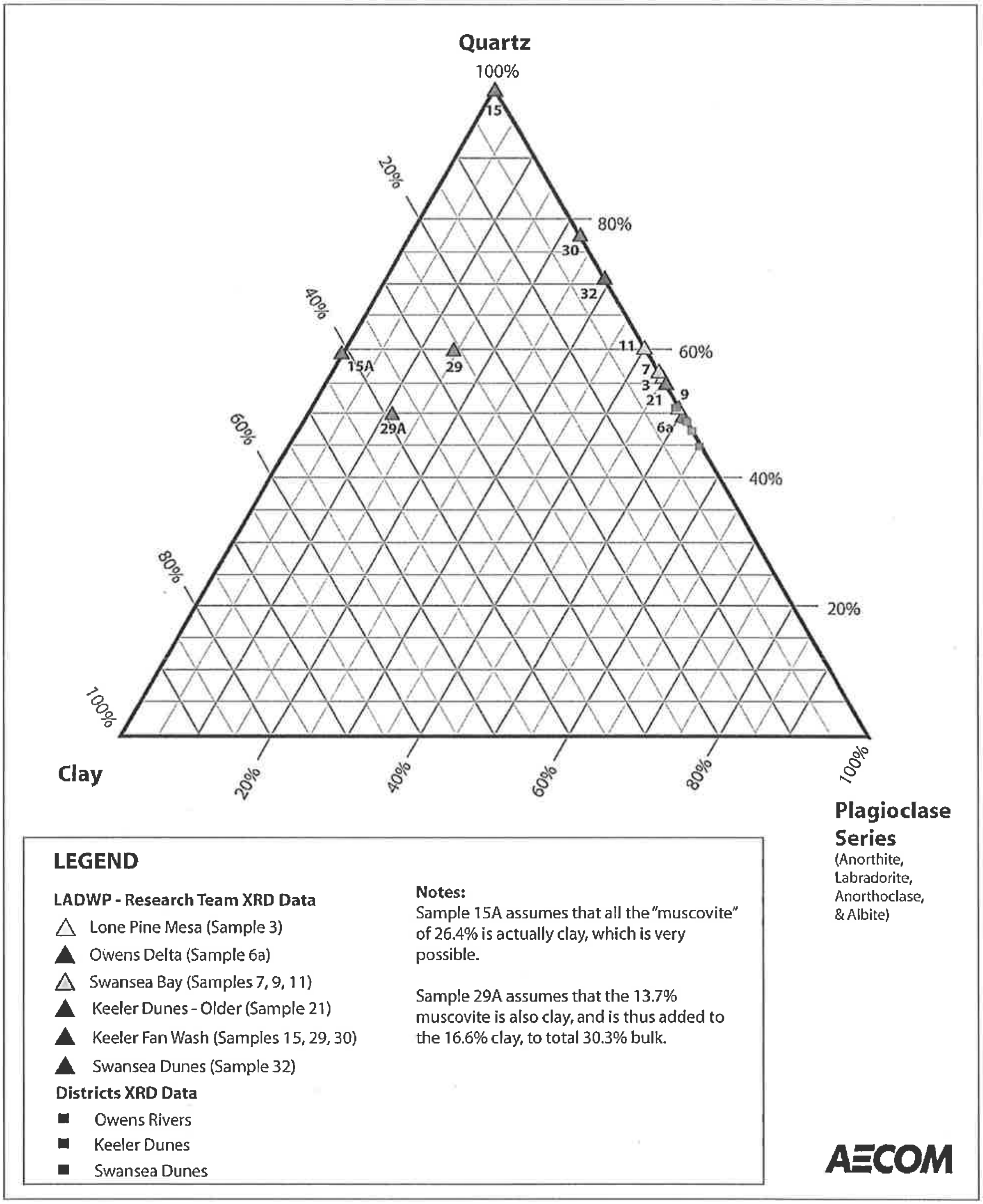
Source: AECOM, December 7, 2012

Plate 5 XRD Ternary Diagram – Quartz, Plagioclase and Halite



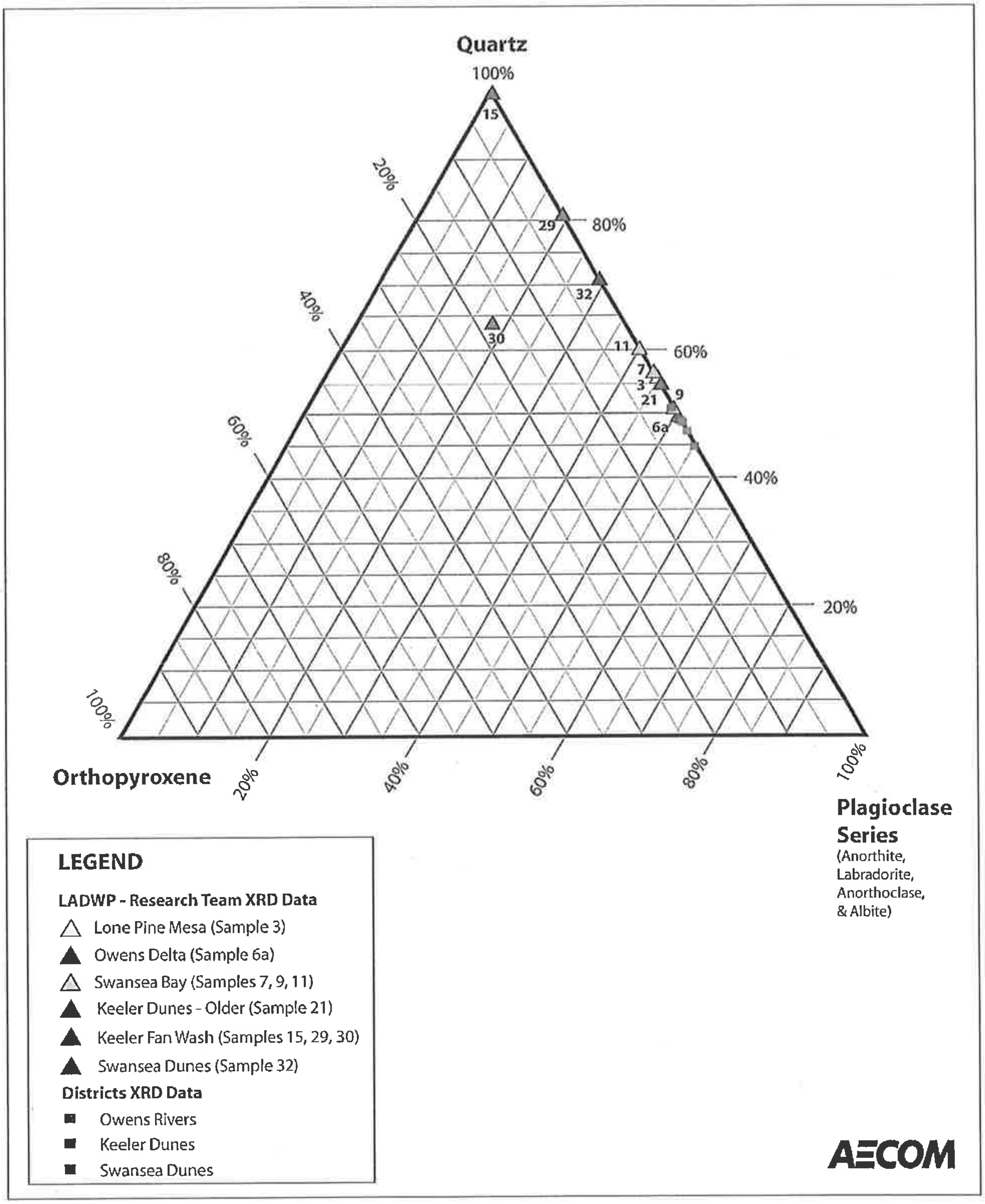
Source: AECOM, December 7, 2012

Plate 6 XRD Ternary Diagram – Quartz, Plagioclase and Mica



Source: AECOM, December 7, 2012

Plate 7 XRD Ternary Diagram – Quartz, Plagioclase and Clay



Source: AECOM, December 7, 2012

Plate 8 XRD Ternary Diagram – Quartz, Plagioclase and Orthopyroxene

APPENDIX A

APPLIED PETROGRAPHICS, X-RAY DIFFRACTION ANALYSIS OF TEN SAMPLES.

November 5, 2012

APS 1012246

X-ray Diffraction Analyses Of Ten Sand Samples

Prepared for AECOM

By Dipayan Jana
Applied Petrographic Services, Inc.

Applied Petrographic Services, Inc.

Berkshire Center, Suite 103B
4727 Route 30
Greensburg, PA 15601 USA
Phone: 724-834-3559
Fax: 724-834-3556
Toll Free: 1-800-899-0522

REPORT OF X-RAY DIFFRACTION ANALYSES

Background

Reported herein are the results of x-ray diffraction analyses of ten sand samples, received from Miles Kenney of AECOM.

The purposes of the examinations are to determine the mineralogical compositions of the sands.

Methodology & Instrumentation

All ten samples were pulverized to ultrafine (< 10-micron size) powders for x-ray diffraction (XRD) analyses. XRD analyses were carried out by using a Siemens D 3000 Diffractometer, using theta-two theta geometry. Samples were scanned at 2 degrees per minute rate, at 30mA current and 40kv voltage, using a copper Kα radiation. The diffraction patterns were searched for all phases present by using the MDI-Jade 9.0 with search-match module.

Figures 1 through 10 show x-ray diffraction patterns of all ten sand samples, where the predominance of siliceous minerals (quartz and feldspar), subordinate amounts of argillaceous minerals (mica and clay), and calcareous minerals (calcite) are shown.

APPLIED PETROGRAPHIC SERVICES, INC.

Dipayan Jana, PhD, PG
President

DJ:jlh

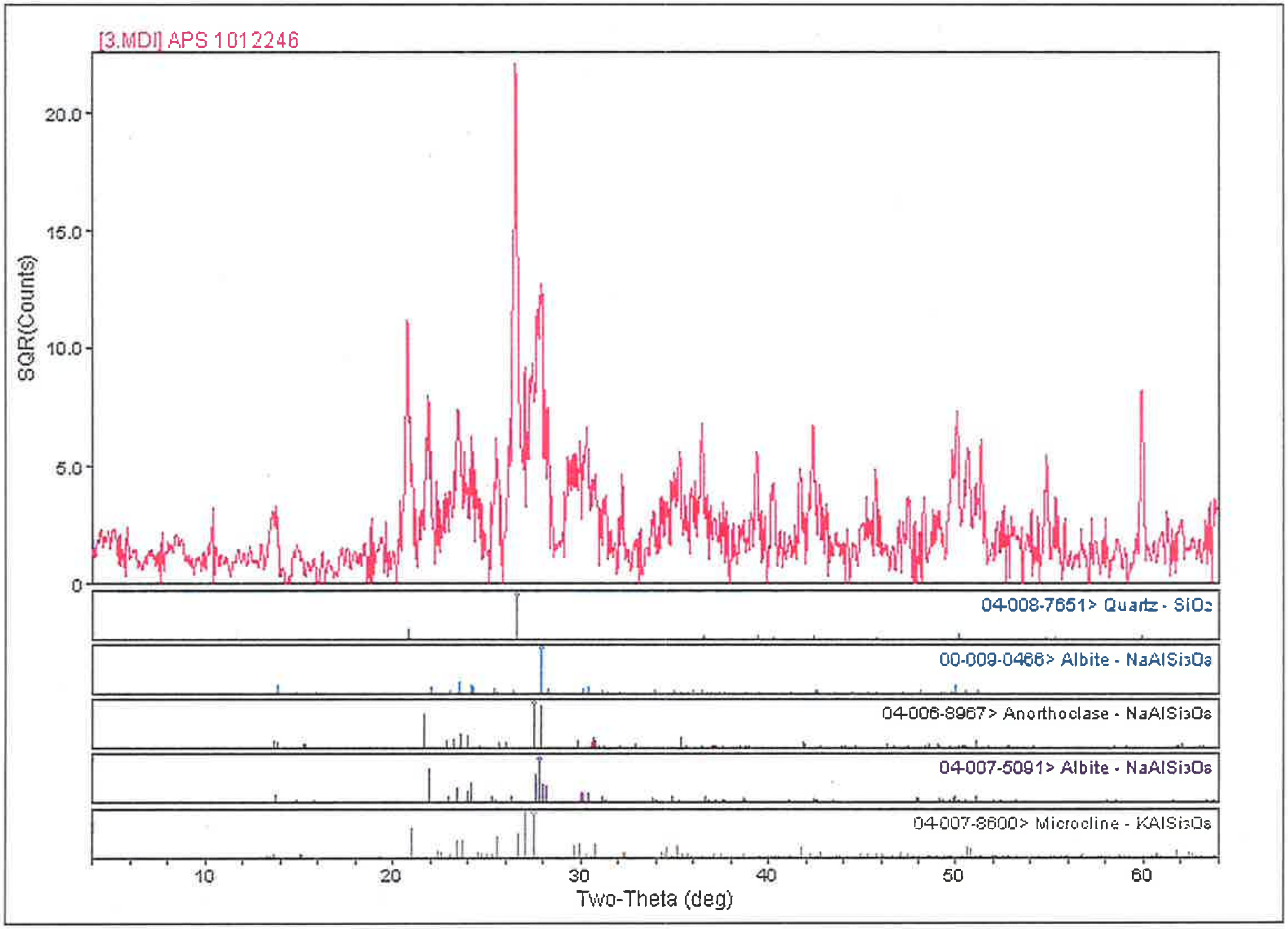


Figure 1: X-ray diffraction pattern of Sample No. 3 showing the presence of quartz, and feldspar (albite, anorthoclase, microcline) phases.

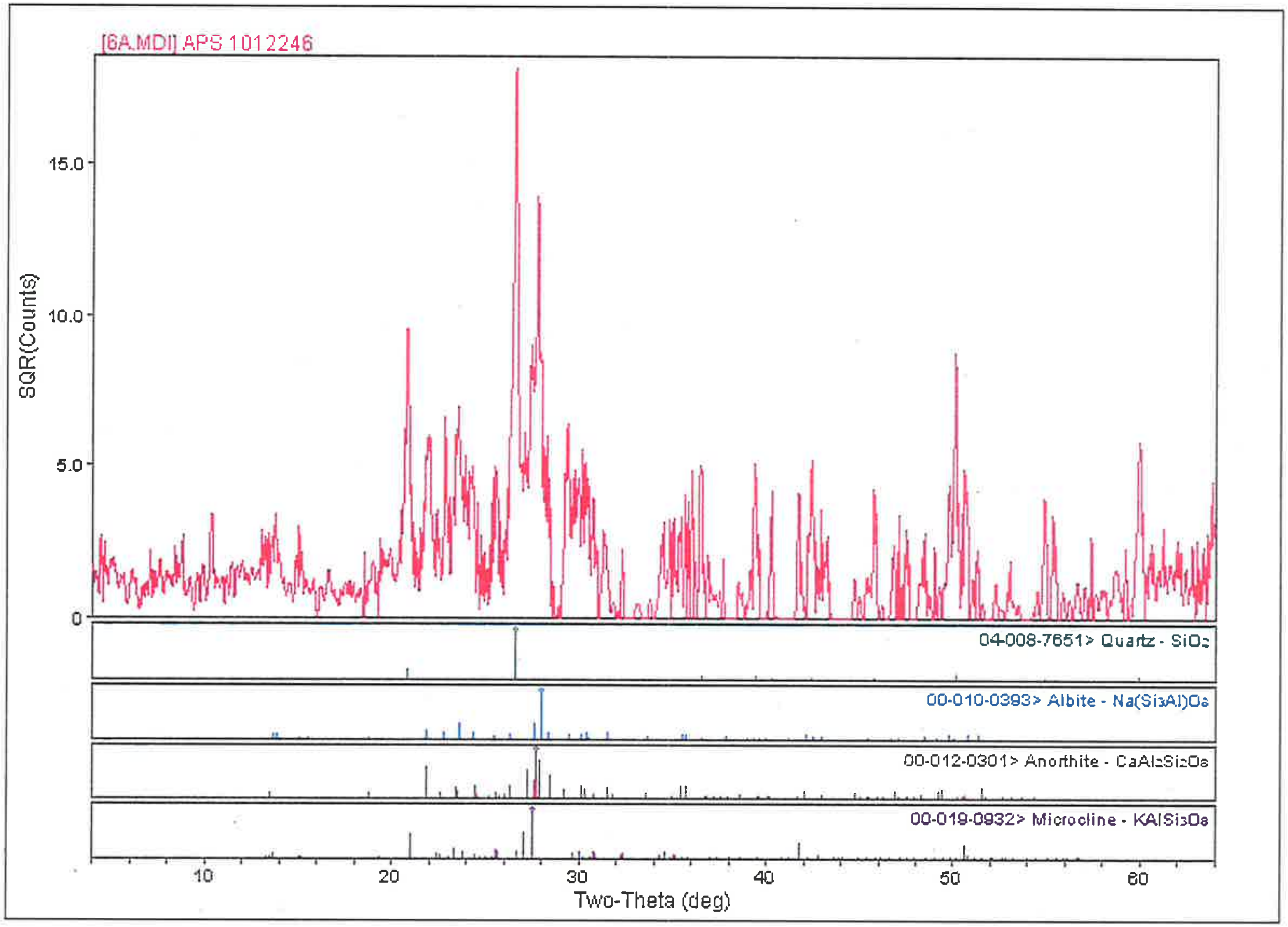


Figure 2: X-ray diffraction pattern of Sample No. 6a showing the presence of quartz, and feldspar (albite, anorthite, microcline) phases.

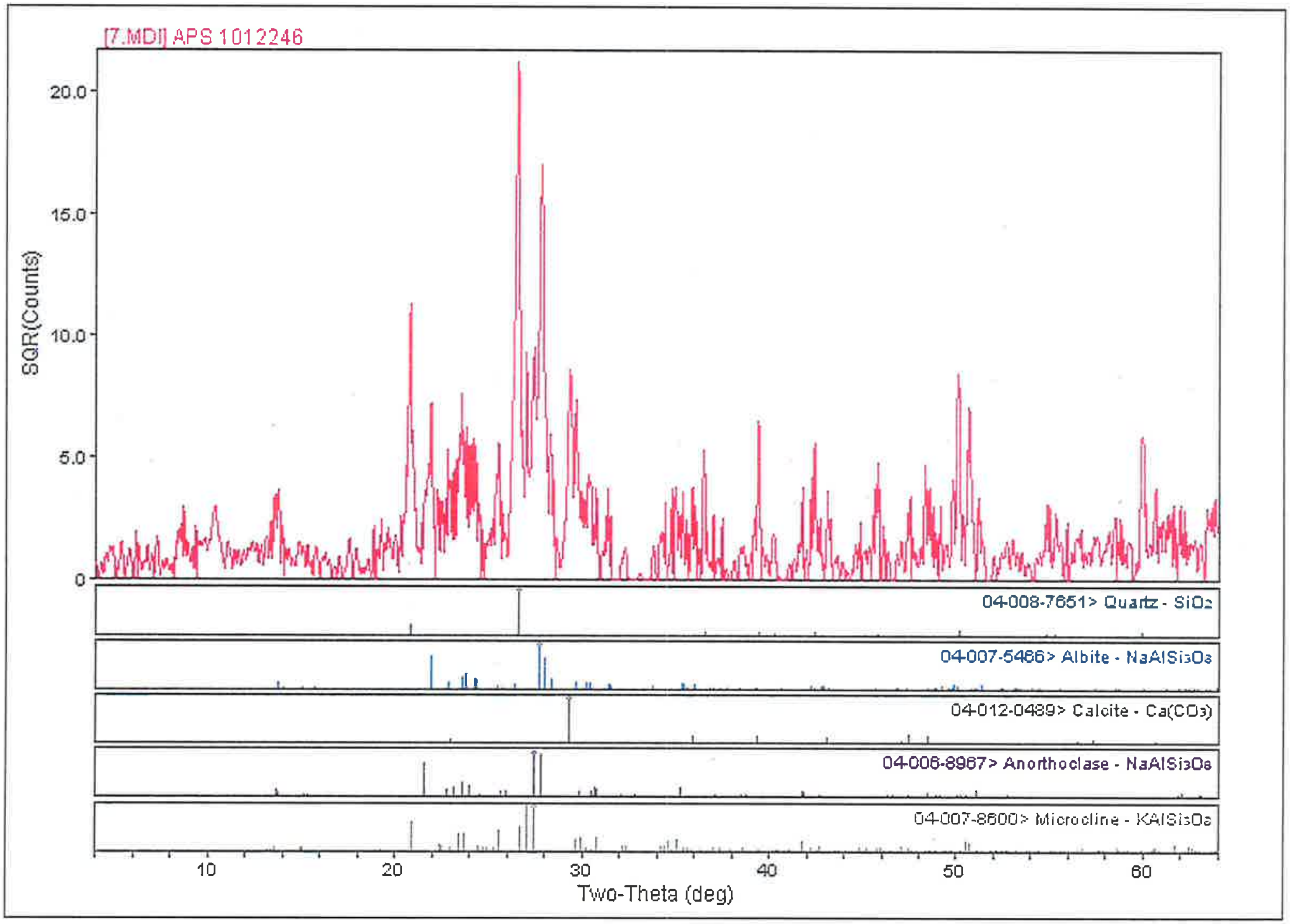


Figure 3: X-ray diffraction pattern of Sample No. 7 showing the presence of quartz, feldspar (albite, anorthoclase, microcline), and calcite phases.

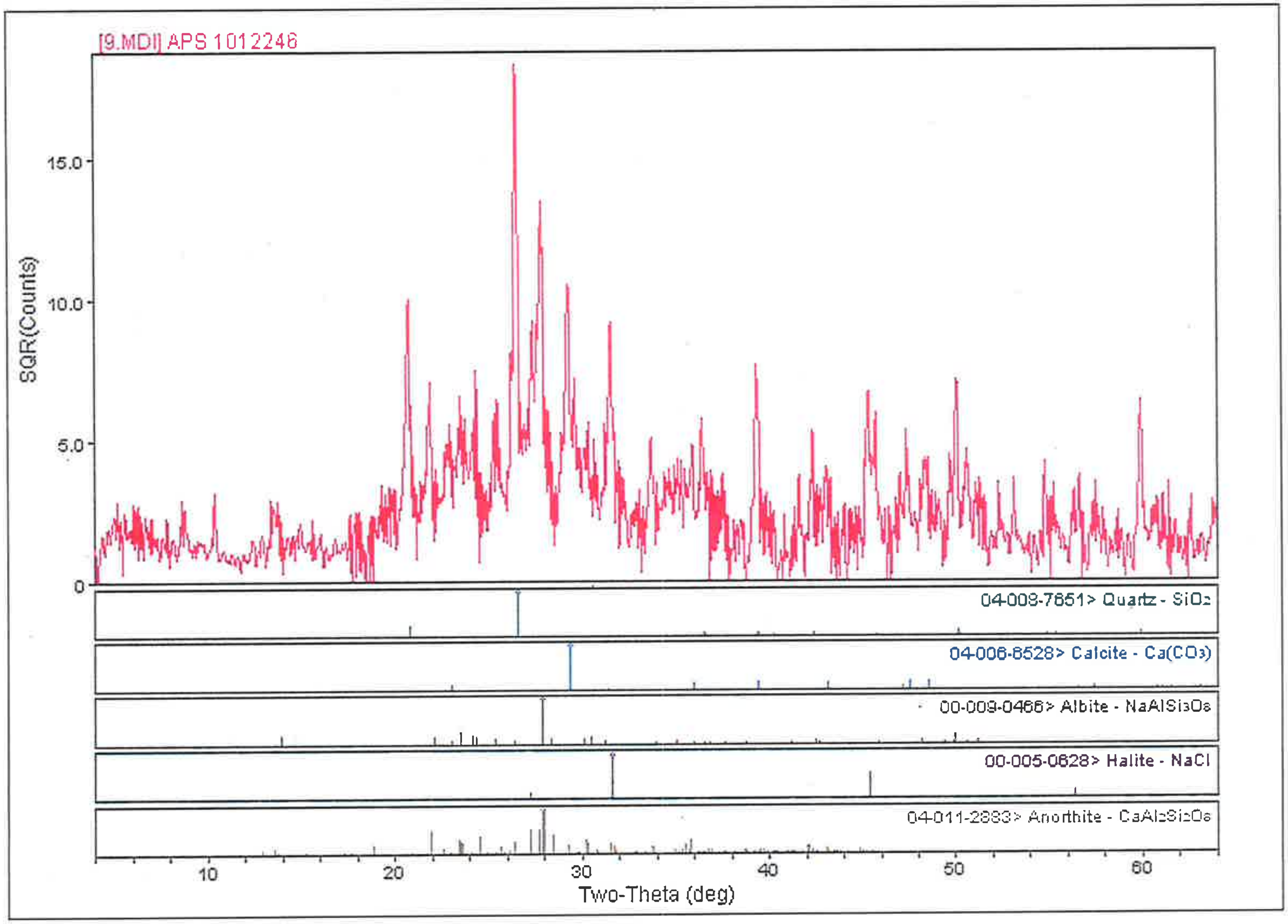


Figure 4: X-ray diffraction pattern of Sample No. 9 showing the presence of quartz, calcite, albite, halite, and anorthite.

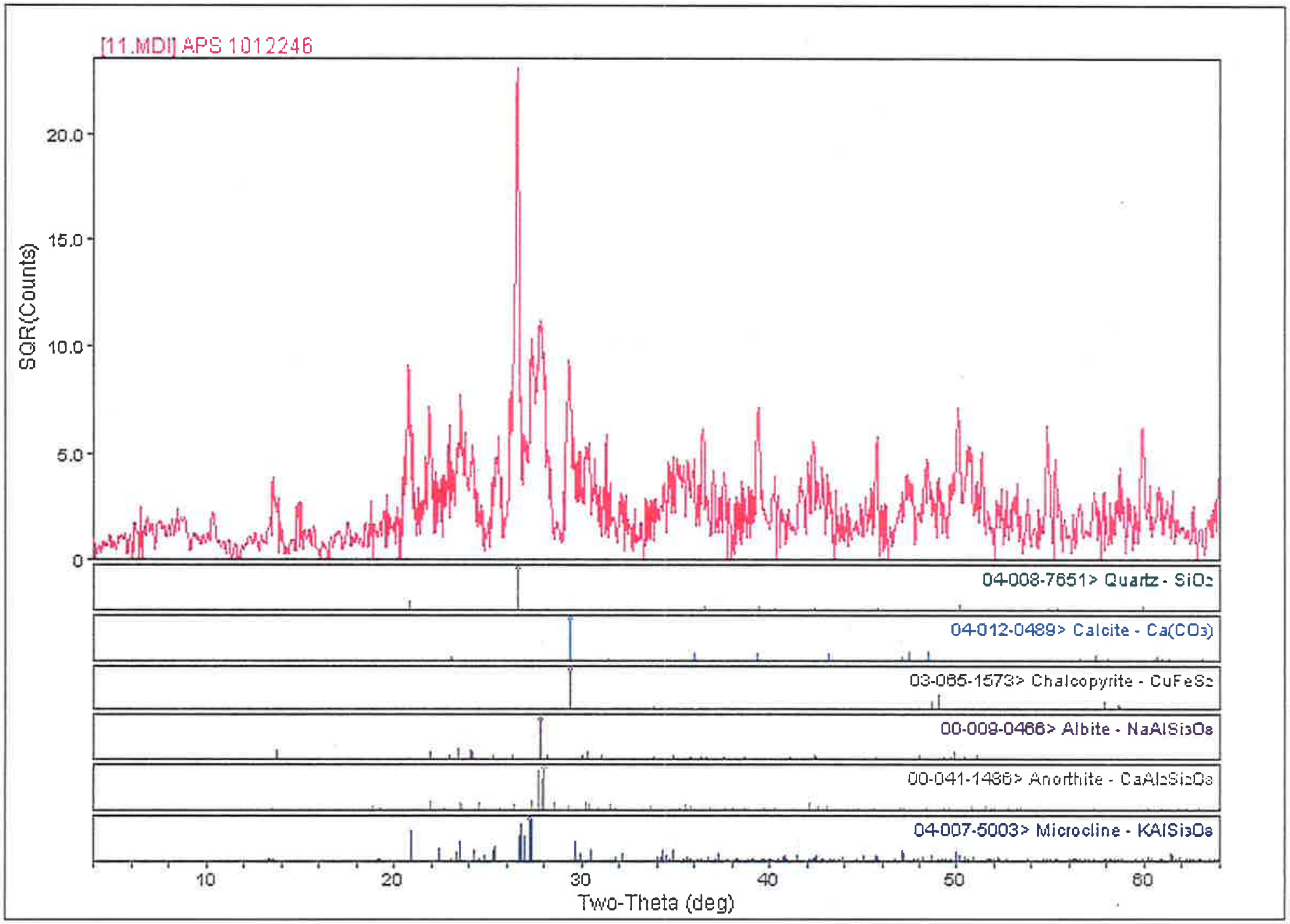


Figure 5: X-ray diffraction pattern of Sample No. 11 showing the presence of quartz, calcite, chalcopyrite, albite, anorthite, and microcline.

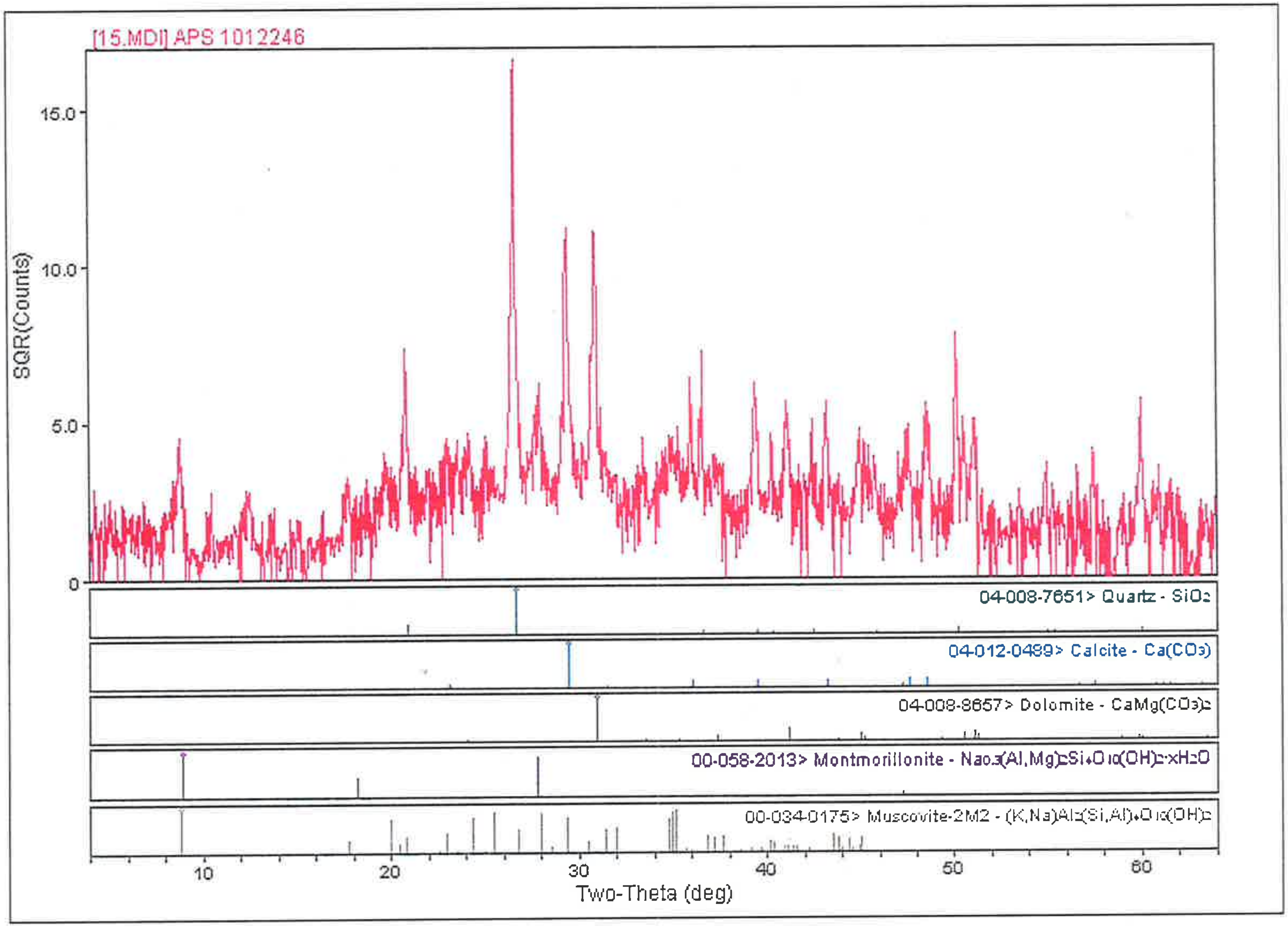


Figure 6: X-ray diffraction pattern of Sample No. 15 showing the presence of quartz, calcite, dolomite, montmorillonite, and muscovite.

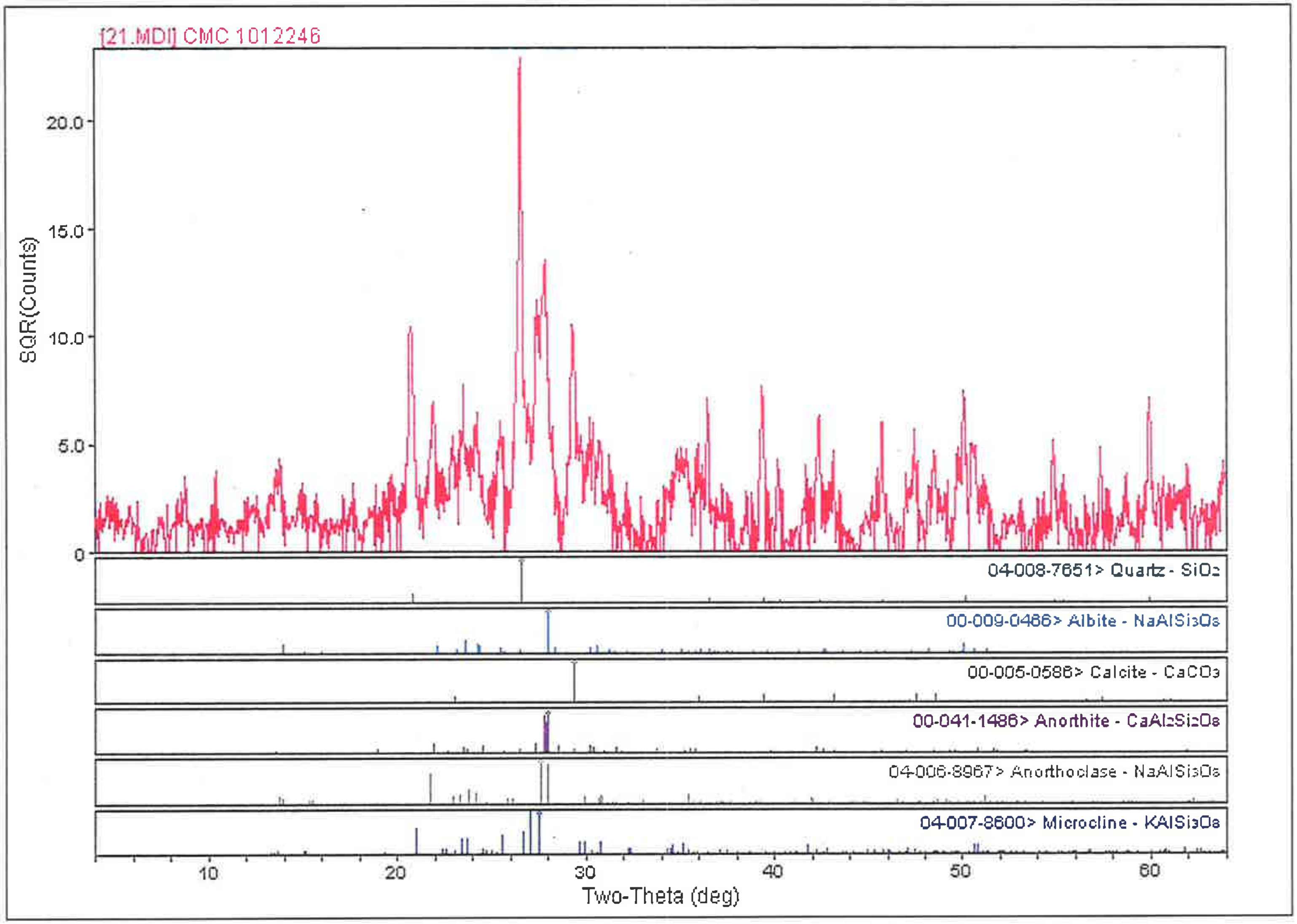


Figure 7: X-ray diffraction pattern of Sample No. 21 showing the presence of quartz, albite, calcite, anorthite, anorthoclase, and microcline.

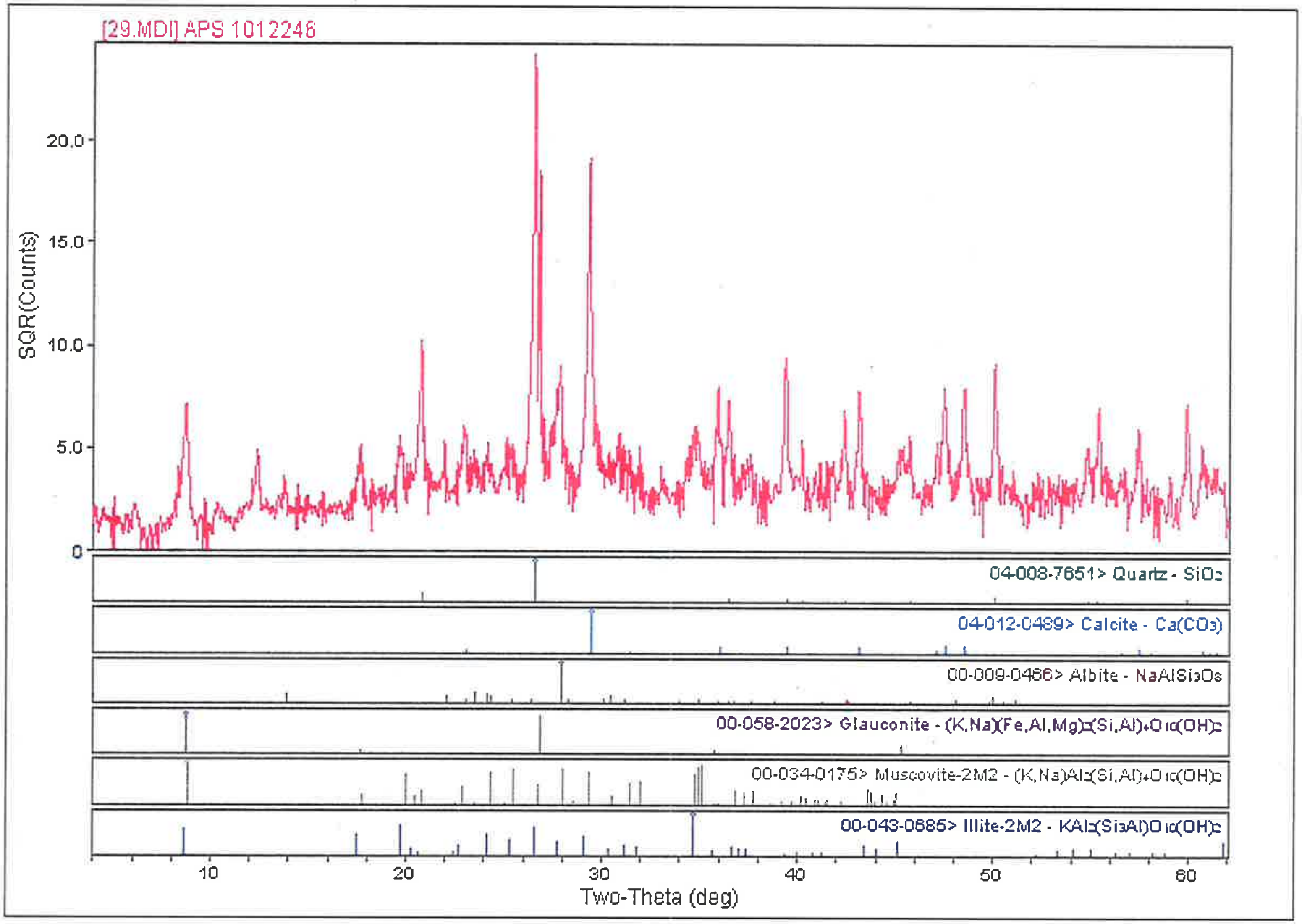


Figure 8: X-ray diffraction pattern of Sample No. 29 showing the presence of quartz, calcite, albite, glauconite, muscovite, and illite.

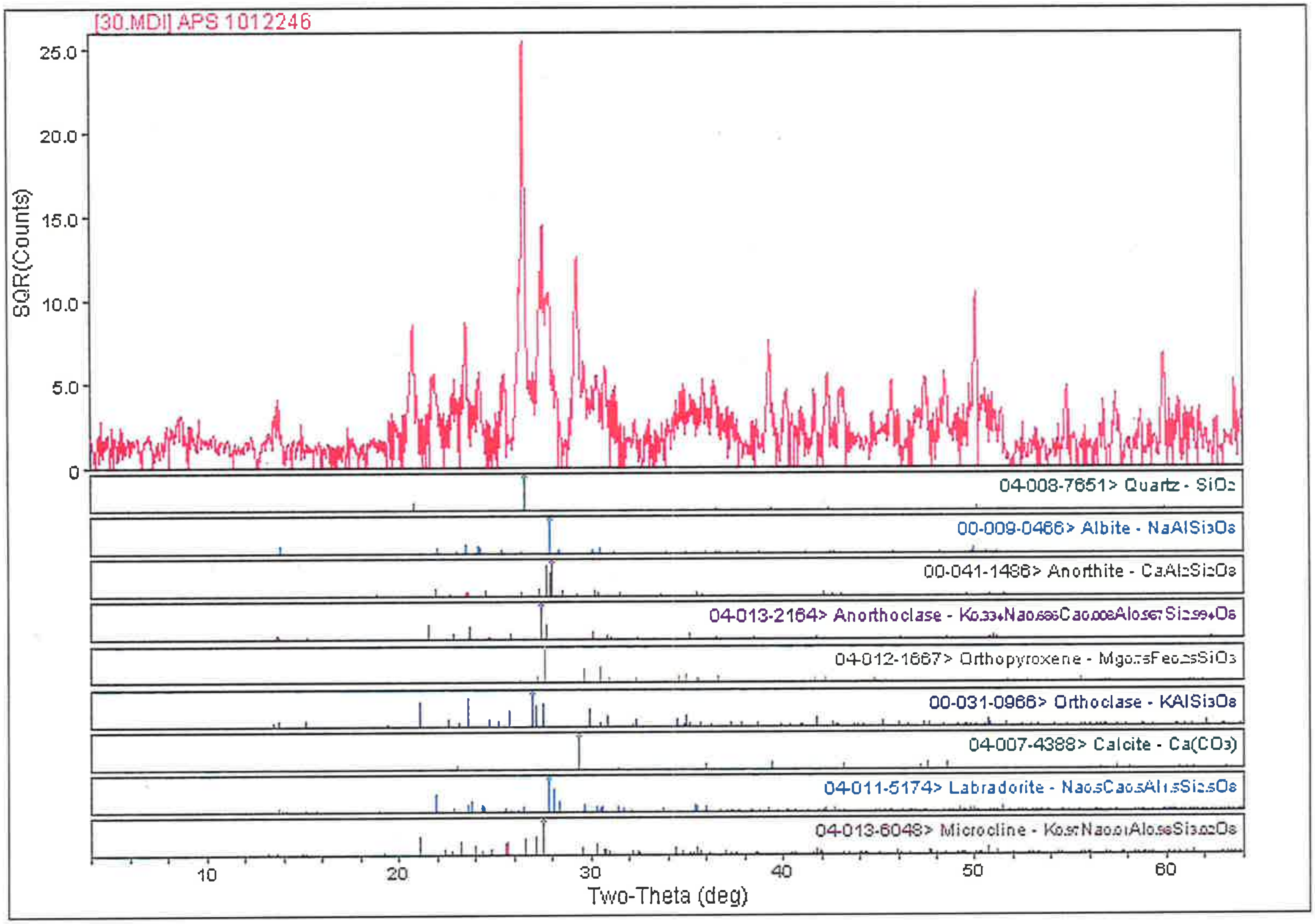


Figure 9: X-ray diffraction pattern of Sample No. 30 showing the presence of quartz, albite, anorthite, anorthoclase, orthopyroxene, orthoclase, calcite, labradorite, and microcline.

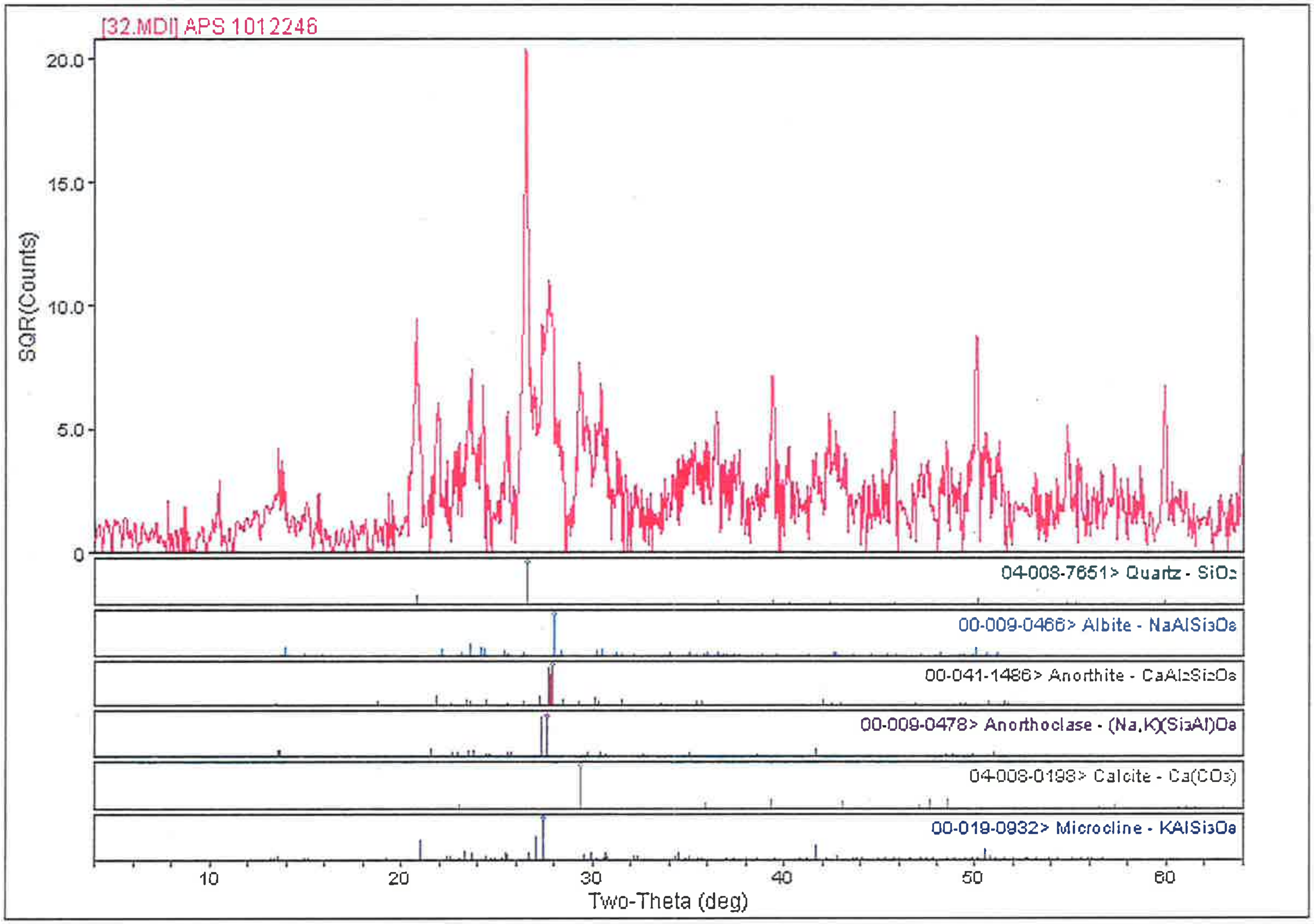


Figure 10: X-ray diffraction pattern of Sample No. 32 showing the presence of quartz, albite, anorthite, anorthoclase, calcite, and microcline.

Phase Proportions (Percent Mass)

Sample ID	3	6a	7	9	11	15	21	29	30	32
Major Minerals										
Quartz	44.7	41.6	43.2	42.1	45.6	37.7	40.2	39.3	44.2	50.3
Albite	35.3	41.7	34.0	40.2	30.6	-	34.2	9.7	12.8	20.8
Microcline	20.0	16.8	17.9	-	16.7	-	18.2	-	13.9	22.4
Calcite	-	-	5.0	12.2	7.1	15.9	7.4	20.7	10.0	6.5
Subordinate Minerals										
Halite	-	-	-	5.5	-	-	-	-	-	-
Dolomite	-	-	-	-	-	20.0	-	-	-	-
Mica (Muscovite)	-	-	-	-	-	26.4	-	13.7	-	-
Clay	-	-	-	-	-	-	-	16.6	-	-
Orthopyroxene	-	-	-	-	-	-	-	-	12.7	-
Orthoclase	-	-	-	-	-	-	-	-	6.34	-

APPENDIX B

IAS LABORATORIES TEXTURE ANALYSIS RESULTS

IAS Laboratories

2515 East University Drive
Phoenix, Arizona 85034
(602) 273-7248
Fax (602) 275-3836

Date: November 2, 2012
Submitted by: Air Sciences
Report To: Miles Kenney
Report #: 6644156
Date Received: October 31, 2012
Project: 300-22A

TEXTURE ANALYSIS

Sender Sample ID	IAS LAB #	Sand %	Silt %	Clay %	Soil Classification
XRD-3	307	96	2	2	Sand
XRD-6a	308	92	4	4	Sand
XRD-15	309	22	52	26	Silt Loam
XRD-29	310	78	16	6	Sandy Loam

Hydrometer Method- Methods of Soil Analysis No.9 Part 1 Pg. 404

IAS Laboratories

2515 East University Drive
Phoenix, Arizona 85034
(602) 273-7248
Fax (602) 275-3836

Date: November 16, 2012
Submitted By: New Fields
Report To: Chris Stall
Project: Owens Lake
Report No: 6644224
Date: November 14, 2012

Sieve Analysis

Sender I.D.	#10 2.00-4.74mm Gravel	#18 1.00-1.99mm V.Coarse Sand	#35 0.50-0.99mm Coarse Sand	#60 0.25-0.49mm Medium Sand	#140 0.10-0.24mm Fine Sand	#270 0.050-0.099mm V. Fine Sand	Hydrometer Silt	Hydrometer Clay	Soil Classification
14F	1.5	0.4	1.0	3.1	15.6	19.9	32.8	25.7	Sandy Clay Loam
5B	14.1	0.5	2.9	27.7	39.2	6.1	3.8	5.7	Sand
33P	15.2	17.1	9.1	13.2	31.7	10.8	1.5	1.5	Sand
22K	37.8	3.5	1.6	3.0	35.1	12.2	ND	6.8	Sandy Loam
20J	ND	0.1	2.0	24.6	52.9	9.7	4.3	6.4	Sand
12D	0.2	44.9	44.3	3.1	3.5	1.0	ND	3.0	Sand
270	ND	0.5	18.7	36.6	38.6	4.3	ND	1.3	Sand
10	9.1	5.2	8.5	20.4	38.4	10.0	5.0	3.4	Sand
23L	37.4	4.1	3.0	2.7	6.5	7.2	23.7	15.4	Loam
7B	ND	5.6	54.1	18.4	15.9	3.7	ND	2.3	Sand
5A	0.8	11.6	12.3	29.1	40.1	5.0	0.5	0.5	Sand
13E	ND	ND	0.4	3.2	5.8	4.4	58.1	28.1	Silty Clay Loam

ND means None Detected

*USDA Sieve Analysis

Locations of Air Sciences Texture Analysis Samples.

Sample	Longitude	Latitude
7B	-117.902	36.51956
10	-117.908	36.52238
12D	-117.904	36.50999
13E	-117.904	36.5097
14F	-117.904	36.50724
20J	-117.895	36.49851
22K	-117.89	36.51508
23L	-117.884	36.51593
27O	-117.935	36.53995
33P	-117.96	36.54816
5A/B	-117.903	36.51454

APPENDIX C

GBUACD (DISTRICT) KEELER DUNES – BULK XRD ANALYSIS, FEBRUARY, 2012

14th February 2012 Sophie Baker

Keeler Dunes – Bulk XRD Analysis
February 2012

Sample Preparation:

Bulk samples were prepared by splitting out ~4g of the oven dried <2mm fraction of the sample and grinding it initially by hand in a pestle and mortar until it passes through a sieve with openings of 500μm. Samples were then ground to a powder in a McCrone mill for 8 minutes in 10 ml of methanol. Subsequently, samples were air dried overnight, gently re-crushed in a pestle and mortar to break up aggregates formed during drying, and side-loaded into specially-designed side-loading sample holders. This process of grinding the samples to a fine homogenous powder, followed by side-loading, helps to minimize preferred orientation of certain crystal phases within the samples, thereby increasing the accuracy of the semi-quantitative analysis.

Analysis parameters:

All samples were run on DRI's Bruker D8 Advance XRD equipped with a Sol-X (solid state) detector with the following scan parameters:

- 5 to 65 ° two theta scan range
- Locked Coupled Step Scan
- 0.05 ° increments (step size)
- 2 seconds/step (step time)
- Variable width divergence and anti-scatter slits (V12)

Data analysis:

The resulting XRD scans were viewed and interpreted using the Bruker XRD data evaluation software called EVA. A background correction was performed on each scan before interpretation. Minerals were identified by matching reference mineral patterns stored in the ICDD (International Centre for Diffraction Data) database to the observed peaks.

The method used to estimate the relative percentages of each mineral identified (i.e., the semi-quantitative analysis) is based on the method of Chung (1975), which assumes that all the minerals are identified correctly and that there are no unidentified phases in the sample. It is carried out within EVA by adjusting the y-scale of the reference patterns (visually represented by sticks in the plots) to match the peak heights on the observed scan. A reference intensity ratio for each mineral (in this case, I/Ic, which is the relative height of the strongest peak of a mineral compared to the relative height of the strongest peak of corundum in a 1:1 mixture) is then used to determine the relative percentages. The calculation is done automatically by the software once each mineral selected is assigned an I/Ic value. The I/Ic values for most of the mineral reference patterns used were provided by the ICDD database. Otherwise values were taken from Davis et al. (1989). Because generic I/Ic values were used (the same basic mineral type can have a range of I/Ic values), the relative percentages of the mineral determined can be assumed only to be semi-quantitative estimations rather than quantitative values (no estimation of uncertainty can be provided). However, even though the accuracy of the percentages cannot be tested, since the same minerals were identified in all samples in the batch and the same reference patterns and I/Ic values were used throughout, the percentages are useful for comparing samples within the batch.

Results:

The scans for all nine samples were very similar. The following minerals were identified: Quartz (major), Plagioclase (major), K-feldspar (minor), Calcite (minor to trace), and Amphibole (trace). Table 1 shows the results of the semi-quantitative analysis, and the scan for each sample is shown below with the reference patterns (stick patterns) for identified minerals.

References:

Chung, F. H., 1975. Quantitative interpretation of X-ray diffraction patterns of mixtures. III. Simultaneous determination of a set of reference intensities. Journal of Applied Crystallography 8 (17-19).

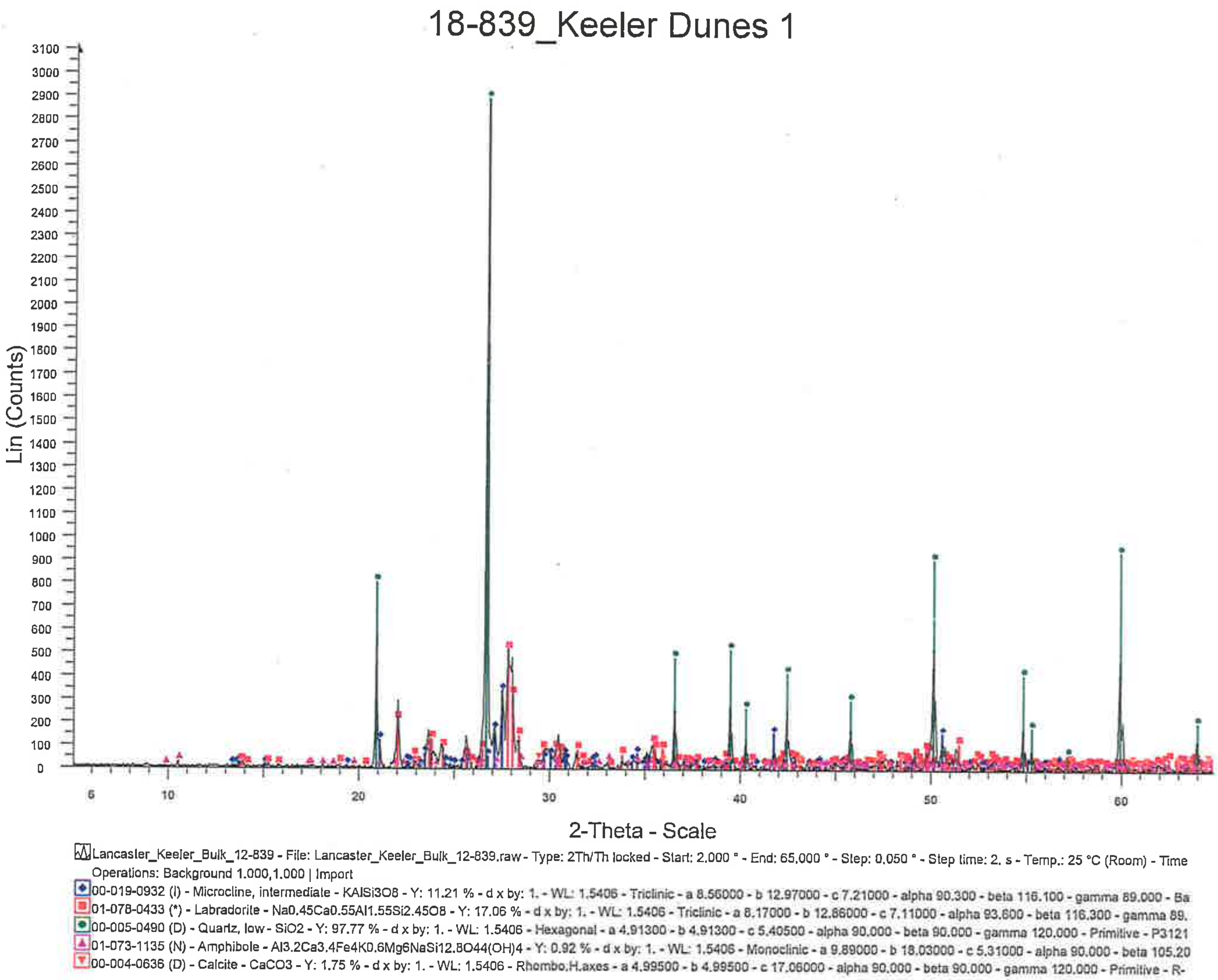
Davis, B. L., Smith, D.K., Holomany, M.A., 1989. Tables of Experimental Reference Intensity Ratios Table No. 2, December 1989. Powder Diffraction 4:4 (201-205).

Table 1. Results of semi-quantitative bulk XRD analysis for Keeler Dunes samples

Field ID	Lab ID	Semi-quantitative XRD results					
		Quartz - % -	Plagioclase - % -	K-feldspar - % -	Calcite - % -	Amphibole - % -	Total - % -
OL-11-001-owens Riv Old Channel	18-839	40	43	15	1	1	100.0
OL-11-002 Delta Well	18-840	38	42	16	3	1	100.0
OL-11-003 NW Swanson	18-841	37	40	15	6	2	100.0
OL-11-004 Icicle? Southern Dune	18-842	39	38	10	11	2	100.0
OL-11-005 West End Gl?? Dune	18-843	38	40	14	7	1	100.0
OL-11-006 Cross-bedded Sand	18-844	35	43	13	8	1	100.0
OL-11-007 North Dune and Sand Sheet	18-845	41	39	12	7	1	100.0
OL-11-008 (7) Horseshoe Dune?	18-846	39	39	14	7	1	100.0
OL-11-009 South end of Swanson Dune	18-847	38	40	15	6	1	100.0
General Summary		Major	Major	Minor	Minor to Trace	Trace	

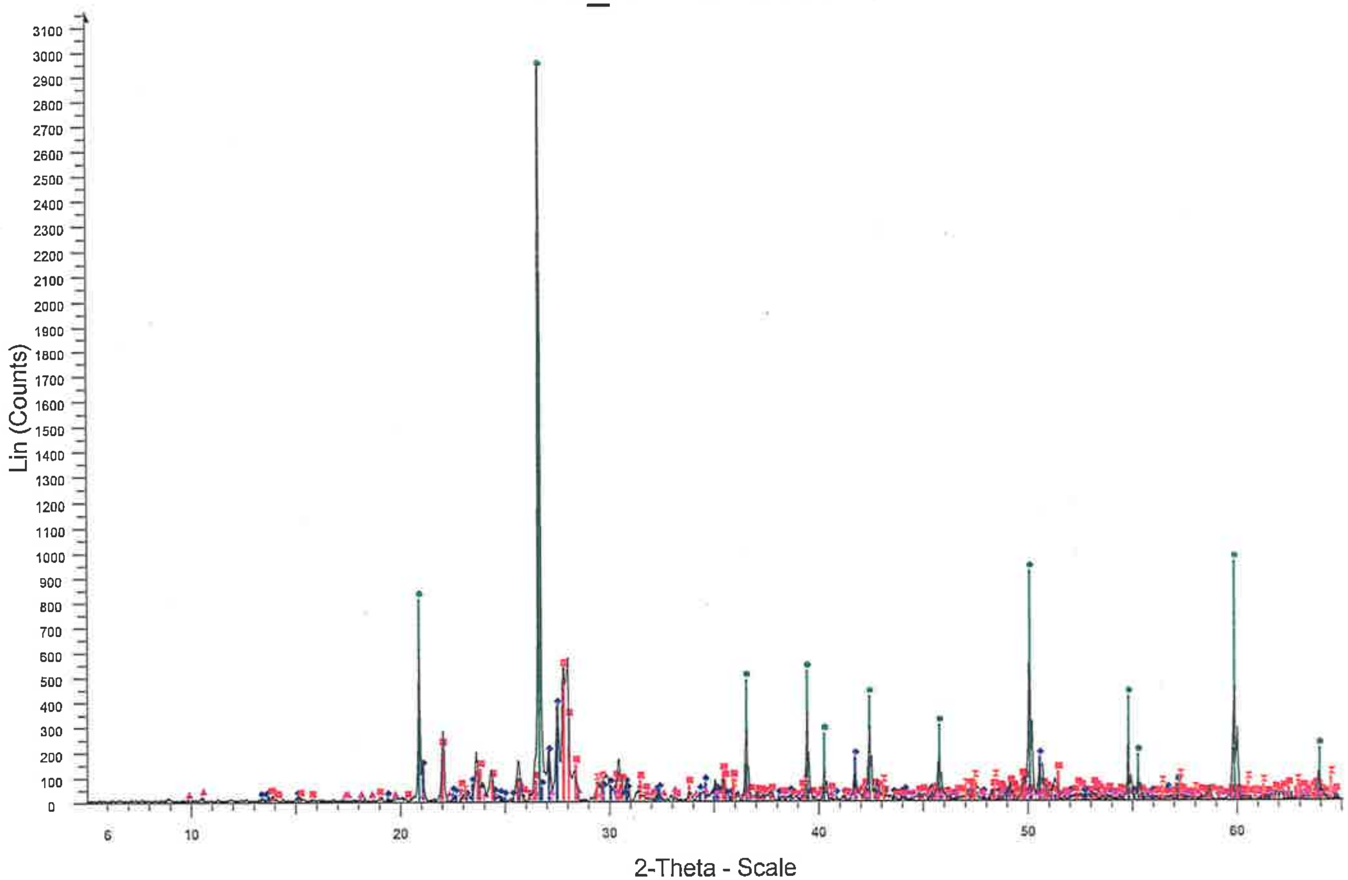
14th February 2012

Sophie Baker



14th February 2012 Sophie Baker

12-840_Keeler Dunes 2



Lancaster_Keeler_Bulk_12-840 - File: Lancaster_Keeler_Bulk_12-840.raw - Type: 2Th/Th locked - Start: 2.000 ° - End: 65.000 ° - Step: 0.050 ° - Step time: 2. s - Temp.: 25 °C (Room) - Time
Operations: Background 1.000,1.000 | Import

00-019-0932 (I) - Microcline, intermediate - KAlSi3O8 - Y: 12.41 % - d x by: 1. - WL: 1.5406 - Triclinic - a 8.56000 - b 12.97000 - c 7.21000 - alpha 90.300 - beta 116.100 - gamma 89.000 - Ba

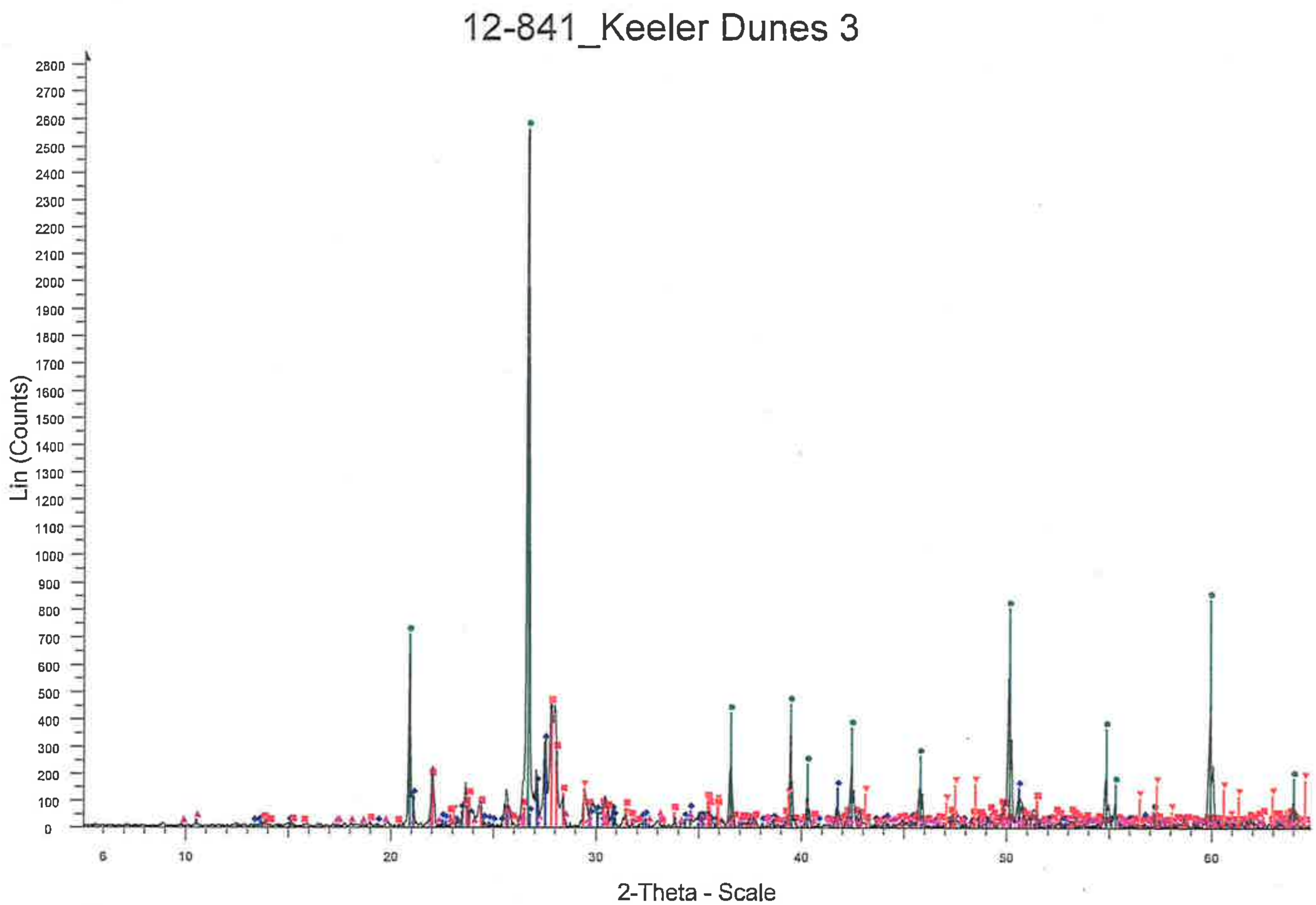
01-078-0433 (*) - Labradorite - Na0.45Ca0.55Al1.55Si2.45O8 - Y: 17.49 % - d x by: 1. - WL: 1.5406 - Triclinic - a 8.17000 - b 12.86000 - c 7.11000 - alpha 93.600 - beta 116.300 - gamma 89.

00-005-0490 (D) - Quartz, low - SiO2 - Y: 97.59 % - d x by: 1. - WL: 1.5406 - Hexagonal - a 4.91300 - b 4.91300 - c 5.40500 - alpha 90.000 - beta 90.000 - gamma 120.000 - Primitive - P3121

01-073-1135 (N) - Amphibole - Al3.2Ca3.4Fe4K0.6Mg6NaSi12.8O44(OH)4 - Y: 0.61 % - d x by: 1. - WL: 1.5406 - Monoclinic - a 9.89000 - b 18.03000 - c 5.31000 - alpha 90.000 - beta 105.20

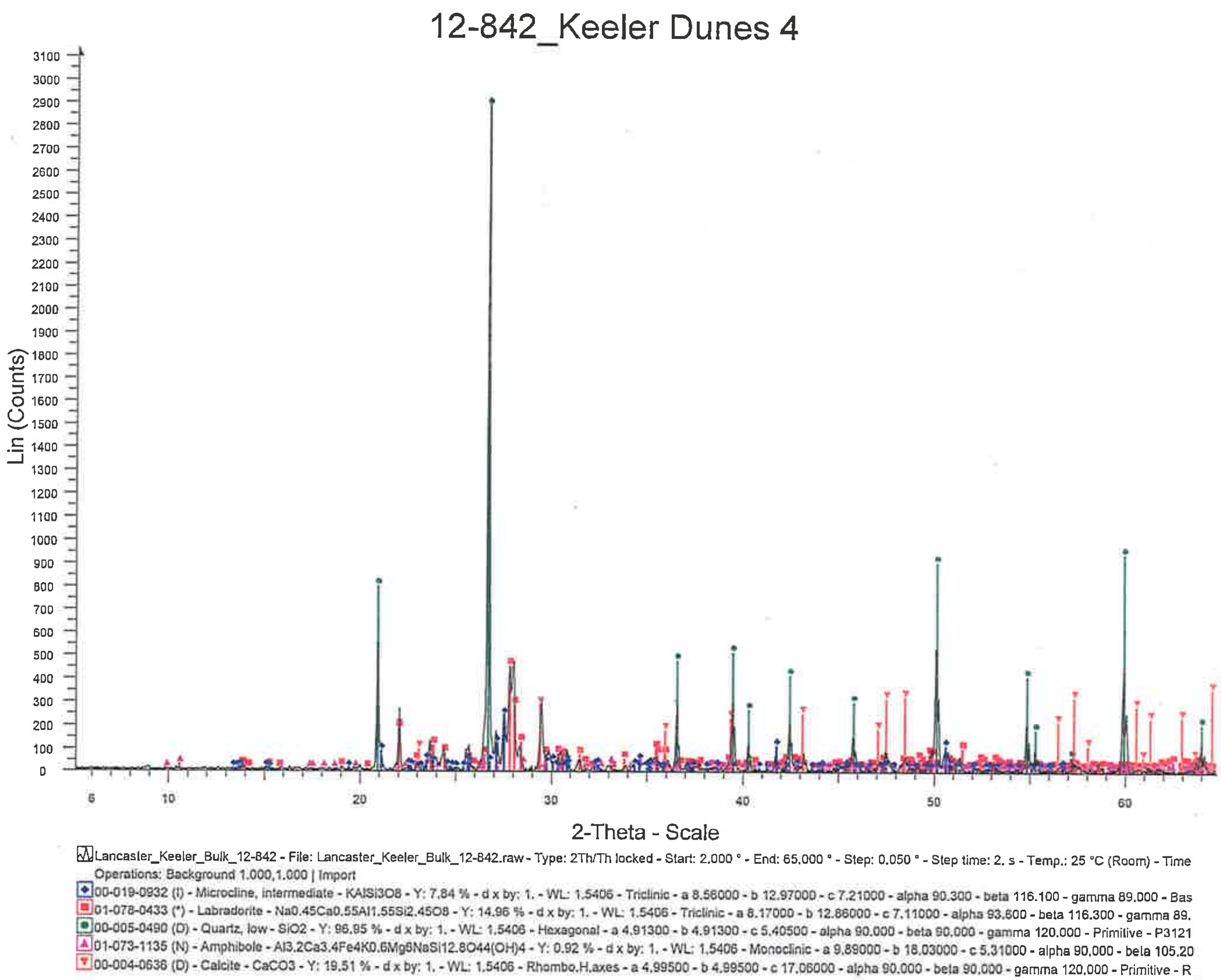
00-004-0636 (D) - Calcite - CaCO3 - Y: 4.90 % - d x by: 1. - WL: 1.5406 - Rhombo.H.axes - a 4.99500 - b 4.99500 - c 17.06000 - alpha 90.000 - beta 90.000 - gamma 120.000 - Primitive - R-

14th February 2012 Sophie Baker

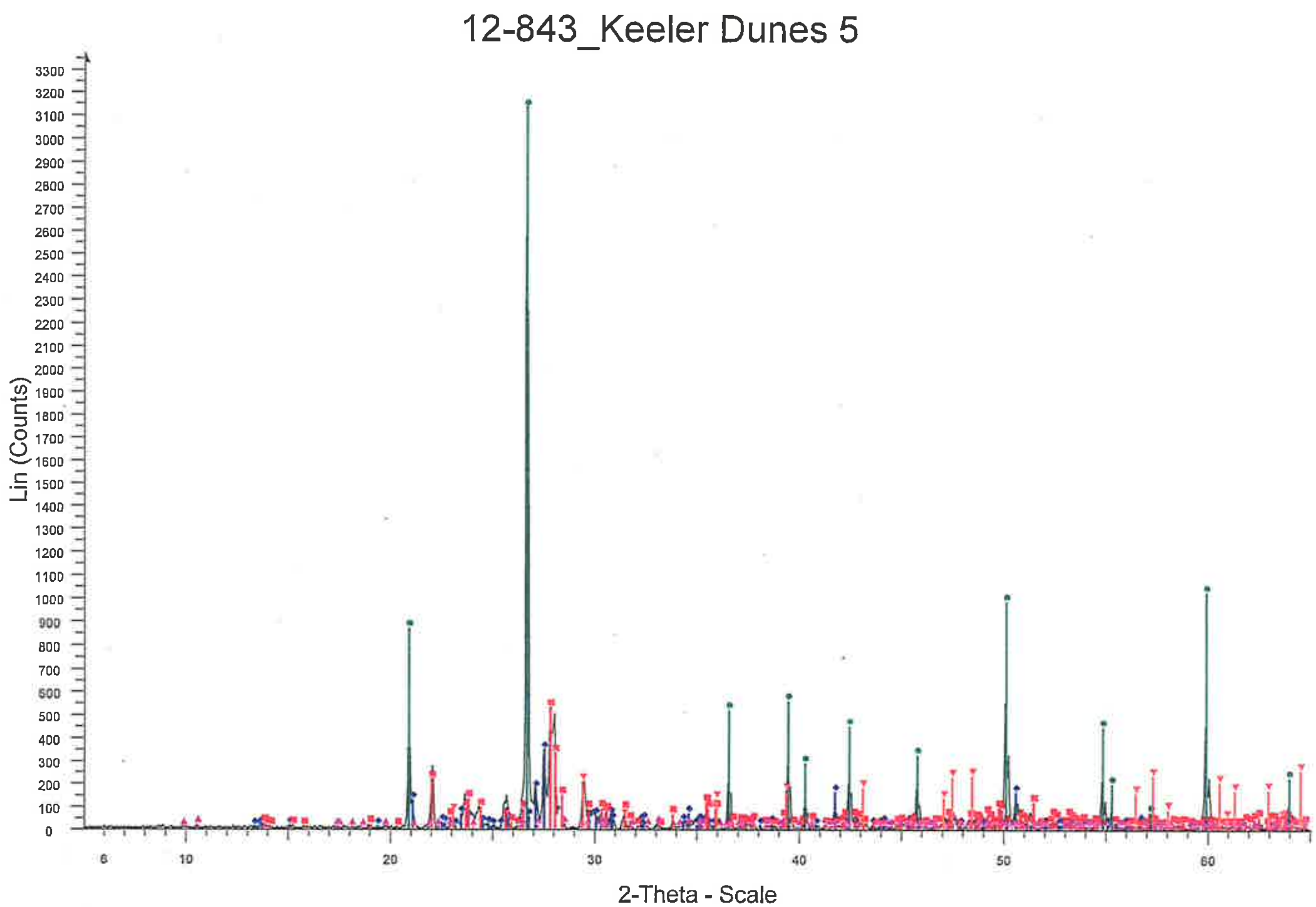


Lancaster_Keeler_Bulk_12-841 - File: Lancaster_Keeler_Bulk_12-841.raw - Type: 2Th/Th locked - Start: 2.000 ° - End: 65.000 ° - Step: 0.050 ° - Step time: 2. s - Temp.: 25 °C (Room) - Time
Operations: Background 1.000,1.000 | Import
00-019-0932 (I) - Microcline, intermediate - KAlSi3O8 - Y: 10.35 % - d x by: 1. - WL: 1.5406 - Triclinic - a 8.56000 - b 12.97000 - c 7.21000 - alpha 90.300 - beta 116.100 - gamma 89.000 - Ba
01-078-0433 (*) - Labradorite - Na0.45Ca0.55Al1.55Si2.45O8 - Y: 14.83 % - d x by: 1. - WL: 1.5406 - Triclinic - a 8.17000 - b 12.86000 - c 7.11000 - alpha 93.600 - beta 116.300 - gamma 89.
00-005-0490 (D) - Quartz, low - SiO2 - Y: 85.40 % - d x by: 1. - WL: 1.5406 - Hexagonal - a 4.91300 - b 4.91300 - c 5.40500 - alpha 90.000 - beta 90.000 - gamma 120.000 - Primitive - P3121
01-073-1135 (N) - Amphibole - Al3.2Ca3.4Fe4K0.6Mg6NaSi12.8O44(OH)4 - Y: 0.91 % - d x by: 1. - WL: 1.5406 - Monoclinic - a 9.89000 - b 18.03000 - c 5.31000 - alpha 90.000 - beta 105.20
00-004-0636 (D) - Calcite - CaCO3 - Y: 9.38 % - d x by: 1. - WL: 1.5406 - Rhombo.H.axes - a 4.99500 - b 4.99500 - c 17.06000 - alpha 90.000 - beta 90.000 - gamma 120.000 - Primitive - R-

14th February 2012 Sophie Baker

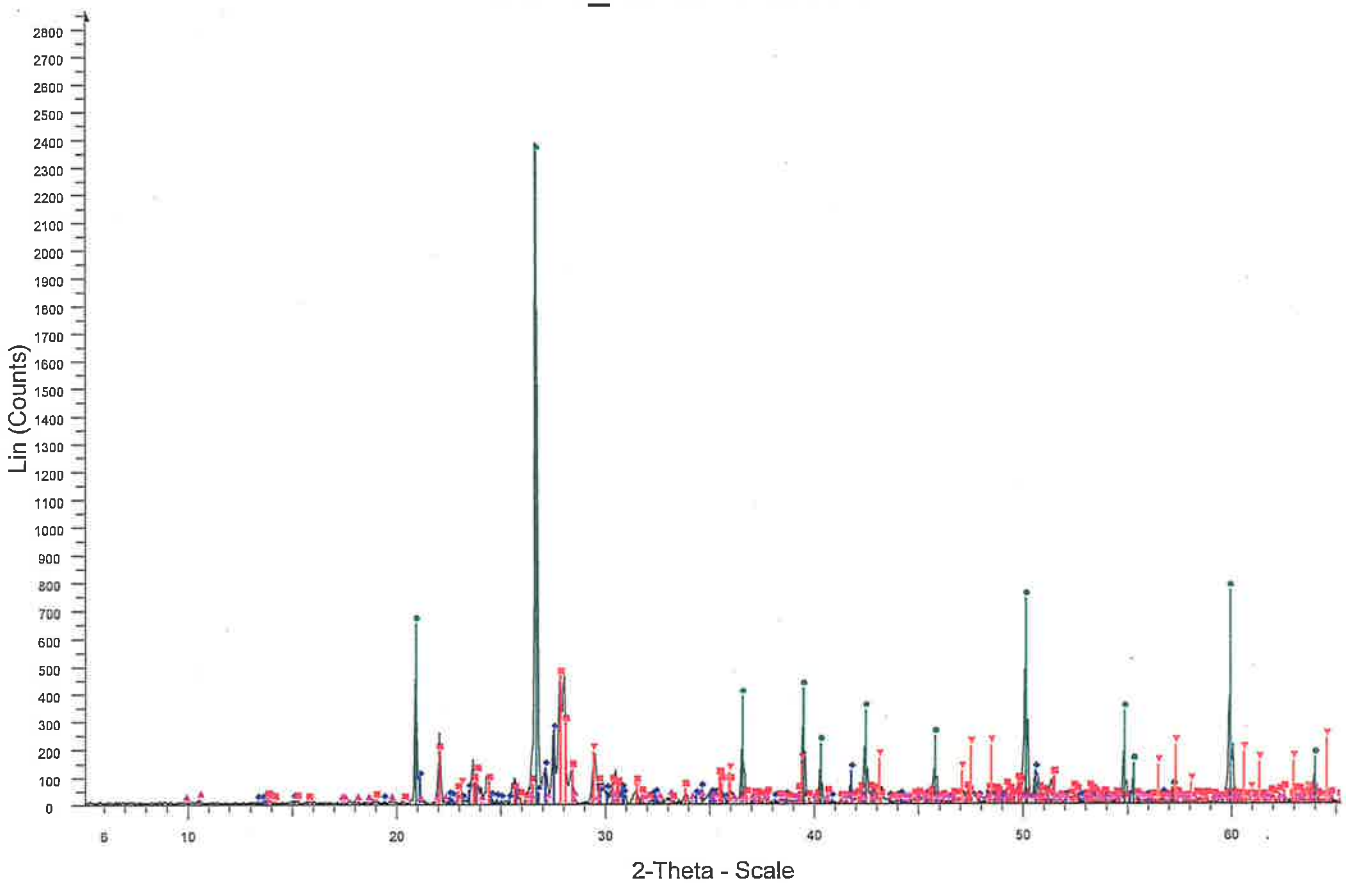


14th February 2012 Sophie Baker



Lancaster_Keeler_Bulk_12-843 - File: Lancaster_Keeler_Bulk_12-843.raw - Type: 2Th/Th locked - Start: 2.000 ° - End: 65.000 ° - Step: 0.050 ° - Step time: 2. s - Temp.: 25 °C (Room) - Time
Operations: Background 1.000,1.000 | Import
00-019-0932 (I) - Microcline, intermediate - KAlSi3O8 - Y: 10.63 % - d x by: 1. - WL: 1.5406 - Triclinic - a 8.56000 - b 12.97000 - c 7.21000 - alpha 90.300 - beta 116.100 - gamma 89.000 - Ba
01-078-0433 (*) - Labradorite - Na0.45Ca0.55Al1.55Si2.45O8 - Y: 16.23 % - d x by: 1. - WL: 1.5406 - Triclinic - a 8.17000 - b 12.86000 - c 7.11000 - alpha 93.600 - beta 116.300 - gamma 89.
00-005-0490 (D) - Quartz, low - SiO2 - Y: 97.78 % - d x by: 1. - WL: 1.5406 - Hexagonal - a 4.91300 - b 4.91300 - c 5.40500 - alpha 90.000 - beta 90.000 - gamma 120.000 - Primitive - P3121
01-073-1135 (N) - Amphibole - Al3.2Ca3.4Fe4K0.6Mg6NaSi12.8O44(OH)4 - Y: 0.50 % - d x by: 1. - WL: 1.5406 - Monoclinic - a 9.89000 - b 18.03000 - c 5.31000 - alpha 90.000 - beta 105.20
00-004-0636 (D) - Calcite - CaCO3 - Y: 12.86 % - d x by: 1. - WL: 1.5406 - Rhombo.H.axes - a 4.99500 - b 4.99500 - c 17.06000 - alpha 90.000 - beta 90.000 - gamma 120.000 - Primitive - R

12-844_Keeler Dunes 6



Lancaster_Keeler_Bulk_12-844 - File: Lancaster_Keeler_Bulk_12-844.raw - Type: 2Th/Th locked - Start: 2.000 ° - End: 65.000 ° - Step: 0.050 ° - Step time: 2. s - Temp.: 25 °C (Room) - Time
Operations: Background 1.000,1.000 | Import

00-019-0932 (I) - Microcline, intermediate - KAlSi3O8 - Y: 7.98 % - d x by: 1. - WL: 1.5406 - Triclinic - a 8.56000 - b 12.97000 - c 7.21000 - alpha 90.300 - beta 116.100 - gamma 89.000 - Bas

01-078-0433 (*) - Labradorite - Na0.45Ca0.55Al1.55Si2.45O8 - Y: 14.21 % - d x by: 1. - WL: 1.5406 - Triclinic - a 8.17000 - b 12.86000 - c 7.11000 - alpha 93.600 - beta 116.300 - gamma 89.

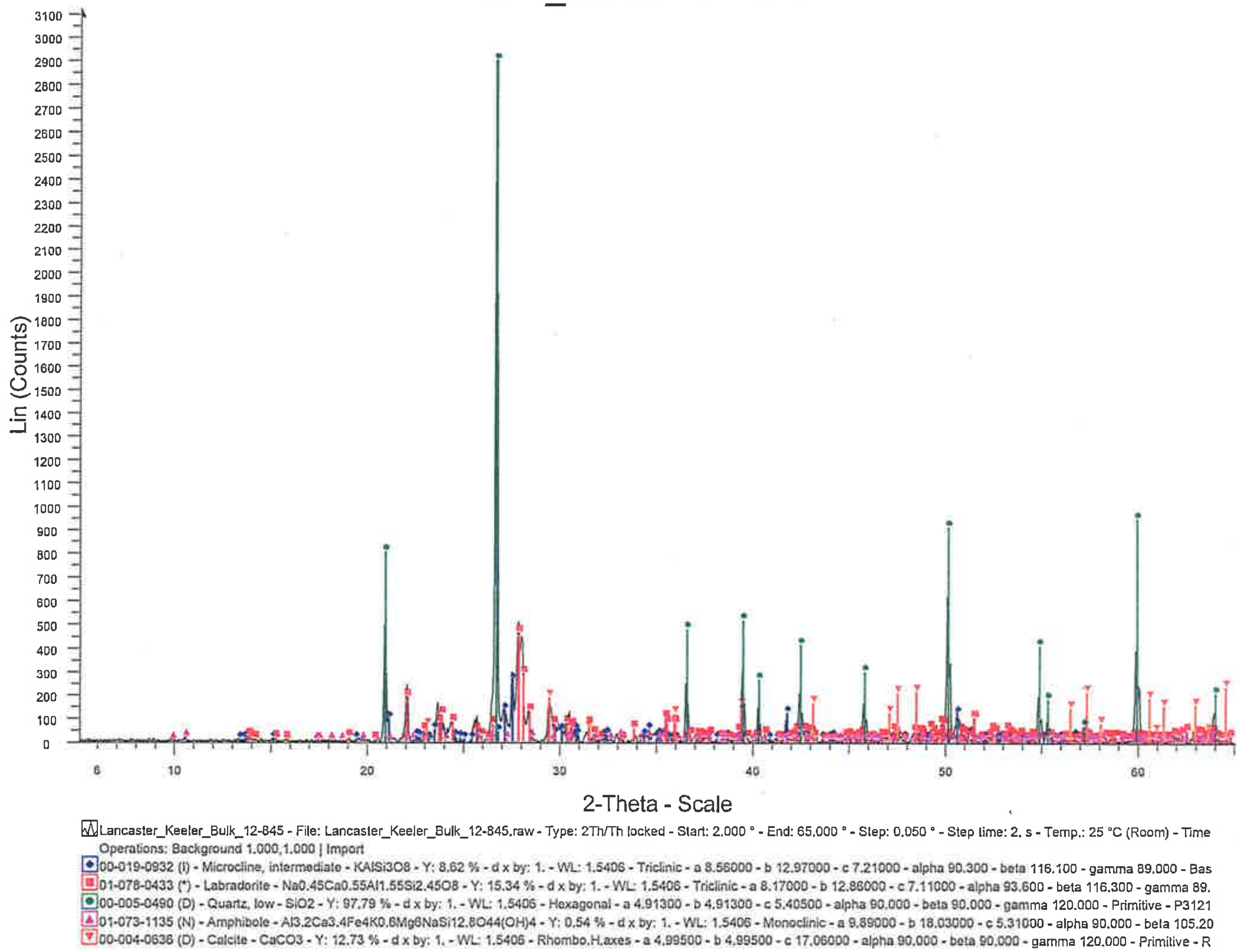
00-005-0490 (D) - Quartz, low - SiO2 - Y: 73.34 % - d x by: 1. - WL: 1.5406 - Hexagonal - a 4.91300 - b 4.91300 - c 5.40500 - alpha 90.000 - beta 90.000 - gamma 120.000 - Primitive - P3121

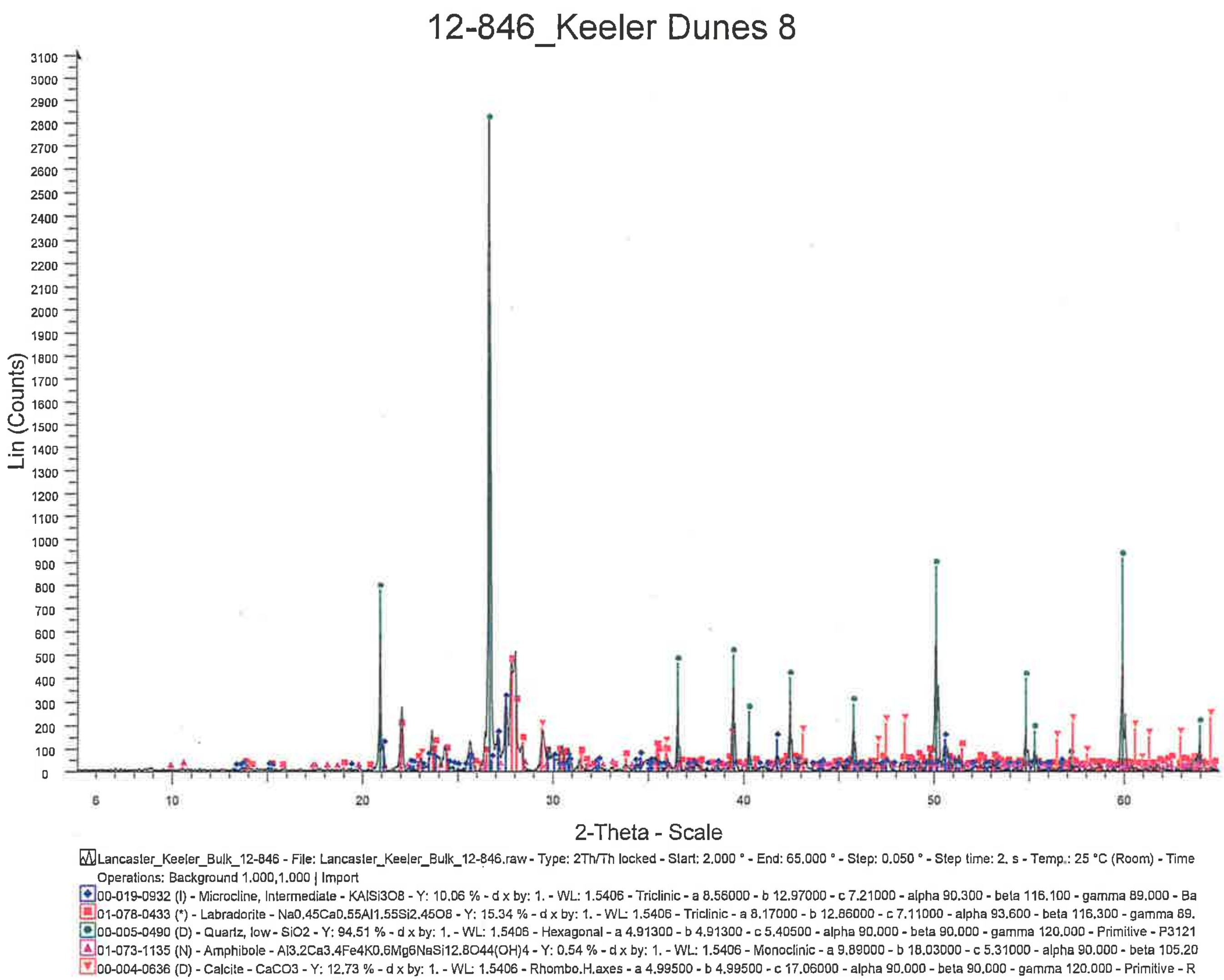
01-073-1135 (N) - Amphibole - Al3.2Ca3.4Fe4K0.6Mg6NaSi12.8O44(OH)4 - Y: 0.50 % - d x by: 1. - WL: 1.5406 - Monoclinic - a 9.89000 - b 18.03000 - c 5.31000 - alpha 90.000 - beta 105.20

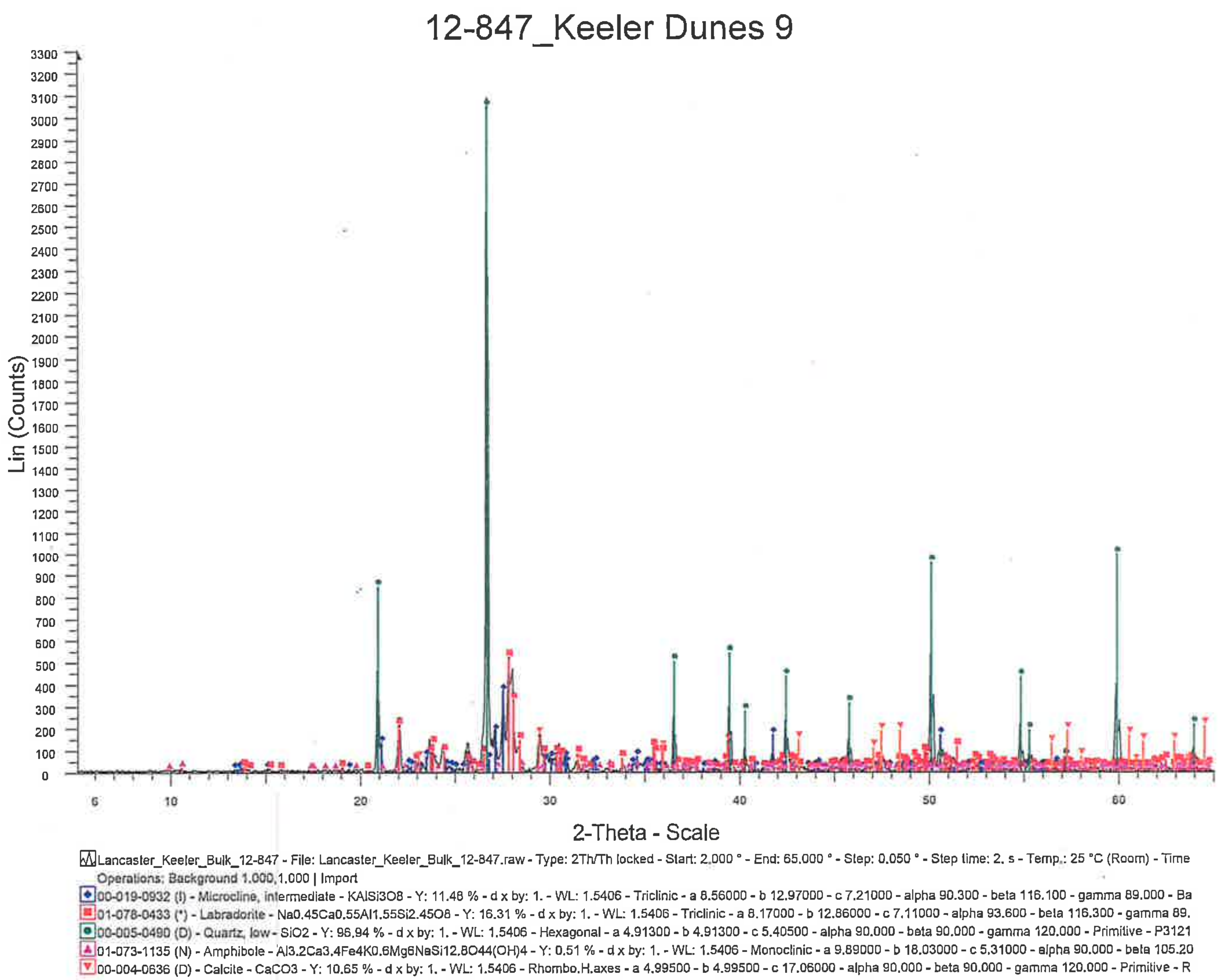
00-004-0636 (D) - Calcite - CaCO3 - Y: 11.79 % - d x by: 1. - WL: 1.5406 - Rhombo.H.axes - a 4.99500 - b 4.99500 - c 17.06000 - alpha 90.000 - beta 90.000 - gamma 120.000 - Primitive - R

14th February 2012 Sophie Baker

12-845_Keeler Dunes 7




12-846_Keeler Dunes 8
Lin (Counts)
2-Theta - Scale
Lancaster_Keeler_Bulk_12-846 - File: Lancaster_Keeler_Bulk_12-846.raw - Type: 2Th/Th locked - Start: 2.000 ° - End: 65.000 ° - Step: 0.050 ° - Step time: 2. s - Temp.: 25 °C (Room) - Time
Operations: Background 1.000,1.000 | Import
00-019-0932 (I) - Microcline, Intermediate - KAlSi3O8 - Y: 10.06 % - d x by: 1. - WL: 1.5406 - Triclinic - a 8.56000 - b 12.97000 - c 7.21000 - alpha 90.300 - beta 116.100 - gamma 89.000 - Ba
01-078-0433 (*) - Labradorite - Na0.45Ca0.55Al1.55Si2.45O8 - Y: 15.34 % - d x by: 1. - WL: 1.5406 - Triclinic - a 8.17000 - b 12.86000 - c 7.11000 - alpha 93.600 - beta 116.300 - gamma 89.
00-005-0490 (D) - Quartz, low - SiO2 - Y: 94.51 % - d x by: 1. - WL: 1.5406 - Hexagonal - a 4.91300 - b 4.91300 - c 5.40500 - alpha 90.000 - beta 90.000 - gamma 120.000 - Primitive - P3121
01-073-1135 (N) - Amphibole - Al3.2Ca3.4Fe4K0.6Mg6NaSi12.8O44(OH)4 - Y: 0.54 % - d x by: 1. - WL: 1.5406 - Monoclinic - a 9.89000 - b 18.03000 - c 5.31000 - alpha 90.000 - beta 105.20
00-004-0636 (D) - Calcite - CaCO3 - Y: 12.73 % - d x by: 1. - WL: 1.5406 - Rhombo.H.axes - a 4.99500 - b 4.99500 - c 17.06000 - alpha 90.000 - beta 90.000 - gamma 120.000 - Primitive - R


12-847_Keeler Dunes 9
Lin (Counts)
2-Theta - Scale
Lancaster_Keeler_Bulk_12-847 - File: Lancaster_Keeler_Bulk_12-847.raw - Type: 2Th/Th locked - Start: 2.000 ° - End: 65.000 ° - Step: 0.050 ° - Step time: 2. s - Temp.: 25 °C (Room) - Time
Operations: Background 1.000,1.000 | Import
00-019-0932 (I) - Microcline, intermediate - KAlSi3O8 - Y: 11.48 % - d x by: 1. - WL: 1.5406 - Triclinic - a 8.56000 - b 12.97000 - c 7.21000 - alpha 90.300 - beta 116.100 - gamma 89.000 - Ba
01-076-0433 (*) - Labradorite - Na0.45Ca0.55Al1.55Si2.45O8 - Y: 16.31 % - d x by: 1. - WL: 1.5406 - Triclinic - a 8.17000 - b 12.86000 - c 7.11000 - alpha 93.600 - beta 116.300 - gamma 89.
00-005-0490 (D) - Quartz, low - SiO2 - Y: 96.94 % - d x by: 1. - WL: 1.5406 - Hexagonal - a 4.91300 - b 4.91300 - c 5.40500 - alpha 90.000 - beta 90.000 - gamma 120.000 - Primitive - P3121
01-073-1135 (N) - Amphibole - Al3.2Ca3.4Fe4K0.6Mg6NaSi12.8O44(OH)4 - Y: 0.51 % - d x by: 1. - WL: 1.5406 - Monoclinic - a 9.89000 - b 18.03000 - c 5.31000 - alpha 90.000 - beta 105.20
00-004-0636 (D) - Calcite - CaCO3 - Y: 10.65 % - d x by: 1. - WL: 1.5406 - Rhombo.H.axes - a 4.99500 - b 4.99500 - c 17.06000 - alpha 90.000 - beta 90.000 - gamma 120.000 - Primitive - R