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J.B. Percival, A.D. Olejarz*, M.L.R. English*, P.M. Belley*, T. Flynn*,
A.B. Laudadio*, and J.A.R. Stirling▪.

* Students
▪ Deceased

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INTRODUCTION

Traditionally, the mineralogical analysis of rock samples is done using X-ray diffraction (XRD) of pulverized or powdered material. The derived powder patterns can be systematically interpreted using a variety of software programs and quantitative analysis can be determined using Rietveld refinement (Percival *et al*., 2001, 2013b). The qualitative and quantitative results can then be applied to resolving various geological problems (e.g., Percival *et al*., 2013a). Normally this type of analysis is carried out in the laboratory, however, recent developments in technology have enabled the conventional XRD unit to become small enough that it is now field portable.

A complementary technique to identifying minerals is using reflectance spectroscopy, specifically infrared spectroscopy. This technique uses energy in the Visible (VIS: 400-720 nm), Near Infrared (NIR: 720-1300 nm) and Short Wave Infrared (SWIR: 1300-2500 nm) regions of the electromagnetic spectrum. It was initially developed in the 1960 and 1970s as a means of remotely detecting rocks and minerals (e.g. Hunt and Salisbury, 1970) and is now established as a rapid, non-destructive method in exploration and other applications where minerals with distinct spectral reflectance characteristics are the target (see King *et al*., 2004, and references therein). It forms the basis of hyperspectral surveys using airborne or space-borne sensors in a variety of remote-sensing applications including remote-predictive mapping (Harris *et al*., 2012), exploration (Perry, 2004; Taranik, 2010; Laakso *et al*., 2015) and assessing environmental contamination (Swayze, 2004; Percival *et al*., 2013b).

Since the inception of the Geological Survey of Canada (GSC) in 1842, representative samples of Canadian rocks, ores and minerals have been collected and many of the first specimens were displayed at international exhibits such as the 1855 Paris Exhibit and 1862 London Exhibit (Logan and Hunt, 1862; Zaslow, 1975; Stirling *et al*., 2011). The National Reference Mineral Collection (NMC) of the GSC boasts more than 100,000 specimens of common, rare and unique minerals. Within this reference collection, formally recognized in 1961 (Steacy and Williams, 1976), 68,000 are properly catalogued and entered into a database (Stirling *et al*., 2011). Verification of many of the original hand specimens has been completed using XRD analysis for crystallographic properties and SEM-Energy Dispersive Spectroscopy (EDS) for chemical properties.

Spectral Libraries

This vast reference collection held at the GSC provides both an opportunity and challenge for reflection spectroscopy studies. Different physical and chemical properties of minerals result in their unique spectral reflectance characteristics. Many minerals are “infrared active” (Clark, 2004) due to the presence of molecules that vibrate when they absorb light (Clark, 2004; Hirschmugl, 2004; Hauff, 2005). However, spectral reflectance (absorption) features may also arise due to electronic charge transfers (VIS), crystal field effects (VIS/NIR) and conduction bands (UV-SWIR). The molecular vibration (SWIR) energy can be correlated with bond length, hence the wavelength position of the mineral bonds can be used to identify mineral species (Table 1). Thus, many rare and unique minerals, in addition to the common minerals, can be analyzed by infrared spectroscopy to provide a searchable spectral database for comparison to unknown minerals in the field or lab. The challenge is in analyzing the large number of available samples. To this end, a recent addition to the NMC was targeted first as a test to produce high quality spectra usable in a mineral spectral library. This addition consists of phyllosilicate minerals collected by Dr. H. Kodama (Department of Agriculture and Agri-Food Canada) over his career. About 50 spectral reflection datasets have been incorporated into the Terraspec Halo Library, which contains over 500 mineral spectra. The spectral library in this Open File report was modelled after the USGS Digital Spectral Library (http://speclab.cr.usgs.gov/spectral-lib.html) and the NASA-Jet Propulsion Laboratory Library (http://speclib.jpl.nasa.gov/documents/jpl_desc). For each mineral specimen analysed, a plot and the raw data (.txt file) has been made available for use in identifying phyllosilicate minerals in exploration, environmental or other geological studies.

MATERIALS AND METHODS

In 2007, Dr. H. Kodama, upon retiring from Agriculture and Agri-Food Canada, donated his extensive clay mineral collection (herein referred to as the Kodama Collection) to the GSC. Over a few of years, Mr. John Stirling painstakingly catalogued the clay mineral samples and incorporated them into the NMC database. Purity of each sample was verified through examination of publications included with the collection, or through follow-up X-ray diffraction analysis at the GSC. The Kodama Collection includes pure clay minerals from the kaolinite-serpentine group, talc-pyrophyllite group, mica-group, chlorite-group, vermiculite-group, smectite-group, sepiolite-palygorskite group and a variety of mixtures and mixed-layer clay minerals. Some of the samples were obtained from the Association of Petroleum Institute (A.P. I. Clay Mineral Standards: http://minerals.gps.caltech.edu/files/atr/myweb5/clay.htm), Source Clays of the Clay Minerals Repository (The Clay Minerals Society: http://www.clays.org/SOURCE%20CLAYS/SCorder.html), Reference Clay Samples from the Japan Clay Science Society (http://www.cssj2.org/english/reference_clay_e.html), and Ward's Natural Science (now Ward's Science), but most were collected during his field excursions or through detailed research on soils.

Spectral Analysis

Spectral analyses of the Kodama Collection, using a TerraSpec Pro™ 4 VIS-NIR-SWIR portable spectroradiometer, were carried out during the summer of 2013. The TerraSpecPro™ 4 instrument was loaned to the Geological Survey of Canada by PANalytical (formerly ASD, Inc.) to ensure collection with a high resolution instrument. The TerraSpecPro™ 4 spectral resolution ranges from 3 nm in the visible and near infrared (VNIR) range and between 8 and 10 nm in the short-wave infrared (SWIR) range, with a spectral sampling of 1 nm across the entire range.

To collect consistent, high quality data, a step by step approach was adopted, based on PANalytical protocols. All measurements were made in a "dark box" (Fig.1A) to reduce interference from extraneous light. Steps followed included calibration of the instrument at the beginning of each collection day, followed by optimization procedures, collection of white reference (using Spectralon® puck; Figs. 1B and 1C) and dark current (Fig. 1B). Each step is outlined in detail in Appendix I. For all measurements, it was necessary to have the instrument and contact probe turned on for at least 40 minutes before spectral measurements, to ensure the probe and spectrometers were sufficiently warmed up and stable.

Collection of Spectra

For every sample, three spectra were collected on the same area (spot size 10 mm). Powdered samples were placed into small aluminum holders (Fig. 1D) and filled to the top to make a good seal with the contact probe. Spectra were brought into ViewSpec® Pro software for further processing. First, each spectrum was corrected using "splice correction" to smooth the spectrometer transition (offset) steps produced between the VNIR and SWIR1 detectors (at 1000 nm), and the SWIR1 and SWIR2 detectors (at 1830 nm). Following this, each spectrum was exported as an ASCII type file. Each set of spectra was then brought into Excel™ and averaged. The average spectrum was then used to create the plots and each plot exported as a .pdf file. The average data with wavelength information was then processed to create a .txt file for easy accessibility.

Description of Samples

The description of each sample in the Kodama Collection is provided as a Word™ document and information is based on notes on the sample vials. The descriptions include mineral name, generic formula, locality, a brief sample description including texture, grain size where applicable, colour, origin (e.g., A.P.I., Ward's etc.) of sample if known, and date of spectral collection. A summary of the textural terms used to characterize the samples is illustrated in Figs. 2-4. No attempt was made to photograph each sample.

RESULTS

Table 2 gives a summary list of samples that have been analysed using the TerraSpecPro™ 4 instrument. The samples have been arranged according to Dana's Classification (Gaines *et al.*, 1997; http://webmineral.com/danaclass.shtml). In all, there were 166 samples analysed. Samples with the same NMC number or name represent a variant of that sample. This variant could be based on grain size (e.g., < 2 µm, 2-5 µm, > 2 µm), texture (e.g., powder, flakey, massive), colour (e.g., white, beige, brown). Each sample is provided with a unique ID number and all files pertaining to that ID are named accordingly.

The raw data for each spectrum is provided in an ASCII file format (*.txt). Each sample has been hyperlinked to obtain the description of the material used, the raw data and the plot. Sample spectra have not been vetted for purity; some may represent mixtures of minerals but the dominant phase is identified. In order to examine the description, plot or raw data, click the hyperlink name outlined in blue font.

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We thank Dr. H. Kodama for entrusting the GSC with his life-long collection of samples. Special thanks to Chris Sherry and Don Campbell (ASD, Inc., now Panalytical) for loan of the TerraspecPro™ 4 instrument for this project and for their careful instructions on calibration and collection of high quality spectral data. We are grateful to Lori Wickert (consultant), Jeff Harris (GSC), H. Peter White (CCMEO) and Jodie Francis (CCMEO) for their engaging discussions on collecting spectral data and development of a spectral library. Thanks also to Ann Therriault (Curator Earth Materials Collections, GSC) for access to the Kodama Collection for this project. This project is supported by GeoMapping for Energy and Minerals (GEM-II) Program under the current Open Geoscience project. Critical review by H. Peter White helped to improve this report.

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APPENDIX I

Procedure for Collecting Infrared Spectra with a PANalytical (formerly ASD, Inc) Instrument (*based on instructions provided by PANalytical*)

A: Calibrating the Terraspec Pro™ 4 Spectrometer

It is important to let the spectrometer run for at least 40 minutes before calibration. Both the spectrometer and the probe must be turned on during this time to "wake up" the spectrometers as well as warm up the probe.

Reference S/N refers to the serial number of the ASD puck that is used for the calibration. The number is found on the back of the Mylar coated puck (S/N 1002).

The system will ask for a baseline to be taken. Before clicking "Baseline", make sure that the probe is flush with the white Spectralon® puck. Make sure the puck is clean and gently place the probe on a smooth part of the puck.

When the instrument prompts you to "cap the fiber", turn off the contact probe and place it flush with the inside of the black spectralon case, then press "OK".

When the instrument prompts you to uncap the fibre, turn on the lamp and place the probe flush with the spectralon, then press "OK".

Place the reference puck (S/N 1002) under the probe and allow the Terraspec to collect a spectrum. The Terraspec will perform 50 different scans and will check its accuracy.

The system may fail the calibration check because the parameters set by ASD are very precise; the acceptable values are +/- 0.2. Save the spectrum.

Create a new folder for each day (e.g., 18-Aug-2013) and record the information in an Excel™ Workbook (e.g., CalCheck18-Aug-2013.xls).

Close the Calcheck software and open the RS^3 software.

B: Optimizing, White Reference, Dark Current

Before data can be collected, the Terraspec must be optimized and a white reference and dark current must be taken.

To optimize the instrument, place the contact probe on the white Spectralon® puck and press the "OPT" button.

The instrument will prompt to "cap the fiber". Turn off the contact probe's light and place the probe on the lid of the spectralon puck.

When the instrument prompts to “uncap the fiber”, turn the contact probe on and place the probe on the white Spectralon® puck.

Optimization should be done once every session, or every four hours. A session consists of a morning or an afternoon. If the instrument is used the whole day, optimize once in the morning and once after lunch.

To take a white reference, gently place the contact probe on the white Spectralon® puck and press the “WR” button. A timer in the top left corner of the program will begin under the title “White Reference”. This must be taken approximately every 15 minutes.

To take a dark current, place the probe on the black lid of the Spectralon® puck and turn off the contact probe. Press the “DC” button to take the dark current. A timer in the top left corner of the program will begin under the title “Dark Current”. This must be taken approximately every 15 minutes.

The white reference and the dark current do not need to be saved.

C: Collecting the Reference Puck Standard

Before collecting sample spectra, the Reference Puck Standard spectrum must be collected. This only needs to be done once per optimization. This can be performed more often to confirm a uniform light source characteristic. Optimization should be done once every session, or every four hours. A session consists of a morning or an afternoon. If the instrument is used the whole day, optimize once in the morning and once after lunch.

It is recommended that the Spectralon® reference puck be calibrated to the specific system used, as the reflectance characteristics of the Spectralon® material has been noted to degrade over time, with changes in reflectance of up to 10% at select spectral regions (e.g., see Anderson *et al*., 2002; Jackson *et al*., 1992).

After completing the optimization, white reference and dark current, place the contact probe on the reference puck. Save the spectrum.

D: Setting Up a Collection Folder

A collection folder helps keep the collections organized and easy to locate.

From the RS^3 software, go into “Control” and then “Spectrum Save”.

Set the destination in the same folder that you put the “CalCheck” worksheet.

Name the first spectra the date you are collecting (e.g., 13-Aug-20130000). After each sample spectrum is collected, the name will automatically change to the next number in the series (i.e., after 13-Aug-20130000 is collected, 13-Aug-20130001 will be collected next). Use the space bar to save a spectrum.

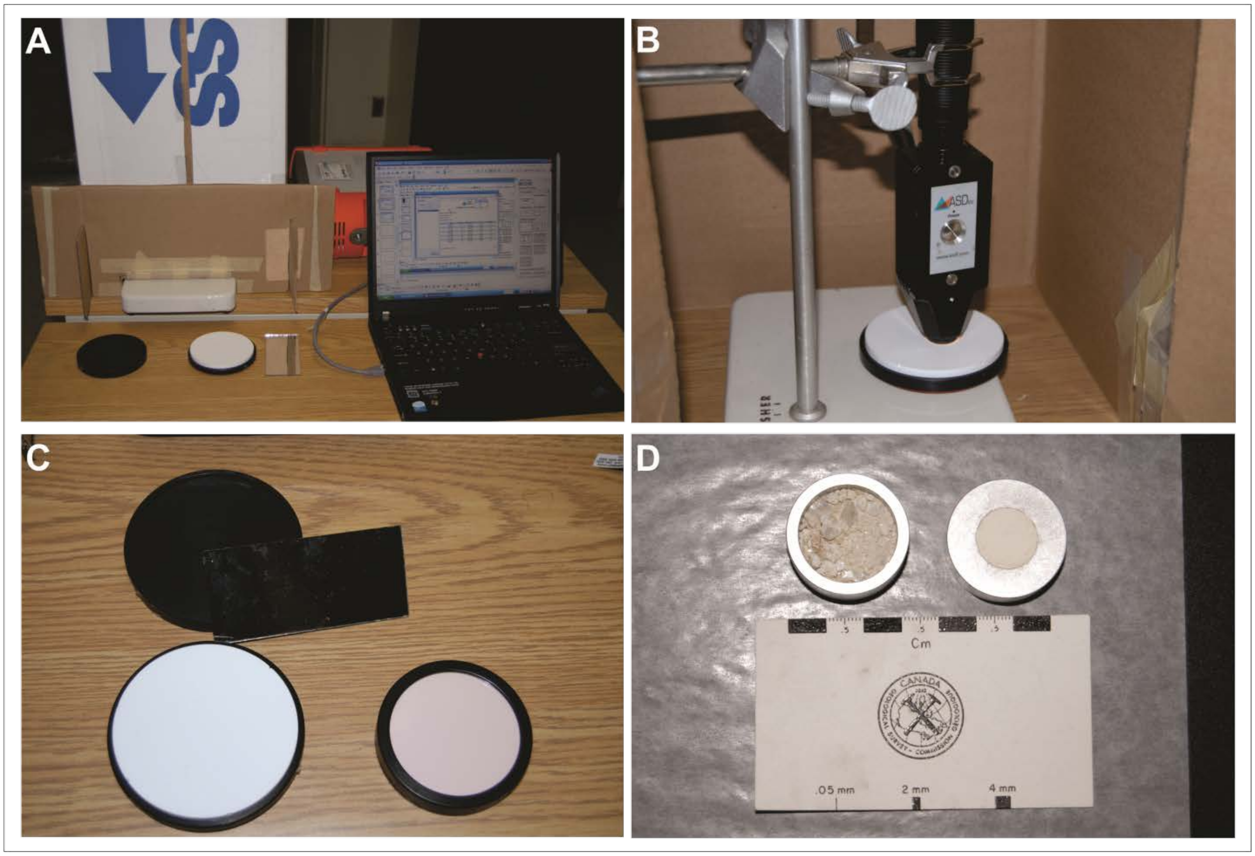

Figure 1. Dark box set-up for collecting spectra: A) light-tight dark box and computer set-up; B) retort stand in box holding Contact Probe in contact with the Spectralon® puck; C) Spectralon® puck, calibration puck and back of holder for dark current measurements; D) aluminum holders used for packing powder samples.

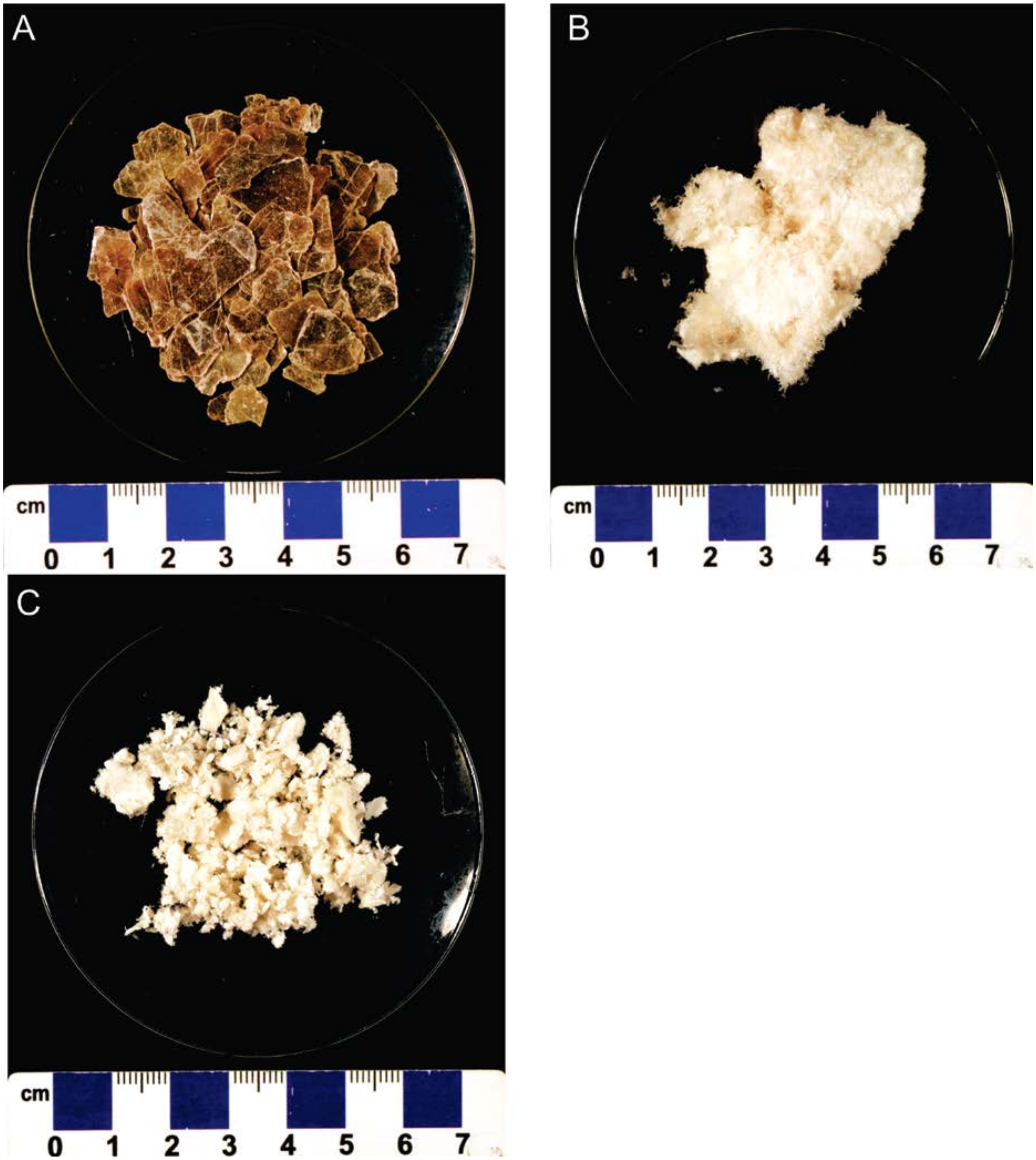

Figure 2. Examples of flakey and fluffy textures: A) flakey (sheets) vermiculite (ID1067); B) fluffy montmorillonite (< 0.2 µm) (ID1091); C) fluffy montmorillonite (< 2 µm) (ID1089).

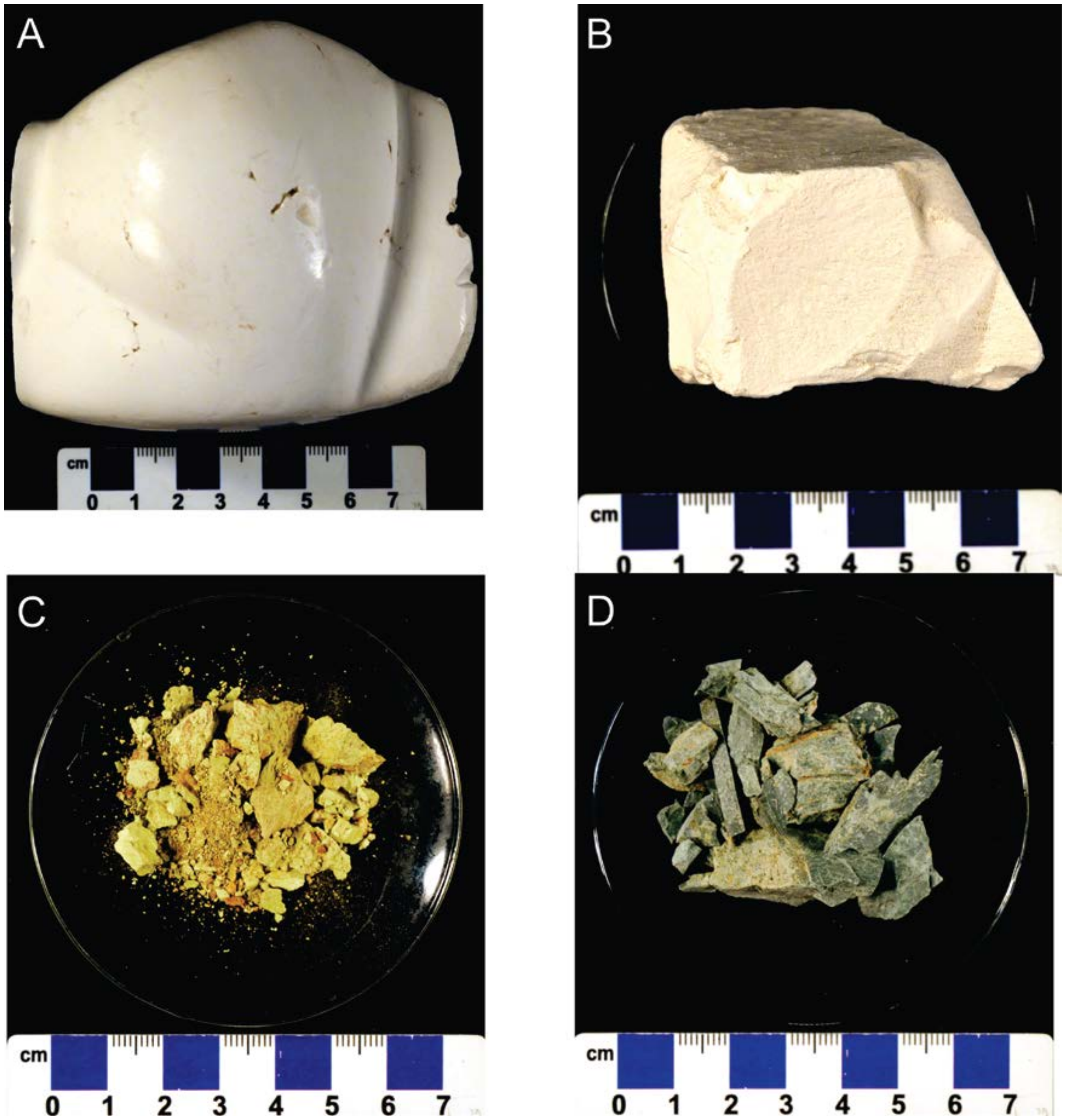

Figure 3. Examples of massive to rubbly texture: A) massive sepiolite (ID1154); B) massive kaolinite (ID1006); C) rubbly nontronite (ID1101); D) rubbly to massive illite (IMt-1)(ID1166).

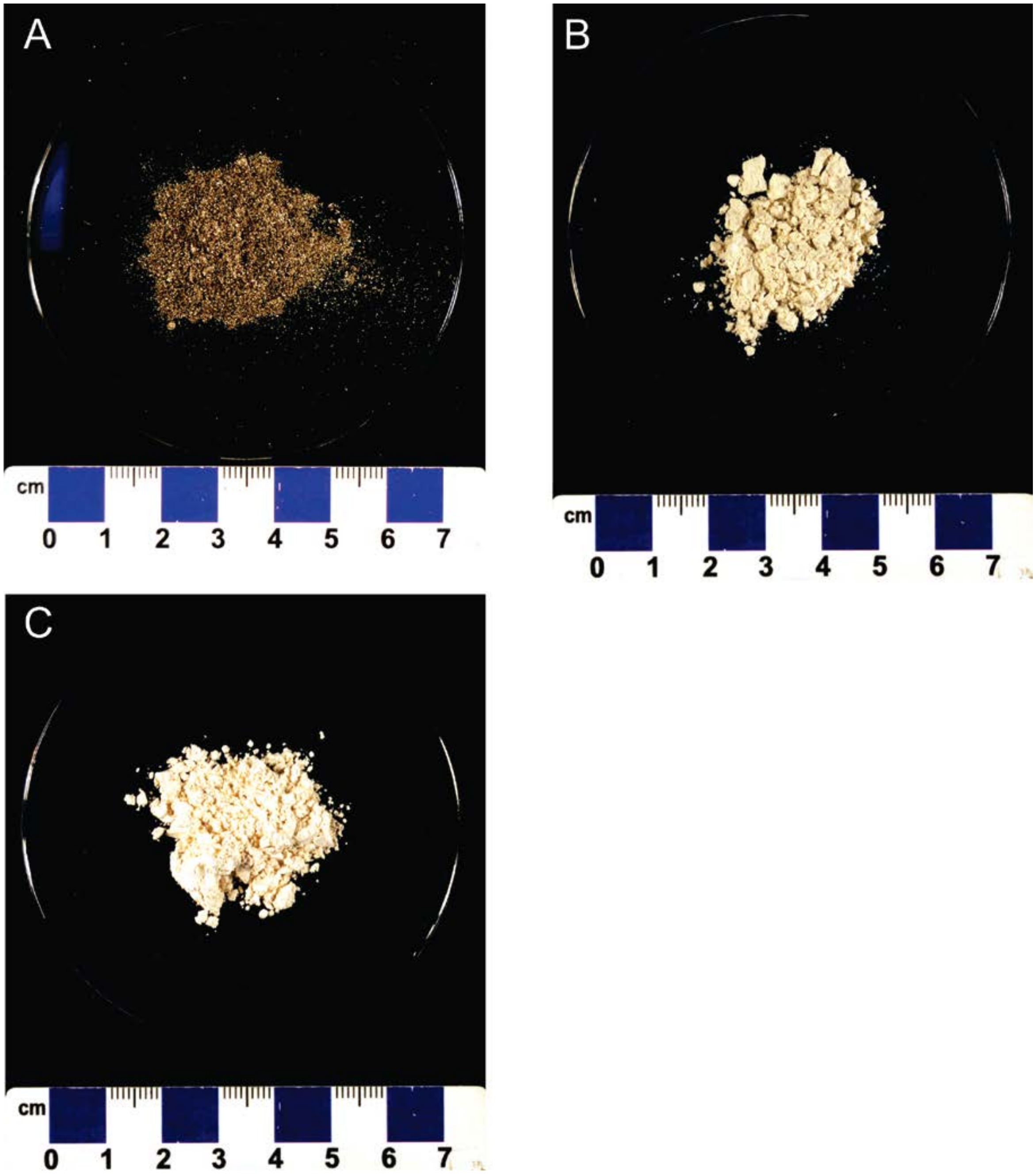

Figure 4. Examples of powdered/pulverized samples: A) Mg-saturated biotite (>5 µm) (ID1059); B) kaolinite (ID1010); C) palygorskite (PFl-1 – attapulgite variety) (ID1150).

Table 1. Wavelength positions of major absorption bands in the SWIR region for common mineral groups (after Hauff, 2005).

Position	Molecule	Mineral Group
1400 nm	OH & Water	Clays, Sulphates, Hydroxides, Zeolites
1560 nm	NH_4	NH_4 Species
1800 nm	OH	Sulphates
1900 nm	Water	Clays
2020, 2120 nm	NH_4	NH_4 Species
2160-2220 nm	Al-OH	Minerals containing Al-OH bonds such as clays, sulphates, micas etc.
2230 -2295 nm	Fe-OH	Minerals containing Fe-OH bonds such as clays, amphiboles, sulphates, micas etc.
2300-2360 nm	Mg-OH	Minerals containing Mg-OH bonds such as clays, amphiboles, chlorites etc.
2300-2350 nm	CO_3^{2-}	Carbonates

Table 2. List of clay minerals, organized according to Dana's Mineralogical Classification, with accompanying sample description (.docx), raw data (.txt) and plot (.pdf) of reflectance spectra. All data organized using a unique ID number (column 3). To view results, click hyperlink name shown in blue font.

Spectrum Title	Date Spectra Collected	ID #	Description	Data	Plot(s)
71.01 Phyllosilicates, Phyllosilicate Sheets of Six-Membered Rings with 1:1 layers					
71.01.01 Kaolinite group, $Al_2Si_2O_5(OH)_4$					
71.01.01.01 Dickite					
NMC068170 Dickite (Massive)	June 14 2013	1001	Description	Data	Plot
NMC068170 Dickite (Rusty)	June 14 2013	1002	Description	Data	Plot
NMC068170 Dickite (Creamy White)	June 14 2013	1003	Description	Data	Plot
NMC068171 Dickite (Powder)	July 24, 2013	1004	Description	Data	Plot
71.01.01.02 Kaolinite					
NMC068120 Kaolinite (KGa-2)	August 15, 2013	1005	Description	Data	Plot
NMC068121 Kaolinite (H-5; Massive)	July 24, 2013	1006	Description	Data	Plot
NMC068122 Kaolinite (H-1)	July 14, 2013	1007	Description	Data	Plot
NMC068123 Kaolinite (H-9; Massive)	July 16, 2013	1008	Description	Data	Plot
NMC068124 Kaolinite (Powder)	August 15, 2013	1009	Description	Data	Plot
NMC068153 Kaolinite (Powder)	August 15, 2013	1010	Description	Data	Plot
NMC068173 Kaolinite (Powder)	June 14, 2013	1011	Description	Data	Plot
NMC068177 Kaolinite (Massive)	June 14, 2013	1012	Description	Data	Plot
NMC068179 Kaolinite (Massive)	June 14, 2013	1013	Description	Data	Plot
NMC068188 Kaolinite (Rubble)	June 14, 2013	1014	Description	Data	Plot
NMC068191 Kaolinite (Massive)	June 14, 2013	1015	Description	Data	Plot
NMC068193 Kaolinite (Powder)	August 14, 2013	1016	Description	Data	Plot
NMC068195 Kaolinite (Massive)	October 15, 2013	1017	Description	Data	Plot
Kaolinite (GOTOMINE)	June 14, 2013	1018	Description	Data	Plot
Kaolinite (Buffalo China Mine)	June 14, 2013	1019	Description	Data	Plot
Kaolinite (KGa-1)	June 14, 2013	1020	Description	Data	Plot
Kaolinite (Macon, GA)	June 14, 2013	1021	Description	Data	Plot

Mg-Kaolinite (NR Provins)	June 14, 2013	1022	Description	Data	Plot

71.01.01.03 Halloysite

NMC068128 Halloysite (H-12; Massive)	July 16, 2013	1023	Description	Data	Plot
NMC068129 Halloysite (H-13; Massive)	July 16, 2013	1024	Description	Data	Plot
NMC068130 Halloysite	July 16, 2013	1025	Description	Data	Plot
NMC068178 Halloysite	July 16, 2013	1026	Description	Data	Plot

71.01.02 Serpentine Group

71.01.02a.01 Antigorite, $(Mg,Fe^{+2})_3Si_2O_5(OH)_4$

NMC068169 Antigorite (Spectra set 2; <2 µm; powder)	June 14, 2013	1027	Description	Data	Plot
NMC068169 Antigorite (Massive)	June 14, 2013	1028	Description	Data	Plot
NMC068169 Antigorite (Spectra set 3; >2 µm; powder)	June 14, 2013	1029	Description	Data	Plot

71.01.02b.02 Lizardite, $Mg_3Si_2O_5(OH)_4$

NMC068181 Lizardite (Massive)	June 14, 2013	1030	Description	Data	Plot

71.01.05.01 Allophane Group*

71.01.05.01 Allophane, $Al_2O_3{\cdot}(SiO_2)_{1.3\text{-}2}{\cdot}(2.5\text{-}3)H_2O$

NMC068184 Allophane (Powder)	July 16, 2013	1031	Description	Data	Plot

71.02 Phyllosilicates, Phyllosilicate Sheets of Six-Membered Rings with 2:1 Layers

71.02.01 Pyrophyllite-Talc Group

71.02.01.01 Pyrophyllite, $Al_2Si_4O_{10}(OH)_2$

NMC068131 Pyrophyllite (H-49; Powder/Flakey)	July 16, 2013	1032	Description	Data	Plot
NMC068180 Pyrophyllite	August 15, 2013	1033	Description	Data	Plot

71.02.01.03 Talc, $Mg_3Si_4O_{10}(OH)_2$

NMC068172 Talc	June 14, 2013	1034	Description	Data	Plot
Talc (Spain)	June 14, 2013	1035	Description	Data	Plot

71.02.02a Mica Group (Muscovite subgroup)

71.02.02a.01 Muscovite, $KAl_2(Si_3Al)O_{10}(OH,F)_2$

Muscovite (Miyori; M7)	July 16, 2013	1036	Description	Data	Plot
Muscovite Standard (MIN 1882)	October 25, 2013	1037	Description	Data	Plot
Muscovite (Effingham)	July 16, 2013	1038	Description	Data	Plot

Phengite, $KAl_2(Si_3Al)O_{10}(OH,F)_2$

Phengite (Tibouron)	June 14, 2013	1039	Description	Data	Plot

Sericite, $NaAl_2(Si_3Al)O_{10}(OH)_2$

Sericite (Nabeyama Mine; Massive)	July 26, 2013	1040	Description	Data	Plot
Sericite (Hikawa; Zenjo Pit; (Powder)	August 9, 2013	1041	Description	Data	Plot
Sericite (Sanshin)	August 9, 2013	1042	Description	Data	Plot
Sericite (Unfractionated; Powder)	August 13, 2013	1043	Description	Data	Plot
Sericite (<0.2µm)	August 13, 2013	1044	Description	Data	Plot
Sericite (2-0.2µm)	August 13, 2013	1045	Description	Data	Plot

71.02.02b Mica Group (Biotite subgroup)

71.02.02b.01 Phlogopite, $KMg_3(Si_3Al)O_{10}(F,OH)_2$

Phlogopite (North Burgess; >50µm; Fine Flakes)	July 26, 2013	1046	Description	Data	Plot
Phlogopite (North Burgess; Bulk Sample)	August 13, 2013	1047	Description	Data	Plot
Phlogopite (North Burgess; <50 µm)	August 13, 2013	1048	Description	Data	Plot
Phlogopite (North Burgess; <2 µm)	August 13, 2013	1049	Description	Data	Plot
Phlogopite (North Burgess; >2 µm)	August 13, 2013	1050	Description	Data	Plot
Phlogopite (North Burgess; 2-5 µm)	August 13, 2013	1051	Description	Data	Plot
Phlogopite (North Burgess; 1-2 µm)	August 13, 2013	1052	Description	Data	Plot

71.02.02b.02 Biotite, $K(Mg,Fe^{+2})_3AlSi_3O_{10}(OH,F)_2$

Biotite (Bancroft-1; flakes)	November 5, 2013	1053	Description	Data	Plot
Biotite (Bancroft-2; >20µm)	November 5, 2013	1054	Description	Data	Plot
Biotite (Bancroft-3; 100-325 mesh)	November 5, 2013	1055	Description	Data	Plot
Biotite (Bancroft-4; <45µm)	November 5, 2013	1056	Description	Data	Plot
Biotite (Bancroft-5; 2-1µm)	November 5, 2013	1057	Description	Data	Plot
Biotite (Bancroft-6; <2µm)	November 5, 2013	1058	Description	Data	Plot
Biotite (Mg-sat; >5µm)	August 13, 2013	1059	Description	Data	Plot

71.02.02d.02 Illite, $(K,H_3O)(Al,Mg,Fe)_2(Si,Al)_4O_{10}[(OH)_2,(H_2O)]$

NMC067552 Illite	August 13, 2013	1166	Description	Data	Plot
Illite	July 26, 2013	1167	Description	Data	Plot

71.02.02d.03 Vermiculite, $(Mg,Fe^{+2},Al)_3(Al,Si)_4$

NMC068167 Vermiculite (VTx-1)	August 2, 2013	1060	Description	Data	Plot
NMC068167 Vermiculite (VTx-1; <2 µm)	August 2, 2013	1061	Description	Data	Plot
NMC068168 Vermiculite (< 2 µm)	August 2, 2013	1062	Description	Data	Plot
NMC068168 Vermiculite (5-20 µm; powder)	August 2, 2013	1063	Description	Data	Plot
NMC068168 Vermiculite (> 20 µm)	August 2, 2013	1064	Description	Data	Plot
NMC068168 Vermiculite (1-3 cm sheets)	August 2, 2013	1065	Description	Data	Plot
NMC068189 Vermiculite (Kenya)	August 26, 2013	1066	Description	Data	Plot
NMC068190 Vermiculite (Transvaal)	August 26, 2013	1067	Description	Data	Plot

71.03.01a Smectite group (Dioctahedral Smectites)

71.03.01a.01 Beidellite, $Na_{0.5}Al_2(Si_{3.5}Al_{0.5})_{10}(OH)_2\cdot n(H_2O)$

NMC068139 Beidellite (Mg-sat; <2µm)	August 2, 2013	1068	Description	Data	Plot

71.03.01a.02 Montmorillonite, $(Na,Ca)_{0.33}(Al,Mg)_2Si_4O_{10}(OH)_2\cdot n(H_2O)$

NMC067551 Montmorillonite (SCa-3)	August 2, 2013	1069	Description	Data	Plot
NMC068146 Montmorillonite (<2µm; powder)	August 2, 2013	1070	Description	Data	Plot
NMC068146 Montmorillonite (H-23)	August 2, 2013	1071	Description	Data	Plot
NMC068147 Montmorillonite (H-24)	August 2, 2013	1072	Description	Data	Plot
NMC068148 Montmorillonite (H-25)	August 2, 2013	1073	Description	Data	Plot
NMC068148 Montmorillonite (H-25; <2µm)	July 26, 2013	1074	Description	Data	Plot
NMC068149 Montmorillonite (H-28)	July 26, 2013	1075	Description	Data	Plot
NMC068149 Montmorillonite (H-28; <2µm)	August 2, 2013	1076	Description	Data	Plot
NMC068150 Montmorillonite (H-31)	July 26, 2013	1077	Description	Data	Plot
NMC068151 Montmorillonite (H-32)	July 26, 2013	1078	Description	Data	Plot
NMC068151 Montmorillonite (H-32; <2µm)	August 2, 2013	1079	Description	Data	Plot
NMC068154 Montmorillonite (H-19; powder)	August 2, 2013	1080	Description	Data	Plot
NMC068154 Montmorillonite (H-19)	Aug 2 2013	1081	Description	Data	Plot
NMC068155 Montmorillonite (SMH-19)	July 26, 2013	1082	Description	Data	Plot
NMC068155 Montmorillonite (SMH-19; <2µm)	August 2, 2013	1083	Description	Data	Plot

NMC068156 Montmorillonite	August 2, 2013	1084	Description	Data	Plot
NMC068175 Montmorillonite	August 2, 2013	1085	Description	Data	Plot
NMC068175 Montmorillonite	August 2, 2013	1086	Description	Data	Plot
NMC068176 Montmorillonite	August 2, 2013	1087	Description	Data	Plot
Montmorillonite (Wy-1)	October 25, 2013	1088	Description	Data	Plot
Na-Montmorillonite (Wy-2)	October 25, 2013	1089	Description	Data	Plot
Na-Montmorillonite (Wy-3; 2-0.2µm)	October 25, 2013	1090	Description	Data	Plot
Na-Montmorillonite (Wy-4; <0.2µm)	October 25, 2013	1091	Description	Data	Plot
Montmorillonite (Wy-5; Mg-sat)	October 25, 2013	1092	Description	Data	Plot
Montmorillonite (Wy-6; K-sat)	October 25, 2013	1091	Description	Data	Plot
Montmorillonite (Osage, Wyoming; Rubbly)	July 26, 2013	1092	Description	Data	Plot

Calcium-Montmorillonite, $Ca(Ca_3,Al_2)Si_5O_{10}(OH)_8$

Montmorillonite (Wy-7; <2µm)	October 25, 2013	1095	Description	Data	Plot
Montmorillonite (Wy-8; <0.2µm)	October 25, 2013	1096	Description	Data	Plot
NMC068152 Montmorillonite (SAz-1)	August 2, 2013	1097	Description	Data	Plot
NMC068152 Montmorillonite (SAz-1; <2µm)	August 2, 2013	1098	Description	Data	Plot
Montmorillonite (STx-1)	August 2, 2013	1099	Description	Data	Plot

71.03.01a.03 Nontronite, $Na_{0.3}Fe^{+3}_2(Si,Al)_4O_{10}(OH)_2\cdot n(H_2O)$

NMC068132 Nontronite (NG-1)	August 2, 2013	1100	Description	Data	Plot
NMC068134 Nontronite (H-33a)	July 26, 2013	1101	Description	Data	Plot
NMC068134 Nontronite (H-33a; Ca-sat; <2µm)	August 2, 2013	1102	Description	Data	Plot
NMC068135 Nontronite (H-33b)	July 26, 2013	1103	Description	Data	Plot
NMC068136 Nontronite	July 26, 2013	1104	Description	Data	Plot
NMC068136 Nontronite (Mg-sat; <2µm)	August 2, 2013	1105	Description	Data	Plot

71.03.01b Smectite group (Trioctahedral Smectites)

71.03.01b.02 Saponite, $Ca_{0.25}(Mg,Fe)_3((Si,Al)_4O_{10})(OH)_2\cdot n(H_2O)$

NMC068140 Saponite	July 26, 2013	1106	Description	Data	Plot

71.03.01b.03 Sauconite, $Na_{0.3}Zn_3(SiAl)_4O_{10}(OH)_2\cdot 4H_2O$

NMC068142 Sauconite	August 8, 2013	1107	Description	Data	Plot
NMC068143 Sauconite	July 26, 2013	1108	Description	Data	Plot

71.03.01b.04 Hectorite, $Na_{0.3}(Mg,Li)_3Si_4O_{10}(OH)_2$

NMC068137 Hectorite (SHCa-1; <2µm)	August 8, 2013	1109	Description	Data	Plot
NMC068137 Hectorite (SHCa-1)	August 8, 2013	1110	Description	Data	Plot
NMC068138 Hectorite (H-34)	July 26, 2013	1111	Description	Data	Plot

71.03.01b.06 Stevensite, $(Ca_{0.5},Na)_{0.33}(Mg,Fe^{+2})_3Si_4O_{10}(OH)_2 \cdot n(H_2O)$

NMC068141 Stevensite	July 26, 2013	1112	Description	Data	Plot
NMC068141 Stevensite (Mg-sat; <2µm)	August 8, 2013	1113	Description	Data	Plot

71.04.01 Chlorite Group (Tri-Dioctahedral)

71.04.01.03 Sudoite, $Mg_2(Al,Fe^{+3})_3Si_3AlO_{10}(OH)_8$

NMC068164 Sudoite (<5µm)	August 8, 2013	1114	Description	Data	Plot
NMC068164 Sudoite (>5µm)	August 8, 2013	1115	Description	Data	Plot

71.04.01.04 Clinochlore, $(Mg,Fe^{+2})_5Al(Si_3Al)O_{10}(OH)_8$

NMC068185 Clinochlore	July 26, 2013	1116	Description	Data	Plot
NMC067558 Fe-Chlinochlore (var. Ripidolite; CCa-1)	August 8, 2013	1117	Description	Data	Plot
NMC067558 Fe-Clinochlore (CCa-1)	July 26, 2013	1118	Description	Data	Plot
NMC068165 Fe-Clinochlore (var. Ripidolite)	July 26, 2013	1119	Description	Data	Plot
NMC068165 Fe-Clinochlore (var. Ripidolite; >2µm)	August 8, 2013	1120	Description	Data	Plot
NMC068165 Fe-Clinochlore (var. Ripidolite; 5-20µm)	August 8, 2013	1121	Description	Data	Plot
NMC068165 Fe-Clinochlore (var. Ripidolite; <50µm)	August 8, 2013	1122	Description	Data	Plot
NMC068165 Fe-Clinochlore (var. Ripidolite; 50-150µm)	August 8, 2013	1123	Description	Data	Plot
NMC068165 Fe-Clinochlore (var. Ripidolite; 150-250µm)	August 8, 2013	1124	Description	Data	Plot
NMC068165 Fe-Clinochlore (var. Ripidolite; >150µm)	August 8, 2013	1125	Description	Data	Plot
NMC068166 Clinochlore (var. Sheridanite)	July 26, 2013	1126	Description	Data	Plot
NMC068166 Clinochlore (var. Sheridanite; <2µm)	August 8, 2013	1127	Description	Data	Plot

71.04.01.07 Chamosite, $(Fe^{+2},Mg,Fe^{+3})_5Al(Si_3Al)O_{10}(OH,O)_8$

Chamosite (140 mesh)	August 9, 2013	1128	Description	Data	Plot
Chamosite (<2µm)	August 9, 2013	1129	Description	Data	Plot
Chamosite (<10µm)	August 9, 2013	1130	Description	Data	Plot
Chamosite (<50µm)	August 9, 2013	1131	Description	Data	Plot

71.04.02 Regularly Interstratified Phyllosilicate Group

71.04.02.04 Tosudite, $Na_{0.5}(Al,Mg)_6(Si,Al)_8O_{18}(OH)_{12}\cdot 5(H_2O)$

Tosudite (Gifu, Japan)	August 14, 2013	1132	Description	Data	Plot

71.04.02.05 Corrensite, $(Ca,Na,K)(Mg,Fe,Al)_9(Si,Al)_8O_{20}(OH)_{10}\cdot n(H_2O)$

Corrensite (St. George Lake, On; 2-0.2µm)	August 14, 2013	1133	Description	Data	Plot

71.04.02.07 Rectorite, $(Na,Ca)Al_4(Si,Al)_8O_{20}(OH)_4\cdot 2(H_2O)$

Rectorite (Burghersdorf)	August 14, 2013	1134	Description	Data	Plot
Rectorite (Goto, Japan)	August 14, 2013	1135	Description	Data	Plot
Rectorite (Arkansas; <2µm)	August 9, 2013	1136	Description	Data	Plot
Rectorite (North Little Rock; <2µm)	August 9, 2013	1137	Description	Data	Plot
Rectorite (North Little Rock)	July 26, 2013	1138	Description	Data	Plot
Rectorite (Crude; <2µm)	August 14, 2013	1139	Description	Data	Plot
Rectorite (Flakey)	August 14, 2013	1140	Description	Data	Plot
Rectorite (2-0.2µm)	August 14, 2013	1141	Description	Data	Plot
Rectorite (Powder)	August 14, 2013	1142	Description	Data	Plot
Rectorite (Pakistan)	August 9, 2013	1143	Description	Data	Plot
Rectorite (var. Allevardite)	August 9, 2013	1144	Description	Data	Plot

71.04.02.08 Aliettite, $Ca_{0.2}Mg_6(Si,Al)_8O_{20}(OH)_4\cdot 4H_2O$

Aliettite (Nure Valley; <2µm)	August 14, 2013	1145	Description	Data	Plot

74.03 Phyllosilicates, Phyllosilicate Modulated Layers with joined Strips

74.03.01a Palygorskite-Sepiolite Group (Palygorskite subgroup)

74.03.01a.01 Palygorskite, $(Mg,Al)_2Si_4O_{10}(OH)\cdot 4H_2O$

Palygorskite (Mg-sat; <2µm)	August 9, 2013	1146	Description	Data	Plot
Palygorskite (Chalautre Le Petite)	August 9, 2013	1147	Description	Data	Plot
NMC068163 Palygorskite (<2µm)	August 8, 2013	1148	Description	Data	Plot
NMV068163 Palygorskite (Attapulgite)	August 8, 2013	1149	Description	Data	Plot
NMC068163 Palygorskite (>2µm)	August 13, 2013	1150	Description	Data	Plot

74.03.01b Palygorskite-Sepiolite Group (Sepiolite subgroup)

$74.03.01b.01$ Sepiolite, $Mg_4Si_6O_{15}(OH)_2 \cdot 6H_2O$

NMC068158 Sepiolite (SEPSP-1)	August 8, 2013	1151	Description	Data	Plot
NMC068159 Sepiolite (SEPNev-1)	July 26, 2013	1152	Description	Data	Plot
NMC068160 Sepiolite (Meerschaum; <2µm)	August 8, 2013	1153	Description	Data	Plot
NMC068160 Sepiolite (Meeschaum; 8-10cm)	August 8, 2013	1154	Description	Data	Plot
NMC068160 Sepiolite (Meeschaum)	July 26, 2013	1155	Description	Data	Plot
NMC068182 Sepiolite	July 26, 2013	1156	Description	Data	Plot
Sepiolite (<2µm)	August 13, 2013	1157	Description	Data	Plot

Iregularly Interstratified Phyllosilicate Group or Synthetic Mixtures

Kaolinite + Smectite

Kaolinite-Smectite	June 14, 2013	1159	Description	Data	Plot

Dickite + Kaolinite

Dickite-Kaolinite	August 9, 2013	1160	Description	Data	Plot

Pyrophyllite + Montmorillonite

Montmorillonite-Pyrophyllite (H-5; <2µm)	August 13, 2013	1161	Description	Data	Plot
Montmorillonite-Pyrophyllite (H-5)	August 13, 2013	1162	Description	Data	Plot

Chlorite-Vermiculite

Chlorite-Vermiculite (20-5µm)	August 9, 2013	1163	Description	Data	Plot
Chlorite-Vermiculite	August 13, 2013	1164	Description	Data	Plot
Mica-Montmorillonite (Synthetic)	August 9, 2013	1165	Description	Data	Plot

Ref:
new Dana Classification
http://webmineral.com/danaclass.shtml#.VdTZRLJzTrh