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FINAL REPORT ON THE EVALUATION OF THE PORTABLE INSTANTANEOUS DISPLAY ANALYSIS SPECTROMETER (PIDAS)

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BY R.J.P. LYON, PRINCIPAL INVESTIGATOR

TOD RUBIN, GRADUATE RESEARCHER

MAKOTO OHASHI, PASCO CORPORATION, JAPAN
CURRENTLY VISITING SCIENTIST, STANFORD UNIVERSITY

FOR

NASA HEADQUARTERS
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REMOTE SENSING LABORATORY
SCHOOL OF EARTH SCIENCES

FINAL REPORT ON THE EVALUATION OF THE PORTABLE INSTANTANEOUS DISPLAY ANALYSIS SPECTROMETER (PIDAS)

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GRANT TITLE: BASIC RESEARCH & EVALUATION OF THE PIDAS
FIELD SPECTROMETER

PERIOD OCTOBER 1, 1987- NOVEMBER 30, 1988

(FIVE COPIES TO NASA)

JUNE 3, 1988

1. INTRODUCTION AND AIMS OF THE PROGRAM

1.1 General Statement.

The original aims of the project were to evaluate the Portable Instantaneous Display Analysis System (PIDAS) by measuring the spectra of fifty (50) mineral specimens and rock samples under the following conditions:

1. In the laboratory under artificial illumination.
2. Outdoors, on the building "patio", while still using the normal (line voltage) electrical power supplies.
3. Outdoors, in the field (at Yerington, Nevada), using battery power.

In addition, the the Stanford Remote Sensing Laboratory (SRSL) owns or had access to three other types of field spectrometers:

1. Geophysical Environmental Research (GER) IRIS Mark IV, a diffraction grating unit;
2. GEOSCAN PFS (West Australia) Circular Variable Filter (CVF) unit, a prototype of a rapid scan, Portable Field Spectrometer (PFS);
3. SPECTRAFAX 440 (from Daedalus Enterprises, Inc.), the US-built production version of the GEOSCAN PFS unit.

The characteristics of these three units are listed in Table I.

Due to PIDAS malfunctions, however, only data from the laboratory and outdoor ("patio") phases of the work were retrievable for analysis.

1.2 Summary of the proposed study effort as per the Grant Statement of Work.

1. PIDAS would be one month at Stanford

2. 125 Spectra would be measured in the following manners;

   2.1 Indoors-- 10 standard clays
   25 field samples (Yerington,NV)

   2.2 "Patio"-- a. in sunlight-- same 25 samples
   b. under lamp -- same 25 samples

   2.3 Field -- a. in sunlight--25 samples from 10 sites. (Yerington--Ann Mason, Blue Hills, Buckskin Ra.-"Pyrophyllite Ridge" & "Alunite Hill" Ludwig skarns).

   b. 25 samples from these locations.

3. In addition PIDAS would be evaluated for (a) same FOV, repeated N-times, and (b) at M sub-sites within the same 20x20m TM-sized "pixel".

4. The Final Report would:
   (a) compare and contrast PIDAS with the other spectrometers available for our use:
   GEOSCAN-PFS;
   DAEDALUS-SPECTRAFAX 440;
   GER IRIS units
   (b) include about 125 spectra,
   and (c) provide those spectra in ASCII files on floppy disk(s) in machine readable form.

1.3 Summary of Proposed & Actual Spectra, Taken & Recovered

PROPOSED		ACTUAL MEASUREMENTS				
TASK	PIDAS	PIDAS		IRIS	PFS	SFAX
		Taken	Recov'd			
1.3.1-Indoors	25	143	45	50	50	100
1.3.2-Patio-sun	25	445	33	50	50	00
-lamp	25	00	00	50	50	100
1.3.2-Field-sun	25	400	00	30	100	220
TOTALS	125	988	78	180	250	420

TABLE I: CHARACTERISTICS OF THE FOUR SPECTROMETERS

	NASA/JPL PIDAS	GER Mark IV	Geoscan PFS	Daedalus SPECTRAFAX
FOV (DEG.)	6 circ.	2 x 4 deg	1 x 2 deg	1 x 2 deg
DISPERSIVE ELEMENT	Gratings 4 (1-vis 1-SWIR,4-step)	Gratings 3 rotating	CVF 3-element wheel	CVF 3-element wheel
Opt. Path	Single	Double	Single	Single
SPECTRAL RANGE nm	400-2400	400-3300	450-2400	450-2500
NOMINAL SPECTRAL RESOLUTION				
400-700nm	0.9 (425-922)	2	3-PERCENT (12-21nm)	2-PERCENT (8-14nm)
700-1400nm	4.7 (856-2490nm)	2	2.5-PERCENT (17-35nm)	2-PERCENT (14-28nm)
1400-2500nm	4.7	4	1.8-PERCENT (25-45nm)	1.5-PERCENT (21-37nm)
ACTUAL SPECTRAL RESOLUTION (um) (Calculated by G.Swayze,USGS)		18.4 at 1.39 um 25.1 at 2.17 um		
SAMPLED DATA POINTS	VIS-512 SWIR-360	880	256	360 280 data pts.
DETECTORS	Si+PbS	Si+PbS	Si+PbS	Si+PbS
ACQUISITION TIME (sec)	2	120	3	3
VOLUME (cm)				
OPT.HEAD	12x12x8	29x21x15	27x16x15	22x17x13
BACKPACK	75x48x31	35x21x22	30X20X7	89X38X31
TOTAL (cub.m)	0.113	0.026	0.011	0.108
RELATIVE SIZE	10	3	1	9
WEIGHT (kg)				
OPT.HEAD	1.0 est.	6.4	4.5	2.2
BACKPACK	29.4 est.	10.5	6.6	13.8
TOTAL (kg)	30.4	16.9	11.1	16.0
STORED SPECTRA IN LIBRARY	288 128	96 No	232 No	on disc No
ELECTRONICS	8-bit (now 12-bit)	12-bit (to 16-bit)	8-bit	10-bit

2. ACCESS TO PIDAS

PIDAS was made available to Stanford for evaluation on three separate occasions over the six month period from October 1987 through March 1988.

Period A: October 14-16, 1987, used indoors in lab, and only briefly outside.

Period B: November 11-12, 1987, field use only, in Nevada.

Period C: March 22-25, 1988, laboratory and patio use only (by JPL request)

Period C occurred after the PIDAS repairs during winter 1987-1988, which included increasing the data precision from 8 to 12-bit and bypassing of the instantaneous display capability. Only the data from Period C have been reducible to spectra.

Figure 2.1 Field evaluation of the four spectrometers, Yerington, NV. From left to right-- PIDAS, PFS, SFAX440, IRIS, with a New Zealand 8-channel radiometer (hand-held).

3. SUMMARY OF PIDAS TRIAL PERIODS

3.1 PERIOD A: LABORATORY & OUTDOORS, October 14-16, 1987

PIDAS: Only one spectrum was ever seen from the "instantaneous" viewing with the PIDAS wand. Considerable trouble was experienced in estimation of the gain-factors in the absence of viewable spectra. Additionally, no software for retrieving and processing data was available. We attempted writing software to reduce the raw PIDAS output to spectral plots, but the attempts were not successful. About 200 spectra were taken during this period, but none were usable.

PFS (GEOSCAN): Inoperable due to broken electronics.

SPECTRAFAX-440 (DAEDALUS): Unavailable

GER Mark IV: Operable, but not used concurrently with the other instruments.

3.2 PERIOD B: FIELD, Yerington, Nevada, November 11-12, 1987

These dates for the field work were determined solely by the availability of PIDAS. Unfortunately these dates also followed a period of light to moderate rain in Nevada. Most clay minerals had absorbed enough moisture so as to be unrecognizable from their shortwave infrared (SWIR) spectra at 2.2 um.

PIDAS: Operable for two field days in Yerington and in Virginia City, Geiger Grade, Nevada. About 200 spectra were taken, however, none were viewable, due to either software or memory-storage problems.

PFS: Operable, 100 spectra taken, all reduced and plotted.

SPECTRAFAX440: Made available to Stanford by Daedalus. Chuck Stanich of Daedalus accompanied us on the fieldtrip to assure the correct use of the instrument. About 220 spectra were taken, all reduced and plotted. Prototype software did not "average" correctly, so the single-spectra plotted below appear quite noisy outside the absorption peak areas.

GER Mark IV: Operable, 30 spectra taken. Not all were usable due to high moisture content in the clays, and to atmospheric moisture (relative humidity 50-75 %), leading to very strong absorptions at 1.4 and 1.9 um completely dominating the spectra.

3.3 PERIOD C: LABORATORY and OUTDOORS, March 22-25, 1988

The third period followed the re-building of PIDAS after the accident, and the revamping of the electronics from two 8-bit split data streams to one 12-bit single data stream. Because the study was designed to compare the instruments under identical conditions, only a single measurement by PIDAS was used for comparison to the single measurements made by the other instruments. This procedure was used rather than the standard JPL practice of averaging many separate PIDAS spectra to obtain a single result.

PIDAS: The system initially worked very well in the laboratory (Day C-1, March 22), but outdoors on the patio (Day C-2, March 23) only the SWIR segments of the data were recoverable. The visible segment apparently was not recorded, or at least recorded incorrectly. The outdoor data set (of Day C-2) was repeated on Day C-4 (March 25); 205 spectra were measured, of which 33 were usable. Subsequently the same samples were measured indoors with the PFS and the GER Mark IV.

PFS: Working well, 50 samples measured indoors.

SFX440: Not available to Stanford this period.

GER Mark IV: Working well. A considerable number of research days were devoted to ensuring that the "mode of operation" selected for the GER Mark IV was one which produced non-noisy spectra, without residual effects (offsets) due to grating changes.

4. COMPARISON OF INDOOR AND OUTDOOR PIDAS DATA

4.1. Geometry of Measurement

Despite our two attempts (October and November 1987) to obtain outdoor/field data we were unable to recover any usable spectra (see Table 1.3). During the third time we had access to PIDAS (March 23-25 1988), after the optical repair and with the new electronic configuration, we measured the sample sets inside the laboratory (with photoflood lamps) and outside using direct sunlight. Because of a poorly operating battery charger the PIDAS was run on line voltage in both locations (lab and patio) using a long extension cord.

In both cases the PIDAS backpack was placed horizontally on a 4-wheel trolley, with the optical head held by a C-clamp viewing downwards. The sample was placed about 30 cm below the head in full illumination from either the lamp or the sun. Phase angles were about 45 degrees. Each sample was measured twice, with a Halon reference measured between each pair of sample measurements.

4.2. Results

Sixteen (16) sample sets (outdoor and indoor) are shown in Set A1 - A16, the side-by-side comparison of the spectra allowing one to view their differences. The outdoor set (on the left, coded 0325A.*) were taken on March 25, from about 10 AM to 2 P.M. The indoor set are displayed on the right, coded 0323A.*.

Both sets have had one pass (SM=1) with the "V-filter" smoothing algorithm. This consists of passing a moving window over three adjacent data points N-1 through N+1, and recalculating the value of the central data point N according to the equation N = [(N-1 * 0.25) + (N * 0.5) + (N+1 * 0.25)].

Only single PIDAS spectra are shown. No averaging of multiple spectra (the JPL standard operating procedure) was attempted for any of the spectrometer data (except for one trial with the SPECTRAFAX 440, although the algorithm in their software was found out later not to be working). This procedure was used because the goal was to evaluate the instruments under identical conditions, not necessarily to produce the most noise-free spectra. The reproducibility of individual measurements and the effective instrument precision can not be evaluated by averaging multiple spectra.

Figure 4.1.1 Outdoor ("Patio") measurements, at Stanford. Left: Rob Green and Hiroshi Okayama measuring with optical head mounted on the side of the trolley. The sample was placed on the black plastic topped stool. Right: Close-up of the measurement geometry.

4.2.1 Outdoor Spectra (March 25)

The gain setting for visible wavelengths was clearly set too high, and despite the efforts of the science advisor (Rob Green) we could not get a spectrum viewed on the LCD wand. Spikes are visible in the 1.15 um water-vapor absorption band and were very strong in the 1.4 and 1.9 um regions during preprocessing. We modified our GER plotting program to omit the 1.4 and 1.0 um region date replacing it with horizontal lines (plateau-like regions in the spectral plots).

In the plot program the Y-axis scaling is "floating" to accommodate the maximum and minimum values in the data and to emphasize spectral features. This practice is best for comparing subtle spectral features as detected by the different instruments. Absolute radiometric accuracy was not investigated.

4.2.2 Indoor Spectra (March 23)

Problems in setting gains for the visible region of the spectrum did not appear as markedly as before, but this region showed considerable noise, even after mathematically smoothing the data (SM=1).

4.2.3 Analysis

Despite the negative effects of over-saturation in the visible, and the missing data in the 1.4 and 1.9 um regions, generally the other significant peaks could be seen in the plot. Spectral curve shapes were quite similar for indoor and outdoor measurements, and kaolinite doublets in the 2.2 um region were resolved.

5. COMPARISON OF THE FOUR SPECTROMETERS

5.1. Geometry of Measurement

All spectra were taken indoors under photoflood illumination. Working distances between sample and optics averaged 30 cm. Phase angle of the illumination was 45 degrees to the viewing optics.

No special preparation of the samples was undertaken. For the rock and mineral specimens, the rough natural surfaces were used. For powdered minerals, an untreated "heap" of powder was measured.

5.2. System Availability

5.2.1 PIDAS was available on 3 separate occasions: October 14 to 16 and November 11 to 12, 1987 and March 23 to 25, 1988, for a total of 9 operating days. For a variety of reasons, some electronic, some software, we have been unable to reduce data from the first two dates, and hence only the March 23 - 25 data (after repair) are used.

5.2.2 The GER Mark IV has had only intermittent availability. It is Stanford-owned but has given irregular service. In the 3 years since purchase (with Keck Foundation funding) we have processed over 2500 spectra and some of its recent troubles are due to this length of operation. Recently we had a mechanical failure of the grating rotation (a "freezing-up of the rotor") which was predictable based upon the 2500 spectra throughput.

5.2.3 The PFS is Stanford-owned and available when running. We have had some electronic problems in recent months, but it has usually operated well both in the field and in the laboratory. Several thousand PFS spectra have been collected, but a discussion of their information content is beyond the scope of this PIDAS report.

5.2.4 The SPECTRAFAX 440 was made available for the field evaluation period (November 10 - 12) and for the subsequent week, at no cost, by Daedalus Enterprises, Inc. In addition Daedalus supplied a field engineer (Chuck Stanich) for the first week to train us in the operation of SPECTRAFAX. Only data from those 2 weeks of operation in November are available, and not all of the following pages (B1-B34) have SPECTRAFAX spectra.

Generally a single pass of the V-filter (SM=1) was used to display the data.

5.2.5 Analysis

Thirty-four (34) sets of spectra from the four units have been compiled in Appendix B. They are arranged alphabetically for the standard minerals and by acquisition date for the field samples from Yerington and Virginia City, Nevada.

5.2.5.1 Spectral Coverage (See Table I)

All four spectrometers covered the same general range and are plotted from 500 to 2500 um, except for PIDAS which is shown from 450 to 2450 um. (The vertical grids mark every 100 um.)

5.2.5.2. Spectral Resolution (See Table I)

The uppermost two spectra on each page of the Appendix are for PIDAS and the GER Mark IV, both of which are grating instruments with nominal resolution of 2 - 4 um. As with most optical instruments the modular transfer function (MTF) actually degrades this to a larger value. In the specific case of our GER Mark 1V, Glen Swayze of the U.S. Geological Survey in Denver has determined the <u>true</u> spectral resolution to be 35 um at 2300 um using both pyrophyllite and datolite standard samples (originally measured on the USGS 1 um resolution spectrometer in Denver).

The lowermost two spectra on each page are for PFS and SPECTRAFAX respectively, each using a circular variable filter (CVF) as their dispersive element. As a result of the CVF design, spectral resolution is not fixed, but varies linearly with wavelength, increasing at a fixed percentage (1 - 3%) of each wavelength. To cover the 450 - 2500 um spread, three (3) wheel segments are needed, each with its own percentage bandpass.

The SPECTRAFAX has a better CVF wheel than the older PFS, and has 1% resolution from 1200 to 2400 um. This gives a 12 um bandpass at 1200 um but degrades to 24um at 2400um. (22 um at 2200 um is the region of shortwave infrared absorption caused by metal-hydroxyl bonds, one of our main interests). This 14um resolution can just resolve the Kaolinite (and Dickite) doublets at 1410 (B21, B8), but <u>not</u> the Kaolinite doublet at 2200 (except B21).

A mathematical algorithm can be used to "increase" the resolution by deconvolving the modular transfer function from the raw spectrum, but its use is not warranted on all spectra (H. Zhu, Masters Thesis, Stanford University, 1987).

5.2.5.3 PIDAS

Indoor spectra from the March 23 measurements were used for this presentation, with a single pass of the V-filter used for display (SM=1). The visible section is still very noisy, but the broad shape is correct ,and is modified in samples with ferric iron (B6, B11, B12, B18,etc.)

Variations in the PIDAS spectra with different amounts of smoothing (SM=0,1,3,5) are shown in Figure 5.2.5.3.A. Because of the large number of data points in PIDAS spectra, these smoothing values show little effect. With high data-density curves such as those from PIDAS, a moving window of width three (i.e. three points used for each pass of the smoothing filter) has a much less visible effect than on curves consisting of fewer data points.

Some grating-change effects (B3, B6, B7, B16, etc.) appear randomly in the spectra at 850 um, for no apparent reason.

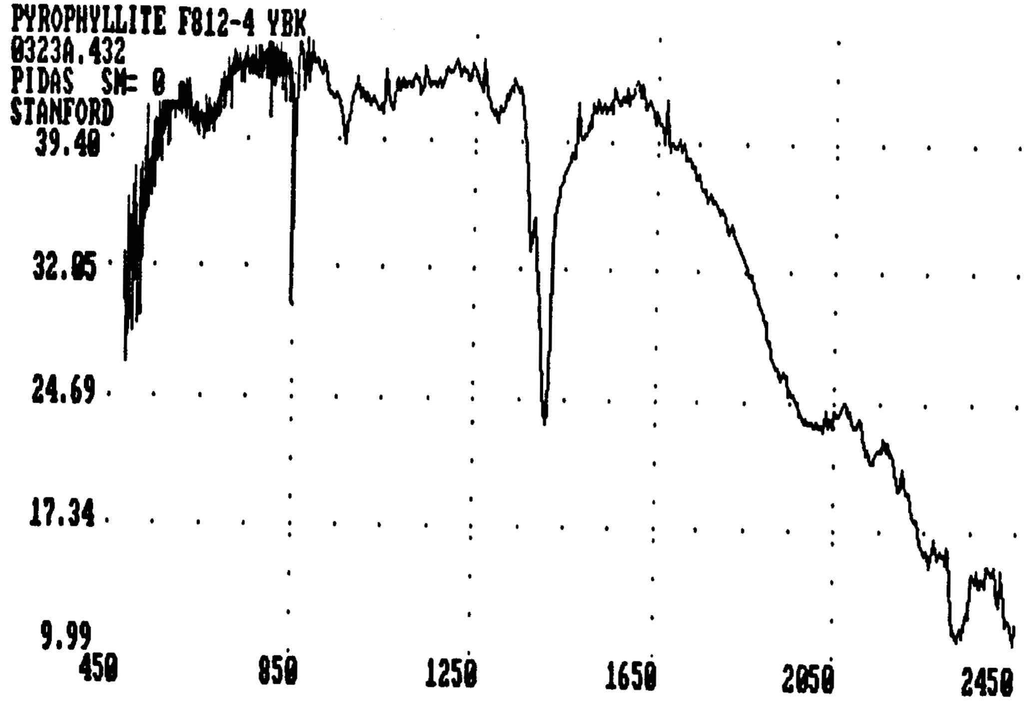
5.2.5.4 GER Mark IV

Indoor spectra, mostly from a set of measurements run on May 13, 1988, are used in these figures. Smoothing by 3 passes (SM=3) was used as this is our normal operating procedure.

The spectra are clean, well resolved and very repeatable. Absorption features occur at the same location (wavelength) and have the same depth (percent reflectance) in separate measurements of the same sample. Both of these spectral characteristics are important in spectral recognition, and are used in the SRSL pattern recognition program "STANXPRT'.

We feel strongly that the GER Mark IV is as good as, if not better than, PIDAS, in both radiometric resolution and precision, for approximately 5% of the cost (and probably 10% of Daedalus' rough estimate of the cost of PIDAS-II - see below.) The GER Mark IV is certainly lighter in weight, smaller in volume, and electronically more reliable than PIDAS.

Unit	Price	
GER Mark IV	$ 58,000	Double beam
PIDAS-I	$ 1,300,000	Single beam
PIDAS-II	$ 650,000	Single beam
MINI-IRIS	$ 28,000	Single beam (under fabrication)


PYROPHYLLITE F812-4 YBK
0323A.432
PIDAS SM= 0
STANFORD
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32.05
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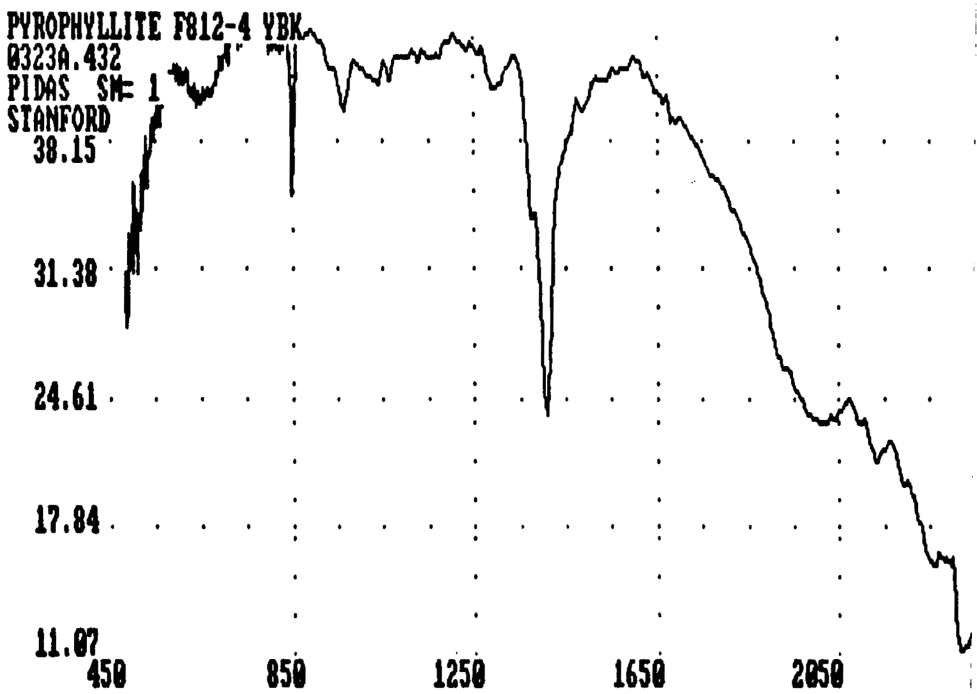
9.99
450
850
1250
1650
2050
2450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0323A.432
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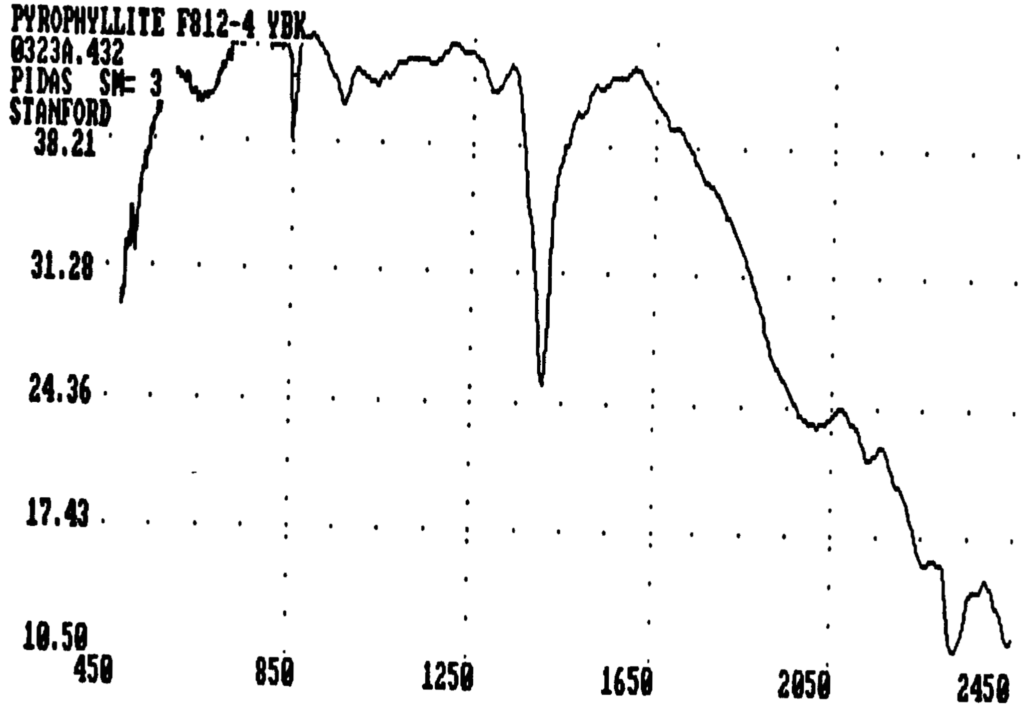
1250
1650
2050


PYROPHYLLITE F812-4 YBK
0323A.432
PIDAS SM= 3
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31.28
24.36
17.43
10.50
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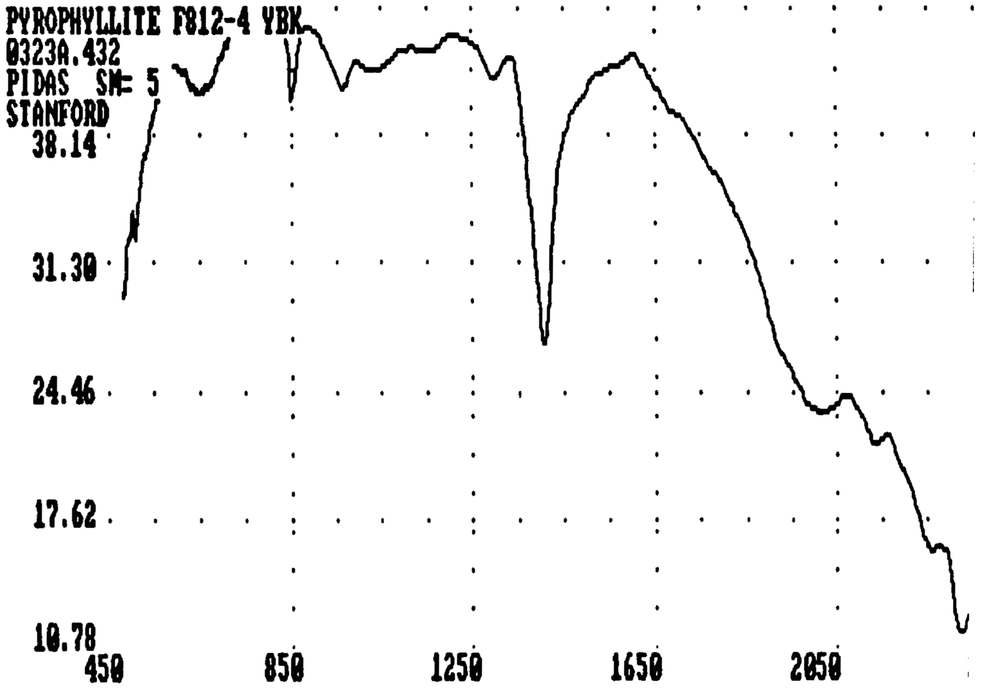
850
1250
1650
2050
2450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PIDAS SM= 5
STANFORD
38.14
31.30
24.46
17.62
10.78
450
850
1250
1650
2050

ORIGINAL PAGE IS
OF POOR QUALITY

5.2.5.5 PFS

Indoor spectra are mostly from measurements done on March 30. After three years of use the visible segment of the CVF is now badly "crazed" and the metal-oxide coating is disintegrating, seriously contributing to the noise in that part of each spectrum. The remaining segments, which are of most interest (1200 - 2500 um), are intact and produce good spectra.

While a CVF instrument has lower resolution than a grating instrument, especially at longer wavelengths, the positions of the absorption minima in CVF spectra (although broadened) are still sufficiently constrained so as to be diagnostic. The SRSL automated pattern recognition program works well with these PFS spectra as input. The database for automated recognition of CVF spectra is different than that for grating spectra to account for the difference in resolution.

The lower resolution of CVF spectra at longer wavelengths can be clearly seen in the dickite sample (B8) where the 1400 um doublet is resolved, but not the 2200 um doublet.

Fig. 5.2.5.5.1

Field use of the PFS. Backpack holds batteries only.

5.2.5.6 SPECTRAFAX

Only 17 SPECTRAFAX spectra of mineral specimens and field samples are shown in Appendix B. Many more were successfully taken from November 10 - 20 but are not included in this PIDAS evaluation.

SPECTRAFAX spectra closely resemble the PFS datasets, but have better spectral resolution (B21, C6).

6. EVALUATION OF THE FOUR SPECTROMETERS

6.1 PIDAS

(1) The instrument is a top-heavy backpack, and almost dangerous to use on steep rocky slopes. Needs redesign of backpack for better carrying stability.

(2) An "averaging N-spectra" mode (automatic) would avoid the considerable number of "wand" actions required, for what has become the "Standard Operational Mode", i.e. taking 5 spectra consecutively, for later averaging. One may wish to retain the actual N single-spectra, for later investigation of variance, rather than the PFS method of storing only the "average-of-N-spectra.

(3) Some considerable thought should be devoted to the ergometrics of instrument operation. This does not mean that the System Software ("firmware") has to be available to every user, but that some options must be programmed into the system, so as to make it more adaptable for easy use. At present PIDAS is anything but "user friendly".

(4) The firmware in PIDAS could be greatly improved by including a sample description in each data file. The description could be entered via the keyboard on the wand. In its present configuration, the PIDAS user must carry a notebook to correlate sample descriptions to the arbitrary sample name given by PIDAS. This procedure can create considerable confusion in field conditions as well as during data reduction in the laboratory, which may occur days after the measurements are taken.

(5) An additional improvement in firmware would be to allow an arbitrary number of spectra to be measured and/or transferred to a separate computer. In the present configuration, data must be handled in large blocks (144 spectra). In retrieving data for later analysis, both the block name and the number of the spectrum within the block must be correlated with the handwritten descriptions in a field notebook. PIDAS software can make separate files from these data, but doing so is an extra, unnecessary step in processing, and additional software is then required to perform operations on the resulting files.

(6) A self contained artificial light source would be extremely useful, and would contribute only marginally to the already considerable weight and complexity of the existing instrument.

(7) Spectral resolution is good when the instrument is operating properly, but there is considerable variability between identical measurements of a sample.

(8) The extremely high nominal spectral resolution in wavelengths measured by the silicon detectors is impressive, but the noise in many of the spectra suggest that a better approach might be to measure broader wavelength intervals in order to increase the signal-to-noise ratio.

(9) The standard operating procedure calls for measuring each sample multiple times (usually two to five), and measuring a reference such as Halon between each sample set. Thus for a single spectral plot of a single sample, from two to six data files are created. This is far more redundancy than with any other instrument, and should not be necessary.

6.2 GER Mark IV

(1) The GER Mark IV is not (yet) really "backpackable", although we are experimenting with this concept. A packframe base will make the unit much more maneuverable, although the optical head (6.4 kg) is itself rather heavy.

(2) The GER Mark IV will always suffer from an inability to simply view the measured spectrum, prohibiting any real-time decision making. Even the inclusion of a "lap-top" PC in the framepack will only allow "post facto" viewing or decision making ("expert system" implementation).

(3) Although somewhat temperamental, the GER instrument produces the most useful spectral data, when it is working.

6.3 PFS

(1) The optical head is too heavy (4.5 kg) and not well balanced with its center of gravity too far forward. After 20-30 minutes of use, holding the unit is quite tiring.

(2) The PFS is unique in allowing truly instantaneous viewing of spectral plots while being used in portable field mode. We feel that the inclusion of a spectrum-viewing LCD is a VITAL part of the field attributes of these spectrometers, the absence of such LCD's allowing either too many spectra to be stored, or the "mapping process" to continue without real-time knowledge of the material being mapped. In addition, when an instantaneous view of the spectrum is available, real-time decisions can be made about the mineralogy itself, whether the gain should be adjusted to enhance spectral contrast, or simply which spectra are to be stored.

(3) Spectral resolution is noticeably lower than that for the grating instruments, but is adequate for resolving many of the features necessary for discriminating different mineral species.

6.4 SPECTRAFAX

(1) The SPECTRAFAX 440 unit is very well designed from a "portability" point of view. The backpack mounting sits easily on the back, and the hand-held optical head is comfortably to use, without excessive weight. All operators who have used this unit were very happy with the design - often volunteering to wear the SPECTRAFAX longer, rather than to "wear" the PIDAS, or even use the lighter-weight GEOSCAN PFS. Ergometrically the design is excellent.

(2) Spectral resolution is comparable to that of the PFS.

Figure 6.4.1 SPECTROFAX 440 in field use.

7. ANALYSIS & RECOMMENDATIONS

We do not recommend PIDAS as the best field spectrometer available. It is far too expensive for what it offers. A point can perhaps be made that its radiometric accuracy is the best of available instruments, but we did not evaluate this aspect of its performance. Our results indicate that relative spectroscopy is not its asset either,

It is very clear that while Circular Variable Filter (CVF) units offer mobility, speed and ease of use over the grating units, their loss of spectral resolution at longer wavelengths (in each wheel segment) leaves them at a disadvantage. However, for many of the applications for field spectrometers, and especially for vegetation analysis (chlorophyll, leaf structure etc.), the CVF approach is imminently suitable.

Much of our research is devoted to mineralogical determinations under field conditions. After a reasonably complete evaluation of PIDAS under varying operational conditions, we do not see the need for such a unit for making geologically significant measurements in the field, especially since the GER grating unit has out-performed the (present-status) PIDAS in all aspects of this study. The fact that the GER Mark IV unit costs only five (5) percent of the assumed PIDAS cost (1.3 million dollars) is further reason not to use it. From a management point of view we cannot see investing any more funds in PIDAS, when the same amount of funds could buy many grating units essentially off-the-shelf. The newer GER "Mini IRIS", a single-beam version of the Mark IV now under construction, will lower the price of a grating instrument to three (3) percent of PIDAS present costs.

What we field experimenters need is MORE grating-type units - not a proliferation of more elegant or exotic units which we can seldom get to use.

TABLE II: RELATIVE RATING OF THE FOUR SPECTROMETERS

FEATURE	BEST		TO	WORST	
SPECTRAL RESOLUTION	PIDAS	IRIS			PFS/SFX
WEIGHT	PFS	SFX		IRIS	PIDAS
BULKINESS	SFX	PFS		IRIS	PIDAS
OPTICAL HEAD SIZE/WEIGHT	SFX	PIDAS		PFS	IRIS
BACKPACK FEEL	SFX	PFS		IRIS	PIDAS
RUGGEDNESS	SFX		IRIS	PFS	PIDAS
AUTOMATIC STORAGE OF SPECTRA	SFX	IRIS		PFS	PIDAS
# STORABLE	PFS	SFX		PIDAS	IRIS
AVERAGING N SPECTRA	PFS	SFX		PIDAS	IRIS
SELF-CONTAINED ILLUMINATION	SFX	PFS		PIDAS	IRIS
USABILITY IN CHANGING LIGHT	IRIS		PIDAS	SFX	PFS
DATA RESOLUTION-RADIANCE	IRIS		PIDAS	SFX	PFS
DATA SAMPLING	IRIS	PIDAS		SFX	PFS
INTERNAL LIBRARY OF SPECTRA	PIDAS		PFS	SFX	IRIS
CAPABILITY FOR EXPERT SYSTEM	PIDAS		PFS	SFX	IRIS
DISPLAY CAPABILITY	PFS		SFX	PIDAS	IRIS

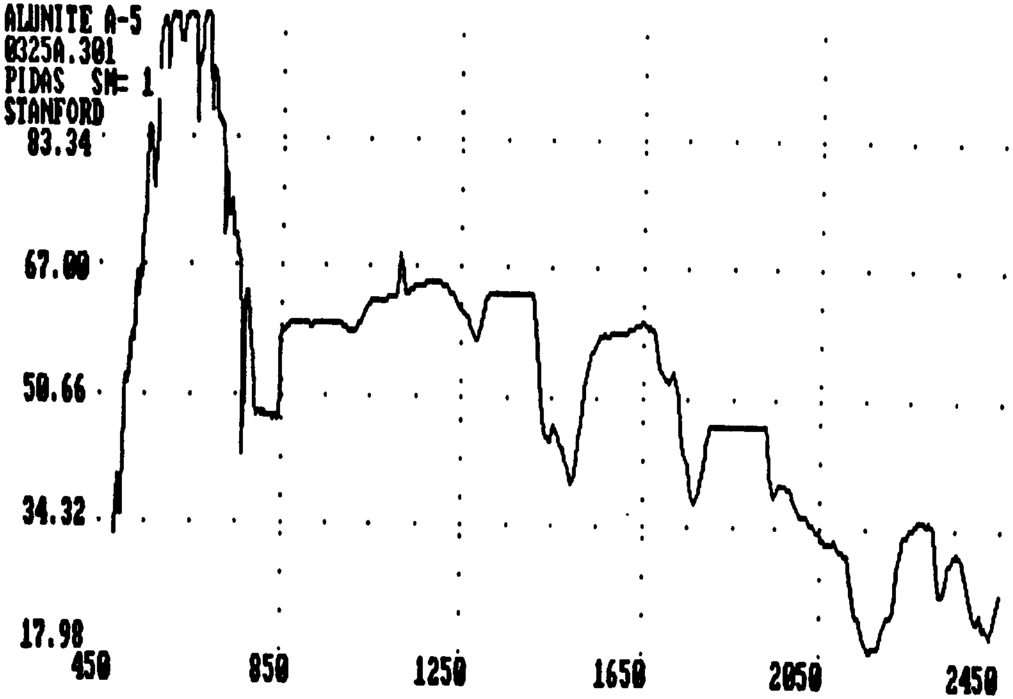
APPENDIX

PLOTS OF MEASURED SPECTRA

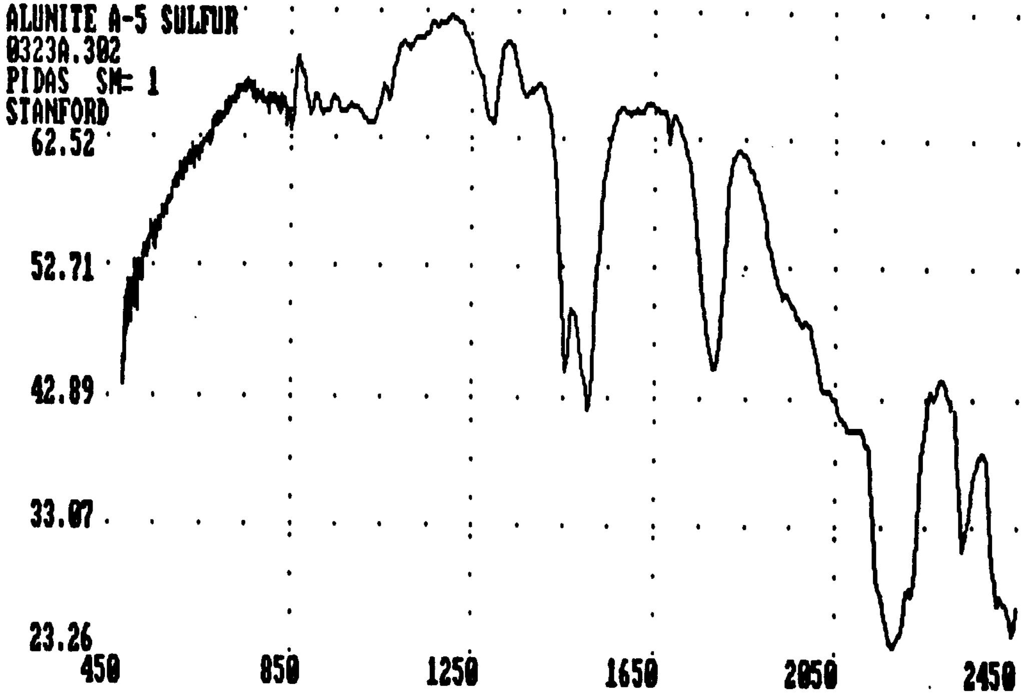
Set A: PIDAS Outdoor (patio) and indoor for a set of 16 samples.

1. Alunite A% Sulfur, NV
2. Alunite A20 Sulfur NV
3. Dickite 29352 Cusihuriachi
4. Dickite API-H14 Ouray, CO
5. Epidote 5538 Camp Apache
6. Epidote 66077 Garnet Hill
7. Jadeite 5558 Clear Creek, San Benito, CA
8. Jadeite 62771 Clear Creek, San Benito, CA
9. Kaolinite 25365 Riverside, CA
10. Kaolinite KGA-1 CMS Standard Clay (well crystallized)
11. Kaolinite KGA-2 CMS Standard Clay (poorly cryatallized)
12. Pyrophyllite 62696 Mariposa, CA
13. Pyrophyllite PYS1A USGS Standard
14. Pyrophyllite P-S RJPL (sand) standard
15. Talc 51485
16. Talc Nottage (with carbonate?)

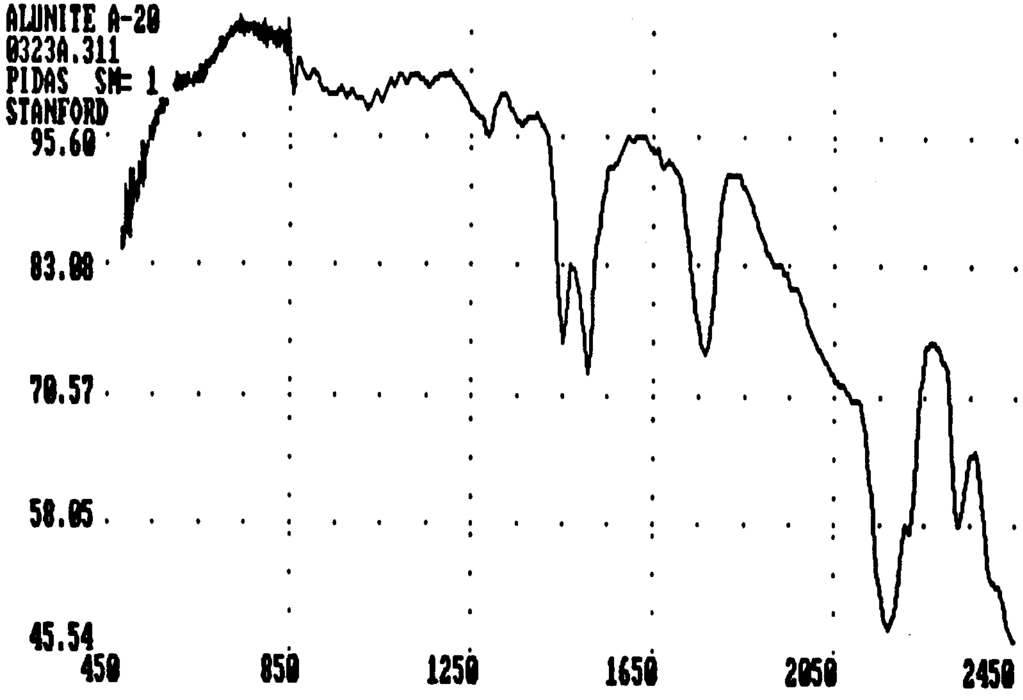
OUTSIDE



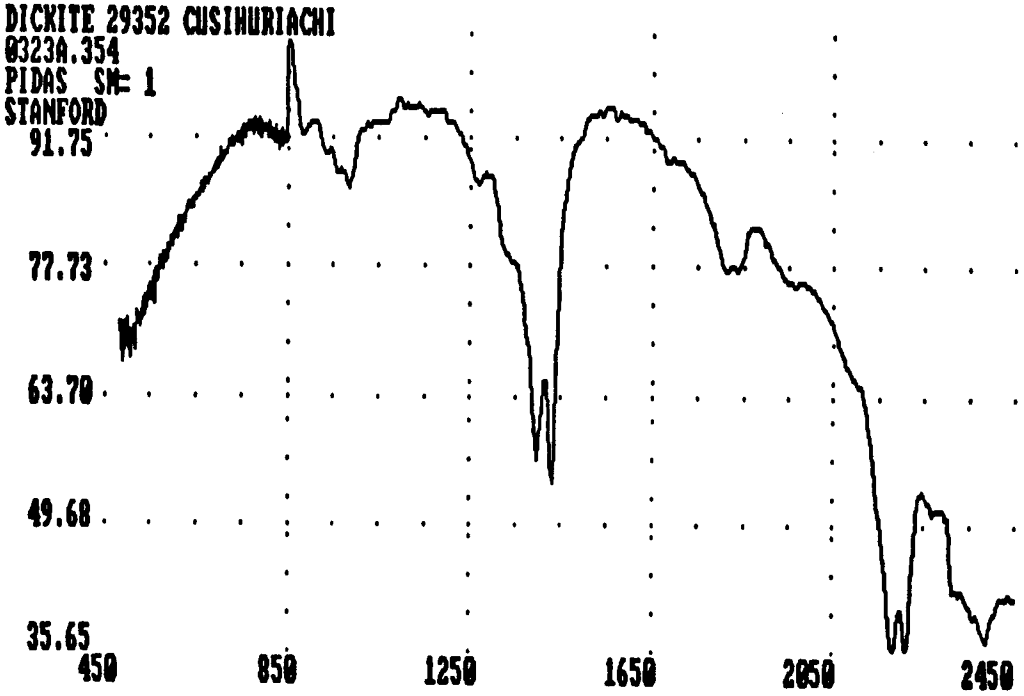
INDOORS



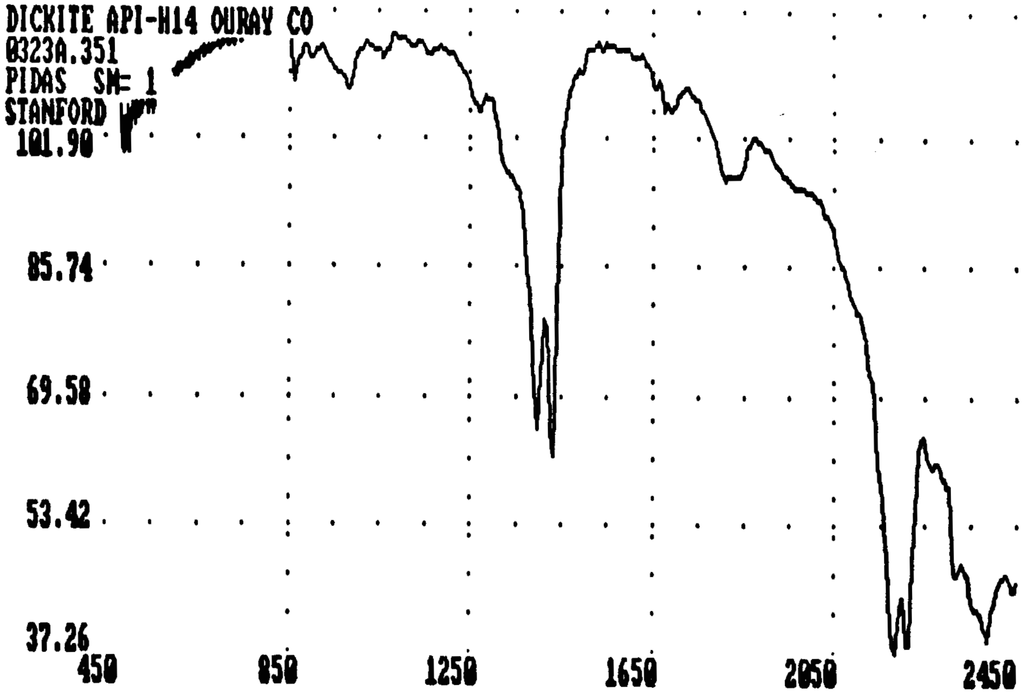

ALUNITE A-20
0325A.307
PIDAS SM= 1
STANFORD
103.34
89.47
75.60
61.72
47.85
450
850
1250
1650
2050
2450


ALUNITE A-20
0323A.311
PIDAS SM= 1
STANFORD
95.60
83.08
70.57
58.05
45.54
450
850
1250
1650
2050
2450

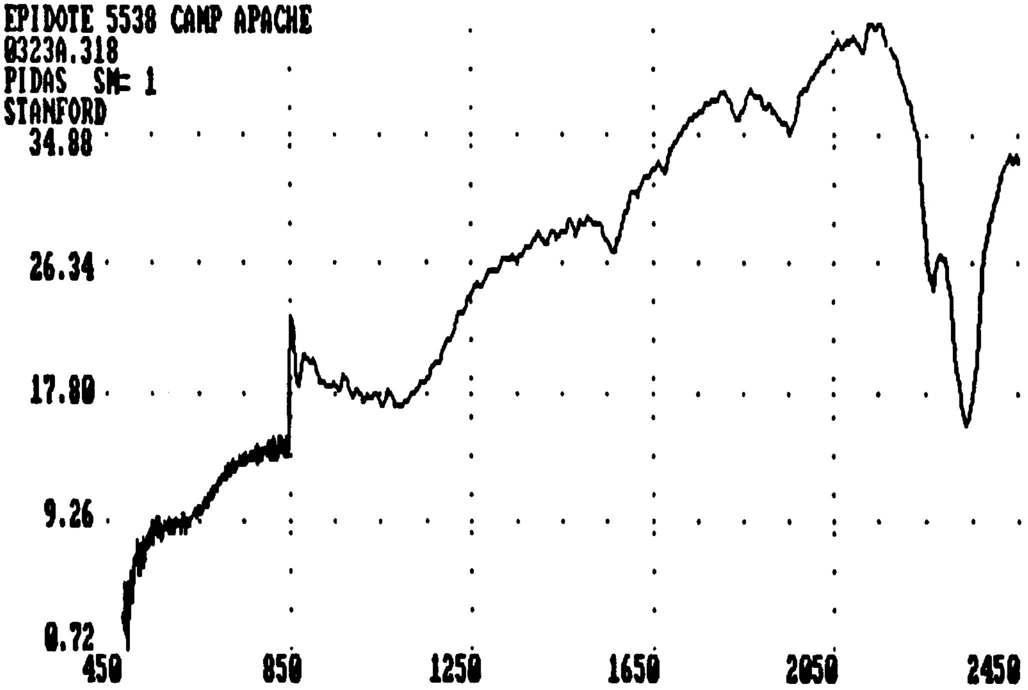

DICKITE 29352
0325A.349
PIDAS SM= 1
STANFORD
86.84
73.39
59.93
46.48
33.03
450
850
1250
1650
2050
2450


DICKITE 29352 CUSIHURIACHI
0323A.354
PIDAS SM= 1
STANFORD
91.75
77.73
63.70
49.68
35.65
450
850
1250
1650
2050
2450

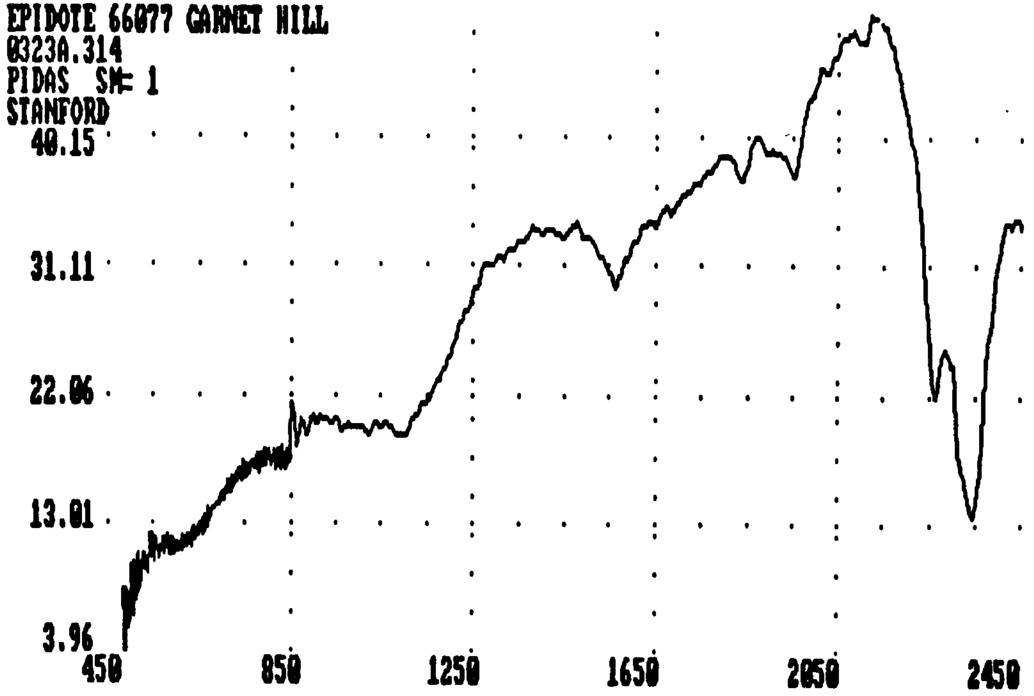

ICKITE API-H14
325A.346J
PIDAS SM= 1
TANFORD
87.31
73.33
59.35
45.37
31.39
450
850
1250
1650
2050
2450


DICKITE API-H14 OURAY CO
0323A.351
PIDAS SM= 1
STANFORD
101.90
85.74
69.58
53.42
37.26
450
850
1250
1650
2050
2450

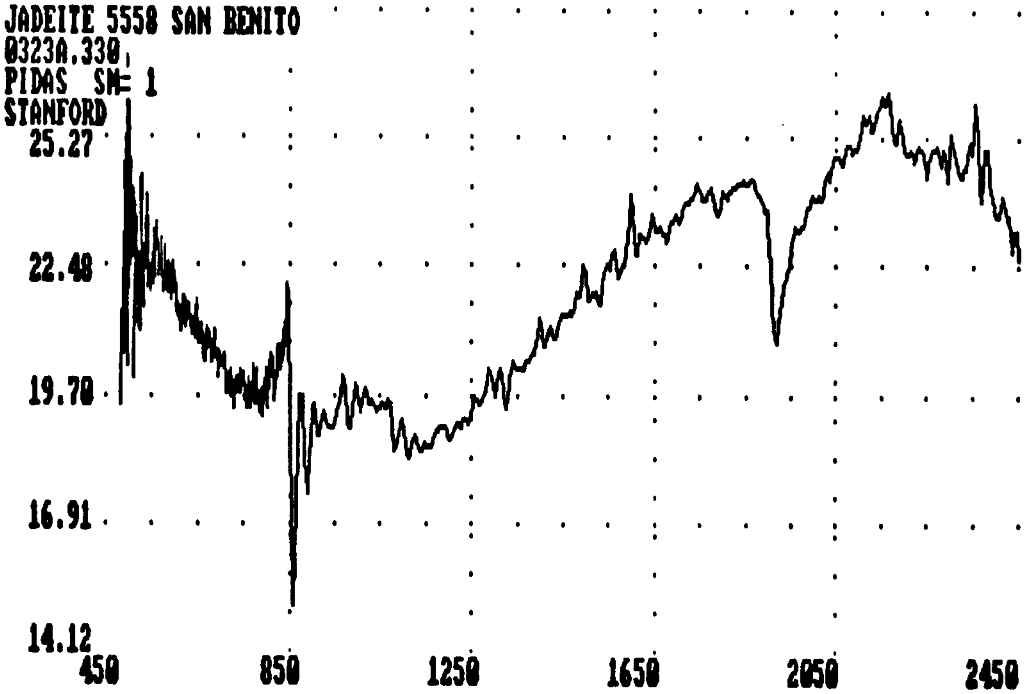

EPIDOTE 5538
0325A.313
PIDAS SM= 1
STANFORD
30.64
23.68
16.71
9.75
2.79
450
850
1250
1650
2050
2450


EPIDOTE 5538 CAMP APACHE
0323A.318
PIDAS SM= 1
STANFORD
34.88
26.34
17.80
9.26
0.72
450
850
1250
1650
2050
2450

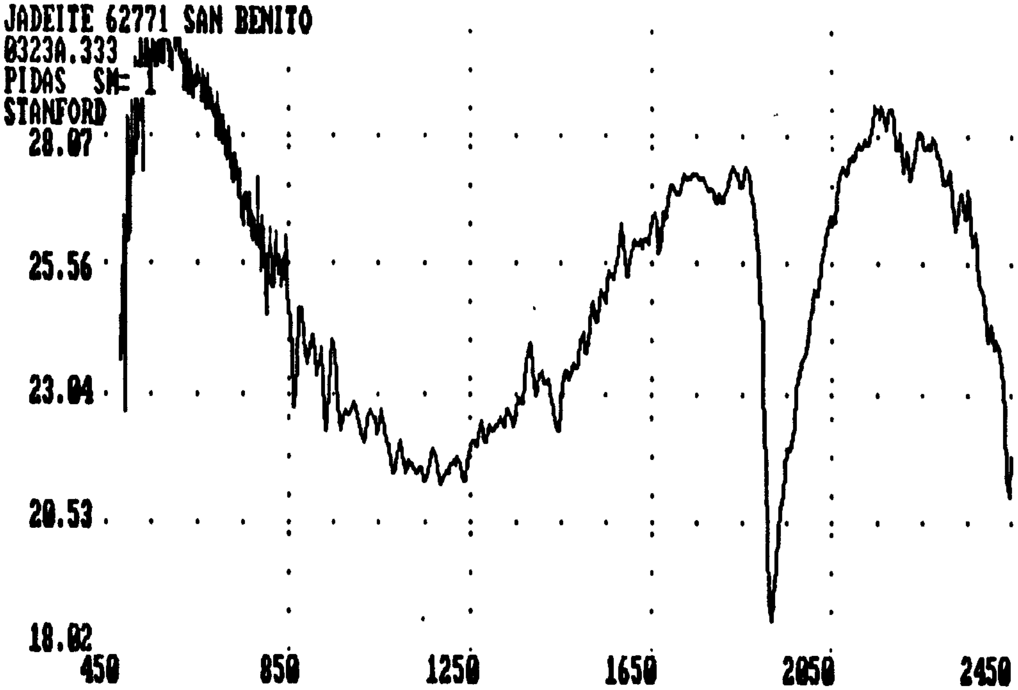

EPIDOTE 203
0325A.310
PIDAS SM= 1
STANFORD
45.40
35.82
26.24
16.66
7.08
450
850
1250
1650
2050
2450

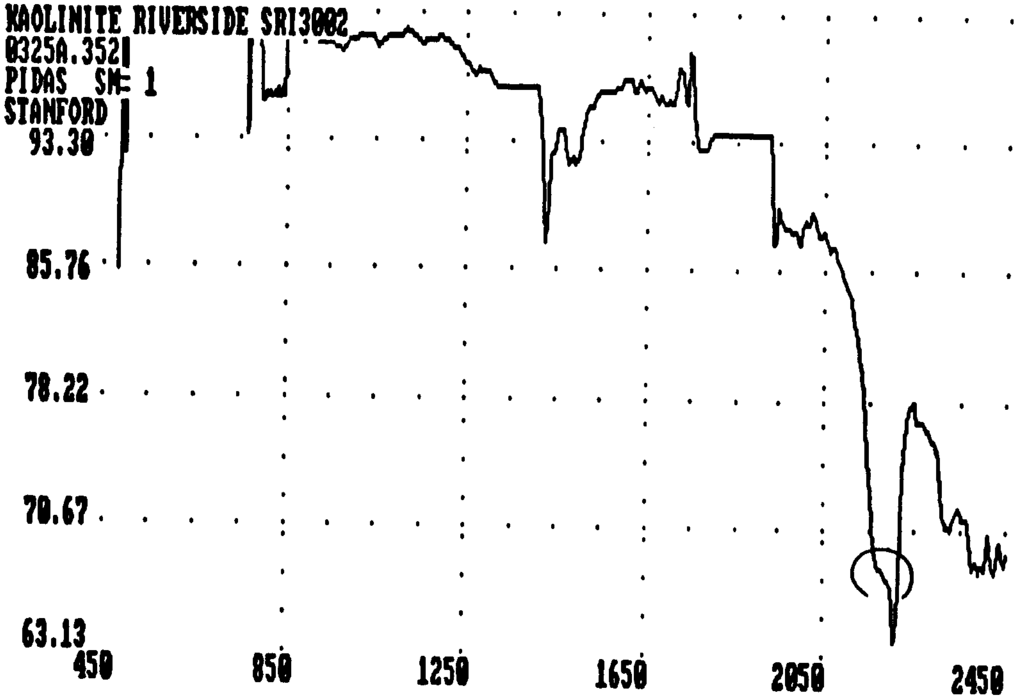

EPIDOTE 66077 GARNET HILL
0323A.314
PIDAS SM= 1
STANFORD
40.15
31.11
22.06
13.01
3.96
450
850
1250
1650
2050
2450

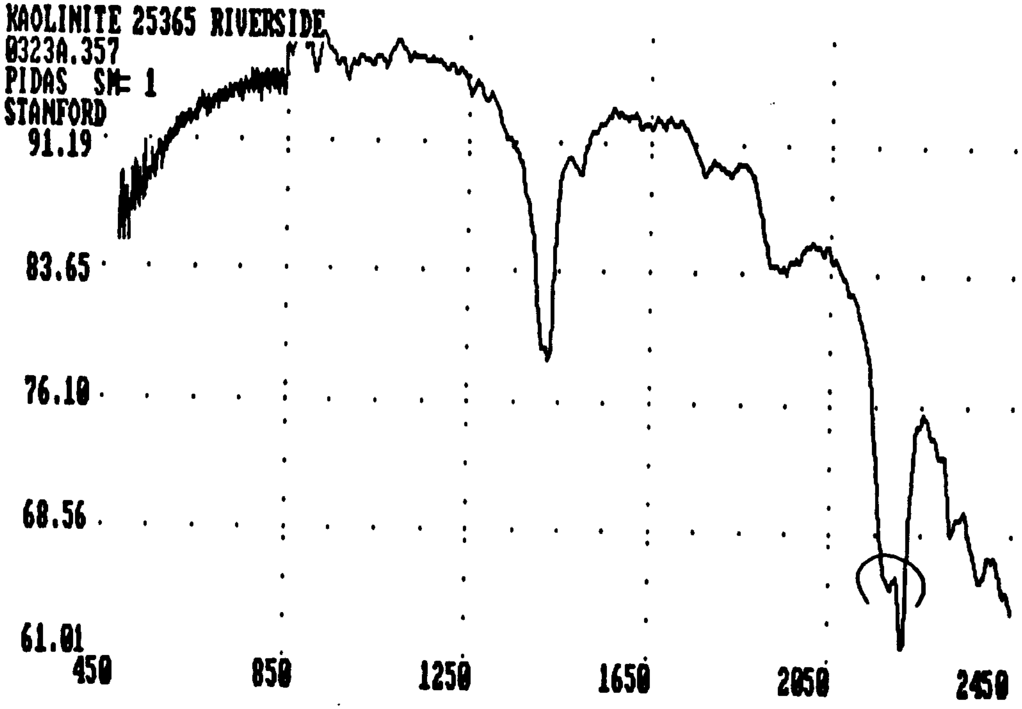

JADEITE 5558
0325A.340
PIDAS SM= 1
STANFORD
55.82
46.53
37.25
27.97
18.68
450
850
1250
1650
2050
2450


JADEITE 5558 SAN BENITO
0323A.330
PIDAS SM= 1
STANFORD
25.27
22.48
19.70
16.91
14.12
450
850
1250
1650
2050
2450

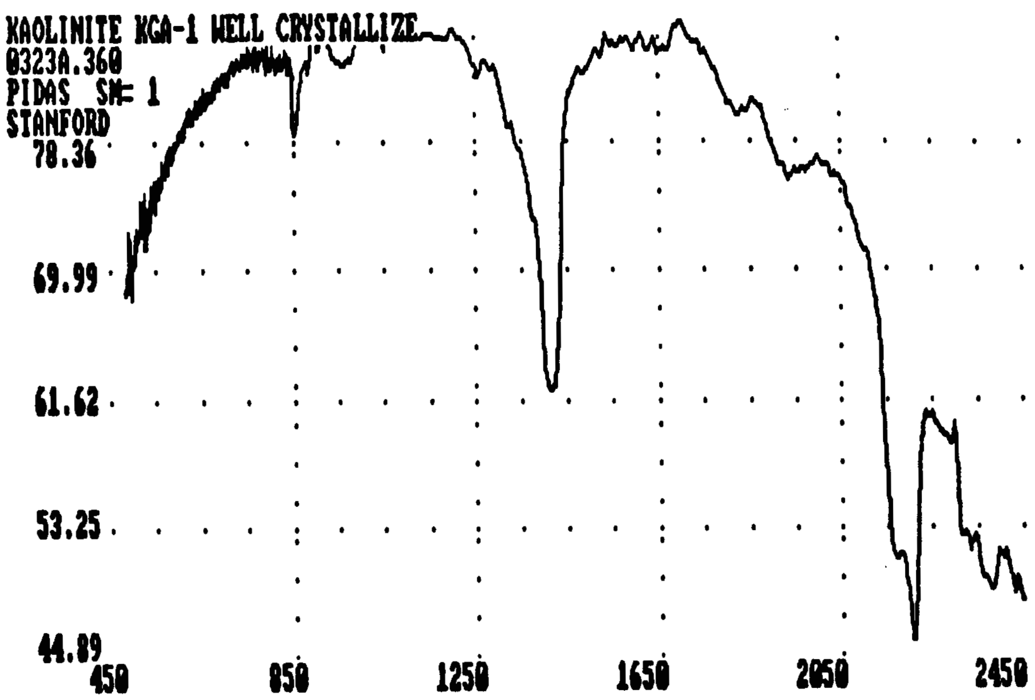

JADEITE 62771
0325A.325
PIDAS SM= 1
STANFORD
36.96
30.69
24.41
18.13
11.85
450
850
1250
1650
2050
2450


JADEITE 62771 SAN BENITO
0323A.333
PIDAS SM= 1
STANFORD
28.07
25.56
23.04
20.53
18.02
450
850
1250
1650
2050
2450

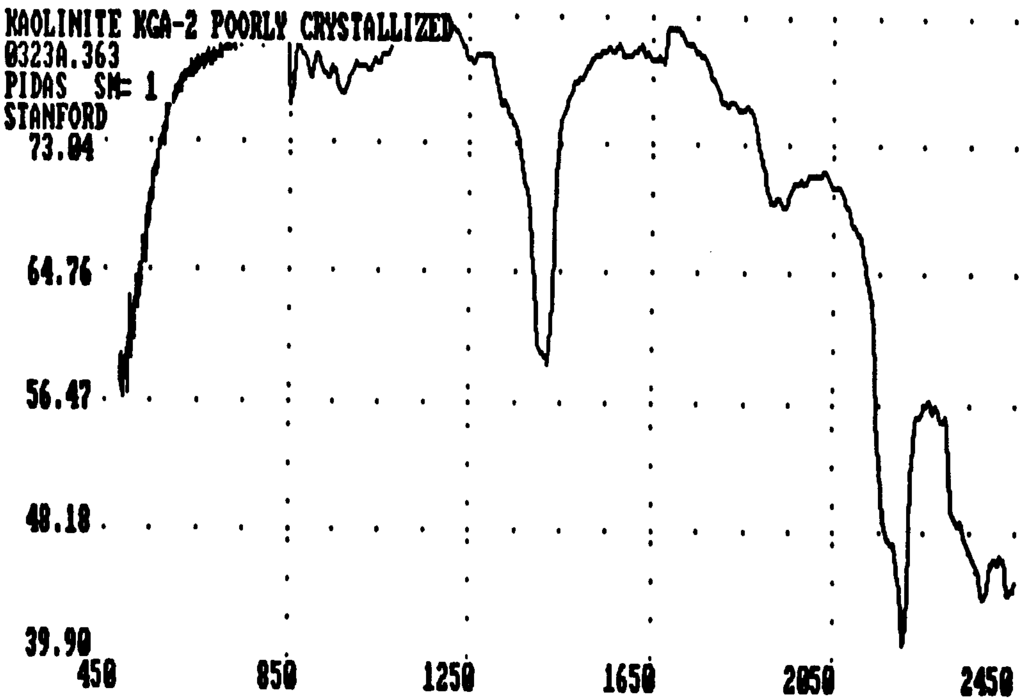

KAOLINITE RIVERSIDE SRI3002
0325A.352
PIDAS SM= 1
STANFORD
93.30
85.76
78.22
70.67
63.13
450
850
1250
1650
2050
2450


KAOLINITE 25365 RIVERSIDE
0323A.357
PIDAS SM= 1
STANFORD
91.19
83.65
76.10
68.56
61.01
450
850
1250
1650
2050
2450

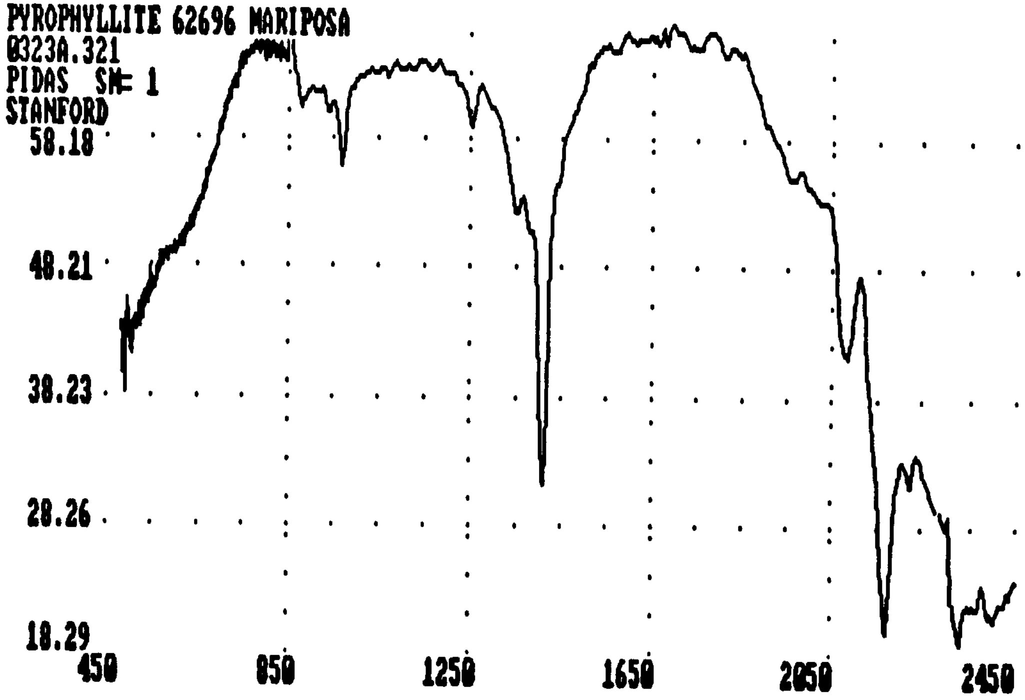

KGA-193
0325A.355
PIDAS SM= 1
STANFORD
89.72
78.50
67.29
56.08
44.86
450
850
1250
1650
2050
2450

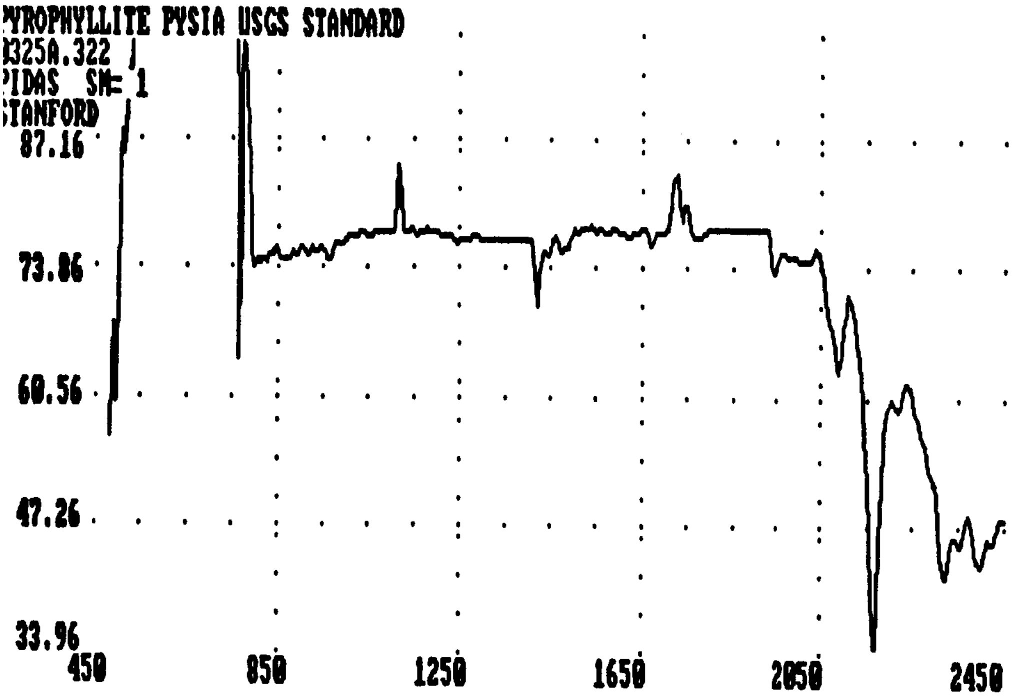

KAOLINITE KGA-1 WELL CRYSTALLIZE
0323A.360
PIDAS SM= 1
STANFORD
78.36
69.99
61.62
53.25
44.89
450
850
1250
1650
2050
2450

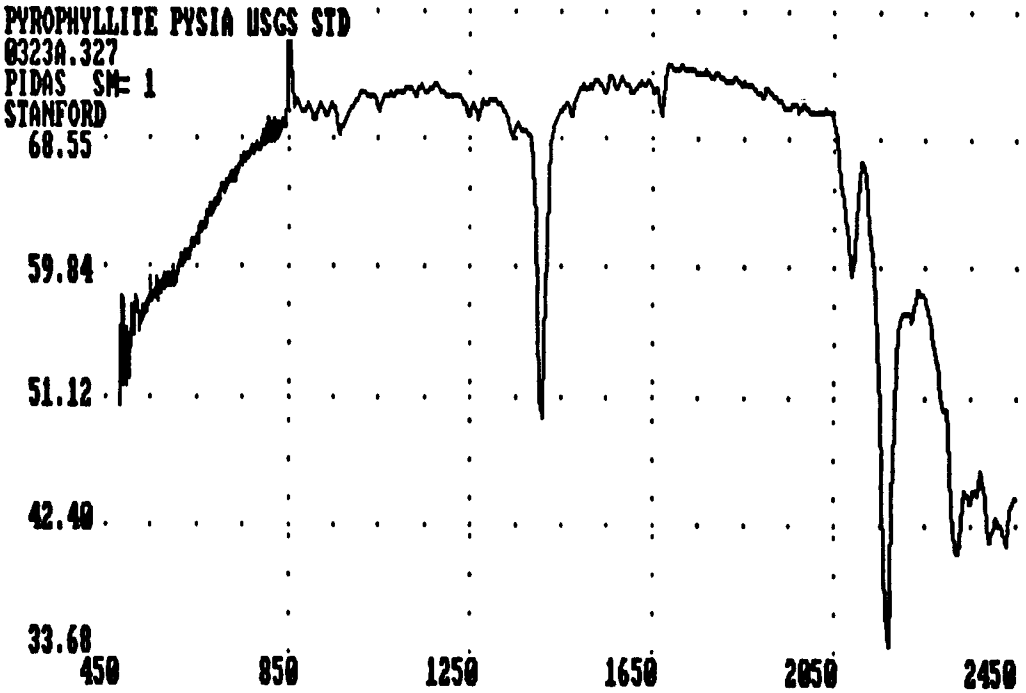

KGA-279
0325A.358
PIDAS SM= 1
STANFORD
89.97
79.15
68.33
57.51
46.70
450
850
1250
1650
2050
2450


KAOLINITE KGA-2 POORLY CRYSTALLIZED
0323A.363
PIDAS SM= 1
STANFORD
73.04
64.76
56.47
48.18
39.90
450
850
1250
1650
2050
2450


PYROPHYLLITE 62696
0325A.316
PIDAS SM= 1
STANFORD
84.92
68.88
52.84
36.79
20.75
450
850
1250
1650
2050
2450


PYROPHYLLITE 62696 MARIPOSA
0323A.321
PIDAS SM= 1
STANFORD
58.18
48.21
38.23
28.26
18.29
450
850
1250
1650
2050
2450





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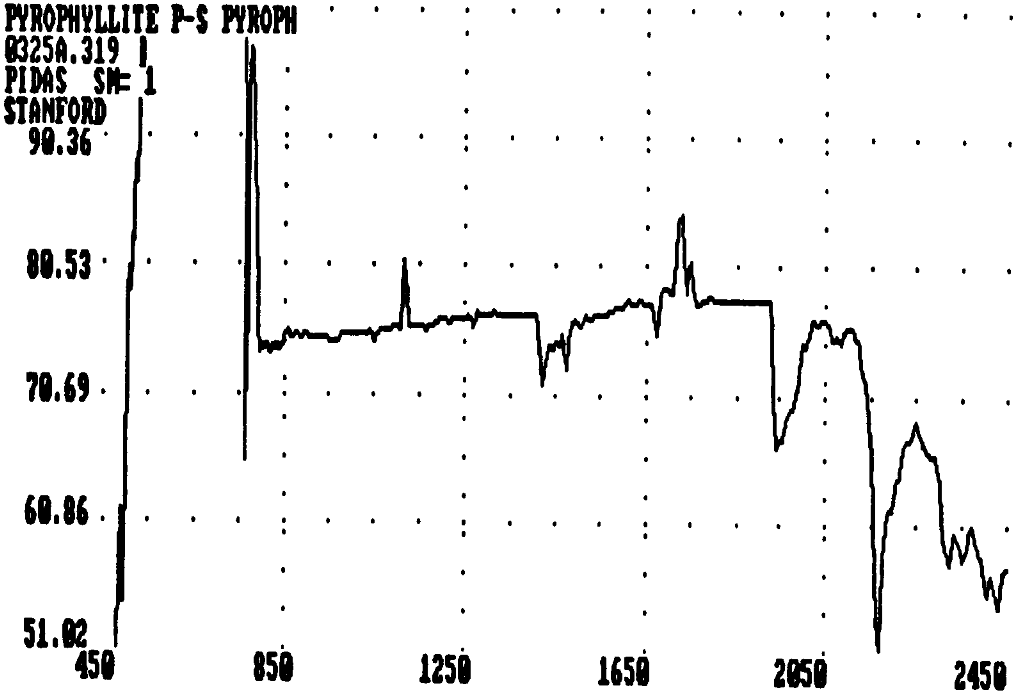
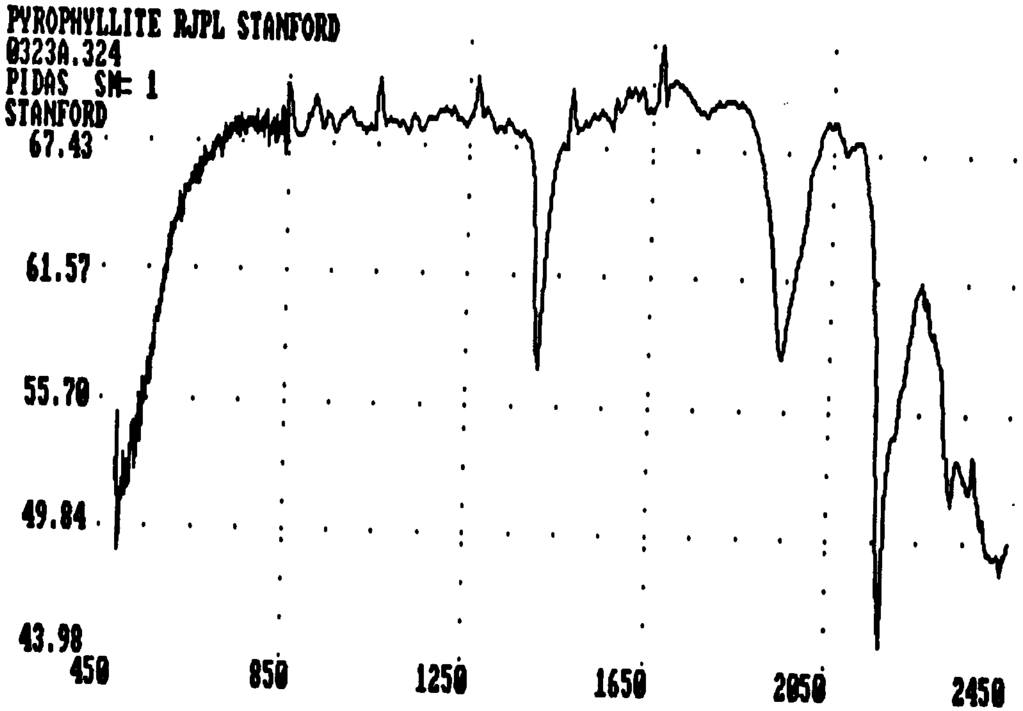
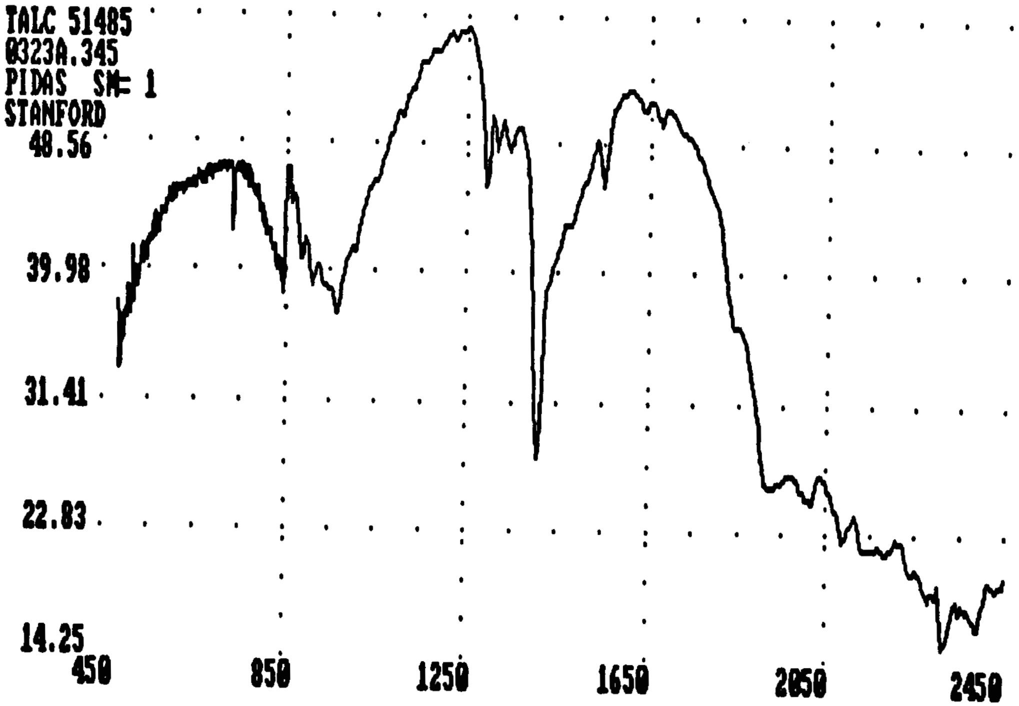

PYROPHYLLITE P-S PYROPH
0325A.319 1
PIDAS SM= 1
STANFORD
90.36
80.53
70.69
60.86
51.02
450
850
1250
1650
2050
2450

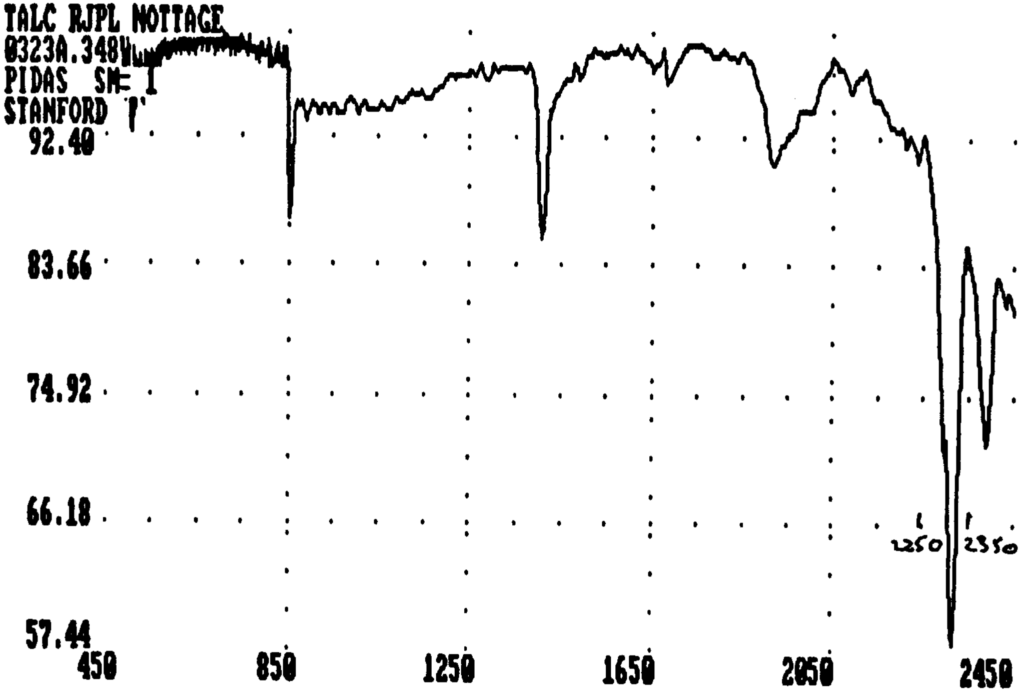

PYROPHYLLITE RJPL STANFORD
0323A.324
PIDAS SM= 1
STANFORD
67.43
61.57
55.70
49.84
43.98
450
850
1250
1650
2050
2450


TALC 51485
0325A.328
PIDAS SM= 1
STANFORD
81.98
63.76
45.54
27.32
9.10
450
850
1250
1650
2050
2450


TALC 51485
0323A.345
PIDAS SM= 1
STANFORD
48.56
39.98
31.41
22.83
14.25
450
850
1250
1650
2050
2450


TALC NOTTAGE
0325A.343
PIDAS SM= 1
STANFORD
91.66
81.89
72.11
62.33
52.55
450
850
1250
1650
2050
2450

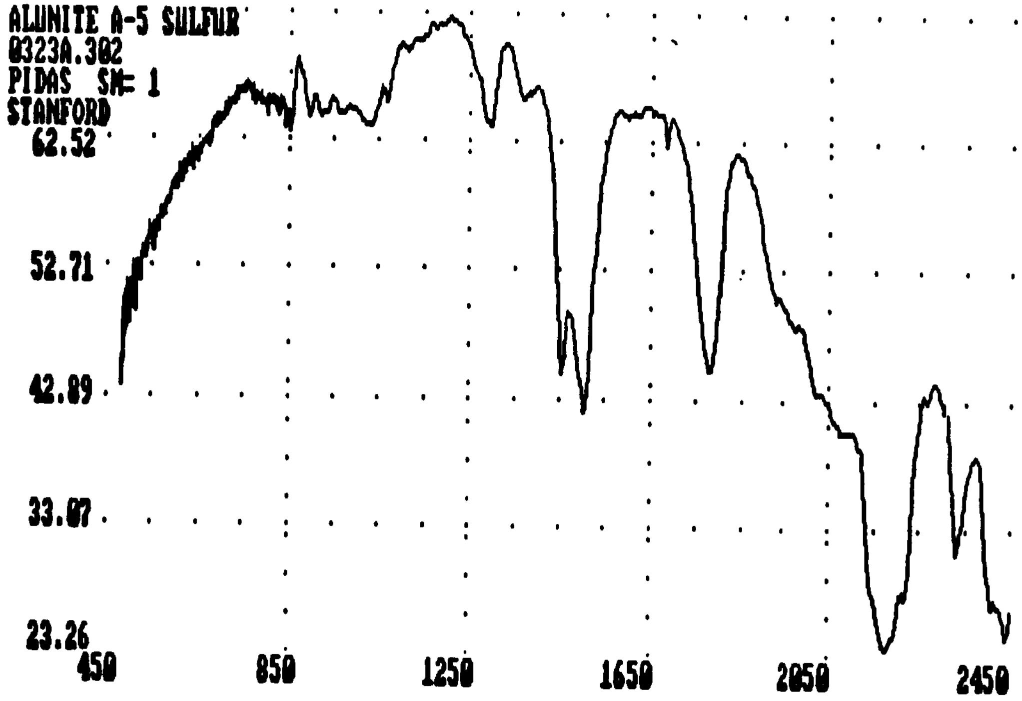
+ Carbonate

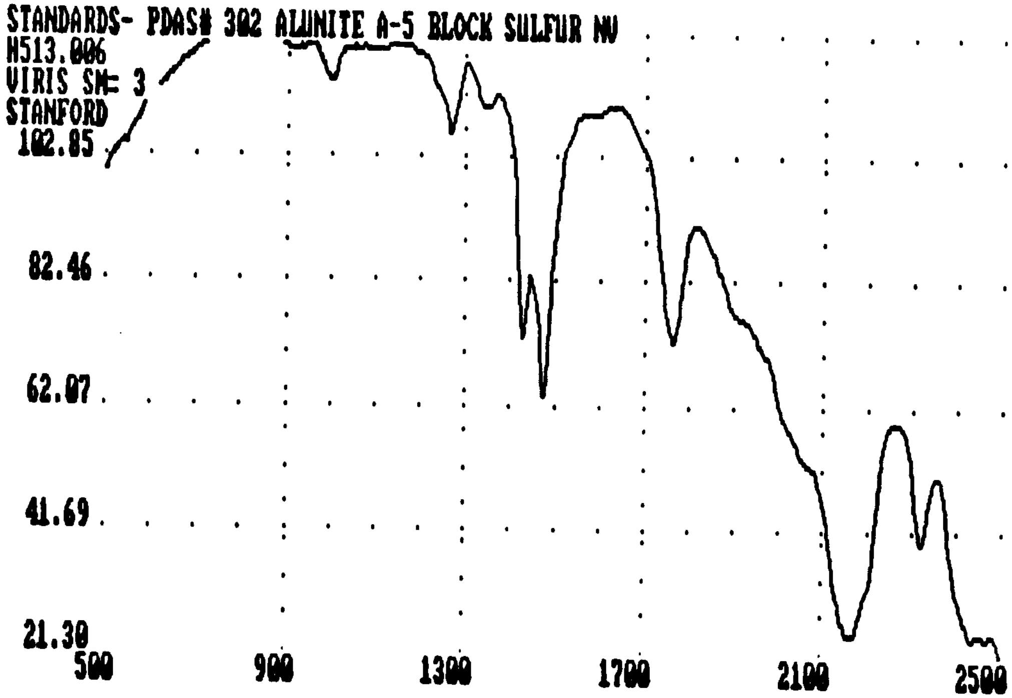

TALC RJPL NOTTAGE
0323A.348
PIDAS SM= 1
STANFORD
92.40
83.66
74.92
66.18
57.44
450
850
1250
1650
2050
2450
2250
2350

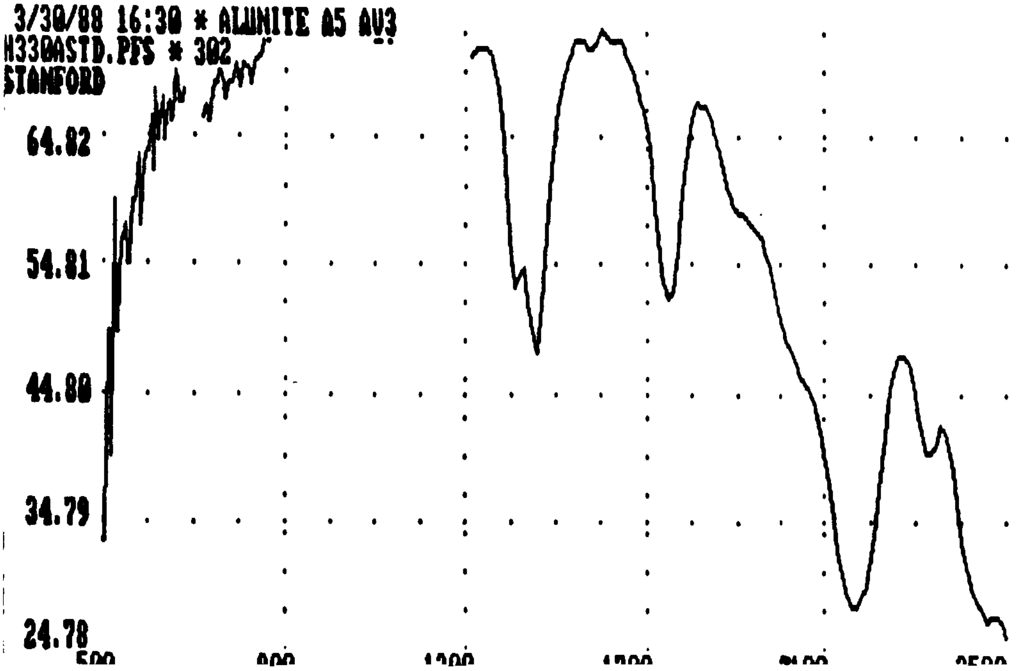
Set B: Comparison of Four Spectrometers, Indoors.

Arranged with PIDAS in the upper left, GER Mark IV (IRIS) in the upper right, PFS in the lower left, and SPECTRAFAX in the lower right.

1. Alunite A-5 Sulfur, NV, block
2. Alunite A-20 Sulfur, NV, powder (PFS average of 3 spectra)
3. Buddingtonite FAO4-11A Buddingtonite Bump, Cuprite, NV
4. Calcite C-99, sand, RJPL 0.5mm
5. Calcite 29349 Riverside, CA (blue)
6. Datolite 51397 New Jersey (brown)
7. Datolite 51399 Massachusetts (white) USGS standard
8. Dickite API-H14 Ouray, CO
9. Dickite 29352 Cusihuriachi, Mexico
10. Dolomite 66313 Carson Hill, CA
11. Epidote 5538 Camp Apache, AZ
12. Epidote 66077 Garnet Hill, Calaveras Co., CA
13. Gypsum G-90 RJPL (sand sized)
14. Illite IMT-1 (1MD) CMS, Silver Hill, MT
15. Illite ISMT-1 CMS Illite-Smectite mixed layer
16. Jadeite 5558 slab, Clear Creek, San Benito, CA
17. Jadeite 62771 vein, Clear Creek, San Benito, CA
18. Jarosite Argentina (GAP)
19. Kaolinite KGA-1 CMS well crystallized
20. Kaolinite KGA-2 CMS poorly crystallized
21. Kaolinite 25365 Riverside, CA
22. Kaolinite CSIRO (3.8.84)
23. Kaolinite K-N Nottage
24. Kaolinite Ball clay
25. Montmorillonite STX-1 Na-Mont, CMS
26. Montmorillonite SAZ-1 Ca-Mont, CMS
27. Montmorillonite SCA-2 moist, CMS
28. Nontronite NG-1 CMS Hagen Hagen, Germany
29. Pyrophyllite PYS1A USGS standard
30. Pyrophyllite PS-101 RJPL (sand)
31. Pyrophyllite 62696 Mariposa, CA
32. Pyrophyllite 64266 Blendon, NC
33. Serpentine 30032 San Benito, CA
34. Talc 51485 flat slab New York
35. Talc Nottage fine powder, impure







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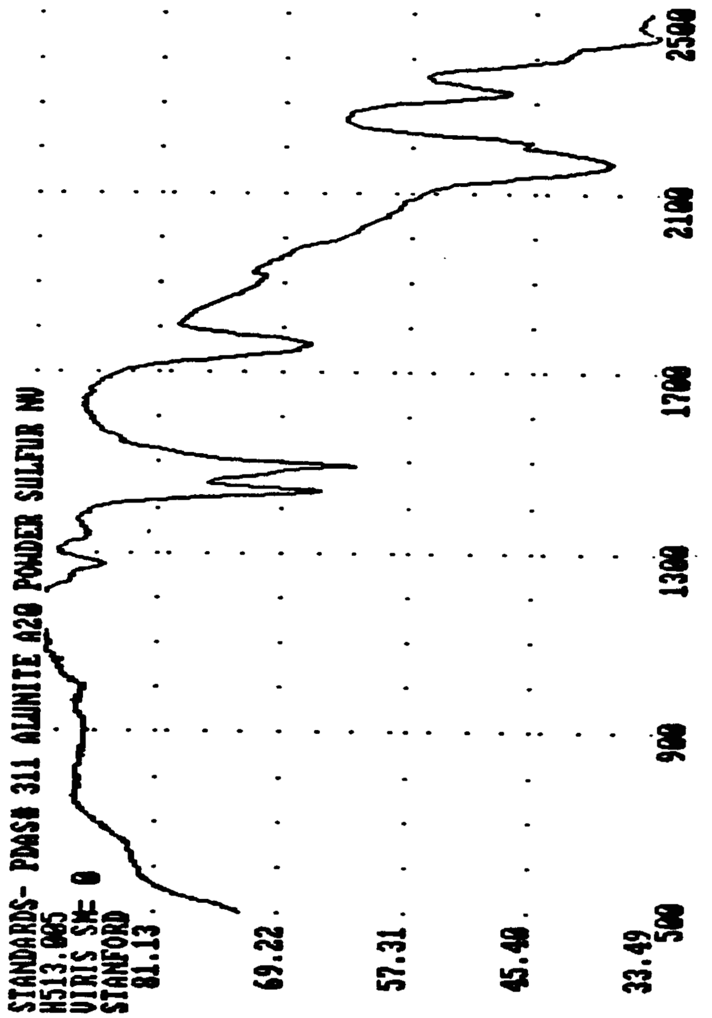

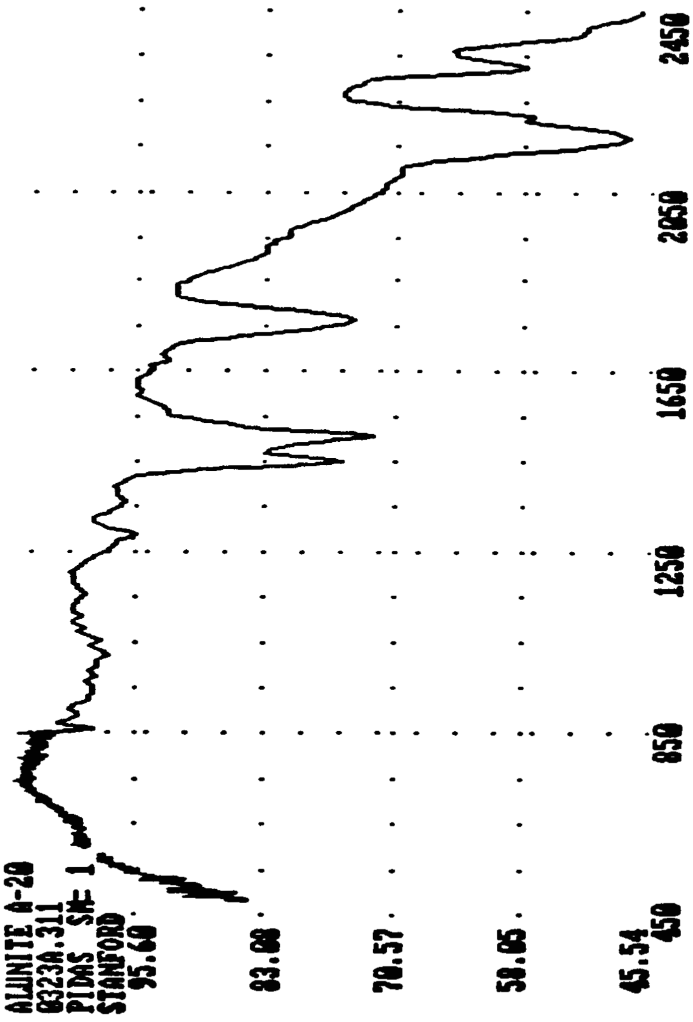

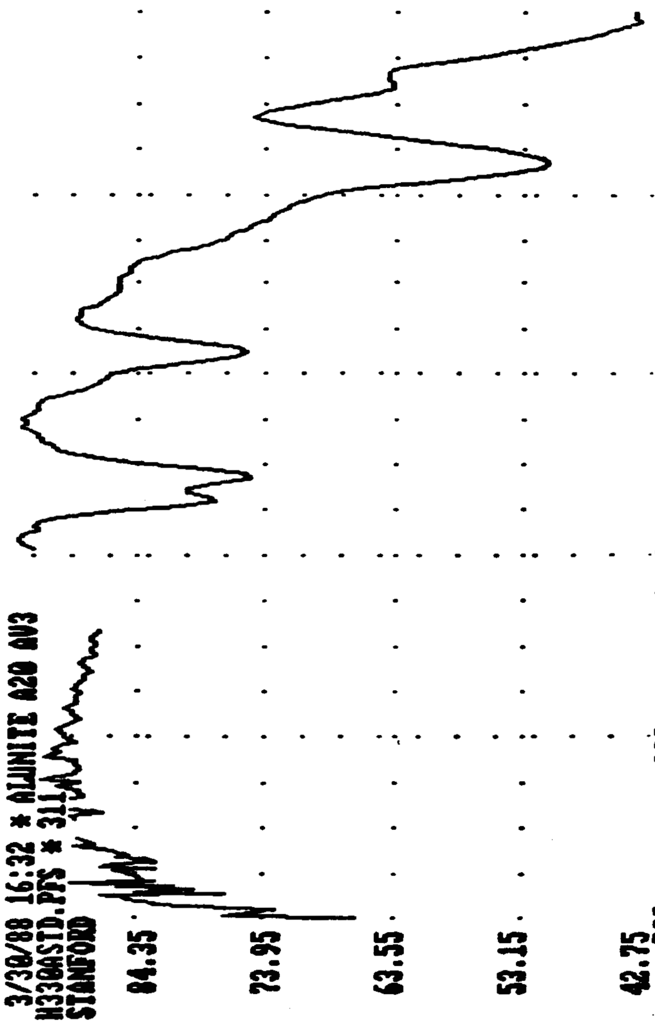

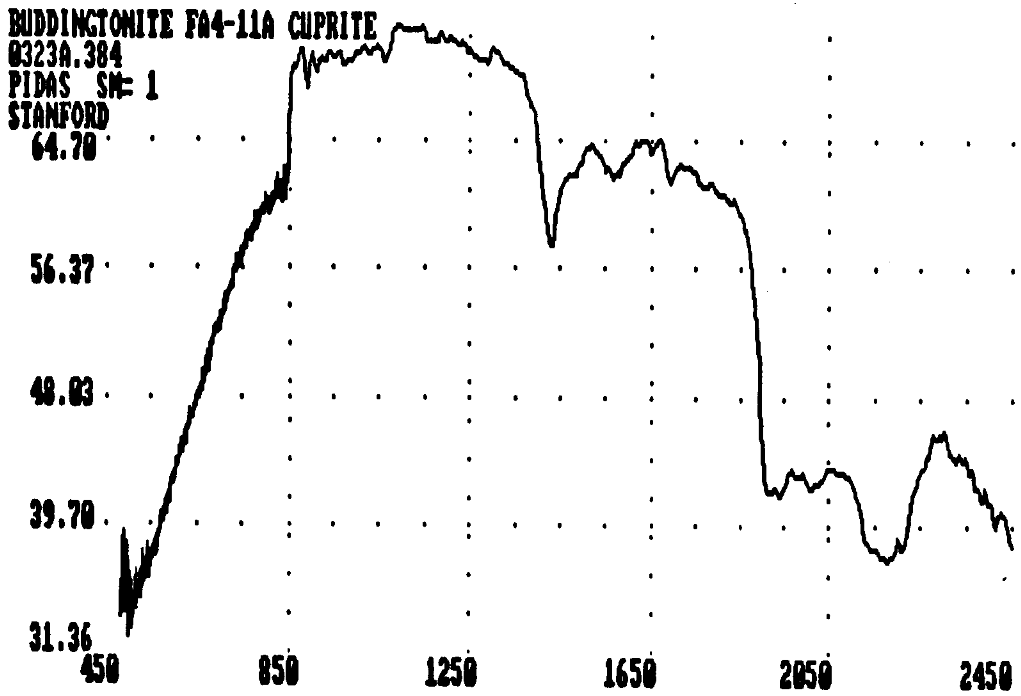

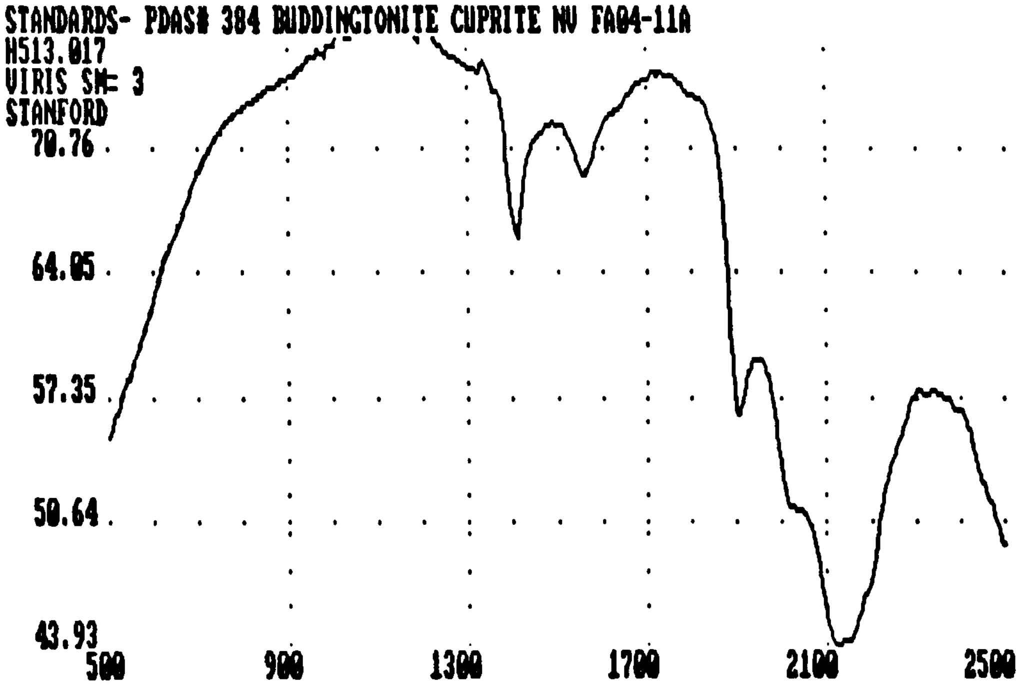

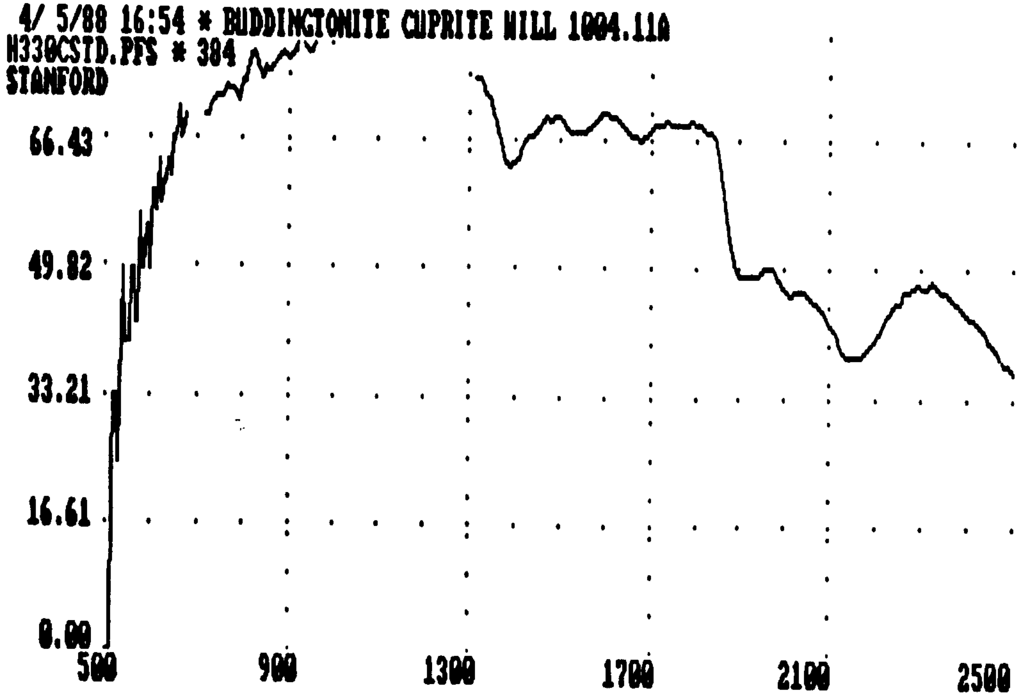

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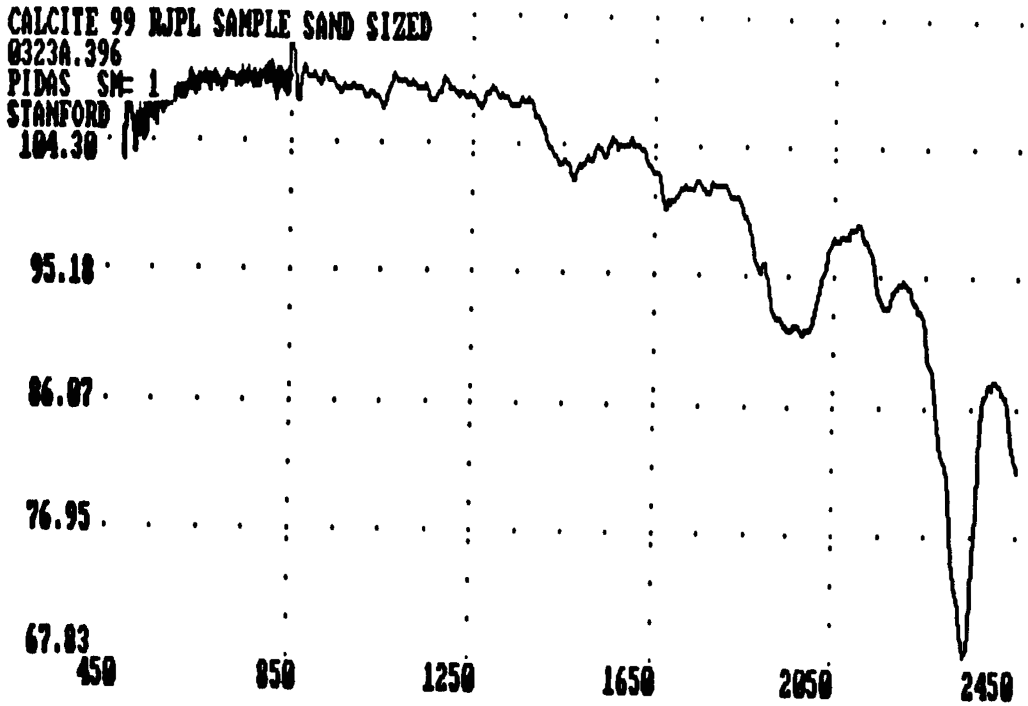
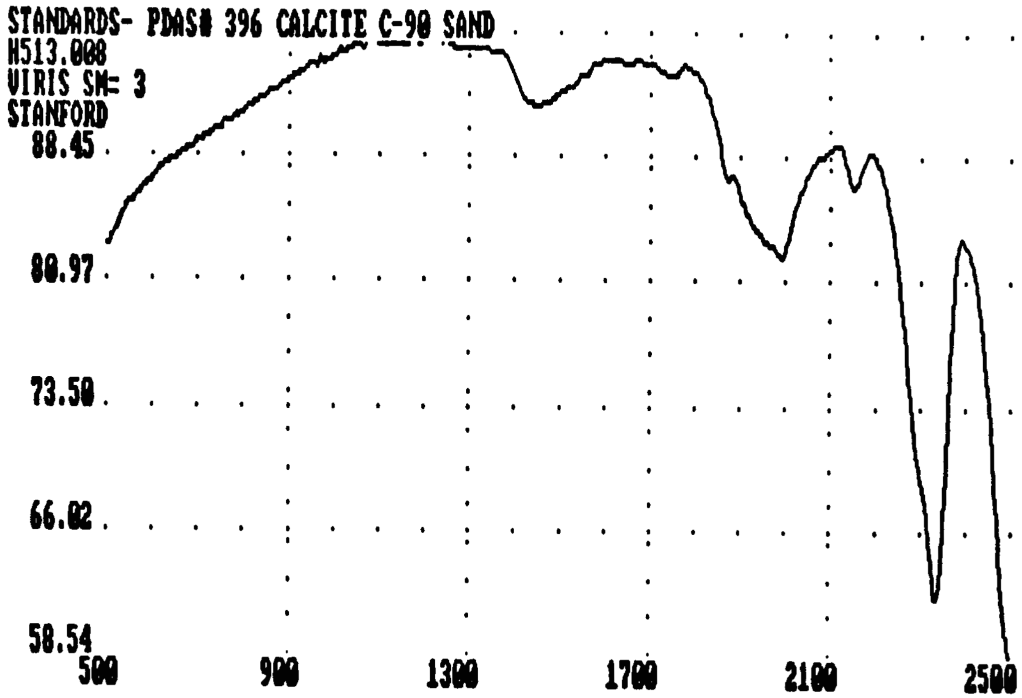
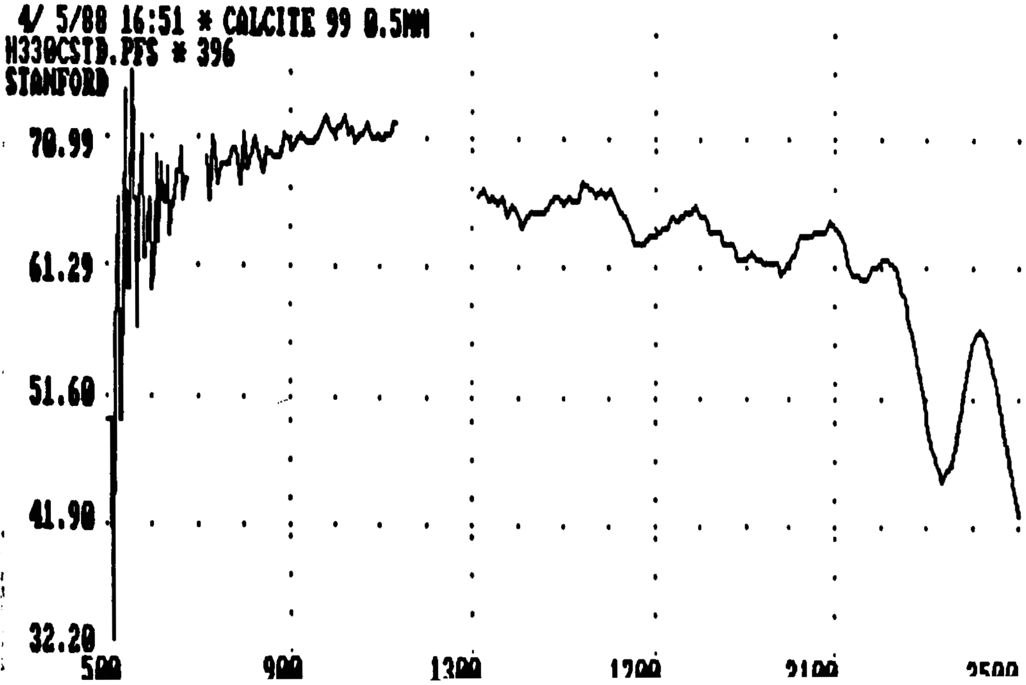
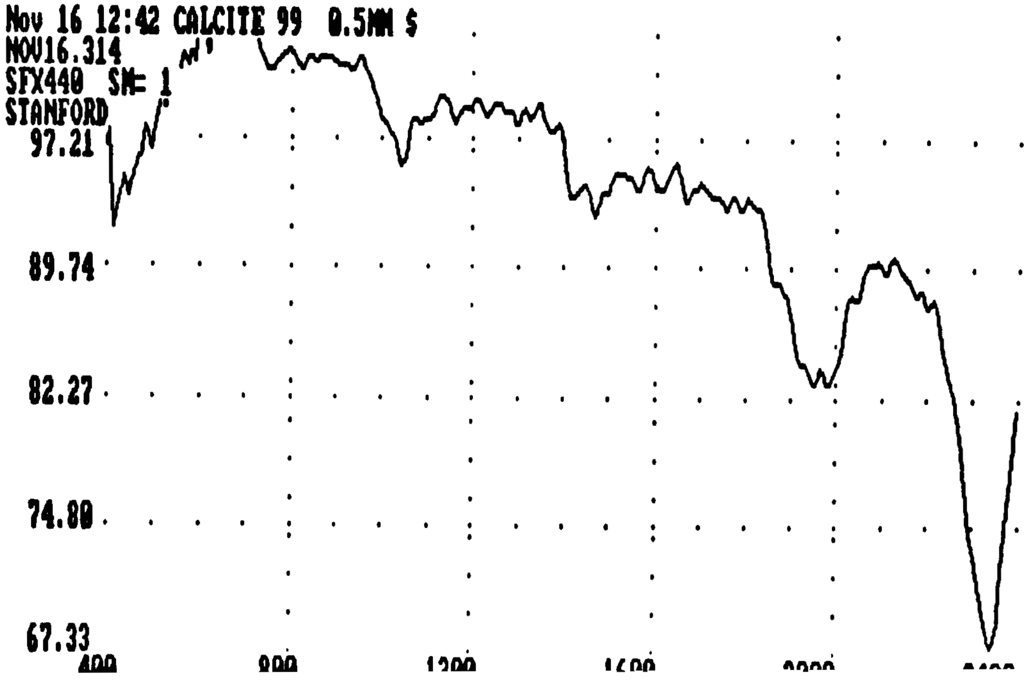
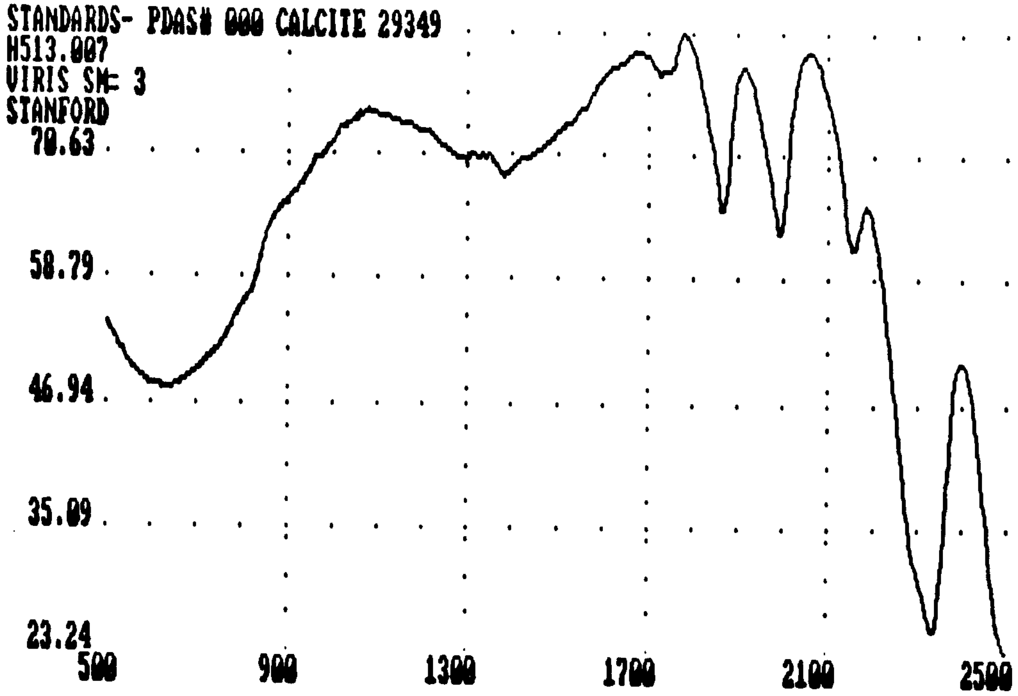
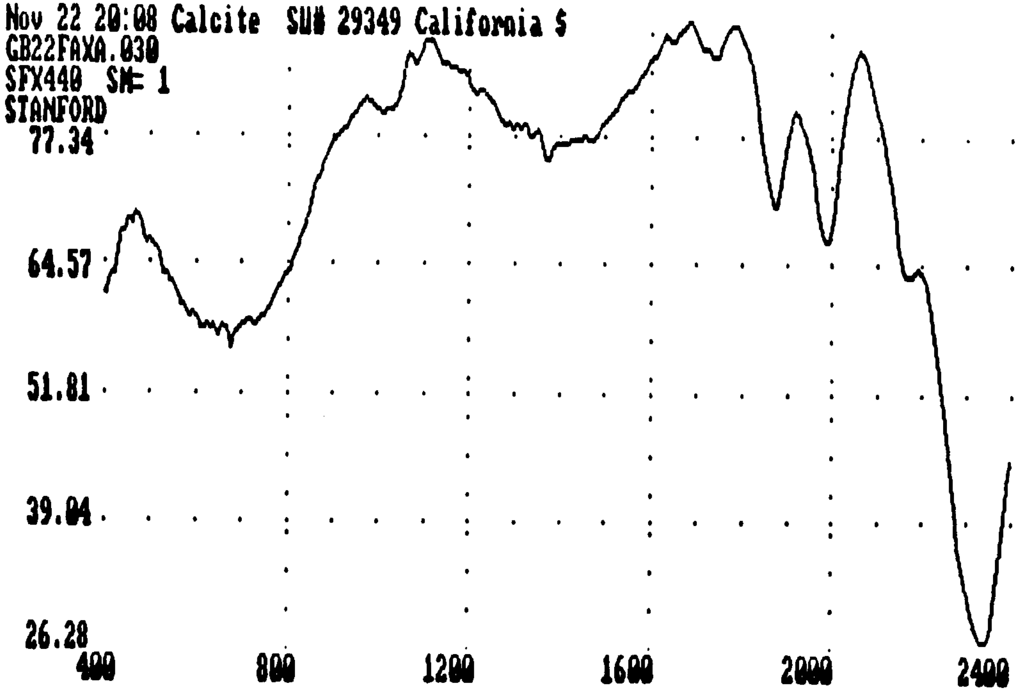

CALCITE 99 RJPL SAMPLE SAND SIZED
0323A.396
PIDAS SM= 1
STANFORD


STANDARDS- PDAS# 396 CALCITE C-90 SAND
H513.008
VIRIS SM= 3
STANFORD

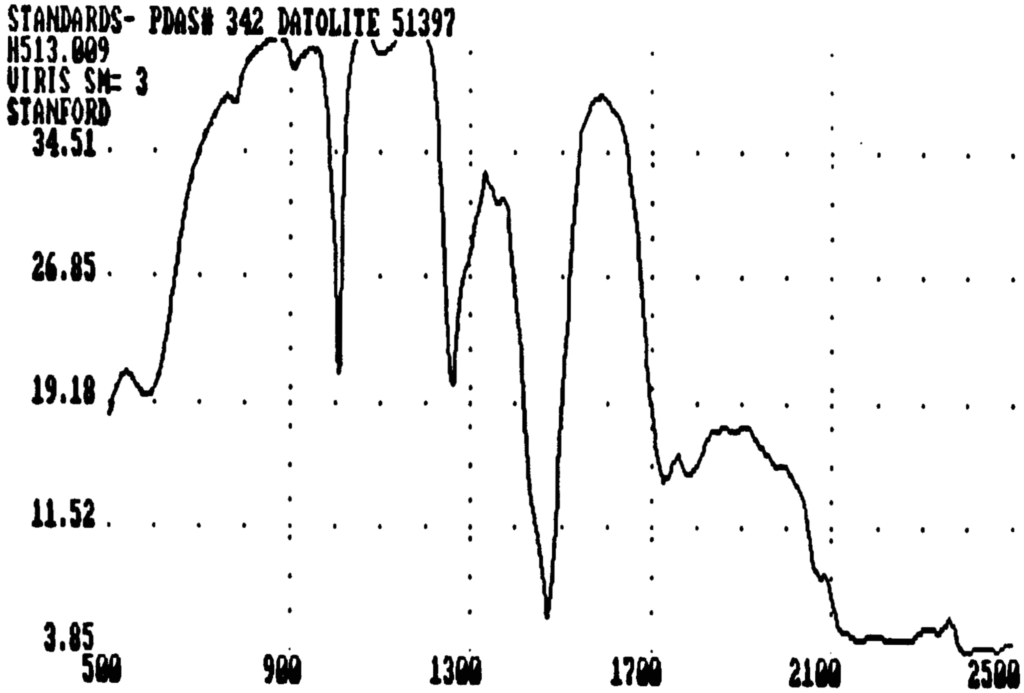

4/ 5/88 16:51 * CALCITE 99 0.5MM
H330CSTD.PFS * 396
STANFORD

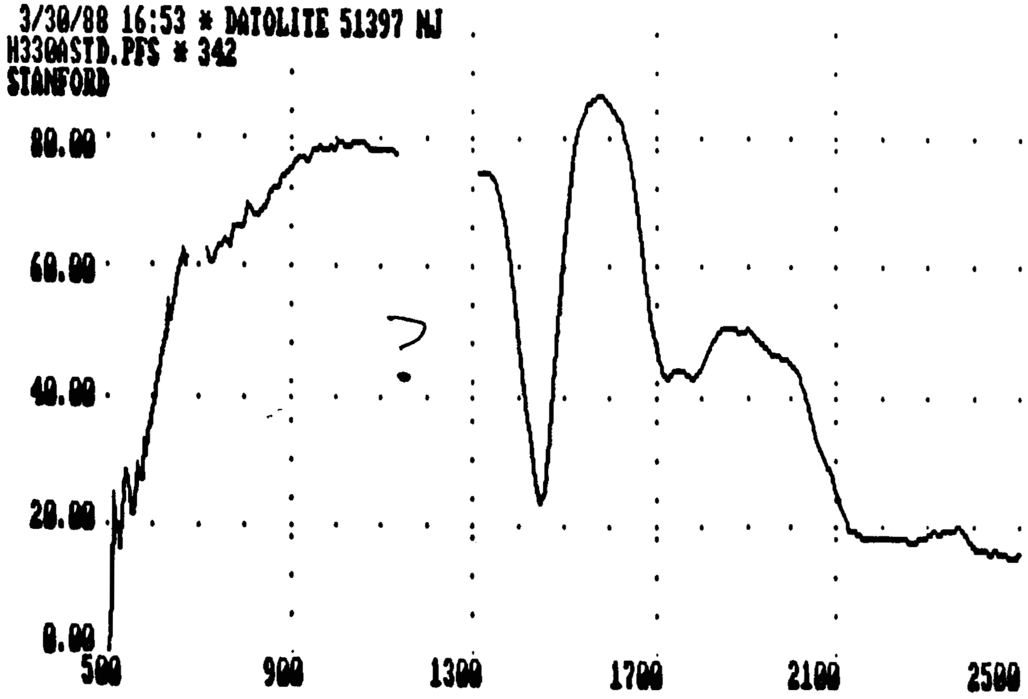

Nov 16 12:42 CALCITE 99 0.5MM $
NOV16.314
SFX440 SM= 1
STANFORD

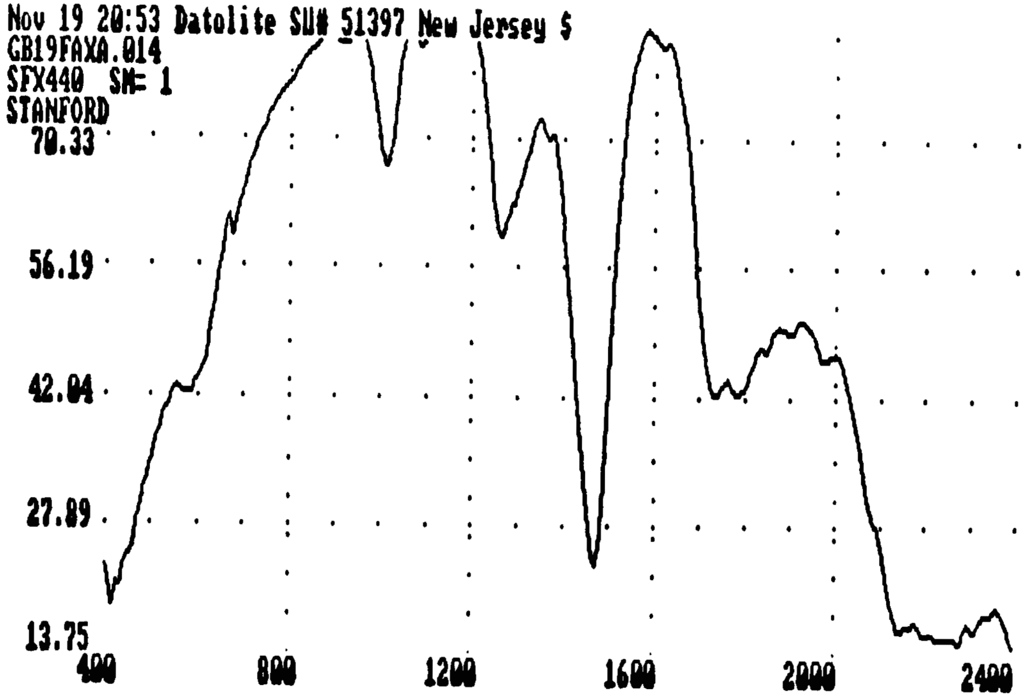

STANDARDS- PDAS# 000 CALCITE 29349
H513.007
VIRIS SM= 3
STANFORD
70.63
58.79
46.94
35.09
23.24
500
900
1300
1700
2100
2500

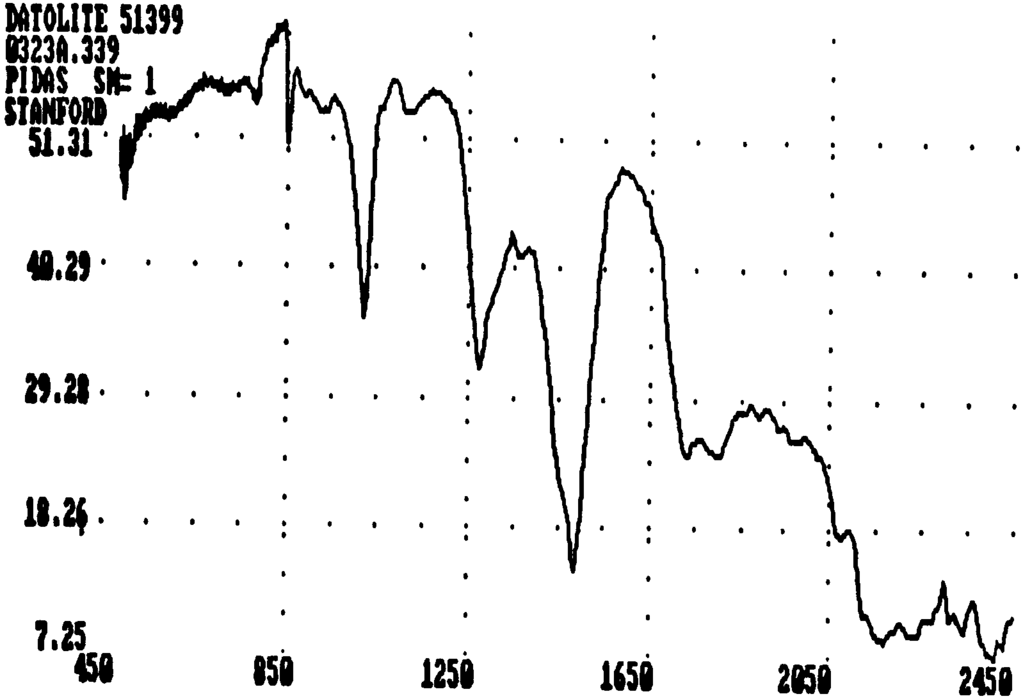

Nov 22 20:08 Calcite SU# 29349 California $
GB22FAXA.030
SFX440 SM= 1
STANFORD
77.34
64.57
51.81
39.04
26.28
400
800
1200
1600
2000
2400

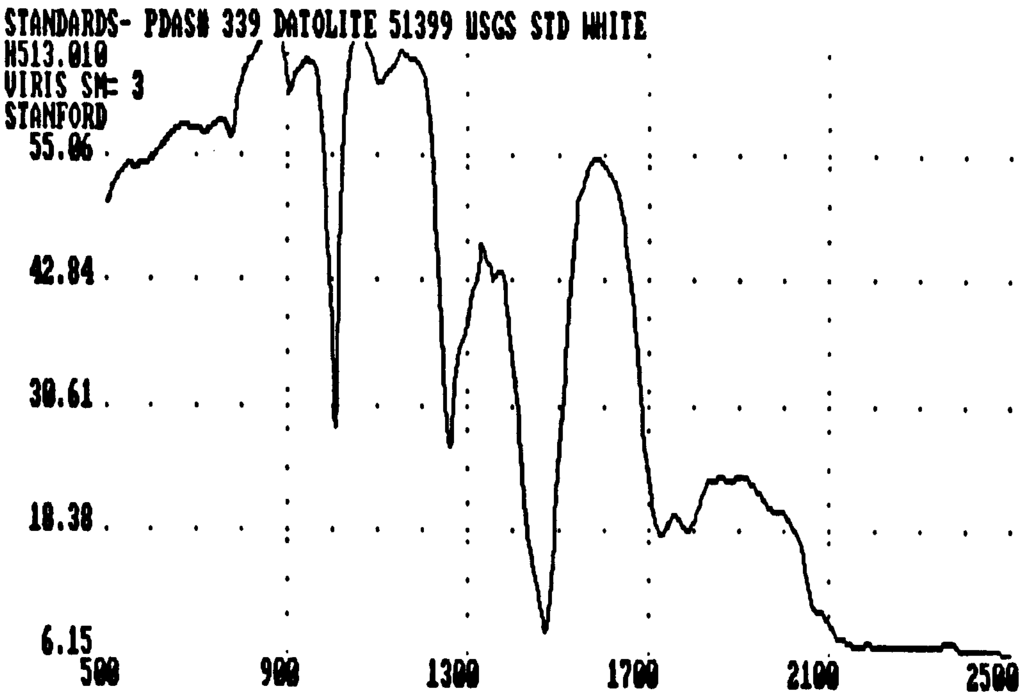

DATOLITE 51397
0323A.342
PIDAS SM= 1
STANFORD

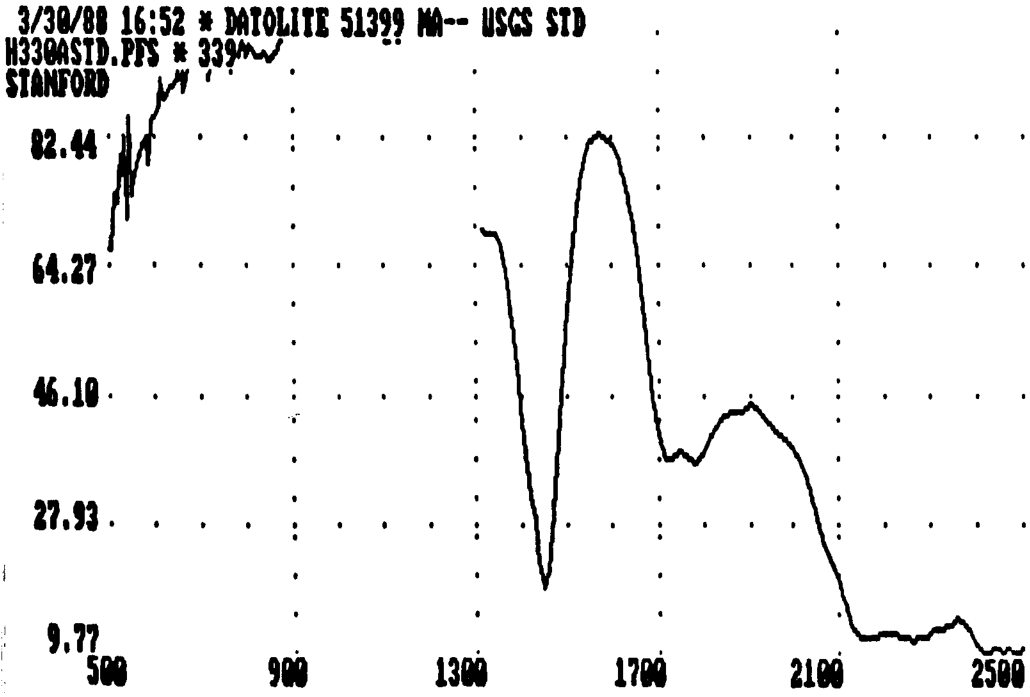

STANDARDS- PDAS# 342 DATOLITE 51397
H513.009
VIRIS SM= 3
STANFORD

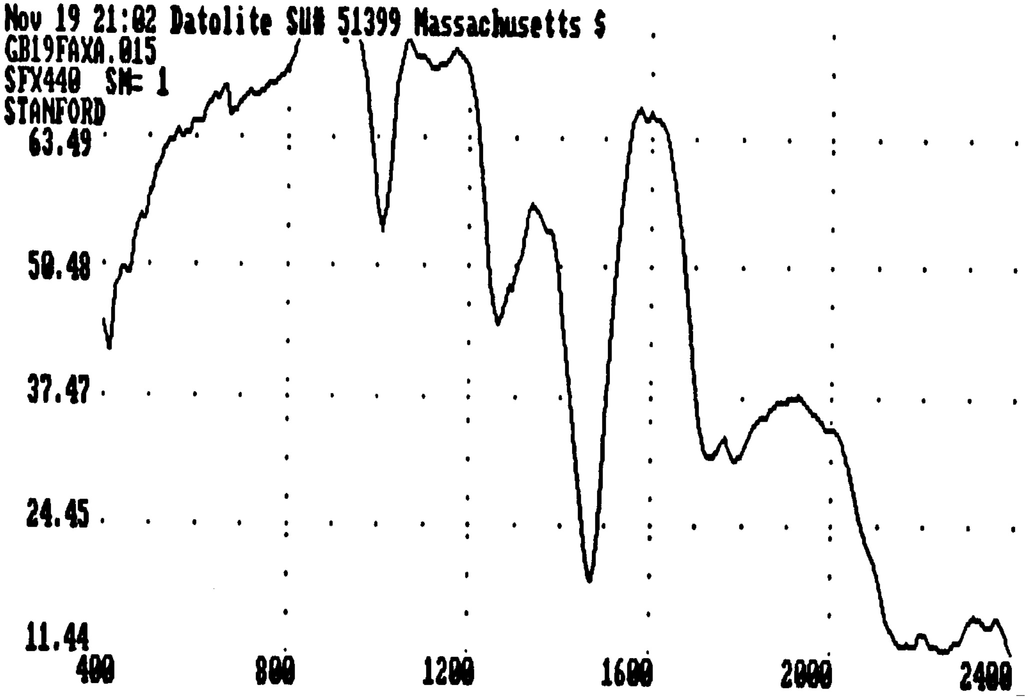

3/30/88 16:53 * DATOLITE 51397 NJ
H330ASTD.PFS * 342
STANFORD

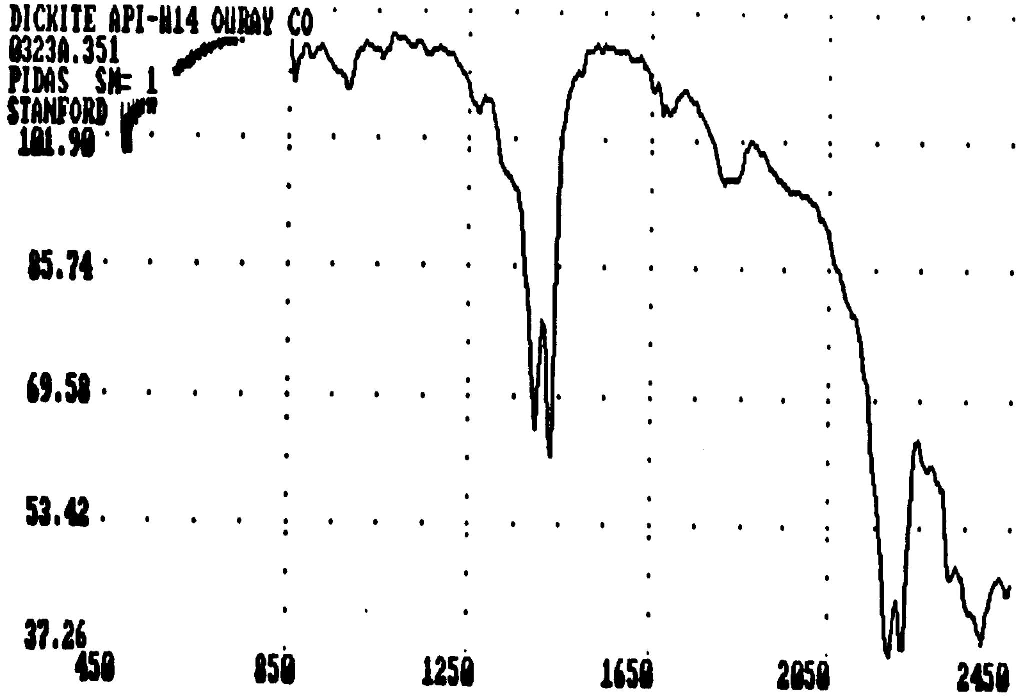

Nov 19 20:53 Datolite SU# 51397 New Jersey $
GB19FAXA.014
SFX440 SM= 1
STANFORD

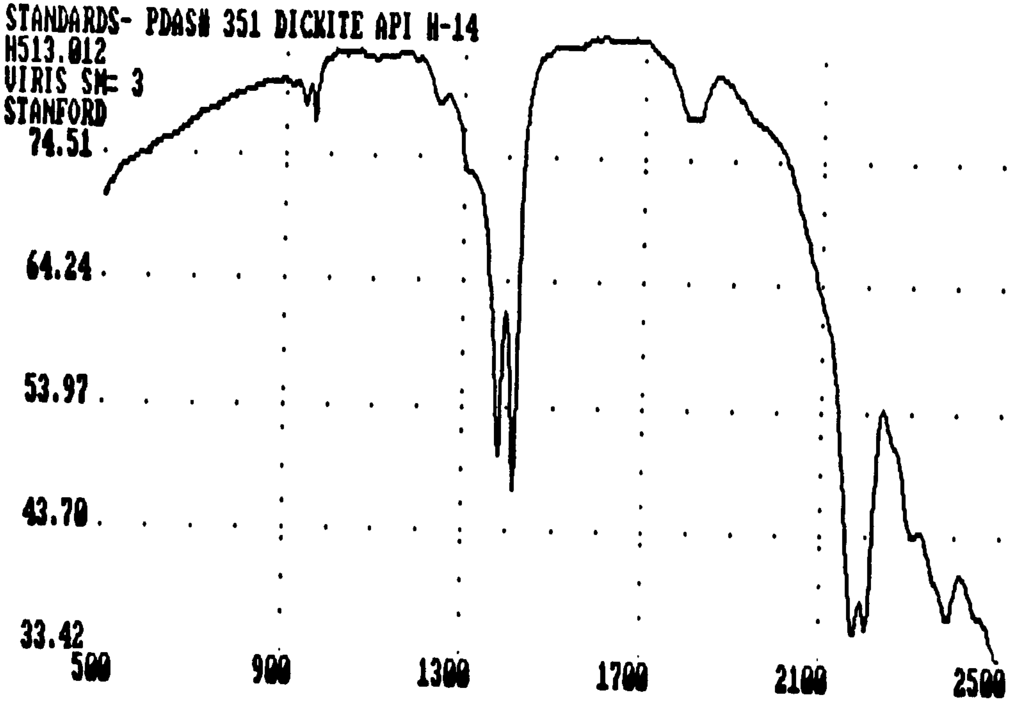

DATOLITE 51399
0323A.339
PIDAS SM= 1
STANFORD
51.31
40.29
29.28
18.26
7.25
450
850
1250
1650
2050
2450

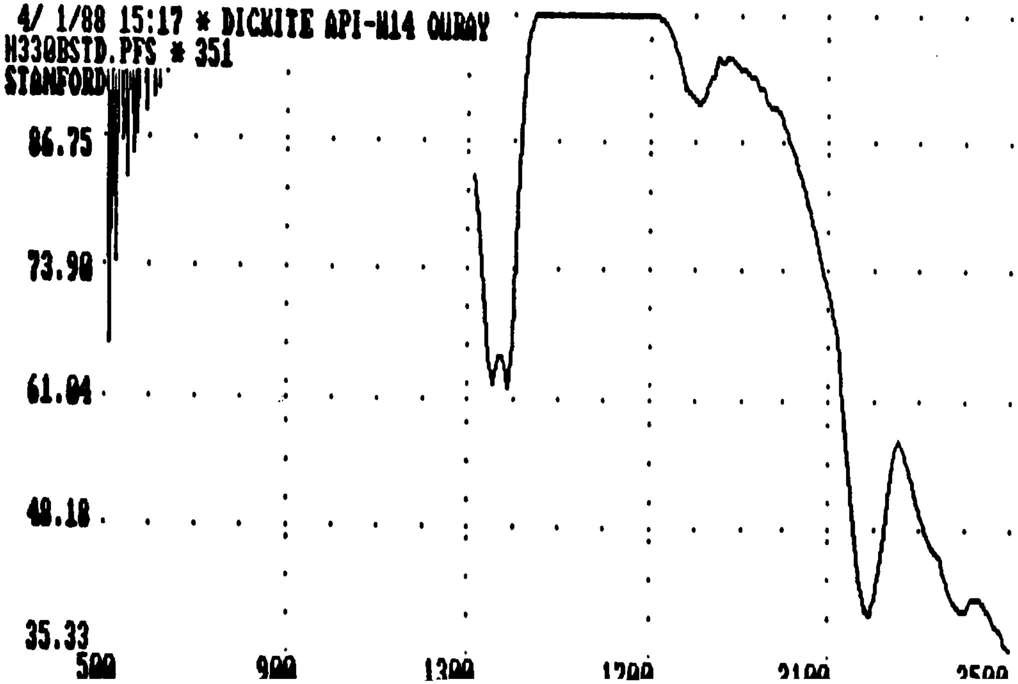

STANDARDS- PDAS# 339 DATOLITE 51399 USGS STD WHITE
H513.010
VIRIS SM= 3
STANFORD
55.06
42.84
30.61
18.38
6.15
500
900
1300
1700
2100
2500

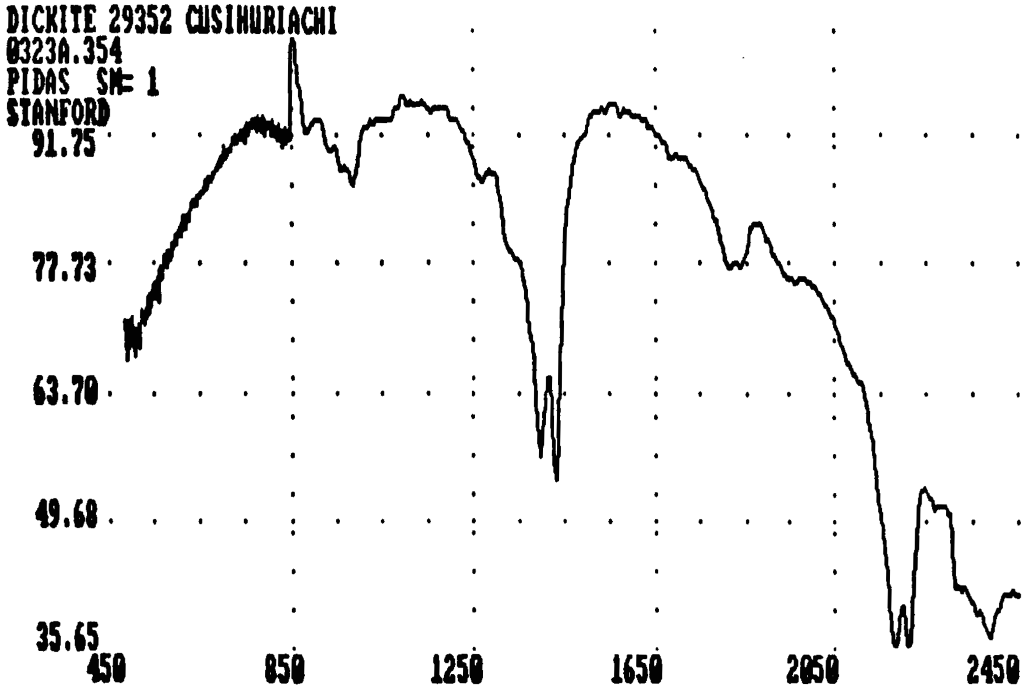

3/30/88 16:52 * DATOLITE 51399 MA-- USGS STD
H330ASTD.PFS * 339
STANFORD
82.44
64.27
46.10
27.93
9.77
500
900
1300
1700
2100
2500

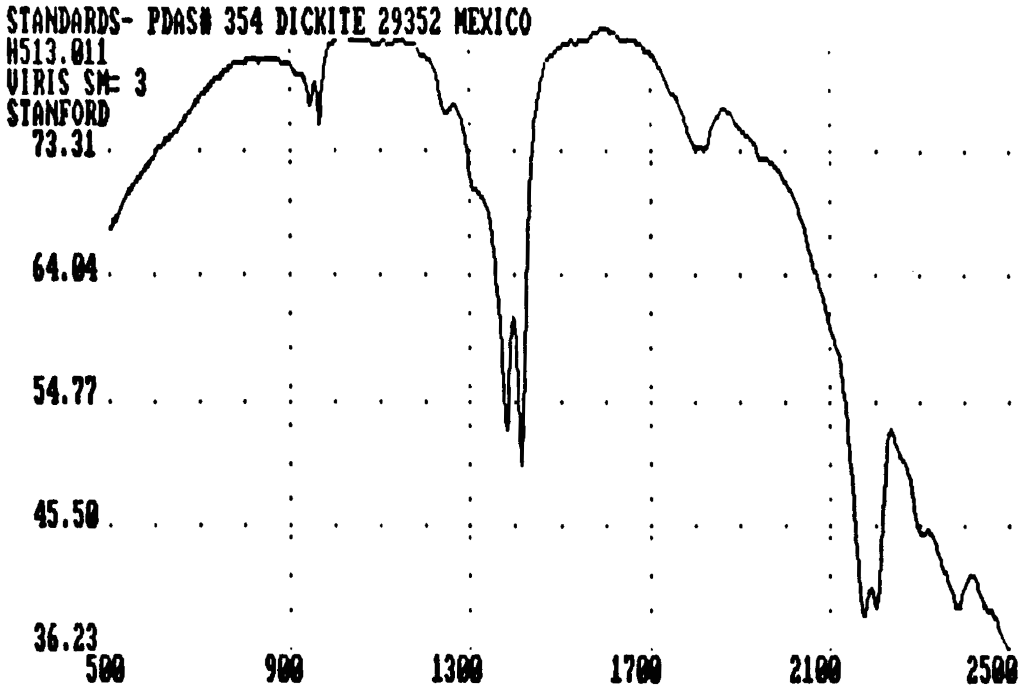

Nov 19 21:02 Datolite SU# 51399 Massachusetts $
GB19FAXA.015
SFX440 SM= 1
STANFORD
63.49
50.48
37.47
24.45
11.44
400
800
1200
1600
2000
2400


DICKITE API-H14 OURAY CO
0323A.351
PIDAS SM= 1
STANFORD
101.90
85.74
69.58
53.42
37.26
450
850
1250
1650
2050
2450

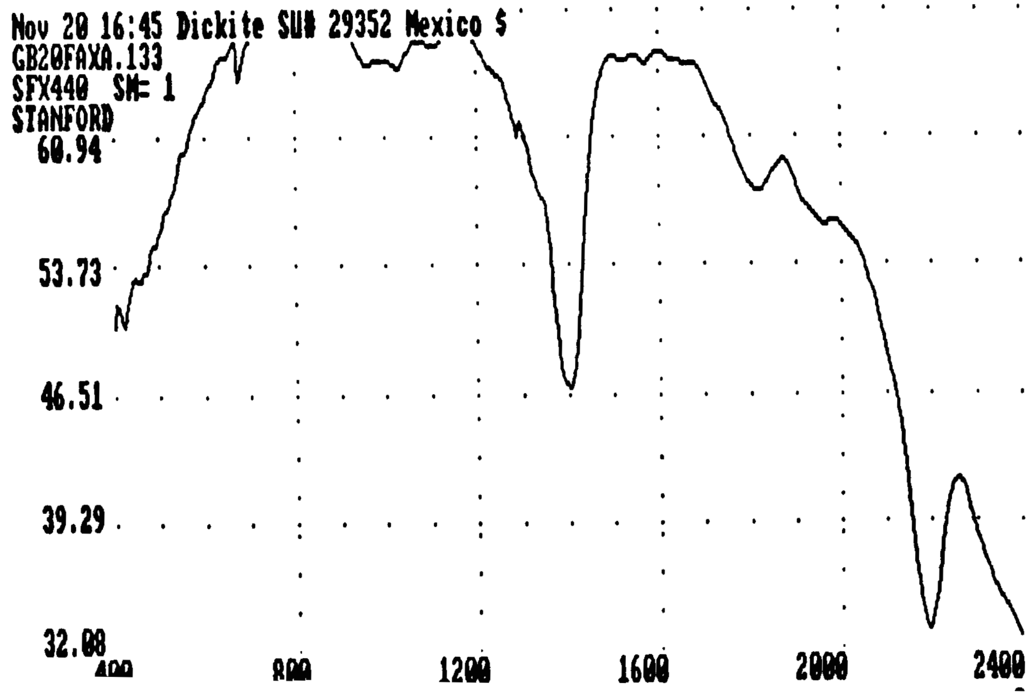

STANDARDS- PDAS# 351 DICKITE API H-14
H513.012
VIRIS SM= 3
STANFORD
74.51
64.24
53.97
43.70
33.42
500
900
1300
1700
2100
2500

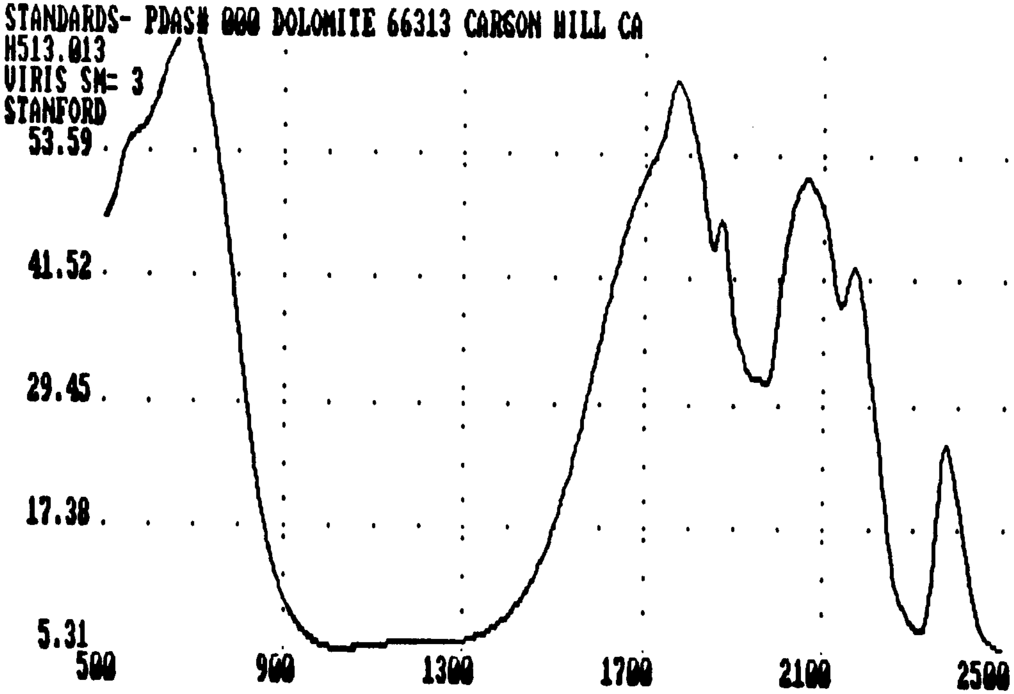

4/ 1/88 15:17 * DICKITE API-H14 OURAY
H330BSTD.PFS * 351
STANFORD
86.75
73.90
61.04
48.18
35.33
500
900
1300
1700
2100
2500


DICKITE 29352 CUSIHURIACHI
0323A.354
PIDAS SM= 1
STANFORD
91.75
77.73
63.70
49.68
35.65
450
850
1250
1650
2050
2450

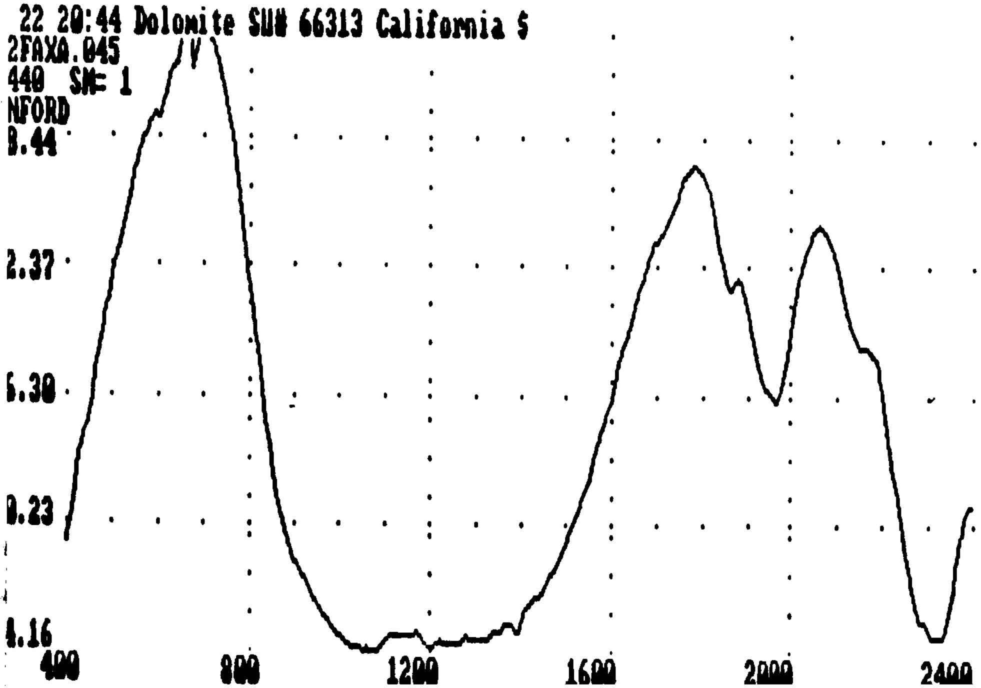

STANDARDS- PDAS# 354 DICKITE 29352 MEXICO
H513.011
VIRIS SM= 3
STANFORD
73.31
64.04
54.77
45.50
36.23
500
900
1300
1700
2100
2500


4/ 1/88 15:14 * DICKITE 29352 MEX
H330BSTD.PFS * 354
STANFORD
75.99
63.48
50.97
38.46
25.95

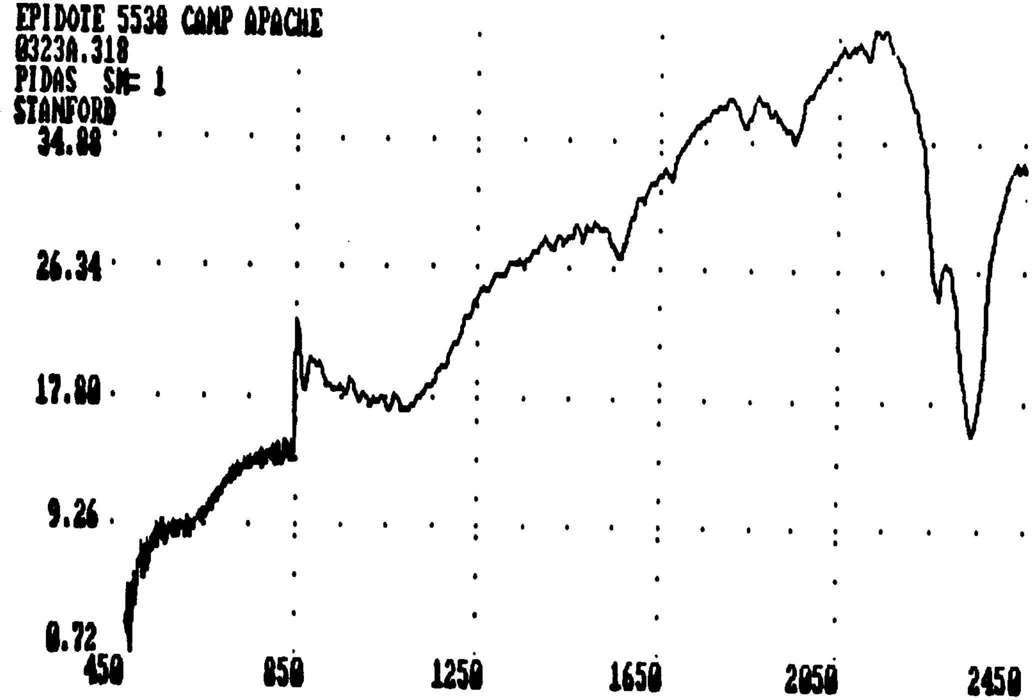

Nov 20 16:45 Dickite SU# 29352 Mexico $
GB20FAXA.133
SFX440 SM= 1
STANFORD
60.94
53.73
46.51
39.29
32.08
400
800
1200
1600
2000
2400

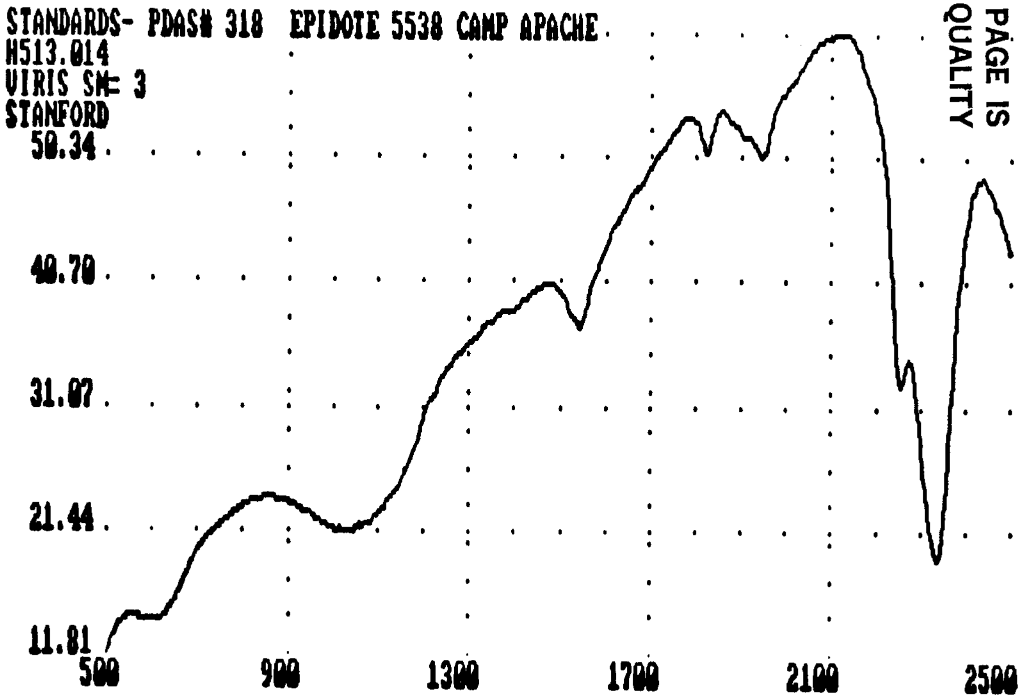


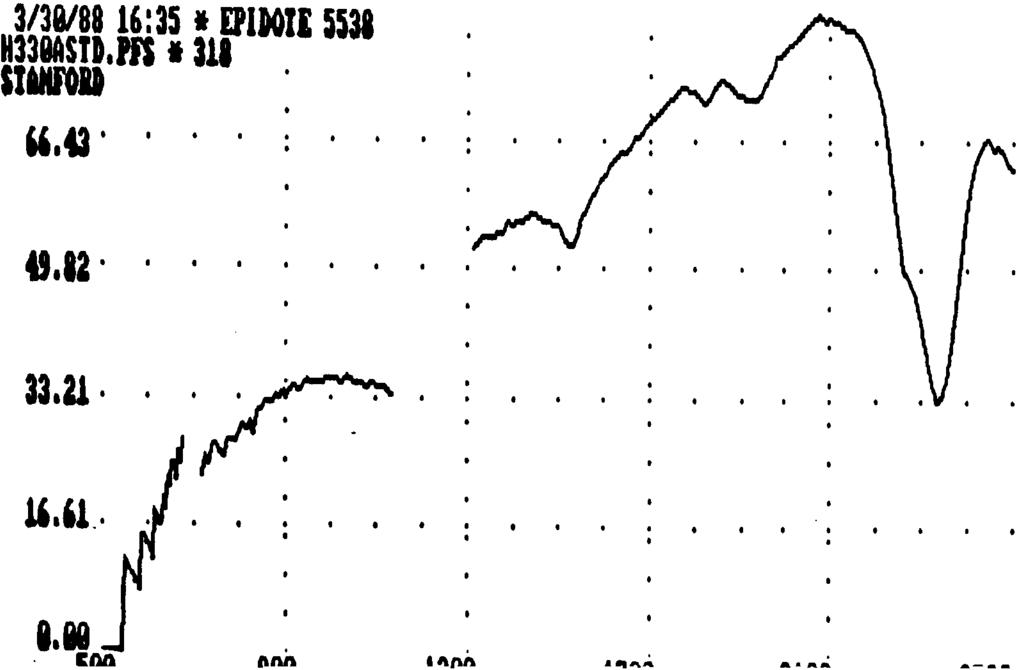
STANDARDS- PDAS# 000 DOLOMITE 66313 CARSON HILL CA
H513.013
VIRIS SM= 3
STANFORD

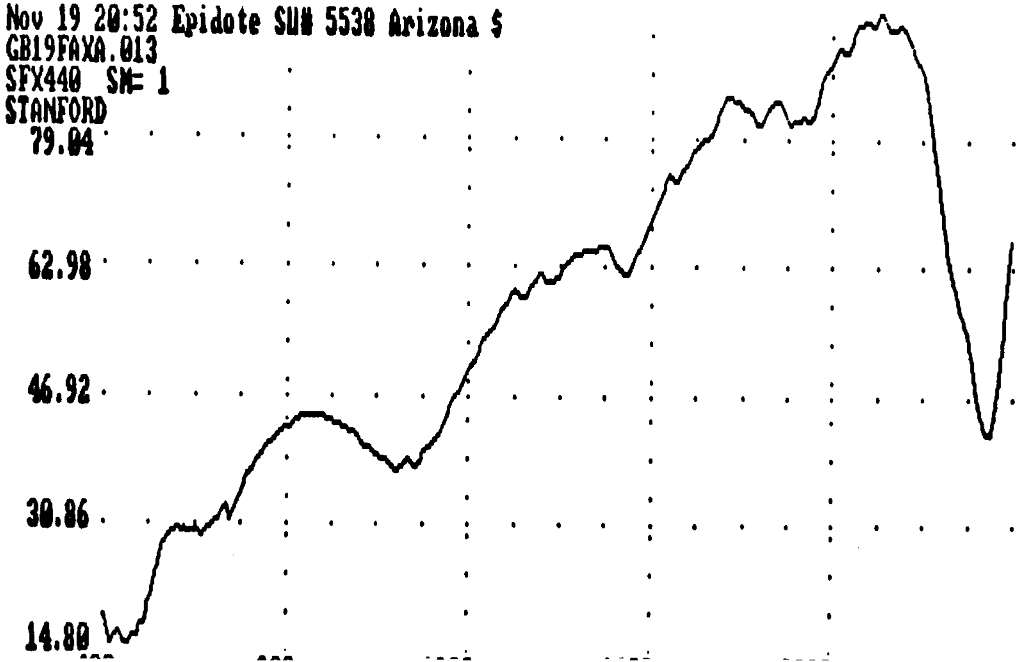


22 20:44 Dolomite SU# 66313 California $
2FAXA.045
440 SM= 1
NFORD


EPIDOTE 5538 CAMP APACHE
0323A.318
PIDAS SM= 1
STANFORD
34.88
26.34
17.80
9.26
0.72
450
850
1250
1650
2050
2450


STANDARDS- PDAS# 318 EPIDOTE 5538 CAMP APACHE
H513.014
VIRIS SM= 3
STANFORD
50.34
40.70
31.07
21.44
11.81
500
900
1300
1700
2100
2500


3/30/88 16:35 * EPIDOTE 5538
H330ASTD.PFS * 318
STANFORD
66.43
49.82
33.21
16.61
0.00


Nov 19 20:52 Epidote SU# 5538 Arizona $
GB19FAXA.013
SFX440 SM= 1
STANFORD
79.04
62.98
46.92
30.86
14.80

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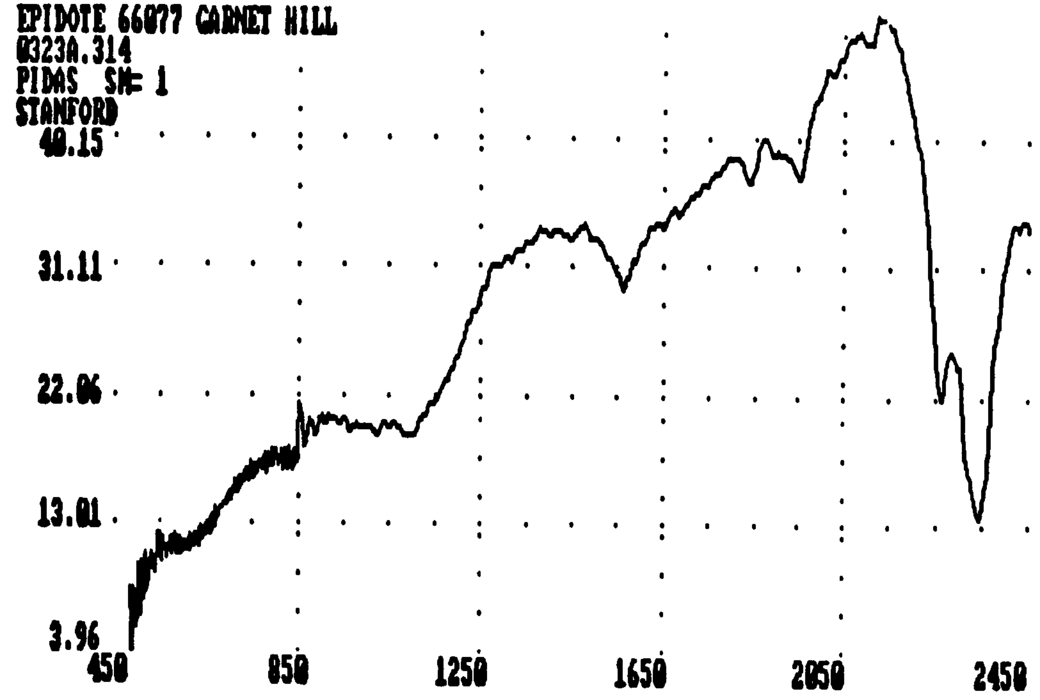
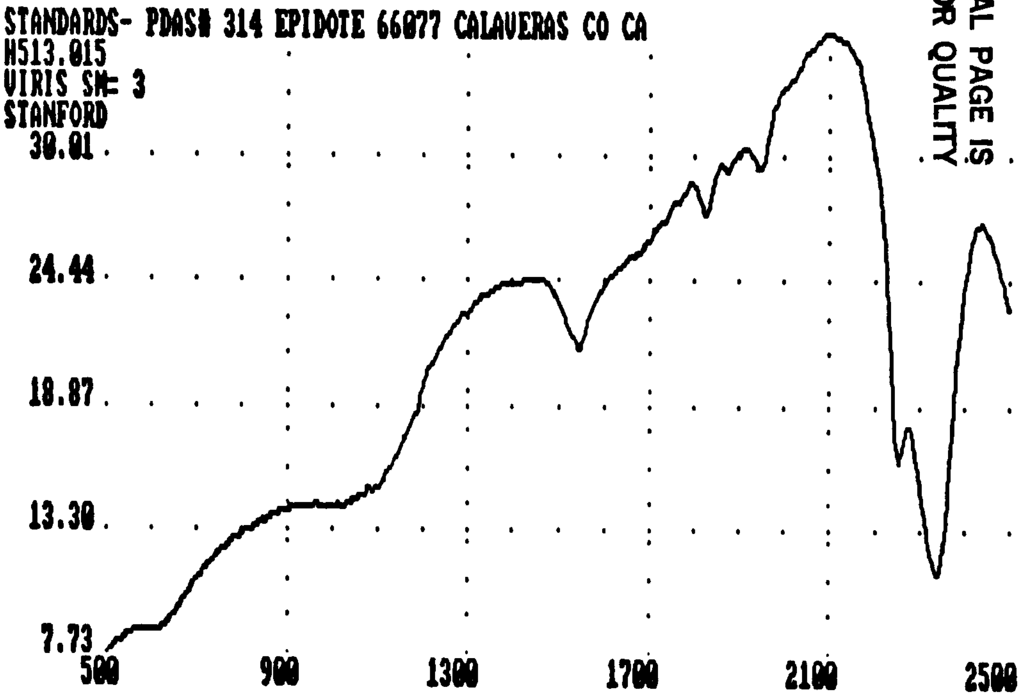
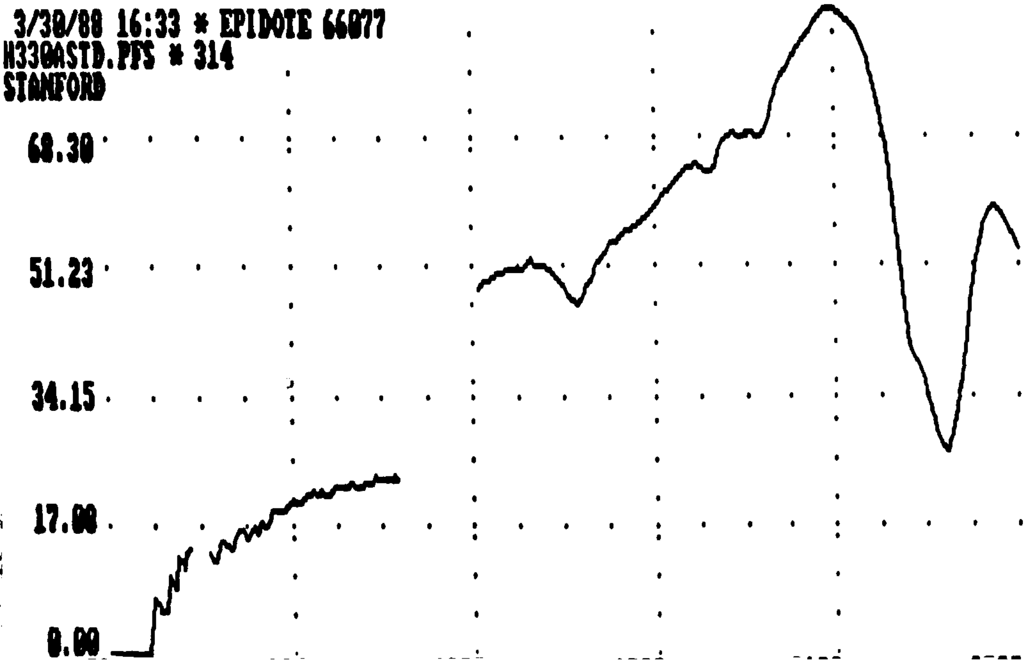
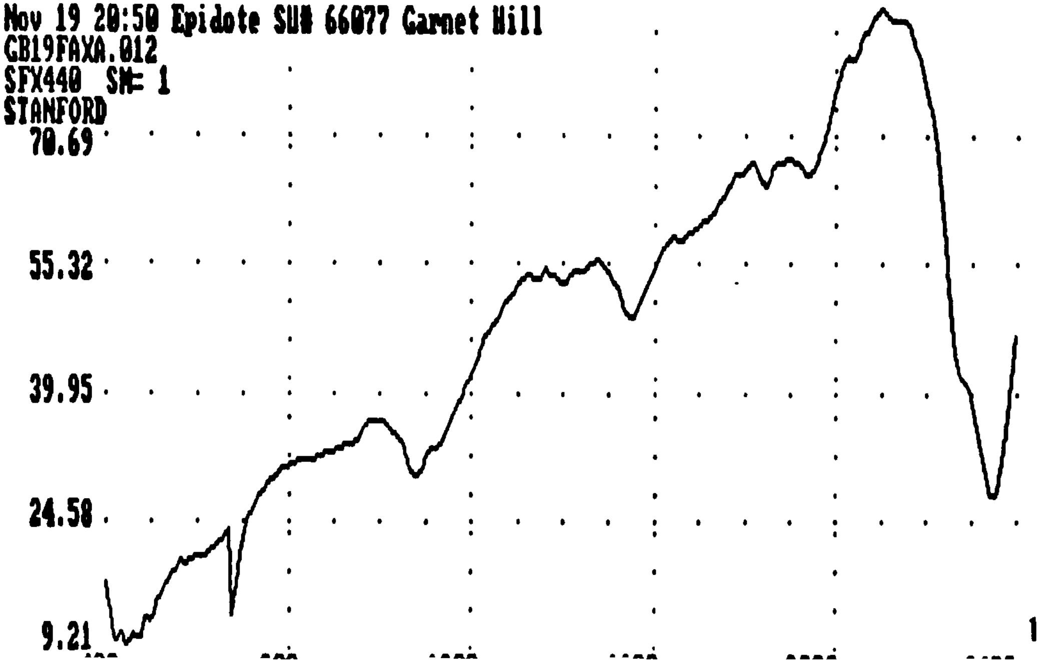
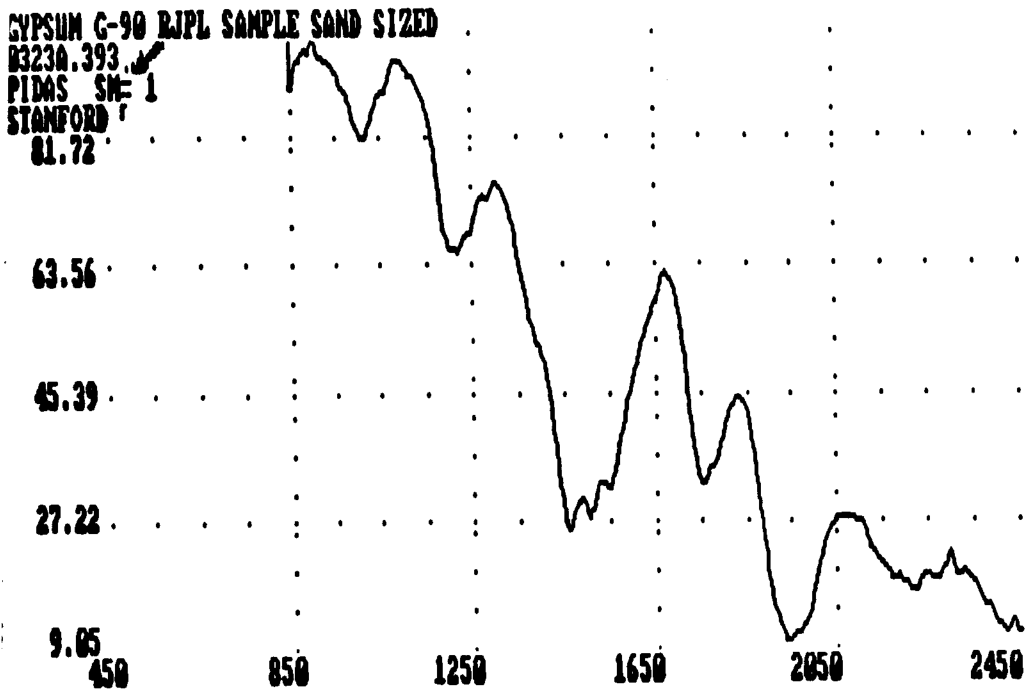
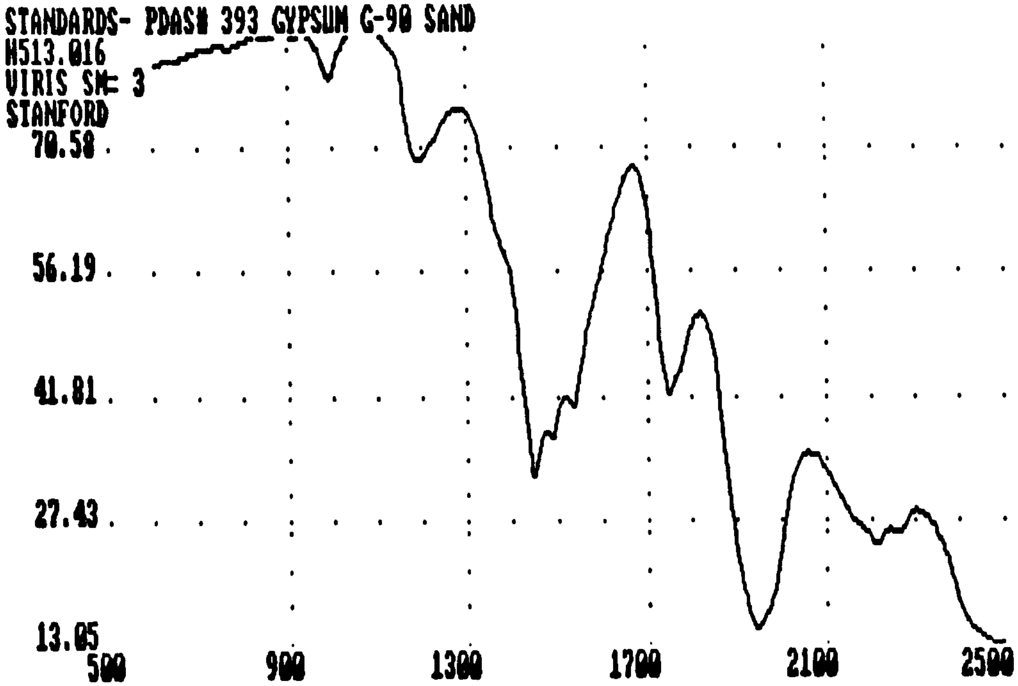


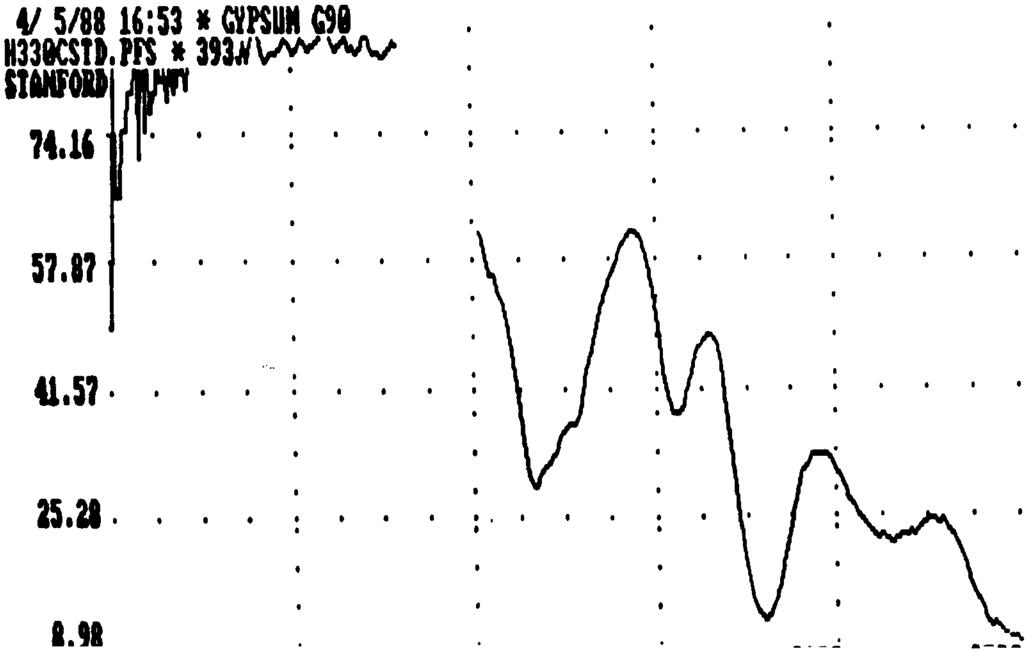




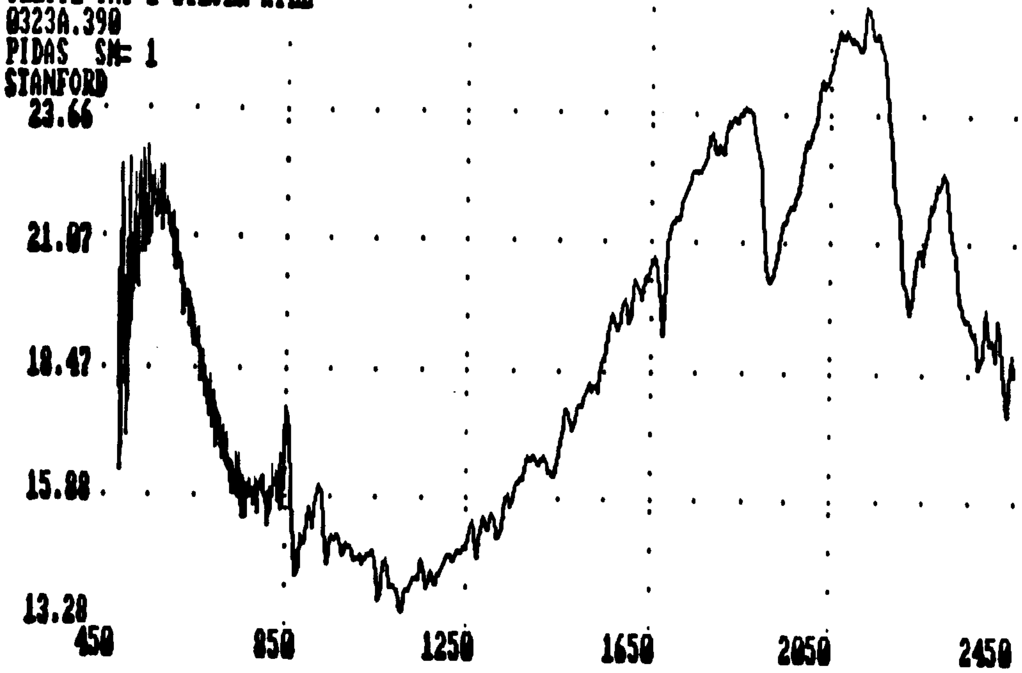



GYPSUM G-90 RJPL SAMPLE SAND SIZED
R323A.393.
PIDAS SM= 1
STANFORD
81.72
63.56
45.39
27.22
9.05
450
850
1250
1650
2050
2450

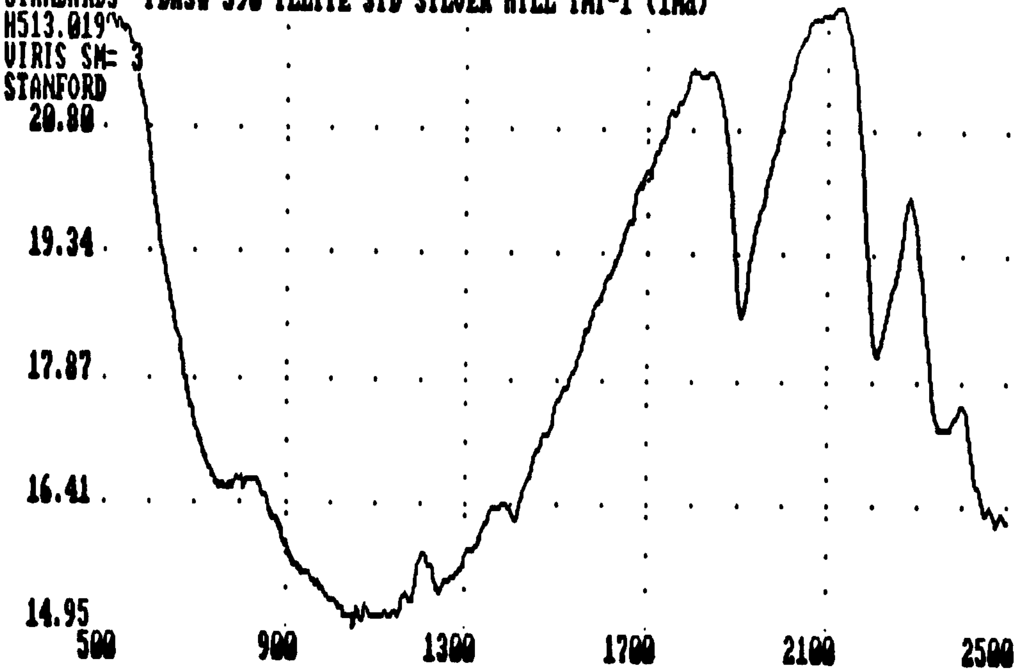

STANDARDS- PDAS# 393 GYPSUM G-90 SAND
H513.016
VIRIS SM= 3
STANFORD
70.58
56.19
41.81
27.43
13.05
500
900
1300
1700
2100
2500


4/ 5/88 16:53 * GYPSUM G90
H330CSTD.PFS * 393
STANFORD
74.16
57.87
41.57
25.28
8.98

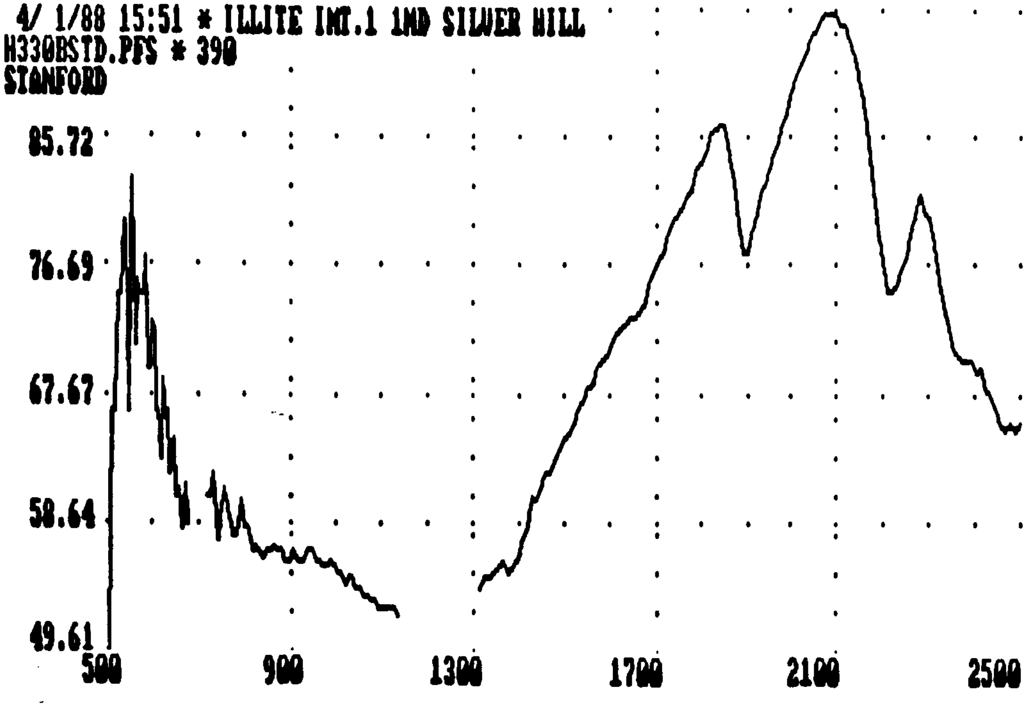
ILLITE IMT-1 SILVER HILL
0323A.390
PIDAS SM= 1
STANFORD



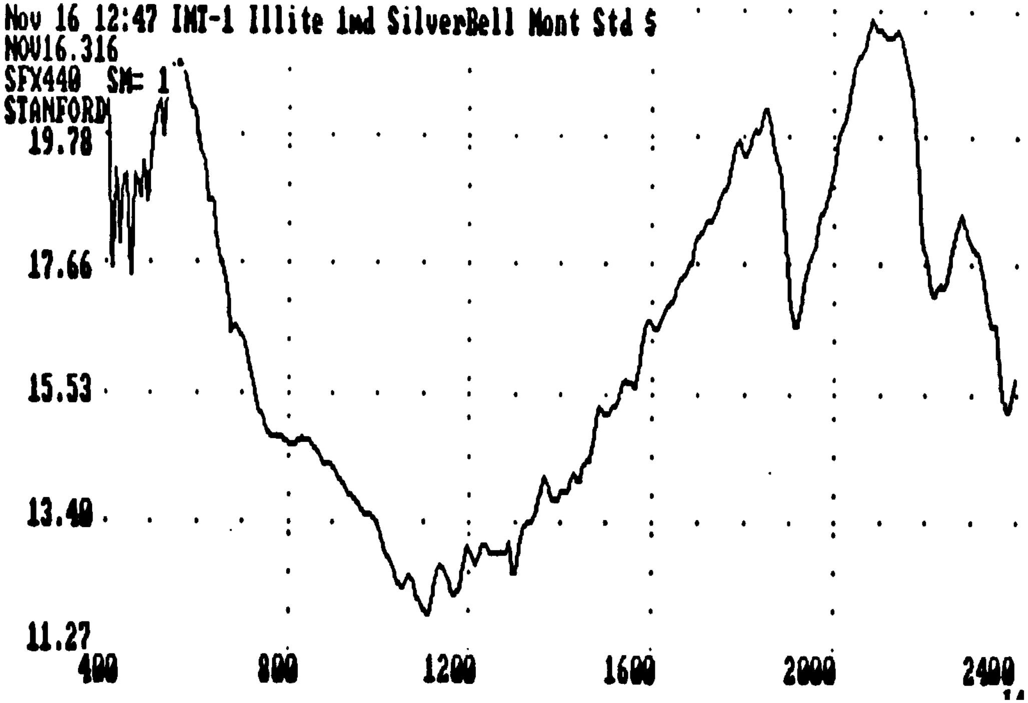
STANDARDS- PDAS# 390 ILLITE STD SILVER HILL IMT-1 (1Md)
H513.019
VIRIS SM= 3
STANFORD

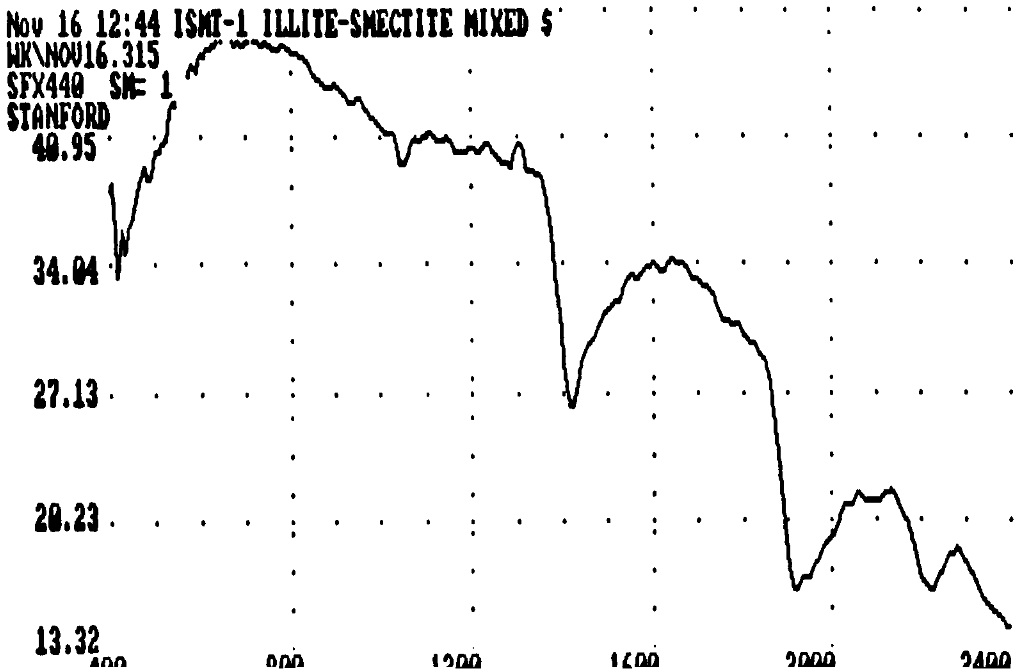


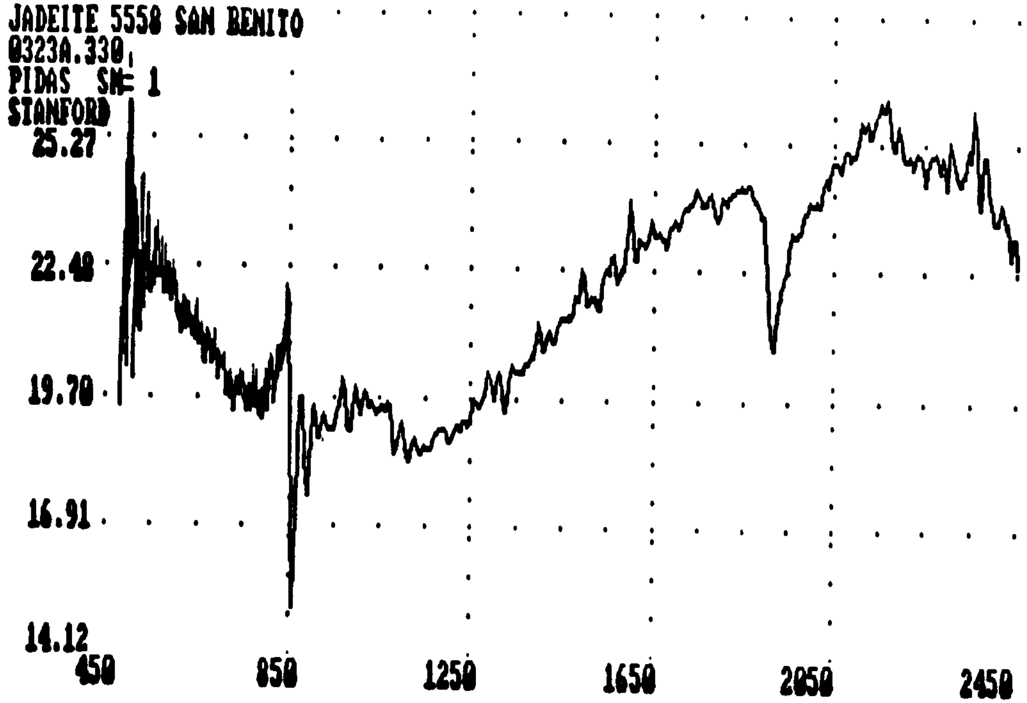
4/ 1/88 15:51 * ILLITE IMT.1 1MD SILVER HILL
H330BSTD.PFS * 390
STANFORD



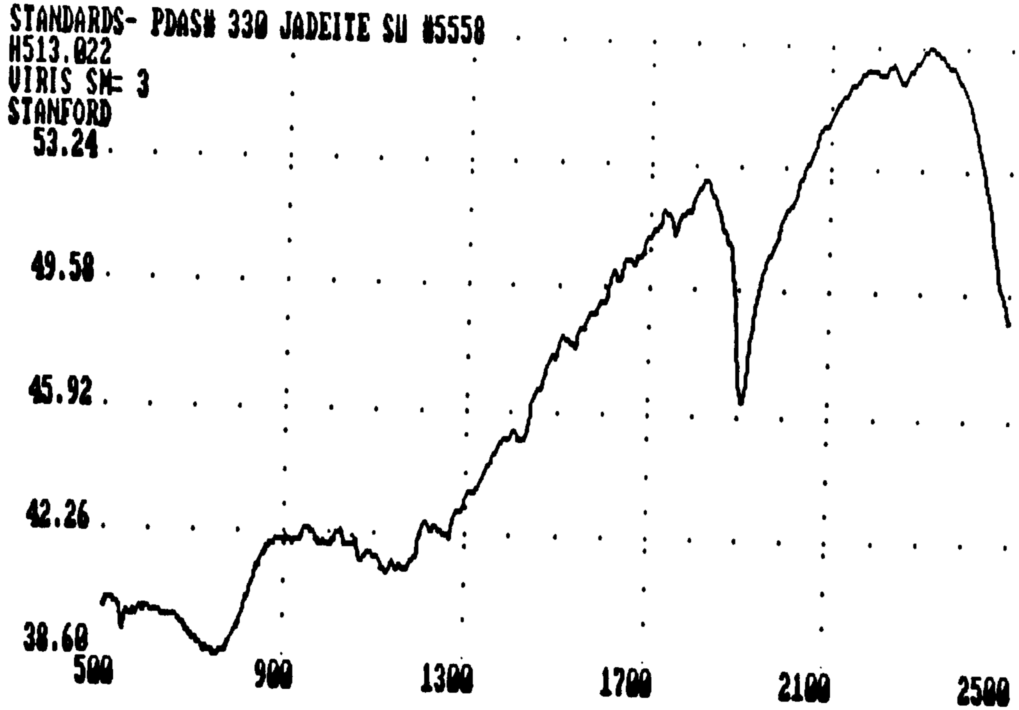
Nov 16 12:47 IMT-1 Illite 1md SilverBell Mont Std $
NOV16.316
SFX440 SM= 1
STANFORD



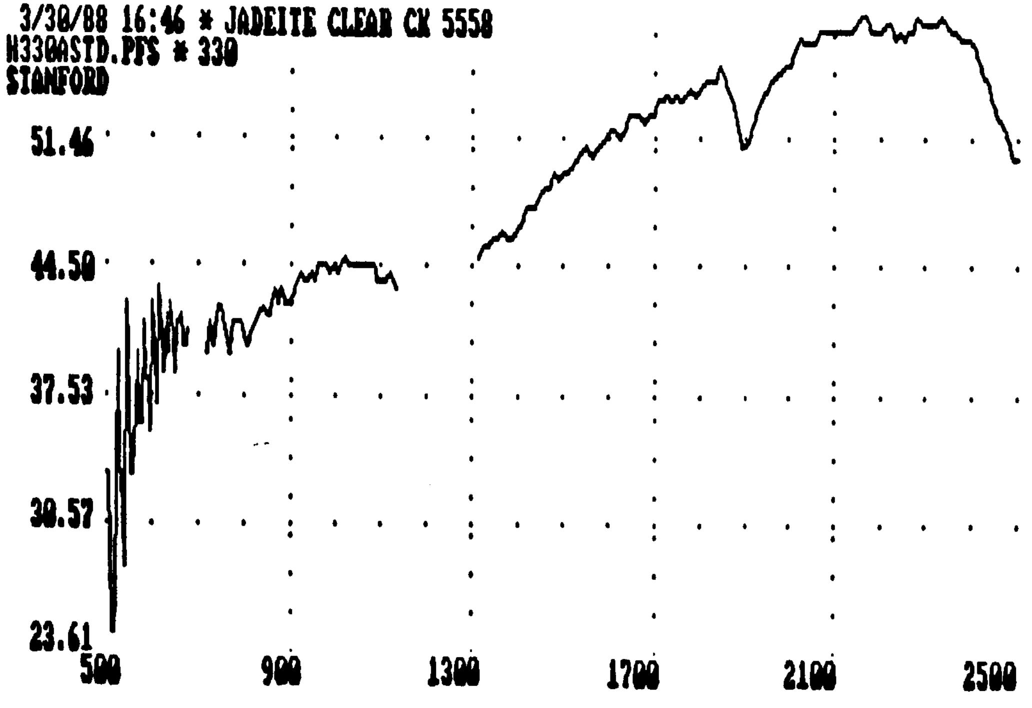

Nov 16 12:44 ISMT-1 ILLITE-SMECTITE MIXED $
WK\NOV16.315
SFX440 SM= 1
STANFORD
40.95
34.04
27.13
20.23
13.32
400
800
1200
1600
2000
2400



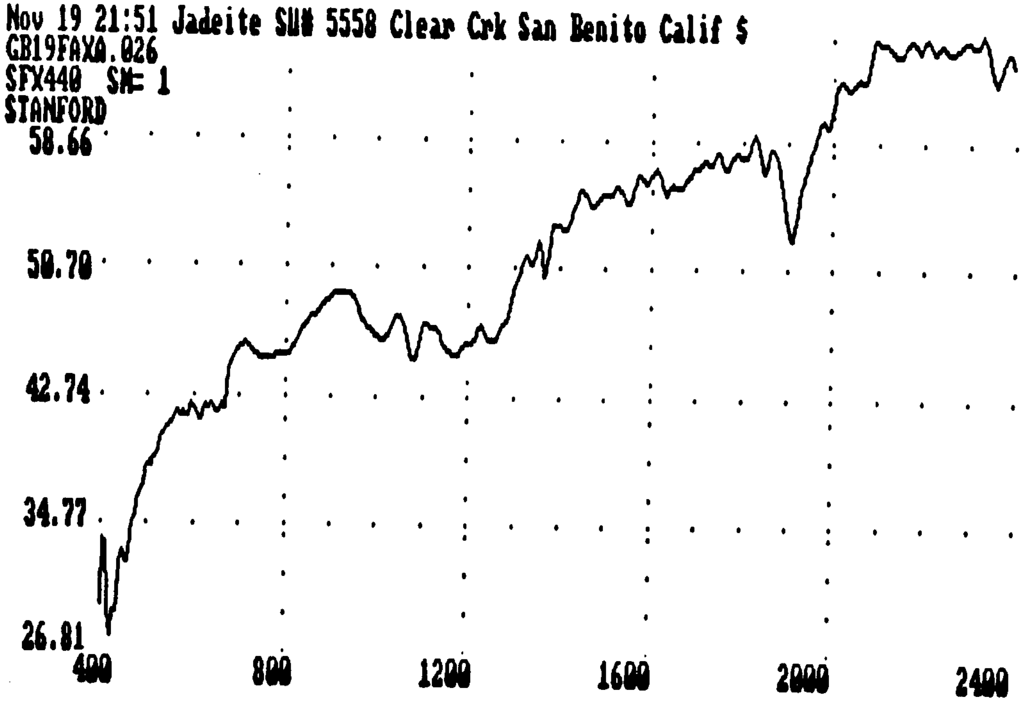
JADEITE 5558 SAN BENITO
0323A.330
PIDAS SM= 1
STANFORD



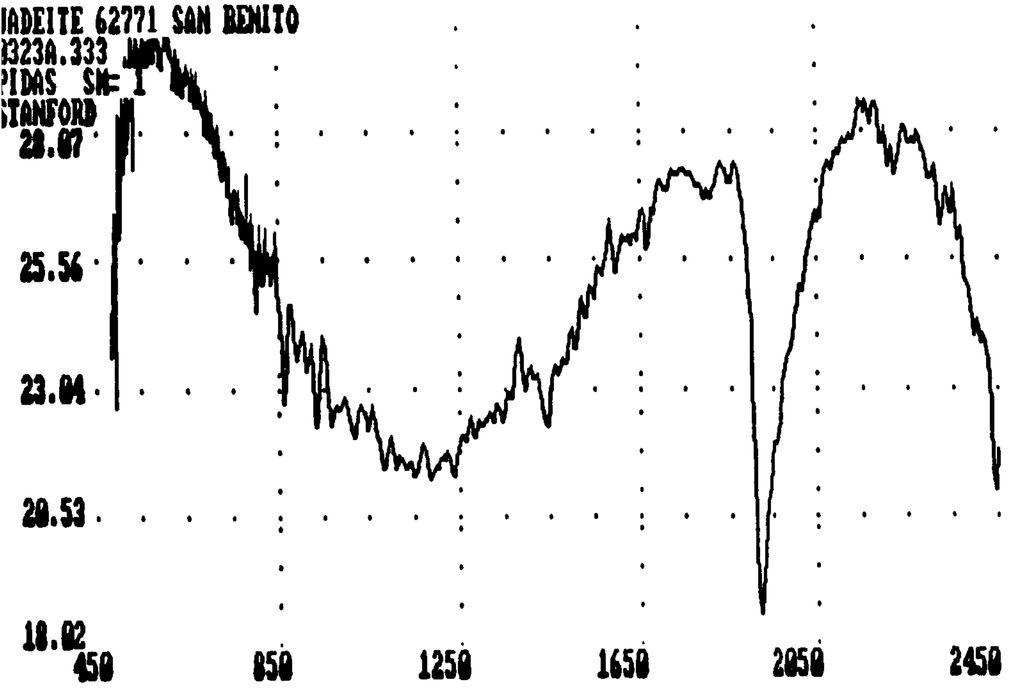
STANDARDS- PDAS# 330 JADEITE SU #5558
H513.022
VIRIS SM= 3
STANFORD

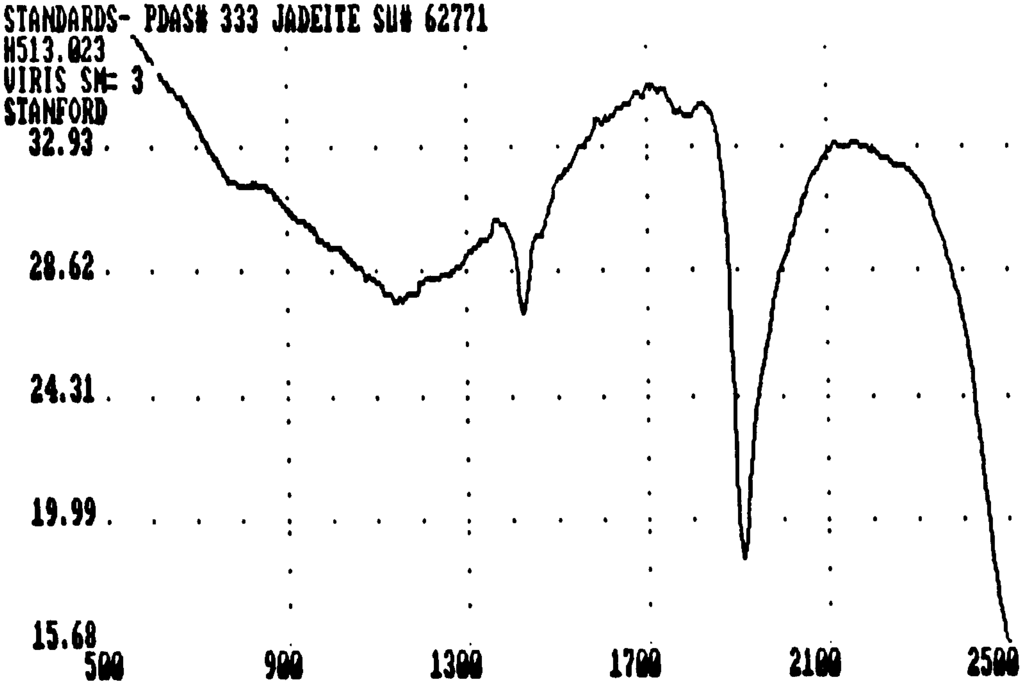


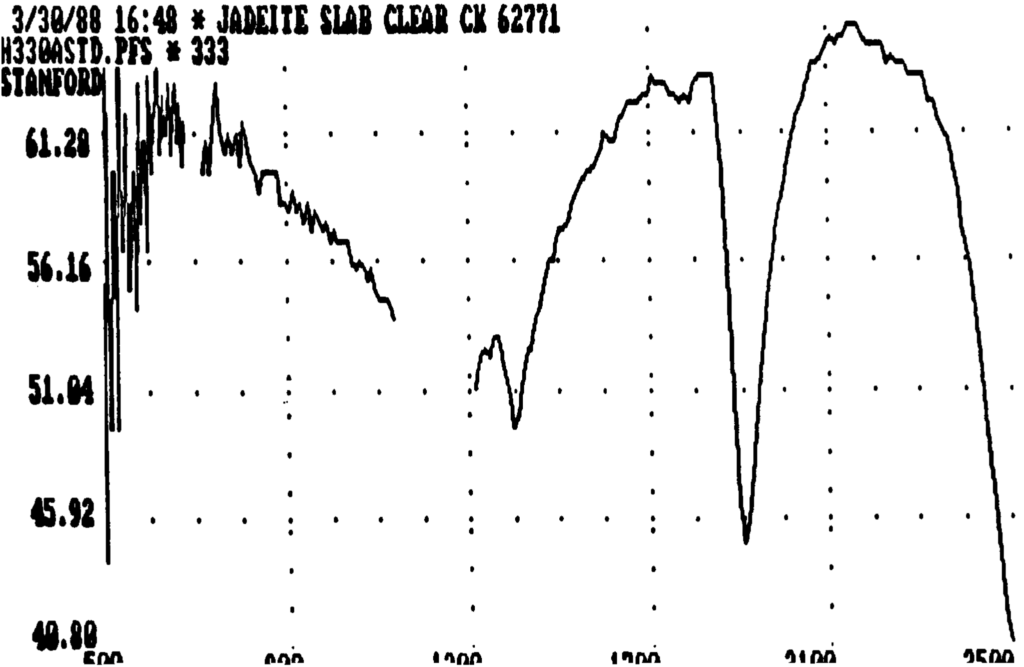
3/30/88 16:46 * JADEITE CLEAR CK 5558
H330ASTD.PFS * 330
STANFORD



Nov 19 21:51 Jadeite SU# 5558 Clear Crk San Benito Calif $
GB19FAXA.026
SFX440 SM= 1
STANFORD







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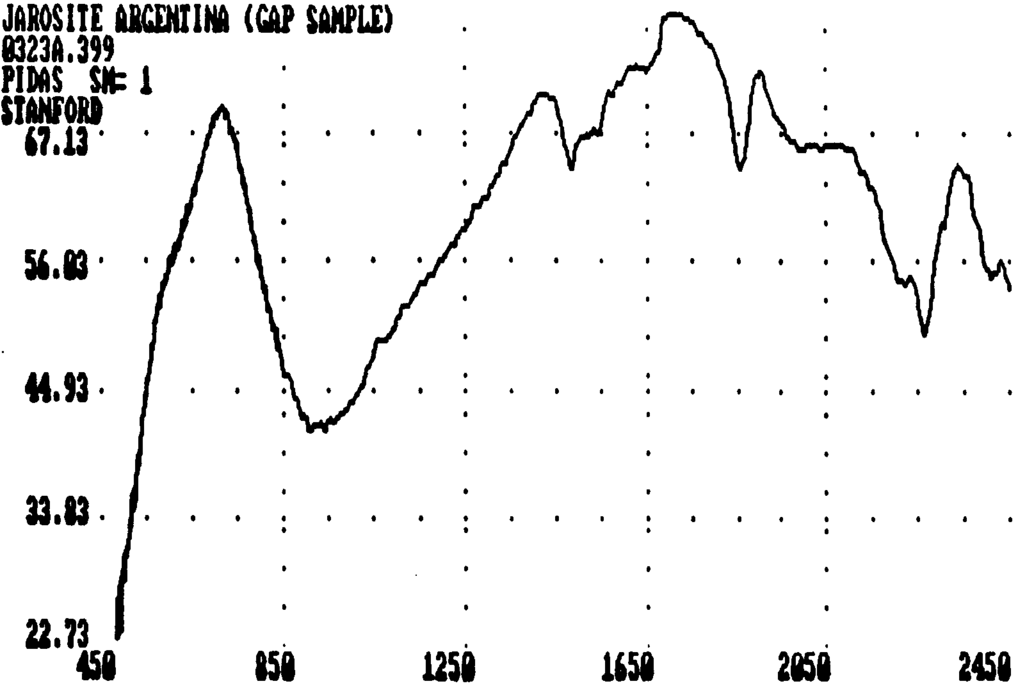
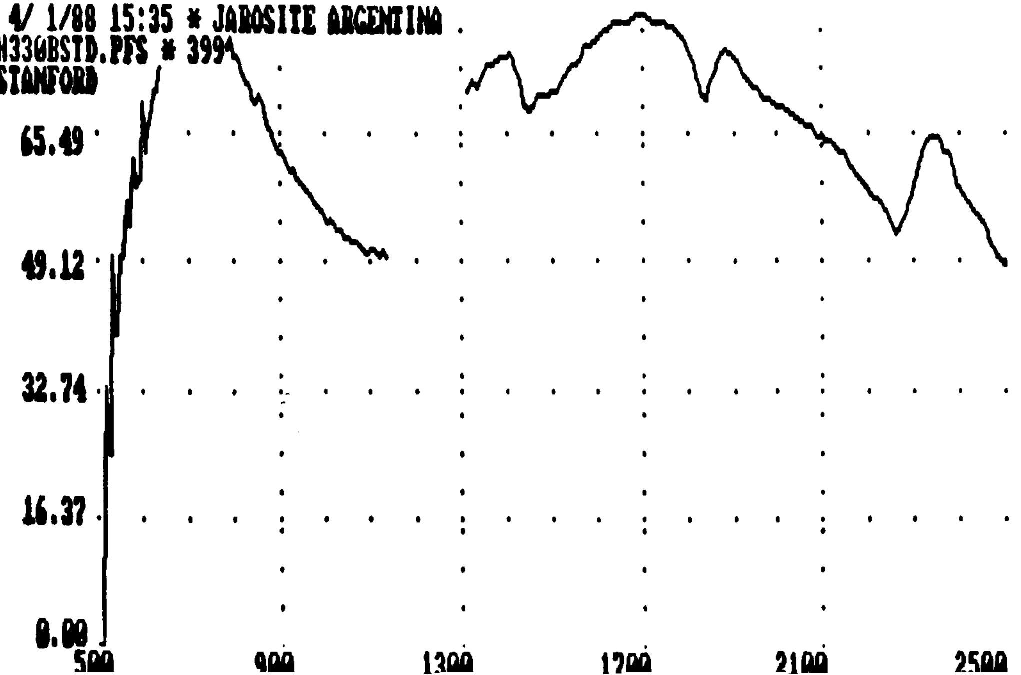
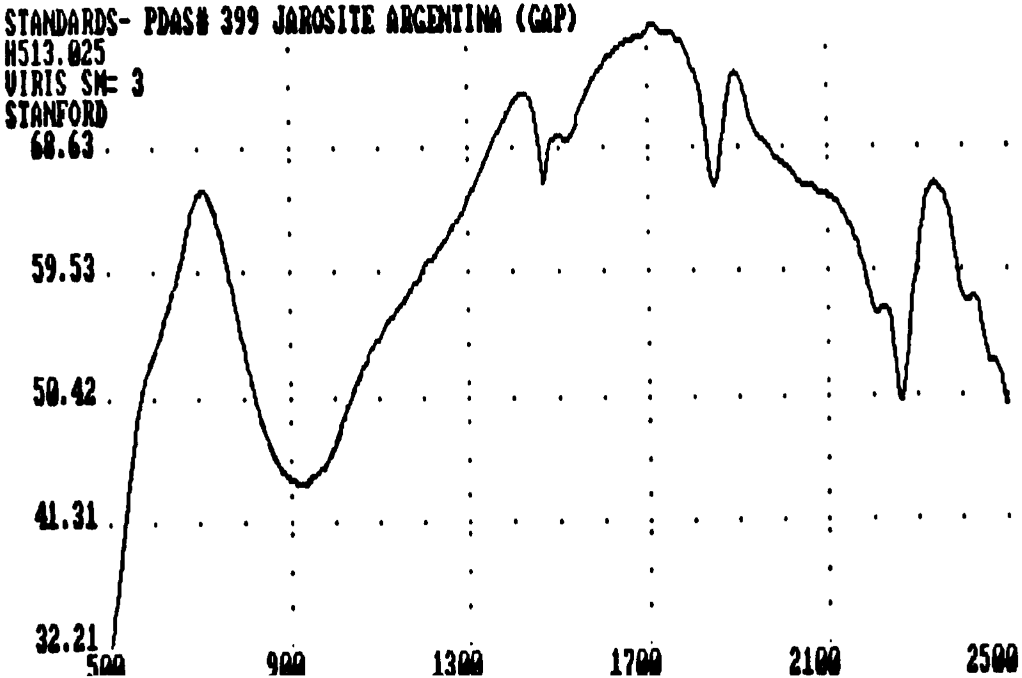
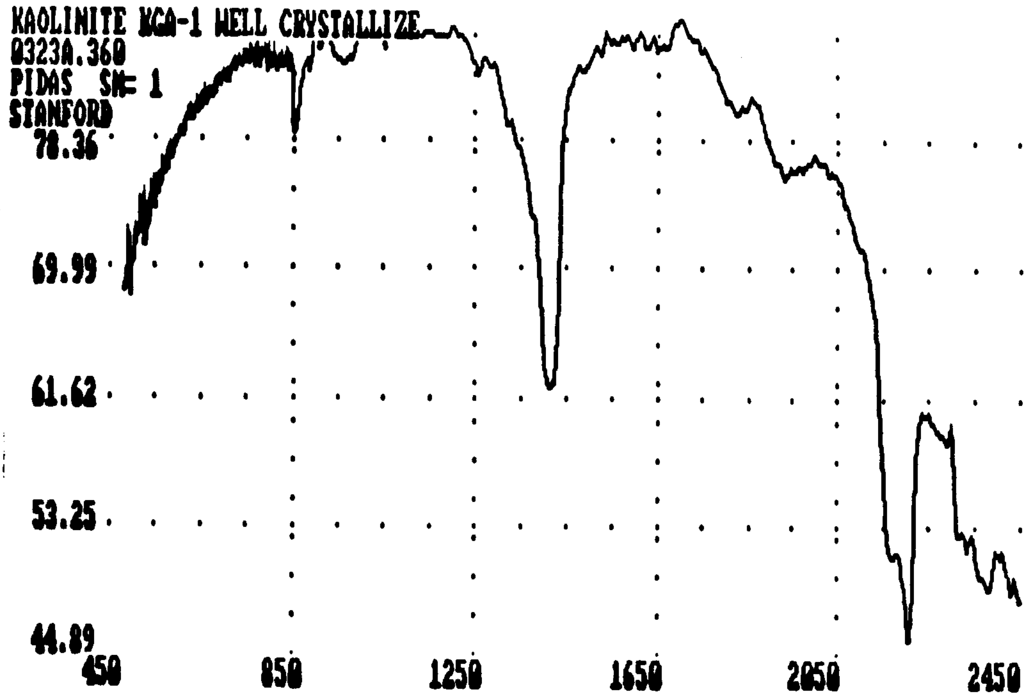
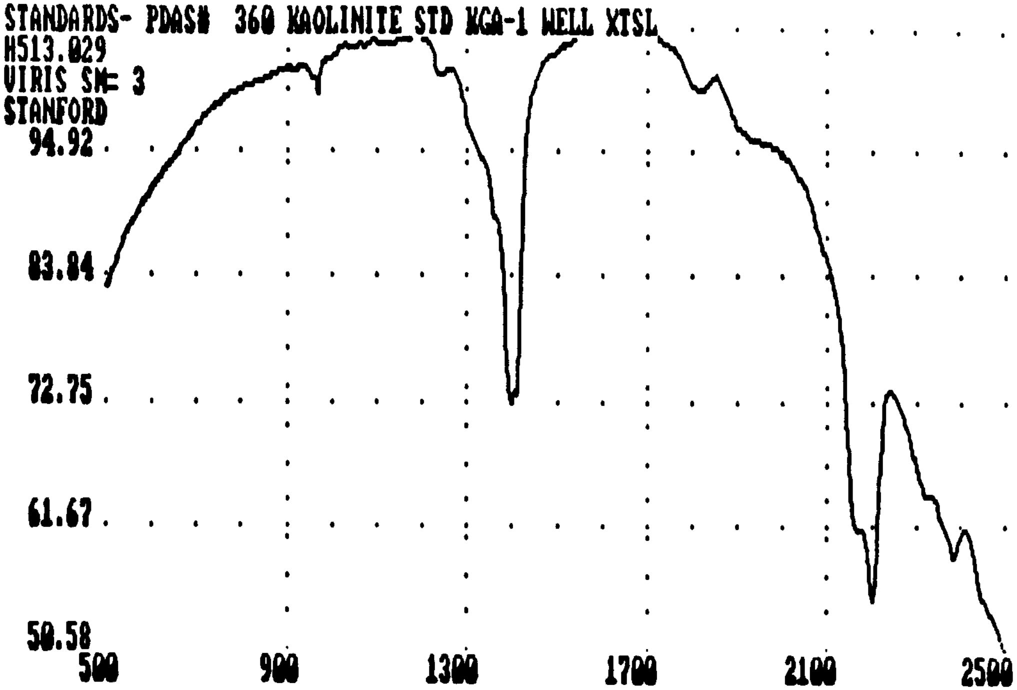
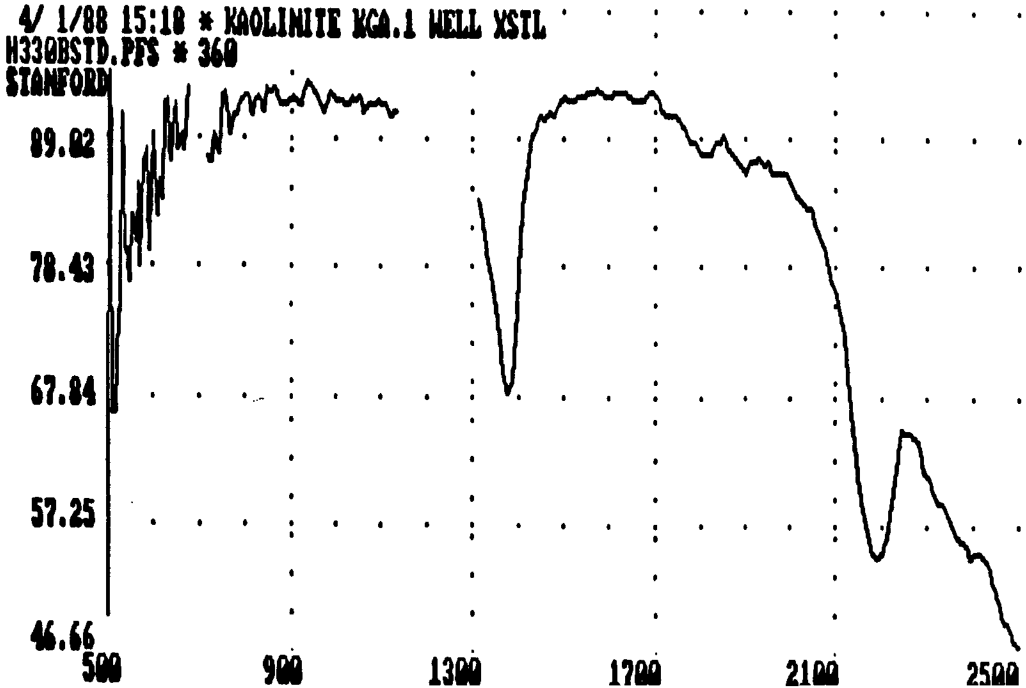

JAROSITE ARGENTINA (GAP SAMPLE)
0323A.399
PIDAS SM= 1
STANFORD
67.13
56.03
44.93
33.83
22.73
450
850
1250
1650
2050
2450

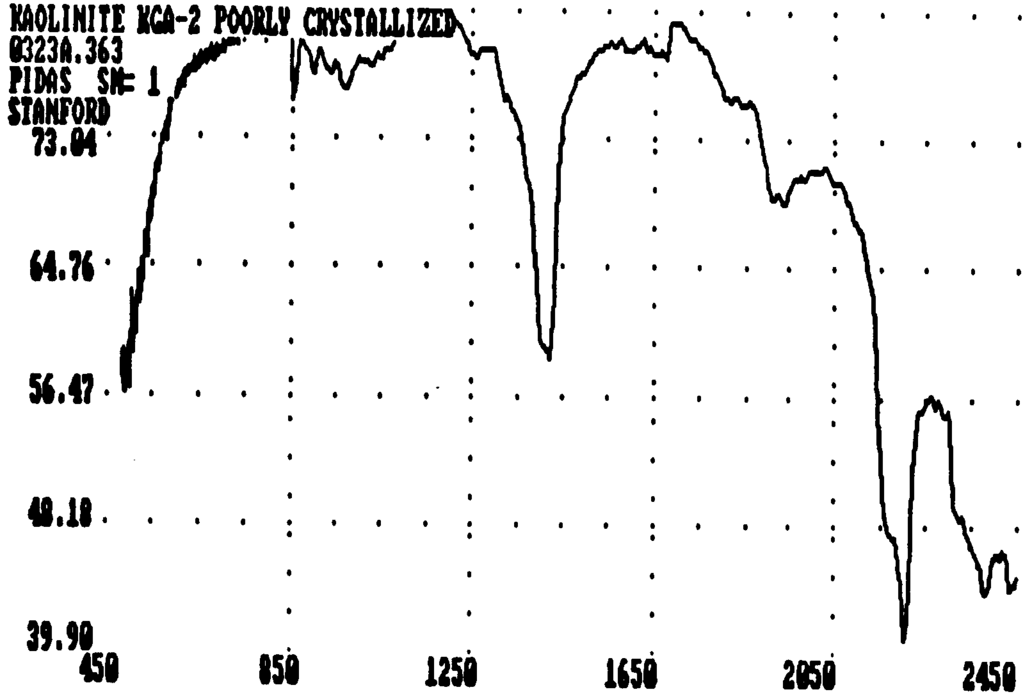

4/ 1/88 15:35 * JAROSITE ARGENTINA
H330BSTD.PFS * 399
STANFORD
65.49
49.12
32.74
16.37
0.00
500
900
1300
1700
2100
2500

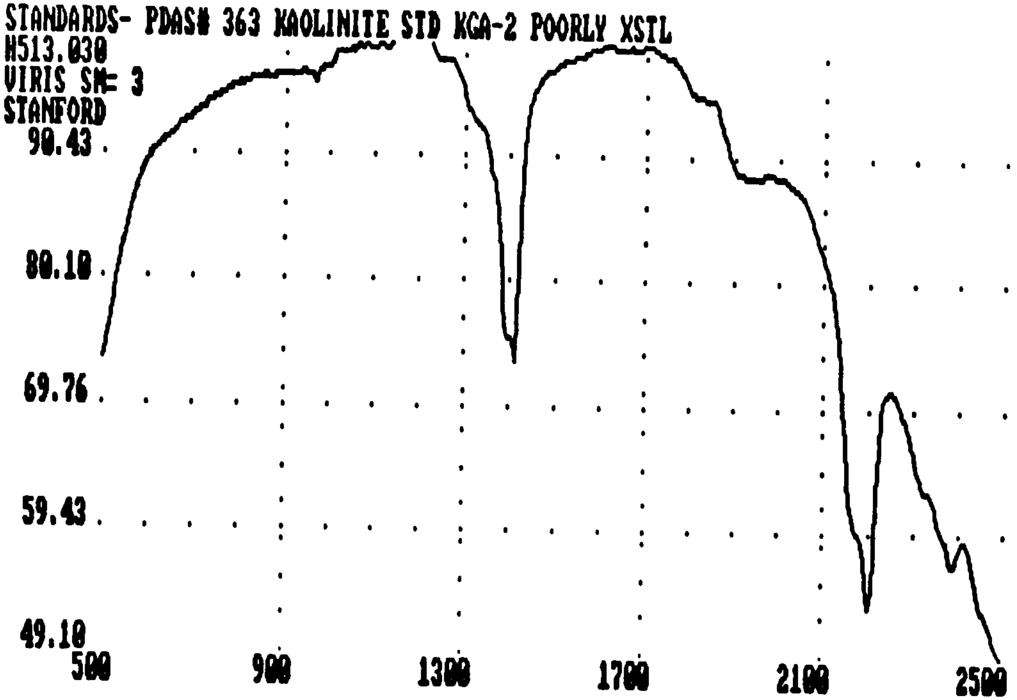

STANDARDS- PDAS# 399 JAROSITE ARGENTINA (GAP)
H513.025
VIRIS SM= 3
STANFORD
68.63
59.53
50.42
41.31
32.21
500
900
1300
1700
2100
2500

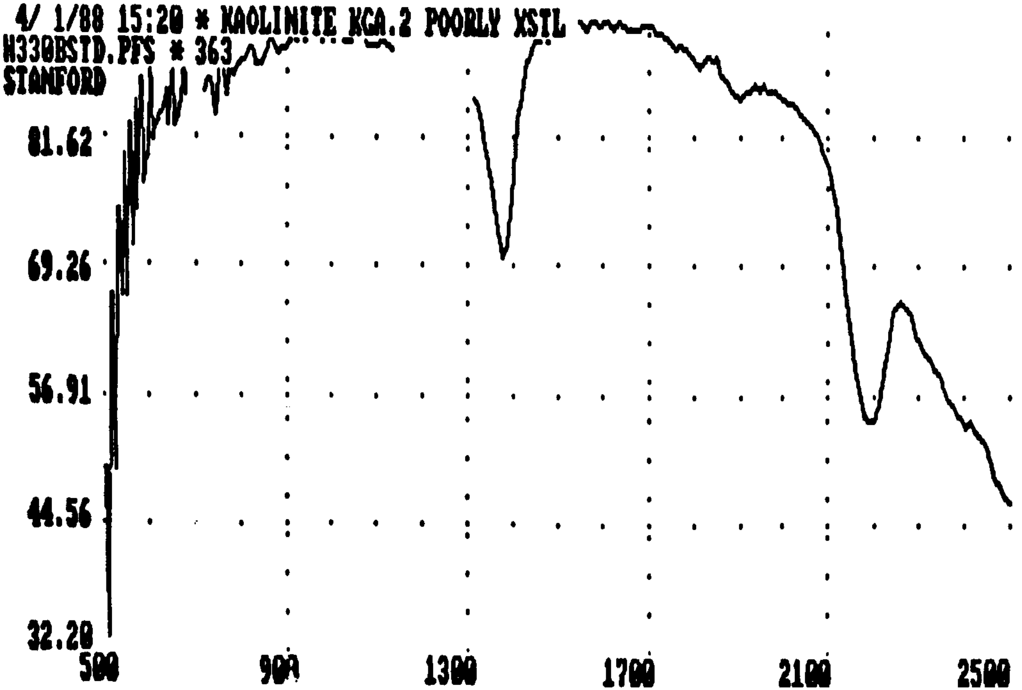

KAOLINITE KGA-1 WELL CRYSTALLIZE
0323A.360
PIDAS SN= 1
STANFORD
78.36
69.99
61.62
53.25
44.89
450
850
1250
1650
2050
2450


STANDARDS- PDAS# 360 KAOLINITE STD KGA-1 WELL XTSL
H513.029
VIRIS SN= 3
STANFORD
94.92
83.84
72.75
61.67
50.58
500
900
1300
1700
2100
2500


4/ 1/88 15:10 * KAOLINITE KGA.1 WELL XSTL
H330BSTD.PFS * 360
STANFORD
89.02
78.43
67.84
57.25
46.66
500
900
1300
1700
2100
2500


KAOLINITE KGA-2 POORLY CRYSTALLIZED
0323A.363
PIDAS SM= 1
STANFORD
73.04
64.76
56.47
48.18
39.90
450
850
1250
1650
2050
2450


STANDARDS- PDAS# 363 KAOLINITE STD KGA-2 POORLY XSTL
H513.030
VIRIS SM= 3
STANFORD
90.43
80.10
69.76
59.43
49.10
500
900
1300
1700
2100
2500


4/ 1/88 15:20 * KAOLINITE KGA.2 POORLY XSTL
H330BSTD.PFS * 363
STANFORD
81.62
69.26
56.91
44.56
32.20
500
900
1300
1700
2100
2500

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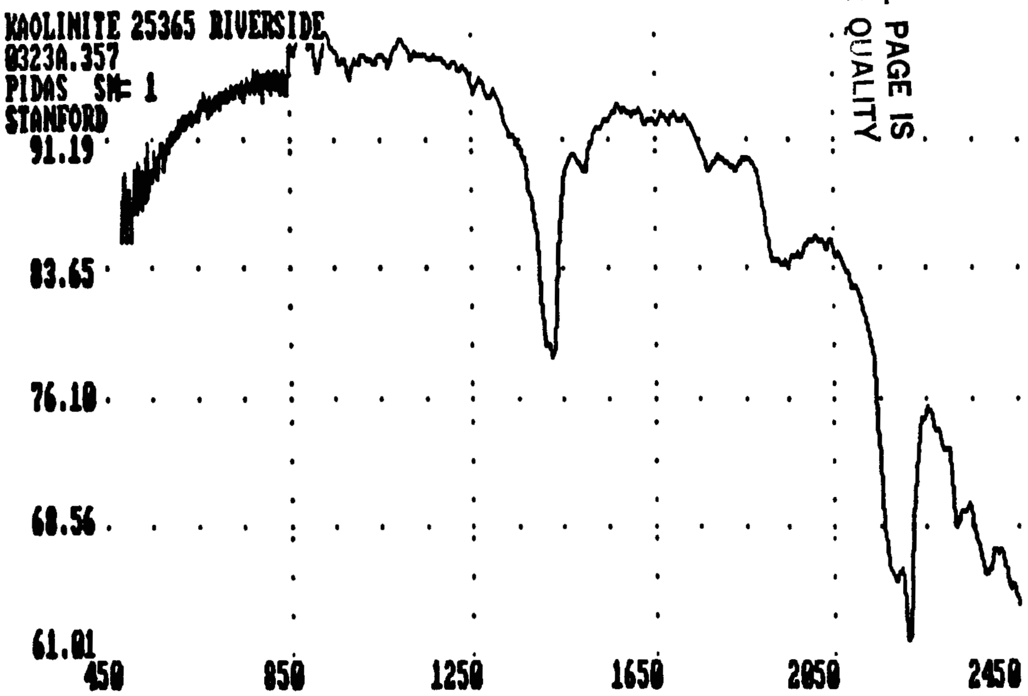
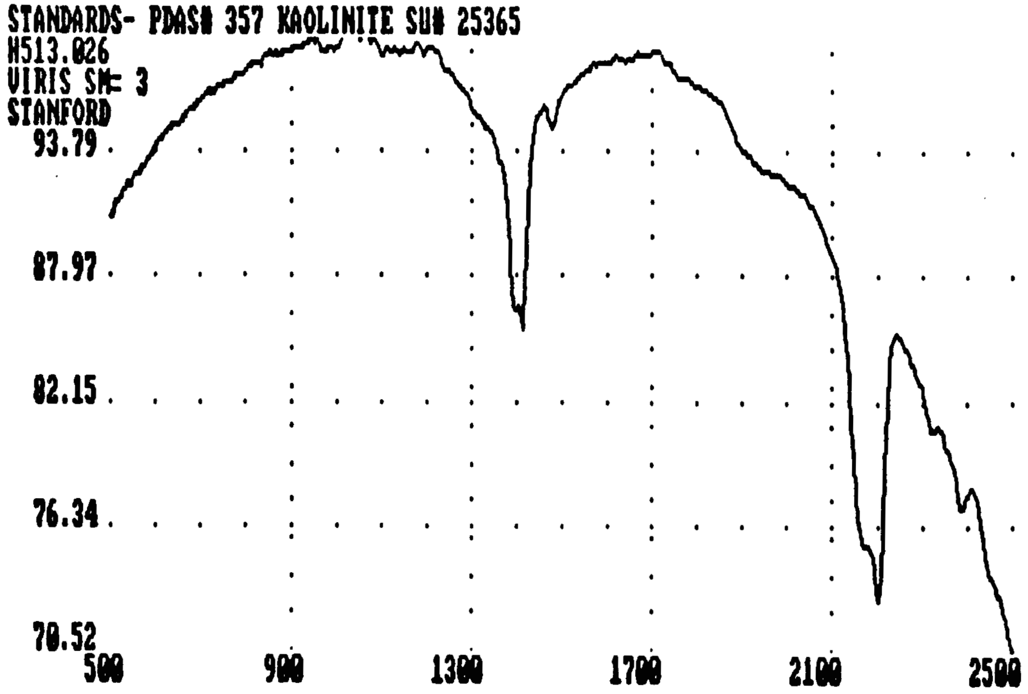
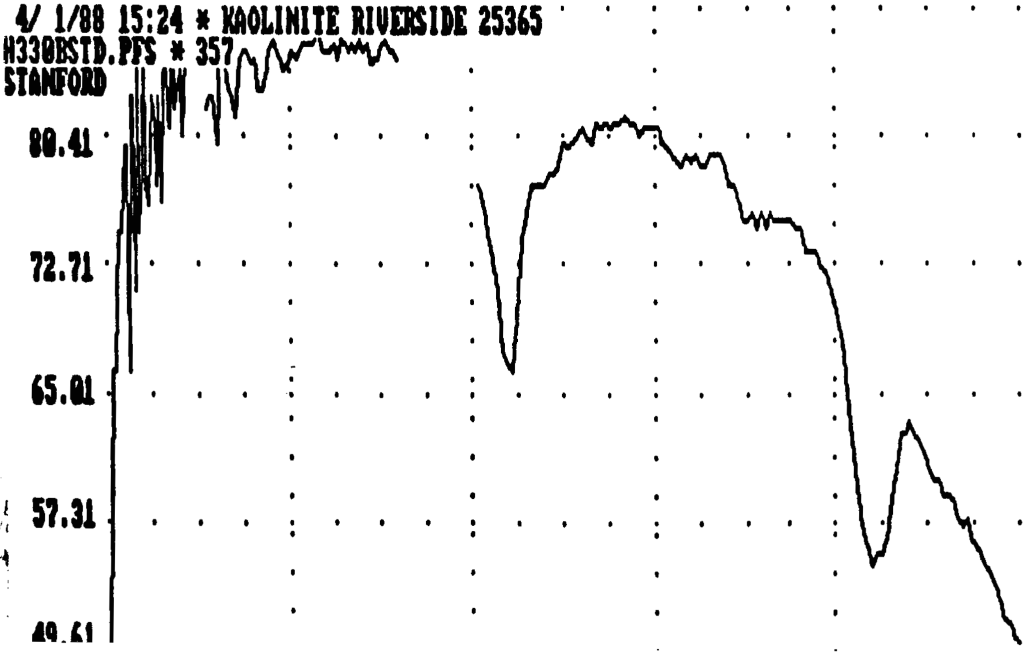
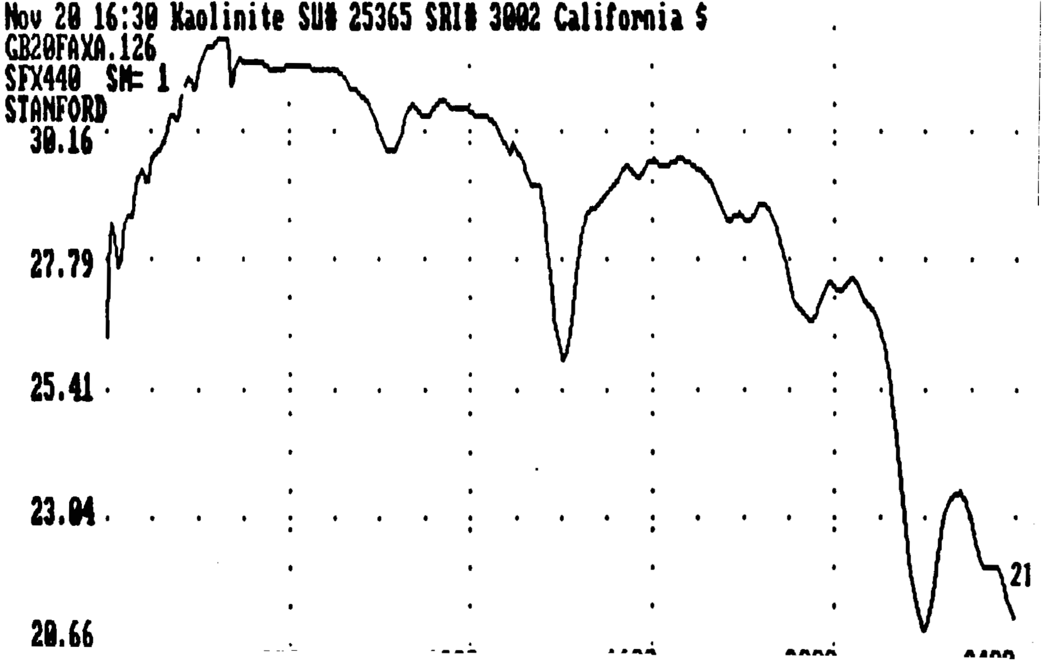
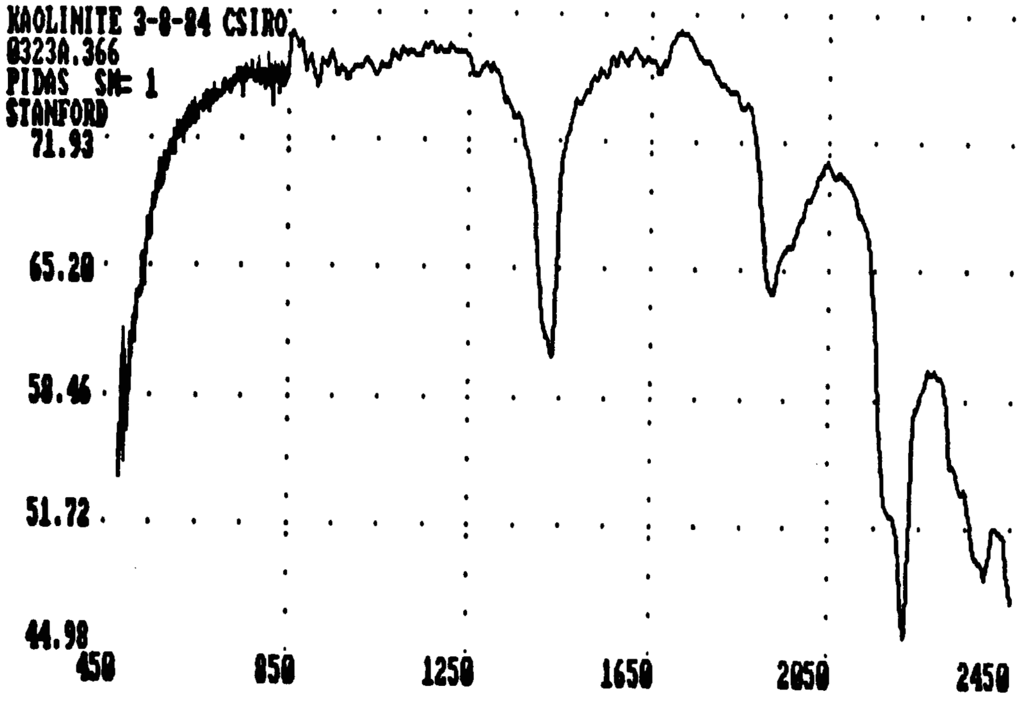
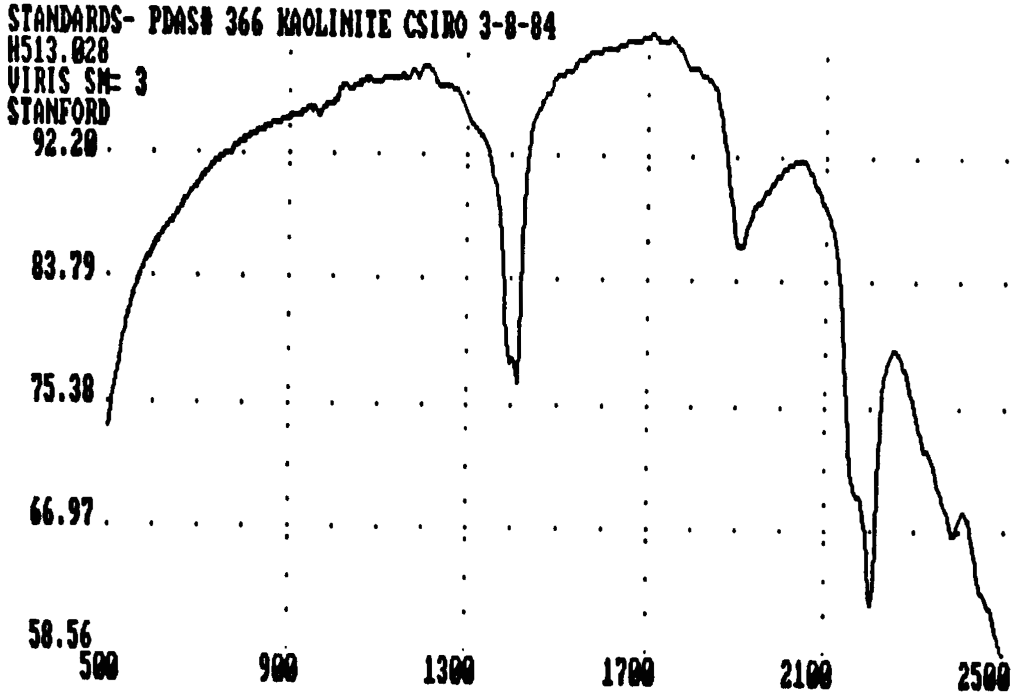


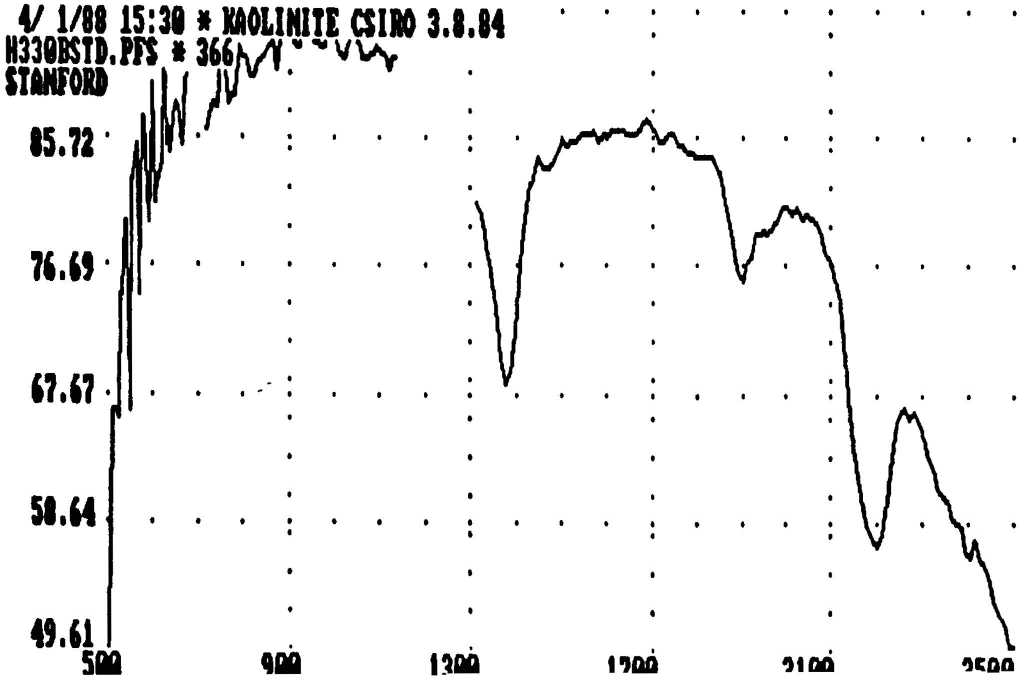


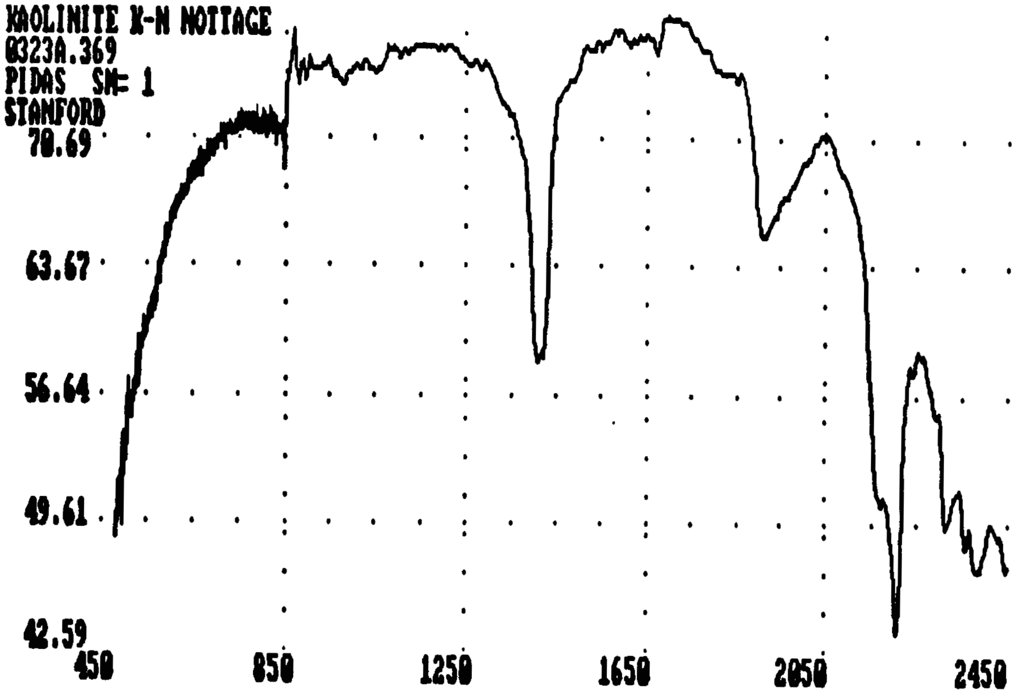


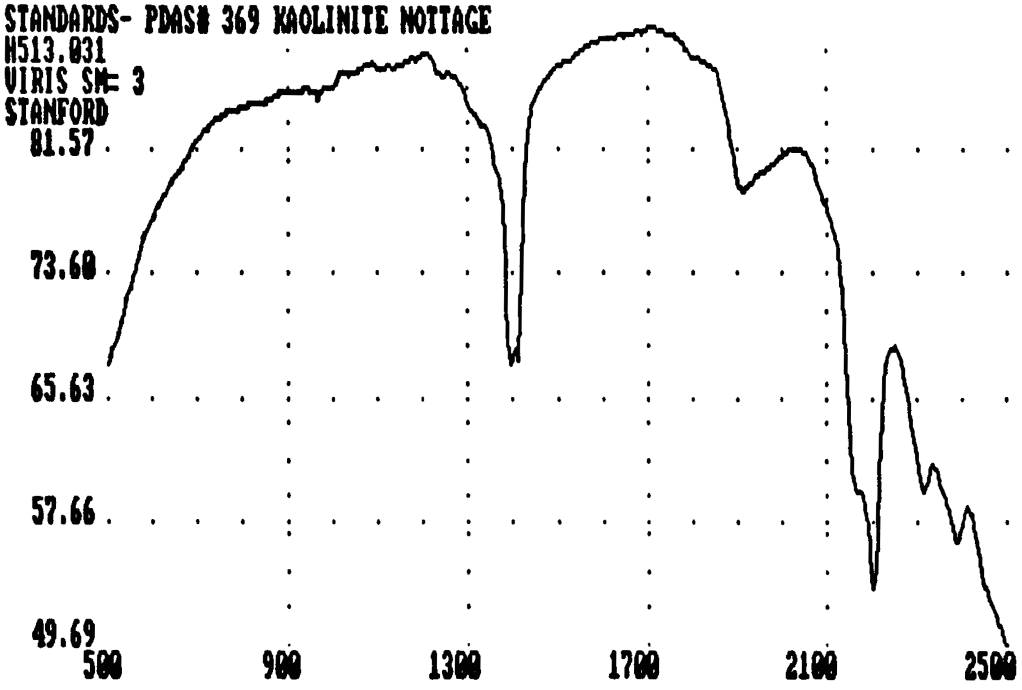


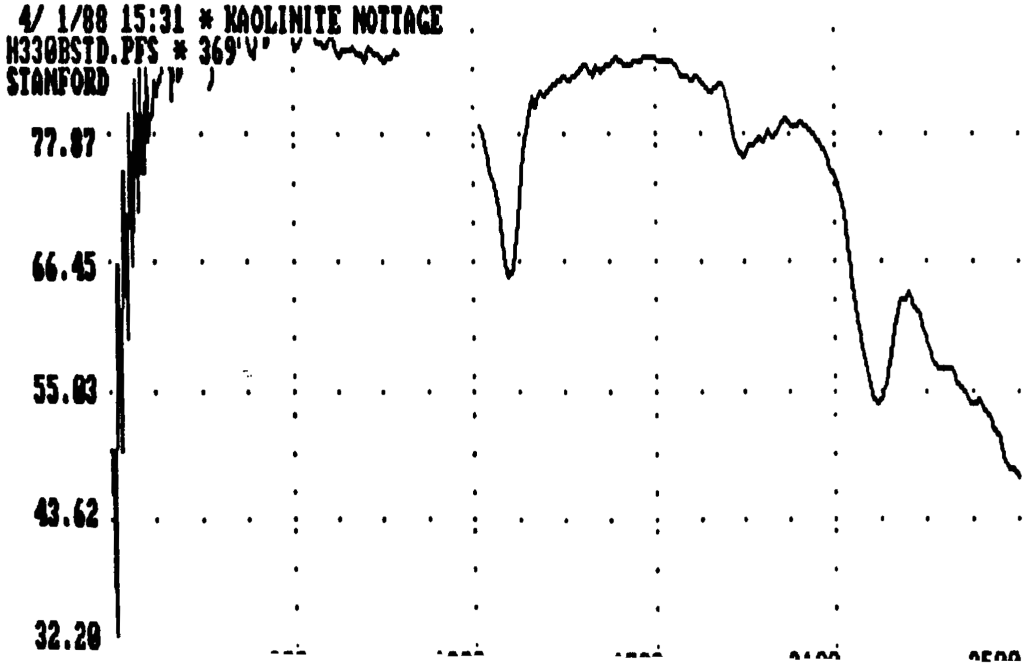

KAOLINITE 3-8-84 CSIRO
0323A.366
PIDAS SM= 1
STANFORD
71.93
65.20
58.46
51.72
44.98
450
850
1250
1650
2050
2450

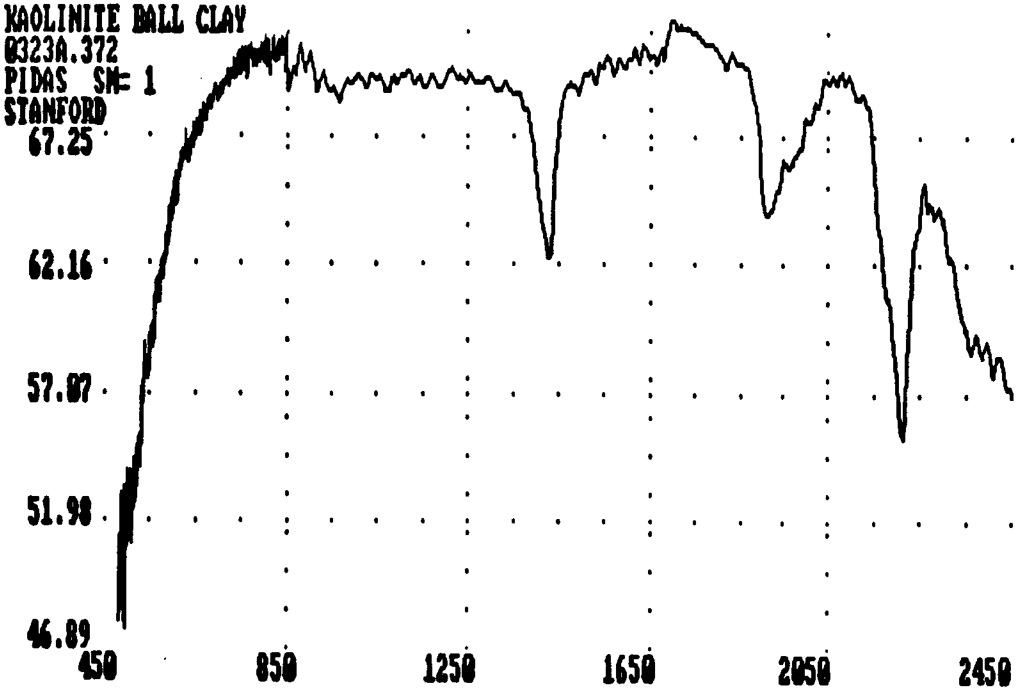

STANDARDS- PDAS# 366 KAOLINITE CSIRO 3-8-84
H513.028
VIRIS SM= 3
STANFORD
92.20
83.79
75.38
66.97
58.56
500
900
1300
1700
2100
2500

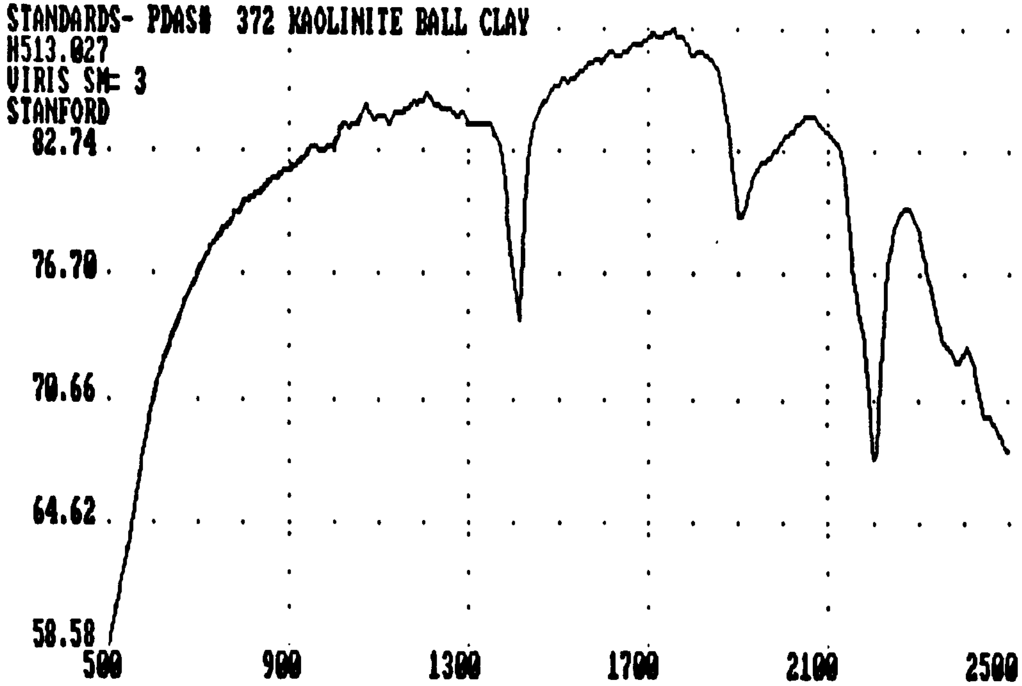

4/ 1/88 15:30 * KAOLINITE CSIRO 3.8.84
H330BSTD.PFS * 366
STANFORD
85.72
76.69
67.67
58.64
49.61
500
900
1300
1700
2100
2500

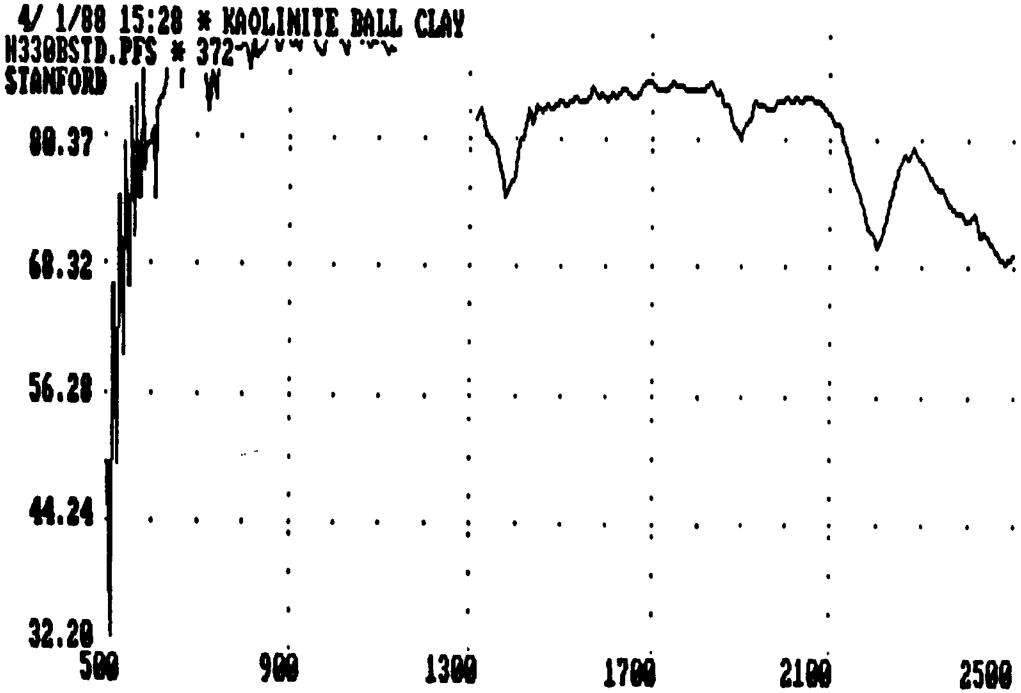

KAOLINITE K-N NOTTAGE
0323A.369
PIDAS SM= 1
STANFORD
70.69
63.67
56.64
49.61
42.59
450
850
1250
1650
2050
2450

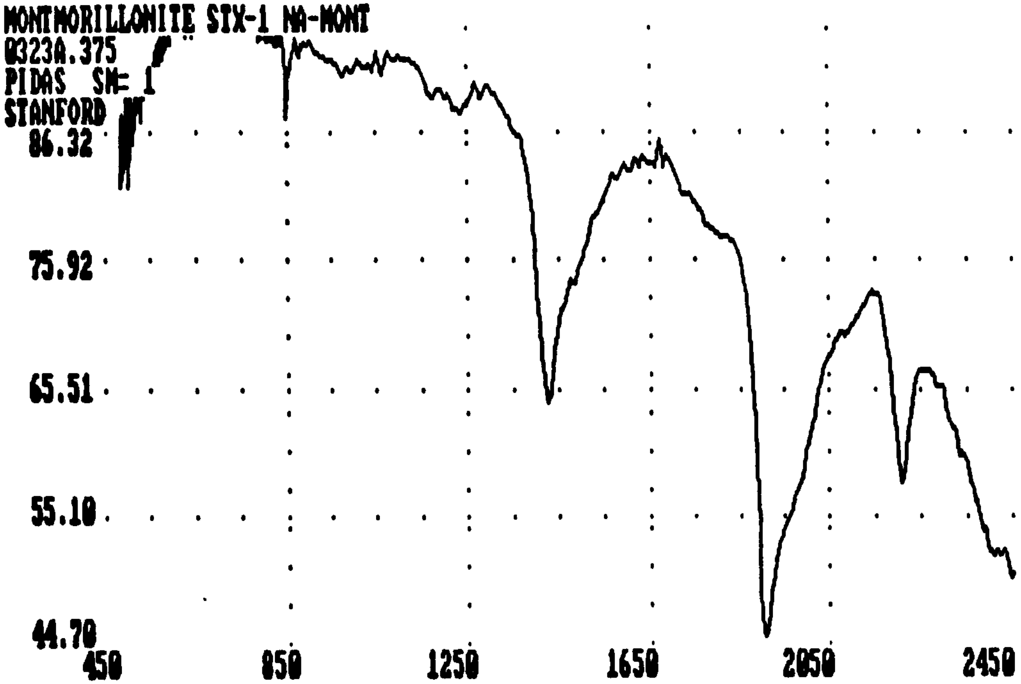

STANDARDS- PDAS# 369 KAOLINITE NOTTAGE
H513.031
VIRIS SM= 3
STANFORD
81.57
73.60
65.63
57.66
49.69
500
900
1300
1700
2100
2500

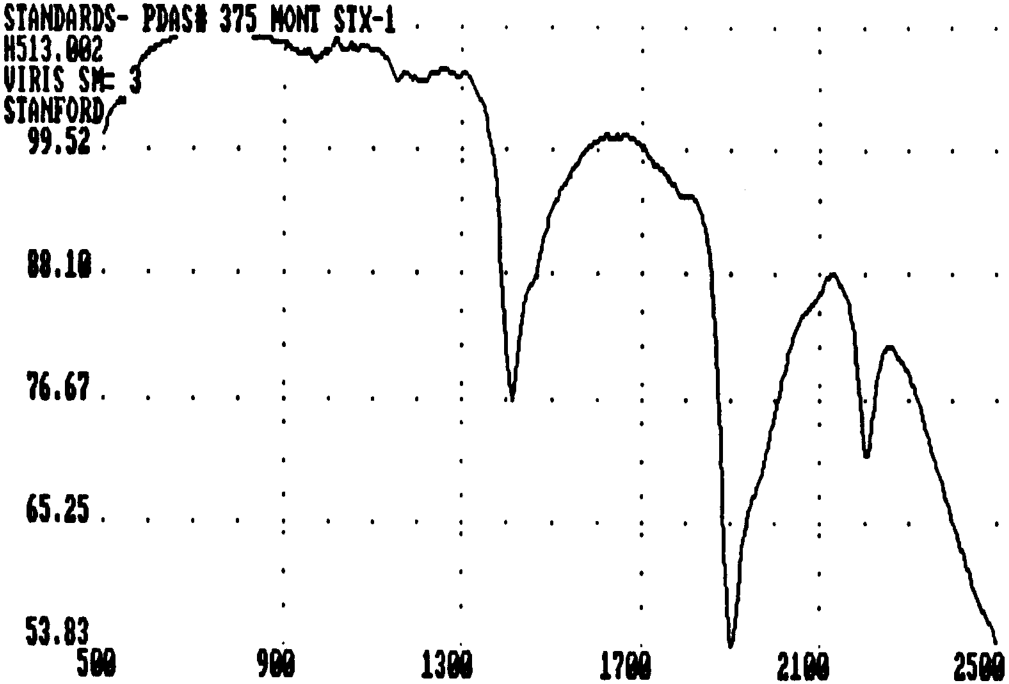

4/ 1/88 15:31 * KAOLINITE NOTTAGE
H330BSTD.PFS * 369
STANFORD
77.87
66.45
55.03
43.62
32.20

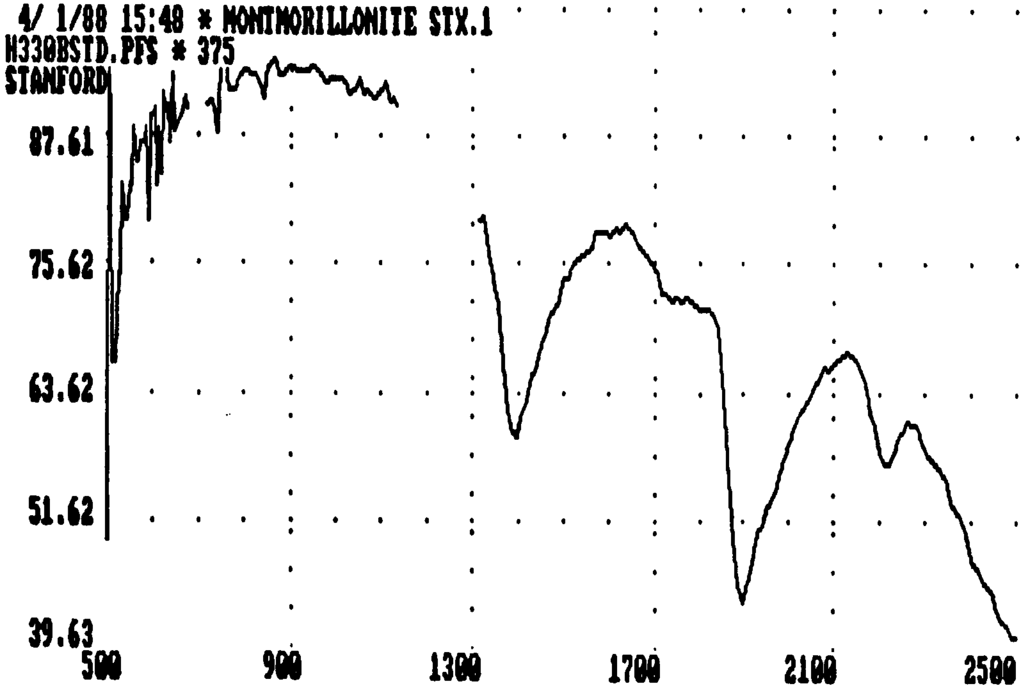

KAOLINITE BALL CLAY
0323A.372
PIDAS SM= 1
STANFORD
67.25
62.16
57.07
51.98
46.89
450
850
1250
1650
2050
2450

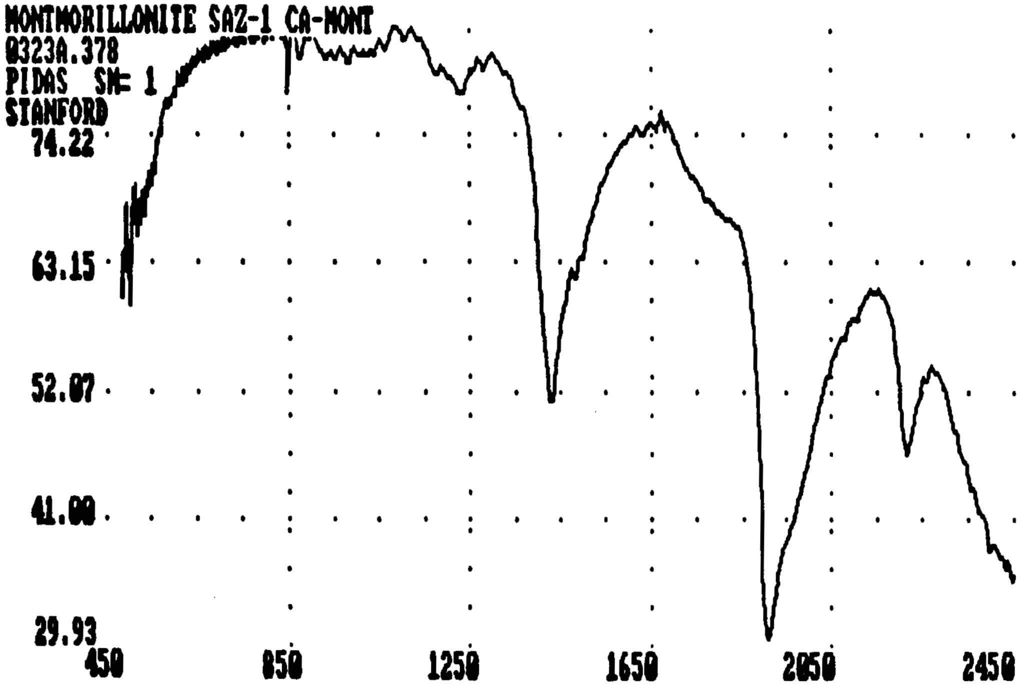

STANDARDS- PDAS# 372 KAOLINITE BALL CLAY
H513.027
VIRIS SM= 3
STANFORD
82.74
76.70
70.66
64.62
58.58
500
900
1300
1700
2100
2500

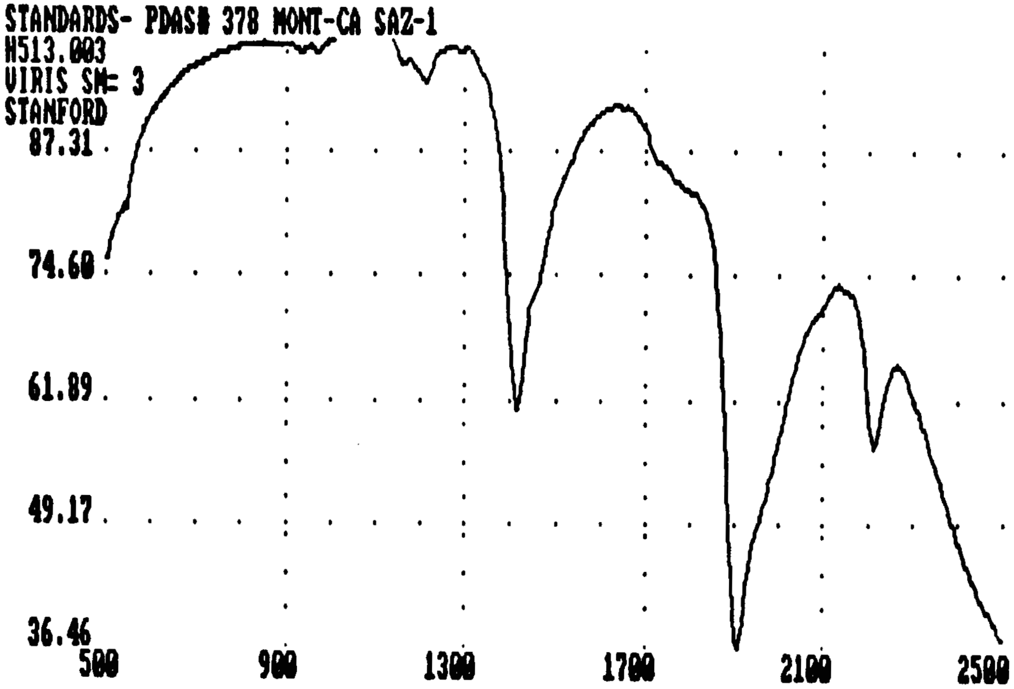

4/ 1/88 15:28 * KAOLINITE BALL CLAY
H330BSTD.PFS * 372
STANFORD
80.37
68.32
56.28
44.24
32.20
500
900
1300
1700
2100
2500

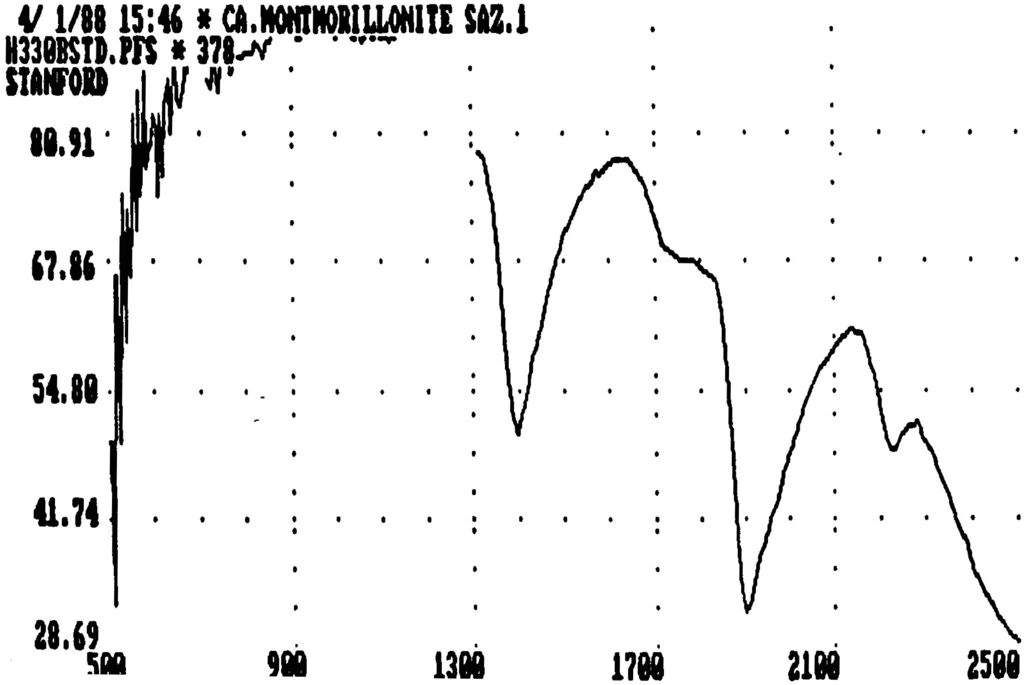

MONTMORILLONITE STX-1 NA-MONT
0323A.375
PIDAS SM= 1
STANFORD
86.32
75.92
65.51
55.10
44.70
450
850
1250
1650
2050
2450

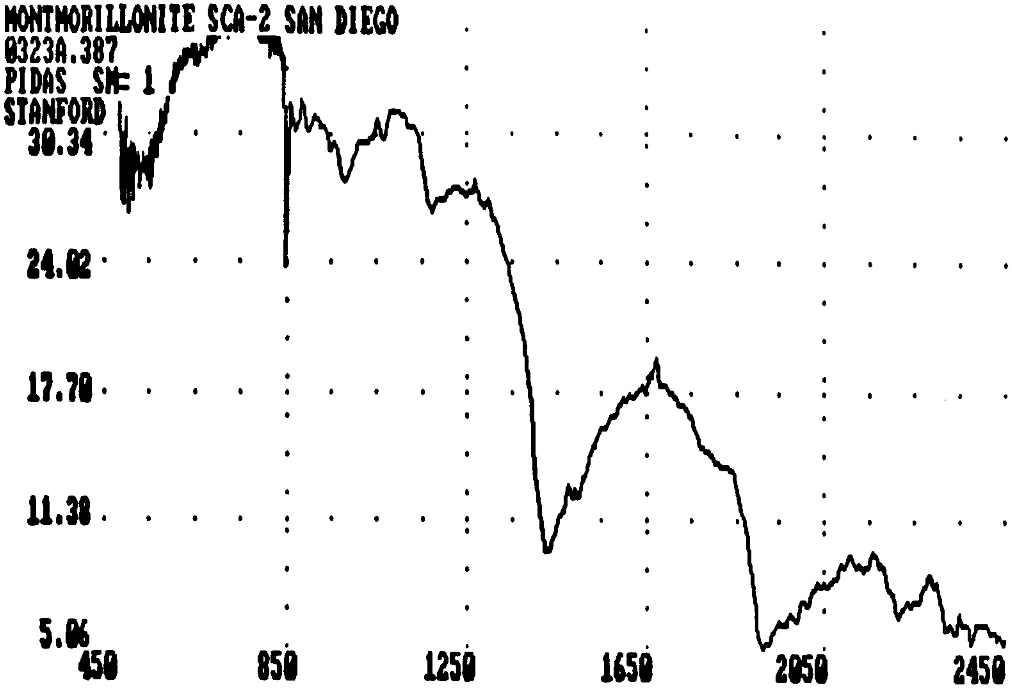

STANDARDS- PDAS# 375 MONT STX-1
H513.002
VIRIS SM= 3
STANFORD
99.52
88.10
76.67
65.25
53.83
500
900
1300
1700
2100
2500

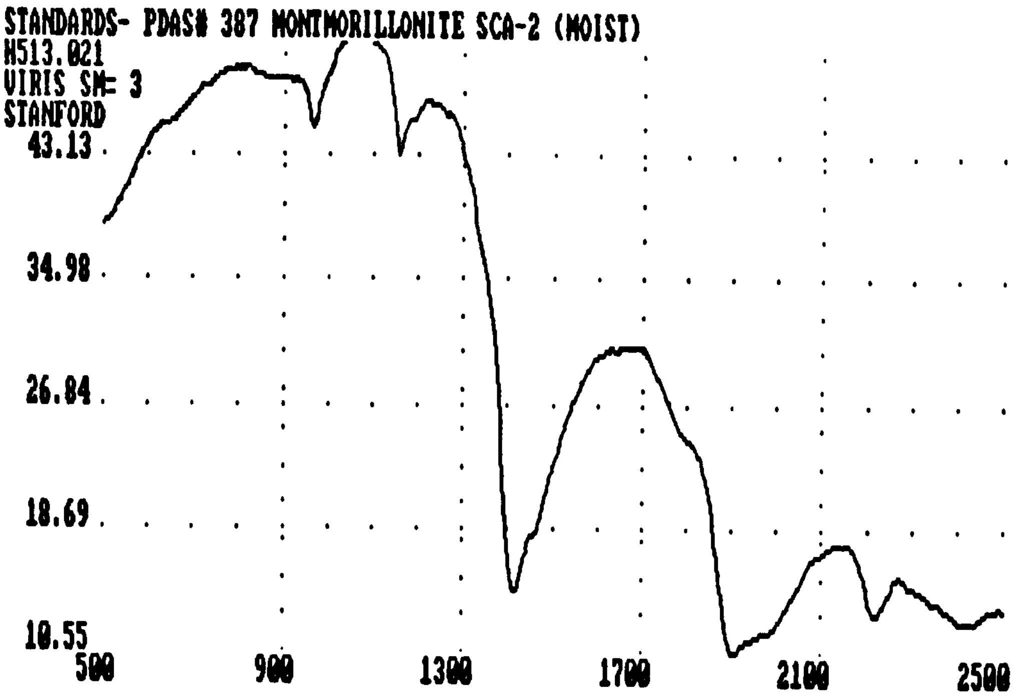

4/ 1/88 15:48 * MONTMORILLONITE STX.1
H330BSTD.PFS * 375
STANFORD
87.61
75.62
63.62
51.62
39.63
500
900
1300
1700
2100
2500

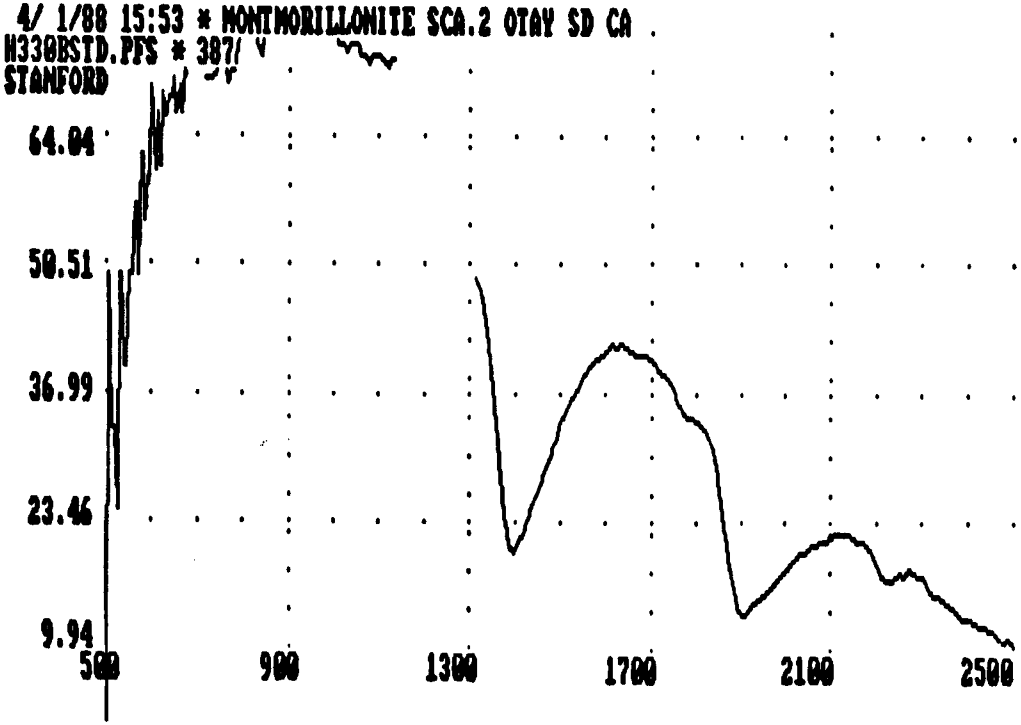

MONTMORILLONITE SAZ-1 CA-MONT
0323A.378
PIDAS SM= 1
STANFORD
74.22
63.15
52.07
41.00
29.93
450
850
1250
1650
2050
2450

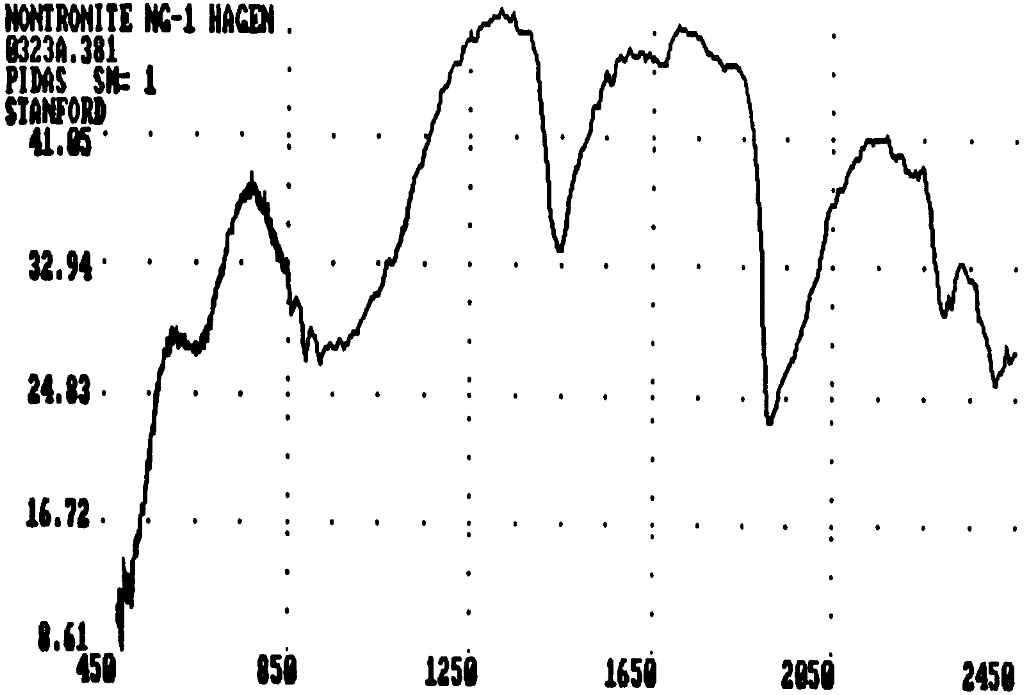

STANDARDS- PDAS# 378 MONT-CA SAZ-1
H513.003
VIRIS SM= 3
STANFORD
87.31
74.60
61.89
49.17
36.46
500
900
1300
1700
2100
2500

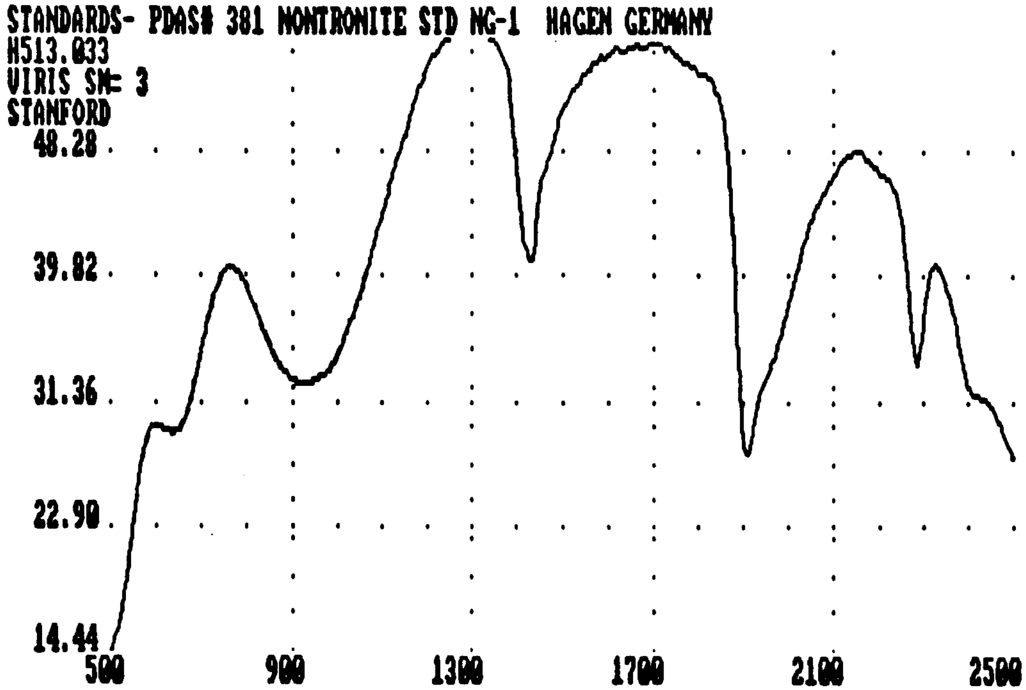

4/ 1/88 15:46 * CA.MONTMORILLONITE SAZ.1
H330BSTD.PFS * 378
STANFORD
80.91
67.86
54.80
41.74
28.69
500
900
1300
1700
2100
2500

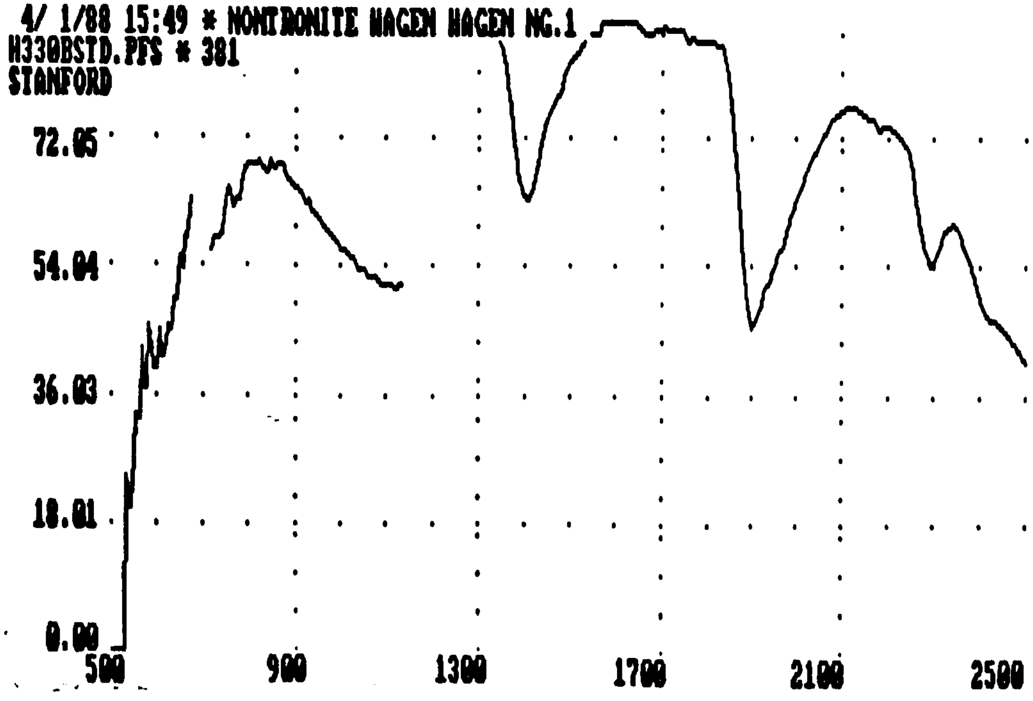

MONTMORILLONITE SCA-2 SAN DIEGO
0323A.387
PIDAS SM= 1
STANFORD

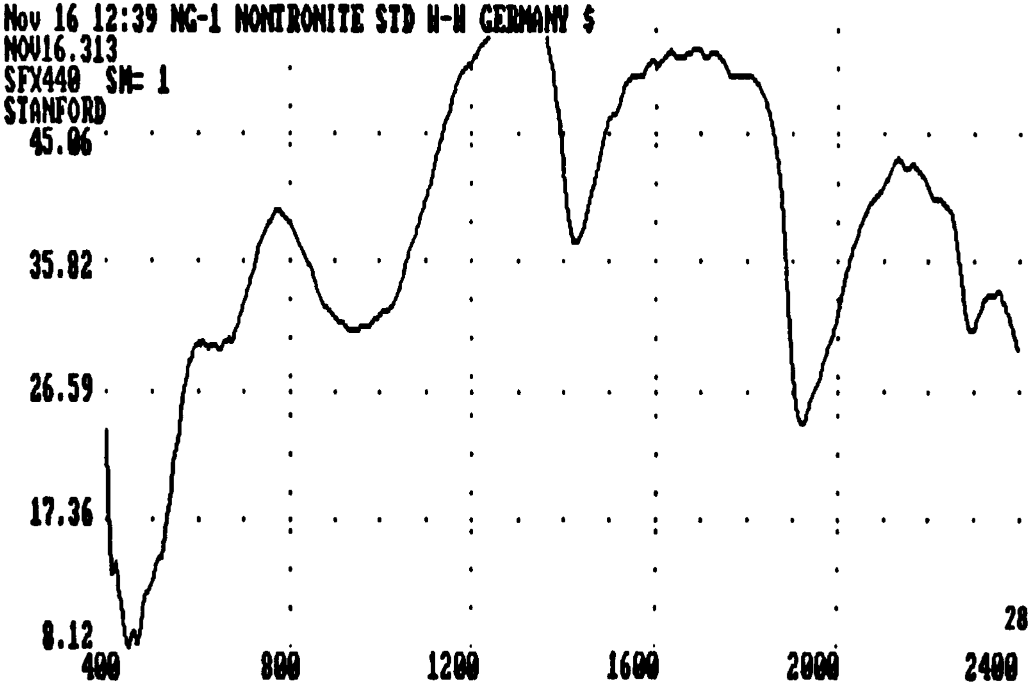

STANDARDS- PDAS# 387 MONTMORILLONITE SCA-2 (MOIST)
H513.021
VIRIS SM= 3
STANFORD


4/ 1/88 15:53 * MONTMORILLONITE SCA.2 OTAY SD CA
H330BSTD.PFS * 387/
STANFORD

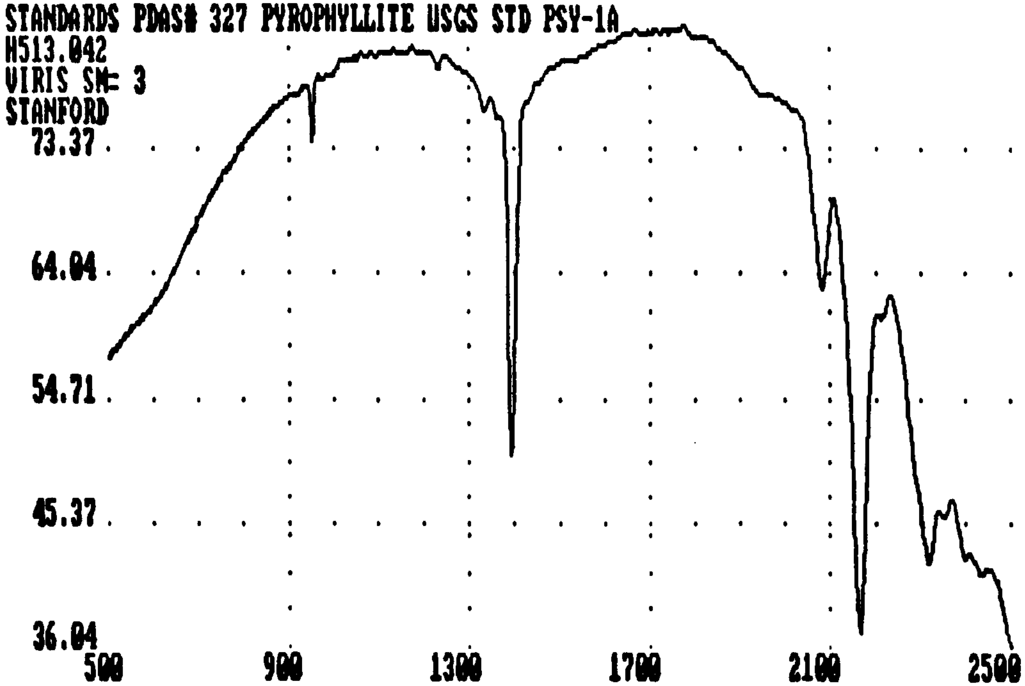

NONTRONITE NG-1 HAGEN
0323A.381
PIDAS SM= 1
STANFORD
41.05
32.94
24.83
16.72
8.61
450
850
1250
1650
2050
2450

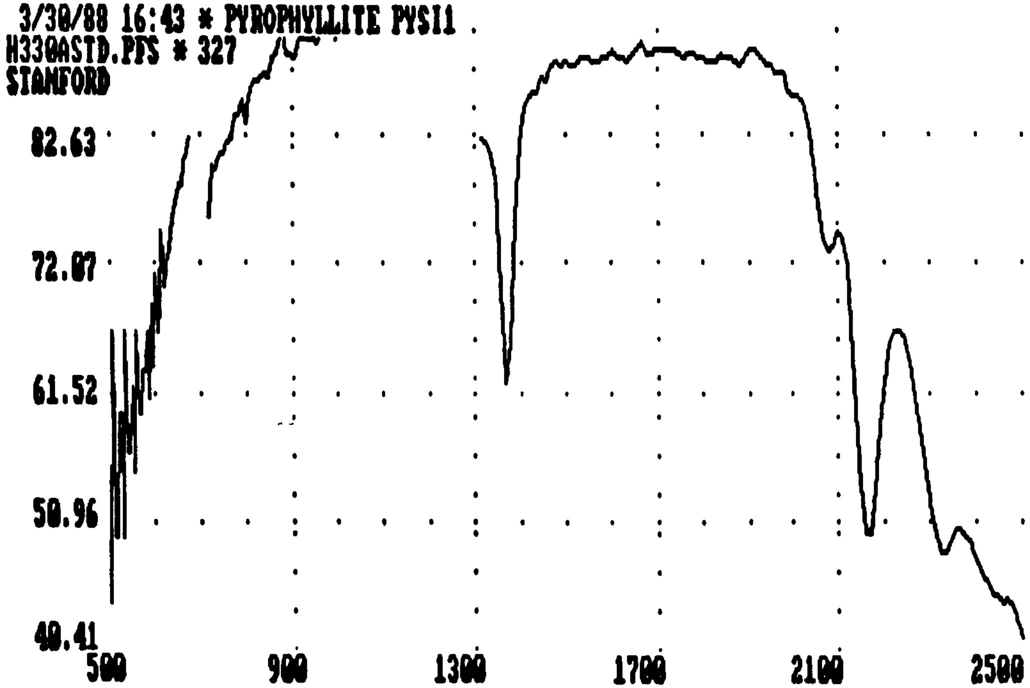

STANDARDS- PDAS# 381 NONTRONITE STD NG-1 HAGEN GERMANY
H513.033
VIRIS SM= 3
STANFORD
48.28
39.82
31.36
22.90
14.44
500
900
1300
1700
2100
2500

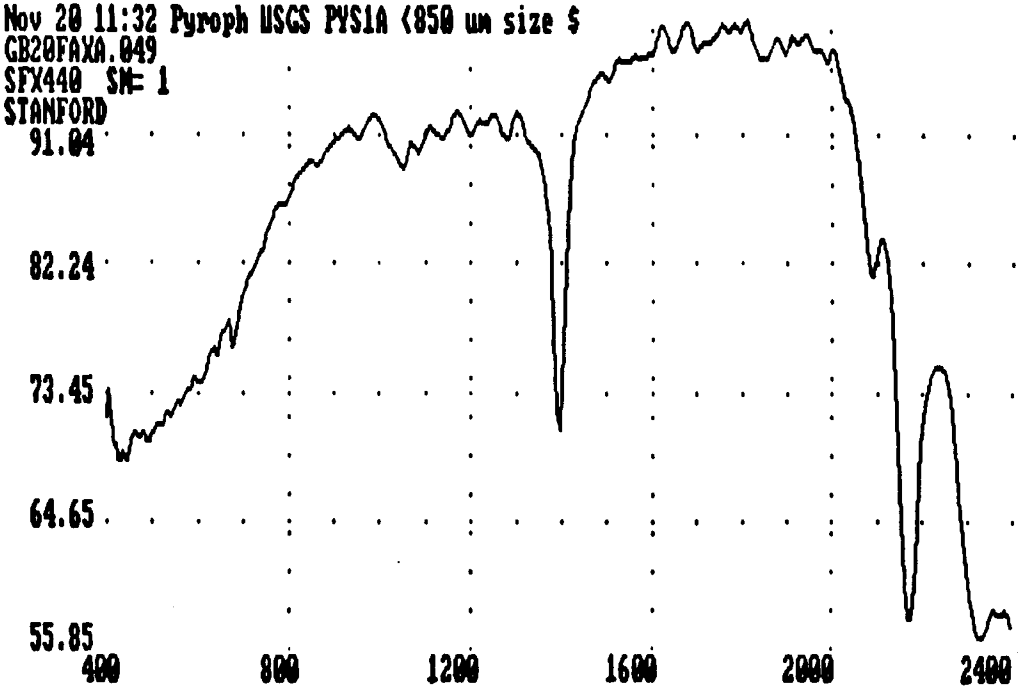

4/ 1/88 15:49 * NONTRONITE HAGEN HAGEN NG.1
H330BSTD.PFS * 381
STANFORD
72.05
54.04
36.03
18.01
0.00
500
900
1300
1700
2100
2500

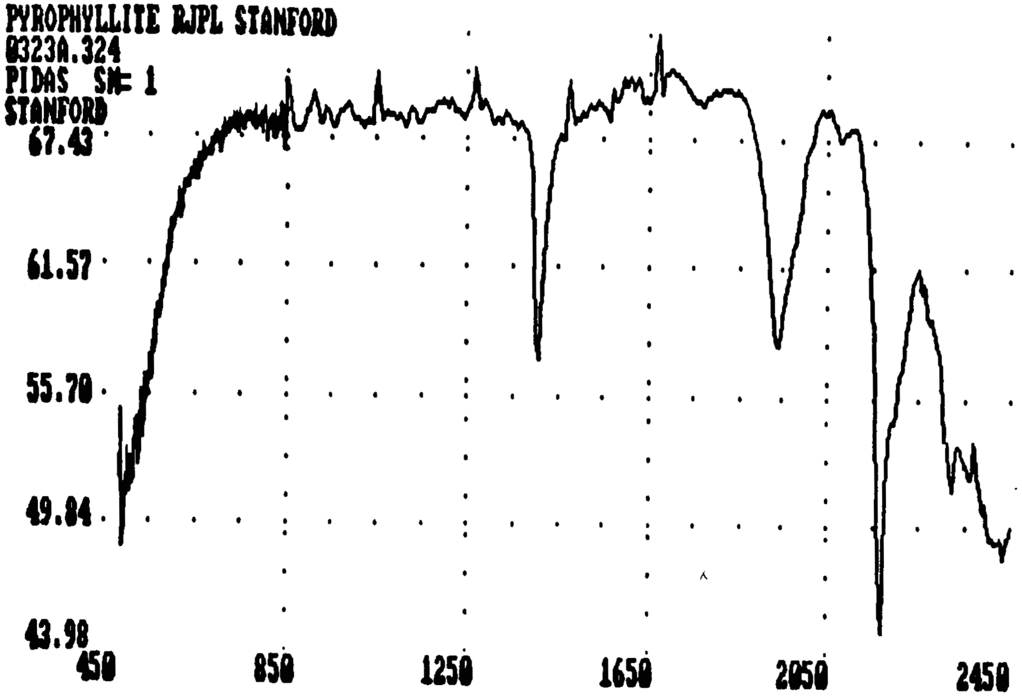

Nov 16 12:39 NG-1 NONTRONITE STD H-H GERMANY $
NOV16.313
SFX440 SM= 1
STANFORD
45.06
35.82
26.59
17.36
8.12
400
800
1200
1600
2000
2400

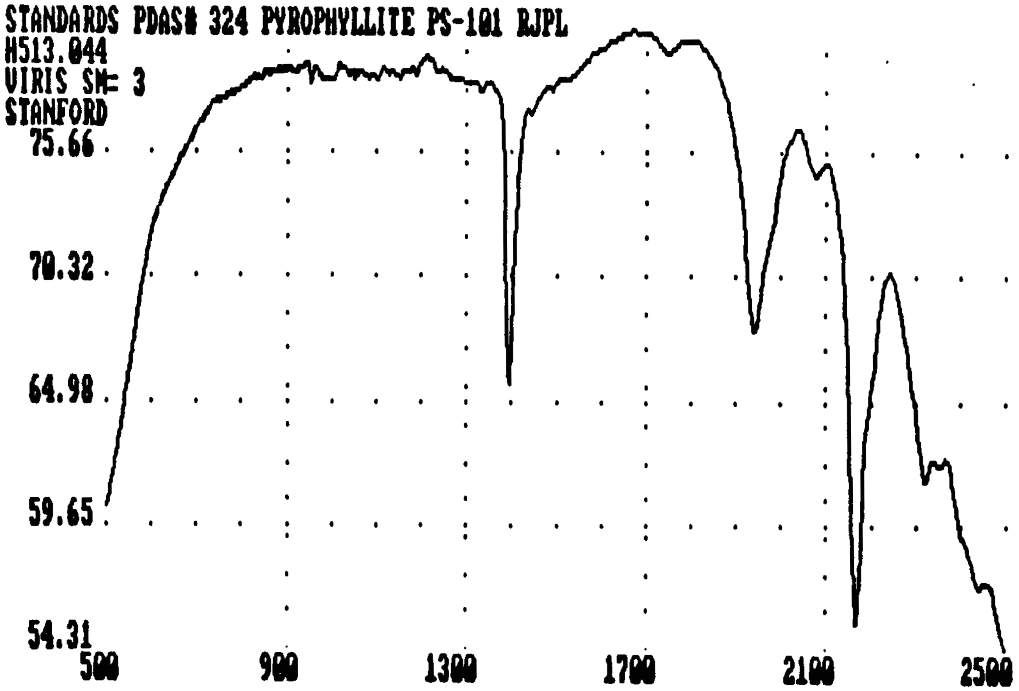

PYROPHYLLITE PYSIA USGS STD
0323A.327
PIDAS SM= 1
STANFORD
68.55
59.04
51.12
42.40
33.68
450
850
1250
1650
2050
2450

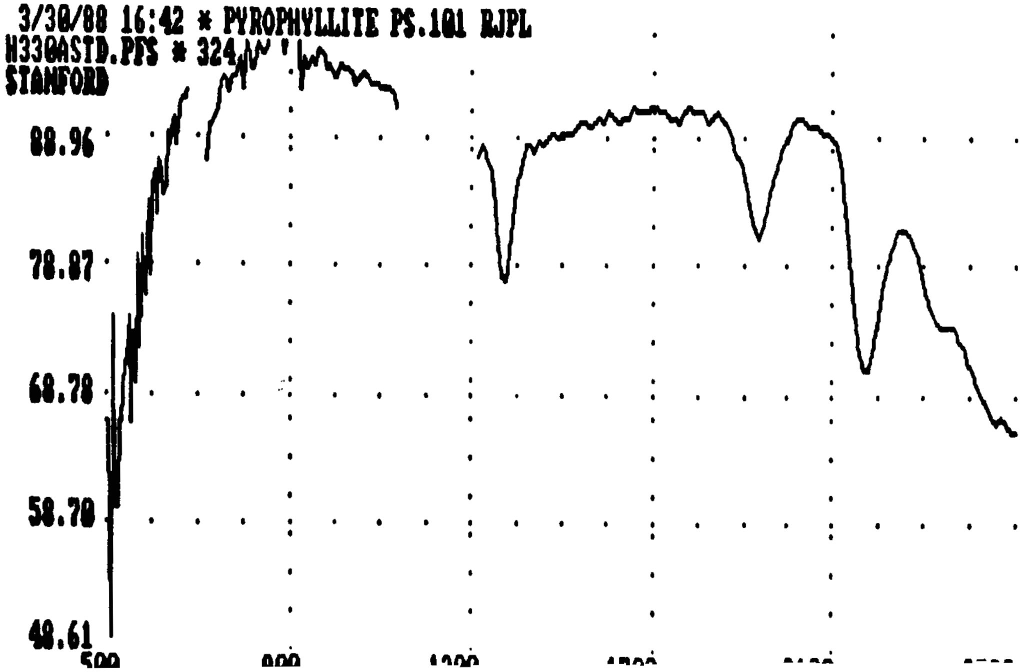

STANDARDS PDAS# 327 PYROPHYLLITE USGS STD PSY-1A
H513.042
VIRIS SM= 3
STANFORD
73.37
64.04
54.71
45.37
36.04
500
900
1300
1700
2100
2500

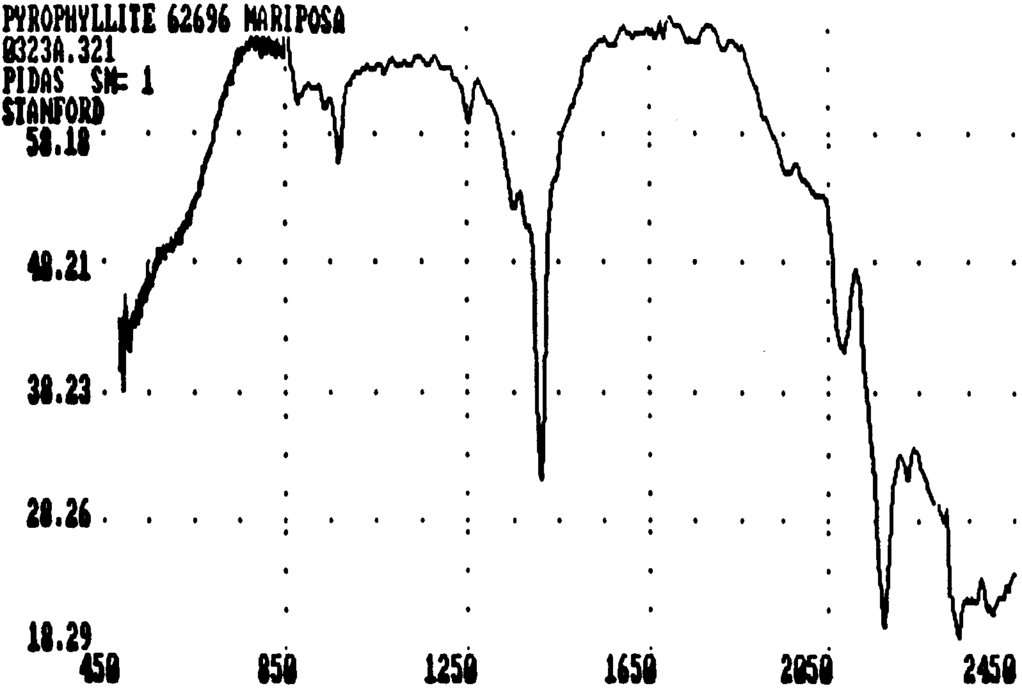

3/30/88 16:43 * PYROPHYLLITE PYSI1
H330ASTD.PFS * 327
STANFORD
82.63
72.07
61.52
50.96
40.41
500
900
1300
1700
2100
2500

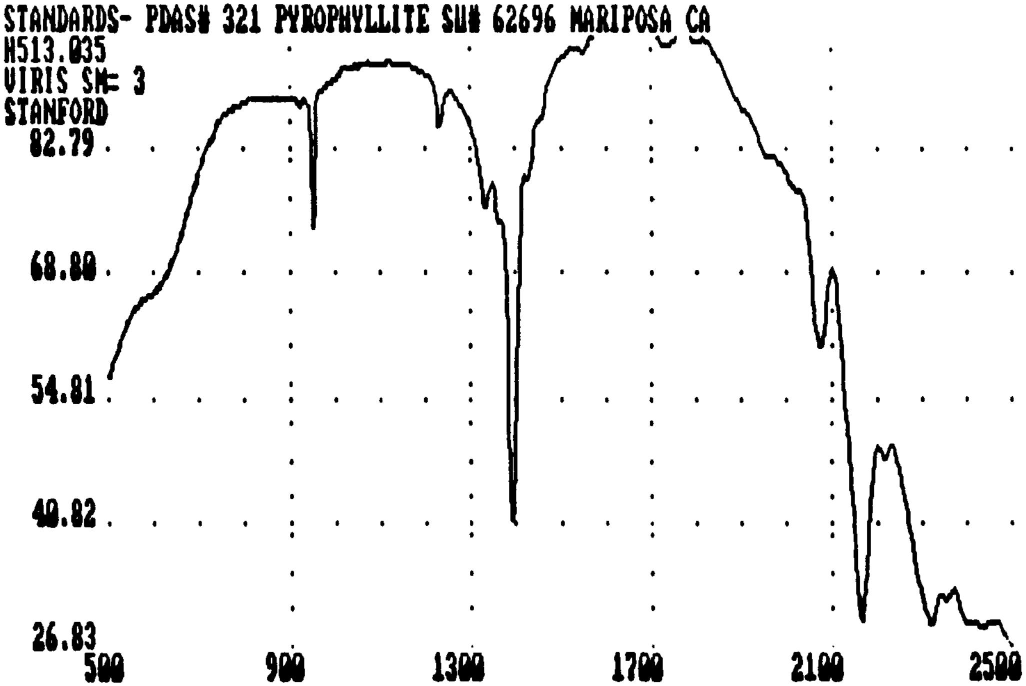

Nov 20 11:32 Pyroph USGS PYS1A <850 um size $
GB20FAXA.049
SFX440 SM= 1
STANFORD
91.04
82.24
73.45
64.65
55.85
400
800
1200
1600
2000
2400

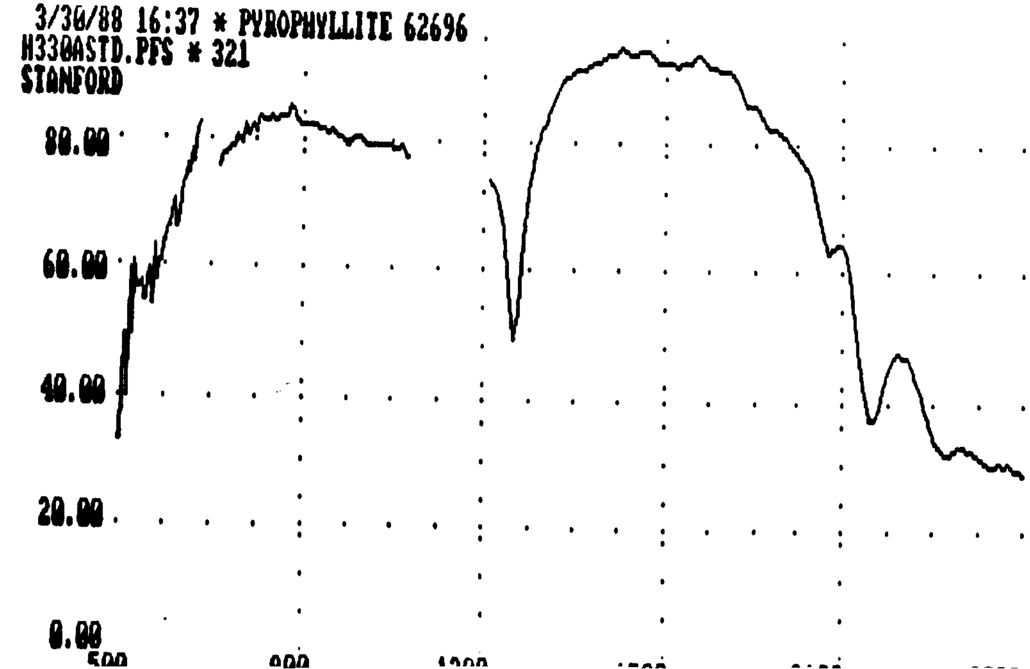

PYROPHYLLITE RJPL STANFORD
0323A.324
PIDAS SN= 1
STANFORD
67.43
61.57
55.70
49.84
43.98
450
850
1250
1650
2050
2450

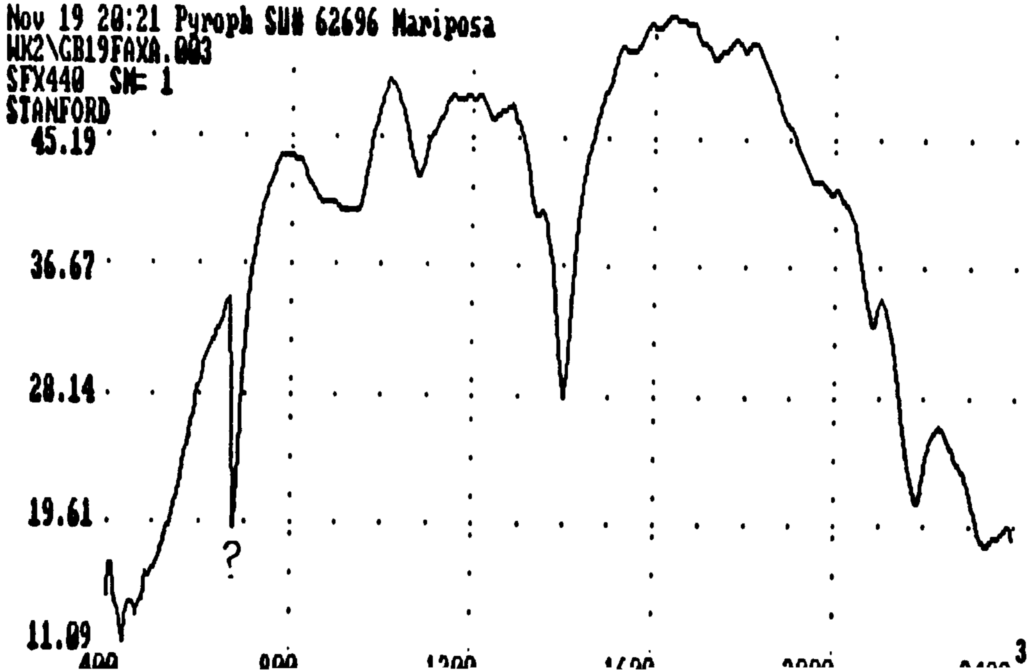

STANDARDS PDAS# 324 PYROPHYLLITE PS-101 RJPL
H513.044
VIRIS SN= 3
STANFORD
75.66
70.32
64.98
59.65
54.31
500
900
1300
1700
2100
2500


3/30/88 16:42 * PYROPHYLLITE PS.101 RJPL
H330ASTD.PFS * 324
STANFORD
88.96
78.87
68.78
58.70
48.61
500


PYROPHYLLITE 62696 MARIPOSA
0323A.321
PIDAS SM= 1
STANFORD
50.18
40.21
30.23
20.26
10.29
450
850
1250
1650
2050
2450


STANDARDS- PDAS# 321 PYROPHYLLITE SU# 62696 MARIPOSA CA
H513.035
VIRIS SM= 3
STANFORD
82.79
68.80
54.81
40.82
26.83
500
900
1300
1700
2100
2500


3/30/88 16:37 * PYROPHYLLITE 62696
H330ASTD.PFS * 321
STANFORD
80.00
60.00
40.00
20.00
0.00
500


Nov 19 20:21 Pyroph SU# 62696 Mariposa
WK2\GB19FAXA.003
SFX440 SM= 1
STANFORD
45.19
36.67
28.14
19.61
11.09
400
?

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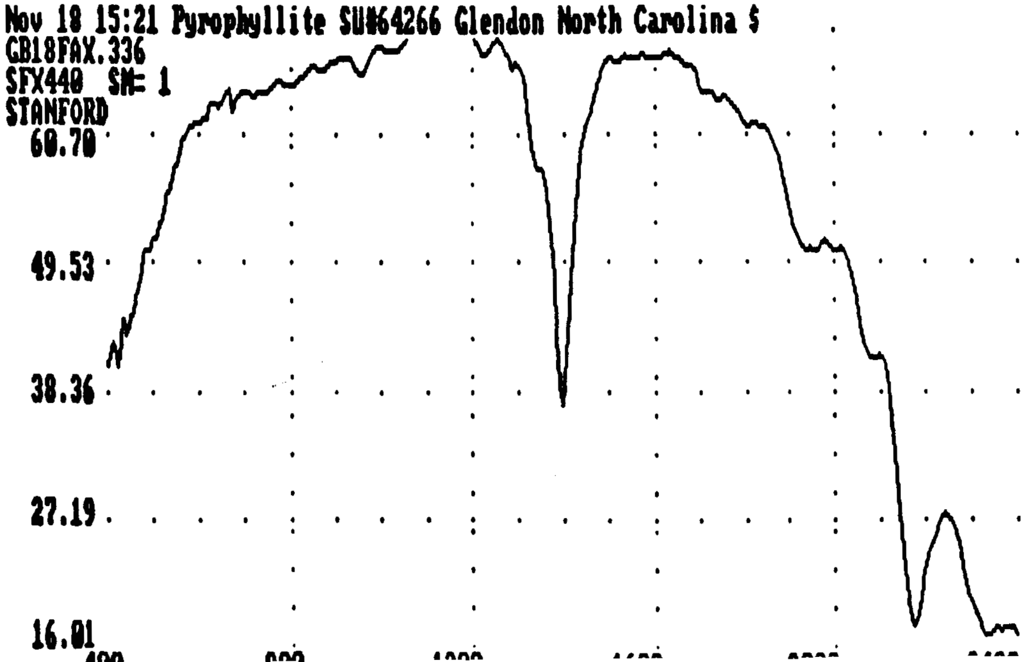
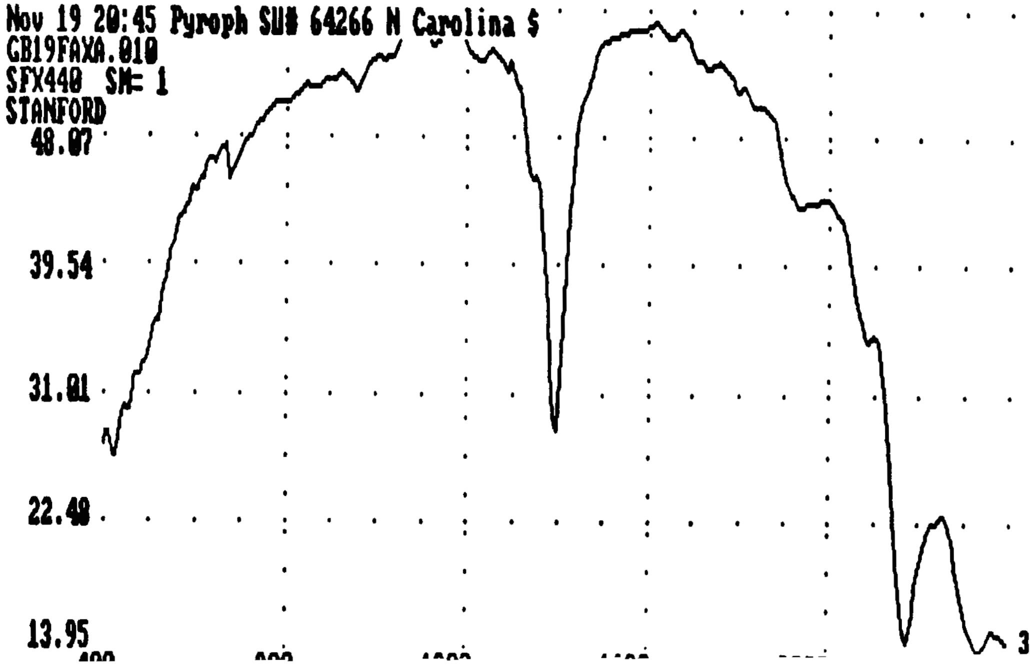
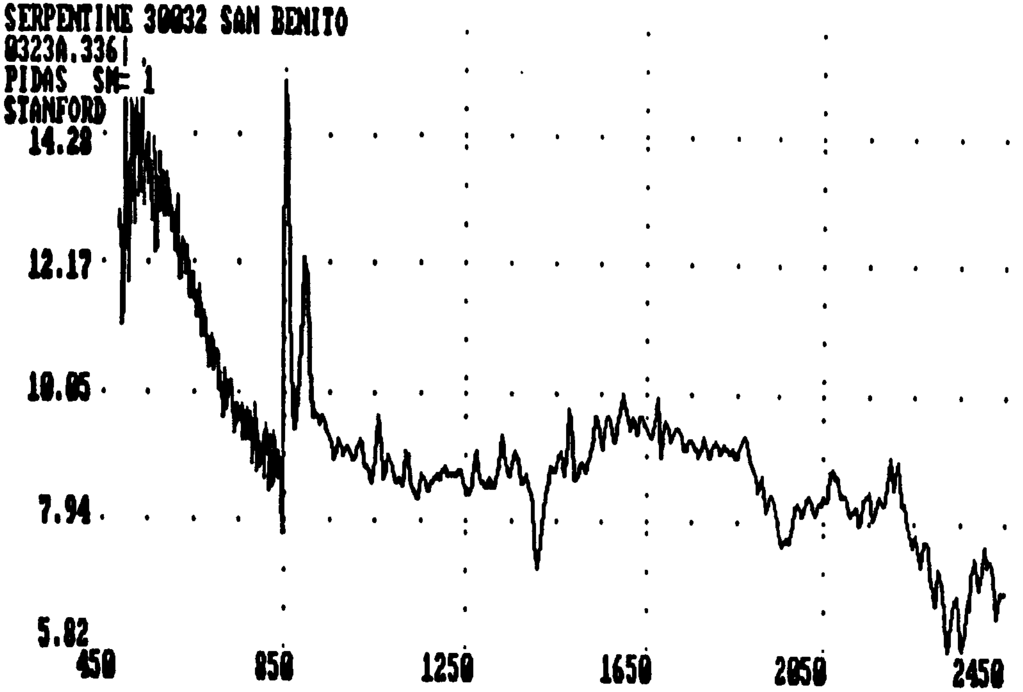
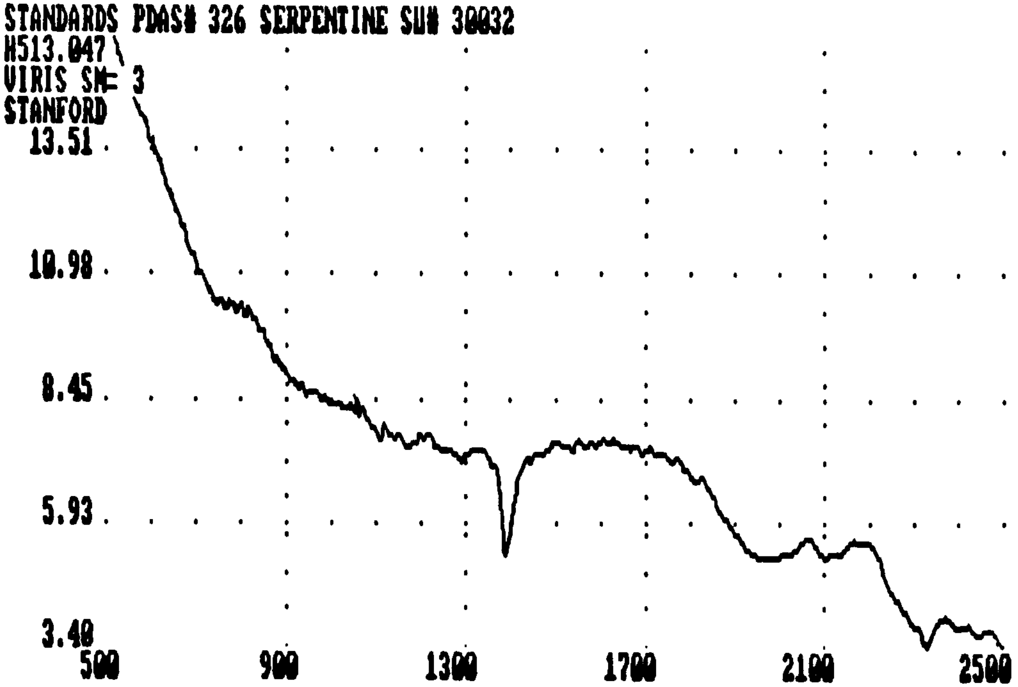
OF POOR QUALITY

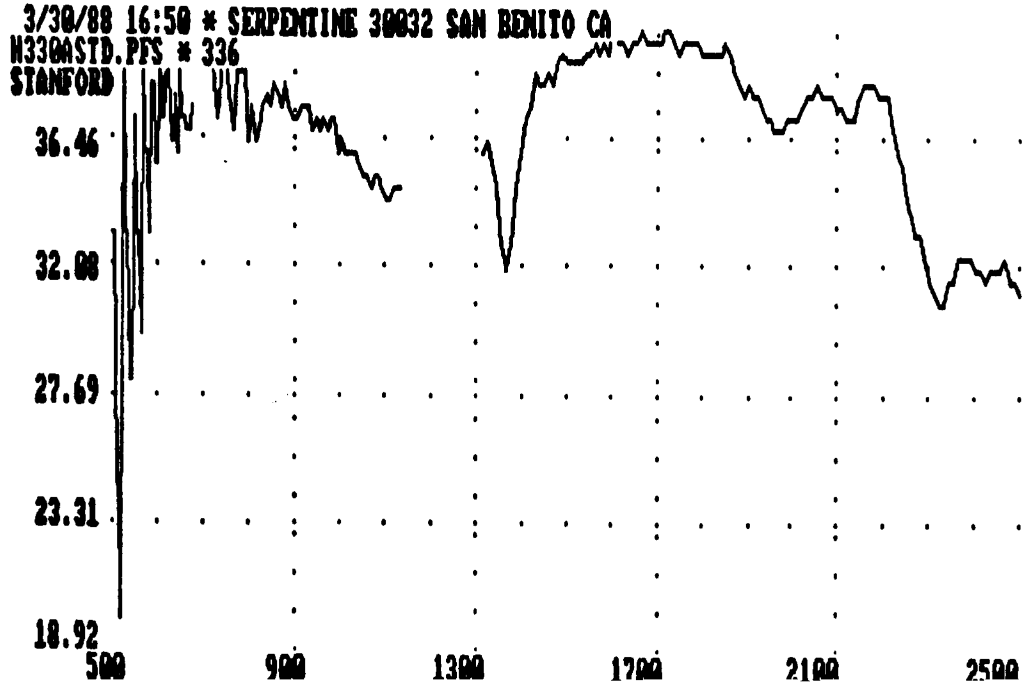

PYROPHYLLITE 64266
0325A.304
PIDAS SM= 1
STANFORD

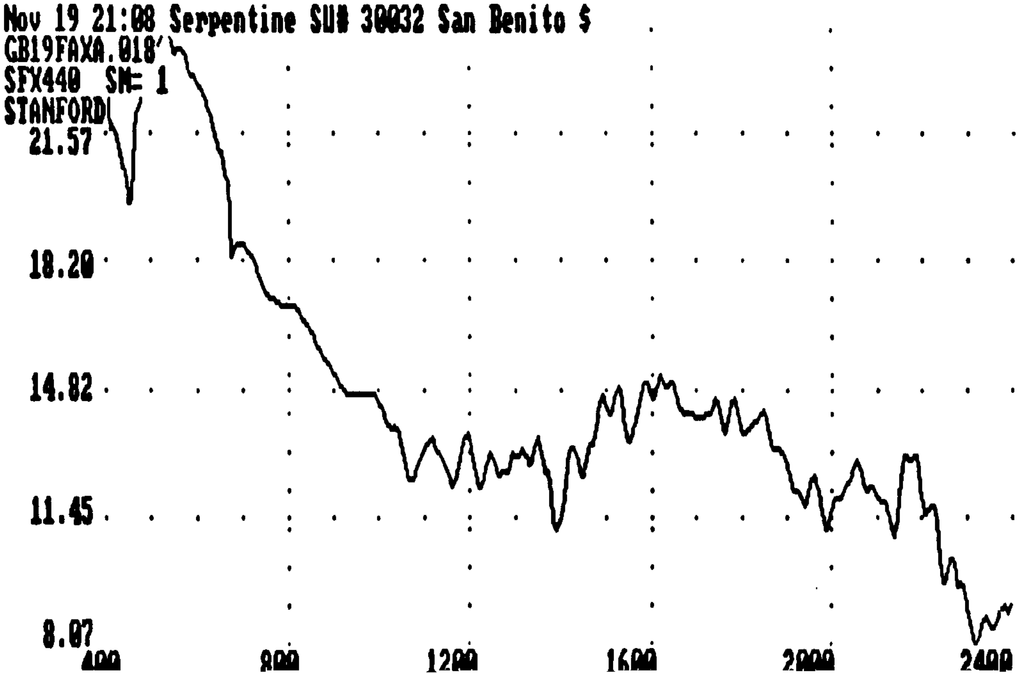

Nov 18 15:21 Pyrophyllite SU#64266 Glendon North Carolina $
GB18FAX.336
SFX440 SM= 1
STANFORD

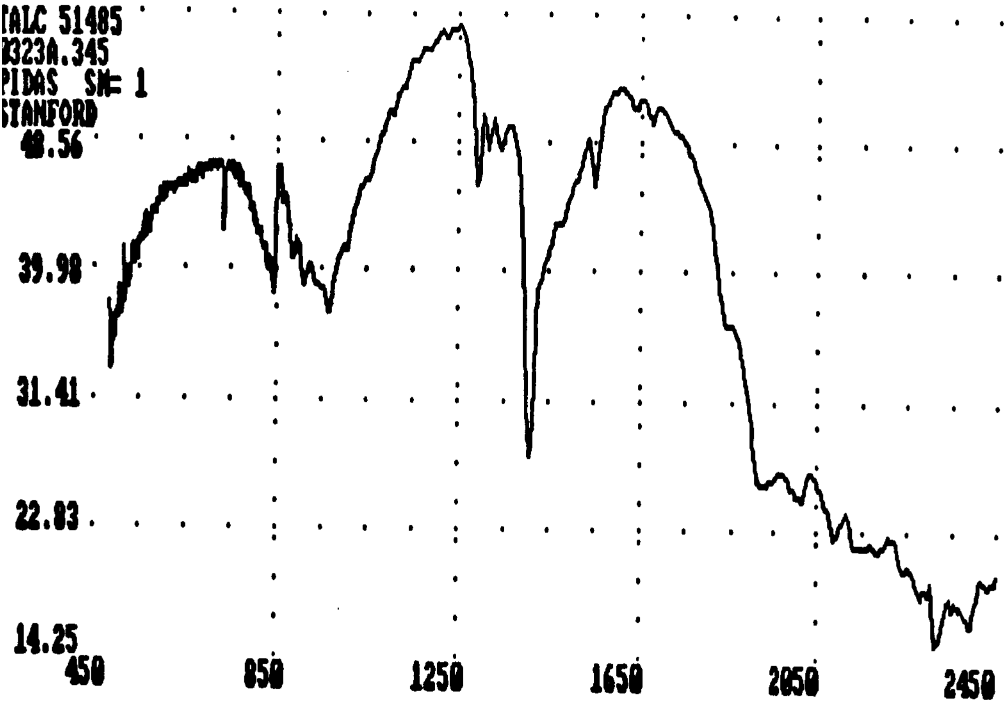

Nov 19 20:45 Pyroph SU# 64266 N Carolina $
GB19FAXA.010
SFX440 SM= 1
STANFORD

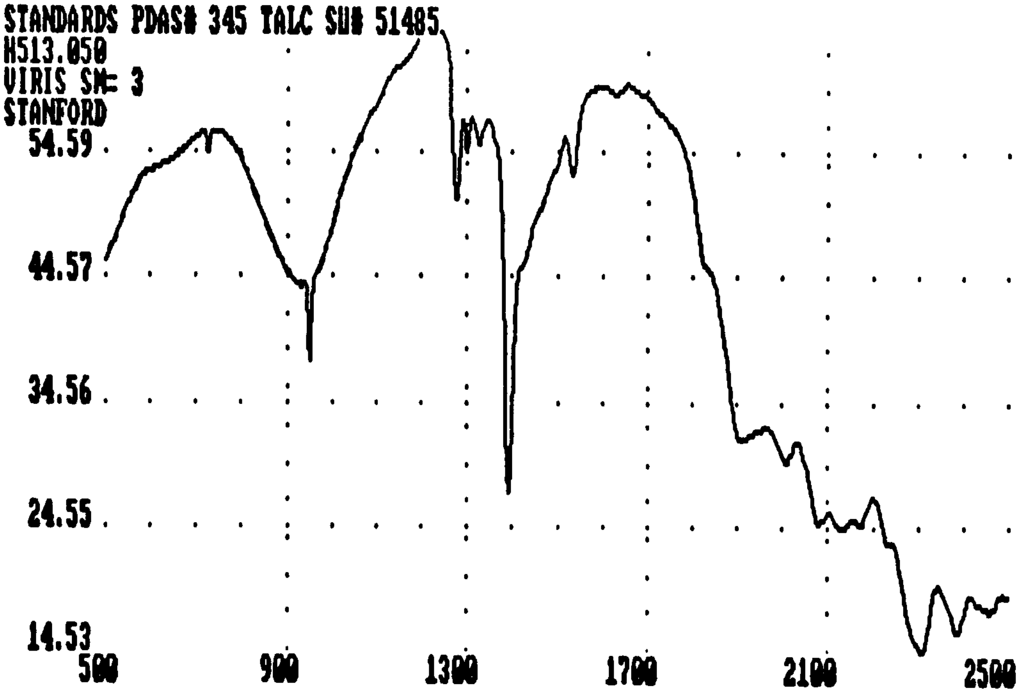

SERPENTINE 30032 SAN BENITO
0323A.336
PIDAS SM= 1
STANFORD
14.28
12.17
10.05
7.94
5.82
450
850
1250
1650
2050
2450

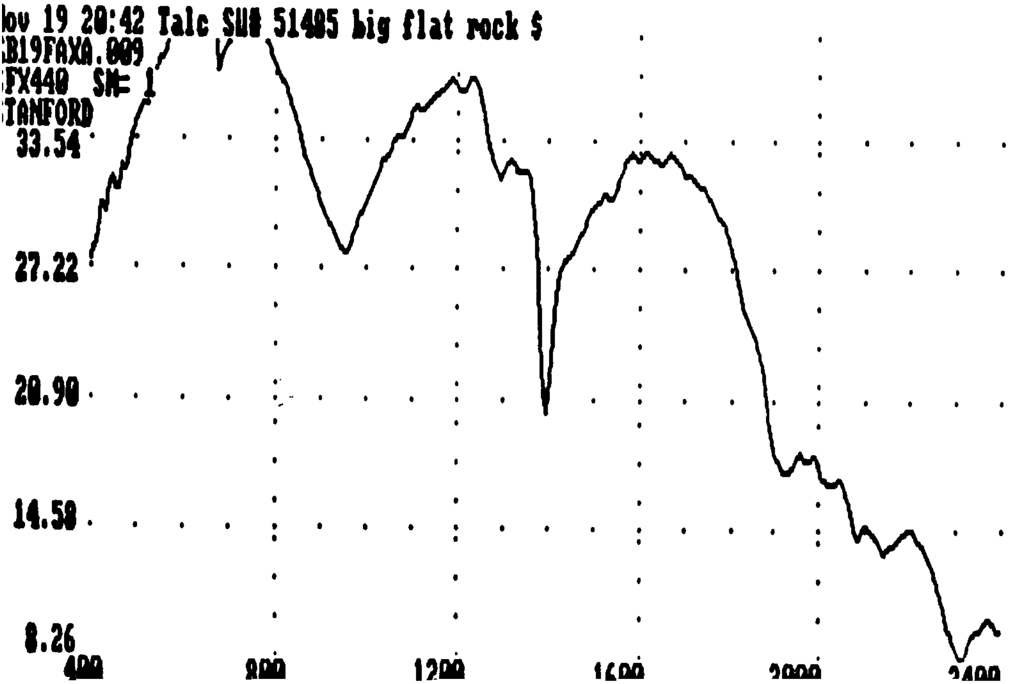

STANDARDS PDAS# 326 SERPENTINE SU# 30032
H513.047
VIRIS SM= 3
STANFORD
13.51
10.98
8.45
5.93
3.40
500
900
1300
1700
2100
2500

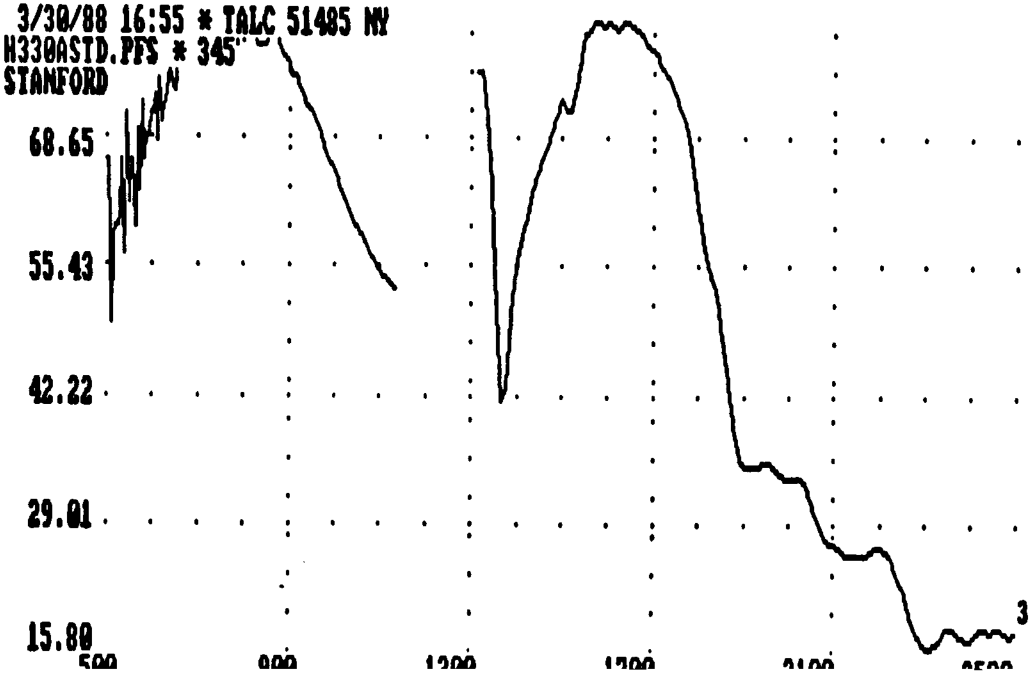

3/30/88 16:50 * SERPENTINE 30032 SAN BENITO CA
H330ASTD.PFS * 336
STANFORD
36.46
32.08
27.69
23.31
18.92
500
900
1300
1700
2100
2500

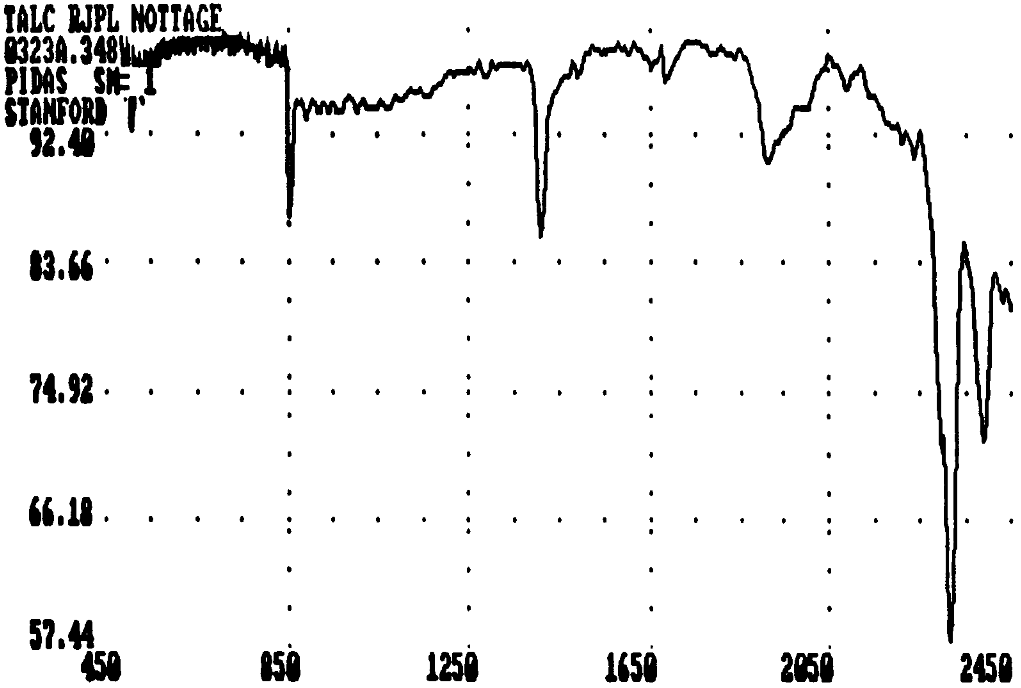

Nov 19 21:08 Serpentine SU# 30032 San Benito $
GB19FAXA.018
SFX440 SM= 1
STANFORD
21.57
18.20
14.82
11.45
8.07
400
800
1200
1600
2000
2400

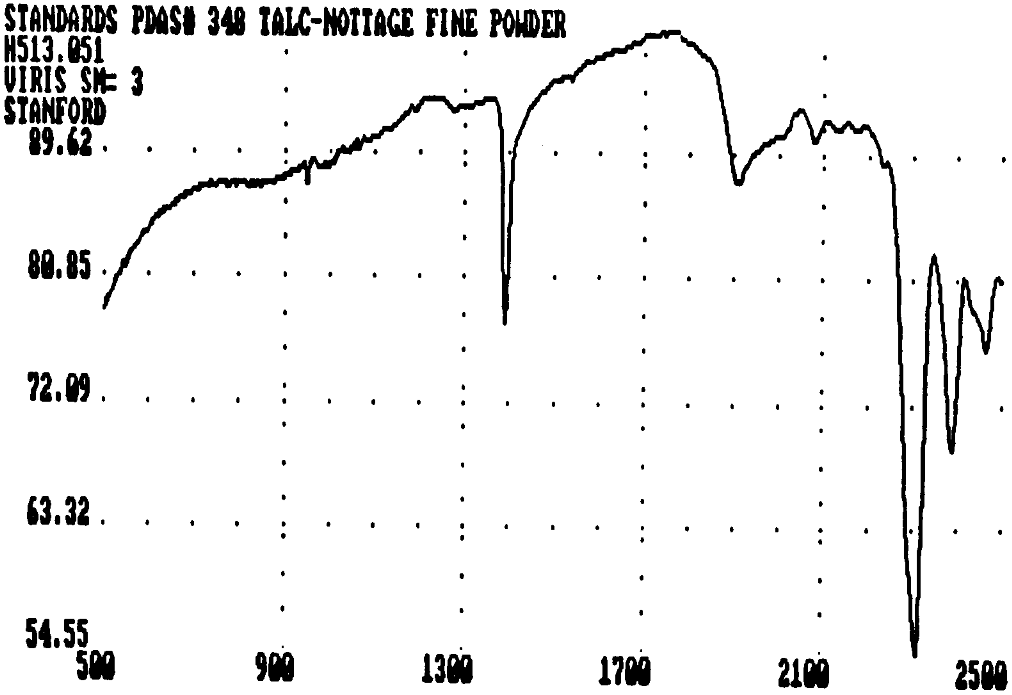

TALC 51485
323A.345
PIDAS SN= 1
TANFORD
48.56
39.98
31.41
22.83
14.25
450
850
1250
1650
2050
2450

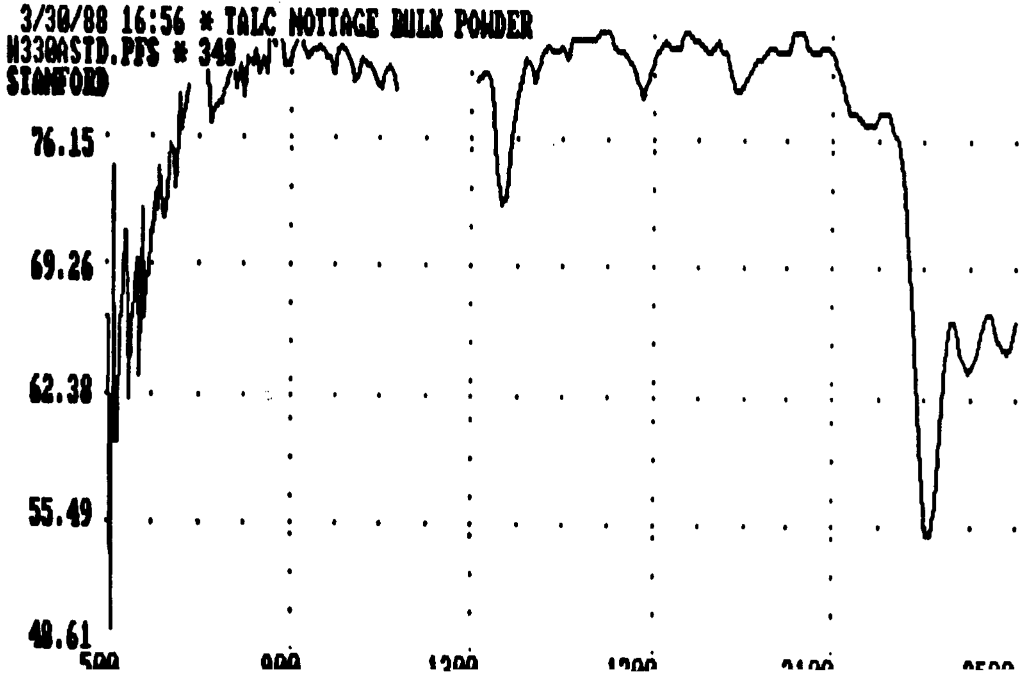

STANDARDS PDAS# 345 TALC SU# 51485
H513.050
VIRIS SN= 3
STANFORD
54.59
44.57
34.56
24.55
14.53
500
900
1300
1700
2100
2500


ov 19 20:42 Talc SU# 51485 big flat rock $
B19FAXA.009
FX440 SN= 1
TANFORD
33.54
27.22
20.90
14.58
8.26
400
800
1200
1600
2000
2400


3/30/88 16:55 * TALC 51485 NY
H330ASTD.PFS * 345
STANFORD
68.65
55.43
42.22
29.01
15.80
500
900
1300
1700
2100
2500


TALC BJPL NOTTAGE
0323A.348
PIDAS SM= 1
STANFORD
92.40
83.66
74.92
66.18
57.44
450
850
1250
1650
2050
2450


STANDARDS PDAS# 348 TALC-NOTTAGE FINE POWDER
H513.051
VIRIS SM= 3
STANFORD
89.62
80.85
72.09
63.32
54.55
500
900
1300
1700
2100
2500


3/30/88 16:56 * TALC NOTTAGE BULK POWDER
H330ASTD.PFS * 348
STANFORD
76.15
69.26
62.38
55.49
48.61

Set C: Rock samples form Yerington, Nevada, as collected in the field. Rock unit names (e.g. Jpqm for #1) are form Proffett and Dilles, 1984, Geologic Map of the Yerington District, Nevada Bureau of Mines Publication #77.

Samples from Yerington, Singatse Range:

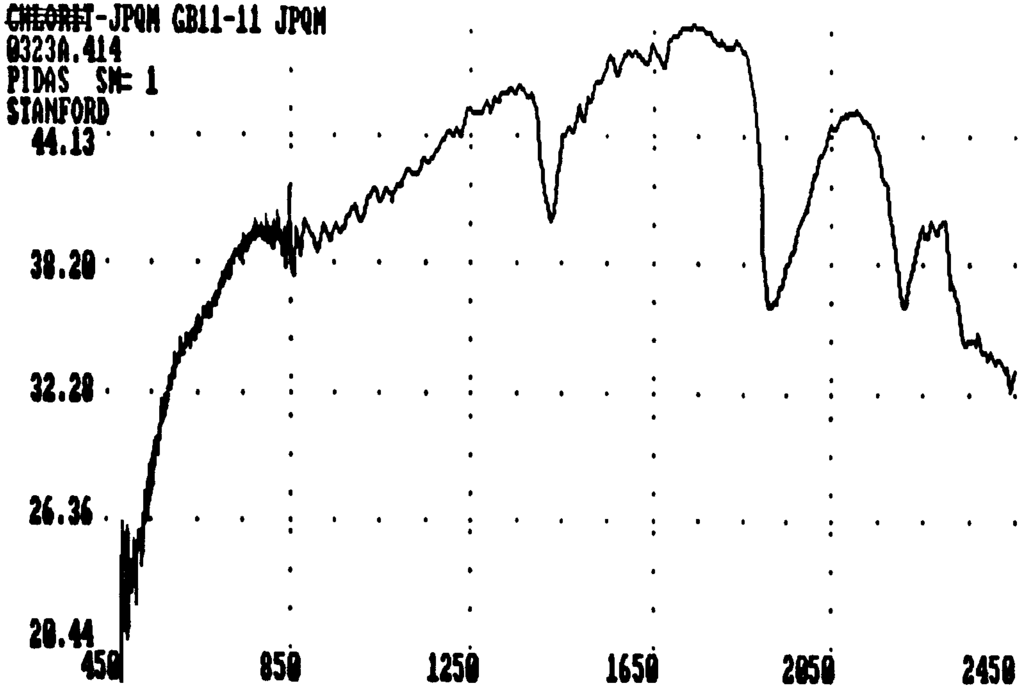
1. GB11-11 Jpqm, sericitic, bleached iron stain
2. GB11-21 Jpqm chloritic (greenish), YAM/YMP
3. GB11-31 Jgd with fresh biotite, YAM/YMP
4. GB11-64B soil under desert pavement, light grey, bubbly, YAM

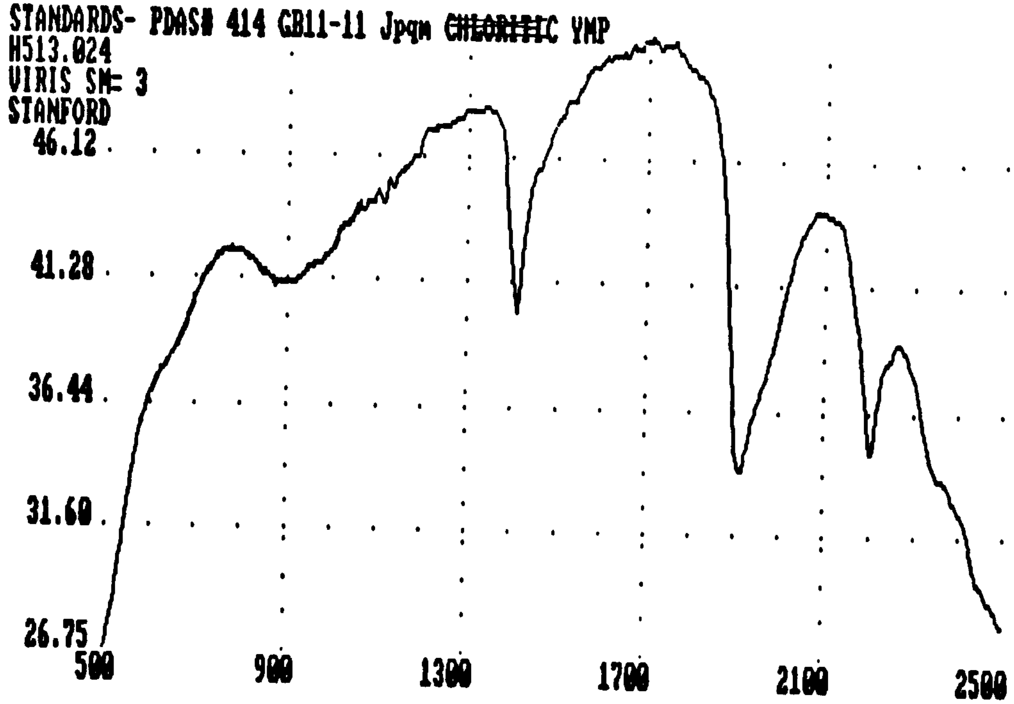
Samples from Yerington, Buckskin Range:

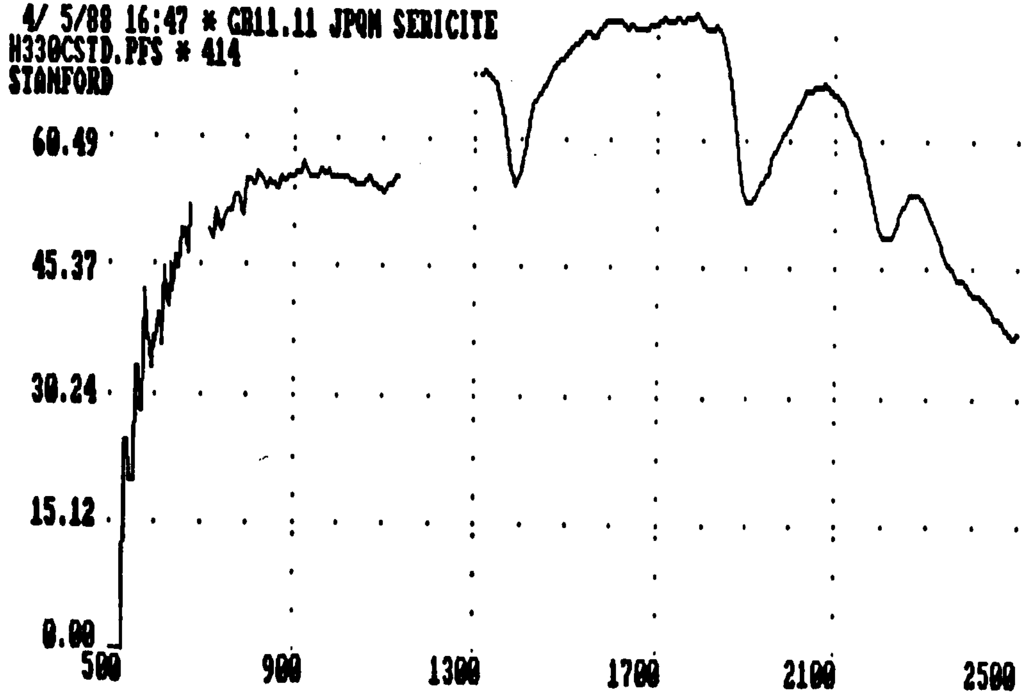
5. GB11-64BL true soil underneath sample GB11-64B
6. GB11-71 DDH site, alunite/pyrophyllite, Alunite Hill, YBK
7. GB11-72E DDH site, altered tuff (chlorite?), YBK
8. GB11-74 Pyrophyllitic tuff, YBK
9. GB11-74B same as GB11-74 but tourmaline rich, sericitic, YBK
10. GB11-75 white pyrophyllite, YBK

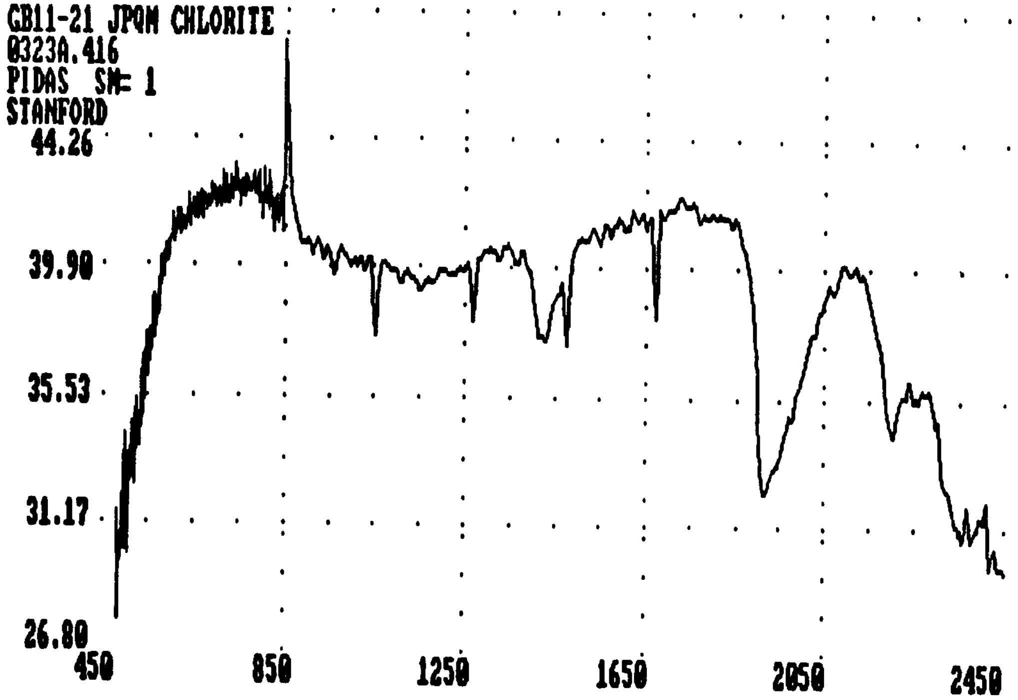
Samples form Virginia City:

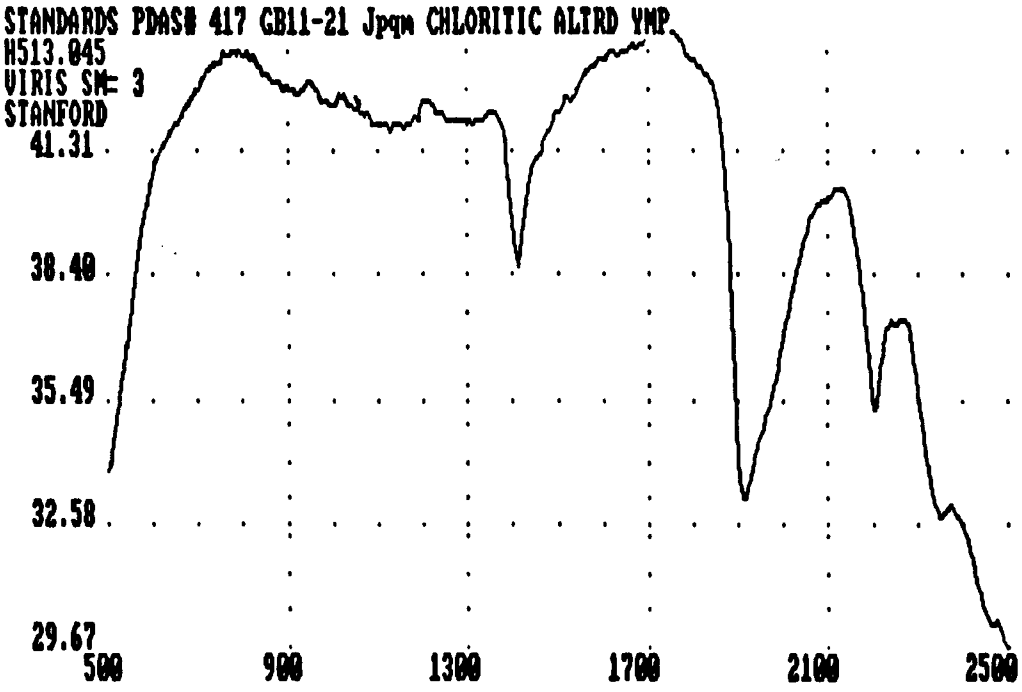
11. GB12-11 Altered Kate Peak Tuff, VCE
12. GB12-43 altered tuff, VCN
13. GB12-52 altered tuff (alunite), VGN

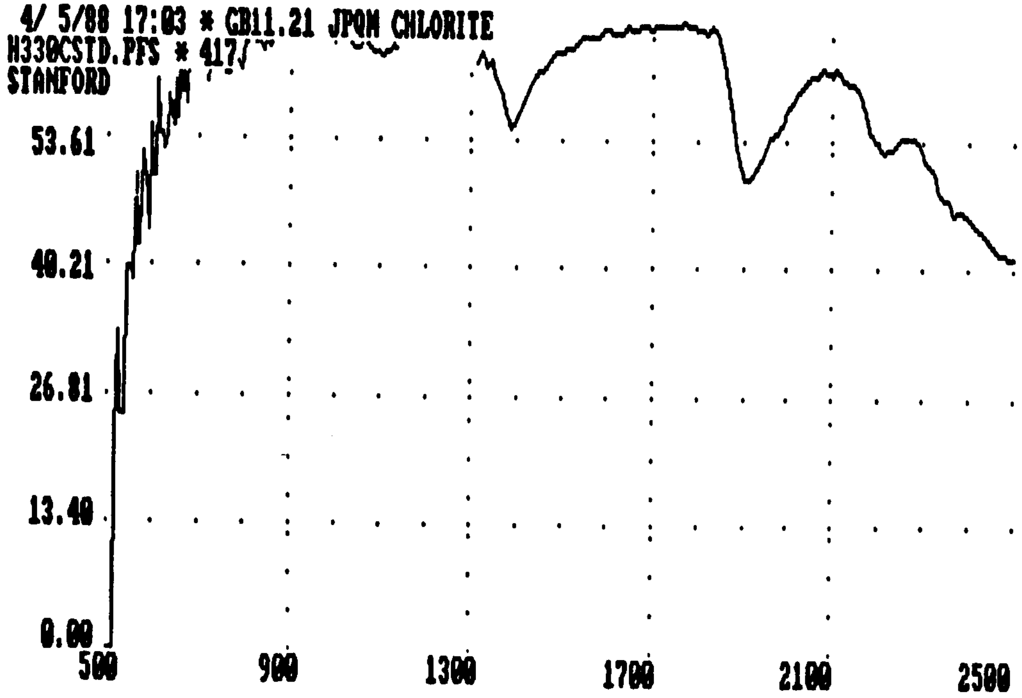

~~CHLORIT~~-JPQM GB11-11 JPQM
0323A.414
PIDAS SM= 1
STANFORD
44.13
38.20
32.28
26.36
20.44
450
850
1250
1650
2050
2450

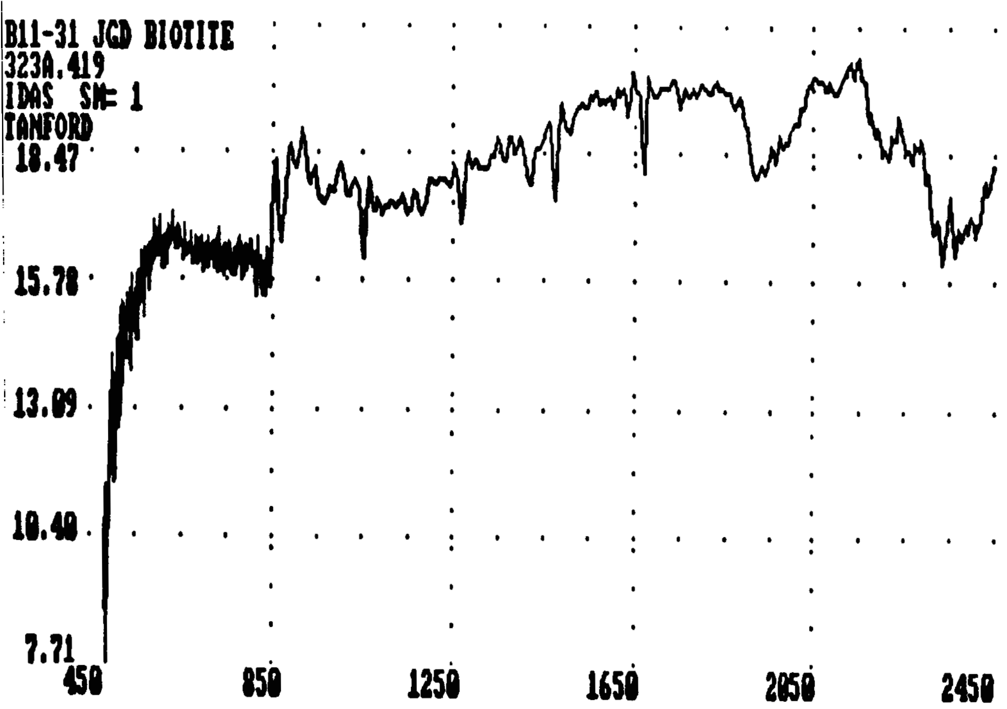

STANDARDS- PDAS# 414 GB11-11 Jpqm ~~CHLORITIC~~ YMP
H513.024
VIRIS SM= 3
STANFORD
46.12
41.28
36.44
31.60
26.75
500
900
1300
1700
2100
2500

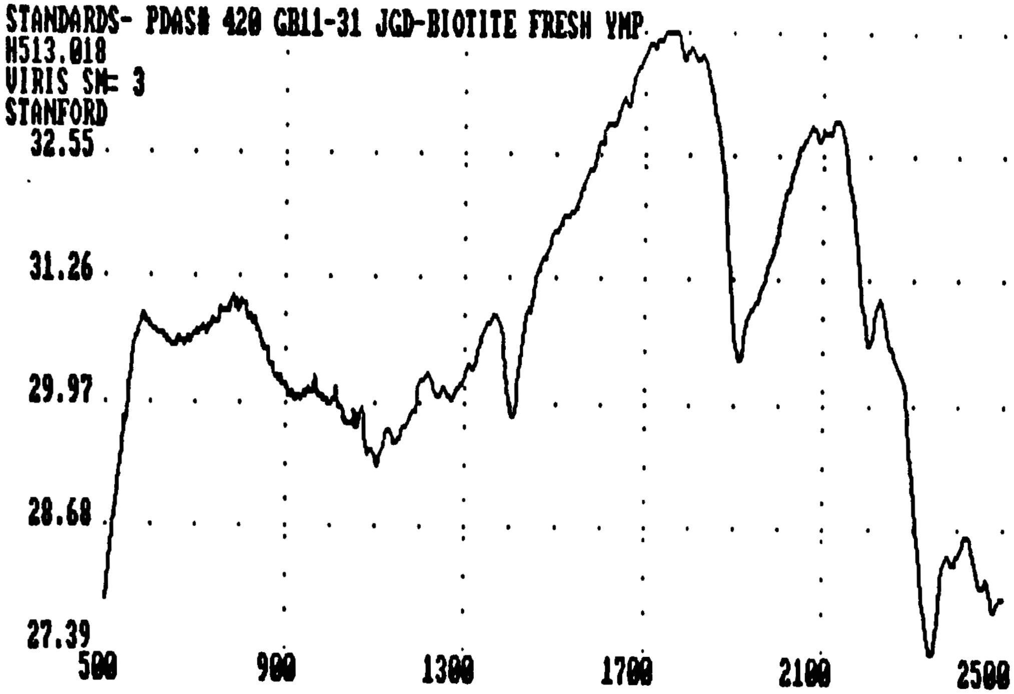

4/ 5/88 16:47 * GB11.11 JPQM SERICITE
H330CSTD.PFS * 414
STANFORD
60.49
45.37
30.24
15.12
0.00
500
900
1300
1700
2100
2500

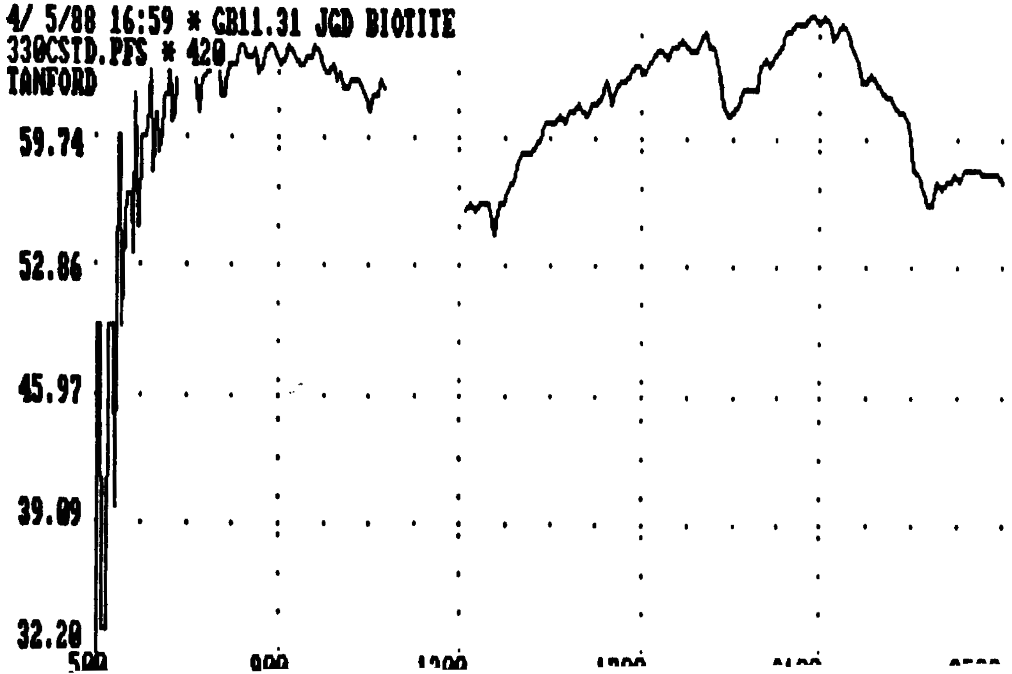

GB11-21 JPQM CHLORITE
0323A.416
PIDAS SM= 1
STANFORD
44.26
39.90
35.53
31.17
26.80
450
850
1250
1650
2050
2450

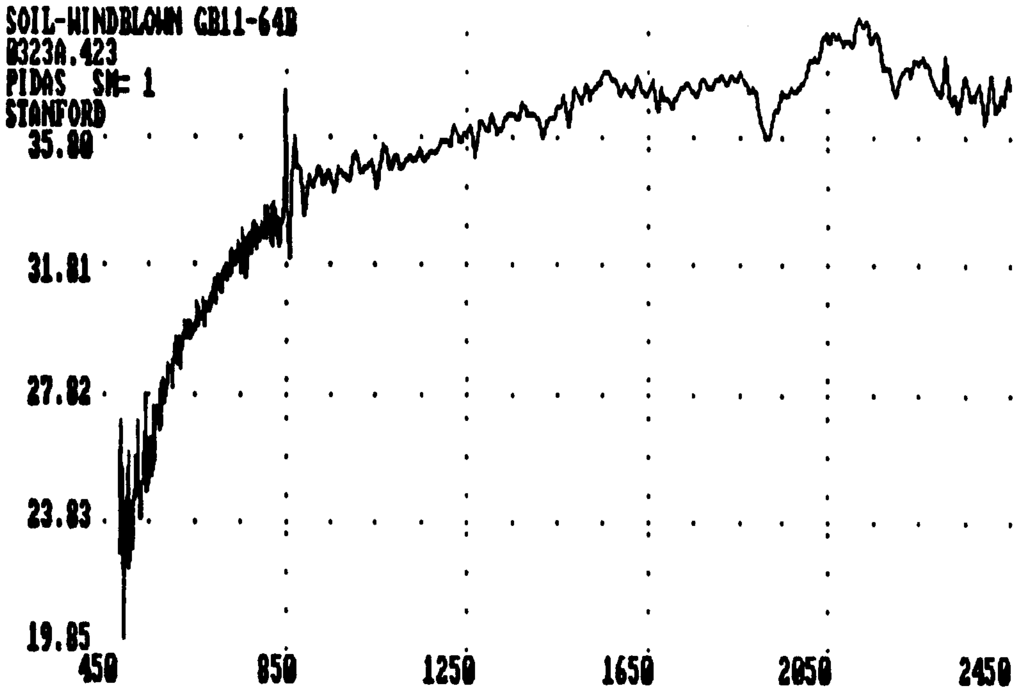

STANDARDS PDAS# 417 GB11-21 Jpqm CHLORITIC ALTRD YMP
H513.045
VIRIS SM= 3
STANFORD
41.31
38.40
35.49
32.58
29.67
500
900
1300
1700
2100
2500

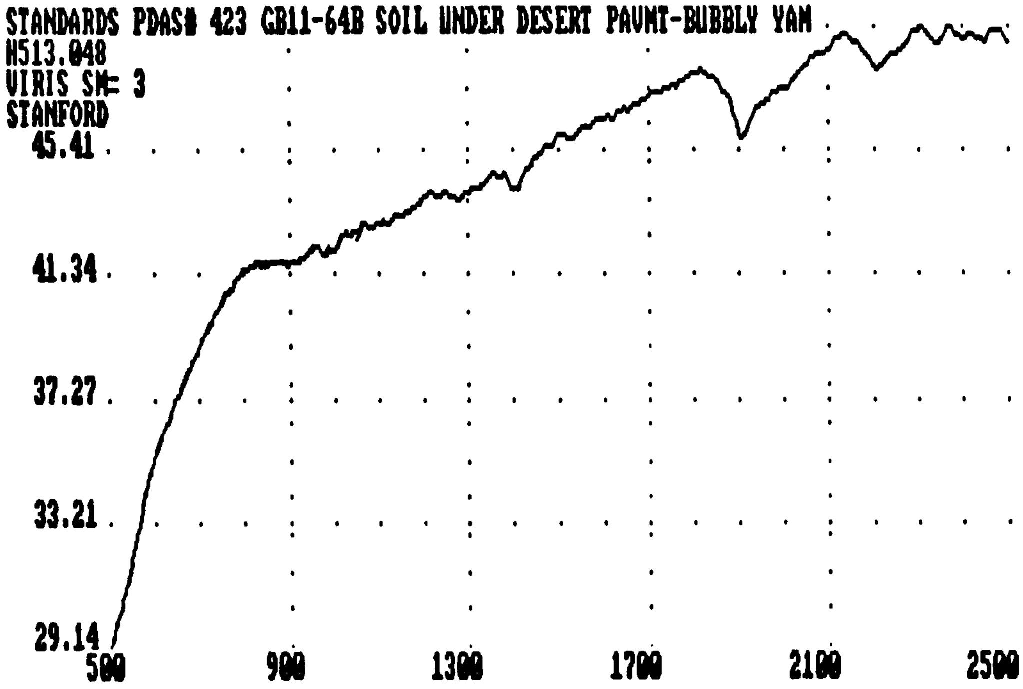

4/ 5/88 17:03 * GB11.21 JPQM CHLORITE
H330CSTD.PFS * 417/
STANFORD
53.61
40.21
26.81
13.40
0.00
500
900
1300
1700
2100
2500

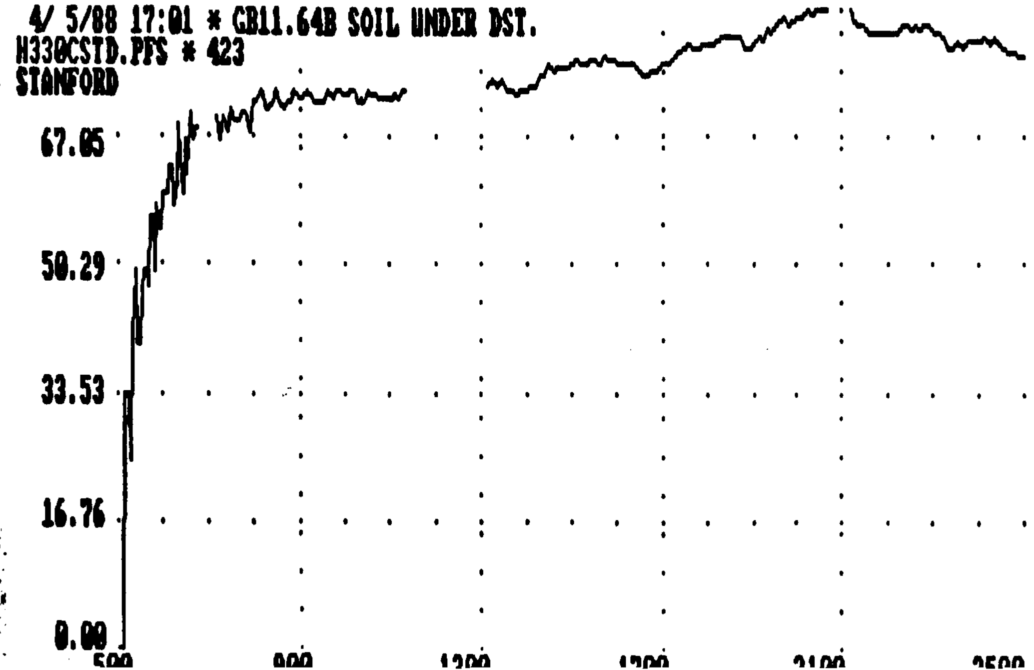

B11-31 JGD BIOTITE
323A.419
IDAS SM= 1
TANFORD
18.47
15.78
13.09
10.40
7.71
450
850
1250
1650
2050
2450

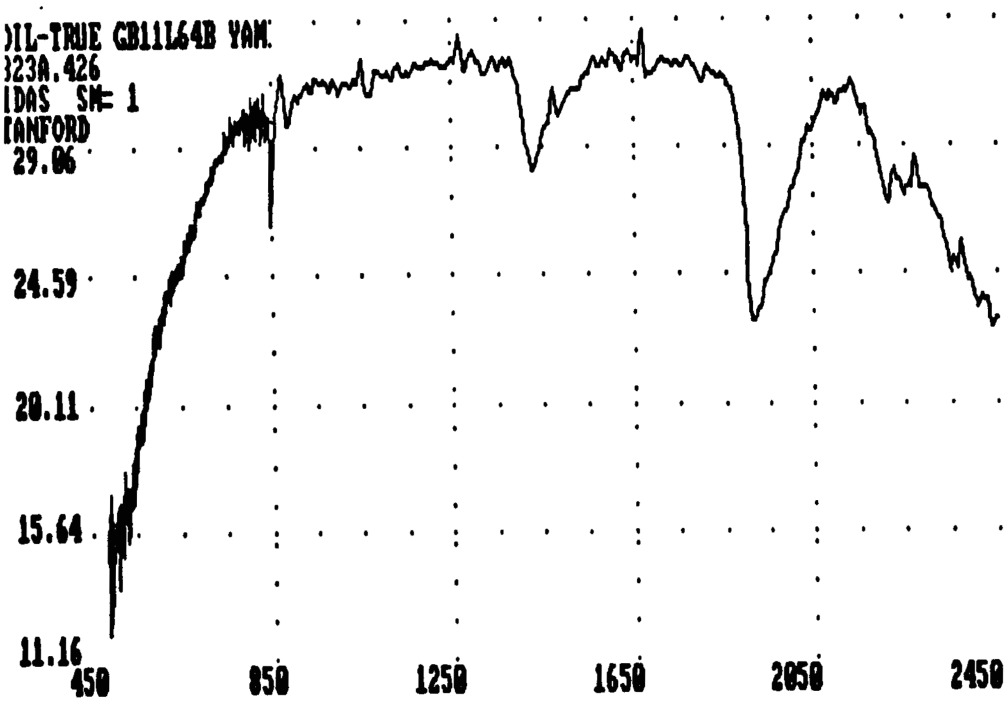

STANDARDS- PDAS# 420 GB11-31 JGD-BIOTITE FRESH VMP
H513.018
VIRIS SM= 3
STANFORD
32.55
31.26
29.97
28.68
27.39
500
900
1300
1700
2100
2500


4/ 5/88 16:59 * GB11.31 JGD BIOTITE
330CSTD.PFS * 420
TANFORD
59.74
52.86
45.97
39.09
32.20
500

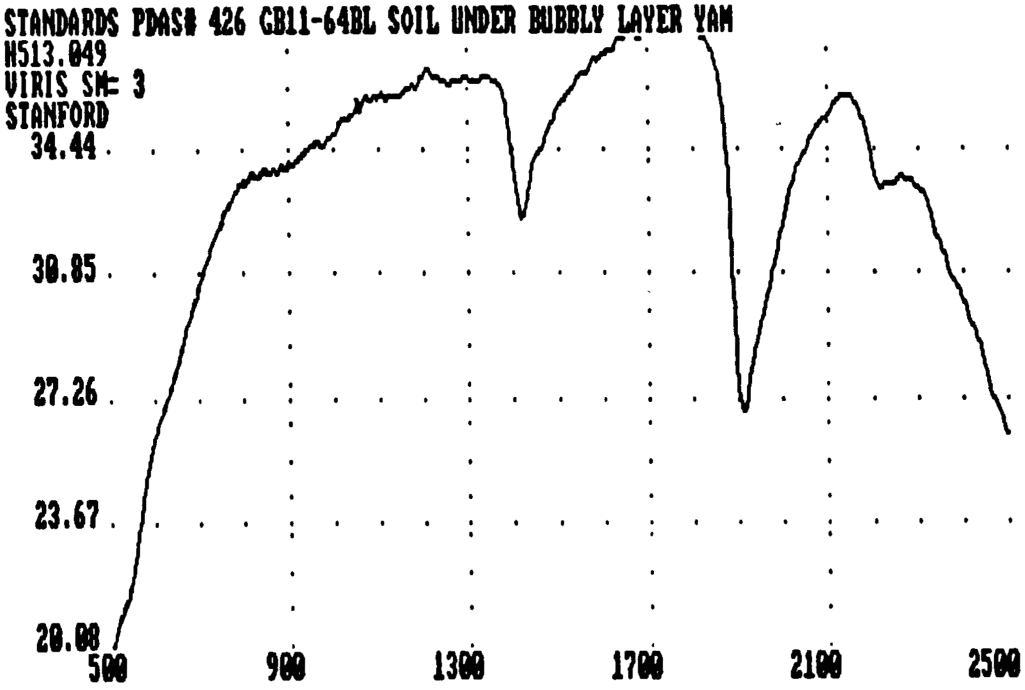

SOIL-WINDBLOWN GB11-64B
B323A.423
PIDAS SM= 1
STANFORD
35.80
31.81
27.82
23.83
19.85
450
850
1250
1650
2050
2450


STANDARDS PDAS# 423 GB11-64B SOIL UNDER DESERT PAVMT-BUBBLY YAM
H513.048
VIRIS SM= 3
STANFORD
45.41
41.34
37.27
33.21
29.14
500
900
1300
1700
2100
2500

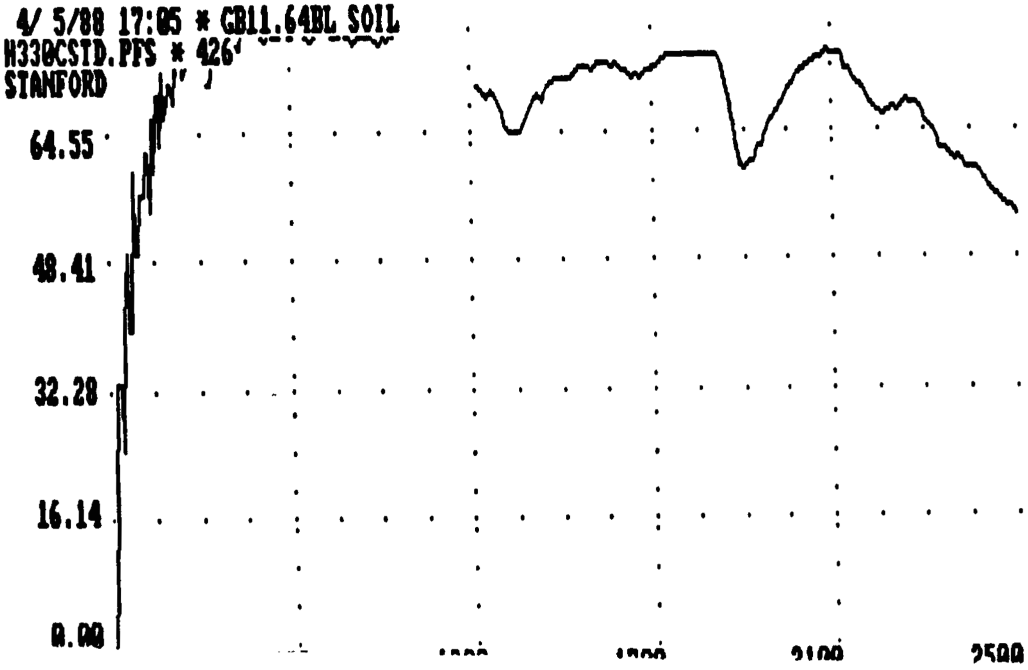

4/ 5/88 17:01 * GB11.64B SOIL UNDER DST.
H330CSTD.PFS * 423
STANFORD
67.05
50.29
33.53
16.76
0.00
500
900
1300
1700
2100
2500



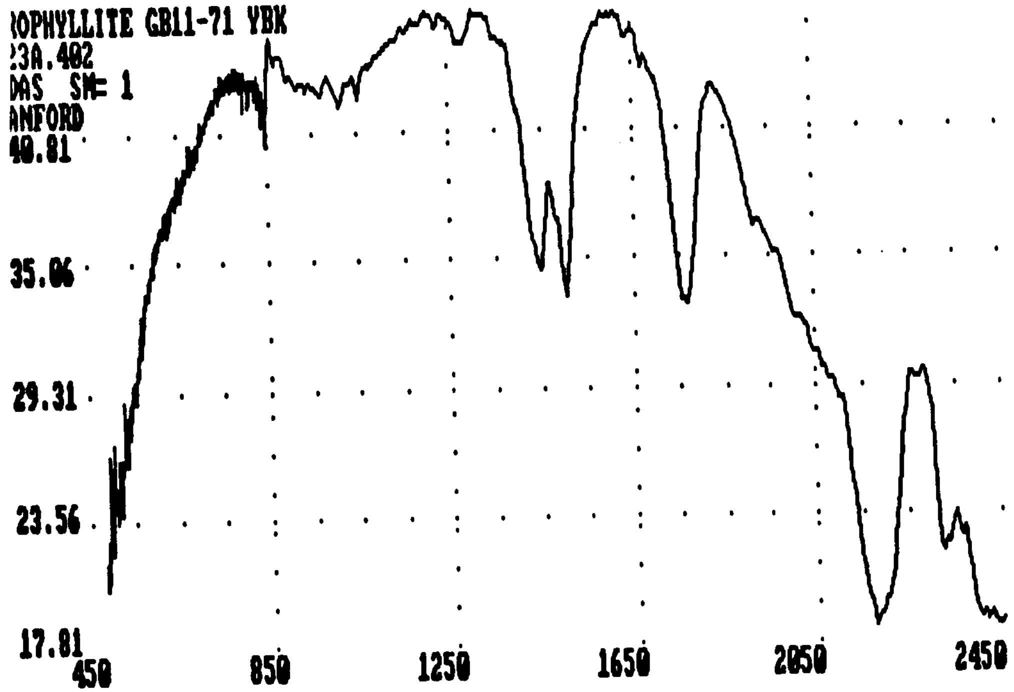
)IL-TRUE GB11L64B YAM.
323A.426
IDAS SM= 1
TANFORD
29.06
24.59
20.11
15.64
11.16
450
850
1250
1650
2050
2450



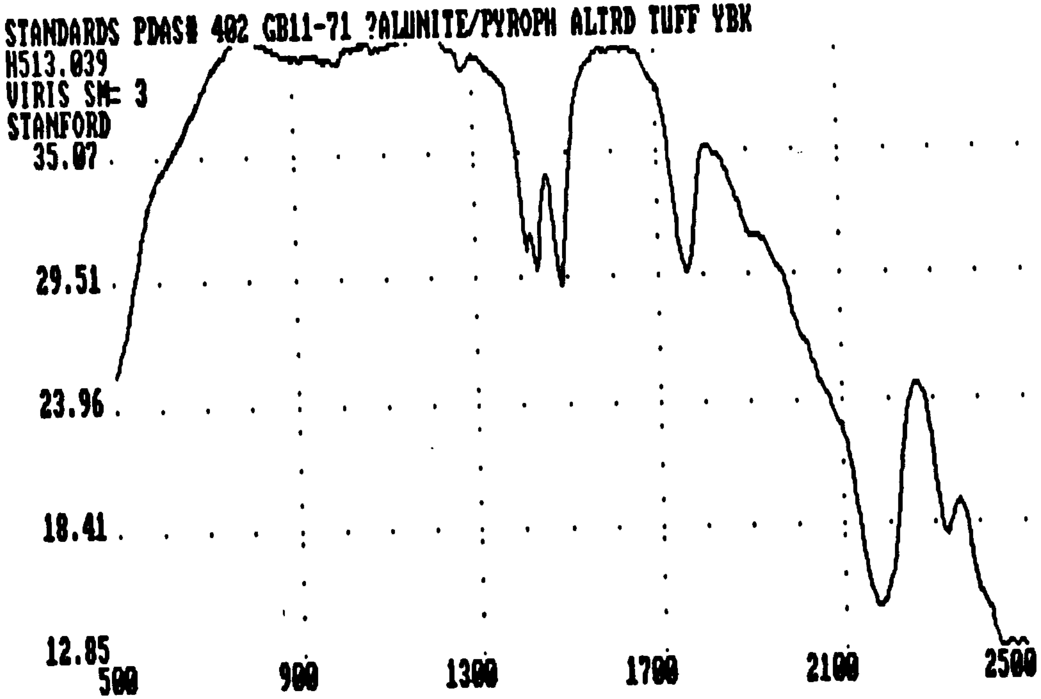
STANDARDS PDAS# 426 GB11-64BL SOIL UNDER BUBBLY LAYER YAM
H513.049
VIRIS SM= 3
STANFORD
34.44
30.85
27.26
23.67
20.08
500
900
1300
1700
2100
2500



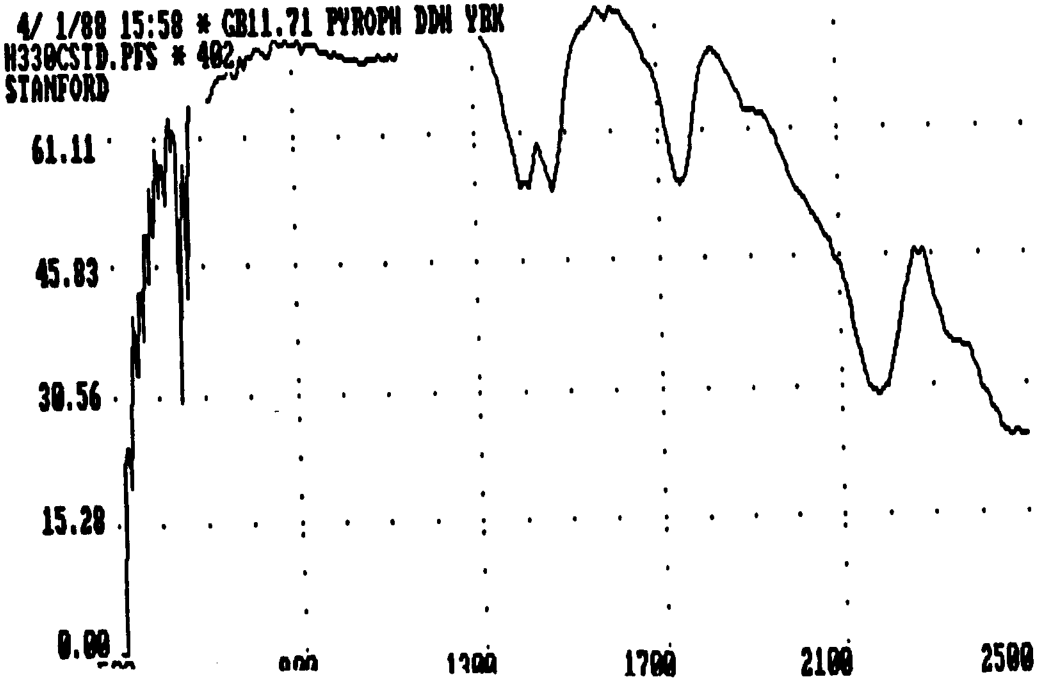
4/ 5/88 17:05 * GB11.64BL SOIL
H330CSTD.PFS * 426
STANFORD
64.55
48.41
32.28
16.14
0.00
2100
2500



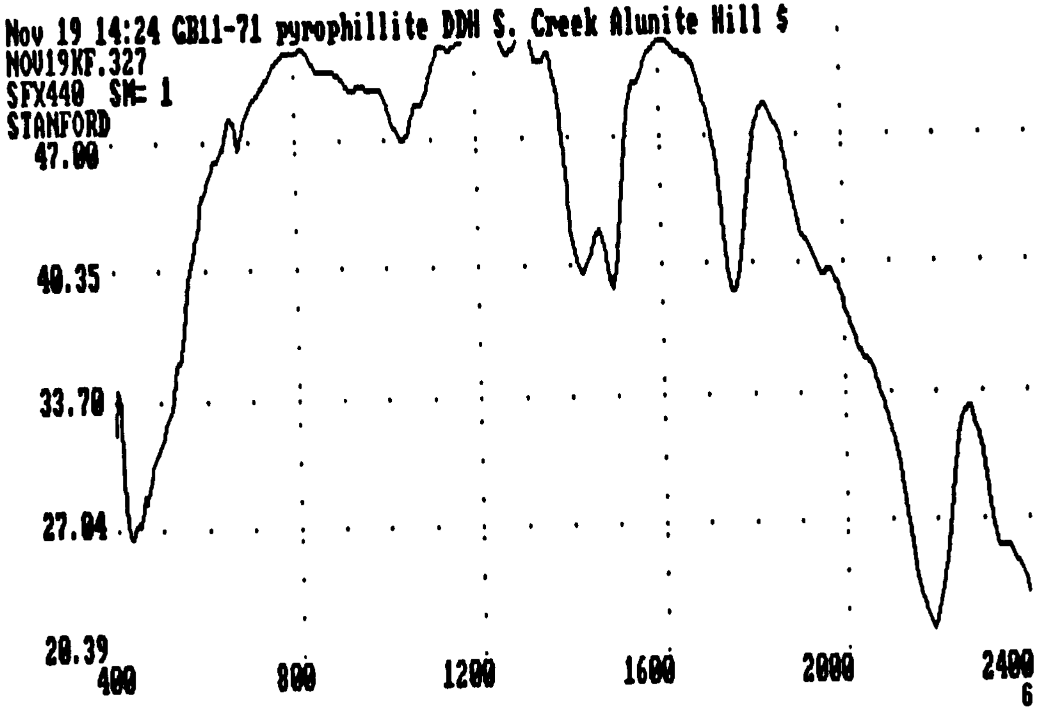
ROPHYLLITE GB11-71 YBK
23A.402
DAS SM= 1
ANFORD
40.81
35.06
29.31
23.56
17.81
450
850
1250
1650
2050
2450



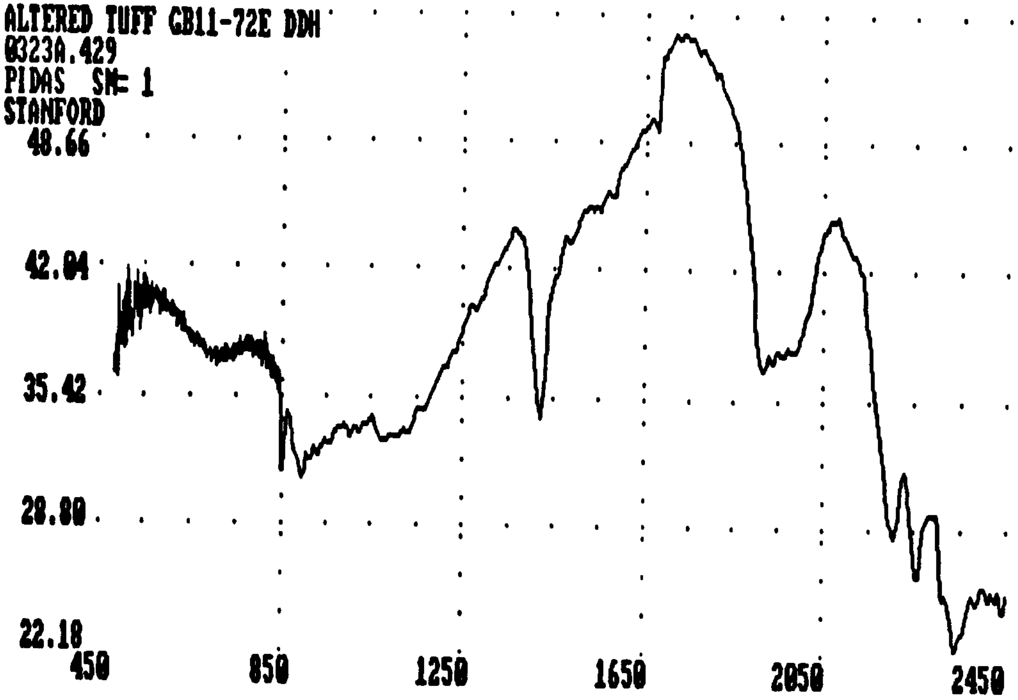
STANDARDS PDAS# 402 GB11-71 ?ALUNITE/PYROPH ALTRD TUFF YBK
H513.039
VIRIS SM= 3
STANFORD
35.07
29.51
23.96
18.41
12.85
500
900
1300
1700
2100
2500

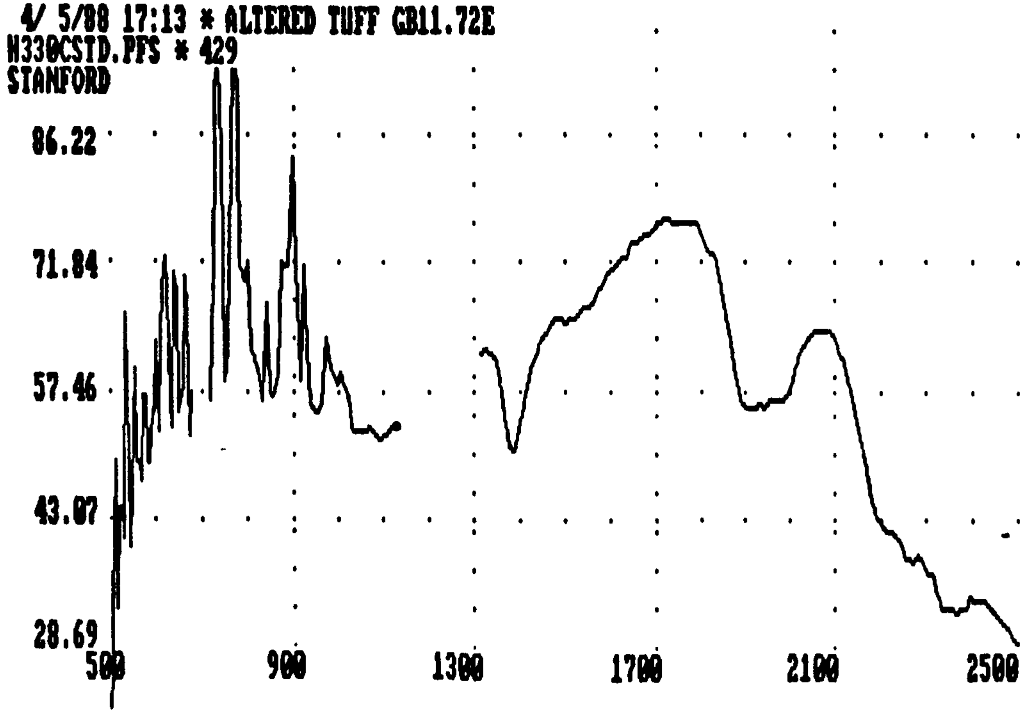


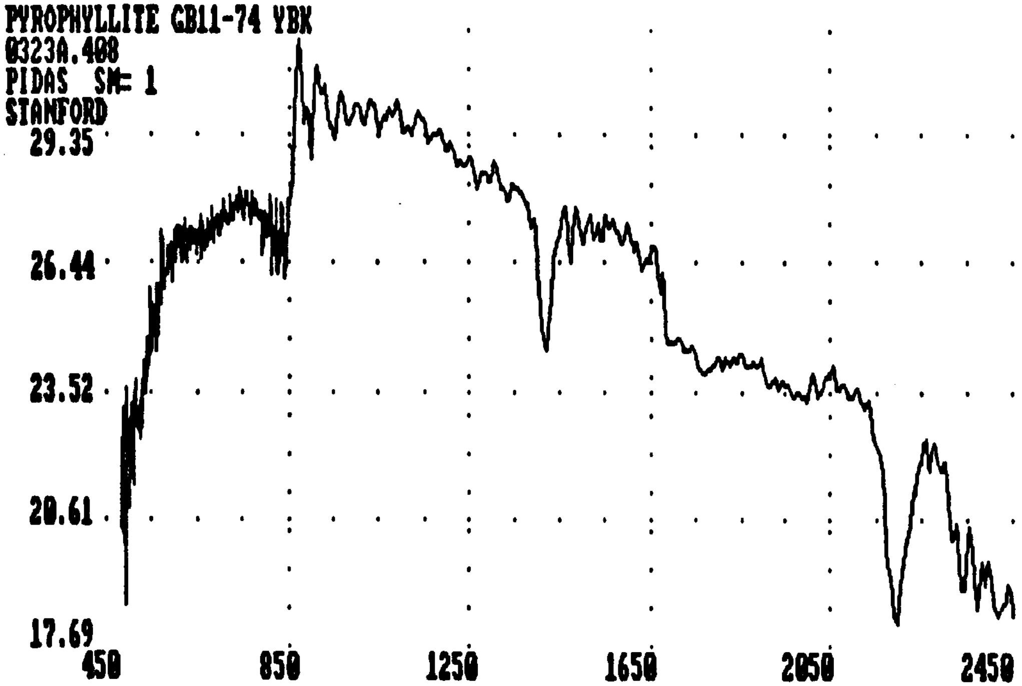
4/ 1/88 15:58 * GB11.71 PYROPH DDH YBK
H330CSTD.PFS * 402
STANFORD
61.11
45.83
30.56
15.28
0.00
900
1300
1700
2100
2500



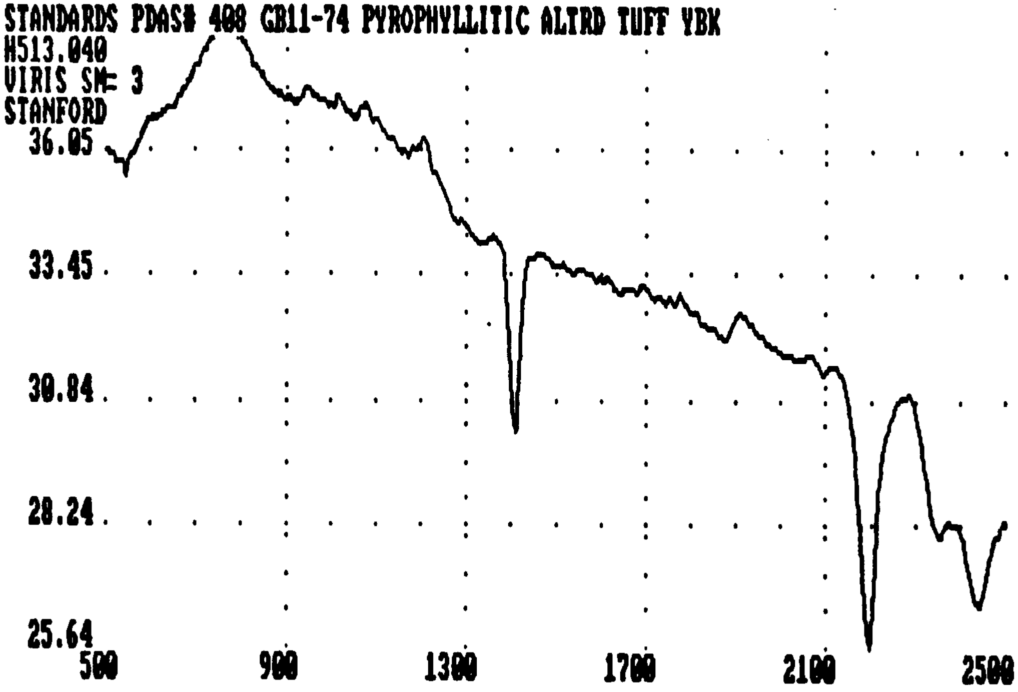
Nov 19 14:24 GB11-71 pyrophillite DDH S. Creek Alunite Hill $
NOV19KF.327
SFX440 SM= 1
STANFORD
47.00
40.35
33.70
27.04
20.39
400
800
1200
1600
2000
2400


ALTERED TUFF GB11-72E DDH
0323A.429
PIDAS SM= 1
STANFORD
48.66
42.04
35.42
28.80
22.18
450
850
1250
1650
2050
2450

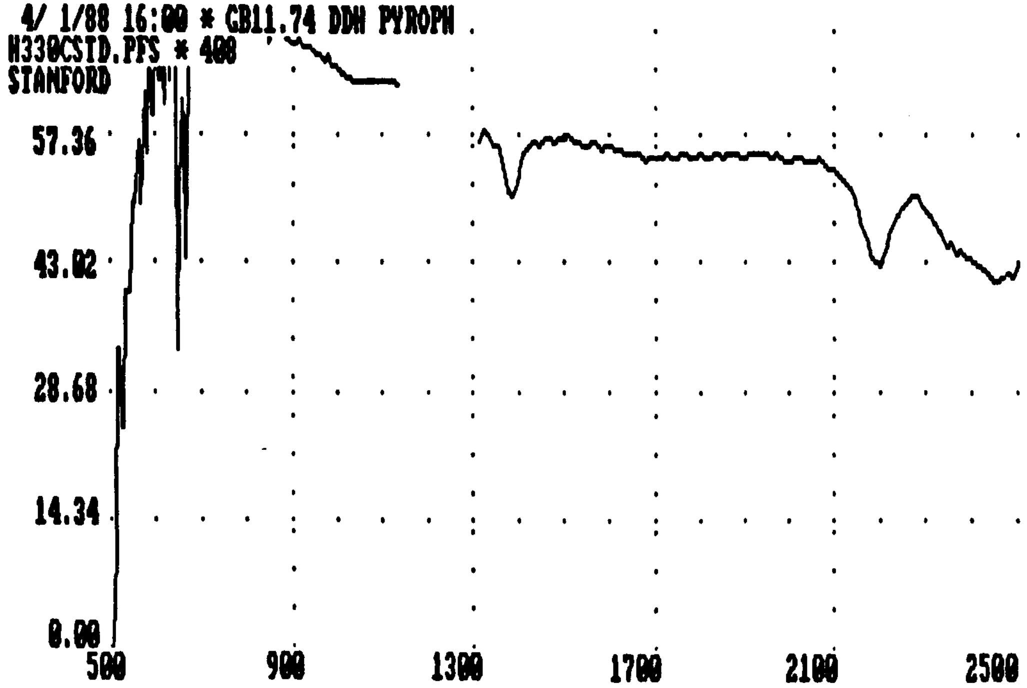

4/ 5/88 17:13 * ALTERED TUFF GB11.72E
N330CSTD.PFS * 429
STANFORD
86.22
71.84
57.46
43.07
28.69
500
900
1300
1700
2100
2500



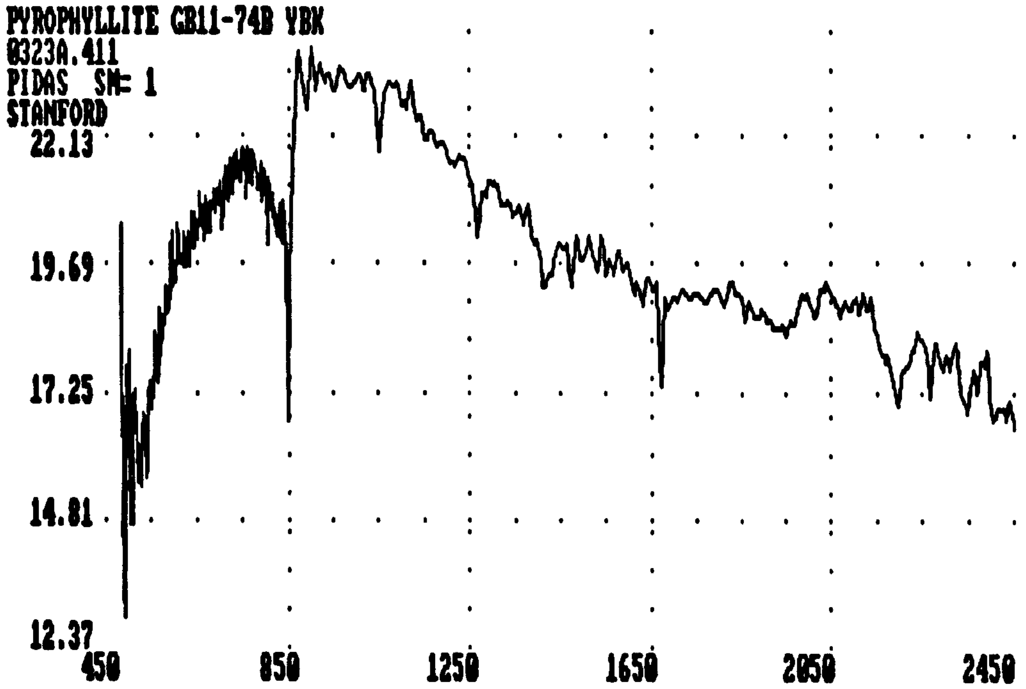
PYROPHYLLITE GB11-74 YBK
0323A.408
PIDAS SM= 1
STANFORD

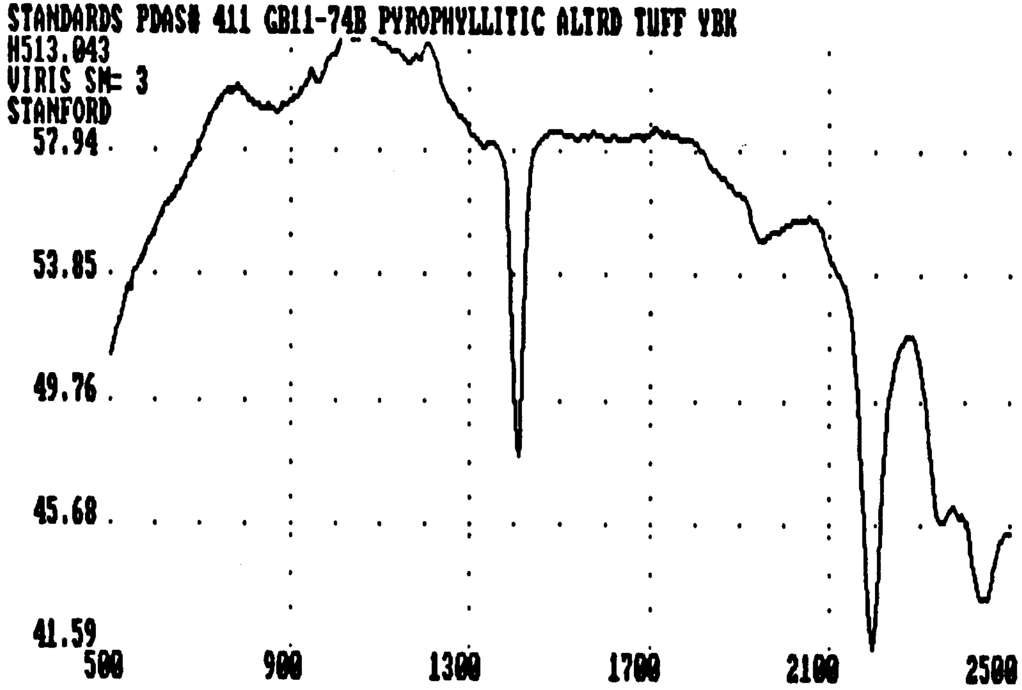


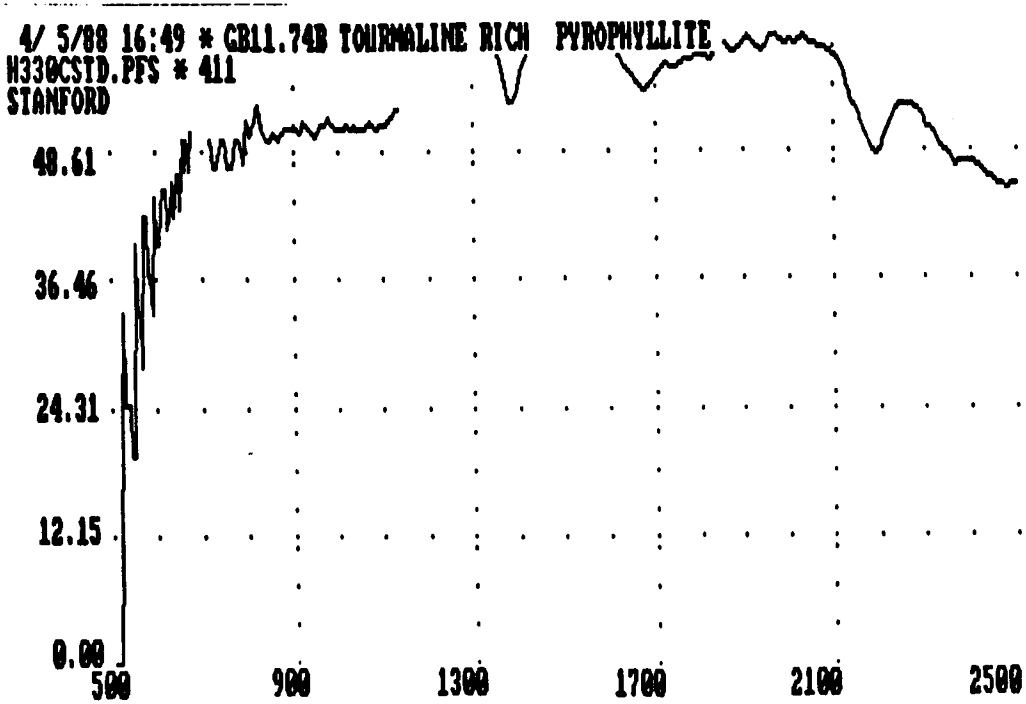
STANDARDS PDAS# 408 GB11-74 PYROPHYLLITIC ALTRD TUFF YBK
H513.040
VIRIS SM= 3
STANFORD

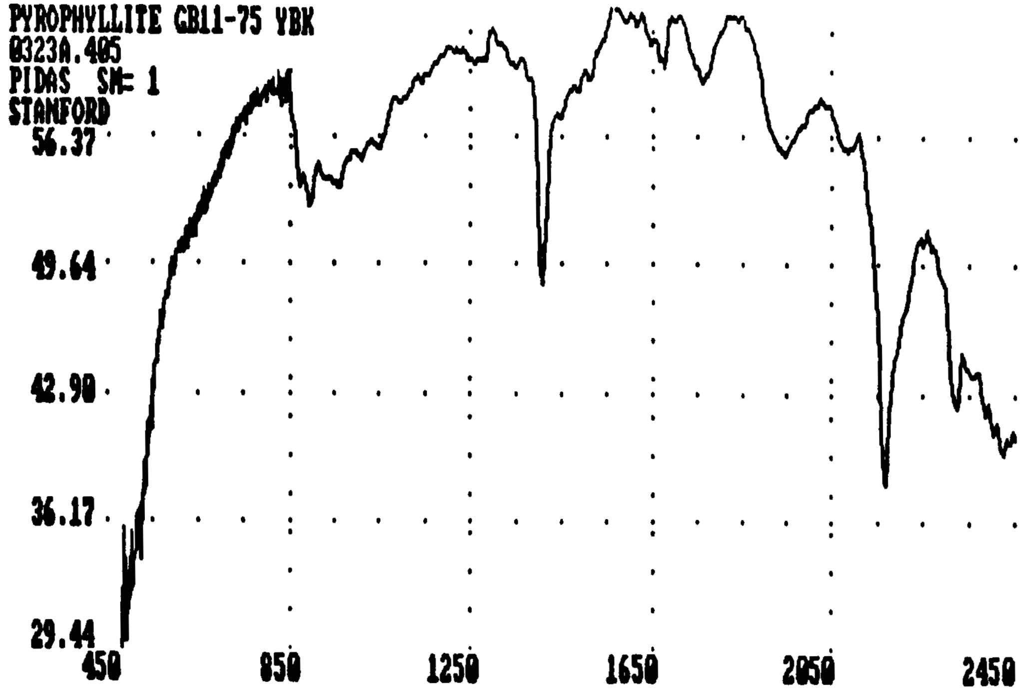


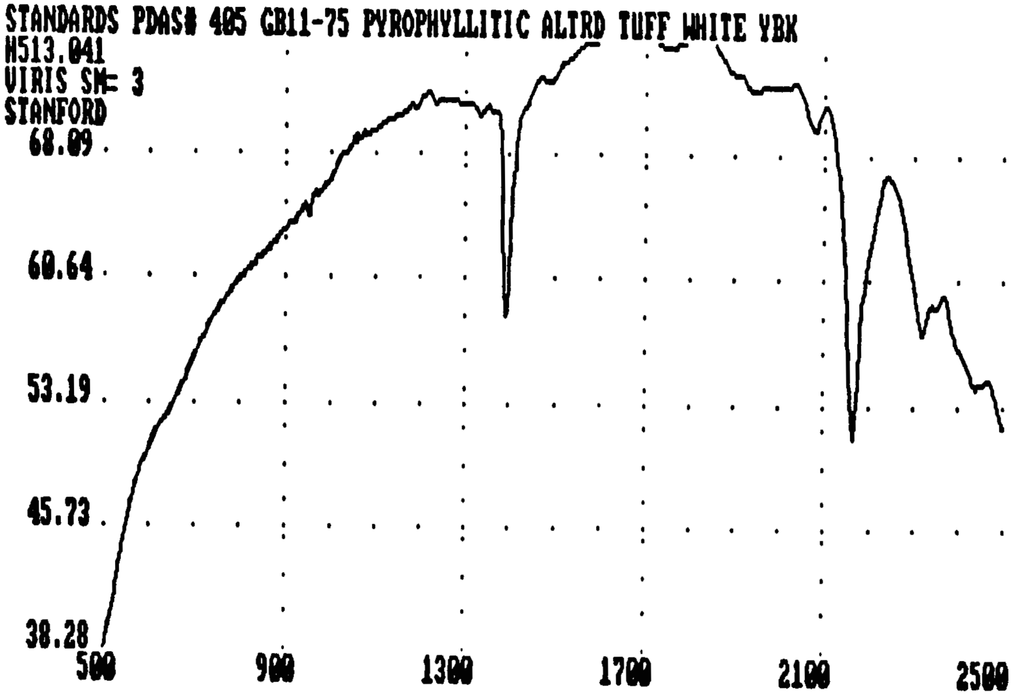
4/ 1/88 16:00 * GB11.74 DDH PYROPH
H330CSTD.PFS * 408
STANFORD

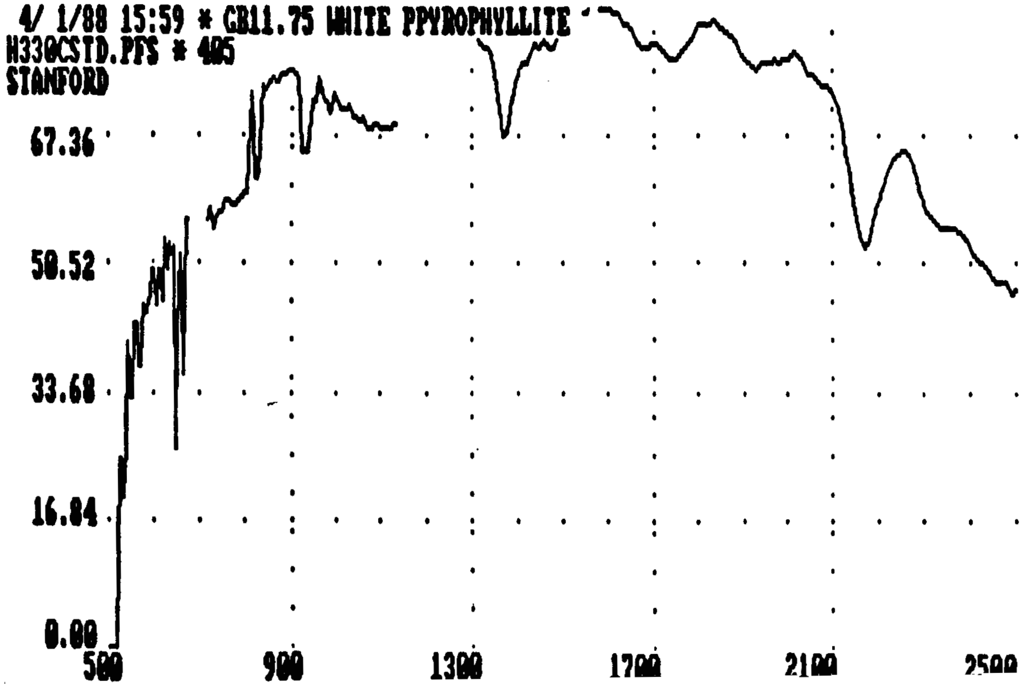

PYROPHYLLITE GB11-74B YBK
0323A.411
PIDAS SM= 1
STANFORD
22.13
19.69
17.25
14.81
12.37
450
850
1250
1650
2050
2450

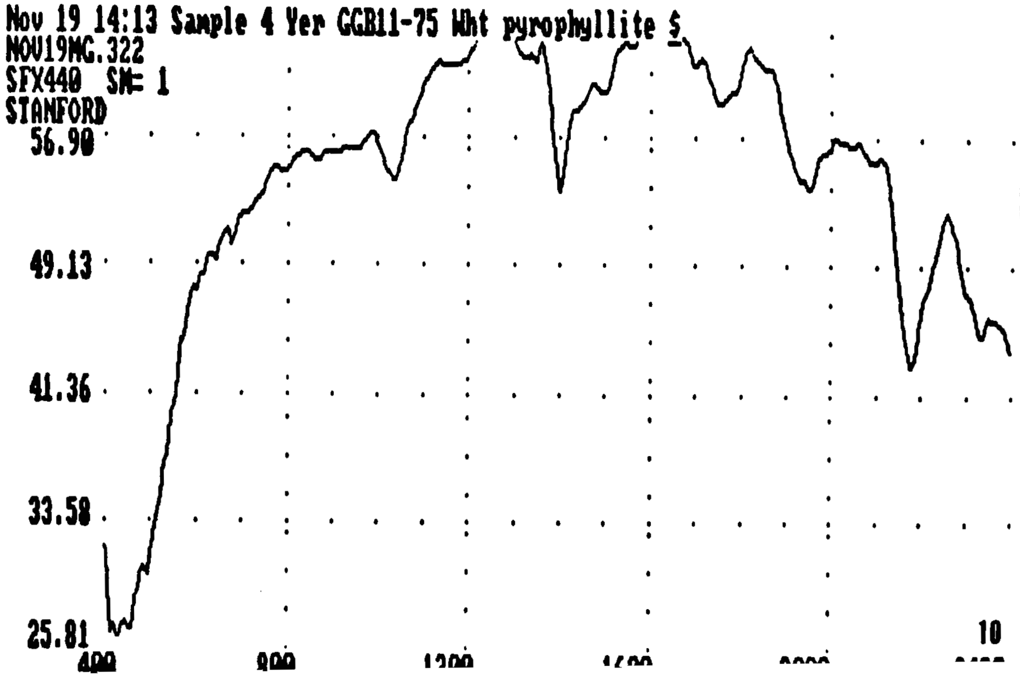

STANDARDS PDAS# 411 GB11-74B PYROPHYLLITIC ALTRD TUFF YBK
H513.043
VIRIS SM= 3
STANFORD
57.94
53.85
49.76
45.68
41.59
500
900
1300
1700
2100
2500


4/ 5/88 16:49 * GB11.74B TOURMALINE RICH PYROPHYLLITE
H330CSTD.PFS * 411
STANFORD
48.61
36.46
24.31
12.15
0.00
500
900
1300
1700
2100
2500

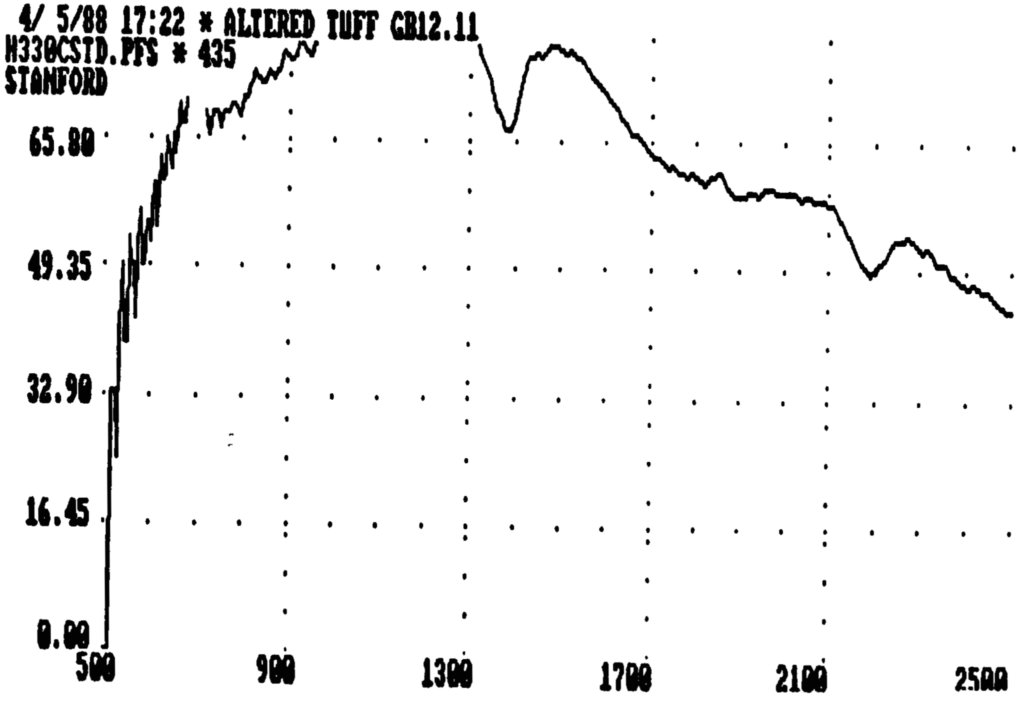

PYROPHYLLITE GB11-75 YBK
0323A.405
PIDAS SM= 1
STANFORD
56.37
49.64
42.90
36.17
29.44
450
850
1250
1650
2050
2450

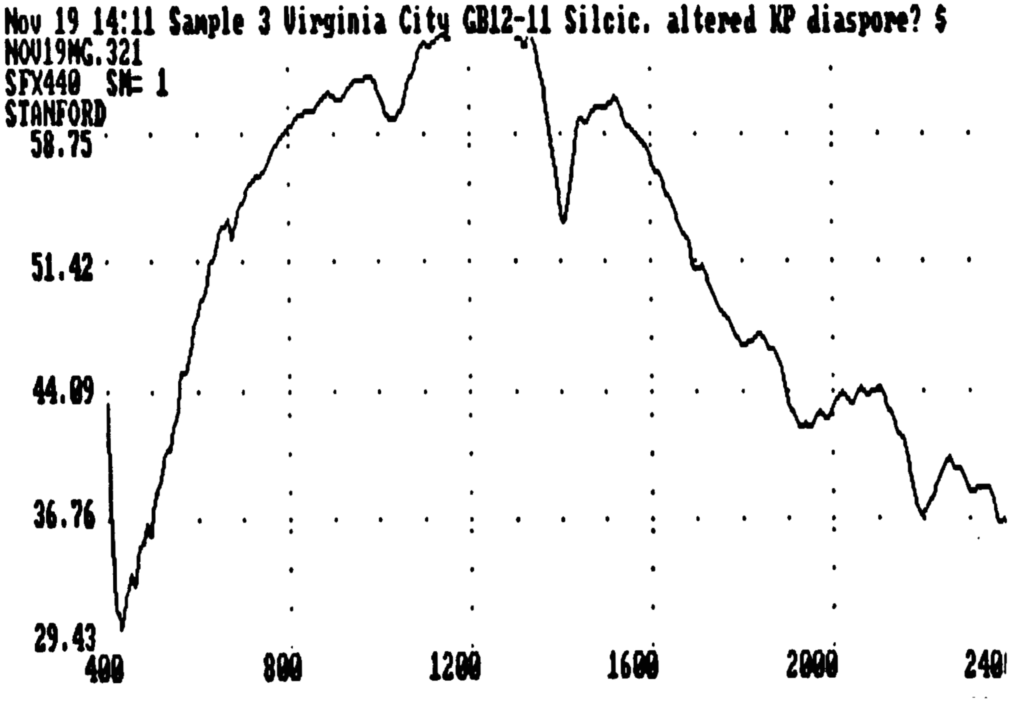

STANDARDS PDAS# 405 GB11-75 PYROPHYLLITIC ALTRD TUFF_WHITE YBK
H513.041
VIRIS SM= 3
STANFORD
68.09
60.64
53.19
45.73
38.28
500
900
1300
1700
2100
2500

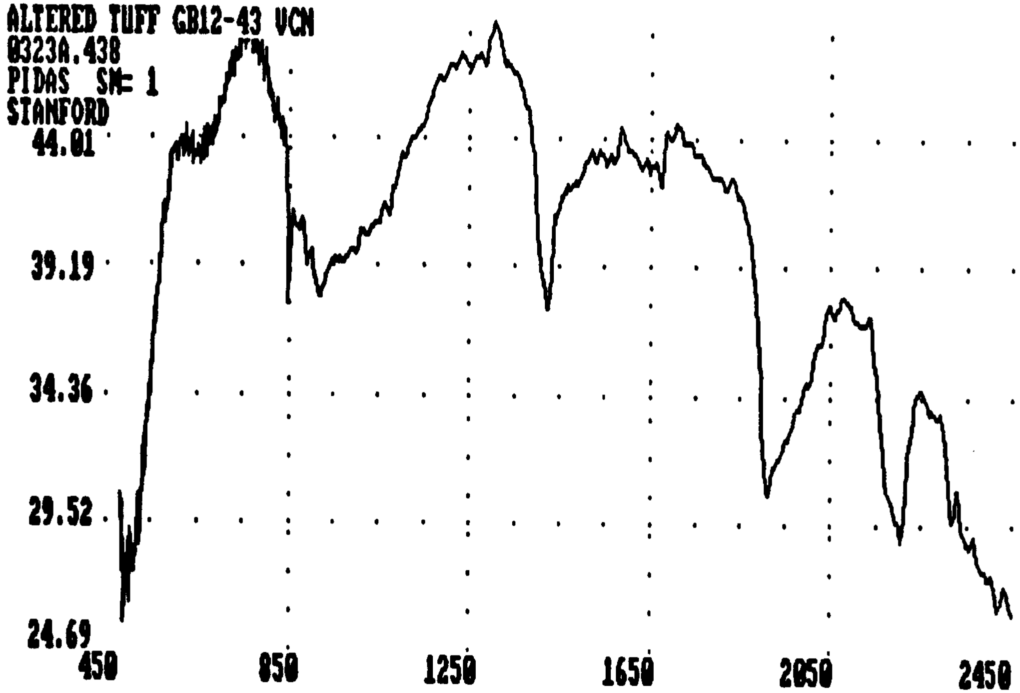

4/ 1/88 15:59 * GB11.75 WHITE PPYROPHYLLITE
H330CSTD.PFS * 405
STANFORD
67.36
50.52
33.68
16.84
0.00
500
900
1300
1700
2100
2500

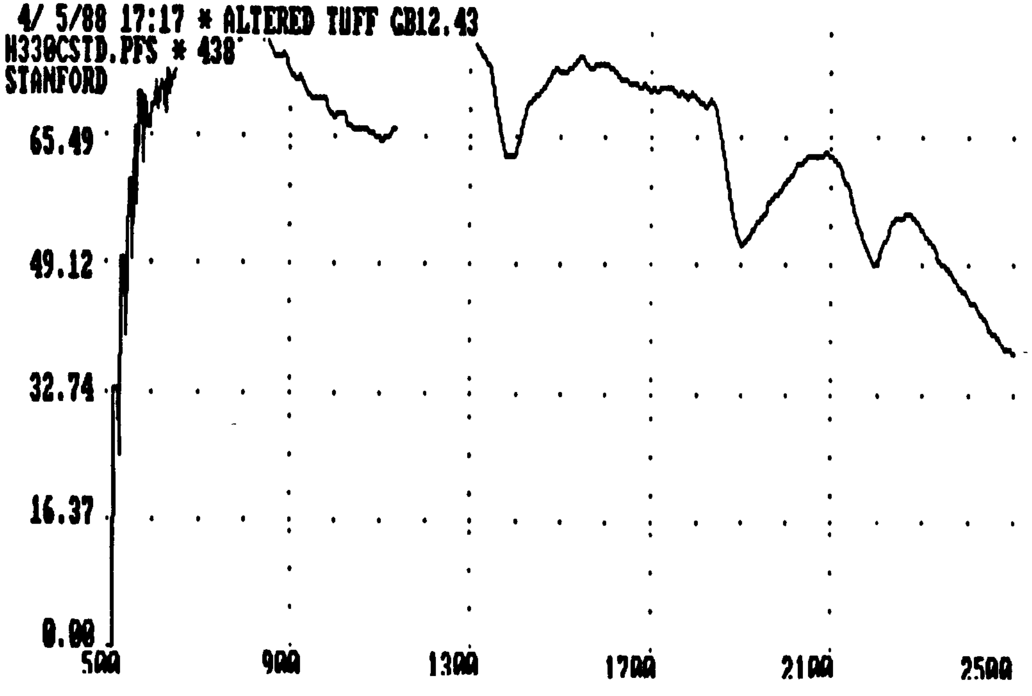

Nov 19 14:13 Sample 4 Yer GGB11-75 Wht pyrophyllite $
NOV19MG.322
SFX440 SM= 1
STANFORD
56.90
49.13
41.36
33.58
25.81
400
10

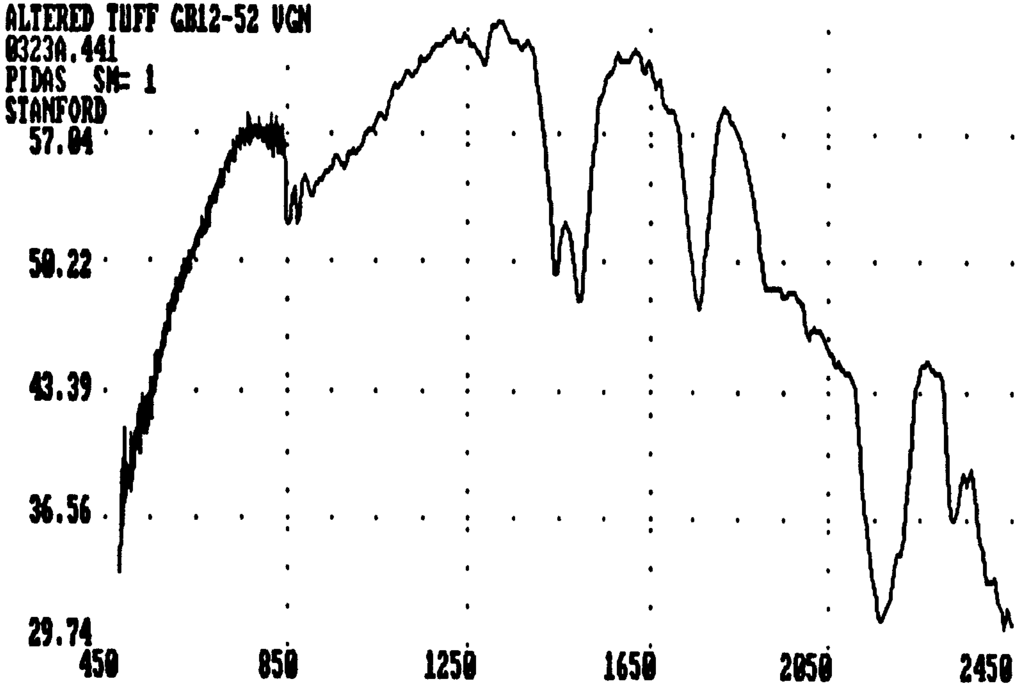

ALTERED TUFF GR12-11 VCE
0323A.435
PIDAS SM= 1
STANFORD
61.96
55.98
50.00
44.03
38.05
450
850
1250
1650
2050
2450

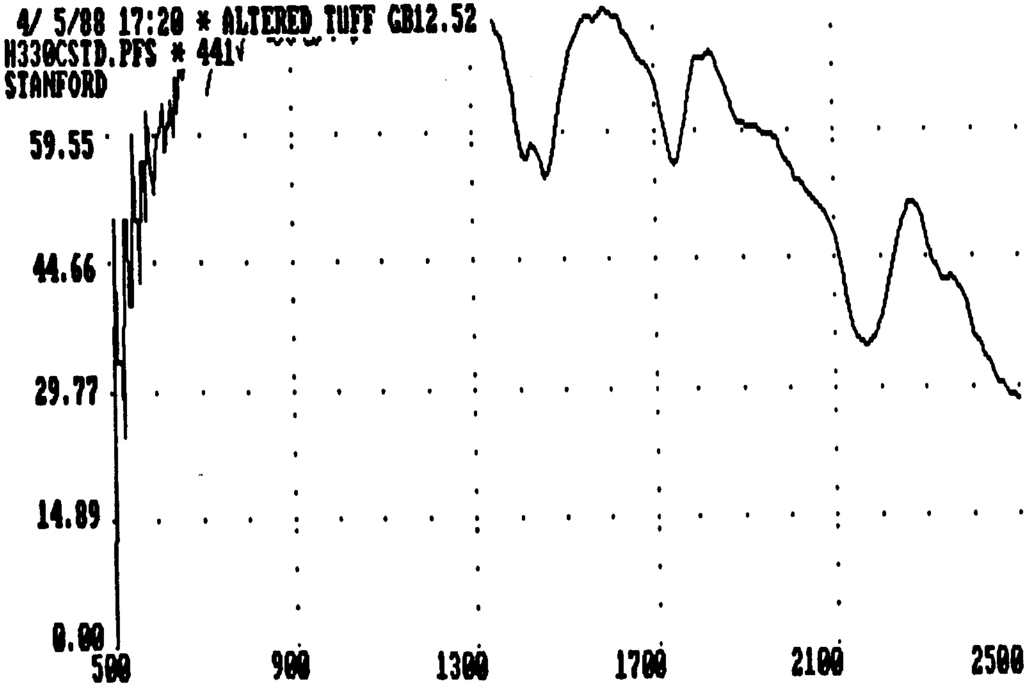

4/ 5/88 17:22 * ALTERED TUFF GR12.11
H330CSTD.PFS * 435
STANFORD
65.80
49.35
32.90
16.45
0.00
500
900
1300
1700
2100
2500


Nov 19 14:11 Sample 3 Virginia City GR12-11 Silcic. altered KP diaspore? $
NOV19MG.321
SFX440 SM= 1
STANFORD
58.75
51.42
44.09
36.76
29.43
400
800
1200
1600
2000
240


ALTERED TUFF GB12-43 VCN
0323A.438
PIDAS SM= 1
STANFORD
44.01
39.19
34.36
29.52
24.69
450
850
1250
1650
2050
2450


4/ 5/88 17:17 * ALTERED TUFF GB12.43
H330CSTD.PFS * 438
STANFORD
65.49
49.12
32.74
16.37
0.00
500
900
1300
1700
2100
2500


ALTERED TUFF GB12-52 VGN
0323A.441
PIDAS SM= 1
STANFORD
57.04
50.22
43.39
36.56
29.74
450
850
1250
1650
2050
2450


4/ 5/88 17:20 * ALTERED TUFF GB12.52
H330CSTD.PFS * 441
STANFORD
59.55
44.66
29.77
14.89
0.00
500
900
1300
1700
2100
2500