823721

Ground Radiometer Survey of the Spectral Reflectance of Trees

Minnova Inc. Samatosum Mt. Property, B.C.

for

Minnova Inc.

Produced by:

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In Association
with MONITEQ Ltd.

October, 1987.

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October 26, 1987

Dr. R. McLachlin
4274 Doncaster Way
Vancouver, B.C.
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Dear Rory:

Enclosed please find the report I described to you recently on the telephone. I would appreciate your reviewing it and providing me with a critique of the methodology, quality of data, and interpretation. My particular interest is in establishing whether or not a multi-spectral airborne survey could provide sufficient resolution to detect areas where vegetation is stressed as a result of growth near toxic mineralization, (e.g., Cu, Zn, Pb, As, Sb). Obviously, other factors could also stress vegetation but "stress anomalies" could easily be checked by ground follow-up.

I am particularly concerned with this report because (a) our own people have no experience in this field, and (b) our field personnel who assisted in data collection unanimously developed the opinion that the individual carrying out the work (Laurim) is a complete incompetent. Nevertheless, the principal remains intriguing and I would appreciate your opinion as to the best means of follow-up to this initial orientation work.

Best regards,

MINNOVA INC.

David H. Watkins/mlg

David H. Watkins
Vice-President, Exploration

DHW:mlg
Enclosure

cc: Alex Davidson

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Krajina, V.J., K. Klinka, J. Worrall. 1982. Distribution and ecological characteristics of trees and shrubs of British Columbia. University of British Columbia, Faculty of Forestry. Faculty of Forestry Publication. 131p.

Engelmann spruce *Picea engelmannii*

Pacific silver fir *Abies amabilis*

Subalpine fir *Abies lasiocarpa*

Lodgepole pine *Pinus contorta*

Douglas-fir *Pseudotsuga menziesii*

Trembling aspen *Populus tremuloides*

Summary

An orientation survey using a Barringer Hand-Held Ratioing Radiometer (HHRR) was conducted on the Samatosum Mt. Property of Minnova Inc. to determine if mineralized and non-mineralized zones could be distinguished from the spectral characteristics of trees in the 650 to 800 nanometer (nm) range. This spectral range corresponds to the chlorophyll red-edge characteristics of normal green vegetation. In vegetation stressed by mineralization, there is often a shift of the red-edge towards the blue or red portion of the spectrum. This orientation survey was conducted to determine the appropriateness of an airborne imaging survey to map the same effect, as a method of locating anomalous zones of mineralization.

Six tree species were sampled and were analyzed using the HHRR. The six species were Engelmann Spruce (Picea engelmanii), Ambilis Fir (Abies ambilis), Alpine Fir (Abies Iasiocarpe), Lodgepole Pine (pinus contorta), Douglas-Fir (Pseudotsuga menziesii) and Trembling Aspen (Populus tremuloides). Reflectance data and normalized reflectance data were analyzed to determine if there was a strong variation between the leaf-needle samples over mineralized sites and the leaf-needle samples over non-mineralized sites.

Tree samples from mineralized areas were obtained from soils overlying or down-slope of the Main Mineralized Zone and the original arsenic zone of Rae Gold. The deposit is located near the contact between mafic volcanic pyroclastics and a complex sedimentary unit consisting of chert, argillite, siltstone and sandstone. Two major types of mineralization were determined thus far:

1) bedded pyritic, massive to semi-massive sulphides with sphalerite, tetrahedrite, chalcopyrite and galena

and

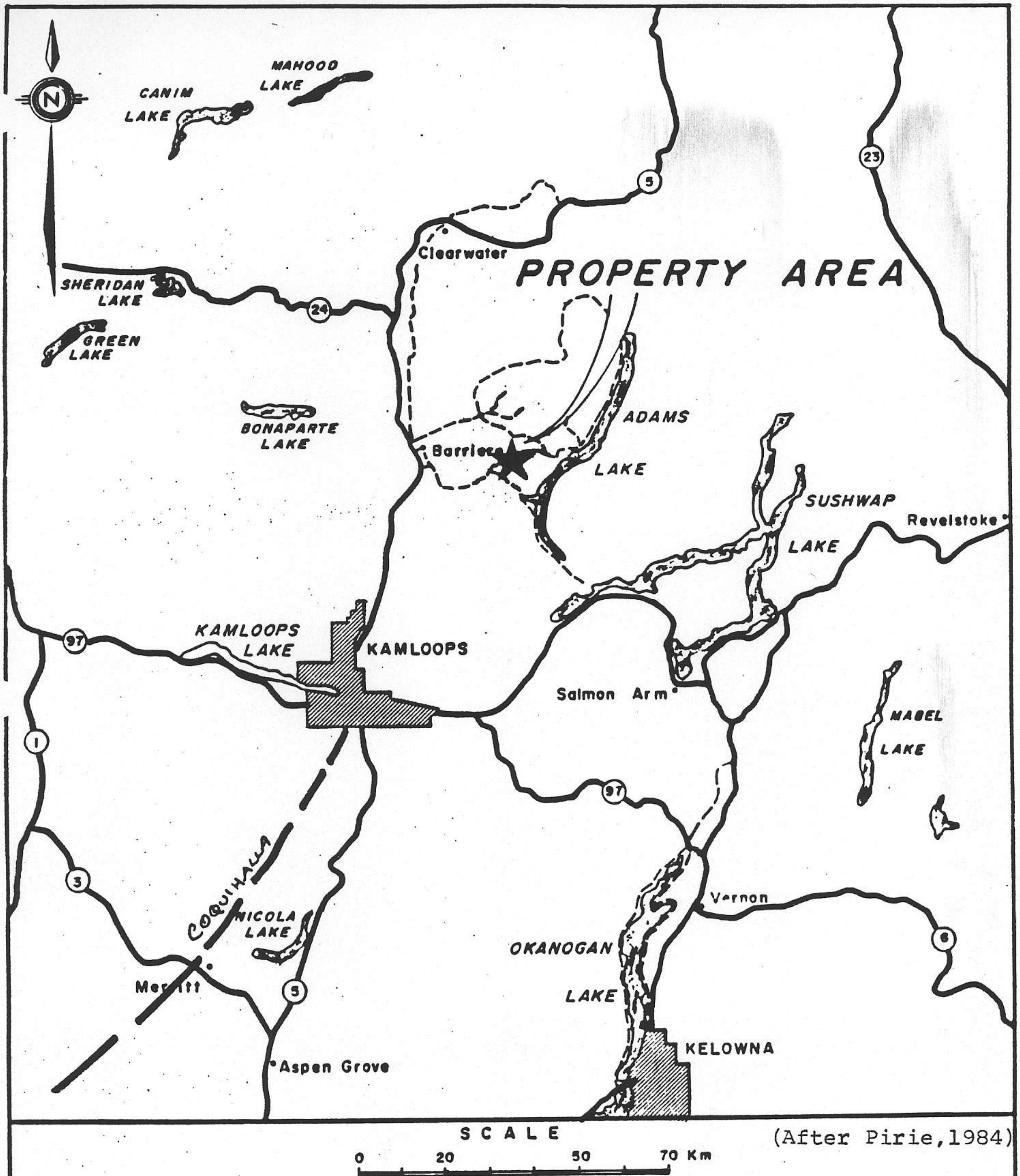
2) massive galena-sphalerite (tetrahedrite - chalocopyrite) ore. (A.J. Davidson, 1987)

Summary (cont'd)

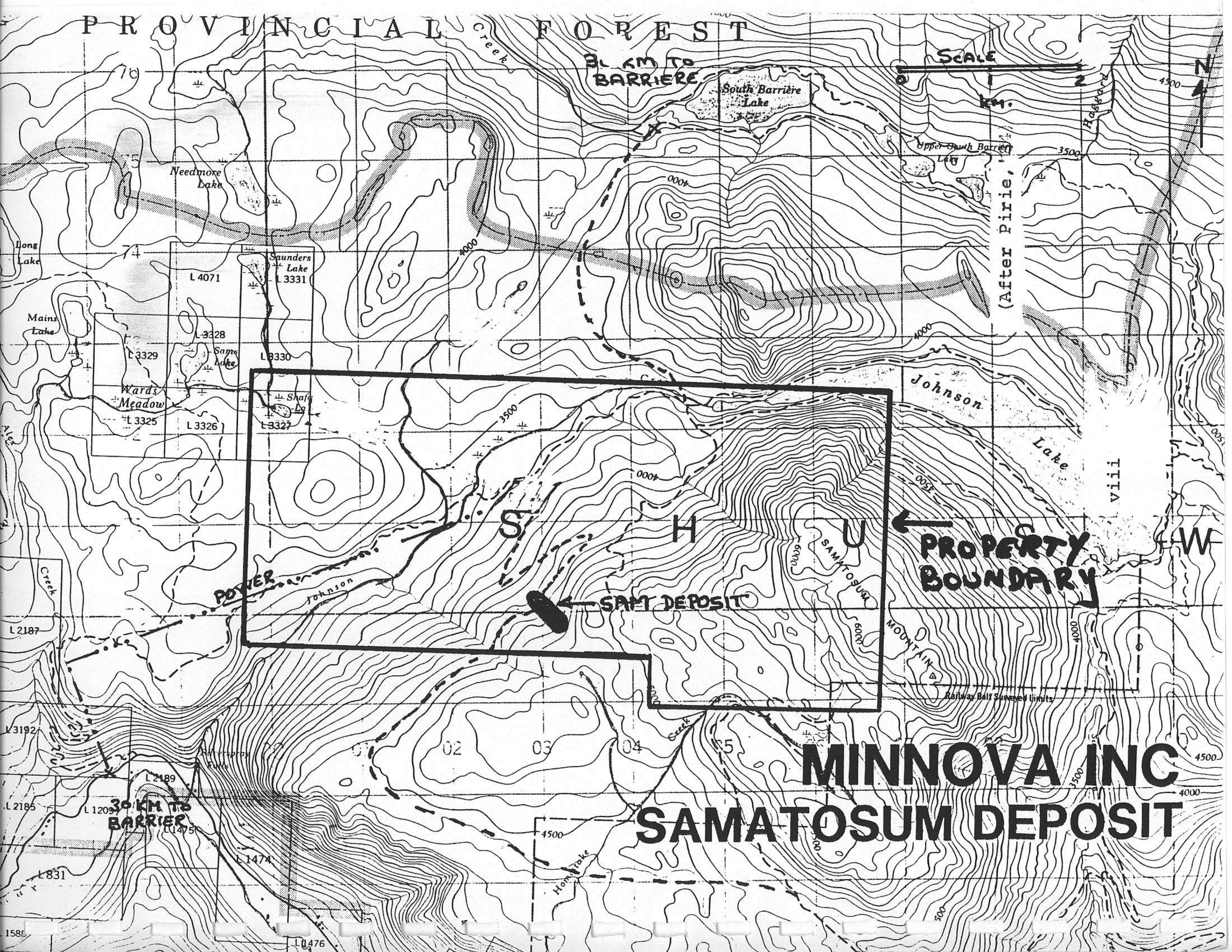
Portions of the property have been subjected to 'slash and burn' and parasitic activity was common on branchlets of Engelmann spruce. These parameters and others may result in non-mineralized anomalies; thus, data interpretation will be required to distinguish these anomalous areas.

The result of the survey is presented in a series of graphs for all six tree species as well as two tables (Table 1 and Table 2.) summarizing the spectral characteristics of the six species. Douglas Fir shows a blue-shift at the red-edge slope of 3.5 to 4.0 nm (Chart 3d), Lodgepole Pine shows a red-shift at the red-edge of 4 nm (Chart 1d), and Trembling Aspen shows a red-shift at the red-edge slope of 4 nm (Chart 6d). This amount of shift is similar to data obtained from other tree species from airborne/ground-based surveys of vegetation (pers. comm. Dr. J. Miller, York University) and will provide a contrasting spectral signature between the mineralized and background data. In addition, Alpine Fir showed a blue-shift at the red-edge slope of 2 to 3 nm.

Due to the presence of these marked spectral features, it is recommended that an airborne survey be undertaken to determine anomalous mineralized zones. Since the most favourable time for conducting airborne surveys of spectral reflectance in vegetation is the "Autumn Window" when stressed vegetation undergoes "early leaf senescence", it is further recommended that the airborne survey be undertaken during the period mid-July to mid-August after full-leaf flush and well-before any early frost.



(After Pirie,1984)



PROVINCIAL FOREST
31 KM TO BARRIERE
SCALE
0 1 2
KM.
N
South Barrière Lake
Upper South Barrière Lake
Needmore Lake
Long Lake
Saunders Lake
Mains Lake
Sams Lake
Wards Meadow
Shaft Lk
L 4071
L 3331
L 3328
L 3329
L 3330
L 3325
L 3326
L 3327
L 2187
L 3192
L 2189
L 2185
L 1475
L 1474
L 831
L 1476
Johnson Lake
(After Pirie,
viii
S H U S W
PROPERTY BOUNDARY
SAM DEPOSIT
POWER
Johnson
SAMATOSUM MOUNTAIN
Railway Belt Surveyed Limits
Creek
02
03
04
05
4500
4000
3500
6000
30 KM TO BARRIER
MINNOVA INC
SAMATOSUM DEPOSIT

INTRODUCTION

The Minnova Inc. property is located about 50 km northeast of Kamloops, B.C. (map i) and is adjacent to joint venture partner, Rae Gold. A radiometer orientation survey was conducted using trees from the Samatosum Mountain mineralized zone and adjacent backgroud areas fo Minnova Inc. (map ii). The purpose of the orientation survey was to determine if mineralized zones and non-mineralized zones could be distinguished from the spectral characteristics of the trees. This work was done as a prelude to undertaking a remote sensing survey using airborne imaging of the spectral characteristics of various tree species as a method of locating anomalous mineralized zones. A few trees were surveyed from Rae Gold, as needed (permission by G. Evans).

Six major tree species were sampled which were found to be present in both the mineralized and the background sites (maps I, II, III in pocket). These were Engelmann Spruce (picea engelmanii), Amibilis Fir (Abies amabilis), Alpine Fir (Pseudotsuga menziesii) and Trembling Aspen (Populus tremuloides). In addition, occasional alder and cottonwood were present but were not sampled because they were not adequately represented in either or both the mineralized and the background areas.

A layer of first-year growth was analyzed using the Barringer Hand-Held Ratioing Radiometer (HHRR) which was fitted with 10 narrow band-width filters whlch include portions of the visible spectra, the red-edge slope and the infrared spectra from 650 to 800 nm.

The technique of determining vegetative stress over a mineralized site is based on the presence of certain minerals which act as toxins. These 'stressor' minerals which occur in bedrock migrate from the mineralized zone through the soil to the tree roots (Miller, et al, 1986). These stressor minerals such as Cu, Pb, Zn, As, etc are associated with Au and Ag but Au and Ag do not themselves affect the physiology of plants (Goetz, et al, 1983), (Singhroy, et al, 1986).

The Minnova/Rae Gold property contains Ag and Au associated with elevated values of As, Cu, Pb, Zn, Sb. The mineralized zone contains abundant copper in the form of malachite, azurite and some chalcopyrite. Arsenic from arsenopyrite is very abundant as are Pb from galena and Zn from 'honey' sphalerite; as well, tennantite-tetrahedrite provide Cu, As and Sb. The mineralized zone dips roughly east and is overlain by a thick sequence of mafic volcanics which are thicker in the up-slope direction. Drilling has outlined the mineralized zone to 800 ft below the volcanics. (Pers. comm. G. Evans, proj. geol.)

Stressed tree samples were taken from soils directly overlying the mineralized zone, from mineralized bedrock and down-slope of mineralization where dispersion halos result from the migration of ions. Unstressed tree samples were taken from adjacent areas with a few samples from the cherty outcrop up-slope of the main mineralized zone.

The stressed tree samples occur in areas with relatively high arsenic values and the Samatosum property in general is an area of exceptionally high arsenic values. Drillhole RG-25 contained near-surface mineralization of 16% As, 7% Zn, 5% Pb and 1% Cu. (Pirie, 1984 Company Rept.). Strong sulphide mineralization is visible in quartz veins in the main mineralized zone of Minnova which is exposed at the surface. This portion of the property is overlain by soil approximately 3 meters thick and extends 100 ft to the south where it is overlain by a sequence of the volcanics (pers, comm. G. Evans). This area is thus heavily mineralized. The areas at elevations below the mineralized zones contain dispersion halos in soils due to down-slope migration of metallic ions, and are also considered mineralized, although soil data was not available at this time.

In general, while mineralized zones may be relatively narrow, soil dispersion halos due to the migration of ions from mineralized areas through the soil to the roots of trees result in stressed trees and the dimensions of the trees' canopies result in a much wider area being affected, thereby facilitating airborne detection. As a result, targets which are not visible due to overburden or targets which are narrow can be delineated by the presence of stressed vegetation as determined from field radiometric and airborne surveys.

TREE SAMPLING AND SAMPLE PREPARATION

Sampling

Six different tree species were sampled on the Samatosum Mt. property. The species sampled were Engelmann Spruce (Picea engelmanii), Amibilis Fir (Abies amabilis), Alpine Fir (Abies iasiocarpe), Lodgepole Pine (Pinus contorta), Douglas Fir (Pseudotsuga menziesii) and Trembling Aspen (Populus tremuloides). In addition, occasional alder and cottonwood were present as well as the very rare hemlock. The tree species were sampled using a Barringer Hand-Held Ratioing Radiometer (HHRR) Mark II in the non-ratioing mode.

Each set of samples was composed of a sub-set of mineralized and un-mineralized or 'background' samples. A total of 57 samples were collected from soil overlying the main mineralized zone, from soils below the mineralized zone and trenches, and from adjacent background areas. (See maps I, II, III in pocket). Leaf-needle samples were taken of full branchlets which included first and second year growth. The samples were placed in plastic bags, moistened with water with a wet paper towel added.

Sample Preparation

Preparing the samples for analysis included providing a bottom layer composed of branchlets of first and second year growth to block out the black background. This was topped by a layer of first year growth which filled the Field of View. Samples were read using the HHRR which was fitted with 10 narrow-band width filters between 650 nanometers (nm) to 800 nm (see below) which includes portions of the visible spectra, the red-edge slope, and the infrared spectra.

Barringer Hand-Held Ratioing Radiometer (HHRR)

The Barringer HHRR is an electro-optical instrument with electronic readout designed to be used in the earth sciences and was developed by the California Insitute of Technology at Jet Propulsion Laboratory, Pasadena during research sponsored by NASA. It measures the energy reflected by a target, covering the visible and short infrared regions from 0.4 microns to 2.5 microns (see Appendix B).

It is a self-contained, dual beam ratioing radiometer with two optical trains directed at the same target and privides a continuous digital read-out of the radiance from two optical trains. Each optical train has a separate 5 position filter wheel for selection of spectral bands. Each individual channel signal or the ratio of the two channels can be displayed for identification of a particular target, on the basis of known spectral characteristics of the target. The instrument can provide pre-selected narrow bands in the spectral range from 0.4 to 2.5 micrometers.

In this study, the instrument was used in the non-ratioing mode and was fitted with 10 narrow band-width filters at 650, 680, 685, 703, 713, 733, 743, 753, 782 and 800 nm. A reflectance standard made of Fiberfax was used which has a high reflectance throughout this spectral region.

GEOLOGY/SITE DESCRIPTION

Geology

The deposit is located near the contact between mafic volcanic pyroclastics and a complex sedimentary unit consisting of chert, argillite, siltstone and sandstone. The deposit appears to be lying in the "easterly overturned limb of a north-west plunging syncline," (A.J. Davidson, 1987) with a strike length of 450 m, a dip extending up to 150 m, with thickness ranging from 0.1 m to 12 m (average thickness 4 m). Two major types of mineralization have been determined thus far:

"1) bedded pyritic, massive to semi-massive sulphides with sphalerite, tertrahedrite, chalcopyrite and galena

and

2) massive galena-sphalerite (tetrahedrite - chalcopyrite) ore." (ibid)

Site Description

1.) The Main Mineralized Zone was covered with new drill roads and drill sites which have disrupted and removed some of the tree stands. Most of the property has not been disturbed by road building and the disturbance from drill roads is of a local nature and in an area already explored and drilled and hence is not critical in the airborne portion as the anomalous zone has been determined.

2) Elevations range up to 4500 ft. in the Main Mineralized Zone with overburden varying from a few metres thick over the Mineralized Zone to several dozen meters thick down-slope of the trenches but since several of the tree species have wide-ranging and/or deep root systems, the overburden is not a problem.

Site Description (cont'd)

3.) Within a fifty mile radius of the property, there are two paper mills and three lumber mills and as a result there is a frequent haze due to smoke and smog. The haze is confined within the valleys by the surrounding mountains and is not easily dispersed.

While flyover missions are regularly conducted over smog covered areas with excellent results, ideal conditions of clear, clean skies are preferred.

4.) Portions of the area have been subjected to logging and reclamation of the land by the lumber companies which involves burning the debris and tree stumps. In at least one instance the 'burn' 'jumped' the fire-line and scorched adjacent trees. An investigation of this area showed trees scorched for over 100 metres. No trees were, as a result, sampled from this area.

5.) Western Red Cedar (Thuja plicata) seen above the Main Mineralized Zone was very rare and shrub-like. Elsewhere on the property, Red Cedar was present in both overstory and understory but were not generally common. This is fortuitous as Red Cedar trees had 20 to 30% dry leaf-needles due to leaf-fall of second and third year growth. Since Red Cedar was localized at lower elevations and was rare and srub-like (4 to 5 ft tall) at higher elevations it will not be problematic for an airborne survey.

6.) Lodgepole Pine in the Kamloops vicinity was said to be under stress by the pine beetle but no evidence of any parasite was seen in the Lodgepole Pines in the Samatosum Mt. area.

7.) An interesting feature of the area is the presence of trees rooted in solid bedrock. Some of these trees such as Douglas Firs and Lodgepole Pines were over 80 ft. tall. Since the depth of the tree-root system can not be ascertained, if a mineralized lens should exist adjacent to tree roots, then trees would show up as stressed although the upper bedrock surface may be one considered to be background. Lodgepole Pine sample BLP-003 was taken from background bedrock along with samples BLP-001 and BLO-002, yet plots much higher in reflectance than the other two. Interestingly enough it is a taller tree with a correspondingly larger root system suggesting the possibility that it is a stressed tree due to possible mineralization adjacent to the area or at depth.

While this feature offers an interesting tool to the explorationist it should also provide a caution to the mining engineer especially in areas of incompetent rock. For example, a sample of Douglas Fir 90 ft. tall was taken over mineralized outcrop. The root system of the Douglas Fir is "strong and wide-spreading" and the taller and older the Douglas Fir, the larger the root system. Some Douglas Fir trees are over 1000 years old. (Hosie,1979).

DATA ANALYSIS AND RESULTS

A series of plots of individual curves of normalized reflectance data and raw reflectance data were produced. The mean of the mineralized curves and the mean of the background curves for reflectance data and normalized reflectance data were plotted to determine if there was a variation between the trees from mineralized sites and the trees from background sample sites.

It is well-documented through field and laboratory studies that vegetation stress can be manifested as changes in spectral reflectance. Such changes may occur in the following ways:

1) in the magnitude of the green reflectance at 550 nm

2) in the magnitude of the 680 nm reflectance at the chlorophyll absorption maximum

3) in the position or the shape of the red reflectance edge from 680 to 800 nm, and/or

4) changes in the magnitude of the infrared reflectance shoulder at wavelengths greater than 780 nm.

It is possible for any or all of these changes to serve as indicators of vegetative stress which can be mapped using suitable field or airborne remote sensing instruments (Hare, et al, 1986).

In the raw reflectance data of the Samatosum Mt. property vegetation, an analysis of the infrared shoulder (4 above) was undertaken because in the non-normalized data a significant variation between the mineralized and background samples can be determined from the separation at the amplitude of the infrared plateau (Miller, et al, 1986). In the normalized data a significant variation between mineralized and background samples can be determined by a blue shift at the red-edge slope or a red-shift at the red-edge slope. (3 above) (see Appendix A).

Data Analysis

The data consist of information obtained from the analysis of six tree species (see above) formed of two sub-sets, one sub-set termed mineralized and the other sub-set termed background samples. A reflectance standard composed of white Fiberfax was read as well as each tree sample to obtain the percent reflectance at each wavelength. The results were plotted on four graphs for each tree species.

The first graphs of each species, 1a, 2a, 3a, 4a, 5a, 6a, show the individual curves of both the mineralized and the background samples of 'percent reflectance' versus 'wavelength'. A simple mean for each point of the mineralized samples was obtained from each wavelength and plotted and a simple mean of each point of the background curves was obtained and plotted on graphs for each species (1b, 2b, 3b, 4b, 5b, 6b) as two separate curves to determine the mean variation of the reflectance at the infrared shoulder of mineralized samples versus background samples.

All of the curves were normalized to a zero and a 'one' by subtracting the lowest values from all of the other values on a curve and by dividing the difference of the maximum and the minimum into the above. The normalized data yields a curve that has a shape which is independent of plant morphology and geometry. The results of the individual curves are plotted on graphs 1c, 2c, 3c, 4c, 5c, 6c.

Mean curves of the normalized data were obtained by the same method as used in the raw reflectance mean curves. The result was two mean curves, one for the background and one for the mineralized which are plotted for each species on graphs 1d, 2d, 3d, 4d, 5d, 6d.

Results

Lodgepole Pine (Pinus Contorta)

Lodgepole Pine ranges over most of British Columbia, from middle mountain to sub-alpine elevations. It may be found in pure stands or with other species (Hosie,1979) (Lyons,1952.)

On the Samatosum Mountain property it is one of the more common species especially at elevations immediately below the Main Mineralized Zone. In the overstory it is found with Engelmann Spruce, Amibilis Fir and some Douglas Fir. Lodgepole Pine is found in a number of diferent soils but commonly grows best on well-drained loam. It is also found on 'stony ridges' (Hosie,1979) and on the Samatosum property several Lodgepole Pines were sampled which were growing in solid outcrop.

Lodgepole Pine may attain heights of 100 feet and a trunk diameter of 2 feet (Ibid). Trees on the property ranged up to 80 to 90 feet or more. Some of these trees were sampled, where possible.

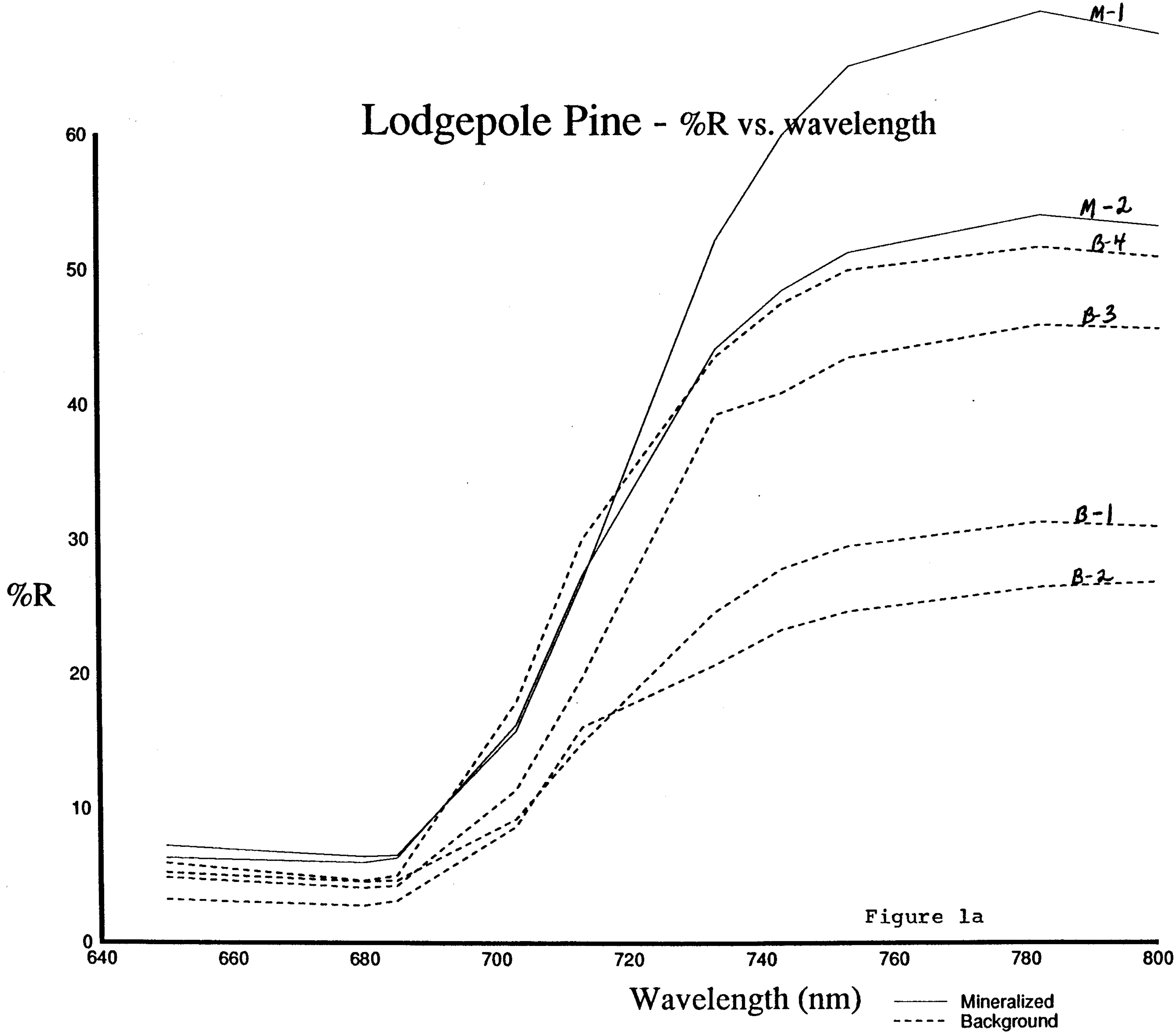
A plot of the reflectance versus wavelength (nm) in chart 1a shows a range in reflectance of 42% at the infrared spectra 'shoulder' for total mineralized and background. Samples B-2 and B-1 are background samples, samples B-3, B-4 and M-2 are threshhold samples and sample M-1 is a relatively heavily stressed sample.

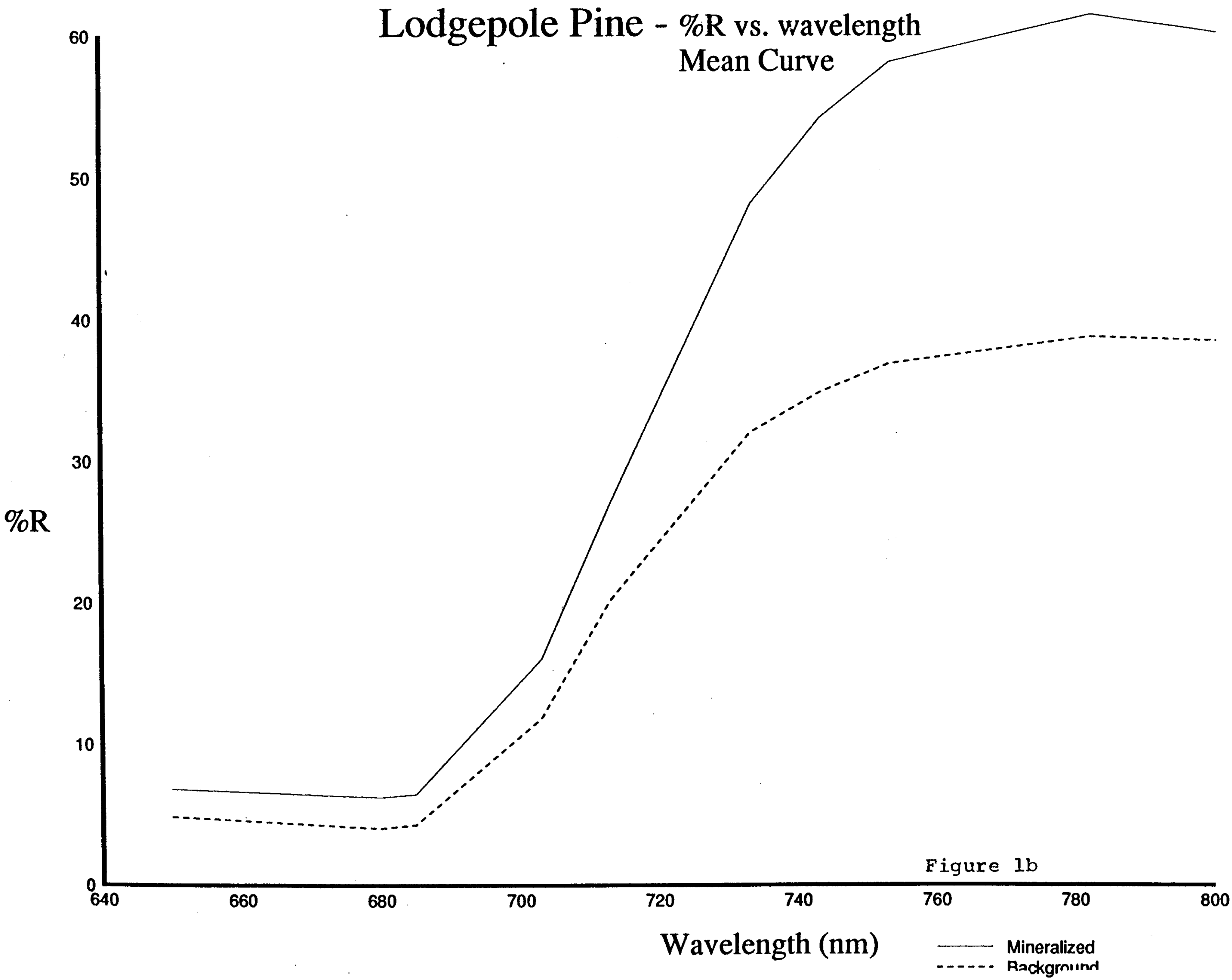
Chart 1b is a plot of the mean reflectance curves of the mineralized and background samples. The separation at the infrared reflectance shoulder is 22%.

Samples B-1 and B-2 are taken from trees growing in cherty outcrop. While they show the strongest absorption, it is interesting to note that sample B-3 is taken from the same bedrock and yet shows a good deal less absorption. It is also the tallest of the three samples and may have a root system that is in touch with below surface mineralization. It plots near sample B-4 which is a small sample adjacent to a road and thus may have been contaminated by road activity or from adjacent mineralization which may have dispersed to this area. Both B-3 and B-4 plot near mineralized sample M-2.

The individual curves were normalized and plotted against wavelength on chart 1c. The range of the normalized reflectance (NR) curves at the red-edge slope is 9 to 10 nm. The normalized reflectance (NR) mean curves of the background and mineralized samples have a 4 nm shift at the red-edge (1d) towards the red spectra which is similar to (Singhroy, et al, 1986.) They found that Jack Pine needles showed 'a 5 nm shift toward the red region of the spectrum.' Jack Pine (Pinus banksiana) is described as 'a close relative east of the Rockies of Lodgepole Pine (Lyons,1952).

While Singhroy and his co-workers found a '10% decrease in amplitude at the infrared shoulder' for background samples, the Minnova samples showed a 22% difference. This variation may be due to the fact that the Lodgepole Pines were in an area which had strong arsenic mineralization along with Cu, Pb, Zn and no arsenic mineralization was reported from the Natal Lake site where Jack Pine were sampled.


Lodgepole Pine - %R vs. wavelength
%R
0
10
20
30
40
50
60
640
660
680
700
720
740
760
780
800
Wavelength (nm)
M-1
M-2
B-4
B-3
B-1
B-2
Figure 1a
Mineralized
Background



Lodgepole Pine - %R vs. wavelength
Mean Curve
%R
60
50
40
30
20
10
0
640
660
680
700
720
740
760
780
800
Wavelength (nm)
Mineralized
Background

Figure 1b

Lodgepole Pine - Normalized Curve

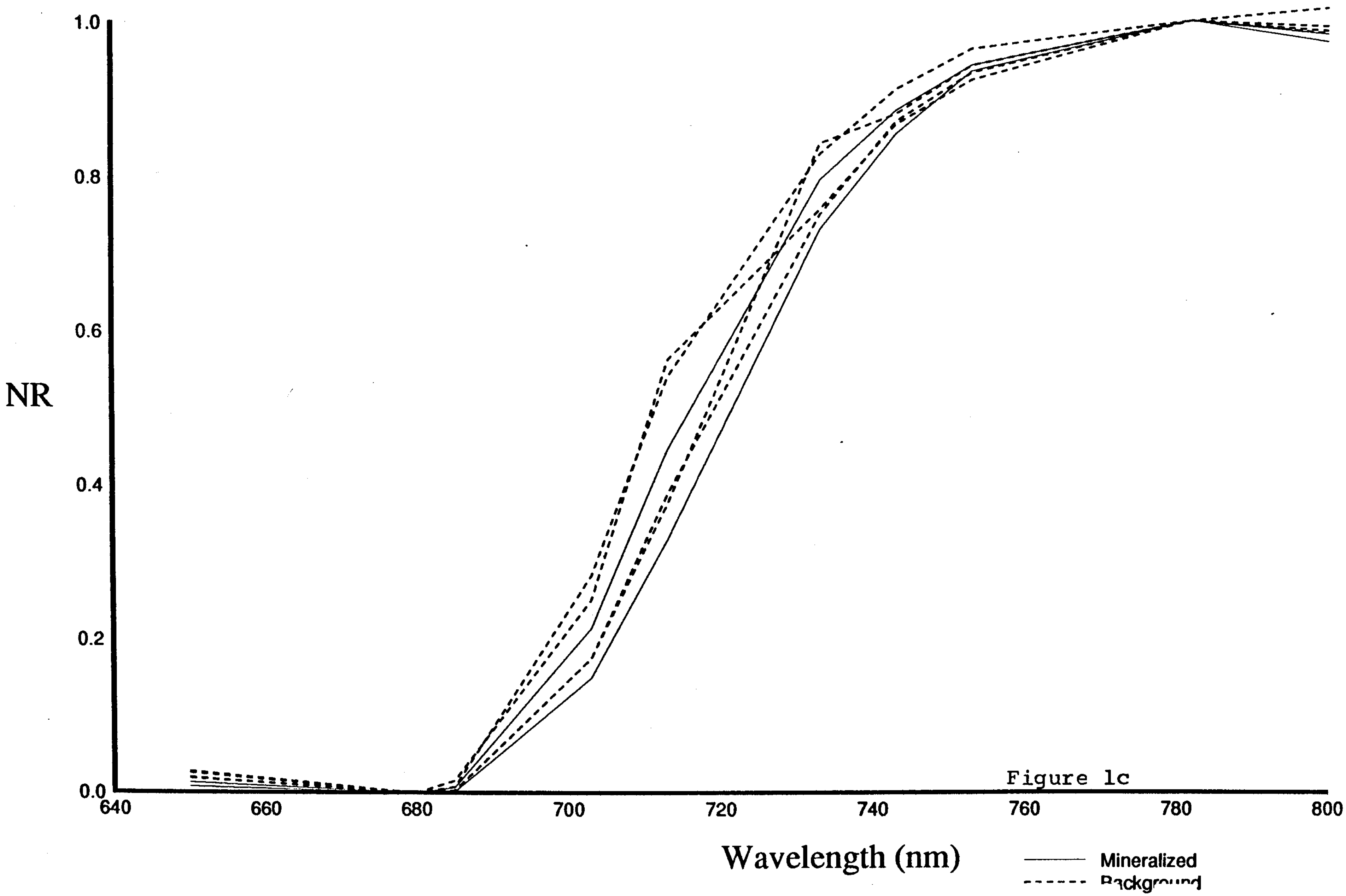
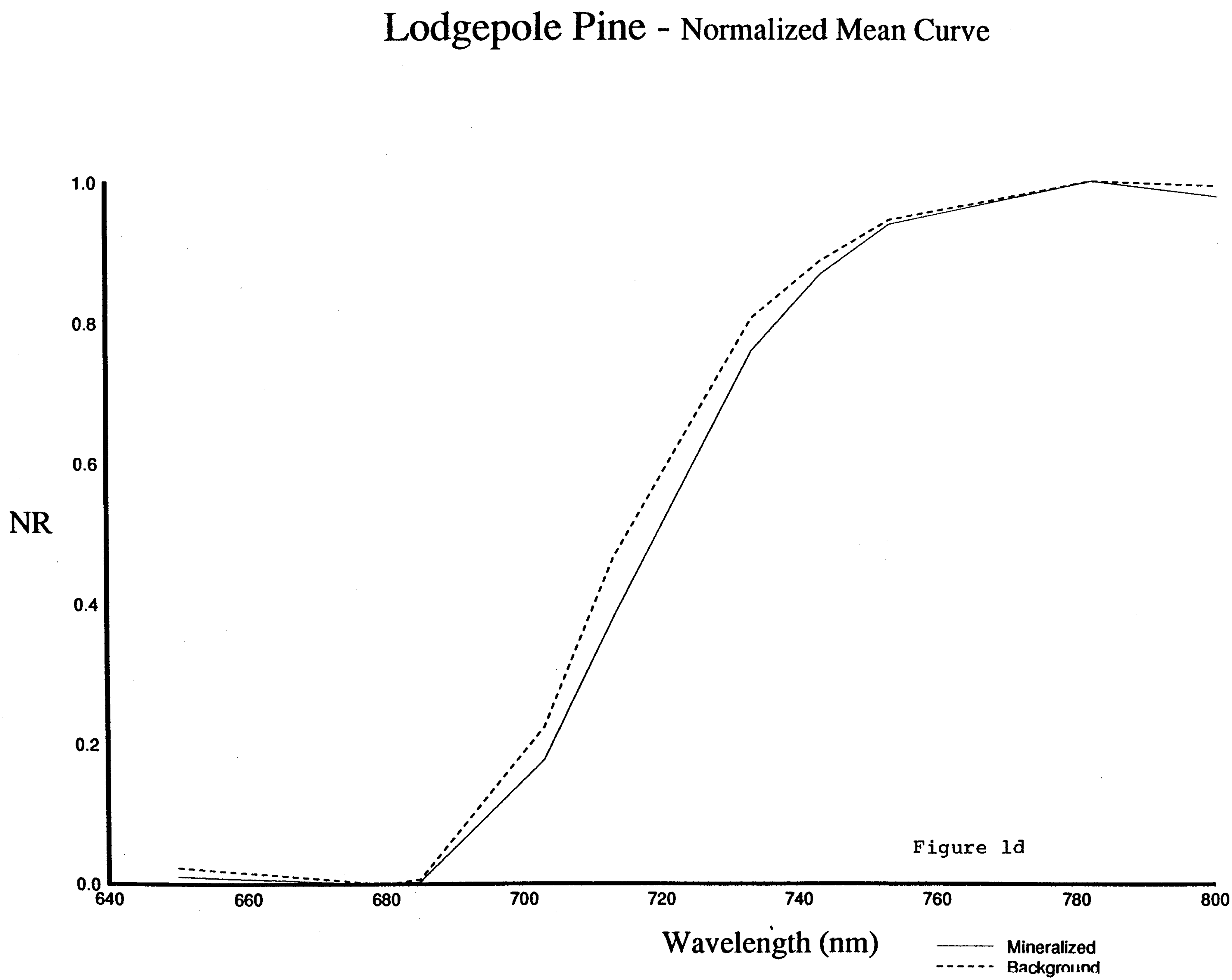


Figure 1c


Lodgepole Pine - Normalized Mean Curve
NR
1.0
0.8
0.6
0.4
0.2
0.0
640
660
680
700
720
740
760
780
800
Wavelength (nm)
Figure 1d
Mineralized
Background

Results: (cont'd)

Alpine Fir (Abies lasiocarpa)

Alpine Fir is common throughout most of British Columbia and it occurs from 3500 feet and continues to the timberline east of the Cascades. It is usually mixed with other species such as Engelmann Spruce but it is also found with Lodgepole Pine, Alpine Larch and, sometimes, Trembling Aspen. Trees normally range from 50 feet to 75 feet in height with trunk diameters of 2 1/2 feet but some grow as tall as 150 feet with trunk diameters of 4 feet. The root system is shallow and wide-spreading and the tree is not wind-firm (Hosie,1979) (Lyons,1952).

Alpine Fir in the Samatosum property occurs with Lodgepole Pine, Engelmann Spruce and Amabilis Fir. A plot of the reflectance versus wavelength shows a range in the infrared shoulder of approximately 15% with no segregation between the mineralized samples and the background samples (Chart 2a). The mean curves show a separation of 4% (2b) between the background and mineralized curves.

A plot of the normalized reflectance (NR) curves at the 0.5 NR point shows a range at the red-edge of 4 nm (2c) and a plot of the normalized mean reflectance (NR) of the background and mineralized samples shows a shift at the red-edge of 2 to 3 nm towards the blue spectra (2d) which is within-species variation and hence not a true shift at the red-edge. In general, the tree samples were relatively short with consequent shallow-root systems and hence may not have been in touch with mineralization.

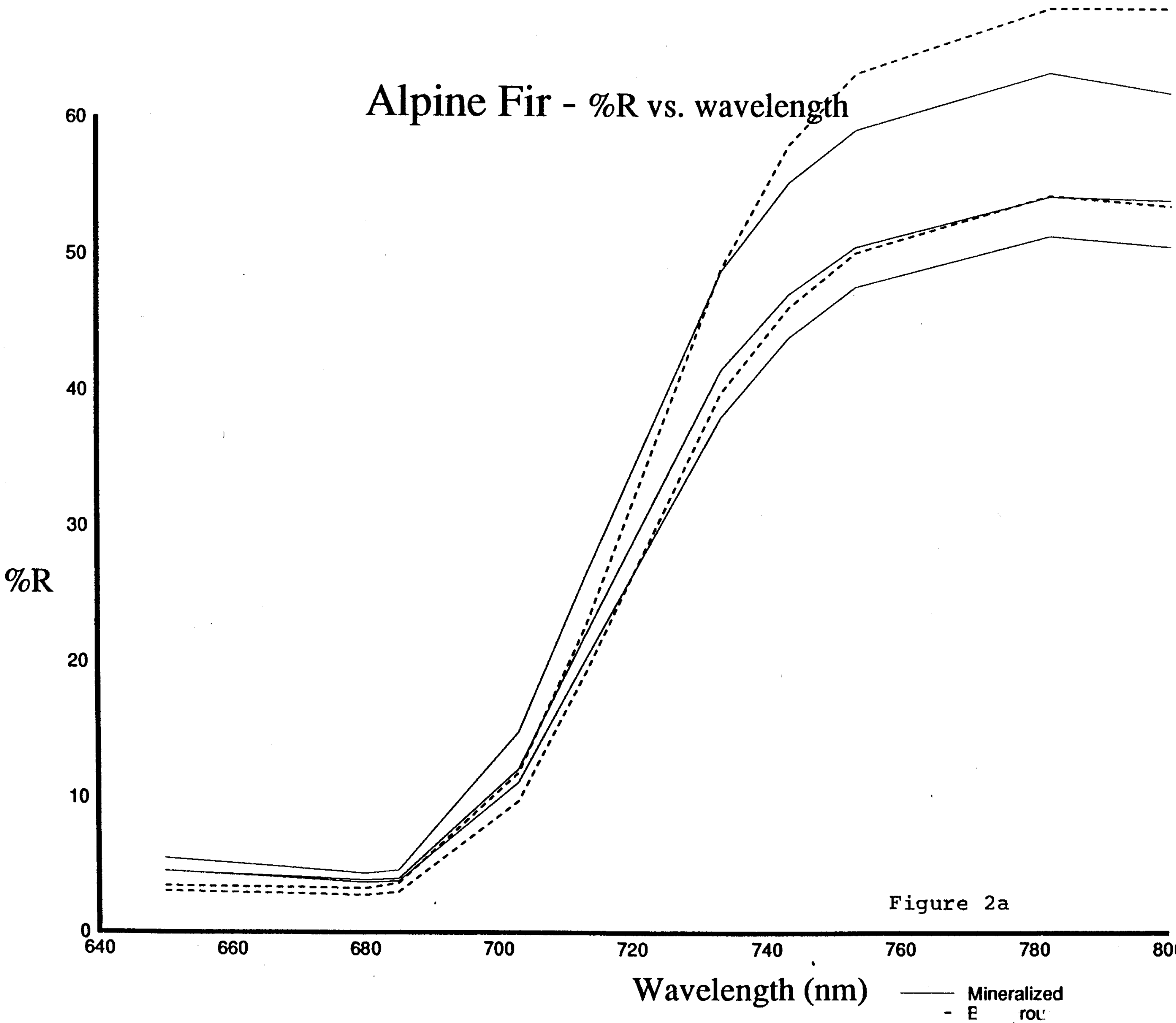

Alpine Fir - %R vs. wavelength
%R
0
10
20
30
40
50
60
640
660
680
700
720
740
760
780
800
Wavelength (nm)
Mineralized

Figure 2a

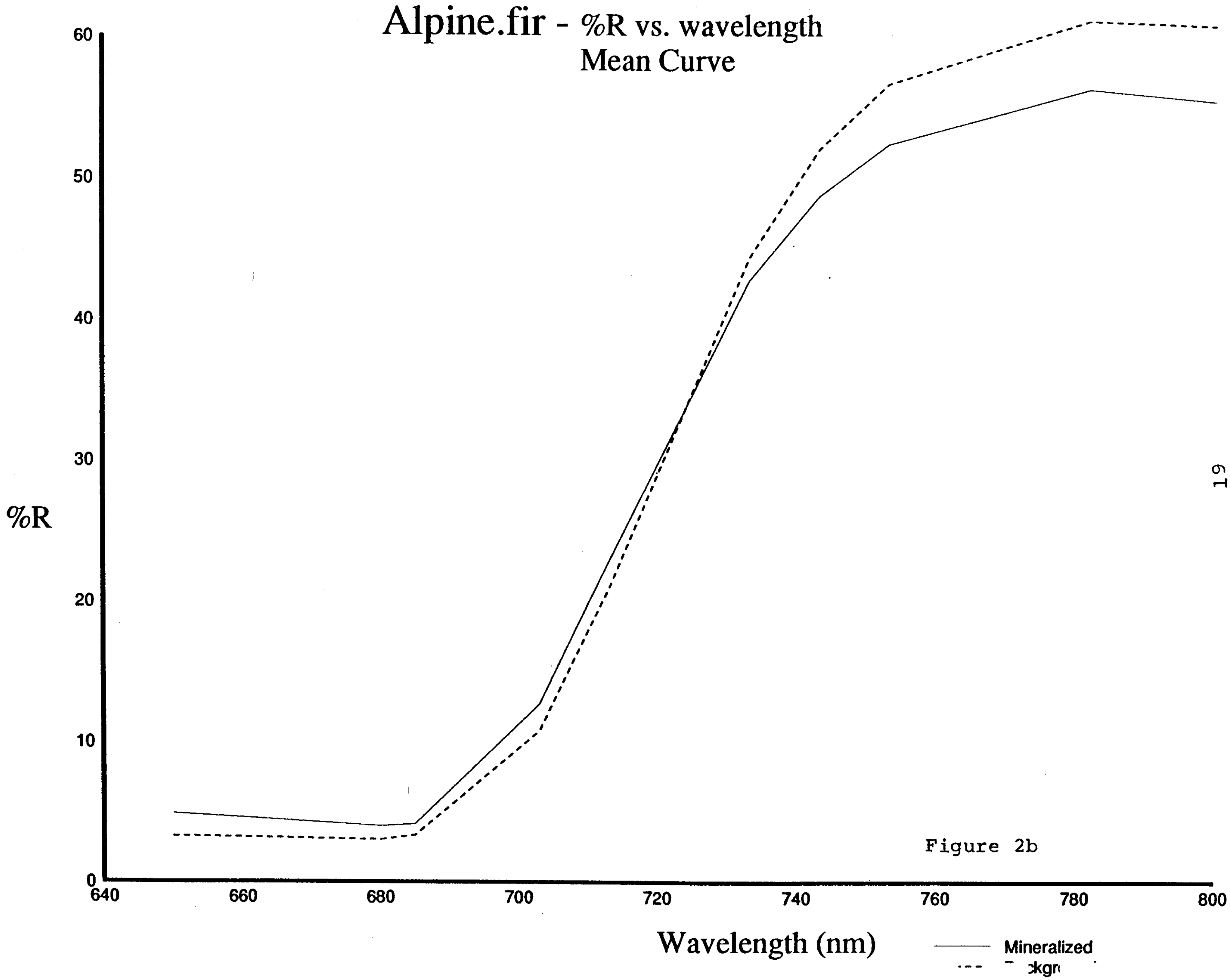

Alpine.fir - %R vs. wavelength
Mean Curve
%R
60
50
40
30
20
10
0
640
660
680
700
720
740
760
780
800
Wavelength (nm)
Mineralized

Figure 2b

Alpine Fir - Normalized Curve

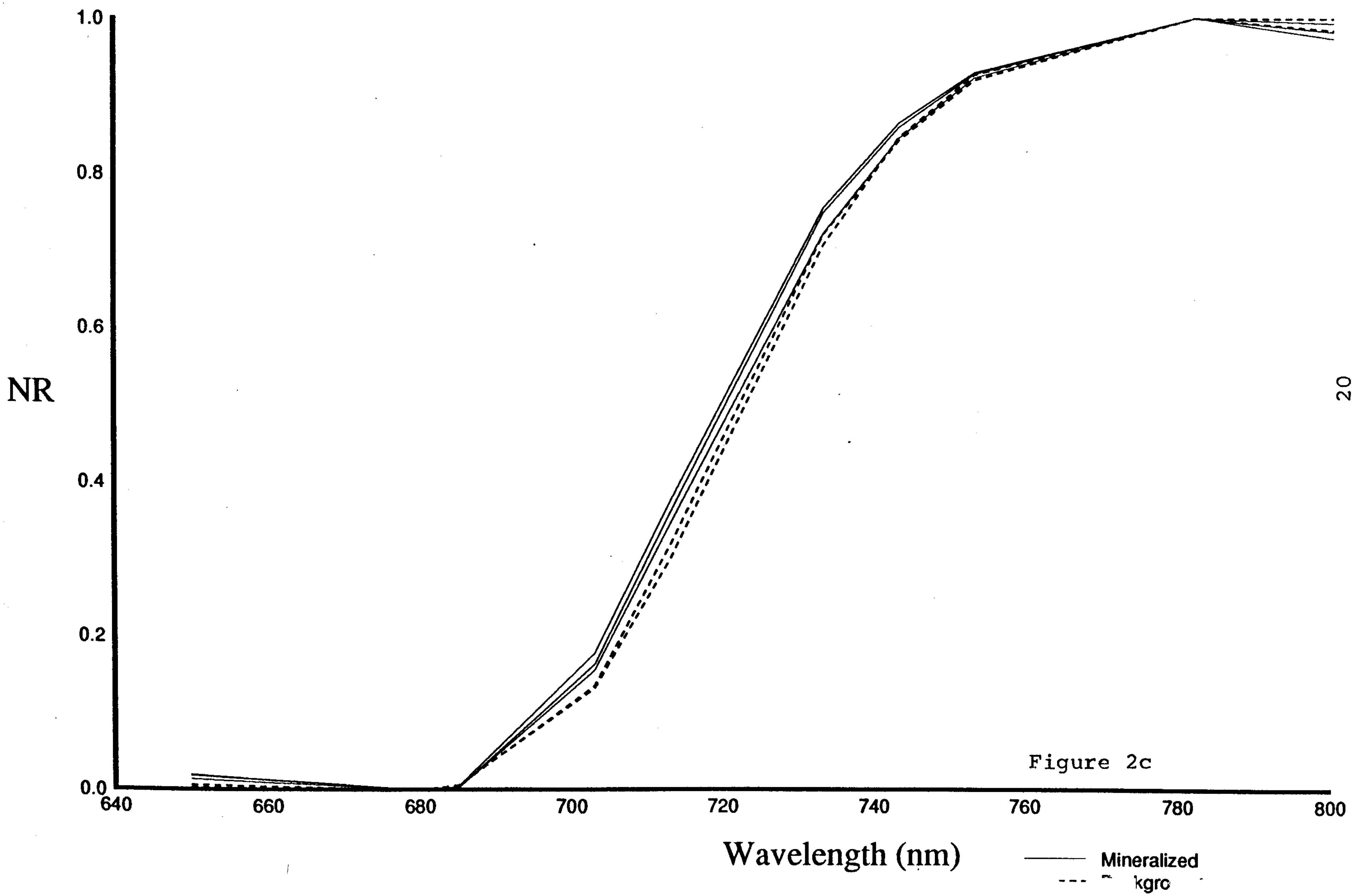


Figure 2c

Alpine.fir - Normalized Mean Curve

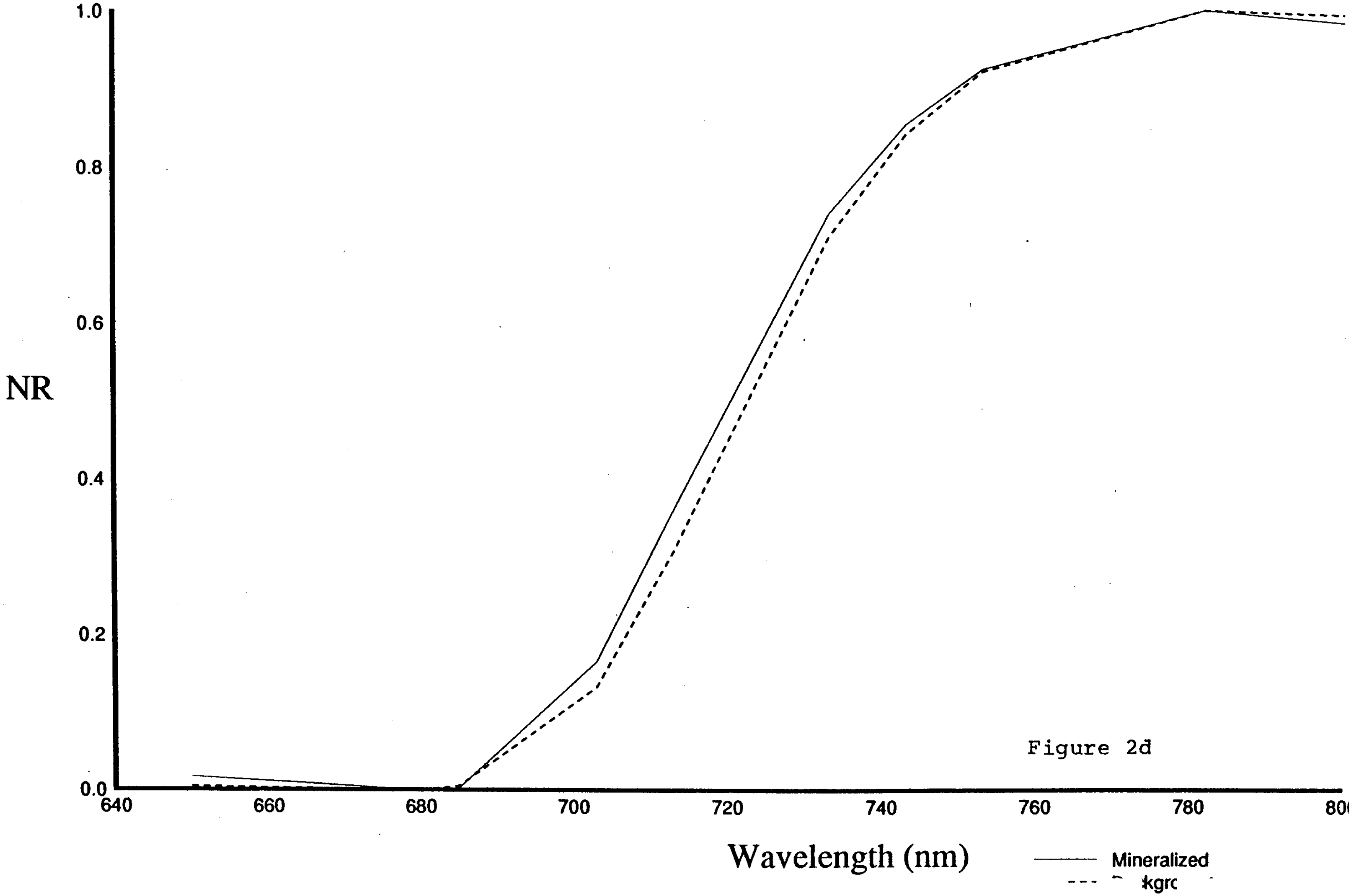


Figure 2d

Results: (cont'd)

<u>Douglas Fir (Pseudotsuga menziesii)</u>

Two varieties of Douglas Fir are generally recognized, a coastal and an interior. The coastal tree grows to 300 feet with a trunk diameter of 9 feet while the stockier interior type seldom exceeds 140 feet (Hosie,1979). Its upper altitudinal range in the southern interior is 3500 feet. It is associated with hemlock, cedar and Amabilis Fir (Lyon,1952). Lyons considers that the differing features are very slight and treats only one tree. It is determined that on the Samatosum Mountain property, there is only the interior Douglas Fir variety. All of the tree species considered in this report are treated at the species level and do not include variety distinctions.

Douglas Fir on the Samatosum property was found with Lodgepole Pine, Amabilis Fir, Engelmann Spruce and Alpine Fir. In the lower portions of the property, below the Johnson Lake Road, Red Cedar occurs with Douglas Fir and Engelmann Spruce. The tallest Douglas Fir sampled was over 80 ft. tall.

A plot of reflectance versus wavelength gives a range of 10% at the infrared shoulder (3a) with the mean curves showing a 4% separation at the reflectance shoulder when all samples are considered. When a selected sub-set containing a balance of samples is considered, the reflectance shoulder has a 10% range (3aa). There is a mean amplitude change of 5% (3bb) at the infrared shoulder with the mineralized curve showing a stronger absorption.

There is a 5 nm range at the 0.5 RN level of the normalized curves (3c) and in the balanced sub-set (3cc). The mean normalized curves show a 1.5 nm shift toward blue at the red-edge (3d) which is within-species variation. The balanced sub-set shows a 3.5 to 4 nm shift (3dd) which is somewhat larger than species variation and is a true shift of the red-edge. The mineralized stressed trees are shifted towards the blue portion of the spectrum.

Results: Douglas Fir (cont'd)

The Douglas Fir samples were taken from cherty outcrop (B-1, B-2), from soils overlying mineralized schists (M-2, M-3, M-4) and from down-slope mineralized soils (M-1, M-5). Tree heights varied from 45 ft to over 80 ft with corresponding root systems in contact with mineralized and non-mineralized sub-strate. A comparison of the samples with the highest reflectance versus the samples with the lowest reflectance or highest absorption is depicted in chart DF-1. (See figure 3a).

	sample #	cherty out-crop	mineralized schist	mineralized downslope soil	Tree Height(ft)
Highest Reflectance	B-1	X			60
	M-1			X	45
	M-3		X		80
	B-2	X			60
	M-2		X		80
	M-4		X		80
Lowest Reflectance (Greatest Absorption)	M-5			X	60

Chart DF-1
Percent Reflectance at the Infrared 'Shoulder'

Since the three types of terrain gave differing reflectance result within the sub-sets of Douglas Fir sampled, it appears that spectral reflectance changes are not due to rock type and related soils but rather are due to mineralized stressors in contact with tree roots.

Results: Douglas Fir (cont'd)

A comparison of the samples with the greatest blue-shift (M-5, M-3) at the red-edge and the samples with the least blue-shift (B-2) at the red-edge slope is depicted in chart DF-2 with the corresponding sampling terrain and tree heights (See 3c).

	sample #	cherty out-crop	mineralized schist	mineralized downslope soil	Tree Height(ft)
Least Blue-shift	B-2	X			60
	M-1			X	45
	B-1	X			60
	M-4		X		80
	M-2		X		80
	M-5			X	60
Greatest Blue-shift at the red-edge slope	M-3		X		80

Chart
DF-2
Blue-shift at the Red-Edge vs. Geological Terrain

Since the three types of terrain sampled gave differing spectral results for Douglas Firs sampled within these sub-sets, it can be concluded that the spectral reflectance changes are due to mineralized stressors in contact with tree roots and not the surficial or bedrock type.

Results: Douglas Fir (cont'd)

Chart DF-1 and figure 3a show that Douglas Fir samples from all three terrains plot within 3% of each other on the infrared reflectance spectrum (samples B-1, M-1, M-3) showing that the terrain in question will not substantially alter the reflectance of the trees unless mineralized stressors are present.

Chart DF-2 and figure 3c show that the tree samples are blue-shifted at the red-edge regardless of terrain and thus, the blue-shift at the red-edge slope is due to mineralized stressors at the tree roots.

Thus, a normalized plot of the two maximum shifted mineralized samples (M-5, M-3) versus a plot of the two background samples (B-1, B-2) as shown in figure 3cc will provide the normalized mean curves of the mineralized versus background Douglas Firs as shown in figure 3dd which shows a blue-shift at the red-edge of 3.5 nm to 4.0 nm which is greater than normal species range.

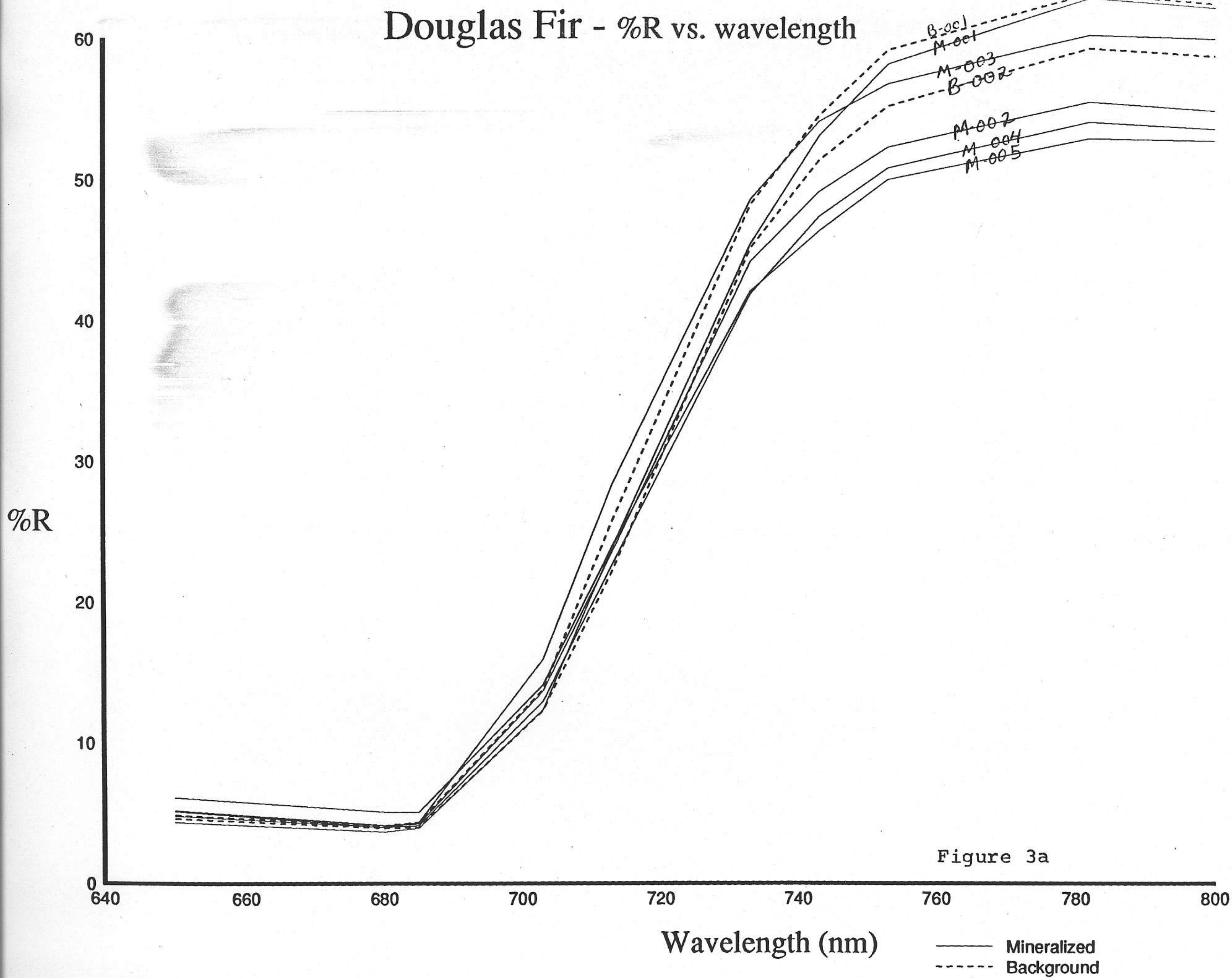

Douglas Fir - %R vs. wavelength
%R
60
50
40
30
20
10
0
640
660
680
700
720
740
760
780
800
Wavelength (nm)
B-001
M-001
M-003
B-002
M-002
M-004
M-005
Mineralized
Background

Figure 3a

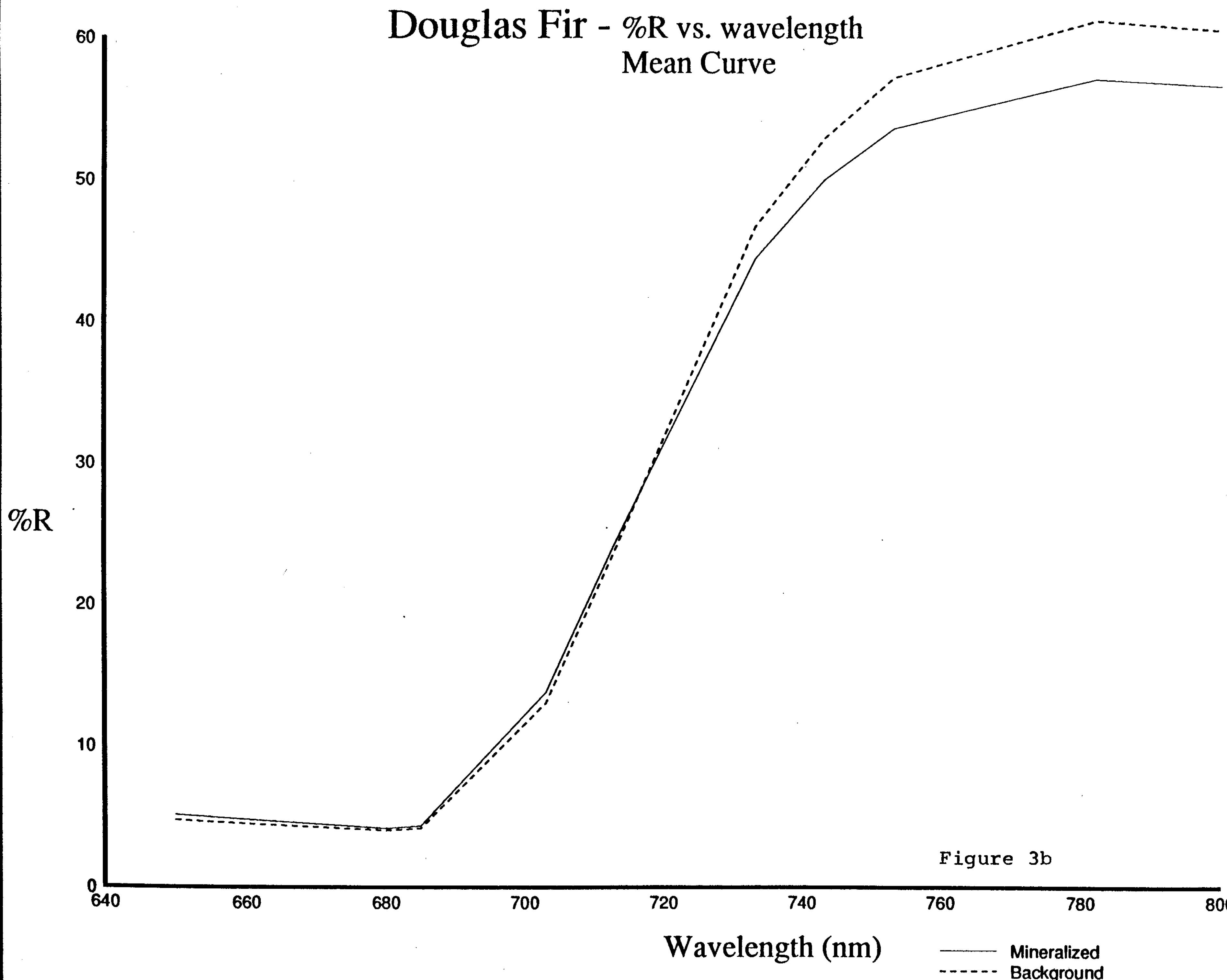
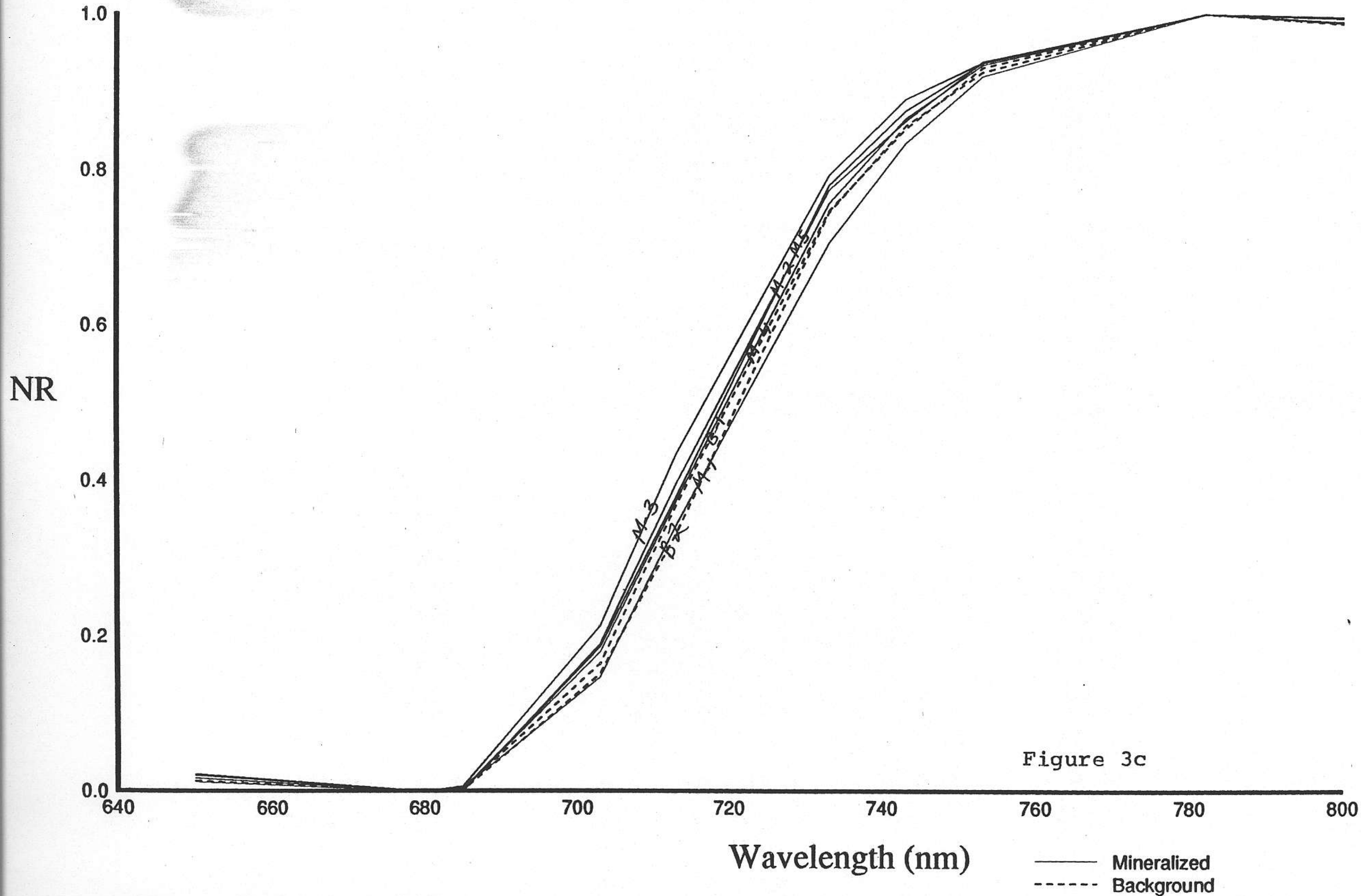
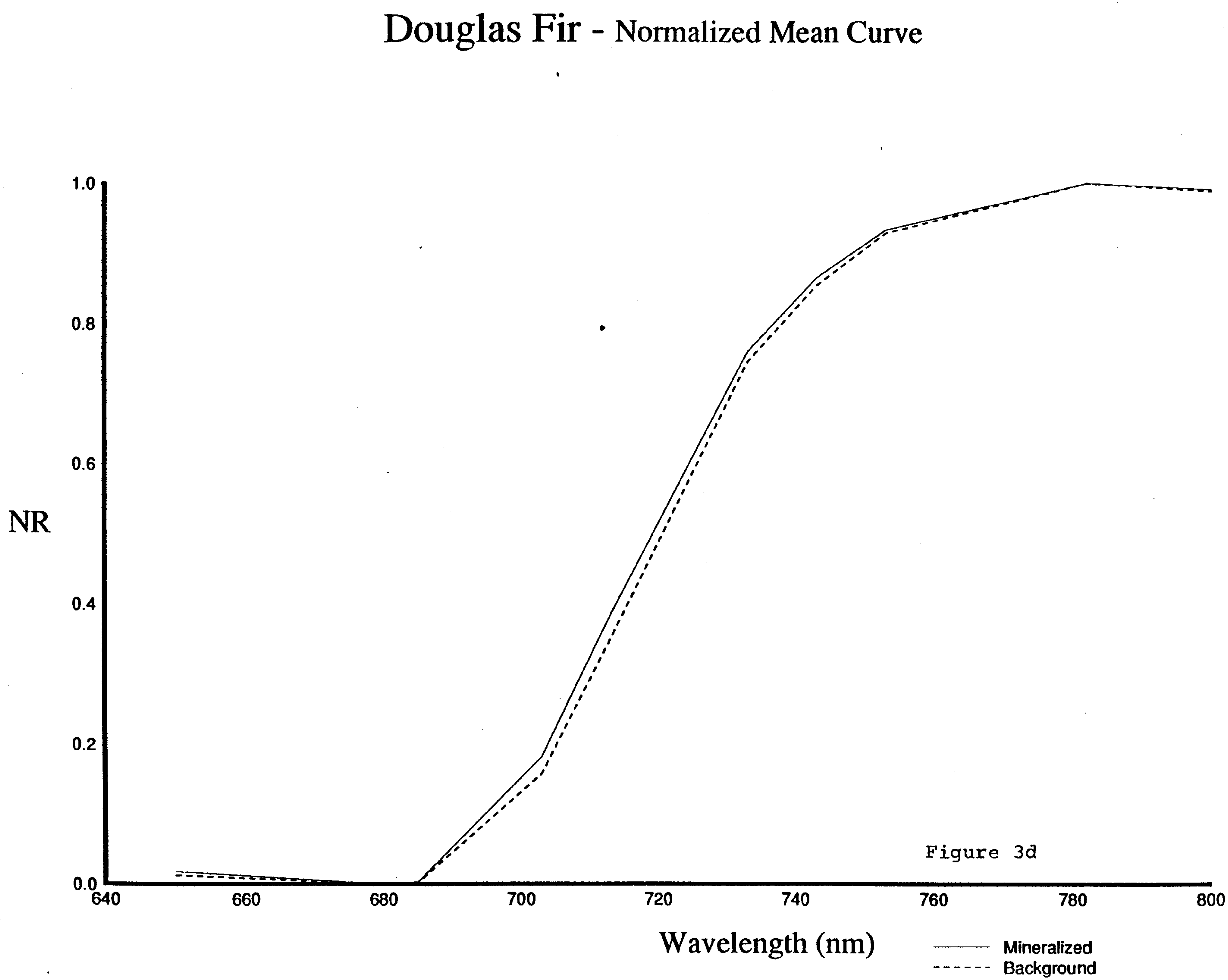

Douglas Fir - %R vs. wavelength
Mean Curve
%R
60
50
40
30
20
10
0
640
660
680
700
720
740
760
780
800
Wavelength (nm)
Mineralized
Background

Figure 3b

Douglas Fir - Normalized Curve




Douglas Fir - Normalized Mean Curve
1.0
0.8
0.6
0.4
0.2
0.0
NR
640
660
680
700
720
740
760
780
800
Wavelength (nm)
Figure 3d
Mineralized
Background

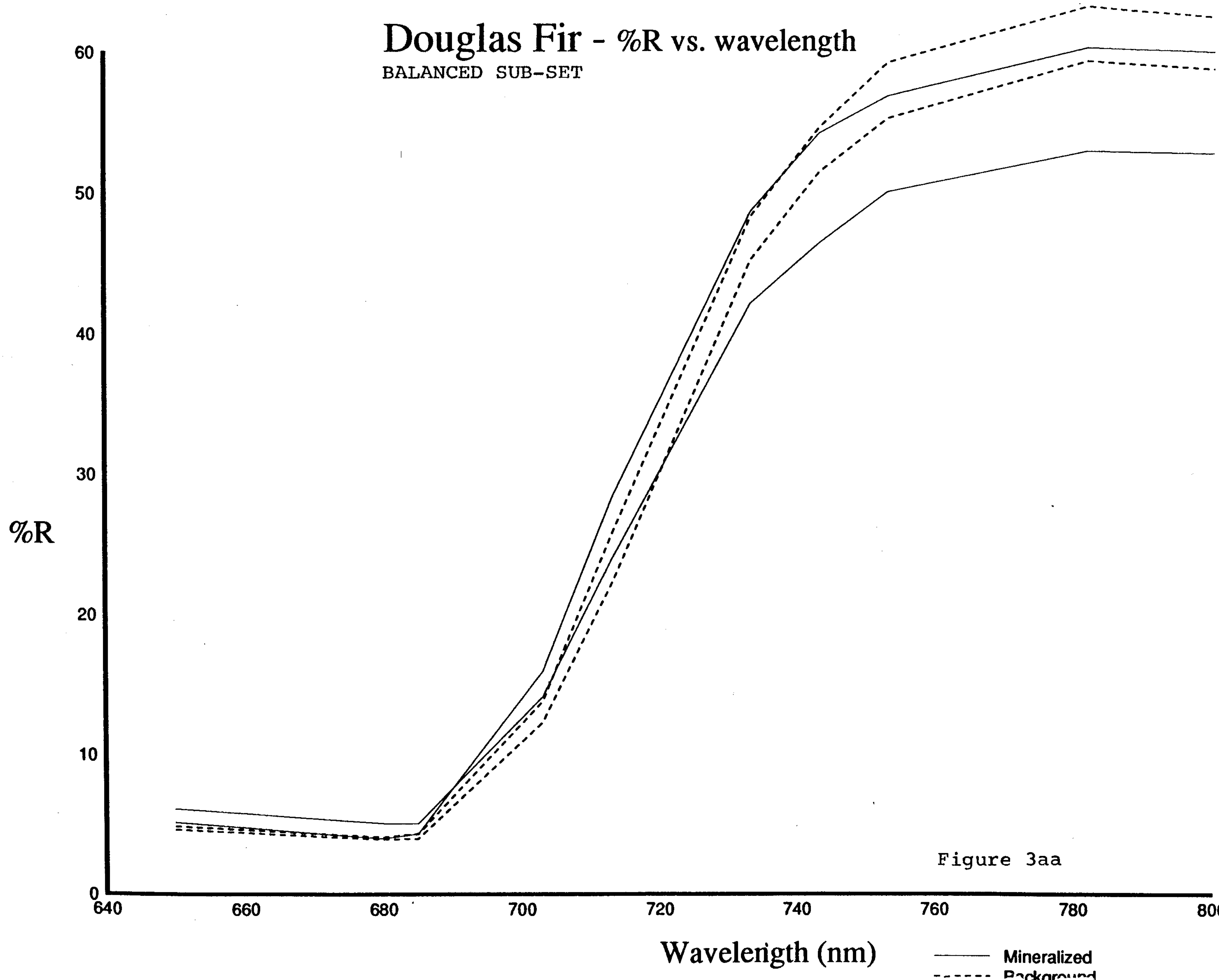

Douglas Fir - %R vs. wavelength
BALANCED SUB-SET
%R
60
50
40
30
20
10
0
640
660
680
700
720
740
760
780
800
Wavelength (nm)
Figure 3aa
Mineralized
Background

Figure 3aa

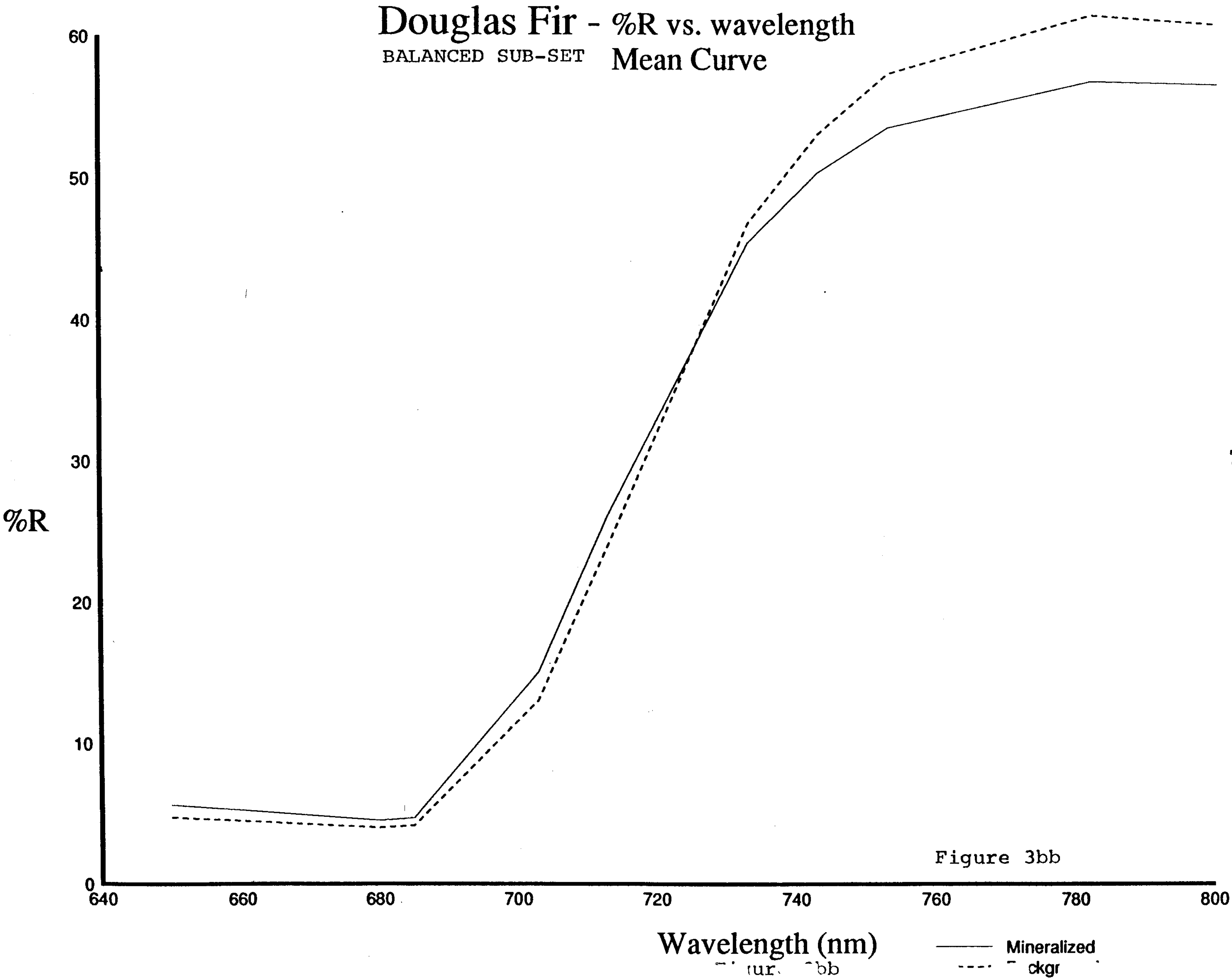
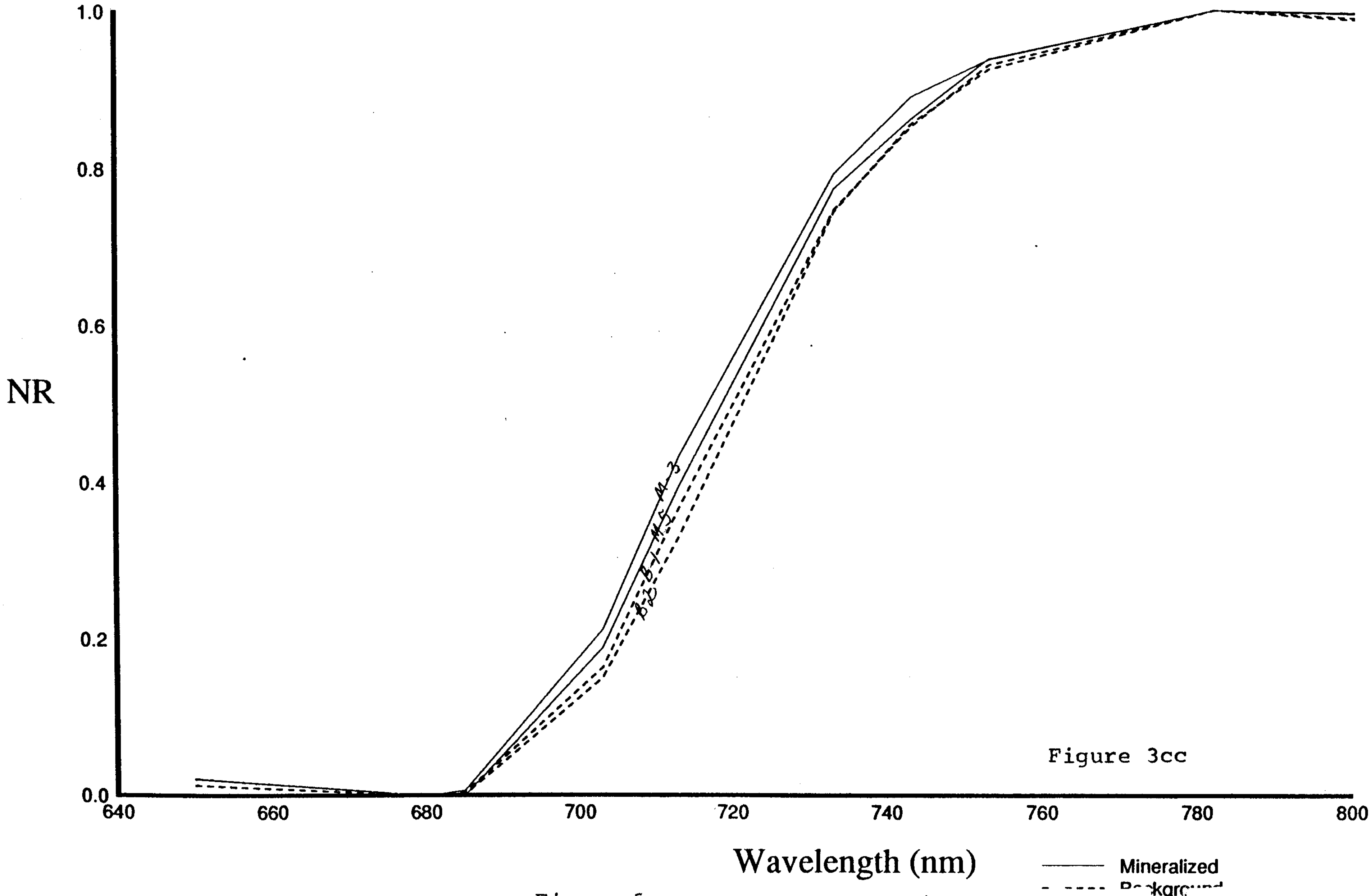

Douglas Fir - %R vs. wavelength
BALANCED SUB-SET Mean Curve
%R
0
10
20
30
40
50
60
640
660
680
700
720
740
760
780
800
Wavelength (nm)
Mineralized
ckgr

Figure 3bb

Douglas Fir - Normalized Curve

BALANCED SUB-SET



Fi e 3

Douglas Fir - Normalized Mean Curve

BALANCED SUB-SET

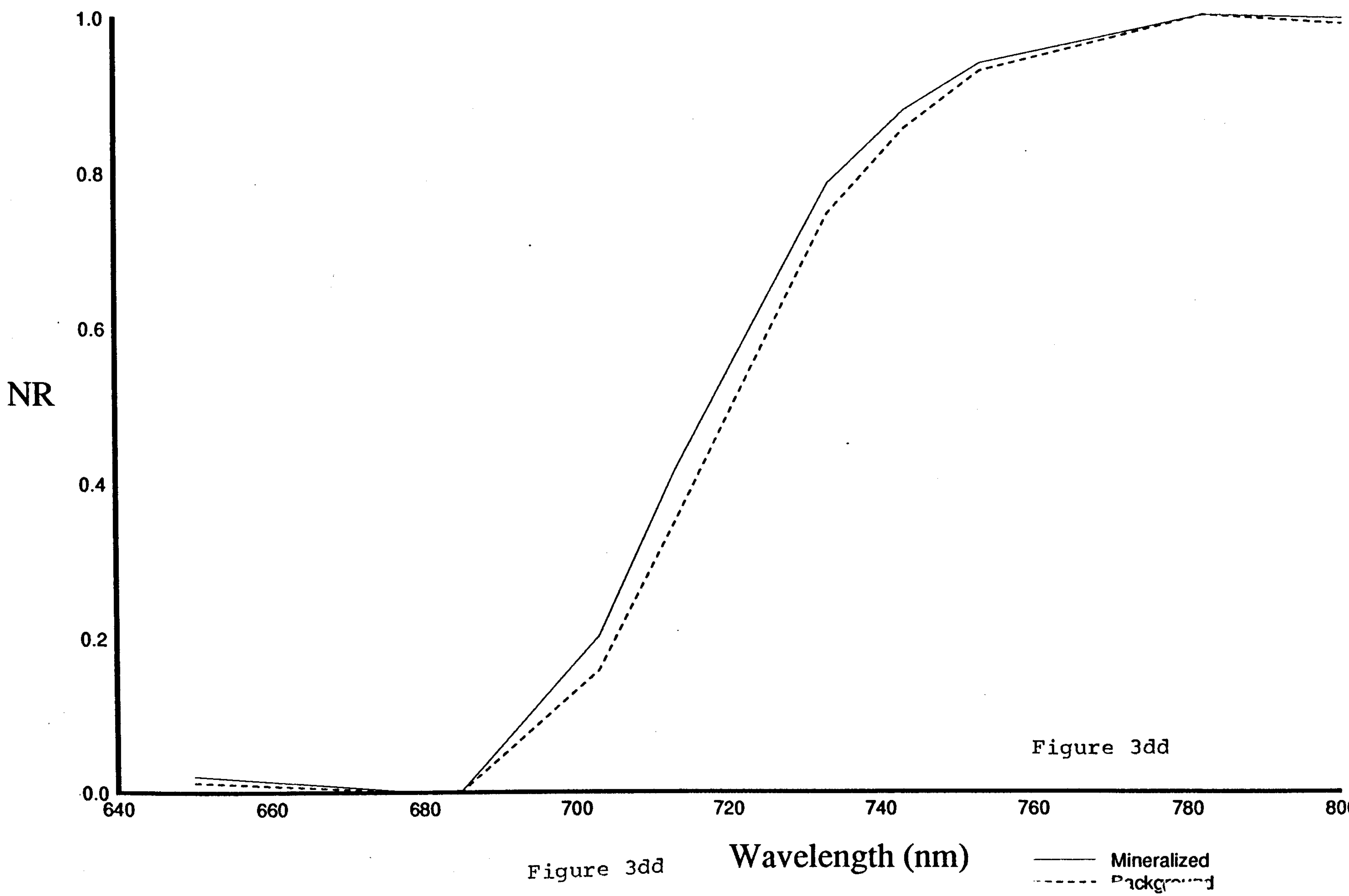


Figure 3dd

Results: (cont'd)

Amabilis Fir (Abies amibilis)

Amibilis Fir which is often mistaken for Balsam Fir (Abies balsamea) occurs only in British Columbia and Balsam Fir only occurs east of British Columbia. Amibilis Fir can occur at any elevation from sea-level to 4500 feet and is generally above the Douglas Fir elevations although it can occur with Douglas Fir. It is also associated with Engelmann Spruce, Sitka Spruce, Western Hemlock and Western White Pine. At maturity it attains heights of 125 feet and trunk diameters of 3 feet. (Hosie,1979) (Lyons,1952).

On the Samatosum Mountain property, Amibilis Fir occurs with Engelmann Spruce, Trembling Aspen, Lodgepole Pine and Alpine Fir. Trees sampled ranged from 12 feet to 50 feet with most samples in the 35 to 40 ft range.

A plot of the reflectance versus wavelength shows a range of 16% reflectance at the infrared spectra (4a), indicating that the tree is sensitive to stress, although there is no clear segregation of mineralized and background samples. This is clearly depicted in the chart of the mean curves (4b). There is only a 2% reflectance separation at the infrared shoulder between the mineralized and the background samples. A plot of the normalized curves shows that at the 0.5 NR there is an 8 to 9 nm range (4c). The normalized mean curves (4d) plot within 1 nm of each other showing virtually no shift at the red-edge.

Amabilis Fir trees on the Samatosum Mt. property are at their maximum range of 4500 ft elevation as well as being outside of their usual climatic range. Normally they are confined to the Coast Forest Region and coastal parts of the Sub-Alpine Forest Region at elevations of less than 4500 ft (Hosie,1979). ?

On the Samatosum Mt. property, the only area where Amibilis Fir was seen in the overstory was below the Johnson Creek Rd. at elevations of 3500 ft and these trees were generally shaded by Engelmann Spruce, Douglas Fir and Red Cedar. Most of the Amibilis Fir trees seen were in

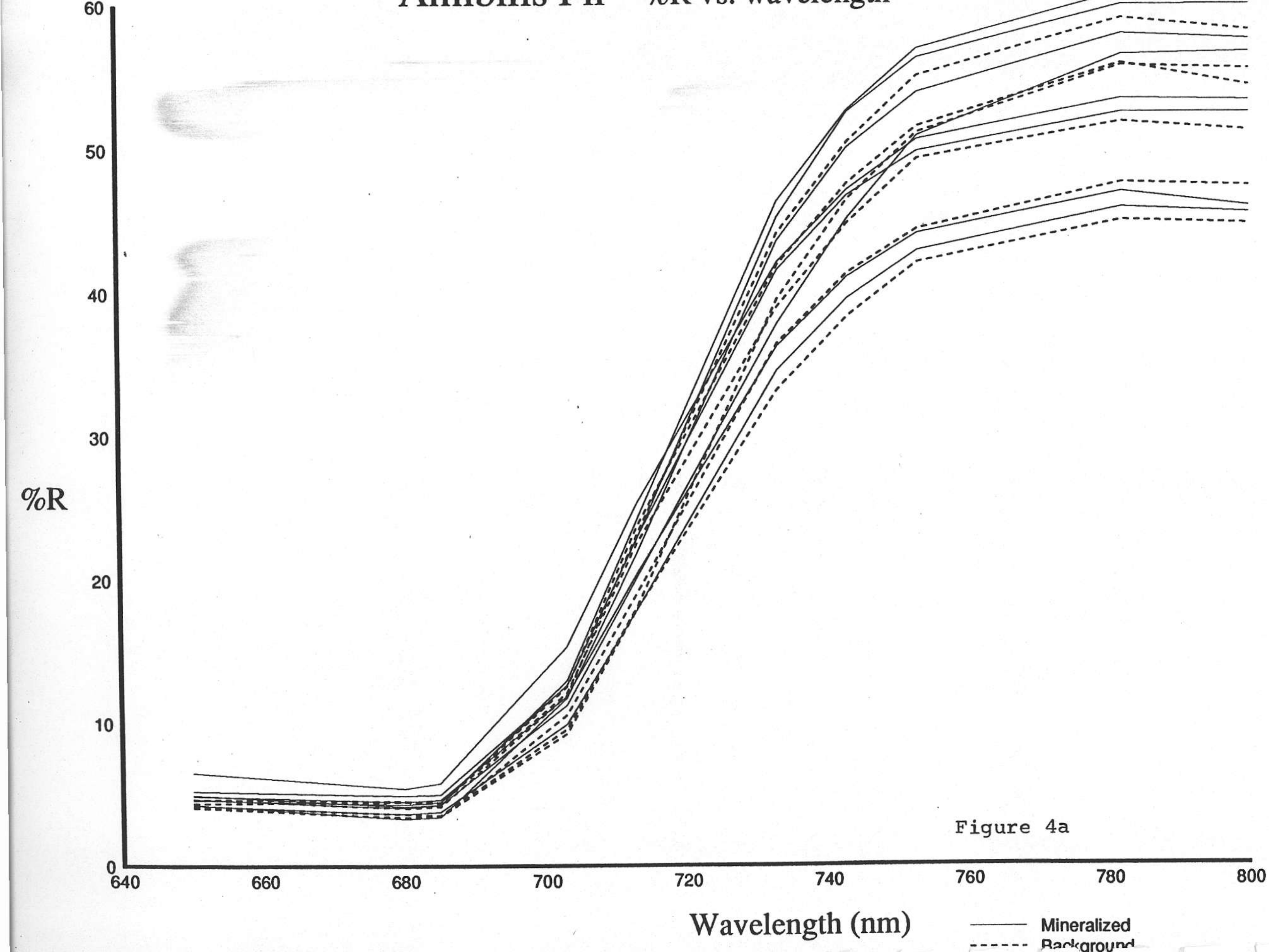
Results: Amabilis Fir (cont'd)

the understory or as immature trees in the overstory. Trees sampled ranged from 2" to 14" in trunk diameter. Mature trees growing under ideal conditions often attain dimensions greater than 3 ft in truck diameter and up to and greater than 125 ft in height.

It is concluded from these factors that the Amabilis Fir in this area is already under stress because it is at its maximum elevation range and outside of its normal climatic range.

The normalized mean curves (4d) which plot within 1 nm of each other are reflecting the stress already present in both mineralized samples and non-mineralized samples of Amabilis Fir trees; thus, when a tree is at its maximum ranges stress from mineralization will be masked and will not provide a useful spectral signature.

Amibilis Fir - %R vs. wavelength



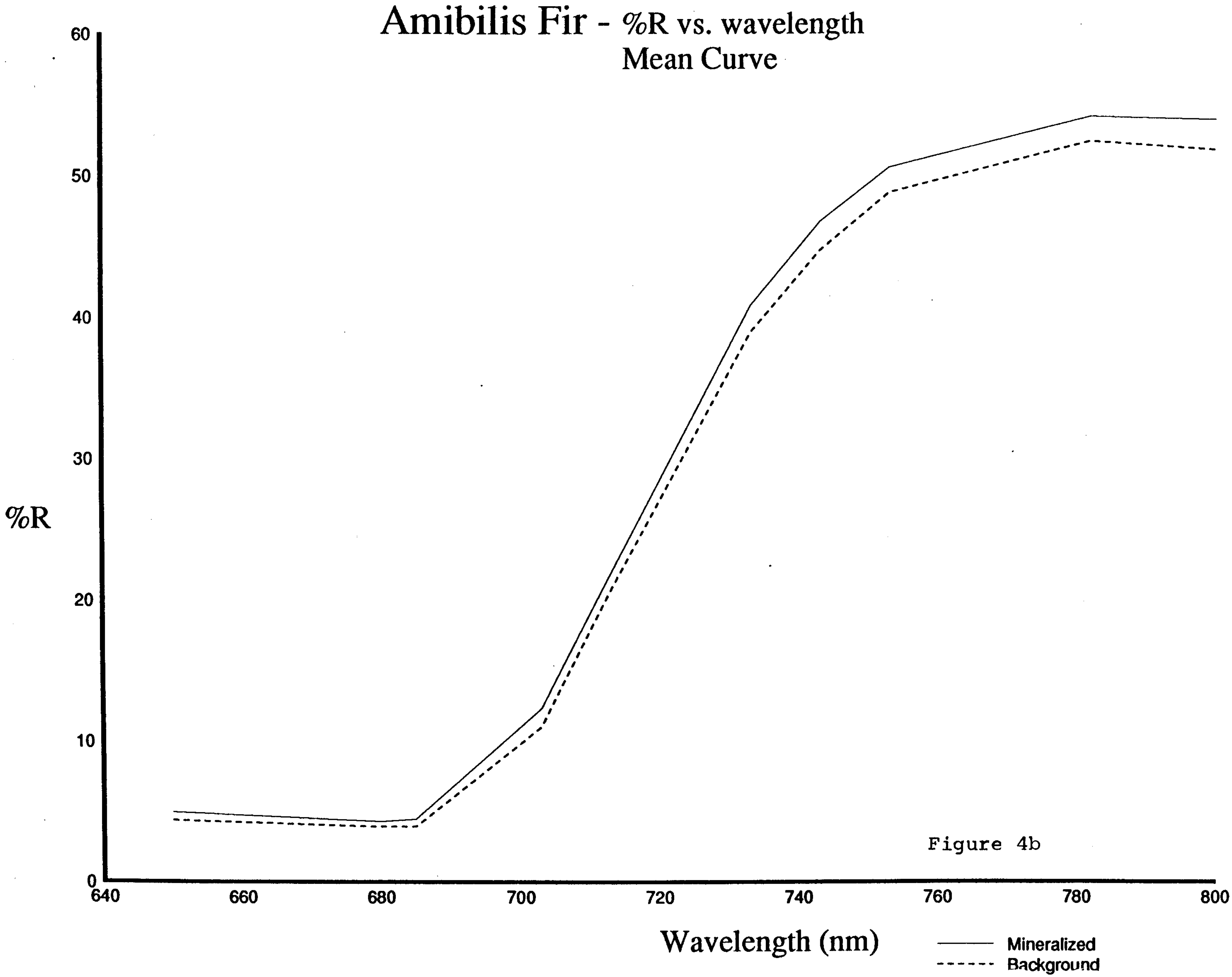

Amibilis Fir - %R vs. wavelength
Mean Curve
%R
60
50
40
30
20
10
0
640
660
680
700
720
740
760
780
800
Wavelength (nm)
Mineralized
Background

Figure 4b

Amibilis Fir - Normalized Curve

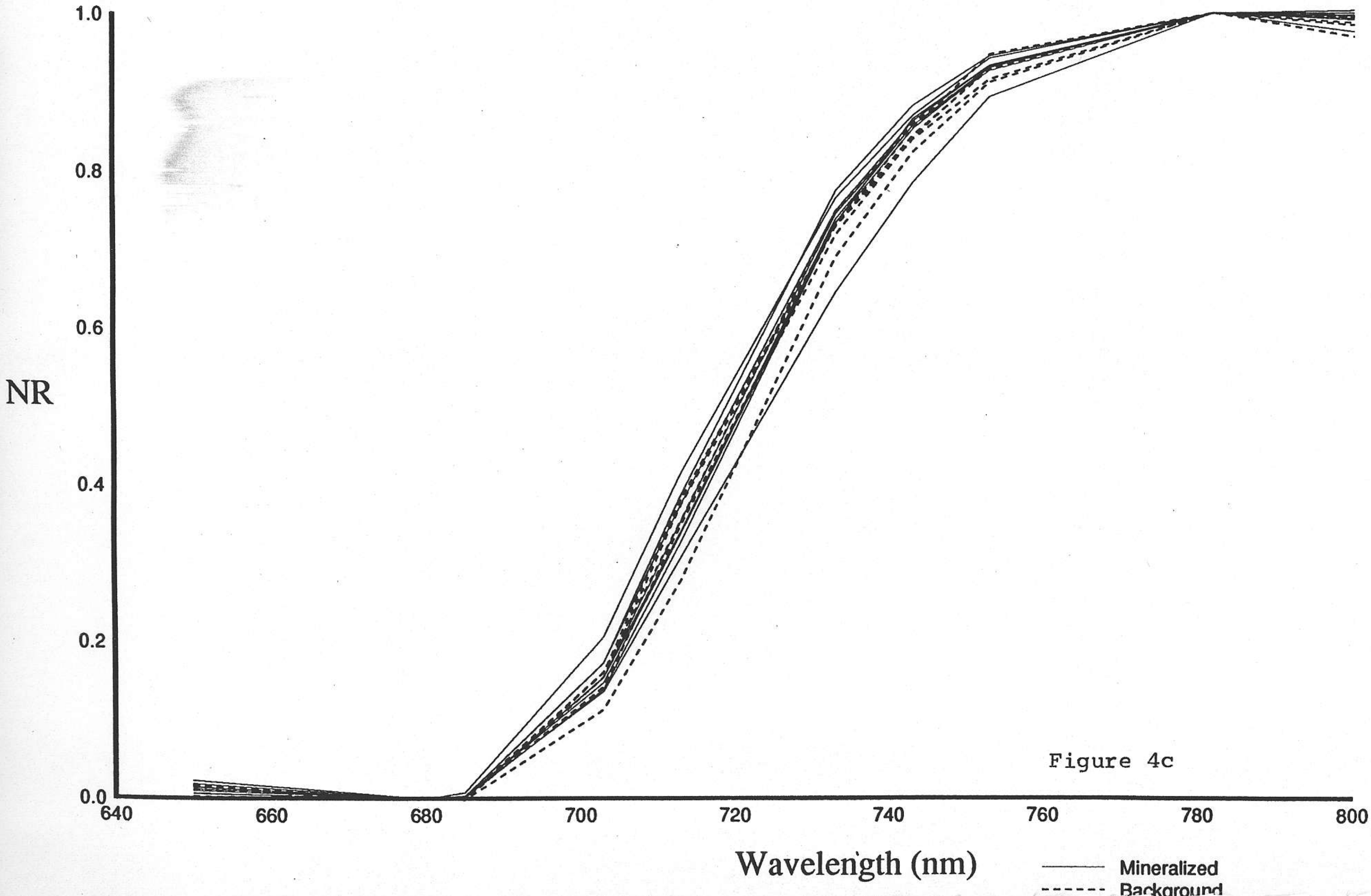
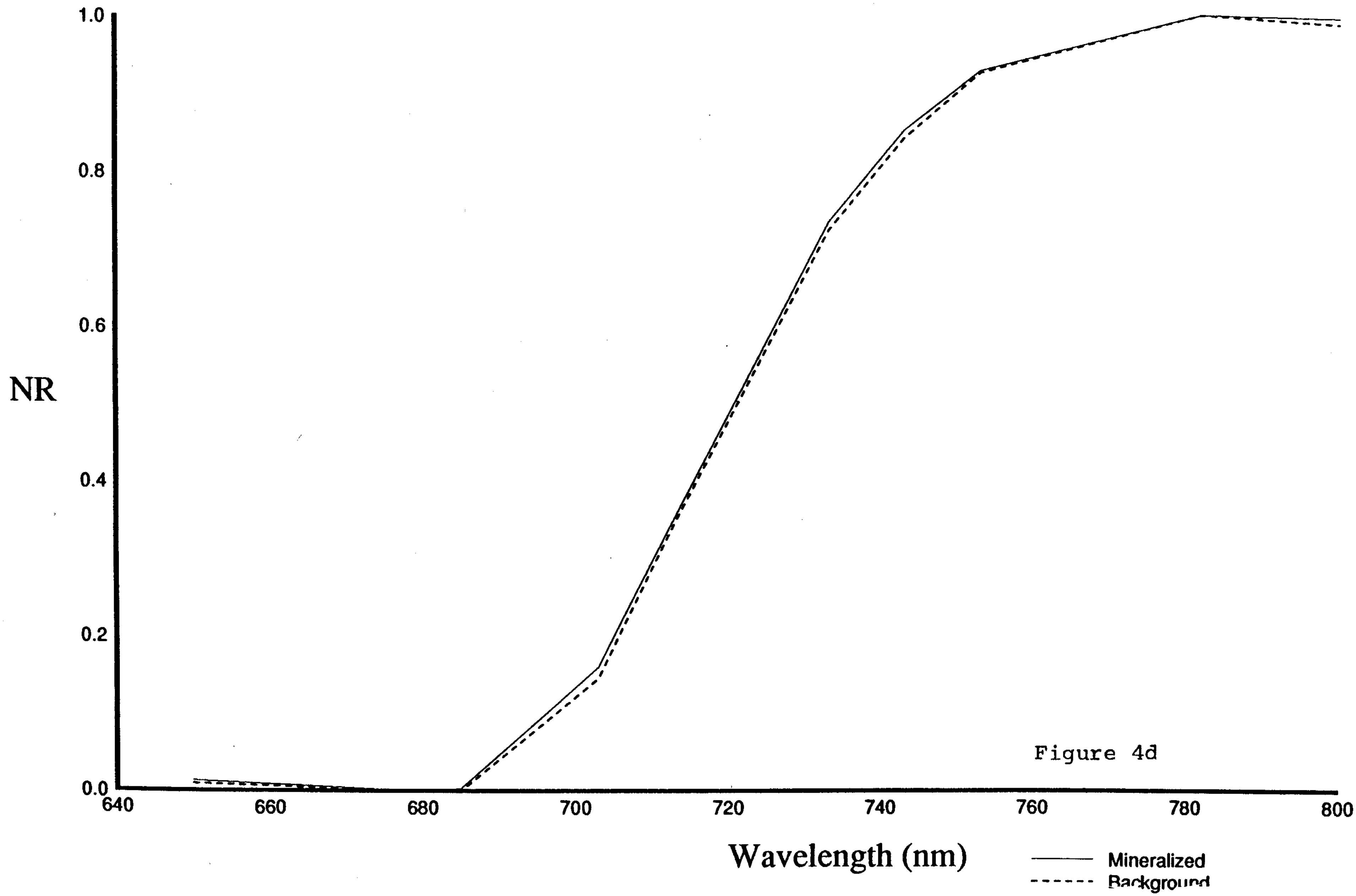


Figure 4c

Amibilis Fir - Normalized Mean Curve



Results: (cont'd)

Engelmann Spruce (Picea engelmannii)

Engelmann Spruce usually grows at elevations between 3000 and 6000 feet but is often found along streams further down. It may form pure stands but it is often mixed with firs, hemlocks, larches and pines. Trees normally reach 100 to 120 feet with trunk diameters of 3 feet and may reach 180 feet in height with 6 ft trunk diameters. On the Minnova property, Engelmann Spruce is found in the overstory with Lodgepole Pine, and Douglas Fir. The occasional Western Hemlock was present, as well.

A plot of the reflectance versus wavelength (5a) shows a range at the infrared shoulder of 25% with no distinct separation between the mineralized and the background samples. The mean curve confirms this with only a 1% separation in the background (5b) and mineralized curves.

A plot of the normalized curves shows a range of up to 11 nm at the 0.5 NR level indicating a certain measure of sensitive response in the tree species although the mean of the normalized curves plot relatively close together and well-within species-variation range.

Engelmann Spruce was under stress by a parasite which was endemic to the tree species (not Spruce Budworm) and which was present in all trees sampled. The trees, whether over a mineralized or a non-mineralized site will not, as a result, give a distinct spectral signature; the mean normalized curves of the mineralized versus non-mineralized samples (5b) plot less than 1 nm apart which is essentially no shift at the red-edge slope.

The Engelmann Spruce samples do not show a clustering due to terrain and hence rock chemistry is relatively unimportant in terms of stress. For example, four samples taken from soils from the main mineralized zone (MES-001, MES-002, MES-003, MES-005) (Chart 5a) show a 13% range in reflectance. Two background samples taken from the same area (BES-004, BES-005,) also show a 13 range in reflectance; thus it is concluded that these effects are due to parasite stress levels and not to rock geochemistry or mineralization.

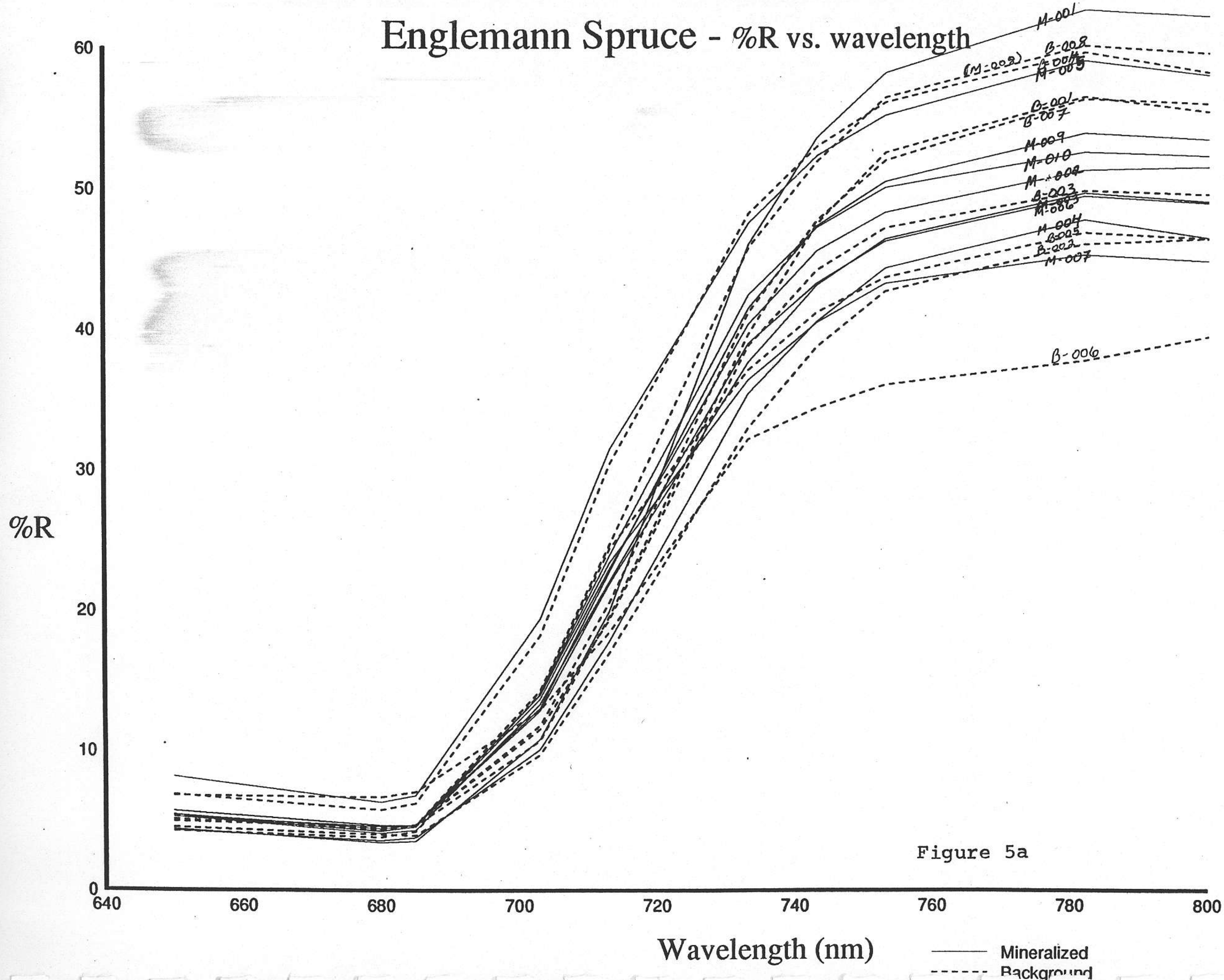
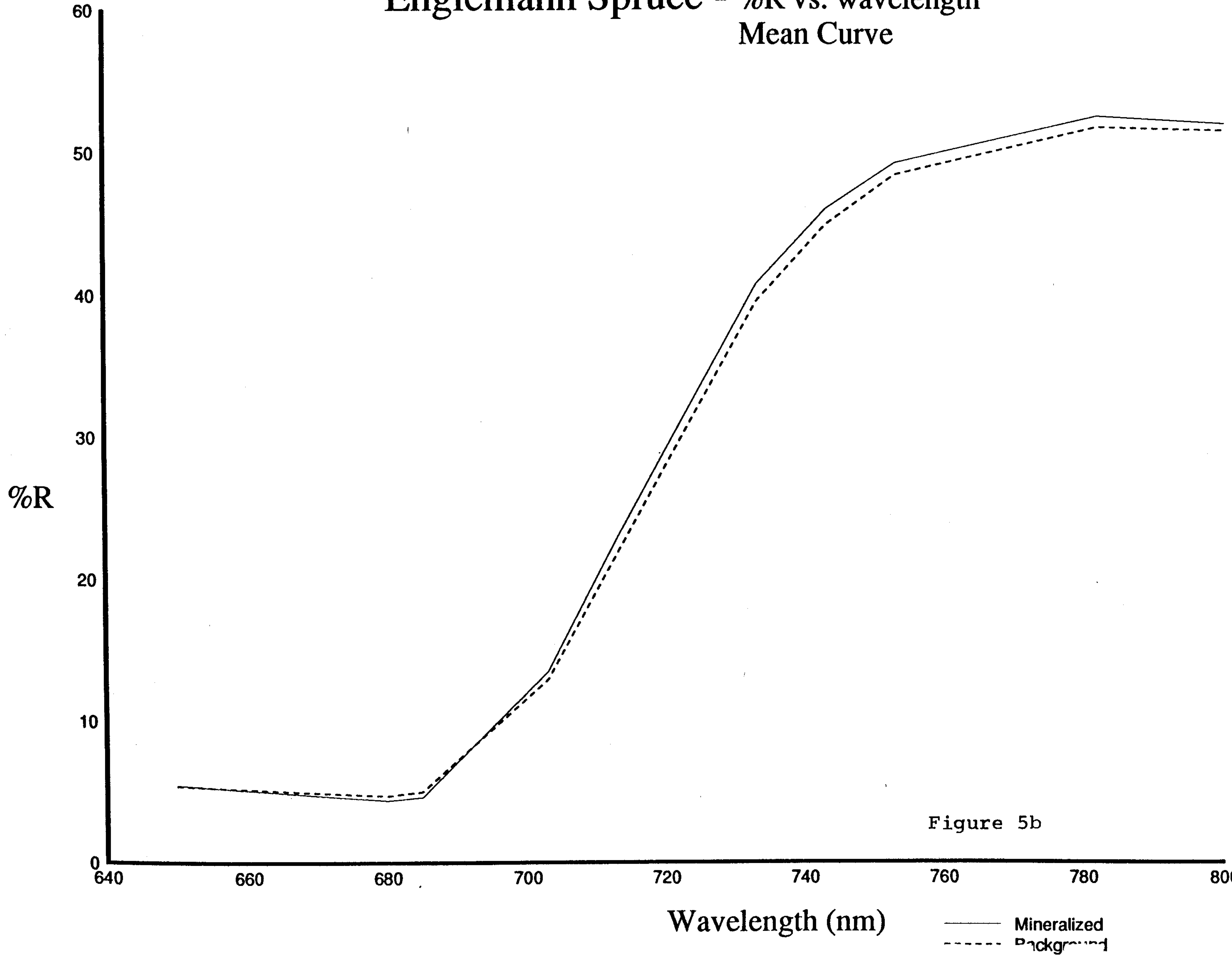

Englemann Spruce - %R vs. wavelength
%R
0
10
20
30
40
50
60
640
660
680
700
720
740
760
780
800
Wavelength (nm)
Mineralized
Background
M-001
B-008
(M-002)
B-004
M-005
B-001
B-007
M-009
M-010
M-008
B-003
M-006
M-004
B-005
B-002
M-007
B-006

Figure 5a

Englemann Spruce - %R vs. wavelength
Mean Curve



Englemann Spruce - Normalized Curve

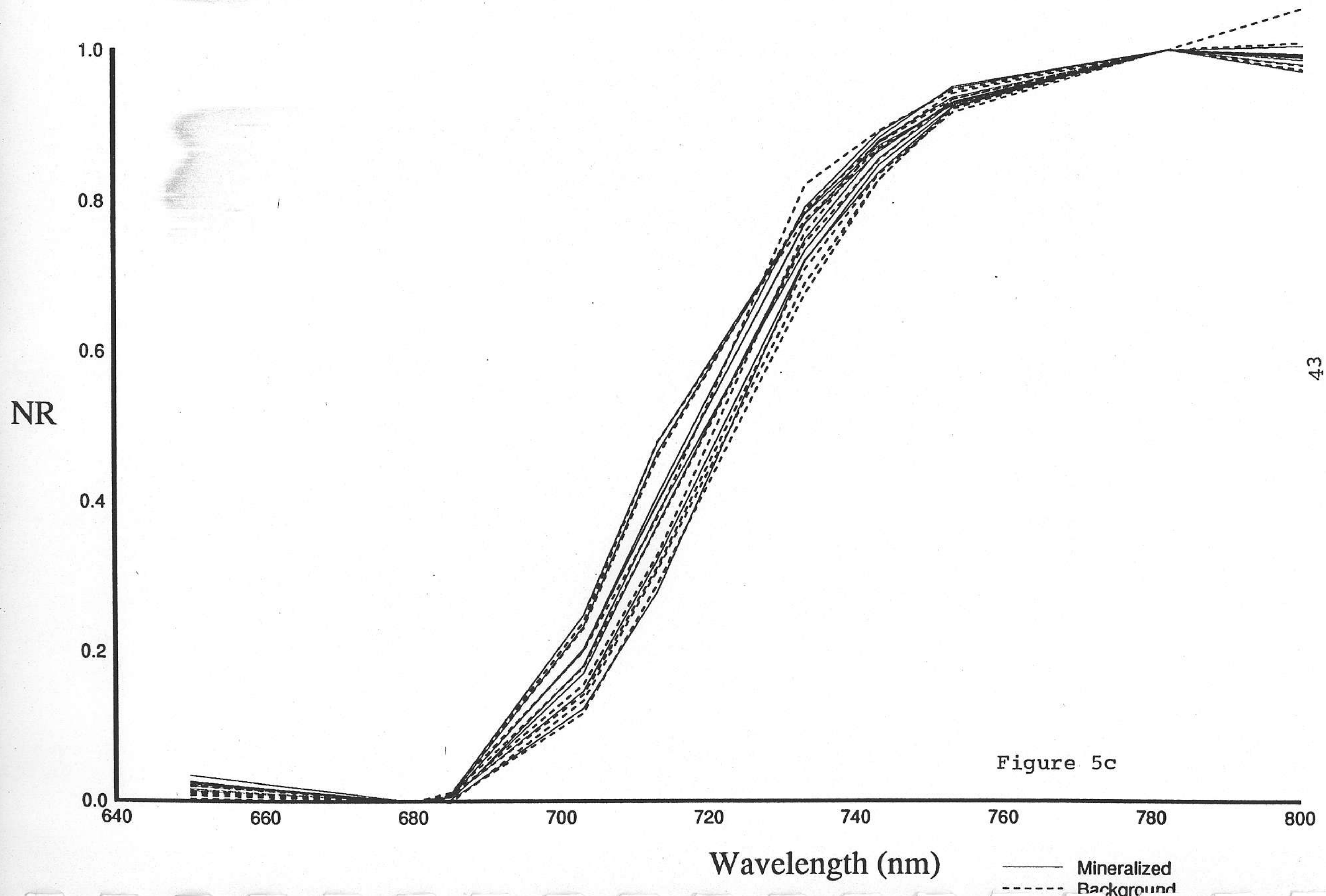


Figure 5c

Englemann Spruce - Normalized Mean Curve

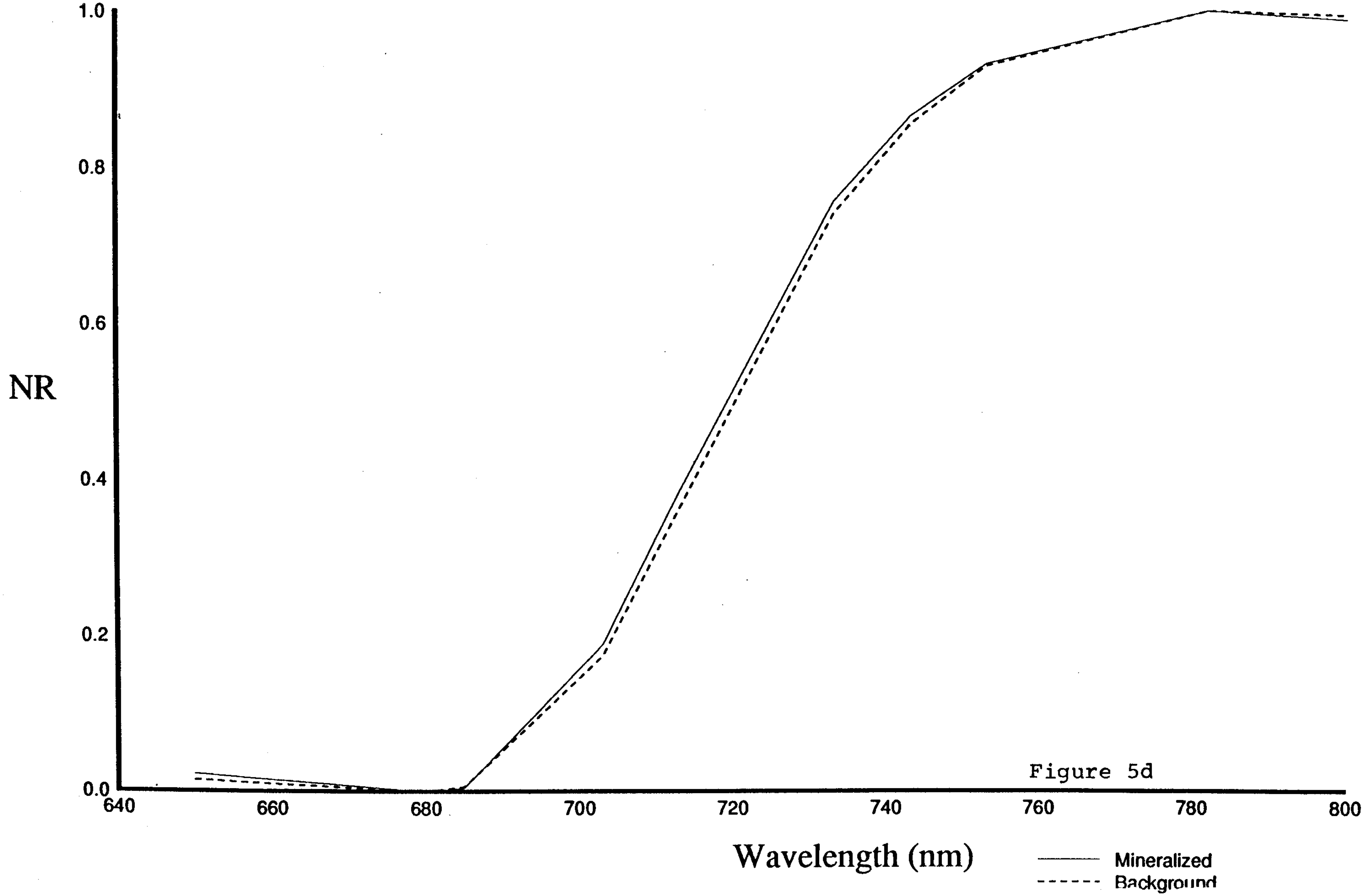


Figure 5d

Results: (cont'd)

Trembling Aspen (Populus tremuloides)

Trembling Aspen is described as an abundant tree throughout British Columbia east of the Cascade Mountains where it extends from valley bottoms to 4000 feet elevations. In the dry interior it gathers in groves 20 to 30 feet high and in wetter regions trees up to 80 feet high are common (Lyons,1952). The root system is very shallow and wide-spreading and commonly produces root suckers or shoots. Following disruption of an area which is favourable to the production of root suckers, Trembling Aspen will produce suckers in great abundance, reforesting an entire area. (Hosie,1979).

In the Samatosum Mt. property groves of immature Trembling Aspen under 20 feet are present in areas with no overstory which is to be expected as Trembling Aspen is very sensitive to shade. Mature Trembling Aspen is present in the overstory as scattered trees, occurring with Lodgepole Pine, Engelmann Spruce, Amibilis Fir and Douglas Fir.

A plot of reflectance versus wavelength gave a 22% range in reflectance at the infrared shoulder (6a) with mean curves showing a 7% decrease in amplitude of the background relative to the mineralized mean curve (6b). A plot of the normalized curves shows a 10 nm range at the 0.5 NR level (6c) while the normalized mean curves show a 4 nm shift towards the red spectra at the red-edge at the 0.5 NR level (6d).

An airborne survey conducted at Natal Lake, Ontario of Trembling Aspen using the PMI gave a 10% increase in reflectance of the mineralized samples as did the results of laboratory work with a SPECTRON SE 590 spectroradiometer (Singhroy,1986). Singhroy, et al, found that "clumps of Trembling Aspen growing in mineralized soil which showed evidence of stress in the laboratory and PMI spectral data demonstrated high reflectance values on the MEIS II imagery." (Ibid)

Results: Trembling Aspen (con'td)

The 10% increase in reflectance is similar to what was found on the Samatosum property.

At the Arnprior site in Eastern Ontario, Singhroy and his co-workers found a 10% increase in reflectance and "no blue-shift at the red reflectance edge was observed..." (Ibid). The data in this study was non-normalized and therefore does not relate to the normalized data determined from the Samatosum Mountain property. This data is obtained using the HHRR shows a red shift at the red-edge of 4 nm in the normalized data at the 0.5 NR level.

In summary:

Singhroy and his co-workers found at the Natal Lake site a blue-shift at the red-edge for trembling Aspen

- the Natal Lake site contained Cu, Ni, Co, Pb, Cr, Mn while the Minnova sited contained As, Cu, Pb, Zn, Ba and it may be this difference that has resulted in a red-shift at the red-edge.

- no shift at the red-edge slope was reported for Arnprior for Trembling Aspen where minerals reported were Cu, Zn, Ba, Sr.

- Their White Lake site which has Zn, Cu, Pb (soils reported to be 150 to 3000 ppm's) showed the presence of a 'blue-shift' and changes in the magnitude of the infrared shoulder. Since their data was non-normalized they cannot be correlated with the Minnova data. As well, no As was present. ?

Arsenic values at the Minnova/Rae Gold property sites are unusually high. One drillhole contained a near-surface result (40 ft) of over 16% Arsenic (RG-25) along with elevated values of Ag, Au, Zn, Pb, and some Cu (Pirie, I.,1984, company report). Arsenic was present in trenches and exposed bedrock in arsenopyrite and tennantite-tetrahedrite. Barite was also present in high concentrations.

Thus the presence of abendant As has resulted in a red-shift at the red edge slope rather than the blue-shift reported in the Singhroy, et al sites. No!

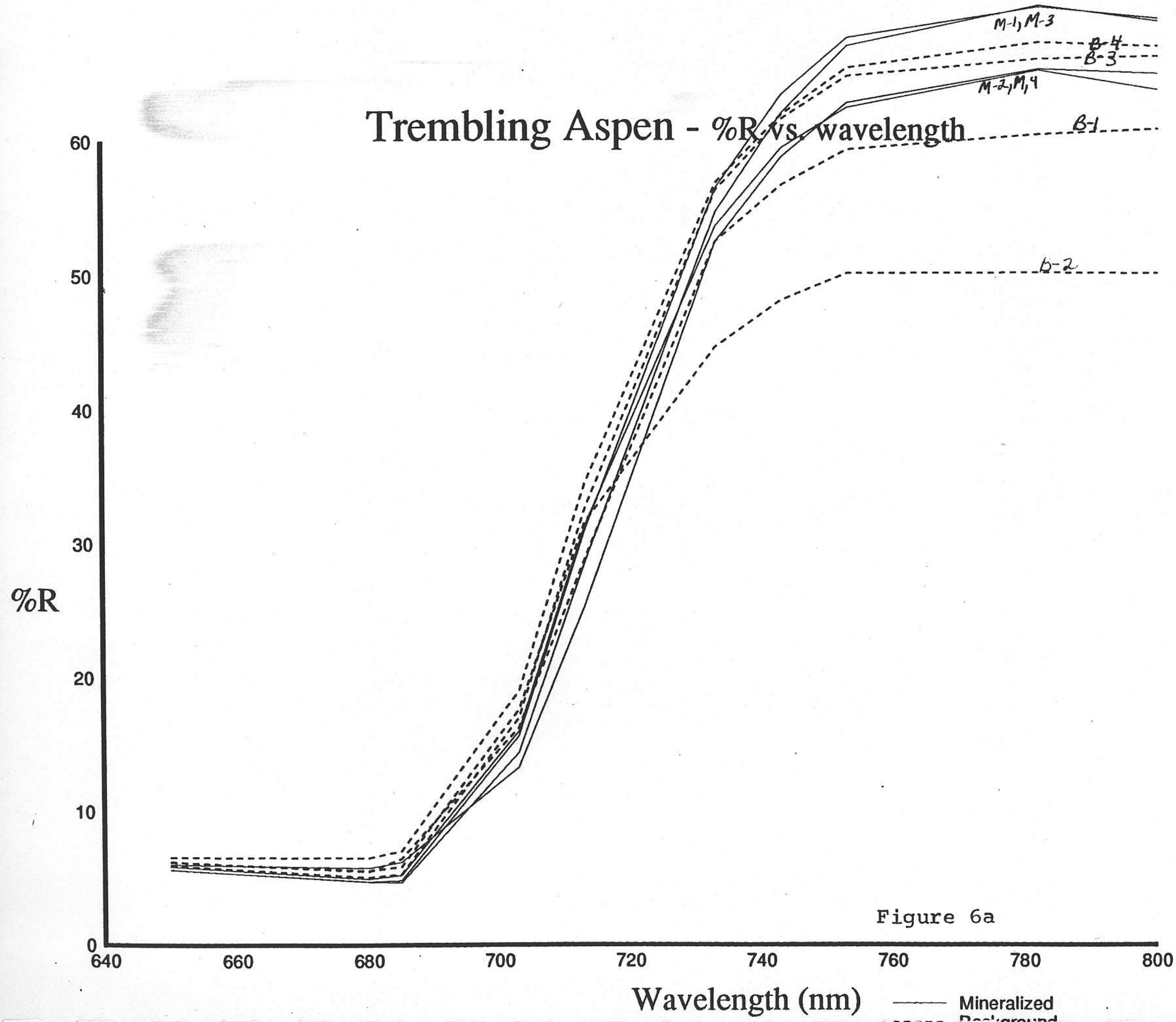
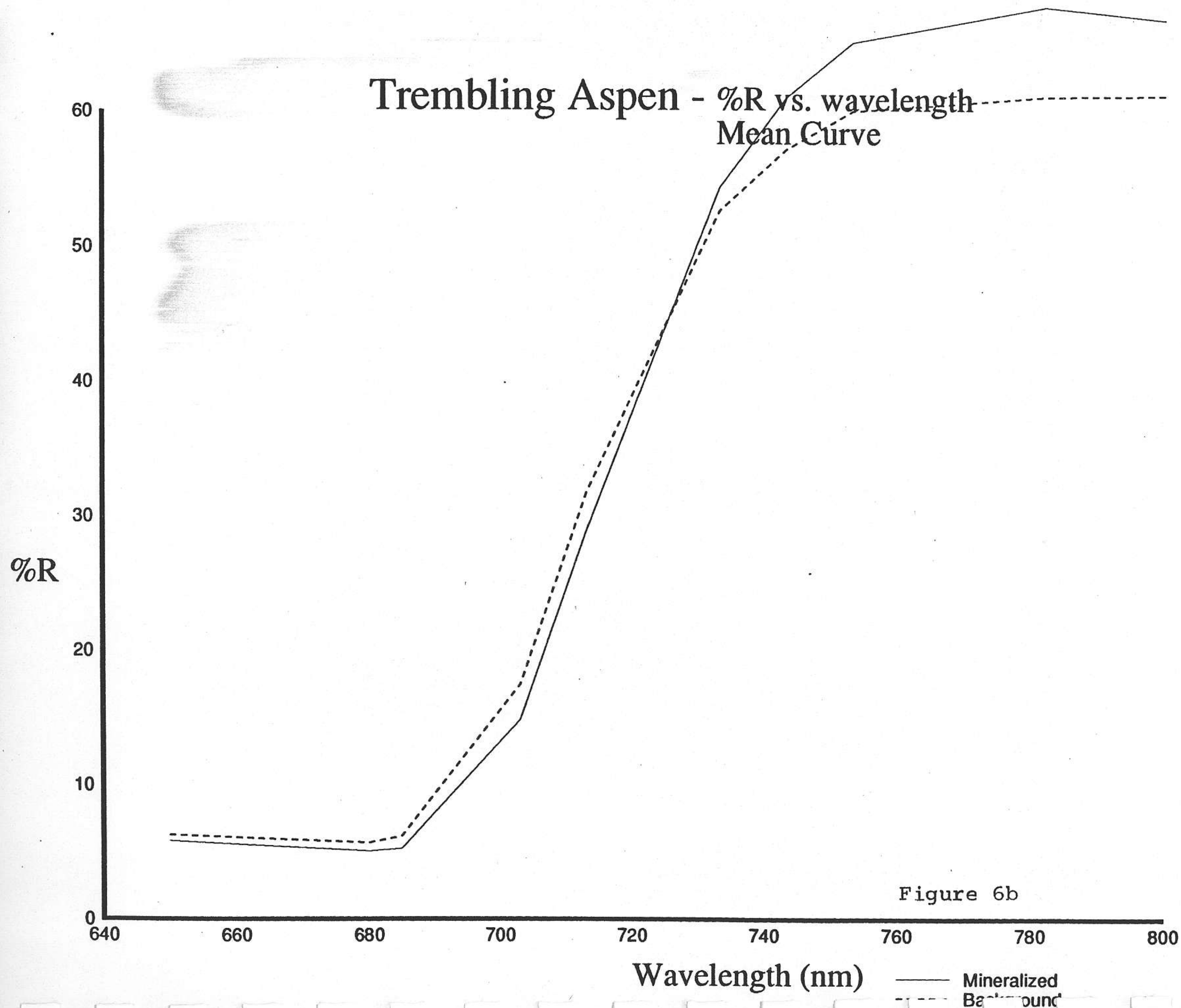
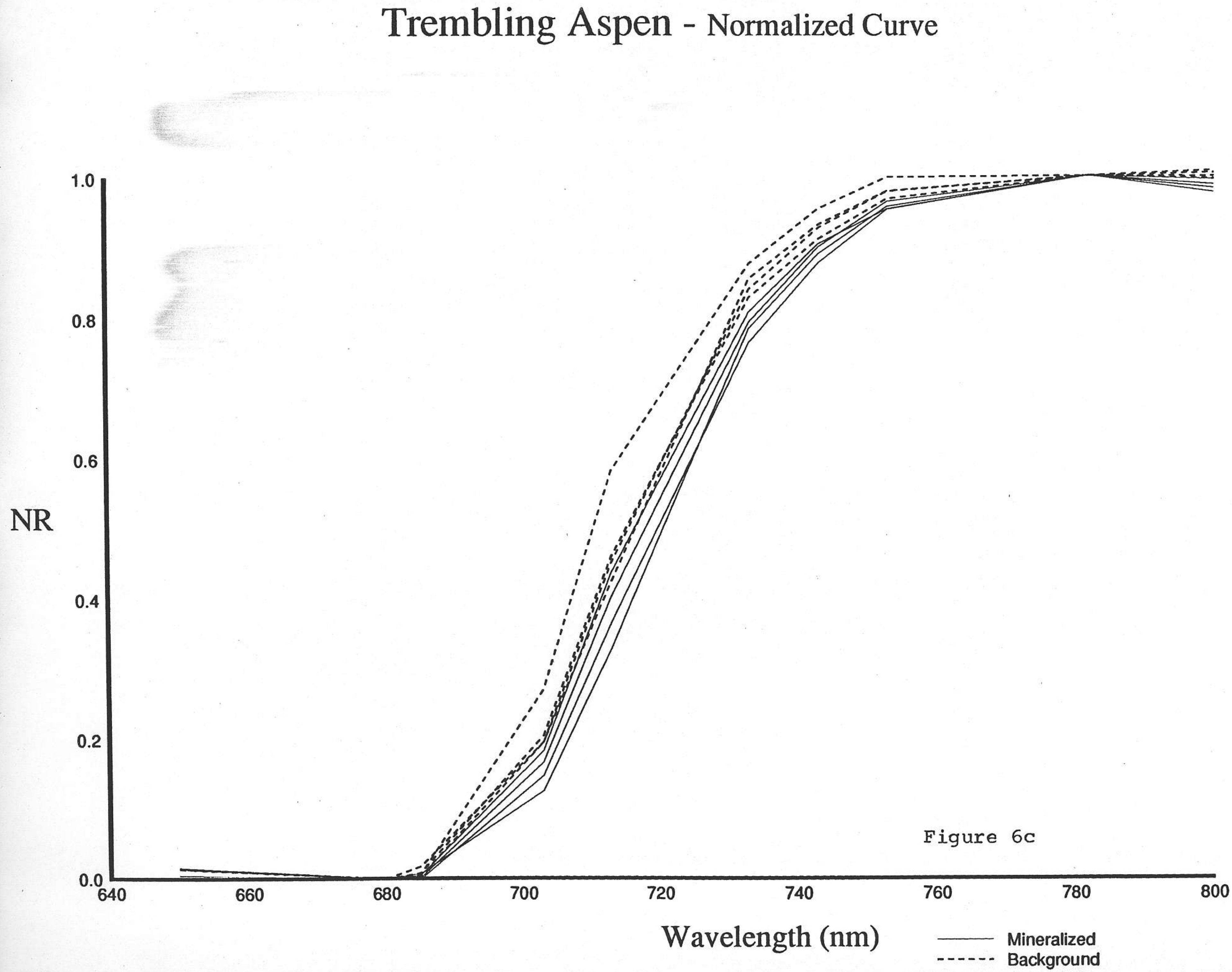

Trembling Aspen - %R vs. wavelength
%R
60
50
40
30
20
10
0
640
660
680
700
720
740
760
780
800
Wavelength (nm)
Mineralized
M-1, M-3
B-4
B-3
M-2, M-4
B-1
B-2

Figure 6a



Trembling Aspen - %R vs. wavelength
Mean Curve
%R
60
50
40
30
20
10
0
640
660
680
700
720
740
760
780
800
Wavelength (nm)
Mineralized

Figure 6b


Trembling Aspen - Normalized Curve
NR
1.0
0.8
0.6
0.4
0.2
0.0
640
660
680
700
720
740
760
780
800
Wavelength (nm)
Mineralized
Background
Figure 6c

Trembling Aspen - Normalized Mean Curve

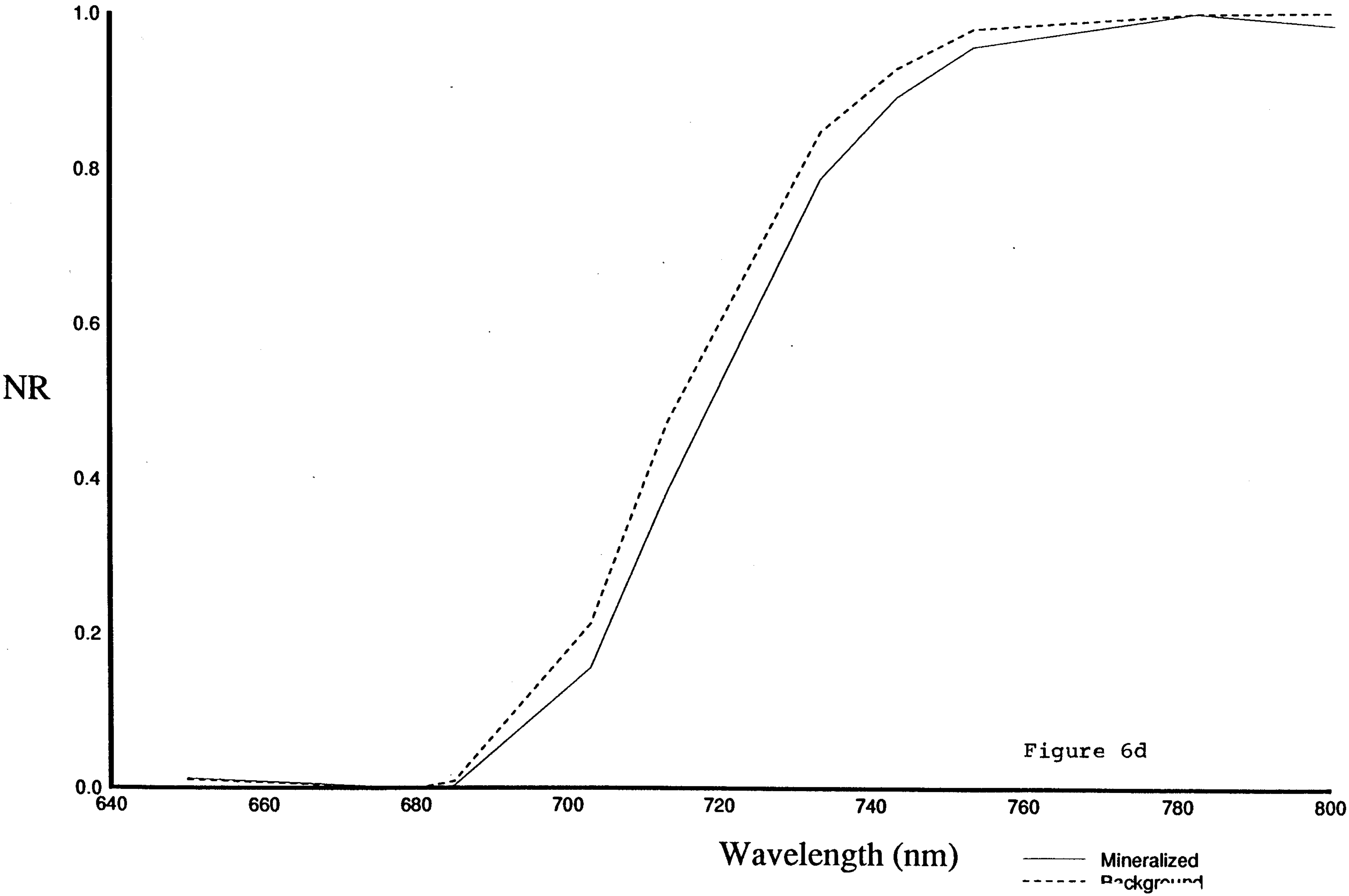


Figure 6d

CONCLUSION

The results of the ground reflectance radiometer survey show that three of the tree species sampled are effective indicators of anomalous mineralized zones and will present remotely sensed spectral images that will differ from images of trees in non-anomalous zones. (Table 1., Table 2.)

No!

Lodgepole Pine is one of the most common trees on the Minnova property and its resultant red-shift at the red-edge makes it a tree species that is useful for an airborne remote sensing survey. ?

Douglas Fir is less common on the Minnova property and shows a 3.5 to 4 nm blue-shift at the red-edge which is greater than within-species variation and hence, is a tree species that is useful for an airborne remote sensing survey. While it was reported that Douglas Fir was under stress by Spruce Budworm this season, all of the Douglas Firs sampled appeared to be quite healthy and on the Samatosum Mt. property were not affected by parasites. ?

Trembling Aspen occurs in pure stands with no overstory or as isolated trees in the overstory since it requires abundant sun and is quite intolerant of shade. Its red-shift at the red-edge will result in a spectral signature which will provide useful imaging data during an airborne mission of mineralized versus background areas.

It should be noted that this study concentrated on individual branchlets while the airborne survey will be looking at large trees canopies and will be able to see spatial patterns not evident in the individual trees; furthermore, the spectral data from this survey shows that there's spectral changes in the individual trees.

RECOMMENDATION

Since three species of trees show shifts at the red-edge slope in samples from mineralized areas over the samples from non-mineralized areas as well as a fourth borderline species (Alpine Fir), there is enough variation in these two sub-sets of data to recommend an airborne survey. The data obtained herein suggests that these spectral changes will be detectable from a suitable airborne imaging sensor thereby delineating anomalous mineralized zones. This will be especially so in areas not adjacent to areas subjected to 'slash and burn'. Due to the sensitive response of Engelmann Spruce (5c) which nonetheless, lacks a good spectral signature, some caution in interpretation of spectral data will be required. These parameters and others may result in non-mineralized anomalies; thus, data interpretation will be required to distinguish these anomalous areas.

It is recommended that an airborne survey be undertaken to determine mineralized anomalous zones and that such a survey be undertaken during the period mid-July to mid-August after full-leaf flush and during the 'Autumn Window' when stressed vegetation undergoes 'early leaf senscence'. It is further recommended that a detailed site report be prepared at the time of the flight in order to document any change in conditions of the site.

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Maps

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NTS 82/M, 1:250,000.

Adam's Lake Geology
Seymour Arm (West Half), G.S.C. Map 48, 1:253,440
1" to 4 miles, 1963.

Adam's Plateau
Kamloops Land District, B.C. NTS 82M/4
Scale, 1:50,000.

FRI - Map 82M.011
Forest Cover Map Series, British Columbia.

Samatosum Deposit
Drillhole Plan Map, Minnova Inc.
Scale 1:1000, 1987.

<u>CERTIFICATE</u>

I, Jeanette Lourim, of the City of Toronto, in the Province of Ontario, hereby declare that:

1. I am a consulting geologist working from my office at 16 Baldwin Street, of the City of Toronto, in the Province of Ontario.

2. I hold an Honours B.Sc. in Geology from the University of Toronto and a B.A. from Wayne State University, in the city of Detroit, Michigan, U.S.A.

3. I have practised my profession as a geologist for twelve years.

4. I conducted the radiometer survey on Samatosum Mt. for Minnova Inc.

5. I have no direct interest in the Samatosum Mt. property nor do I anticipate receiving such interest.

Date October 20, 1987
Toronto, Ontario

Jeanette Lourim
Jeanette Lourim
J. Lourim & Associates
Consulting Geologists.

Appendix A
Normalized and Reflectance Data

lodge.dat Wed Sep 16 14:45:06 1987 1

Sample	650.00	680.00	685.00	703.00	713.00	733.00	743.00	753.00	782.00	800.00
mlp-001	7.26	6.43	6.52	15.73	26.92	52.21	59.95	65.03	69.10	67.42
mlp-002	6.36	5.98	6.31	16.19	27.34	44.14	48.45	51.25	54.01	53.18
Mean	6.81	6.21	6.42	15.96	27.13	48.17	54.20	58.14	61.55	60.30
blp-001	5.27	4.58	4.66	9.21	14.87	24.55	27.76	29.44	31.22	30.88
blp-002	3.26	2.79	3.16	8.66	16.03	20.62	23.21	24.56	26.36	26.75
blp-003	4.90	4.12	4.26	11.37	19.71	39.26	40.85	43.47	45.87	45.58
blp-004	5.97	4.65	5.02	17.84	30.03	43.56	47.49	49.95	51.65	50.90
Mean	4.85	4.03	4.28	11.77	20.16	32.00	34.83	36.86	38.78	38.53

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Sample	650.00	680.00	685.00	703.00	713.00	733.00	743.00	753.00	782.00	800.00
mlp-001	0.0133	0.0000	0.0015	0.1485	0.3269	0.7304	0.8540	0.9350	1.0000	0.9731
mlp-002	0.0079	0.0000	0.0069	0.2126	0.4447	0.7946	0.8844	0.9427	1.0000	0.9828
Mean	0.0106	0.0000	0.0042	0.1805	0.3858	0.7625	0.8692	0.9388	1.0000	0.9779
blp-001	0.0259	0.0000	0.0030	0.1738	0.3863	0.7496	0.8703	0.9330	1.0000	0.9872
blp-002	0.0200	0.0000	0.0159	0.2492	0.5618	0.7564	0.8663	0.9237	1.0000	1.0165
blp-003	0.0188	0.0000	0.0035	0.1737	0.3734	0.8417	0.8797	0.9426	1.0000	0.9931
blp-004	0.0280	0.0000	0.0078	0.2807	0.5399	0.8279	0.9116	0.9638	1.0000	0.9840
Mean	0.0232	0.0000	0.0076	0.2193	0.4654	0.7939	0.8820	0.9408	1.0000	0.9952

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Sample	650.00	680.00	685.00	703.00	713.00	733.00	743.00	753.00	782.00	800.00
maf-006	4.56	3.88	3.98	12.01	21.90	41.39	46.95	50.43	54.12	53.81
maf-003	4.58	3.70	3.79	11.03	20.05	37.90	43.76	47.50	51.23	50.40
maf-004	5.52	4.37	4.60	14.72	26.34	48.66	55.12	58.99	63.20	61.66
Mean	4.89	3.98	4.12	12.59	22.77	42.65	48.61	52.30	56.19	55.29
baf-004	3.48	3.27	3.65	11.73	22.55	48.84	57.86	63.12	67.95	67.92
baf-005	3.09	2.77	3.00	9.66	19.04	39.70	45.96	50.00	54.19	53.39
Mean	3.29	3.02	3.33	10.69	20.80	44.27	51.91	56.56	61.07	60.66

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Sample	650.00	680.00	685.00	703.00	713.00	733.00	743.00	753.00	782.00	800.00
maf-006	0.0137	0.0000	0.0020	0.1618	0.3588	0.7465	0.8571	0.9264	1.0000	0.9937
maf-003	0.0184	0.0000	0.0017	0.1540	0.3440	0.7195	0.8429	0.9215	1.0000	0.9824
maf-004	0.0196	0.0000	0.0039	0.1760	0.3735	0.7529	0.8627	0.9284	1.0000	0.9739
Mean	0.0172	0.0000	0.0025	0.1639	0.3587	0.7396	0.8542	0.9254	1.0000	0.9833
baf-004	0.0032	0.0000	0.0058	0.1309	0.2981	0.7046	0.8441	0.9254	1.0000	0.9996
baf-005	0.0064	0.0000	0.0046	0.1340	0.3165	0.7182	0.8400	0.9185	1.0000	0.9844
Mean	0.0048	0.0000	0.0052	0.1324	0.3073	0.7114	0.8421	0.9219	1.0000	0.9929

Sample	650.00	680.00	685.00	703.00	713.00	733.00	743.00	753.00	782.00	800.00
mdf-001	4.37	3.66	3.92	12.27	23.80	45.42	53.08	58.20	62.97	62.23
mdf-002	5.19	4.12	4.23	13.59	23.49	44.16	49.12	52.30	55.54	54.90
mdf-003	5.15	3.98	4.33	15.85	28.31	48.58	54.12	56.80	60.32	60.00
mdf-004	4.82	3.98	4.11	12.87	22.59	41.86	47.36	50.82	54.11	53.60
mdf-005	6.11	5.06	5.05	14.04	23.89	42.05	46.33	50.00	52.94	52.76
Mean	5.13	4.16	4.33	13.72	24.42	44.41	50.00	53.62	57.18	56.70
bdf-001	4.87	4.09	4.32	13.71	25.71	48.21	54.52	59.19	63.29	62.51
bdf-002	4.63	3.92	3.98	12.22	22.12	45.12	51.35	55.21	59.36	58.76
Mean	4.75	4.01	4.15	12.96	23.91	46.67	52.93	57.20	61.32	60.63

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Sample	650.00	680.00	685.00	703.00	713.00	733.00	743.00	753.00	782.00	800.00
mdf-001	0.0120	0.0000	0.0044	0.1452	0.3396	0.7041	0.8333	0.9197	1.0000	0.9877
mdf-002	0.0207	0.0000	0.0020	0.1841	0.3766	0.7787	0.8752	0.9370	1.0000	0.9877
mdf-003	0.0207	0.0000	0.0062	0.2107	0.4318	0.7916	0.8900	0.9375	1.0000	0.9943
mdf-004	0.0169	0.0000	0.0027	0.1774	0.3713	0.7555	0.8652	0.9344	1.0000	0.9898
mdf-005	0.0219	0.0000	-.0002	0.1875	0.3933	0.7726	0.8619	0.9386	1.0000	0.9961
Mean	0.0184	0.0000	0.0030	0.1810	0.3825	0.7605	0.8651	0.9334	1.0000	0.9911
bdf-001	0.0133	0.0000	0.0040	0.1625	0.3652	0.7453	0.8518	0.9308	1.0000	0.9869
bdf-002	0.0129	0.0000	0.0010	0.1497	0.3283	0.7432	0.8556	0.9252	1.0000	0.9892
Mean	0.0131	0.0000	0.0025	0.1561	0.3467	0.7442	0.8537	0.9280	1.0000	0.9880

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Sample	650.00	680.00	685.00	703.00	713.00	733.00	743.00	753.00	782.00	800.00
mdf-003	5.15	3.98	4.33	15.85	28.31	48.58	54.12	56.80	60.32	60.00
mdf-005	6.11	5.06	5.05	14.04	23.89	42.05	46.33	50.00	52.94	52.76
Mean	5.63	4.52	4.69	14.95	26.10	45.32	50.23	53.40	56.63	56.38
bdf-001	4.87	4.09	4.32	13.71	25.71	48.21	54.52	59.19	63.29	62.51
bdf-002	4.63	3.92	3.98	12.22	22.12	45.12	51.35	55.21	59.36	58.76
Mean	4.75	4.01	4.15	12.97	23.92	46.67	52.94	57.20	61.33	60.64

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douglas.nor **Tue Sep 22 08:15:15 1987** **1**

Sample	650.00	680.00	685.00	703.00	713.00	733.00	743.00	753.00	782.00	800.00
mdf-003	0.0208	0.0000	0.0062	0.2107	0.4318	0.7916	0.8900	0.9375	1.0000	0.9943
mdf-005	0.0219	0.0000	-.0002	0.1876	0.3933	0.7726	0.8619	0.9386	1.0000	0.9962
Mean	0.0213	0.0000	0.0030	0.1991	0.4126	0.7821	0.8760	0.9381	1.0000	0.9953
bdf-001	0.0132	0.0000	0.0039	0.1625	0.3652	0.7453	0.8519	0.9307	1.0000	0.9868
bdf-002	0.0128	0.0000	0.0011	0.1497	0.3283	0.7431	0.8555	0.9251	1.0000	0.9892
Mean	0.0130	0.0000	0.0025	0.1561	0.3467	0.7442	0.8537	0.9279	1.0000	0.9880

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Sample	650.00	680.00	685.00	703.00	713.00	733.00	743.00	753.00	782.00	800.00
maf-010	4.97	4.17	4.28	12.89	24.10	46.22	52.51	56.79	60.70	60.51
maf-001	4.70	4.07	4.26	11.18	20.06	37.72	45.00	50.75	56.36	56.56
maf-002	6.52	5.41	5.77	15.24	25.24	42.00	47.00	50.50	53.30	53.20
maf-005	4.92	4.50	4.63	11.81	20.32	36.15	40.96	43.98	46.84	45.85
maf-007	5.25	4.92	4.98	12.55	22.79	45.11	52.38	56.16	59.86	59.88
maf-008	4.64	4.31	4.46	12.59	22.84	41.46	46.62	49.68	52.35	52.35
maf-009	4.32	3.30	3.42	11.68	21.77	43.48	49.93	53.76	57.81	57.46
maf-011	4.27	3.65	3.79	9.86	17.80	34.49	39.47	42.78	45.75	45.40
Mean	4.95	4.29	4.45	12.23	21.86	40.83	46.73	50.55	54.12	53.90
baf-006	4.10	3.39	3.48	9.20	17.85	33.12	38.21	41.96	44.85	44.62
baf-007	4.11	3.42	3.51	10.50	18.95	36.35	41.23	44.29	47.47	47.26
baf-008	4.25	3.64	3.55	9.52	18.00	39.42	46.33	50.98	55.60	55.37
baf-001	4.41	4.47	4.39	12.05	22.45	38.89	44.68	49.17	51.69	51.11
baf-002	4.70	4.55	4.45	12.46	23.64	41.80	47.44	51.40	55.76	54.23
baf-003	4.70	4.06	4.14	11.87	23.09	44.00	50.29	54.91	58.90	58.08
Mean	4.38	3.92	3.92	10.93	20.66	38.93	44.70	48.78	52.38	51.78

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Sample	650.00	680.00	685.00	703.00	713.00	733.00	743.00	753.00	782.00	800.00
maf-010	0.0142	0.0000	0.0020	0.1544	0.3525	0.7439	0.8550	0.9307	1.0000	0.9966
maf-001	0.0122	0.0000	0.0036	0.1361	0.3068	0.6436	0.7827	0.8926	1.0000	1.0037
maf-002	0.0231	0.0000	0.0075	0.2052	0.4139	0.7640	0.8684	0.9415	1.0000	0.9979
maf-005	0.0098	0.0000	0.0030	0.1727	0.3737	0.7475	0.8610	0.9323	1.0000	0.9766
maf-007	0.0060	0.0000	0.0011	0.1390	0.3253	0.7315	0.8639	0.9327	1.0000	1.0003
maf-008	0.0069	0.0000	0.0031	0.1723	0.3857	0.7734	0.8808	0.9445	1.0000	1.0000
maf-009	0.0188	0.0000	0.0023	0.1538	0.3389	0.7372	0.8555	0.9256	1.0000	0.9935
maf-011	0.0149	0.0000	0.0034	0.1476	0.3361	0.7326	0.8510	0.9294	1.0000	0.9918
Mean	0.0133	0.0000	0.0033	0.1601	0.3540	0.7342	0.8523	0.9287	1.0000	0.9951
baf-006	0.0171	0.0000	0.0023	0.1402	0.3489	0.7172	0.8399	0.9303	1.0000	0.9946
baf-007	0.0156	0.0000	0.0019	0.1608	0.3525	0.7474	0.8583	0.9278	1.0000	0.9952
baf-008	0.0118	0.0000	-.0016	0.1133	0.2764	0.6888	0.8216	0.9111	1.0000	0.9958
baf-001	-.0013	0.0000	-.0017	0.1605	0.3807	0.7289	0.8514	0.9465	1.0000	0.9877
baf-002	0.0029	0.0000	-.0021	0.1544	0.3727	0.7274	0.8377	0.9149	1.0000	0.9703
baf-003	0.0117	0.0000	0.0013	0.1424	0.3470	0.7283	0.8429	0.9272	1.0000	0.9850
Mean	0.0096	0.0000	0.0000	0.1453	0.3464	0.7230	0.8420	0.9263	1.0000	0.9881

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engleman.dat Wed Sep 16 14:43:35 1987 1

Sample	650.00	680.00	685.00	703.00	713.00	733.00	743.00	753.00	782.00	800.00
mes-001	4.40	3.42	3.52	10.76	19.87	46.02	53.62	58.22	62.78	62.33
mes-002	5.42	4.23	4.56	13.64	22.91	40.33	45.56	48.29	51.31	51.53
mes-003	5.70	4.66	4.65	12.78	21.83	37.62	43.12	46.41	49.68	49.07
mes-004	4.30	3.57	3.78	10.04	17.71	35.38	40.53	44.33	47.78	46.50
mes-005	8.13	6.29	6.76	19.33	31.46	47.52	52.32	55.19	59.12	58.08
mes-006	5.29	4.09	4.31	13.27	21.99	38.96	43.26	46.24	49.46	40.96
mes-007	5.43	4.42	4.68	13.90	23.35	36.36	40.46	43.24	45.28	44.84
mes-009	5.28	4.58	4.68	12.97	22.69	41.46	47.33	50.49	53.94	53.49
mes-010	5.29	4.28	4.54	13.97	23.86	42.42	47.21	50.06	52.59	52.32
Mean	5.47	4.39	4.61	13.41	22.85	40.68	45.93	49.16	52.44	51.90
bes-001	4.96	4.54	4.60	10.65	19.48	39.60	47.48	52.54	56.53	55.46
bes-002	4.54	4.01	3.92	9.65	16.87	32.92	38.73	42.68	46.05	46.43
bes-003	5.40	4.42	4.70	11.47	19.26	38.79	44.19	47.19	49.85	49.58
bes-004	6.86	5.75	6.21	18.13	30.41	48.20	52.97	56.11	59.72	58.29
bes-005	4.27	3.81	4.21	14.05	24.34	37.07	41.18	43.67	46.86	46.44
bes-006	6.78	6.65	7.02	12.85	18.36	32.13	34.36	36.02	37.75	39.45
bes-008	5.40	4.25	4.66	14.24	24.63	45.78	51.91	56.47	60.20	59.66
bes-007	5.11	4.36	4.67	11.74	20.50	41.14	47.72	51.98	56.37	56.04
Mean	5.41	4.72	5.00	12.85	21.73	39.45	44.82	48.33	51.67	51.42

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Sample	650.00	680.00	685.00	703.00	713.00	733.00	743.00	753.00	782.00	800.00
mes-001	0.0165	0.0000	0.0016	0.1237	0.2771	0.7177	0.8458	0.9232	1.0000	0.9924
mes-002	0.0253	0.0000	0.0069	0.2000	0.3967	0.7669	0.8779	0.9360	1.0000	1.0048
mes-003	0.0231	0.0000	-.0001	0.1803	0.3814	0.7321	0.8541	0.9273	1.0000	0.9863
mes-004	0.0166	0.0000	0.0047	0.1464	0.3199	0.7193	0.8358	0.9219	1.0000	0.9709
mes-005	0.0349	0.0000	0.0089	0.2469	0.4763	0.7804	0.8713	0.9254	1.0000	0.9802
mes-006	0.0265	0.0000	0.0049	0.2024	0.3946	0.7686	0.8634	0.9291	1.0000	0.9890
mes-007	0.0247	0.0000	0.0064	0.2320	0.4634	0.7818	0.8821	0.9501	1.0000	0.9893
mes-009	0.0141	0.0000	0.0019	0.1699	0.3667	0.7471	0.8661	0.9300	1.0000	0.9907
mes-010	0.0209	0.0000	0.0055	0.2007	0.4054	0.7896	0.8887	0.9476	1.0000	0.9944
Mean	0.0225	0.0000	0.0045	0.1891	0.3868	0.7559	0.8650	0.9323	1.0000	0.9887
bes-001	0.0081	0.0000	0.0012	0.1174	0.2873	0.6743	0.8258	0.9233	1.0000	0.9793
bes-002	0.0125	0.0000	-.0022	0.1341	0.3059	0.6878	0.8260	0.9199	1.0000	1.0092
bes-003	0.0216	0.0000	0.0062	0.1552	0.3266	0.7564	0.8755	0.9413	1.0000	0.9940
bes-004	0.0206	0.0000	0.0086	0.2293	0.4570	0.7865	0.8750	0.9330	1.0000	0.9734
bes-005	0.0107	0.0000	0.0094	0.2378	0.4770	0.7726	0.8681	0.9259	1.0000	0.9903
bes-006	0.0040	0.0000	0.0117	0.1994	0.3766	0.8193	0.8910	0.9446	1.0000	1.0549
bes-008	0.0206	0.0000	0.0075	0.1785	0.3644	0.7423	0.8520	0.9334	1.0000	0.9904
bes-007	0.0143	0.0000	0.0060	0.1419	0.3103	0.7072	0.8338	0.9156	1.0000	0.9937
Mean	0.0141	0.0000	0.0060	0.1742	0.3631	0.7433	0.8559	0.9296	1.0000	0.9982

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Sample	650.00	680.00	685.00	703.00	713.00	733.00	743.00	753.00	782.00	800.00
mta-001	5.68	4.73	4.68	14.31	28.43	54.64	62.03	67.04	70.13	68.92
mta-002	5.92	4.96	5.24	15.91	31.20	53.60	59.43	62.43	65.25	63.78
mta-003	5.67	4.75	4.84	15.55	30.88	56.44	63.40	67.65	70.00	69.13
mta-004	6.08	5.77	6.20	13.21	25.16	52.44	58.75	62.79	65.35	64.99
Mean	5.84	5.05	5.24	14.75	28.92	54.28	60.90	64.98	67.68	66.70
bta-001	6.28	5.51	6.45	16.18	28.71	52.45	56.67	59.31	60.47	60.84
bta-002	6.25	5.56	5.86	17.52	31.49	44.61	48.10	50.11	50.18	50.11
bta-003	6.00	5.08	5.30	16.90	32.50	56.27	61.58	64.78	66.10	66.30
bta-004	6.62	6.52	7.01	18.89	34.40	56.83	61.89	65.40	67.35	67.04
Mean	6.29	5.67	6.15	17.37	31.78	52.54	57.06	59.90	61.02	61.08

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Sample	650.00	680.00	685.00	703.00	713.00	733.00	743.00	753.00	782.00	800.00
mta-001	0.0146	0.0000	-.0007	0.1465	0.3624	0.7631	0.8762	0.9527	1.0000	0.9816
mta-002	0.0161	0.0000	0.0048	0.1817	0.4353	0.8068	0.9035	0.9533	1.0000	0.9756
mta-003	0.0141	0.0000	0.0014	0.1655	0.4005	0.7923	0.8989	0.9640	1.0000	0.9866
mta-004	0.0052	0.0000	0.0072	0.1249	0.3255	0.7832	0.8892	0.9570	1.0000	0.9939
Mean	0.0125	0.0000	0.0032	0.1547	0.3809	0.7864	0.8919	0.9568	1.0000	0.9844
bta-001	0.0139	0.0000	0.0171	0.1941	0.4222	0.8541	0.9308	0.9789	1.0000	1.0068
bta-002	0.0154	0.0000	0.0067	0.2681	0.5810	0.8752	0.9533	0.9984	1.0000	0.9984
bta-003	0.0151	0.0000	0.0036	0.1937	0.4494	0.8390	0.9260	0.9783	1.0000	1.0834
bta-004	0.0016	0.0000	0.0080	0.2034	0.4584	0.8272	0.9103	0.9680	1.0000	0.9950
Mean	0.0115	0.0000	0.0088	0.2148	0.4777	0.8489	0.9301	0.9809	1.0000	1.0009

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Appendix B
Barringer HHRR

5548A/0095A

HAND HELD RATIOING RADIOMETER, MK I

BARRINGER RESEARCH LIMITED
304 CARLINGVIEW DRIVE
REXDALE, ONTARIO
M9W 5G2

Rev. 7

December 1982

SECTION 1 - INTRODUCTION

The Hand Held Ratioing Radiometer (HHRR) is an electro-optical instrument with electronic readout designed primarily for use in the Earth Sciences for the classification of various rock types, detection of rock type changes caused by mineralization, classification of clays and shales, and various other uses. The instrument was developed by the California Institute of Technology at Jet Propulsion Laboratory, Pasadena during research sponsored by NASA. The HHRR is manufactured and sold by Barringer under an exclusive license from the California Institute Research Foundation and is protected by patents filed in various countries.

The HHRR instrument measures the energy reflected by a target scene of interest. Various materials reflect sun radiation in different and characteristic fashion, this instrument covering the visible and short infared regions from approximately 0.4 to 2.5 microns. The HHRR instrument when pointed at a target scene analyzes the received radiation in two preset wavelengths, the wavelengths being preset by the selection of narrow band filters contained on two filter wheels within the instrument. The incoming radiation is therefore analyzed at two quite separate and diagnostic optical wavelengths which are then ratioed by the instrument to provide a number indicative of the materials analyzed.

The HHRR is thus able to remotely classify various rock types and clays by analysis of their characteristic spectral peaks and thereby greatly assisting field geologists in rock mapping and land utilization mapping. Since mineral and oil exploration activities are critically dependent upon analysis of rock types and sediment composition, this instrument greatly facilitates field exploration and other field work where such classification is required.

The instrument as shown in Fig 1 has been designed to be fully lightweight for hand held use and battery powered for easy field operation. An output jack is available on the instrument so that its readings can be recorded on a data logger or on an analog chart recorder if a permanent record of the measurements are required.

A technical description of the instrument, its operation and brief application notes are provided herein, together with maintenance procedures. A Bibliography is provided for more detailed references to a wide body of literature and references dealing with reflectance spectra.

SECTION 2 - TECHNICAL BACKGROUND

2.1 CONCEPT

The instrument is a self-contained, dual beam ratioing radiometer with two optical trains directed at a common target area. It provides a continuous digital readout of ratio values from the two optical trains each of which includes a separate filter for selection of the narrow spectral bands to be ratioed for identification of the presence of a particular target, on the basis of known spectral characteristics of the target. In addition to the ratio of the two channels, each channel can also be displayed separately.

Positive target identification can be achieved by measuring the ratio of the two most prominent spectral peaks characterizing the target. The instrument can provide a preselected ratio of such spectral peaks in any of up to 25 pairs of preselected narrow bands in the spectral range from 0.4 micrometers to 2.5 micrometers. This spectral range can be extended from 0.3 to 3.5 microns if required, but requires special IR detectors.

The 25 ratios are the result of ratioing any one filter of 5 on the first wheel against any one of 5 on the second wheel, i.e. a maximum of 5 x 5 ratio combinations.

2.2 DESIGN FEATURES

The major design features include:

- Two balanced detectors simultaneously measure radiance through pairs of reference filters, preselected for their spectral position and mounted into the two filter wheels which are independently rotatable about a common axis. The PbS detectors detect the received radiation and convert this into electrical signals amplified by the preamplifier; each channel has its own detector-preamp.

FIGURE 2

SCHEMATIC DIAGRAM

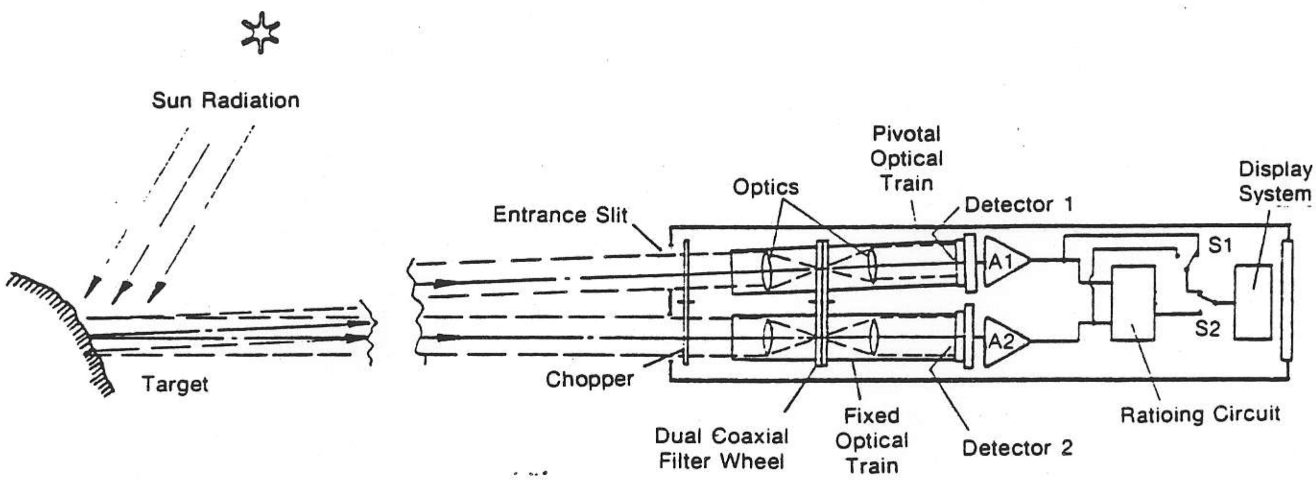
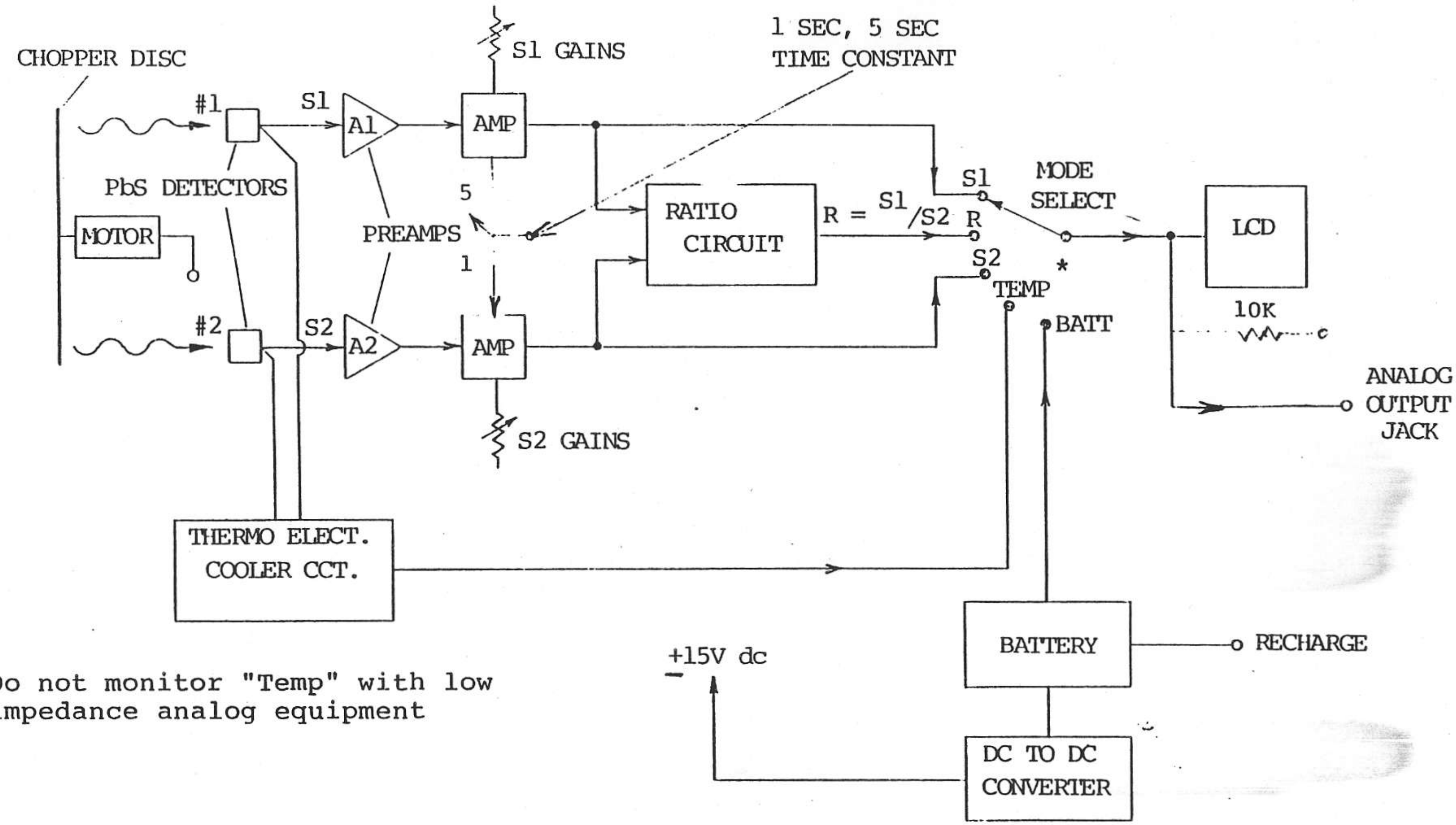


FIGURE 3

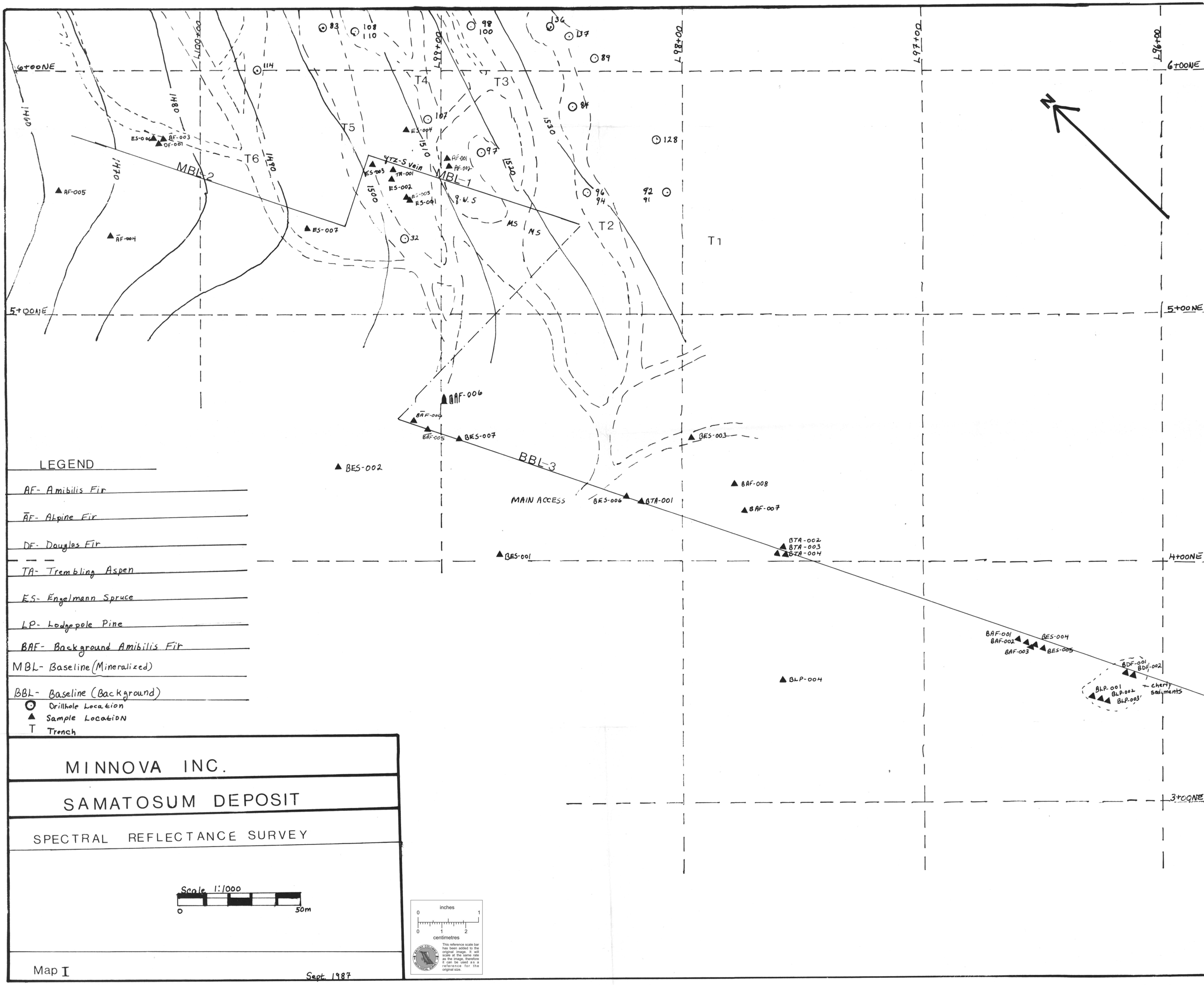
ELECTRONICS SIGNAL PROCESSING



*<u>Note</u>: Do not monitor "Temp" with low impedance analog equipment


RATIOING RADIOMETER
BRL
1s
5s
TIME CONST
FILTER NUMBER
CH1 GAIN
GAIN CH2
CH2
CH1
OFF
RATIO
TEMP
BATT
∞ — FOCUS — 1m

FIGURE 5



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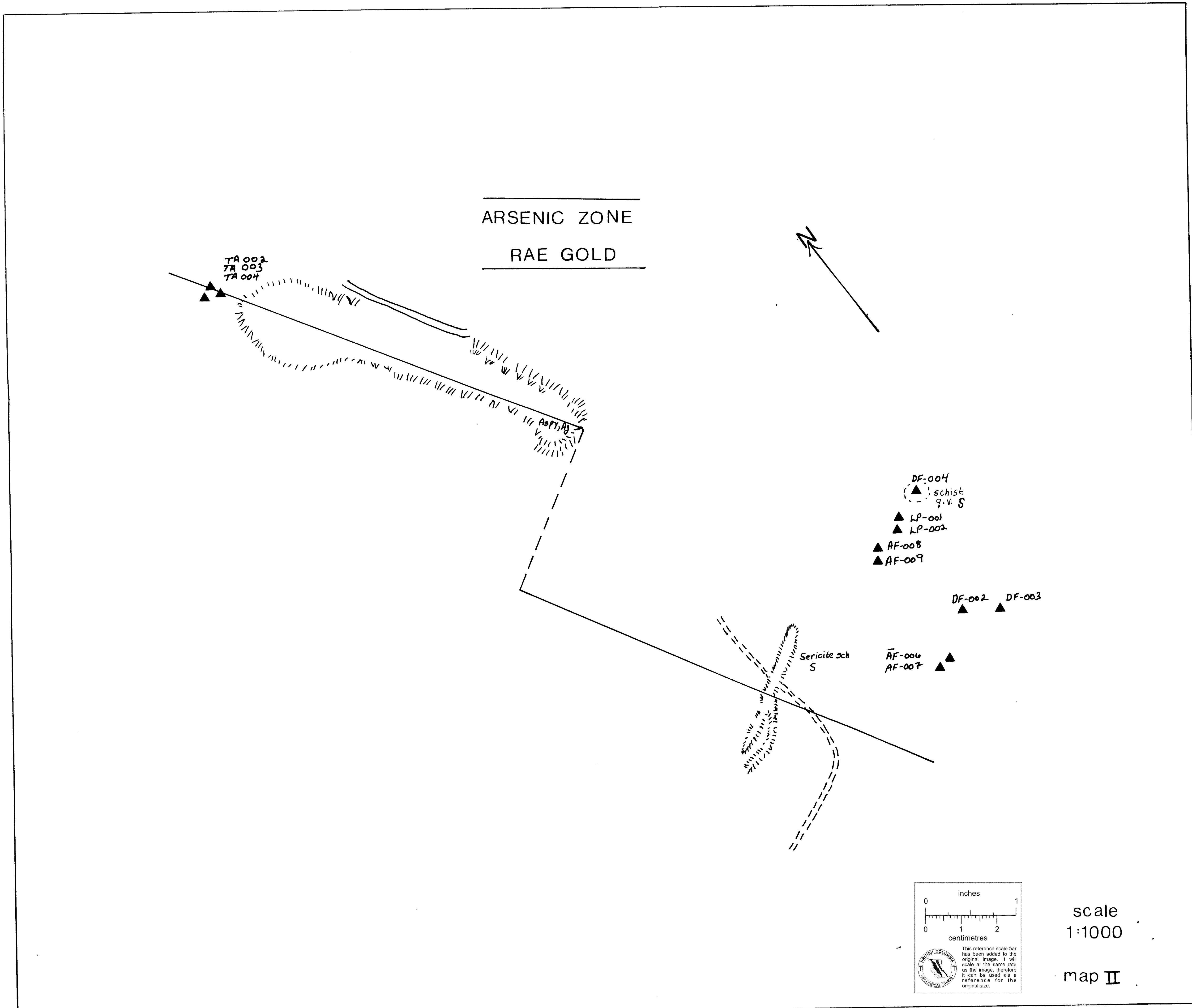
SAMATOSUM DEPOSIT

SPECTRAL REFLECTANCE SURVEY

Map I

Sept. 1987


ARSENIC ZONE
RAE GOLD
N
TA 002
TA 003
TA 004
Aspy, Ag
DF-004
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LP-001
LP-002
AF-008
AF-009
DF-002
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This reference scale bar has been added to the original image. It will scale at the same rate as the image, therefore it can be used as a reference for the original size.
BRITISH COLUMBIA
GEOLOGICAL SURVEY
scale
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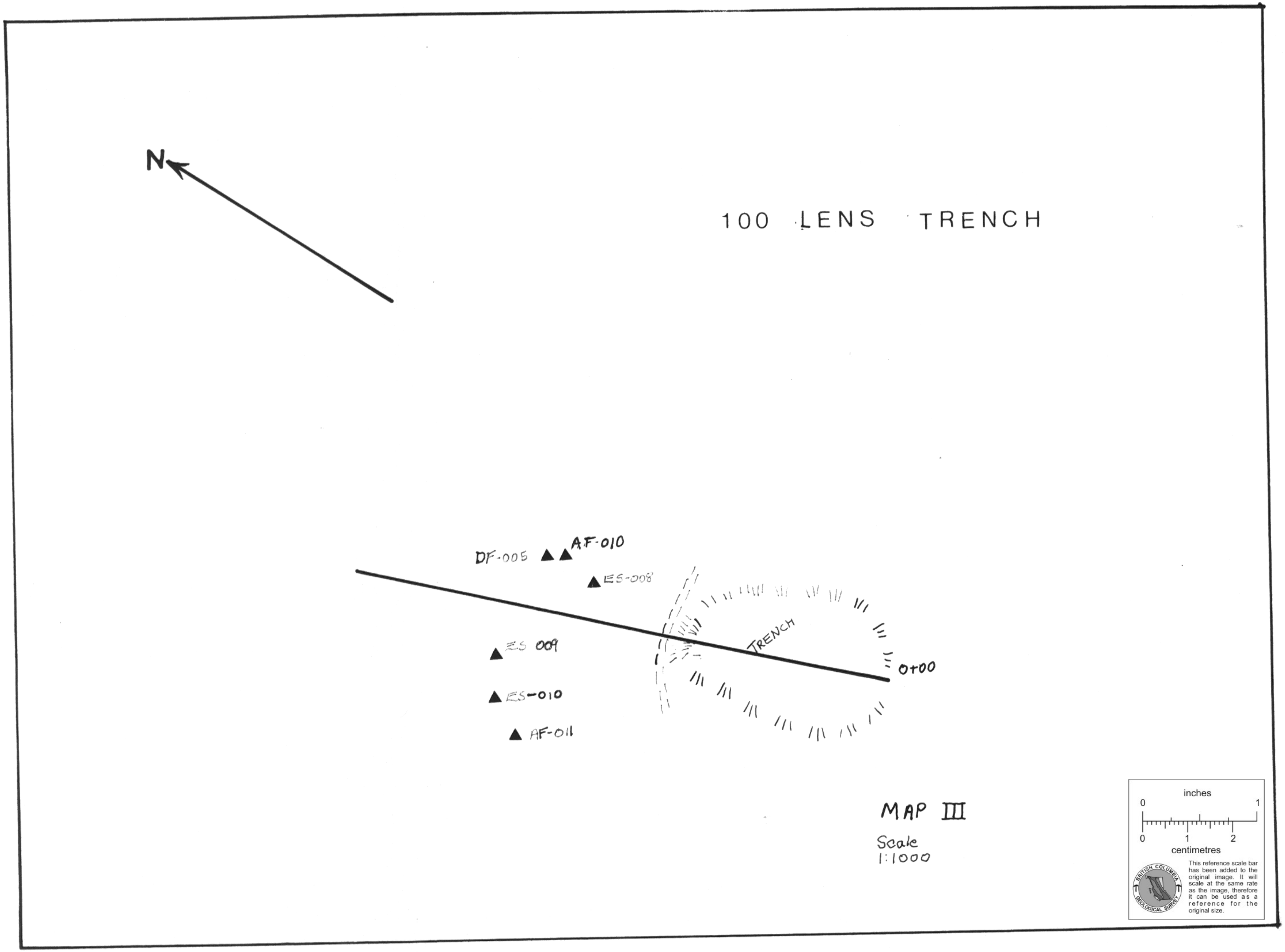
map II


N
100 LENS TRENCH
DF-005
AF-010
ES-008
ES 009
ES-010
AF-011
TRENCH
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MAP III
Scale
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