UNITED STATES ENVIRONMENTAL PROTECTION AGENCY REGION VIII EPA-908/9-85-001

INVESTIGATION INTO THE HEALTH OF FORESTS IN THE VICINITY OF GOTHIC, COLORADO

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INVESTIGATION INTO THE HEALTH OF FORESTS IN THE VICINITY OF GOTHIC, COLORADO

A SCIENTIFIC REPORT

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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION VIII

PREFACE

Last summer, two scientists observed damage to trees near Gothic, Colorado which appeared similar to air pollution damage to forests in northeastern United States and central Europe. The scientists, one from New England, the other from West Germany, announced their observation that evening to attendees of an acid rain conference at Western State College in Gunnison, Colorado. About 300 people were at the July 23-25 conference, including several news reporters.

While the scientists had not said the tree damage was definitely caused by acid rain, some conference attendees interpreted the remarks as a definite 'discovery' of acid rain damage in Colorado. The next day media reports ranged from a major story headlined, "First Acid Rain Damaged Trees Found in State", to comparisons of the Gothic situation to those in known areas of acid rain damage outside the western states. Several days later, questions emerged over the possible effect the reports of "Colorado's acid-rain-damaged forests" would have on the state's important tourism industry. A seemingly casual report of possible damage had escalated into considerable public concern about a potential environmental and economic threat.

Because of a general lack of knowledge about atmospheric deposition and its effect on western forest ecosystems, public agencies could not support or refute the allegations quickly and decisively. Based on the high level of public concern, several state and federal agencies formed a team of scientists to assess the health of forests in the Gothic area. The team was composed of experts familiar with the ecosystems in the Rocky Mountain region and pathologists expert in identifying and assessing air pollution damage to forests.

Dr. Robert I. Bruck of North Carolina State University was named to head the team because of his expertise in air pollution forest damage in eastern United States and central Europe.

The team's sole purpose was to assess and document the health of forests in the Gothic area and to identify probable causes of reported forest decline. This report presents their methods and findings.

THE MAJOR CONCLUSION IS THAT THERE IS NOW NO EVIDENCE TO INDICATE THAT AIR POLLUTION IS CONTRIBUTING TO NATURAL FOREST PROCESSES IN THE GOTHIC AREA.

Still, this experience contains some important lessons. First, where public and media interest is intense, scientists should use extra care in offering conclusions to extremely complex questions. Second, we need comprehensive baseline research and monitoring to assess the link between atmospheric deposition and forest health in the western United States.

If either of these principles is neglected, the scientific community, public decision makers and the public at large may be misled when making important policy decisions about changes to ecosystems. We intend to pursue the recommendations for cooperative interagency research on western atmospheric deposition as described in this report.

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for James Torrence
Regional Forester
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Robert A. Arnott, Ph.D.
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ACKNOWLEDGEMENTS

This report, describing investigations into the health of forests around Gothic, Colorado was made possible only by the dedicated efforts and hard work of numerous individuals. The spirit of cooperation demonstrated among and between all members of the investigative team, invited observers and representatives of the U.S. Environmental Protection Agency, (EPA), Region VIII was outstanding. Special thanks are extended to Larry Svoboda of EPA for his highly objective approach in dealing with this sensitive issue and for his assistance in the preparation of this report. The scientific team never found itself "predisposed" to forming premature conclusions about the investigation and was given free reign to explore all areas of concern and ready access to required data. The investigative team also thanks our official observers: Jim Lehr (EPA), Dr. Ray Herrmann (National Park Service), Ronald Cattany (Colorado Department of Natural Resources), and Beth Baird (Colorado Department of Health), for adding the necessary scientific expertise to our field excursions, providing needed data bases, and excellent and objective reviews of this document. In addition, we thank Dr. Ellis B. Cowling of North Carolina State University, Dr. Eric Preston of EPA (Corvallis, Oregon), Dr. James Gibson of Colorado State University (and Director of the National Acid Deposition Program) and Dr. Carse Pustmueller of the Colorado Department of Natural Resources for their prompt and constructive review of this document. Finally, we are grateful to Dr. Chris Bernabo, Executive Director of the National Acid Precipitation Assessment Program, for his support and encouragement throughout this project.

The forest decline investigation team believes that it had a most valuable experience in assessing the alleged anthropogenic damage to the forests in the vicinity of Gothic Colorado. We hope the substance and recommendations presented in this report serve both the scientific and policy making communities in directing future strategies for the protection of our environment.

For the Colorado Forest Decline
Investigation Team,

Robert I. Bruck, Ph.D.
Chairman
January, 1985

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Executive Summary

This report summarizes the activities of a task force assembled by the United States Environmental Protection Agency (Region VIII) in cooperation with the Colorado Department of Natural Resources, Colorado Department of Health, the Colorado State Forest Service, and the U.S. Forest Service in response to the alleged decline of forests in the Crested Butte/Gothic area of Colorado. Following two preliminary field trips conducted in August and September 1984, a team visited the Gothic site during September 19-21, 1984 to make on-site observations, collect and analyze soil samples, perform increment core sampling and analysis, and assess the potential for both biotic and abiotic causal agents in the alleged tree damage. Team members include:

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Chairman, Associate Professor
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Included as observers were:

Jim Lehr
U.S. Environmental Protection Agency,
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Denver, Colorado

Ronald Cattany, Assistant Director
Colorado Department of
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Denver, Colorado

Ray Herrmann, Ph.D.
U.S. Department of the Interior
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Fort Collins, Colorado

Beth Baird
Colorado Department of Health
Denver, Colorado

A preliminary reconnaisance of the Gothic area was made by a team of forest pathologists and entomologists from the Colorado State Forest Service and U.S. Forest Service in August 1984. In September, eight test plots were established by Dr. Jacobi. Soil samples were taken at these test plots, and analyzed for heavy metal content. More than one hundred increment cores of Engelmann spruce and subalpine fir were collected and annual increments measured. Both symptomatic and asymptomatic trees were examined for the presence of biotic and abiotic etiological agents that could be causal in the decline symptomology. Spruce and fir needle samples were also collected and analyzed under a scanning electron microscope.

It is essential to state the fact that "trees are always dying in our forests." Spruce and fir trees in the Rocky Mountain forests are affected by manv abiotic and biotic agents that may stress, injure and often lead to tree death. This is, in fact, a "natural" and expected phenomenon in a normal "healthy" forest.

The needle chlorosis (yellowing) leading to necrosis (cell death) of spruce or fir trees is often attributable to common and potentially deadly forest pathogens and insects. At all sites visited, this team specifically identified fungal pathogens and/or insects that can, and often will, cause their hosts to yellow, decline and exhibit suppressed annual increment growth, leading to tree death.

Although the appearance of many spruce and fir trees in and around Gothic is similar to trees observed at the European and eastern U. S. sites, the symptoms on trees observed in Colorado appear NOT to parallel those in the affected forest decline Waldsterben areas. A detailed description of the Waldsterben type of symptoms and decline is provided in Appendix A and B of this report. In Dr. Bruck's observations, there is little or no correlation between the normal forest disease syndrome found near Gothic and the inexplicable damages observed in the Waldsterben areas (central Europe and eastern U.S.) where air pollution is suspected as a major factor in forest decline. In addition to these visual observations, various data were collected and analyzed which confirm and scientifically support the observations and conclusions of this investigation. In summary, these additional data and analyses revealed the following:

(1) Microscopic analysis of spruce and fir increment cores revealed NO severe synchronous growth suppression (as is often observed in boreal montane ecosystems in the eastern U.S. and West Germany). Approximately twenty percent of the cores examined exhibited a marked INCREASE in growth over the past twenty years.

(2) Analysis of surface soils from the eight test plots indicated no abnormal loading of heavy metals. Loading of lead, copper and nickel was usually four to ten times less than documented eastern U.S. sites and virtually two orders of magnitude below levels currently being observed in central Europe.

(3) Scanning electron microscope observations of needle tissues collected from spruce and fir trees at the eight Gothic test sites indicated NO surface cuticular or cell damage (highly indicative of a lack of oxidant damage).

(4) Ambient concentrations of ozone (O_3) were monitored in the area for a four week period. This monitoring revealed very low levels of ozone. From these limited data, there is little evidence to indicate that the observed ozone levels would cause environmental effects in forests or other vegetation. Dr. Miller observed several 'ozone sensitive species' in the understory which showed no evidence of oxidant damage.

(5) NADP (National Acid Deposition Program) data included herein do not indicate that an aqueous, acidified precipitation problem presently exists in the area where annualized rainfall pH isopleths normally exceed a value of 4.9 in measured pH. A review of quality controlled, yet unpublished high elevation data*, reveals precipitation pH values consistent with those observed at the established low elevation NADP sites as presented in this paper.

The members of the team therefore unanimously conclude that:

A. Symptoms and signs of "declining" Engelmann spruce and subalpine fir in the Gothic area do not correspond with those symptoms and signs reported and observed in central Europe and at high elevations of the eastern U.S. There are a limited number of symptoms which a diseased tree can exhibit. Although the yellowing and browning of individual spruce and fir <u>may appear</u> similar to Waldsterben damage, <u>thorough and careful observation of</u> the specific <u>symptoms</u> and <u>signs</u> <u>can clearly differentiate between</u> the two syndromes. Forest conditions were observed to be consistent up to timberline, unlike abnormally declining forests which tend to express increased decline symptoms with rising elevation.

B. Precipitation pH and ozone incidence and severity data (included herein) do not indicate levels of sufficient magnitude to cause vegetation damage. Several ozone sensitive species were identified within the understory of the observed forests and were found to have no ozone related damage.

C. ALL specific symptoms observed at the Gothic sites of alleged "declining" spruce and fir can, in good confidence, be attributed to well known and clearly defined <u>natural</u> disease/insect complexes found in "normal healthy forests". There is no evidence <u>to believe</u> that atmospheric deposition is contributing to or exacerbating this natural process.

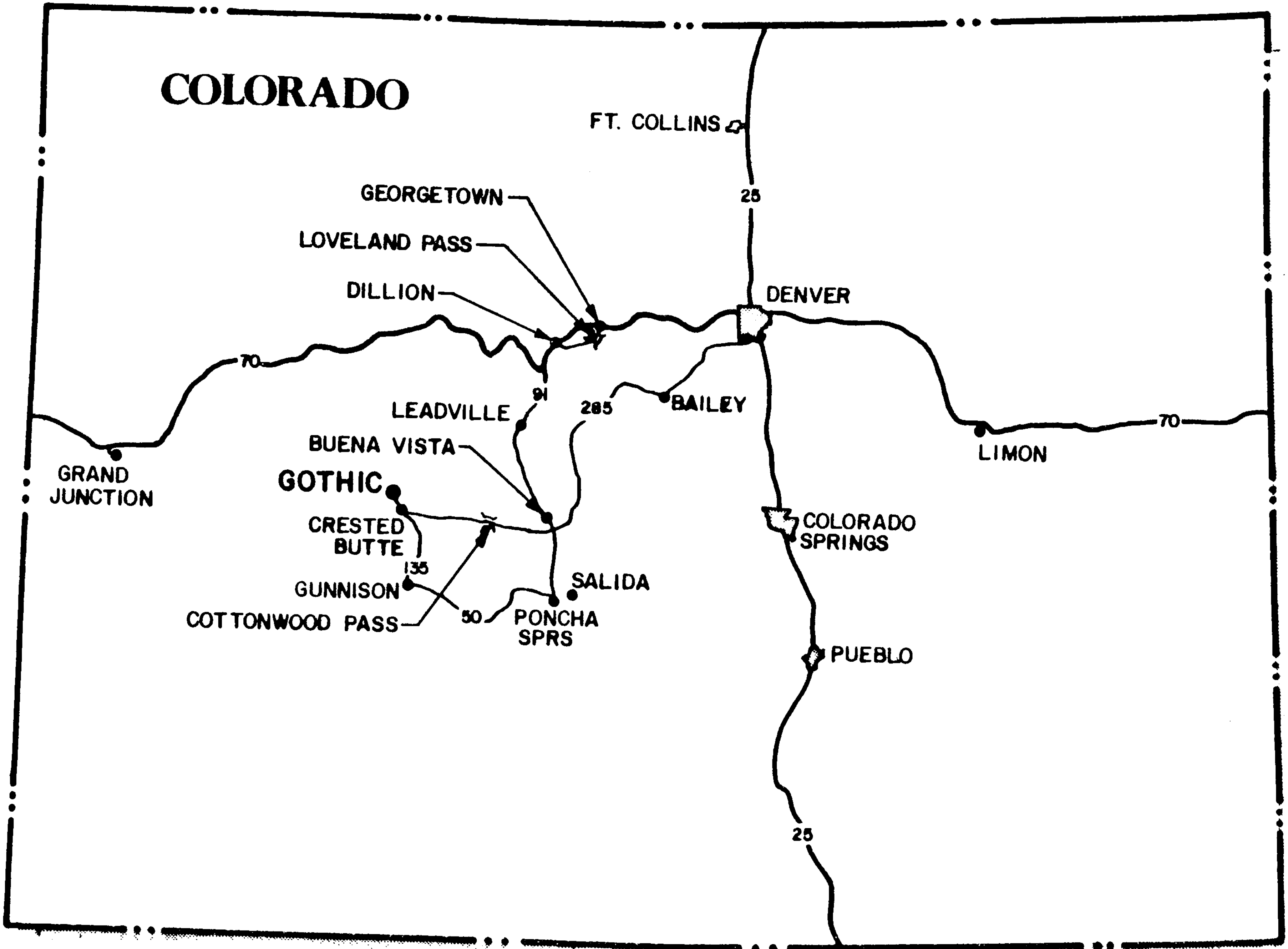
* NADP data from the recently established Buffalo Pass site near the Mt. Zirkel Wilderness Area in northwest Colorado. Obtained through personal communication with Dr. James Gibson, NADP.

D. Increment core analysis indicates there has been no abnormal tree growth suppression in the Gothic area. In addition, observations of foliage on tree limbs in Gothic forests showed an average of six to eight years of needle growth on branches rather than the one to three years of needle retention found in Waldsterben damaged forests.

E. The members of the team strongly recommend, however, that responsible well supported monitoring of atmospheric deposition and forest conditions be implemented in the Rocky Mountain states to create an early warning system for potential unexplained forest damage that may occur in the future. These recommendations are presented in detail within the text of this report.

I. INTRODUCTION

The purpose of this report is to present the findings of an investigation of suspected anthropogenic forest decline near Gothic, Colorado. Map 1 shows the general location of the Gothic study area within the state of Colorado. The investigation was initiated by the U. S. Environmental Protection Agency (Region 8), the Colorado Department of Health, Colorado Department of Natural Resources and the U.S. Forest Service. The objective of the investigation was to provide a scientific evaluation of the validity and possible extent of alleged anthropogenic forest decline near Gothic, Colorado. The investigation was planned as an effort to provide initial information on the reported tree damage at the earliest possible date. Therefore, this study should not be construed as a comprehensive or definitive evaluation of potential air pollution related forest damage in Colorado. The focus of this effort is limited to the subalpine forests in the immediate vicinity of Gothic. Additionally, the information included in this report is limited to the most important and relevant data and analyses available given the resource and time constraints of the study.



MAP I
TOUR ROUTE

II. DESCRIPTION OF STUDY AREA

Ecology of Subalpine Forests in Colorado

The forest vegetation in the vicinity of Crested Butte and Gothic is predominantly Engelmann spruce (*Picea engelmanni*) and subalpine fir (*Abies lasiocarpa*)*. This forest type occupies the highest forest environment over much of the Rocky Mountains of the United States and Canada. In Colorado these species are predominant in elevations over 8,000 feet, on north-facing slopes, and above 10,000 feet on all other aspects. Spruce and fir forests occupy one-third of the commerical forest land.

The climate of the spruce-fir zone is characterized by extremes that limit tree growth and reproduction. It is relatively cool and humid, with long, cold winters and short, cool summers. Mean annual temperature is below 35°F, and frost can occur any month of the year. Precipitation, largely as winter snow, is usually greater than twenty five inches annually.

Spruce-fir forests are considered the climax forests where they occur in the central Rocky Mountains. Climax forests are not easily displaced by other vegetation; however, complete removal of a stand by fire, logging or mining activity results in such drastic environmental change that spruce and fir are usually replaced by lodgepole pine, aspen, or shrub and grass communities. The type of vegetation initially occupying disturbed sites usually determines the length of time required to return to climax spruce-fir forests.

The composition of spruce-fir forests varies considerably with elevation. At high elevations, spruce may form nearly pure stands, while at mid-elevations spruce usually predominates in the overstory and fir in the understory. At lower elevations, where sites are drier, the ratio of spruce to fir may be low and lodgepole pine may replace spruce in the overstory. Aspen is also a common associate at mid to lower elevations.

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* Alexander, R.R. 1974 Silviculture of Subalpine Forests in the Central and Southern Rocky Mountains: The Status of Our Knowledge. U.S.D.A. Forest Service Paper RM121, 88 pp.

In the Crested Butte-Gothic area, spruce-fir forests occur from streamsides at elevations of 8,500 to 12,500 feet, where they occur as patches of dwarfed trees known as Krummholz. At higher elevations, trees are often dwarfed as a result of extreme environmental conditions such as cold and strong winds, forming a dense mat with branches pointing leeward to the prevailing wind. At lower elevations, the forest is characterized by unevenness of age and size of trees and is often interspersed with aspen and meadowland. Numerous standing dead trees and downed trees are common.

The spruce-fir community type in this area forms a continuous belt from 10,500 to 11,500 feet and appears more similar to those of southwestern Colorado and mountainous areas of the Great Basin than to those of other areas in the Colorado Rockies.

Damaging Agents in Spruce-fir Forests

The spruce-fir forest is affected by numerous abiotic and biotic agents that cause stress, injury and frequent mortality of trees. The most common diseases and insects are listed in Tables 1 and 2. Many of the symptoms expressed by trees injured or damaged by abiotic agents, including extremes of weather and exposure to toxic materials, may mimic those caused by diseases and insects. Specialized knowledge and local experience are often needed to separate symptoms of airborne pollutant damage from those caused by natural stresses such as nutrient deficiency, weather extremes, diseases and insects. Water availability, hail, temperature extremes, light, and road cuts are frequent causes of vegetation injury or mortality. Declining radial and height growth of spruce and fir can result from root-infecting fungi such as *Armillaria mellea* and *Inonotus circinatus*. Other symptoms associated with root diseases include yellowing foliage and abundance of "stress" cones. Various needle infecting fungi (*Lirula* spp.) and insects (spider mites and aphids) may also cause yellowing of foliage and premature shedding of needles. Dieback of tree tops can be caused by numerous agents, including adverse weather, bark-feeding rodents and birds, canker fungi, and insects (*Ips* and *Scolytus* species).

Table 1. List of Diseases Commonly Found in Spruce-fir Forests.

Diseases

	Common name	Scientific name	Distribution	Size Class[1]	Principal Damage[2]
Englemann spruce	red ring rot	*Phellinus (Fomes) pini*	entire range of host	3, 4	c
	white pocket rot	*Phellinus nigrolimitatus*	entire range of host	3, 4	c
	spruce broom rust	*Chrysomyxa arctostophyli*	entire range of host	3, 4	a, b, c
	cankers	*Valsa kunzei*	central Colorado	2, 3, 4	b, d, e
	brown felt blight	*Herpotrichia juniperi*	entire range of host	1, 2, 3	b, e
	winter injury	warm, dry, winter winds	Colorado	3, 4	e
	needlecast	Lirula macrospora	Colorado	5	e
	circinatus root rot	*Inontus circinatus* (= *Polyporus tomentosus*)	entire range of host	3, 4	c
	Armillaria root disease	*Armillaria mellea*	entire range of host	2, 3, 4	d
Subalpine fir	red ring rot	*Phellinus (Fomes) pini*	entire range of host	3, 4	c
	red heart rot	*Haematostereum (= Stersum) sanguinolentum*	entire range of host	3, 4	c
	butt rot	*Peniophora puteana*	Colorado	3, 4,	c
	fir broom rust	*Melampsorella caryophyllacearum*	entire range of host	2, 3, 4	a, b, d
	Armillaria root disease	*Armillaria mellea*	entire range of host	2, 3, 4	c, d
	annosus root disease	Fomes annosus	Southern Colorado	2, 3, 4	d
	cankers	*Scleroderris abieticola*	Colorado	1, 2	b, d, e
		Valsa abietis	Colorado	1, 2	b, d, e
	brown felt blight	*Herpotrichia juniperi*	entire range of host	1, 2	b, e
	winter injury	warm, dry, winter winds	Colorado	2, 3, 4	b, e
	sunscald	increased light	entire range of host	2, 3	b, d
	needlecast	*Lirula abietis-concoloris*	Colorado	5	e
	foliage disease	*Virgella robusta*	Colorado	5	e

Table 2. List of Insects Commonly Found in Spruce-Fir Forest

	Common name	Scientific name	Distribution	Size Class[1]	Principal Damage[2]
ENGLEMANN SPRUCE	Cooley spruce gall aphid	Adelges cooleyi (Gill.)	entire range of host	2, 3, 4	b, e
	spruce beetle	Dendroctonus rufipennis (Kirby.)	Colorado, Wyoming	3, 4	d
	Englemann spruce engraver	Ips engelmanni (Sw.)	Colorado, Wyoming	2, 4	b, d
	pine engraver	Ips pini (Say)	entire range of host	3, 4	b, d
	spruce engraver	Ips spp.	Colorado, Wyoming	3, 4	b, d
SUBALPINE FIR	western spruce budworm	Choristonsura occidentalis Freeman.	Colorado, Wyoming	2, 3, 4	e
	western balsam bark beetle	Dryocoetes confusus Sw.	entire range of host	3, 4	d
	fir engraver	Scolytus ventralis LeC.	entire range of host	3, 4	d

1 Size Class Primarily Affected:

1 = seedlings (1.0" dbh); 2 = saplings (2.0 - 4.0" dbh); 3 = poletimber (5.0 - 8.9" dbh); 4 = sawtimber (8.0" + dbh); 5 = all size classes

2 Principal Damage:

a = growth reduction; b = deformity; c = cull; d = mortality; e = defoliation

Abnormal masses of foliage and twigs, commonly referred to as witches' brooms, are caused by needle-infecting fungi (*Chrysomyxa arctostaphyli* on spruce and *Melampsorella caryophyllaceareum* on fir). These brooms may appear similar to those reported in European literature as caused by air pollutants.

Rapid decline and death of spruce and fir, within one to two years, can often be attributed to several species of bark beetles, including spruce beetle (*Dendroctonus rufipennis*), western balsam bark beetle-in fir (*Dryocoetes confusus*), and fir engraver (*Scolytus ventralis*).

III. SCIENTIFIC METHODS

General Approach

There are a number of key symptoms and signs which serve as important indicators in identifying air pollution related tree damage. Given the constraints of both time and funds, this investigation established five key sets of data from which air pollution related forest damage could be identified. These included:

(1) VISUAL OBSERVATION- Both symptomatic and asymptomatic trees were carefully examined for the presence of biotic and abiotic etiological agents that could cause decline symptomology in trees and other vegetation.

(2) INCREMENT CORES- Plots were established with both dominant and co-dominant tree species. Within the eight plots over 100 radial increment cores were taken and analyzed. Cores are used to provide evidence of significant deviations in growth patterns.

(3) SOIL SAMPLES- Soil samples were taken at each of the eight plots using standard ecological methods. Samples were analyzed for calcium, magnesium, sodium, potassium, phosphorous, aluminum, iron, manganese, titanium, copper, zinc, nickel, molybdenum, cadmium, chromium, strontium, barium, lead, pH, and a number of other important soil parameters.

(4) SCANNING ELECTRON MICROSCOPY (SEM)- Tree samples (needles) were taken and observed using SEM. This method of analysis is important in identifying air pollution related effects on the wax and cuticle surface of needles.

(5) AMBIENT OZONE CONCENTRATIONS- A monitoring station was installed near the reported areas of tree damage in an effort to quantify levels of ozone which could be damaging to trees and other vegetation. In addition, species sensitive to elevated ozone levels were identified and examined for existing oxidant damage.

These data were collected from each of the eight plots at the Gothic site. Other areas examined involved visual observation only. Collectively, these preliminary data would provide a sufficient information base on which anthropogenic effects could be identified. These preliminary data could then be used to direct additional research efforts as needed.

Investigations-Data Gathering

On August 6, 1984, a preliminary reconnaissance of the Gothic area was conducted by a team of forest insect and disease specialists from the U.S. Forest Service and the Colorado State Forest Service. Based on visual observation and subsequent laboratory analysis, including culturing of decay fungi, this group found that declining and dying Engelmann spruce and subalpine fir were affected by a root disease-insect complex that is common throughout the spruce-fir ecosystems in Colorado and other mountainous areas of western North America. Other insects and disease-causing organisms were also identified. This preliminary information was submitted to the U.S. Environmental Protection Agency (Region VIII) on August 10, 1984 and served as background for the more detailed investigation.

Following the decision to conduct further investigations with scientists having special air pollution and "acid rain" expertise, Dr. William Jacobi, a graduate student and an EPA representative visited the site and took increment cores from 100 trees in eight separate stands for radial growth analysis and surface soil samples from each of those stands for chemical analysis. Table 3 provides a brief description of each of the eight study plots. The first four plots were established on the basis of previously reported forest decline. Plots 5 through 8 were selected to represent the natural ecosystem with relatively little apparent human-caused disruption. The last four plots were established in pairs with one plot (5 and 7) showing stressed trees and the other (6 and 8) showing few symptoms of stress. Maps 2 and 3 show the general location of the study plots near Gothic.

In addition, the Colorado Department of Health installed an ozone monitor with an outdoor sensor at the Rocky Mountain Biological Laboratory at Gothic. Ozone levels were monitored from August 12, 1984 to September 21, 1984.

During September 19-21, 1984, an additional comprehensive field trip to the Gothic site was conducted by: John Laut, William Jacobi, Dave Johnson, Robert Bruck, and Paul Miller.

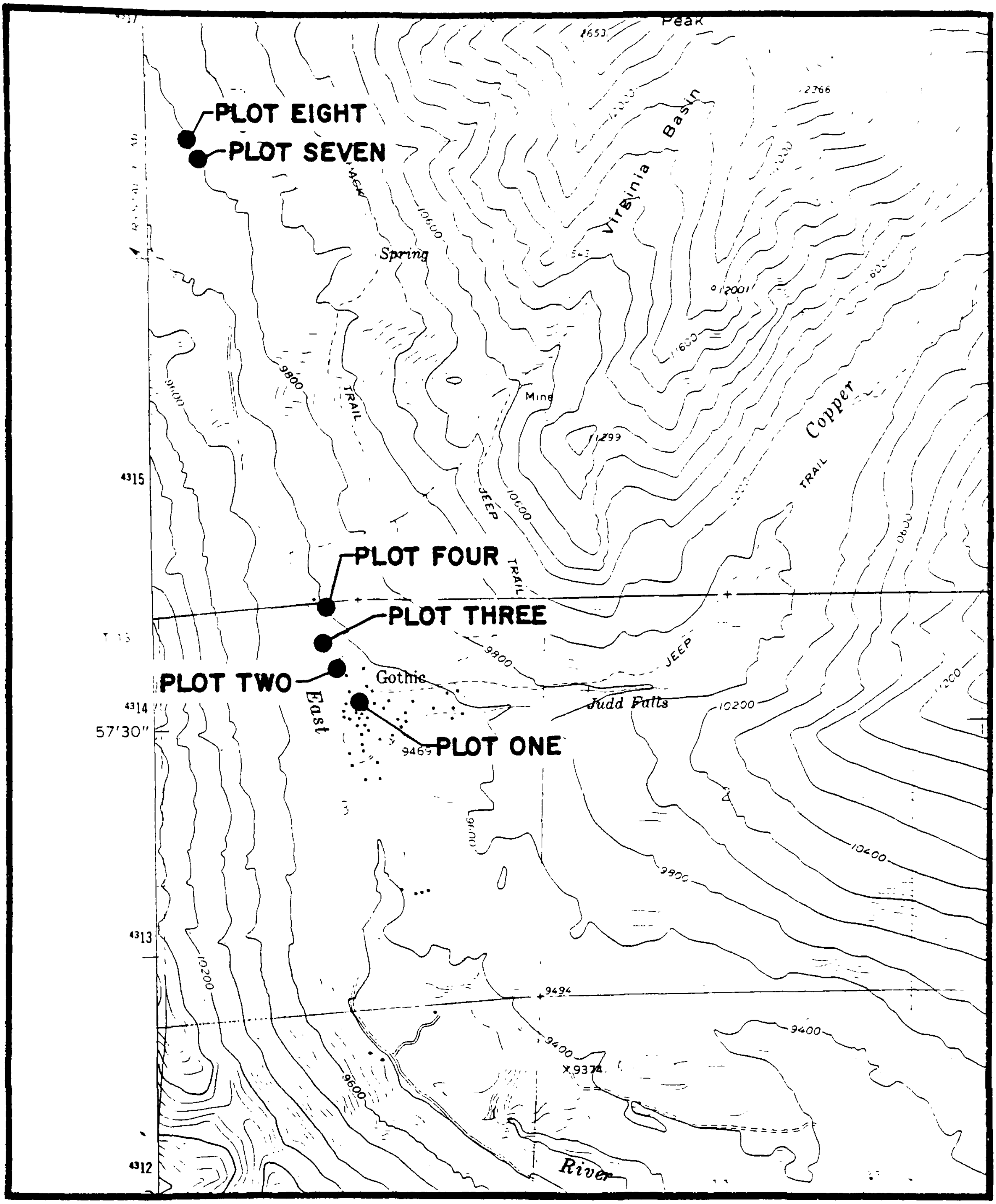
TABLE 3.

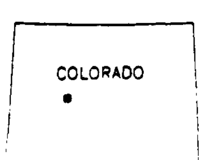
GENERAL PLOT INFORMATION

PLOT	LOCATION	SLOPE (%)	ASPECT	ELEVATION (feet)	TREES SAMPLED[1] ES	SAF	AVERAGE DBH (inches)
1	Near Swallow's Nest Cabin 32	NNE	9,470		2	3	13.2
2	Near Ore House 32	N	9,470		5	0	13.3
3	At top of hill - north of Gothic	-[2]	9,560		3	2	15.2
4	East of Barr Cabin	27	W	9,600	7	8	10 9
5	West of Avery Peak Campground	25	NE	9,640	7	8	13.4
6	West Avery Peak Campground 10	NE	9,640		9	6	16.6
7	East of Avery Peak Campground	35	SW	9,800	6	9	17.3
8	East of Avery Peak	35	SW	9,800	8	7	18.5

[1] ES = Englemann spruce
SAF = Subalpine fir

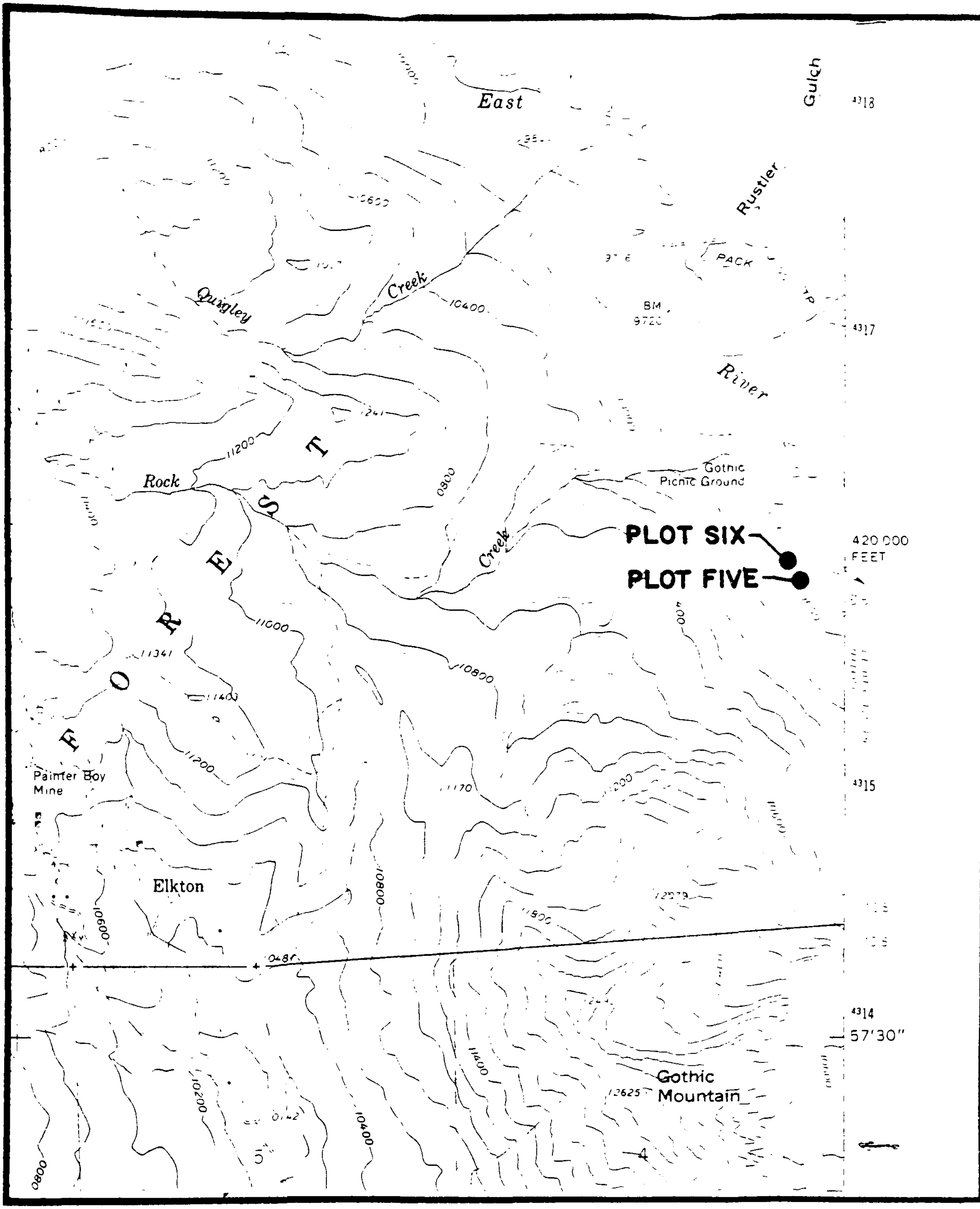
[2] Terrain was undulating



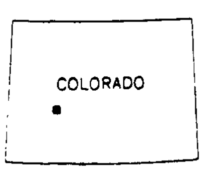


QUADRANGLE LOCATION

MAP 2
GOTHIC, COLORADO
PLOTS 1-4, AND PLOTS 7-8



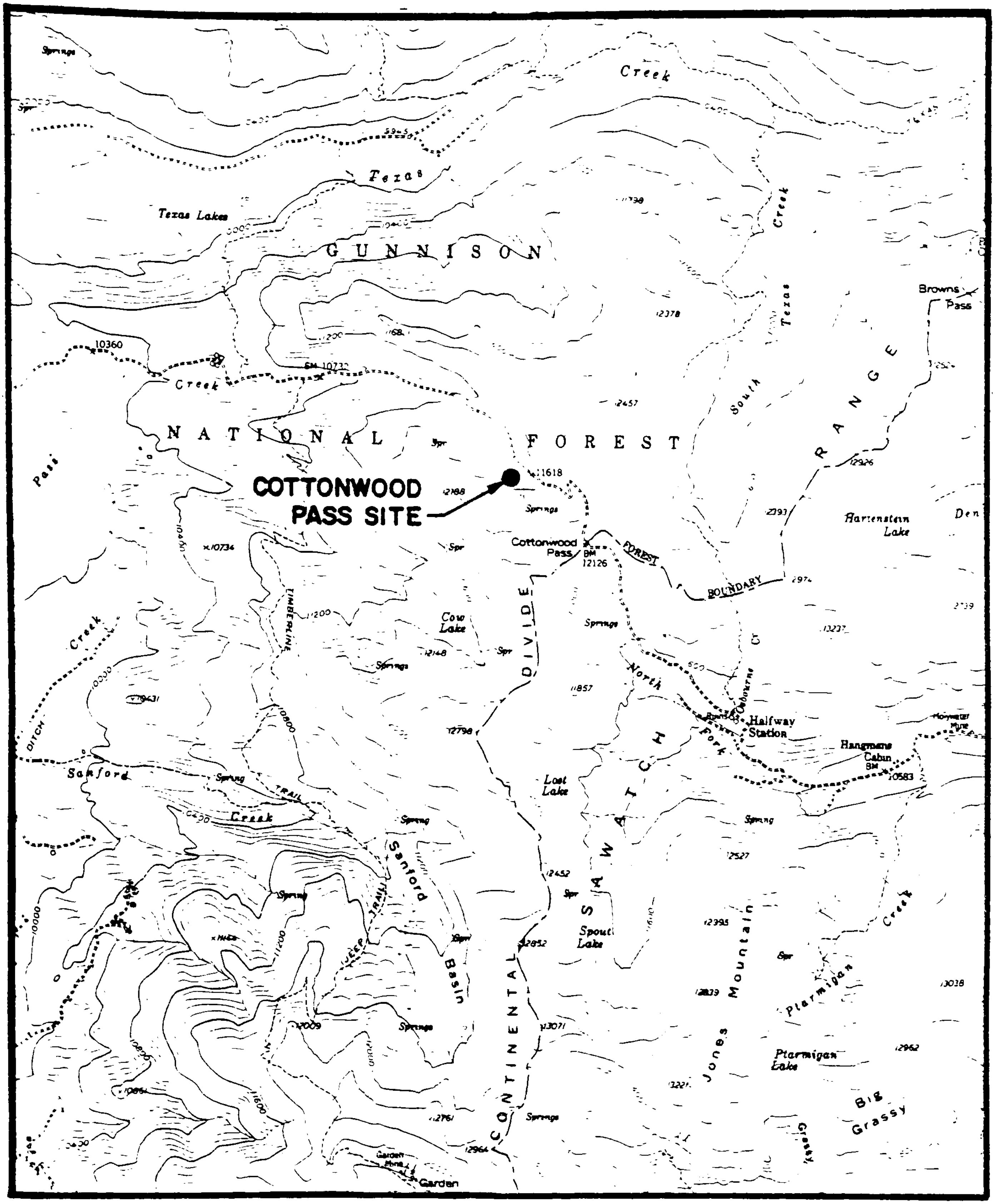
MAP 3
GOTHIC, COLORADO
PLOTS 5 AND 6

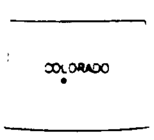


QUADRANGLE LOCATION

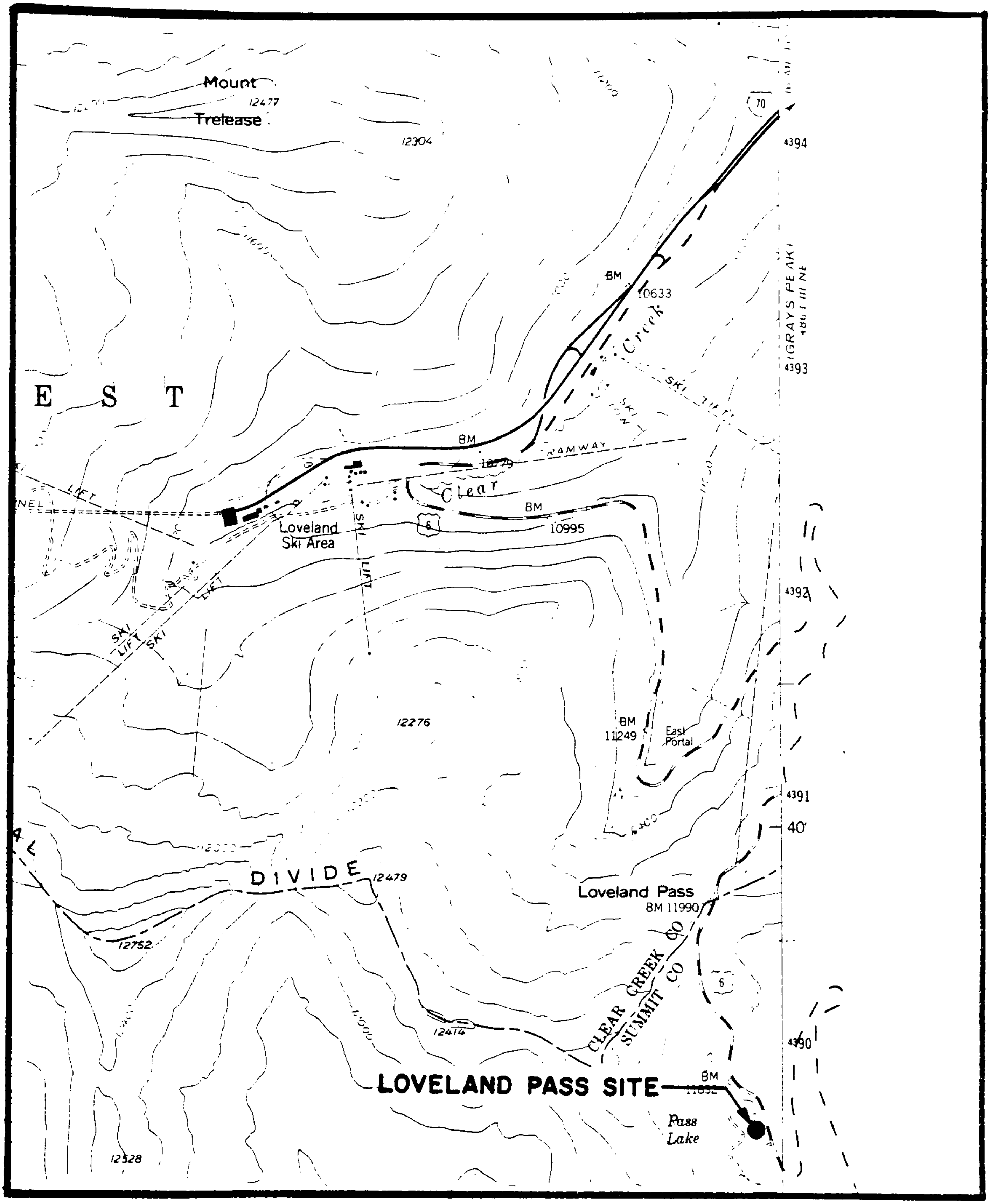
Observers were Jim Lehr, EPA Region VIII, Denver; Ray Herrmann, United States Department of the Interior, National Park Service; Ronald Cattany, Colorado Department of Natural Resources; and Beth Baird, Colorado Department of Health.

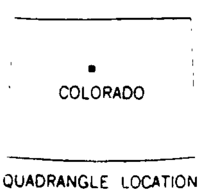
The team also visited additional high elevation spruce and fir stands between Gothic and Denver at Cottonwood Pass and Loveland Pass. The purpose was to observe symptoms and signs of disease on spruce-fir forests possibly attributable to air pollution. The general locations of these sites are shown in Maps 4 and 5.





MAP 4
COTTONWOOD PASS





MAP 5
LOVELAND PASS

IV. RESULTS AND DISCUSSION

Visual Observation

Plate 1 (page 25) and Table 4 (page 26) describe the type of symptoms, signs and causal agents observed during the investigation. These agents, alone, can in good confidence, explain the forest decline observed in the Gothic area and other high elevation spruce-fir forests observed during the field investigation.

Plate 1 illustrates some of the observations made by the team at sites where alleged anthropogenic forest decline was occurring. It is often difficult to diagnose insect and disease problems *in situ* (on site), even for an experienced pathologist. However, this was not the case at Gothic. Trees exhibiting yellowing, browning and general decline symptomotology were examined and all had signs (actual fungal pathogens) of disease. Fungal sporophores and mycelial fans of *Inonotus circinatus* and *Armillaria mellea*, respectively, were observed on virtually all "sick" trees. In addition to these root disease problems, *Fomes pini* was often fruiting on symptomatic trees. From these initial visual observations the team had strong evidence that spruce and fir exhibiting decline symptoms were, in fact, always associated with root disease centers. No further pathogen identification (aseptic culturing) was deemed necessary as positive identification was easily made on site.


1
2
3
4
5
6
7

TABLE 4
LEGEND TO PLATE 1

(1) View of study areas near Gothic Peak.

(2) View of study areas near Avery Peak.

(3) Root rot focus near Plot 2. Typical yellowing and browning of foliage due to A. mellea and I. circinatus infections.

(4) "Declining tree" symptoms on lodgepole pine near Cottonwood Pass, due to heavy dwarf mistletoe infestation.

(5) Fungal conk of F. pini on spruce in plot 3 near Gothic. The "red ring rot" disease leads to slow decline and death of its host.

(6) Mycelial (fungal) fans of A. mellea on buttress roots of spruce in plot 2 root rot center (see Picture 3) near Gothic. This disease leads to yellowing, browning and eventual death of the tree.

(7) Fungal fruiting bodies of I. circinatus root rot in plot 1 near Gothic. Signs and symptoms of I. circinatus and A. mellea are common on "declining" trees throughout the area.

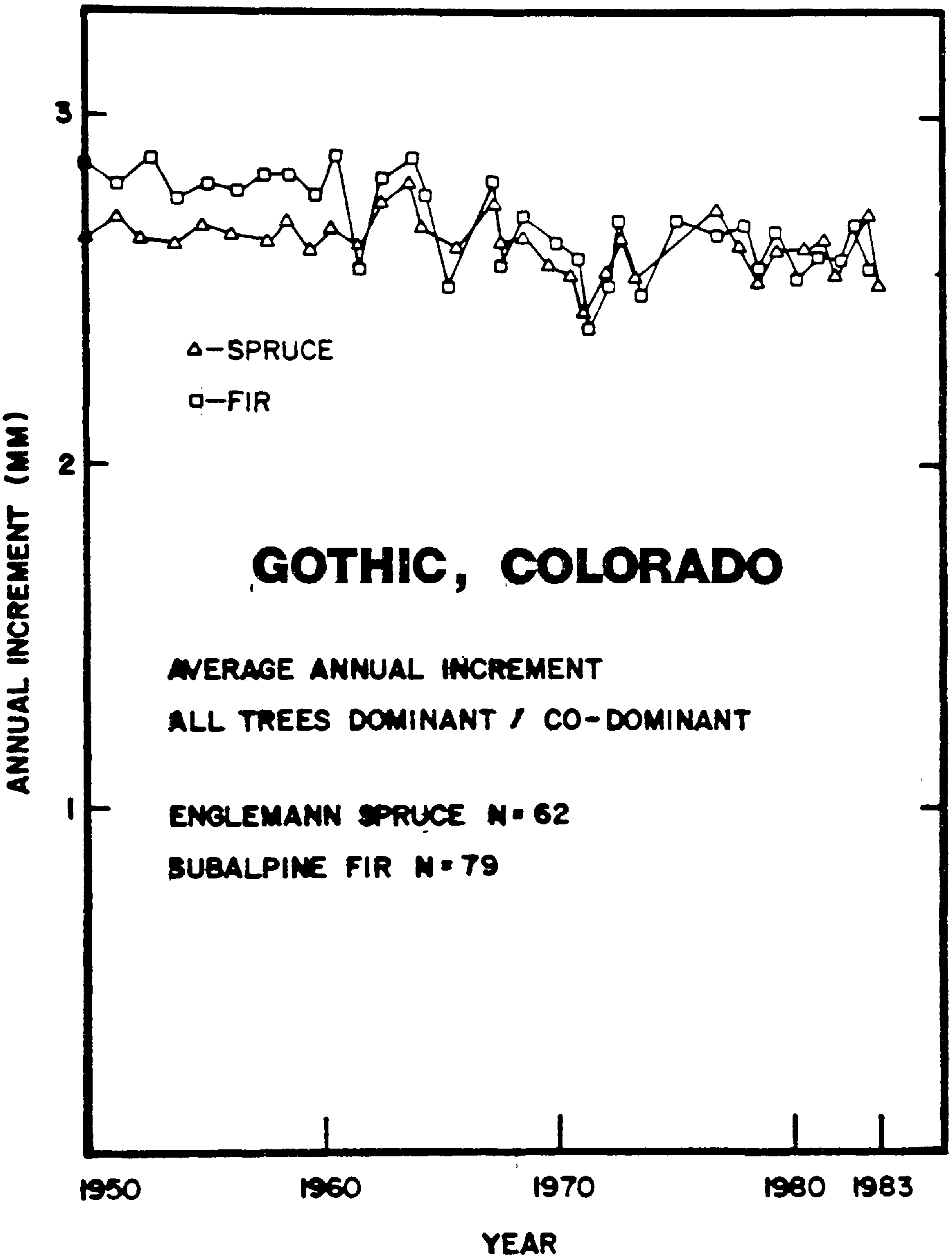
Analysis of Increment Cores, Soils and Ozone Levels at Gothic, Colorado

Increment Cores

Figure 1 illustrates the average annual growth increment of Engelmann spruce and subalpine fir at the eight plots representing age distribution of 70-389 years. 11 trees were dominant or co-dominant growing at an elevation of from 9,469 feet to 10,028 feet above mean sea level.

There is little or no growth increment suppression in trees that were asymptomatic or trees showing slight to moderate root rot or insect damage. Severely insect or disease damaged trees exhibited only recent (3-5 years) ring suppression commonly seen in the final stages of a terminal root rot or insect infestation. Twenty percent of the cores exhibited growth stimulation over the past 20 years. From this information there appears to be no similarity or correlation between the central European and eastern U.S. growth increment phenomenon (see Appendix 1) and the Gothic spruce-fir population.

FIG I



3
2
1
ANNUAL INCREMENT (MM)
Δ–SPRUCE
□–FIR
GOTHIC, COLORADO
AVERAGE ANNUAL INCREMENT
ALL TREES DOMINANT / CO-DOMINANT
ENGLEMANN SPRUCE N = 62
SUBALPINE FIR N = 79
1950
1960
1970
1980
1983
YEAR

Soil Analysis

Eight soil pits were excavated in and around the Gothic site. Surface soil (0-5cm) samples were collected and sent to the Colorado State University Soil Testing Lab. The results of the analyses are presented in Tables 5 and 6. The incidence of all heavy metals possibly attributed to atmospheric deposition, with the exception of zinc (ZN), are in many cases an order of magnitude or more below levels documented in the eastern U.S. and central European Waldsterben areas. Levels of ZN, although elevated, are lower than impacted areas in Europe and the eastern U.S. but are not in excess of levels considered dangerous to tree growth. High elevation concentrations of lead and cadmium considered prime suspects in forest decline are, in fact, considerably lower in the Rocky Mountain boreal ecosystem soils sampled than in those reported low elevation hardwood forest soils in the eastern U.S. There is no evidence to indicate that anthropogenic atmospheric deposition of heavy metals to the soils in and around Gothic could either trigger or sustain a forest decline syndrome.

Table 5. RESULTS OF SOIL ANALYSIS

PLOT NO.	pH	Cond. (Salts)	Lime (est.)	Wt. loss on ign. % O.M.	ppm NO3-N	ppm P	ppm K	ppm Zn	ppm Fe	ppm Mn	ppm Cu	Texture (est.)
1	6.3	0.2	Low	53.6	48	53.6	562	56.2	163.2	85.8	4.5	Org.
2	6.7	0.2	Low	45.9	12	41.0	572	55.4	178.6	50.6	3.6	Org.
3	6.8	0.3	Low	69.4	24	69.6	1,012	114.8	100.8	80.0	3.9	Org.
4A	5.7	0.2	Low	36.8	12	37.4	378	79.0	318.0	77.0	3.8	Org.
5	5.9	0.2	Low	56.3	20	53.2	412	31.2	246.0	79.0	3.5	Org.
6	6.1	0.2	Low	55.4	16	56.8	404	36.0	228.0	103.8	3.1	Org.
7	6.5	0.2	Low	62.1	24	66.0	516	46.4	86.8	68.8	4.3	Org.
8	5.9	0.2	Low	75.4	32	76.0	488	80.8	92.8	128.0	5.4	Org.

--------------------Total (HF digest)------------------
----------------------mg/kg--------------------------

	Mo	Cd	Cr	Sr	Ba	Pb
1	3	1	18	121	519	52
2	3	1	34	112	423	32
3	3	1	18	130	383	20
4A	5	1	42	125	604	77
5	3	1	27	95	332	27
6	3	1	28	88	392	28
7	3	1	27	78	391	18

TABLE 6.

RESULTS OF SOIL ANALYSIS

Total (HF digest)

Plot No.	% Ca	% Mg	% Na	% K	mg/kg P	% Al	% Fe	mg/kg Mn	% Ti	mg/kg Cu	mg/kg Zn	mg/kg Ni
1	1.76	0.55	0.69	1.12	972	3.09	1.48	760	0.36	19	128	12
2	1.49	0.63	0.60	1.52	983	4.09	1.89	480	0.46	22	166	22
3	1.99	0.37	0.27	0.84	940	2.16	1.09	550	0.27	17	273	12
4A	0.99	0.62	0.76	1.73	890	5.19	3.26	780	0.50	27	397	33
5	1.36	0.51	0.33	1.02	914	3.04	1.51	710	0.40	18	109	14
6	1.50	0.47	0.30	1.00	989	2.95	1.42	670	0.39	18	115	14
7	1.65	0.48	0.37	1.02	986	2.79	1.31	490	0.39	20	97	15
8	2.07	0.27	0.16	0.57	977	1.53	0.72	590	0.22	18	125	10

Ozone Monitoring

Through the services of the Colorado Department of Health, an ozone monitor was placed at the Rocky Mountain Biological Laboratory within a kilometer of the alleged forest decline site. Although ozone (O_3) monitoring was limited to a four week period (insufficient data to draw definite conclusions), the highest hourly reading during the measurement period was .047 parts per million (ppm)(August 23, 1100 hours and September 20, 1500 hours). Tables 7 through 10 present the O_3 data collected on an hourly basis during the monitoring period. Most readings were consistently lower than ambient background levels for wide areas of the eastern U.S. Observations of spruce and fir trees and natural herbaceous vegetation revealed no indication of ozone damage, as determined by Dr. Paul Miller. Although much more data would be necessary to draw "concrete" conclusions, the team believes it is unlikely that ozone or other oxidants are either acutely or chronically affecting spruce-fir ecosystems in the Gothic area.

The limited amount of continuous ozone monitoring data for the Gothic area suggests that concentrations are typical of natural background levels in the western United States. Measured ozone levels at Gothic ranged from .004 to

.036 ppm on an hourly average basis. Sensitive conifers in California are injured after exposure to 24 hour average ozone concentrations of 0.06 to 0.08 ppm. Under intense California ir pollution conditions, to achieve 24 hour averages of this magnitude, it is necessary to have daily peak values reaching at least 0.10 to 0.175 ppm.

Particular attention was paid by Dr. Miller to herbaceous species in the forest understory and in open grassy areas in an attempt to identify ozone symptoms on plants that would be expected to be more sensitive than conifers. One genus, Osmorhiza, was observed commonly in the spruce-fir understory. In California this genus is considered to be ozone sensitive but no evidence of leaf injury was identified in the Gothic area.

Scanning Electron Microscope (SEM) Examination of Spruce and Fir Foliage.

Twenty spruce and fir needle samples were collected on September 20 from the othic area. The samples were returned to the North Carolina State University SEM Laboratory, fixed, coated and observed via SEM for cuticular or cellular damage attributable to oxidant injury. All samples proved to be negative for signs of ozone damage.

TABLE 7 HOURLY OZONE DATA FOR GOTHIC, COLORADO
(PPM)

DAY	00	01	02	03	04	05	06	07	08	09	10	11
01												
02	0.008	0.010	0.009	0.007	0.007	0.007	0.005	0.010		0.032	0.035	0.035
03	0.008	0.008	0.008	0.008	0.007	0.008	0.005	0.009		0.032	0.033	0.033
04												
05										0.033	0.033	0.034
06												
07										0.040	0.039	0.036
08	0.031	0.030	0.024	0.019	0.016	0.016	0.019	0.019		0.041	0.040	0.038
09	0.016	0.018	0.021	0.025	0.019	0.019	0.021	0.029		0.033	0.031	0.031
10	0.018	0.018	0.014	0.013	0.013	0.010	0.013	0.015		0.027	0.030	0.033
11	0.010	0.009	0.009	0.010	0.012	0.007	0.00	0.008		0.019	0.027	0.024
12	0.020	0.016	0.015	0.015	0.021	0.022	0.019	0.020		0.040	0.037	0.037
13	0.014	0.012	0.010	0.010	0.009	0.009	0.009	0.015		0.035	0.039	0.040
14	0.015	0.015	0.012	0.011	0.012	0.014	0.012	0.014		0.030	0.033	0.035
15	0.010	0.013	0.008	0.009	0.012	0.007	0.005	0.010		0.028	0.030	0.033
16	0.012	0.009	0.012	0.008	0.008	0.010	0.013	0.018				0.032
17	0.008	0.008	0.009	0.010	0.012	0.010	0.010			0.027	0.032	0.038
18	0.008	0.008	0.009	0.010	0.009	0.008		0.013	0.025	0.034	0.037	0.034
19	0.013	0.009	0.009	0.008	0.009	0.009	0.004	0.012	0.025	0.039	0.042	0.043
20	0.012	0.014	0.023	0.037	0.029	0.019	0.019	0.024		0.039	0.044	0.045
21	0.009	0.008	0.010	0.008	0.010	0.012	0.015	0.035				
MEAN	.0132	.0126	.0126	.013	.0128	.0116	.0117	.0167	.025	.033	.0351	.0353
MAX	0.031	0.030	0.024	0.037	0.029	0.022	0.021	0.035	0.025	0.041	0.044	0.045

TABLE 8 HOURLY OZONE DATA FOR GOTHIC, COLORADO
(PPM)

DAY	12	13	14	15	16	17	18	19	20	21	22	23	NO.	MEAN	MAX
01					0.030	0.023	0.017	0.017	0.014	0.010	0.010	0.009	8	.0162	0.030
02	0.035	0.035	0.035	0.035	0.032	0.017	0.014	0.010	0.012	0.010	0.009	0.009	23	.0181	0.035
03	0.033	0.038											13	.0176	0.038
04													0		
05	0.034												4	.0335	0.034
06													0		
07	0.033	0.029	0.028	0.034	0.033	0.031	0.033	0.034	0.034	0.038	0.034	0.033	15	.0339	0.040
08	0.034	0.038	0.039	0.035	0.031	0.025	0.021	0.016	0.015	0.018	0.018	0.014	23	.0259	0.041
09	0.031	0.029	0.029	0.034	0.033	0.023	0.023	0.018	0.018	0.019	0.018	0.018	23	.0241	0.034
10	0.032	0.033	0.034	0.032	0.032	0.028	0.020	0.015	0.013	0.013	0.014	0.012	23	.0208	0.034
11	0.029	0.034	0.035	0.035	0.036	0.038	0.020	0.020	0.028	0.020	0.024	0.017	23	.0206	0.036
12	0.040	0.042	0.045	0.044	0.042	0.044	0.036	0.021	0.016	0.014	0.012	0.014	23	.0274	0.045
13	0.040	0.041	0.041	0.041	0.040	0.035	0.020	0.019	0.019	0.020	0.016	0.015	23	.0238	0.041
14	0.035	0.035	0.034	0.033	0.029	0.020	0.010	0.010	0.014	0.012	0.010	0.010	23	.0197	0.035
15	0.035	0.039	0.035	0.034	0.030	0.019	0.015	0.013	0.020	0.020	0.014	0.012	23	.0196	0.039
16	0.032	0.033	0.033	0.030	0.024	0.015	0.009	0.014	0.019	0.013	0.012	0.015	21	.0176	0.033
17	0.039	0.038	0.039	0.037	0.033	0.032	0.024	0.019	0.012	0.008	0.009	0.008	22	.021	0.039
18	0.034	0.034	0.034	0.028	0.020	0.023	0.019	0.025	0.014	0.009	0.009	0.012	23	.0198	0.037
19	0.040	0.043	0.043	0.043	0.044	0.039	0.025	0.020	0.017	0.014	0.015	0.010	24	.0239	0.044
20	0.044	0.044	0.045	0.047	0.044	0.038	0.029	0.019	0.020	0.017	0.013	0.012	23	.0294	0.047
21															
MEAN	.0352	.0365	.0366	.0361	.0333	.028	.0209	.0181	.0176	.0159	.0148	.0137		.0224	
MAX	0.044	0.044	0.045	0.047	0.044	0.044	0.036	0.034	0.034	0.038	0.034	0.033			0.047

TABLE 9 HOURLY OZONE DATA FOR GOTHIC, COLORADO
(PPM)

DAY	00	01	02	03	04	05	06	07	08	09	10	11
01												
02												
03												
04												
05												
06												
07												
08												
09												
10												
11												
12												
13	0.009	0.007	0.007	0.007	0.008	0.009	0.017	0.033		0.033	0.034	0.033
14	0.010	0.009	0.009	0.010	0.010	0.009	0.010	0.020		0.033	0.034	0.035
15	0.005	0.005	0.005	0.007	0.007	0.005	0.008	0.018				0.035
16	0.005	0.005	0.005	0.007	0.005	0.004	0.007	0.017		0.028	0.029	0.033
17	0.005	0.005	0.005	0.007	0.004	0.005	0.007	0.015		0.029	0.033	0.034
18	0.012	0.008	0.010	0.007	0.007	0.008	0.008	0.013	0.022	0.033	0.035	0.039
19	0.013	0.012	0.010	0.013	0.009	0.010	0.009	0.019		0.032	0.034	0.037
20	0.013	0.015	0.013	0.009	0.009	0.008	0.008	0.013		0.023	0.028	0.032
21	0.010	0.010	0.009	0.013	0.008	0.007	0.008	0.013		0.026	0.030	0.034
22	0.020	0.016	0.020	0.009	0.007	0.008	0.008	0.014		0.034	0.034	0.035
23	0.007	0.007	0.006	0.008	0.004	0.005	0.005	0.012		0.034	0.044	0.047
24	0.010	0.012	0.030	0.025	0.015	0.014	0.015	0.025		0.032	0.037	0.035
25	0.007	0.006	0.006	0.005	0.003	0.002	0.003	0.012		0.035	0.037	0.038
26												
27												
28												
29												
30												
31	0.008	0.006	0.008	0.004	0.002	0.005	0.009	0.009		0.019	0.026	
MEAN	.0094	.0087	.01	.0092	.0064	.0068	.008	.0155	.022	.03	.0334	.0359
MAX	0.028	0.018	0.030	0.025	0.015	0.014	0.015	0.025	0.022	0.035	0.044	0.047

TABLE 10 HOURLY OZONE DATA FOR GOTHIC, COLORADO
(PPM)

DAY	12	13	14	15	16	17	18	19	20	21	22	23	NO.	MEAN	MAX
													0		
01													0		
02													0		
03													0		
04													0		
05													0		
06													0		
07													0		
08													0		
09													0		
10													0		
11													0		
12	0.030	0.030	0.040	0.037	0.033	0.032	0.028	0.025	0.024	0.022	0.013	0.008	12	.0268	0.040
13	0.034	0.036	0.038	0.035	0.033	0.030	0.020	0.021	0.013	0.014	0.011	0.011	23	.0203	0.038
14	0.035	0.030	0.029	0.023	0.025	0.024	0.010	0.009	0.007	0.007	0.005	0.005	23	.0173	0.035
15	0.035	0.032	0.032	0.029	0.027	0.022	0.023	0.020	0.017	0.012	0.009	0.009	21	.0172	0.035
16	0.033	0.028	0.030	0.030	0.027	0.025	0.028	0.018	0.009	0.009	0.008	0.005	23	.0171	0.033
17	0.033	0.032	0.030	0.025	0.019	0.019	0.010	0.010	0.009	0.019	0.015	0.013	23	.0166	0.034
18	0.039	0.038	0.040	0.039	0.038	0.032	0.039	0.039	0.035	0.028	0.020	0.015	24	.0251	0.040
19	0.039	0.039	0.038	0.039	0.035	0.025	0.018	0.017	0.029	0.030	0.028	0.019	23	.0239	0.039
20	0.034	0.040	0.040	0.035	0.038	0.030	0.033	0.033	0.020	0.019	0.015	0.015	23	.0227	0.040
21	0.036	0.035	0.036	0.037	0.036	0.029	0.028	0.027	0.026	0.020	0.017	0.024	23	.0224	0.037
22	0.034	0.039	0.039	0.037	0.030	0.026	0.029	0.022	0.019	0.017	0.011	0.009	23	.0223	0.039
23	0.045	0.044	0.042	0.043	0.043	0.038	0.034	0.028	0.030	0.028	0.018	0.013	23	.0253	0.047
24	0.035	0.036	0.035	0.034	0.032	0.031	0.029	0.030	0.031	0.026	0.016	0.102	23	.0259	0.037
25	0.034	0.035	0.035	0.040	0.040								16	.0211	0.040
26													0		
27													0		
28													0		
29													0		
30					0.024	0.025	0.017	0.006	0.006	0.005	0.004	0.009	8	.012	0.025
31					0.030	0.024	0.017	0.030	0.029	0.022			16	.0152	0.030
MEAN	.0354	.0352	.036	.0342	.0318	.0274	.024	.0223	.0202	.0185	.0135	.0119		.0210	
MAX	0.045	0.044	0.042	0.043	0.043	0.038	0.039	0.039	0.035	0.030	0.028	0.024			0.047

Review of Available NADP Precipitation Data

There is a limited amount of wet deposition monitoring data available for the central Rocky Mountain area and Colorado. Many of the established National Acid Deposition Program monitoring sites in Colorado are located at lower elevations or are remotely located from the Gothic site. Therefore, none of the existing monitoring sites are truly representative of the Gothic area and caution must be exercised in making inference from the NADP sites to the unique Gothic situation.

However, an examination of existing NADP data (which have been subject to careful quality control) shows that precipitation pH, hydrogen ion deposition, sulfate deposition and nitrate deposition in Colorado for 1980 and 1981 are well below the values believed to cause aquatic or terrestrial damage and well below those values found in the eastern United States. Relative values of atmospheric deposition parameters in central Europe, eastern U.S. and Colorado are compared in Table 11. The information in Table 11 is presented to document the relative differences in certain anthropogenically produced air pollutants found in central Europe, high elevations of the eastern U.S. and rural mid-altitude Colorado. Perhaps the most significant and striking difference (with respect to this document) is the observed difference in rain pH.

TABLE 11.

TABLE OF ATMOSPHERIC DEPOSITION PARAMETERS*

	CENTRAL EUROPE	EASTERN U. S. (High Elev.)	COLORADO (Rural)
Rain pH	3.6 - 4.5	3.8 - 4.6	4.9 - 6.0
Sulfate Deposition	50 kg/ha/yr	Approx. 50 kg/ha/yr	20 kg/ha/yr
Nitrate Deposition	50 kg/ha/yr	40 kg/ha/yr	20 kg/ha/yr
Surface Soil Lead	300 - 600 ppm	150 - 300 ppm	50 ppm
Ozone	.06 - .19 ppm	.06 - .20 ppm	.03 ppm

* Average values of atmospheric deposition products attributed to anthropogenic emissions.

A review of the relevant literature indicates that significant perturbation due to acidified precipitation in terrestrial ecosystems has only been observed below pH 4.0, both in simulator and field studies. Quality assured and controlled data in Colorado have never been observed to reach these pH extremes, while events below pH 4.0 are common in the eastern U.S. and frequent in central Europe. Nitrate and sulfate deposition are much lower in the intermountain region with total deposition rarely exceeding 10 kilograms/hectare/year (kg/ha/yr), eastern U.S. and central European values, particularly in documented areas of forest decline, often exceed 50 kg/ha/yr deposition of these toxic and nutritive compounds.

Finally, maximum ozone levels as assessed from rural Colorado data usually do not exceed values that are considered 'ambient' for many affected areas of the eastern U.S. and central Europe. Since the effect of ozone on plants is usually considered an <u>acute</u> reaction (short time duration of very high levels of oxidant), the preliminary analysis of rural Colorado data does not indicate ozone levels of sufficient magnitude to induce herbaceous or tree plant damage.

Some important Colorado data are presented in Tables 12-14 which show average annual ion concentrations for 1980 and 1981 and deposition for 1981 at each of the state's monitoring stations. In Table 12 data are presented not only for hydrogen ion, sulfate and nitrate concentrations but also for calcium, magnesium and ammonium which represent alkaline materials reponsible for reducing potential acidity. Included in this Table are two sites which demonstrate the extreme values found in the United States: Olympic National Park in Washington and Parson, West Virginia. The values for Olympic National Park (not corrected for marine salts) are relatively similar to those found in the southern hemisphere in areas where values are considered to be at or near natural background levels. Table 13 presents similar data for 1981, and Table 14 presents deposition values for hydrogen ion, sulfate and nitrate. Table 15 depicts data collected from the Rocky Mountain National Park NADP site. This, the highest elevation and quality controlled site presently operating in the state of Colorado, indicates a total volume weighted annual average precipitation pH of approximately 5.0.

Table 12. Average annual concentration, 1980

Site	pH	SO_4	NO_3	NH_4	Ca & Mg
	ueq/l - precipitation weighted				
Alamosa, CO	5.6	27.0	15.0	20.0	18.5
Sand Springs, CO	4.8	22.0	14.0	8.4	16.0
Rocky Mountain National Park, CO	5.0	25.0	22.0	20.0	17.0
Manitou, CO	4.9	45.0	33.0	21.0	33.0
Pawnee, CO	5.5	31.0	28.0	38.0	22.0
Olympic National Park, WA	5.4	7.0	1.5	1.0	5.0
Parson, WV	4.2	74.0	33.0	13.0	17.0

Table 13. Average annual concentration, 1981.

Site	pH	SO_4	NO_3	NH_4	Ca & Mg
	ueq/l - precipitation weighted				
Alamosa, CO	5.2	38.0	17.0	23.0	28.0
Sand Springs, CO	5.0	33.0	16.0	10.0	31.0
Rocky Mountain National Park, CO	5.0	33.0	23.0	19.0	26.0
Manitou, CO	4.8	34.0	24.0	13.0	24.0
Pawnee, CO	5.1	45.0	28.0	39.0	29.0
Olympic National Park, WA	5.4	8.0	1.5	1.0	10.0
Parson, WV	4.2	74.0	30.0	16.0	18.0

Table 14. Annual deposition, 1981.

Site	H^+	SO_4	NO_3	ppt (cm)
	kg/ha			
Alamosa, CO	0.01	5.4	2.7	22.0
Sand Springs, CO	0.04	7.3	4.4	40.0
Rocky Mountain National Park, CO	0.03	4.9	4.5	32.0
Manitou, CO	0.07	6.7	6.2	40.0
Pawnee, CO	0.03	7.2	5.7	30.0
Olympic National Park, WA	0.10	18.0	4.4	366.0
Parson, WY	0.90	46.0	24.0	130.0

Table 15. Volume weighted annual average precipitation values for Rocky Mountain National Park headquarters NADP site. Values are in ueq/l.

YEAR	Total Precip (cm)	Ca++	Mg++	K+	Na+	NH_4	NO_3	Cl^-	$SO_4^=$	pH
1980	13.77[1]	13.90	2.87	1.14	2.43	20.47	22.10	5.04	25.29	4.99
1981	31.70	19.41	6.76	1.18	5.09	18.73	23.33	4.38	32.69	5.01
1982	28.30	10.47	2.96	1.23	2.44	7.76	14.97	2.54	18.95	4.97

[1] 1980 reflects only 6 months of data, as the site began operation in June of that year.

One of the major factors in determining the potential for acidification in aquatic and terrestrial systems is the rate of deposition. A 1983 survey of data in Scandinavia and the United States suggests that acidification of lakes and streams in sensitive areas occurs when the pH of precipitation drops below 4.7. This is comparable to a sulfate deposition between 20-30 kg/ha. Rainfall pH in Rocky Mountain National Park on the average is not below 5.0*. It should be kept in mind that the threshold value of 4.7 was determined in areas of the world that receive considerably more rain volume than in the Rocky Mountain region of Colorado. The deposition of nitrates and sulfates is less that twenty percent of that in the eastern United States. Deposition can therfore be considered to be currently below that which is considered significant in terms of lake or stream acidification. Nitrate levels in Rocky Mountain National Park are higher than expected which may be cause for concern regarding potential effects upon vegetation.

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* Personal communication, Dr. Jill Baron, National Park Service, Ft. Collins, Colorado.

Several conclusions can be reached when reviewing the Colorado NADP data:

1. Precipitation pH ranges from approximately 4.8 to 5.6.

2. Calcium and ammonium concentrations represent significant levels for alkalizing materials which are responsible for lower acidities than would be expected from the concentrations of sulfate and nitrate (if these are considered to originate as sulfuric and nitric acid).

3. *Concentrations of sulfate in Colorado are four to five times greater* than those levels found in Olympic National Park and approximately one half to one third less than those observed in Parsons, West Virginia.

4. While there are small variations, sulfate concentrations are reasonably consistent across the state indicating limited influence of local sources.

5. Concentrations of nitrate are ten to twenty times more than those found in Olympic National Park. NADP stations located on Colorado's eastern slope indicate similar concentrations of nitrate as those observed in West Virginia.

6. Nitrate concentrations are approximately fifty percent of sulfate levels on the western slope but seventy percent of those on the eastern slope most likely due to mobile sources in urban areas.

7. Because of lower concentrations and low precipitation at Colorado sites (20 to 40 cm/yr), sulfate deposition values are less than twenty percent of those in West Virginia and nitrate deposition values are less than twenty five percent.

As stated earlier, one of the major factors in determining potential for acidification of aquatic and terrestrial ecosystems is the level of deposition. It has been stated that acidic deposition represented by rainfall pH of 4.6 or greater (sulfate deposition less than 20-30 kg/hectare) is not believed to be significant in terms of acidification even in sensitive areas. In Colorado, data suggest that rainfall pH on the average is not below 4.8. The pH value of 4.7 was determined in areas of the world where rainfall amounts are considerably higher than in the Rocky Mountain region in Colorado. Sulfate deposition averages 5-7 kg/hectare and the deposition of nitrates and sulfates is less than twenty percent of that in the eastern U.S. Therefore, from these limited data it appears that wet deposition velocities in Colorado are currently below the levels which are believed to cause damage to forests and other vegetation.

V. CONCLUSIONS

Trees are always dying in our forests. The Rocky Mountain spruce-fir forests are affected by many abiotic and biotic agents that may stress, injure and often lead to tree death. This is, in fact, a "natural" and expected phenomenon in a normal "healthy" forest. These types of effects are illustrated in Plate 1 with the corresponding description in Table 11.

The chlorosis (yellowing) leading to necrosis (cell death) of spruce or fir trees is often attributable to common and potentially deadly forest pathogens and insects. At all sites visited, the investigative team specifically identified fungal pathogens that can, and often will, in and of themselves, cause their hosts to yellow, decline and exhibit suppressed annual increment growth, leading to tree death. The forest decline observed can be considered a natural phenomenon typical of Rocky Mountain spruce-fir forests. Conversely, the team found no evidence to suggest that anthropogenic factors are contributing to forest decline in the Gothic area at the present time.

Although the superficial appearance of many spruce and fir trees in and around Gothic is similar to that observed in other species of coniferous trees found in central Europe and the eastern U.S., the symptoms and signs observed at all Gothic sites appear NOT to parallel those in the affected Waldsterben areas of central Europe, which are described in detail in the text of this report, Appendix A and B. In Dr. Bruck's observations, there is little or no correlation between the Gothic normal forest disease syndrome and the inexplicable damages observed in the forest decline in Waldsterben areas, of central Europe and the eastern U.S.

NADP data included herein (Figure 7-10) do not indicate an acid rain problem presently existing in Colorado where annualized rainfalls usually exceed pH 4.9 to over 5.0.

Microscopic analysis of spruce and fir increment cores revealed no severe synchronous growth suppression (as is often observed in boreal montane ecosystems in the eastern U.S. and Germany). Approximately twenty percent of the cores examined exhibited a marked increase in growth over the past twenty years.

Analysis of surface soils from the eight test plots indicated no abnormal loading of heavy metals. Loadings of lead, copper and nickel are usually 4-10 times less than comparable eastern U.S. sites and virtually 2 orders of magnitude below levels currently being observed in central Europe.

Scanning electron microscope observations of needle tissues collected from spruce and fir trees at the 8 Gothic test sites indicated no surface cuticular or cell damage (highly indicative of a lack of oxidant damage.)

The members of the forest investigation team therefore unanimously conclude that:

A. Symptoms and signs of "declining" Engelmann spruce and subalpine fir in the Gothic, Colorado area DO NOT closely resemble those reported and observed from central Europe and high elevations of the eastern U.S. There are only so many ways that a "tree can die" and although the yellowing and browning of individual spruce and fir may appear similar to Waldsterben damage--thorough and careful observations of the specific symptoms and signs can clearly differentiate between the two syndromes.

B. Precipitation pH and ozone incidence and severity data (included herein) do NOT indicate levels of sufficient magnitude to cause vegetation damage.

C. Virtually all specific symptoms observed at the Gothic test sites of allegedly "declining" spruce and fir can, in good confidence, be attributed to well known and clearly defined natural pathogen/insect complexes found in a "normal healthy forest."

D. The members of the team strongly recommend, however, that responsible well supported monitoring of atmospheric deposition and forest conditions be implemented in the Rocky Mountain states to create an early warning system for potential unexplained forest damage in the future.

VI. RECOMMENDATIONS

Based on this investigation, the team strongly recommends the establishment of a comprehensive atmospheric deposition research and monitoring program in the western United States. While it does not appear necessary to support additional research at the Gothic site, research and monitoring should be supported at representative sites within Colorado and other western states.

This investigation was initiated by a cursory observation of stressed trees near Gothic, Colorado displaying visual symptoms of damage similar in appearance to those observed in the forests of central Europe and the eastern United States. The need for the investigation emerged from the fact that no public agency had reliable information to demonstrate that the reports of 'acid rain' damage were incorrect. The lack of specific information on atmospheric deposition in the West and the effect this deposition has or may have on forests hindered an immediate and informed response by public agencies. If more were known about the western situation, the public alarm over 'acid rain' damage near Gothic could have been substantiated, prevented or promptly defused.

This investigation was designed to gather as much reliable information as possible at a specific geographic site for a limited and specific period of time. A more extensive research program should and must be developed and supported to understand current and projected levels of atmospheric deposition and to identify the real or potential impact of atmospheric deposition on western terrestrial and aquatic ecosystems. Unlike many areas of the world, the opportunity to prevent serious environmental problems is very high in many parts of the western United States. However, to adequately protect these resources, it is necessary to understand the existing situation in the diverse western ecosystems some of which appear to be highly susceptible to the acidification process. It appears that slight increases in atmospheric deposition could result in serious damage to western ecosystems. It is important to initiate baseline monitoring and research in atmospheric, aquatic and terrestrial systems to protect the environment of the western United States.

It is critical at this point in time to begin by asking the right questions. The forest decline phenomenon is frighteningly complex. Steps should be initiated in the western U.S. to assess the value of central European and eastern U.S. short and long term research and survey strategies and their applicability to the western situation.

Specifically, the team believes that a western research program should be initiated to include:

1. A program to establish the baseline ambient air quality and atmospheric deposition levels at various representative locations in the western United States. This could be accomplished by adding new NADP monitoring sites (particularly at high elevations) to the present network and by establishing a series of comprehensive atmospheric monitoring stations at key locations in the Rocky Mountain region. At the Gothic site, it would be advisable to monitor air quality for a longer period of time and to establish the seasonal peak values of ozone in the area.

2. The watershed studies currently being conducted by EPA (Region VIII), NPS, USGS, USFS et. al. should be continued to establish baseline information from which trends can be detected and to estimate the acidification potential of high elevation lakes.

3. A program should be initiated to survey, monitor and conduct research on terrestrial ecosystems in the West. An effort should be initiated to utilize research and survey strategies already employed in central Europe and the eastern United States, and to test their applicability to the western situation. Species sensitive to atmospheric deposition should be identified and monitored for vegetation damage. Long term monitoring plots should be established in representative ecosystems to identify, at the earliest possible date, the presence of damage to trees and other vegetation from air pollution related causes.

4. Linkage between current and future research and survey programs (i.e. U.S. EPA, National Park Service, U.S. Forest Service, Colorado Department of Natural Resources and the Colorado Department of Health) should be encouraged in order to enhance the efficiency and timeliness of new initiatives.

5. Finally, it must be emphasized that this report should not serve as an "end" but rather as the beginning of an effort to establish meaningful programs to address potential damage of valuable western resources by atmospheric deposition. A unique opportunity is at hand to gather

critical baseline data to establish the current status of air pollution and forest health in managed and natural terrestrial ecosystems. Scientists and policy makers in the western states can avoid the "crisis" atmosphere associated with central European and Eastern U.S. forest decline by becoming more knowledgable of the conditions of non-air pollution damaged forests. If and when pollution induced damage occurs, it may be dealt with in a scholarly and responsible manner. In addition, the spruce-fir ecosystems of the Rocky Mountain region serves as an important "experimental" control for NAPAP (National Acid Precipitation Assessment Program) initiatives in assessing the impact of anthropogenic pollution on our environment. We strongly encourage inter-agency cooperation to meet the above recommendations.

APPENDIX A

FOREST DECLINE IN CENTRAL EUROPE AND THE EASTERN UNITED STATES.

"Waldsterben" or forest decline is a rapidly developing pattern of changes in the appearance and behavior of forests in many parts of Germany and other central and eastern European nations. The symptoms of decline are not identical in rate or sequence of development in various species of trees. Nevertheless, they include the following features, some of which have never or only very rarely been reported before in the literature of forestry and plant pathology.

Changes in the forests have developed very rapidly and unevenly but roughly simultaneously since 1979. Symptoms of decline have been observed in many different species and types of forests, principally silver fir (Abies alba Mill.), Norway spruce (Picea abies Karst.), European beech (Fagus sylvatica L.), and Scotch pine (Pinus sylvestris L.), but also including red maple, white oak, larch, white birch, alder, and white ash. The symptoms include a general thinning, change in color and altered morphology of the leaves and total tree canopy, particularly in spruce, fir, beech and pine. Loss of foliage is common in both spruce and fir. A loss or sparse development of foliage and abnormal development of branches are common in European beech. The formation of smaller than normal leaves, especially in beech and spruce, and misshapen (lobed) leaves, especially in beech, have been noted.

Active casting (shedding) of green leaves during the growing season especially in beech, fir, spruce, larch, alder and oak and of green shoots whith intact leaves and needles, most notably in spruce and pine and occasionally in oak have also been observed by German scientists. A decrease in diameter growth, particularly in fir and spruce during the past 20 years, has been noted. In spruce and fir the width of annual rings in affected trees have been found to be greater higher on the stem and much reduced or absent toward the base of the stem. This kind of abnormal distrubution of annual increment has rarely been reported before.

Abnormally heavy cone and seed crops have been observed three years in a row in spruce, pine and beech. This has not been reported in silver fir. Unusually large numbers of adventitious shoots are formed on affected spruce; epicormic branches are common on affected European beech trees. The complete lack or great suppression of fine feeder roots and ectomycorrhizal roots, a symbiotic association of fine roots and beneficial fungi, has been observed. This poor development of fine roots is especially common in affected beech, but is also less common and not as intense in spruce and fir.

Wood, most notably of branches, has become unusually brittle in affected beech trees. Marked deficiency of magnesium has been confirmed in the foliage of affected spruce trees. Death of most or all of herbaceous vegetation immediately beneath the canopy of some affected trees has been observed in two locations in Bavaria. The formation of crystals of calcium sulfate in the stomata on needles of affected spruce have been observed by electron microscopy. This wide array of symptoms has developed very rapidly (since 1979) and is so widespread in occurrence that many private, industrial and government foresters in West Germany are concerned that the forests as they have known them may not survive.

In seeking to understand the possible causes of forest decline in central Europe it is important to note that trees growing on fertile or infertile soils, in both basic and acidic soils, are affected by "Waldsterben". In forest stands regardless of aspect or orientation in southern Germany, and particularly in Bavaria but more commonly on northwest-facing slopes in northwestern German, north Rhine Westfalia and on west-facing slopes on elevations above 100 meters in the Black Forest area of Baden Wurtenberg have been most severely affected.

Although the most severe symptoms have been reported at high elevations, 800-1400 meters and above, essentially similar symptoms have also been observed in forests at moderate and low elevation sites. The first survey conducted in 1980 to delimit the geographic extent of forest decline in German forests are showing some stage of forest decline.

Several hypotheses have been proposed alone and in combination on the cause of forest decline including gaseous pollutants, magnesium deficiency induced by atmospheric deposition, general stress resulting from a combination of pollutants and drought, acidification of forest soils causing aluminum toxicity to the roots, and other biotic and abiotic stress factors.

FOREST DECLINE IN THE EASTERN UNITED STATES

Over the past 20 years red spruce (<u>Picea rubens</u> Sarg.) located in the high elevation forests of New York, Vermont and New Hampshire have exhibited marked dieback and decline symptoms. Certain northern Appalachian red spruce stands are presently exhibiting in excess of 80% dieback incidence and 60% incidence of mortality. The decline is characteristic of a stress related disease, and the etiology is not typical of a single biotic pathogen. In November 1983, a preliminary survey of Mt. Mitchell, NC was conducted from the summit (6,684 feet MSL) to below 5,200 feet MSL to characterize and photodocument the presence of any decline or dieback of red spruce in the southeastern United States. Mount Mitchell is the highest peak in eastern North America and its main peak and three high altitude ridges support vast populations of red spruce and Fraser fir which comprise one of the largest subalpine ecosystems east of the Mississippi River. All trees sampled at or above 6,350' elevation regardless of vigor exhibited marked growth reduction beginning in the early 1960's. On numerous samples the 21 annual growth increments from 1962-1983 were equivalent in total diameter to the four annual increments from 1958-1961. Precipitation data from 1930-1983 show that at no time during these 53 years was there a drought at the summit of Mt. Mitchell. Therefore growth suppression cannot be attributed to lack of moisture. In May 1984 a survey was begun to quantify and characterize the extent and rate of high altitude spruce-fir forest decline in the southern Appalachian Mountains. Our preliminary analysis indicates that the forest decline syndrome is observed in varying degrees throughout the southern Appalachian Mountains. West-facing slopes appear to have greater decline and dieback incidence along with greater annual ring increment suppression, which is observed on an average of 82% of all sampled red spruce dominant and co-dominant trees. Preliminary soil analysis suggests higher loading of lead on west-facing slopes. A series of permanent plots has been established on eight high elevation peaks which will be periodically revisited to quantify the temporal and spatial dynamics of the forest decline.

RESULTS OF SOUTHERN U.S. INVESTIGATIONS

During the 1984 field season, permanent plots were established on six of eight mountain areas visited. The northernmost area studied was Mt. Rogers in Virginia. Moving southward, plots were established on Grandfather Mountain, Roan Mountain, Mt. Mitchell, Clingsman's dome (GSMNP), and Mount Le Conte (GSMNP). The southernmost site visited was the Joyce Kilmer Wilderness area, however, permanent plots were established at this site due to a lack of suitable stands of red spruce and Fraser fir. This was also true of the Plott Balsams which are located east of the Great Smokey Mountain National Park.

The frequency of decline for all low altitude sites between 5200 ft and 5,600 ft is summarized in Figure 1, while the frequency of decline for all high elevation sites between 5,600 ft and 6,684 ft is summarized in Figure 2.

A decline class rating of 1 signifies relatively healthy trees with a defoliation index of between 0 and 10%. As can be noted in Figure 1, the average number of trees throughout the southern Appalachians showing a decline class rating of 1 is approximately 79%. It should be noted, however, that the west-facing slope of the respective mountainsides have a significantly greater amount of deline symptomatology with only 62% of the trees in decline class 1. Figure 2 illustrates the frequency of decline for all high elevation sites sampled. The average percent of the high elevation trees showing decline class 1, i.e., healthy trees, is generally less, with an average of 68% in this category. Only 54% of trees on west-facing slopes fell into decline class 1, thus indicating that approximately one-half of all high altitude trees exhibited some decline symptomatology.

Increment cores were removed from only dominant and co-dominant red spruce and Fraser fir trees. Figures 3-9 outline the results of this increment core analysis on Mt. Rogers, Roan Mountain, Grandfather Mountain and both high and low elevation sites on Mt. Mitchell. For the purpose of this report, the results from additional increment cores taken outside of established plots were included in Figures 3-9. On these mountains there was an abrupt and synchronous suppression of annual growth of both Fraser fir and red spruce beginning between 1958-1965.

However, we consistently found that red spruce was in a much more serious state of growth suppression than was Fraser fir in all sites. Perhaps the most abrupt increment suppression observed was on Mt. Rogers in Virginia. Although the amount of visible decline here was the least of the sampled, with approximately a five-fold decrease in radial increment since 1960 as compared to the annual increments from 1950 to 1960. The overall frequency of red spruce increment suppression averaged approximately 82%. The lowest incidence of approximately 43% was found in the low elevation red spruce trees on Mt. Mitchell. It should be noted that the definition of severe increment suppression in this particular study is at least a 2 1/2 fold decline in the average annual increments of 1960-1970 as compared to 1950-1960. Virtually all red spruce trees showed a slowing of growth during this period; however, many natural factors such as the natural aging process can account for a relatively slower growth rate.

Figures 8 and 9 illustrate a comparison between high and low elevation sites and red spruce growing at east and west aspects on Mt. Mitchell. It is interesting to note that not only are westward-facing trees in a more severe state of decline as illustrated in Figures 1 and 2, but there also appears to be a greater amount of relative increment suppression in westward-facing trees as compared to eastward-facing trees. Although this correlates nicely with soils data showing higher amounts of loading of lead on the westward-facing slope of the mountain (Table 1), it is premature to conclude that in fact decline symptomatology and growth increment suppression are necessarily cause and effect related to the west-facing aspect of the mountain and hence the incoming atmospheric deposition. Many other natural phenomena such as wind damage and more severe temperatures may also account for the greater decline and increment suppression on the west fact of the mountain.

DISCUSSION OF SOUTHEASTERN U. S. STUDIES

Presented in this report is a preliminary analysis of some data collected by a survey during the past field season. Work is continuing in the field and the laboratory to further characterize our permanent plots. Therefore, it is inappropriate at this time to attempt further evaluation of the data in Figures 1-9, and in Table 1.

CONCLUSIONS OF SOUTHEASTERN U.S. STUDIES

1. Boreal montane forest tree decline of red spruce and Fraser fir in the southern Appalachian Mountains appears to be a visible and quantifiable phenomenon.

2. Incidence of decline symptomatology is present throughout the southern high altitude mountains and may be more pronounced on west-facing slopes.

3. Severe synchronous annual growth increment suppression in red spruce and to a lesser degree in Fraser fir has been documented for four sites in the southern Appalachian Mountains. Preliminary analysis indicates that more severe suppression may occur on west-facing slopes, which correlates with both the incidence of tree decline and the presence of atmospheric deposition products.

OBSERVATIONS AND EXPERIMENTS WITH MYCORRHIZAE IN SOUTHEASTERN U. S.

Roots of spruce, pines and other needle-bearing trees usually show a symbiotic association with beneficial fungi. These fungus-root structures are called mycorrhizae (myco = fungus, rhiza = root). We observed a statistically significant correlation (P = 0.05) between the percent of spruce short roots that are mycorrhizal and the elevation at which the tree was growing. Trees growing above 6,350 feet averaged about 35% mycorrhizal incidence and spruce at or below 5,200 feet averaged about 72% mycorrhizal incidence.

When percent mycorrhizal roots were plotted against the degree of decline of the host tree, a highly significant correlation coefficient (P = 0.01) was found. Trees exhibiting 80% or more defoliation (spruce at high altitudes) averaged about 30% mycorrhizal roots, whereas trees with few decline symptoms averaged about 75% mycorrhizal roots.

High altitude red spruce roots exhibited a far greater degree of disintegration (fine root necrosis) than did the creamy white, fungus mantle covered, tree roots found at lower elevations.

Acid rain simulation mycorrhizae experiments in greenhouses at North Carolina State University have demonstrated that incidence and vigor of loblolly pine were severely retarded at pH 4.0 compared to pH 2.4, 3.2 or 5.6. We believe this is the first significant biological effect to be documented at the pH of ambient rainfall for the state of North Carolina.

Mycorrhizal roots of red spruce at low and high elevations on Mt. Mitchell were very similar in appearance and state of necrosis to the pine roots in these rain simulation experiments and were similar in morphology and state of necrosis as compared to the pH 4.0 rain simulation experiments.

OBSERVATIONS ON ROOT-INHABITING FUNGI

Root isolations made from declining (high elevation) and non-declining (low elevation) red spruce roots revealed that at least two species of the fungal root pathogen *Pythium* were frequently isolated only from the roots of delining trees. Roots of vigorous trees at low elevation often failed to yield any pathogenic fungi.

OBSERVATIONS OF FOREST REPRODUCTION

At altitudes above 6,350 feet little successful fir, spruce, or shrub reproduction was observed. The ground was barren of any living woody vegetation. Slopes on the mountain below this altitude showed normal reproduction--they were heavily colonized with seedlings and saplings of all age classes. By contract, a vegetation survey in 1958 showed that all Mt. Mitchell slopes from the summit down had lush and abundant ground covers.

OBSERVATIONS OF TOXIC METAL ACCUMULATION

Lead concentrations in excess of 2 grams per square meter were commonly observed in forest litter at elevations above 6,000 feet. Lower elevations (5,000-5,500 feet) showed considerably less lead loading. It was also found that western-facing slopes (predominant wind direction) had higher lead content than east, south and north-facing slopes. The high altitude soil and litter lead contents are greater than those found in similar samples in the mountains of the northeastern United States. Unusually large amounts of Cu, Ni, Zn, and Mn were also detected on Mt. Mitchell, all in amounts greater than those observed from northeastern mountain litter samples, and in amounts that far exceed those for low elevation forests in North Carolina. The possibility that lead and copper toxicity to plants may exist on Mt. Mitchell must be investigated.

SUMMARY REMARKS--SOUTHEASTERN U.S.

These observations, which suggest that major climatic perturbation (drought, abnormal high or low temperatures) is not of significance in the southern Appalachian mountains, strengthen the hypothesis that atmospheric deposition may contribute or be causal in the etiology of red spruce decline. Some of the possible mechanisms that need to be investigated include:

1. Hydrogen ion deposition inducing aluminum leaching, resulting in root toxicity and tree decline.

2. Calcium depletion from the soil matrix causing deficiency.

3. Nitrogen deposition (averaging about 40 pounds per acre per year causing nitrogen toxicity, (i.e., death of ectomycorrhizae), uptake of excess N resulting in abnormally succulent crowns and shoots, thus decreasing the resistance of red spruce to frost, wind desiccation, and fungal or insect parasites.

4. Effects of the abnormally high concentrations of heavy metals in organic matter and soils on the vigor of roots and hence the vitality of red spruce.

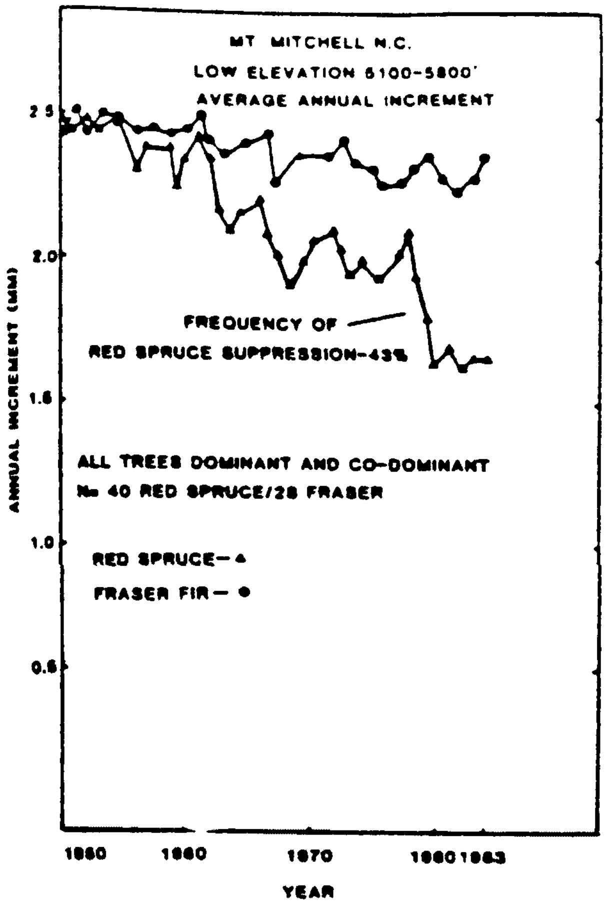

Figure 1: Annual increment of red spruce and fraser fir at lower elevations at Mt. Mitchell, NC (Bruck, 1984b)

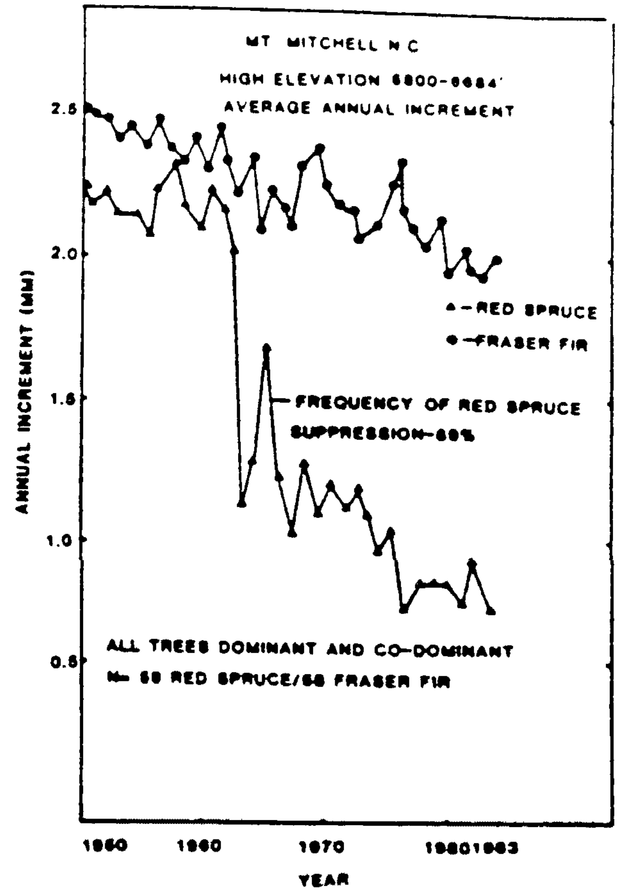

Figure 2. Annual increment of red spruce and fraser fir at high elevations at Mt. Mitchell, NC (Bruck, 1984b)

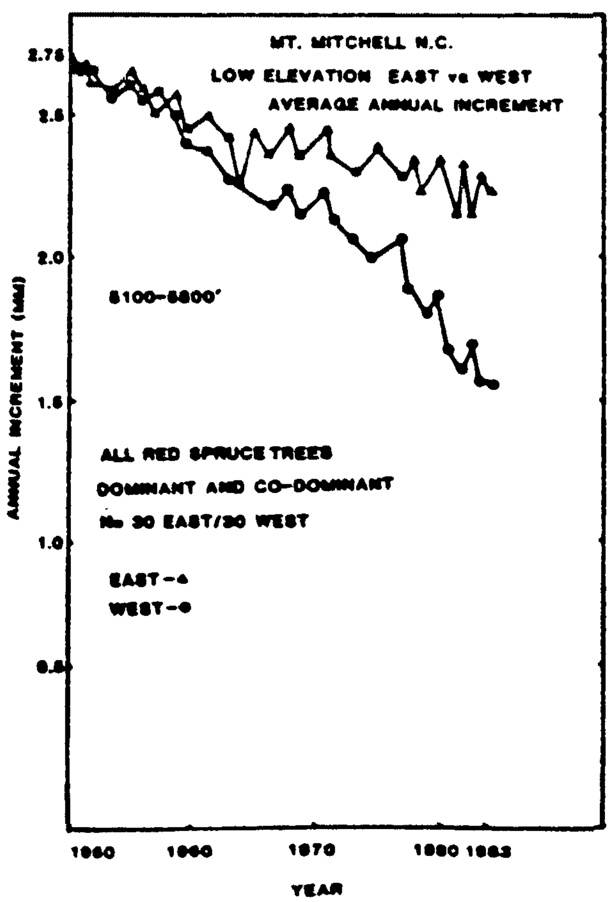

Figure 3: Legend is the same as in Figure 1 except for the aspect (Bruck, 1984b)

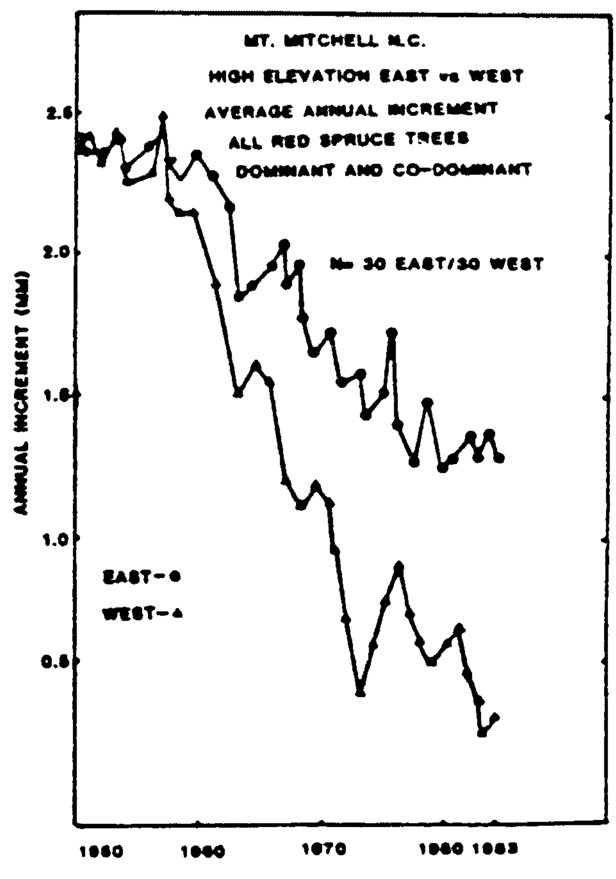

Figure 4: Legend is the same as in Figure 2 except for the aspect (Bruchk, 1984b)

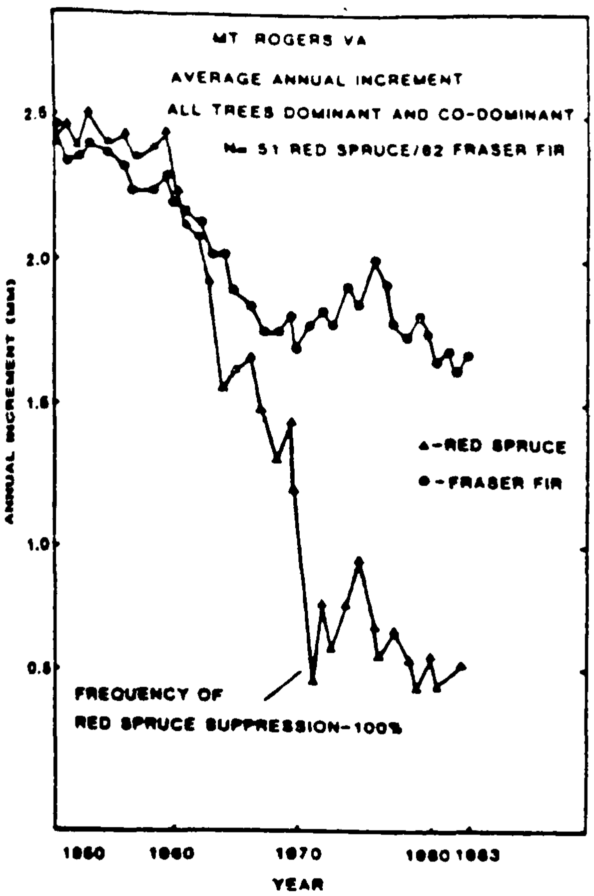

Figure 5: Red spruce and fraser fir decline at Mt. Rogers, VA (Bruck, 1984b).

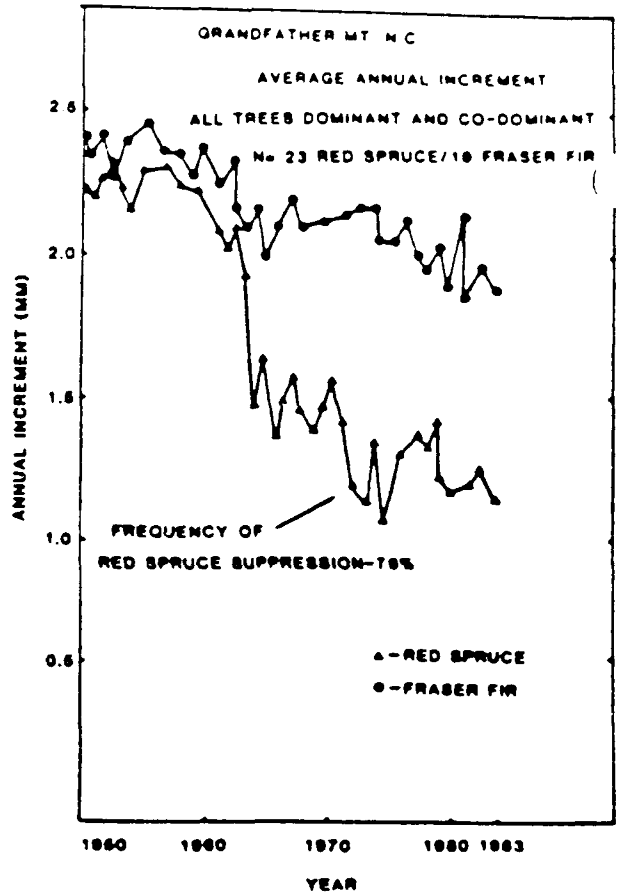

Figure 6: Red spruce and fraser fir decline at Grandfather Mt., NC (Bruck, 1984b).

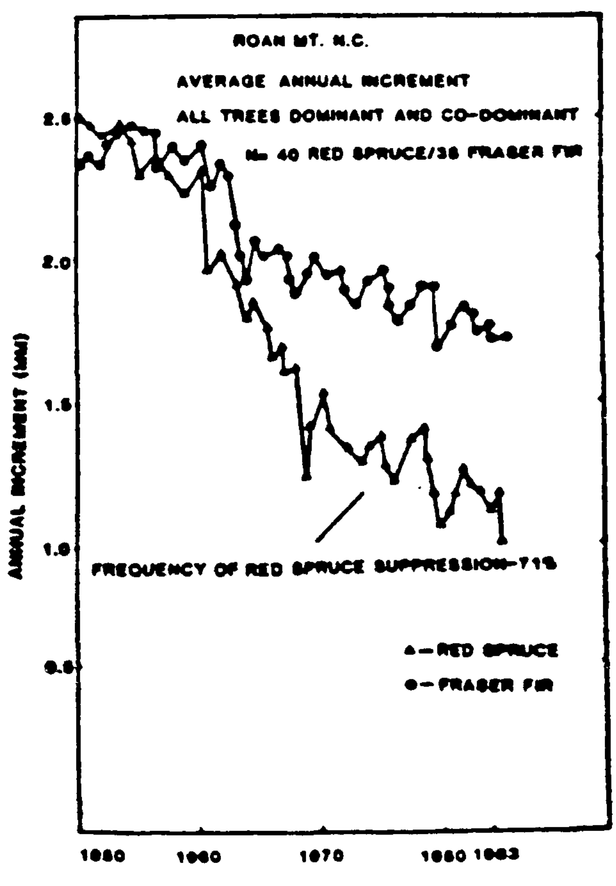

Figure 7: Red spruce and fraser fir decline at Roan Mt., NC (Bruck, 1984b).

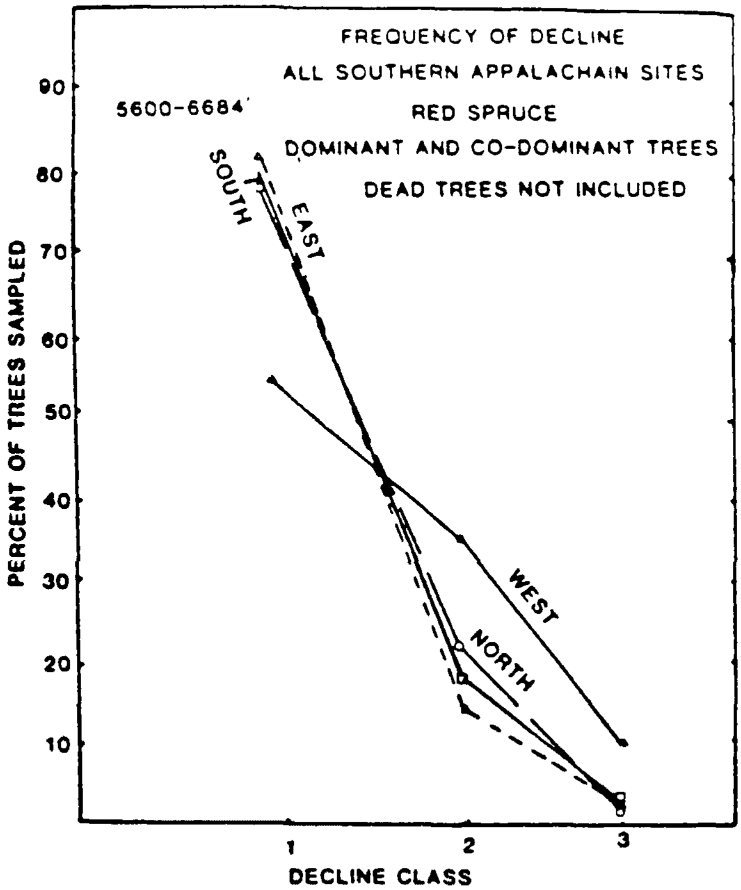

Figure 8: Decline frequency of red spruce at high elevations (Bruck, 1984b).

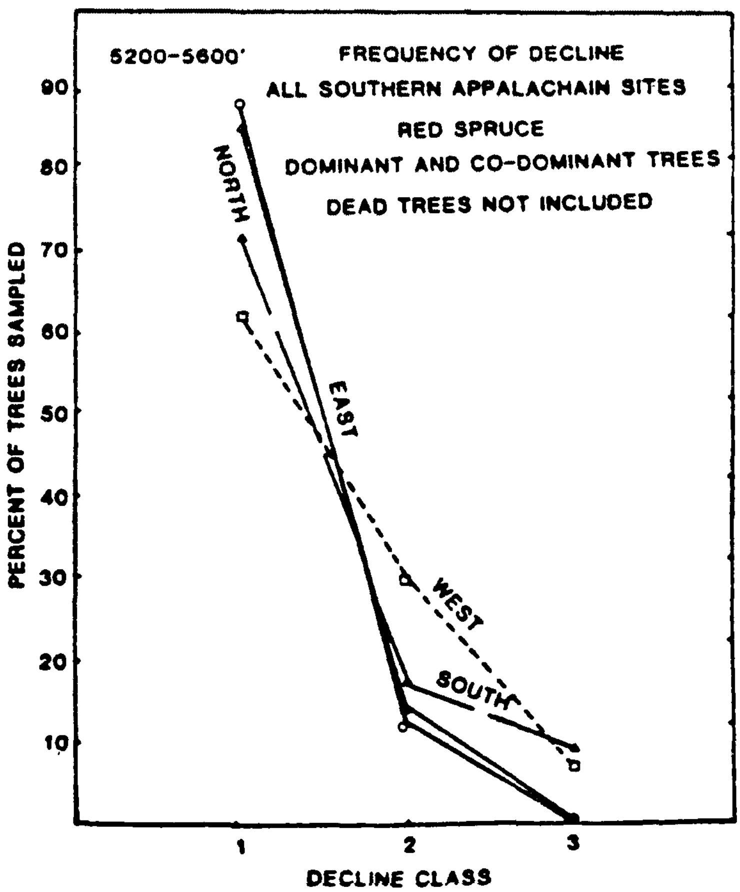

Figure 9: Decline frequency of red spruce at low elevations (Bruck, 1984b).

APPENDIX B*

TABLE 1. Comparison of Symptoms of Forest and Tree Decline in Central Europe and Eastern North America

Symptoms	Central Europe	Eastern North America
Growth-decreasing symptoms:		
1. Yellowing of foliage from the lower to the upper and from the inner to the outer portion of branches -- oldest tissues affected first.	Observed mainly in white fir and Norway spruce at high elevation.	Observed recently in red spruce in New York and Vermont.
2. Dying back from the top of trees -- youngest tissues affected first.	Common in oak and ash, less common in birch and beech. diebacks.	Conspicuous in red spruce, maple, and oak decline; ash and birch
3. Increased transparency of crowns due to gradual loss of leaves but with leaves retained to the very top of the trees. alder.	Observed in Norway spruce, white fir, Scots pine, larch, beech, birch, oak, maple, ash, and	Observed only in the littleleaf disease of shortleaf pine and in the beech-bark disease
4. Losses of fine-root biomass and mycorrhizae (beneficial symbiosis between tree roots and soil fungi).	Common in white fir, Norway spruce and beech. Not studied in other species.	Observed mainly in red spruce decline, birch dieback, and little leaf disease.
5. Synchronized decrease in diameter growth other visible symptoms	Not reported in Europe.	Observed in pitch pine and shortleaf pine.
6. Synchronized decrease in diameter growth with other visible symptoms leading to death.	Studied mainly in Norway spruce, white fir and beech. Not	Observed in red spruce and Fraser fir mainly at high elevation.

7. Progressive decrease in diameter growth with other visible symptoms leading to death.	Not reported in Europe.	Observed in ash and birch, diebacks, some maple and oak declines, sweetgum blight, littleleaf disease, pole blight.
8. Death of herbaceous vegetation beneath some affected trees.	Observed in high elevation spruce and beech forests.	Not observed in North America
<u>Abnormal-growth symptoms:</u>		
9. Active casting off (abscission) of leaves and shoots while still green.	Common in spruce, fir, and beech, ash larch, and Scots pine.	Reported only once in North America.
10.Change in relative length of long shoots and short shoots.	Common in beech and larch.	Reported only in the mycoplasma-induced "yellows" of ash.
11.Concentration of leaves at tips of branches in tufts or clumps.	Common in beech and ash.	Reported only in the declines of broad-leaved trees.
12.Change in size and shape of leaves.	Common in beech, occasionally in spruce, fir, birch, and oak.	Common in white pine, littleleaf disease of shortleaf pine, and some maple and oak declines.
13.Excessive production of seeds and cones	Common in spruce, fir, beech, and birch; often observed several years in a row.	Observed in many stressed trees but mainly one year at a time

General Observations

Many different species suddently showing substantially similar symptoms	Yes.	No.
Commerical forests showing extensive decline.	Yes.	No, except for red spruce in certain parts of eastern North America.
Soil relationships	Trees affected on nutrient-rich and acid soils and basic	Trees affected more on nutrient poor and acid soils.
Elevation relationship.	Needle-bearing trees affected at all elevations.	Needle-bearing trees affected mainly at high elevation.

Symptom 3 has not been reported before 1979 affecting more than one species of tree.

Symptom 8, 10, 13, and 14 have not been reported before 1980 affecting any tree species.

Symptom 9 has been reported only once in North America and not before 1979 in central Europe.

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16. ABSTRACT

This document presents the methods and findings of a scientific team of forest experts assembled to investigate reports of air pollution damaged forests near Gothic Colorado. Tree damage similar in appearance to the acid rain damaged forests in the Eastern U. S. and central Europe was observed by two visiting scientists in 1984. The report presents the findings of the team which concluded that no evidence now exists that air pollution in contributing to the natural forest decline in the area.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
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