U.S. DEPARTMENT OF THE INTERIOR

U.S. GEOLOGICAL SURVEY

BRISTLECONE PINE FROST-RING AND LIGHT-RING CHRONOLOGIES, FROM 569 B.C. TO A.D. 1993, COLORADO

By

F. Craig Brunstein[1]

Open-File Report 95-63

[1]U.S. Geological Survey, Denver, Colo.

1995

INTRODUCTION

PURPOSE

In this report I continue work started by LaMarche and Hirschboeck (1984) and Krebs (1972) in the Southern Rocky Mountains by providing chronologies of frost rings and light rings recorded in 243 Rocky Mountain bristlecone pines (*Pinus aristata*) over the past 2,500+ years. The report also provides descriptions of the visual appearance of frost rings and light rings in bristlecone pines and descriptive data for the five study sites.

FROST RINGS

Frost rings form during uncommon occurrences of subfreezing temperatures in the growing season of certain tree species. Under such conditions, wood cells are deformed because of intercellular ice formation, leaving a permanent thin layer of anatomical damage within the annual ring (Glerum and Farrar, 1966). At least two consecutive nights of freezing temperatures down to 23°F (-5°C), separated by a day of about freezing temperatures, during the growing season can cause a frost ring in trees (Glock and Reed, 1940; Glock, 1951).

Two types of frost damage have been noted in the annual rings of trees: (1) earlywood frost damage, which affects the light-colored cells (earlywood) formed in the early part of the growing season and (2) latewood frost damage, which affects the darker cells (latewood) formed at the end of the growing season. LaMarche (1970) related unusual occurrences of sustained freezing temperatures in early July 1902 and mid-September 1965 to earlywood frost damage and latewood frost damage, respectively, in bristlecone pines in the Snake Range, Nev. (fig. 1). Such frost rings provide synchronous "marker" rings that are helpful in crossdating increment cores from bristlecone pines (LaMarche, 1970).

Many of the latewood frost rings that are recorded in bristlecone pines have been linked to climatic cooling that follows large to very large, sulfur-rich volcanic eruptions (LaMarche and Hirschboeck, 1984) and to strong El Niño events (Stahle, 1990). LaMarche and Hirschboeck (1984) found that some latewood frost rings in bristlecone pines in the Great Basin occurred in years in which notably cooler than normal summer temperatures occurred in that region.

Bristlecone pine frost-ring chronologies from the Southern Rocky Mountains have limited length and detail. Krebs (1972) listed less than 15 frost-ring dates over the past 800 years, with one frost ring date in A.D. 405. LaMarche and Hirschboeck (1984) documented less than 20 dates of frost rings in bristlecone pines in the Southern Rocky Mountains over the past 800 years.

LIGHT RINGS

The origin of light rings (light latewood) in bristlecone pines has not been studied, and chronologies of light rings in bristlecone pines do not exist. Light rings in Arctic black spruce (*Picea mariana*) have been linked to (1) the adverse climatic effects that follow large volcanic eruptions (Filion and others, 1986) and (2) cooler than normal May-September temperatures in the Bush Lake region of northern Quebec in the years that light rings form in more than 5 percent of sampled trees (Yamaguchi and others, 1993).

STUDY SITES

The five study sites are in the Colorado Rocky Mountains at (1) Almagre Mountain and Mount Big Chief, both in the southern Front Range; (2) Black Mountain, at the southern end of South Park; (3) Mount Princeton, in the Sawatch Range; (4) North Peak, at the southern end of the Wet Mountains; and (5) Stanley

Mountain, in the central Front Range (figs. 1-2). Because Almagre Mountain is only 2 mi (3 km) north of Mount Big Chief and the two mountains are connected by a long ridge, the chronologies for the two mountains are combined in this report and are referred to as the Almagre Mountain chronology. Table 1 provides descriptive data for each site.

Sampled trees in this study are Rocky Mountain bristlecone pines (*Pinus aristata*), which are native to parts of Colorado, New Mexico, and Arizona (fig. 1). They are related to Great Basin bristlecone pines (*Pinus longaeva*), which are native to parts of California, Nevada, and Utah, and to Foxtail pines (*Pinus balfouriana*), which are native to California (Bailey, 1970). Numerous white resin specks on the needles of Rocky Mountain bristlecone pines are one of the diagnostic features that distinguish them from Great Basin bristlecone pines and Foxtail pines (Bailey, 1970).

The study sites are on the east side of the Continental Divide at altitudes of 10,950-12,140 ft (3,340-3,700 m). Analyses of physiographic settings and precipitation maps show that Almagre Mountain, Black Mountain, and Mount Princeton are relatively dry mountain areas as compared to most high mountain areas in Colorado (Brunstein and Yamaguchi, 1992). Study sites are on the eastern flanks of these three mountains, which are probably drier than the western flanks because of local "rain-shadow" effect. The relatively dry environments at the Almagre Mountain, Black Mountain, and Mount Princeton study sites may promote longevity of bristlecone pines. The ages of some of the living trees at these sites exceed 1,500 years (table 3 and Brunstein and Yamaguchi, 1992).

Topography at the study sites is rugged. Steep, windswept, barren or sparsely vegetated slopes, steep boulder talus slopes, and bedrock spurs and cliffs exist at the sites. Persistent snowfields that cover unpaved roads above 11,000 ft (3350 m) altitude usually prevent vehicle access to the Almagre Mountain and Mount Princeton sites from mid November to mid June. A small, northeast-facing, shallow cirque, which extends from 12,200 ft (3,720 m) down to 11,700 ft (3,570 m) altitude, is near one of the sample sites at Almagre Mountain. Snow avalanche chutes above U.S. 40 are close to some of the bristlecone pine groves at Stanley Mountain.

Bristlecone pines at the sites grow interspersed with other tree species or in nearly pure stands, and they grow as isolated trees, scattered open-spaced small groves, and open-spaced groves that cover large areas. Other tree species that grow at the sites are listed in table 1. The Black Mountain site is unusual because no Limber pines (*Pinus flexilis*) were found there (or on nearby Thirtynine Mile Mountain), even though site characteristics are similar to other mountain areas in Colorado that have Limber pines. The possible absence of Limber pines in this part of Colorado could be related to a physiographic setting that has limited the spread of Limber pine into this region.

Charred tree remnants provide evidence of forest fires within and near many of the bristlecone pine groves. Extensive burned areas exist on Almagre Mountain and Black Mountain. Charred wood looks to range from ancient (>1,000? years old) to as recent as 100-200 years old. Young living bristlecone pines grow on relatively recent burned areas that extend in some places to upper treeline on the south and east slopes of Almagre Mountain. Standing "ghost forests" consisting of dead bristlecone pines exist on some of these burned areas. Other small areas of "ghost forests" near upper treeline on Almagre Mountain have no evidence of fire. Trees in these areas may have died because of lowering of upper treeline due to past climatic cooling. Charred wood is generally absent in bristlecone pine groves that contain living bristlecone pines more than 1,500 years old. Such groves are usually isolated from surrounding forests by barren areas of bedrock and boulder talus. Areas of charred wood on some living bristlecone pines show that such trees have survived forest fires.

Forms of sampled trees vary from young, bark-enclosed trees to old, bark-strip-growth trees that have exposed, wind-sculptured wood. Most of the sampled mature trees are stunted, being only 10-20 ft (3-6 m) tall; however, in more sheltered areas, sampled trees are as tall as about 35 ft (11 m).

Dates of death of sampled dead trees vary from about A.D. 100 to 1800. Many of the erosion-sculptured old remnants (such as 91-R6 on Almagre Mountain, cores of which contain the ring sequence from 569 B.C. to A.D. 170) have no roots or limbs and are lying loose on the ground. A few old remnants are still standing (such as 93-R17 on Mount Princeton, cores of which contain the ring sequence from 359 B.C. to A.D. 1003); erosion has removed all but a few of the largest limbs on such trees. Sampled trees that have been dead a few centuries are standing, barkless, and have branches as small as about 1 in. (2.5 cm) in diameter.

METHODS

Cores (about 4 mm in diameter) were collected in 1968-69 and 1988-94 from 243 standing living and dead bristlecone pines and from fallen, dead bristlecone pines. None of the sampled trees were the prostrate "krummholz" growth form. Because frost rings in bristlecone pines are more numerous near upper treeline (LaMarche, 1970) and because the purpose of this study was to establish bristlecone pine frost-ring chronologies, most of the core samples were collected from bristlecone pines near local upper treeline (table 1). At each site, an effort was made to sample the oldest living trees as well as younger trees (table 2). During the study, light rings were observed in the core samples, so the purpose of the study was amended to include light rings. Work was concentrated on Almagre Mountain because of the abundance of living 500-1,100-year-old bristlecone pines and remnant bristlecone pine wood near upper treeline at that site. At Almagre Mountain, 67 living and 59 dead sampled trees are at altitudes of 11,600-12,000 ft (3,540-3,660 m) and 33 living and 32 dead sampled trees are at altitudes of 11,800-12,000 ft (3,600-3,660 m).

Cores for each site were air dried for at least several days, glued to wood mounts, sanded, and crossdated according to standard dendrochronological methods (Stokes and Smiley, 1968; LaMarche, 1970; Swetnam and others, 1985; Phipps, 1985; Yamaguchi, 1991; Yamaguchi and Brunstein, 1991). The sanding sequence started with 60- and (or) 100-grit sandpapers, continued with 150- and 280-grit sandpapers, and finished with 300-, 400-, and 600-micron sanding films. The ring-width chronologies from Almagre Mountain and Mount Evans (Drew, 1974) were useful in crossdating the Almagre Mountain and Stanley Mountain cores, respectively. Dates of frost rings listed in Krebs (1972) and LaMarche and Hirschboeck (1984) and dates of light rings in the cores were also useful in crossdating. Light rings in the cores were noted from visual microscopic scans at 10× and 20× magnification. Latewood density was not measured.

At Almagre Mountain, the most intensely studied of the sample sites, a 2,563-year-long (569 B.C.-A.D. 1993) tree-ring chronology was made from 147 living and dead bristlecone pines. Dates of frost rings, light rings, and narrow and wide rings in crossdated cores from living trees were plotted on scale-stable graph mylar. Undated tree-ring sequences from many of the sampled dead trees were also plotted on graph mylar and crossdated with the living trees. Many cores were crossdated when diagnostic frost-ring sequences were recognized during preliminary microscopic scans of the cores (see results section and table 6).

The frost-ring and light-ring record presented in this report is probably accurately dated because of (1) visual ring-width crossdating of the core samples within each site and with existing bristlecone pine ring-width chronologies from nearby sites (such as Almagre Mountain and Mount Evans; Drew, 1974) and (2) crossdating of frost-rings and light-rings at multiple sites as far back as 269 B.C. In addition, the dates of many of the frost rings are identical to those reported by LaMarche and Hirschboeck (1984) and Krebs (1972).

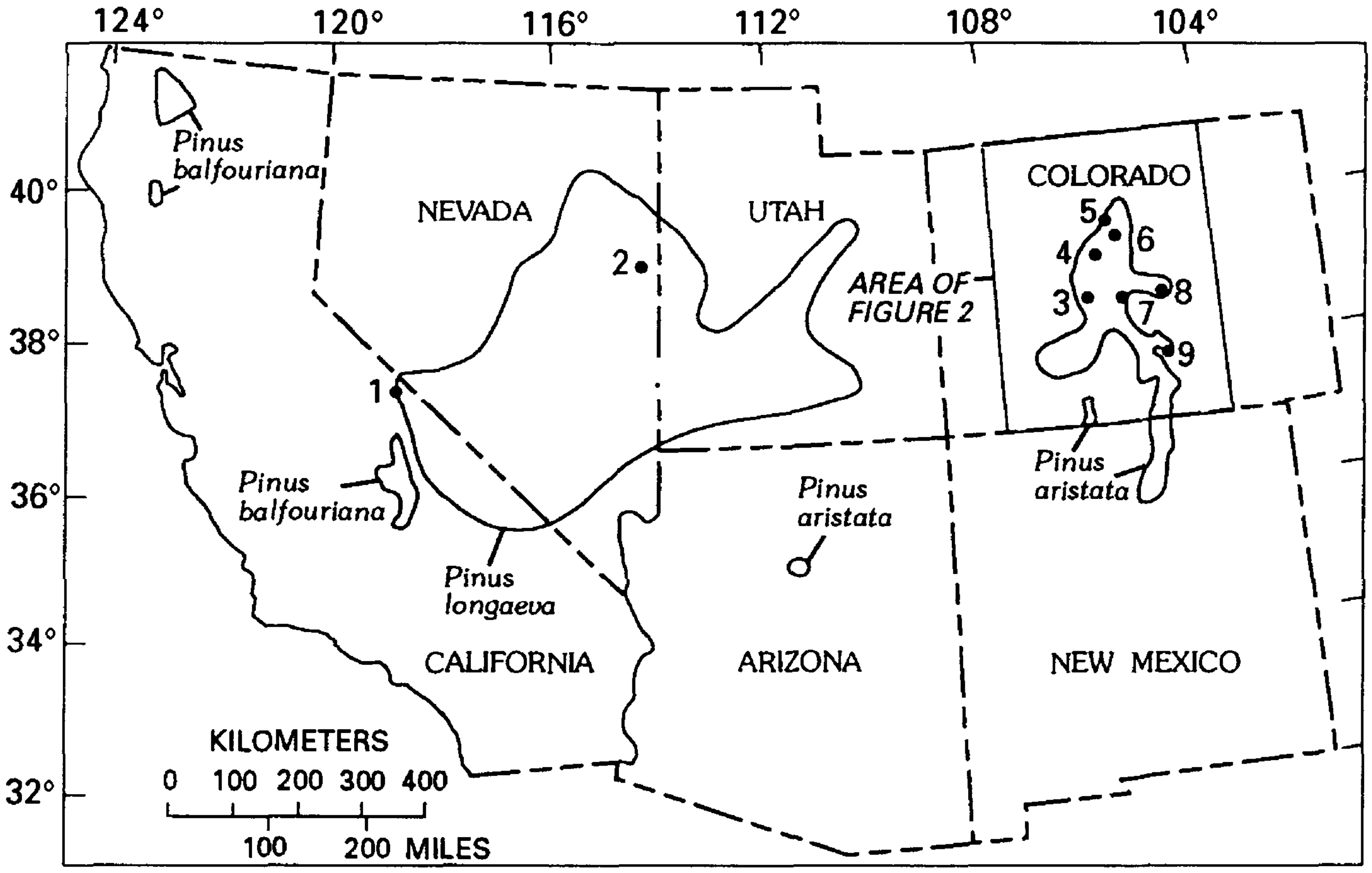

Figure 1. Index map of the southwestern United States showing bristlecone pine sites mentioned in this report. Distributions of Rocky Mountain bristlecone pine (*Pinus aristata*), Great Basin bristlecone pine (*Pinus longaeva*), and Foxtail pine (*Pinus balfouriana*) are from Bailey (1970) and Krebs (1972). 1, White Mountains; 2, Snake Range; 3, Mount Princeton; 4, Mount Bross-Windy Ridge; 5, Stanley Mountain; 6, Mount Goliath and Mount Evans; 7, Black Mountain; 8, Almagre Mountain; 9, North Peak.

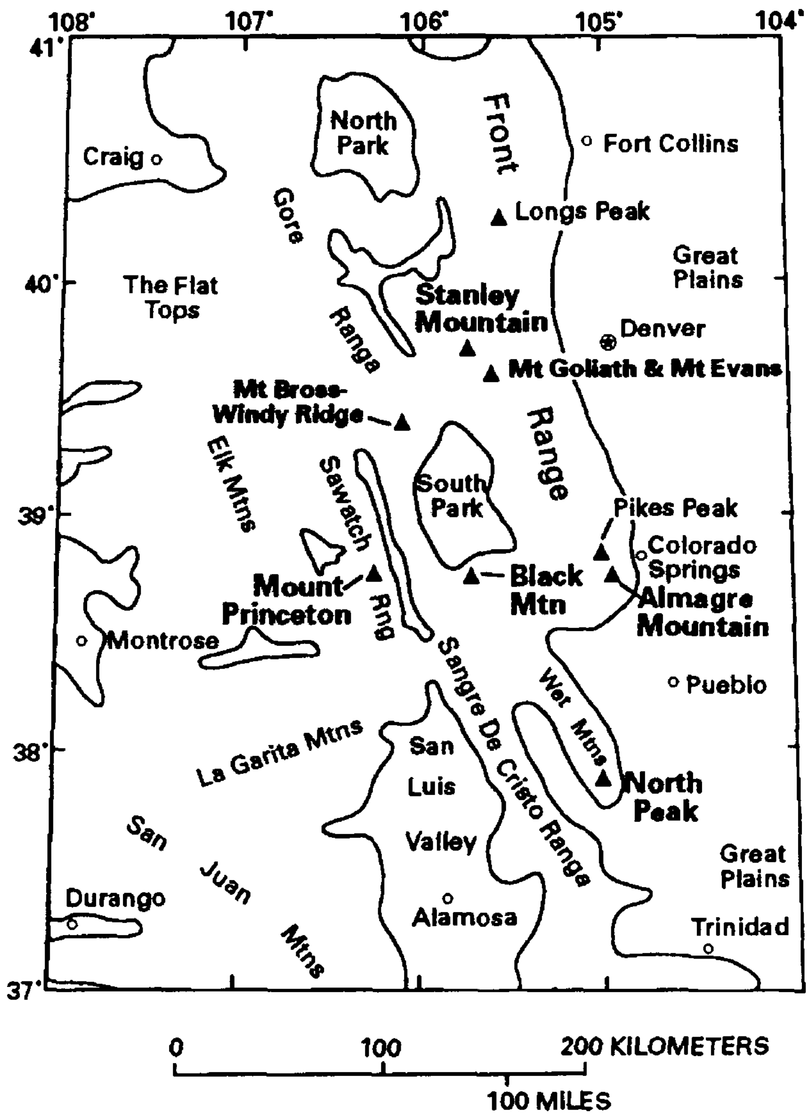

Figure 2. Map of part of Colorado showing locations of the study areas and other selected features.

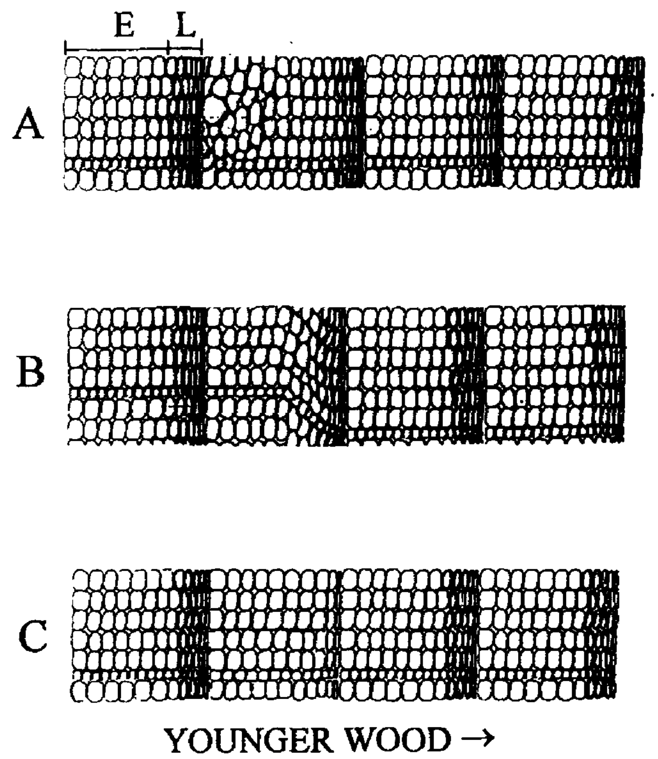

Figure 3. Generalized drawings from bristlecone pine core samples. (A) earlywood frost ring showing enlarged and distorted cells and disruption of some of the radial rows of cells, (B) latewood frost ring showing bent radial rows of cells and a few slightly distorted cells, and (C) light ring showing latewood less than half the thickness of latewood in surrounding rings. Four annual rings are shown in each example. E, earlywood; L, latewood. About 50 times natural size.

VISUAL APPEARANCE OF FROST RINGS AND LIGHT RINGS

Under the microscope weak earlywood frost damage noted in this study is characterized by slightly distorted and enlarged cells at the earliest part of the annual ring; such cells grade into younger normal earlywood cells. Strong damage consists of enlarged, distorted, and crushed cells; in addition some to many radial rows of cells are disrupted (fig. 3). Such damage is similar to that described by Glerum and Farrar (1966) in other evergreen tree species.

Latewood frost damage in the core samples ranges from light freeze damage, consisting of slightly "bent" radial rows of latewood cells (visible at 20× magnification), to severe freeze damage, consisting of dark bands of severely damaged and destroyed cell tissue (visible to the unaided eye). Typical latewood frost rings have noticeably bent radial rows of cells that are visible at 10× and 20× magnification and none to many slightly distorted to crushed cells (fig. 3). Bent radial rows of cells are curved in the same direction, generally remaining parallel to each other. Such latewood frost damage ("bent" radial rows of cells) often extends partly into the earlywood within the annual ring. Bent radial rows of cells in some latewood frost rings occupy almost half the thickness of the annual ring (this study; also see photograph on p. 123 in LaMarche and Hirschboeck, 1984). Careful surface preparation of core samples enabled detection of frost damage in latewood that is only 2-3 cells thick.

Light rings in the core samples have fewer layers of latewood cells than surrounding rings, so latewood is narrower and looks lighter than that for surrounding rings (fig. 3). Most of the light rings generally have latewood that is only moderately lighter than latewood in surrounding rings when viewed at 10× and 20× magnification. However, some of the light rings are visually striking because latewood appears to be almost missing. Such light rings have only one row of latewood cells, which also have thinner than normal cell walls. Light-ring dates that are recorded in >20 percent of the sampled trees at Almagre Mountain (such as 27 B.C. and A.D. 112, 994, 1192, and 1337; table 4) generally have the "lightest" latewood. Light rings in this study are similar to those described by Filion and others (1986) in Arctic black spruce.

RESULTS

Crossdated cores from 243 living and dead Rocky Mountain bristlecone pines (*Pinus aristata*) at the five sites reveal 47 earlywood frost-ring dates, 182 latewood frost-ring dates, and 178 light-ring dates in one or more bristlecone pines at one or more of the five sites over the past 2,500 years (tables 4 and 5). Nine of the earlywood frost-ring dates, 37 of the latewood frost-ring dates, and 24 of the light-ring dates are recorded at two or more bristlecone pine sites in the Southern Rocky Mountains.

Latewood frost rings are recorded at bristlecone pine sites in both the Southern Rocky Mountains and the Great Basin at 14 dates (tables 4 and 5). Some of the light-ring dates in this study (for example, A.D. 687, 1171, 1601, and 1884; table 4) coincide with latewood frost-ring dates in bristlecone pines in the Great Basin (LaMarche and Hirschboeck, 1984).

Both latewood frost rings and light rings exist at the same date for 59 of the dates listed in table 4. Of these 59 dates, 24 consist mostly of latewood frost rings, 21 consist mostly of light rings, and 14 consist of equal numbers of latewood frost rings and light rings. Some latewood frost rings have noticeably light latewood (table 4). Occasionally, a latewood frost ring and a light ring were observed at the same date in different cores (different radii) from the same tree.

Multiple cores from any given tree at altitudes above about 11,600 ft (3,540 m) on Almagre Mountain often provide mixed results: a few frost-ring and light-ring dates in a first core, the same dates as the first core as well as additional dates in a second core, and occasionally no frost-rings or light-rings in a third core. An occasional tree yields multiple cores that have no frost rings or noticeable light rings.

Each latewood frost-ring event that occurred from 1800 to 1993 (where sample population is largest) is recorded in multiple trees (table 4). A larger sample population before 1800 would probably show that latewood frost-rings found in only one sampled tree (table 4) are probably present in multiple trees at one or more sites in the Colorado Rockies.

As crossdating of the cores progressed, certain frequently occurring latewood frost-ring sequences (table 6) could oftentimes be recognized in preliminary microscopic scans of the cores. These sequences, in conjunction with (1) broad age classifications based on field observations of the amount of erosion of sampled dead trees, (2) recognition of "marker" narrow and light rings, and (3) followed by careful crossdating with previously crossdated cores or existing ring-width chronologies, enabled relatively fast crossdating of core samples.

Frequencies of events before about A.D. 1500 in the Almagre Mountain chronology (tables 4 and 5) may be slightly inflated compared to frequencies after about A.D. 1500. That is because cores from 12 old remnants were not confidently crossdated, so they were not included in the chronology. The 12 remnants were judged to predate A.D. 1500 on the basis of the amount of erosion of the remnants. Cores from these remnants were not confidently crossdated because they have few or no frost rings and light rings, and ring sequences in these cores have either (1) relatively low sensitivity (year to year ring-width variance is low) or (2) extremely narrow ring widths (120+ rings per inch of radius) and probably numerous missing rings.

Most earlywood frost rings in this study are less than 100 years from the pith of sampled trees (table 5). However, some of the earlywood frost rings at A.D. 1269, 1865, and 1894, are 400-1,100 years from the pith of sampled trees (table 5).

Detailed frost-ring and light-ring chronologies could be made for other bristlecone pine sites in the Southern Rocky Mountains and the Great Basin. Such chronologies would permit mapping of the geographic extent of individual frost-ring and light-ring dates in the western United States and would fill gaps that possibly exist in the bristlecone pine frost-ring and light-ring record. Further work needs to be done to determine the climatic significance of the bristlecone pine frost-ring and light-ring record.

ACKNOWLEDGMENTS

I thank Sherry Agard and Paul Carrara (U.S. Geological Survey) and Dave Yamaguchi (Forestry and Forest Products Research Institute, Japan) for their advice over the years; their reviews improved early drafts of this report. My gratitude goes to Bob Thompson (U.S. Geological Survey), whose review also improved this manuscript; to Dave Yamaguchi who compiled the ranges of tree species in figure 1; and to Pat L. Wilber (U.S. Geological Survey) for computer-graphics advice. I thank Chuck Kienast, Laura Knapp, and James Montoya (Pike National Forest, U.S. Forest Service), Johnny Hodges, Clint Kyhl, Charles Medina, and Cindy Rivera (Pike and San Isabel National Forests, U.S. Forest Service), and Corey Wong (Arapaho National Forest, U.S. Forest Service) for permission to obtain increment cores from trees on Almagre Mountain, Black Mountain, Mount Big Chief, Mount Princeton, North Peak, and Stanley Mountain.

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Table 1. Descriptive data for bristlecone pine sites

[UTL, altitude of upper treeline for erect mature living bristlecone pines. Bedrock data from Johnson (1969); Scott and Wobus (1973); Scott and others (1975); Trimble and Machette (1979); Epis and others (1979), Eppinger and others (1985), and from field observations. Sampled trees grow on thin gravelly soil, colluvium, boulder talus, and bedrock. E, Engelmann spruce (*Picea Engelmannii*); Lm, Limber pine (*Pinus flexilis*); Lo, Lodgepole pine (*Pinus contorta* var. *latifolia*); S, Subalpine fir (*Abies lasiocarpa*). Aspen (*Populus tremuloides*) are present near all sample sites and on relatively wet parts of some sample sites. Subalpine fir may be present on Almagre Mountain, Black Mountain, and Mount Princeton, but none were observed at the sample sites.]

Site	Altitude of sampled trees in feet (m)	Slope (degrees)	Slope aspect	Bedrock	Number of living (dead) trees sampled	Number of rings crossdated	Site UTL in feet (m)	Other tree species
Almagre Mountain	10,950-12,000 (3,340-3,660) 11,400-12,140[a] (3,470-3,700)	10-50	SW, S, SE, E, NE, NW	Middle Proterozoic Granite of Almagre Mountain (pink biotite granite) and Precambrian Pikes Peak Granite (orange-pink biotite granite)	80 (67)[b]	>75,000	12,000[c] (3,660)	E, Lm
Black Mountain	11,100-11,600[d] (3,380-3,540)	10-40	SW, SE	Oligocene upper member of Thirtynine Mile Andesite (brownish-gray andesite lava flows, breccia, ash-flow tuff)	15	>9,000	Tree covered summit	E
Mount Princeton	11,760-12,140 (3,585-3,700) 12,070-12,130[a] (3,680-3,695)	20-30	SW, SE	Oligocene(?) to Eocene(?) Mount Princeton Quartz Monzonite (gray monzonite--similar to granite)	31 (2)	>17,000	12,140[c] (3,700)	E, Lm
North Peak	11,600-11,720 (3,540-3,570)	15-30	SW, S, SE	Miocene(?) gray and brown lava flows, red flow breccia, tuff	21	>6,000	11,720 (3,570)	E, Lm, S
Stanley Mountain	11,250-11,650 (3,430-3,550)	15-35	SW, S, SE	Middle Proterozoic Silver Plume Granite (pink monzonite--similar to granite); contains pink gneiss and other metamorphic rocks	27	>6,000	11,800 (3,600)	E, Lm, Lo, S

[a]Altitude range of sampled dead trees.
[b]Twelve additional dead trees were sampled but they were not confidently crossdated.
[c]Varies from 11,880 to 12,000 ft (3,620 to 3,660 m) at Almagre Mountain sites and from about 11,900 to 12,140 ft (3,625 to 3,700 m) at Mount Princeton sites.
[d]Thirty-two living bristlecone pines, ranging in age from about 200 to 2,500 years, were sampled at 10,600-11,100 ft (3,230-3,380 m) altitude; none of the cores from these trees contained frost rings, so the cores were not used in this study.

Table 2. Approximate lifespans of sampled bristlecone pines in this study

[Number of sampled trees shown for each age range. Numbers in parentheses are sampled dead trees.]

Lifespan (years)	50-150	150-300	300-500	500-1,000	1,000-1,500	1,500-2,000
Almagre Mtn.	11	16 (12)	17 (29)	15 (20)	19 (3)	3 (1)
Black Mtn.	2	2	3	5	1	2
Mt. Princeton	0	12	9	6 (1)	2 (1)	2
North Peak	4	9	8	0	0	0
Stanley Mtn.	5	8	8	6	0	0

Table 3. Ancient living Rocky Mountain bristlecone pines (*Pinus aristata*) useful for this study

[Many ancient bristlecone pines have been dated on Black Mountain (Brunstein and Yamaguchi, 1992) but only the core samples from the trees listed below contained latewood frost rings. Only latewood frost rings are listed in this table because they were more useful to crossdate cores than were earlywood frost rings and light rings.]

Tree number	Long diameter inches[a] (cm)	Long radius inches[a] (cm)	Innermost sampled ring date	Minimum age (years in 1994)	Missing inner radius (cm)[b]	Inner growth rate[c]	Age estimate (years in 1994)[d]	Sampled interval	Latewood frost-ring dates
						Almagre Mountain			
CB-68-3	44 (112)	26 (66)	A.D. 14	1,981	4, H	11 (10)	2,000-2,050	A.D. 14-1005	54, 58, 142, 268, 553, 627
CB-89-2	36 (91)	24 (61)	A.D. 99	1,896	4, E	23 (16)	1,950-2,000	A.D. 99-828	142, 553, 627
CB-93-61	30 (76)	20 (51)	A.D. 395	1,600	<1, M	8 (10)	1,610	A.D. 395-800	536, 553, 627
						Black Mountain			
CB-90-4	28 (71)	20 (51)	A.D. 152	1,843	<1, M	10 (10)	1,850	A.D. 152-1989	1453
CB-91-6	39 (99)	22 (56)	A.D. 334	1,661	<1, M	14 (16)	1,670	A.D. 334-970	553, 627
						Mount Princeton			
CB-93-39	40 (102)	22 (56)	A.D. 172	1,823	1, M	28 (28)	1,850	A.D. 172-1992	536, 553, 627, 1008, 1029, 1171, 1225, 1453, 1484
CB-93-40	28 (71)	22 (56)	A.D. 214	1,781	4, M	21 (20)	1,860	A.D. 214-710	553
CB-93-55	21 (53)	12 (30)	A.D. 509	1,486	<1, M	24 (28)	1,500	A.D. 509-1992	553, 627, 1008, 1171, 1453, 1484, 1490, 1761, 1805

[a]All trees described in this table have the "strip bark" growth habit (Schulman, 1954, 1958; LaMarche, 1969), which, over the long lifespans of these trees, has exaggerated their diameters and radii in the direction of growth of the bark strip. These longest dimensions are shown in the table. Radius measurements include amounts of missing inner radii.

[b]Amount of inner radius missing from oldest core and cause; M, pith present but core missed pith; additional core(s) would increase minimum age slightly; H, heart rot; E, pith missing because of erosion.

[c]Growth rate (years per cm) in innermost 5 cm and 1 cm (in parentheses) of core.

[d]Age estimates for all trees are minimum ages plus estimated years in missing inner radii (based on inner growth rates) and do not include time for trees to grow to sampling heights of 2.5-4 ft (0.8-1.2 m).

Table 4. Latewood frost rings and light rings in bristlecone pines sampled on Almagre Mountain, Black Mountain, Mount Princeton, North Peak, and Stanley Mountain from 569 B.C. to A.D. 1993, and comparison to reported frost rings at other bristlecone pine sites

[L, light-ring event; other dates are latewood frost-ring events. Underlined years indicate events recorded in multiple trees. Indented years indicate co-occurrence of latewood frost rings and light rings. BCP, bristlecone pine; p, date precedes chronology; n, not present in cores; --, not listed in sources of data; *, one or two latewood frost rings have noticeably light latewood. Under each site heading, first number is number of sampled trees; second number is number of sampled trees that record event; third number is percent of sampled trees that record event. B, Mount Bross-Windy Ridge, Colo. (Krebs, 1972); G, Mount Goliath, Colo. (Krebs, 1972); S, Snake Range, Nev. (LaMarche, 1970); W, White Mountains, Calif. (LaMarche and Hirschboeck, 1984); X, both Great Basin and southern Rocky Mountains (sites not specified; LaMarche and Hirschboeck, 1984); Y, Great Basin or southern Rocky Mountains (site(s) not specified; LaMarche and Hirschboeck, 1984). Start and end dates for chronologies: Almagre Mountain, 569 B.C.-A.D. 1993; Black Mountain, A.D. 152-1992; Mount Princeton, 359 B.C.-A.D. 1992; North Peak, A.D. 1536-1993; Stanley Mountain, A.D. 1380-1993.]

Year	Almagre Mtn	Black Mtn	Mt Princeton	North Peak	Stanley Mtn	Frost ring at other BCP sites
B.C.						
512	1-1-100	p	p	p	p	--
501L	1-1-100	p	p	p	p	--
467	2-1-50	p	p	p	p	--
445L	2-1-50	p	p	p	p	--
417L	2-1-50	p	p	p	p	--
396	2-1-50	p	p	p	p	--
387	2-1-50	p	p	p	p	--
357L	2-1-50	p	n	p	p	--
356	2-1-50	p	n	p	p	--
354L	3-1-33	p	n	p	p	--
349	3-1-33	p	n	p	p	--
345L	3-1-33	p	n	p	p	--
341	3-1-33	p	n	p	p	--
327	3-1-33	p	n	p	p	--
323L	3-1-33	p	n	p	p	--
296	3-1-33	p	n	p	p	--
294L	3-1-33	p	n	p	p	--
269	3-1-33	p	2-1-50	p	p	--
259	3-1-33	p	n	p	p	--
256L	3-2-66	p	2-1-50	p	p	--
248	3-1-33	p	2-1-50	p	p	--
228L	3-1-33	p	n	p	p	--
225L	3-1-33	p	n	p	p	--
203	4-1-25	p	2-1-50	p	p	--
186L	5-1-20	p	n	p	p	--
186	5-1-20	p	n	p	p	--
177	6-1-17	p	n	p	p	--
177L	6-1-17	p	n	p	p	--
161	6-1-17	p	n	p	p	--
152	7-1-14	p	n	p	p	--
143L	8-2-25	p	n	p	p	--
139	9-9-100	p	2-1-50	p	p	--
127	9-8*-89	p	2-1-50	p	p	--
127L	9-1-11	p	n	p	p	--

Table 4. Latewood frost rings and light rings in bristlecone pines sampled on Almagre Mountain, Black Mountain, Mount Princeton, North Peak, and Stanley Mountain from 569 B.C. to A.D. 1993, and comparison to reported frost rings at other bristlecone pine sites--Continued

Year	Almagre Mtn	Black Mtn	Mt Princeton	North Peak	Stanley Mtn	Frost ring at other BCP sites
124	9-2-22	p	n	p	p	--
124L	9-2-22	p	n	p	p	--
119L	9-1-11	p	n	p	p	--
92	12-1-8	p	n	p	p	--
44L	17-2-12	p	n	p	p	--
43L	17-3-18	p	n	p	p	--
42	17-12-71	p	2-2-100	p	p	W
37L	17-4-24	p	n	p	p	--
33	18-3-17	p	n	p	p	--
33L	18-3-17	p	n	p	p	--
27L	18-7-39	p	n	p	p	--
24L	18-4-22	p	n	p	p	--
21L	18-3-17	p	n	p	p	--
10	16-6-38	p	n	p	p	--
10L	16-1-6	p	n	p	p	--
A.D.						
43L	21-1-5	p	n	p	p	--
52L	22-1-5	p	n	p	p	--
53	23-1-4	p	n	p	p	--
54	23-11-48	p	n	p	p	--
58	23-8-35	p	n	p	p	--
58L	23-1-4	p	n	p	p	--
62	24-3*-12	p	n	p	p	--
62L	24-2-8	p	n	p	p	--
63L	24-2-8	p	n	p	p	--
78	24-11-46	p	n	p	p	--
78L	24-1-4	p	n	p	p	--
84L	24-2-8	p	n	p	p	--
86L	24-2-8	p	n	p	p	--
94	23-12-52	p	n	p	p	--
94L	23-1-4	p	n	p	p	--
103L	23-1-4	p	n	p	p	--
105L	24-4-17	p	n	p	p	--
105	24-2-8	p	n	p	p	--
112L	24-12-50	p	n	p	p	--
112	24-3-12	p	n	p	p	--
114L	24-4-17	p	n	p	p	--
114	24-1-4	p	n	p	p	--
124L	24-2-8	p	n	p	p	--
128	24-2-8	p	n	p	p	--
128L	24-2-8	p	n	p	p	--
132L	24-5-21	p	n	p	p	--
132	24-1-4	p	n	p	p	--
142	24-11-46	p	n	p	p	--
144	23-1-4	p	n	p	p	--

Table 4. Latewood frost rings and light rings in bristlecone pines sampled on Almagre Mountain, Black Mountain, Mount Princeton, North Peak, and Stanley Mountain from 569 B.C. to A.D. 1993, and comparison to reported frost rings at other bristlecone pine sites--Continued

Year	Almagre Mtn	Black Mtn	Mt Princeton	North Peak	Stanley Mtn	Frost ring at other BCP sites
158L	23-3-13	n	n	p	p	--
158	23-1-4	n	n	p	p	--
164L	23-1-4	n	n	p	p	--
177L	22-1-5	n	n	p	p	--
180	22-1-5	n	n	p	p	--
204L	21-2-10	n	n	p	p	--
227L	18-4-22	n	n	p	p	--
230	18-2-11	n	n	p	p	--
234L	18-1-6	n	n	p	p	--
241L	18-3-17	n	4-1-25	p	p	--
241	18-1-6	n	n	p	p	--
243L	18-3-17	n	n	p	p	--
243	18-1-6	n	n	p	p	--
247L	18-1-6	n	n	p	p	--
253	18-1-6	n	n	p	p	--
259	18-1-6	n	n	p	p	--
259L	18-1-6	n	n	p	p	--
263	18-2-11	n	n	p	p	--
267	18-1-6	n	n	p	p	--
267L	18-1-6	n	n	p	p	--
268	18-6-33	n	n	p	p	--
273	18-2-11	n	n	p	p	--
280	18-1-6	n	n	p	p	--
280L	18-1-6	n	n	p	p	--
285L	18-2-11	n	n	p	p	--
287L	18-1-6	n	n	p	p	--
303L	18-3-17	n	n	p	p	--
304	18-2-11	n	n	p	p	--
323	18-1-6	n	n	p	p	--
325	18-4-22	n	n	p	p	--
337L	18-1-6	n	n	p	p	--
338	18-1-6	n	n	p	p	--
342L	18-2-11	n	n	p	p	--
343	18-3-17	n	n	p	p	--
357L	19-3-16	n	n	p	p	--
358L	19-1-5	n	n	p	p	--
370L	20-3-15	n	n	p	p	--
378L	19-2-11	n	n	p	p	--
378	19-1-5	n	n	p	p	--
393L	19-2-11	n	n	p	p	--
393	19-1-5	n	n	p	p	--
416L	20-1-5	n	n	p	p	--
437L	21-2-10	n	n	p	p	--
447L	21-1-5	n	n	p	p	--
461L	21-2-10	n	n	p	p	--
471	21-2-10	n	n	p	p	--

Table 4. Latewood frost rings and light rings in bristlecone pines sampled on Almagre Mountain, Black Mountain, Mount Princeton, North Peak, and Stanley Mountain from 569 B.C. to A.D. 1993, and comparison to reported frost rings at other bristlecone pine sites--Continued

Year	Almagre Mtn	Black Mtn	Mt Princeton	North Peak	Stanley Mtn	Frost ring at other BCP sites
473L	21-1-5	n	n	p	p	--
477L	21-1-5	n	n	p	p	--
484	21-2-10	n	n	p	p	--
494L	21-1-5	n	n	p	p	--
503L	21-1-5	n	n	p	p	--
504L	21-1-5	n	n	p	p	--
508L	21-2-10	n	n	p	p	--
527	24-1-4	n	n	p	p	--
536	25-7*-28	n	4-1-25	p	p	--
536L	25-3-12	n	n	p	p	--
544	27-1-4	n	n	p	p	--
544L	27-1-4	n	n	p	p	--
553	27-23*-85	2-1-50	4-4-100	p	p	--
574	26-6-23	n	n	p	p	--
577L	26-3-12	n	n	p	p	--
583L	26-1-4	n	n	p	p	--
591L	27-2-7	n	n	p	p	--
626	29-1-3	n	n	p	p	--
626L	29-1-3	n	n	p	p	--
627	29-24*-83	2-1-50	4-2-50	p	p	--
630L	29-1-3	n	n	p	p	--
631L	29-2-7	n	n	p	p	--
632L	29-2-7	n	n	p	p	--
634L	29-1-3	n	n	p	p	--
640L	29-1-3	n	n	p	p	--
650	29-5-17	n	n	p	p	--
655L	29-2-7	n	n	p	p	--
656	29-3-10	n	n	p	p	--
670L	29-1-3	n	n	p	p	--
686L	29-1-3	n	n	p	p	--
687L	29-4-14	n	n	p	p	W
689	29-1-3	n	n	p	p	--
699	29-2-7	n	n	p	p	--
710	28-2-7	n	n	p	p	--
718	28-2-7	n	n	p	p	--
719L	28-1-4	n	n	p	p	--
721	28-2-7	n	n	p	p	--
727L	28-2-7	n	n	p	p	--
730L	28-1-4	n	n	p	p	--
746	28-1-4	n	n	p	p	--
747	28-1-4	n	n	p	p	--
767	29-1-4	n	n	p	p	--
772	29-3-10	n	n	p	p	--
783	28-7-25	n	n	p	p	--
804	29-1-3	n	n	p	p	--
809	27-3-11	n	n	p	p	--

Table 4. Latewood frost rings and light rings in bristlecone pines sampled on Almagre Mountain, Black Mountain, Mount Princeton, North Peak, and Stanley Mountain from 569 B.C. to A.D. 1993, and comparison to reported frost rings at other bristlecone pine sites--Continued

Year	Almagre Mtn	Black Mtn	Mt Princeton	North Peak	Stanley Mtn	Frost ring at other BCP sites
821L	27-1-4	n	n	p	p	--
832	26-2-8	n	n	p	p	--
858	25-6-24	n	n	p	p	--
877	28-3*-11	n	n	p	p	--
886	28-20-71	n	n	p	p	--
890	28-14-50	n	n	p	p	--
890L	28-1-4	n	n	p	p	--
895L	28-3-11	n	n	p	p	--
895	28-1-4	n	n	p	p	--
903	28-11-39	n	n	p	p	--
916	28-6-21	n	n	p	p	--
918L	28-1-4	n	n	p	p	--
923L	28-1-4	n	n	p	p	--
925	28-3*-11	n	n	p	p	--
930L	28-1-4	n	n	p	p	--
942L	29-8-28	n	n	p	p	--
945	29-7*-24	n	n	p	p	--
945L	29-5-17	n	n	p	p	--
952L	29-1-3	n	n	p	p	--
964	30-3-10	n	n	p	p	--
973	30-4-13	n	n	p	p	--
976L	30-4-13	n	n	p	p	--
984	30-7-23	n	n	p	p	--
985	30-6*-20	n	n	p	p	--
993L	30-6-20	n	n	p	p	--
993	30-2-7	n	n	p	p	--
994L	30-10-33	n	2-1-50	p	p	--
1008	28-10*-36	n	2-2-100	p	p	--
1020L	30-1-3	n	n	p	p	--
1024L	31-1-3	n	n	p	p	--
1029	31-16*-52	2-1-50	2-1-50	p	p	W
1051	32-2-6	n	n	p	p	--
1058	32-1-3	n	n	p	p	--
1066	31-1-3	n	n	p	p	--
1076L	30-1-3	n	n	p	p	--
1079	30-1-3	n	n	p	p	--
1079L	30-1-3	n	n	p	p	--
1080	29-2-7	n	n	p	p	--
1136	28-2-7	n	n	p	p	--
1139	28-1-4	n	n	p	p	--
1171	28-3*-11	2-1-50	2-2-100	p	p	W
1171L	28-2-7	n	n	p	p	W
1179L	28-1-4	n	n	p	p	--
1187L	28-4-14	n	n	p	p	--

Table 4. Latewood frost rings and light rings in bristlecone pines sampled on Almagre Mountain, Black Mountain, Mount Princeton, North Peak, and Stanley Mountain from 569 B.C. to A.D. 1993, and comparison to reported frost rings at other bristlecone pine sites--Continued

Year	Almagre Mtn	Black Mtn	Mt Princeton	North Peak	Stanley Mtn	Frost ring at other BCP sites
1192L	29-7-24	n	n	p	p	B
1192	29-5*-17	n	n	p	p	B
1199	29-4-14	n	n	p	p	--
1208	28-3-11	n	n	p	p	--
1214L	28-2-7	2-1-50	n	p	p	--
1214	28-1-4	n	n	p	p	--
1225	29-16*-55	n	2-1-50	p	p	--
1225L	29-4-14	n	n	p	p	--
1237	29-1-3	n	n	p	p	--
1260	29-5*-17	n	n	p	p	--
1275	30-3-10	n	n	p	p	--
1293	30-2-7	4-1-25	n	p	p	--
1293L	30-1-3	n	n	p	p	--
1298	31-4-13	n	n	p	p	--
1298L	31-2-6	n	n	p	p	--
1311L	31-3-10	n	n	p	p	--
1329	27-10*-37	5-2-40	n	p	p	--
1329L	27-1-4	5-1-20	n	p	p	--
1336L	27-1-4	n	n	p	p	--
1337L	27-10-37	5-1-20	4-1-25	p	p	--
1341	27-1-4	n	n	p	p	--
1383	28-1-4	n	n	p	n	--
1406	31-15*-48	n	n	p	n	--
1408	31-23-74	6-2-33	7-3-43	p	3-1-33	--
1420	n	n	7-1-14	p	n	--
1420L	n	n	n	p	3-1-33	--
1429L	34-1-3	n	n	p	n	--
1442L	34-1-3	n	n	p	n	--
1443	34-1-3	n	n	p	n	--
1450L	34-4-12	n	n	p	n	--
1453	34-25-74	6-4-66	7-6-87	p	n	B-G-S-W
1473L	34-3-9	n	n	p	n	--
1481	34-5-15	n	8-1-13	p	6-1-17	--
1484	34-19-57	6-1-17	8-6-75	p	6-1-17	G
1490	34-3-9	6-2-33	9-6-67	p	6-2-33	B-G
1521	n	n	n	p	8-5-63	--
1526L	34-1-3	n	n	p	n	--
1536L	34-4-12	n	n	n	9-3-33	--
1536	n	n	n	n	9-2-22	--
1539	n	n	n	n	9-1-11	--
1540L	34-1-3	n	n	n	n	--
1543L	34-2-6	n	n	n	n	--
1546	34-1-3	n	n	n	n	--
1546L	34-1-3	n	n	n	n	--
1549	n	n	n	n	9-2-22	--
1556	34-4-12	n	10-1-10	n	n	G

Table 4. Latewood frost rings and light rings in bristlecone pines sampled on Almagre Mountain, Black Mountain, Mount Princeton, North Peak, and Stanley Mountain from 569 B.C. to A.D. 1993, and comparison to reported frost rings at other bristlecone pine sites--Continued

Year	Almagre Mtn	Black Mtn	Mt Princeton	North Peak	Stanley Mtn	Frost ring at other BCP sites
1570	35-1-3	n	n	n	9-2-22	--
1572	35-1-3	n	n	n	9-2-22	--
1572L	35-4-11	n	n	n	n	--
1588L	35-2-6	n	n	n	n	--
1588	35-1-3	n	n	n	n	--
1595	36-1-3	n	n	n	n	--
1596	36-1-3	n	n	n	n	B
1601L	36-2-6	n	n	n	10-1-10	W
1609L	37-5-14	n	n	n	n	--
1609	37-1-3	n	n	n	n	--
1613L	38-1-3	n	n	n	n	--
1615	38-1-3	n	n	n	n	--
1626	39-2-5	n	n	n	n	--
1639	n	n	n	n	13-2-15	--
1643	43-1-2	n	n	n	n	--
1646L	43-1-2	n	n	n	n	--
1648	43-10-23	8-2-25	n	6-1-17	n	--
1648L	n	n	n	6-1-17	n	--
1651L	n	n	n	6-1-17	n	--
1654L	n	n	n	6-1-17	n	--
1657L	n	n	n	6-1-17	n	--
1658	45-5-11	n	n	n	14-1-7	--
1658L	45-1-2	n	n	n	n	--
1660	45-2-4	n	n	n	n	X
1663	45-4-9	n	n	7-1-14	14-1-7	--
1671	46-6-13	n	n	n	n	--
1677	46-1-2	n	n	n	n	--
1677L	46-1-2	n	n	n	n	--
1680	46-2-4	n	n	n	n	X
1683	46-3-6	n	n	n	n	--
1687L	46-3-6	n	n	n	n	--
1687	46-1-2	n	n	n	n	--
1692	48-1-2	n	n	n	n	--
1697	48-2-4	n	n	n	n	--
1700	50-1-2	n	n	n	n	--
1706	51-5-10	n	n	n	n	--
1717L	53-3-6	n	n	7-1-14	n	--
1718	53-4-8	n	n	n	n	--
1719L	53-1-2	n	n	n	n	--
1721L	53-4-8	n	n	n	n	--
1725L	53-10-19	n	n	7-1-14	15-1-7	--
1725	53-1-2	n	n	n	n	--
1728	53-1-2	n	n	n	n	--
1730	53-1-2	n	n	n	n	--
1734L	54-3-6	n	n	n	n	--
1740	54-1-2	n	n	n	n	--

Table 4. Latewood frost rings and light rings in bristlecone pines sampled on Almagre Mountain, Black Mountain, Mount Princeton, North Peak, and Stanley Mountain from 569 B.C. to A.D. 1993, and comparison to reported frost rings at other bristlecone pine sites--Continued

Year	Almagre Mtn	Black Mtn	Mt Princeton	North Peak	Stanley Mtn	Frost ring at other BCP sites
1748L	n	n	n	7-2-29	n	--
1748	n	n	21-1-5	n	n	--
1752L	58-10-17	9-2-22	n	7-2-29	n	--
1752	58-1-2	n	n	n	n	--
1761	60-17*-28	9-2-22	24-8-33	12-2-17	n	B-X
1761L	60-2-3	9-2-22	24-4-17	n	17-1-6	B-X
1766	61-11*-18	n	n	n	n	--
1786L	60-2-3	n	n	n	n	--
1790	60-1-2	n	n	n	n	--
1793L	n	n	26-1-4	n	n	--
1805	59-36*-61	9-4-44	29-15-52	13-4*-31	19-1-5	B-G-X
1805L	n	n	n	13-2-15	19-2-11	B-G-X
1816L	59-1-2	n	29-1-3	n	n	--
1817	59-13*-22	11-1-9	29-1-3	14-4*-29	21-1-5	X
1817L	n	n	n	14-1-7	n	X
1828	59-27*-46	13-4-31	29-15-52	16-5-31	21-1-5	G-X
1831	58-10-17	13-1-8	29-1-3	n	21-1-5	Y
1831L	n	n	29-1-3	n	n	Y
1835	58-10*-17	13-2-15	n	17-1-6	21-1-5	--
1837	59-3*-5	13-1-8	n	n	n	X
1843	n	n	n	n	23-2-9	--
1847	59-2-3	n	n	n	n	--
1852	59-3-5	n	n	n	n	--
1854L	n	n	29-1-3	n	n	--
1866	61-17-28	13-2-15	30-2-7	n	25-2-8	Y
1866L	61-2-3	n	30-1-3	n	n	Y
1869	61-6-10	n	n	n	n	--
1878	61-3-5	n	n	n	27-2-7	--
1882	61-1-2	15-1-7	n	21-1-5	27-1-4	--
1884L	n	n	30-2-7	21-1-5	n	W
1893L	n	n	n	21-3-14	n	--
1900L	n	15-2-13	n	n	n	--
1901L	64-2-3	n	n	n	n	--
1903	64-13-21	15-1-7	30-2-7	n	n	--
1905L	n	15-2-13	n	n	n	--
1912	65-7-11	15-2-13	n	n	27-3-11	X
1915L	n	15-2-13	n	n	n	--
1917L	65-2-3	15-3-20	n	21-1-5	n	--
1920L	66-11-15	15-2-13	n	21-2-10	27-2-7	--
1923L	66-8-12	15-2-13	30-1-3	21-2-10	27-1-4	--
1925L	66-3-5	n	n	n	n	--
1941	69-12-17	n	n	n	n	S-Y
1941L	n	n	30-2-7	n	n	S-Y
1952L	n	n	n	21-1-5	n	--
1957L	70-9-13	n	n	n	27-1-4	--

Table 4. Latewood frost rings and light rings in bristlecone pines sampled on Almagre Mountain, Black Mountain, Mount Princeton, North Peak, and Stanley Mountain from 569 B.C. to A.D. 1993, and comparison to reported frost rings at other bristlecone pine sites--Continued

Year	Almagre Mtn	Black Mtn	Mt Princeton	North Peak	Stanley Mtn	Frost ring at other BCP sites
1961	70-7-10	n	n	n	n	--
1961L	n	n	n	21-1-5	n	--
1965	70-8*-11	n	n	n	n	S-X
1965L	n	n	30-1-3	n	n	S-X
1967L	70-4-6	n	30-6-20	21-4-19	n	--
1972L	70-3-4	n	n	n	n	--
1978L	n	15-2-13	30-3-10	21-1-5	27-1-4	--
1981L	70-4-6	n	n	21-1-5	n	--
1984L	70-3-4	15-1-7	n	n	27-1-4	--

Table 5. Earlywood frost rings in bristlecone pines sampled on Almagre Mountain, Black Mountain, Mount Princeton, North Peak, and Stanley Mountain from 569 B.C. to A.D. 1993, and comparison to reported frost rings at other bristlecone pine sites

[BCP, bristlecone pine; E, earlywood frost ring; p, date precedes chronology; n, not present in cores; --, not listed in sources of data; *, one or more core samples have frost ring 100-400 years from pith; **, one or more core samples have frost ring more than 400 years from pith. Underlined years indicate events recorded in multiple trees. Under each site heading, first number is number of sampled trees; second number is number of sampled trees that record event; third number is percent of sampled trees that record event. Start and end dates for chronologies are the same as in table 4.]

Year	Almagre Mtn	Black Mtn	Mt Princeton	North Peak	Stanley Mtn	Frost ring at other BCP sites
B.C.						
181E	6-1-17	p	n	p	p	--
121E	9-1-11	p	n	p	p	--
60E	15-1-7	p	n	p	p	--
A.D.						
1E	19-1-5	p	n	p	p	--
3E	19-2-11	p	n	p	p	--
17E*	17-1-6	p	n	p	p	--
204E*	21-1-5	p	n	p	p	--
732E	28-1-4	n	n	p	p	--
735E	28-1-4	n	n	p	p	--
875E	28-1-4	n	n	p	p	--
1060E*	32-2-6	n	n	p	p	--
1261E*	29-1-3	n	n	p	p	--
1269E**	29-7-24	3-1-33	n	p	p	--
1275E	30-1-3	n	n	p	p	--
1483E	n	n	n	p	6-1-17	--
1485E	n	n	n	p	6-1-17	--
1509E	n	n	n	p	6-1-17	--
1515E*	34-2-6	n	9-1-11	p	n	--
1518E	n	n	n	p	8-1-13	--
1520E	n	n	n	p	8-4-50	--
1550E	n	n	n	p	9-1-11	--
1619E	39-1-3	7-1-14	n	n	n	--
1673E	46-2-4	n	n	n	n	--
1676E*	n	n	14-1-7	7-1-17	n	--
1711E	52-1-2	n	18-1-6	n	n	--
1720E	53-1-2	n	19-2-11	n	n	--
1723E	n	n	19-1-5	n	n	--
1745E	57-1-2	n	n	n	n	--
1749E	57-2-4	n	n	n	n	--
1751E	n	n	22-1-5	n	n	--
1764E	n	n	24-1-4	n	n	--
1791E	n	n	26-2-8	n	n	--
1801E	n	n	29-2-7	n	n	--
1808E	n	n	29-1-3	n	n	--
1820E	n	n	29-1-3	n	n	--
1842E	59-1-2	n	n	n	22-1-5	--
1853E	n	n	n	n	24-1-4	--
1865E**	61-4-7	12-1-8	29-1-3	n	25-3-12	--
1888E	n	n	n	n	27-3-11	--

Table 5. Earlywood frost rings in bristlecone pines sampled on Almagre Mountain, Black Mountain, Mount Princeton, North Peak, and Stanley Mountain from 569 B.C. to A.D. 1993, and comparison to reported frost rings at other bristlecone pine sites--Continued

Year	Almagre Mtn	Black Mtn	Mt Princeton	North Peak	Stanley Mtn	Frost ring at other BCP sites
1894E**	62-4-6	n	n	n	n	--
1912E	65-1-2	n	n	21-1-5	n	--
1925E	67-1-1	n	n	n	n	--
1927E	67-1-1	n	n	n	n	--
1928E	67-2-3	n	n	n	n	--
1943E	70-1-1	n	n	n	n	--
1945E	70-1-1	n	n	n	n	--
1947E	70-1-1	n	n	n	n	--

Table 6. Frequently observed latewood frost-ring sequences before A.D. 1500 useful for preliminary visual crossdating of increment cores in this study

[AM, Almagre Mountain; BM, Black Mountain; MP, Mount Princeton. Many core samples contained full or partial frost-ring sequences listed below; some core samples had no frost rings. Frost-ring sequences listed below are generally most useful for crossdating cores from bristlecone pines above about 11,500 ft (3,500 m) altitude at the sites shown below. However, sequences are sometimes useful for crossdating cores from bristlecone pines at lower altitude. For example, A.D. 553 and 627 frost rings were useful for crossdating cores from a bristlecone pine (CB-91-6; table 3) at 11,200 ft (3,410 m) altitude on Black Mountain.]

Latewood frost-rings	Useful narrow rings	Study sites	Comments
139, 127, 42 B.C.	A.D. 37	AM, MP	Light rings and latewood frost rings at 124 B.C., light rings at 27 B.C., and latewood frost rings at 10 B.C. useful for Almagre Mountain cores.
A.D. 54, 58, 78, 94, 142	A.D. 37	AM	Light rings and latewood frost rings at A.D. 112 useful.
A.D. 553, 627	A.D. 611, 631, 632 A.D. 611, 626, 627	AM, BM MP	A.D. 536 latewood frost rings and light rings useful for Almagre Mountain cores.
A.D. 886, 890, 903	A.D. 915	AM	none
A.D. 1406, 1408, 1453, 1484	A.D. 1399	AM	none
A.D. 1408, 1453, 1484, 1490	A.D. 1399	MP	none