Peter W. Dunwiddie[1]
Quaternary Research Center
University of Washington
Seattle, WA 98195

Dichotomous Key to Conifer Foliage in the Pacific Northwest

Abstract

Plant macrofossils offer an important means for reconstructing past forest composition in the Pacific Northwest. Conifer foliage preserved in sediments can be identified to species using characters visible under a dissecting microscope. A dichotomous key is presented that describes these characters used in the identification of fossil conifer foliage from trees in western Washington.

Introduction

The forests in much of western Washington, Oregon, and British Coumbia are presently dominated by conifers (Franklin and Dyrness 1973). Numerous studies have traced the history of these forests since the retreat of Pleistocene glaciers (Hansen 1947; Huesser 1973, 1977; Mathewes and Rouse 1975; Tsukada *et al.* 1981; Leopold *et al.* 1982). Most of this work has relied on fossil pollen preserved in lowland lake and bog sediments to reconstruct changes in forest composition within a radiocarbon-dated time framework.

One difficulty with this approach has been the inability to identify certain pollen types to species. *Picea, Abies, Pinus,* and Cupressaceae are several taxa where different species cannot be distinguished on the basis of pollen. Specific identifications of pollen made by some authors have been considered unreliable following more thorough analyses (Mack 1971). Therefore, recent work increasingly relies on macrofossil remains of plants preserved in association with the pollen to distinguish species (Wasylikowa 1979, Birks and Birks 1980). This technique has revealed some unexpected past species occurrences, such as the presence of *Picea engelmannii* Parry and *Abies lasiocarpa* Hook. (Nutt.) in the Puget Lowland during the late Pleistocene (Barnosky 1981).

My recent studies on Mt. Rainier have suggested that past forest composition can be reconstructed using macrofossil assemblages of conifer foliage (Dunwiddie 1983). It was found that coriaceous conifer leaves are frequently well-preserved in sediments from small ponds at most elevations. Furthermore, since macrofossils are usually identifiable to species, past floristic changes could be detected even when, for example, several species of *Abies* grew together.

In this paper, I present a dichotomous key to the macroscopic features of conifer foliage that is frequently preserved in ponds in western British Columbia, Washington, and northern Oregon.

[1]Present address: Lost Farm, Hummock Pond Rd., Nantucket, MA 02554

Identification of Conifer Foliage

Excellent keys exist for identification of conifers in the Pacific Northwest, based on characters evident on living material or on herbarium specimens (Hitchcock and Cronquist 1973). However, these keys are often unsuitable for distinguishing fossil needles, since critical choices in the key may rely on characters unavailable to the paleobotanist—cone shape, size, leaf arrangement on the branch, bark color, etc. Even when key characters describe foliage, they may be of little use with fossil material. Frequently, macrofossils are broken or fragmented and important features—the shape of the leaf apex or base, for example—may be missing. In quantitative studies, such as the Mt. Rainier work described above, it is critical that all needles and fragments are identified, and not merely the occasional intact one.

A second body of literature relevant to macrofossil identification includes anatomical studies of leaf structure. An excellent bibliography of this work, much of which is in older and less well-known publications, is presented by Delcourt *et al.* (1979). These studies emphasize microscopic cellular features that are evident in thin sections cut with a microtome from modern specimens. One limitation of this approach with macrofossil material is that poor preservation, at times, makes resolution of critical fine cellular features difficult or impossible. A second drawback is the considerable time and effort involved in properly mounting and sectioning material for study with a compound light microscope. This becomes prohibitive in studies where hundreds of needles are examined.

These painstaking microscopic procedures were found to be unnecessary to identify accurately the species of most conifer foliage recovered from pond sediments in the North Cascades. The dichotomous key presented below uses macroscopic features visible with a dissecting microscope at magnifications of 7X to 40X. It was prepared from observations made on fresh and dried foliage collected in western Washington, in conjunction with several anatomical studies (Coulter and Rose 1886, Durrell 1916, Fulling 1934, Harlow 1947, Liu 1971).

Revisions of the key were made on the basis of features noted from examination of hundreds of macrofossil needles in the Mt. Rainier studies (Dunwiddie 1983). Careful study of macrofossils revealed that several features could be seen in preserved needles that normally are not visible in unsectioned fresh material. Some important features are the presence, size, and position of resin canals. These are frequently visible through the epidermis, which is often translucent in fossil needles. Identification of species of *Abies, Tsuga, Pseudotsuga,* and *Pinus* all rely on these features. Thus the emphasis of the key is on features visible in fossil needles, although it can be used on fresh material as well.

As with other vegetative keys, this key at times deviates from a strict sequence that separates species according to families, genera, and then species. This is because when certain features are missing in fossil material, the resemblance between species in different genera may be stronger than between congeneric species. The key has been constructed so that many species may be identified through different leads. This ensures that a proper identification can be made, even when an apex or base may be missing from a needle.

Dichotomous Key to Conifer Foliage

1a Leaves scale-like, less than 5mm long; single or more often several-many pairs oppositely attached. —Cupressaceae

1b Leaves needle-like, entire needles rarely less than 5mm long; single (may be fascicled in *Pinus*). —Pinaceae

Cupressaceae

Most foliage remains attached to small branches. In sediments, individual leaves may break off, but usually some fragments remain with several leaves attached. Leaf arrangement on these multiple-leaved fragments is a useful character in distinguishing the two tree genera.

1a Multiple-leaved fragments distinctly flattened on all but the smallest branches; apex of dorsi-ventral leaves often obtuse, abruptly narrowing to apiculate tip; lateral leaves rounded on back, tapering gradually to apex; tips of lateral and dorsi-ventral leaf pairs close to same level. —*Thuja plicata* Donn.

1b Multiple-leaved fragments rounded, 4-angled, or only somewhat flattened (smallest branches may be indistinguishable from *Thuja*); dorsi-ventral and lateral leaves similar, gradually narrowing to acute apex, often keeled on back; tips of lateral and dorsi-ventral leaf pairs at different levels (may be sub-equal on smallest branches). —*Chamaecyparis nootkatensis* (D. Don) Spach

Pinaceae

1a Needles triangular or semi-circular in cross-section, with sharp edges; tips tapering to sharp point; bases not greatly differentiated from needle body; needles sometimes attached to woody shortshoot, forming fascicles of 2, 3, or 5; needles parallel-sided, linear, often breaking cleanly into short segments; intact needles rarely preserved. —*Pinus* (p. 189)

1b Needles variously flattened or 3- or 4-sided, often with a medial groove on adaxial surface, if triangular in cross-section, with rounded edges; tips notched, rounded, or acute; bases petiolate or apetiolate, often with conspicuous oval or circular attachment scar; needles always single, parallel-sided and linear only in *Larix*. —2a

2a Needles delicate and linear (less than 1mm thick), sometimes with a short, hooked petiole; tips acute to obtuse; needles flattened, but usually with a prominent to obscure ridge on the ab- and adaxial sides; 2 stomatal rows may be apparent on either side of the midrib on both ab- and adaxial surfaces; usually preserved relatively intact (contrast with *Pinus*).—*Larix* (p. 189)

2b Needles generally robust, neither slender nor linear; other characters various, but not combined as in *Larix* (p. 189) —3a

3a Needles sharply acute, without a medial groove on the adaxial surface; often relatively straight and pungent; base abruptly truncated at point of attachment, or only slightly tapered. —*Picea* (p. 190)

3b Needles blunt, notched, or acute (if derived from cone-bearing branches); medial groove more or less evident on adaxial surface; always more or less dorsi-ventrally flattened; base twisted or straight, but not truncated. —4a

4a Resin canals 1, central near abaxial surface; needles narrowed to a slender petiole; tip obtusely rounded but not notched (if characters not apparent, go to 4b). —*Tsuga* (p. 190)

4b Resin canals 2, laterally arranged on opposite sides of central vascular bundle; petiole little-constricted, or slender in *Pseudotsuga*; tip obtuse, acute, or notched. —*Abies* and *Pseudotsuga*

Abies, Pseudotsuga, and *Tsuga*

1a Needle tips notched; point of attachment round and broad (if tip absent, go to 1b, p. 188) —2a

2a Stomata present on ab- and adaxial surface; resin canals remote from lateral margins; petiole little-constricted, often not twisted. —3a

3a Needles frequently C-shaped, curving adaxially; resin canals large, medially located between ab- and adaxial epidermises, but usually not evident near needle base; adaxial stomata in 10-13 irregular rows forming a broad band 1/2 to 2/3 the width of needle surface, often absent near base, but present very close to tip; medial adaxial groove prominent; abaxial stomata in 4-8 rows forming bands on either side of prominent midrib; abaxial margins and midrib free of stomata, and often equal in width to stomatal bands; abaxial epidermis usually concave between midrib and margin. —*Abies lasiocarpa* (Hook.) Nutt.

3b Needles S- or hockystick-shaped; resin canals small, near abaxial epidermis, about midway between midrib and margin; adaxial stomata in 2 distinct bands on either side of shallow medial groove, merging to form a single band near tip; abaxial stomata in 4 bands of 3-5 rows each, separated by midrib and resin canals; stomate-free margins relatively narrow; abaxial epidermis nearly flat between midrib and margin, hence needle cross-section more or less triangular.*Abies procera* Rehder

2b Stomata present only on abaxial surface (occasionally a few on adaxial tip); resin canals small, close to abaxial epidermis and lateral margins; base usually twisted, sometimes hooked or straight.

—*Abies amabilis* (Dougl.) Forbes and *Abies grandis* (Dougl.) Forbes (Needles of these 2 species are difficult to distinguish. Liu (1971) reports that the hypodermis is more conspicuous and well-developed in *A. amabilis* than in *A. grandis*, but microtome cross-sections would be necessary to examine this feature.)

1b Needle tips obtuse, acute, or absent; point of attachment round or elliptical.—4a

4a Stomata present on ab- and adaxial surface —5a

5a Needles more or less straight, not C- or S-shaped; petiole slender; point of attachment small and elliptical.

—*Tsuga mertensiana* (p. 190)

5b Needles C- or S-shaped; petiole broad; point of attachment round and broad (needles with acute tips from fertile branches of *Abies lasiocarpa* and *A. procera* may key out here

—see leads 3a and 3b, p. 188)

4b Stomata present only on abaxial surface. —6a

6a Needles with slender petiole; point of attachment elliptical, longer than broad; tip rounded, not notched. —7a

7a Needle length:width ratio less than 10; needle abruptly contracted into petiole. —*Tsuga heterophylla* (p. 190)

7b Needle length:width ratio greater than 10; needle gradually tapering into petiole.
—*Pseudotsuga menziesii* (Mirbel) Franco
(These 2 species are normally readily distinguished by the number of resin canals—lead 4a, p. 188).

6b Needles with broader petiole; point of attachment nearly round; tip various. —*Abies amabilis, A. Grandis,* and *Pseudotsuga menziesii* (See lead 2b, p. 188 regarding these *Abies* species. *Pseudotsuga* is normally distinguished by its slender petiolate base and rounded, unnotched tip. *Abies* tips are usually notched, or occasionally acutely pointed on needles from fertile branches. If both tip and base are absent, distinguishing these taxa is difficult, although *Pseudotsuga* needles tend to be slenderer than these *Abies* species. Durrell (1916) reports that *Pseudotsuga* has 1 vascular bundle, whereas *Abies* has 2. This feature would require microtome sectioning to see.)

Pinus

Entire needles are rarely found in sediment. Occasionally the lower portions of the fascicles are recovered still attached to woody shortshoots, or the shortshoots alone may be found. Attachment scars are preserved on these shortshoots, such that 2, 3, and 5-needle species can be readily distinguished from each other.

1a Needles semi-circular in cross-section, adaxial surface sometimes concave; convex abaxial surface with 9-10 (15) distinct, evenly spaced rows of stomata across entire surface; stomata regularly spaced within each row as well; adaxial stomata (rarely absent) in 6-8 (11) similar distinct rows; resin canals 2, medial, usually not apparent through epidermis; minute marginal serrations may be present entire length of needle. —*Pinus contorta* Dougl.

1b Needles 3-angled in cross-section; abaxial stomata present or absent. —2a

2a Abaxial surface broadly convex, much longer than either adaxial surface; other features similar to *P. contorta*, although presence of adaxial ridge forming 2 adaxial surfaces, and overall larger size, are diagnostic. —*Pinus ponderosa* Dougl.

2b Abaxial surface not much longer than either adaxial surface, needles appearing nearly equiangular in cross-section; resin canals nearer to abaxial epidermis, hence often visible in unsectioned material. —3a

3a Stomata usually present only on adaxial surface; when rarely present on abaxial surface, then only near tip; margins minutely serrate up to 1/2 length of needle. —*Pinus monticola* Dougl.

3b Stomata present on both abaxial and adaxial surfaces; 1 to several rows of stomata present along most of abaxial surface; margins minutely serrate only near tip. —*Pinus albicaulis* Engelm.

Larix

Distinguishing *L. occidentalis* Nutt. from *L. lyallii* Parl. is difficult based on needle morphology alone. Carlson and Blake (1969) report 8 epithelial cells surrounding resin canals in *L. occidentalis*, 5 in *L. lyallii*. This feature would require microtome sectioning to see.

Picea

1a Needles more or less flattened; adaxial surface planar or slightly ridged, with numerous rows of stomata; abaxial surface with prominent midrib, without stomata, or with only 1 or 2 rows on either side of the midrib; resin canals absent. —*Picea sitchensis* (Bong.) Carr.

1b Needles nearly equally 4-angled; stomata abundant in 4 grooves between angled edges of needles; 1 or 2 large resin canals usually present (needles usually must be sectioned to see resin canals). —*Picea engelmannii* Parry

Tsuga

1a Needles strongly flattened; stomata only on abaxial surface; adaxial surface usually with a conspicuous medial groove; petiole very slender and abruptly twisted; tip obtuse. —*Tsuga heterophylla* (Raf.) Sarg.

1b Needles usually only somewhat flattened; stomata on both ab- and adaxial surfaces; medial groove present or inconspicuous; petiole often more gradually tapered, less slender, and not as abruptly twisted as 1a; tip often more acute. —*Tsuga mertensiana* (Bong.) Carr.

Acknowledgements

Financial support for this study was provided by a doctoral dissertation grant from the National Science Foundation (DEB-8107491), as well as by awards from the Danforth Foundation, the Geological Society of America, the American Alpine Club, and Sigma Xi.

Literature Cited

Barnosky, C. W. 1981. A record of late Quaternary vegetation from Davis Lake, southern Puget Lowland, Washington. Quat. Res. 16:221-239.

Birks, H. J. B., and H. H. Birks. 1980. Quaternary Palaeoecology. Edward Arnold, London.

Carlson, C. E., and G. M. Blake. 1969. Hybridization of western and subalpine larch. Mont. For. and Cons. Exp. Sta. Bull. 37, University of Montana, Missoula. Pp. 1-12.

Coulter, J. M., and J. N. Rose. 1886. Synopsis of North American pines, based upon leaf-anatomy. Bot. Gaz. 11:256-262, 302-209.

Delcourt, P. A., O. W. Davis, and R. C. Bright. 1979. Bibliography of taxonomic literature for the identification of fruits, seeds, and vegetative plant fragments. ORNL/TM-6818, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Dunwiddie, P. W. 1983. Holocene forest dynamics on Mount Rainier, Washington. University of Washington, Seattle. Dissertation.

Durrell, L. W. 1916. Notes on some North American conifers based on leaf characters. Proc. Iowa Acad. Sci. 23:519-582.

Franklin, J. F., and C. T. Dyrness. 1973. Natural vegetation of Oregon and Washington. General Technical Report PNW-8, U.S. Forest Service, Washington, D.C.

Fulling, E. H. 1934. Identification, by leaf structure, of the species of Abies cultivated in the United States. Bull. Torr. Bot. Club 61(9):497-524.

Hansen, H. P. 1947. Postglacial forest succession, climate and chronology in the Pacific Northwest. Trans. Am. Phil. Soc. 37:1-130.

Harlow, W. M. 1931. The identification of the pines of the United States, native and introduced, by needle structure. N.Y. State Coll. For. at Syracuse Univ., Tech. Pub. No. 32. (Bull. Vol. XX, No. 2), 19 p.

Heusser, C. J. 1973. Environmental sequence following the Fraser advance of the Juan de Fuca lobe, Washington. Quat. Res. 3:284-306.

______. 1977. Quaternary palynology of the Pacific slope of Washington. Quat. Res. 8:282-306.

Hitchcock, C. L., and A. Cronquist. 1973. Flora of the Pacific Northwest. University of Washington Press, Seattle.

Leopold, E. B., R. Nickmann, J. I. Hedges, and J. R. Ertel. 1982. Pollen and lignin records of late Quaternary vegetation, Lake Washington. Science 218:1305-1307.

Liu, Tang-Shui. 1971. The genus *Abies*. Taipei, Taiwan, Mus. Quart. J. 24:105-172.

Mack, R. N. 1971. Pollen size variation in some western North American pines as related to fossil pollen identification. Northw. Sci. 45:257-269.

Mathewes, R. W., and G. E. Rouse. 1975. Palynology and paleoecology of postglacial sediments from the lower Fraser River Canyon of British Columbia. Can. J. Earth Sci. 12:745-756.

Tsukada, M., S. Sugita, and D. M. Hibbert. 1981. Paleoecology in the Pacific Northwest I. Late Quaternary vegetation and climate. Verh. Internat. Verein. Limnol. 21:730-737.

Wasylikowa, K. 1979. Plant macrofossil analysis. *In* B. E. Berglund (ed.) Palaeohydrological Changes in the Temperate Zone in the Last 15000 years. Subproject B. Lake and Mire Environments. Vol. 2. Guideline for Specific Methods. International Geological Correlation Programme Project 158. Pp. 291-313.

Received 8 March 1984
Accepted for publication 7 June 1984