A New Genus and Species in Cupressaceae (Coniferales) from Northern Vietnam, *Xanthocyparis vietnamensis*

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ABSTRACT. Botanical explorations of heretofore poorly inventoried limestone formations in the northern Vietnamese border province of Ha Giang have yielded a new taxon of conifer that is to be classified in a cupressoid clade of Cupressaceae. It has foliage and ovuliferous cone characters that compare closely to *Chamaecyparis nootkatensis* (D. Don) Spach, as well as a feature peculiar to it and rare in conifers: the simultaneous occurrence of juvenile and mature leaves on normal plagiotropic branching systems of mature trees. It is proposed in this paper to unite *C. nootkatensis* with the newly discovered species in a new genus *Xanthocyparis*; of this new genus and species a full description and illustrations are provided. Additional contributions to this paper include observations on its habitat, conservation status, and a taxonomic discussion.

Key words: conifers, conservation, Cupressaceae, North America, taxonomy, Vietnam, *Xanthocyparis*.

The discovery of a new living conifer that is sufficiently distinct so as not to be accommodated comfortably in any known genus is an exceptional event which has only occurred a few times in the last 50 years. The conifers have received much attention from taxonomists and others over a long time even though they are a small group of plants with no more than 650 species worldwide. This discovery has become even more interesting because detailed comparisons and subsequent analysis have revealed it to be related to a species of which the generic placement has been controversial. It has thus not only enlarged our knowledge of biodiversity, but also increased our understanding of phylogenetic relationships of the conifers in the wider context of the family Cupressaceae to which it belongs. Implied in these relationships is a biogeographic history encompassing eastern Asia and North America that has been known from numerous previously discovered relationships among plants of both continents. The new conifer, its characters, and taxonomic relationships are presented below.

Xanthocyparis Farjon & Hiep, gen. nov. TYPE: *Xanthocyparis vietnamensis* Farjon & Hiep.

A genere *Chamaecypari* stomatibus utrinque in superficiebus foliorum maturorum lateralium equaliter dispositis, foliis maturiis lateralibus apices liberos (non adpressos) gerentibus, strobilis bracteis-squamis 4 (raro 6) suffultis; a genere Cupresso strobilis minoribus bracteis-squamis seminibusque minus numerosis diagnoscenda.

Small or large evergreen trees, monoecious, with fibrous bark exfoliating in longitudinal strips; heart

wood yellowish, slow growing. Foliage branches spreading in plagiotropic sprays or drooping, forming a pyramidal, conical, or irregular flat-topped crown. Foliage of three types: juvenile linear leaves, transitional leaves, and mature scale leaves. Juvenile leaves present on seedlings only or also in mature trees, radially disposed in alternating whorls of four; foliage branchlets with this type of leaves always sterile. Transitional leaves present on seedlings only or also in mature trees, decussate, divided in facials and laterals of nearly equal size, the laterals weakly disposed in a plane; foliage branchlets with this type usually sterile. Mature leaves present in mature trees, decussate, dimorphic in shape and size with the laterals strongly flattened and disposed in a plane; foliage branchlets with this type often fertile. Leaves in whorls of four or decussate. Pollen cones terminal and solitary on lateral branchlets with small scale leaves, 2.5–5 × 2–2.5 mm; microsporophylls 10 to 16, decussate, peltate, bearing 2 (or 3) relatively large microsporangia. Seed cones terminal and solitary on lateral branchlets with unmodified scale leaves, maturing to 7–11 × 10–12 mm, opening wider. Bract-scale complexes in 2 (sometimes 3) decussate pairs, fused at base, the upper pair(s) connate, spreading wide to release the seeds, valvate to subpeltate, with a prominent central umbo. Central columella present or absent, small. Ovules axillary to bracts, 1 to 5 per bract; seeds usually fewer, concentrated on the upper pair (if 2 pairs) or middle pair (if 3 pairs) of scales, flattened, with two thin lateral wings. Seedlings with 2 cotyledons, followed by juvenile linear leaves in whorls of four.

Eponymy. From Greek *xantho* = yellow, the color of the wood, and *cyparis* = cypress.

1. Xanthocyparis vietnamensis Farjon & Hiep, sp. nov. TYPE: Vietnam. Ha Giang: Quan Ba, Bat Dai Son, Bat Dai Son Provincial Protected Area, 10 Feb. 2001, *D. K. Harder, N. T. Hiep, P. K. Loc, L. V. Averyanov, G. E. Schatz & S. Bodine DKH 6091* (holotype, HN; isotypes, HN, K, LE, MO). Figure 1.

Arbor 10–15-metralis, sempervirens, monoica; cortex fibrosus. Rami longes, horizontaliter dispositi; ramulorum frondes dimorphae foliis adultis et juvenilibus praeditae. Folia adulta decussata, inconspicue glandulifera; ea ramulorum (sub)ultimorum 1.5–3 mm longa, 1–1.3 mm lata, dimorpha: folia dorsi-ventralia (anglice "the facials") adpressa, anguste angulato-ovata vel rhombica, in parte distali carinata, margine minute denticulata praeter apicem versus integra, apice acuto; folia lateralia moderate longiora, conduplicata, basin versus decurrentia, recta vel falcata, margine minute denticulata praeter apicem versus integra, apice libero acuto vel pungenti; stomata foliorum adultorum inconspicua plerumque adaxialia, pauca in parte proximali superficiei abaxialiae. Folia juvenilia in verticillis quadrifolii disposita, basin versus decurrentia, patentia, 15–20 mm longa, 1.5–2 mm lata, monomorphia, linearia, eglandulifera, margine integra, apice acuto; stomata foliorum juvenilium in vittis 2 in superficie abaxiali solum disposita. Amenta mascula solitaria, in ramulis folia adulta gerentibus terminalia, 2.5–3.5 mm longa, 2–2.5 mm lata; microsporophylla 10–12, peltata; microsporangia 2(–3), abaxialia. Strobili feminei solitares, in ramulis folia adulta gerentibus terminales vel subterminales, post duos annos maturi, subglobosi, post dehiscentia 9–11 mm longi, 10–12 mm lati; bracteae-squamae 2(–3) paribus, oppositae, decussatae, pare supero majore connato vel recluso valvato vel subpeltato, distaliter latiores, rugosae et recurvo-umbonatae. Semina ca. 8–9, ovoidea vel irregularia, 4.5–6 mm longa, 4–5 mm lata, testa in alas 0.5–1 mm latas expansa.

Small to medium-sized tree to 10–15 m; trunk monopodial, terete, up to 50 cm diam.; bark smooth and thin on branches, purplish to red-brown, exfoliating in thin flakes and strips, on the trunk of larger trees becoming soft and fibrous, brown to gray-brown, exfoliating in numerous thin strips. Branches long, spreading ± horizontally; foliage branches numerous, spreading mostly in plagiotropic overlapping sprays or slightly drooping, forming a pyramidal crown in young trees but a spreading, irregular or flat-topped crown in old trees. Foliage in mature trees predominantly with mature leaves, also with juvenile leaves, often also with transitional leaves. Foliage sprays with juvenile leaves bushy, sparsely branched, ultimate branchlets 20–50 mm long, not flattened. Foliage sprays with mature leaves flattened, with rounded outline; leading foliage branches quadrangular to terete, with ca. 4 orders of branching, still covered with green leaves in 3rd to 4th year of growth; subultimate branchlets pinnate, ultimate branchlets of unequal and irregular length and spreading at 30°–45°, 5–20 × 1.5–3 mm, distinctly flattened. Juvenile leaves in whorls of four, decurrent, monomorphic, the distal part spreading at nearly 90°, the proximal decurrent part 4–5 mm long, the distal free parts 15–20 × 1.5–2 mm, linear, margins entire, tapering to a fine point. Stomata in two whitish bands on the abaxial side only, in each band ca. 6–7 irregular rows, oriented parallel to the leaf axis. Transitional leaves similar to mature leaves but longer (5–7 mm), lanceolate, the laterals spreading at 45°. Mature leaves decussate, short decurrent, imbricate, dimorphic, on (sub)ultimate branchlets 1.5–3 × 1–1.3 mm (the laterals slightly longer than the facials); the facials narrowly ovate-rhombic, keeled, ± appressed, margins minutely denticulate to entire toward the acute or acuminate and free apex; the laterals conduplicate, the proximal part decurrent, the distal part

Figure 1. Photograph of the holotype of *Xanthocyparis vietnamensis* Farjon & Hiep, *D. K. Harder, N. T. Hiep, P. K. Loc, L. V. Averyanov, G. E. Schatz & S. Bodine DKH 6091*(HN).

spreading free from the leaf above at ca. 30°, straight or falcate, margins minutely denticulate except toward the acute or pungent apex. Stomata on mature leaves inconspicuous, mostly adaxial, a few scattered on the proximal abaxial faces, covered with a layer of cuticular wax. Glands inconspicuous, in a depression below the keeled distal part of some of the facials. Pollen cones 2.5–3.5 × 2–2.5 mm, oval-terete; microsporophylls 10 to 12, ca. 1 × 1 mm, with erose-denticulate margins and mucronate apex, green turning yellow-brown; each bearing abaxially two large, subglobose yellow microsporangia containing spherical pollen. Seed cones sparse but sometimes grouped with 2 or 3 together at the outer margins or nearer the base of foliage sprays with mature leaves, initially consisting of the 2 upper pairs of green leaves (bracts) with axillary ovules. Mature cones developing in two years, green, turning dark or dull brown, subglobose, 9–11 × 10–12 mm when open, some ± persistent after seed dispersal. Bract-scale complexes in 2 (sometimes 3) decussate pairs in normally developed cones (irregular or underdeveloped cones are found), valvate to subpeltate (the third pair if present ± peltate and 4–5-angled), the lower pair oblong, all widest distally, with rounded but irregular upper margin; outer surface smooth, becoming rugose or radiately furrowed from a prominent, 1–2.5 mm long umbo (including the bract apex); inner surface red-brown marked proximally with white or gray seed scars; a small columella present or absent at the shoot apex. Ovules 1 to 3 per fertile bract (upper bracts in 6-scaled cones sterile); seeds max. 8 or 9 per cone, ovoid or irregular, flattened (1.5–2 mm thick), 4.5–6 × 4–5 mm including two lateral wings, body of seed ± pustulate, light brown or red-brown, with white hilum at base and micropylar beak often persistent at the apex; seed wings 0.5–1 mm wide, thinly membranous, lighter colored. Seedlings not seen.

Distribution. Vietnam: North Vietnam, Ha Giang Province, very locally in the Bat Dai Son mountain system near the Chinese border; altitudinal range 1060–1180 m.

Ecology. In mixed angiosperm-conifer cloud forest with the conifers *Amentotaxus argotaenia* (Hance) Pilger, *Nageia wallichiana* (C. Presl) Kuntze, *Pseudotsuga sinensis* Dode var. *brevifolia* (W. C. Cheng & L. K. Fu) Farjon & Silba, *Podocarpus pilgeri* Foxworthy, and *Taxus chinensis* (Pilger) Rehder. Dominant among angiosperms are species of *Acer, Carpinus, Lithocarpus, Quercus,* and *Ulmus*; frequent are *Pistacea weinmannifolia* J. Poisson ex Franchet and *Platycarya strobilacea* Siebold & Zuccarini. In a second stratum under the ca. 20 m tall canopy species of *Elaeocarpus, Eriobotrya, Sorbus, Schefflera,* and many others frequently occur. Shrubs and herbs abound; among the latter are numerous species of Orchidaceae, terrestrial as well as epiphytic, sometimes determining the aspect of the ground cover vegetation. Ferns and especially bryophytes are similarly abundant both as lithophytes and as epiphytes. The limestone ridges on which *Xanthocyparis* occurs are extremely eroded, composed of resistant, marble-like rock outcrops interspersed with thin soil pockets. The climate is subtropical but damp and wet much of the year.

Conservation. Newly discovered *Xanthocyparis vietnamensis* is restricted to a few localities in close proximity, mostly now in inaccessible sites on steep limestone ridges. Logging has increased in recent years and is estimated to have caused serious decline in numbers of larger, well-growing trees. This practice may have had negative effects on genetic diversity. Regeneration is poor due to heavy competition in remaining populations. This species is Critically Endangered under the IUCN Red List Categories Version 3.1 (IUCN, 2001): CR (B2a–c).

Uses. This species produces fine, yellow-brown, very hard, fragrant timber. The superb quality of the wood, in conjunction with the widespread desirability of cupressaceous wood in traditional uses of many kinds in eastern Asia, combined with slow growth, has made it a highly prized timber. Due to lack of transport facilities and other factors, most of the timber has been traded locally.

Paratypes. VIETNAM. **Ha Giang:** Quan Ba, Bat Dai Son, Bat Dai Son Provincial Protected Area, 10 Feb. 2001, *D. K. Harder et al. DKH 6090* (HN, MO, LE), 12 Feb. 2001, *D. K. Harder et al. DKH 6224* (HN, K, MO, LE); Can Ty, Sing Xuoi Ho, 12 Oct. 1999, *Nguyen Tien Hiep, L. V. Averyanov & P. J. Cribb NTH 3594* (HN, MO, LE, K).

In October 1999 a conifer was found in North Vietnam (*N. T. Hiep et al. NTH 3594*) that appeared to have morphological characters suggesting a relationship with species in the cupressoid clade of Cupressaceae s.l. (Gadek et al., 2000). The specimen compared in particular with *Chamaecyparis* and *Cupressus*, yet showed some traits not found in any known species in these or related genera, immediately suggesting that a new taxon could have been found. The only known species in that group that are certain to be indigenous in this part of Asia (including most of Myanmar, North Laos, South Yunnan, Guangxi, Guangdong, and Hainan [China]) are *Calocedrus macrolepis* Kurz and *Fokienia hodginsii* (Dunn) A. Henry & H. Thomas. The new co-

Figure 2. —A. Tree of *Xanthocyparis vietnamensis* at Bat Dai Son (photograph by L. Averyanov). —B. Branch of *X. vietnamensis* with two different foliage types (photograph by D. K. Harder). —C. Branchlet of *X. vietnamensis* with mature seed cones (photograph by D. K. Harder). —D. Branchlet of *X. vietnamensis* with pollen cones (photograph by D. K. Harder).

nifer (Figs. 2, 4) appeared to occur very locally on limestone karst ridges known to have yielded other narrow endemics, some of which have turned out to be new species, e.g., orchids. Such habitats are also frequently the refuges of relict conifer taxa, presumably because these conifers have adapted to the poor growing conditions associated with karst where competitor broad-leaf tree species could not follow. The most conspicuous feature of this new conifer taxon is the occurrence of juvenile leaves, transitional leaves, and mature leaves in the foliage of crowns of mature trees (Figs. 2B, 4). These juvenile, monomorphic leaves 15 × 1.8 mm can alternate on a branch with mature dimorphic leaves 2.5–3 × 1.2–1.3 mm (*D. K. Harder et al. 6224*). This trait is reminiscent of the foliage in mature trees of *Callitris macleyana* F. Mueller; however, unlike that species, *Xanthocyparis vietnamensis* does not produce cones on branchlets with these juvenile leaves. In *Widdringtonia nodiflora* (L.) E.

Figure 3. Branchlet of *X. nootkatensis* with mature seed cones (photograph by A. Farjon).

Powrie, coppiced (fire-damaged) plants produce similar juvenile leaves usually on basal reiterated branches (Pauw & Linder, 1997). A mixture of needle-like and scale-like leaves is common in *Juniperus chinensis* Roxburgh, where the needle leaves represent the juvenile stage because such leaves are the first to appear after the cotyledons. Indeed, in all species of Cupressaceae s.l. (Farjon, 1998, 2001) this transition from juvenile (via transitional forms) to mature leaves takes place in the seedlings, often accompanied by a change in phyllotaxis. Normally, in most cupressoid taxa, juvenile leaves do not reoccur; when they are present these branches are often the result of reiteration. This seems to be the case in some specimens of *X. vietnamensis* (e.g., *N. T. Hiep et al. NTH 3594*), but in others (e.g., *D. K. Harder et al. DKH 6091* holotype, *D. K. Harder et al. DKH 6224*) the branching pattern of both foliage types shows a normal alternation not suggesting reiteration. In the known species of *Chamaecyparis* and *Cupressus* juvenile leaves are restricted to the seedling stage. However, juvenile leaf characters have been retained in some cultivars of *Chamaecyparis*. It is possibly a neotenic trait controlled by certain genes that can be "switched on or off" at different stages of growth in several taxa. By itself, this would be a somewhat doubtful character to indicate the existence of a distinct species; however, its coexistence with mature foliage throughout the life history of the tree is rare in conifers.

Careful comparison of the morphology of the new discovery in Vietnam with that of other, more or less similar, species in Cupressaceae leads to *Chamaecyparis nootkatensis* (Fig. 3) as the most similar species. This taxon has very similar seed cones with 4(to 6) bract-scale complexes ("–12" is certainly an error for *C. nootkatensis* in Taylor & Sziklai, 1976), which are quite distinct from both its congeners and from those of *Cupressus*, with which *Chamaecyparis* has been united from time to time (see, e.g., Camus, 1914, for a monographic treatment). There has been debate concerning the placement of *C. nootkatensis* in either genus, with some authors arguing for inclusion in *Cupressus* based on characters of the ovuliferous cones (Frankis, 1993; Jagel & Stützel, 2001). Recent cladistic evidence based on molecular data (*mat*K gene) gives only weak support for its inclusion in *Cupressus* (Gadek et al., 2000); similar evidence using a combined data set (*mat*K + non-molecular data) does not and places it as a sister group to *Cupressus* + *Juniperus* with stronger bootstrap support (Gadek et al., 2000). Inclusion of the new Vietnamese species in a phylogenetic analysis of Cupressaceae s.l. based on morphological data (a full

account of which will be published later) resulted in a separate clade for *C. nootkatensis* + *X. vietnamensis* within a major clade distinct from both *Chamaecyparis* and *Cupressus* (Fig. 5). Sequencing of DNA of *X. vietnamensis* has yet to be undertaken.

Apart from the markedly different ages of plants between *C. nootkatensis* and *X. vietnamensis* in which juvenile leaves still occur, the leaf morphology of both is very similar, both of juvenile, transitional and mature (Figs. 2D, 3, 4) leaves. In both species the mature leaves are markedly dimorphic (differently shaped facials and laterals) on plagiotropic foliage branchlets. This is common in all Cupressaceae with such branching systems, causing a bilateral flattening of the leaf-covered branchlets. Growth of branches profoundly determines leaf shape in Cupressaceae (Daguillon, 1899; Rouane, 1973; Offler, 1984). Unlike other taxa with this marked leaf dimorphism (e.g., *Chamaecyparis* s. str., *Calocedrus, Fokienia, Platycladus, Thuja, Thujopsis*), in which the distribution of abaxial stomata is asymmetrical, i.e., largely confined to the physiological underside of the lateral leaves and the abaxial side of facials on that side of the branchlet, both *Chamaecyparis nootkatensis* and *Xanthocyparis vietnamensis* have only a weakly developed stomatal asymmetry. In this respect they resemble certain species of Asian *Cupressus* with (weakly) dimorphic adult leaves on pendulous branchlets (*C. cashmeriana* Royle ex Carrière, *C. funebris* Endlicher). Leaf dimorphism in Cupressaceae is strongly correlated (i.e., adaptive) with moist climates (e.g., *Chamaecyparis, Fokienia, Thuja*); monomorphism of mature leaves resulting in quadrangular to terete branchlets is correlated with (seasonal) aridity (e.g., *Cupressus arizonica, Juniperus* sect. *Sabina*). Glands on the facial mature leaves of *X. vietnamensis* are less conspicuous than those of *Chamaecyparis nootkatensis*; neither normally produce droplets of resin.

Pollen cones of both species are very similar (in *C. nootkatensis* slightly larger) with 2(or 3) relatively large microsporangia; in *Chamaecyparis* s. str. and especially *Cupressus* the latter are more numerous (3 to 6) and relatively smaller (Figs. 2D, 4). Seed cones of *Xanthocyparis vietnamensis* (Fig. 2C) and *Chamaecyparis nootkatensis* (Fig. 3) are also similar; the most striking feature is the predominance of only two decussate pairs of bract-scale complexes in the mature cones. In both species an occasional third distal pair develops (or sometimes only one of these); although the sampling of *X. vietnamensis* studied is still somewhat limited (ca. 30 cones seen) it seems that this is somewhat more frequent in this species (Figs. 2C, 4). In both taxa a small columella develops at the shoot apex of 4-scaled cones, sometimes consisting of two parts. As in all Cupressaceae s.l. (incl. Taxodiaceae) the ovuliferous cone starts with ovule development borne on, subtended by, or surrounded by leaves (bracts); the scale forms by secondary (intercalary) growth. In both species this growth is more pronounced on the adaxial side of the bracts and more rapid in the second pair of the bract-scale complexes, resulting in semi-valvate cone scales that remain largely fused proximally. The only other taxon in the cupressoid clade (Gadek et al., 2000) with somewhat similar cone development is *Tetraclinis*; this type is more fully developed in the callitroid clade (Gadek et al., 2000) with which both fossil (e.g., Engelhardt & Kinkelin, 1908) and Recent species (Li, 1953) of *Tetraclinis* have erroneously been identified. Whereas in *Tetraclinis* the number of bract-scale complexes (2 pairs) seems primary in origin, in *Chamaecyparis nootkatensis* and *Xanthocyparis vietnamensis* it is almost certainly reduced, as evidenced by the occasional third pair that is much smaller and never associated with the ovules. Poorly developed, smaller cones of *Cupressus lusitanica* Miller sometimes have only 2 pairs (instead of 3 to 4, rarely 5 pairs) but they are more peltate. The ontogeny of the bract-scale complexes and the placement of ovules of *X. vietnamensis* and *Chamaecyparis nootkatensis* are likely to be similar but were only studied in detail for the latter species (Jagel & Stützel, 2001). Seedling development and seedling characters of *X. vietnamensis* remain to be studied.

Considering the evidence based on morphology, it is very likely that there is a closer relationship of *Xanthocyparis vietnamensis* with *Chamaecyparis nootkatensis* than with any other Recent taxon in Cupressaceae. We appear to have found a very interesting relict taxon on the western margin of the Pacific that belongs to a lineage distinct from both *Chamaecyparis* and *Cupressus* and is possibly more ancient than either of these. A comparison with the Late Cretaceous taxon *Mesocyparis* McIver & Basinger, which has been found in northwestern North America and northeastern Asia (McIver & Basinger, 1987; McIver & Aulenback, 1994) is of interest. In this fossil genus short dimorphic leaves appear on opposite (pen)ultimate lateral branchlets, and long dimorphic leaves follow a series of short leaves on leading shoots. Although the opposite branching pattern contrasts with the alternate branching in Recent cupressoid genera, the alternation of two leaf shapes is also found in *Xanthocyparis vietnamensis*, but with monomorphic (juvenile) longer leaves. The seed cones of *Mesocyparis*

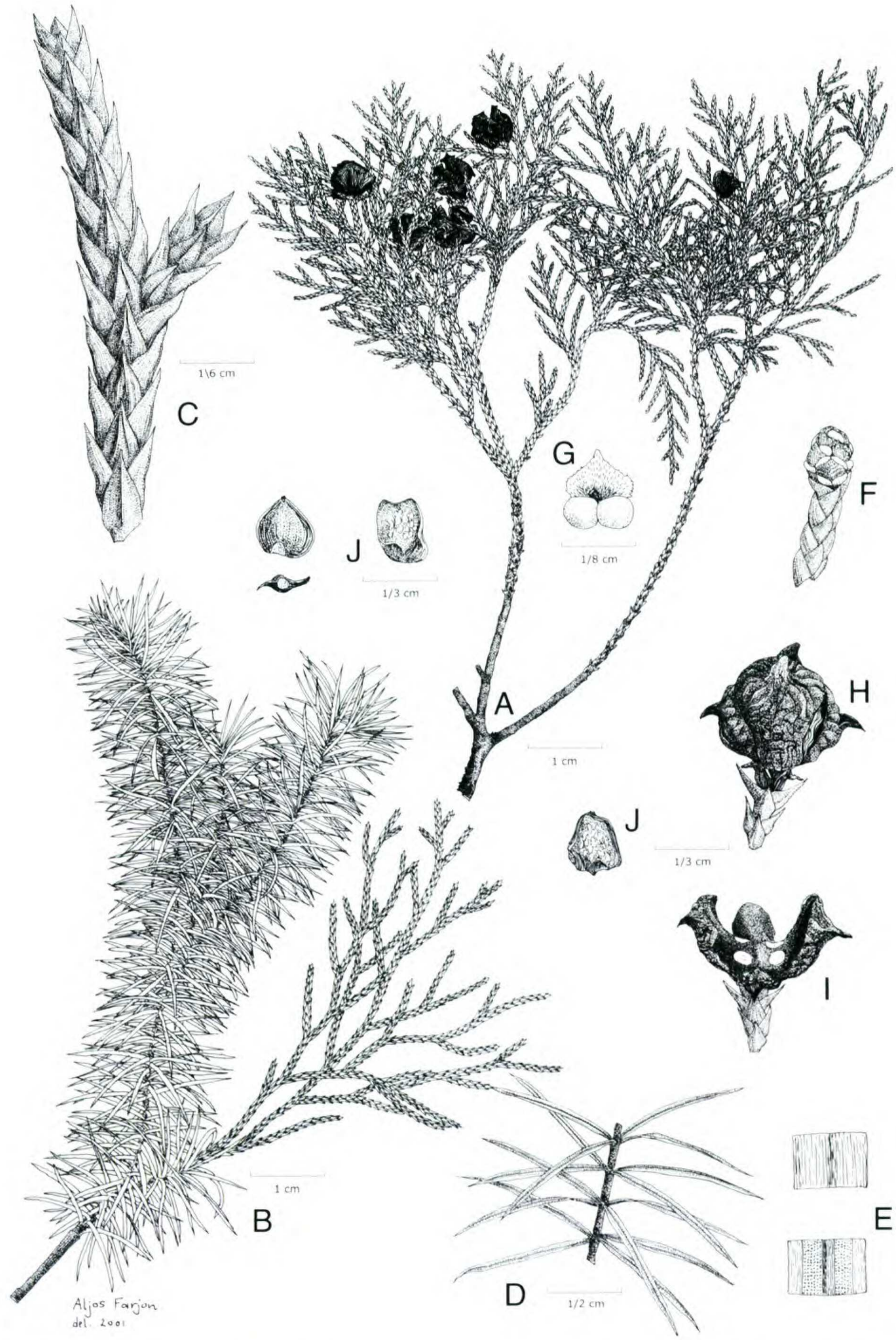

Figure 4. *Xanthocyparis vietnamensis* Farjon & Hiep. —A. Branchlet with scale leaves and seed cones. —B. Branchlet with scale leaves and needle leaves. —C. Branchlet with scale leaves. —D. Branchlet with needle leaves. —E. Detail of upper and lower side of needle leaf. —F. Branchlet with pollen cone. —G. Microsporophyll with two microsporangia. —H, I. Seed cones, closed and open. —J. Seeds. [A, C, F–J = *Harder et al. 6091* (HN, K); B, D, E = *Harder et al. 6224* (K). Illustration by Aljos Farjon.

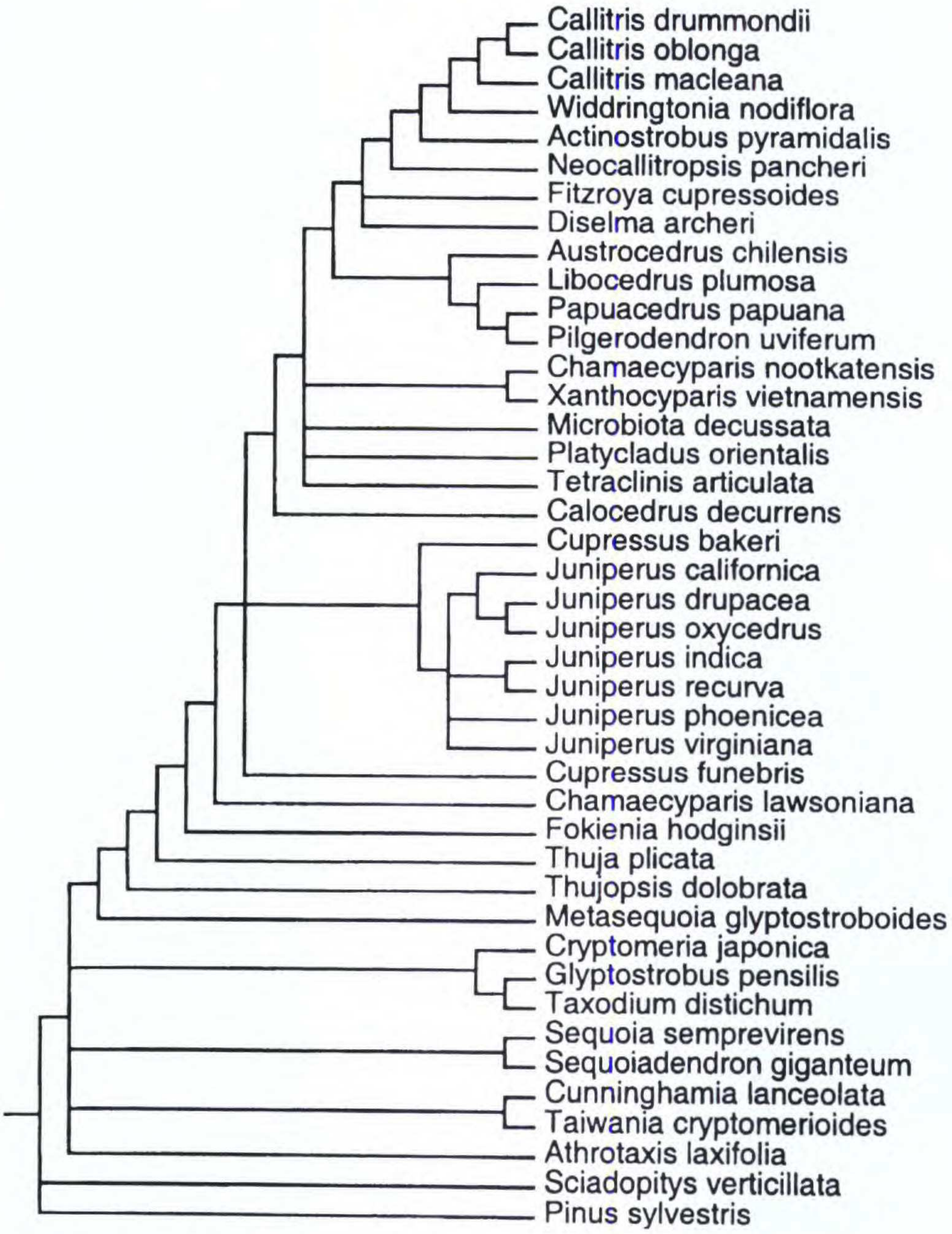

Figure 5. Strict consensus of 144 equally parsimonious trees of 523 steps found from a heuristic search of morphological and anatomical data (53 characters) in Cupressaceae s.l. and *Sciadopitys verticillata*, using *Pinus sylvestris* as outgroup. CI = 0.2428; RI = 0.3077; RC = 0.0747. [A full account of the characters and the data set will be given by Farjon in his monograph of Cupressaceae.]

umbonata McIver & Basinger are similar to those of *Chamaecyparis nootkatensis* and *X. vietnamensis* with two paired bract-scale complexes. However, the position of seed cones on the foliage branches of *Mesocyparis umbonata* is quite different especially from *C. nootkatensis*. They are not terminal on foliage sprays but appear lower on foliage shoots, on opposite, very short branchlets axillary to long leaves. A lower position does also occur in *X. vietnamensis*, but these cones are not in decussate pairs. Early developmental stages observed in fossil seed cone specimens of *Mesocyparis umbonata* are essentially similar to those in *C. nootkatensis* (McIver & Aulenback, 1994) but in the fossil the cones remain notably smaller, i.e., development after pollination of the ovules lags behind. In both *C. nootkatensis* and *X. vietnamensis* seed cone growth after pollination alters the relative sizes of bract and scale, considerably influencing the size and shape of these bract-scale complexes at maturity. The seeds of fossil *Mesocyparis* and of *Chamaecyparis* and *Xanthocyparis* are very similar. Another Late Cretaceous fossil, *Chamaecyparis corpulenta* (Bell) McIver (McIver, 1994) from Vancouver Island, Canada, has leaves more similar to other Recent species in *Chamaecyparis*, but again very small seed cones with four scales. This low number of bract-scale complexes is apparently primitive, as it occurs in all earliest (Cretaceous) members of Cupressaceae thus far known (McIver, 1994).

We conclude from the above evidence that *Chamaecyparis nootkatensis* should be placed with *Xanthocyparis vietnamensis* in a separate genus.

Xanthocyparis has retained several characters or traits that were evident in similar cupressoid members of Cupressaceae s.l. in the Late Cretaceous, but which have been lost or replaced by other features in more advanced members of *Chamaecyparis* and *Cupressus* during the Tertiary.

The following new combination has to be made as a result of the new taxonomy here proposed:

2. **Xanthocyparis nootkatensis** (D. Don) Farjon & Harder, comb. nov. Basionym: *Cupressus nootkatensis* D. Don, in Lambert, Descr. Pinus 2: 18. 1824. *Chamaecyparis nootkatensis* (D. Don) Spach, Hist. Nat. Vég. Phan. 11: 333. 1841. *Cupressus nutkatensis* Hooker, Fl. Bor. Amer. 2 (10): 165. 1838. *Chamaecyparis nutkaensis* Lindley & Gordon, J. Hort. Soc. London 5: 207. 1850. TYPE: Canada. British Columbia: Hecate Strait, Banks Island ["northwest coast of North America behind Bank's Island"], 1787, *A. Menzies s.n.* (holotype, not seen; isotypes, K, MO).

Thuja excelsa Bongard, Mém. Acad. Imp. Sci. Saint-Petersbourg, sér. 6, Sci. Math. 2: 164. 1832. *Cupressus americana* Trautvetter, Pl. Imag. Descr. Fl. Russ. 1 (1/2): 12, t. 7. 1844. TYPE: U.S.A. Alaska: Baranof Island, Sitka, "Dr. Mertens" s.n. (no date) (holotype, not seen; isotype, MO).

Thujopsis borealis hort. ex Carrière, Traité Gén. Conif.: 113. 1855. TYPE: Unknown, based on cultivated plant.

The species *Cupressus macrocarpa* Hartweg ex Gordon is considered to be the male parent of the generic hybrid ×*Cupressocyparis leylandii* (A. B. Jackson & Dallimore) Dallimore & A. B. Jackson; the female parent, from which hybrid seeds were collected, is thought to be *Chamaecyparis nootkatensis* (D. Don) Spach (Jackson & Dallimore, 1926). Reversed parentage was also reported to have occurred (Jackson & Dallimore, 1926), but both the protologue and the type specimens at K indicate that this hybrid was first raised from seed obtained in 1888 from *C. nootkatensis*. Two further nothospecies with male parentage from *C. nootkatensis*, but involving as female parents *Cupressus arizonica* Greene var. *glabra* (Sudworth) Little and *Cupressus lusitanica* Miller, were described by Mitchell (1970). Under the rules of the *Code* (Art. H6.2; Greuter et al., 2000) the name of a nothogeneric hybrid is to be combined from the first part or the whole of one and the last part or the whole of the other parent. The reclassification of *Chamaecyparis nootkatensis* in a new genus *Xanthocyparis* therefore requires a name change of the hybrid genus of which it is one of the parents; after ample deliberation it has been considered best practice to effect as minimal a change as possible. The necessary new combinations are given below.

×**Cuprocyparis** Farjon, nom. nothogen. nov.

Cupressocyparis Dallimore & A. B. Jackson, Forestry 11: 3. 1937; Roy. Bot. Gard. Kew Hand-list Conif., ed. 4: 37. 1938.

3. ×**Cuprocyparis leylandii** (A. B. Jackson & Dallimore) Farjon, comb. nov. Basionym: *Cupressus leylandii* A. B. Jackson & Dallimore, Kew Bull. 1926: 114. 1926. ×*Cupressocyparis leylandii* (A. B. Jackson & Dallimore) Dallimore & A. B. Jackson, Forestry 11: 3. 1937; Roy. Bot. Gard. Kew Hand-list Conif., ed. 4: 37. 1938. TYPE: England. Northumberland: Haggerston Castle (cultivated), 26 Nov. 1925, *E. J. Leyland s.n. (specimen marked D, with cones)* (lectotype, designated here, K).

Hybrid formula: ♂*Cupressus macrocarpa* Hartweg ex Gordon × ♀*Xanthocyparis nootkatensis* (D. Don) Farjon & Harder [*Cupressus macrocarpa* Hartweg ex Gordon × *Cupressus nootkatensis* D. Don; *Cupressus macrocarpa* Hartweg ex Gordon × *Chamaecyparis nootkatensis* (D. Don) Spach]

4. ×**Cuprocyparis notabilis** (A. F. Mitchell) Farjon, comb. nov. Basionym: ×*Cupressocyparis notabilis* A. F. Mitchell, J. Roy. Hort. Soc. 95 (10): 453. 1970. TYPE: England. Hampshire: Forest Research Station, Alice Holt Lodge, 31 July 1963, *A. F. Mitchell s.n.* (holotype, K).

Hybrid formula: ♀*Cupressus arizonica* Greene var. *glabra* (Sudworth) Little × ♂*Xanthocyparis nootkatensis* (D. Don) Farjon & Harder.

5. ×**Cuprocyparis ovensii** (A. F. Mitchell) Farjon, comb. nov. Basionym: ×*Cupressocyparis ovensii* A. F. Mitchell, J. Roy. Hort. Soc. 95(10): 454. 1970. TYPE: England. Hampshire: Forest Research Station, Alice Holt Lodge, 1970, *A. F. Mitchell s.n.* (holotype, K).

Hybrid formula: ♀*Cupressus lusitanica* Miller × ♂*Xanthocyparis nootkatensis* (D. Don) Farjon & Harder.

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Literature Cited

Camus, A. 1914. Les *Cyprès* (genre *Cupressus*). [Encyclopédie économique de Sylviculture II.] Paul Lechevalier, Paris.

Daguillon, A. 1899. Observations morphologiques sur les feuilles des Cupressinées. Rev. Gén. Bot. (Paris) 11: 168–205.

Engelhardt, H. & F. Kinkelin. 1908. I. Oberpliocäne Flora und Fauna des Untermaintales, insbesondere des Frankfurter Klarbeckens. Abh. Senckenberg. Naturf. Ges. 29(3): [150]151–306.

Farjon, A. 1998. World Checklist and Bibliography of Conifers. Royal Botanic Gardens, Kew. [2nd ed. 2001.]

Frankis, M. P. 1993. Nootka Cypress: *Chamaecyparis* or *Cupressus*? Conifer Soc. Austral. Newsl. 12: 9–10.

Gadek, P. A., D. L. Alpers, M. M. Heslewood & C. J. Quinn. 2000. Relationships within Cupressaceae *sensu lato*: A combined morphological and molecular approach. Amer. J. Bot. 87: 1044–1057.

Greuter, W., J. McNeill, F. R. Barrie, H. M. Burdet, V. Demoulin, T. S. Filgueiras, D. H. Nicolson, P. C. Silva, J. E. Skog, P. Trehane, N. J. Turland & D. L. Hawksworth. 2000. International Code of Botanical Nomenclature (St. Louis Code). Regnum Veg. 138.

IUCN. 2000. IUCN Red List Categories: Version 3.1. Prepared by the IUCN Species Survival Commission. IUCN, Gland, Switzerland, and Cambridge, U.K.

Jackson, A. B. & W. Dallimore. 1926. A new hybrid conifer. Kew Bull. 1926: 113–115.

Jagel, A. & T. Stützel. 2001. Zur Abgrenzung von *Chamaecyparis* Spach und *Cupressus* L. (Cupressaceae) und die systematische Stellung von *Cupressus nootkatensis* D. Don [= *Chamaecyparis nootkatensis* (D. Don) Spach]. Feddes Repert. 112(3–4): 179–229.

Li, H. L. 1953. A reclassification of *Libocedrus* and Cupressaceae. J. Arnold Arbor. 34: 17–34.

McIver, E. E. 1994. An early *Chamaecyparis* (Cupressaceae) from the Late Cretaceous of Vancouver Island, British Columbia, Canada. Canad. J. Bot. 72: 1787–1796.

——— & K. R. Aulenback. 1994. Morphology and relationships of *Mesocyparis umbonata* sp. nov.: Fossil Cupressaceae from the Late Cretaceous of Alberta, Canada. Canad. J. Bot. 72: 273–295.

——— & J. F. Basinger. 1987. *Mesocyparis borealis* gen. et sp. nov.: Fossil Cupressaceae from the early Tertiary of Saskatchewan, Canada. Canad. J. Bot. 65: 2338–2351.

Mitchell, A. F. 1970. A note on two new hybrid Cypresses. J. Roy. Hort. Soc. 95(10): 453–454.

Offler, C. E. 1984. Extant and fossil Coniferales of Australia and New Guinea. Part 1: A study of the external morphology of the vegetative shoots of the extant species. Palaeontogr. Abt. B, Palaeophytol. 193: 18–120.

Pauw, C. A. & H. P. Linder. 1997. Tropical African cedars (*Widdringtonia*, Cupressaceae): Systematics, ecology and conservation status. Bot. J. Linn. Soc. 123: 297–319.

Rouane, P. 1973. Etude comparée de la répartition des ramifications au cours de l'ontogenèse de quelques Cupressacées. Trav. Lab. Forest. Toulouse T. 9(3) 4: 1–277.

Taylor, S. D. & Sziklai. 1976. *Chamaecyparis nootkatensis* (D. Don) Spach—Yellow Cedar, member of the family Cupressaceae. Davidsonia 7(4): 56–62.