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The Genus *Calocedrus* (Cupressaceae) in the Flora of Vietnam

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ABSTRACT: Taxonomic review of the genus *Calocedrus* in Vietnam accompanied with modern available data on distribution, ecology and habitat conditions of its two aboriginal species is presented. Detailed illustrated description of recently discovered species *C. rupestris* endemic to rocky limestone mountains of northern Vietnam is provided. This rare species differs from wide-spread *C. macrolepis* in obtuse to broadly-obtuse leaf apex; small, subsessile, 4-scaled, broadly-ovate seed cones 4-5(6) x 2.5-3(3.5) mm with very short stalk 0.5-1(1.5) mm long, having 6-8(12) obtuse scales, and fertile seed scales with incurved rounded apex having rough, more or less flat surface without any mucro. Trees of *C. rupestris* were found as a co-dominant in relictual coniferous forests on rocky hills and ridges composed of highly eroded limestone. Relictual primary, highly endangered woods with this rare tree, as well as their floristic complex represent a unique plant diversity center of global significance. Urgent and effective protection of these areas should be of highest priority for nature conservation activity.

KEY WORDS: Cupressaceae, Taxonomy, *Calocedrus macrolepis, Calocedrus rupestris,* Vietnam.

INTRODUCTION

Calocedrus Kurz is small genus of the cypress family with trans-oceanic distribution typical for many relict taxa of the Tertiary floras. Before recent floristic investigations in Vietnam it comprised 3 extant species (Li and Keng, 1994; Nguyen Tien Hiep and Vidal, 1996; Fu et al., 1999; Farjon, 2001), namely - *Calocedrus formosana* (Florin) Florin (distributed in Taiwan), *C. macrolepis* Kurz (occurring in southern part of China, north eastern Myanmar, Thailand, Laos, southern Vietnam) and - *C. decurrens* (Torr.) Florin (found in Mexico and southwestern part of the U.S., in California and Oregon). Another species of this relictual genus – *Calocedrus rupestris* Aver., H. T. Nguyen & L. K. Phan was recently discovered in northern Vietnam (Averyanov et al., 2004). This species is an important addition to our knowledge in Cupressaceae missed out in modern treatment of this family (Farjon, 2005).

The only species of *Calocedrus* reported before for mainland Asia including Vietnam is *C. macrolepis.* In Vietnam this rare plant is observed in the wild only in the territory of South Annamese floristic province (Dac Lac, Phu Khanh, Ninh Thuan and Lam Dong provinces in southern Vietnam) in mountains composed of acidic silicate rocks at elevations 1000-2000 m. (Nguyen Tien Hiep and Vidal, 1996). Collections of this species from other parts of Vietnam were presumably made from cultivated plants. There are no yet really reliable reports of wild populations of *C. macrolepis* in northern Vietnam.

Morphological analysis of collected materials on *C. rupestris* reveals distinct and significant differences of this plant and all hitherto known extant species of the genus. Without any doubt, this recently discovered conifer represents well-defined obligate calcium dependent species. It represents the terminal link in one of evolutionary lines of successive reduction of scale number in the seed cones of Cupressaceae. Meanwhile, this outstanding novelty was formally described with insignificant diagnosis in local conference proceedings (Averyanov et al., 2004), which did not get wide distribution. Appropriate description of this plant, as well as key for determination of *Calocedrus* species in the flora of Vietnam are presented below.

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TAXONOMIC TREATMENT

***Calocedrus* Kurz,** J. Bot. 11: 196, 1873.

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Key to the species in the flora of Vietnam

1. Leaf apex acute to apiculate, adult canopy leaves with distinct or indistinct white stomatal bands abaxially; seed cones with 6 scales, cylindrical to broadly cylindrical, 7-8(12) mm long, 3.5(5) mm wide, distinctly stalked, pendulous or sub-pendulous; stalk commonly recurved, 3-5 mm long, with 16-20 imbricate scales, acute at apex; fertile seed scale distinctly recurved, with apiculate apex, with a short distinct mucro .... 1. *C. macrolepis*

1. Leaf apex obtuse to broadly obtuse, adult canopy leaves uniform green or with indistinct whitish green stomatal bands abaxially; seed cones commonly with 4 scales (very rarely with additional basal pair of small rudimentary scales), broadly ovate, 4-6(7) mm long, 2.5-4 mm wide, subsessile, erect or suberect; stalk very short, straight, 0.5-1(1.5) mm long, with 6-8(12) imbricate scales, obtuse-rounded to broadly obtuse at apex; fertile seed scale incurved, rounded at apex, sometimes with indistinct slightly flattened plate with rough surface bearing rarely a very small central umbo ..... 2. *C. rupestris*

1. *Calocedrus macrolepis* Kurz, J. Bot. 11: 196, Tab. 133, 1873.

Type: CHINA, Yunnan: Daying River, Hotha, *Anderson s. n.* (holotype, CAL?; isotype, K).

Tree up to 25 m tall, evergreen, monoecious, with broadly rounded crown, trunk to 0.8 m in diam., bark thick, light-brown to gray, fissured, fibrous and exfoliating in longitudinal stripes; timber light yellow, usually fragrant; branchlets flattened, arranged in a plane, ascending, prominently jointed. Leaves decussate, in whorls of 4, imbricate, scale-like, acute to obtuse-acuminate at apex, base decurrent, dimorphic along branchlet, facial pair flattened, oblong to obtrullate, (1.5)2-8 mm long, (1.5)2-4 mm wide, lateral pairs conduplicate, boat shaped, linear-lanceolate, with recurved-incurved acute apex, (1.5)2-8 mm long, (0.3)0.5-1 mm wide, in overlapping facial pairs, commonly with distinct whitish-green stomatal bands. Pollen cones terminal, solitary, oblong to shortly-cylindrical, terete, 5-8 mm long, 2-3 mm broad, light green turning to dull purple-brown, with 10-14 pairs of decussate scales, each with 4 pendulous pollen sacs; microsporophylls (pollen cone scales) about 1 mm long and wide, peltate-orbicular, obtuse-acuminate, with finely denticulate margin; microsporangia (pollen sacs), ovate to sub-spherical, 0.3-0.4 mm long. Seed cone-bearing branchlets (stalks), usually curved, terete or 4-angled, 3-5 mm long, with 16-20 imbricate, decussate, acute scales. Seed cones terminal, solitary, distinctly stalked, pendulous or sub-pendulous, broadly-cylindrical to elongate, 7-12 mm long, 3.5-5 mm wide, dehiscent when mature in first year, with 6 decussate scales; seed cone scales distinctly recurved, somewhat leathery, smooth or slightly rugose, often glaucous, elongate, 5-10 mm long, 2.5-4.5 mm wide; dehiscent when ripe, 1-2-seeded, at apex recurved, apiculate, with short distinct mucro; apical pair straight, laterally flattened, sterile, connate. Seeds ovoid-oblong, acute at apex, slightly flattened, with 2 large sub-apical, unequal wings, 7-12 mm long.

Phenology: Pollination occurs in November – January, with seeds maturing in September to October.

Etymology: With large scales, from Greek *μάχρος* – large and *λέρίς* – squama (meaning large scales of seed cone).

Calocedrus macrolepis is widely distributed in southern China (Guangdong, Hainan, Guangxi, Guizhou, southeastern Yunnan), northeastern Myanmar, Thailand, Laos and southern Vietnam (Li and Keng, 1994; Nguyen Tien Hiep, Vidal, 1996; Fu et al., 1999; Farjon, 2001, 2005). However, across its distribution this species is very rare. Natural populations of *C. macrolepis* are disjunct and relictual, often standing on the verge of extinction in their native habitats. In southern Vietnam this species is recorded from the provinces of Dac Lac (between Buon Tria and Buon Trian Cao and Chu Yang Sin mt), Phu Khanh (Hon Ba mountains), Lam Dong (Da Lat, Camly, Prenh, Trai Mat Municipality and Dan Tala watershed) and Ninh Thuan in Bi Doup mountains (Nguyen Tien Hiep, Vidal, 1996). Few available records of *C. macrolepis* from northern Vietnam (Tan Vien Mountain, Ba Vi district, Ha Tay province) probably came from cultivated samples (Fig. 1). In Vietnam this tree grows in primary woods with closed canopy, which are evergreen tropical, humid, broad-leaved, mixed or coniferous submontane and montane forests at elevations of 1000-2000 m on soils developed primarily from silicate rocks. Across Vietnam *C. macrolepis* is represented by single or rarely scattered trees. The trees are widely logged for its valuable timber and therefore the species deserves in the country a conservation status of endangered species (EN) according to RED list Categories and Criteria (EN, A-C, E): Version 3.1 of IUCN (2001).

Specimens examined: VIETNAM. Ha Tay Prov.: Ba Vi, 1200 m, *Ban 6888* (LE); *sine coll. 3670* (HN) all probably cultivated or naturalized. Dac Lac Prov.: between Buon Tria and Buon Trian Cao, 1000-1200 m, *Poilane 32620* (P). Khanh Hoa Prov.: Nha Trang, Hon Ba mountain, *Krempf 1598* (P). Lam Dong Prov.: near Dalat city, *Evrard 1355* (P); *Hayata 176*; Soviet-Vietnamese expedition *LX-VN 1455* (HN, LE); Nguyen Duy Chinh *sine n.* (HN); *Schmid 860*, id., Apr. 1954, *sine n.*, id., June 1960, *sine n.* (P); *Vu Van Cuong 1151* (P) all probably cultivated or naturalized; Camly, *Evrard 249* (P); Prenn, *Evrard 1458, 2202* (P). Border of Lam Dong and Ninh Thuan Prov.: Bi Doup mountains, *Poilane s.n.* October 1940 (P); Lam Dong Prov.,

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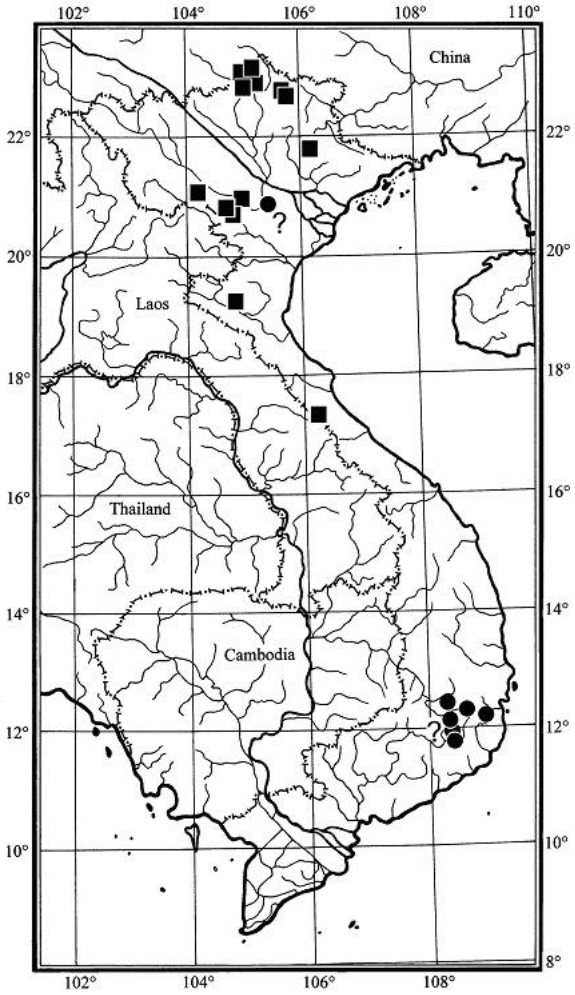


Fig. 1. Map of distribution of *Calocedrus macrolepis* (round marks) and *C. rupestris* (quadrate marks) in Vietnam. Location of presumably cultivated or naturalized specimens are marked with question mark.

Da Lat city area, Trai Mat Municipality, *P.K.Loc, L.Averyanov, T.V.Thao, HLF 5192* 13 October 2005 (HN, LE); Lam Dong Prov., vicinities of Da Lat city, near Dan Tala watershed, *L.Averyanov, P.K.Loc, N.V.Duy, N.T.Vinh, HLF 5379* 24 October 2005 (HN, LE); Lam Dong Prov., Dalat city, *L.C.Doan, L.Averyanov, P.K.Loc, HLF 5380* 25 October 2005 (HN, LE); Dak Lak Prov., Krong Bong Distr., Hoa Son Municipality, Krong Kmar river, NE slopes of Chu Yang Sin mt, L.*Averyanov, T.V.Thao, N.T.Vinh, HLF 5435* 28 October 2005 (HN, LE).

2. *Calocedrus rupestris* Aver., H.T. Nguyen & L.K. Phan, 2004, in Aver., Nguyen Tien Hiep, Pham Van The, Phan Ke Loc, 2004, Proc. Nat. Conf. Life Sci. Thai Nguyen Univ. Sept. 2004: 41*.
Figs. 2, 3 & 4

Footnote*: *Arbor 25 m.; folia decussata, dimorpha: folia dorsi-ventralia adpressa, (1)2–6(7) mm longa, (1.5)2-2.5 mm lata; folia lateralia, conduplicata, (1.5)2-6(7) mm longa, (0.3)0.5-0.75(1) mm lata, apice obtuso (non acuto); strobili feminei ovate, (4)5-6(7) mm longa, (2.5)3-4 mm lata; squamae 2 paribus, oppositae, decussatae, squamae inferiore subpeltato, apice incurvo, obtuse-rotundato (non acuminato); pare superioro connato, sterilis.*

Type: Vietnam, Prov. Bac Kan: Na Ri Distr., Liem Thuy Mun., Na Bo, 21°56'44"N, 106°05'09"E, 650-700 m, 3 June 2004 *L. Averyanov, N.T .Hiep, P.V.The, N.T.Vinh HAL 5441* (holotype HN; isotype LE, MO).

Paratypes: VIETNAM. Prov. Bac Kan: Na Ri Distr., Liem Thuy Mun., Na Bo, 21°56'44"N, 106°05'09"E, 27 May 2004 *L. Averyanov, N. T. Hiep, P. V. The, N. T. Vinh HAL 4919* (HN), 3 June 2004 *L. Averyanov, N. T. Hiep, P. V. The, N. T. Vinh HAL 5439* (HN), *L. Averyanov, N. T. Hiep, P. V. The, N. T. Vinh HAL 5440* (HN).

Tree up to 25 m tall, evergreen, monoecious, with broadly rounded crown, trunk to 1 m in diam., bark 8-12 mm thick, grayish-brown to brown, fissured, fibrous and exfoliating in longitudinal stripes, with numerous large resin ducts, resin abundant, bright yellow-orange, with pine-like fragrance; timber light yellow, odorless or fragrant; branchlets arranged in a plane, spreading and ascending, flattened, prominently jointed. Leaves decussate, in whorls of 4, scale-like, broadly-obtuse to obtuse at apex, base decurrent, dimorphic along branchlet, facial pair flattened (1)2-6(7) mm long, (1.5)2-2.5 mm wide, lateral pairs conduplicate, boat shaped (1.5)2-6(7) mm long, (0.3)0.5-0.75(1) mm wide, in overlapping facial pairs, without glands, uniform green or with very indistinct stomatal whitened bands abaxially. Pollen cones terminal, solitary, cylindrical, terete, (4.5)5-6 mm long, 1.5-2 (2.2) mm broad, with (8)9-11 pairs of scales (the lowest 2-4 pairs sterile), each with 2-6 pendulous pollen sacs; microsporophylls (pollen cone scales) 0.8-1(1.2) mm long, 1-1.2 mm wide, obtuse-rounded to broadly-obtuse, with finely erose margin, obtuse to broadly obtuse at apex, light green turning to light brown; microsporangia (pollen sacs) broadly-ovate to sub-spherical, 0.3-0.4 mm broad. Seed cone-bearing branchlets (stalks) terete or 4-angled, 0.5-1(1.5) mm long, with 6-8(12) imbricate scales, obtuse to broadly obtuse at apex. Seed cones greenish brown, terminal, solitary or paired at apex of lateral branchlets, ovate, (4)5-6(7) mm long, (2.5)3-4 mm wide, dehiscent when mature in first year, with 4 decussate, flat scales (very rarely with 1 additional basal pairs of scale rudiments); seed cone scales flattened, woody or somewhat leathery, broadly ovate, 4-6 mm long,

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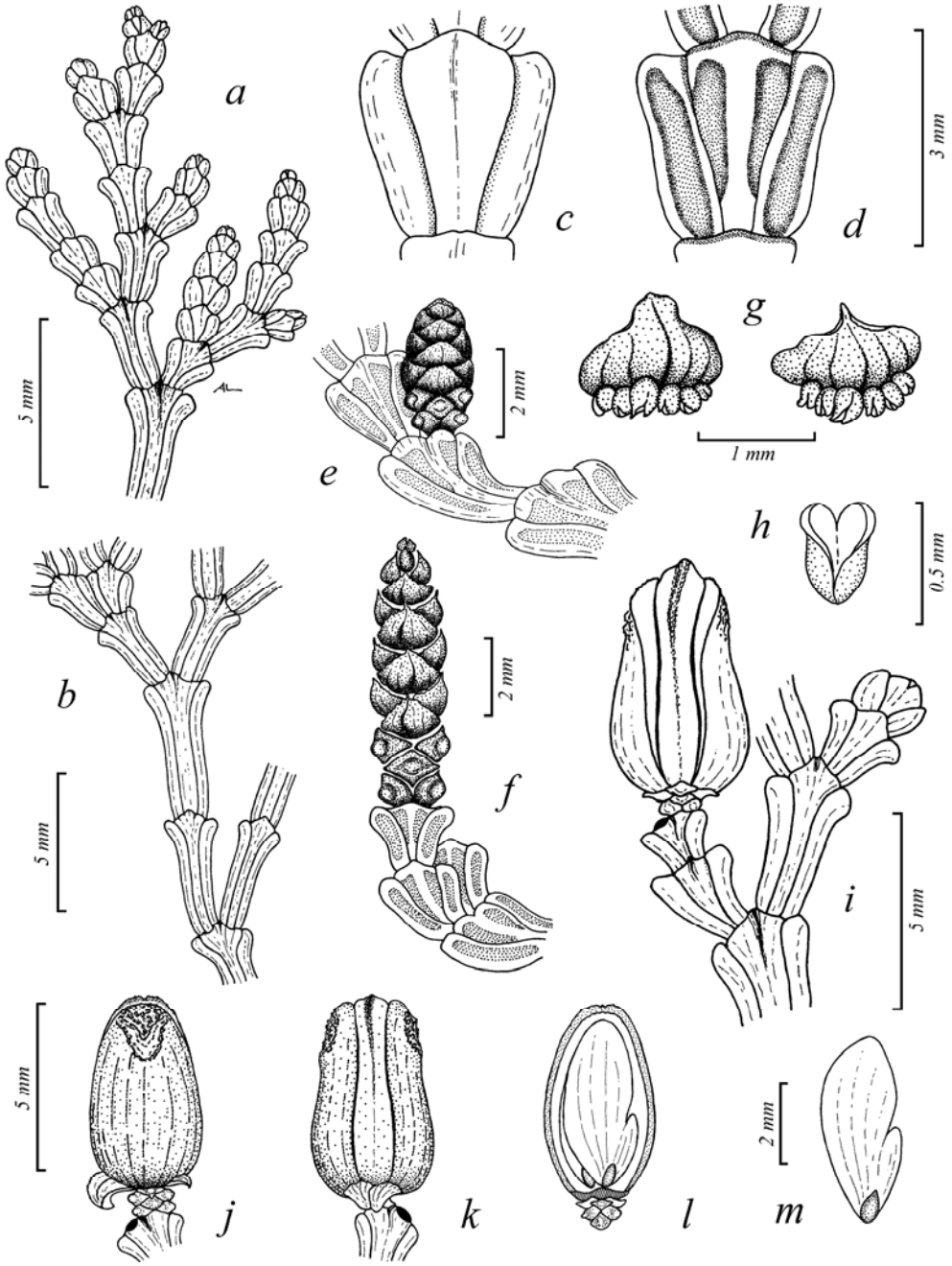


Fig. 2. *Calocedrus rupestris* Aver., H. T. Nguyen & L. K. Phan. a: Portion of young adult canopy branch. b: Portion of old adult canopy branch. c: Decussate leaves of young adult canopy branch (adaxial side). d: Decussate leaves of young adult canopy branch (abaxial side). e: Young pollen cone on portion of adult canopy young branch. f: Mature pollen cone on portion of adult canopy young branch. g: Microsporophylls with pollen sacs. h: Open pollen sac. i: Portion of young adult canopy branch with seed cone. j & k: Seed cones (front and lateral views) with rudimentary additional pair of sterile scales. l: Seed cone, with fertile cone-scale removed, front view. m: Seed (all drawn from the holotype *HAL 5441* by Leonid V. Averyanov).

2.5-4 mm wide; basal 2 scales fertile, dehiscent when ripe, normally 2-seeded (rarely 1), at apex incurved, rounded, sometime with an indistinct, slightly flattened or concave plate with rough surface, rarely with very small insignificant central umbo; apical pair sterile, connate. Seeds ovoid or sub-ovoid, acute at apex, slightly flattened, with 2 large sub-apical, unequal wings, 4-5 mm long.

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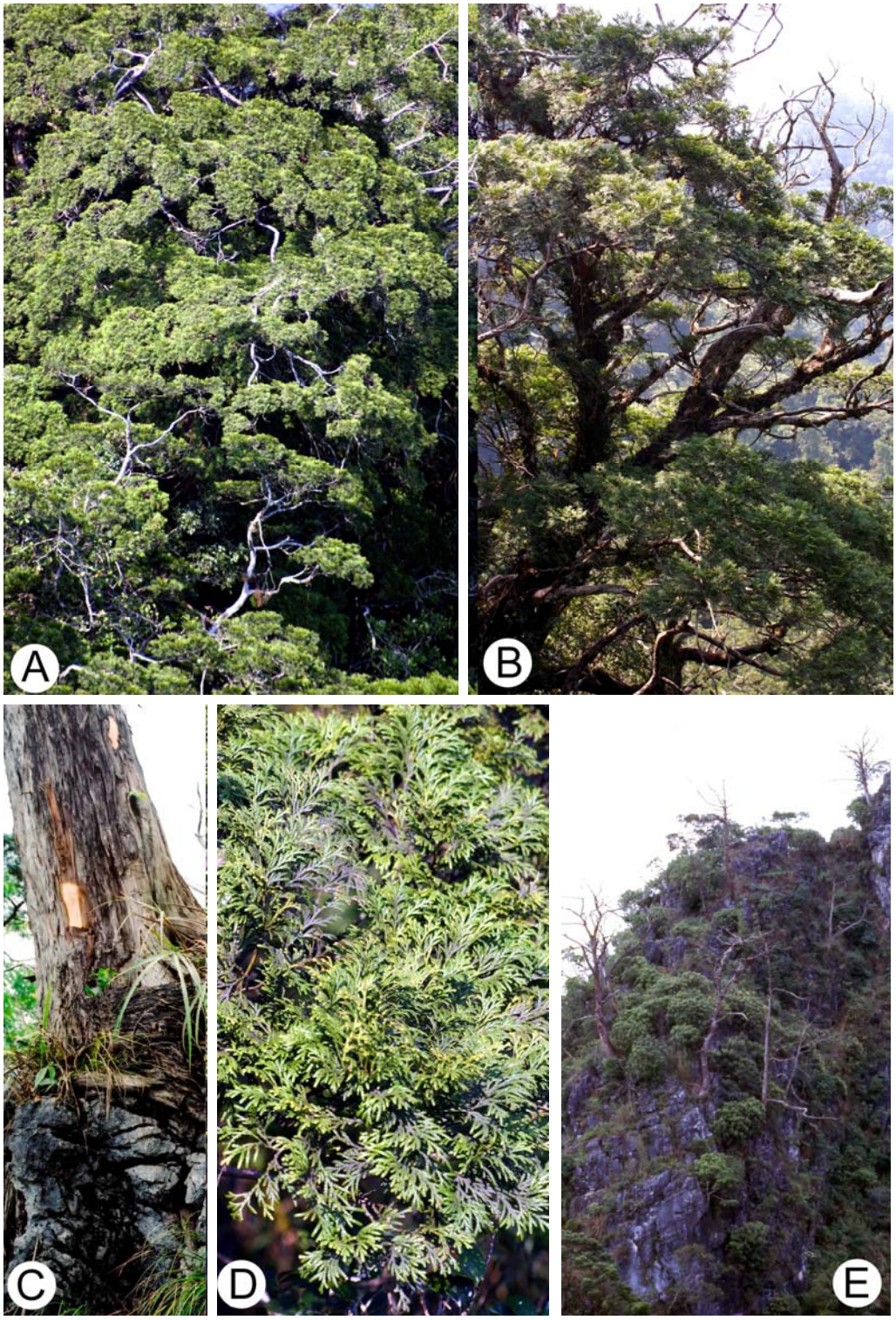


Fig. 3. Habitats and habit of *Calocedrus rupestris* Aver., H. T. Nguyen & L. K. Phan. A: Pure mono-dominant stand of *C. rupestris* on steep slopes of rocky limestone ridges in Phong Nha Ke Bang national park (Quang Binh Province); B: Typical canopy shape (same area). C: Base of middle aged tree bole (Bac Kan Province). D: Canopy branches (*HAL 6109*). E: Extinction of conifers (*Calocedrus rupestris, Pinus kwangtungensis* and *Pseudotsuga sinensis)* on south faced cliffs of low elevated limestone mountains in Bac Kan Province (photographs of Leonid V. Averyanov and Pham Van The).

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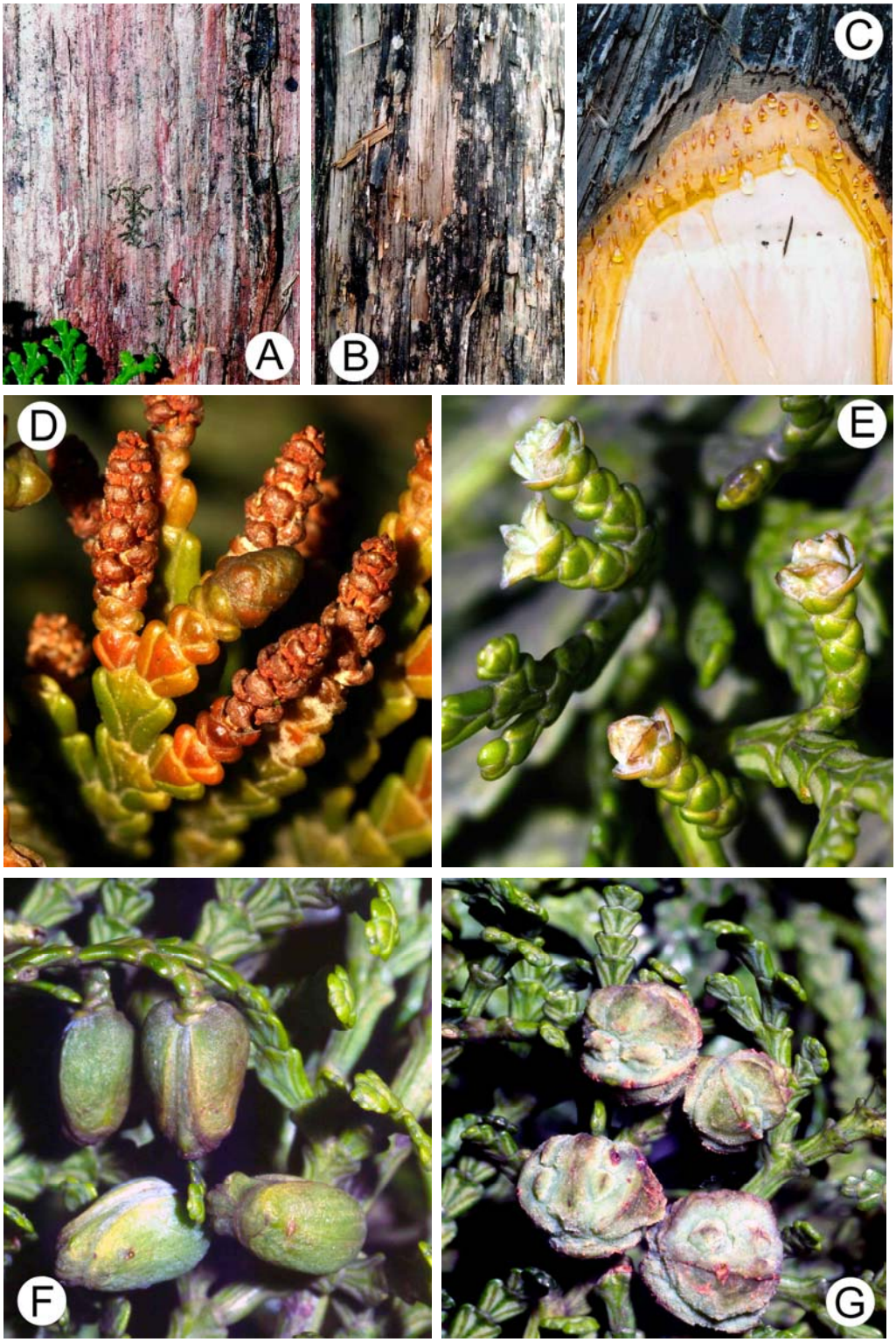


Fig. 4. Morphology of *Calocedrus rupestris* Aver., H. T. Nguyen & L. K. Phan. A & B: Bark of middle (A) and old aged tree (B) at the base of boles (*HAL 4919*). C: Bole cut to reveal resin ducts and resin drops (*HAL 4919*). D: Young and ripe pollen cones (*HAL 6200*). E: Young seed cones (*HAL 6200*). F: Ripening seed cones (*HAL 5441*). G: Seed cone formations (*HAL 5441*) damaged by invasion of insect larvae (photographs Leonid V. Averyanov and Pham Van The).

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Phenology: Pollination occurs in December – January, with seeds maturing probably in September to October.

Etymology: From the Latin word "*rupestris*" meaning rock-dwelling, growing on rocky slopes or cliffs.

Specimens examined: VIETNAM. Prov. Cao Bang, Bao Lac Distr., Yen Lac Municipality, vicinities of Yen Lac village, 22°44' N, 105°50' E, 1450-1500 m, 16 April 1999, *P.K.Loc, P.H.Hoang, L.Averyanov CBL 1462* (HN), sterile; Bao Lac Distr., Dinh Phung Municipality, Man Lung ridge, 22°47' N, 105°49' E, 1550-1600 m, 18 April 1999, *P.K.Loc, P.H.Hoang, L.Averyanov CBL 1515* (HN), sterile.- Prov. Ha Giang, Yen Minh Distr., Lao Va Chai Municipality, vicinities of Ngan Chai village, 6 km to W of Yen Minh town, 23°07' N, 105°08' E, cultivated treelet introduced from wild at 1600-1700 m, 1 May 1999, *P.K.Loc, P.H.Hoang, L.Averyanov CBL 1977* (HN), sterile.; Quan Ba Distr., Bat Dai Son Municipaliry, Bat Dai Son Nature Reserve, around point 22°59'50" N, 105°05'46" E, about 1600 m, 10 May 2002, *P.K.Loc, L.Averyanov, N.T.Vinh HAL* (HN), sterile; Quan Ba District, Can Ty Municipality, at Sin Suoi Ho village and river, 23°06'57" N, 105°01'48" E, 514-900 m, 1 April 2000, *D.K.Harder, N.T.Hiep, L.Averyanov DKH 4854* (HN), sterile; Quan Ba Distr., Can Ty Municipality, in the vicinity of Lung Vai village at left side of Mien River, 23°05'09" N, 105°03'23" E, 1440 m, 8 May 2002, *P.K.Loc, L.Averyanov, N.T.Vinh HAL 1457* (HN), sterile; Quan Ba Distr., Can Ty Municipality, Ha Tung Sung Valley, Bat Dai Son Natural Reserve around point 23°05'46'' N, 105°01'05''E, 1230 m, 18 January 2003, *T.V.Thao, N.S.Khang VT 021* (HN), sterile.- Quan Ba Distr., Thanh Van Municipality, cultivated tree taken from the wild in the vicinity of Lung Cung village at right side of Mien River, around point 23°07'12" N, 105°00'52" E, 980 m, 8 May 2002, *P.K.Loc, L.Averyanov, N.T.Vinh HAL 1471* (HN), sterile; Quan Ba Distr., Thanh Van Municipality, in the vicinity of Lung Cung village, around 1 km to the E from point 23°05'32" N, 105°00'10" E, 1100-1200 m, 9 May 2002, *P.K.Loc, L.Averyanov, N.T.Vinh HAL 1493* (HN), sterile; Quan Ba Distr., Thai An Municipality, in the vicinity of Lo Thang village, 22°59'50" N, 105°05'46" E, 1600 m, 10 May 2002, *P.K.Loc, L.Averyanov, N.T.Vinh HAL 1513* (HN), sterile; Quan Ba District, Thai An Municipality, December 1999, *N.Tap 2B* (HN), sterile.- Prov. Son La, Yen Chau Distr., Muong Lum municipality, Lum village, 21°00'47" N, 104°29'30" E, 1200-1350 m, 2 March 2001, *D.Harder, P.K.Loc, N.T.Hiep, L.Averyanov DKH 7066* (HN), young female cones; Moc Chau Distr., Van Ho Municipality, Hua Tat village, 20°46'18" N, 104°47'45" E, 1200-1350 m, 6 October 2000, *D.Harder et al. DKH 5763* (HN), sterile.- Prov. Hoa Binh, Da Bac Distr., to the SW of Doan Ket village, 20°54'01" N, 105°04'19" E, 900-1000 m, 29 March 2001, *N.T.Hiep, L.Averyanov, N.T.Vinh, D.T.Doan HAL 367* (HN), sterile.; Mai Chau Distr., Hang Kia Municipality, near Thung Ang village, mountain Tao Xinh, 20°43'43" N, 104°51'21" E, 1000-1100 m, 6 April 2001, *N.T.Hiep, L.Averyanov, N.T.Vinh, D.T.Doan HAL 629* (HN), sterile.- Prov. Nghe An, Con Cuong Distr., Binh Chuan Municipality, Phu Pha Cau mt., 19°18'13" N, 104°53'50" E, 1100-1250 m, 26 February 2004, *V.M.Son, N.T.Vinh HLF 3136* (HN), sterile. - Prov. Quang Binh, Bo Trach Distr., Tan Trach Municipality, vicinities of A Rem village, 17º23'32" N, 106º12'46" E, 650-750 m, 24 January 2005 *L.Averyanov, P.K.Loc, P.V.The, A.Averyanova, N.T.Vinh, N.Q.Vinh, N.T.Binh HAL 6109* (HN, d-EXSICCATE OF VIETNAMESE FLORA 0001/HAL6109), male and young female cones, 25 January 2005, *HAL 6164* (HN), male and young female cones, 26 January 2005, *HAL 6200* (HN), male and young female cones.

Most significant morphological differences between *Calocedrus macrolepis* and *C. rupestris* are summarized in Table 1.

Calocedrus rupestris along with other endemic and sub-endemic conifers like *Callitropsis vietnamensis* (Farjon & T. H. Nguyen) D. P. Little, *Keteleeria davidiana* (Bertrand) Beissn., *Pinus kwangtungensis* Chun ex Tsiang, *Pseudotsuga sinensis* Dode, *Tsuga chinensis* (Franch.) Diels, as well as other gymnosperm trees such as *Amentotaxus argotaenia* Pilger, *A. hatuyenensis* N. T. Hiep, *A. yunnanensis* Li, *Cephalotaxus mannii* Hook.f., *Dacrycarpus imbricatus* (Blume) de Laub., *Dacrydium elatum* Wall., *Nageia fleuryi* (Hickel) de Laub., *Podocarpus neriifolius* D. Don, *P. pilgeri* Foxworthy and *Taxus chinensis* Roxb. represents formative element of primary mixed and coniferous forests in rocky limestone areas of northern Vietnam. These woods form here floristic nucleus of highly endemic limestone floras and support specific very sensitive ecosystems of outstanding high level of biodiversity. A great number of strict endemics of high taxonomic rank are associated with woods of this kind. Among them are recently discovered endemic and sub-endemic genera such as *Caobangia* A. R. Smith &t X. C. Zhang (Polypodiaceae), *Grushvitskya* Skvorts. et Aver. (Araliaceae), *Vietorchis* Aver. et Averyanova and *Zeuxinella* Aver. (Orchidaceae), *Callitropsis* (Cupressaceae), and some others (Skvortsova & Averyanov, 1994; Farjon et al., 2002; Averyanov et al., 2002; A. R. Smith and X. C. Zhang, 2002; Averyanov and Averyanova, 2003).

In the past *Calocedrus rupestris* was undoubtedly widely distributed in northern Vietnam. This tree was one of the most important species-edificator of woody communities and indicator of intact pristine primary climax aboriginal zonal relictual woods typical for ancient highly eroded remnant rocky limestone ridges in northern part of eastern Indochina. During modern explorations it was commonly found as a more or less usual co-dominant of the first forest stratum in last remains of primary mixed and coniferous forests associated regularly with *Dacrycarpus imbricatus*, *Dacrydium elatum, Keteleeria davidiana*, *Pinus kwangtungensis* and *Pseudotsuga sinensis.* Presently this tree form majestic mono-dominant pure stand in a few places of the country (Fig. 3A). Forests with *C. rupestris* commonly cover the rocky tops of ridges and hills composed with highly eroded solid crystalline white and gray marble-like limestone. The coniferous canopy stratum in these forests commonly does not

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Table 1. Morphological differences between *Calocedrus macrolepis* and *C. rupestris*.

Morphological feature	*C. macrolepis*	*C. rupestris*
Apex of canopy leaves	acute	obtuse to broadly obtuse
Seed cone position	distinctly stalked, stalk usually recurved, cone commonly pendulous, or sub-pendulous	subsessile (cone erect or sub erect)
Seed cone form, dimensions	broadly cylindrical to elongate 7-8(12) x 3.5-4(5) mm	broadly ovate 4-6(7) x 2.5-4 mm
Seed cone stalk & scales	3-5 mm long, with 16-20 imbricate scales, each acute at apex	0.5-1(1.5) mm long, with 6-8(12) imbricate scales, each obtuse to broadly obtuse at apex
Number of scales in seed cone	6	4 (very rarely 6)
Apex of fertile scale in seed cone	distinctly recurved, apiculate, with short distinct mucro	incurved, rounded, sometimes with indistinct slightly flattened plate with rough surface, rarely with very small insignificant central umbo
Number of seeds (ovules) on fertile scale	1 or 2	2 (rarely 1)

exceed 15-20 m tall on more or less open isolated rocky tops of limestone remnant mountain formations. However, on steep slopes near the tops, some conifers (particularly *Keteleeria davidiana*) often reach 30 m tall with trunks to 1.5 m in diameter. The largest observed samples of *C. rupestris* were about 25 m tall and about 1.2 m in diameter. Preliminary observation of timber rings indicates that these trees are probably more than 600-800 years old. The maturity of micro sporangia and pollination of this species come in December – January, while seed dispersing falls probably on September – October.

In our days distribution of *Calocedrus rupestris* in northern Vietnam due to deforestation is very limited and comprises miserable isolated disjunctive rocky limestone hilly and mountain systems with predominant elevations 600-1000 (1600) m. Available data on distribution of this species are summarized on the map of distribution (Fig. 1). This cypress tree probably may be also found in many other isolated rocky limestone mountains of northern Vietnam, which still keep primary woody vegetation. However, in most observed localities this tree definitely becomes rare due to many factors and exactly moves to its coming extinction. Some discovered localities of *C. rupestris* were found very near to Chinese and Laotian borders (Fig. 1). This fact indicates that species may be also found in limestone regions of both mentioned countries allied to the territory of Vietnam.

Largest intact stands of *Calocedrus rupestris* were recently found and studied in south-eastern part of Bac Kan Province (bordering with Thai Nguyen and Lang Son provinces in the center of northern Vietnam) and in Quang Binh Province (in limestone area of Phong Nha – Ke Bang national park). In these studied areas *C. rupestris* represents an integral element of primary coniferous forests with *Keteleeria davidiana, Pinus kwangtungensis* and *Pseudotsuga sinensis* (Bac Kan) and with *Dacrycarpus imbricatus* and *Dacrydium elatum* (in Quang Binh Province). Fragments of these forests cover isolated rocky tops and edges of ridges of highly eroded remnant limestone formations, which appear as a numerous hills, small mesae-like mountains or rocky ridges with very steep slopes and numerous vertical cliffs. Mountains in studied areas are composed of solid crystalline white to gray marble like limestone, which represents relictual geologic formation derived from marine deposits presumably of late Paleozoic age (Dovzikov et al., 1965a, b). Deep erosion of ancient highly metamorphosed marble-like limestone formed spectacular landscape in this area, which still keeps primary vegetation typical for rocky limestone areas of north-eastern Indochina.

Recent climatologic studies define climate in the area of *Calocedrus rupestris* distribution as monsoon tropical climate with cold winter and summer to summer-autumn rains (Nguyen Khanh Van et al., 2000). Summers here are wet, with rainfall peaks coming to July - October. Annual rainfall commonly varies from 1200 to 3000 with mean annual rainfall for the region averaged at about 2200 mm. Temperature regimes have a strong seasonality and depend of elevation. Winter conditions with cool temperatures extend usually from November to April with normal lows in lowlands of 14-16°C. The mountain regions experience cooler temperatures and higher levels of mean annual rainfall with increasing elevation. At elevations above 900-1000 m night hoarfrost is sometimes observed in open places during winter months. Persistent cool drizzling rains are very typical from early February until the end of March. Summers are hot and humid, with maximum temperatures reaching to 35°. Common mean annual temperatures are about 23.5 C. Detailed description of climate conditions of the mentioned area was presented earlier (Averyanov et al., 2003a, b).

Canopy forest stratum in the area of *Calocedrus rupestris* distribution reaches on tops of limestone mountains 15-20 m tall, but is elevated up to 25-30 m on slopes protected from winds. Some broad-leaved

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trees, like *Platycarya strobilacea* and several tropical oaks (*Quercus* spp.) occur sometimes in this stratum besides mentioned conifers. On mountain slopes broad-leaved trees become more common in the first forest stratum and often include such species as *Anogeissus acuminata*, *Bischofia javanica*, *Dracontomelon duperreanum*, *Pometia pinnata*, *Radermachera sinica*, *Streblus macrophyllus*, as well as species of *Aglaia*, *Lagerstroemia*, *Paulownia*, *Sterculia* and *Toona*.

Second forest stratum includes many species of trees commonly 6-15 m tall. Among them most common are *Acer tonkinense*, *Boniodendron parviflorum*, *Carpinus* sp., *Celtis* sp., *Cinnamomum* sp., *Ficus* spp., *Garcinia* sp., *Knema* sp., *Lysidice rhodostegia*, *Machilus* sp., *Myrsine seguini*, *Nephelium* sp., *Ormosia* sp., *Pistacia weinmannifolia*, *Radermachera boniana*, *Reevesia* sp., *Schefflera pes-avis*, *Sinosideroxylon racemosum* and *S. wightianum*. Some gymnosperm trees, such as - *Amentotaxus yunnanensis*, *Cephalotaxus mannii*, *Nageia fleuryi* and *Podocarpus neriifolius* are also regular component in this stratum.

Next stratum of the forest includes small trees and shrubs commonly (1.5)2-6 m tall. They are creating more or less dense cover composed with great number of species. Main co-dominants here are such species as *Alstonia guangsiensis*, *Blastus cochinchinensis, Campylotropis henryi*, *Decaspermum parviflorum*, *Illicium cambodianum*, *Licuala* sp., *Ligustrum* sp., *Mahonia nepalensis*, *Memecylon edule*, *Myrsine kwangsiensis*, *Phyllanthus* sp., *Pistacia cucphuongensis*, *Psychotria* sp., *Rhapis divaricata*, *R. subtilis*, *Rhodamnia trinervia*, *Schefflera* sp. and *Tirpitzia sinensis*. On steep more or less open slopes and cliffs may be observed short palm-like cycads - *Cycas dolichophylla* and *C. chevalieri*.

Herbaceous species composition in habitats of *Calocedrus rupestris* is extraordinarily rich and includes a great number of terrestrial and lithophytic species among which most common are species of *Aglaonema*, *Alpinia*, *Amorphophallus*, *Ardisia*, *Arisaema*, *Carex*, *Disporum*, *Elatostema*, *Ophiopogon*, *Ophiorrhiza*, *Peliosanthes*, *Polygonatum* and *Tupistra*. On the shady forest floor are occasionally observed rare achlorophyllous mycotrophyc and parasitic species of *Balanophora*, *Burmannia unguiculata*, *Didymoplexis pallens*, *Epipogium roseum* and *Sciaphila stellata*. Vertical cliffs represent typical habitat of numerous obligate lithophytes, such as *Begonia aptera*, *B. cavaleriei*, *Calcareoboea coccinea,* numerous species of *Aeschynanthus* and *Boea,* as well as many ferns (*Adiantum caudatum*, *A. gravesii*, *Amphineuron tonkinense, Antrophyum* sp., *Arthropteris repens, Asplenium antrophyoides, A. cardiophyllum, A. griffithianum*, *Colysis bonii*, *Colysis elliptica*, *Colysis pothifolia, Ctenitopsis austrosinensis*, *Cyclopeltis crenata, Cyrtomium fortunei*, *Lemmaphyllum microphyllum*, *Neocheiropteris ensata*, *Polystichum* spp., *Pyrrosia porosa*, *Tectaria polymorpha*, *T. stenomioides, T. subpedata*).

The orchids reach extraordinary high diversity in coniferous forests with *Calocedrus rupestris.* Most of them are rare obligate calcium dependent species growing as lithophytes and epiphytes. More than hundred such species may be commonly observed in habitats of *C. rupestris*. Most typical orchid species growing here are *Acampe rigida, Aerides rosea, Bulbophyllum macraei, Ceratostylis himalaica, Cheirostylis yunnanensis, Cleisostoma rostratum, Coelogyne fimbriata, Cymbidium ensifolium, C. lancifolium, C. sinense, Dendrobium fimbriatum, D. hercoglossum, D. loddigesii, D. nobile, D. spatella, D. thyrsiflorum, Eria pannea, E. pusilla, E. siamensis, Liparis distans, L. latilabris, L. mannii, Oberonia ensiformis, O. kwangsiensis, Paphiopedilum concolor, Pelatantheria insectifera and Renanthera coccinea.* Primary coniferous forests with *C. rupestris* also support habitats of numerous very rare, endangered endemics of South Chinese and North Indochinese floristic provinces (Averyanov et al., 2003a, b). Among them are such orchids as *Anoectochilus calcareus*, *Biermannia calcarata*, *Bulbophyllum ambrosia*, *B. longibrachiatum*, *Cleisostoma melanorachis*, *C. simondii*, *Eria thao*, *Habenaria ciliolaris*, *Liparis averyanoviana*, *L. petraea*, *L. pumila*, *Luisia appressifolia*, *Paphiopedilum emersonii*, *P. hangianum*, *P. helenae*, *P. esquirolei*, *P. malipoense*, *Pholidota roseans*, *P. yunnanensis*, *Renanthera citrina*, *Rhomboda petelotii* and *Vanda fuscoviridis*. Without any doubts, all discovered stands of *C. rupestris* represent highly endemic, unique plant diversity centers of global significance. Urgent and effective protection of nature in these areas should be regarded as a goal of highest priority in the World nature protection strategy.

Logging of *Calocedrus rupestris,* as well as other cypress trees (like *Fokienia hodginsii*, *Calocedrus macrolepis*, or *Callitropsis vietnamensis*) with fragrant valuable timber highly demanded on domestic and international market is serious factor of their fast extinction in most areas of their primary distribution in Vietnam.

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Very few seedlings and saplings of *Calocedrus rupestris* were observed during field exploration in most studied localities. Definitely, general climate desertification connected with wide deforestation in northern Vietnam is the important limiting factor which damaged natural age-spectrum of population *C. rupestris* in their natural habitats. Certainly, in prehistoric ages coniferous limestone forests found acceptable conditions on relatively low elevations and spread widely in northern Vietnam. In our days these plant communities and populations of concrete coniferous species on low elevations rapidly degrade due to global decrease of humidity (even being not directly damaged by human activity). The climate warming connected with very wide deforestation shifts ecological optimum of most conifers to more high elevations. This process leads to slow invincible extinction of conifers in mountain systems where elevations do not exceed 700-800 m (Fig. 3E). Ecological optimum of most native coniferous species is now out of this mountain belt and their populations on low elevations are highly endangered and extremely sensitive to any damage. It is particularly true for *C. rupestris*. Obviously, this unique relict of the world flora desires status of endangered species and should be reasonably included in Red Data Book of Vietnam as endangered species (EN) according to RED list Categories and Criteria EN, A2cd, C1, E (Version 3.1 of IUCN, 2001, Nguyen Tien Hiep et al., 2004). Certainly, all populations of this species need urgent effective protection that may prevent future extinction of this significant endemic species in nature.

In our days largest stands of intact primary woods with *C. rupestris* in Vietnam were observed in rocky limestone areas of Phong Nha – Ke Bang national park (Fig. 3A). Relatively large pristine forest lands on this territory probably still support appropriate humidity, microclimate, soil, edaphic, watering regime and other natural conditions peculiar to indigenous intact plant zonal limestone communities of northern part of eastern Indochina. This is alone observed locality of *C. rupestris* with normal age spectrum of populations, which exhibit normal succession of natural species regeneration from seedlings and saplings to ripe trees up to 25 m tall and 1.2 m of bole diameter presumably 600-800 years old (Fig. 3B). Definitely *C. rupestris* woods in this area represent unique intact model of primary zonal limestone vegetation typical for pristine indigenous nature of Indochinese peninsular. It is necessary underline, that coniferous forests on rocky limestone are most endangered type of vegetation in the world. Such forests were extinct completely in most areas of their natural distribution and their natural regeneration always very problematic. In this connection, absolute integrated protection of coniferous woods with *C. rupestris* on the territory of Phong Nha – Ke Bang national park are extraordinary important point of nature protection activity of high national, as well as global significance.

It was noticeably to observe that sometimes many seed cones in populations of *Calocedrus rupestris* were damaged by very small unidentifiable insect larvae. All damaged cones became enlarged and were uniformly developed into spherical seedless formations with hemi-woody connate sub peltate scales, which superficially resemble cones of *Fokienia hodginsii* or some species of *Chamaecyparis* (Fig. 4G). Formation of such unusual peculiar terats may give indirect evidence on certain relationship of mentioned genera. On the other hand, the occasional insect invasion and damage of female cones may be limiting factor for successful seed propagation of this species in natural localities. Meanwhile, its introduction into cultivation may be an additional important effective action for protection of this relictual tree *ex situ.*

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越南植物誌中的肖楠屬(柏科)植物

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摘　　要

本文主要是訂正越南產肖楠屬（*Calocedrus*）植物，並報導一產自越南北部石灰岩山區的特有新種岩生肖楠（*Calocedrus rupestris*）及廣佈種大鱗肖楠（*C. macrolepis*）的分佈、生態及生育地等資訊。岩生肖楠與大鱗肖楠最大差異在於前者鱗葉先端鈍狀或寬鈍狀；四鱗片排列的小型毬果呈寬卵形約 4-5(6) x 2.5-3(3.5) mm^2，共約 6-8(12) 枚鈍狀鱗片，具短柄 (約 0.5-1.5 mm)；肥厚的種鱗具彎曲圓形的先端但絕不呈微凸狀，表面平坦但粗糙。岩生肖楠植株主要出現在由腐蝕性強的石灰岩組成山脊或石山，伴隨著殘存的松林而岩生肖楠幾乎也是該處優勢種。在此瀕危森林及此稀有物種所組成的複雜區系卻也是代表這片森林具有獨特地植物分化中心意義。有鑑於此，緊急與有效的保育此自然生育地將是刻不容緩的當前之務。

關鍵詞：柏科、分類學、岩生肖楠、大鱗肖楠、越南。

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