Spruces (*Picea*: Pinaceae)

in the Yarlung Tsangpo drainage of southeast Tibet (Xizang, China)

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Abstract: An over-view of the genus *Picea* (Pinaceae) in China is given, with particular reference to the *P. likiangensis* group of species. This group is considered to include *P. likiangensis* (Franch.) E.Pritz. subspecies *likiangensis*, *P. likiangensis* subsp. *balfouriana* (Rehder & E.H.Wilson) Rushforth and *P. purpurea* Mast. The species of *Picea* occurring above 3000m in the drainage of the Yarlung tsangpo and its main tributary the Po Tsangpo, southeast Tibet (Xizang) is allied to *P. likiangensis* & *P. purpurea* but with some characters shared with *P. spinulosa* (Griff.) A.Henry from south of the Himalaya (which also occurs at lower elevations in the Yarlung Tsangpo drainage). The new combination *P. linzhiensis* (W.C.Cheng & L.K.Fu) Rushforth is made. A key to the species in the *P. likiangensis* and *P. brachytyla* groups is presented.

The genus *Picea* in China falls into six distinct groups of species. The simplest to consider is the grouping which includes *P. neoveitchii* Mast. This rare northern species from southern Gansu to Shanxi just west of Beijing has never, as far as I am aware been introduced into the west (one "introduction" produced another spruce). It forms a natural group with the Japanese *Picea torano* (Siebold ex K.Koch) Koehne and the rare Mexican species *P. martinezii* T.F.Patt. from Nuevo Leon. From a horticultural perspective these species are characterised by needles which are extremely sharp to the touch. Botanically, they are characterised by the rather large rounded cone scales and the rather flattened needles with two bands of stomata on the two sides; the unusual aspect is that the leaves on vegetative shoots are laterally compressed along the axis of the shoot (not dorsiventrally compressed as in other flat-leaved spruces). This group is superficially similar to the species clustered around *P. asperata* Mast. which also has leaves with two pairs of stomatal bands, but here the leaves are distinctly four sided and not or scarcely laterally compressed; the cones have rounded to bluntly triangular scales but these are smaller and less woody than those in the above group, with more scales. Species in China include *P. crassifolia* Kom., *P. meyeri* Rehder & E.H.Wilson and *P. koraiensis* Nakai, and outwith China, *P. koyamae* Shiras. from central Honshu, Japan, and *P. chihuahuana* Martínez from the Mexican states of Durango & Chihuahua. The European *P. abies* (L.) H.Karst. probably also belongs here. *P. asperata*, or one of its varieties, may just get into the eastern part of southeast Tibet but not

into the Yarlung Tsangpo[1] drainage system.

Also with four sided needles and cones with smoothly rounded woody scales is the group which, from a Chinese perspective, is centred around *P. wilsonii* Mast. In this group I include *P. morrisonicola* Hayata from Taiwan. To the north there is *P. obovata* Ledeb. which has a boreal distribution, getting to northeastern Europe where it has introgressed with *P. abies*. In the Tien Shan there is *P. schrenkiana* Fisch. & C.A.Mey. which is related to the western Himalayan *P. smithiana* (Wall.) Boiss. This group skirts around Tibet, except that *P. smithiana* is found in the far southwest of Tibet where river valleys penetrate through the Himalaya into the plateau.

The fourth group includes *P. brachytyla* (Franch.) E.Pritz. and *P. farreri* C.N.Page & Rushforth from Upper Burma and the extreme west of Yunnan; they are only distantly related to other species, perhaps closest to *P. omorika* (Pančić) Purk. from the Serbia-Bosnia border. The fifth group is *P. jezoensis* (Siebold & Zucc.) Carrière which occurs in the north-eastern provinces of Heilongjiang, Jilin & Nei Mongolia and in adjacent eastern Russia, Korea and Japan, and is allied to several species in North America.

The sixth, *P. likiangensis* (Franch.) E. Pritz. group is found in western China from Yunnan north to southern Gansu. Outwith China, *P. alcoquiana* (Veitch ex Lindl.) Carrière and *P. glehnii* (F.Schmidt) Mast. from Japan are clearly included here; and more distantly *P. mariana* (Mill.) Britton, Spong & Poggenb. and *P. rubens* Sarg.

The astute reader will have noticed no mention of *P. spinulosa* (Griff.) A.Henry. My opinion is that *P. spinulosa* is part of the *P. likiangensis* group, of which it is the oldest name, but that it also shows characters of the *P. brachytyla* group. Treating it as part of the *P. likiangensis* group is consistent with Ran *et al.* (2006). The type locality of *P. spinulosa* is the Rudong La in central Bhutan which Griffith traversed in 1838 when with the Pemberton diplomatic mission from India to Bhutan. The older plants in cultivation as *P. spinulosa* have rather long (to 3 cm or so), slender leaves set radially around glabrous and somewhat pendulous shoots and cones with shiny semi-woody rhombic scales. The leaves have stomata on one side only in two greyish green or greyish white bands. The plants on the Rudong La may have glabrous shoots (see Griffith 2608 (BM) and young cultivated plants under Rushforth 1419 from the Rudong La and 1608 from the Phephe La, the next ridge to the west); however, Ludlow, Sherriff & Hicks 18702 (BM) is also from the Rudong or Rudo La and has shoots which are densely glandular pubescent, as is Ludlow, Sherriff & Hicks 16038 (BM) from the Ha valley of western Bhutan and Tokyo 4142 (BM) from

[1] Tsangpo is Tibetan for Big river. Yarlung is the region from which the river emanates. After turning south past Namche Barwa the river cuts through the eastern end of the Himalaya. On entering India it is the Siang or Dihang. Only when it reaches the plain of Assam and joins with the Dibang and Lohit does it become the Bramhaputra. The Po Tsangpo (also called Parlung Tsangpo) drains the province of Pome before flowing into the Yarlung Tsangpo. This drainage is separated by mountain ranges on the eastern side which exceed 4500 m, and to the north and west by the Tibetan plateau.

above Chendebji, central Bhutan. Most collections from Bhutan have cones with shiny semi-woody, generally rounded scales, (loosely) pressed down at the tips (e.g. Cooper 2471 (BM) from the Zado La (BM), Ludlow, Sherriff & Hicks 16675 from the Upper Pho Chu (BM), Rushforth 1039 (Jele La, east of Paro)[2], Rushforth 1140 (Yotong La) & Rushforth 1164 (Phephe La) and Tokyo 4142 from above Chendebji (BM)), but cones from Rushforth 1200 from the Rudong La have the scales somewhat rhombic. The leaves on Bhutanese trees tend to be shorter than on cultivated trees, up to *circa* 2cm. Rarely one or two incomplete lines of stomata may be found on the upper surface of the leaves (Rushforth 785, above Sharna Sampa, Paro district).

Picea spinulosa occurs from Sikkim (not being found in eastern Nepal) east across Bhutan into Arunachal Pradesh of northeast India; it is found in the Yatung valley in Tibet just north of Sikkim (Ludlow, Sherriff & Taylor 4005, BM). Exactly how far east it extends is uncertain. In the lower reaches of the Yarlung Tsangpo near the hamlet of Gyala (Jiala) at circa 2900 m, the trees near the river best fit as part of *P. spinulosa* in their incurved cones scales (Rushforth 3622 & 5869). However, only a little way upstream (Rushforth 3593 and Ludlow, Sherriff & Taylor 5349 (BM)) from between Gyala & Langpe have cones with the scales free at the apex and are clearly not referable here, see later. In the lower Rong Chu (which drains into the Po Tsangpo) at Chunyima at circa 2900m the cone of Rushforth 5986 fits *P. spinulosa*.

Some collections within this range have been named as *P. brachytyla*, with the Flora of China questioning whether *P. brachytyla* may occur in Bhutan (Fu *et al.*, 1999). *Picea brachytyla* shares the thinly woody cones scales but these are slightly recurved at the margin during the growing season and are not shiny when ripe. In foliage *P. brachytyla* is easily separated by the leaves which point forwards; they are appressed on the upper side of the shoot, but parted below, and usually less than 2cm; the underside of the leaf (as held) has a single niveous waxy covering overlaying the stomata, with no stomata on the glossy green side; the apex is rounded with a small mucro. The shoot is pale whitish yellow, glabrous or sparsely glandular hairy, and the buds are non-resinous, ovoid or ovoid-pointed, with chestnut coloured scales. It is found from west Henan west to Sichuan and in northwest Yunnan. It may occur in the far east of Xizang but I do not consider that trees matching these characters are found in the Yarlung Tsangpo drainage, or in adjacent Arunachal Pradesh.

What is normally treated as the *P. likiangensis* group occurs from the Yulongxue Shan (Jade Dragon Snow Mountain, aka Lijiang or Likiang Shan) north into Gansu. The unifying feature is the cone with flexible, rhombic scales which are loosely appressed at the free apex, shoots which are setose pubescent and have relatively short (less than 1.8cm and usually around 1–1.2cm) leaves which are bevelled at the apex.

[2] Unlocated collections refer to cones in M. P. Frankis's cone collection.

Picea likiangensis sensu stricto has bluish leaves with stomata in four bands; the leaves are set loosely on the shoot, rising above it and slightly forward. The shoot is lightly setose hairy. The cones are generally 8–12cm in length, rarely up 15cm or so. This taxon is found on the Lijiang range and adjacent areas of Yunnan and into southwest Sichuan[3].

At the northern range of the group, from northwest Sichuan to southern Gansu the trees have leaves which are rather appressed onto the shoot and pectinate below, shoots which are generally slender, flexible and densely setose haired, needles with a dark green shiny upper surface which is often without lines of stomata, or with one or two (often incomplete) lines, and cones 2.5–5.5cm in length with rounded erose scales. The leaf apex ranges from pointed (as in plants from Wilson 4063 from Songpan, northern Sichuan) to rounded with a small mucro, as in a tree at Tannadice, Forfar, from Hillier Nurseries in the 1940s and probably from a Joseph Rock collection from Gansu. These are *P. purpurea* Mast.

Between these two populations is a vast area of wooded valleys across western Sichuan and extreme northwest Yunnan. The spruce in this alliance from here has leaves appressed onto the shoot and thus similar to *P. purpurea*. However, the shoots are generally stouter than those of *P. purpurea* (but equally densely setose hairy), the leaves thicker with two broad bands of stomata on one side and two lesser bands on the other, and bluish green in colour with a bluntly pointed tip. The cones are generally 4.5–9cm in length (rarely to 10cm), thus larger than those of *P. purpurea* but smaller than those of *P. likiangensis*. The cones scales apices may be rounded or notched, variation which is also found in *P. purpurea*.

This plant is thus intermediate between *P. likiangensis* and *P. purpurea*.

In the Flora of China (Fu *et al.*, 1999), it is treated under three different varietal names under *P. likiangensis*. The key to these taxa in the Flora of China (on page 30) is:

> "3a. Seed cones red-brown or black-purple before maturity; 1st year branches usually with short nodes
>
> var. *rubescens*
>
> "3b. Seed cones green-yellow or yellow, or with green scales tinged red-brown or reddish purple on distal margin before maturity; 1st year branchlets with long nodes
>
> 4

[3] The tree at Edinburgh (19942811C) from SICH 1126 from Muli, Liangshan Yi Autonomous Prefecture in Sichuan fits here, and not as part of *Picea brachytyla* as originally identified.

photograph © Michael Frankis

Comparative photograph of the cones of the *Picea likiangensis* group - left hand pair of cones *P. likiangensis* subsp. *likiangensis*, centre-left pair *P. linzhiensis*, centre-right pair *P. likiangensis* subsp. *balfouriana*, far right trio *P. purpurea*. The *P. linzhiensis* cones are (Rushforth collections) 3548 on left, 5317A on right, the other cones are from cultivated trees in the UK.

"4a. Seed cones green-yellow or yellow before maturity
var. *hirtella*

"4b. Seed cones with green seed scales tinged red-brown or reddish purple on distal margin before maturity
var. *montigena*"

The original description of *P. montigena* Mast. includes "Strobili faeminei juveniles terminales ascendentes rubro-violaceae ..." and "purplish-violet" in the English, which continues "The ripe cones, 11 to 12 cent. long, 5 cent. lat., scales subcoriaceous, ascending, oblong, ovate, undulate, light brown flushed with purple. The scales of the ripe cone retain something of the purple colour of the young scales..." (Masters, 1906). It is only in Rehder & Wilson's emendation that the mature cones are "cinnamomei" (Rehder & Wilson, 1916, p. 33). Rehder & Wilson's description of *P. hirtella* has "strobili ... pallide flavo-brunnei" (ibid, p. 32). The original description of *P. likiangensis* var. *rubescens* Rehder & Wilson has the "strobili squamis ... purpurascentibus (ibid, p. 31) and in *P. balfouriana* "Strobili ... violaceo-purpurei, squamis extus ad apicem brunnescentibus" (ibid, p. 30).

My opinion is that these characters are slight and I do not consider them of

Picea linzhiensis – left to right: (Rushforth collections) 3548, 3593, 6432, 3657.

sufficient botanical significance to justify more than one entity. Furthermore, the way in which they are used in the Flora of China key (Fu *et al.*, 1999) is not consistent with the original descriptions for the entities.

Accordingly, my opinion is that it is appropriate to accept only one taxon for this part of the group, the question being at what level and therefore what is the appropriate name?

The oldest species name for this entity may be *P. montigena* Mast. However, as David Hunt recorded in *Curtis's Botanical Magazine* (CLXXXIV (4), 155-157, 1983), *P. montigena* "is equivocal in its characters between *P. likiangensis* and *P. asperata*". It is not reliably in cultivation, plants so named from Wilson's 1910 collection (4084) falling within the *P. asperata* alliance whereas Masters' original description places it within the *P. likiangensis* alliance. Masters described the cone as 11–12cm in length and 5cm wide, which is substantially larger than the present taxon. However, Rehder & Wilson suggested that the cones Masters described were of a different species, their *P. hirtella*. However, their description of the cone for that species has cones 5.5–8cm! The cones of *P. asperata* can be up to 14cm in length. There is the possibility that *P. montigena* is a hybrid (Bean 1976), or the result of introgression between, *P. asperata* and the *P. likiangensis* group; in this context, Wilson (in Rehder & Wilson, 1916, p 33) describes it as rare and from a restricted area west and south-west of Kangting (Tachien lu). It is uncertain, therefore, whether the name *P. montigena* is appropriate for this taxon.

Other names at the species level are *P. balfouriana* Rehder & E.H.Wilson, based on Wilson 4080 which is still in cultivation and is the next oldest species name, and *P. sikangensis* W.C.Cheng. *P. hirtella* Rehder & E.H.Wilson was named from Wilson's collection but is invalid, being a later homonym for *P. hirtella* Humboldt, Bonpland & Kunth (now included in *Abies religiosa* (H.B.K.) Schltdl.).

At varietal level, the oldest name is *P. likiangensis* var. *rubescens* Rehder & E.H.Wilson (Rehder & Wilson, 1916, p 31). Other varietal combinations under *P. likiangensis* are var. *balfouriana* (Rehder & E.H.Wilson) Hillier ex Slavin, var.

montigena (Mast.) W.C.Cheng (although with the above caveat) and var. *hirtella* W.C.Cheng[4].

However, the taxon does not fit the criteria of a variety in modern botanical treatment, as the variation is clearly of a geographical nature; where it approaches *P. likiangensis* in NW Yunnan (Rushforth 4100, Shu Du Hu near Zhongdian at 3660m), it occurs at higher altitudes. In these features it fits the criteria for a subspecies (Rushforth 1984). The valid name at this level is *P. likiangensis* subsp. *balfouriana* (Rehder & E.H.Wilson) Rushforth (Rushforth 1999).

Accordingly, the following combination is adopted with synonomy:
Picea likiangensis (Franchet) E.Pritz. subsp. *balfouriana* (Rehder & Wilson) Rushforth *International Dendrology Society Yearbook* 1998: 61 (1999). Basionym: *Picea balfouriana* Rehder & E.H.Wilson in Sargent, Plantae Wilsonianae 2: 30 (1916). Type: Wilson 4080. West Sichuan, Orangche, 3600–4000m October 1910 (A holotype, n.v., E isotype).

Syn.: *P. balfouriana* Rehder & E.H.Wilson; *P. likiangensis* var. *balfouriana* (Rehder & E.H.Wilson) Hillier ex Slavin; *P. likiangensis* var. *rubescens* Rehder & E.H.Wilson; *P. hirtella* Rehder & E.H.Wilson, non Humboldt, Bonpland & Kunth; *P. likiangensis* var. *hirtella* W.C.Cheng; *P. sikangensis* W.C.Cheng.

In the drainage of the Yarlung Tsangpo in southeast Tibet, there are forests composed of *Picea* growing between *circa* 3000m and 3300m at the lower end (and thus above the level of the *P. spinulosa* at Gyala and Chunyima) and 3800m at the upper end. These trees are allied to *P. likiangensis* in the cones with flexible scales with free tips. However, the scales are rounded or rhombic with a rounded apex with erose margins. This taxon has been described as *P. likiangensis* var. *linzhiensis* W.C.Cheng & L.K.Fu.

Other points of difference are that the hairs on the one year shoot are not setose, as in *P. likiangensis* and *P. purpurea*, but are set on a short filament tipped by a round gland. The leaves are pointed without the bevelled tip in these species. The buds are conical with a basal ring of whitish resin, but at the tip the chestnut brown scales are free of resin or with only a thin layer of resin.

These characters show a relationship both with *P. likiangensis* and with *P. spinulosa*. In view of this I consider that this taxon is better treated as a species, distinct from both *P. likiangensis* and *P. spinulosa*.

Accordingly the following new combination is made:
Picea linzhiensis (W.C.Cheng & L.K.Fu) Rushforth., **comb. et stat. nov.**

[4]Because the basionym is invalid, *P. likiangensis* var. *hirtella* is effectively a new name based on Rehder & Wilson's type.

Basionym: *Picea likiangensis* (Franch.) E.Pritz. var. *linzhiensis* W.C.Cheng & L.K.Fu., Acta Phytotax. Sin. 13 (4): 83-84, 1975. Xixang: Linzhi; at 3,100m. Fu GuoXun 676. Holotype PE, n.v.

Description: Tree to 50m, but usually only 30–40m, to 2m diameter in old trees but mainly 0.6m, crown columnar. Bark silvery grey, with thin brownish fissures. Shoots light brown or slightly orange-brown in first year, becoming greyish in second to fourth years, with dark brown glandular hairs (0.2mm) in first year; pulvinus 1mm, glandular hairy. Buds ovoid-conic, bluntly pointed to pointed, resinous at the base with thinly resinous or non-resinous chestnut-brown scales, to 0.9cm; bud scales remain at base of the first year shoot, ascending-spreading at the tip. Foliage loosely radial above at *circa* 30 degrees to the shoot and at the sides of the shoot at 60–80 degrees, widely parted below; leaves longest in mid portion of shoot, leaves nearly parallel-sided, tapering very gently to the short acuminate bony very sharp tip of nearly 1 mm, not bevelled, length to 2–3cm by 0.1–0.15cm but usually less than 2cm; stomata on lower surface only (or very rarely one or two incomplete rows above) in two greyish green bands of four to six rows, upper surface glossy green. Cones 5–12cm, purplish, ripening to brown. Scales free but appressed at the tip during the growing season, thin, flexible, rounded or rhombic, erose. Seeds 4mm by 2.5mm, dark brown, wing 5mm by 4mm, pale brown.

Herbarium specimens seen which are referable to *P. linzhiensis* are:
TIBET: Dongkar, 17/8/1934, Ludlow & Sherriff 839 (BM); Trun, Chayul Chu, 25/4/1934, Ludlow & Sherriff 1345 (BM); Lung, Chayul Chu, 1/5/1936, Ludlow & Sherriff 1395 (BM); Molo, Kongbo, 15/4/1938, Ludlow, Sherriff & Taylor 3627 (BM); Lilung Chu, 24/6/1938, Ludlow, Sherriff & Taylor 4420 (BM); ibid, 29/6/1938, Ludlow, Sherriff & Taylor 5691 (BM); Tsangpo valley, Kongbo, 6/5/1924, Kingdon-Ward 5651 (BM); ibid, Oluong, 105km from Linzhi, 19/10/1995, Rushforth 3376 (E); ibid, Oluong, 80km from Linzhi, 19/10/1995, Rushforth 3381 (E); Tron, Loro Chu, 25/6/1935, Kingdon-Ward 11791 (BM).

Other material: Cones of the following Rushforth collections from southeast Tibet: Doshong La, 3487, 3543, 3548*[5], 5089, 5115; Bidu Tsepu La 5071; between Gyala & Langpe 3593*; Nyima La above Timpe 3657*, 5317A (trees 30–40 m by 1.5–2 m); Pasum Tso (Draksum Tso in Lhasa dialect), south side, 3803, 3835*, 6448; between the Nambu La and Pasum Tso, 6428, 6432*; Rong Chu 3716, 3717; Bago (Paku) 6334*; Sobhe La, 6788*; between Showa & Bomi, 6288*.

P. linzhiensis may occur in India. Kingdon-Ward 11652 from Mago, Monyul, West Kameng, Arunachal Pradesh, 8/6/1935 (BM) includes two separate

[5] In cultivation from collections marked with an *.

Comparative photograph of *Picea spinulosa* and *P. brachytyla* cones: From left, old introduction [from Sikkim?] of *P. spinulosa* growing at Bicton, Devon, *P. spinulosa* KR 1039 from the Jele La above Paro, Bhutan, *P. spinulosa* KR 1200 from the Rudong La, central Bhutan, *P. spinulosa* KR 3622 from Gyala, southeast Tibet, with two *P. brachytyla* from cultivated trees in the UK on the right.

shoots, one glabrous, the other densely pubescent. Young trees from Mago are in cultivation but too immature to assist in determining whether *P. linzhiensis* or *P. spinulosa* occurs there. Although on the south side of the McMahon line which forms the *de facto* boundary between India and Tibet, the area is in the rain shadow of the Se La range and thus drier than the outer ranges to the south where *P. spinulosa* is found.

In the original description, the type, Fu GuoXun 676, is cited from 3100m at Linzhi in southeast Tibet, along with other specimens from Tibet. Specimens are also cited from Zhongdian in Yunnan. I am uncertain as to whether *P. linzhiensis* occurs, or is likely to occur, in the Zhongdian area, and have seen no referable material from there.

Phylogeography: *Picea linzhiensis* is found in the coniferous forest zone. At the lowest elevations it occurs with *Pinus armandii* Franchet (at Gyala and on the Doshong La) or rarely with *P. densata* Mast., where it occurs as scattered trees but often of great size. In the middle forest zone it may be in pure stands or with *Abies* spp or *Larix kongboensis* R.R.Mill, giving way to pure *Abies* forest above *circa* 3600–3800m. Understorey trees include *Betula szechuanica* (Schneid.) Jansson, *B. utilis* D.Don, *Sorbus* sp, *Acer caudatum* Wall. and *Malus baccata* agg. Shrubs include species of *Lonicera, Rhododendron, Euonymus, Enkianthus* and *Borinda.*

P. linzhiensis is isolated by the Tibetan plateau to the north and west which is too high and dry for spruces. It abuts the range of *P. spinulosa* where they meet at low elevations where the river has eroded the plateau, such as near Gyala and around Chunyima. It is possible that there may be some introgression in these localities.

photographs © Keith Rushforth

Foliage from a tree of *Picea linzhiensis* (collection number KR 3835) growing in a private arboretum in England. On the left is the upper surface of the spray, on the right the lower surface.

Clark *et al.* (2004) propose that the Yarlung Tsangpo originally was part of the Red River drainage and flowed into the Gulf of Tonkin through Vietnam. The evidence suggests that the upper Yangtse, the Mekong, Salween and Irrawady systems were all part of the same drainage pattern, comparable to the Mississippi in North America or the Congo in Africa. A series of river capture events initiated by the uplifting of the land following India's migration into Asia about 50 million years ago has given the current pattern. The uplifting has occurred in stages, and the one relevant to the Yarlung Tsangpo seems to have been between 19 and 24 million years ago (at the Oligocene/Miocene boundary). This was when the Indo-Burman range was formed. This event initially caused the Lohit to capture the Po Tsangpo (at this time the Yarlung Tsangpo flowed east through the Po Tsangpo valley), and the dating is confirmed by molecular work on fishes (Ruber *et al.* 2004, Guo *et al*. 2005). The date when the Siang captured the Yarlung is currently not known, with Clark *et al.* (2004) suggesting before 4 million years ago and An *et al.* (2002) noting a major rise in the Tibetan plateau between 10 and 8 million years ago.

Of course, whilst fishes will be separated by river flow reversals, plants and land animals are capable of crossing such divides, at least until they become sufficiently high to preclude normal genetic transfer. Molecular evidence from Oriental voles (see Luo *et al.* 2004) suggests that the uplift event which restricted their spread occurred between 3.6 and 2.6 million years ago.

I suspect that the Yarlung Tsangpo drainage has been cut off by the existing high ridges since this time, and that the separation of *P. linzhiensis* from the rest of the *P. likiangensis* group can be dated at least back to this period.

Key to the species in the *P. likiangensis* & *P. brachytyla* groups:

1a Bands of stomata on lower[6] surface only, none on the upper surface or rarely 1 or 2 incomplete lines above but then the leaf apex not bevelled, shoot glabrous or glandular hairy
2

1b Stomata mainly on the lower surface in 2 discrete bands but some complete rows in two bands on the upper face, or if no stomata on the upper face the apex bevelled, shoot variously hairy but not glandular hairy
5

2a Leaves with a covering of niveous or glaucous wax on lower face
3

2a Leaves greenish blue or greyish green on lower face
4

3a Leaf apex bluntly pointed, usually distinctly bevelled, cone scales lightly cupped or flattish, apex of scales spreading or recurved
P. brachytyla

3b Leaf apex pointed, not distinctly bevelled, cone scales cupped, rounded, tightly pressed down in immature cone
P. farreri

4a Cones glossy brown, scales semi-woody, rounded or bluntly pointed
P. spinulosa

4b Cones matt, purplish, ripening light brown, scales rhombic with a pointed apex, flexible
P. linzhiensis

5a Leaves mid to dark green above, flattened, few stomata or occasionally no stomata above, cones 2.5–5.5cm
P. purpurea

[6] Upper and lower are used in this key to denote the leaf surfaces as seen on a side branch. In *Picea*, these are the abaxial and adaxial faces respectively, as the leaf is twisted at the pulvinus. This is shown in the vascular bundle in the leaf by the orientation of the xylem (wood) and phloem (bark) tissues.

5b Leaves grey-green, bluish green or blue, cones (4.5–)6–12(–15)cm
6

6a Leaves blue or silvery blue, arrangement sparse on the shoot, shoot lightly hairy, cones (7–)9–12(–15)cm
P. likiangensis subsp. *likiangensis*

6b Leaves grey-green or bluish green, arrangement dense, appressed above the shoot, shoot densely hairy, cone (4.5–)6–9(–10)cm
P. likiangensis subsp. *balfouriana*

Acknowledgements
I would like to thank Michael Frankis, David Chamberlain, Hugh McAllister, Laurie Springate and Allen Coombes for comments on the text and the Keeper of the Natural History Museum London and the Curator of the Herbarium at the Royal Botanic Garden Edinburgh for access to their collections.

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