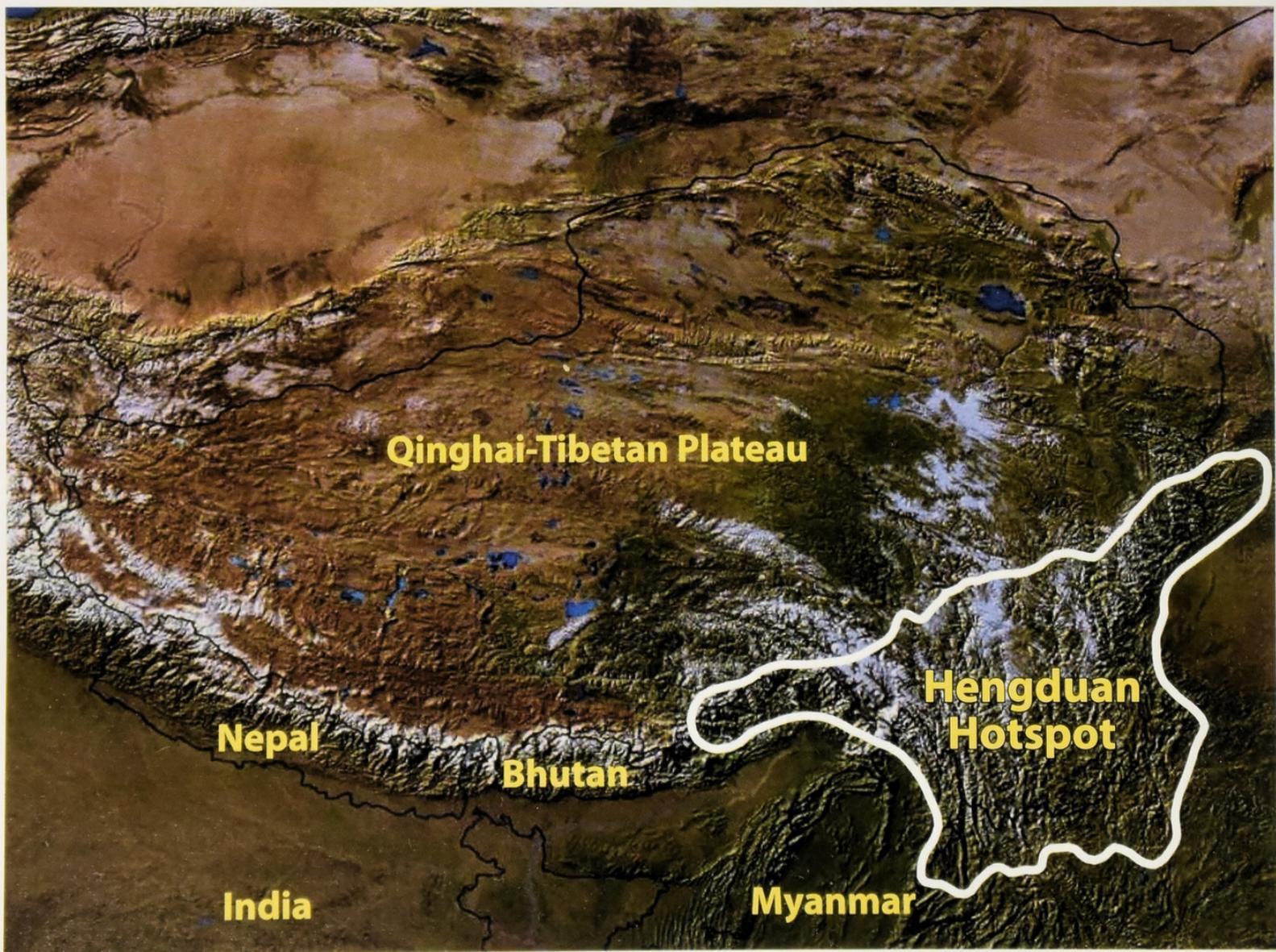


Biodiversity Hotspot: China's Hengduan Mountains

David E. Boufford

In southwestern China, in the southeastern corner of the Qinghai-Tibet Plateau, lies one of the world's 35 biodiversity hotspots: the Hengduan Mountains. This hotspot occurs at the juncture of mountain systems where precipitation can vary tremendously due to a combination of topography, climate, and hydrology. The terrain forms topographic channels that funnel seasonal monsoon rains up through the river valleys from the lowland tropics of south-

ern China, India, and Myanmar (Burma) to the southeastern edge of the 5,000-plus-meter-high (16,400-plus-feet) Qinghai-Tibet Plateau. The region also receives vast amounts of water from the five major rivers that drain the plateau: the Yarlung Zangbo Jiang (which becomes the Brahmaputra in India and the Jamuna in Bangladesh); the Ayayerwaddy (Irrawaddy); Nu Jiang (Salween); Lancang Jiang (Mekong); and Jinsha Jiang (known in the West as the Yangtze, and





Sichuan, Batang Xian. A glacial lake lies at about 4,500 meters (14,764 feet) on the south side of the pass at Haizi Shan, surrounded by a *Kobresia* (bog sedge) meadow and with scattered dwarf *Salix* and *Rhododendron* on nearby slopes.

What's a Biodiversity Hotspot?

As defined by Conservation International, to qualify as a biodiversity hotspot a region must meet two strict criteria:

- It must have at least 1,500 vascular plants as endemics, which is to say, it must have a high percentage of plant life found nowhere else on the planet. A hotspot, in other words, is irreplaceable.
- It must have 30% or less of its original natural vegetation. In other words, it must be threatened.
- Around the world, 35 areas qualify as hotspots. They represent just 2.3% of Earth's land surface, but they support more than half of the world's plant species as endemics—i.e., species found no place else—and nearly 43% of bird, mammal, reptile, and amphibian species as endemics. (<http://www.conservation.org/How/Pages/Hotspots.aspx>)

by several different names in China: Tongtian He in Tibet, Jinsha Jiang from Qinghai through Yunnan, and Chang Jiang from the point where it enters Sichuan from Yunnan). The Nu Jiang, Lancang Jiang, and Chang Jiang have carved deep gorges through the region, and in some places flow less than 70 kilometers (44 miles) apart. The Huang He (Yellow River), not included within the Hengduan area, flows northeast from the Qinghai-Tibet Plateau, but its source is just one mountain range north of the source of the Tongtian He/Jinsha Jiang/Chang Jiang/Yangtze.

Extreme topographic relief is a characteristic feature of the Hengduan region. Hutiaoxia (Tiger Leaping Gorge), the gorge of the Jinsha Jiang between Yulong Xueshan (Jade Dragon Snow Mountain) and Haba Xueshan (Haba Snow Mountain), is at an elevation of around 1,900 meters (6,234 feet). Haba Xueshan on the northwest side rises to 5,396 meters (17,703 feet) and Yulong Xueshan on the southeast side rises to 5,596 meters (18,360 feet). The peaks of the two mountains are 21 kilometers (13 miles) apart.

To the north and west, the hotspot is bounded by the high, dry Qinghai-Tibet Plateau. On the east, the Hengduan region drops precipitously from over 3,000 meters (9,843 feet) to the low, flat, Sichuan basin at about 600 meters (1,969 feet). The southern boundary in Yunnan is at the 2,000 meter (6,562 feet) level of the Yunnan plateau (Boufford and Van Dijk 2000). The average elevation in the easternmost part of the Hengduan region is over 3,000 meters (9,843 feet) and nearly 5,000 meters (16,400 feet) in the west. The highest peaks are Gongga Shan (7,556 meters [24,790 feet]) in Sichuan and Namjagbarwa (7,782 meters [25,530 feet]) at the western end of the hotspot in southeastern Xizang.



(Top) *Carpinus cordata*, *Pinus*, *Helwingia japonica*, and *Rhododendron augustinii* (in bloom) on a rock outcrop on Motianling Shan, Baishui Jiang Nature Reserve in Gansu Province. (Bottom) The flowers of *Rhododendron augustinii*.

VEGETATION

Within the hotspot are numerous vegetation types, each with its characteristic floristic associations. On the east and southeast, the vegetation comprises mixed broadleaved deciduous and evergreen forests with such characteristic plants of central China and the Sino-Japanese Floristic Region as *Cercidiphyllum*, *Tetra-*



Sichuan, Litang Xian. North of Litang between Litang and Xinlong. A broad ravine with numerous side seepages and both moist and dry upland meadows, featuring the tall, yellow-bracted floral spikes of *Rheum alexandrae* (a rhubarb relative) and yellow-flowered *Pedicularis longiflora* var. *tubiformis* in the foreground along the stream.

centron, *Acer* (maple—45 species!), *Aesculus* (buckeye), *Tilia* (linden), several genera within Lauraceae (the laurel family), *Meliosma*, *Phellodendron* (corktree), *Evodia*, *Cornus* (dogwood), *Ostryopsis*, *Carpinus* (hornbeam), *Ostrya* (hophornbeam), *Betula* (birch), *Quercus* (oak), *Lithocarpus*, *Fagus* (beech), *Elaeocarpus*, and *Ailanthus* (Boufford and Ohba 1998). In formerly glaciated valleys and on higher slopes, *Abies* (fir), *Picea* (spruce), *Betula* and other boreal plants intermix with vegetation generally considered to be warm-temperate. Full grown, well-formed oak and fir trees reach an elevation of around 4,600 meters (15,092 feet) in some places and intermix with alpine

meadows, scree slopes, and *Rhododendron* thickets. Herbaceous vegetation reaches to 6,000 meters (19,685 feet), although few plant specimens have been collected above 5,500 meters (18,045 feet).

The east and southeast portions of the Hengduan region are the best known, since they were easily reached by explorers and researchers coming up the Chang Jiang (Yangtze) or entering from Chengdu, about 100 kilometers (62 miles) away, or from Kunming. The forests on the eastern slopes also harbor some of the last surviving populations of giant panda, and China's best known and perhaps largest panda research station at Wolong Shan. About half

of the Hengduan region within Sichuan was originally forested; the other half is part of what in China is called the Chuan-Zang-Gaoyuan (Sichuan-Xizang Plateau) (Sichuan Vegetation Study Group 1980; Wu 1988). Emei Shan (Mt. Omei), well-known as a center of plant diversity and for its many temples, is the best known and most thoroughly documented site within the Hengduan Mountains (Li and Shi 2007).

Above 3,500 meters (11,483 feet) is a rich mixture of alpine meadows, scree slopes, cliff faces, marshes surrounding glacial lakes, and other vegetation types generally dominated by a highly diverse flora of herbaceous plants and shrubs (Zhang et al. 2008). These intermix with conifer forests of primarily fir, spruce, and juni-

pers in protected ravines and gorges. Rhododendron thickets are a conspicuous feature of the landscape, especially where Sichuan, Xizang, and Yunnan meet. They are best developed on sites protected from direct solar radiation, which can cause heating and drying of the soil, a phenomenon also noted on south-facing slopes in northern Myanmar (Burma) by Ward (1937). Alpine meadows, in the broad sense, typically dominated by species of *Kobresia* (bog sedges), are used for grazing throughout the region, particularly in the summer when herds of sheep, goats, and especially yaks are moved to higher elevations by the semi-nomadic Tibetan pastoralists. Most of the area is so heavily grazed that herbaceous plants survive only by growing



In Sichuan, just west of Gongya Xiang along the Serqu River. Three generations of Tibetan Buddhist pilgrims on a journey to Lhasa. At this point they were still 1410 kilometers (876 miles) from their destination with six months of walking to go.



Wang Qia photographing plants at Haizi Shan, an extensive cold, glaciated plateau with numerous lakes, ponds, and streams that often flow out of sight under the glacial debris.

up through the middle of shrubs, which offer some protection from the animals. The reason that so many herbarium specimens of herbaceous plants from these areas lack underground organs is because of the difficulty in extracting them from the middle of the coarse, frequently spiny shrubs in which they grow.

BIODIVERSITY

High diversity is generally associated with equitable, tropical climates. In contrast, the Hengduan region can experience snow, hail, freezing rain, and below freezing temperatures on any day of the year. Temperatures of -40°C (-40°F) and driving wind and snow are not unusual in the winter, yet plant diversity approaches that of the tropics. The vascular plant diversity is truly impressive, with as many as a third of China's vascular flora of 31,500 species growing just in the Hengduan regions. Of those, at least 3,500 species, including about 100 ferns and 20 gymnosperms, plus more than 30 genera of vascular plants, occur nowhere else in the world.

The diversity is also unusual in that a large proportion of species occur in relatively few, but characteristic, Hengduan genera: *Rhodo-*

dendron (226 species), *Pedicularis* (217), *Saussurea* (100+), *Ligularia* (70), *Cremanthodium* (38), *Anaphalis* (33), *Leontopodium* (25), *Artemisia* (55), *Gentiana* (117), *Primula* (113) *Saxifraga* (136), *Salix* (103), and *Corydalis* (89).

EARLY EXPLORATION

The first western explorers (and essentially the first naturalists) in the area were French missionaries who traveled to the remotest regions of China to convert the locals to Christianity (Kilpatrick 2014). Most were also trained in the natural sciences and were encouraged to collect and send specimens back to Paris. Among the most notable of these missionaries were Père Jean-Pierre-Armand David (1826–1900), the first westerner to send skins of the panda to Europe (in addition to many plant specimens); Père Jean Marie Delavay (1834–1895), who explored in western Yunnan and sent back thousands of plants specimens; Père Jean-Théodore Monbeig (1875–1914), who collected and was murdered in southeast Xizang; and Jean André Soulie (1858–1905), who collected in western Sichuan and southeast Xizang, where he, too, was murdered. The rich and varied collections

of so many unusual plants arriving in Paris, when distributed to other herbaria in Europe, prompted the nurseries and scientific institutions of the day to send their own collectors to gather seeds and living plants for the garden trade and for science.

Western plant explorers including Joseph Rock (1885–1969), George Forrest (1873–1932) and Ernest H. Wilson (1876–1930) visited parts of the Hengduan region, and Frank Kingdon-Ward touched its southern and western edges. From the 1920s to the 1940s, Chinese botanists including T. T. Yü (1908–1986), Ching Ren-Chang (1898–1986), K. M. Feng (1917–2007), C. W. Wang (1913–1987), W. P. Fang (1899–1983), and H. T. Tsai (1901–1981) made extensive collections along the southern and eastern edges of the area, but no comprehensive study of the entire region was undertaken until the Chinese Academy of Sciences organized a major multidisciplinary expedition to the area between 1973 and 1980. The findings from the expedition were published in *Vascular Plants of the Hengduan Mountains*, volumes 1 and 2 (Wang et al. 1993, 1994). Those two volumes provide detailed documentation on the plants of the area, not only those gathered on Chinese expeditions, but also specimens made by earlier Chinese and western collectors.

I and several colleagues have made numerous trips to document the biodiversity of the Hengduan region. Our own expeditions avoided areas where others had been, since the Harvard Herbaria are already richly represented by specimens from those areas. Instead, we focused on more remote regions and those that had been closed to the earlier explorers for various reasons.

THE FLORA

The Hengduan hotspot is botanically one of the richest temperate regions in the northern hemisphere. The high species diversity and endemism derives from the extremes of topography and climate, the island-like isolation of numerous high peaks and ridges, and the wide diversity of habitats they harbor. Broadleaved and coniferous forests, bamboo groves, scrub communities, savannas, meadows, prairies, freshwater wetlands, alpine scrubs, and scree slopes are among the broadly defined plant

communities there (Sichuan Vegetation Study Group 1980). Because of the complex local geomorphology, the north-south orientation of the mountains, and the huge vertical differences in topography, vertical zonation of the vegetation is also well developed (Zhang et al. 2008). Areas between 1,000 and 3,000 meters (3,281 and 9,843 feet) provided conditions for humid mixed evergreen-deciduous broadleaved forests, xeric river valley scrub, and sclerophyllous evergreen broadleaved forests, depending on slope and moisture conditions. The drier formations are often characterized by introduced *Opuntia* (a cactus genus) on cliffs along the dry river gorges, making them reminiscent of a West Texas landscape.

Between 3,000 and 4,000 meters (9,843 and 13,123 feet) are subalpine coniferous forests dominated by *Pinus densata*, *Picea likiangensis*, other species of *Picea*, and *Abies squamata*, as well as by deciduous broadleaved species of *Betula* (birch), *Populus* (poplar), *Acer* (maple), *Quercus* (oak), *Prunus* (cherry), *Tilia* (linden), *Fraxinus* (ash) and *Sorbus* (mountain ash). Above 3,800 meters (12,467 feet) are alpine scrub and alpine meadows dominated by Cyperaceae (sedge family) members, particularly *Kobresia* (bog sedge). The subalpine scrub vegetation is dominated by shrubs of *Rhododendron*, *Juniperus*, *Caragana* (peashrub), *Artemisia*, *Salix* (willow), and a complex number of forms of *Dasiphora* (syn. *Potentilla*) *fruticosa* and *D. glabra*. Species of *Kobresia*, *Arenaria* (sandwort), *Bistorta*, *Aster*, *Saussurea*, *Pedicularis* (lousewort), various Apiaceae (carrot family), *Primula* (primrose), *Allium* (onion), *Cyananthus*, *Corydalis*, *Astragalus*, *Hedysarum* and *Oxytropis* dominate the alpine meadows.

On steep slopes at 4,500 meters (14,764 feet), the alpine scrub and meadows are replaced by alpine scree vegetation or by stony soils that provide habitat for numerous interesting endemic species of *Saussurea*, *Corydalis*, *Solms-laubachia* and other Brassicaceae (mustard family), and *Meconopsis* (a genus in the poppy family), or by high cold grasslands or high cold desert meadows where the major species are members of *Stipa*, *Kobresia*, *Carex*, *Arenaria*, *Bistorta* and *Artemisia*. The photos on the following pages provide just a small sample of the floristic richness of this unique and fascinating region.

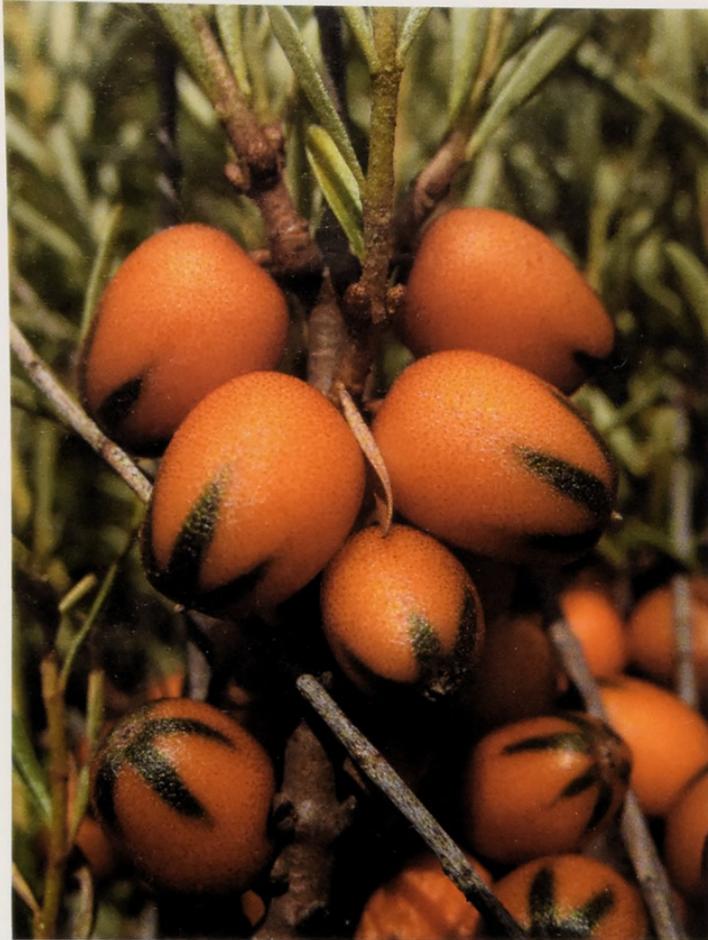


Sichuan, Baiyu Xian, Zhandu Xiang. Mixed conifer-mixed broadleaved deciduous forests, with *Salix* (willow) growing near the stream, along a branch of the Ou Qu in Ase Gou (Ase Gorge).

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WOODY PLANTS

A few of the woody plants of the Hengduan region, clockwise from upper left:

- The orange fruits of Tibetan sea-buckthorn (*Hippophae tibetana*).
- Immature cone of Prince Rupprecht larch (*Larix gmelinii* var. *principis-rupprechtii*).
- Flowers of *Clematis rehderiana*, named in honor of Alfred Rehder.
- Flowers of *Dipelta wenzianensis*.
- Young leaves of the shrub *Helwingia japonica* var. *papillosa*, which are cooked in oil with chopped garlic and eaten as a green vegetable.
- Fruits of *Eleutherococcus cissifolius*, a shrub in the aralia family (Araliaceae).



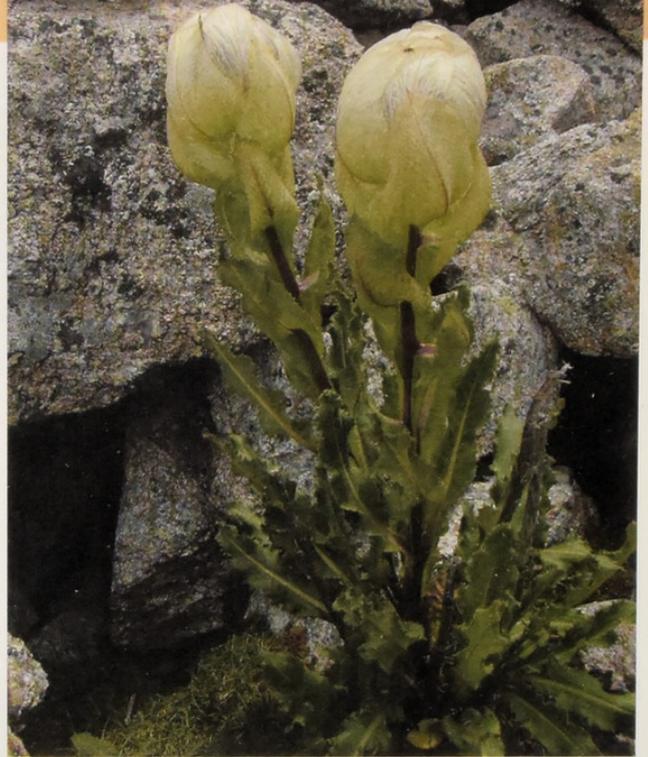


GENTIANACEAE

Gentians (*Gentiana*) and their relatives, notable for blue flower color, are characteristic of the Hengduan flora. Of the 248 species of *Gentiana* in China, 117 occur in the Hengduan region. Clockwise from upper left:

- *Gentianopsis contorta*
- *Gentiana crassicaulis*
- *Lomatogonium perenne*
- *Gentiana aristata*
- *Comastoma falcatum*
- *Gentiana atuntsiensis*





ASTERACEAE

The Asteraceae (aster or composite family) is another diverse plant group in the Hengduan region. *Saussurea*, *Ligularia*, *Cremanthodium*, *Anaphalis*, and *Leontopodium* (edelweiss) are among the most species-rich genera in the Hengduan region. Clockwise from upper left:

- *Saussurea stella* displays showy purple leaf bases.
- *Saussurea obvallata* has translucent bracts that form a protective globe around the small purple flowers within.
- These *Anaphalis* inflorescences feature pearly white bracts.
- *Cremanthodium humile* growing on a scree slope.
- The foliage of *Saussurea pilinophylla* is densely covered with soft hairs.
- Because it grows at elevations as high as 5,000 meters (16,404 feet), *Rhodiola crenulata* is believed to have special medicinal properties and is being extirpated by herb collectors throughout its range.





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