

## Nature Around the ALMA Site – Part 2

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The natural environment around the ALMA site, its flora, fauna and landscape morphology, are presented and interpreted in terms of combined geological and climatic evolution with, in parallel, the necessary biological adaptations. This part covers vegetation and animal life.

### The vegetation belts

The vegetation belts contain plant associations adapted to a given range of atmospheric parameters, soil composition and texture. A recent phytosociological survey by Richter (2003) provides vegetation transects in the ALMA area, namely at Sairecabur, Toco Toco and Miñiques (Figure 1). On the western slopes of Toco Toco, all belts are present, because the rocks are old enough to have been altered into sand and clay, and hence are able to retain water.

At the lowest level, 2900–3350 m, the limiting factors are the scarcity of precipitation, the high evapotranspiration and the salt and nitrate content in the soil. *Atriplex* communities – tall greyish bushes – develop on the shore of the Atacama Salar in salt rich soils. On undisturbed rocky places, the cactus *Maihueniopsis camachoii* forms colonies of spiny pillows (Figure 2), among several other plants. In wind shadow places, the tall cactus *Trichocereus atacamensis*, an invader from Argentina, grows.

At higher altitudes, evapotranspiration becomes the dominant factor. The efficiency of the evaporation increases with the square of the wind velocity. Low humidity and high wind velocity favour high rates of water loss by the plant epiderm. Several techniques are developed by plants to reduce these losses.

In the second vegetation zone, 3350–3850 m, is found *Fabiana bryoides*, with leaves reduced to minute rosettes, forming a compact cover on the stem, mimicking coral branches (Figure 3). In the same zone, *Fabiana denudata* represents an extreme case: its leaves are

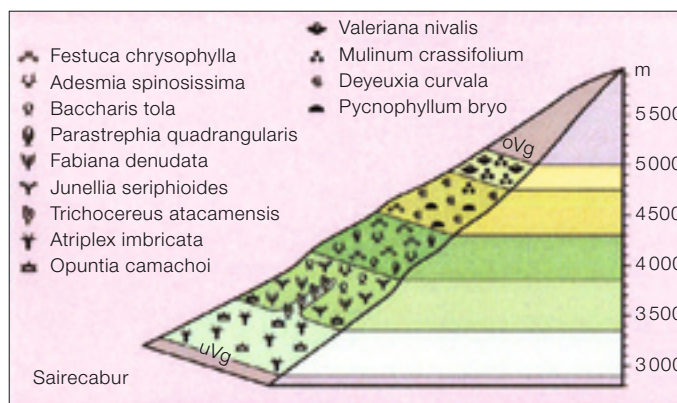


Figure 1: The vegetation belts as described by Richter (2003) on the slopes of Sairecabur volcano, NW of ALMA, with indication of characteristic plants.



Figure 2: The *Maihueniopsis* pillows show the effect of the katabatic winds. The side exposed to the cold flow is redder, an indication of a higher content in anthocyanine, a molecule acting as anti-freeze.



Figure 3: Thanks to the reduction of the leaf size, *Fabiana bryoides* resists desiccating winds and may grow up to 4900 m.

suppressed and photosynthesis takes place at the upper stem surface. The whole plant is varnished with a viscous resin. In other plants, such as some Senecios, the water losses are minimised through the development of a white tomentum of dense crispy hairs, reflecting the solar radiation and setting the wind velocity to zero at the epiderm surface.

In the zone 3850–4300 m, the vegetation becomes scarce and the graminaceae herbs are dominant. The golden *Festuca chrysophylla* gives the landscape its colour and specific character (Figure 4). Behind the tufts of *Festuca*, in the wind shadow, several plant species may develop. *Parastrephia quadrangularis* is another typical plant with leaves reduced

to scales, covering the stem as tiles. The association of *Festuca*, *Parastrephia* and *Baccharis* provides the preferred pasture of *guanacos* and *vicuñas* (Figure 5).

The high-altitude vegetation

In the zone 4 350 m to 4 850–5 150 m, the wind intensity, the eolian erosion and the temperature are the limiting factors for vegetation. On flat surfaces, plants have to minimise their cross section with respect to the thermal and zonal winds. To expand horizontally is a frequently encountered adaptation, e.g. by *Pycnophyllum bryoides* (Figure 6) and by the *Calyceras* genus (Figure 7). This strategy is also adopted by some dwarf trees as *Adesmia* sp., which develops an underground stem and branch systems extending well below the surface. Leaves are covered with hygroscopic glanduliferous hairs able to absorb directly the humidity from the air.

In rocky places, plants may develop provided the soil is evolved. Fresh lava or lapilli cannot retain water close to the surface and several centuries of weathering are needed before the first plant colony may settle. On older substrates, such as at Toco Toco, plants use rock cracks, at wind shadow, to expand their roots in clay, searching for residual humidity. *Nototriche holosericea* and *Chaetanthera revoluta* (Figure 9), and *Oxalis* sp. (Figure 10), are typical examples of this behaviour.

In small valleys oriented NS, perpendicular to the afternoon and zonal winds, the soil and plant evaporation is noticeably reduced. Snow may accumulate during winter and stay until the next blossoming season. Plant communities requiring less protection against evapotranspiration may develop up to very high altitudes, as the *Werneria-Senecio* association, consisting of a dozen different species. Around ALMA, this association is characterised by the presence of *Werneria poposa* and *Valeriana nivalis* (Figure 11). In these sites, the limiting factor is the temperature, which reduces the duration of the vegetation period to nearly zero above 4 850–4 900 m.



Figure 4: *Festuca chrysophylla* forms large populations giving a golden aspect to the landscape at altitudes where most bushes, except *Parastrephia*, have disappeared.



Figure 5: *Vicuñas* in the altoandine steppe near Maricunga Salar, 3 800 m.



Figure 6 (below): *Pycnophyllum bryoides* expands as rings on flat gravel surfaces (left). Leaves are reduced to ovoid cones (right), petals are translucent, and so the plant offers a minimum surface to desiccating winds.



Figure 7 (above): In *Calyceras* genus, the hemispherical head of green flowers is the only part emerging above ground level (Laguna Miscanti, 4 000 m).

Figure 9 (below): In *Nototriche holosericea* (left) leaves are undulated and cerebriform; the surface available for gas exchanges exposed to the wind is manyfold. A white indumentum protects the leaf from transpiration and UV radiation. *Chaetanthera revoluta* flowers (right) open on top of 1 cm long cones, covered by hairy leaves (Llano de Pajonales, 4 410 m).

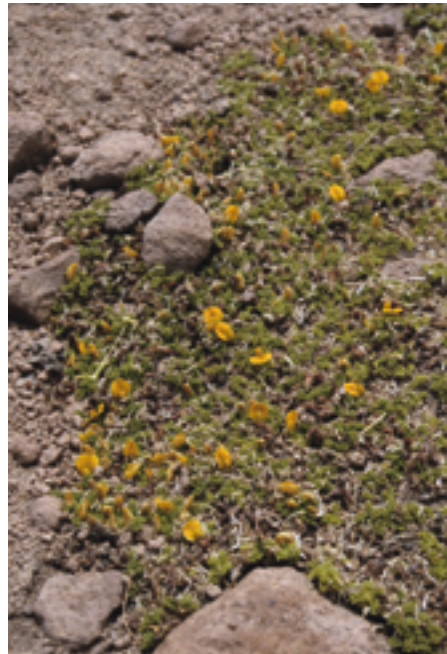


Figure 8: This *Adesmia* sp. is an underground dwarf tree. Strong spines prevent grazing by *viscachas* or *vicuñas* (Toco Toco, 4 500 m).



Figure 10: This *Oxalis* sp. expands along narrow cracks, in sunny places, at Toco Toco, 4 400 m.

Figure 11: *Werneria poposa* (left) grows in wet and wind-shadow rocky places, close to *Valeriana nivalis* (right), a rather common plant reaching the upper limit of the vegetation; its thick root is strongly aromatic, reminiscent of the Celtic Nard (N of Toco Toco, 4520 m).



Figure 13: *Calceolaria stellariifolia* is a rare plant found between 4000 and 4300 m around ALMA. Its geographical distribution shows a typical area disjunction consequent on the postglacial climate warming.



Figure 12: Four representative plants at the vegetation limit in humid places at Cerro Toco Toco. Top left: *Calandrinia* sp.; top right: *Menonvillea* sp. (4820 m); lower left: *Perezia atacamensis* (4700 m); lower right: *Werneria pinnatifida* (4700 m).

A notable character of the high-altitude flowers is the restriction of their colour range. They look unattractive to the human eye: blue, orange, red colours are no longer present. Most flowers are white, yellowish or at best bright yellow (Figure 12). With a very low ground coverage, plants appear to rely more on petal UV-reflectivity, (increasing the contrast between the flowers and the

ground), than on bright colours, in order to attract hymenopter pollinators whose eyes, or ocelli, are sensitive down to UV-B radiation.

The present geographical distribution of high Andes plants reflects the restriction of areas consequent on the climate warming after the Ice Age. Intermediate altitude plant communities had to move up by about 1 km, migrating towards the altiplano on gentle slopes east of the Atacama Desert core, or towards the top of isolated mountain ranges. Those already growing on the altiplano during the Ice Age are found presently on isolated peaks, close to the upper vegeta-

tion limit. As a result, the areas occupied by high Andian plants are now disjunct. An example of severe area restriction is that of *Calceolaria stellariifolia* (Figure 13), found in only half a dozen sites, spread over 1500 km in the high Andes. When isolated, plants may follow divergent genetic evolution, they have no chance to merge their genes again before the next glaciation.

Plants reaching the maximum altitude around ALMA belong to the *Senecio* genus. *Senecio Puchii* is frequently seen up to 4750 m. *Senecio aff. algens* (Figure 14), replaces it at higher altitude, in sunny places between 4850 and 5150 m.

### Hot springs and high altitude vegas

Wet biotopes are due either to hot springs in hydrothermal fields as at El Tatio, or to the development of high altitude vegas, the southern counterpart of peat bog in the Northern Hemisphere. In the Andes, the bog is made up of a very compact plant interlacing, where the Juncaceae *Oxychloe andina* plays a central role (Figure 15). Water pools are resting places for many birds, including the large andine goose, as well as for migrating birds, transporting seeds from one vega to the next. The vega vegetation is hence very uniform along the Andes. Hot springs host highly specialised life forms, adapted both to high soil temperature and high mineral content, such as *Frankenia triandra* (Figure 16), widespread over 1200 km in the Central Andes.

### Many more adaptations

Not only plants, but also wildlife, show surprising adaptations to the extreme arid and cold conditions prevailing in North East Chile. As an example, a group of reptiles from the Iguanidae family, the genus *Liolaemus*, has evolved in parallel to plants, into an incredible number of species and varieties, able to colonise nearly all biotopes from the margin of the absolute desert up to the upper vegetation limit. As insects are often uncommon, they had to become omnivorous, some totally vegetarian. At high altitude, they are adapted to absorb the solar radiation, and hence able to move even if the external temperature is well below 0°C. The specimen shown in Figure 17 is an extreme case of this kind of adaptation.

### ... and final remarks

After this quick overview of the ALMA site natural history and climate, and of some of the adaptations imposed on life – at the cost of massive extinction – we may appreciate even more the apparent paradox that scientists had to put the ALMA complex at the upper limit for evolved terrestrial life, to be in a good position to search for molecules in space, progenitors of terrestrial and extraterrestrial life. We may simply regret that, thanks to ser-



Figure 15: High andine vegas are formed of compact material, strong enough to resist the weight of vicuñas or even llamas (Chungara, 4500 m).

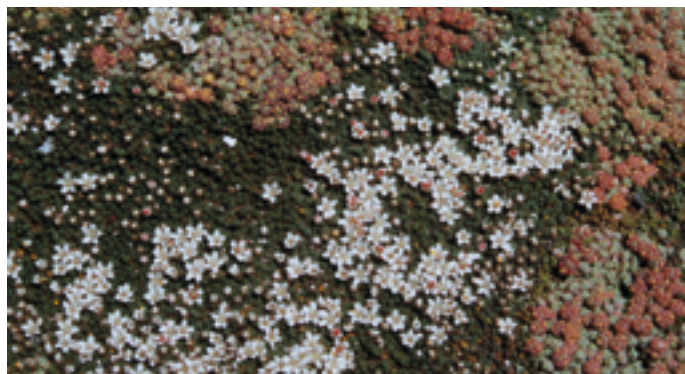


Figure 16: *Frankenia triandra* grows on warm bumps in the immediate vicinity of hot springs (El Tatio geyser, 4350 m).



Figure 17: This *Liolaemus* sp. lizard is perfectly mimetic with the rocky environment. Able to absorb the solar radiation, it may start hunting in the early morning when the air temperature is still -25°C (Laguna Verde, East of Copiapo, 4500 m).

vice observations, very few observers will have the opportunity to visit and enjoy the unique natural surroundings of Chajnantor, even if *Homo sapiens* is still not yet perfectly tuned to activities above 5000 m. A more serious concern is the expected final extinction of a large fraction of the high-altitude species as a result of the global warming during the XXIst century. A local warming by about +3.5°C would increase the vegetation belts altitude by 500 to 600 m.

All meteorological, climatic and biological indicators converge to qualify the Chajnantor site as the best possible for milli-

metre and submillimetre astronomy by the end of the XXth century. Whether its exceptional qualities will be preserved through the XXIst century, depends on the amplitude of the climate change and the evolution of precipitation patterns in the area. Most Global Circulation Models (GCM) predict an aridification of the Atacama area, but an increase of wetness and precipitation on the eastern side of the Andes.

### Reference

Richter M. 2003, *Lyonia* 4(1), 1