Bull. Soc. linn. Provence, t. 47, 1996
ISSN 0373-0875 – Date de parution : 18.09.1996

Delimitation of the supra–forest zone in the Catalan Pyrenees [1]

by J. CARRERAS, E. CARRILLO, R. M. MASALLES, J. M. NINOT, I. SORIANO and J. VIGO

Dept. Biologia vegetal, Univ. Barcelona. Av. Diagonal, 645, ES—08028 Barcelona, Spain.

Abstract

This paper summarizes a study concerning the establishment of the theoretical upper forest boundary, or timber–line, in the Catalan Pyrenees and Andorra, and the subsequent delimitation of its supra–forest zone. We take into account both general criteria on this topic — referring to Pyrenees and to similar ranges — and our own previous detailed knowledge of several sub–areas of the area concerned. The results, yielded through photo–interpretation, field work and data integration in the laboratory, consist of a set of 1: 50,000 scale maps, a reduction of which is shown in Fig. 2. Subsequently, some general conclusions concerning the timber–line location in the area studied and the phyto–geographical interpretation of its altitude fluctuations end the work.

Key words
Mountain vegetation, Timber–line, Alpine belt, Pyrenees.

Résumé

Délimitation de la zone supraforestière dans les Pyrénées catalanes.
Ce travail a pour objet la localisation de la limite supérieure naturelle des forêts dans les Pyrénées de la Catalogne et l'Andorre, c'est–à–dire, d'y délimiter la zone supraforestière.
Nous nous sommes basés sur des renseignements généraux concernant les Pyrénées— et d'autres chaînes analogues— et de notre connaissance directe de diverses contrées pyrénéennes. Au moyen de l'interprétation des photographies aériennes, des recherces de terrain et de l'intégration finale des données, nous avons porté les résultats sur une carte à l'échelle 1/50.000, dont nous présentons ici une image réduite (figure 2). Nous faisons des commentaires généraux ainsi que quelques remarques à propos de la limite supérieure de la forêt et l'interprétation géobotanique des fluctuations qu'elle subit dans le territoire étudié.

Mots clés
Végétation de montagne, limite supérieure de la forêt, étage alpin, Pyrénées.

1 This study was partially supported by the Spanish D.G.I.C.Y.T. projects PB84-742, PB87-0160, PB90-0059 and PB92-0547.

Resumo

Limdifino de la supra arbarzono en la Kataluniaj Pireneoj.
Tiu laborajo celas loki la naturan supran limon de la arbaroj de la Kataluniaj k Andoraj Pireneoj, t.e. tie limdifini la supran arbarzonon.
Ni baziĝis sur ĝeneralaj informoj pri Pireneoj — k aliaj analogaj montaroj— k sur niaj propraj scioj pri diversaj Pireneaj regionoj. Per la interpreto de aviadilaj fotografajoj, surterenaj esploroj k fina kunordigado de donitajoj, ni surskribis la rezultojn sur mapon je la skalo 1/50 000, ĉi–tie prezentitan sub reduktita formo (figuro 2).
Ni faras ĝeneralajn komentojn k kelkajn rimarkojn pri la supra arbarlimo k pri la geobotanika interpreto de ties fluktuoj en la studita teritorio.

Ŝlosilvortoj
Arbara vegetajaro, supra arbarlimo, alpa etaĝo, Pireneoj.

1. Introduction

In most of the large mountain ranges of the world — excluding those located in arctic or in sub–desert zones — the landscape is formed by some lower or medium levels containing forest formations (forest belts) and a higher zone not suitable for colonization by dense, extensive forests. This zone is the potential natural area of pastures and other non–forest vegetation, and is formed by the supra–forest belts.

In the main ranges of the temperate zone of central and south Europe —called Alpine ranges, because they fit the theoretical model of the Alps — a sub–alpine (or higher forest) and an alpine (supra–forest) belt have been traditionally distinguished among others. The sub–alpine belt is originally covered by needle–leaved formations and the alpine belt roughly corresponds to the zone of natural pastures. In these ranges the (theoretical) upper limit of the forests coincides, by definition, with the boundary between the sub–alpine and the alpine belts, also called the timber–line.

The occurrence of an alpine belt and the location of its lower limits, are explained by particular climatic conditions. In mountains climatic parameters mainly depend on the altitude, and so any range should show a clear, fixed upper forest boundary, where natural forests could reach. However, at the same altitude the climate can be modified by physiographic site factors such as slope aspect and protection or degree of exposure to winds. Moreover, the absence of forests may be locally due to special features of the substratum (too little soil in rocky areas, or sliding movements of surface formation). Therefore, the forest upper boundary does not stand generally at a uniform altitude; it varies according to local conditions of climate, physiography and substratum. This limit is lower in the alpine cirques and depressions (alpine belt of nival character), where the more persistent snow cover shortens the growing period; it rises in the sunny slopes (alpine belt of thermal character) provided that the snow cover remains quite regularly; it falls under areas of cliffs and screes, etc.

The boundary between alpine and sub–alpine levels may be clearly defined, or, more frequently, it is a transition area where the forest shows small vitality and very slow dynamics, the trees being more and more short, irregular and disperse («Kampfzone» or struggle zone). Yet above the timber–line small groves of trees or isolated trees under local ecologic conditions may occur. Such forest «islands» (sub–alpine islands) are considered here as a part of the alpine or supra–forest belt. Similarly, sometimes in the sub–alpine belt unfavourable local conditions can prevent the establishment of forests (for example, in low snow beds). These isolated areas appear as non–forested spots in the woody sub–alpine belt (alpine glades).

2. Aims

The delimitation of the natural supra–forest zone is of great scientific concern, and is also of outstanding practical interest, mainly as regards land management and its regulations. Some years ago the regional government of Catalonia (Generalitat de Catalunya, Dept. de Política Territorial) commis-

sioned the authors to establish the boundary of the natural supra–forest zone within the territory under its rule. In this paper, we briefly report the procedure followed and present the results, which are summarized in the map provided (Fig. 2). In the interests of biogeographical consistency, we have included Andorra in the study.

The object of our study was to delimit the natural lower boundary of the supra–forest zone, or timber–line, on a 1 : 50,000 scale map, taking into account the present evidence of the limit between forest and natural alpine belt, and a detailed analysis of the vegetation. The overall picture offered by the results has allowed us to present some general conclusions concerning the factors that control this boundary and the trends it follows within the area studied.

3. Previous premises

3.1. Some general ideas

Before adopting working criteria, we examined the current knowledge of the present location of the upper border of the forests in the european mountains, particularly in the Pyrenees. This knowledge includes concepts discussed at length and already fairly widely accepted (see, among others, GAUSSEN 1926, BRAUN–BLANQUET 1948, Bolòs 1966, WALTER and BRECKLE 1986 and SOUTADÉ, BAUDIÈRE and BÉCAT 1982).

The establishment of the uppermost boundary of the forest would be merely a matter of direct recognition in the field if the landscape remained unaltered or had only been conditioned by natural fluctuations since the last glacial pulsation. Yet obviously the pyrenean landscape has been greatly influenced by human activity. In spite of the fact that man has never effectively settled on the high altitudes of the Pyrenees, land management has clearly affected the timber–line. Forest and pasture have since ancient times been the pillars of the pyrenaean cultures. Economic interests and the effects of the management (suitable or not) of natural resources have led to policies which have aided the maintenance of forests and others which have brought about their recession and even their removal.

In its higher spread, the sub–alpine forest experiences very extreme subsisting conditions, and is thus highly vulnerable; any injury or limiting action may cause it to disappear. When extinct, the forest can only recover — in the absence of any disturbance — over a period of many years. This process can easily exceed a historic time scale, chiefly because of edaphic limitations. Today, due to the fragility of the forest ecosystem, and to the fact that for centuries the powerful stockbreeding interests in the pyrenean traditional land management have caused the area of pastures to spread, higher sub–alpine forests have been largely destroyed. Moreover, for several millenia wild herbivores — and then prehistoric man and his cattle — may have disturbed the natural sub–alpine forest dynamics. In this time scale, it can be supposed that the forest upraising in altitude since the last glacial period has been broadly conditioned by these factors, and indeed in certain parts, completely wiped out.

Therefore, as a general rule it can be accepted that only in a few and small areas the uppermost forest level has remained intact. In most cases cutting, fire and grazing pressure have reduced the former woods and, thus, the boundary of the sub–alpine forests normally runs at lower altitudes than in pre–human landscapes, or those that would be reached if anthropogenic pressure were to disappear. The depletion of the forest above certain levels has allowed alpine–like pastures to settle on the deforested land (pseudoalpine zone). In spite of their physiognomy, the structure and species composition of these pastures reveal their secondary origin fairly clearly.

3.2. Criteria

The ideas put forward in 3.1, added to our own experience and thorough knowledge of the vegetation of several pyrenean areas, gave us the basis for outlining the theoretical natural border of the supra–forest zone. As general rules we took into account:

– The present uppermost limit of sub–alpine forests cannot be considered a natural limit everywhere.

– Small stands of forest or isolated trees do not necessarily show any evidence of ancient continuous woodlands. In some places, the presence of isolated trees is due to a local anomalous ecological situation.

– In long snow–covered places because of topographic local factors, the tree–line runs lower than

general factors would suggest (i.e., altitude, general exposure,...).

– Isolated peaks and watercrests have a particular topoclimate which is unfavourable to forest development.

– The presence of shrublands analogous to the undergrowth of sub–alpine forests is not necessarily evidence of the forestry character of the area.

– As in all alpine ranges, in the Pyrenees the border is expected to be higher in internal valleys with a continental climate than in external zones or in isolated massifs, whose climate has atlantic influence.

4. Method

The project consisted of the following parts:

a. Search for the present upper limit of forests along Catalan Pyrenees by means of photo–interpretation (from aerial photographs taken by CEFTA, in 1978–79, scale 1: 18,000) and transfer of these results on a topographic map, scale 1: 50,000. This limit was only drawn when over the altitude of 1800 m a.s.l.; at lower altitudes, as was already clear from previous studies and confirmed through initial field work, the limit is in any case a natural border.

b. Re–drawing of the limit according to the criteria defined before and on the basis of our previous vegetation study of several areas along the range.

c. Field work, in order to prove the hypothesis assumed *a priori*, to have a direct survey of the areas less known and to analyze the delimitations which were unclear. This last aspect involved analysis *in situ* of the ecologic and dynamic meaning of the present communities.

d. Establishment of the definitive theoretical natural limit as a synthesis of the data yielded and of previous knowledge.

e. Digitation and transformation of the limit into a coverage of ARC–INFO G.I.S., for calculation of the sub–areas detailed in the following paragraph.

5. Results

a. The main results of this study are summarized on the map in Figure 2, which contains both the present upper forestry limit and the theoretical natural one. This map, here at the approximate scale 1: 300,000, is a reduced version of the 1: 50,000 scale maps which we formerly made. The present limit of the forest is represented by the dashed line bordered below by a dotted area. The solid line located higher (locally coincident) indicates the theoretical border; it encloses the supra–forest surfaces of the study area, which are shaded with dashes.

b. In the area concerned, the total surface occupied by the supra–forest belts amounts 734.5560 km^2 — 593.0417 in Catalonia and 141.5143 in Andorra. We break down the supra–forest area into the following groups and subgroups, according to the altitude where the timber–line stands, the extension of the supra–forest area enclosed and other physiographic factors.

b.1. In the south–eastern sector, between Costabona peak and Port del Compte, a supra–forest area of 83.2355 km^2 can be estimated. It includes six detached areas:

b.1.1. Axial range between Costabona peak (2464 m a.s.l.) and Les Salines plateau. The tops generally reach between 2600 and 2800 m in altitude, Puigmal (2909 m) being the highest. The supra–forest surface amounts to 49.5264 km^2. The forest border usually ranges from 2300 to 2400 m, although in some depressions snow–covered for a very long time it can drop down to 2000 m or even lower.

b.1.2. Puigllançada (2409 m) and La Tossa d'Alp massifs, with 3.2435 km^2 of supra–forest area. The wood limit comes to 2300 m, but on steep slopes it does not exceed 2100 m because of the lack of suitable soils.

b.1.3. Cadí range. The crest line repeatedly exceeds 2500 m, and reaches its highest point at the Canal Baridana peak (2648 m). It has 23.7267 km^2 of supra–forest surface. On the south–facing slope the timber–line seems to stand at about 2300 m, while on the north–facing aspect, the massive occurrence of cliffs and screes stops the woods at altitudes generally between 1900 and 2200 m.

b.1.4. Pedraforca (2497 m). A 1.3840 km^2 supra–forest area. The imposing rocky mass shaping the upper part of this massif prevents the forest from settling on areas higher than 1700–2200 m, depending on the degree of rockiness.

b.1.5. Serra d'Ensija (summit at 2307 m). 1.5199 km^2 of supra–forest surface. The somewhat isolated location of this small massif causes the forest boundary to stand at about 2250–2300 m. In

its steepest aspect, the woods do not exceed 2050 m for physiographic reasons.

b.1.6. Port del Comte (2386 m at the highest point). A supra-forest area of 3.8351 km^2. It is also a somewhat isolated massif, mainly of gentle contours. The timber-line ranges between 2200 and 2300 m.

b.2. A central sector stretches from the Puigpedrós massif to the western border of Aran valley. Its supra-forest area amounts to about 652.3205 km^2, and can be distributed into the following sub-areas:

b.2.1. Orri massif (2440 m). With 3.1815 km^2 of supra-forest surface, it is the sole sub-area in this sector clearly detached from the others. As in the other isolated massifs, the timber-line stands rather low, ranging from 2200 to 2300 m and locally falling to 2100 m a.s.l. The relatively high snow cover may also influence this low forest border.

b.2.2. Cerdanya and eastern Alt Urgell, in the main range. Most of the peaks reach about 2800 m a.s.l., and two of them exceed 2900 m (Tossa Plana de Lles, 2916 m, and Puigpedrós, 2911 m). The supra-forest surface is 42.5550 km^2. The climate of this area, somewhat continental, allows the forest to reach very high altitudes, between 2300 and 2500 m.

b.2.3. Andorra and Pallars (and western Alt Urgell). Most of the summits are about 2800-2900 m high, some of them reaching higher than 3000 m a.s.l. (Pica d'Estats, 3143 m, etc.). The supra-forest area amounts to 389.0837 km^2, and lies in the most continental zone of the Pyrenees, as are Cerdanya and Alt Urgell. The timber-line on most of the slopes stands between 2200 and 2400 m. But as this sub-area is vast and diverse, the forest can locally stop at 2100 m or, in contrast, climb up to about 2500 m, as occurs on some slopes of Espot valley.

b.2.4. Aran valley. The altitude of the higher peaks ranges from 2500 to 2800 m a.s.l., but the Besiberri, in the south border, reaches 3014 m. The supra-forest area is 129.3603 km^2, and the climate is quite atlantic. The boundary of the forest stands mainly between 2100 and 2300 m, although locally it falls to 1950 m or rises up to some 2400 (in the high part, under less oceanic trends).

b.2.5. Alta Ribagorça, with the higher summits between 2700 and 2900 m high and some exceeding 3000 m (Comaloforno, 3030 m, etc.). It has a supra-forest surface of 87.1399 km^2. The continental climate weakens from East to West. The timber-line runs normally between 2200 and 2400 m, reaching about 2500 m on some slopes of eastern Boí valley.

6. Conclusions

a. The hypothesis that the natural upper limit of the forest only coincides with the present limit in a few cases is clearly corroborated.

b. This theoretical border experiences natural and regular variations in space, which are mainly related to:

- The aspect of the slopes (north-facing / south-facing effect), the north-facing ones showing a drop in the timber-line.
- The thickness and the span of the snow cover, features related to the aspect of the slopes and regime of strong, constant winds. As a general rule, the forest boundary remains markedly low in depressions and cirques on north-facing aspects and rises perceptibly on sunny, south-facing slopes.
- The soil and bedrock features. In the most evident cases, the areas with rocky substrate or with poorly developed soil show low timber-lines.

c. The influence of both the mesoclimate (more oceanic or more continental) and the particular topoclimates (in isolated peaks, windy crests, thermal slopes, etc.) modify the expected situation of the forest border, as formerly commented by several authors.

d. As a general rule, *Pinus uncinata* Ramond ex DC. is the tree which makes up the uppermost forests on any aspect, with very few exceptions. However, in the most rainy and snowy areas of the range — as in the north-western part of the Aran valley — the sub-alpine needle-leaved forest is sometimes surpassed by a hygrophylous deciduous forest or thicket (with *Betula pubescens* Ehrh., *B.pendula* Roth, *Sorbus aucuparia* L.,...), which represent the highest woody vegetation. Moreover, on some north-facing slopes of the same area *Abies alba* Mill. seems to end upwards the forest vegetation, and the same occurs with *Pinus sylvestris* L. on south-facing aspects, coinciding with the lowering effect of the oceanic trend on the timber-line.

e. In general, the upper sub-alpine limit of pyrenean forests can be established at the altitudes detailed above; the intervals given for each case correspond to the variations due to topoclimate, mainly to the differences between north-facing and south-facing aspects and to depression and convexity locations respectively:

- 2100-2350 m a.s.l. in the eastern part of the range, strongly influenced by the proximity of the

sea (high Ter valley, eastern part of Serra de Cadí,...).

– 2300–2400 m in the inner valleys of eastern Pyrenees, under more or less continental climate (Freser valley, Cerdanya, Alt Urgell, Andorra).

– 2350–2500 m in the most internal valleys of central Pyrenees, strongly continental (Pallars, high part of Aran valley, ...).

– 2150–2350 m in subatlantic areas of central Pyrenees, more influenced by the maritime climate (central and medium parts of Aran valley, north–western part of Alta Ribagorça).

References

ARCHILOQUE, A., BOREL, L. and LAVAGNE, A., 1971.– La notion d'étage pseudo–alpin dans les Préalpes françaises méridionales. *Coll. Interd. Mil. Nat. Supra–for. Mont. Bass. Occ. Médit.*: 201–232.

BIROT, P., 1965.– *Les formations végétales du globe.* 508 pp. Sedes. Paris.

BOLÒS, O. DE, 1965.– Les étages de végétation dans les Pyrénées. *Ann. Féd. Pyr. Econ. Mont.*, **28**: 7–13.

BOLÒS, O. DE, 1979.– Els sòls i la vegetació dels Països Catalans. *Geografia física dels Països Catalans* (ed. by O. RIBA *et al.*): 107–158. Ketres. Barcelona.

BRAUN–BLANQUET, J., 1948.– *La végétation alpine des Pyrénées Orientales.* 306 pp. C.S.I.C. Barcelona.

BRAUN–BLANQUET, J., 1950.– La végétation de l'étage alpin des Pyrénées Orientales comparée à celle des Alpes. *Act. I Congr. Int. Est. Pir.*, **29**: 5–16. Zaragoza.

CARRERAS, J., 1993.– *Flora i vegetació de Sant Joan de l'Erm i de la vall de Santa Magdalena (Pirineus catalans).* 321 pp. Institut d'Estudis Ilerdencs. Lleida.

CARRERAS, J.; CARRILLO, E.; MASALLES, R.M.; NINOT, J.M. and VIGO, J., 1993.– El poblament vegetal de les valls de Barravés i de Castanesa. I—Flora i vegetació. *Acta Bot. Barc.*, **42**: 1–392.

CARRILLO, E. and NINOT, J.M., 1992.– *Flora i vegetació de les valls d'Espot i de Boí.* 474 + 350 pp. I.E.C. Arx. Sec. Cièn. 99/1 and 2. Barcelona.

FLAHAULT, CH., 1901.– Les limites supérieures de la végétation forestière et les prairies pseudo–alpines. *Rev. Eaux et Forêts*: **40**: 385–417.

GAUSSEN, H., 1926.– Végétation de la moitié orientale des Pyrénées. *Bull. Soc. Hist. Nat. Toulouse*, **55**: 4–564.

LABROUE, L. and LASCOMBES, G., 1970.– L'évolution de la végétation et des sols au Pic du Midi de Bigorre. L'étage alpin inférieur en versant Sud. *Bull. Soc. Hist. Nat. Toulouse*, **106**(1–2): 156–169.

LABROUE, L. and LASCOMBES, G., 1972.– L'évolution de la végétation et des sols au Pic du Midi de Bigorre (Hautes Pyrénées): l'étage alpin supérieur. *Bull. Soc. Hist. Nat. Toulouse*, **108**(1–2): 9–37.

PANAREDA, J.M., 1982.– Le passage des milieux forestières aux milieus supraforestiers et sa valeur de seuil dans le massif du Montseny (Chaîne pre–littorale catalane). *La limite supérieure de la forêt et sa valeur de seuil* (ed. by SOUTADÉ, G. *et al.*): 63–69. Terra Nostra. Prada de Conflent.

RAYNAL, R., 1982.– Le seuil supraforestier dans les montagnes méditerranéennes. *La limite supérieure de la forêt et sa valeur de seuil* (ed. by SOUTADÉ, G. *et al.*): 31–42. Terra Nostra. Prada de Conflent.

REFRAY, A., 1982.– De quelques aspects presentés par la limite supérieure de la fôret dans la zone temperée. *La limite supérieure de la forêt et sa valeur de seuil* (ed. by SOUTADÉ, G. *et al.*): 19–25. Terra Nostra. Prada de Conflent.

RICHARD, L., 1982.– Limites supérieures de la forêt et des arbres dans la vallée de Chamonix (Haute Savoie). *La limite supérieure de la forêt et sa valeur de seuil* (ed. by SOUTADÉ, G. *et al.*): 43–53. Terra Nostra. Prada de Conflent.

SOUTADÉ, G. and BAUDIÈRE, A., 1973.– Mutations phytogéographiques et variations climatiques durant l'Holocène dans les Pyrénées mediterranées françaises. *IX Congr. Int. INQUA*: 90–93.

SOUTADÉ, G.; BAUDIÈRE, A. and BÉCAT, J. (ed.), 1982.– *La limite supérieure de la forêt et sa valeur de seuil.* 174 pp. Terra Nostra. Prada de Conflent.

VIVES, J., 1964.– Vegetación de la alta cuenca del Cardener. *Acta Geobot. Barcin.*, **1**: 1–218.

WALTER, H. and BRECKLE, S., 1986.– *Ecological Systems of the Geobiosphere, vol. 3.* Berlin, Heidelberg, New York, Tokyo.

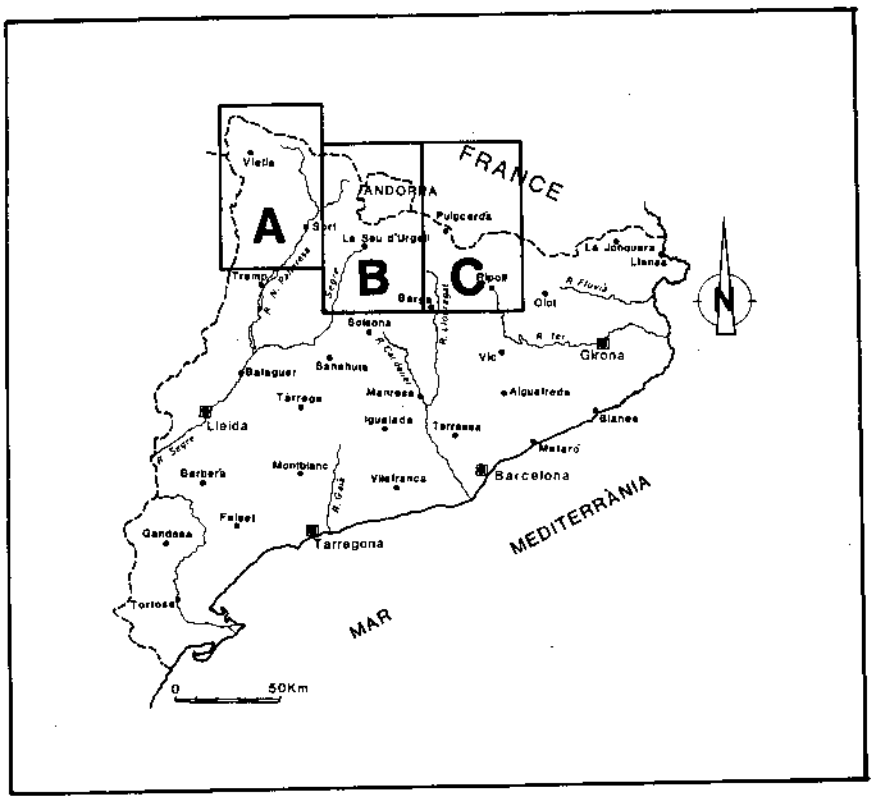
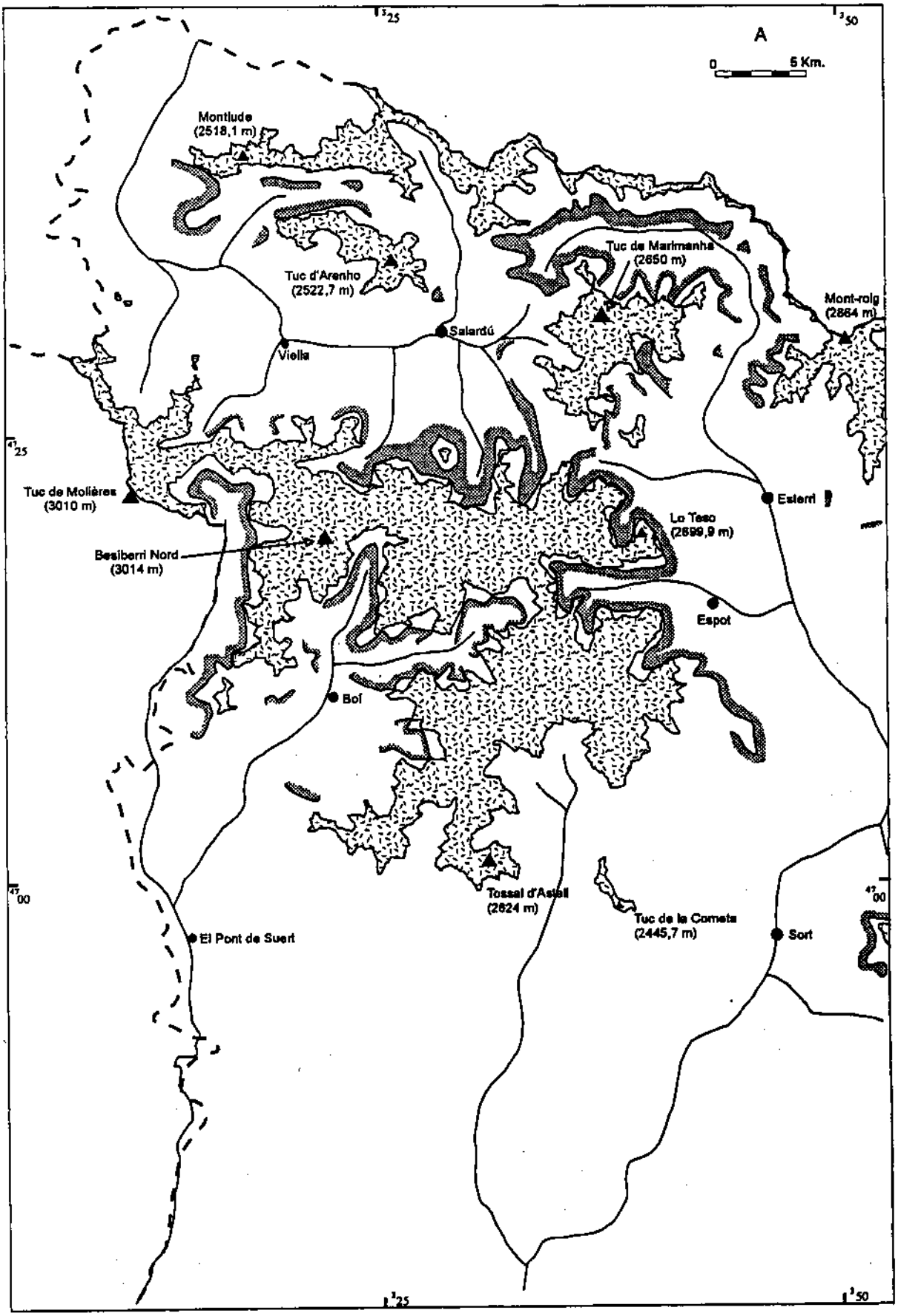
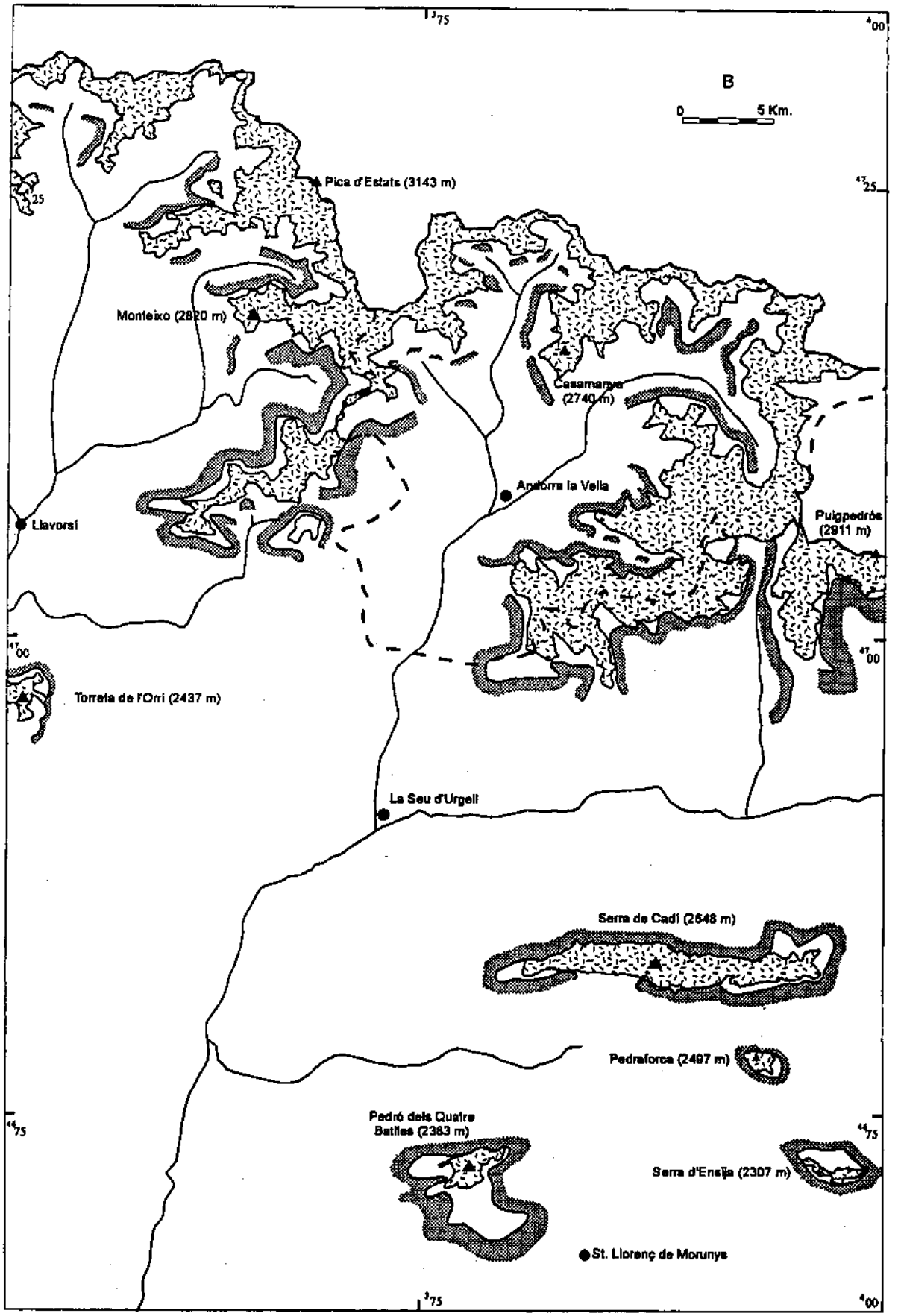
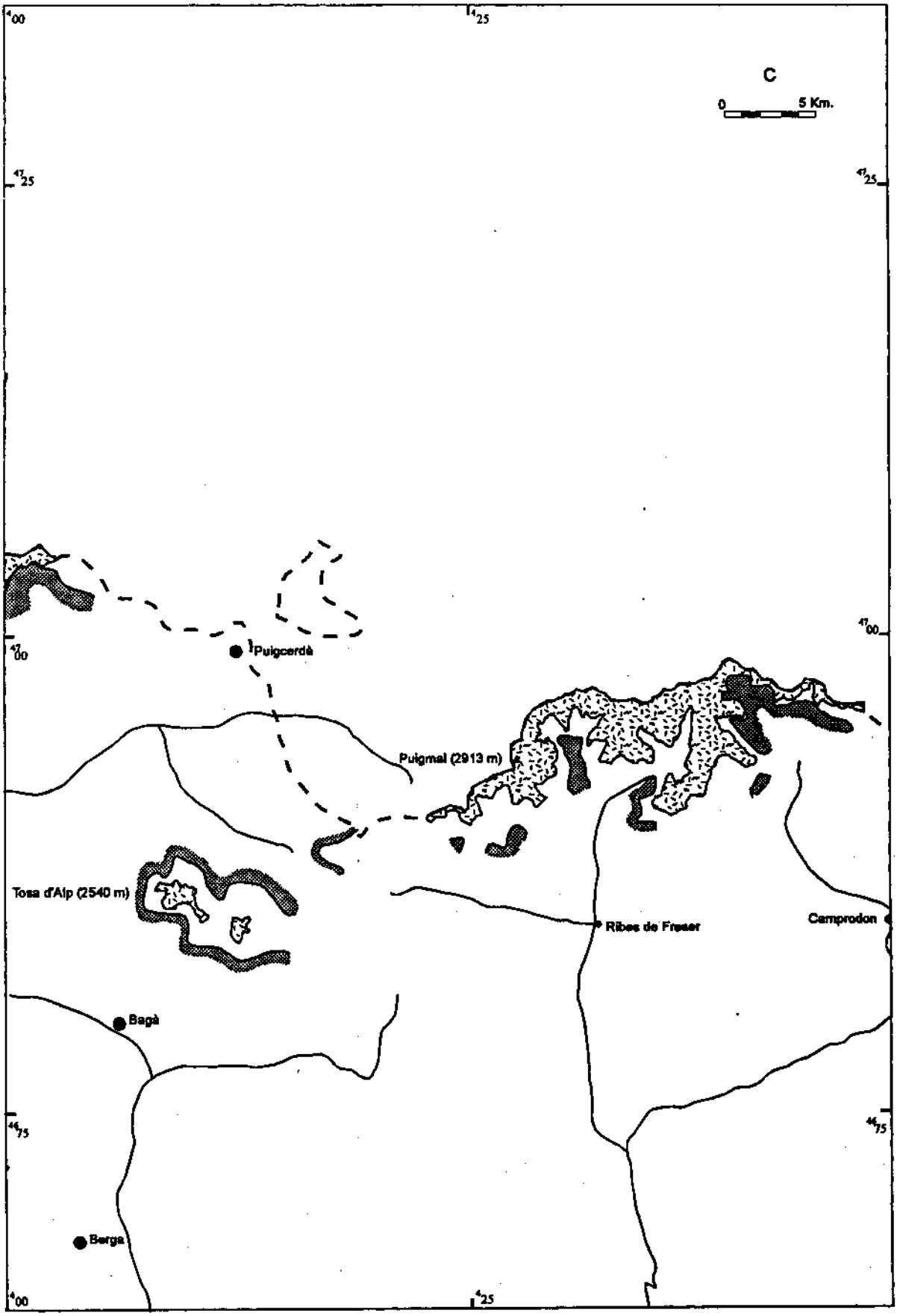


Fig. 1—Location of the area studied in Catalonia.

Fig. 2 a, b and c—Map of the area studied showing the present limit of the forest (bordered above by a dotted area) and the theoretical timber–line or delimitation of the natural supra–forest area (which encloses areas shaded with dashes). ⟶ (next pages)


A
0 5 Km.
Montlude (2518,1 m)
Tuc d'Arenho (2522,7 m)
Tuc de Marimanha (2650 m)
Mont-roig (2864 m)
Salardú
Vielha
Tuc de Molières (3010 m)
Besiberri Nord (3014 m)
Esterri
Lo Teso (2899,9 m)
Espot
Bol
Tossal d'Astell (2824 m)
Tuc de la Cometa (2445,7 m)
Sort
El Pont de Suert


B
0 5 Km.
Pica d'Estats (3143 m)
Monteixo (2820 m)
Casamanya (2740 m)
Andorra la Vella
Llavorsí
Puigpedrós (2911 m)
Torreta de l'Orri (2437 m)
La Seu d'Urgell
Serra de Cadí (2648 m)
Pedraforca (2497 m)
Pedró dels Quatre Batlles (2383 m)
Serra d'Ensija (2307 m)
St. Llorenç de Morunys


C
0 5 Km.
Puigcerdà
Puigmal (2913 m)
Tosa d'Alp (2540 m)
Ribes de Freser
Camprodon
Bagà
Berga