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Wind and water transport and sedimentation of miospores along two rivers subject to major floods and entering the Mediterranean Sea at Calvi (Corsica, France)

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Introduction

In the Mediterranean region, several studies have been devoted to the distribution of pollen in coastal marine areas (Rossignol, 1961; Koreneva, 1971; Rossignol & Pastouret, 1971; Belfiore *et al.*, 1981; Brun, 1983). Other studies have tried to understand the pollen rain in mountain areas where peat bogs are excellent pollen recorders (Reille, 1975; Beaulieu, 1977). However, little is known about how much of the pollen produced in high and middle altitudes is transported to the area of sedimentation near the shoreline, and how it is transported.

The region of Calvi in Corsica is typical of Mediterranean climatic conditions, where mountains rise to 2000 m a short distance (20 km) from the coast, with rather humid climate at the top (near 2000 mm precipitation, concentrated during the cold season; Simi, 1964), and rather dry climate (near 700 mm precipitation) near the coast. Autumn, winter, or spring high rainfall on the top and on steep slopes (Fig. 5.1) produces huge and violent floods (Guilcher, 1979), which carry large stones that accumulate on the narrow coastal plain and which also deliver fine material to the sea. During the dry season (summer) the rivers are at minimum flow and often vanish in the coarse sediments of the coastal plain. Two small rivers enter the sea near Calvi, the Fiume Secco and the Ficarella (Fig. 5.1). Both cross a succession of distinctive vegetation zones (Richelot & Streel, 1985) present on the slopes (Fig. 5.1):

(1) *at the lower level*, a xerophytic 'maquis' of Cistaceae and Asteraceae with a few riverside forests of alder (*Alnus glutinosa*); there are also cultivated olive trees (*Olea europaea*), more in the Fiume Secco than in the Ficarella areas;

(2) *at the intermediate level*, forests of pine (*Pinus pinaster* subsp. *hamiltonii*) and oak (*Quercus ilex*), with shrubs of heath (*Erica arborea*); this forest is more widespread in the Ficarella than in the Fiume Secco areas;

(3) *at a higher level*, forests of pine (*Pinus nigra* subsp. *laricio*), a forest more widespread in the Fiume Secco than in the Ficarella areas. Alpine moor-heaths ('Landes') with peat bogs top the mountains.

Sampling

Samples were taken from various sediments on the bottom of the sea in Calvi Bay and on land, in the rivers and between them. The nearshore bottom of the sea is too sandy to have accumulated pollen grains except where *Posidonia oceanica*, a marine angiosperm grass, is developed in thick mats (Bay, 1984). The dense vertical growth of its axes allows this grass to avoid being covered by sediment, and it traps fine sediment which otherwise would be carried offshore by the marine currents. Twelve samples were taken in the uppermost 5-cm-thick layer of the *Posidonia* mats (Fig. 5.2).

Two samples of muddy sands were available from the center (Fig. 5.2) of Calvi Bay (Burhenne, 1981): sample 19 at 70 m depth, 2 km offshore, and sample 75 at 45 m depth, 500 m offshore. These two samples probably represent more time than any shallow samples taken nearshore or on land, because they correspond to several cm of sediment, but they were helpful to check the relative proportions of pollen of the selected taxa in offshore sediments. On land, samples were taken between the rivers at eight localities and sub-localities (Fig. 5.3). All are mosses covering granitic rocks at levels never reached by any flood. Each locality is a mean sample averaged from several small samples in an area of about 5 m^2. Twenty-five samples were taken from the bottom, or more commonly, near the sides of the two rivers (Fig. 5.2).

Maceration and counting methods and display of results

All samples were sieved with water on a 200 μm sieve, the fine material being macerated with 10% KOH for 15 minutes and then with cold 38% HF, continuously stirred

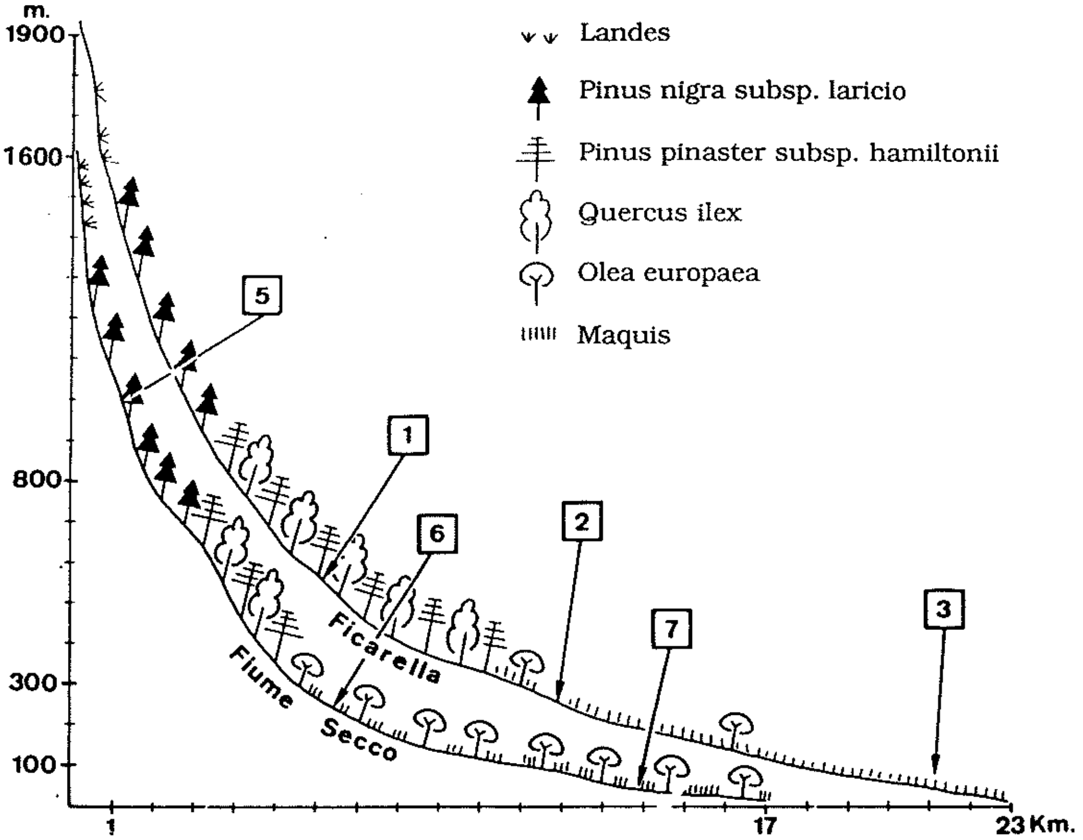

Figure 5.1. Sample localities and vegetation along the two rivers entering the Mediterranean Sea near Calvi. 'Landes' refers to moor-heaths. (From Richelot & Streel, 1985.)

for 12 hours and again sieved at 61 μm to eliminate the abundant organic matter. Material retained on this sieve was checked for any significant amount of pollen and was found almost barren. The fine material was then acetolysed and the residue filtered on a 11 μm sieve. Three hundred pollen grains were counted in each sample, more when one of the taxa was over-represented. Forty taxa were identified, 20 being present in most samples. The complete record (Richelot, 1984) is available from the Palynological Laboratory of the University of Liège, Belgium. In this chapter we will be concerned with only eight taxa: (A) *Pinus nigra*, (B) *Pinus pinaster*, (C) *Quercus ilex*, (D) Oleaceae, (E) *Alnus*, (F) Poaceae, (G) *Erica arborea*, and (H) Cistaceae and Asteraceae. These are the most abundant kinds of pollen recorded and represent the different kinds of land environments described above. The relative value of each is given in percentage of the total. The results from the two marine muddy sands are given individually (Fig. 5.4), but the data from the *Posidonia* mats, which happened to be quite homogeneous, are given as mean values (Figs. 5.2, 5.4). On land, the eight localities of samples taken between the rivers and the 25 samples from the river bottoms are grouped in three altitude classes for each of the rivers (Figs. 5.2, 5.3). We made one exception, however, grouping in the same class (Fig. 5.2, locality 4) river samples from short, lateral tributaries of the two main rivers, because these short tributaries do not originate from high altitude in the mountains.

Local pollen rain and transport by winds

Winds blow from the mountains during the night and from the sea during the day, and one might wonder whether these quite regular winds have the effect of making the pollen rain uniform throughout the region from the coast to the mountain. The analysis of the samples taken away from the rivers (Fig. 5.3, localities 8–12) is most helpful in finding an answer to this question. Transport of pollen by winds is indeed obvious. Small amounts of pollen (less than 20%) of Oleaceae are present at localities 8, 9 and 11, although the producing plants live only at lower levels. Smaller amounts were noted by Reille (1975) in the peat bogs on the top of the mountains and were explained by wind transport.

Small amounts of *Pinus nigra* are present in the lowest localities, 10 and 12, although the producing plants live only higher in the mountains. Because these localities are

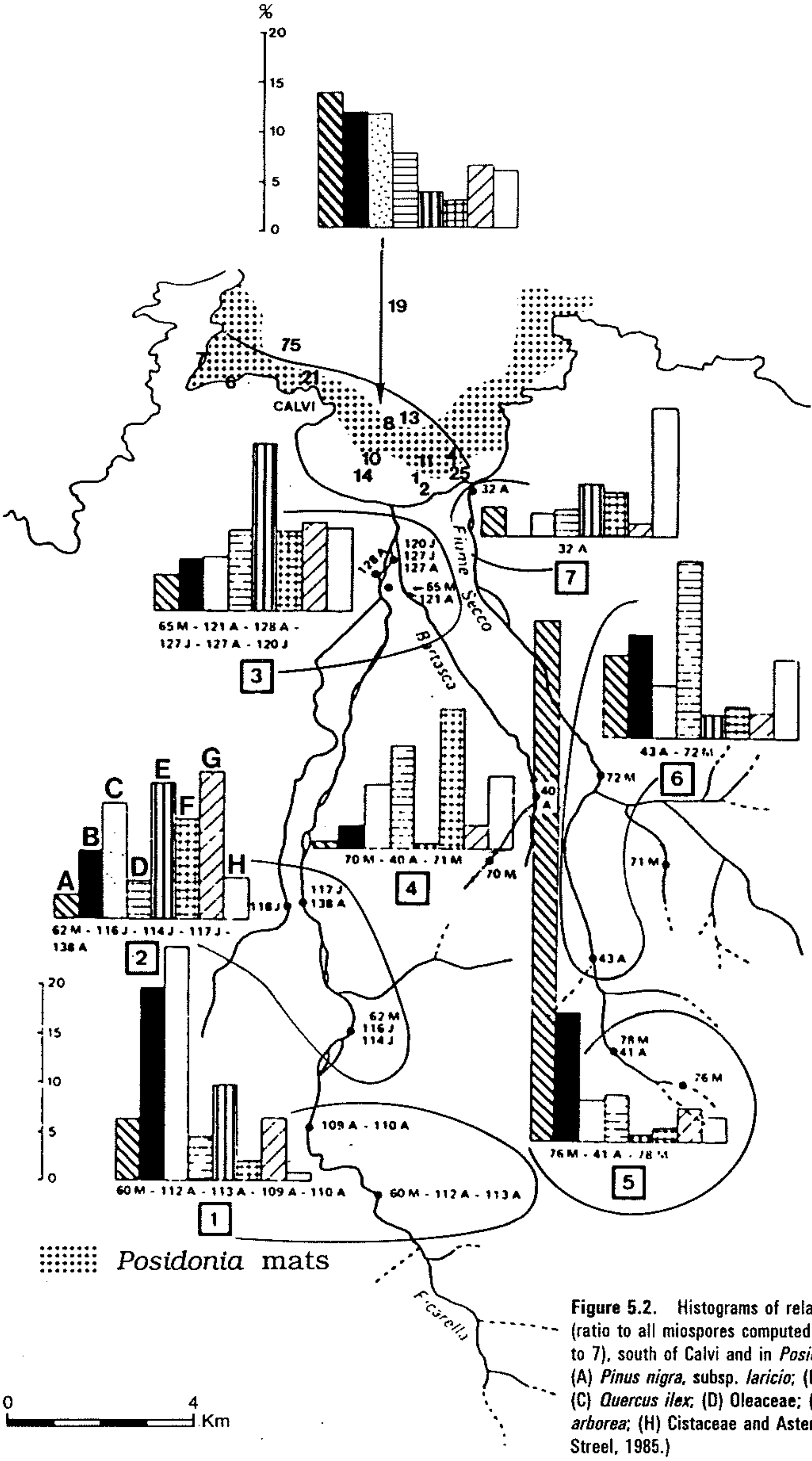

Figure 5.2. Histograms of relative frequencies of eight pollen taxa (ratio to all miospores computed) in river samples (mean localities 1 to 7), south of Calvi and in *Posidonia* samples in the Bay of Calvi. (A) *Pinus nigra*, subsp. *laricio*; (B) *Pinus pinaster* subsp. *hamiltonii*; (C) *Quercus ilex*; (D) Oleaceae; (E) *Alnus* sp.; (F) Poaceae; (G) *Erica arborea*; (H) Cistaceae and Asteraceae. (Modified from Richelot & Streel, 1985.)

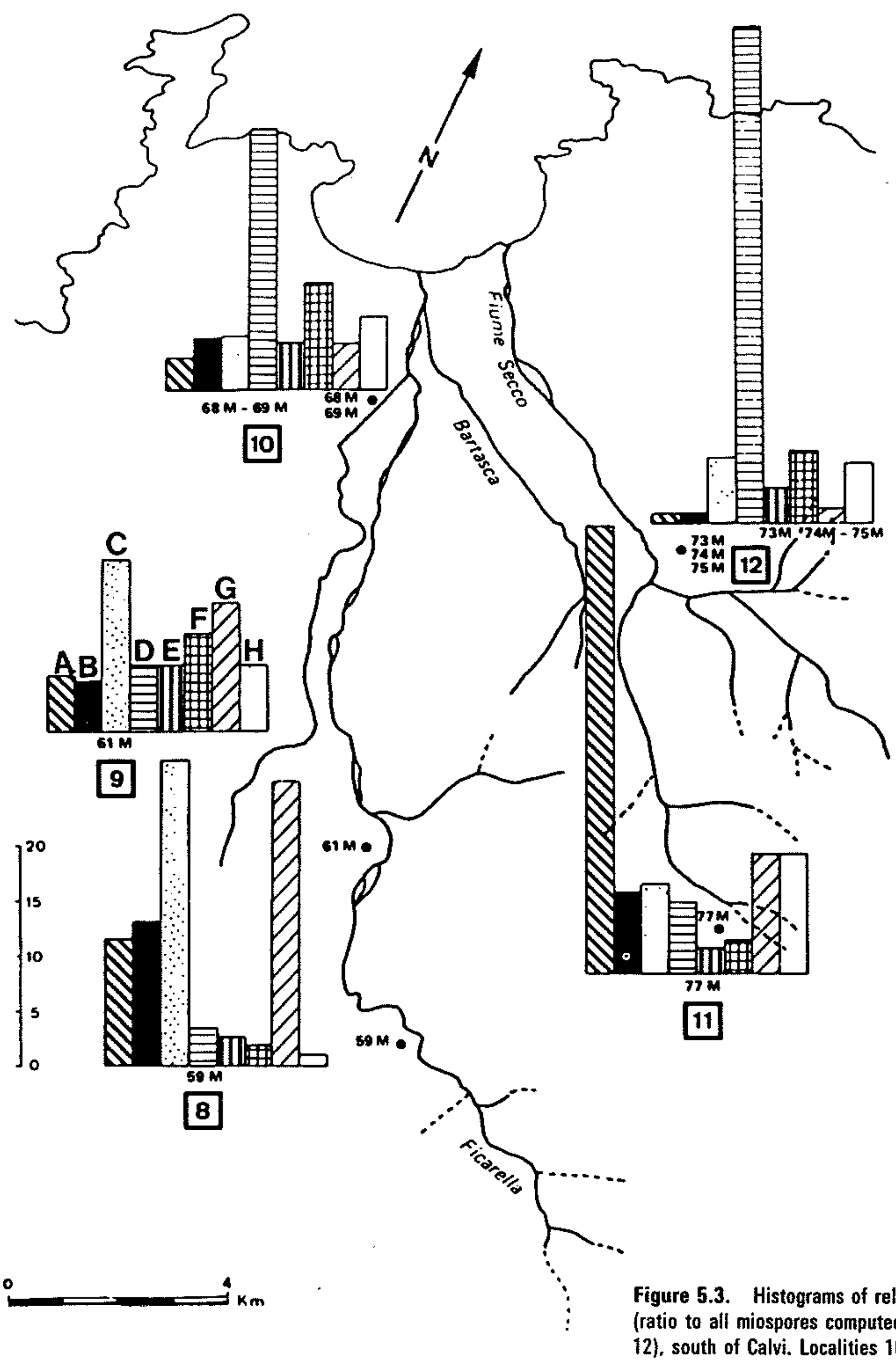

Figure 5.3. Histograms of relative frequencies of eight pollen taxa (ratio to all miospores computed) outside the rivers (localities 8 to 12), south of Calvi. Localities 10 and 12 include sub-localities. (A) *Pinus nigra*, subsp. *laricio*; (B) *Pinus pinaster* subsp. *hamiltonii*; (C) *Quercus ilex*; (D) Oleaceae; (E) *Alnus* sp.; (F) Poaceae; (G) *Erica arborea*; (H) Cistaceae and Asteraceae. (Modified from Richelot & Streel, 1985.)

never flooded by the rivers, wind transport is obvious. So, both day and night winds carry pollen grains.

However, the dominant pollen types are not transported by these rather long-ranging winds. Instead, such pollen is produced by the locally dominant vegetation:

(1) *lower level* (*plain*), Oleaceae (Fig. 5.3, localities 10 and 12), with a larger proportion where (in the Fiume Secco area) *Olea* is more abundant;

(2) *intermediate level of Ficarella area, Quercus ilex* and *Erica arborea* (Fig. 5.3, localities 8 and 9);

(3) *high level of the Fiume Secco area, Pinus nigra* (Fig. 5.3, locality 11).

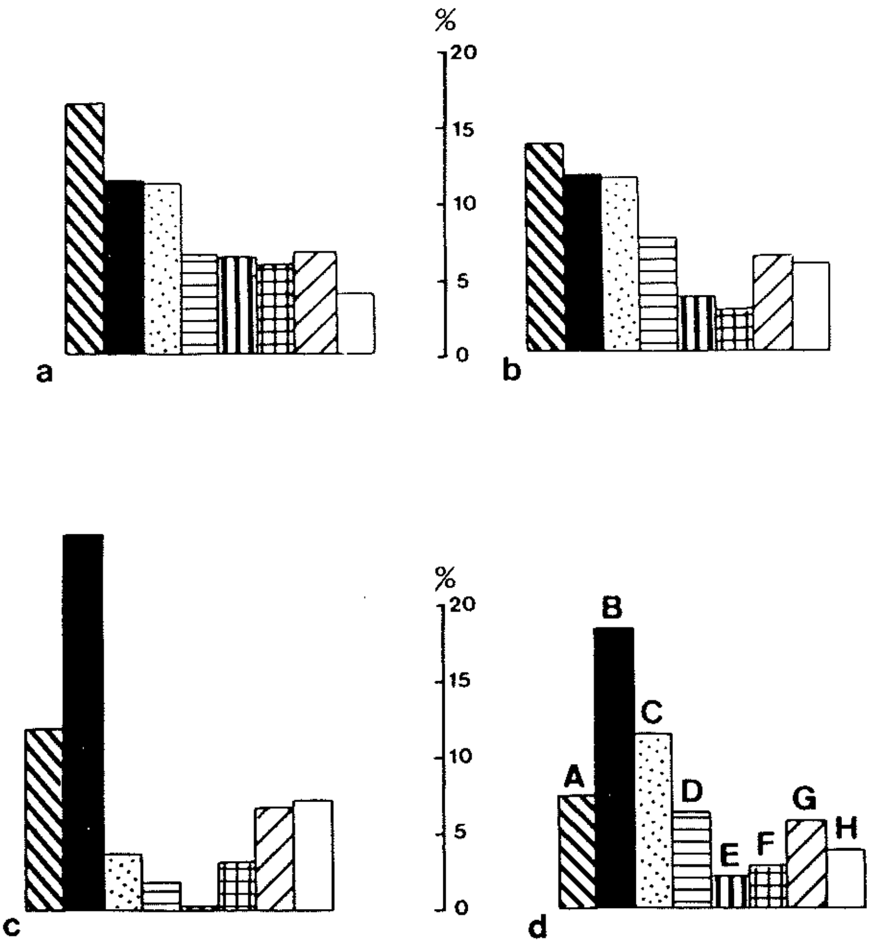

Figure 5.4. Histograms of relative frequencies of eight pollen taxa (ratio to all miospores computed): (a) mean of four river sample localities (1, 2, 5, 6) in the intermediate and high level; (b) mean of all samples in the *Posidonia* mats. (c) sample 19, at 70 m depth and 2 km offshore. (d) sample 75, at 45 m depth and 500 m offshore. (See Fig. 5.2 for localities of samples 19 and 75.) (A) *Pinus nigra*, subsp. *laricio*; (B) *Pinus pinaster* subsp. *hamiltonii*; (C) *Quercus ilex*; (D) Oleaceae; (E) *Alnus* sp.; (F) Poaceae; (G) *Erica arborea*; (H) Cistaceae and Asteraceae.

Pollen transport and sedimentation in the rivers

Pollen transport by the rivers depends on the energy level of the flow. We have noted that large floods, under the climatic–topographic conditions of this region, carry the fine sediments directly to the sea. Most of the coastal onshore deposits are too coarse to contain any pollen. The deposition of pollen with muddy sediments on the bottom and sides of steep rivers is possible only under conditions of low energy current, when the rivers are near minimum flow. The data shown in Figure 5.2 reflect this condition.

Analyses of sediment from locality 5 (Figs. 5.1 and 5.2) are typical for the results obtained from sediments taken in the Fiume Secco at high altitude. Percentages are rather similar to those described away from the river (Fig. 5.3, locality 11), except that the proportion of conifers is higher in the river sediment than away from the river, probably reflecting the well-known capacity of bisaccate pollen to be easily carried by water. This is confirmed by the data obtained from the intermediate level in the same river. Indeed, locality 6 (Figs. 5.1 and 5.2) has significant proportions of bisaccate pollen when compared to the nearby localities 4 (Fig. 5.2) and 12 (Fig. 5.3). Locality 4 combines the data obtained from sediments taken in short, lateral tributaries to the main river, which do not originate high in the mountain and therefore were not fed by the montane conifer forest pollen rain, where *Pinus nigra* is dominant. Locality 12 demonstrates that the pollen rain there is very poor in bisaccate pollen. The bisaccate pollen found at locality 6, therefore, must have been transported downstream by the Fiume Secco River.

Along the Ficarella River, two groups of localities at the intermediate level were analyzed (Fig. 5.2, localities 1 and 2). When compared with the corresponding sites away from the river (Fig. 5.3, localities 8 and 9), larger proportions of *Alnus* pollen are noted in the river sediments. These proportions increase downstream, as confirmed by locality 3, the nearest to the coast. *Alnus* pollen is from a dominant tree of the riverside forest, and the local pollen rain is mainly produced by this tree and accumulates downstream. Winds have little influence in this transport, as can be deduced from comparison of the data at locality 3 (Fig. 5.2), in the river sediment, and locality 10 (Fig. 5.3), away from the river, where *Alnus* pollen is largely overwhelmed by other taxa.

Pollen delivery into the sea

In low-energy conditions, when the streams contain little water, only the Ficarella has a permanent, very slow delivery of surface water to the sea. The Fiume Secco, most often, vanishes into its own coarse alluvium before reaching the sea.

Should this low but almost permanent delivery of the Ficarella feed the pollen content of the *Posidonia* mats immediately nearshore, we should expect the pollen spectrum of the coastal locality 3 (Fig. 5.2) to match the pollen spectrum found in the *Posidonia* samples. In fact, it does not. The relative values (Fig. 5.2) are very different, almost complementary, rather than similar.

The pollen spectrum in the *Posidonia* samples is dominated by *Pinus nigra*, *P. pinaster* and *Quercus ilex*, which are represented by the lowest values at locality 3 onshore. On the contrary, *Alnus* pollen is rare nearshore but dominates in the onshore distal alluvium of the Ficarella. A sorting effect at such short distance might explain the bisaccate abundance offshore, but not the dominance of *P. nigra* over *P. pinaster* pollen and the high frequency of *Quercus ilex* in the *Posidonia* samples. Most probably, this pollen is delivered to the sea by the irregular large floods occuring in autumn, winter or spring. The *Posidonia* pollen spectrum is indeed more similar to the intermediate and upstream river samples than to any samples from the low level. We suggest that these intermediate and high level sediments are recycled by the floods. The contribution of the Fiume Secco to these floods is certainly important because of the dominance of *P. nigra* pollen in the marine nearshore sediments, the related forest being mostly developed upstream of this river. Locality 10 (Fig. 5.3), 3 km from the coast, has a pollen spectrum very different from that of *Posidonia*, which rules out direct wind transport from high and middle altitude to the sea. If wind were a factor, we would expect the pollen rain to be similar at nearby localities on both sides of the shoreline. By mixing in equal parts the pollen contribution found in the four intermediate and high level localities 1, 2, 5 and 6 of both rivers, one would obtain a mean spectrum very similar to the *Posidonia* spectrum (Fig. 5.4).

Pollen in offshore sediments

An alternative origin for the pollen found in the nearshore *Posidonia* mats might be searched for offshore, where *Pinus* pollen is known to be dominant in almost all bottom sediments studied in the Mediterranean Sea (Koreneva, 1971) and elsewhere (Lubliner-Mianowska, 1962; Koreneva, 1968; Heusser & Florer, 1973). This might reflect the excellent hydrodynamic capacity of this pollen (Traverse & Ginsburg, 1966; Heusser & Balsam, 1977) and maybe also its optimum preservation capacity (Havinga, 1964). Distinguishing among the possible *Pinus* species has almost never been attempted by any of these authors.

Could offshore water currents introduce to Calvi Bay the pollen found trapped in the *Posidonia* mats? The two muddy sands that we have analyzed from Calvi Bay demonstrate that *P. pinaster* is (Fig. 5.4) two times as abundant as *P. nigra*, bisaccate pollen being largely dominant over all other pollen (14.3% of bisaccate pollen of size intermediate between *P. pinaster* and *P. nigra* should be added to sample 19, 9.5% to sample 75). Bisaccates are more common in sample 19 (2 km from the coast) than in sample 75 (500 m from the coast). If one excludes the *P. pinaster*/*P. nigra* ratio, the pollen spectrum of sample 75 (500 m) is very close to the *Posidonia* mat pollen spectrum and therefore might have, in part, a common origin. Sample 19 might, on the other hand, be interpreted as more thoroughly sorted than sample 75. Heusser and Balsam (1977) consider that the decrease in proportion of *Alnus* pollen in the offshore direction might be the result of poor adaptation to water transport and of poor resistance to sea water. Brun (1983) also observed that the proportions of Oleaceae pollen decreased in the offshore direction. Therefore, we interpret the muddy-sand pollen spectrum as originating from the coastal discharge of the two rivers. In these muddy sands, bisaccate pollen was probably selectively sorted and also mixed to some extent with *P. pinaster*-type pollen carried by Mediterranean Sea currents.

Discussion and conclusion

Our results support the conclusion that most of the pollen trapped in the mixed mineral and organic littoral deposits formed by the *Posidonia* mats originates from the intermediate and high altitude coastal vegetation. It is mostly delivered to the sea by river systems during large floods. The Fiume Secco, which drains a large, high altitude, *P. nigra* forest, plays a major part in this delivery process. The very slow but permanent delivery of surface water to the sea by the Ficarella should carry, by

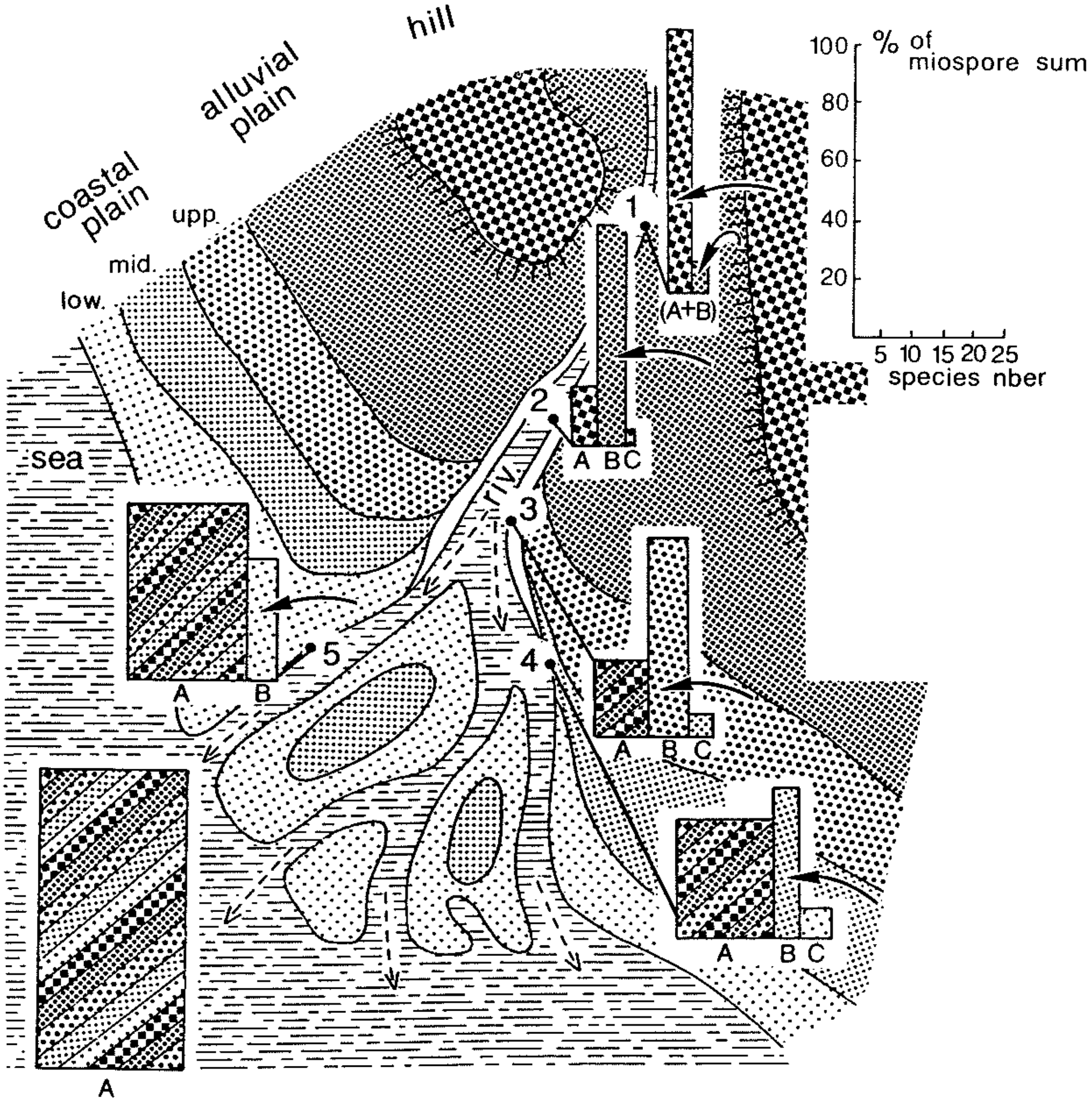

Figure 5.5. Reconstruction of wind and river transport of miospores to the sea in a deltaic environment with well developed coastal and alluvial plains. (A) wind and river transport from upstream; (B) local wind transport; (C) wind transport from downstream. (See also Hopping, 1967).

comparison, only a small quantity of pollen, and the proportions of taxa of this small supply are very different from those observed in the *Posidonia* mats.

Delivery to the sea of miospores through the fluviatile system has been studied by Hopping (1967), who developed a model for the distribution pattern of Tertiary pollen in a deltaic environment. By combining the data provided by Hopping (1967), we have tried to determine the progressive downstream enrichment of species (x-axis of the histograms in Fig. 5.5, as well as the changing proportion of the miospores originating upstream (y-axis of the histograms in Fig. 5.5). This model shows extended coastal and alluvial plains, features which are not matched near Calvi (Fig. 5.6), where the supply of sediments to the sea has no true deltaic character.

Among the similarities between the models, the local vegetation provides most of the miospore content in each locality. Winds carrying spores and pollen for long distances are obviously less important than local pollen rain. We also note that the miospore spectra are distorted by fluviatile supply originating upstream. Among the differences, it should be emphasized that we have not observed near Calvi the progressive downstream enrichment of species noted in the ancient deltaic environment. Moreover, the sporomorph proportions

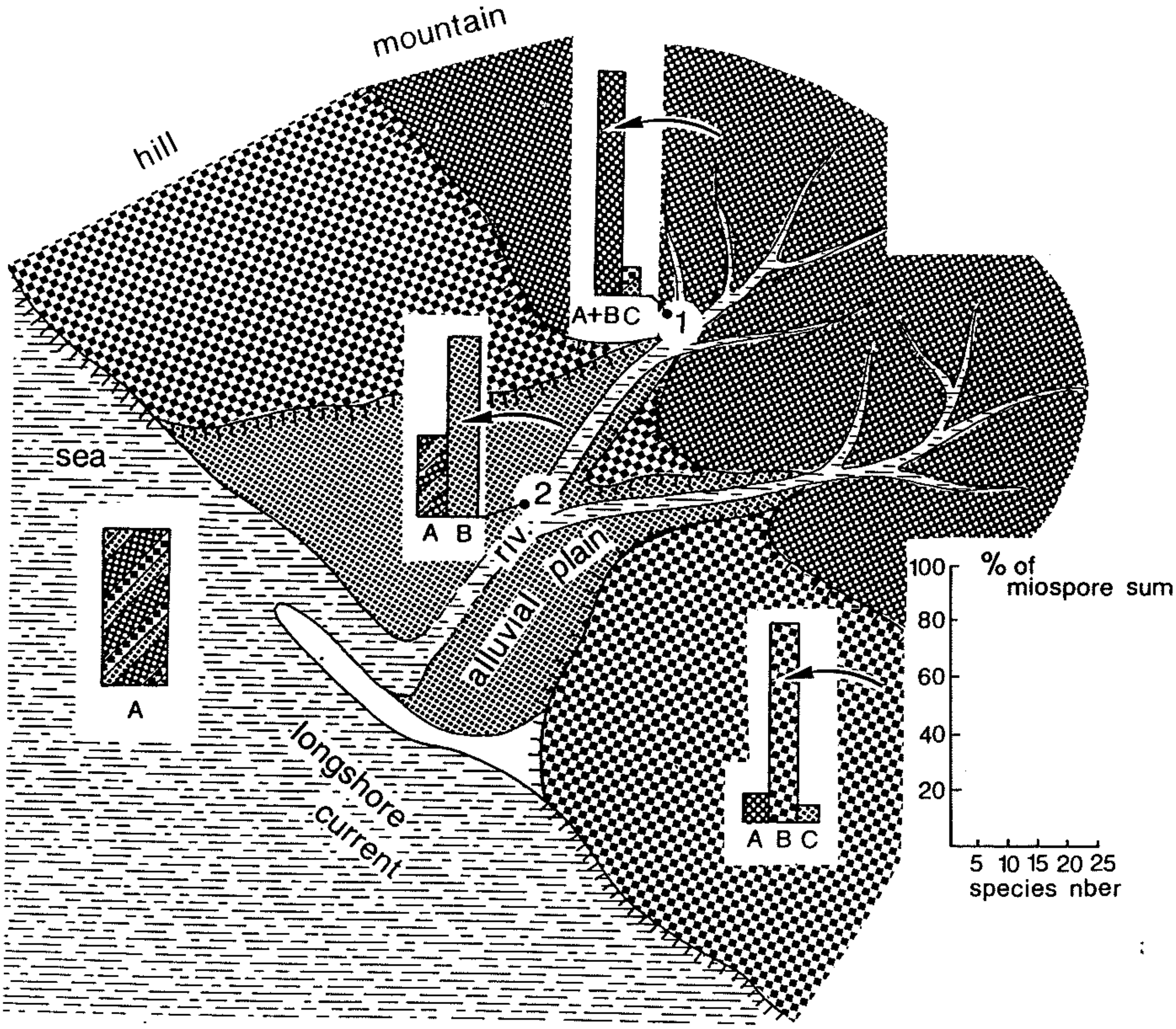

Figure 5.6. Reconstruction of wind and river transport of miospores to the sea in a coastal mountainous environment with poorly developed coastal and alluvial plains, such as that in the Calvi area. (A) wind and river transport from upstream; (B) local wind transport; (C) wind transport from downstream.

seen nearshore do not show, in this environment, equivalent supply from all upstream vegetation, but, near Calvi, a more important supply from upland mountainous vegetation.

Important and direct supplies to the sea of miospores originating upstream and/or upland have been discussed by several authors (even for the Paleozoic), and these data are well summarized by Chaloner and Muir (1964). These authors refer to the 'Neves effect,' a mechanism of miospore dispersion, 'in which miospore assemblages change successively in response to varying proximity and extent of the parent communities brought about by changing base-level.'

This 'Neves effect' mechanism is based on the assumption that the relative total quantity of miospore production by communities within the region concerned, carried by the wind, would dictate the composition of the miospore assemblage in the nearshore marine sediments. It does not emphasize the possible importance of water transportation of miospores, and, moreover, does not take into account the possibility that relatively remote upland vegetation might directly feed the nearshore marine sediments through the river system, as it does indeed at the present time near Calvi.

A study of spore assemblages in Jurassic rocks of various lithologies (Muir, in Chaloner & Muir, 1964) has given results more consistent with the present situation near Calvi than with the 'Neves effect' *sensu stricto*. In this Jurassic delta, the marine rocks and the coarse fluviatile sandstones are rich in miospores of plants that were apparently growing in a habitat remote from the marine environment. They represent water-transported miospores from the hinterland. We want to exclude this kind of mechanism of miospore dispersion in the Jurassic from the 'Neves effect' *sensu stricto*, and propose two new concepts where miospore assemblages are more dependent on water transportation than on wind transportation:

(1) The 'Hopping effect' refers to a mechanism resulting in assemblages which are dominated by water-transported miospores mainly derived from nearby coastal and alluvial plains, as well as from remote 'upland.'
(2) The 'Muir effect' refers to a mechanism resulting in assemblages which contain dominant water-transported miospores mainly derived from the remote 'upland.'

Being dependent on the regime of the river systems, both mechanisms are probably more closely related to climatic changes than to base-level changes, which mainly explain the 'Neves effect.'

References

Bay, D. (1984). A field study of the growth dynamics and productivity of *Posidonia oceanica* (L.) Delile in Calvi Bay, Corsica. *Aquatic Botany*, **10**, 43–64.

Beaulieu, J.-L. de (1977). Contribution pollenanalytique à l'histoire tardiglaciaire et holocène de la végétation des Alpes méridionales françaises. Thèse ès Sciences, Univ. Aix-Marseille III.

Belfiore, A., Dambion, F., Moncharmont, M., Ozer, A., Pescatore, T., Streel, M. & Thorez, J. (1981). La sédimentation récente du golfe de Tarente (Italie méridionale). Aspects minéralogiques et micropaléontologiques. *Bulletin de la Société Royal des Sciences de Liège*, **50** (11–12), 373–83.

Brun, A. (1983). Etude palynologique des sédiments marins holocènes de 5000 BP à l'actuel dans le golfe de Gabès (mer pélagienne). *Pollen et Spores*, **3–4**, 437–60.

Burhenne, M., (1981). Faciès sédimentaires du précontinent calvais. Notes introductives. *Bulletin de la Société Royal des Sciences de Liège*, **50** (11–12), 387–404.

Chaloner, W. & Muir, M. (1964). Spores and floras. In *Coal and Coal-bearing Strata*, ed. D. G. Murchison & T. S. Westoll. Edinburgh: Oliver & Boyd, 127–46.

Guilcher, A. (1979). *Précis d'hydrologie marine et continentale*. Paris: Masson.

Havinga, A. J. (1964). Investigation into the differential corrosion susceptibility of pollen and spores. *Pollen et Spores*, 4, 621–635.

Heusser, C. J. & Florer, L. E. (1973). Correlation of marine and continental Quaternary pollen records from the northeast Pacific and western Washington. *Quaternary Research*, 3, 661–70.

Heusser, L. E. & Balsam, W. L. (1977). Pollen distribution in the northeast Pacific Ocean. *Quaternary Research*, 7, 45–62.

Hopping, C. A. (1967). Palynology and the oil industry. *Review of Palaeobotany and Palynology*, **2**, 23–48.

Koreneva, E. V. (1968). Distribution and preservation of pollen in sediments in the western part of the Pacific Ocean. *Geological Bulletin* (Department of Geology, Queens College, Flushing, NY), **2**, 1–17.

Koreneva, E. V. (1971). Spores and pollen in Mediterranean bottom sediments. In *The Micropaleontology of Oceans*, ed. B. M. Funnell & W. R. Reidel. New York: Cambridge University Press, 361–71.

Lubliner-Mianowska, K. (1962). Pollen analysis of the surface samples of bottom sediments in the Bay of Gdansk. *Acta Societatis Botanicorum Poloniae*, **31**, 305–12.

Reille, M. (1975). Contribution pollenanalytique à l'histoire tardiglaciaire et holocène de la végétation de la montagne corse. Thèse ès Sciences, Univ. Aix-Marseille III.

Richelot, C. (1984). Le transport du pollen par les courants aériens, fluviatiles et marins dans la région de Calvi (Corse). *Mémoire de Licence en Sciences Géographiques, Université de Liège.*

Richelot, C. & Streel, M. (1985). Transport et sédimentation du pollen par les courants aériens, fluviatiles et marins à Calvi (Corse). *Pollen et Spores*, **3–4**, 349–64.

Rossignol, M. (1961). Analyse pollinique de sédiments marins quaternaires en Israël, 1. Sédiments récents. *Pollen et Spores*, **3**, 303–24.

Rossignol, M. & Pastouret, L. (1971). Analyse pollinique de niveaux sapropéliques post-glaciaires dans une carotte en Méditerranée orientale. *Review of Palaeobotany and Palynology*, **11**, 227–38.

Simi, P. (1964). Le climat de la Corse. *Bulletin de la Section de Geographie/Comité des Travaux Historiques et Scientifiques* **76**. Paris: Imprimerie nationale.

Traverse, A. & Ginsburg, R. (1966). Palynology of the surface sediments of Great Bahama Bank, as related to water movement and sedimentation. *Marine Geology*, **4**, 417–59.