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Metamorphism and deformation in Alpine Corsica*

by *Jean-Michel Caron*[1]

Abstract

This paper attempts to summarize structural and petrologic data collected over a period of fifteen years by several groups of geologists in Alpine Corsica.

The lithostratigraphic, metamorphic and structural features of the different nappes are briefly reviewed. Amongst successive episodes of thrusting, attention is devoted to the Upper Cretaceous (eo-Alpine) events. The importance of mechanical transpositions is emphasized, in order to explain the apparent discrepancy between the mineralogic memory of early events (Upper Cretaceous to Eocene), and the strong imprint of late deformation stages (Upper Eocene to Miocene) on prominent structures.

Keywords: nappe structure, high-pressure metamorphism, mineral lineation, eo-Alpine belt, Corsica.

Introduction

The island of Corsica is, morphologically and historically, divided by the central depression of Corte in two parts, which are geologically very different (Durand-Delga et al., 1978; Caron and Bonin, 1980; Rossi and Rouire, 1980). The western region is mainly constituted by Variscan granitoids, with areas of metamorphic rocks and of Paleozoic formations. The northeastern third, which is the subject of this paper, is referred to as Alpine Corsica. It consists of a stack of nappes, well-known for the occurrence of high pressure–low temperature (HP-LT) metamorphic rocks (Brouwer and Egeler, 1952; Amaudric du Chaffaut et al., 1976; Caron, 1984; Gibbons et al., 1986).

Several groups of geologists, in charge of the detailed geological mapping of Corsica over fifteen years, have collected much new lithological, petrological and structural data (Amaudric du Chaffaut et al., 1985; Lahondère, 1983; Caron et al., 1990, Lahondère et al., 1990; Rossi et al., in press; Guieu et al., in press). These data have allowed interpretative models for the tectonometamorphic evolution of Alpine Corsica to be made and have highlighted the following controversial points.

– Although the nappes structure is commonly accepted, the limits, the contents, and even the number of these nappes, have been questioned (e.g. Durand-Delga, 1984; Egal, 1989, 1992).

– The relative chronology of the nappes emplacement and of the HP-LT metamorphism has been discussed by numerous authors (Mattauer and Proust, 1975; Amaudric du Chaffaut, 1982; Bezert and Caby, 1988; Egal and Caron, 1988, 1989).

– A difference in tectonic styles between the north (Faure and Malavielle, 1981; Lahondère, 1991; Fournier et al., 1991) and the south (Caron, 1977; Scius, 1981; Péquignot and Potdevin, 1984) of the Alpine Corsica is obvious on the published cross sections, and needs to be explained.

– Some authors interpret the prominent stretching lineation as reflecting the general westwards emplacement of the nappes onto the autochthonous Western Corsica (Mattauer et al., 1977, 1981), while others consider it as, at least in part, a later feature of the polyphased tectonic history (Péquignot and Potdevin, 1984; Fournier et al., 1991).

– The late broad anticlines and synclines are related either to post-Miocene shortening

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(AMAUDRIC DU CHAFFAUT, 1982; WATERS, 1990) or to postcollisional ductile extension (EGAL, 1989, 1992; JOLIVET et al., 1990, 1991).

This paper aims to bring together data from different areas of Alpine Corsica, and tries to reduce some of these discrepancies in the relationship between metamorphism and deformation. I will pay special attention to early (eo-Alpine) stages of the evolution, and to problems arising from the late mechanical transposition of previous minerals and structures.

The nappes in Corsica

Beside the recognition of flat-lying thrust planes or shear zones, two kinds of arguments demonstrate the existence of nappes, and are used to map their limits: lithostratigraphically abnormal successions and breaks in the metamorphic sequence.

LITHOSTRATIGRAPHIC UNITS

Four groups of lithostratigraphic series, each corresponding to a group of tectonic units, are recognized in Alpine Corsica (EGAL, 1989). These tectonic units are broadly juxtaposed, with the structurally lowest unit present to the west, and the structurally highest unit to the east (Fig. 1).

1. The autochthonous and parautochthonous units comprise the Variscan basement of Western Corsica, with its reduced Mesozoic and Eocene sedimentary cover.
2. The external nappes, with thicker Mesozoic sedimentary series, are slices which originated from the thinned European margin of the Tethys (DURAND-DELGA, 1984).
3. The composite Schistes lustrés nappes comprise Liguro-Piemontese ophiolites and their, presumably, Uppermost Jurassic–Lower Cretaceous sedimentary cover; these nappes make up most of Alpine Corsica (Fig. 2).
4. The Upper Nappe of Ligurian affinities, with post-ophiolitic series as young as Eocene in age, constitutes klippes in the Balagne, Nebbio, and Macinaggio areas.

Units of each group have a tectonic contact with units of all other three groups (Fig. 1).

METAMORPHIC EVOLUTION

Low temperature eclogites occur in some Schistes lustrés units. In the Monte San Petrone–Punta Caldane area, east of Corte, the prograde transition between blueschists and eclogites is somewhere still preserved in metabasalts (PÉQUIGNOT and POTDEVIN, 1984; CARON and PÉQUIGNOT, 1986). The syntectonic recrystallization of mylonitic eclogites, related to deformation D_1, occurred at about 420 °C and 10–14 kbar (PÉQUIGNOT et al., 1984). Retrogressive evolution into blueschists, and then greenschists, is related to later deformation stages D_2 to D_5 (Fig. 3). In Cap Corse (Fig. 4), eclogites register slightly higher peak temperatures, about 500 to 600 °C according to HARRIS (1984) and LAHONDÈRE (1988), and about 414–465 °C according to WATERS (1989). In orthogneisses of the Golo valley, parageneses with glaucophane, paragonite, chloritoid and jadeite (LAHONDÈRE, 1991) are consistent with very high pressures of 20–25 kbar.

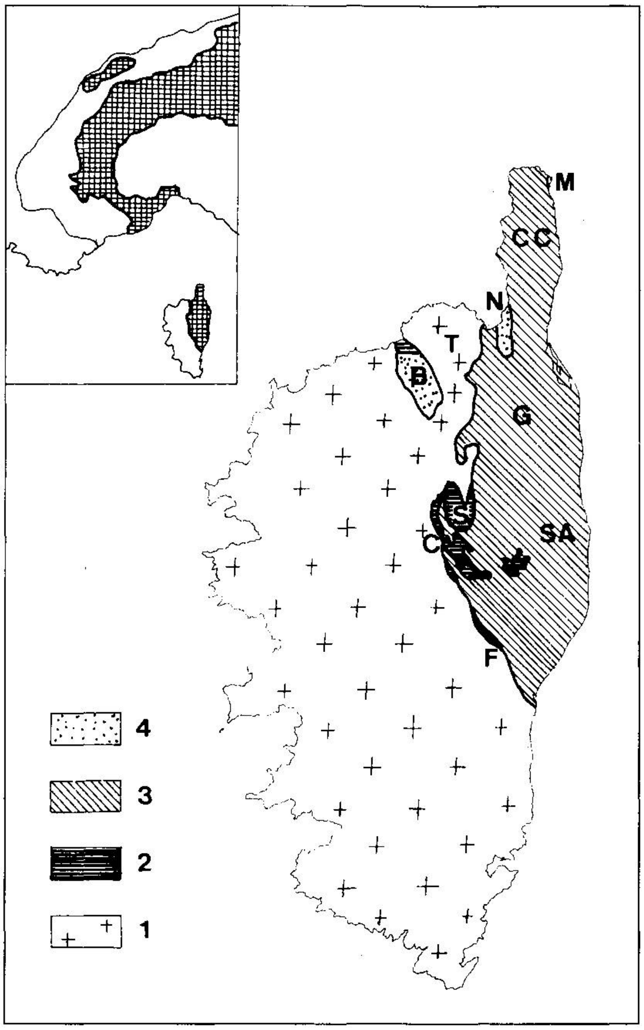

Fig. 1 Structural sketch map of Corsica (located with respect to the inner zones of the Alps).
1: Autochthonous Western Corsica. 2: External nappes. 3: Schistes lustrés nappes. 4: Upper nappes.
B: Balagne. C: Corte. CC: Cap Corse. F: Fium'Orbo. G: Golo. M: Macinaggio. N: Nebbio. S: Santa Lucia di Mercurio. SA: Sant'Andrea di Cotone. T: Tenda massif.

In the major mass of the external and Schistes lustrés nappes, no relic eclogites have been ob-

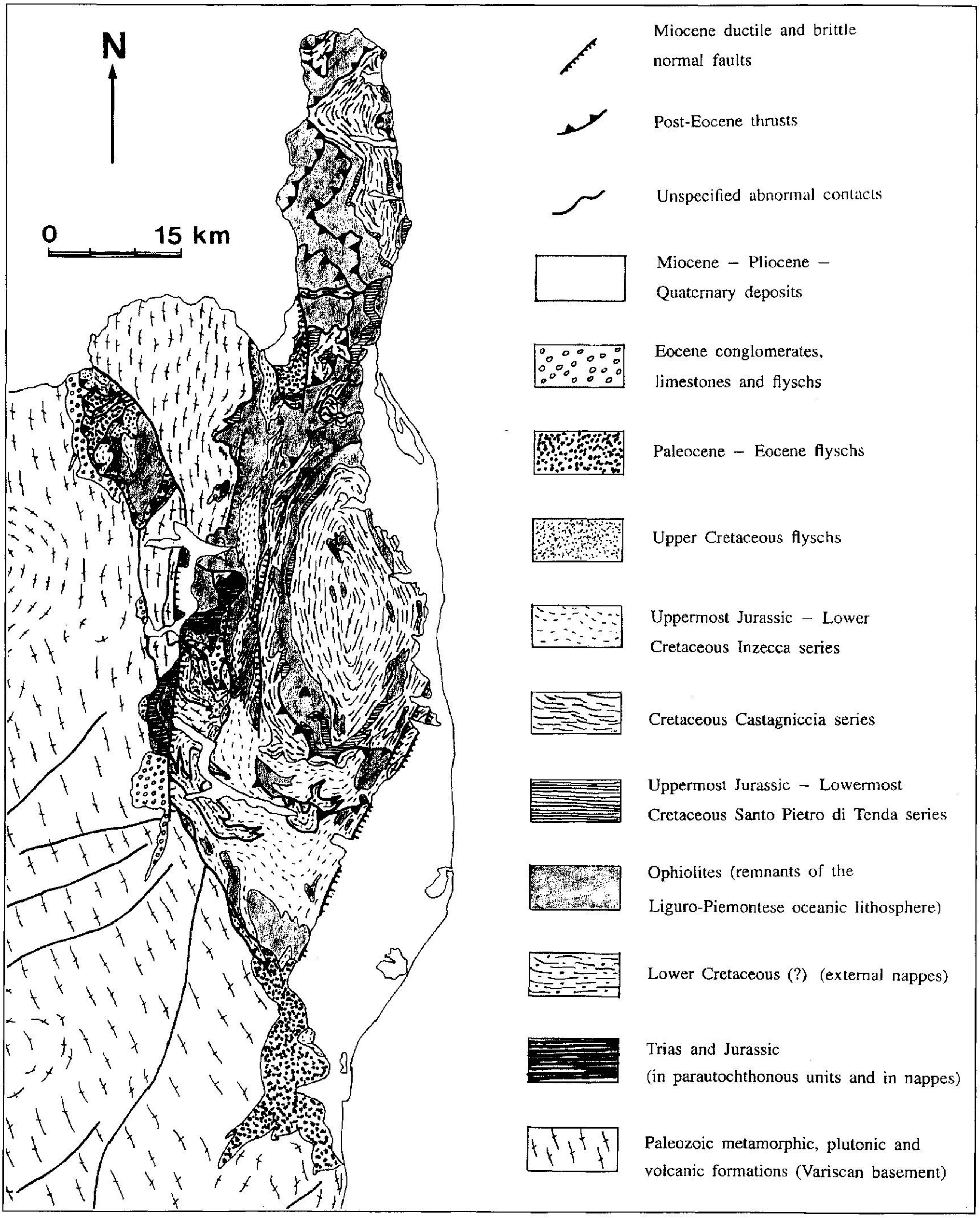

Fig. 2 Simplified geological map of Alpine Corsica.

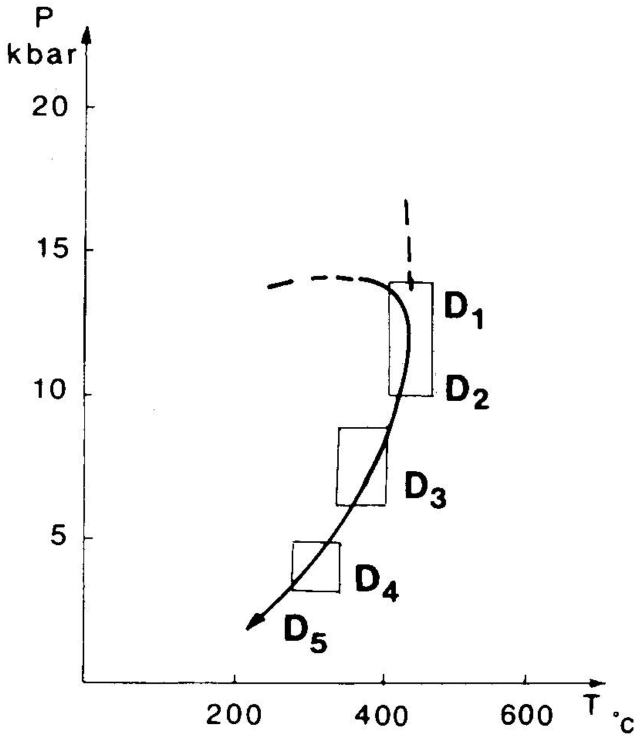

Fig. 3 Metamorphic evolution of the eclogites in the Monte San Petrone–Punta Caldane area (East of Corte) (from Péquignot and Potdevin, 1984).

served, and the maximum metamorphic conditions correspond to blueschist facies (Fig. 4). In the lowermost units of tectonic pile, Waters (1989), as well as Harris (1984) and Péquignot and Potdevin (1984), argued in favour of a slight increase in temperature during the late stages of the retrogression of blueschists into greenschists (related to the D_3 tectonic event). However, it is recognized that the estimates of P-T conditions during this phase of retrogression are poorly constrained.

In the autochthonous and parautochthonous units, blue amphiboles are described, as well as epidote, pumpellyite and stilpnomelane (Amaudric du Chaffaut et al., 1976, 1979; Bezert and Caby, 1988; Egal and Caron, 1989). However, they are crossites (Gibbons and Horák, 1984; Egal, 1989), and nowhere in these units did the metamorphism reach blueschist conditions.

The principal metamorphic discontinuities correspond to the main thrusts evidenced by the lithostratigraphic series: (1) the limit between the units displaying HP relics (blueschist and eclogite) and the greenschist ones coincides with the nappes front; (2) the Upper Nappe escaped the HP metamorphism, and thus differs from the Schistes lustrés nappes which originated also in the Liguro-Piemontese oceanic realm. Other metamorphic discontinuities exist within the Schistes lustrés: eclogitic units are interleaved between blueschist units; the petrological data confirm thus the lithostratigraphic arguments in favour of the composite character of this stack.

SUCCESSIVE THRUSTS

Different generations of abnormal contacts must be distinguished in Alpine Corsica, from their relations with the metamorphism and with the superimposed folds (Caron et al., 1990; Egal, 1992; Rossi et al., in press).

– The oldest tectonic contacts, between ophiolitic Schistes lustrés units, predate the phase of blueschist metamorphism of these units (Péquignot and Potdevin, 1984). These tectonic contacts appear to be deformed by the first phase folds F_1 associated with the glaucophane-lawsonite-phengite bearing schistosity (Caron, 1977; Scius, 1981; Caron et al., 1990; Rossi et al., in press).

– The main thrust, between the nappes and the autochthonous (with its Eocene discontinuous cover), juxtaposes a composite tectonic pile, already deformed and metamorphosed, onto a still undeformed substratum (Egal, 1989, 1992). Both types of units are then subjected to a common polyphased tectonic evolution, under greenschist metamorphism conditions. Eastward in the Schistes lustrés, some thrusts present the same relative chronology with respect to the folds and cleavages (between D_1 and D_2), but the later evolution (associated with D_2 and even D_3) is there associated with the recrystallization of blueschist minerals and, only then, with greenschist retrogression (Péquignot and Potdevin, 1984).

– Later (post-D_2) obvious thrusts, with an eastward sense of shear (backthrusts), cut the Schistes lustrés pile into slices, some hundred meters thick (Caron, 1977; Péquignot and Potdevin, 1984; Warburton, 1986; Waters, 1990; Lahondère, 1991). These thrusts developed under greenschist conditions.

– During the Miocene extension stage, former thrusts may be inverted and act as normal shear zones (Jolivet et al., 1990; Caron and Egal, submitted). This accounts for opposite senses of shear observed along some contacts, and especially along the main thrust.

The eo-Alpine Belt

As pointed out above, the main thrust constitutes the external boundary of nappes, the tectono-metamorphic evolution of which began before

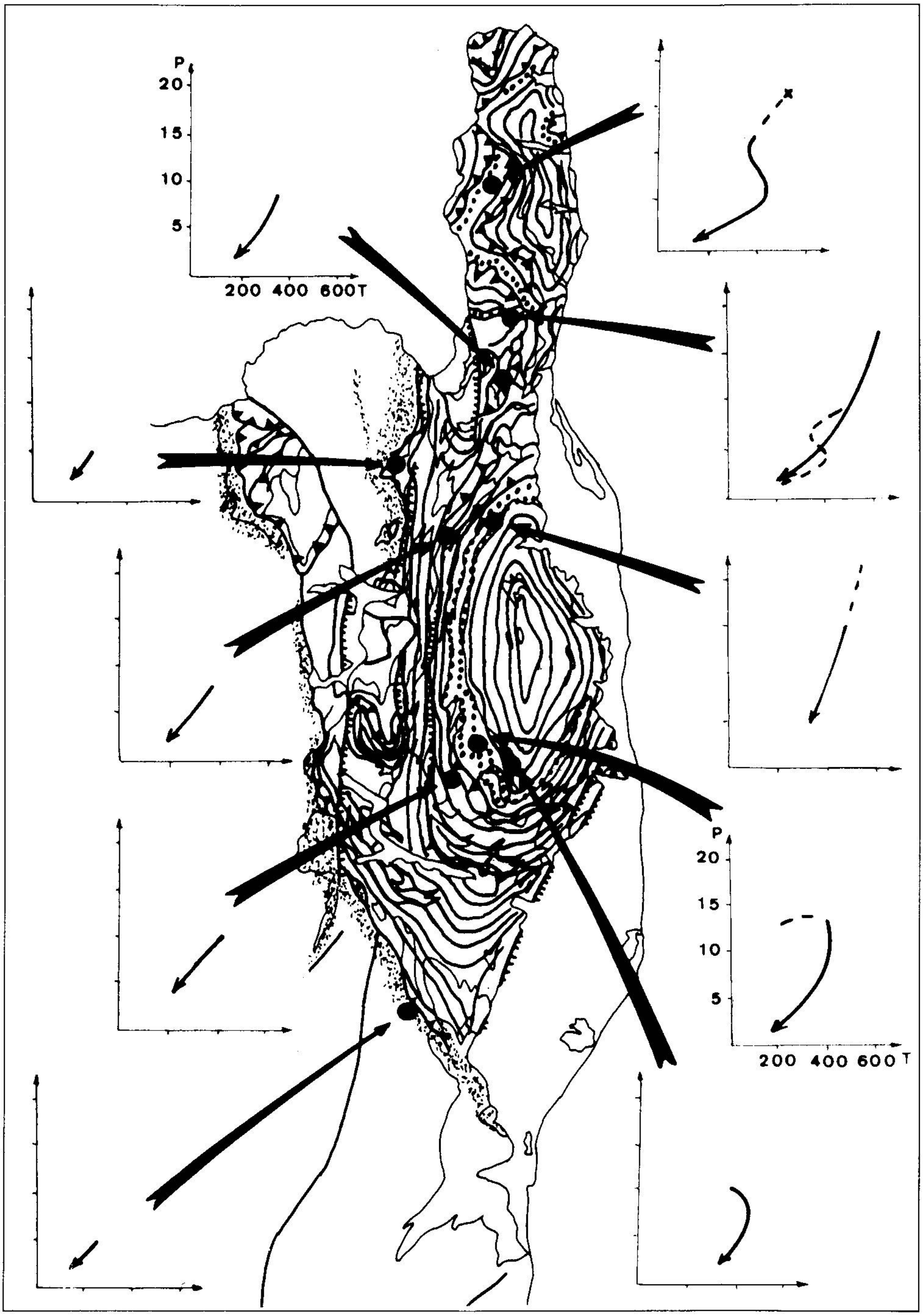

Fig. 4 Alpine metamorphism in Corsica (after data from AMAUDRIC DU CHAFFAUT et al., 1976; CARON, 1977; CARON et al., 1981; SCIUS, 1981; HARRIS, 1984; PÉQUIGNOT and POTDEVIN, 1984; CARON and PÉQUIGNOT, 1986; LAHONDÈRE, 1988; WATERS, 1989; EGAL, 1989; FOURNIER et al., 1991; LAHONDÈRE, 1991).
Peak of metamorphic conditions: heavy dots, eclogites; lines, blueschists; light dots, greenschists. Metamorphic evolutions in P-T diagrams, as documented in some points (the scale of all diagrams is the same).

they were emplaced onto the Variscan autochthonous and Eocene deposits. These nappes belong to the eo-Alpine belt, in which Cretaceous metamorphic and tectonic events are recognized.

THE MAIN THRUST

The main thrust is mapped continuously from the Fium'Orbo area (S) to the eastern side of the Tenda Massif (N), and at the sole of the Balagne nappes (Figs 1 and 2). Egal (1989, 1992) has documented the features of this discontinuity. It forms a break in the metamorphic sequence (Fig. 4) and separates units with a different early structural history (Fig. 5).

Conversely to previous interpretations (Mattauer and Proust, 1975; Amaudric du Chaffaut, 1982), it has been demonstrated that no Cretaceous tectonometamorphic event occurred in the autochthonous and parautochthonous units (Egal and Caron, 1988, 1989; Bezert and Caby, 1988).

The magnitude of the westwards displacement increases from the south to the north (Egal, 1989; 1992): in Southeastern Corsica, Paleocene-Eocene (?) sediments rest unconformably upon both Variscan basement and deformed Schistes lustrés (Amaudric du Chaffaut, 1973); further to the north, in the Corte and in the Balagne areas, Eocene deposits are overlain by the external nappes and by ophiolitic nappes.

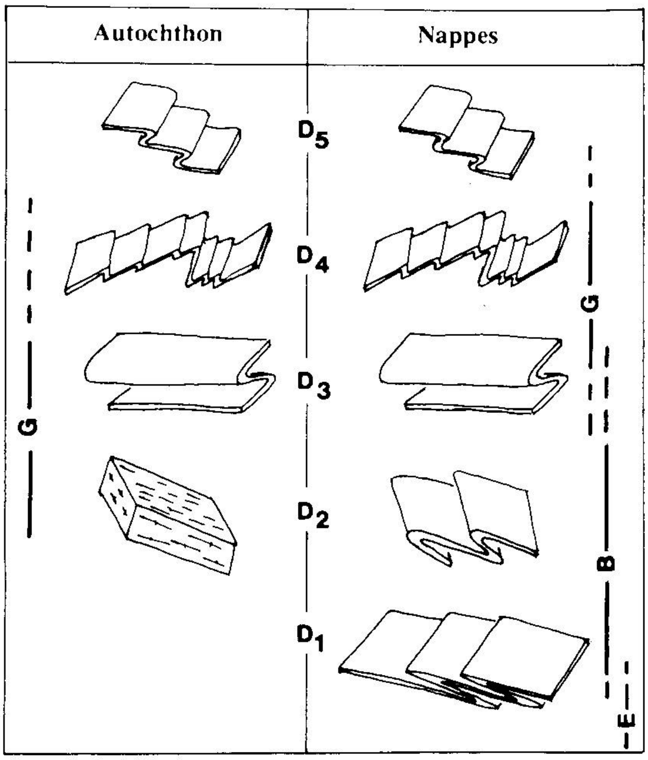

Fig. 5 Comparison of structures between autochthonous units and nappes (from Egal, 1989).
The first deformation event in the nappes (D_1) is absent in the autochthon; the second event in the nappes (D_2) corresponds to the first one in the autochthon.
The structural discontinuity corresponds to a break in the metamorphic sequences. B: blueschist. E: eclogite. G: greenschist.

ARGUMENTS IN FAVOUR OF CRETACEOUS EVENTS

Scarce radiometric data poorly constrain the age of HP metamorphism in Corsica. ^{40}Ar–^{39}Ar analyses at Sant'Andrea di Cotone give two steps at 48 and 90 Ma for glaucophanes, and a plateau at 35–40 Ma for phengites (Maluski, 1977). Cohen et al. (1981) record a whole-rock Rb–Sr isochron at 105 ± 8 Ma from blastomylonitic gneisses in the Tenda massif, whereas the fission track method on apatites gives 40 Ma (Carpéna et al., 1979); the geological significance of these numbers is debated: true tectonometamorphic events, or incomplete isotopic reequilibration for the oldest values, or thermal resetting for the youngest ones. These data are, however, often taken as arguments for a Cretaceous blueschist event followed by HP syntectonic recrystallizations during the Eocene, but obviously new measurements are needed, strictly constrained by mineralogical and microstructural observations.

An unambiguous but indirect datum is the occurrence of detrital glaucophane in the Lower Maastrichtian (about 70 Ma) of eastern Sardinia (Dieni and Massari, 1982), which indicates that some units had already undergone HP metamorphic conditions, and had been then exhumed.

On the eastern side of the Santa Lucia Nappe (one of the external nappes), the Bagliacone-Riventosa series is stratigraphically intercalated between the Tomboni conglomerate (presumably Cretaceous) and the Senonian Tralonca flysch; this series ends up locally with serpentinite arenites in limestones. The Tralonca flysch rests unconformably, from west to east, upon the Tomboni conglomerate, the Bagliacone Riventosa series, and the post-ophiolitic Schistes lustrés of the Erbajolo formation. The whole sequence is strongly deformed by all of the five tectonic phases common to the nappes (Fig. 5). In the first phase schistosity of the different units here described, the Si-content of the phengites ranges between 3.35 and 3.40. In my opinion, this demonstrates (1) the pre-Senonian emplacement of ophiolitic Schistes lustrés onto the continental margin from which the Santa Lucia external nappe originated; (2) the subsequent common metamorphism and deformation of both units (Schistes lustrés and Santa Lucia Nappe) and of the sealing Upper Cretaceous flysch.

The first phase schistosity is related to the development of glaucophane, lawsonite, phengite, and garnet in the blueschist nappes, and to the syntectonic recrystallization of garnet and omphacite in eclogitic nappes. The first development of eclogitic parageneses occurred, therefore, probably before this tectonometamorphic event. This argument is consistent with the deformation of earliest contacts by F1 folds, as mentioned above. It could explain the metamorphic break between eclogitic and blueschist units by an eo-Alpine intra-oceanic imbrication.

Evidently, these assumptions about the eo-Alpine evolution in Corsica need to be checked by careful radiochronologic investigations.

The Alpine mechanical transpositions

As a consequence of the eo-Alpine metamorphism and/or of Alpine recrystallizations, HP-LT minerals are well-developed in the Corsican nappes. Their preferred orientations are usually interpreted in terms of strain or displacement markers related to the nappes motion (Mattauer et al., 1977; 1981; Faure and Malavieille, 1981; Harris, 1984; Gibbons et al., 1986). I intend however to show that such well-aligned lineations are best developed where later tectonic phases have had a prominent effect.

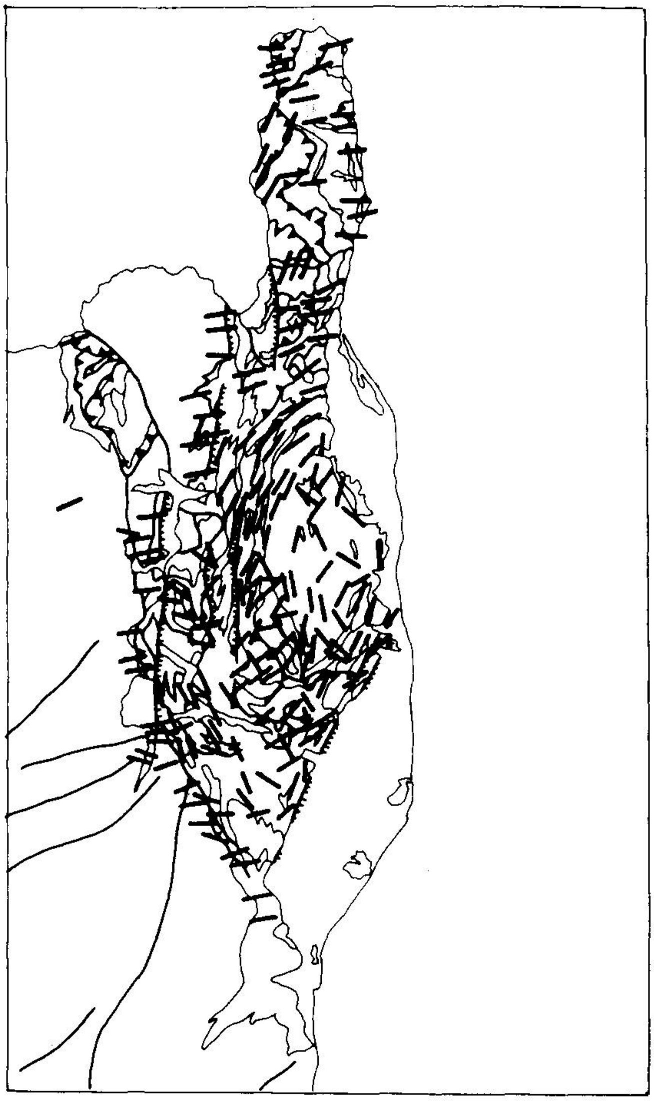

Fig. 6 Stretching lineations in Alpine Corsica.

N–S DIFFERENCES IN TECTONIC STYLES

A difference in style of the structures between the south and the north of Alpine Corsica results from the previously mentioned difference in the magnitude of displacement on the main thrust. Other differences are obvious in the field as well as on maps or on cross sections. East of Corte, the units bounded by the backthrusts have a kilometric thickness, and superimposed folds are the most evident feature at all scales (Amaudric du Chaffaut et al., 1985; Caron et al., 1990; Rossi et al., in press). In the Golo-Cap Corse area, conversely, the slices are a few hundred meters thick (Faure and Malavieille, 1981; Lahondère, 1983), and the tectonic style is better described in terms of ductile shear zones.

Another difference parallels the increasing effect of late deformation phases: the trend of the stretching lineation, quite dispersed at the map scale in the south, is more constantly aligned in the north (Fig. 6). This change is partly related to the increasing amount of late transformation of blueschists into greenschists, with the common alignment of actinolite and albite parallel to the stretching lineation (Fournier et al., 1991). However, it is also marked in many places by the preferred orientation of glaucophane.

REORIENTATION OF MINERAL LINEATIONS

When a metamorphic rock is subjected to new strain increments, different kinds of mineral lineations may develop (Ildefonse and Caron, 1987). Syntectonic new minerals, often fiber-shaped, may grow in rheological discontinuities, and they are assumed to parallel the stretch axis. This is the case for omphacite fibers parallel to the L_1 lineation (Caron and Péquignot, 1986; Lahondère, 1991), for glaucophane fibers parallel to the L_2 lineation

(CARON et al., 1981; LAHONDÈRE, 1991), and for actinolite fibers parallel to the L_3 lineation (FOURNIER et al., 1991; LAHONDÈRE, 1991). Older elongate grains, with initially either random or preferred orientation, are rotated toward the new stretching axis, at an angle dependent upon their original orientation and on the new strain amount. They may be boudinaged, and sealed, or rimmed, or partly replaced by new minerals. But the preferred orientation of these relic minerals tends to parallel the stretching axis of the final penetrative deformation event to affect the rock.

This allows us to interpret the stretching lineation map (Fig. 6). Assuming that HP-LT minerals developed before, during, or immediately after the D_1 deformation event in the nappes, their current preferred orientation depends on the timing of the last penetrative deformation. In the south, they parallel the L_2 long axis; as with the D_2 structures, these minerals are deformed around D_3, D_4 and D_5 folds, and their orientation is dispersed, but the later bulk strain is too low to develop a well-defined new lineation. In the north, the stronger reorientation reflects a higher amount of late finite strain.

In several areas (Fig. 7) the stretching lineation is also reoriented by post-collisional ductile extension: it is folded around the latest Miocene folds (EGAL, 1992; CARON and EGAL, submitted), and rotated on both limbs toward a N60 to N70 direction.

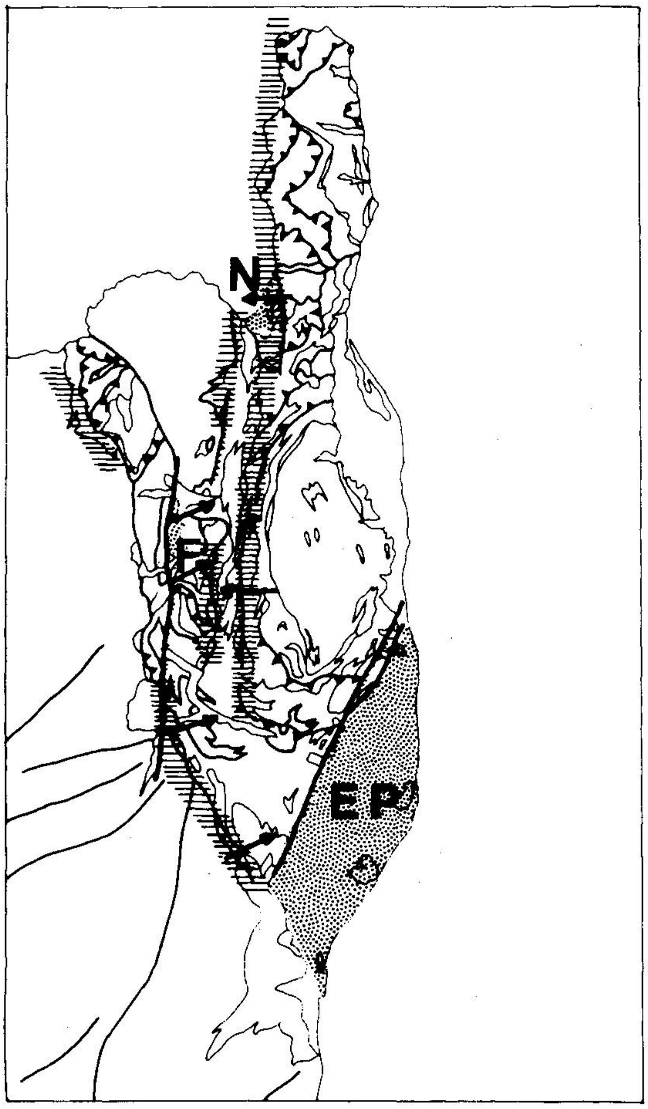

Fig. 7 Zones of extensional ductile deformation (ruled) in Alpine Corsica. Arrows represent the direction and sense of extension. The Miocene basins are dotted (EP: Eastern Plain; F: Francardo; N: Nebbio).

Conclusions

Regarding the tectonometamorphic evolution of the Alpine belt in Corsica, we recognize the same general pattern and the same problems as in the Western Alps. HP-LT metamorphism, and related deformation, affected portions of the Liguro-Piemontese oceanic units and of distal continental margins; but the geometry, and above all the age of this eo-Alpine belt need to be better constrained. A major thrust event occurred in the Upper Eocene, and is responsible for the most obvious nappes stack, as well as much metamorphic crystallization and recrystallization. The importance of the late ductile extension is now recognized, but the related structures are not everywhere clearly distinguished from the final compressional ones.

Considering the relationship between metamorphic parageneses and structures, there is a major discrepancy: the two kinds of data frequently record in a given rock different stages of the tectonometamorphic evolution. Minerals usually preserve the memory of early HP-LT conditions, while the most obvious structures reflect late stages of deformation, which they accommodate by mechanical transposition. This explains probable difficulties in interpreting radiometric data in such regions. It is also the reason for an apparent internal contradiction on some geological maps: the shape of the represented cleavage trajectories is significant for late stages of the history, while the colour and the size of these lines are related to the peak metamorphic conditions and relevant to early events.

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