Ductile extension in alpine Corsica

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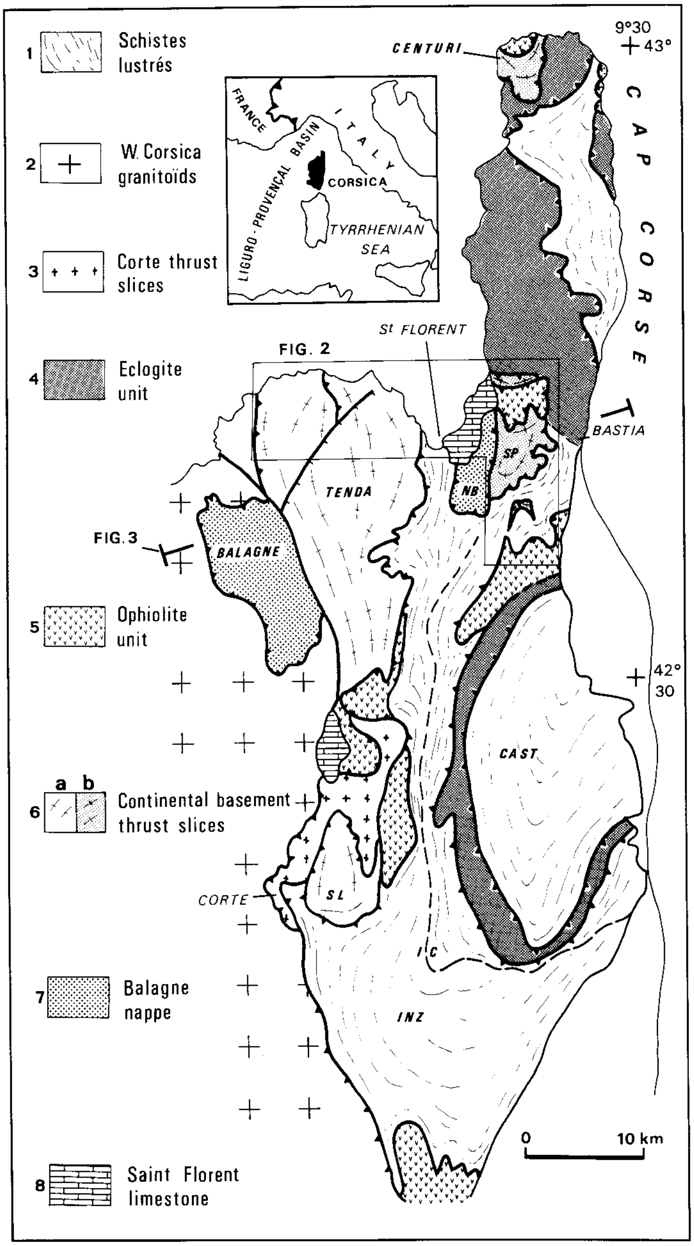

Figure 1. Simplified tectonic map of alpine Corsica (1, 4, and 5 constitute Schistes Lustrés nappe; 2, 3, and 6 constitute continental margin of western Corsica). Note: 6b is same as 6a, but shows higher pressure metamorphism (occurrence of jadeite + quartz in Sera di Pigno [SP] and Farinole). SL = Santa Lucia nappe. NB = Nebbio, part of Balagne nappe; other small klippes of nappe rest upon Schistes Lustrés nappe near northern tip of Cap Corse. Dotted line represents contact between Inzecca Schistes Lustrés (I) and Castagniccia Schistes Lustrés (C) units of Caron (1977).

ABSTRACT

Ductile deformation in high-pressure (*P*)–low temperature (*T*) conditions due to the westward thrusting of oceanic material onto a continental basement in alpine Corsica is overprinted by a late deformation event with a reverse shear sense (eastward) that took place in less severe *P-T* conditions. We show that the late deformation can be linked to extension during rifting and spreading of the Liguro-Provençal basin from late Oligocene to late-middle Miocene time. Major compressive thrust contacts were reactivated as ductile normal faults and, in some units, only a penetrative eastward shear can be observed. This extension following the thickening of the crust brought tectonic units which underwent very different *P-T* conditions during the earlier stage into close contact. The Balagne nappe, which shows neither significant ductile deformation nor metamorphism, directly overlies the high-*P* units. The extensional deformation is distributed through the entire thickness of the nappe stack but is more important along the major thrust contacts, which localize the strain. The geometry of the crustal extension is controlled by that of the early compressive thrusts. The latest structures are east-dipping brittle normal faults which bound the early to middle Miocene Saint Florent half graben.

INTRODUCTION

The superposition of a ductile extensional deformation on ductile deformation linked with the thickening of a crust has been described from several places (e.g., Lister et al., 1984; Coney and Harms, 1984; Malavieille, 1987). Alpine Corsica shows metamorphosed oceanic material (the Schistes Lustrés nappe) thrusted upon the continental margin of Europe (western Corsica) in high-pressure (*P*)–low-temperature (*T*) conditions and, unlike the western Alps, has been isolated from the main part of the belt by the rifting of the Liguro-Provençal basin during Oligocene-Miocene time. The ductile deformation associated with thrusting has been described in detail by Mattauer et al. (1981) and Warburton (1986), who reported consistent west-vergent shear criteria along a typical east-west cross section (Fig. 1). In contrast, retrograde metamorphism of high-*P*–low-*T* paragenesis under greenschist conditions is associated with "backthrusts" (i.e., faults showing an eastward shear sense) (Amaudric du Chaffaut, 1982; Gibbons et al., 1986; Jourdan, 1988) in alpine Corsica, and the nature of the basal contact of the unmetamorphosed Balagne nappe and the Schistes Lustrés nappe is not well understood (Durand-Delga, 1978; Amaudric du Chaffaut, 1982; Dallan and Nardi, 1984; Dallan and Puccinelli, 1986). A preliminary comparison of similar poorly metamorphosed upper plates on highly deformed and metamorphosed rocks (see Platt, 1986; Coney and Harms, 1984; Lister et al., 1984) suggests to us a large detachment fault, and that alpine Corsica is a metamorphic core complex similar to that of the North American Cordillera of the Aegean Sea.

GEOLOGIC SETTING

The broad-scale structure is that described by Mattauer et al. (1981) or Warburton (1986). There are four major units (Figs. 1 and 2): (1) the thinned continental margin of the Eurepean plate (western Corsica, Tenda massif, and Sera di Pigno), pressure conditions increasing from west to east; (2) the Castagniccia-Inzecca units with oceanic crust and its cover (Schistes Lustrés nappe); (3) the Eclogites unit, predominantly basic rocks and some schists; and (4) the Adria units (oceanic crust and Austro-Alpine[?] crust; Balagne-Nebbio nappe).

Western Corsica

Alpine high-*P* metamorphic paragenesis is observed in western Corsica near the thrust contact with the Schistes Lustrés nappe (Gibbons and Horak, 1984). The massif underwent ductile deformation at intermediate pressures during westward shear (Amaudric du Chaffaut, 1982; Gibbons and Horak, 1984; Jourdan, 1988). Mattauer et al. (1981) and Jourdan (1988) described the progressive transition—from relatively undeformed granitoids in the core of the Tenda massif to orthogneiss along the thrust contact above the massif—and medium-pressure mineral assemblages associated with this deformation. Jourdan (1988) also proposed that the Tenda massif is allochthonous and has been thrust westward over western Corsica. Acidic volcanics which constitute the Paleozoic cover of the granitoids are in turn covered with a sequence of Mesozoic quartzites and marbles, and the entire section displays the same deformation as the basement (Jourdan, 1988; Mattauer et al., 1981).

Schistes Lustrés Nappe

The Schistes Lustrés nappe is folded in a broad anticline, the axis of which is parallel to the strike of Cap Corse Peninsula (Fig. 1). The Castagniccia schists (Caron, 1977) constitute a monotonous sequence of calc-schists intercalated with rare glaucophane and epidote-bearing metabasites. The schists contain lawsonite (Caron, 1977) and carpholite that have undergone partial retrograde metamorphism typical of high-*P*–low-*T* conditions (Goffé and Velde, 1984). Carpholite and lawsonite are preserved in the western part of the Castagniccia antiform near the contact with the overlying eclogites. Preserved eclogitic associations in the overlying unit have been described (Caron et al., 1981; Harris, 1984; Pequignot, 1984; Lahondère, 1988). It is overlain by the Inzecca schists, which also contain pseudomorphs of carpholite and lawsonite, preserved only along the contact with western Corsica. Allochthonous lenses of orthogneiss with a metasedimentary cover are included in the schists (Sera di Pigno, Farinole, Centuri) (Mattauer et al., 1981). They contain jadeite + quartz at Farinole (Lahondère, 1988) and Sera di Pigno (Dubois and Jolivet, unpublished). A complete (though disturbed) sequence of ophiolitic bodies that have undergone high-*P*–low-*T* conditions (Ohnenstetter et al., 1976) constitutes the uppermost unit of the nappe pile.

Balagne Nappe

The uppermost Balagne nappe is an unmetamorphosed olistostrome of Ligurian affinity that includes Late Jurassic ophiolite (Durand-Delga, 1984). It has been folded together with the Schistes Lustrés nappe in broad antiforms (Tenda, Cap Corse) and synforms, wherein klippes of the nappe are preserved (Balagne, Nebbio, Maccinaggio). The Balagne nappe was emplaced during Eocene and Oligocene time in a terrigenous basin on western Corsica (Durand-Delga, 1984). The early Miocene Saint Florent limestone unconformably covers the basal contact of the nappe (Orszag-Sperber and Pilot, 1976).

STRUCTURE AND DEFORMATION IN THE SAINT FLORENT AREA

The eastern limb of the Tenda antiform is a top-to-the-east shear zone (Fig. 3). East-dipping brittle normal faults cut through the east-dipping foliation; the foliation is associated with predominantly east-dipping duc-

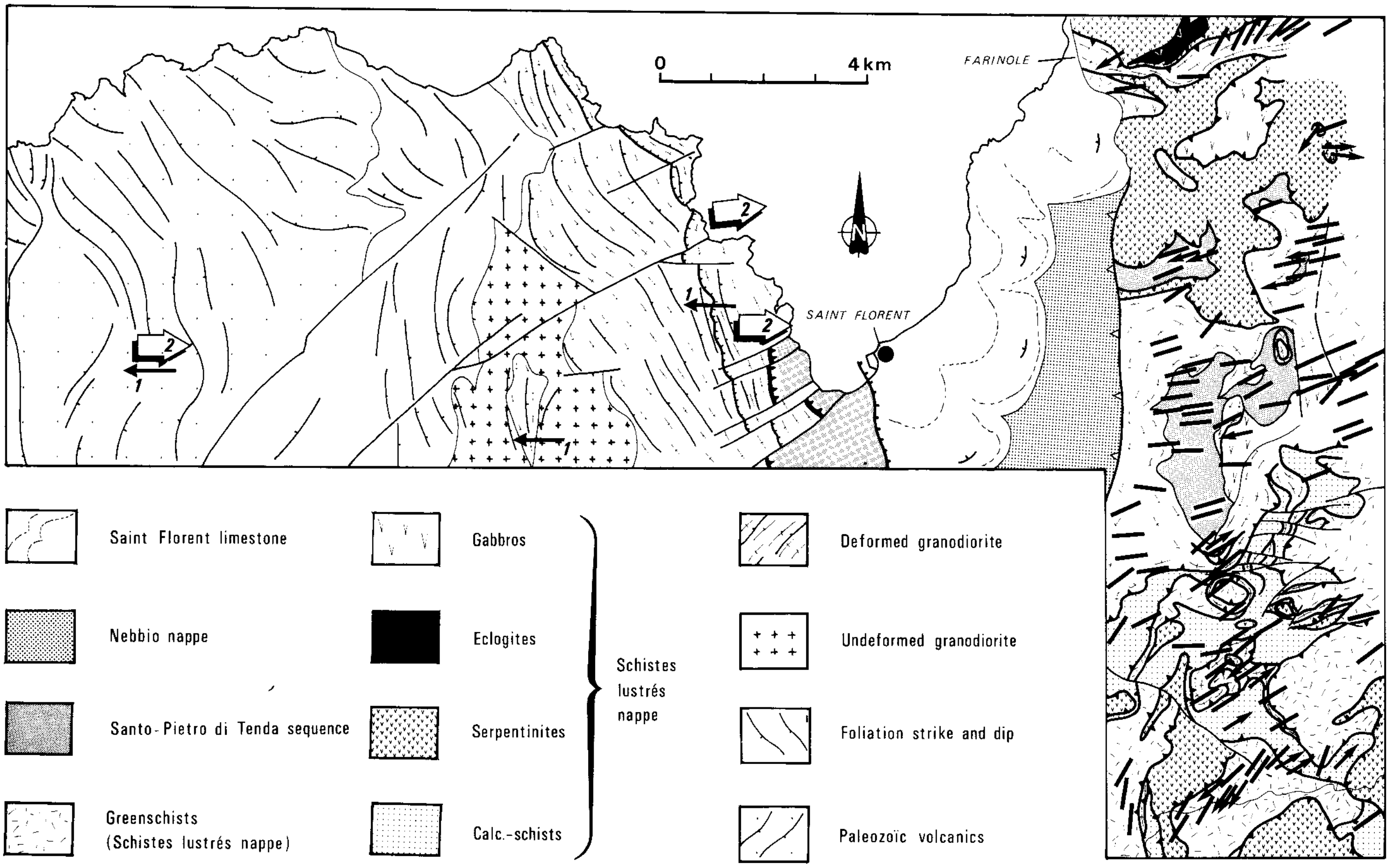

Figure 2. Structural map of Saint Florent area (see location in Fig. 1) after this work and Jourdan (1988), Mattauer et al. (1981), and Fournier et al. (unpublished). Black bars represent direction of stretching lineation in Schistes Lustrés nappe; small arrow shows sense of shear. Large arrows indicate average direction of lineation in Tenda massif (after Jacquet, 1983; Jourdan, 1988). Direction of arrow indicates sense of shear.

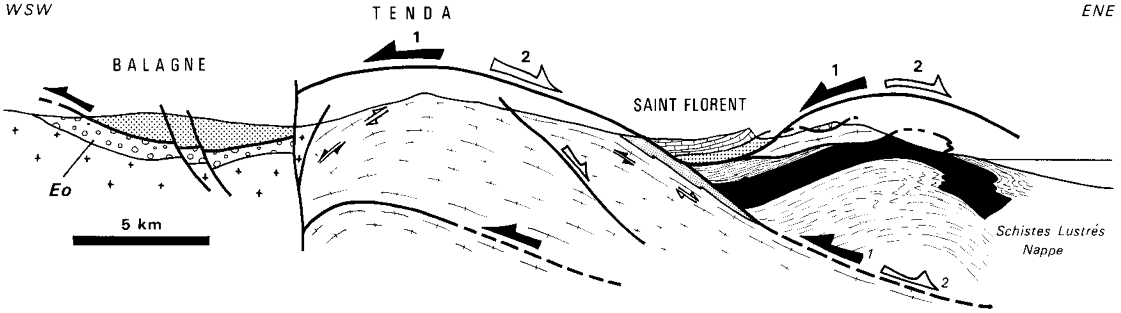

Figure 3. Cross section from Balagne nappe to Bastia (see Fig. 1). Black arrows indicate early high-pressure–low-temperature event; white arrows indicate late extensional event. For symbols see Figures 1 and 2. Eo = Eocene sedimentary rocks.

tile normal shear bands, which are often reworked as brittle normal faults with the same sense of shear. This foliation and the shear bands clearly postdate an early foliation associated with blue amphiboles (Jourdan, 1988). The basal depositional contact of the Saint Florent limestone is faulted along east-dipping brittle normal faults. The East Tenda shear zone thus shows consistent eastward ductile to brittle faulting. In the core of the Tenda massif, shear zones that contain crossite always show a westward shear sense, whereas those associated with retrograde mineral assemblages generally show east-verging shear (Jourdan, 1988). The recent eastward deformation corresponds to east-dipping normal shear bands and to the reorientation of quartz fabrics.

In the Cap Corse area, east-vergent open folds form interference structures with the earlier synfolial sheath folds, which have axes parallel to the regional stretching lineation (Mattauer et al., 1981) and which imply a high shear strain in a ductile simple shear context (Cobbold and Quinquis, 1980). The stretching lineation strikes consistently east-west. This led Mattauer et al. (1981) to relate this deformation to a single stage of westward thrusting. We observed that west-vergent criteria are always associated with high-*P*–low-*T* minerals in the Sera di Pigno or Zucarello orthogneiss units or in the basic rocks. However, the earlier high-*P*–low-*T* foliation in the metabasites is frequently overgrown by large albite crystals, which are in turn deformed and stretched by an east-vergent shear (Fournier et al., unpublished). Eastward shear indicators in the orthogneiss or metabasite are restricted to outcrops near the thrust contacts or near the contact between the orthogneiss and the metasedimentary cover. In contrast, the schists show only normal east-vergent shear bands, which cut through the foliation at acute angles. These bands are associated with the retrograde metamorphism of carpholite and the crystallization of albite.

The basal contact of the Balagne nappe on the Schistes Lustrés nappe is seen at the base of the Maccinaggio klippe. Normal faults and tilted blocks are observed in the klippe, and the basal contact is a slightly east-dipping normal fault.

We conclude that the westward shear described by Mattauer et al. (1981) was followed by eastward shear.

AGE OF THE EAST-VERGENT SHEAR

The east-vergent shear event is associated with a greenschist facies retrograde metamorphism which has been dated by Maluski (1977) as between 30 and 40 Ma. According to Cohen et al. (1981) and Mattauer et al. (1981), the compression event began in Late Cretaceous time. Bézert and Caby (1988) showed instead that the ductile deformation of western Corsica occurred after middle Eocene time. Ages of phengites, dated by ^{39}Ar-^{40}Ar as 32–33 Ma, in the strain-slip cleavage in the Tenda massif shear zones correspond to the latest tectonic event responsible for the reorientation of quartz c-axis fabrics during eastward shear (Jourdan, 1988). Lower to middle Eocene sedimentary rocks are involved in thrust slices (Amaudric du Chaffaut, 1982). An Oligocene conglomerate on the western part of the Tenda massif has open folds (Jourdan, 1988). The basal conglomerate of the Saint Florent limestone is cut by east-dipping normal faults, the youngest evidence of eastward shear. The eastward ductile shear thus occurred during late Oligocene–early Miocene time, before, during, and perhaps after the deposition of the Miocene limestone.

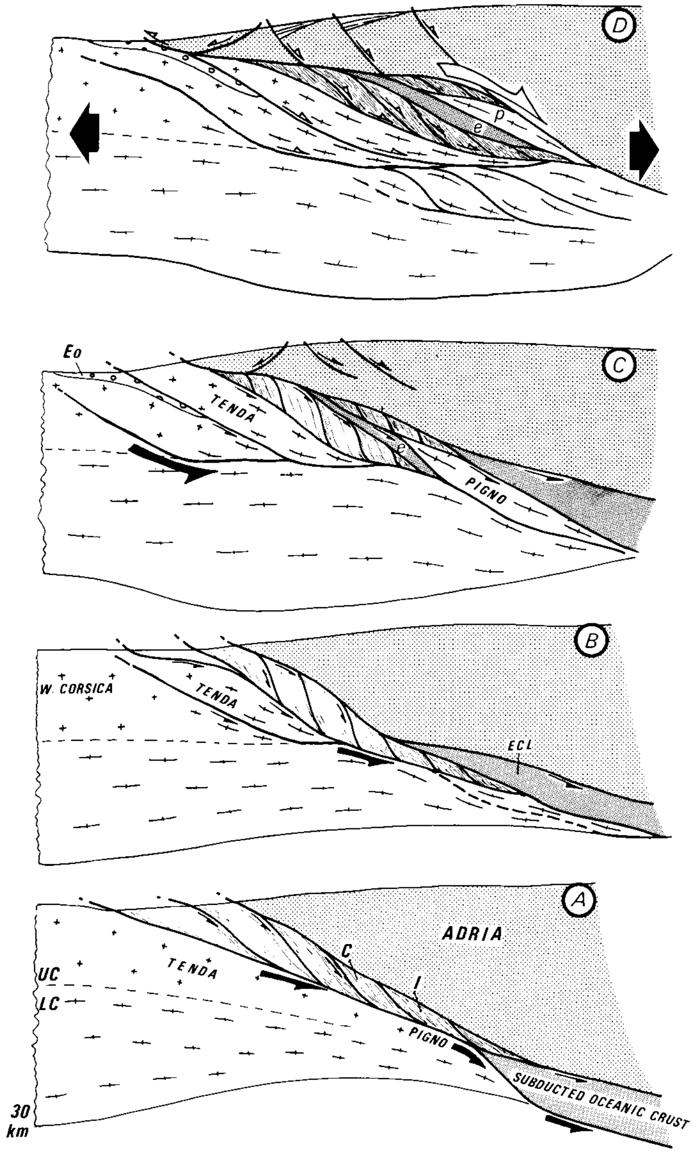

Figure 4. Evolution scheme along cross section of Figure 3 from early compression in high-pressure–low-temperature gradient to recent extension (see text). I = Inzecca, C = Castagniccia, ECL and e = eclogites, UC = upper crust, LC = lower crust, Eo = Eocene sedimentary rocks, p = Pigno. A, B: Late Cretaceous; C: Eocene and early Oligocene; D: Late Oligocene to present.

EXTENSION HYPOTHESIS

Because the major part of the early Miocene basin is tilted toward the west, it may be a half graben above the east-dipping normal fault which reworks the thrust contact between the Tenda massif and the Schistes Lustrés nappe. In this hypothesis the Cap Corse and Tenda antiforms can be interpreted as roll-overs associated with the normal faulting or due to isostatic rebound (Wernicke and Axen, 1988). This extension, probably contemporaneous with the deposition of the Saint Florent limestone, occurred from the Burdigalian to Tortonian (Orszag-Sperber and Pilot, 1976; Dallan and Puccinelli, 1986), i.e., during part of the rifting (24–19 Ma; Burrus, 1984; Réhault et al., 1984) and during the spreading of the Liguro-Provençal basin. It is also possible that the extension continued during the rifting of the Tyrrhenian sea.

The eastward ductile shear can be related to this extension event (Fig. 4). The high-*P* metamorphism is attributed to the underthrusting of the oceanic crust of the Ligurian Tethys and the thinned continental margin of Europa under an Adria plate (Mattauer et al., 1981; Warburton, 1986). The progressive underthrusting of the light material of the continental margin raised the high-*P* rocks in a continuous high-*P*–low-*T* gradient, which preserved the high-*P* paragenesis (Fig. 4, A–C) (Goffé and Velde, 1984; Davy and Gillet, 1986). The deepest parts of the schist units underwent progressive heating, while the shallower parts, continuously underthrust by colder material, preserved their high-*P*–low-*T* paragenesis (i.e., formation of carpholite and lawsonite). During the convergence the imbricate thrusting migrated westward, and involved western Corsica at the end of the Eocene. After crustal thickening, extension started in the upper crust (Platt, 1986) and the Balagne nappe slid into the Eocene sedimentary basin at the thrust front (Fig. 4C). During Oligocene time, compression stopped and the entire crust was subjected to east-west extension (Fig. 4D). The geotherm rose. Major thrust contacts were reworked as ductile normal faults. Eastward shear was active throughout the thrust stack, but the deformation was mainly concentrated along the major contacts and within the less-competent units (schists), where retrograde *P-T* conditions occurred. Continuous brittle extension in the upper plate reduced it to its present thickness and shallow-marine limestones were deposited in half grabens (see Fig. 3). North-south strike-slip faulting on the fault which bounds the Tenda massif and the Balagna nappe, together with brittle normal faulting in the Tenda massif, occurred during the late stages of extension (Jourdan, 1988).

CONCLUSIONS

Extension followed crustal thickening in high-*P*–low-*T* conditions in the alpine Corsica metamorphic core complex, making it similar to other metamorphic core complexes such as in the North American Cordillera (Coney and Harms, 1984; Malavieille, 1987) or the Aegean Sea (Lister et al., 1984). The crust is cut by a flat-lying normal fault (Wernicke, 1981; Wernicke and Burchfiel, 1982). The simple shear is here distributed over the entire thickness of the nappe stack, and the asymmetry of the ductile extension in alpine Corsica is controlled by the position of the early thrust planes on which strain is localized.

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