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AGE OF EMPLACEMENT OF THE SCHISTES LUSTRES NAPPE, ALPINE CORSICA *

CURTIS R. COHEN [1], **, RICHARD A. SCHWEICKERT [1] and A. LEROY ODOM [2]

[1] *Lamont-Doherty Geological Observatory and Department of Geological Sciences, Columbia University, Palisades, NY 10964 (U.S.A.)*
[2] *Department of Geology, The Florida State University, Tallahassee, FL 32306 (U.S.A.)*

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ABSTRACT

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Structural studies in the Schistes lustrés nappe west of Bastia, Corsica, demonstrate the existence of a tectonic mélange in which km-scale blocks and smaller lozenges of basement granite gneiss, thick-layered marble and dismembered Mesozoic ophiolite are enveloped in a matrix of calc-schist and blueschist. The main (S_1) foliation is developed in both block and matrix and is concordant with lithologic contacts. Blueschist facies metamorphism was syn-kinematic with the main foliation.

The S_1 in the Schistes lustrés was refolded about ENE—WSW trending, tight similar and monoclinal fold axes (F_2). These second folds verge to the southeast and show km-scale axial culminations and depressions that are reflected by topography and residual Bouguer gravity anomalies.

Parautochthonous Hercynian basement (Tenda-Corte complex) beneath the western edge of the Schistes lustrés nappe contains a mylonitic foliation which is concordant with the main foliation in the Schistes lustrés. The intensity of deformation in the basement decreases away from this contact and undeformed granites are found 3 km to the west.

Whole rock samples of the deformed basement immediately beneath the Schistes lustrés yield an Rb-Sr isochron diagram ($n = 4$) which has an age of 105 ± 8 Ma (1σ) and initial $^{87}Sr/^{86}Sr$ ratio of 0.7228 ± 0.0005 (1σ). This result is more precise than our preliminary age and initial ratio estimate of 98 ± 14 and 0.7296 ± 0.0068, respectively (Cohen et al., 1979). It is similar to a recently published mid-Cretaceous (90 Ma) ^{40}Ar—^{39}Ar age from glaucophane mineral separates. We interpret this date as the age of a metamorphic overprint related to the emplacement of the Schistes lustrés nappe and associated ophiolites, the formation of the main foliation and blueschist facies metamorphism.

These results indicate that the mid-Cretaceous blueschist facies metamorphism documented in the Western Alps formerly extended farther south of its present terminus. The data are consistent with mid-Cretaceous obduction of Tethyan oceanic crust onto the

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* Lamont-Doherty Geological Observatory of Columbia University Contribution No. 2919.

** Present address: Gulf Research and Development Company, Exploration Interpretation Department, P.O. Box 36506, Houston, TX 77036 (U.S.A.).

present-day eastern continental margin of Corsica. We postulate that during Eocene—early Oligocene time a polarity flip occurred outboard of the obducted crust and a new, south-facing subduction zone developed. This change in polarity was responsible for the development of southeast-vergent second folds and for the resetting of ^{40}Ar—^{39}Ar and K-Ar geochronologic clocks described in the literature.

INTRODUCTION

Because of general similarities in lithology, structural vergence and sequence of nappe assembly, the tectonic history of Corsica has long been related to that of the Western Alps (Termier, 1907; Termier and Maury, 1909; Argand, 1924) (Fig. 1). Alvarez (1976) suggested that northeastern or Alpine Corsica not only represented the former southern continuation of the Alpine fold chain but that, additionally, the chain probably extended even farther south and west, through what is now Calabria, the Kabylies and the Betics (Fig. 1).

A rigorous test of this hypothesis, through a study of the comparative tectonic histories of these displaced terrains, has been hampered by the lack of

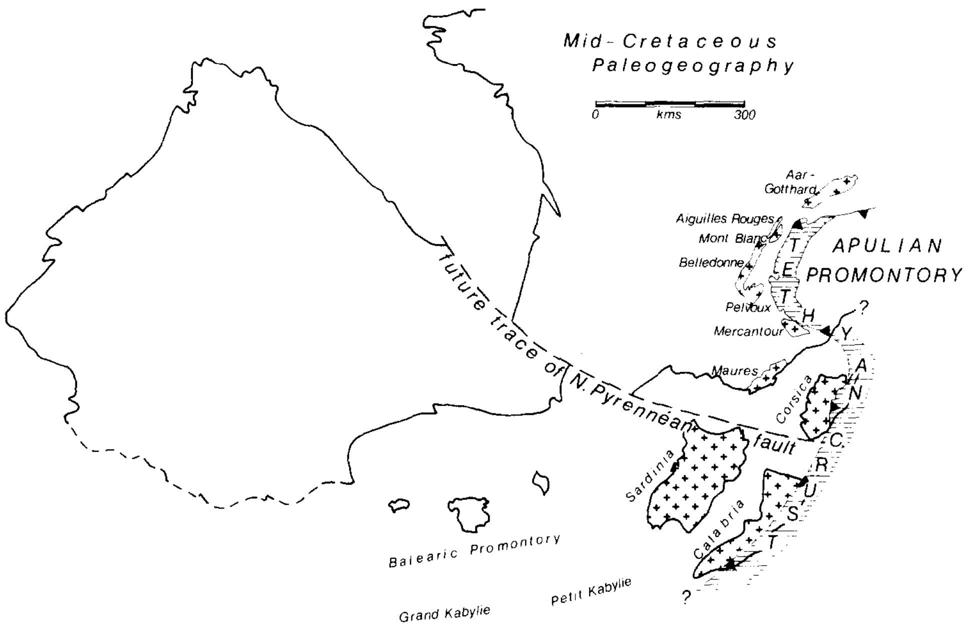

Fig. 1. Mid-Cretaceous paleogeography of the western Mediterranean region showing southern continuation of the western Alpine fold chain. Hercynian crystalline massifs west of allochthonous Tethyan oceanic crust are also shown. Positions of Corsica, Sardinia and the Balearic promontory after Cohen (1980).

data on the nature and timing of regional deformational and metamorphic events.

We present here the results of structural and Rb-Sr geochronological studies in Alpine Corsica regarding the absolute age of emplacement there of Alpine nappes. These constraints provide compelling evidence supporting the decades-old hypothesis for a former, now fragmented, southern continuation of the Western Alps.

TECTONO-STRATIGRAPHIC UNITS

Nardi (1975) subdivided Alpine Corsica into four tectono-stratigraphic units which rest structurally above autochthonous Hercynian basement (Fig.

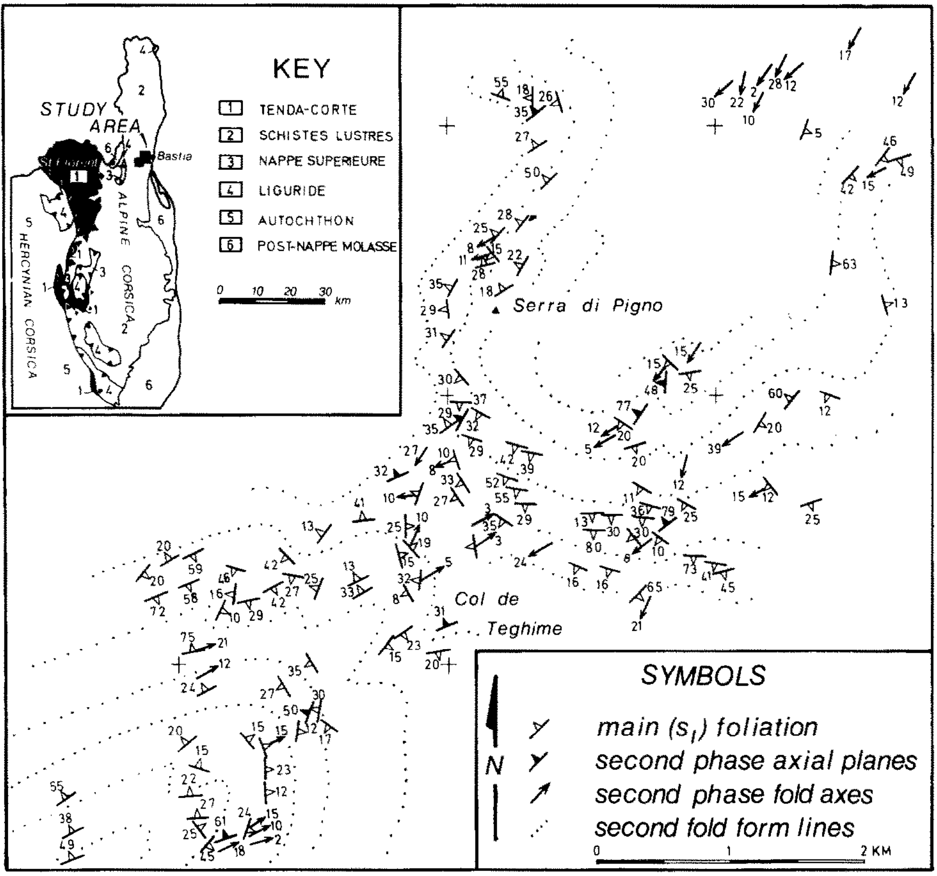

Fig. 2. Structure map of study area in Schistes lustrés showing Col de Teghime depression. Form lines of main (S_1) foliation define second-phase folds which trend ENE—WSW and verge southeast. Inset: Tectono-stratigraphic units comprising Alpine Corsica after Nardi (1975).

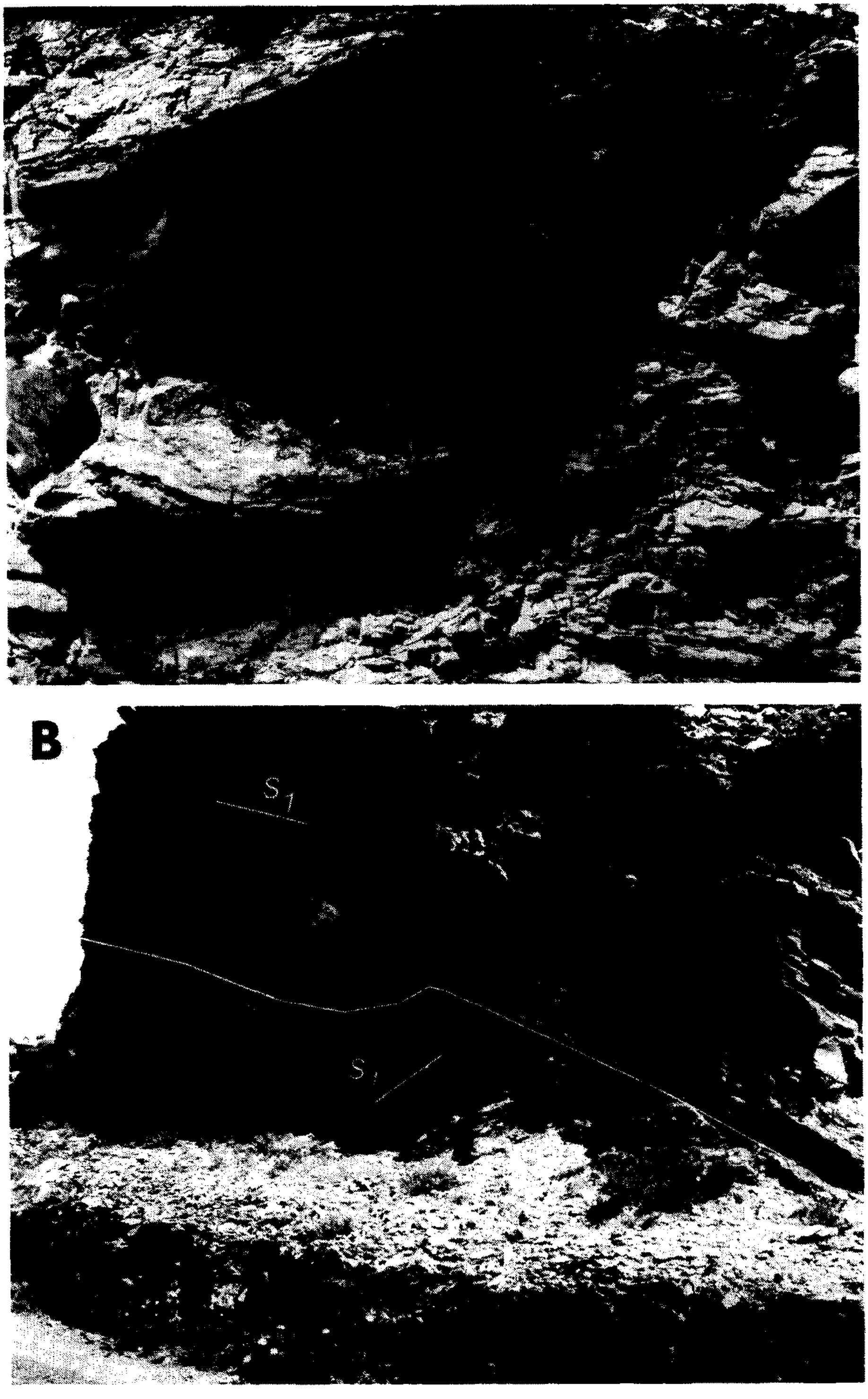

Fig. 3. Schistes lustrés mélange structures. A. Marble lozenge enveloped by blueschists and calc-schists. Note parallelism between flattening plane in lozenge and main phase (S_1) foliation. Blueschist facies metamorphism is syn-kinematic with S_1; B. Discontinuity of S_1 across later thrust fault (heavy white line). Darker units, serpentinites; lighter units, calc-schists.

2, inset). The structural sequence, in ascending order, is: (1) parautochthonous Tenda-Corte complex, representing remobilized granitic basement and cover; allochthonous (2) Schistes lustrés nappe, representing Tethyan oceanic crust (Rocci et al., 1976; Ohnenstetter and Ohnenstetter, 1976; Beccaluva et al., 1977), now intensely deformed and chaotically mixed; (3) Nappa supérieure, representing an unmetamorphosed sequence of Mesozoic shelf carbonates (Gindrat, 1942); and (4) Ligurides, representing a less recrystallized and deformed suite of dismembered ophiolites. Dismembered ophiolites within the Schistes lustrés have yielded a Liassic (190 Ma) U-Pb zircon age (Ohnenstetter and Vidal, cited in Sauvage-Rosenberg et al., 1978).

Detailed studies to date (Caron, 1977; Sauvage-Rosenberg et al., 1978; Caron et al., 1979) suggest that the Schistes lustrés nappe is by far the most complex of the four nappes and is, as a result, the most poorly understood unit.

SCHISTES LUSTRES STRUCTURES

The Schistes lustrés consist of slivers of dismembered ophiolite, Hercynian basement gneiss and thick-layered marble that are structurally enveloped within a matrix that includes calc-schists, prasinites and serpentinites. All have experienced blueschist facies metamorphism syn-kinematic with the development of a penetrative foliation (S_1) (Fig. 3).

First-phase structural elements include a strongly developed axial plane foliation (S_1), a mineral streaking lineation (L_1) and isoclinal folds (F_1) (Fig. 4). The main-phase foliation is manifest as a compositional layering of the granitic gneiss and marble, as a schistosity in blueschist and calc-schist and as a weakly anastomosing cleavage in serpentinite. Mineral streaking lineations are best defined by glaucophane in blueschists and prasinites and by quartz in silicic layers within the marbles. Orientation of L_1 lineations (Fig. 4A) and F_1 axes (Fig. 4C), though scattered, show a clear NE—SW trend; they maintain a shallow plunge, however, irrespective of trend. In outcrop F_1 axes are frequently coaxial with ENE—WSW-trending mesoscopic second-phase fold axes (F_2) (Figs. 4B and 5). Stereoplots of poles to S_1 foliations define well-developed girdle patterns, the poles of which are colinear with measured F_2 axes (Fig. 6).

The S_1 foliation in the Schistes lustrés is concordant with both the contact with the Tenda-Corte basement and a mylonitic foliation within the basement. Apparently associated with proximity to the Schistes lustrés—Tenda-Corte basement contact is the intensity of deformation as judged in outcrop and thin-section. The intensity of development of mesoscopic structural elements and microscopic deformation twins, undulose extinction, fracture and elongation/flattening all increase to a maximum at the contact beneath the Schistes lustrés.

Second-phase structures include axial planes to second folds (S_2), crinkle lineations (L_2) and axes of tight similar to monoclinal folds (F_2). Second-

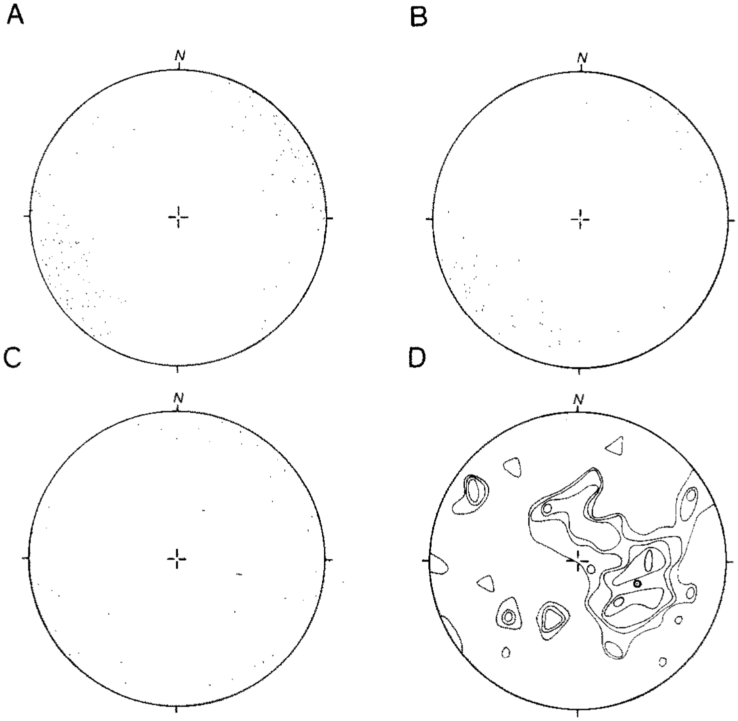

Fig. 4. Stereoplots of structural elements. A. First-phase streaking lineations (n = 146); B. Second-phase crinkle lineations (n = 52); C. First-phase folds axes (n = 38); D. Poles to second-phase axial planes (n = 141; contour interval: 6, 4, 3, 2, 1% per one percent equal area; bull's eye is mean pole to axial planes).

phase folds have axial planes which generally strike NE and dip NW (Figs. 4D and 6) and axes which trend ENE—WSW (Fig. 6).

The geometries of second generation structural elements thus characterize gently-plunging, SE-overturned folds. The structural saddle seen in Fig. 2, here termed the Col de Teghime depression, is very closely mirrored by contours of residual Bouguer gravity anomalies determined by Bayer et al. (1976) (Fig. 7). Sauvage-Rosenberg et al. (1977) interpret their gravity and magnetic data as indicating relative thickness variations of the Schistes lustrés nappe. The geological and geophysical data thus suggest that the Col de Teghime structural depression is probably related to a thinner allochthonous cover rather than to strain variations (e.g., Ramsay, 1962).

First and second phase structures are overprinted sporadically by minor conjugate kinks with N—S-trending, subvertical axial planes and subvertical fold axes.

We thus regard the Schistes lustrés as a transposition mélange because no stratal continuity exists; disruption of lithologic layers occurred during intense ductile deformation and high P/low T metamorphism. These observa-

Fig. 5. Schistes lustrés marble unit at station CO 189 showing southeast-vergent second folds coaxial with earlier, main-phase isoclines.

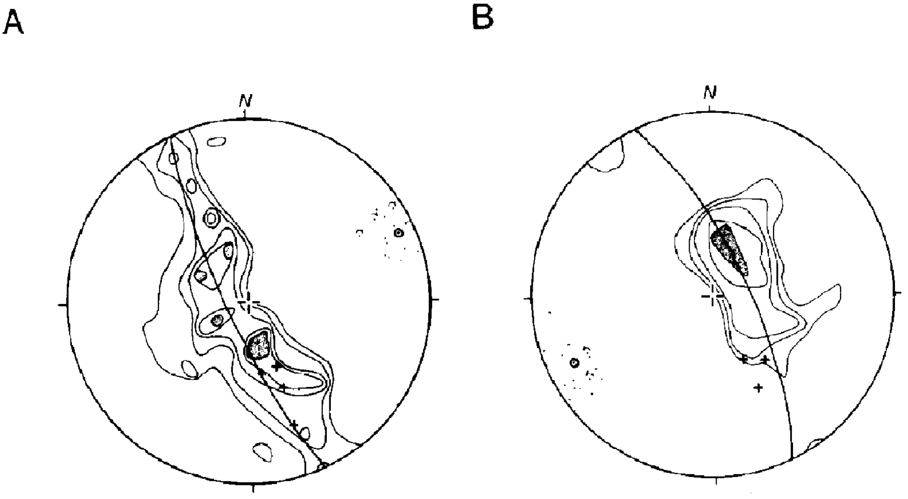

Fig. 6. Stereoplots of main foliation. These plots illustrate plunging inclined nature of major second folds at Col de Teghime depression. A. Southern domain showing N66°E-trending, gently (@10°) plunging fold axis (contour interval: 8, 6, 4, 3, 1% per one percent' equal area; n = 115 poles to S_1); B, Northern domain showing S66°W-trending, gently (@16°) plunging fold axis (contour interval: 12, 8, 4, 3, 1% per one percent equal area; n = 137 poles to S_1). Bull's eye is mean pole to great circle of S_1; dots are measured fold axes, crosses are measured axial planes.

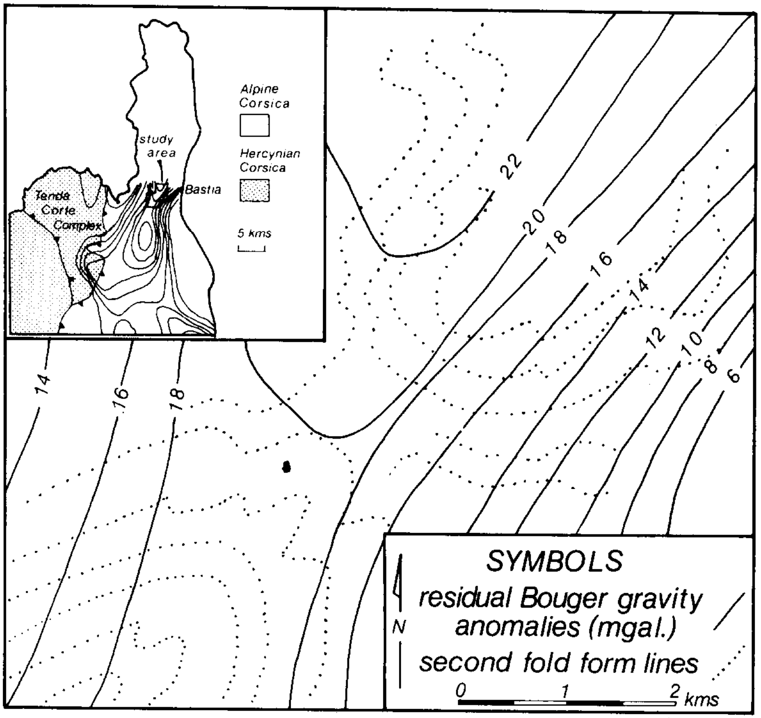

Fig. 7. Second-fold form lines and contours of residual Bouguer gravity anomalies (the latter after Sauvage-Rosenberg et al., 1978 and Bayer et al., 1976). Strong parallelism between these data suggests that Col de Teghime depression is the result of a thinner allochthonous cover in this area; see text for discussion.

tions are consistent with the Schistes lustrés forming in a subduction zone (c.f. Cowan, 1978).

TIMING OF DEFORMATION

Absolute age constraints on the timing of main-phase deformation and blueschist facies metamorphism are provided by Rb-Sr dates on remobilized

TABLE I

Rb-Sr whole rock data for Tenda-Corte basement complex, Alpine Corsica

Sample	Rb (ppm)	Sr (ppm)	^{87}Rb/^{86}Sr	^{87}Sr/^{86}Sr
529A	82.6	44.7	5.35	0.7302
529B	81.2	54.7	4.30	0.7298
531	141.6	46.0	8.92	0.7361
532	156.8	6.89	65.90	0.8211
534	104.9	96.7	3.14	0.7599
536	105.5	228.0	1.34	0.7148
537	121.3	85.25	4.12	0.7215

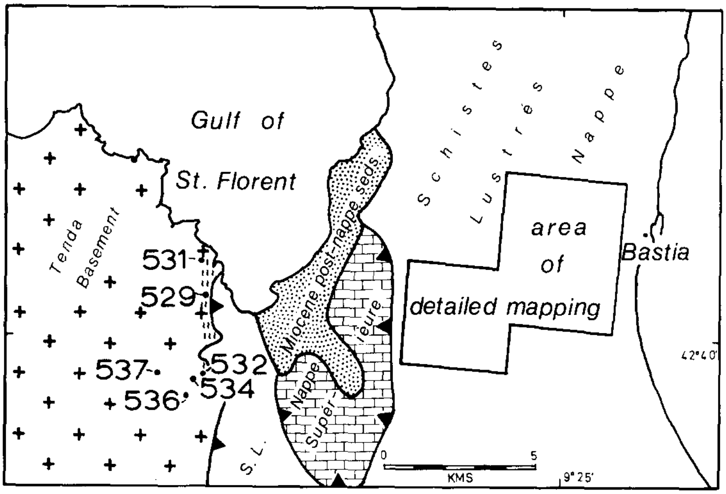

Fig. 8. Rb-Sr sample location map showing mylonitic contact between Schistes lustrés and Tenda-Corte complex; see text for discussion.

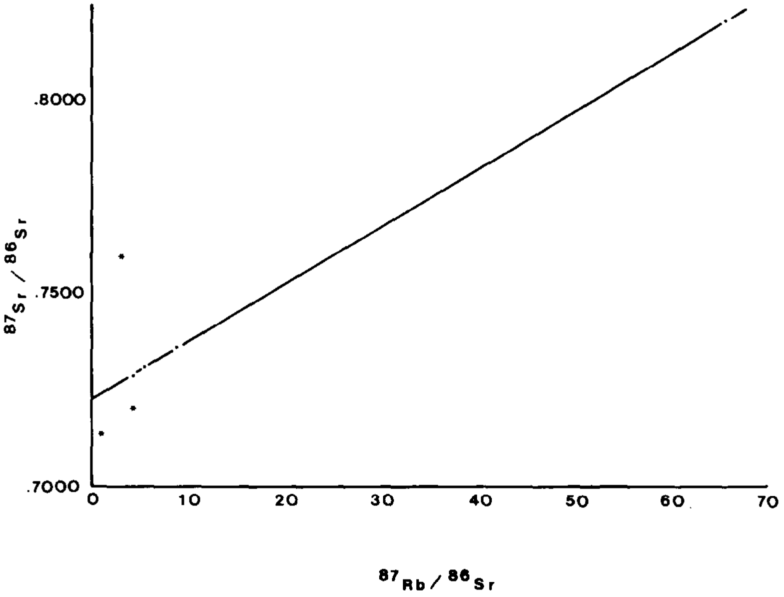

Fig. 9. Rb-Sr whole-rock isochron plot of deformed Hercynian basement. Four point whole-rock isochron plot from blastomylonites immediately beneath the Schistes lustrés, has age of 105 ± 8 Ma and $^{87}Sr/^{86}Sr$ initial ratio of 0.7228 ± 0.0005. Three other less deformed samples, collected up to 2 km away from Schistes lustrés contact, do not plot on the mid-Cretaceous isochron. See text for discussion.

Hercynian basement of the Tenda-Corte complex at its mylonitic contact with the Schistes lustrés nappe. Blastomylonitic basement was sampled approximately along strike of the main foliation (Fig. 8). Seven whole-rock samples of basement gneiss and blastomylonite were analyzed by a standard method of stable isotope dilution using ^{84}Sr and ^{87}Rb enriched spikes. Procedures are given in Fullagar and Odom (1973). The following values were used in the age calculations: $\lambda^{87}\mathrm{Rb} = 1.42 \cdot 10^{-11}\ \mathrm{yr}^{-1}$, $^{85}\mathrm{Rb}/^{87}\mathrm{Rb} = 2.593$ and $^{86}\mathrm{Sr}/^{88}\mathrm{Sr} = 0.1194$. Uncertainties in data are reported as one standard deviation. Analytical data are given in Table I.

Four blastomylonites at the contact with the Schistes lustrés yield a whole rock isochron with an age of 105 ± 8 Ma and $^{87}\mathrm{Sr}/^{86}\mathrm{Sr}$ initial ratio of 0.7228 ± 0.0005 (Fig. 9). Three other samples of less deformed basement beneath the Schistes lustrés nappe and collected up to 2 km away from the contact (Fig. 8), do not plot near the mid-Cretaceous isochron (Fig. 9) and indeed show no meaningful isotopic relationships. The above age and initial ratio are more precise than preliminary results of 98 ± 14 and 0.7296 ± 0.0068 that we reported earlier (Cohen et al., 1979).

DISCUSSION

Stratigraphic studies farther south, near Solenzara (Du Chaffaut, 1973), place a pre-Senonian age limit on the timing of blueschist facies metamorphism and main-phase deformation in the Schistes lustrés. Moreover, a glaucophane separate from the Tenda-Corte complex dated by Maluski (1977) in a preliminary study using the ^{40}Ar—^{39}Ar method gives a similar mid-Cretaceous (90 Ma) age as that shown in Fig. 9. The Rb-Sr whole rock isochron diagram thus is corroborated by two independent forms of evidence. This is an interesting result in light of K-Ar (white mica) age data which evidence a later, Eocene-Oligocene deformational and metamorphic episode in both Alpine Corsica and the Ligurian Alps (Maluski, 1977; Schamel and Hunziker, 1977).

The observation that samples 534, 536 and 537 (Fig. 9), which were collected up to 2 km away from the Schistes lustrés contact, do not plot on the mid-Cretaceous isochron line suggests that these samples reequilibrated to a lesser degree than samples 529A, 529B, 531 and 532 which were collected along the strike of the contact. That the intensity of deformation in the former three samples, as judged in out-crop and thin-section (Fig. 10), was less than in the latter four suggests that the extent to which a system experiences complete isotopic homogenization is a function of the intensity of deformation and/or degree of recrystallization.

The process of isotopic reequilibration through mylonitization has been documented elsewhere (Abbott, 1972; Odom and Fullagar, 1973). In a previous study, Odom and Fullagar (1973) suggested a mechanism by which complete isotopic reequilibration may be attained during mylonitization. This involved isotopic exchange between an aqueous phase and the fine-grained by-products of mylonitization syn-kinematic with mylonitic folia-

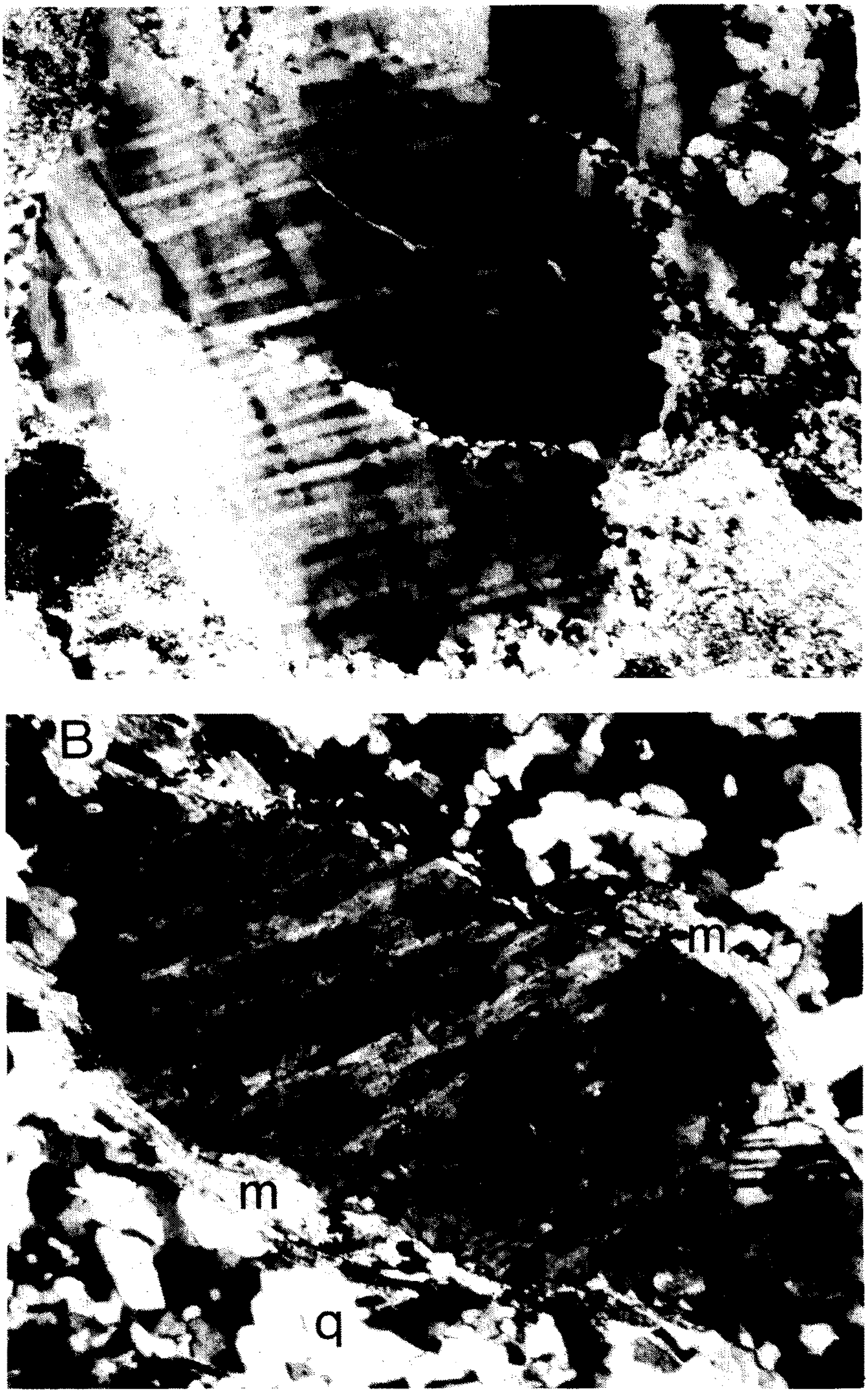

Fig. 10A, B. For legend see p. 278.

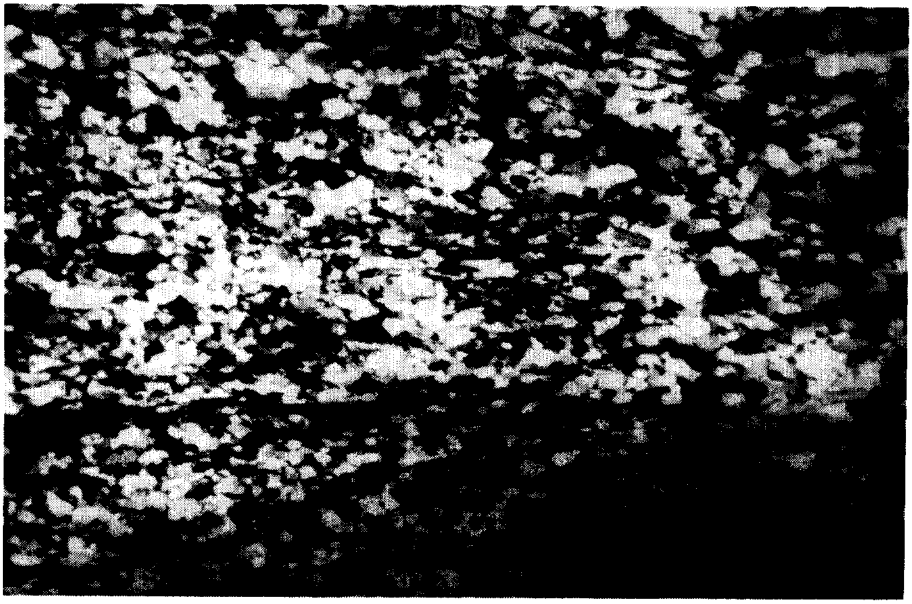

Fig. 10. Tenda-Corte complex microstructures. A. Deformation bands in K-feldspar from sample 537, 2 km away from Schistes lustrés—Tenda-Corte basement contact. B. K-feldspar becoming progressively more flattened into plane of S_1. Note new white mica growth at perimeter of K-feldspar grain in sample 532. C. Extremely flattened quartz grains and white micas define recrystallized mylonitic foliation at contact; sample 531.

tion development. Petrographic observations (Fig. 10) of differing stages of K-feldspar destruction, concomitant white mica growth and quartz elongation/recrystallization in the Tenda-Corte complex support this isotopic exchange model.

In a somewhat similar structural setting Weathers et al. (1979) found that: (1) the degree of recrystallization of Moine thrust zone mylonites increases from 0% 100 m away from the Moine thrust contact to ~100% at the contact; (2) the degree of elongation of relict quartz grains increases towards the fault contact from nearly equidimensional grains (elongation ~1 : 1) at ~100 m to grains with aspect ratios ~85 : 1 at the contact; and (3) the dislocation density in quartz grains is independent of distance from the fault. Weathers et al. (1979) concluded that differential stress is independent of the distance to the shear zone but that strain increased towards the fault. They speculated that the new, smaller sized (~15 μm) grains produced during the deformation could have enhanced grain-boundary deformation mechanisms (e.g., grain-boundary diffusion, sliding). The contribution to the total strain from this mechanism would likely have exceeded that from grain matrix mechanisms (e.g., dislocations) (Weathers et al., 1979). Thus, the strain would have been concentrated in the zone of fully recrystallized rocks at the fault surface (Weathers et al., 1979). Although our study involved no such similar quantitative measurements of strain at the Schistes lustrés—Tenda contact, we have noted petrofabric observations similar to the above in this zone of mid-Cretaceous-reset Rb-Sr isotopic ages. Those four samples which define the mid-Cretaceous isochron are as well the most intensely deformed; conversely those three samples which scatter from the isochron line are least deformed. It seems clear that the degree of isotopic homogenization is directly related to the intensity of deformation and/or degree of recrystallization.

In demonstrating that Hercynian-age Rb-Sr geochronological clocks at the Schistes lustrés—Tenda-Corte complex contact were completely reset in the mid-Cretaceous under conditions of high stress but low (blueschist facies) temperature, this study has applied the Rb-Sr method as a metamorphic veil detector, similar to common use of the K-Ar system in other metamorphic terrains.

PLATE-TECTONIC MODEL

Mattauer and Proust (1976) postulate that main-phase deformation and blueschist facies metamorphism in the Schistes lustrés developed during the Cretaceous in response to major crustal shearing when Tethyan oceanic crust was obducted onto Corsica's eastern continental margin. Our structural and geochronological data concur with earlier stratigraphic (Du Chaffaut, 1973) and ^{40}Ar—^{39}Ar (Maluski, 1977) evidence in support of this hypothesis. These constraints evidence a former southern continuation of the Western Alps (Fig. 1).

Hypotheses for an Eocene age of *initial* blueschist facies metamorphism and nappe emplacement (Nardi, 1975; Schamel and Hunziker, 1977; Reutter et al., 1978) are not supported by our data. Rather, the Eocene ^{40}Ar—^{39}Ar and K-Ar ages probably reflect our *second* deformational event. We speculate that Corsica's tectonic history evolved in the following way. After mid-Cretaceous obduction (Fig. 11B) which resulted in intense deformation and blueschist facies metamorphism, Paleocene isostatic uplift occurred (Fig. 11), exposing deeper crustal levels that had experienced high P/low T metamorphism. The hypothesis that the Schistes lustrés and its ophiolites were emplaced *prior* to the development of the main (S_1) foliation and blueschist facies metamorphism (Caron et al., 1979) in our view remains unproven. Both basement and obducted oceanic crust experienced erosion during this period, producing the strata mapped by Du Chaffaut (1973). This uplift, the earlier reverse polarity nature of subduction and the continued convergence of African and European plates (Biju-Duval et al., 1977; Smith and Briden, 1977) resulted in an Eocene polarity flip outboard of the obducted Tethyan crust (Fig. 11D). This tectonic polarity change occurred in Eocene—early Oligocene time because: (1) a south-facing arc-trench system with normal polarity is known to have formed southeast of Sardinia and Corsica by 30 Ma (Bellon et al., 1977; Cohen, 1980) and (2) 35 Ma ^{40}Ar—^{39}Ar

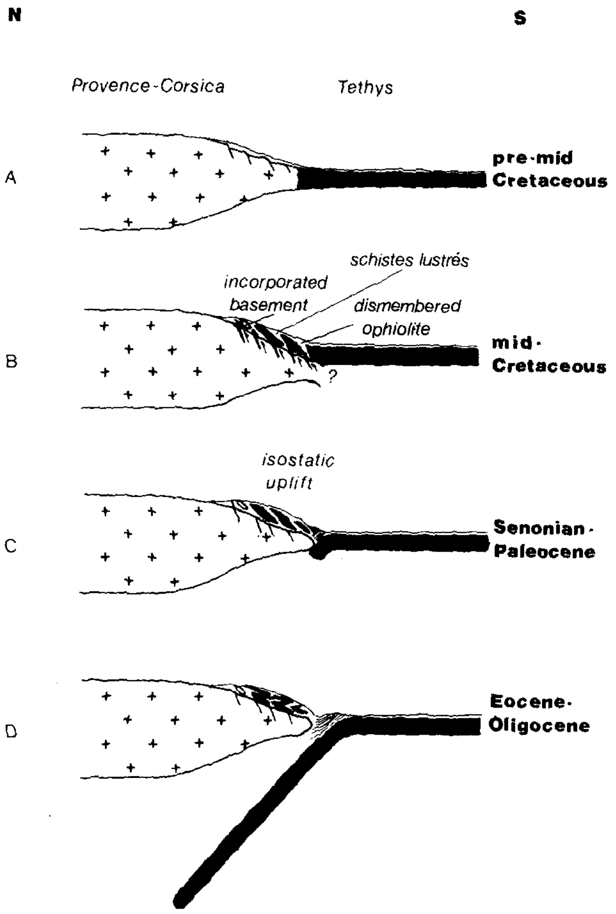

Fig. 11. Schematic plate tectonic model for the structural evolution of Corsica. A. Pre-mid-Cretaceous tectonic setting of "Atlantic"-type margin. B. Mid-Cretaceous obduction of Tethyan oceanic crust via reverse-polarity subduction with concomitant blueschist facies metamorphism, main-phase deformation and mélange formation. C. Paleocene isostatic uplift and cessation of subduction. D. Eocene—Oligocene polarity flip, development of normal subduction polarity and formation of second-phase folds.

dates from Tenda-Corte complex phengite separates (from the same sample which yielded the 90 Ma glaucophane date) are interpreted by Maluski (1977) as relating to the effects of a later, overprinting deformative event. This later event would correlate with our second-phase folds and the Eocene K-Ar ages of Schamel and Hunziker (1977).

This southeast tectonic polarity remained through 17—15 Ma when Corsica and Sardinia rotated away from Europe (Bellon et al., 1977; Reutter et al., 1978, 1980; Cohen, 1980). The rotation resulted in obduction of Liguride oceanic crust, along the leading edge of Corsica, onto the western Italian continental margin and formation of the northern Apennines (Kligfield et al., 1977; Carmignani et al., 1978; Kligfield, 1979; Cohen, 1980). Interpretation of seismic refraction data between Corsica and the northern Apennines support the post-polarity flip history presented here (Reutter et al., 1978, 1980).

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