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K/Ar AGE DETERMINATIONS ON SOME TETHYAN OPHIOLITES

ABSTRACT. — 30 K/Ar determinations are presented on 25 whole rock samples and 5 mineral concentrates from Corsican, Northern Apennines and Calabrian ophiolites. The K/Ar age of brown-green amphibole from a Corsican metagabbro is 181.4 ± 6.0 m.y. confirming that ocean crust accretion which generated the major ophiolite complexes of the Western Alpine-Apennine system has occurred since Early-Middle Jurassic time.

However most datings represent isotopic re-equilibration during tectonic-metamorphic events after ophiolite generation.

The Northern Apennine metabasalts and metagabbros give a Late Cretaceous age (isochron 83 m.y.) considered to be re-equilibration age of the sub-greenschist metamorphism which affected the Ligurian ophiolites during early orogenic phases.

Since these tectonic-metamorphic events chronologically correspond to the HP-LT metamorphism of the Western Alps it may be argued that the Ligurian ophiolites slices were involved in the same westward (Europe-vergent) compression phases which characterized the initial stages of closure of the Western Tethyan basin.

Most data on Corsican ophiolites, and possibly also those on Calabria, indicate extensive isotopic re-equilibration during Oligocene-Early Miocene times. This appears to be related to the Apennine orogeny and the back folding of the Alpine chain, in connection with the predominant tectonics characterized by eastward (Africa-vergent) thrusting.

RIASSUNTO. — Vengono presentate 30 determinazioni K/Ar su campioni di roccia totale e su minerali separati di ofioliti della Corsica, dell'Appennino settentrionale e della Calabria. L'età K/Ar dell'anfibolo bruno separato da un metagabbro delle ofioliti della Corsica è risultata $181,4 \pm 6,0$ m.y., confermando che i processi di accrescimento di crosta oceanica che originarono i complessi ofiolitici del sistema alpino-appenninico si verificarono a partire dal Giurassico medio-inferiore. La maggior parte delle datazioni rappresentano tuttavia l'età dei processi di riequilibrio isotopico verificatisi durante eventi tettonico-metamorfici successivi alla creazione dei complessi ofiolitici. L'età Cretaceo superiore (isocrona di 83 m.y.) dei metabasalti e metagabbri dell'Appennino settentrionale può essere interpretata come l'età di riequilibrio del metamorfismo di facies scisti verdi di grado molto basso che interessò le ofioliti liguri durante fasi orogeniche precoci. Dal momento che l'età di questi eventi tettonico-metamorfici è analoga a quella del metamorfismo di alta pressione/bassa temperatura delle Alpi occidentali, si può ipotizzare che anche le ofioliti liguri siano state coinvolte nelle stesse fasi compressive a vergenza occidentale (Europa vergenti), che caratterizzarono gli stadi iniziali di chiusura del bacino della Tetide occidentale. La maggiore parte dei dati sulle ofioliti della Corsica e della Calabria indicano estesi processi di riequilibrio isotopico in età Oligocene-Miocene inferiore, connessi all'orogenesi appenninica ed in relazione a fasi tettoniche a vergenza orientale (Africa vergenti).

Introduction

Reliable geochronological data on the age of formation of and later tectonic-metamorphic events affecting ophiolite complexes are fundamental to a correct

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geodynamic reconstruction of the major geological processes occurring at accreting and consuming plate margins.

Unfortunately, datings on ophiolites produce results often difficult to interpret due to most rocks of these associations having suffered mineralogical and chemical transformation during deuteresis and complex post-magmatic metamorphic events. Therefore much caution should be exercised in interpreting K/Ar data, which in many cases may represent mixed ages between ophiolite formation and later partial re-equilibration processes.

Despite these objective difficulties, K/Ar dating is a valuable tool to detect isotopic re-equilibration and to put chronological constraints on the generation and tectonic-metamorphic events of ophiolites, which are otherwise generally difficult to obtain.

In this paper we present 17 new K/Ar determination on whole rocks and mineral concentrates of ophiolites from Corsica, the Northern Apennines and Calabria, for which radiometric age data are so far scarce or completely lacking. In order to complete the Northern Apennine geochronology, we add here 13 isotopic age determinations (CRIVELLI, 1976, unpublished thesis) measured in the Department of Mineralogy, University of Genève.

K/Ar age data on ophiolites from the Western Alps (Bocquet et al., 1974; DELALOYE and DESMONS, 1976) and the Eastern Mediterranean area have been presented elsewhere (DELALOYE et al., 1980 a and b).

Geological framework

Ophiolites of the Western Alpine-Apennine orogenic belt (the Western Alps, Corsica, the Apennines, Calabria) are widely regarded as fragments of oceanic lithosphere created during the Jurassic opening of the Penninic-Ligurian oceanic basin which separated the paleo-European and Insubrian (Apennine-African) continental blocks (ABBATE et al., 1976, with references).

The Cretaceous-Eocene compressive events (HUNZIKER, 1974), due to the inversion of Europe and Africa's relative motion (DEWEY et al., 1973), brought about lithospheric subduction and westwards (Europe-vergent) overthrusting of segments: 1) from the Insubrian and European continental margins and 2) from both Penninic (Alpine-type) and Ligurian (Apennine-type) oceanic lithosphere (DAL PIAZ, 1974 a; LAUBSHER, 1974; TRUMPY, 1975; DAL PIAZ and ERNST, 1978).

The later Oligocene-Miocene Apennine orogeny was responsible for back-thrusting and eastward tectonic transport of the Ligurian nappe complex on to the Apulian (African) foreland (ZANZUCCHI, 1978; REUTTER et al., 1978; SCANDONE, 1979).

Three main types of metamorphism have been recognized in the Penninic ophiolites from the Western-Alps: 1) an early sub-sea floor metamorphisms of greenschist to amphibolite facies which developed during ocean crust formation (DAL PIAZ, 1974 a); 2) *HP-LT* metamorphism, blue-schist to eclogite facies, related

to subduction processes during early orogenic events (Eoalpine phase 78-100 m.y.; DAL PIAZ, 1974 b); 3) a late greenschist to amphibolite facies event, with glaucophane recrystallization, probably due to the burial of the nappe pile (Leontine phase 35-50 m.y., with climax at 38 ± 2 m.y.; HUNZIKER, 1974; DAL PIAZ, 1974 b; BOQUET et al., 1974; FREY et al., 1974; DELALOYE and DESMONS, 1976).

Moreover, a Late Oligocene - Lower Miocene (30-15 m.y.; BOQUET et al., 1974) tectonic event which produced a recrystallization of blue and blue-green amphibole has been detected in the Western Alps.

In the Eastern Alps, the Alpidic metamorphism of the Penninic rock series of the Western Tauern window occurred at the same time (RAITH et al., 1978).

Similar metamorphic events have been recognized in Corsica (OHNNENSTETTER et al., 1976) where ophiolites are present in different tectonic units referable to either Penninic (e.g. the « Schistes lustrés » nappe with *HP-LT* metamorphism) or Ligurian types (e.g. the Balagne nappe; NARDI, 1968; GLOM, 1977).

Northern Apennine ophiolites, belonging to different Ligurian units (DECANDIA and ELTER, 1972; ABBATE et al., 1970 a and b; BRAGA et al., 1972; PAGANI et al., 1972), only show the effects of an early oceanic, greenschist to amphibolite facies, metamorphism, followed by a subgreenschist facies metamorphism in the orogenic environment (GALLI and CORTESOGNO, 1970).

In Calabria, recently considered to be a southern fragment of the dismembered Alpine belt (HACCARD et al., 1972; DIETRICH and SCANDONE, 1972), ophiolites occur in several tectonic units (which may, e.g. Diamante-Terranova unit, or may not, e.g. Malvito unit, show *HP-LT* metamorphism) and tectonically underlying a dioritic-kinzigitic continental unit (AMODIO-MORELLI et al., 1976).

K/Ar determinations

Results

30 K/Ar determinations have been carried out on 25 whole rock samples and five mineral concentrates (2 brown-green amphiboles, 2 blue amphiboles and 1 plagioclase) respectively. Location, mineral assemblages and nature (in brackets % of the enrichment degree) of the analysed samples are reported in fig. 1 and table 1. Results are reported in table 2.

All the samples come from ophiolitic associations except the quartz diorite which belongs to a dioritic-kinzigitic continental unit.

The 25 whole rock samples are metabasalts and metagabbros which have geochemical affinities with oceanic tholeiites and gabbros generated at accreting plate margins (BECCALUVA et al., 1976; GLOM, 1977; DOSTAL et al., 1979; BECCALUVA et al., 1980 b).

Corsica

The rocks and minerals from the Ligurian-type Balagne ophiolites (2 brown-green amphibole concentrates and 3 whole rock metabasalts) and the *HP-LT*

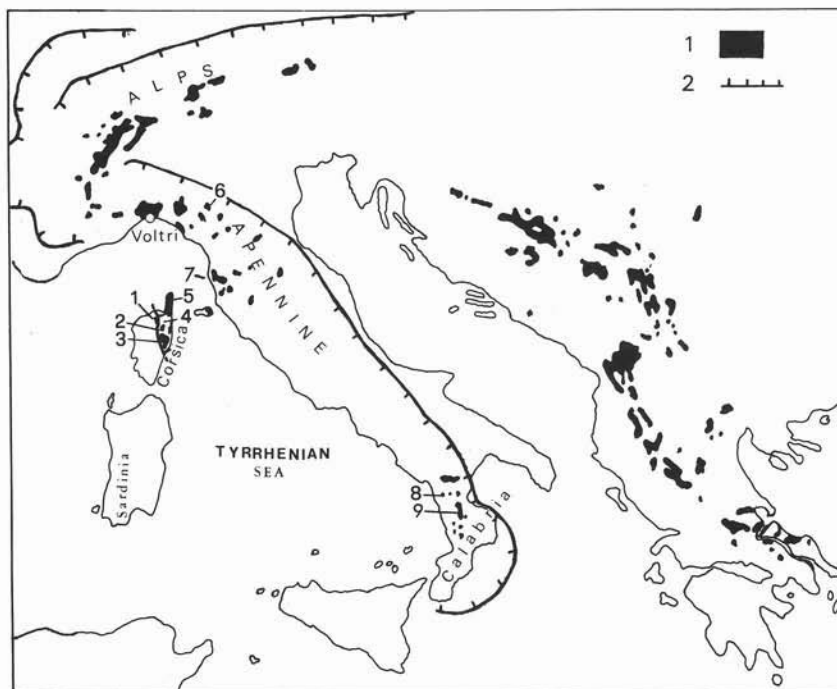


Fig. 1. — Distribution of ophiolites in the Mediterranean area (1); compression front of the Alps and Apennine chains (2) (after LAUBSCHER, 1974). Numbers refer to location of the analysed samples as reported in table 1.

TABLE 1

Location and main mineral assemblage of the analysed samples

1 Balagne (Corsica)

CS51-CS55-CS61 metabasalts: saussuritized plagioclase, clinopyroxene, Fe-Ti oxides, chlorite, sphene, + calcite + epidote + brown green amphibole, + pumpellyite.
CS79A brown-green hornblende (~90%) from metagabbro.
CS79B brown hornblende (~60%) + plagioclase from doleritic metabasalt.

2 Aiti (Corsica)

C20 plagioclase (~90%) from troctolite.

3 Pietricaggio (Corsica)

CG31 massive metabasite; blue amphibole, albite, epidote, chlorite, white mica, hematite, green amphibole, Fe-Ti oxides.

4 Sarchetta (Corsica)

C10 schistose metabasite: blue amphibole, albite, green and blue-green amphibole, epidote, chlorite, white mica.

5 Fieno (Corsica)

C39 blue amphibole (~60%) + chlorite + epidote + green biotite from metabasite.

Marine de Giottani (Corsica)

CG4 schistose metabasite: blue amphibole, albite, epidote, white mica, chlorite, green-amphibole, Fe-Ti oxides.

6 Monte maggiorasca - M. Quatene (Northern Apennine)

BC12-BC13-BC14-MZ71 metabasalts: saussuritized plagioclase, clinopyroxene, Fe-Ti oxides, sphene, chlorite, + epidote, + calcite, + green amphibole, + prehnite, + pumpellyite.

7 Livorno-Volterra (Northern Apennine)

T46-C1-Abl-R158 metagabbros: pyroxene, amphibole, plagioclase, epidote.
N66-R154-R90-Ro381-C83-Ro261: doleritic metabasalts: pyroxene, brown and green hornblende, actinote, chlorite, plagioclase, prehnite, pumpellyite, calcite, olivine, epidote and oxides.
V72-C74: metabasalts (pillow lavas): plagioclase, pyroxene, olivine, chlorite, hematite, pumpellyite.

8 Intavolata (Calabria)

CA6 schistose metabasite: albite, lawsonite, chlorite, white mica, sphene, Fe-Ti oxides, epidote.

9 Pollino (Calabria)

CAB metabasalt: saussuritized plagioclase, chlorite, epidote, sphene, Fe-Ti oxides, calcite.
CA10 quartz-diorite: quartz, sericitized plagioclase, albite, white mica, chlorite, sphene, Fe-Ti oxides.

TABLE 2
Radiometric results

SAMPLE NUMBERS	LOCATIONS		% K	AGE in m.y.	$\frac{^{40}\text{Ar}}{^{36}\text{Ar}}$ $\times 10^2$	$\frac{^{40}\text{K}}{^{36}\text{Ar}}$ $\times 10^4$	$\frac{^{40}\text{Ar}}{^{36}\text{Ar}}$ rad $\times 10^{-10}$ moles/g	% Ar rad
1 CS 51	BALAGNE	(CORSICA)	1.850	37.65 ± 1.25	10.302 ± 0.310	33.349 ± 1.230	1.220 ± 0.032	71.3 ± 0.8
2 CS 55	"	"	0.980	54.31 1.86	9.902 0.302	21.635 0.807	0.938 0.026	70.2 0.9
3 CS 61	"	"	0.230	70.07 2.84	6.733 0.170	9.099 0.291	0.285 0.010	56.0 1.1
4 CS 79A	"	"	0.350	181.39 6.04	7.357 0.192	3.977 0.126	1.158 0.034	59.6 1.0
5 CS 79B	"	"	0.221	16.01 3.30	3.345 0.083	4.176 0.127	0.062 0.012	11.6 2.2
6 C 20	AITI	(CORSICA)	0.204	136.95 5.24	5.063 0.080	2.550 0.054	0.503 0.017	41.6 0.9
7 CG 31	PIETRICAGGIO	(CORSICA)	0.770	34.36 1.44	9.024 0.381	30.108 1.472	0.463 0.016	66.9 1.4
8 C 10	BARCETTA	(CORSICA)	0.060	59.10 8.18	4.297 0.235	3.877 0.238	0.063 0.008	31.0 3.7
9 C 39	FIENO	(CORSICA)	0.088	198.33 44.38	3.141 0.043	0.152 0.003	0.320 0.074	5.9 1.3
10 CG 4	MARINE DI GIOTTANI	"	0.242	71.93 6.67	4.720 0.217	4.141 0.212	0.308 0.027	37.0 2.8
11 BC 12	M. MAGGIORASCA -		0.080	117.98 7.72	4.391 0.098	2.026 0.059	0.169 0.010	32.6 1.5
12 BC 13	- M. QUATESE		0.515	83.05 2.37	8.800 0.201	11.835 0.335	0.759 0.018	66.2 0.8
13 BC 14	(NORTHERN APENNINE)		0.398	55.65 2.40	5.675 0.137	8.295 0.246	0.390 0.015	47.8 1.2
14 MZ 71	"	"	0.282	95.98 3.47	6.828 0.171	6.748 0.207	2.329 0.015	56.5 1.1
15 T 46	LIVORNO - VOLTERRA		1.120	98.88 4.97	8.771 0.364	9.849 0.502	1.974 0.082	65.5 1.4
16 C 1	(NORTHERN APENNINE)		1.130	59.14 4.01	6.859 0.343	11.175 0.657	1.178 0.070	55.9 2.1
17 AB 1	"	"	0.140	145.61 26.88	3.628 0.133	0.764 0.035	0.368 0.067	18.2 2.9
18 R 158	"	"	1.670	84.36 3.91	8.822 0.296	11.691 0.502	2.501 0.094	65.9 1.1
19 R 66	"	"	0.800	83.39 6.06	6.869 0.368	7.894 0.470	1.184 0.076	55.1 2.3
20 R 154	"	"	0.650	80.61 6.97	4.676 0.158	3.592 0.156	0.929 0.073	35.7 2.1
21 R 90	"	"	0.440	130.39 7.63	6.994 0.286	5.141 0.258	1.032 0.052	56.1 1.7
22 RO 259	"	"	0.470	100.75 8.22	4.964 0.181	3.336 0.154	0.844 0.062	39.7 2.1
23 RO 381	"	"	0.370	115.20 12.97	4.068 0.130	1.611 0.065	0.763 0.081	27.0 2.3
24 C 83	"	"	0.810	118.14 6.23	6.295 0.171	4.708 0.173	1.715 0.076	52.4 1.3
25 RO 261	"	"	0.840	55.53 5.13	4.138 0.105	3.611 0.126	0.821 0.069	28.2 1.8
26 V 72	"	"	0.970	88.70 4.80	6.519 0.197	6.746 0.268	1.529 0.069	54.0 1.4
27 C 74	"	"	0.270	91.62 9.74	4.030 0.115	1.969 0.075	0.440 0.044	26.1 2.1
28 CA 6	INTAVOLATA	(CALABRIA)	0.220	48.15 2.27	6.894 0.241	13.915 0.580	0.186 0.008	56.9 1.5
29 CA 8	POLLINO	(CALABRIA)	1.460	29.70 1.58	5.671 0.168	15.612 0.569	0.758 0.035	47.7 1.6
30 CA 10	"	"	0.730	144.86 3.69	23.712 0.811	23.673 0.970	1.909 0.037	87.4 0.5

The isotopic composition of argon has been measured with an AEIMS 10 mass spectrometer. Potassium was determined by isotopic dilution technics and by flame photometry. The ages have been calculated with the new decay constants (STEIGER and JÄGER, 1977). The 2 σ error on the age determination was estimated to be $\pm 4\%$.

metaophiolites (1 blue-amphibole and 1 plagioclase concentrate, 3 whole rock metabasites) associated to the «Schistes lustrés» nappe, have been dated.

The K/Ar age of brown-green amphibole concentrate of a metagabbro from Balagne is 181.4 ± 6.0 m.y.

Considering the good argon retentivity of amphiboles, a Lower Jurassic age may be considered as reliable for the development of metamorphic hornblende in gabbros during ocean-floor metamorphism, shortly after the generation of the ocean crust. This is consistent with the age of about 170 m.y. obtained by U/Pb method on zircons separated from some Eastern Corsica plagiogranites (OHNENSTETTER M., OHNENSTETTER D. and VIDAL PH., personal communication).

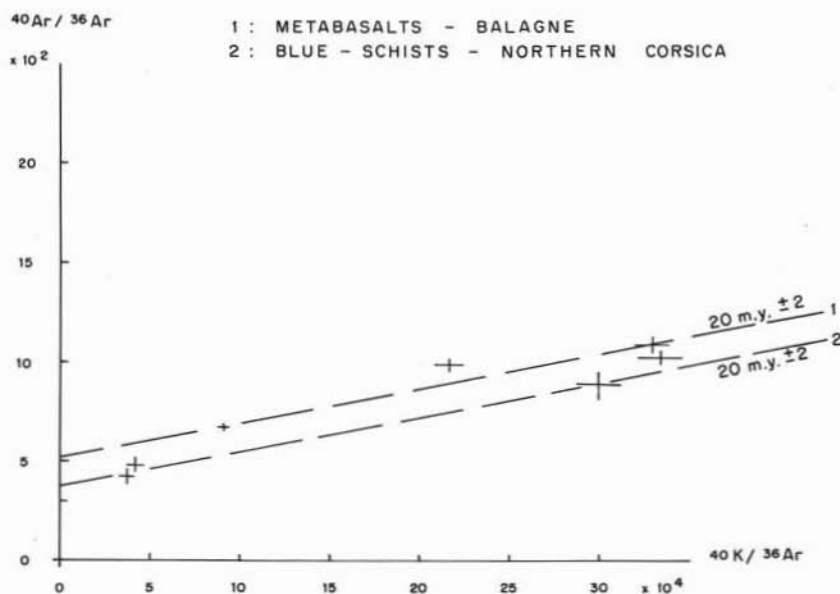


Fig. 2. — Isochron plot of metabasites and mineral separates from Corsican ophiolites.

The Late Jurassic-Early Cretaceous ages obtained on brown hornblende (148 ± 15 m.y., LOOMIS T.P., in GIANELLI and PRINCIPI, 1974) and on plagioclase from troctolite (136.9 ± 5.2 m.y., this work) should be therefore considered as due to isotopically re-equilibration after the generation of oceanic crust (later ocean-floor metamorphism and/or early orogenic event).

Four individual datings on blue amphibole and whole rock blue-schist metabasites have been made only. Three of these are useful, due to the very low potassium and radiogenic argon contents of C39 blue-amphibole, which is discarded.

The remaining data refer to three whole rock samples and one brown amphibole from Balagne metabasalts.

All apparent ages from Northern Corsica may be plotted on a $^{40}\text{Ar}/^{36}\text{Ar}$ vs.

$^{40}\text{K}/^{36}\text{Ar}$ diagram. Blueschist metabasites on one hand, and metabasalts on the other, plot on two parallel straight lines whose slopes correspond to an isochron age near 20 m.y. and indicate an argon over-pressure: $^{40}\text{Ar}/^{36}\text{Ar} = 400$ and 500 respectively (fig. 2).

Thus Corsican ophiolites, from both Balagne metabasalts (Ligurian-type) and from *HP-LT* blue-schist metabasites associated with the « Schistes lustrés » nappe (Penninic type) have undergone Upper Oligocene-Lower Miocene isotopic re-equilibration as in the Western Alps (30-15 m.y., on average around 20 m.y.; Bocquet et al., 1974; Hunziker, 1974).

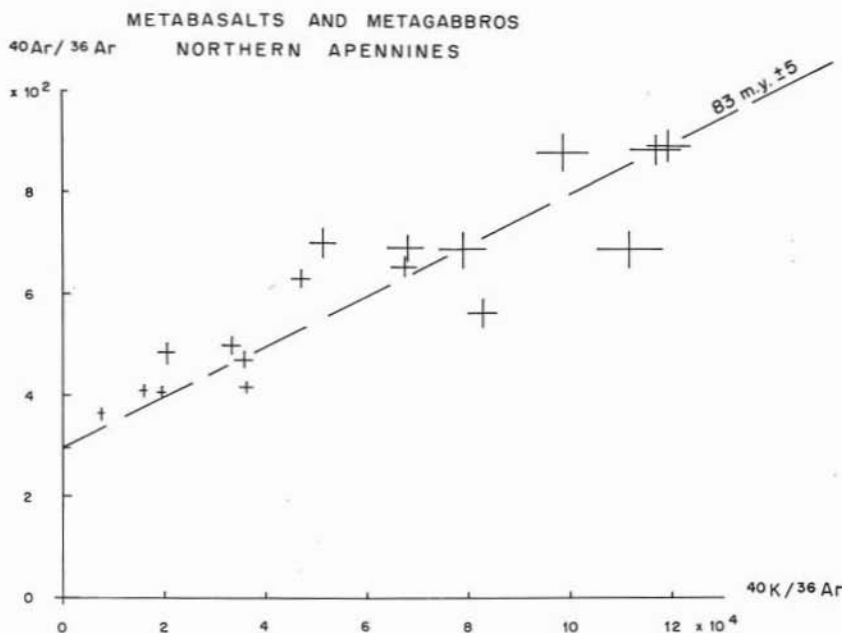


Fig. 3. — Isochron plot of metabasalts and metagabbros from the Northern Apennine ophiolites.

It is interesting to note that the mid-Cretaceous blue schist facies metamorphism (glauconite from Tenda-Corte complex 90 m.y., MALUSKI, 1977; isochron age 105 ± 8 m.y. for the blastomylonites at the contact with the « Schistes lustrés », COHEN et al., 1981) and the Eocene-Oligocene metamorphic effects (K/Ar ages of white micas in the Alpine Corsica; MALUSKI, 1977; SCHAMEL and HUNZIKER, 1977) appear isotopically re-equilibrated in the studied samples during the later Oligocene-Miocene event.

Northern Apennines

Four whole rock data have been obtained on ophiolitic metabasalts intercalated as olistoliths in the Cretaceous Paleocene Casanova Complex, a Ligurian wild-flysch sequence partly affected by anchizone metamorphism (ZANZUCCHI, 1978).

The basaltic rocks show the effects of an early ocean-floor metamorphism followed by a further sub-greenschist (prehnite-pumpellyite) event, probably developed in orogenic environment.

The individual datings are 118.0 ± 7.7 , 96.0 ± 3.5 , 83.1 ± 2.4 , 55.6 ± 2.4 m.y. This significant spread of data is probably due to different response of the samples to the variable intensity of the metamorphism which they have undergone.

Apparent ages have been calculated on ophiolitic metabasalts and metagabbros from the Tuscan Apennines (CRIVELLI, 1976). A plot of $^{40}\text{Ar}/^{36}\text{Ar}$ vs. $^{40}\text{K}/^{36}\text{Ar}$ for all the results from the Northern Apennines show that the group is homogeneous (fig. 3). A theoretical line at 83 ± 5 m.y. has also been calculated and is shown on fig. 3. This value is close to the beginning of the Eo-alpine metamorphic event.

Since the fission track datings on zircons indicate a Lower/Middle Jurassic generation of the Northern Apennine oceanic association (180-165 m.y.; BIGAZZI et al., 1973), the K/Ar ages may be interpreted as being due to reheating (possibly up to 300°) and isotopic re-equilibration of the analysed rocks during later orogenic events. Moreover, as Upper Cretaceous to Paleocene is also the chronological span of the Eoalpine *HP-LT* metamorphic events of the Western Alps (HUNZIKER, 1974; BOCQUER et al., 1974), it may be argued that the subgreenschist orogenic metamorphism of the Ligurian ophiolites is possibly related to the same compressive phases which characterized (by westward Europe-vergent overthrusting of both Penninic and Ligurian ophiolitic slices) the initial stages of closure of the oceanic basin. This interpretation appears to be consistent with the paleogeographic reconstruction proposed by GRANDJAQUET and HACCARD (1977), where the Upper Cretaceous-Paleocene substratum of flysch is constituted by a sequence of ophiolite units in which orogenic metamorphism decreases upward: 1) the eclogite/blueschist Penninic units; 2) the blueschist Montenotte nappe of probable Ligurian affinity (CHIESA et al., 1975; BECCALUVA et al., 1979 a) and 3) the subgreenschist Ligurian ophiolite units.

Finally it should be noted that the later Apennine orogenic events, responsible for the eastward nappe transport on to the Apulian foreland, do not appear to have reached temperatures high enough to induce isotopic re-equilibration in the analysed rocks.

Calabria

One blue-schist (with greenschist overprint) metabasite and one sub-greenschist metabasalt from the Diamante-Terranova and Malvito ophiolitic units, respectively, gave ages of 48.1 ± 2.3 and 29.7 ± 1.6 m.y.

The interpretation of this data is not simple. However, considering a possible radiogenic argon inheritance as for the analogous Corsican samples, an isotopic re-equilibration event in the Oligocene-Miocene time almost certainly occurred. A single quartz-diorite sample belonging to the Polia-Copanella unit gives an age of 144.9 ± 3.7 m.y., a value in the range of those of biotites from gneiss and tonalites of the same formation (147-127 m.y., AMODIO-MORELLI et al., 1976).

These ages seem to be interpretable as a Lower Cretaceous isotopic re-equilibration of continental crust material from the African plate reaching shallow levels during the initial stage of formation of the Calabria « Alpine belt » (AMODIO-MORELLI et al., 1976; SCANDONE, 1979).

Concluding remarks

The available geochronological data indicate that ocean crust accretion which generated the major ophiolite complexes of the Western Alpine-Apennine systems, occurred as far back as 180-170 m.y.

In the Hellenides, amphibolites from beneath the Pindos, Vourinos, Othris and Euboea ophiolites, probably related to metamorphism within oceanic lithosphere, have ages of 170-180 m.y. (SPRAY and RODDICK, 1980), thus suggesting a Lower Jurassic formation also for these ophiolites.

Similar ages of 154-182 m.y. (KARAMATA and LOVRIČ, 1978) and 164 ± 15 m.y. (MAYER et al., 1979) were reported for sub-ophiolite metamorphic rocks and amphibolite, respectively, from the Dinarides.

All the data indicate that continental fragmentation and development of multiple deep seaways (SCANDONE, 1975), which later evolved to ridge segment/fracture zone systems (PICCARDO, 1977; BECCALUVA and PICCARDO, 1978; BECCALUVA et al., 1980 b), took place from Lower-Jurassic time and was related to separation of Africa from North America, and its eastward motion with respect the Euro-asiatic plate (DEWEY et al., 1973).

It should be noted, however, that the petrological characteristics of ophiolites such as VOURINOS and PINDOS indicate an island arc/back arc basin rather than an ocean ridge original tectonic setting (BECCALUVA et al., 1978, 1979 b and 1980 b; CAPEDE et al., 1980). This suggests the existence, since Jurassic times, of convergent plate motions in the Eastern Mediterranean area.

Similarly, ophiolites from Cyprus (PEARCE, 1975; BECCALUVA et al., 1979 b and 1980 b with references), Turkey, Oman (PEARCE, 1980) and Western Iran (DESMONS and BECCALUVA, in preparation) exhibit petrological features consistent with their generation in an island arc/back arc basin system during the Upper Cretaceous (DELALOYE et al., 1980 a and b; THUIZAT and MONTIGNY, 1979; MALCOM et al., 1979; DELALOYE and DESMONS, 1980). This age corresponds to the inferred major change in the relative motion of the African plate with respect to the Euro-asiatic plate (DEWEY et al., 1973), and ophiolite generation in such a period appears to be controlled by a predominant convergent plate regime in the Tethyan realm.

In the Western Tethys, the Cretaceous compression caused reduction of the oceanic basin, and the Jurassic ophiolite lithologies began to be affected by several tectonic-metamorphic events and isotopic re-equilibration in orogenic environment.

In the Northern Apennines the Upper Cretaceous isotopic re-equilibration of metabasalts and metagabbros (83 ± 5 m.y.) supports the existence of a single compressive phase, which brought about, in addition to the well known Eoalpine HP-LT metamorphism of the Western Alps, Eastern Corsica and Calabria ophiolites,

tectonic-metamorphic effects also on the Ligurian ophiolites which were later involved in the Apennine orogeny.

We suggest that the sub-greenschist metamorphism of the Northern Apennine ophiolites may have developed during these early westward (Europe-vergent) tectonic phases.

Subsequently, Corsican ophiolites (either from Balagne and the «Schistes lustrés» nappes) and possibly also those from Calabria, suffered extensive isotopic re-equilibration during Oligocene-Early Miocene times. This period corresponds to the eastward Apennine orogeny and the back folding («*rérocharriage*») of the Alpine chain, in connection with the predominant tectonics characterized by Africa-vergent thrusting (cf. REUTTER et al., 1978, with references).

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