

Radiometric geochronology in Tuscany: results and problems

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ABSTRACT. — All the age data up today published for the Tuscan rocks are presented, together with some unpublished ones. Age results of the young intrusive and effusive rocks of the tuscan anatectic province show often excess of $^{40}\text{Ar}/^{39}\text{Ar}$ and strontium isotopic disequilibrium among different minerals of the same rocks or isotopic disomogeneity among rocks of the same intrusion. These facts easily evident in very recent rocks, can be obscured by aging, but can be the source of errors also in determining the age of old rocks of anatectic origin.

Key words: Geochronology, Tuscany, Isotopic disequilibrium, Anatexis.

RIASSUNTO. — Tutti i dati di età sino ad oggi pubblicati sulle rocce della Toscana ed una serie di dati inediti vengono presentati e commentati. I dati relativi alle vulcaniti e alle rocce intrusive della provincia anatettica toscana mettono in evidenza la presenza di $^{40}\text{Ar}/^{39}\text{Ar}$ in eccesso e l'esistenza di disequilibrio isotopico tra fasi minerali e rocce totali. Questi due fatti, ben evidenti a causa delle età molto basse (2,5-7,3 Ma) dei prodotti della provincia anatettica toscana possono essere causa di errore anche in rocce più antiche aventi la stessa origine.

Parole chiave: Geocronologia, Toscana, Disequilibrio isotopico, Anatexis.

The Paleozoic basement

According to PUXEDDU (1984) the Palaeozoic complex of Tuscany is composed of the following informal stratigraphic units: 1) Permian breccia and red sandstone; 2) Carboniferous, slightly metamorphic lithic greywacke; 3) phyllite and quartzite of the Buti Group, partly of Upper Silurian-Lower Devonian age; 4) quartzite and phyllite of the Filladi Inferiori Group of probable Si-

lurian age; 5) micaschist of the Micaschist Group and gneiss with thin interbedded amphibolite levels of Lower Palaeozoic to the Precambrian age. Another unit of uncertain stratigraphic position is the Boccheggiano formation, of probable Silurian age showing petrologic and geochemical analogies with formations of both the Buti and Filladi Inferiori Groups (PUXEDDU et al., 1984). Radiometric age determinations are available for the phyllites and quartzites of Buti Group (BORSI et al., 1966) and from samples of micaschists, gneisses and amphibolites from deep wells in the Larderello Geothermal Field (DEL MORO et al., 1982). In the first case the Rb/Sr method has been used on total rock samples (table 3), in the second one both Rb/Sr and K/Ar method have been applied on separate minerals (biotite, muscovite and hornblende, tables 3 and 4). The total rocks isochron age obtained on the Buti samples (285 ± 12 Ma) represents the age of the metamorphism of the sediments of Silurian-Devonian ages. Mineral ages obtained on the samples of the Larderello Deep Wells cluster in the range of 2.5-3.7 Ma revealing the existence of a Pliocene thermal event to which the origin of the field may be attributed; only a muscovite yields an undisturbed Hercynian age (285 ± 11).

Another series of Hercynian ages has been obtained by EBERHARDT et al. (1962) on some samples of the allochthonous granites of the « argille scagliose » complex (table 3 and 4).

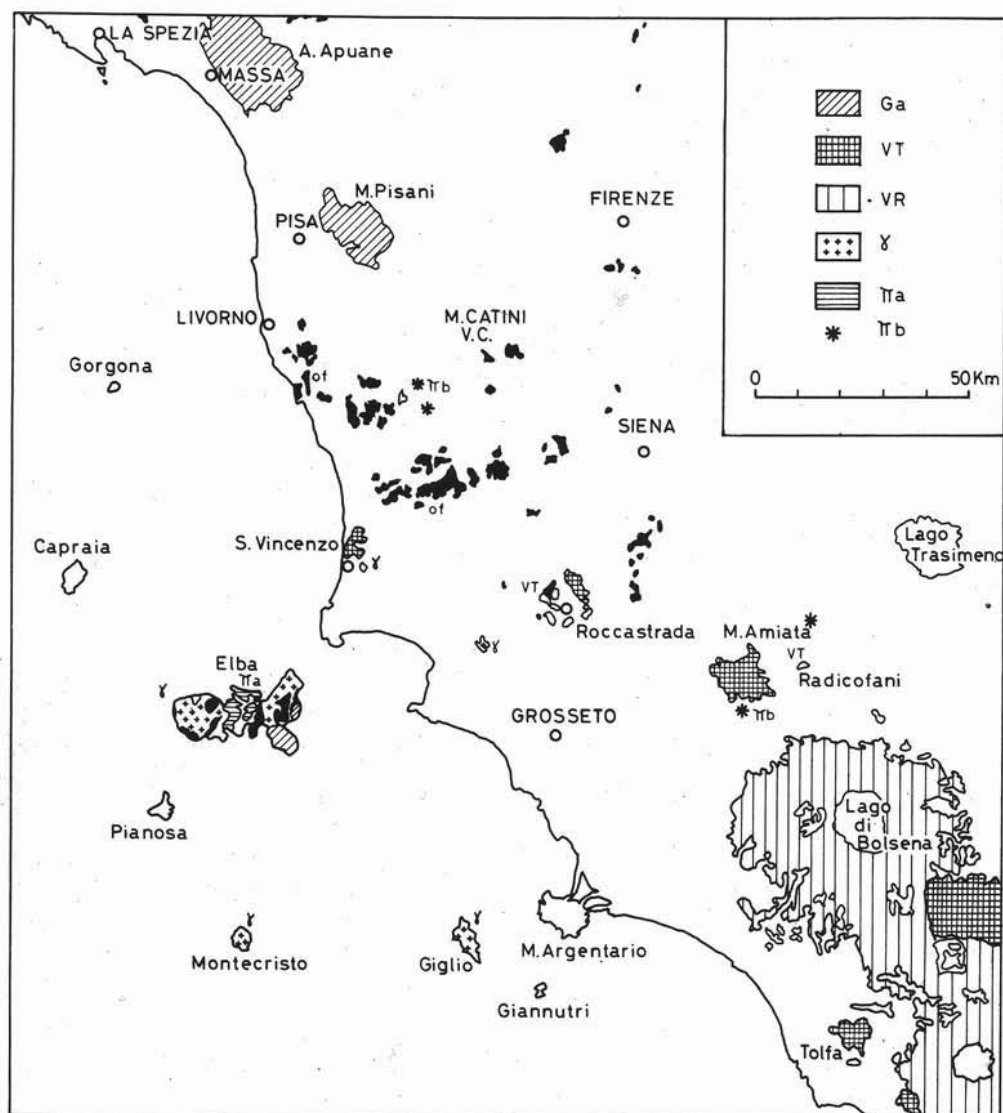


Fig. 1. — Map of Tuscany showing the localization of the considered major units. - Ga = tuscan metamorphic rocks; VT = tuscan magmatic province (volcanites); VR = roman magmatic province; γ = granodiorites and granites; πa = acidic sub-volcanic rocks; πb = basic sub-volcanic rocks (from BARBERI et al., 1971, slightly modified).

The ophiolitic complex

In Tuscany the ophiolitic complex can be found in the Toscana Marittima and in the Elba island. The ophiolites consist of ultramafic rocks almost completely serpentinized, submarine tholeiitic basalts often spilitized, pillow lavas, hyaloclastites and minor amounts of gabbroic rocks and dykes. In this assemblage of rocks it is impossible

to use the Rb/Sr or the U/Pb methods because of the extremely low content of the radioactive isotopes of these rocks; it is also difficult to apply the K/Ar method because of the alteration and the metamorphism ⁽¹⁾. The only possibility is to use

⁽¹⁾ Today the Sm/Nd method has been successfully applied in the age determination of ophiolitic complexes (DE PAOLO & WASSERBURG, 1979) also of very young age (ZINDLER et al., 1982).

the zircon that can be found in very small amounts in some acidic differentiates that are scarcely present in the gabbros of the Apennines (MARINELLI, 1964; BARBERI et al., 1971). Zircons formed in this kind of rocks must contain relatively small uranium amounts, and are suitable to be used for the fission track method of age determination. BIGAZZI et al. (1972, 1973) have successfully applied this technique on some samples of the Northern Apennines obtaining results (table 5) in good agreement with the geological knowledge.

Apuan Alps

The Tertiary metamorphic event that the Apuan Alps have experienced has been dated by several authors (GIGLIA & RADICATI, 1970; KLIGFIELD et al., 1977) using the K/Ar method on muscovites separated from the metamorphic rocks. The first quoted authors have found two groups of ages (14 Ma and 11 Ma, table 6) while KLIGFIELD et al. (1977), report also ages of 26 Ma. Unfortunately we did not find these results published anywhere, but only as abstract (V ECOG, Pisa 1977).

The rocks of the Tuscan anatectic province

The problem of precise dating on very young rocks is still a difficult goal for the geochronology because of the small amounts of radiogenic isotopes to be determined; besides this general fact, there are several more complications when dating anatectic rocks as those of the Tuscan province. The anatectic origin of the Tuscan intrusives and effusives has been proved on petrological (MARINELLI, 1961) and isotopic (FERRARA, 1969; TAYLOR & TURI, 1976) grounds and there is no doubt now that these rocks have been formed by (partial) melting of crustal material (Tuscan basement of Hercynian age). Theoretically the main causes of error in applying the various methods of age determination can be briefly synthesized as following:

- 1) *K/Ar method*. It is possible to find excess of radiogenic ^{40}Ar due to un-

complete outgassing during the melting of the old Hercynian rocks. Also if the amounts of $^{40}\text{Ar}_{\text{rd}}$ can be very small they are likely to influence young age values, especially in low K minerals.

- 2) *Rb/Sr method*. Partial melting of rocks of acidic composition can generate batches of magma with disomogeneous Sr isotopic composition thus precluding the use of Rb/Sr for total rock isochrons. Besides this fact, the magma generated by the partial melting can be a mixture of minimum melt and different proportions of restite, sometimes represented by common mineral phases as plagioclase, biotite or cordierite; this fact will produce rocks with isotopic disequilibrium among coexisting mineral phases (FERRARA, 1983) thus vanifying also the use of internal isochrons (FERRARA et al., 1977).
- 3) *U/Pb method*. There is the risk, using zircons (the only suitable material) that old zircons not completely resettled to be present, and also in very small quantities, very young ages can be seriously affected. Fission tracks on glass and, when possible, on zircons, is probably in such situation the best technique to use, but this method can be sometimes not so precise as the above quoted ones.

Concluding, extremely care must be taken in the interpretation of data obtained in this kind of rocks and when possible different methods have to be applied in order to have more meaningful results. Data up to now obtained in the Tuscan anatectic rocks are presented together with some new ones, unpublished till today.

Volcanites

The radiometric data up today available for the volcanites of Tuscany are reported in tables 7, 8 and 9 according to the different methods used for the age determinations. Some samples have been measured with different techniques and it will be worth to compare and comment the obtained results in the light of what already written. For two samples of Roccastrada and S. Vincenzo we have results by the K/Ar, Rb/Sr and Fission

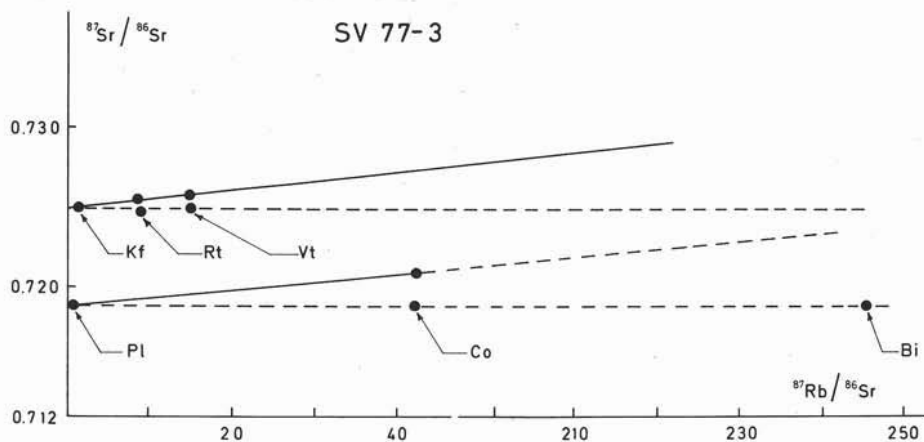


Fig. 2. — Nicolaysen diagram relative to separated minerals of an acidic-volcanite sample from S. Vincenzo. The existence of restitic phases with initial isotopic composition equal to 0.719 (*Pl* = plagioclase; *Co* = cordierite and *Bi* = biotite) and phases with higher initial isotopic composition (0.725) which represents the anatectic liquid (*Kf* = K-feldspars; *Rt* = whole rock; *Vt* = glass) have to be noted. The two groups of minerals define two parallel isochrons yielding (in the error limit) two same ages, that correspond to the volcanite cooling age (from FERRARA, 1983).

Track methods. For the sake of clarity results are compared in table 1.

For the Roccastrada samples the results by Rb/Sr and F.T. methods are in agreement within the limits of the error (that is large in the case of Rb/Sr due to the very young age of the sample). The K/Ar result is significantly lower but we must point out that a different sample has been used for this measurement. It is important in comparing age results obtained by different methods to use the same sample. For S. Vincenzo there is a good agreement between the K/Ar and F.T. methods, but Rb/Sr on biotite is much lower than the other ones. In order to understand this difference a Rb/Sr study on separated minerals was carried on (FERRARA et al., 1977) showing the existence of a disequilibrium in the initial Sr isotopic composition among the different mineral phase, thus precluding the use of the Rb/Sr method on biotite-total rock (fig. 2).

Another comparison can be done with the M. Amiata samples that have been dated by K/Ar and F.T. methods (tables 7 and 9); we cannot repeat here the comments on these data, that can be found in the paper by BIGAZZI et al. (1981), but we want to stress out the existence of excess of $^{40}\text{Ar}_{\text{rd}}$ in biotites; the isochron method in this case

gives good results showing also that $^{40}\text{Ar}_{\text{rd}}$ is not in excess in the sanidines, that represent, due to their high K content, a useful mineral for dating very young volcanic rocks by the K/Ar method.

Volcanites from Capraia island do not belong to the Tuscan anatectic province being of subcrustal origin (FRANZINI, 1964; BORSI, 1967) they can possibly be linked to the calc-alkaline volcanic activity of Sardinia (BARBERI et al., 1971). The few K/Ar data available (table 10) are from BORSI (1967) and PIERATTINI (1978). The two authors give different ages for the onset of the Capraia volcanic activity (placed at 9.5 and 8.26 Ma); the same discrepancy exists also for the end (4.8 and 2.65 Ma). Further data are necessary in order to achieve a better definition of the time span of the Capraia volcanic activity.

Intrusive rocks

The Elba granodiorite, which covers about 42 per cent of the island surface, is the most important stock among the intrusive rocks of Tuscan magmatic province. Numerous age determinations have been carried out on the Elba samples by the K/Ar and Rb/Sr methods (table 11 and 12). We can start in analyzing the K/Ar result beginning with the

western Elba (M. Capanne granodiorite). Together with the already published results of EBERHARDT & FERRARA (1962), EVERNDEN & CURTIS (1965) and BORSI et al. (1967) we report here the data that BORSI & FERRARA presented at a congress (1971) and which have been available, up today, only as a summary. If we put together all data on the biotites of M. Capanne granodiorite we have ages between 7.0 and 7.6 Ma, except two low values of 6.4 and 6.7 Ma. A very large sample of M. Capanne biotite (STE 74) has been prepared and measured several times in order to be used as an internal laboratory standard (VILLA, 1978); the mean age value (on 24 runs) is 7.3 Ma. Taking also into account the data of table 11 we can safely assume for the « apparent » K/Ar age of M. Capanne biotite a value of 7.2 ± 7.3 Ma that we can use to compare with the Rb/Sr data. Before doing that we will also examine the data obtained on dykes of aplites of M. Capanne (table 11). In this case the data show a big scatter ranging from 6.8 to 14.8 largely in excess with any previously published results. This scatter is interpreted as due to $^{40}\text{Ar}_{\text{rd}}$ in excess. To further testing such possibility BORSI & FERRARA (1971) have carried on K/Ar determinations on separate minerals of a granodiorite sample of M. Capanne.

The apparent age results (table 2) clearly demonstrate an excess of $^{40}\text{Ar}_{\text{rd}}$. Due to the scarcity of suitable material, a minor number of K/Ar data are available for the central and eastern Elba. Some data have been obtained by BORSI & FERRARA (1971) and more recently by SAUPÉ et al. (1982). Generally ages lower than M. Capanne ones have been obtained: from 5.7 to 6.2 Ma (BORSI & FERRARA, 1971) from 5.1 to 6.1 Ma (SAUPÉ et al., 1982).

In table 12 all the Rb/Sr data are gathered together including some writers' unpublished results. The 1961 and 1962 data represent the first age results obtained on Elba samples by the Rb/Sr method and are to be considered affected by a larger error than the recent ones produced by VENZLAFF & WALDECK (1971) and FERRARA & TONARINI (in press). The comparison of the Rb/Sr results obtained by the different authors for the M. Capanne granodiorite is puzzling

because the mean value of 5.3 Ma (re-calculated from VENZLAFF & WALDECK, 1971, with $= 1.42 \cdot 10^{-11}$) strongly differs from the value for 6.73 ± 0.04 and 6.88 ± 0.04 obtained on two granodiorite samples (using the isochron method on separate minerals) by FERRARA & TONARINI (in press). In any case the Rb/Sr data are lower than K/Ar ones, thus confirming the existence of a $^{40}\text{Ar}_{\text{rd}}$ excess.

Besides the Elba island, other intrusive rocks have been found in the Tuscan magmatic province; the most important are the granites of the Giglio and Montecristo islands and the Gavorrano granitic outcrop (fig. 1). A few kms from Gavorrano on a locality called Tor di Pietra a hidden granitic intrusion has been found (ARISI ROTA & VIGHI, 1974). The few K/Ar data available in literature are presented in table 13 together with some unpublished results. The data from Castel di Pietra granite are quite discordant and only one has a value close to the nearby Gavorrano outcrop (which is very likely coeval). The other two samples, showing higher apparent ages, can be affected by an excess of $^{40}\text{Ar}_{\text{rd}}$. Rb/Sr age determinations have been also carried on the same rocks (table 14). In the case of Giglio, Montecristo and Gavorrano they agree with the K/Ar ones; this is not the case for the Castel di Pietra samples, that give lower ages (BORSI et al., 1979) close to the Gavorrano results.

Nothing more can be said from these results because they are very scarce, but again we face with the existence of $^{40}\text{Ar}_{\text{rd}}$ excess which seems to be a common feature for the Tuscan intrusive and effusive rocks. Rb/Sr data for Montecristo and Giglio show the existence of an isotopic equilibrium for the $^{87}\text{Sr}/^{86}\text{Sr}$ ratio among the coexisting minerals as reported for the granodiorite of M. Capanne (FERRARA & TONARINI, in press). This is not true for the Castel di Pietra samples in which an isotopic disequilibrium has been found (FERRARA, 1983). Concluding this critical examination of the age data for the rocks of the Tuscan anatectic province, we can remark that both $^{40}\text{Ar}_{\text{rd}}$ excess on Sr isotopic disequilibrium have been frequently found. This finding, that can easily be evidenced on very recent rocks,

can be obscured by aging and can be source of errors also in determining the age of old rocks of anatectic origin.

Acknowledgements. — The authors would like to point out that most of the unpublished data reported in this paper were obtained by their colleague and good friend Prof. SERGIO BORSI, whose research career was abruptly ended by his untimely departure.

TABLE 1

	K/Ar	Rb/Sr	F.T.	Rock type	Sample	Material	K%	$^{40}\text{Ar}_{\text{rd}}$ ml/g	$^{40}\text{Ar}_{\text{rd}}/\text{AGE Ma}$
Roccastrada	2.3±0.2	2.6 ±0.5	3.23±0.23	granodiorite	STE 74	Bi	7.56	2.147·10 ⁻⁶	54 7.3
S. Vincenzo	4.7±0.14	3.26±0.25	4.96±0.37	"	"	KF	10.70	3.563·10 ⁻⁶	63 8.5
				"	"	Pl	0.325	2.281·10 ⁻⁷	15 17.9
				"	"	Qz	0.19	7.864·10 ⁻⁷	17 25.0

TABLE 2

TABLE 3
Rb/Sr analytical data - Paleozoic basement

Rock type	Sample n.	Material	Rb ppm	Sr ppm	$^{87}\text{Rb}/^{86}\text{Sr}$	$(^{87}\text{Sr}/^{86}\text{Sr})_{\text{m}}$	$(^{87}\text{Sr}/^{86}\text{Sr})_{\text{i}}$	AGE Ma	Ref.
Rambecko granite		Mu	1250	88.6	40.8	.875	.712	281 +16	1
Pregola granite		Bi	672	3.26	608	2.703	.712	230 + 7	
Mt. Buti group quartzite	FBA	WR	122	51.8	6.84	.743	.712		2
Mt. Buti group quartzite	FBB	WR	142	231	1.77	.714	.712		
Mt. Buti group quartzite	FBC	WR	184	135	3.94	.725	.712		
Mt. Buti group quartzite	FBD	WR	172	110	4.55	.730	.712	285	
Mt. Buti group quartzite	FBE	WR	136	179	2.20	.719	.712		
Mt. Buti group quartzite	FBF	WR	291	82.2	10.3	.753	.712		
Mt. Buti group quartzite	FBG	WR	85	26	9.4	.746	.712		
	SS 2076	WR	149	147	2.93	.7263			
		Mu	306	135	--	.7411		285 +11	3
Micaschists and gneisses from deep wells Larderello	SA 2502	WR	177	164	3.13	.7312			
		Mu	288	97	8.60	.7331		24.5 + 6	
		Bi	460	5.9	228.2	.7408		3 + 0.8	
	SA 2636	WR	81	263	.89	.7148			
		Bi	296	2.4	351.8	.7459		6.2 + 0.7	
	SA 3530	WR	138	180	2.22	.7226			
		Bi	541	5.4	290.5	.7362		3.3 + 0.2	
Micaschists Serrazzano	SA 3800	WR	136	169	2.34	.7217			
		Bi	648	3	633.3	.7509		3.3 + 0.4	
	SA 4028	WR	102	190	1.55	.7200			
		Bi	615	3.2	549.6	.7443		3.1 + 0.1	
	SA 2242	WR	164	193	2.46	.7336			
		Bi	484	5.6	250.8	.7393		1.6 + 0.1	

TABLE 4

K/Ar analytical data - Paleozoic basement

Rock type	Sample n.	Material	K%	$^{40}\text{Ar}_{\text{rd}}$ ml/g	$^{40}\text{Ar}_{\text{rd}}/\text{AGE Ma}$	AGE Ma	Ref.
Mt. Frascaro granite		Mu	6.8	8.23·10 ⁻⁵	97.8	287 +10	■ 1
Rombecko granite		Mu	7.7	10.01·10 ⁻⁵	97.4	310 +10	■
		Mu	7.7	9.99·10 ⁻⁵	97.4	308 +10	■
Pregola granite		Bi	6.8	6.47·10 ⁻⁵	98.1	229 + 8	■
	SA 2502	Mu	8.10	12.12·10 ⁻⁷	53.4	3.71 ± .04	● 3
		Bi	6.85	8.30·10 ⁻⁷	50.5	3.11 ± .04	●
Micaschists and gneisses from deep wells Larderello	SA 2636	Bi	7.16	9.78·10 ⁻⁷	51.9	3.50 ± .04	●
		Amph	.50	2.02·10 ⁻⁷	15.7	10.35 ± .27	●
	SA 3800	Bi	7.35	9.36·10 ⁻⁷	24	3.20 ± .10	●
	SS 2242	Bi	6.69	6.78·10 ⁻⁷	37.1	2.48 ± .05	●

constants: ■ $\lambda_{\text{B}} = 5.30 \cdot 10^{-10} \text{y}^{-1}$; $\lambda_{\text{K}} = .585 \cdot 10^{-10} \text{y}^{-1}$
● $\lambda_{\text{B}} = 4.96 \cdot 10^{-10} \text{y}^{-1}$; $\lambda_{\text{K}} = .581 \cdot 10^{-10} \text{y}^{-1}$; $40_{\text{K}}/\text{K} = 1.17 \cdot 10^{-4}$

TABLE 5
Fission tracks data - Ophiolitic complex

Rock type	Sample n.	Material	ρ_F tracks/cm ² (tracks)	ρ_I tracks/cm ² (tracks)	Φ neutrons/cm ²	$\frac{D_F/D_I}{M}$ or temper.	AGE Ma	Number of grains or fields	$\bar{S}$ %	Ref.
LDT Poggio Caprona (Livorno)	11A	Zr	1148	2245	$5.3 \cdot 10^{15}$		167 $\pm$ 17			5-6
LDT Poggio Caprona (Livorno)	69	Zr	223	450	$5.3 \cdot 10^{15}$		162 $\pm$ 31			
LDT Mt. Orello (Elba)		Zr			$7.3 \cdot 10^{15}$		161 $\pm$ 23			6
		Ap			$7.3 \cdot 10^{15}$		75			
Basalt Bartolina (Grosseto)		Zr			$7.3 \cdot 10^{15}$		166 $\pm$ 21			
		Zr			$4.1 \cdot 10^{15}$		164 $\pm$ 27			
		Ap			$7.3 \cdot 10^{15}$		38 $\pm$ 8			
LDT Sonnino (Livorno)		Zr			$4.1 \cdot 10^{15}$		171 $\pm$ 29			
LDT Pavullo (Modena)		Zr			$4.1 \cdot 10^{15}$		170 $\pm$ 25			
LDT Siena I		Zr			$7.3 \cdot 10^{15}$		185 $\pm$ 23			
LDT Siena II		Zr			$7.3 \cdot 10^{15}$		185 $\pm$ 21			

LDT = Trondhjemitic leucocratic differentiate

TABLE 6
K/Ar analytical data - Apuan Alps

Rock type	Sample n.	Material	K%	^{40}Ar rd ml/g	^{40}Ar rd%	AGE Ma	Ref.
Arni veined marble	1	Mu	5.77	$1.12 \cdot 10^{-6}$ $1.69 \cdot 10^{-6}$	44 65	11.0 11.3	7
Arni schistose vein	2	Mu	6.18	$2.19 \cdot 10^{-6}$	79	11.2	
Mt. Brugiana veined marble	Br 1	Mu	3.96	$1.44 \cdot 10^{-6}$	60	15.2	
Mt. Brugiana veined marble	Br 2	Mu	2.62	$8.17 \cdot 10^{-7}$	51	15.3	
Mt. Brugiana veined marble	Br 3	Mu	5.45	$1.66 \cdot 10^{-6}$	74	17	
Mt. Brugiana veined marble	Br 4	Mu	2.52	$5.17 \cdot 10^{-7}$	35	14.5	
Mt. Brugiana veined marble	Br 5	Mu	3.32	$6.57 \cdot 10^{-7}$	41	12.1	
Mt. Brugiana veined marble	Br 6	Mu	8.02	$2.24 \cdot 10^{-6}$	53	13	
Mt. Brugiana veined marble	Br 7	Mu	4.70	$1.26 \cdot 10^{-6}$	43	15.3	
Cipolline (Cardoso)	Pr 1	Mu	6.03	$1.33 \cdot 10^{-6}$	53	10.8	
Schist (Stazzema)	P 1	Mu	2.97	$5.70 \cdot 10^{-7}$	44	10.9	

constants: $\lambda_K = .584 \cdot 10^{-10} \cdot \text{y}^{-1}$; $\lambda_S = 4.72 \cdot 10^{-10} \cdot \text{y}^{-1}$; $^{40}\text{K}/\text{K} = 1.19 \cdot 10^{-4}$

TABLE 7
K/Ar analytical data - Volcanic rocks of Tuscan anatectic province

Rock type	Sample n.	Material	K%	^{40}Ar rd ml/g	^{40}Ar rd%	AGE Ma	Ref.
Roccastrada rhyolite	R 109	Bi	7.73	$6.950 \cdot 10^{-7}$	27	$2.3 \pm .2$ ▲	8
St. Vincenzo rhyolite		Bi	5.92	$1.125 \cdot 10^{-6}$	25	$4.7 \pm .14$ ▲	9
Montecatini minette		Bi	7.65	$1.255 \cdot 10^{-6}$	25	$4.1 \pm .13$ ▲	
Radiconfi trachybasalt		Bi	2.71	$1.027 \cdot 10^{-6}$	47	$.97 \pm$ ▲	10
Mt. Amiata rhyodacite	KA 441	KF	6.94	--	85	$.430 \pm$ ▲	11
Mt. Amiata Qz-latite	MA77-1	KF	9.91	$1.138 \cdot 10^{-7}$	41	$.268 \pm .005$ ●	12
		glass	5.21	$.556 \cdot 10^{-7}$	22	$.268 \pm .013$ ●	
		Bi	7.63	$.257 \cdot 10^{-7}$	5	$.850 \pm .110$ ●	
		P1	.52	$.148 \cdot 10^{-7}$	10	$.728 \pm .116$ ●	
Mt. Amiata Qz-latite	MA77-19	KF	10.44	$1.003 \cdot 10^{-7}$	40	$.241 \pm .007$ ●	
		glass	5.18	$.597 \cdot 10^{-7}$	28	$.290 \pm .014$ ●	
		Bi	7.43	$1.217 \cdot 10^{-7}$	10	$.413 \pm .041$ ●	
		P1	.54	$.135 \cdot 10^{-7}$	10	$.627 \pm .046$ ●	
Mt. Amiata Qz-latite	MA80-89	KF	10.83	$1.221 \cdot 10^{-7}$	35	$.284 \pm .005$ ●	
		glass	5.30	$.605 \cdot 10^{-7}$	26	$.287 \pm .009$ ●	
		Bi	7.56	$1.119 \cdot 10^{-7}$	10	$.373 \pm .015$ ●	
		P1	.63	$.199 \cdot 10^{-7}$	8	$.796 \pm .075$ ●	
Mt. Amiata Qz-latite	MA77-12	KF	10.88	$.881 \cdot 10^{-7}$	21	$.204 \pm .010$ ●	
Mt. Amiata Qz-latite	MA77-14	KF	8.92	$.743 \cdot 10^{-7}$	46	$.210 \pm .003$ ●	
Mt. Amiata Qz-latite	MA77-17	KF	10.14	$.836 \cdot 10^{-7}$	15	$.208 \pm .010$ ●	
Mt. Amiata Qz-latite	MA77-21	KF	9.83	$1.128 \cdot 10^{-7}$	19	$.289 \pm .014$ ●	
Mt. Amiata Qz-latite	MA77-24	KF	10.48	$1.189 \cdot 10^{-7}$	15	$.285 \pm .014$ ●	
Mt. Amiata Qz-latite	MA77-32	KF	11.03	$1.070 \cdot 10^{-7}$	48	$.244 \pm .005$ ●	

constants: ▲ $\lambda_K = 5.85 \cdot 10^{-11} \text{y}^{-1}$; $\lambda_B = 4.72 \cdot 10^{-10} \text{y}^{-1}$; $^{40}\text{K}/\text{K} = 1.19 \cdot 10^{-4}$
 ● $\lambda_K = 5.81 \cdot 10^{-11} \text{y}^{-1}$; $\lambda_B = 4.962 \cdot 10^{-10} \text{y}^{-1}$; $^{40}\text{K}/\text{K} = 1.167 \cdot 10^{-4}$

TABLE 8
Rb/Sr analytical data - Volcanic rocks of Tuscan anatectic province

Rock type	Sample n.	Material	Rb ppm	Sr ppm	$^{87}\text{Rb}/^{86}\text{Sr}$	$(^{87}\text{Sr}/^{86}\text{Sr})_0$	$(^{87}\text{Sr}/^{86}\text{Sr})_t$	AGE Ma	Ref.
St. Vincenzo rhyolite	SV77-3	WR	306	104	8.55	$.7254 \pm .2$	$.7248$	$3.26 \pm .25$	13
		Bi	687	8.07	247	$.7370 \pm .10$	--		
Roccastrada rhyolite	R2V	WR	454	48	27.7	$.7196 \pm .6$	$.7186$	$2.6 \pm .5$	
		Bi	959	3.1	907	$.7525 \pm .46$	--		

TABLE 9
Fission tracks data - Tuscan anatectic province

Rock type	Sample n.	Material	ρ_f	ρ_i	Φ	$\frac{D_f}{D_N} \frac{D_N^1}{D_N}$	AGE Ma		Number of grains or fields	$\bar{S} \pm$	Ref.	
			tracks/cm ² (tracks)	tracks/cm ² (tracks)			neutrons/cm ²	or temper.				apparent
St. Vincenzo rhyolite		glass	16350 (512)	215900 (786)	0.82·10 ¹⁵	0.86	3.84	4.96 ±0.37	200	40	3.5	14
Roccastrada rhyolite	R 2V	glass	18650 (491)	477600 (2166)	0.82·10 ¹⁵	0.75	1.98	3.23 ±0.23	178	36	2.7	
Mt. Amiata (Qz-latitude)	2 V	glass	1390 (176)	555400 (1398)	2.11·10 ¹⁵	0.85	0.33	0.42 ±0.05	276	45	2.6	
Mt. Amiata (Qz-latitude)	77-1	glass	572 (100)	455000 (1228)	---	0.84	0.148	0.197±0.024	194	30	2.9	12
Mt. Amiata (Qz-latitude)	77-19-1	glass	1490 (203)	564000 (1016)	---	0.83	0.31	0.431±0.043	152	20	3.3	
Mt. Amiata (Qz-latitude)	77-19-2	glass	1450 (204)	539000 (970)	---	0.82	0.317	0.440±0.044	156	20	3.3	
Mt. Amiata (Qz-latitude)	77-20	glass	608 (101)	456000 (1230)	---	0.89	0.157	0.180±0.023	185	30	2.6	
Mt. Amiata (Qz-latitude)	77-21	glass	674 (140)	508000 (1372)	---	0.86	0.156	0.200±0.023	231	30	3.0	
Mt. Amiata (Qz-latitude)	77-28-1	glass	549 (103)	447000 (1006)	---	0.85	0.144	0.190±0.023	208	25	2.9	
Mt. Amiata (Qz-latitude)	77-28-2	glass	608 (100)	518000 (466)	---	0.84	0.138	0.185±0.025	183	10	5.1	
Montepoli volcanic ashes		glass	--	--	---	--	--	0.59 ±0.08	--	--	--	15
St. Vincenzo rhyolite		Zr	269	1315	2.9 · 10 ¹⁴			3.7±0.6				4
Elba granite		Zr	298	2101	1.2 · 10 ¹⁵			10 ±1.5				

constants: $^{238}\text{U} \cdot \lambda_f = 5.85 \cdot 10^{17} \text{y}^{-1}$; $^{235}\text{U} \cdot \phi = 5.82 \cdot 10^{-22} \text{cm}^2$; $^{238}\text{U}/^{235}\text{U} = 137.88$

TABLE 10
K/Ar analytical data - Capraia island

Rock type	Sample n.	Material	K%	^{40}Ar rd ml/g	^{40}Ar rd%	AGE Ma	Ref.
Latite	C 14	Bi	5.53	$2.146 \cdot 10^{-6}$	29	9.5 ± 3 ▲	16
Qz-latitude	C 45	Bi	5.19	$1.536 \cdot 10^{-6}$	30	7.4 ± 3 ▲	
Trachybasalt	C 20	WR	2.09	$4.138 \cdot 10^{-7}$	43	4.9 ± 2 ▲	
Trachybasalt	C 23	WR	1.70	$3.264 \cdot 10^{-7}$	34	4.8 ± 2 ▲	
Trachybasalt	CPR 1	WR	1.89	---	9.5	2.65 ± 15 ♦	17
Perlitic flow	CPR 6	Bi	6.02	---	37.8	8.26 ± 23 ♦	

constants: ▲ $\lambda_B = 4.72 \cdot 10^{-10} \text{y}^{-1}$
 $\lambda_K = 5.85 \cdot 10^{-11} \text{y}^{-1}$
 $^{40}\text{K}/\text{K} = 1.19 \cdot 10^{-4}$
 ♦ $\lambda_B = 4.72 \cdot 10^{-10} \text{y}^{-1}$
 $\lambda_K = 5.85 \cdot 10^{-11} \text{y}^{-1}$
 $^{40}\text{K}/\text{K} = 1.22 \cdot 10^{-4}$

Rock type	Sample n.	Material	Ks	⁴⁰ Ar rd ml/g	⁴⁰ Ar rd%	AGE Ma	Ref.
<u>Western Elba</u>							
Pegmatite	---	Le	---	---	--	6.4+ .6 ■	18
Granodiorite	---	Bi	---	---	--	7.6+ .4 ■	
Granite	KA 857	Bi	7.36	---	45	6.4 ▲	11
Granite	---	Bi	7.78	2.093·10 ⁻⁶	46	6.7+ .2 ▲	19
Granodiorite	E 10/2	Bi	7.10	2.052·10 ⁻⁶	--	7.2+ ▲	
Granodiorite	E 10/1	Bi	7.24	2.056·10 ⁻⁶	47	7.1 ▲	
Granodiorite	E 40	Bi	7.62	2.111·10 ⁻⁶	31	7 ▲	
Granodiorite	E 31	Bi	6.86	1.989·10 ⁻⁶	46	7.2 ▲	
Granodiorite	E 38	Bi	6.70	1.930·10 ⁻⁶	38	7.2 ▲	
Granodiorite porphyry	E 1	Bi	6.90	1.884·10 ⁻⁶	40	6.8 ▲	
Granodiorite porphyry	E 3	Bi	7.20	1.987·10 ⁻⁶	47	6.9 ▲	
Aplite	E 40F	WR	4.20	2.150·10 ⁻⁶	66	12.8 ▲	
Aplite	E 33	WR	3.75	1.264·10 ⁻⁶	30	8.5 ▲	
Granite porphyry	E 6	Bi	5.95	1.981·10 ⁻⁶	30	8.3 ▲	
Aplite	Eu/M	WR	3.43	1.856·10 ⁻⁶	69	13.5 ▲	
Aplite	Eu/1	WR	3.09	1.835·10 ⁻⁶	79	14.8 ▲	
Aplite	Eu/5	WR	2.51	1.242·10 ⁻⁶	72	12.4 ▲	
<u>Central Elba</u>							
Granite porphyry	E 17	Bi	5.88	1.646·10 ⁻⁶	34	7 ▲	
Granite porphyry	E 8/1	Bi	5.26	1.845·10 ⁻⁶	35	8.8 ▲	
Granite porphyry	E 8/2	Bi	5.38	1.921·10 ⁻⁶	36	8.9 ▲	
Aplite	Eu/PA	KF	3.40	1.176·10 ⁻⁶	64	8.6 ▲	
Aplite	E 7	WR	2.59	.886·10 ⁻⁶	59	8.5 ▲	
<u>Eastern Elba</u>							
Qz-monzonite	E02	Bi	5.58	1.367·10 ⁻⁶	40	6.1 ▲	
Qz-monzonite	E0 2 _b	Bi	6.40	1.594·10 ⁻⁶	44	6.2 ▲	
Granite porphyry	E0 5	Bi	5.95	1.410·10 ⁻⁶	31	5.7 ▲	
Granite porphyry	E/AS	KF	11.84	2.688·10 ⁻⁶	37	5.7 ▲	
Granite porphyry	E/AD	KF	12.14	2.878·10 ⁻⁶	61	5.9 ▲	
Aplite	E 77.155a	WR	2.15	4.805·10 ⁻⁷	18.5	5.7+ .4 ●	20
Aplite	E 77.156	WR	3.39	6.756·10 ⁻⁷	41	5.1+ .1 ●	
Aplite	C 10	WR	3.56	7.559·10 ⁻⁷	32.1	5.4+ .4 ●	
Aplite	C 11	WR	4.04	7.280·10 ⁻⁷	30	4.7+ .2 ●	
Schist	C 15a	WR	4.52	10.03 ·10 ⁻⁷	36	5.7+ .2 ●	
Aplite	G 2	WR	1.83	4.985·10 ⁻⁷	10.3	6.9+ .7 ●	
Aplite	G 11	WR	2.35	4.681·10 ⁻⁷	24.2	5 + .9 ●	
Aplite	G 19	WR	1.96	4.112·10 ⁻⁷	16.6	5.3+ .5 ●	
Amphibolite	G 13	WR	2.21	5.640·10 ⁻⁷	15	6.6+ .9 ●	
Schist	G 12a	WR	1.37	3.689·10 ⁻⁷	11	6.9+ .9 ●	
Qz-monzonite	E 75.16b	WR	3.89	8.581·10 ⁻⁷	58.5	5.7+ .6 ●	
Qz-monzonite	E 75.17	WR	2.91	7.132·10 ⁻⁷	44	6.3+ .5 ●	
Qz-monzonite	E 75.18	WR	3.77	8.252·10 ⁻⁷	54.5	5.6+ .1 ●	
Qz-monzonite	E 75.19	WR	3.14	7.131·10 ⁻⁷	44.5	5.9+ .3 ●	
Qz-monzonite	E 75.20	WR	3.78	8.543·10 ⁻⁷	48.2	5.8+ .3 ●	
Schist	E 77.138A	WR	1.86	3.722·10 ⁻⁷	15.3	5.2+ .5 ●	
Schist	A 77.138B	WR	2.84	5.370·10 ⁻⁷	27.1	4.9+ .6 ●	
Schist	A 77.138D	WR	3.30	6.864·10 ⁻⁷	28.4	5.4+ .3 ●	
Qz-monzonite	E 75.16b	Bi	10.51	2.196·10 ⁻⁶	70.8	5.4+1.1 ●	
		KF	7.44	1.792·10 ⁻⁶	49.5	6.2+ .5 ●	
constants: ■ $\lambda_K = 5.85 \cdot 10^{-11} \text{y}^{-1}$; $\lambda_B = 5.30 \cdot 10^{-10} \text{y}^{-1}$; $40\text{K}/\text{K} = 1.19 \cdot 10^{-4}$							
▲ $\lambda_K = 5.84 \cdot 10^{-11} \text{y}^{-1}$; $\lambda_B = 4.72 \cdot 10^{-10} \text{y}^{-1}$; $40\text{K}/\text{K} = 1.19 \cdot 10^{-4}$							
● $\lambda_K = 5.81 \cdot 10^{-11} \text{y}^{-1}</$							

TABLE 12
Rb/Sr analytical data - Elba island

Rock type	Sample n.	Material	Rb ppm	Sr ppm	$^{87}\text{Rb}/^{86}\text{Sr}$	$(^{87}\text{Rb}/^{86}\text{Sr})_m$	$(^{87}\text{Rb}/^{86}\text{Sr})_i$	AGE Ma	Ref.
<u>Western Elba</u>									
Pegmatite		Pe	1846	5.05	1066	.796	.712	5.6	18-24
Pegmatite		Pe	1434	1.70	2500	.943	.712	6.5	
Pegmatite		Le	16400	10.9	4541	1.184	.712	7.3	
Pegmatite		Le	17380	9.6	5503	1.229	.712	6.6	
Pegmatite		Le	3107	3.58	2576	.979	.712	7.3	
Pegmatite		Le	10920	3.68	9294	1.550	.712	6.3	
Granodiorite		Bi	1110	3.24	1007	.858	.712	10.2	
Granodiorite	ER 15	WR	271	239	3.28	.7152+ 3	.7149	6.88+ .04	21
		P1	9.9	522	.055	.7149+ 2	.7149		
		KF	488	237	5.97	.7154+ 1	.7149		
Granodiorite	STE 74	Bi	1135	1.22	2759	.9845+35	.7149	6.73+ .04	
		WR	295	221	3.87	.7153+ 4	.7150		
		P1	60.6	218	.803	.7151+ 4	.7150		
		KF	339	205	4.73	.7155+ 3	.7150		
		Bi	1130	1.45	2305	.9358+14	.7150		
Granite	W	WR	276.6	242.6	3.279	.7141	.7138	5.18	22
Granite	W ₁	Bi	1066	9.627	318.3	.7341	.7138		
Granite	W ₂	Bi	1064	9.879	309.9	.7372	.7138		
Pegmatite	W ₃	Le	6082	4.138	4227	1.0339	.7138		
Pegmatite	W ₄	Le	7177	2.377	8686	1.3951	.7138		
Pegmatite	W ₅	Le	6963	3.849	5203	1.1132	.7138	5.40	
<u>Central Elba</u>									
Granite	M	WR	287.6	122.8	6.736	.7152	.7146	6.42	
Granite	M ₁	Bi	868.5	15.07	165.8	.7297	.7146		
Granite	M ₂	Bi	872.3	14.42	173.9	.7303	.7146		
<u>Eastern Elba</u>									
Qz-monzonite	E75.16b	WR	302	149	5.87	.7201+ 3	.719	4.9	20
		Bi	1371	8.4	471.5	.7534+ 4	.719		
Qz-monzonite	E75.18	WR	312	152	5.94	.7204+ 5	.719	4.9	
		Bi	1376	8.5	470.3	.7545+ 9	.719		
Qz-monzonite	E75.19	WR	211	162	3.77	.7173+ 1	.717	5	
		Bi	993	12.4	231	.7338+ 2	.717		
Qz-monzonite	E75.20	WR	264	192	3.98	.7151+ 1	.715	5.4	
		Bi	952	12.5	221	.7323+ 1	.715		

TABLE 13
K/Ar analytical data - Minor intrusions

[illegible]

TABLE 14
Rb/Sr analytical data - Minor intrusions

Rock type	Sample n.	Material	Rb ppm	Sr ppm	$^{87}\text{Rb}/^{86}\text{Sr}$	$(^{87}\text{Sr}/^{86}\text{Sr})_m$	$(^{87}\text{Sr}/^{86}\text{Sr})_i$	AGE Ma	Ref.
Roccastrada granite	R 102	Bi	1109	1.9	1645	.776	.712	2.7	8
Gavorrano granite	GAV 79-1	WR	279	206	3.91	.7140 $\pm$ 3	.7138	4.4 $\pm$.6	23
		Bi	799	4.6	507	.7456 $\pm$ 12	.7138		
Castel di Pietra granodiorite	S ₂ 779-5	WR	296	176	4.85	.7152 $\pm$ 4	.7149	4.3 $\pm$.3	
		Bi	776	7.8	289	.7326 $\pm$ 12	.7149		
Castel di Pietra granite	S ₃ 895	WR	230	261	2.56	.7147 $\pm$ 3	.7145	4.3 $\pm$.15	
		Bi	795	7	328	.7343 $\pm$ 10	.7145		
Montecristo granite	N 11	WR	367	103	10.3	.7159 $\pm$ 3	.7151	7.3 $\pm$.3	21
		P1	12	51	.68	.7157 $\pm$ 4	.7151		
		KF	762	123	18	.7168 $\pm$ 4	.7151		
		Bi	1976	2.1	2841	1.0133 $\pm$ 36	.7151		
Giglio granite	G 16	WR	286	136	6.08	.7176 $\pm$ 4	.7174	5.1 $\pm$.1	
		P1	8.7	219	.12	.7174 $\pm$ 4	.7174		
		KF	460	188	7.09	.7181 $\pm$ 4	.7174		
		Bi	1026	1.86	1617	.8337 $\pm$ 12	.7174		

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