RENDICONTI Soc. Italiana di Mineralogia e Petrologia, 32 (2) 637-646 (1976)

ALESSANDRA CESANA *, LAURA DEMONTE **, MARINA VENEGONI **

ORIGIN OF THE CERVO PLUTON ACCORDING TO THE U AND Th CONTENT AND DISTRIBUTION

ABSTRACT. — Uranium and thorium content has been determined in 16 samples of total rock, drawn from the plutons of Biella and Traversella and from several country rocks. The aim of the investigation is to find geochemical suggestions in favour of a primary or secondary origin of the two intrusive bodies. The high U and Th concentration in the rocks of the above plutons and the observed Th/U ratios allow to neglect the possibility that the parent magmas of the two plutons can be derived by partial or total remelting of the Sesia-Lanzo metamorphic country rocks. Several hypotheses have been put into discussion; nevertheless geochemical features together with well known geophysical data lead to be inclined to the following interpretation: the Cervo and Traversella plutons could represent the residual system of hybrid magmas.

RIASSUNTO. — Sono stati determinati i contenuti di U e Th in 16 campioni di roccia totale, tratti dai plutoni di Biella (Valle del Cervo) e di Traversella e da alcune rocce circostanti, allo scopo di trovare indizi geochimici sull'origine primaria o secondaria dei due corpi intrusivi. Le alte concentrazioni di U e Th nelle rocce dei plutoni e i rapporti Th/U osservati, permettono di escludere la possibilità che i magmi dei due plutoni siano derivati da rifusione parziale o totale delle rocce metamorfiche Sesia-Lanzo. Sulla loro origine si possono formulare varie ipotesi; tuttavia le caratteristiche geochimiche e i dati geofisici, permettono di propendere per la seguente: il plutone della valle del Cervo e quello di Traversella potrebbero rappresentare i sistemi residuali di magmi ibridi.

Introduction

In the Cervo Valley pluton several occurrences of secondary U minerals has been mentioned in the joins of the syenite and monzonites: β-uranophane (FIORENTINI POTENZA, 1959 a), autunite and torbernite in this case (FIORENTINI POTENZA, 1958).

Besides an high α, γ - radioactivity and U Th preliminary distribution have been pointed out by DEUTSCH & LONGINELLI (1958) and later by FIORENTINI POTENZA (1959 b).

The above items seem to indicate an high significance of the uranium and thorium content in this pluton and suggest now the opportunity to perform more extensive geochemical investigations on the U, Th distribution and related geochemical association in the pluton as well as in its surrounding rocks. The aim of such

* Centro Studi Nucleari "Enrico Fermi" (CeSNEF), Politecnico di Milano.
** Istituto di Mineralogia, Petrografia e Geochimica, Università di Milano.

TABLE 1

Modal composition of the selected intrusive rocks

Rocks and provenience	Plagioclase	K-feldspar	Amphibole	Pyroxene	Biotite	Quartz	Ore minerals	Sphene	Apatite	Accessory minerals
Porphyritic pink granite * (Migliacci)	34.02	32.24	4.45		6.5	20.59	1.07	0.57	0.55	
White granite * (Campiglia)	31.62	42.62	4.46		0.47	19.05	0.24	0.58	0.24	
Granodiorite (S. Giovanni Andorno)	46.6	32.2	10.0		1.0	7.2	0.7	1.4	0.9	
Granodiorite (Piaro)	48.6	9.7	14.3		11.4	12.3	1.1	0.7	1.2	
Granodiorite (Balma)	46.2	28.3	12.7		2.9	7.0	1.0	0.6	1.3	
Syenite (Balma) *										
⊥ Texture	27	53	12		0.6	4				4
// Texture	30.5	40.7	17.9	0.8	0.6	5.3				3.9
Syenite (Rialbella)										
⊥ Texture	24	46.7	18.5	0.1	2	5.5				3
// Texture	23	43	24.5		2.3	2.8				4.1
Monzonite ** (Cascina Veglio)	41.6	39.2	8.9		4.1	3.5	1.06	0.5	0.2	
Monzonite (Casoni)	40.4	38.4	3.9	6.3	5.5	3.0				2.4
Quartz Monzonite * (La Pietraccia)	27.1	42.8	7.6		7.0	12.5	1.5	0.9	1.3	
Monzonite granite (Cascina Fienbello)	30.33	43.81	15.56		0.82	7.89				1.71
Monzonite granite (Rialbella)	31.12	35.56	15.78		5.9	9.23	1.13	0.55	0.78	
Monzonite (Rosazza)	33.54	42.62	16	0.49	0.11	3.6				3.5
Diorite (Pian Vittone) (Traversella)	61.13	7.49	21.18		2.86	4.42	2.28	0.26	0.38	
Mangerite (Cava Grande) (Traversella)	53.7	13.41	15.18		11.72	4.38	1.27	0.19	0.15	

For the marked rocks there is also chemical analysis: * (Fiorentini Potenza M., 1959b) ** (Peyronel Pagliani G., 1961)

a comparision should be that to look the U and Th like possible indicators of the origin of the Cervo pluton magma.

The question rising is, in fact, that to realize if the Cervo magma has to be thought like an autoctone rather than alloctone melt. In the second case does it represent a residue system or the removed fraction of a partial melting?

Geology

The Cervo pluton emplacement took place according to the transition between gneisses and micaschists of the Sesia-Lanzo zone; the widest elongation of the pluton itself still runs accordingly to the above boundary zone.

There is very field evidence of masses exchange between the melt and its wall rocks: fragments of micaschists and gneisses are enclosed in the syenites and monzonites and appear to be affected by its thermometasomatic activity; whereas feldspar injections occur in the wall rocks.

Plantifull chemical data (FIORENTINI POTENZA M., 1969 a) support such a metasomatic exchange in the eterogeneous system.

In the Sesia-Lanzo metamorphic zone another pluton outcrops: the Traversella one of granodioritic-dioritic composition; this pluton has been enclosed in the present geochemical comparison, showing a slightly younger Oligocenic age and similar emplacement conditions (SCHIAVINATO G., 1972). Table 1 gives modal analyses of the main types of rocks of the Cervo and Traversella plutons: these are original analyses but for the marked rocks are known also chemical composition.

In the same Sesia-Lanzo metamorphic complex some autoctone granitoid outcrops and several porphyrite dykes appear; the field evidence suggests that the granitoids have been formed « in situ » probably by mobilization of the only feldspars and quartz phases mainly. Therefore no removal and separation seems to have taken place, between the mobilized and resistant phases.

The bulk essential chemical composition of these granitoids and that of the surrounding gneisses results to be substantially the same as it has been checked by FIORENTINI POTENZA (1969 b). These granitoids, however, cut the porphyrite dykes but appear to be affected, in their turn, by the contact aureole of the Cervo Tertiary pluton.

Besides, chemical data (in preparation) play in favour of a closeness between the Sesia-Lanzo porphyrite dykes and the Canavese igneous belt.

In the light of such a chemical closeness and taking into consideration the geotectonic association, the Sesia-Lanzo porphyrites could represent some of the continental volcanic pypes of the Canavese extrusion.

Some small or large blocks of porphyrites occour enclosed in the granite core and in the other rocks of the pluton.

Therefore, all together these field relations suggest the following sequence of geologic events:

1) Sesia-Lanzo metamorphism;
2) Porphyrite dyke - Canavese extrusion emplacements;
3) « Granitoid » recrystallizations;
4) Tertiary pluton emplacements.

Sampling

In order to prepare some terms of comparision for the origin of the pluton, the following samples have been collected:

9 samples of selected rocks of the Cervo pluton;
2 samples of the selected rocks of the Traversella pluton;
4 samples of Sesia-Lanzo metamorphic rocks;
1 sample of Canavese « porphyrite ».

The main care in such a sampling program has been that to provide for absolutely no altered samples of rocks.

Difficulties thereat arose in sampling micaschists, granite and Canavese « porphyrite ». The former for secundary iron hydroxides diffusion, the latter for the extensively altered plagioclase.

The care comes from the well known strange tendence of U in respect of Th concentration to be leached and removed from the crystalline lattice and from interstitial spaces by late stage solutions and filtering waters.

The main risk, indead, should be that of a selective leaching of U which could compromise Th/U ratio in the total rock.

Thereat, upon such a ratio it has been based the comparision between the pluton and its neighbouring rocks.

Experimental procedure

U and Th concentrations in the selected rocks were measured by neutron activation analysis (KRUGER P., 1971), (MORGAN J. W. et al., 1963).

For this purpose all the collected samples were crushed and the powder, without any handling, was sealed in lucite phials in the quantity of 100 mg about.

For every group of samples, a « standard » was made adding to the powder a known amount of U and Th in the form of solution, then dried.

The irradiations were performed at the surface of the core of L54 reactor at CeSNEF, Politecnico - Milan.

The total available flux is $\simeq 3.5\ 10^{11}$ n/cm^{2}sec.: typical irradiation time for the samples was about two hours.

After a cooling time of three or four days, the obtained γ - spectra were analysed by a coaxial, 35 cm^3 Ge-Li detector connected to a Laben 8192 channel pulse height analyser.

The U and Th content was determined counting the 0.228 MeV γ ray from 2.35 d ^{239}Np and the 0.312 MeV γ ray from 27 d ^{233}Pa, both obtained after (n, γ) reaction on U and Th in the samples.

Besides this possibility, the U concentration was measured on the same samples by delayed neutron counting (NASS H. W. et al., 1972).

TABLE 2

U, Th mean concentration and Th/U ratio in the Sesia-Lanzo Tertiary plutons and surrounding metamorphic rocks

	Samples	U (ppm)	Th (ppm)	Th/U
A	Pink Granite (Piaro)	37.62 (2%)	71.18 (2%)	1.89
	Pink Granite (Jondini)	34.74 (3%)	61.96 (3%)	1.78
	White Granite (Campiglia)	29.57 (3%)	63.68 (2%)	2.15
	Syenite (Balma)	29.45 (2%)	84.24 (1%)	2.86
	Syenite (Quittengo)	33.44 (3%)	99.12 (1%)	2.96
	Syenite (Rosazza)	39.93 (1%)	96.40 (1%)	2.41
	Monzonite (Rio Vajet)	32.47 (2%)	96.65 (1%)	2.98
	Monzonite (Rialbella)	36.78 (1%)	72.38 (2%)	1.97
	Type Monzonite (Gragliasca)	29.03 (1%)	78.96 (2%)	2.72
	Granodiornite (Traversella)	4.33 (4%)	13.63 (4%)	3.15
	Mangerite (Traversella)	27.65 (2%)	42.26 (3%)	1.52
B	"Porphirite" (Bocchetto Sessera)	5.83 (4%)	17.75 (4%)	3.04
C	Micaschist (Oneglie)	3.86 (5%)	19.90 (4%)	5.16
	Micaschist (Mucrone)	5.15 (4%)	17.75 (4%)	4.09
	Gneiss (Lago della Vecchia)	1.70 (5%)	8.40 (4%)	4.94
	Granitoid (Gneiss) (Colle della Vecchia)	< 1	4.26 (5%)	> 4

A : Tertiary Plutons B : Canavese-Volcanites C : Sesia-Lanzo zone

TABLE 3

Large cation content (ppm) in some of the selected rocks

ROCKS	Ba	Rb	Sr	Pb	Zr	Be	U*	Th*	K_2O
Porphyritic Granite (San Paolo) Cervo-Valley	1400	310	>700	55	220	14	33.98	65.61	4.30
Syenite (Balma) Cervo-Valley	> 1500	360	> 700	60	310	13	34.27	93.25	5.60
Mangerite (Bersella) Traversella	> 1500	> 30	> 700	30	190	3	27.75	42.26	3.62
Diorite (Pian Vittone) Traversella	> 1500	162	600	20	220	2.5	4.33	13.63	2.57

* The U and Th concentrations are an average of several samples

For the other cations, the values are taken from (Fiorentini Potenza M. et al., 1975)

Moreover, as comparision, natural activity due to U and Th by γ ray spectrometry was measured with Ge-Li detector: now the countings were performed on 150-200 g of powder sealed in cylindrical lucite containers and the samples were allowed to attain secular radioactive equilibrium before the analysis (ADAMS J.A.S. et al., 1970).

The results are shown in Table 2: for every selected rocks the concentration of U and Th is given as weighted mean value and standard error of the concentrations measured in the different methods.

Table 3 gives the large cations content for some of the analysed rocks.

Results

The mean concentration of U and Th in the Cervo pluton as a whole results to be 7-9 times higher than in the sialic crust (WHITFIELD et al., 1959) and higher than in other Tertiary or younger Italian plutons.

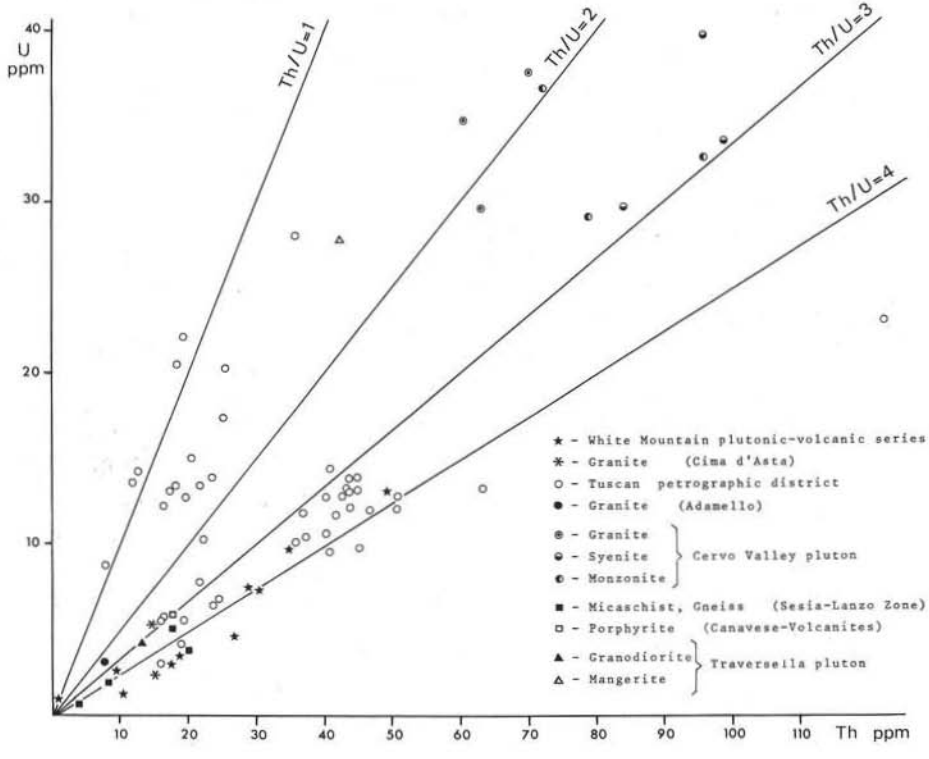

Fig. 1. — Uranium and Thorium content in some igneous rocks.

The Traversella pluton appears, also, to exceed igneous crustal average. The range of Th/U ratio in the selected rocks of the Cervo and Traversella plutons appears to be slightly lower (1.5-3) than the range (3.5-4) of mean Th/U ratio values given by WITHFIELD et al. (1959) for the crustal rocks.

This fact means that the Cervo and Traversella plutons are more enriched in U and Th respect of the 2.8 ppm and 10 ppm of sialic rocks average.

Besides it can be noted that in the Traversella pluton the mangerite facies, the richest one in K-feldspar, attains U and Th concentration and Th/U ratio ranging in the Cervo granites values. The comparison between U and Th content in these plutons and the U and Th ranges of some types of alkaline rocks shows the general good correlation between Th, U and K.

TABLE 4

Range of U and Th concentration and Th/U ratio drawn from literature in intrusive alkaline rocks (a), metamorphic roks (b), sedimentary rocks (c)

	Rocks	U (ppm) range	U (ppm) average	Th(ppm) range	Th(ppm) average	Th/U + average
a	Precambrian	2.2-5.7	3.9	16-33	24.5	6.28
	Paleozoic	3.4-5.1	4.8	--	16	3.33
	Mesozoic	2.4-15	8.7	8-56	32	3.68
	Tertiary	5.1-5.5	5.2	11-32	21.4	4.12
b	Micaschist	2-4	3	0.8-19	9.8	3.27
	Gneiss	0.2-5.8	3	0.9-27	9	3
c	Sandstone	0.4-3.3	1,9	1-9.1	5.02	2.64
	Shales	2-8	5	10-73	11.5	2.30
	Blackshales	3-1250	--	--	--	low

+ The average Th/U ratio is the ratio of the means of Th and U content.

The mean Th/U ratio of the Cervo pluton results thus to be lower than in many other plutonic districts of the Tertiary orogens and lower than the crustal average of Tertiary rocks (see Fig. 1).

According to Paterman (in WEDEPOHL, Handbook of Geochemistry, 1969) there would be a general tendence of Th/U ratio to increase continously from ancient intrusions to the younger ones.

In this light the Cervo pluton would have ancestral character. Nevertheless mean values from Wedepohl (see Table IV) don't support such a trend pointed out by Paterman.

At this point it becomes usefull to call attention on the marked abundance in large cations like Ba, Pb, Rb, and so on; they appear to be geochemically associated with U and Th in the Cervo pluton and mainly with K.

On the other hand, taking into consideration the surrounding and neighbouring rocks of the Cervo pluton, the U and Th concentration appear to be lower of some order of magnitude in the Sesia-Lanzo metamorphic rocks than in the pluton selected rocks; on the contrary, it appears that the range of Th/U ratio (2-3) of monzonites and syenites is close to the Th/U ratio of Canavese volcanic rocks (3.04).

The above direct comparision results to be based upon single values of Th and U content in neighbouring rocks and upon mean values in the pluton rocks; nevertheless credit may be attached to the above comparision, because the Th, U and Th/U ratio values in the Sesia-Lanzo metamorphic rocks and Canavese dacitic andesitic ones range in their respective crustal average. Moreover the Sesia-Lanzo schists latu sensu, appear to be incomparably voider in large cations than the rocks of the Cervo pluton.

Discussion

The comparision between U, Th content and Th/U ratio in the two Sesia-Lanzo plutons and its neighbouring rocks leads to exclude the possibility of an autoctone origin of the formers, whereas suggests that their origin can be discussed taking into consideration the following three hypotheses:

a) the Cervo pluton, and probably the Traversella one, represent residual systems of a parent hybrid melt;

b) otherwise they represent the mobilizated fractions of partial meltings;

c) eventually the parent melt assimilated ancient sedimentary black shales, generally radioactive.

All together the above three hypotheses imply in any case that a parent magma is invoked of which no larger surviving evidence still exists now apart from the thin igneous Canavese eruptive belt and the Sesia-Lanzo porphyritic dykes of latite-dacite composition.

It turns to be out very clear that the ratio between appearing volumes of the plutons and of the Canavese belt don't play in favour evidently of a relationship that should be that of parent magma-residual system.

On the other hand well known geophysical data suggest the presence of a surviving light melt, probably potash-rich underlying the mantle ultramafic solder ridge giving rise to the I.V. positive Bourguer anomaly.

An undoubted character of residual system of the Cervo and Traversella plutons however rises from their particolar geochemical association and abundance of large cations with U and Th.

Thus the two Tertiary plutons could really represent residual systems of the hybrid parent melts due to the partial mixing between the light alkaline melt and the basaltic product of the ridge. Keeping in mind that mobilized fractions of a partial melting cannot be geochemically distinguished from residual systems without the help of isotope geochemistry (Ferrara G. et al., 1975) the second hypothesis

cannot be better discussed than by answering what may be the parent material in the present geochemical setting: the Cervo pluton hardly can be derived by partial melting from Sesia-Lanzo metamorphic rocks.

These appear to be typically void of U, Th and large cations in respect of the pluton, whereas titanium has similar concentration. Besides the Th/U ratio of the Sesia-Lanzo schists appears to be much higher than in the pluton; thereby even a strongly partial melting could have not concentrate U enough to lower the Th/U ratio from 5 to 2 about, keeping in mind the ratio of masses between the pluton and the schists. Besides the partial melting would have affected also the titanium which remains instead about the same.

At present there is no geochemical evidence in favour of buried sedimentary ancient deposits in the Northern subduction zone and the third hypothesis still remains more or less in the realm of fancy.

The origin of the uncommon U and Th content has to be searched mainly in the strong increasing U and Th content with increasing K_2O content in the selected rocks; if credit may be given to the above unquantified correlation, the origin of these radioactive elements in the pluton could be assigned to their geochemical association with K and other large cations.

Conclusion

Uranium, Thorium and large cation content as well as Th/U ratio suggests that the Cervo pluton cannot be seen as an autoctone product of complet partial melting of Sesia-Lanzo metamorphic rocks.

The above geochemical characters together with the magmatic means of the well known geophysical data about the Ivrea Verbano Bouguer positive anomaly, lead to believe the following: the Cervo pluton and the Traversella one, probably represent residual systems of hybrid melts between light alkaline melt underlying the ultramafic folded ridge and the primitive basaltic product of the last itself.

Acknowledgments - To Prof. M. POTENZA FIORENTINI who advised and discussed the present work.

REFERENCES

ADAMS J. A. S., GASPARINI P. (1970) - *Gamma-Rays spectrometry of rocks.* Elsevier Publishing Company, Amsterdam.

DEUTSCH S., LONGINELLI A. (1958) - *Distribuzione della radioattività nella sienite di Biella.* Studi e ricerche della divisione geomineraria. Vol. I, parte II, 711-724.

FERRARA G., MACERA P., VALENTINETTI R. (1975) - *Contenuti di U e Th nelle rocce della provincia magmatica toscana.* Parte I Rend. Soc. It. Min. Petrol., XXXI, 209-219.

FIORENTINI POTENZA (1958) - *Autunite nella sienite di Biella.* Rend. Soc. It. Min., XIV, 215-223.

FIORENTINI POTENZA M. (1959 a) - *Minerali radioattivi nella massa granitico-sienitica della Valle del Cervo (Biella): uranofane* β. Rend. Ist. Lombardo Sc. e Lett., Classe A 93, 495-505.

FIORENTINI POTENZA M. (1959 b) - *Distribuzione delle principali facies petrografiche e della radioattività nel plutone sienitico di Biella (Valle del Cervo).* Rend. Soc. It. Min., XV, 89-131.

FIORENTINI POTENZA M. (1969 a) - *Movimento di elementi durante l'intrusione e metamorfismo di contatto del plutone della Valle del Cervo (Biella).* Rend. Soc. Min. It., XXV, 353-374.

FIORENTINI POTENZA M. (1969 b) - *Ruolo della mica nel metamorfismo Sesia-Lanzo (Piemonte).* Atti Soc. It. Sc. Nat. Mus. Civ. Milano, CIX, 55-86.

FIORENTINI M., SCHWANDER H., STERN W. (1975) - *Chemical distribution patterns in the tertiary and triassic igneous districts of the Central Alps.* Chem. Erde Bd., 34, 257-282.

KRUGER P. (1971) - *Principles of Activation Analysis.* Wiley, Interscience, New York.

MORGAN J. W., LOWERING J. F. (1963) - *Determination of U and Th in rocks by neutron activation analysis.* Anal. Chem. Acta, 28, 405-417.

NASS H. W., MOLINSKI V. J., KRAMER H. H. (1972) - *Determination of Uranium in various materials by delayed neutron counting.* Mater. Research and Stand., 12 (4), 24-26.

PEYRONEL PAGLIANI G. (1961) - *Chimismo e differenziazione delle rocce nel settore occidentale del plutone di Biella.* Rend. Ist. Lombardo Sc. e Lett., Classe A 95, 317-334.

SCHIAVINATO G. (1972) - *Plutonismo e vulcanismo sul versante italiano delle Alpi Centrali ed Orientali.* Acc. Naz. dei Lincei, 4, Vol. LII, 523-538.

WEDEPOHL K. H. (1969) - *Handbook of Geochemistry.* Springer Verlag, Berlin.

WHITFIELD J. M., ROGERS J. J. W., ADAMS J. A. S. (1959) - *The relationship between petrology and Thorium and Uranium contents of some granitic rocks.* Geochim. Cosmochim. Acta, 17, 248-271.