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RESEARCHES ON THE GEOCHEMISTRY OF THE URANIUM: AUTORADIOGRAPHIC STUDY ON THE α - RADIOACTIVITY DISTRIBUTION IN THE MOST IMPORTANT FACIES OF THE BIELLA PLUTON (WESTERN ALPS)

by

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RESUMEN.—Se ha estudiado la distribución de la radioctividad en las principales facies del pluton de Biella. Los resultados obtenidos han sido comparados con los de otros investigadores. Se puso en evidencia la constancia de la actividad de los minerales con respecto a la de sus inclusiones.

ABSTRACT.—The α—radioactivity distribution in the principal facies of the Biella pluton has been recognized. The data has been comparated with those of other investigators. The constancy of some relations between the activity of the minerals and their inclusions has been put on evidence.

Acknowledgment

This work has been executed in the I.N.F.N. (National Institute of Nuclear Phisics), branch of Milan, directed by prof. G. Occhialini, who is cteerely thanked for his gentle helf, and was included in my "Tesi di Laurea" presented in the Faculty of Geological Sciences of the University of Milan in January 1960.

A) THE FACIES OF THE BIELLA PLUTON

Field and laboratory researches brought to te identification of the most important facies of the Biella pluton.

This pluton is made up, from center outwards, as follows:

1) Core of porphyric alcaligranite, for the presence of phenocrysts of pink orthose, included in a quartziferous, plagioclasic, coarse matrix with biotite and green hornblende;

In the central part, this granite is crossed by a aplitic whitish porphyric granitic dike, with a matrix much finer, in which are easily found two different generations of K-feldspar. The K-feldspar in both these rocks is frequently micro- or macroperthitic.

2) Crown of medium grained amphibolic syenite (Balma syenite), violet coloured for the presence of orthose; besides the standard components (orthose, plagioclase, amphibole, biotite, quartz, zircon, titanite, apatite) uraninite and some methamitic minerals could be spotted, with some difficulty, due to their very small dimensions, between the minerals of this rock.

3) Crown of monzonite and quartz-monzonite, in the composition of which appears the pyroxene group, in different quantities from place to place.

4) A very wide outside crown with monzonitic facies, characterized by flow stage structure.

Excluding the relative proportions, and the piroxene group, the mineral composition of these rocks is basically the same of the typical syenite (Balma syenite).

5) Two narrow areas, on the periphery of the pluton, made out of fine grained dark monzonite, in which the tourmaline take the place of the apatite, which is the typical mineral for all the other facies of the pluton.

B) AUTORADIOGRAPHIC RESEARCHES

Autoradiographic researches have been conducted on the most interesting facies mentioned (i. e. pink granite, white granite, Balma violet syenite, syenitic monzonite, which represents an intermediate type between the peripheric ones).

a) *Technique and method of work*

A thin layer of about 50 microns of "nuclear emulsion Ilford C2 in gel form" was spread over some thin not covered sections, according to the method suggested by E. E. PICCIOTTO (11).

In order to get the necessary statistical data, the exposure time was 76 days; at regular intervals sample-sections were developed. The "Temperature Development processing" was used for all the developings (1).

In this way an even track (made of silver grains) was obteined along the range of each single α—particle emitted by the minerals.

The process of casting the emulsion film directly on the thin section allows a better location of the α—particles sources.

About 2 sq. cm. for each section have been scanned with the microscope (800x) and it has been able to divide the particles emitted by the main minerals and those emitted by small inclusions, which usually could not be recognized.

In doing so it was considered only the tracks left by the particles with a range of 2 microns or longer.

It was not considered, on the contrary, the α—particles emitted from particularly active centers (1000α/month) as uraninite, which otherwise would have mislead the statistic and upset the comparison with rocks lacking in active centers.

b) *The α—radioactivity distribution in the rocks of Biella pluton*

The results of these computes are shown in the enclosed charts, in which are also shown both examined surface of each mineral (obtained with volumetric analysis system) and the U concentrations, referred to the main minerals taken from I. Curie's formula:

$N = 3.10^3.cU.d.k.(35—8,3r) + 10^3.\ cTh.d.k(28,7—6r)$
in the assumption that $Th/U = 3$.

From the charts I to IV can be easely observed that:

1) The minerals with maximum activity are the accessory ones, apatite, titanite, zircon.

2) Radioactivity is not constant in the various plutonic facies, but it is top in the typical syenitic facies (Balma syenite) and it is sensibly lower in the pink porphyric granitic core, in comparison to which the activity of the aplitic granite is almost double.

The data obtained were similar to the radiometric reticule drawn by researchers of the University of Milan on the same pluton (8).

In order to put into more evidence the results of the various measurements, I thought to include the minerals into three groups by considering the standard minerogenetic suite: quartz, feldspar, femic minerals. I calculated for these three groups the actual activity and the total activity (minerals + inclusions), considering as inclusions, for their reduced size, also zircon and apatite, while I considered separatedly the titanite for the big size presented in the Biella pluton.

I reworked in this way also the results obtained from other sources (E. PICCIOTTO, Un. Liv. Bruxelles; HIECKE MERLIN et al., Un. Padova) (11) (12) (13) (9).

The results are given in the following charts V-VI, thus including also the ratio between activity of minerals/activity minerals + inclusions.

This ratio is of most interest. It could be observed that:

1) The subdivision of the radioactivity between the minerals and the inclusions are quite homogeneous in the femic group.

2) In the acid group of the Balma syenite the ratio is showing a bigger activity for the inclusions: field researches found, as a matter facts, developed pegmatitic phenomena in this facies.

3) The distribution of the radioactivity in the aplitic white granite is completely different from that of the other facies; the ratio shows a great activity of the actual minerals: this fact seems correlated to the second acid injection in this rock.

Further studies are in my mind in order to confirm an extend these results.

Minerals	Number α in 76 days	% miner. inclus.	Surface cm^2	N(activ. α/cm^2. sec.)	Relat. activ. (orth. = 1)	concU grU/gr.
Thin section	2951		2,17			
Orthose	590	72	1,59	5,65.10-5	1	0,26.10-6
Inclusions	231	28				
Orth. tot.	821	100		7,86.10-5	1,39	0,36.10-6
Plagiocl.	77	60	0,18	6,51.10-5	1,15	0,25.10-6
Inclusions	48	40				
Plag. tot.	125	100		10,58.10-5	1,87	0,46.10-6
Quartz	137	30	0,24	8,52.10-5	1,51	0,35.10-6
Inclusions	327	70				
Quarz tot.	464	100		28,84.10-5	5,10	1,20.10-6
Amphibole	171	82	0,03	94,01.10-5	16,64	4,00.10-6
Inclusions	37	18				
Amph. tot.	208	100		114,35.10-5	20,24	4,85.10-6
Biotite	467	73	0,11	68,85.10-5	11,65	2,50.10-6
Inclusions	170	27				
Biot. tot.	637	100		89,82.10-5	15,90	3,26.10-6
Apatite	200		0,005	483, 5.10-5	85,57	
in:						
orth.	73					
plag.	8					
quartz	29					
amph.	34					
biot.	56					
Zircon	191		0,003	1077, 3.10-5	190,67	
in:						
orth.	62					
plag.	7					
quartz	89					
amph.	—					
biot.	33					
Titanite	305		0,005	1161, 2.10-5	205,52	

TABLE I — α—particles distribution in the white granite of Biella

Minerals	Number α in 76 days	% miner. inclus.	Surface cm^2	N(activ. α/cm^2. sec.)	Relat. activ. (orth. = 1)	concU grU/gr.
Thin section	1220		1,75			
Orthose	79	28	1,09	$1,10.10^{-5}$	1	$0,05.10^{-6}$
Inclusions	171	72				
Orth. tot.	250	100		$3,49.10^{-5}$	3,16	$0,16.10^{-6}$
Plagiocl.	21	20	0,18	$1,77.10^{-5}$	1,6	$0,07.10^{-6}$
Inclusions	84	80				
Plag. tot.	105	100		$8,83.10^{-5}$	8,0	$0,34.10^{-6}$
Quartz	18	17	0,30	$0,91.10^{-5}$	0,82	$0,04.10^{-6}$
Inclusions	89	83				
Quartz tot.	107	100		$5,40.10^{-5}$	4,89	$0,22.10^{-6}$
Amphibole	16	32	0,07	$3,66.10^{-5}$	3,32	$0,16.10^{-6}$
Inclusions	34	68				
Amph. tot.	50	100		$11,43.10^{-5}$	10,35	$0,49.10^{-6}$
Biotite	29	27	0,10	$4,51.10^{-5}$	4,09	$0,16.10^{-6}$
Inclusions	80	73				
Biotite tot.	109	100		$16,94.10^{-5}$	15,34	$0,62.10^{-6}$
Apatite	11		0,004	$52,10.10^{-5}$	47,19	
in:						
orthose	7					
plagiocl.	—					
quartz	4					
amphib.	—					
biotite	—					
Zircon	357		0,003	$2174,70.10^{-5}$	1969,85	
in:						
orthose	217					
plagiocl.	69					
quartz	3					
amphibole	21					
biotite	47					
Titanite	229		0,004	$871,86.10^{-5}$	789,73	

TABLE II — α—particles distribution in pink granite of Biella

Minerals	Number α in 76 days	% miner. inclus.	Surface cm^2	N (activ. α/cm^2. sec.)	Relat. activ. (orth. = 1)	concU
Thin section	5580		2,02			
Orthose	133	6	1,21	$1{,}67.10^{-5}$	1	$0{,}08.10^{-6}$
Inclusions	1983	94				
Orth. tot.	2116	100		$26{,}60.10^{-5}$	15,93	$1{,}20.10^{-6}$
Plagioclase	163	13	0,48	$5{,}17.10^{-5}$	3,10	$0{,}20.10^{-6}$
Inclusions	1097	87				
Plag. tot.	1260	100		$39{,}98.10^{-5}$	23,94	$1{,}54.10^{-6}$
Quartz	25	10	0,06	$6{,}24.10^{-5}$	3,74	$0{,}26.10^{-6}$
Inclusions	215	90				
Quartz tot.	240	100		$59{,}92.10^{-5}$	35,88	$2{,}48.10^{-6}$
Amphibole	224	29	0,20	$17{,}06.10^{-5}$	10,22	$0{,}82.10^{-6}$
Inclusions	643	71				
Amph. tot.	867	100		$66{,}02.10^{-5}$	39,53	$2{,}80.10^{-6}$
Piroxene	3	—	0,01	$5{,}40.10^{-5}$	3,23	$0{,}18.10^{-6}$
Inclusions	147	100				
Pirox tot.	150	100		$270{,}34.10^{-5}$	161,88	$10{,}00.10^{-6}$
Biotite	—	—	0,01			
Inclusions	73	100				
Biot. tot.	73	100		$118{,}90.10^{-5}$	71,20	$4{,}30.10^{-6}$
Apatite in:	151		0,01	$280{,}40.10^{-5}$	167,90	
orthose	50					
plagiocl.	—					
quartz	63					
amphib.	38					
biotite	—					
Zircon in:	576		0,005	$1808{,}65.10^{-5}$	1083,02	
orthose	329					
plagiocl.	104					
quartz	59					
amphib.	50					
biotite	34					
Titanite	147		0,01	$207{,}30.10^{-5}$	124,13	

TABLE III — α—particles distribution in the Balma syenite

Minerals	Number α in 76 days	% miner. inclus.	Surface cm^2	N(activ. α/cm^2. sec.)	Relat. activ. (orth. = 1)	concU grU/gr.
Thin section	2491		1,88			
Orthose	122	18	0,95	$1{,}94.10^{-5}$	1	$0{,}09.10^{-6}$
Inclusions	545	82				
Orth. tot.	667	100		$10{,}58.10^{-5}$	5,45	$0{,}48.10^{-6}$
Plagioclase	42	22	0,50	$1{,}28.10^{-5}$	0,66	$0{,}05.10^{-6}$
Inclusions	147	78				
Plagiocl. tot.	189	100		$5{,}76.10^{-5}$	29,97	$0{,}22.10^{-6}$
Quartz	47	40	0,15	$0{,}48.10^{-5}$	0,25	$0{,}02.10^{-6}$
Inclusions	57	60				
Quartz tot.	104	100		$1{,}06.10^{-5}$	0,55	$0{,}04.10^{-6}$
Amphibole	62	21	0,08	$12{,}11.10^{-5}$	6,24	$0{,}52.10^{-6}$
Inclusions	203	79				
Amph. tot.	265	100		$51{,}74.10^{-5}$	26,67	$2{,}20.10^{-6}$
Piroxene	59	100	0,02	$39{,}07.10^{-5}$	20,14	$1{,}45.10^{-6}$
Inclusions	—	—				
Pirox. tot.	59	100		$39{,}07.10^{-5}$	20,14	$1{,}45.10^{-6}$
Biotite	88	29	0,12	$11{,}55.10^{-5}$	5,95	$0{,}42.10^{-6}$
Inclusions	212	71				
Biot. tot.	300	100		$39{,}38.10^{-5}$	20,30	$1{,}43.10^{-6}$
Apatite	53		0,002	$384{,}35.10^{-5}$	198,12	
in:						
orthose	29					
plagiocl.	3					
quartz	7					
amphib	12					
biotite	2					
Zircon	368		0,002	$2436{,}65.10^{-5}$	1256,01	
in:						
orthose	29					
plagiocl.	—					
quartz	30					
amphib.	130					
biotite	179					
Titanite	486		0,02	$321{,}80.10^{-5}$	165,88	

TABLE IV — α—particles distribution in the syenitic monzonite

Minerals	(1) White granite of Biella	(2) Pink granite of Biella	(3) Balma syenite of Biella	(4) Syenitic monzonite of Biella	(5) Adamello granodiorite	(6) Adamello granodiorite	(7) Adamello granodiorite	(8) Adamello granodiorite	(9) Mte Capanne granite (Elba)	(10) Lac Blanc granite (Vosges)	(11) Kasai granite (Congo)
Quartz	8,52.10-5	0,91.10-5	6,24.10-5	0,48.10-5	4,10.10-5	1,90.10-5	2,40.10-5	1,00.10-5	45,00.10-5	1,60.10-5	11,00.10-5
Quartz tot.	36,18.10-5	5,75.10-5	90,20.10-5	1,43.10-5	7,20.10-5	7,50.10-5	5,50.10-5	1,00.10-5	64,00.10-5	36,00.10-5	23,00.10-5
concU	0,35.10-6	0,04.10-6	0,26.10-6	0,02.10-6	0,16.10-6	0,08.10-6	0,10.10-6	0,04.10-6	1,90.10-6	0,10.10-6	0,40.10-6
Feldspars	5,74.10-5	1,20.10-5	2,46.10-5	1,71.10-5	3,70.10-5	1,20.10-5	1,60.10-5	3,70.10-5	9,70.10-5	25,00.10-5	16,00.10-5
Feldsp. tot.	9,40.10-5	7,76.10-5	34,80.10-5	9,65.10-5	8,40.10-5	6,60.10-5	5,90.10-5	39,00.10-5	42,00.10-5	61,00.10-5	91,00.10-5
concU	0,26.10-6	0,05.10-6	0,11.10-6	0,07.10-6	0,15.10-6	0,05.10-6	0,07.10-6	0,15.10-6	0,40.10-6	1,00.10-6	0,30.10-6
Femics	71,60.10-5	4,16.10-5	15,65.10-5	14,60.10-5	0,97.10-5	2,32.10-5	4,30.10-5	2,60.10 5	83,70.10-5	170,00.10-5	18,00.10-5
Femics. tot.	108,60.10-5	21,19.10-5	83,80.10-5	65,30.10-5	26,40.10-5	18,20.10-5	21,10.10-5	21,00.10-5	858,00.10-5	1000,00.10-5	46,00.10-5
concU	2,60.10-6	0,16.10-6	0,63.10-6	2,86.10-6	0,32.10-6	0,08.10-6	0,16.10-6	0,11.10-6	3,00.10-6	6,10.10-6	0,10.10-6

NOTE: columns (1) to (4) facies of Biella pluton; (5) to (8), facies of the Adamello pluton by Hiecke Merlin et al.; (9) to (11) by Picciotto.
concU are relative to the main minerals.

TABLE V — Activity α/cm^2sec — concU

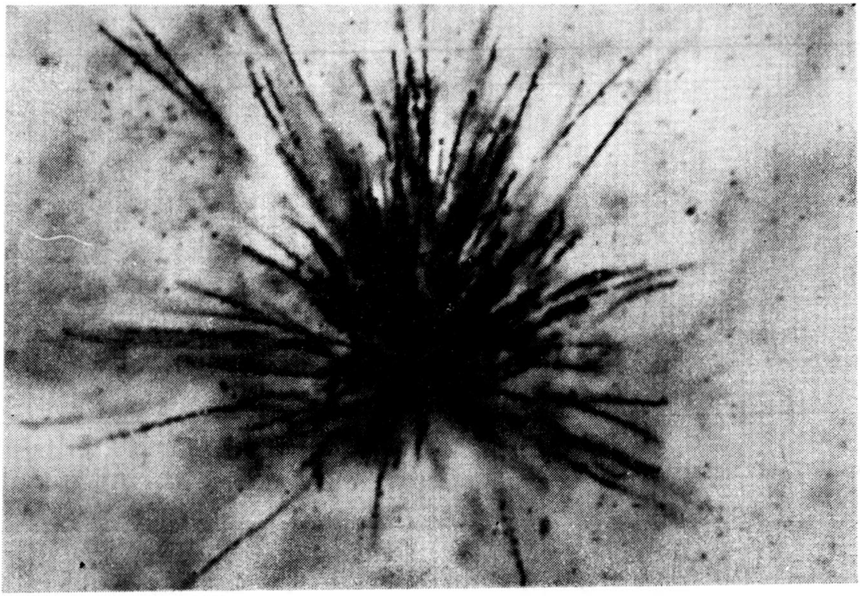
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
	White granite (Biella)	Pink granite (Biella)	Balma syenite (Biella)	Syenitic monzonite (Biella)	Adamello granodiorite	Adamello granodiorite	Adamello granodiorite	Adamello granodiorite	Mte Capanne granite (Elba)	Lac Blanc granite (Vosges)	Kasai granite (Congo)
Quartz/Quartz tot.	0,24	0,16	0,07	0,28	0,57	0,25	0,44	1,00	0,70	0,05	0,48
Feldspars/Feld. tot.	0,61	0,15	0,07	0,18	0,48	0,18	0,27	0,95	0,23	0,41	1,76
Femics/Femics tot.	0,67	0,19	0,19	0,22	0,36	0,13	0,28	0,12	0,97	0,17	0,39

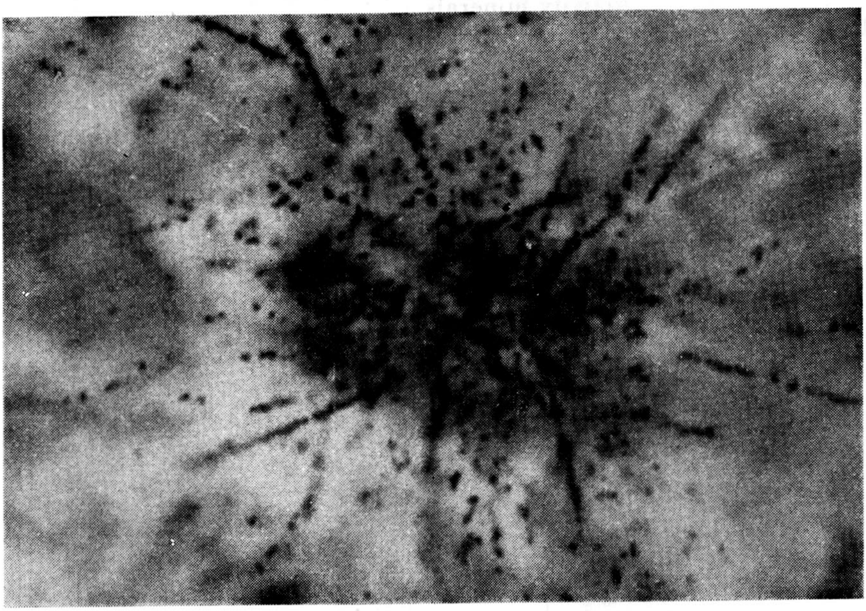
TABLE VI: $\dfrac{\text{Activity minerals}}{\text{Activity minerals} + \text{inclusions}}$

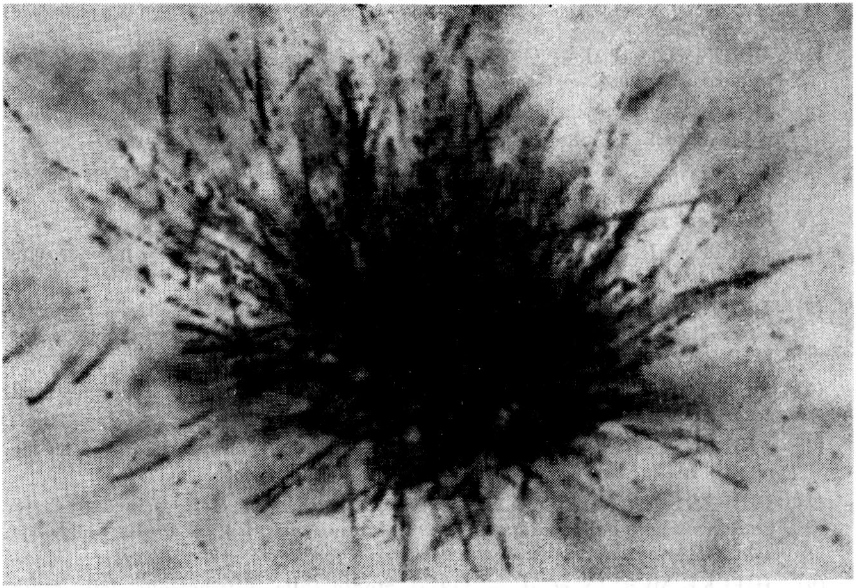
NOTE: (1) to (4), facies of the Biella pluton; (5) to (8) reworked from Hiecke Merlin et al.; (9) to (11) reworked for Picciotto.

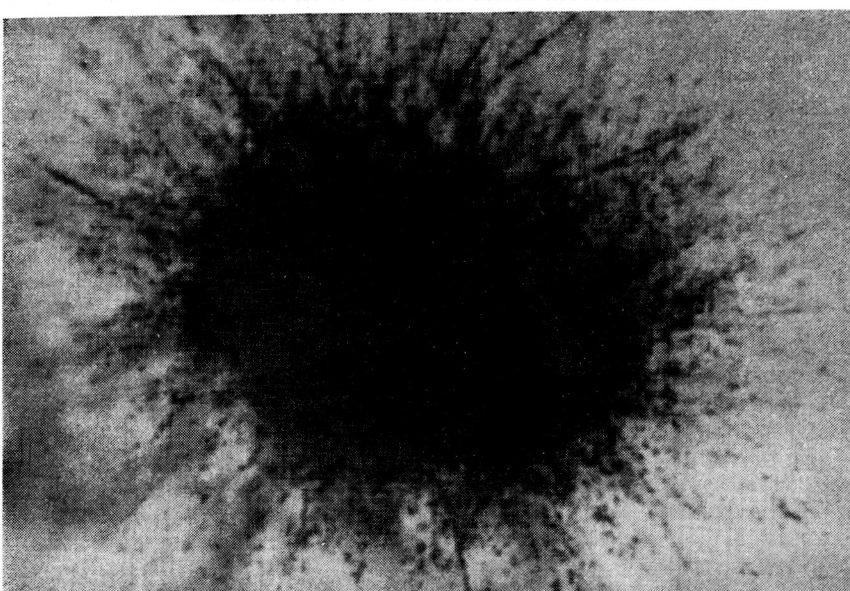
ACTIVE CENTERS IN THE ROCKS OF THE BIELLA PLUTON

(Natural light; aprox. 550 x)









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