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Chemical mass transfer in shear zones
a comparison of four mass l

CYRIL DURAND[1,*], EMILIEN OLIOT[2,3], DIDIER M

[1] UMR 8217 Géosystèmes, University of Lille 1, Bâtiment
*Corresponding author, e-mail: cyri
[2] Institut de Physique du Globe de Strasbourg; UMR 7516, Uni
67084 Strasbourg Ced
[3] UMR 6249 Chrono-environnement, University of Franche-Com

J. metamorphic Geol., 2012, **30,** 703–722

Role of chemical processes on shear
from the Grimsel metagranodiorite (A

P. GONCALVES,[1] E. OLIOT,[1,2] D. MARQUER[1] AND J. A. D
[1]*UMR-CNRS 6249 Chrono-Environnement, Université de Franche-Co*
(philippe.goncalves@univ-fcomte.fr)
[2]*UMR-CNRS 7516 Institut de Physique du Globe de Strasbourg, 1 rue*
[3]*Earth Science Department, Swiss Federal Institute of technology, CH-*

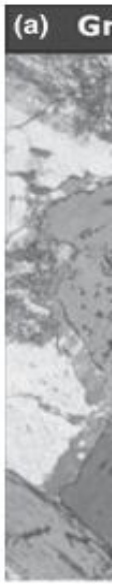
PrePub Article

and metacarbonate xenoliths: balance approaches

[ARQUER[3] and JEAN-PIERRE SIZUN[3]

SN5, 59655 Villeneuve d'Ascq Cedex, France
l.durand@univ-lille1.fr
iversity of Strasbourg/EOST, CNRS, 1 rue Blessig,
ex, France
ité, 16 route de Gray, 25030 Besançon Cedex, France

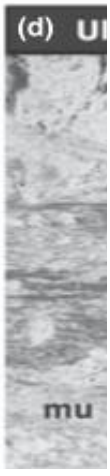
doi:10.1111/j.1525-1314.2012.00991.x

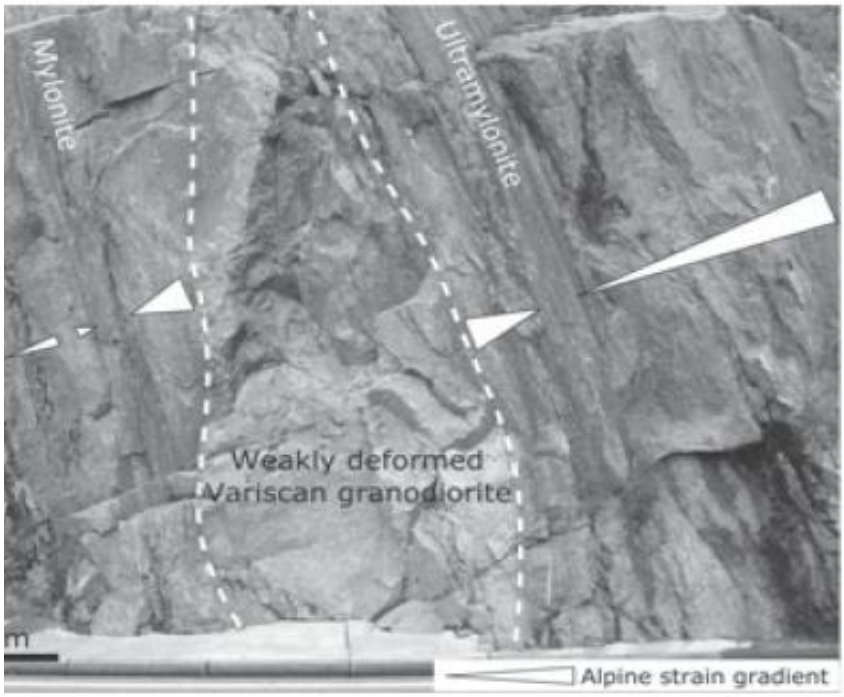


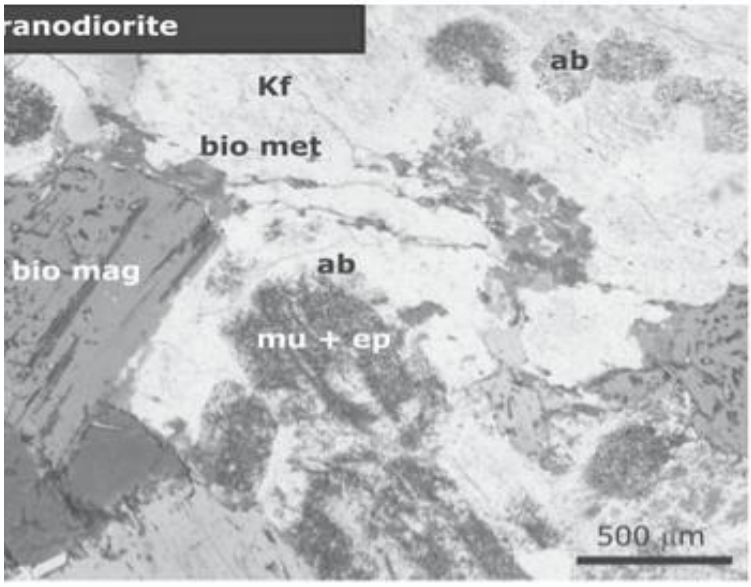
zone formation: an example Aar massif, Central Alps)

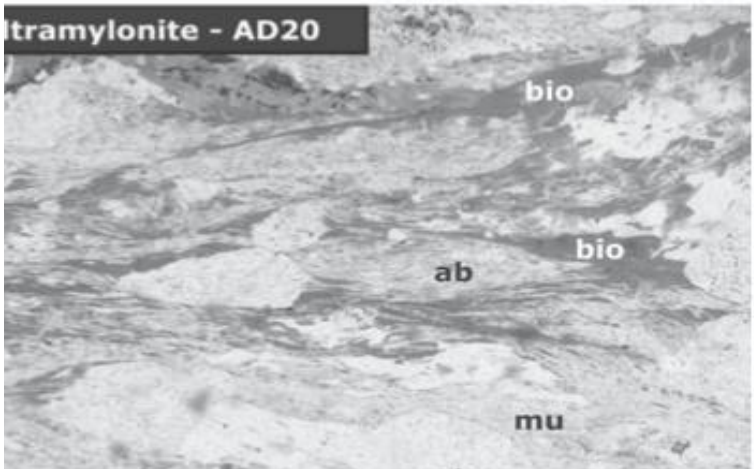
D. CONNOLLY[3]
nté, 16 route de Gray 25030 Besançon cedex, France

Blessig, 67084 Strasbourg Cedex, France
8092 Zürich, Switzerland




Mylonite
Ultramylonite
Weakly deformed
Variscan granodiorite
Alpine strain gradient


ranodiorite
ab
Kf
bio met
bio mag
ab
mu + ep
500 µm

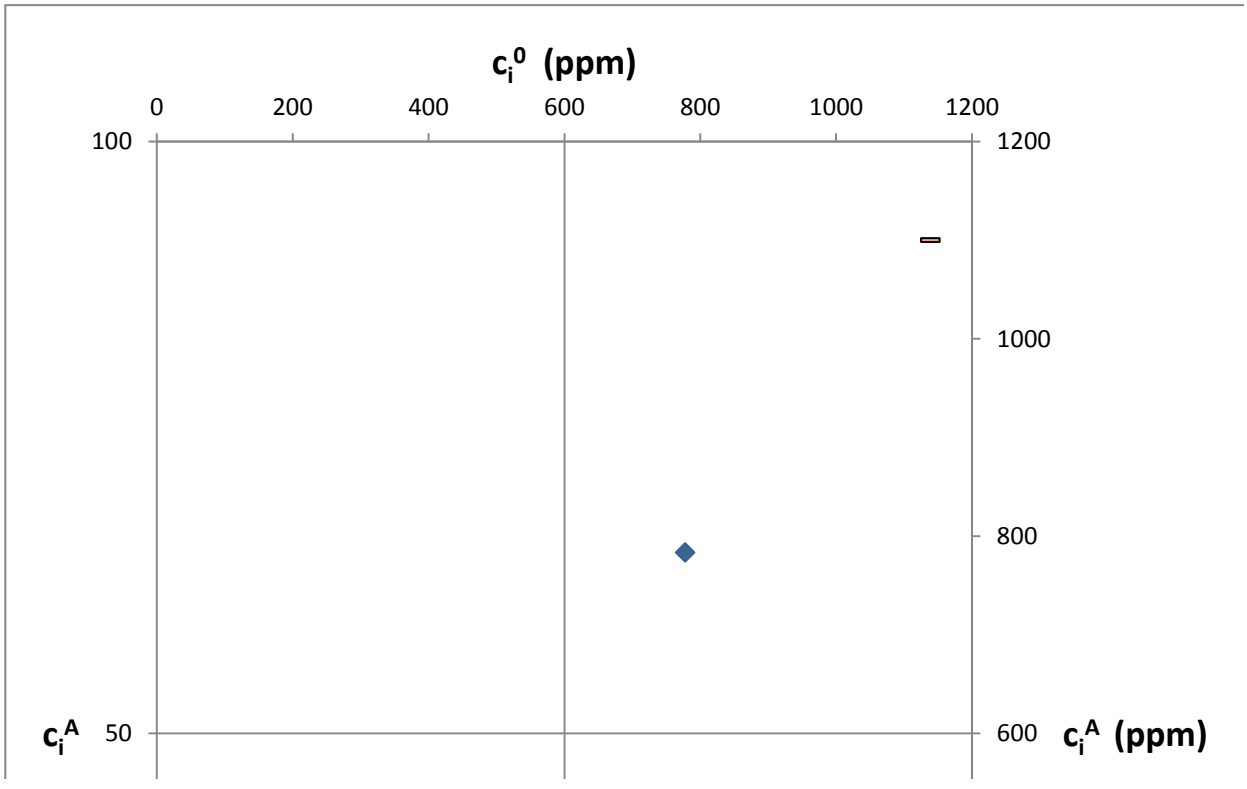

tramylonite - AD20
bio
bio
ab
mu

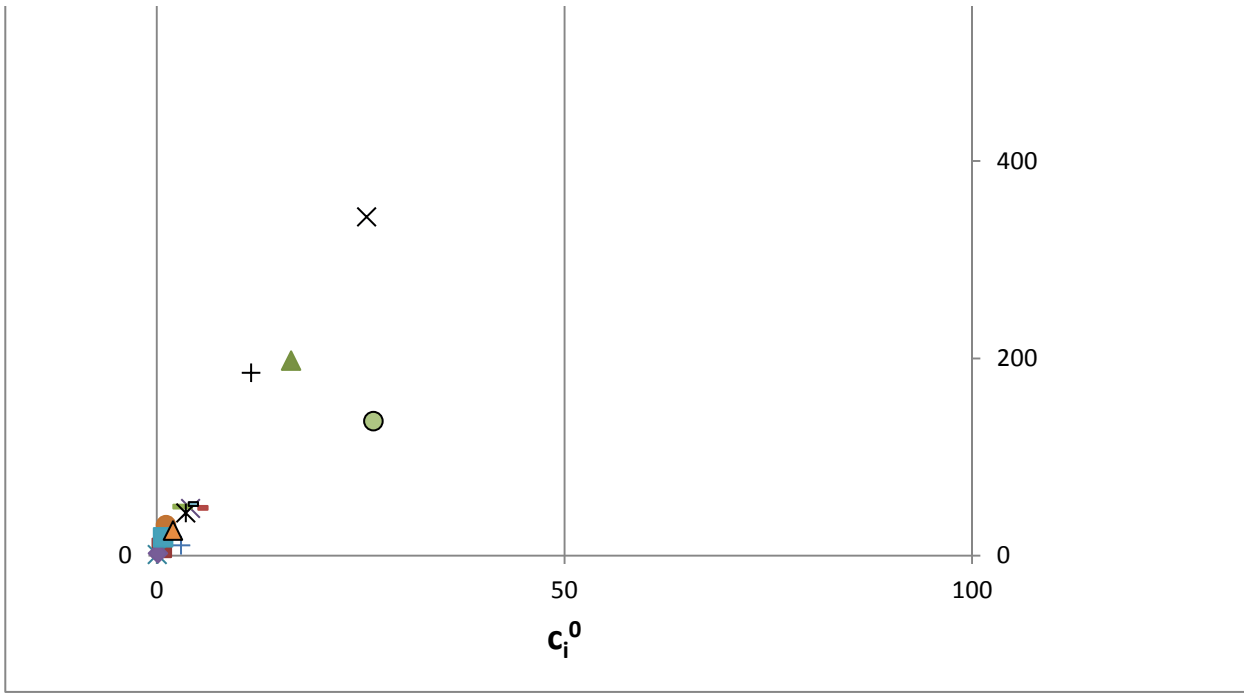

ab
500 µm

Chemical mass transfer in shear zones and metacarbonate xenoliths: a cc

Durand et al. (2015), EJM **Table 2 (Grimsel granodiorite → ultramylonite alteration)** Al2O3

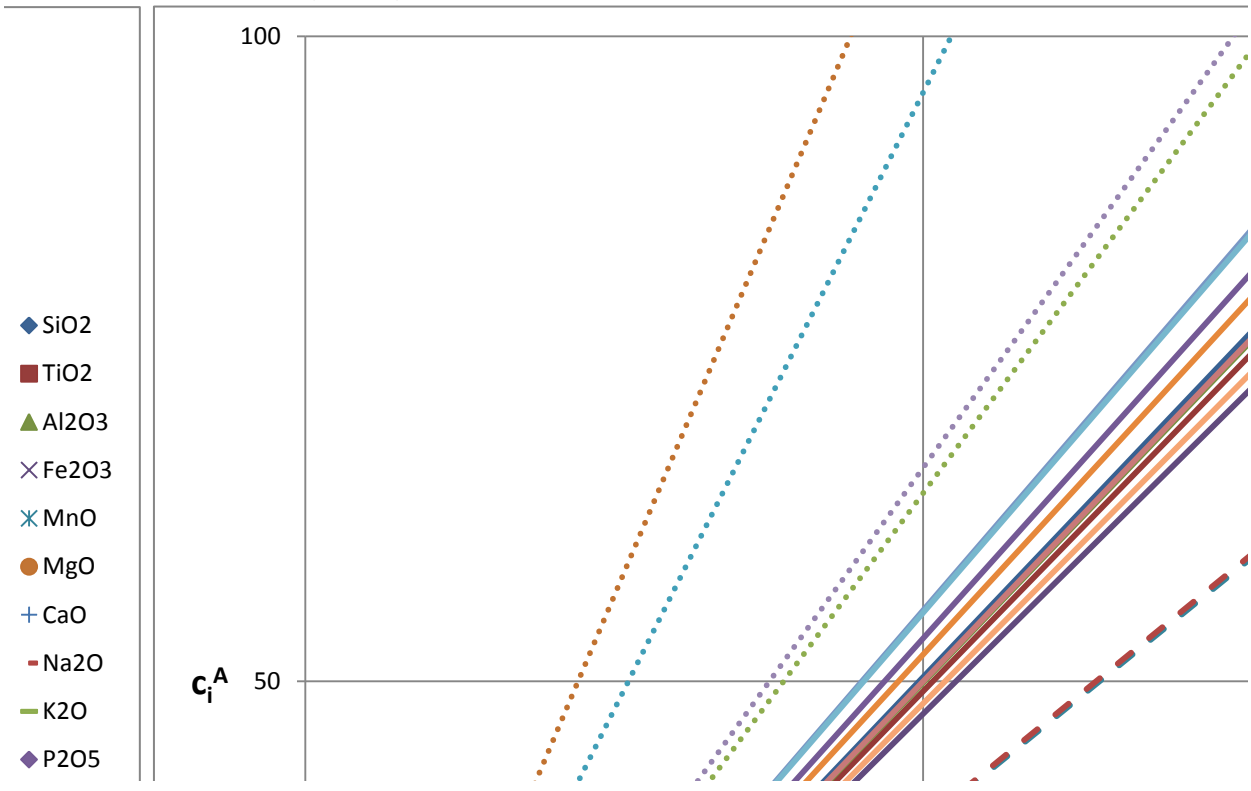
	c_i^0	σ_i^0	c_i^A	σ_i^A	b_i		Δm_i
SiO2	64.85	1.27	65.27	1.16	1.0065	1.0065	0.58
TiO2	0.65	0.05	0.64	0.07	0.9846	0.9846	-0.01
Al2O3	16.49	0.62	16.45	0.47	0.9976	0.9976	0.00
Fe2O3	4.17	0.28	3.96	0.36	0.9496	0.9496	-0.20
MnO	0.09	0.01	0.07	0.01	0.7778		-0.02
MgO	1.13	0.09	2.56	0.13	2.2655		1.44
CaO	2.98	0.27	0.84	0.35	0.2819		-2.14
Na2O	5.12	0.43	4	0.6	0.7813		-1.11
K2O	3.19	0.2	4.12	0.49	1.2915		0.94
P2O5	0.15	0.03	0.16	0.02	1.0667	1.0667	0.01
H2O	0.8	0.13	1.53	0.16	1.9125		0.73
Total	99.62		99.57				
ppm							
Nb	24	5	25	6	1.0417	1.0417	1
Zr	309	18	343	25	1.1100	1.1100	35
Y	43	8	43	4	1.0000	1.0000	0
Sr	319	47	136	63	0.4263		-183
Rb	139	29	185	53	1.3309		46
V	47	4	52	4	1.1064	1.1064	5
Ba	1139	114	1100	151	0.9658	0.9658	-36
					AVERAGE	**1.0229**	
						Δm	0.24

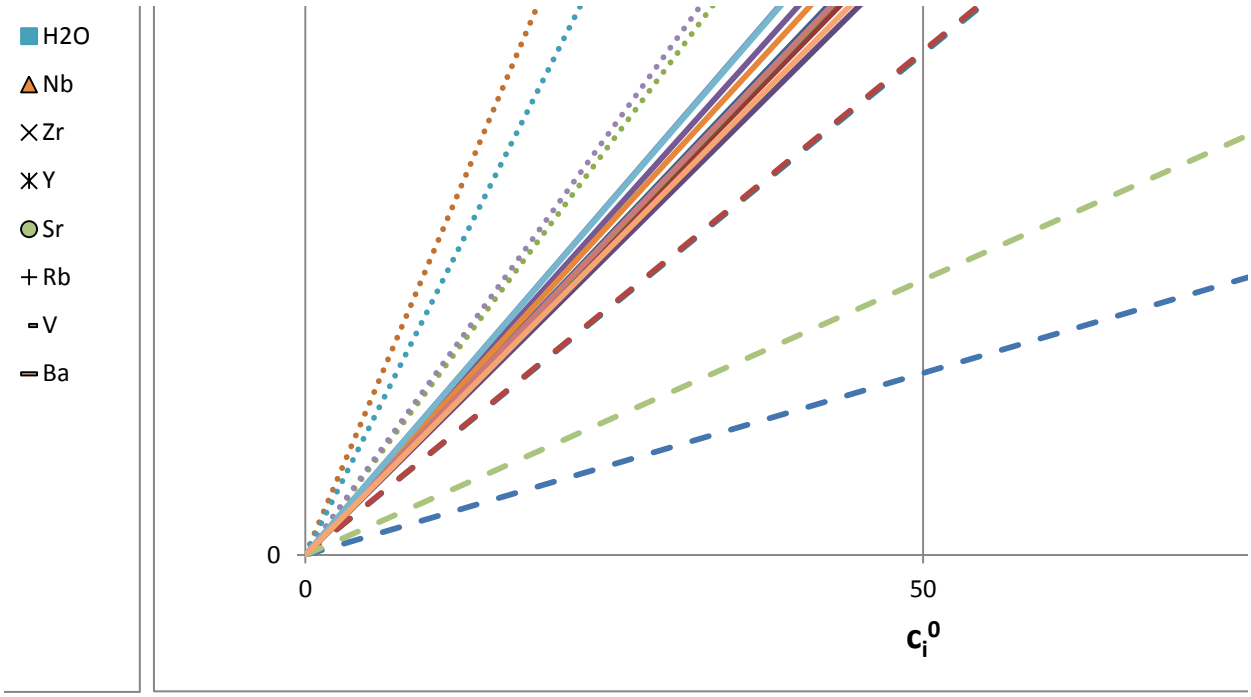



400
200
0
0
0
50
100
c_i^0

ɔmparison of four mass balance approaches

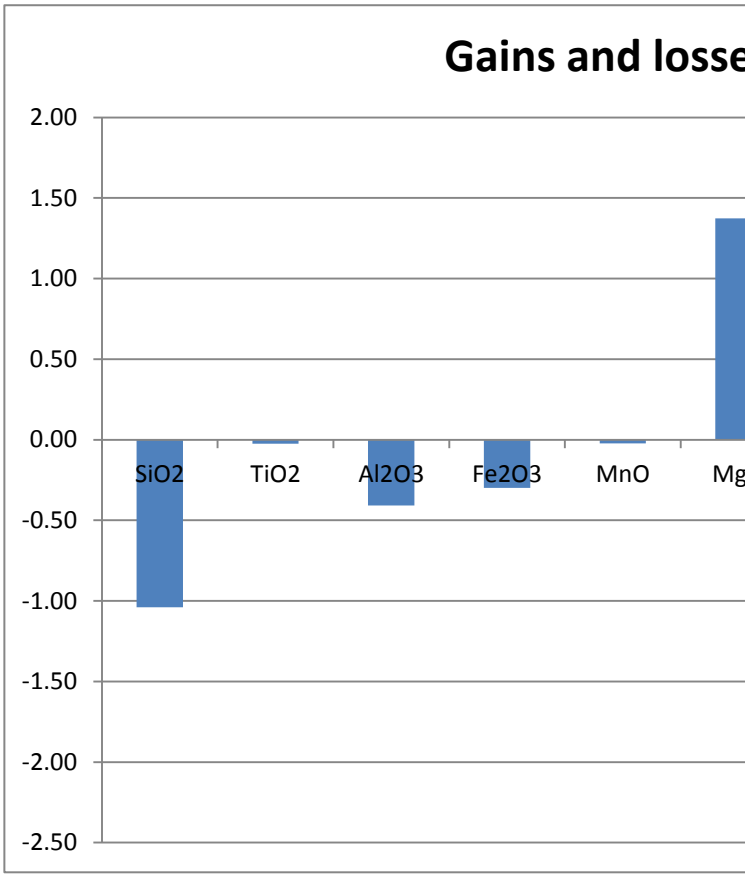
Fe2O3	Zr	10 comp	BO95	Al2O3	Fe2O3	Zr	10 comp
Δm_i	Δm_i	**Δm_i**					
3.88	-6.05	-1.04	-0.28	0.9%	6.0%	-9.3%	-1.6%
0.02	-0.07	-0.02	-0.02	-1.3%	3.7%	-11.3%	-3.7%
0.83	-1.67	-0.41	-0.22	0.0%	5.0%	-10.1%	-2.5%
0.00	-0.60	-0.30	-0.25	-4.8%	0.0%	-14.4%	-7.2%
-0.02	-0.03	-0.02	-0.02	-22.0%	-18.1%	-29.9%	-24.0%
1.57	1.18	1.37	1.40	127.1%	138.6%	104.1%	121.5%
-2.10	-2.22	-2.16	-2.15	-71.7%	-70.3%	-74.6%	-72.4%
-0.91	-1.52	-1.21	-1.16	-21.7%	-17.7%	-29.6%	-23.6%
1.15	0.52	0.84	0.89	29.5%	36.0%	16.4%	26.3%
0.02	-0.01	0.01	0.01	6.9%	12.3%	-3.9%	4.3%
0.81	0.58	0.70	0.71	91.7%	101.4%	72.3%	87.0%
		ppm					
2	-1	0	1	4.4%	9.7%	-6.2%	1.8%
52	0	26	30	11.3%	16.9%	0.0%	8.5%
2	-4	-1	0	0.2%	5.3%	-9.9%	-2.2%
-176	-196	-186	-184	-57.3%	-55.1%	-61.6%	-58.3%
56	28	42	44	33.4%	40.2%	19.9%	30.1%
8	0	4	4	10.9%	16.5%	-0.3%	8.2%
19	-148	-64	-51	-3.2%	1.7%	-13.0%	-5.6%
5.30	-9.91	**-2.24**	**-1.07**				
		b (isocon)	1.0108				



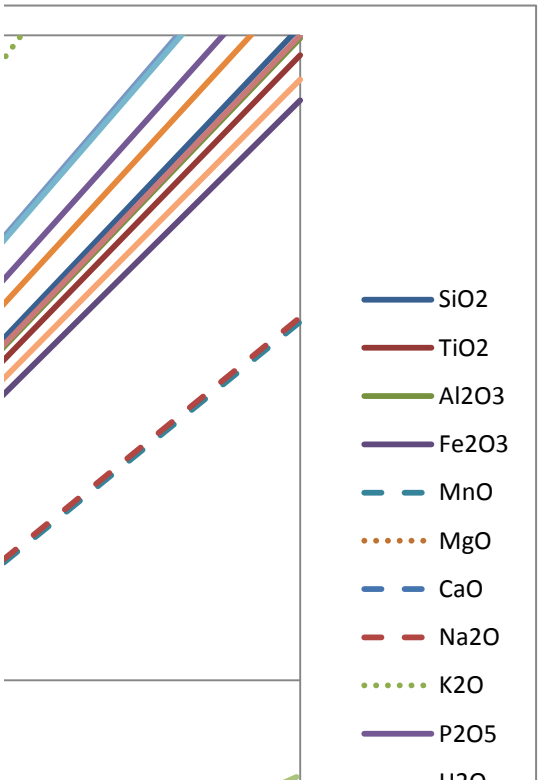

H2O
Nb
Zr
Y
Sr
Rb
V
Ba
0
0
50
c_i^0

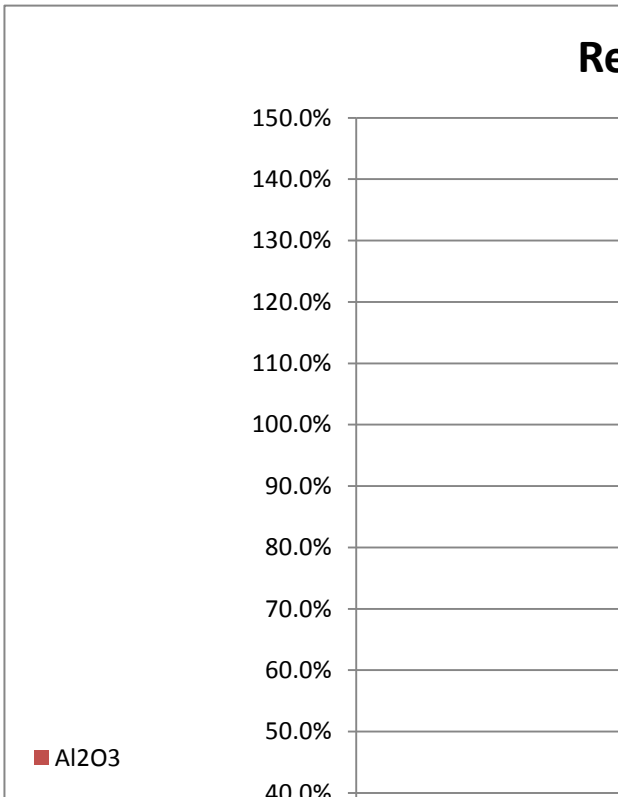
BO95

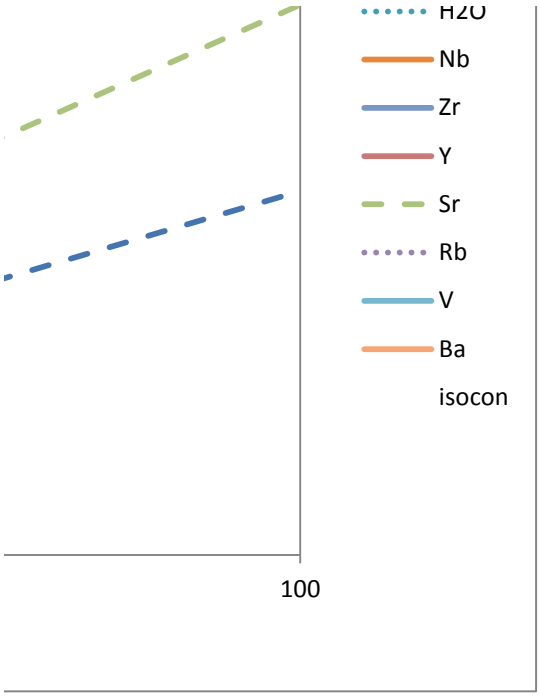
-0.4%
-2.6%
-1.3%
-6.1%
-23.1%
124.1%
-72.1%
-22.7%
27.8%
5.5%
89.2%

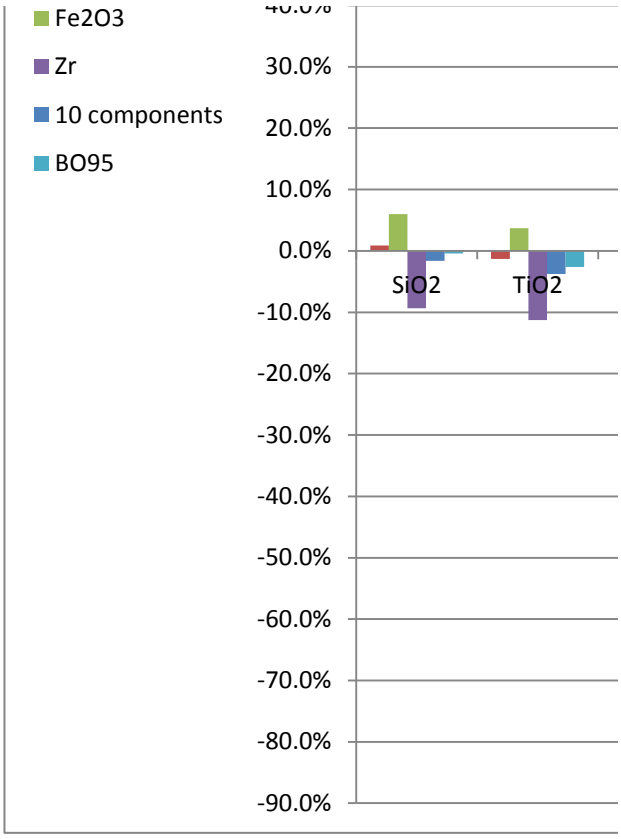


3.1%
9.8%
-1.1%
-57.8%
31.7%
9.5%
-4.5%

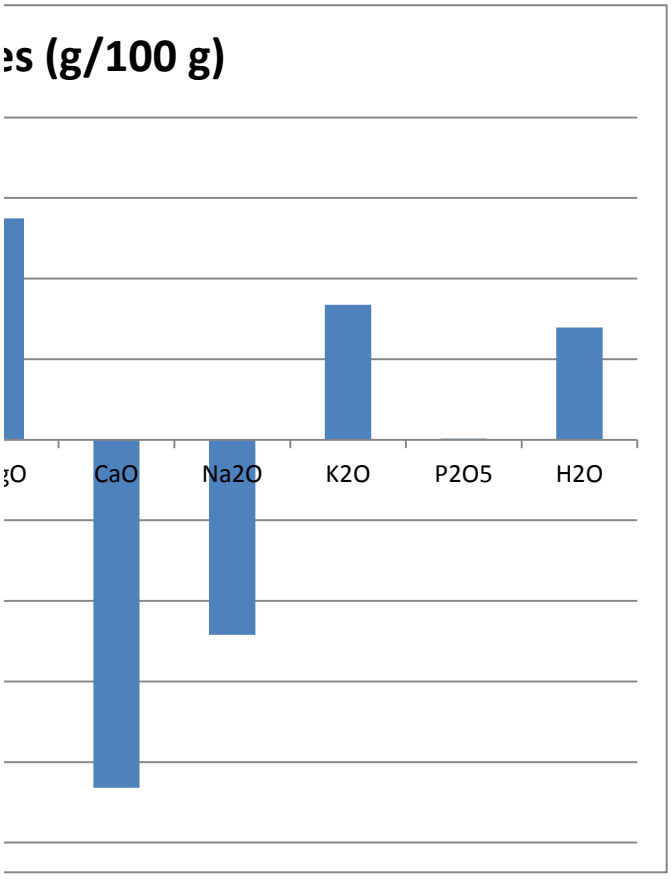


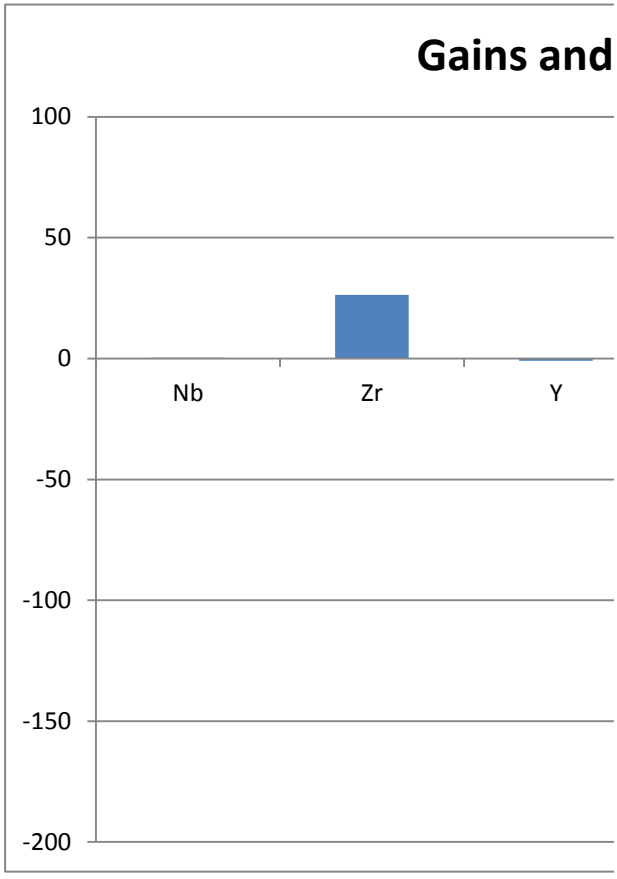


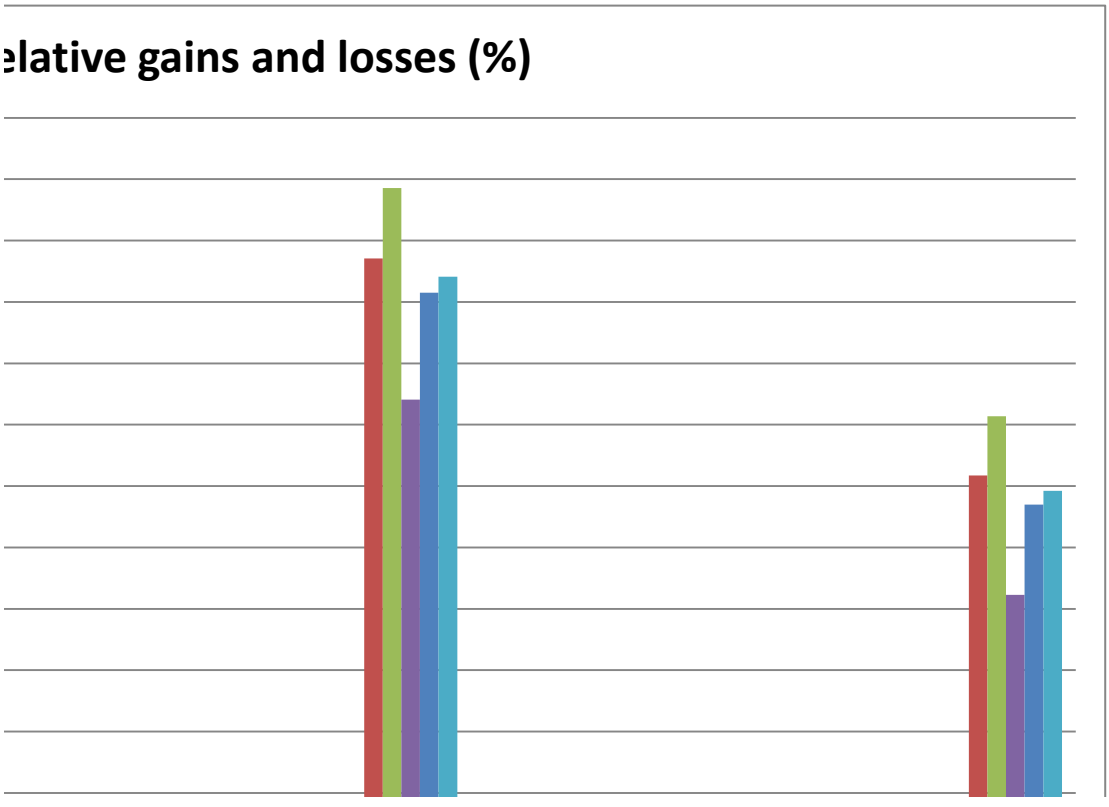

H2O
Nb
Zr
Y
Sr
Rb
V
Ba
isocon
100

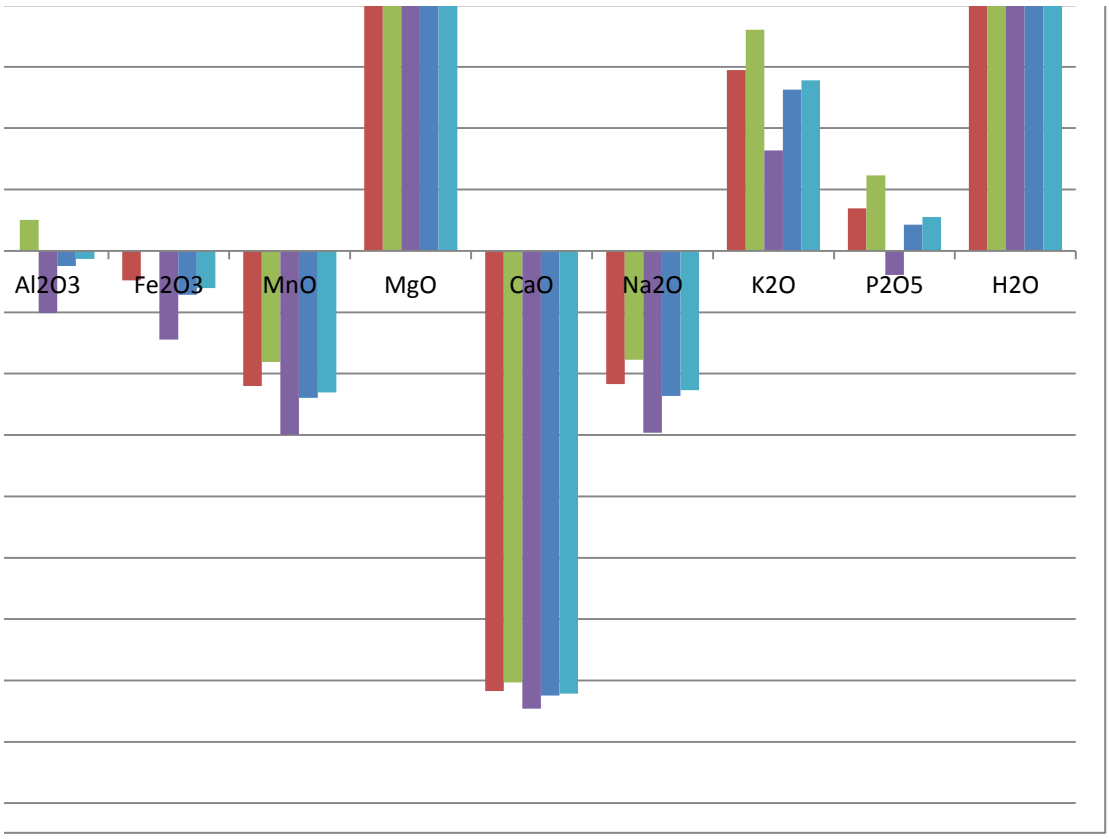

Fe2O3
Zr
10 components
BO95
30.0%
20.0%
10.0%
0.0%
-10.0%
-20.0%
-30.0%
-40.0%
-50.0%
-60.0%
-70.0%
-80.0%
-90.0%
SiO2
TiO2

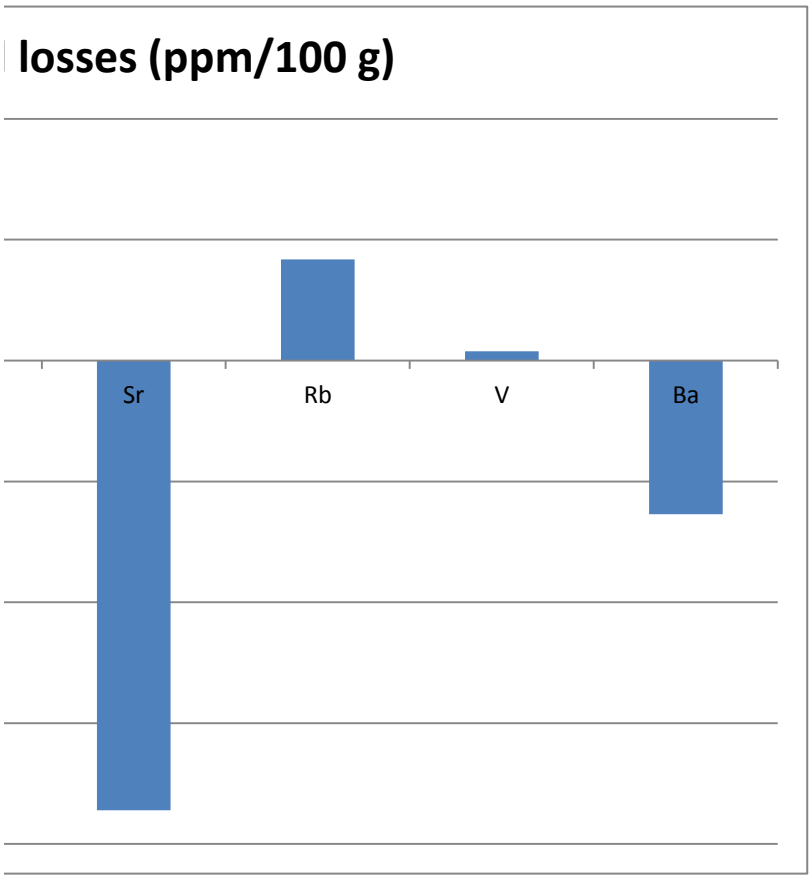
	scaled c_i^0		scaled c_i^A
0.00	100.00	0.00	100.65








Al2O3
Fe2O3
MnO
MgO
CaO
Na2O
K2O
P2O5
H2O

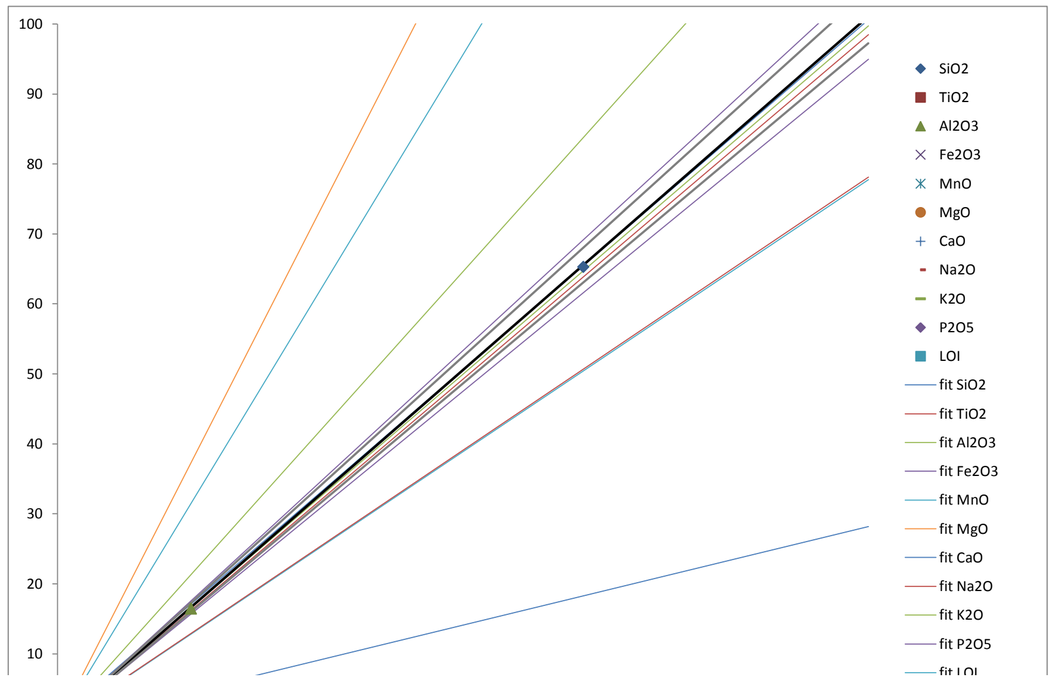

losses (ppm/100 g)
Sr
Rb
V
Ba

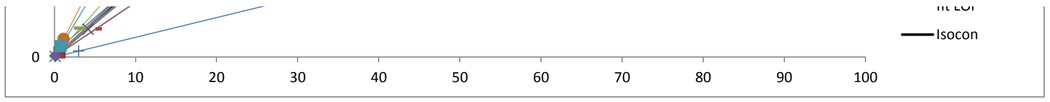
	c_i^0	σ_i^0	c_i^A	σ_i^A	b_i	K	L	M	rovnice	b	1.01	K	L	M	rovnice
SiO2	64.85	1.27	65.27	1.16	1.006476	0.000002	0.000000	8.877179	0.000000			109.393704	-0.258839	8.961614	12.1780367
TiO2	0.65	0.05	0.64	0.07	0.984615	0.000000	0.000000	0.000054	0.000000			0.000165	-0.000001	0.000056	2.94418014
Al2O3	16.49	0.62	16.45	0.47	0.997574	0.000000	0.000000	0.364137	0.000001			4.420922	-0.037081	0.376584	11.641076
Fe2O3	4.17	0.28	3.96	0.36	0.949640	0.000000	0.000000	0.040121	0.000000			0.446198	-0.010316	0.043977	9.91168624
MnO	0.09	0.01	0.07	0.01	0.777778	0.000000	0.000000	0.000000	0.000000			0.000001	0.000000	0.000000	
MgO	1.13	0.09	2.56	0.13	2.265487	0.000000	0.000000	0.003419	0.000000			-0.080669	-0.032916	0.000634	
CaO	2.98	0.27	0.84	0.35	0.281879	0.000000	0.000000	0.016459	-0.000001			2.550300	-0.695425	0.038804	
Na2O	5.12	0.43	4	0.6	0.781250	0.000000	0.000000	0.223591	0.000000			6.606915	-0.516435	0.301317	
K2O	3.19	0.2	4.12	0.49	1.291536	0.000000	0.000000	0.094140	0.000000			-1.605231	-0.064845	0.078944	
P2O5	0.15	0.03	0.16	0.02	1.066667	0.000000	0.000000	0.000002	0.000001			-0.000003	0.000000	0.000002	-1.97774986
LOI	0.8	0.13	1.53	0.16	1.912500	0.000000	0.000000	0.007641	0.000000			-0.049476	-0.017778	0.001838	
Total	99.62		99.57												
ppm															
Nb	24	5	25	6	1.041667	0.002140	0.000000	3984.985006	0.000001			-2186.911052	-27.698285	3787.661638	-0.58469038
Zr	309	18	343	25	1.110032	0.480134	0.000000	1049034.146212	0.000000			-18112926.657702	-615585.515822	914031.598755	-20.4900052
Y	43	8	43	4	1.000000	-0.005844	0.000000	6399.999595	-0.000001			3257.034389	-28.013172	6624.754066	0.48741752
Sr	319	47	136	63	0.426332	-10.396674	0.000000	19101323.528700	-0.000001			740629969.312529	-155250761.916788	38763900.206613	
Rb	139	29	185	53	1.330935	4.911870	0.000000	18479147.672205	0.000000			-45376321.845382	-3366198.232596	13456421.456126	-3.62224981
V	47	4	52	4	1.106383	0.000490	0.000000	1266.315913	0.000000			-13657.144660	-652.513552	1046.402682	-13.675097
Ba	1139	114	1100	151	0.965759	-292.298532	-0.000006	###############	0.000000			4218405877.741190	-69211049.633529	1301750759.711000	3.18739574
			smodch		0.5206643										0.000000
			smodch	Si, Al, Ti, P,	0.038105										

Fitting of the isocon:

(Baumgartner and Olsen, 1995)

$$\frac{\partial \chi^2}{\partial b} = \frac{\partial}{\partial b}\left[\sum_{i=1}^{n} \frac{(c_i^A - b c_i^0)^2}{(\sigma_i^A)^2 + b^2 (\sigma_i^0)^2}\right] = 0.$$




0
0
10
20
30
40
50
60
70
80
90
100
Isocon

0.01	0.65	100	100.65
0.01	0.01	100	98.46
0.01	0.16	100	99.76
0.01	0.04	100	94.96
0.01	0.00	100	77.78
0.01	0.03	100	226.55
0.01	0.01	100	28.19
0.01	0.04	100	78.13
0.01	0.04	100	129.15
0.01	0.00	100	106.67
0.01	0.02	100	191.25
0.01	1.00	100	
0.01	0.00	100	
0.01	0.25	100	104.17
0.01	3.43	100	111.00
0.01	0.43	100	100.00
0.01	1.36	100	42.63
0.01	1.85	100	133.09
0.01	0.52	100	110.64
0.01	11.00	100	96.58
0.01	0.00		
0.01	########	100	101.08
0.01	########	100	104.8927
0.01	0.00	100	97.27157

Lithos 236–237 (201

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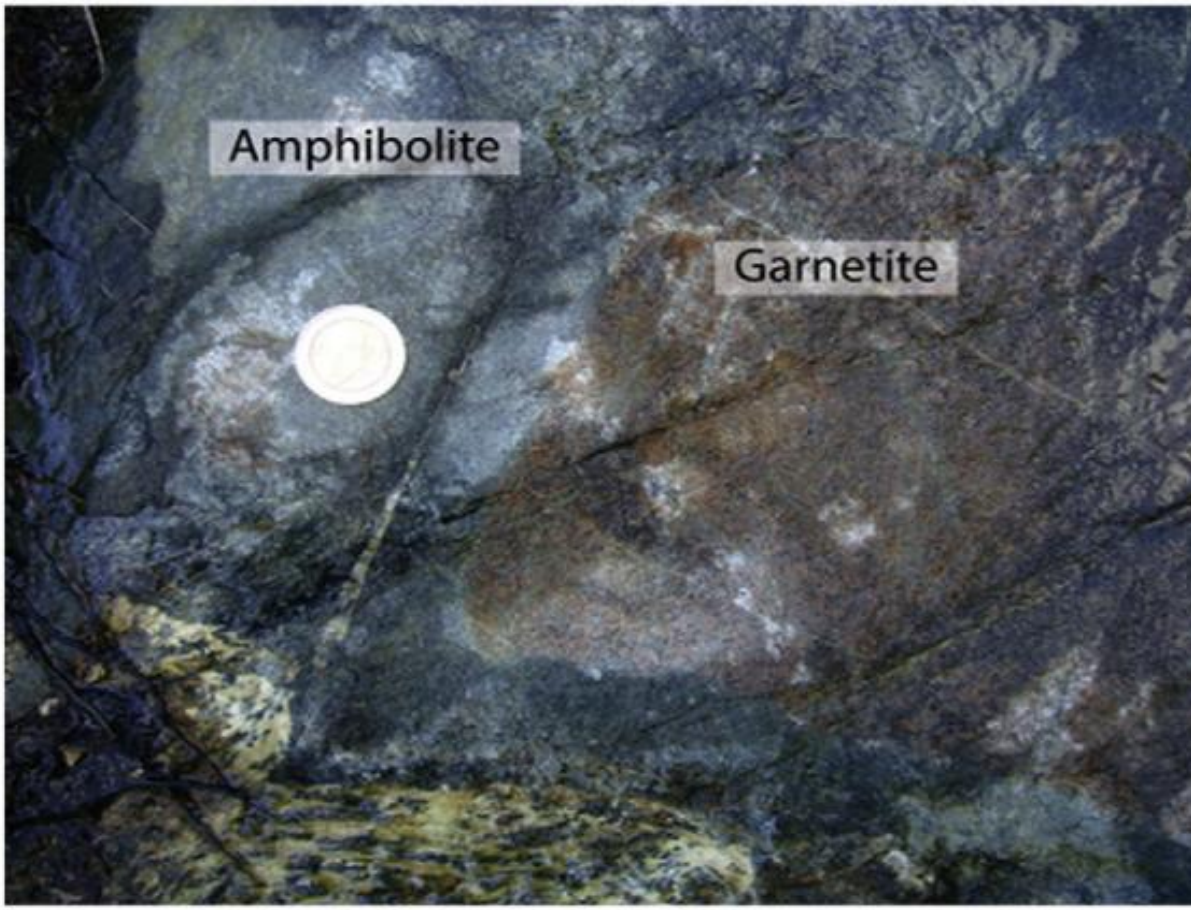
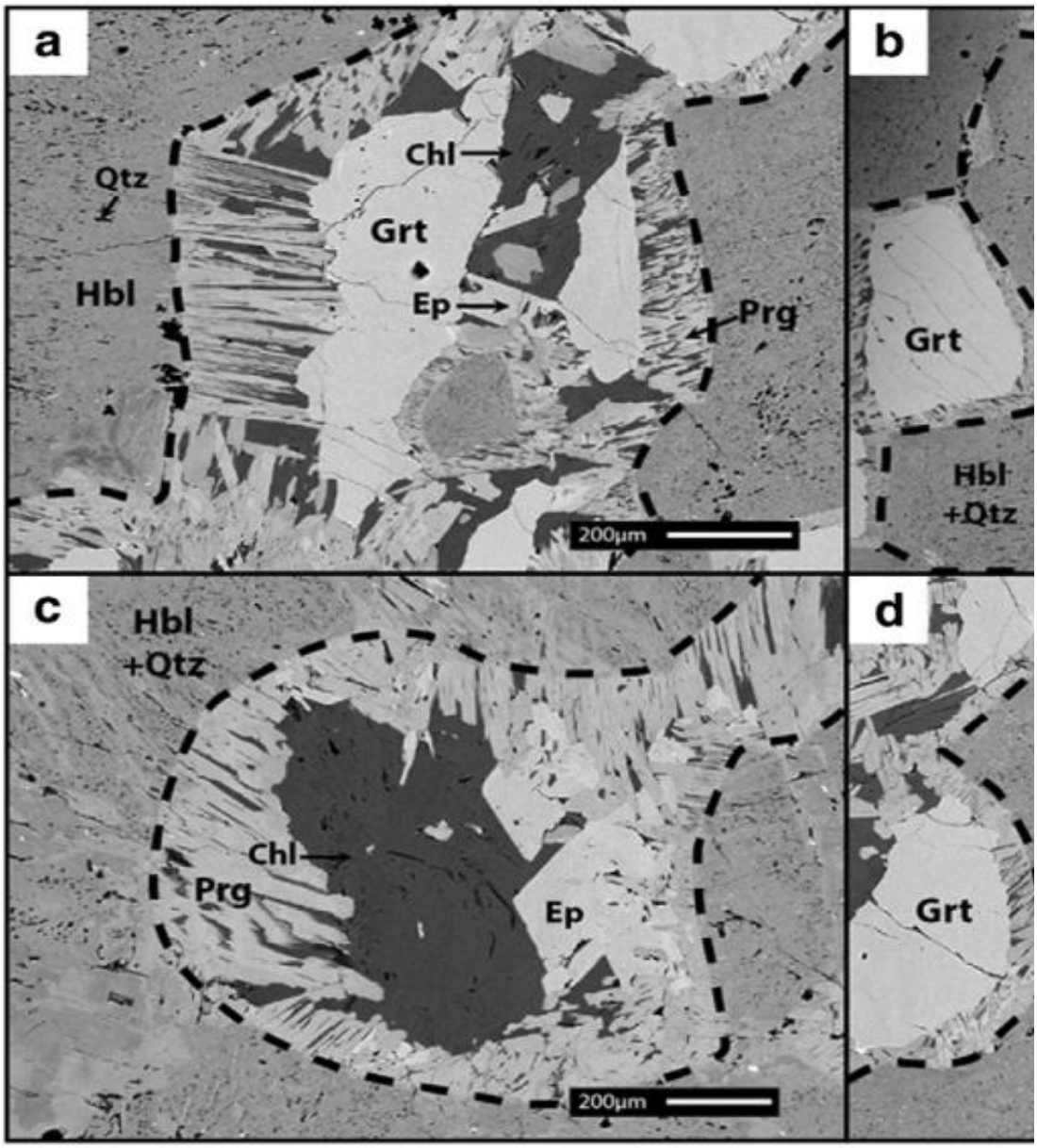
Coupled mass transfer through a fluid phase a during the hydration of granulite: An exampl Arcs, Norway

Stephen Centrella [a,*], Håkon Austrheim [b], Andrew Putnis [a]

[a] Institut für Mineralogie, University of Münster, D-48149 Münster, Germany
[b] PGP, Department of Geosciences, University of Oslo, N-0316, Norway
[c] The Institute for Geoscience Research (TIGeR), Curtin University, Perth 6102, Australia




a
Qtz
Chl
Grt
Hbl
Ep
Prg
200μm
b
Grt
Hbl
+Qtz
c
Hbl
+Qtz
Chl
Prg
Ep
200μm
d
Grt

5) 245–255

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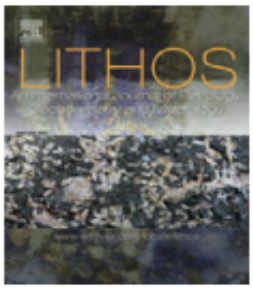
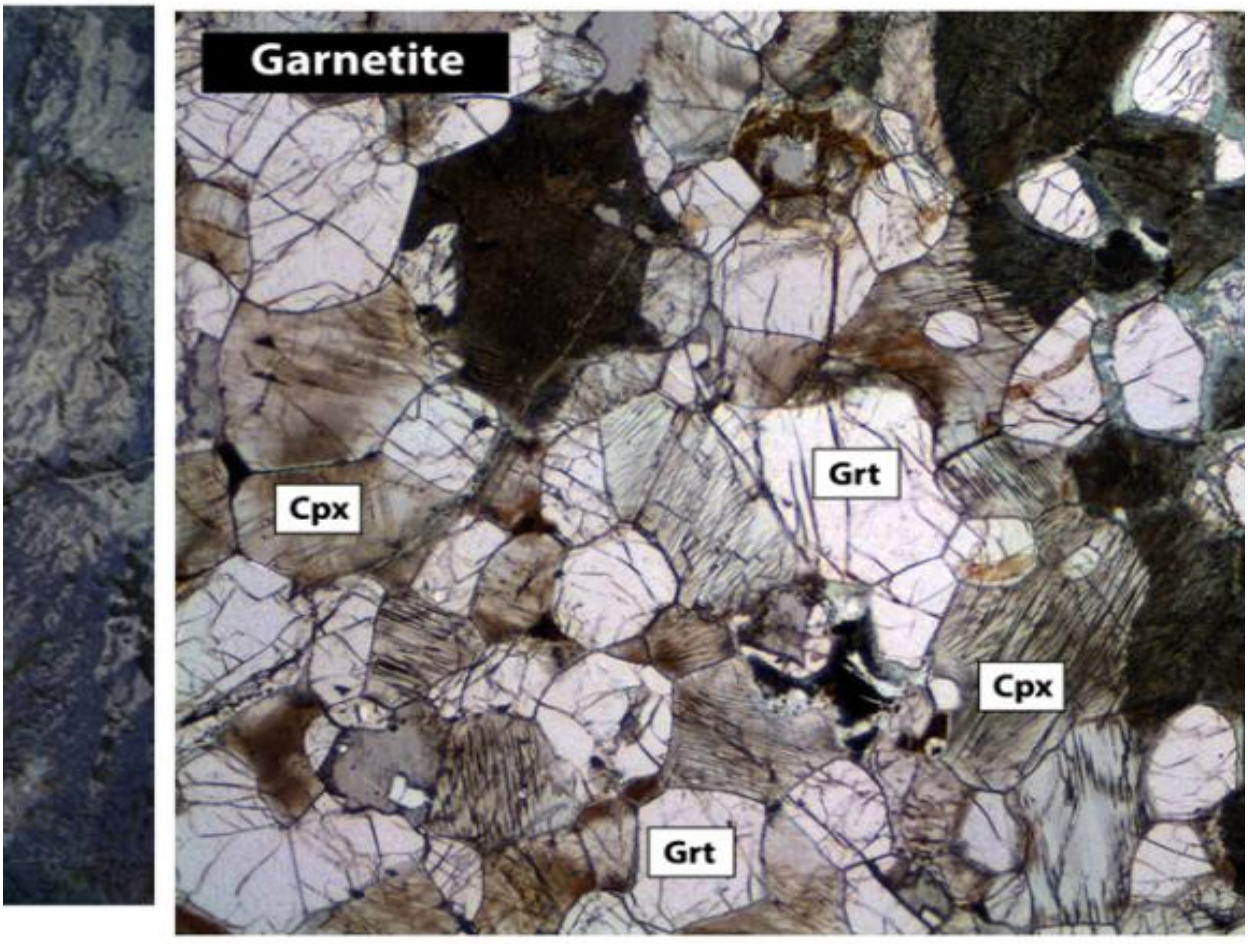
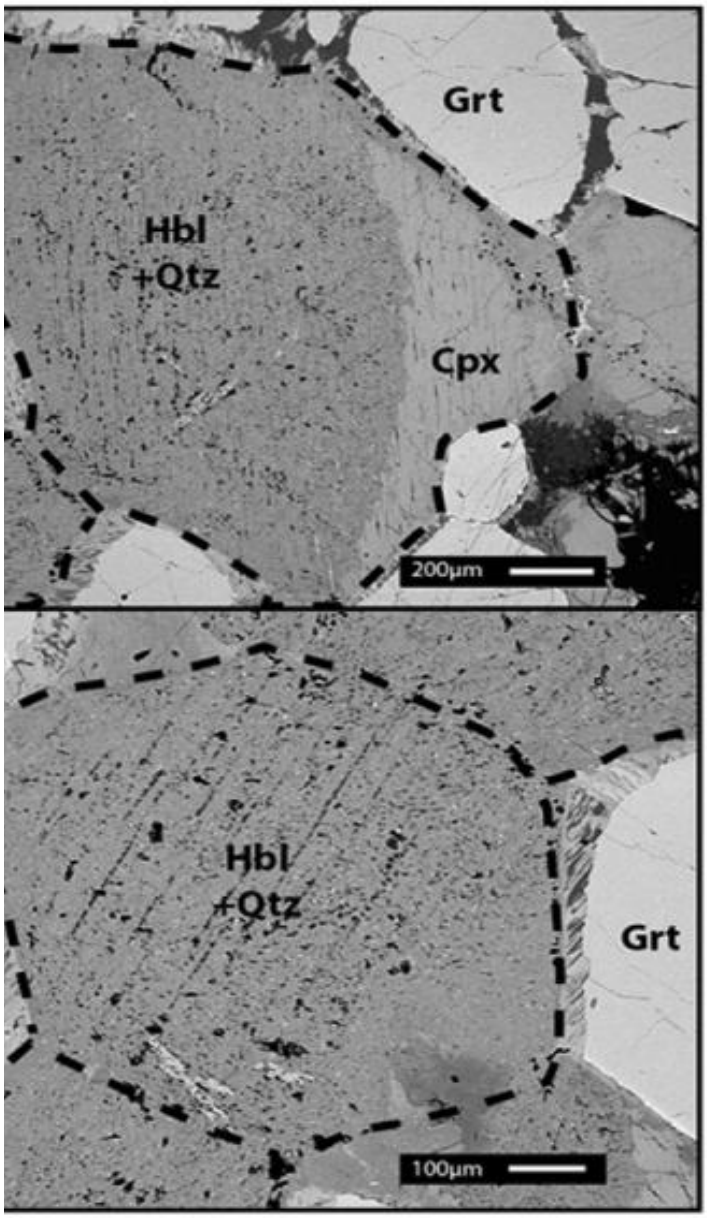
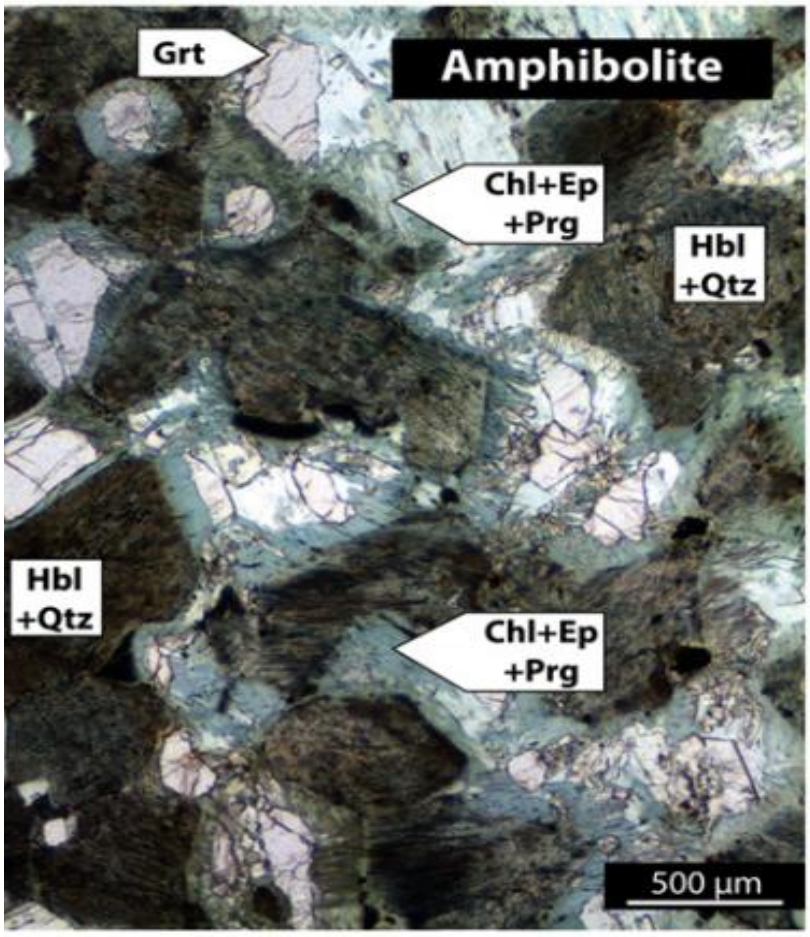


and volume preservation
e from the Bergen

,c




Grt
Hbl
+Qtz
Cpx
200μm
Hbl
+Qtz
Grt
100μm


Grt
Amphibolite
Chl+Ep
+Prg
Hbl
+Qtz
Hbl
+Qtz
Chl+Ep
+Prg
500 µm

Coupled mass transfer through a fluid phase and volume preservation

Centrella et al. 2015, Lithos

	Cpx	Hbl+Qz	Grt	Prg+Chl+Ep	garnetite	amphibolite
ρ	3.2	3.2	3.8	3	3.5	3.1
SiO2	48.92	53.64	40.61	37.64	44.57	45.1
TiO2	0.81	0.64	0.07	0.5	0.59	0.58
Al2O3	7.23	7.98	22.59	19.44	13.94	13.57
FeO	7.13	9.48	17.69	11.5	12.45	12.45
MnO	0.01	0.18	0.4	0.04	0.18	0.18
MgO	13.01	13.37	13.96	13.24	13.13	13.6
CaO	19.44	12.72	5.44	9.59	12.72	11.6
Na2O	1.49	0.38	0	1	0.97	1.23
K2O	0	0.06	0	0.3	0	0.19
H2O	0	1.55	0	7.25	0.16	2.43

during the hydration of granulite: An example from Bergen Arcs, Norv

vay

	scaled	scaled