

**FC-AFC-FCA and mixing modeler: a  
Microsoft® Excel® spreadsheet  
program for modeling geochemical  
differentiation of magma by crystal  
fractionation, crustal assimilation and  
mixing**

by

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# 1. The goal of the study

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*Several petrological processes modifying the geochemical composition of the magma are graphically programmed using Microsoft® Excel© spreadsheet on the basis of differentiation equations.*

The ***FC-AFC-FCA and mixing modeler*** is a spreadsheet program that models the consequent theoretical vectors of

- **Fractional crystallisation (FC)**
- **Combined fractional crystallisation and assimilation (AFC)**
- **Decoupled fractional crystallisation and assimilation (FCA)**
- **Mixing (Mix)**

# 2. Introduction

## Magmatic rocks are differentiated by

- \* different degrees of enrichment processes in the source
- \* different degrees of melting of the source rocks
- \* crystal fractionation in magma chambers
- \* contamination of the magma via assimilation of the wall-rocks
- \* mixing of magmas of different compositions

→ may occur as combined (AFC) *or*

→ may occur as decoupled (FCA)

# 3. Modeling the Magmatic Processes

## 1. CRYSTALLISATION of MAGMAS

### a. Equilibrium Crystallisation

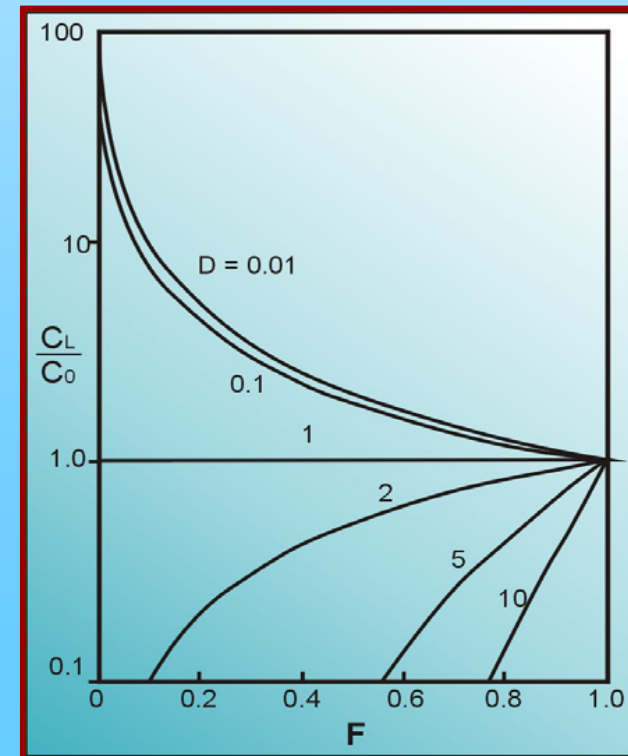
solid phases remain in the melt and stays in chemical equilibrium with the liquid phase

$$C_l^{EC} = C_0 / [F + D(1 - F)]$$

### b. Fractional Crystallisation

solid phases fractionate from melt  
the new composition of the melt remaining:

$$C_l^{FC} = C_0 F^{(D-1)}$$



# 3. Modeling the Magmatic Processes

## 2. COMBINED FRACTIONAL CRYSTALLIZATION AND ASSIMILATION (DePaolo 1981)

During the AFC process there is a strict relationship between the amount of material assimilated and the amount of material crystallized during cooling of the magma.

<b>for elements</b>	$C_l^{AFC} = C_0 \left[ F^{-z} + \left( \frac{r}{r-1} \right) \frac{C_a}{z C_0} (1 - F^{-z}) \right]$	$r = \frac{m_a}{m_c} \quad z = \frac{r + D - 1}{r - 1}$
<b>for isotopes</b>	$I C_l^{AFC} = \frac{\left( \frac{r}{r-1} \right) \left( \frac{C_a}{z} \right) (1 - F^{-z}) I C_a + C_0 F^{-z} I C_0}{\left( \frac{r}{r-1} \right) \left( \frac{C_a}{z} \right) (1 - F^{-z}) + C_0 F^{-z}}$	

- $C_l^{AFC}$      $I C_l^{AFC}$     concentration of an element and ratio of an isotope in the resulting magma
- $C_0$          $I C_0$         concentration of an element and ratio of an isotope in the original magma
- $C_a$          $I C_a$         concentration of an element and ratio of an isotope in the assimilant
- $m_a$         amount of assimilated material
- $m_c$         amount of crystallized material
- $D$           bulk partition coefficient
- $F$           fraction of melt remaining

# 3. Modeling the Magmatic Processes

## 3. DECOUPLED FRACTIONAL CRYSTALLIZATION AND ASSIMILATION (Cribb & Barton 1996)

Assimilation and fractional crystallization in a magma system are not strictly related; the mass assimilated may be decoupled from mass crystallized, and therefore varies independently.

$$C_l^{FCA} = \frac{C_0 R M_c + C_f (1 - M_c)}{F}$$

$C_l^{FCA}$  concentration of an element in the resulting magma

$C_0$  concentration of an element in the original magma

$C_f$  concentration of an element resulting from fractional crystallization

$M_c$  amount of crystallized material

$F$  fraction of melt remaining

# 3. Modeling the Magmatic Processes

## 4. Mixing Process

(e.g., Powell 1984)

Trace element and isotope composition of a magma resulted from mixing of magmas *a* and *b*:

$$C_m = X(C_a - C_b) + C_b$$

$$Ic_m = Ic_a \left( \frac{C_a X}{C_m} \right) + Ic_b \left( \frac{C_b (1 - X)}{C_m} \right)$$

# 4. Other parameters in the program

$$Eu / Eu^* = Eu_N / \sqrt{(Sm_N) \times (Gd_N)}$$

$$Mg\# = MgO / (MgO + FeO_t)$$

$$\varepsilon Sr = \frac{(^{87}Sr / ^{86}Sr)_{sample} - (^{87}Sr / ^{86}Sr)_{chondrite}}{(^{87}Sr / ^{86}Sr)_{chondrite}} \times 10^4$$

$$\varepsilon Nd = \frac{(^{143}Nd / ^{144}Nd)_{sample} - (^{143}Nd / ^{144}Nd)_{chondrite}}{(^{143}Nd / ^{144}Nd)_{chondrite}} \times 10^4$$

$$\tau_{DM}^{Nd} = \frac{1}{\lambda} \times \ln \left( \frac{(^{143}Nd / ^{144}Nd)_{sample} - (^{143}Nd / ^{144}Nd)_{DM}}{(^{147}Sm / ^{144}Nd)_{sample} - (^{147}Sm / ^{144}Nd)_{DM}} + 1 \right)$$



# 5. Structure of the Program

**A.Data input section**

**B.Data output section**

The data input section contains two sheets:

- (1) **parameters** *and*
- (2) **samples**

The output section is consist of

- (1) **modeling**
- (2) **classification**
- (3) **Harker1** (for major elements)
- (4) **Harker2** (for trace elements)
- (5) **isotopes**, *and*
- (6) **numerical output**



# 5. Structure of the Program

## 1. PARAMETERS SHEET (elements and minerals)

Enter the elements		
MAJOR OXIDES	802	
	Al2O3	
	Fe2O3 (f)	
	FeO (f)	
	MgO	
	CaO	
	Na2O	
	K2O	
	P2O5	
	MnO	
LILE	Cs	
	Rb	
	K	
	Ba	
	Sr	
	Pb	
	HFSE	Th
		U
		Zr
		Hf
Ti		
Ta		
Y		
Nb		
Sc		
Cr		
OTHERS	Cu	
	V	
	W	
	Co	
	Zn	
	Cd	
	La	
	Ce	
	Pr	
	Nd	
REE'S	Sm	
	Eu	
	Gd	
	Tb	
	Dy	
	Hu	
	Er	
	Tm	
	Yb	
	Lu	
ISOTOPES	87Sr/86Sr	
	143Nd/144Nd	
	147Sm/144Nd	
	208Pb/204Pb	
	207Pb/204Pb	
	206Pb/204Pb	
	δ18/16O (‰)	
	AGE	
	εSr	
	εNd	
σNd (DM) (Ma)		

Enter fractionating mineral name
Olivine
O-pyroxene
C-pyroxene
Garnet
Amphibole
Biotite
K-Feldspar
Plagioclase
Apatite
Magnetite
Sphene
Ilmenite
Zircon
Spinel

LILE	MnO
	Cs
	Rb
	K
	Ba
	Sr
HFSE	Pb
	Th
	U
	Zr
	Hf
	Ti
	Ta
	Y
	Nb
	Sc
Cr	

The user can change only uncolored cells

The changings are simultaneously reflected to the other sheets

ISOTOPES	Lu
	87Sr/86Sr
	143Nd/144Nd
	147Sm/144Nd
	208Pb/204Pb
	207Pb/204Pb
	206Pb/204Pb
	δ18/16O (‰)
	AGE
	εSr
εNd	
σNd (DM) (Ma)	

Enter fractionating mineral names
Olivine
O-pyroxene
C-pyroxene
Garnet
Amphibole
Biotite
K-Feldspar
Plagioclase
Apatite
Magnetite
Sphene
Ilmenite
Zircon
Spinel

# 5. Structure of the Program

## 1. PARAMETERS SHEET (partition coefficients)

INTERMEDIATE										BASIC																
	Amphibole	Biotite	K-Feldspar	Plagioclase	Apatite	Magnetite	Sphene	Ilmenite	Zircon	Albite	B	Olivine	Orthopyroxene	Clinoorthopyroxene	Garnet	Amphibole	Biotite	K-Feldspar	Plagioclase	Apatite	Magnetite	Sphene	Ilmenite	Zircon	Albite	
				0.11	0.11							0.0150	0.4300	0.5800	2.0000	0.9670	0.8540		1.6300							
																0.9400	1.1400									
																2.4900	3.3200									
																1.3770										
																	0.7310	0.1820								
																0.5800	3.6700									
																1.4900	1.7680									
																0.8000										
	0.0100	0.1900	0.0440	0.0300	0.7000	0.3900						0.0004	0.0100	0.1300	0.0040	0.0460	0.6260	0.0440	0.1300							
50	0.1300	3.2000	0.1800	0.1300	0.4000	0.0100						0.0020	0.0030	0.0047	0.0420	0.1000	5.1800									
98				0.1810		0.0100						0.0130	0.0091	0.0072	0.0150		2.6500	1.4900	0.1560		0.0445					
60	0.5000	6.0000	0.5000	0.5000	0.4500	0.0100						0.0020	0.0020	0.0006	0.0230	0.4500	3.4800						0.0003			
80	0.6000	0.1500	0.9000	2.6000	8.0000	0.1000	0.0600					0.0022	0.0070	0.0963	0.0120	0.4500	0.1830									
65	0.5300	0.890	0.2080	0.6100	2.9000							0.0001	0.0013	0.0056	0.0005	0.1000	0.1000	0.2080	0.3600							
	0.1500	0.1500	0.0080	0.0150	1.6000	0.1000						0.0400	0.1300	0.0300	0.0500	0.0145									0.0006	
	0.0080	0.0800	0.0170	0.0100	2.6000	0.0120						0.0450	0.0350	0.0400	0.0150	0.0800	0.0011								0.0082	
00	1.4000	0.1500	0.1500	0.0300	2.0000							0.0045	0.0300	0.1210	0.3000	0.4000	0.0232				0.1000				0.2900	
				0.0300	2.0000							0.0037	0.0850	0.2630	0.3000	0.5000	0.1900				0.4000				0.3800	
				0.0300	0.0700							0.0110	0.0240	0.1000	0.1000	0.6900	0.9000				0.1000				0.0510	
00	3.0000			0.0500	9.0000							0.0000	0.1500	0.0130	0.0600	0.2500	0.1069				7.5000				0.0400	
00	0.6000	0.7000	0.0090	0.0250	0.0500	6.6000						0.0038	0.2000	0.4380	2.0000	1.1000	0.0070	0.0170	0.0300		5.0000				1.7000	
##	3.0000	0.4500	0.0170	0.0600	0.6400	3.0000						0.0017	0.1500	0.0027	0.1000	0.3000	0.0853				0.2000				0.0048	
00	1.0000	1.4000		0.0250	6.1000	4.6000						0.6800	1.2000	3.2000	2.6000	4.2000	8.3000				0.4000				0.5800	
##	#####			0.0100	0.3000	2.0000						0.7000	#####	#####	0.6000	#####	5.4000				#####				6.0000	
00	#####	3.3000		0.0100	#####	3.8000						29.0000	5.0000	#####	5.1000	6.8000	1.3000				0.0800				3.8000	
00	#####			0.0100	0.2000	8.0000						5.9000	3.0000	2.0000	0.9550	2.0000	#####				0.0400				1.9000	
00	#####			0.0100	#####	#####						0.8000	0.6000	1.3500				0.0220			0.4000				0.0700	
				0.0100	#####	#####															0.260000				#####	
																									0.4000	
																									3.0000	
																									0.7900	
00	0.5000	0.1500		0.2300	#####	2.0000																			0.0003	
00	0.7000	0.1600	0.0170	0.1800	#####	0.2000																			0.0006	
				0.1300																					0.0002	
00	1.7000	0.2000		0.1700																					0.0005	
00	2.3000	0.1500	0.0100	0.1500	#####	0.3000	#####																		0.0006	
00	2.0000	0.1700	1.0000	0.9500	#####	0.2500																			0.0011	
00	2.7000	0.1500		0.1300																					0.0034	

The partition coefficients for any element and any mineral are entered to these tables.

The partition coefficient tables have been prepared for “acid”, intermediate” and “basic” melt compositions.

# 5. Structure of the Program

## 1. PARAMETERS SHEET (assimilants)

ASSIMILANTS (Ca)							
	Upper Continental Crust (Taylor & McLennan 1995)	Bulk Continental Crust (Taylor & McLennan 1995)	Lower Continental Crust (Taylor & McLennan 1995)	Rahmanlar	Menderes Massif Gneisses	UC (Cribb Barton)	Upper Continental Crust (Hart et al. 1999)
SiO <sub>2</sub>			58.94	71.4625	70.03	66.22	45.8
Al <sub>2</sub> O <sub>3</sub>			14.95	13.4375	15.23	14.99	15.53
Fe <sub>2</sub> O <sub>3</sub> (t)			8.05	2.41	2.47	4.62	
FeO (t)							9.02
MgO			5.15	0.24	0.9	2.33	6.66
CaO			7.4	0.955	1.95	4.05	12.88
Na <sub>2</sub> O			2.48	2.9425	2.59	3.34	2.07
K <sub>2</sub> O			1.97	4.63	3.32	3.44	0.56
TiO <sub>2</sub>			0.17	0.3625	0.4	0.2	1.12
P <sub>2</sub> O <sub>5</sub>			0.76	0.2075	0.19	0.71	0.11
MnO			0.15	0.0375	0.02	0.1	0.17
LOI				3	2.1		
Mg <sup>#</sup>							
Cs	3.700	1.000	0.100	6.275	3.800		0.173
Rb	112.000	32.000	5.300	158.075	115.500	110.000	9.040
K			16353.561	38435.019	27560.316	28556.472	4648.728
Ba	550.000	250.000	150.000	1007.050	649.500	700.000	16.850
Sr	350.000	260.000	230.000	150.000	158.800	350.000	117.500
Pb	20.000	8.000	4.000	20.000	27.700	20.000	0.690
Th	10.700	3.500	1.060	14.550	13.900	10.500	0.072
U	2.800	0.910	0.280	5.450	2.100	2.800	0.321
Zr	190.000	100.000	70.000	277.700	184.700	240.000	67.000
Hf	5.800	3.000	2.100	8.875	4.900	5.800	
Tl			1013.030	2160.138	2383.600	1191.800	6674.080
Ta	2.200	1.000	0.600	1.375	0.600	2.200	
Y	22.000	20.000	19.000	59.500	36.900	22.000	32.000

Several assimilant factors can be entered by the user to this table. Upper, bulk and lower continental crust values of Taylor and McLennan (1995) have already been entered to the program. These parameters also changed by the users.

These factors, later can be selected in order to model the AFC, FCA and mixing processes.

# 5. Structure of the Program

## 1. PARAMETERS SHEET (normalizing factors)

NORMALIZING VALUES				
	E-MORB (Sun & McDonough 1989)	N-MORB (Sun & McDonough 1989)	PM (Sun & McDonough 1989)	C1-chondrite (Sun & McDonough 1989)
SiO <sub>2</sub>				
Al <sub>2</sub> O <sub>3</sub>				
Fe <sub>2</sub> O <sub>3</sub> (t)				
FeO (t)				
MgO				
CaO				
Na <sub>2</sub> O				
K <sub>2</sub> O				
TiO <sub>2</sub>				
P <sub>2</sub> O <sub>5</sub>				
MnO				
LOI				
Mg#				
Cs	0.063	0.007	0.032	0.188
Rb	5.010	0.560	0.635	2.320
K	2100.000	600.000	250.000	545.000
Ba	57.000	6.300	6.989	2.410
Sr	156.000	90.000	21.100	7.260
Pb				
Th	0.600	0.120	0.085	0.029
U	0.180	0.047	0.021	0.008
Zr	73.000	74.000	11.200	3.870
Hf				
Ti	6000.000	7600.000	1300.000	445.000
Ta				
Y	22.000	28.000	4.550	1.570


Several normalizing factors can be entered by the user to this table. E-MORB, N-MORB, PM and C1-chondritic values of Sun and McDonough (1989) have already been entered to the program. These parameters also changed by the users.

These factors, later can be selected in order to plot normalized REE and multy-element diagrams.

# 5. Structure of the Program,

## 1. PARAMETERS SHEET (isotope values)

Isotope ratios	Value	Type
( $^{87}\text{Sr}/^{86}\text{Sr}$ ) standard (for $\epsilon\text{Sr}$ )	0.705000	chondrite
( $^{143}\text{Nd}/^{144}\text{Nd}$ ) standard (for $\epsilon\text{Nd}$ )	0.512638	chondrite
( $^{143}\text{Nd}/^{144}\text{Nd}$ ) standard (for PM model age)	0.513150	PM
( $^{143}\text{Sm}/^{144}\text{Sm}$ ) standard (for PM model age)	0.213700	PM



These values, which will be used to calculate several parameters on the “sample” sheet, can also be changed by the users



# 5. Structure of the Program

## 2. "SAMPLES" SHEET (1 of 10 sample tables)

DATASETS:		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	MIN	MAX	MEAN
SAMPLE#:		SH-32	SI-178	Santorini																				
MAJOR OXIDES	SiO2	50.78	54.23																			50.78	54.23	52.50
	Al2O3	18.49	18.49																			18.49	18.49	18.49
	Fe2O3 (t)	8.18	7.84																			7.84	8.18	8.01
	FeO (t)	7.37	7.06																			7.06	7.37	7.22
	MgO	6.74	4.35																			4.35	6.74	5.55
	CaO	11.27	9.60																			9.60	11.27	10.44
	Na2O	2.72	3.05																			2.72	3.05	2.88
	K2O	0.48	0.48																			0.48	0.48	0.48
	TiO2	0.88	0.96																			0.88	0.96	0.92
	P2O5	0.15	0.12																			0.15	0.15	0.14
LOI																								
Mg#	62.2	52.4																			62.2	52.4	57.28	
LILE	Cs																							
	Rb	10.000																				10.000		10.000
	K	3984.0	3984.0																			3984.0	3984.0	3984.0
	Ba	69.000																				69.000		69.000
	Sr	236.000																				236.000		236.000
HFSE	Pb																							
	Th	1.200																				1.200		1.200
	U																							
	Zr	69.000																				69.000		69.000
	Hf																							
OTHERS	Ti	5203.0	5203.0																			5203.0	5203.0	5203.0
	Ta																							
	Y																							
	Nb	3.000																				3.000		3.000
	Sc																							
REE	Cr	142.000																				142.000		142.000
	Ni	54.000																				54.000		54.000
	Co																							
	V																							
	W																							
	Ga																							
	P	654.7	523.8																			523.75	654.66	580.22
	Zn																							
	Cu																							
	ISOTOPES	La																						
Ce																								
Pr																								
Nd		8.400																				8.400		8.400
Sm																								
Eu																								
Gd																								
Tb																								
Dy																								
Ho																								
WATER-FREE RESULTS OF	Er																							
	Tm																							
	Yb																							
	Lu																							
	87Sr/86Sr	0.70489																				0.70489	0.70489	0.70489
	143Nd/144Nd	0.51285																				0.51285	0.51285	0.51285
	147Sm/144Nd																							
	208Pb/204Pb																							
	207Pb/204Pb																							
	206Pb/204Pb																							
δ18/16O (‰)																								
AGE																								
εSr	-13.05																				-13.05	-13.05	-13.05	
εNd	4.31																				4.31	4.31	4.31	
σNd (DM) (Ma)																								

Total 200 samples (in 10 rock group) can be entered

ISOTOPES	Lu	
	Eu/Eu*	
	87Sr/86Sr	0.70
	143Nd/144Nd	0.51
	147Sm/144Nd	
	208Pb/204Pb	
	207Pb/204Pb	
	206Pb/204Pb	
	δ18/16O (‰)	
	AGE	

WATER-FREE RESULTS OF			
SiO2	50.80	54.06	
Al2O3	18.52	18.49	
Fe2O3 (t)	8.18	7.50	
MgO	6.80	4.30	
CaO	11.20	9.60	
Na2O	2.72	3.05	
K2O	0.48	0.48	
TiO2	0.88	0.91	
P2O5	0.15	0.12	
Mg#	100.00	100.00	
LOI			
SAMPLES	SH-32	SI-178	

Minimum, maximum and mean values are calculated

Name of rock group and sample numbers are entered

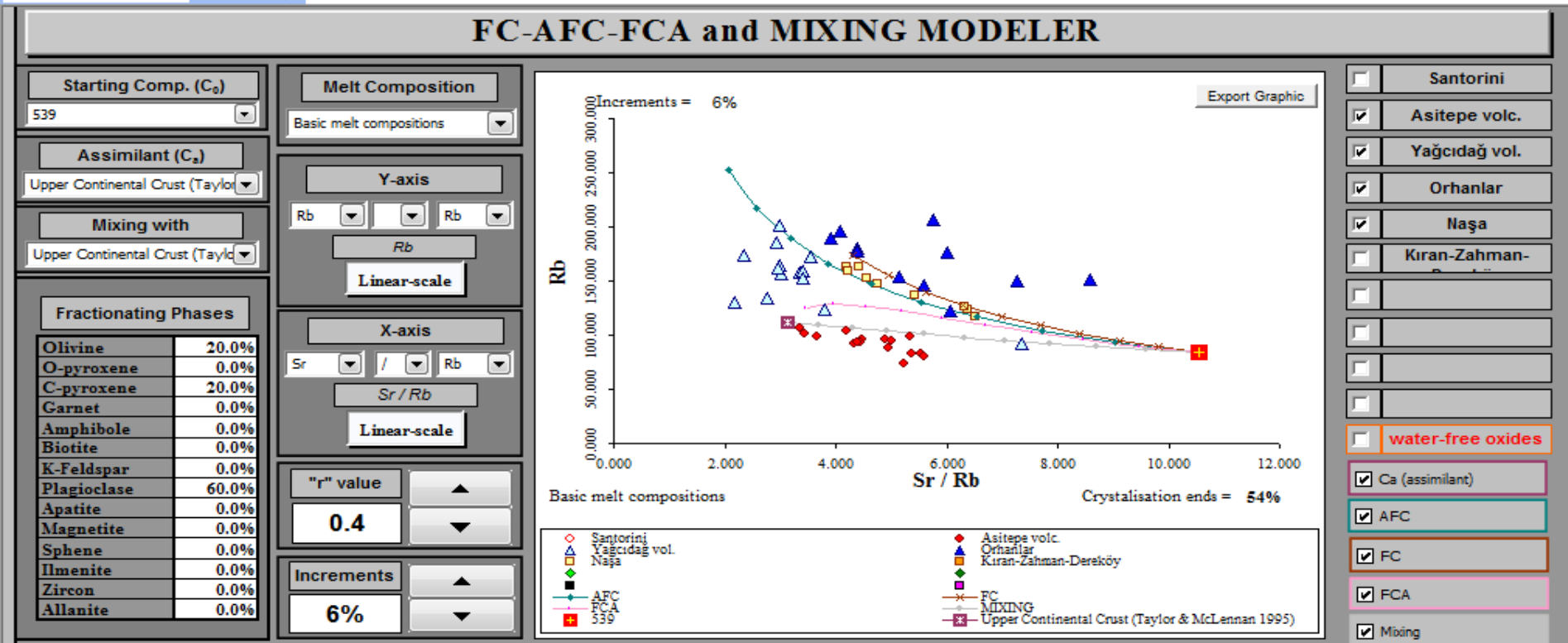
Mg#, Eu/Eu\* values are automatically calculated

Several isotopic parameters are automatically calculated

Water-free results of major oxides (normalized to 100) are automatically calculated

# 5. Structure of the Program

## 3. "MODELING" SHEET (upper section)



A bivariate diagram can be constructed.

**The parameters that can be changed are:**

starting composition, assimilant material, the material mixing with the starting composition, fractionating phase, melt composition, "r" value for AFC and FCA models, increments for model curves and axes of the bivariate diagram



# 5. Structure of the Program

## 3. “MODELING” SHEET (upper section)

**Starting Comp. ( $C_0$ )**  
539

**Assimilant ( $C_a$ )**  
Upper Continental Crust (Taylor)

**Mixing with**  
Upper Continental Crust (Taylor)

**Fractionating Phases**

Olivine	20.0%
O-pyroxene	0.0%
C-pyroxene	20.0%
Garnet	0.0%
Amphibole	0.0%
Biotite	0.0%
K-Feldspar	0.0%
Plagioclase	60.0%
Apatite	0.0%
Magnetite	0.0%
Sphene	0.0%
Ilmenite	0.0%
Zircon	0.0%
Allanite	0.0%

**Melt Composition**  
Basic melt compositions

**Y-axis**  
Rb / Rb  
Linear-scale

**X-axis**  
Sr / Rb  
Linear-scale

**"r" value**  
0.4

**Increments**  
6%

The parameters to models on the bivariate diagram

To show on the diagram these can be selected

Santorini

Asitepe volc.

Yağcıdağ vol.

Orhanlar

Naşa

Kiran-Zahman-...

water-free oxides

Ca (assimilant)

AFC

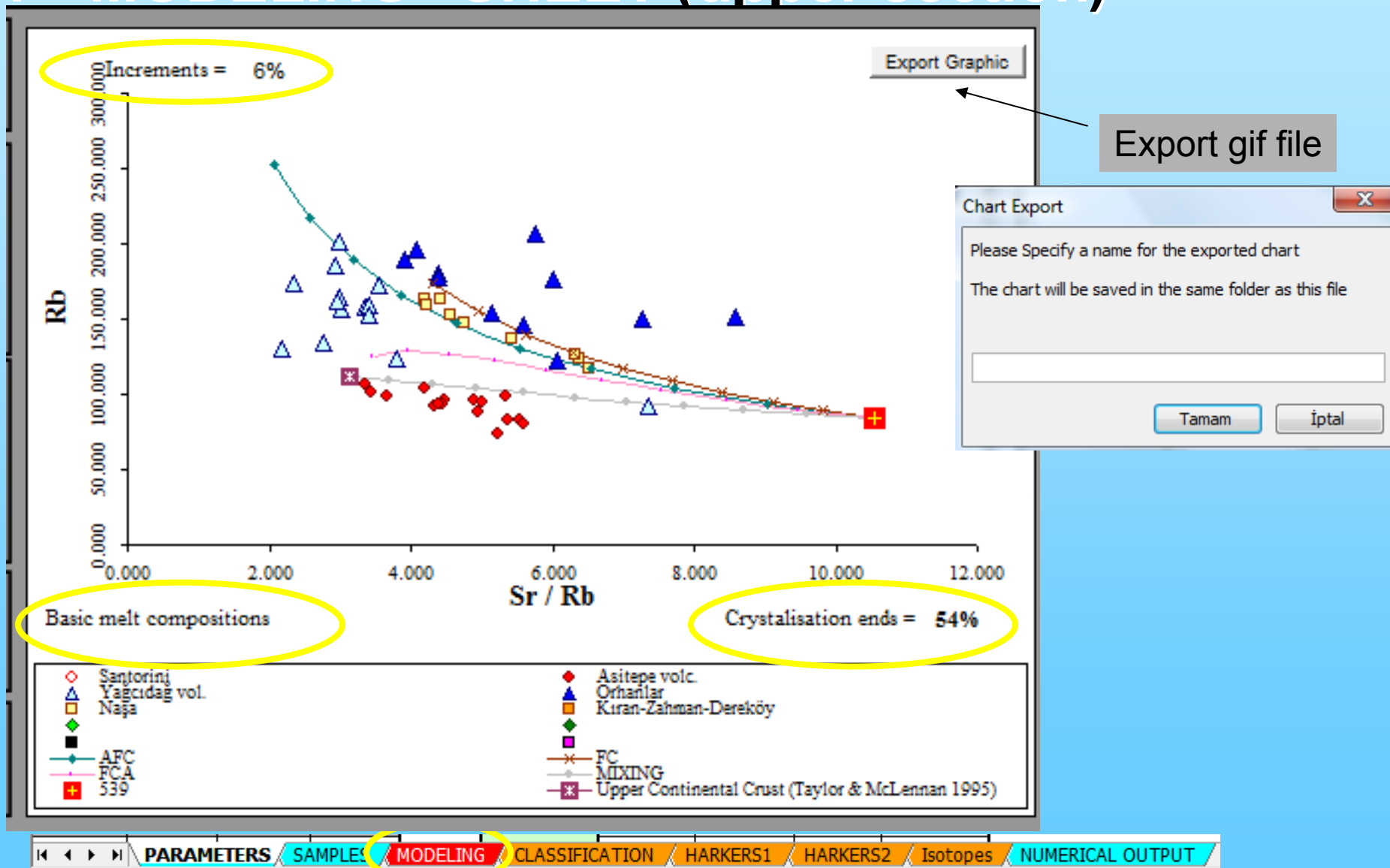
FC

FCA

Mixing

# 5. Structure of the Program

## 3. "MODELING" SHEET (upper section)



# 5. Structure of the Program

## 3. "MODELING" SHEET (lower section)

**Left Graph:** C0= Upper Continental Crust (Taylor & McLennan 1995), F = 0.64, C0= 539. The y-axis is Rock/CI-chondrite (Sun & McDonough 1989) on a log scale from 1.0 to 1000.0. The x-axis lists elements: La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu. An orange box with the text "Export gif file" has an arrow pointing to the "Export Graphic" button in the top right corner.

**Right Graph:** C0= Upper Continental Crust (Taylor & McLennan 1995), F = 0.64, C0= 539. The y-axis is Rock/CI-chondrite (Sun & McDonough 1989) on a log scale from 1.00 to 10000.00. The x-axis lists elements: Cs, Rb, Ba, Th, K, U, Nb, La, Ce, Pr, Nd, Zr, Sm, Ti, Gd, Tb, Dy, Y, Ho, Er, Tm, Yb, Lu.

**Control Panels:**

- Normalizing Values:** C1-chondrite (Sun & McDonough 1989)
- Melt Composition:** Basic melt compositions
- (F) Fraction of melt remaining:** 64.0%
- Starting Composition (C<sub>0</sub>):** 539
- Assimilant (C<sub>2</sub>):** Upper Continental Crust (Taylor & McLennan 1995)
- Checkboxes:**  C0,  Ca,  FCA,  FC,  MIXING,  AFC

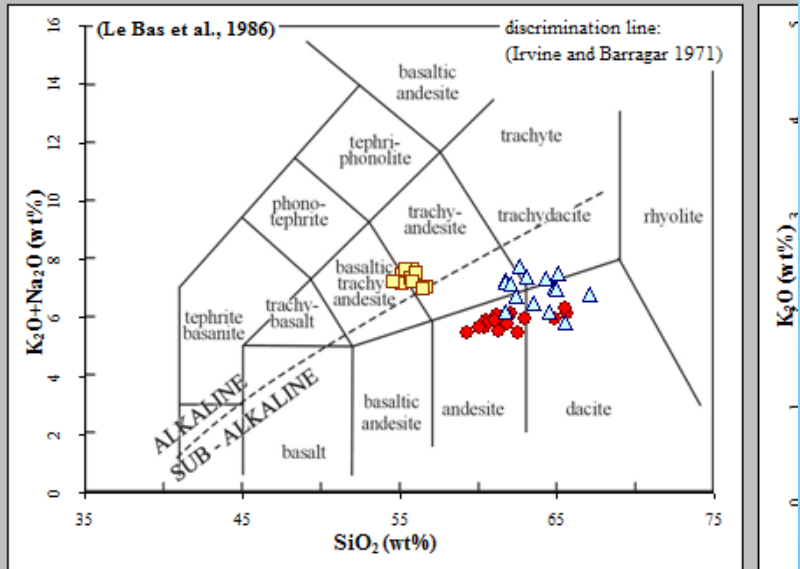
**Software Information:** FC-AFC-FCA and MIXING MODELER, E. YALÇIN ERSOY, Dokuz Eylül University, Engineering Faculty, Department of Geology, TR-35160 Buca-İzmir TURKEY, yalcin.ersoy@deu.edu.tr

# 5. Structure of the Program

## 4. "CLASSIFICATION" SHEET (lower section)

### Discrimination and

<input type="checkbox"/>	Santorini	<input type="checkbox"/>	Kıran-Zahman-
<input checked="" type="checkbox"/>	Asitepe volc.	<input type="checkbox"/>	
<input checked="" type="checkbox"/>	Yağcıdağ vol.	<input type="checkbox"/>	
<input type="checkbox"/>	Orhanlar	<input type="checkbox"/>	
<input checked="" type="checkbox"/>	Naşa	<input type="checkbox"/>	
<input checked="" type="checkbox"/> Major oxides are based on water-free calculations			



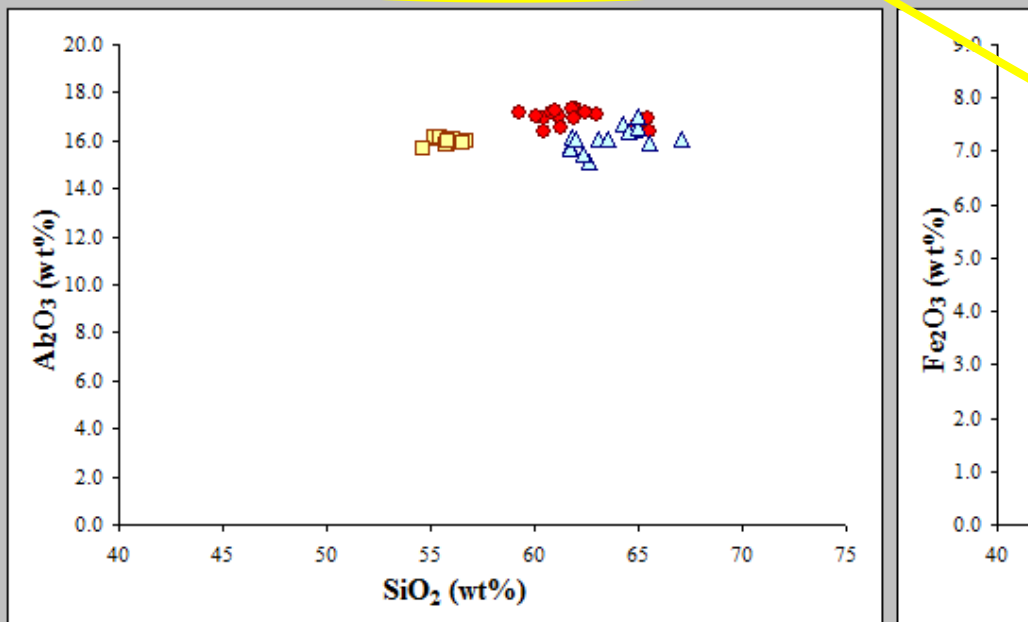
- \* TAS diagram of [LeBas et al \(1986\)](#) with alkaline-subalkaline discrimination of [Irvine and Baragar \(1971\)](#)
- \*  $K_2O-SiO_2$  diagram of [LeMaitre \(2002\)](#)
- \* TAS diagram of [Cox et al \(1978\)](#)
- \*  $K_2O-Na_2O$  diagram of [Peccerillo and Taylor \(1976\)](#)
- \*  $Th/Yb - Ta/Yb$  diagram of [Pearce \(1983\)](#)
- \*  $Sr/Y-Sr$  diagram of [Castillo \(2006\)](#)

# 5. Structure of the Program

## 5. "HARKERs" SHEET

<input type="checkbox"/>	Santorini	<input type="checkbox"/>	Kiran-Zahman-
<input checked="" type="checkbox"/>	Asitepe volc.	<input type="checkbox"/>	
<input checked="" type="checkbox"/>	Yağcıdağ vol.	<input type="checkbox"/>	
<input type="checkbox"/>	Orhanlar	<input type="checkbox"/>	
<input checked="" type="checkbox"/>	Naşa	<input type="checkbox"/>	
<input checked="" type="checkbox"/>	Major oxides are based on water-free calculations		

Major and trace elements can be plotted on SiO<sub>2</sub>-dependent Harker variation diagrams.



Major elements can also be plotted on the basis of water-free contents

# 5. Structure of the Program

## 6. "ISOTOPES" SHEET

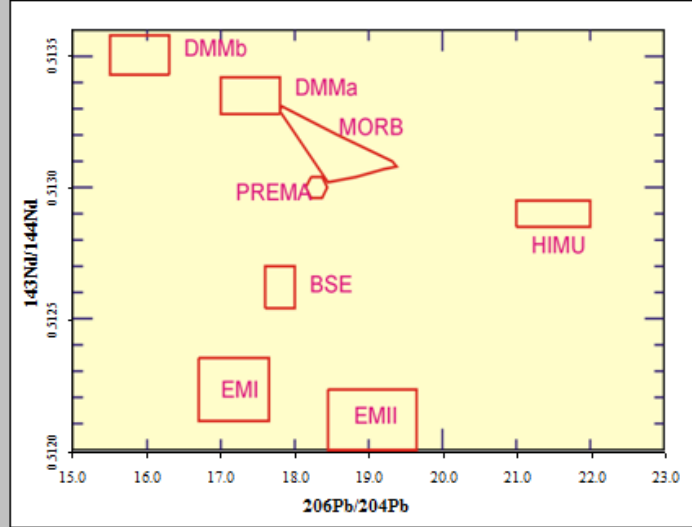
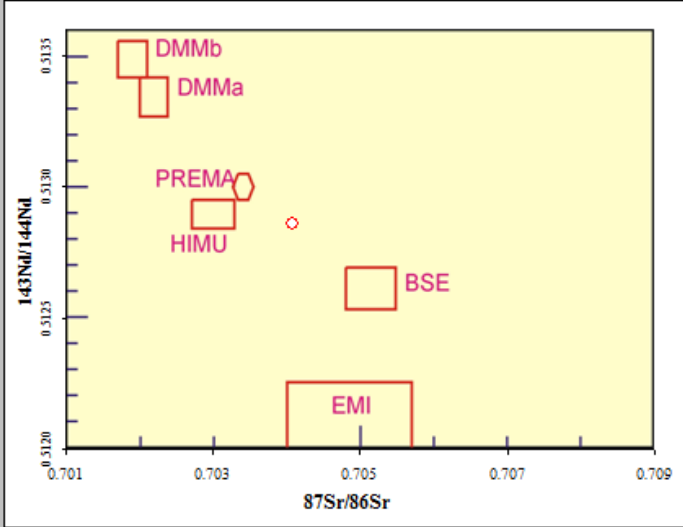
### Isotope Diagrams

- |                                     |               |                                     |                      |
|-------------------------------------|---------------|-------------------------------------|----------------------|
| <input checked="" type="checkbox"/> | Santorini     | <input checked="" type="checkbox"/> | Kiran-Zahman-Dereköy |
| <input checked="" type="checkbox"/> | Asitepe volc. | <input checked="" type="checkbox"/> |                      |
| <input checked="" type="checkbox"/> | Yağcıdağ vol. | <input checked="" type="checkbox"/> |                      |
| <input checked="" type="checkbox"/> | Orhanlar      | <input checked="" type="checkbox"/> |                      |
| <input checked="" type="checkbox"/> | Naşa          | <input checked="" type="checkbox"/> |                      |

FC-AFC-FCA  
and MIXING  
MODELER

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- |                 |                        |
|-----------------|------------------------|
| ○ Santorini     | ● Asitepe volc.        |
| △ Yağcıdağ vol. | ▲ Orhanlar             |
| □ Naşa          | ■ Kiran-Zahman-Dereköy |
| ◆               | ◆                      |
| ■               | ■                      |



Four isotope diagrams can be plotted on this sheet.

# 5. Structure of the Program

## 7. “NUMERICAL OUTPUT” SHEET

AFC RESULTS										
r= 0.40	F (fraction of melt remaining)									
	0.00%	6.0%	12.0%	18.0%	24.0%	30.0%	36.0%	42.0%	48.0%	54.0%
SiO2	#YOK	#YOK	#YOK	#YOK	#YOK	#YOK	#YOK	#YOK	#YOK	#YOK
Al2O3	#YOK	#YOK	#YOK	#YOK	#YOK	#YOK	#YOK	#YOK	#YOK	#YOK
Fe2O3 (t)	#YOK	#YOK	#YOK	#YOK	#YOK	#YOK	#YOK	#YOK	#YOK	#YOK
FeO (t)	#YOK	#YOK	#YOK	#YOK	#YOK	#YOK	#YOK	#YOK	#YOK	#YOK
MgO	#YOK	#YOK	#YOK	#YOK	#YOK	#YOK	#YOK	#YOK	#YOK	#YOK
CaO	#YOK	#YOK	#YOK	#YOK	#YOK	#YOK	#YOK	#YOK	#YOK	#YOK
Na2O	#YOK	#YOK	#YOK	#YOK	#YOK	#YOK	#YOK	#YOK	#YOK	#YOK
K2O	#YOK	#YOK	#YOK	#YOK	#YOK	#YOK	#YOK	#YOK	#YOK	#YOK
TiO2	#YOK	#YOK	#YOK	#YOK	#YOK	#YOK	#YOK	#YOK	#YOK	#YOK
P2O5	#YOK	#YOK	#YOK	#YOK	#YOK	#YOK	#YOK	#YOK	#YOK	#YOK
MnO	#YOK	#YOK	#YOK	#YOK	#YOK	#YOK	#YOK	#YOK	#YOK	#YOK
Cs	9.60	10.26	11.00	11.84	12.80	13.91	15.21	16.76	18.62	20.93
Rb	84.00	93.55	104.33	116.60	130.70	147.09	166.38	189.44	217.52	252.51
K	#YOK	#YOK	#YOK	#YOK	#YOK	#YOK	#YOK	#YOK	#YOK	#YOK
Ba	1023.60	1092.04	1168.32	1254.00	1351.03	1462.02	1590.46	1741.14	1920.88	2139.72
Sr	886.90	845.98	805.15	764.40	723.76	683.22	642.79	602.49	562.33	522.32
Pb	2.10	3.03	4.05	5.20	6.50	7.98	9.68	11.66	14.01	16.85
Th	25.40	27.42	29.71	32.33	35.36	38.89	43.08	48.12	54.30	62.06
U	4.90	5.32	5.79	6.34	6.97	7.70	8.57	9.61	10.89	12.49
Zr	610.10	653.51	702.55	758.43	822.70	897.46	985.56	1090.98	1219.53	1379.92
Hf	15.80	16.91	18.16	19.58	21.20	23.09	25.30	27.93	31.12	35.08
Ti	#YOK	#YOK	#YOK	#YOK	#YOK	#YOK	#YOK	#YOK	#YOK	#YOK
Ta	2.10	2.32	2.57	2.86	3.19	3.58	4.03	4.58	5.26	6.10
Y	29.10	31.55	34.30	37.42	40.99	45.10	49.92	55.63	62.54	71.07
Nb	34.70	37.95	41.65	45.88	50.77	56.50	63.29	71.48	81.55	94.23
Sc	26.00	25.92	25.83	25.74	25.65	25.55	25.45	25.34	25.22	25.09
Cr	554.24	287.87	143.74	68.93	31.91	14.57	6.96	3.86	2.71	2.33
Ni	218.80	96.21	40.41	16.32	6.55	2.84	1.55	1.15	1.03	1.00

Numerical results for AFC, FC, FCA and Mixing modelings can be taken into tables from this sheet.

# 6. RESULTS

- \* The FC-AFC-FCA and mixing modeler program is a Microsoft® Excel© spreadsheet program designed on the basis of already proposed magmatic differentiation equations for crystal fractionation, assimilation and mixing processes in magmatic systems.
- \* The results of geochemical analyses of magmatic rocks can easily be transferred to the program.
- \* The program also has the advantage that the user can output the graphical and/or numerical results of FC, AFC, FCA and mixing processes in addition to several geochemical parameters.
- \* The program allows the users to change the several parameters and to see the different modeling results on the same diagram.
- \* The graphical results of any modeling can be exported and saved as a GIF file.
- \* The numerical results can also be taken into tables.

**The program will be available at:**  
*Computers and Geosciences, Elsevier (accepted to be published)*

## Acknowledgements

Ercan Aldanmaz and Mehmet Keskin are thanked for their help and comments during preparing the program