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GEOCHEMISTRY OF THE St. CATHERINE BASEMENT ROCKS, SINAI, EGYPT

By

M.L. ABDEL KHALEK* M.A. ABDEL MAKSOUD** M.A. ABDEL TAWAB*** and K.A. OWEISS***
* Department of Geology, Faculty of Science,Cairo University, Cairo, Egypt
** Department of Geology, Faculty of Science, University of Qatar, Doha, Qatar
*** Geological Survey of Egypt, Cairo, Egypt

جيوكيمياء صخور القاع بمنطقة سانت كاترين
سيناء - مصر

لطفي عبد الخالق و محمد عبد المقصود و محمد عبد التواب و خليفة عويس

تتكون منطقة سانت كاترين من صخور نيس قاري من النوع القديم ورسوبيات متحوله وبنية صخرية خضراء وجرانيت كلسي قلوي وبركانيات تكونت نتيجة للخسف وجرانيت قلوي قاري لاتكتوني .

وقد تم تحليل ٣٩ عينه من القاعيات والبركانيات لمعرفة محتوى العناصر الأساسية والشحيحة فيها وبحساب مقاييس جيوكيمائية عديدة وتوقيع النتائج على منحنيات عالمية ومقترحة تبين وجود علاقة جيوكيميائية بين القاعيات والبركانيات . وقد دلت الدراسة على أن البركانيات التي تكونت في نطاق اندساس قد قذفت في أقواس جذرية بركانية أما الجرانيت الكلسي القلوي فقد تداخل في نطاق حزي . وقد أثبتت الدراسة أيضاً أن أنسب الأوضاع التكتونية لتكون بركانيات الخسف والجرانيت القلوي القاري هو البيئة التكتونية التي تسود داخل الألواح .

Key Words: Sinai, St. Catherine, Geochemistry

ABSTRACT

St. Catherine area, dominated by basement rocks encompass old continental gneisses, metasediments, greenstone belt, calc-alkaline granites (G-II-granites), rift-related volcanics (RV), and anorogenic within plate granites (G-III-granites).

Comparative geochemical study has been carried out between the G-II-, and the G-III-granites and between the SV-, and RV-volcanics. The geochemical criteria strongly confirm island arc environment for the SV, and suture related environment for the G-II-granites. The most reasonable setting for the RV-volcanics and the G-III-granites is the anorogenic or within plate environment.

INTRODUCTION

St. Catherine province is located in the southern part of Sinai. The area is dominated by basement rocks previously investigated by Abdel Maksoud *et al.* [1]. The area is covered mainly by granitic as well as volcanic suites. The granitic masses belong to the G-II-, and G-III-types recognized by Hussein *et al.* [2]. Volcanics include subduction related (SV), and rift related (RV) types.

Few workers were concerned with the chemistry of the different rocks units of St. Catherine. Eyal [3] studied 18 plutons from a major segment in the southern Sinai, including St. Catherine and distinguished 16 plutons as calc-alkaline and two as alkaline. Eyal *et al.* [4] stated that St. Catherine area is dominated by biotite-granite of alkaline affinities.

The object of the present work is to investigate the geochemical criteria of the basement rocks encountered in the area to determine their tectonic setting.

The results of 39 analyses for major constituents covering the different plutonic and volcanic rocks encountered in the area are given in Tables 1, 2, 3, 5, 6 and 7. Tables 4, and 8 show the trace element contents of the examined plutonites and volcanics.

Table 1

Chemical composition of the St. Catherine plutonites

Rock type	Sample No.	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MgO	H_2O	CaO	Na_2O	K_2O	MnO	P_5O_5	LOI	H_2O+	Total	Alkalinity Ratio	Felsic Index	Mafic Index
(+)	1	57.71	0.83	16.5	4.12	4.93	4.44	5.58	2.5	1.2	0.18	0.03	1.88	0.27	100.17	1.4	39.9	67.1
	2	57.88	0.72	16.2	4.22	3.66	3.77	6.15	2.74	2.56	0.08	0.16	1.45	0.23	99.82	1.6	46.3	67.6
	3	67.3	0.47	14.98	2.35	1.19	1.56	3.29	3.07	3.74	0.06	0.15	1.56	0.1	99.82	2.2	67.4	69.4
	4	67.94	0.5	15.17	3.17	1.19	1.9	2.84	3.1	2.13	0.4	0.26	1.14	0.16	99.9	1.8	64.8	69.6
	5	68.5	0.32	13.36	2.44	1.52	2.73	2.32	3.1	3.4	1.3	0.08	0.88	0.44	100.39	2.4	73.7	59.2
	6	64.93	0.83	15.43	2.85	1.97	1.54	3.32	3.05	4.34	0.09	0.01	1.44	0.41	100.21	2.3	69.0	75.8
	7	66.13	0.6	14.97	3.41	1.42	1.43	3.09	3.72	4.22	0.1	0.03	0.71	0.12	99.95	2.6	72.0	77.2
	8	64.83	0.7	15.39	2.97	1.02	1.62	3.09	5.1	3.7	0.1	0.14	1.15	0.33	100.4	2.8	74.0	71.1
	9	64.96	0.52	15.1	3.15	1.83	1.18	4.14	3.47	3.46	0.15	0.13	1.54	0.22	99.85	2.1	62.6	80.8
	10	66.78	0.35	16.06	1.28	0.16	0.79	2.38	5.67	5.18	0.09	0.05	0.98	0.18	99.95	3.9	89.0	64.6
	11	63.52	0.48	15.75	2.87	1.86	2.19	4.03	4.21	3.57	0.06	0.11	1.02	0.17	99.84	2.3	65.9	68.4
(•)	12	64.37	1.5	14.79	3.53	0.26	0.8	1.47	5.95	6.02	0.12	0.07	1.09	0.27	100.27	1.4	89.0	82.6
	13	63.57	0.33	16.9	3.61	0.03	0.26	3.37	5.78	3.18	0.05	0.14	0.45	0.1	99.46	0.4	81.0	93.3
	14	63.71	0.3	16.18	3.21	1.07	1.29	2.51	4.7	5.51	0.13	0.07	0.77	0.21	99.66	3.4	80.0	76.8
	15	62.8	0.58	17.01	3.68	0.92	0.73	2.89	5.02	5.62	0.09	0.04	0.58	0.22	100.19	3.3	78.6	86.3
	16	71.56	0.67	13.98	1.94	0.18	0.52	1.72	4.29	4.4	0.05	0.04	0.64	0.06	100.07	3.5	83.5	80.3
	17	72.03	0.47	13.34	1.88	0.24	0.62	1.95	4.48	4.78	0.07	-	0.66	0.07	100.59	4.1	82.6	77.4
	18	70.67	0.83	13.91	2.36	0.42	0.51	1.8	4.92	3.33	0.13	-	0.82	0.07	99.77	3.2	82.1	84.5
	19	71.27	0.43	13.92	2.92	0.19	0.21	2.31	3.39	4.73	0.14	0.05	0.76	0.25	100.57	3.0	77.85	93.7
	20	70.1	0.22	14.29	2.17	1.54	1.39	1.35	3.55	3.9	0.05	0.02	1.06	0.23	99.87	2.8	84.7	72.8
	21	73.81	0.18	13.4	0.81	1.51	1.02	1.7	3.71	3.9	0.03	0.03	0.62	0.1	100.82	3.0	81.7	69.5
	22	74.58	1.33	13.31	0.3	0.11	0.5	0.92	5.06	3.12	-	0.01	0.91	0.09	100.24	3.7	29.9	45.1
	23	74.34	1.33	12.54	0.3	0.11	0.43	0.92	4.59	3.72	-	0.01	0.94	0.6	100.13	4.1	90.03	48.8
	24	73.16	0.57	13.34	1.15	0.1	0.43	0.48	5.12	5.62	0.08	0.07	0.18	0.16	100.46	8.0	95.7	74.4
	25	73.39	0.47	12.01	1.5	0.17	0.12	0.76	4.23	5.93	0.11	0.02	0.76	0.33	99.8	8.8	93.0	93.3
	26	73.13	0.2	13.74	1.09	0.16	0.08	1.3	4.45	4.32	0.02		0.64	0.36	99.99	4.2	87.7	93.98
	27	73.71	0.27	13.39	1.38	0.31	0.68	1.01	4.86	4.63	0.04	0.02	0.5	0.11	100.91	4.9	90.4	71.3
	28	73.14	0.23	13.77	1.37	0.32	0.83	1.08	4.7	4.5	0.05	0.16	0.34	0.17	100.7	4.3	89.5	67.1

(+) G II GRANITES (•) G III GRANITES

Table 2

Catanorms of the St. Catherine plutonites

	Sample No.	ap	il	Or	ab	an	mt	cor.	sp	hm	wo	en	hy	di	ac	ru	ns	qz
	1	0.05	1.2	7.35	23.25	28.55	4.42	1.13					16.74					17.26
	2	0.35	1.04	15.65	25.35	25.08	4.55			-			10.5	4.2				13.28
	3	0.32	0.68	22.75	28.4	15.8	2.28	0.29		0.17		4.44						24.87
	4	0.56	0.72	12.95	28.	12.8	2.73	3.62		0.46		5.4						32.06
(+)	5	0.16	0.46	20.55	28.45	11.25	2.61	0.6					9.98					25.94
	6	0.03	1.18	26.4	28.2	16.03	3.06						4.12	0.64				20.34
	7	0.05	0.86	25.35	34.0	11.88	2.31			0.88	1.42	4.02						19.23
	8	0.29	0.98	22.05	46.15	8.23	1.17			1.31	2.53	4.5						12.79
	9	0.29	0.74	21.1	32.15	15.9	3.41						1.75	3.52				21.14
	10	0.11	0.38	30.45	50.65	3.05			0.15	0.89	1.98	2.18						8.9
	11	0.24	0.66	21.35	38.3	13.7	3.05						4.12	4.64				13.94
	12	0.13	0.58	35.55	45.2				2.28	0.81	1.24	2.22			6.6			5.39
	13	0.29	0.12	30.55	51.85	4.03			0.51	2.51	4.36	0.72						5.06
	14	0.16	0.42	32.75	42.5	6.83	2.19			0.79	2.08	3.58						8.7
	15	0.08	0.8	33.2	45.05	7.28				1.8	2.72	2.07						5.91
	16	0.08	0.36	26.3	38.95	5.95			0.87	11.36	0.4	1.46						24.27
	17		0.48	28.35	40.15	2.18			0.27	1.32	2.82	1.72						22.51
	18		0.86	19.95	44.85	6.13			0.48	1.67	0.84	1.42						23.8
(•)	19	0.11	0.52	28.5	31.05	8.98			0.12	2.07	0.88	0.6						27.2
	20	0.05	0.32	23.6	32.65	6.7	2.33	2.04					4.56					27.75
	21	0.05	0.26	23.2	33.55	8.35	0.86	0.05					4.4					29.28
	22	0.03	0.18	18.6	45.8	4.4			0.06	0.21		1.38				0.82		28.52
	23	0.03	0.18	22.35	41.95	3.53			0.6	0.21		1.2				0.65		29.3
	24	0.16	0.3	33.0	39.35				0.72		0.26	1.18			3.16		0.72	21.15
	25	0.05	0.46	35.65	31.1			0.3		1.28	0.34				4.24		0.68	25.9
	26			28.8	40.4	3.33	0.03			0.75	1.26	0.22						24.93
	27	0.05	0.38	27.2	43.45	1.05	0.24			0.8	1.5	1.86						23.79

(+) G II GRANITES (•) G III GRANITES

Table 3

Niggli values of the St. Catherine plutonites

	Sample No.	al	fm	c	alk	si	ti	k	mg	Qr
(+)	1	29.52	42.61	18.18	9.69	175.51	1.89	0.24	0.48	+56.58
	2	29.47	36.91	20.37	13.25	178.97	1.67	0.38	0.47	+25.97
	3	38.58	22.53	15.43	23.46	294.65	1.55	0.45	0.46	+100.01
	4	38.99	28.66	13.3	19.05	296.90	1.64	0.31	0.44	+140.64
	5	33.01	34.83	10.44	21.72	287.76	1.01	0.42	0.49	+100.88
	6	37.02	25.14	14.51	23.33	264.79	2.54	0.48	0.38	471.47
	7	36.12	24.49	15.58	25.81	271.24	1.85	0.43	0.38	+68.
	8	35.85	22.15	13.11	28.89	256.72	2.08	0.32	0.44	+41.16
	9	35.00	23.45	17.88	22.57	263.32	1.58	0.4	0.31	+73.04
	10	40.82	10.17	11.02	37.99	288.53	1.14	0.18	0.5	+36.57
	11	34.35	26.09	16.01	21.55	235.49	1.34	0.36	0.47	+41.29
(•)	12	36.19	17.33	6.55	39.93	267.75	4.68	0.4	0.29	+19.23
	13	38.37	12.44	14.20	34.99	249.93	0.41	0.37	0.12	+9.97
	14	37.15	20.86	10.50	31.49	248.7	0.88	0.44	0.36	+22.74
	15	38.12	17.9	11.8	32.18	239.27	1.66	0.43	0.23	+10.55
	16	42.27	12.48	9.47	35.78	367.76	2.59	0.4	0.32	+124.84
	17	39.38	13.05	10.49	37.08	361.56	1.77	0.41	0.36	+113.24
	18	40.93	14.98	9.65	34.44	353.48	3.12	0.31	0.26	+115.72
	19	41.47	14.09	12.53	31.91	360.96	1.64	0.48	0.11	+133.32
	20	40.38	24.21	6.95	28.46	336.76	0.79	0.42	0.41	+134.84
	21	41.04	17.81	9.49	31.66	384.33	0.7	0.41	0.45	+157.68
	22	46.69	6.36	5.88	41.07	444.72	5.95	0.29	0.2	+180.44
	23	46.29	5.90	6.04	41.77	455.62	6.12	0.35	0.67	+188.54
	24	42.27	8.94	2.77	46.02	394.13	2.31	0.42	0.39	+110.05
	25	40.84	8.9	4.71	45.55	424.27	2.04	0.48	0.12	+142.07
	26	45.04	6.06	7.76	41.14	407.5	0.34	0.42	0.11	+142.14
	27	41.53	12.38	5.71	40.38	388.66	1.07	0.39	0.44	+121.14
	28	41.98	13.56	6.00	38.46	379.09	0.9	0.39	0.48	+125.25

(+) G II GRANITES (•) G III GRANITES

Table 4

The trance elements in plutonites (in ppm)

	Sample No.	Ti X 1000	V	Zr	Cr	Ni	Co	Cu	Ba	Sr	Zn	Pb	Sn	Mo	Y	Yb	Be
(+)	1	0.6	100	100	200	100	30	30	400	300		10	5	3	40	4	3
	2	0.7	100	100	200	200	30	30	300	400	100	10	-	-	-	-	1
	3	0.6	100	100	40	10	-	10	400	400	-	-	4	-	10	-	2
	4	0.2	100	200	40	20	-	10	300	300	-	-	5	-	30	3	3
	5	0.3	100	100	30	10	-	10	200	300	-	-	-	-	-	-	1
	6	0.3	100	200	40	10	-	10	300	300	100	10	5	10	20	2	4
	7	0.3	30	200	30	20	-	6	300	300	-	10	4	-	-	-	3
	8	0.6	10	100	100	30	-	-	200	600	-	-	-	-	10	1	4
	9	0.7	60	100	100	100	8	20	200	300	-	-	-	-	-	-	1
	10	0.3	60	80	100	100	-	6	300	400	-	-	4	-	-	-	2
	11	0.5	40	60	100	60	5	10	200	400	-	-	-	-	-	-	1
(•)	12	0.7	100	100	80	60	8	20	300	400	-	-	4	-	-	1	2
	13	0.3	-	400	-	-	-	6	200	-	100	10	4	-	10	1	3
	14	0.4	50	100	30	30	-	30	300	300	-	-	4	-	-	-	3
	15	0.6	100	100	200	100	8	20	300	300	-	-	4	-	-	1	3
	16	0.1	10	100	10	6	-	3	200	300	100	20	4	6	40	2	2
	17	0.3	-	300	50	30	-	3	100	300	300	10	5	5	30	2	3
	18	0.1	20	200	60	20	-	10	300	300	100	20	5	5	20	3	2
	19	0.6	100	200	200	200	30	30	300	300	100	-	-	5	30	3	3
	20	0.08	30	100	30	10	-	-	200	300	-	10	4	2	20	2	2
	21	0.3	10	100	80	20	-	6	200	400	-	10	5	1	20	1	3
	22	0.6	100	100	100	100	20	30	300	300	-	10	-	-	30	1	2
	23	0.6	100	100	100	80	10	30	300	300	-	10	-	-	40	-	2
	24	0.6	100	80	100	80	10	20	300	400	-	10	-	-	30	1	2
	25	0.6	100	100	200	200	10	30	300	400	-	10	-	-	20	2	2
	26	0.7	80	80	200	200	20	30	300	400	-	10	3	-	20	1	2
	27	0.2	-	100	-	-	-	-	400	400	-	10	3	-	10	1	2
	28	0.5	60	100	100	60	4	8	400	300	-	10	3	-	30	1	2

(+) G II GRANITES (•) G III GRANITES

Table 5
Chemical composition of the volcanic rocks

Rock type	Sample No.	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K2O	MnO	P_2O_5	L.O.I.	H_2O^+	TOTAL
	1	75.59	0.9	12.45	1.34	0.18	0.42	1.83	3.6	3.4	0.08	0.05	0.76	0.11	100.21
SV	2	71.18	0.57	12.79	3.14	0.13	0.85	4.21	3.17	2.41	0.08	0.07	1.0	0.12	99.72
(x)	3	73.79	0.3	12.44	1.29	0.28	0.79	0.82	4.7	4.8	0.043	0.037	0.58	0.22	100.09
	4	69.05	0.42	14.82	3.83	0.12	0.32	1.82	4.15	4.13	0.02	0.05	1.09	0.21	100.03
	5	71.61	0.5	12.93	2.72	0.24	0.31	1.25	3.94	5.06	0.04	-	0.89	0.08	99.58
	6	70.85	0.27	13.21	3.43	0.2	0.12	2.21	4.91	3.51	0.02	-	0.55	0.15	99.45
RV	7	74.63	0.22	10.93	2.65	0.31	0.08	1.19	3.64	5.43	0.08	-	0.33	0.12	99.61
(O)	8	75.92	0.23	10.76	1.37	0.09	0.11	0.22	5.04	5.54	0.04	-	0.25	0.1	99.67
	9	75.91	0.2	10.12	1.07	0.76	0.12	1.19	4.88	5.06	0.05	0.01	0.5	0.15	100.02
	10	75.09	0.33	10.35	1.56	0.44	0.79	0.38	5.97	4.5	0.07	0.19	0.42	0.25	100.34
	11	73.98	0.42	10.53	1.29	0.76	0.28	1.53	5.67	4.03	0.15	0.02	0.79	0.38	99.83

Table 6
The Naggli Norms of the Volcanic Rocks

	Sample No.	Ap	Il	Or	Ab	An	Mt	Cor.	Sp	Hm	Wo	En	Hy	Di	Ac	Ru	Ns	Qz	Normative Plagioclase	Normative C.I.
	1	0.11	0.14	20.55	33.05	7.98	0.42	-	-	0.68	0.38	1.18	-	-	-	-	-	35.51	2.42	19.45
SV	2	0.16	0.36	14.75	29.45	14.0	-	-	0.9	2.26	2.24	2.42	-	-	-	-	-	33.46	5.04	32.22
(X)	3	0.08	0.42	28.55	39.8	-	0.12	-	-	0.29	1.54	2.18	-	-	2.16	-	-	24.84	3.01	-
	4	0.11	0.22	24.95	38.1	8.9	-	0.37	-	2.73	-	0.9	-	-	-	0.18	-	23.54	4.3	18.94
	5		0.44	30.6	36.25	2.73	-	-	-.42	1.94	1.16	0.9	-	-	-	-	-	25.56	3.28	7.0
	6	-	0.36	21.15	44.95	3.68	-	-	0.03	2.43	2.98	0.34	-	-	-	-	-	24.08	3.13	7.57
RV	7	-	0.32	32.85	28.25	-	0.45	-	-	0.54	2.42	0.22	-	-	4.2	-	-	30.75	1.53	-
(O)	8	-	0.2	33.0	26.15	-	-	0.18	-	-	0.32	0.32	-	-	3.84	-	4.4	31.59	0.52	-
	9	0.03	0.28	30.2	25.6	-	-	-	-	-	1.02	-	-	2.64	3.00	-	4.49	32.74	0.28	-
	10	0.4	0.46	26.55	29.8	-	-	-	-	-	-	-	2.24	0.52	4.32	-	5.49	30.22	3.22	-
	11	0.05	0.26	24.15	24.15	-	-	-	-	-	1.08	3.64	-	3.88	3.64	-	3.87	28.92	4.14	-

Table 7
Niggli values of volcanic rocks

	Sample No.	al	fm	c	alk	si	ti	k	mg	qz
	1	43.62	11.03	11.68	33.67	450.16	0.45	0.38	0.34	+215.48
SV	2	36.79	18.62	22.06	22.53	348.12	2.46	0.33	0.34	+158.0
(X)	3	40.14	13.29	4.82	41.75	404.75	1.23	0.4	0.49	+137.75
	4	41.93	16.69	9.38	32.0	332.13	1.52	0.4	0.14	+114.06
	5	40.58	14.69	7.15	37.58	382.09	2.0	0.46	0.17	+131.77
	6	38.73	14.63	11.8	34.84	363.68	1.01	0.32	0.06	+113.72
RV	7	37.54	14.21	7.44	40.81	435.73	0.96	0.5	0.05	+172.49
(O)	8	38.88	7.99	1.45	51.68	466.33	1.06	0.42	0.13	+159.61
	9	35.35	9.85	7.57	47.23	450.80	0.89	0.41	0.11	+161.88
	10	34.01	15.39	2.28	48.32	419.49	1.38	0.33	0.43	+126.21
	11	34.33	11.91	9.09	44.67	410.07	1.75	0.32	0.2	+131.39

Table 8
The trace element in volcanic recks

	Sample No.	Mn	Ti	V	Zr	Cr	Ni	Co	Cu	Ba	Sr	Zn	Pb	Sn	Mo	Y	Yb	Be
	1	0.3	0.5	20	100	80	10	-	10	600	400	-	-	-	-	-	-	1
	2	0.1	0.6	80	80	100	20	6	20	500	300	-	-	-	-	-	-	1
SV	3	0.1	0.3	30	200	100	10		20	500	300	-	-	3	-	-	-	1
(X)	4	0.1	0.7	80	80	200	40	20	30	600	400	-	-	-	-	-	-	2
	5	0.1	0.2	10	200	100	10		30	500	300	-	-	5	-	20	1	2
	6	0.05	0.5	80	400	80	-	8	20	800	300	-	-	4	-	-	-	1
	7	0.1	0.6	40	400	100	10	5	20	500	300	-	-	-	-	-	-	2
RV	8	0.1	0.1	10	400	40	10	-	10	400	300	100	30	6	8	10	4	3
(O)	9	0.1	0.6	60	300	100	10	8	10	500	300	-	-	-	-	-	-	2
	10	0.1	0.6	80	300	200	10	6	20	600	400	-	-	-	-	-	-	2
	11	0.1	0.5	30	300	100	-	3	10	600	300	-	-	-	-	-	-	2

1. THE PLUTONIC ROCKS

Major Oxides

The K-C-N diagram of figure 1. indicates that the G-II-granites are richer in calcium and poorer in alkalies relative to the G-III-granites. Plotting the chemical data on the AFM diagram (Fig. 2) shows that the G-II-granites are richer in iron and magnesium, and are emplaced in extensional environment (Petro *et al.,* 5). The diagram of Wright [6], Figure 3 indicates that the G-II-granites are calc-alkaline in nature while the G-III-granites are alkaline with per-alkaline tendency.

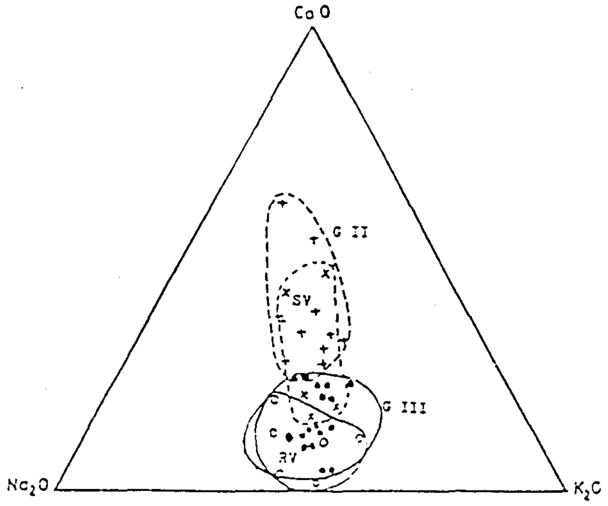

Fig. 1: Na$_2$O-CaO-K$_2$O diagram for the plutonites.

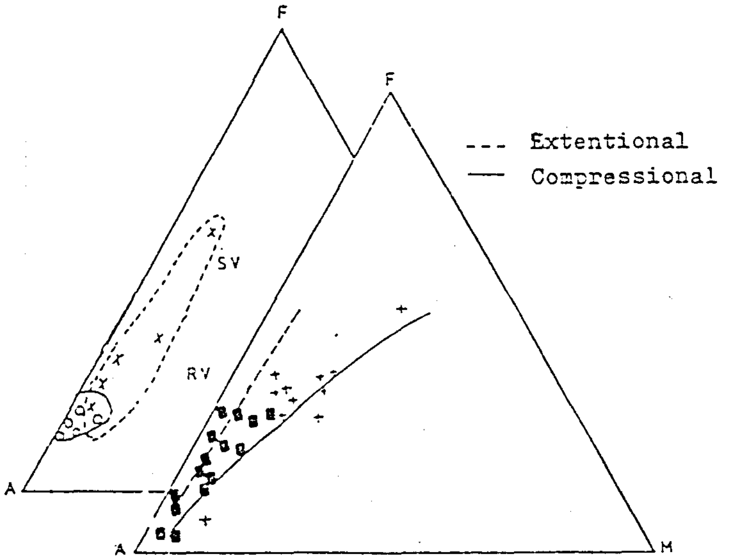

Fig. 2: AFM diagram for the studied plutonites, showing the trends proposed by Petro *et al.* (1979) for compressional suites and extentional environments.

The plot of al-values versus fm-values (Fig. 4) shows that the magma of the G-II- is isofalic to salic in nature (mostly hybrid oceanic and crustal materials) while the magma of the G-III-granites is salic (of pure crustal origin).

The catanorm data of the examined plutonites (Table 2) are plotted on the Ab-Or-Qz ternary diagram (Fig. 5). According to the experimental data of Tuttle and Bowen [7] the G-II-granites were formed at intermediate to low water-vapour pressure, while the G-III-granites were formed at intermediate to low water-vapour pressure. The relation between Ab-Or-Qz ternary diagram (Fig. 6) indicates that the analyzed granites contain equal proportion of Or and Ab while G-II-granites contain more An (calcium) than the G-III-granites.

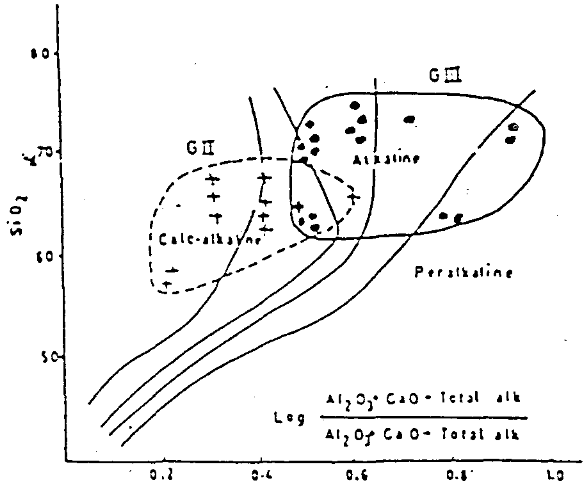

Fig. 3: Alkalinity ratio versus SiO$_2$ after Wright (1968).

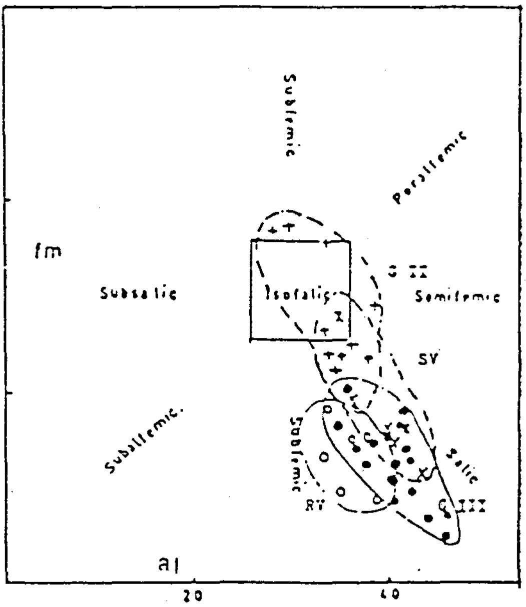

Fig. 4: fm-al correlation diagram after Burri and Niggll (1945).

The normative contents of the examined plutonites are plotted on the Ab-Or-Qz diagram of O'Connor [8] which is later modified by Barker [9], figure (7). The plots show that the G-II-spread over the field of tonalite, granodiorite, guartz-monzonite, and granite, while the G-III- spread over the field of granites. It is also evident that the granites have been formed at different pressure environments i.e. they do not belong to a single phase of intrusion but are multiphased.

Trace Elements

The average content of Ba (Table 4) for the G-II- and G-III-granites is (296.7) and (283.3) respectively. It decreases with differentiation index (Fig. 8). Ba^{2+} (1.34 A°) substitutes K, 1.33 A° (Mason, 10) and increases with the normative alkalifeldspar content (Table 2). Sr (1.12 A°) may replace either Ca^{2+} (0.99 A°) or K (1.33 A°) particularly in feldspars (Niggll, 11). Average Sr- contents are 358.3 and 323.5 ppm respectively, which indicates that Sr replaces Ca, in the examined granites. Pb^{2+} ion (1.2 A°) is diadochic with K^+, and might be captured by the potassium bearing minerals. Accordingly it shows an increase as Ba increases from the G-II- to the G-III-granites (Fig. 8).

Titanium is related to either the large highly charged cations (Zr-type) or to ferromagnesian elements. It shows lower content in the G-III-granites (Fig. 8).

Mo shows a decrease from the G-II to the G-III-granites with the increase in the D.I-values (Fig. 8). The molybdenum ions substitute for Ti^{4+}, Zr, and Fe^{3+} and may be expected in magnetite, ilmenite, and biotite.

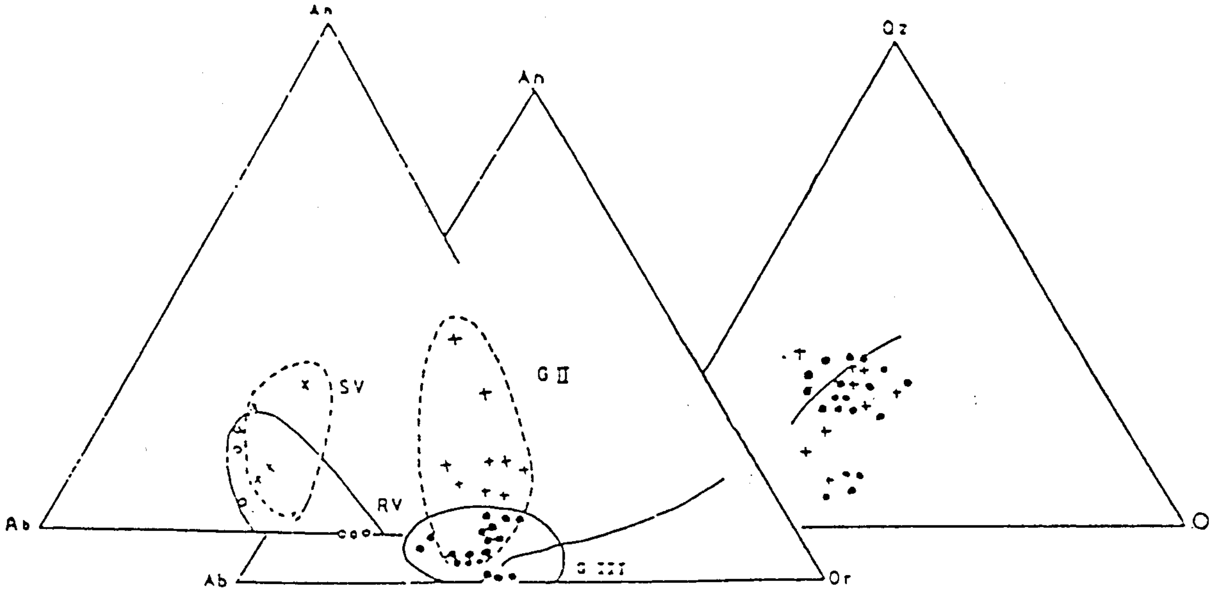

Fig. 5: Ternary diagram for normative Ab-Or-Qz. The solid line represents the variation in position of minimum melting in granite system at water vapour pressure from 500 to 1000 bars (after Tuttle and Bowen, 1958).

Fig. 6: Ternary diagram for normative Ab-Or-An. The solid line represents the two feldspar boundary curve for the quartz saturated ternary feldspar system at 1000 bars water vapour pressure (James and Hamilton, 1972).

The average content of V in the G-II-, and G-III-granites is 80 and 52.3 ppm respectively. It decreases with the decrease in the D.I. values (Fig. 8). Y^{3+} (0.24) is comouflaged by Fe^{3+} (0.64) during the fractionation of a silicate magma and decreases with the decrease in the ferromagnesin content of the enclosing rocks. Cr decreased from the G-II- to G-III-granites from 107.8 to 87.5 ppm (Fig. 8). Usually acid differentiates are comparatively poor in chromium. The average content of Ni for the G-II-, and G-III-granites is 74.8 and 65.64 ppm respectively. Notable decrease in the Ni-content with the decrease in the differentiation state is observed (Fig. 8). Nickel follows Fe $^{2+}$ rather than Mg $^{2+}$, and decreases with the decrease in ferromagnesian mineral content. Cobalt has almost the same ionic radius (0.72 A°) as ferrous iron (0.74 A°)) and thus can be camouflaged in ferrous compounds. It decrease with the decreases in the D.I-value from the G-II-, to the G-III-granites with average of 10.9 and 4.6 ppm respectively.

The average content of Y in the G-II-granites is 5.5 and G-III-granites 12.3 ppm. The Yb shows the same trend as Y, where both increase with increase in the differentiation values (Fig. 8).

The average content of Zr in the G-II-granites and the G-III-granites is 119.3 and 132.7 ppm respectively. It increases with differentiation (Fig. 8). Zr usually forms a specific mineral phase, the zircon.

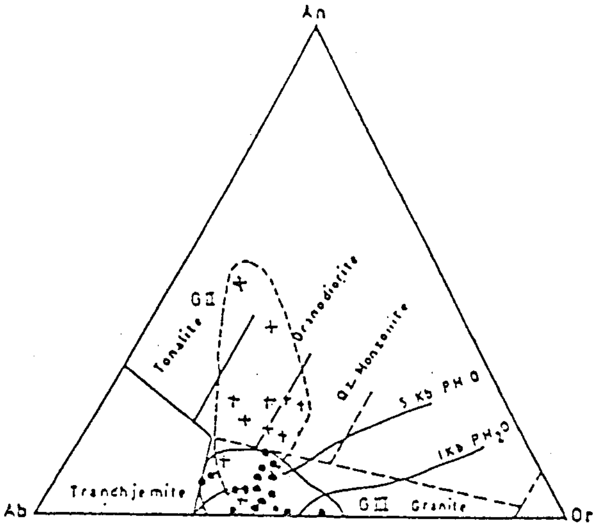

Fig. 7: Ab-An-Or ternary diagram classification boundaries from O'Conner (1965) and Barker (1979).

Sn has a tendency to increase with the D.I. -values (2.5, and 3ppm for the G-II-, and the G-III-granites respectively).

Be (0.34 A°) is mainly confined to albite (Beus *et al.,* 12, and Hugi, *et al.,* 13) and muscovite (Goldscmidt, 14). It increases from the G-II to the G-III-granites with averages of 2.2, and 2.4 ppm respectively (Fig. 8).

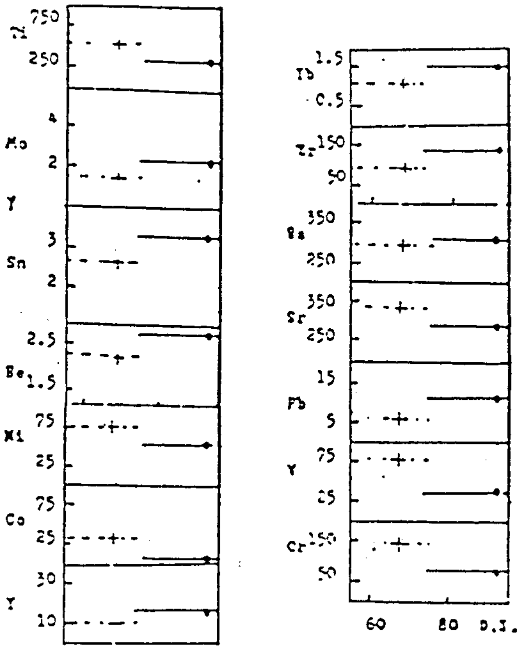

Fig. 8: The plot of various trace elements contents versus D.I. of the examined plutonites. (+) average for G-II-granites. and (o) average for the G-III-granites.

The average content of Cu in the G-II-, and G-III-granites is 16.1, and 17.7 ppm respectively. These averages are milling around the averages given by Turekian and Wedepohl [15] for the high calcium ganite (30 ppm), and low calcium granite (10 ppm). This indicates that the recorded cupper ore in El Riqeita location, St. Catherine area is not related genetically to the enclosing host granite.

From the previous study on the trace element distribution, it is evident that, although the average contents show decrease or increase from the G-II- to the G-III-granites, yet it is not possible to relate the samples of the two types collectively to one differentiation trend. Accordingly, both G-II-, and G-III-granites are derived from different sources and different tectonic environments.

THE VOLCANIC ROCKS

The dominant rock variety in the subduction-related volcanics (SV) is not andesite but is mostly rhyolite, a phenomenon usually recorded in the Chilian type of collision between oceanic- and continental-crustal masses (Uyeda, 16) where the volcanics forming up the arc have the opportunity to differentiate under passing through a thick continental crust and to be mixed with crustal materials. Dealing with geochemistry of the volcanic rocks, focus will be on how they differ among their rhyolitic portions and how the (RV) are related to the G-III-granites formed by the same mechanism (rifting).

MAJOR ELEMENTS

From the K-C-N diagram of (figure 1). It is clear that the RV-volcanics are enriched in alkalies and depleted in CaO when compared with SV-volcanics. The AFM diagram (Fig. 2) reveals that the RV-volcanics are enriched in alkalies and depleted in iron. The relation between al, and fm- values (Fig. 4) shows clearly that the character of the magma produced the (RV) is salic (mostly of crustal origin) while the magma produced the (SV) is isolfalic to salic (originated form an oceanic crust by differentiation or representing oceanic derivative contaminated with crustal materials).

The plot of normative data of Table 6 on the Ab-Or-An diagram (Fig. 6) shows that the SV-volcanics contain more anorthite than the RV-volcanics, while the RV are enriched more in the sodic feldspars than the SV.

The plot of major elements against D.I. (Fig. 9) shows parallel trends to the previously investigated plutonic rock suites. On the diagram of Irvine and Baragar [17], Figure 10 the representative points of both SV-, and RV-volcanics spread over subalkaline and alkaline fields. The RV-composition is more affiliated to the alkaline field. The plot of chemical data on the classificational diagram of Church [18], figure 11, shows that the SV-volcanics fall in the field of rhyolite and dacite, while the RV-volcanics fall in the field of rhyolite.

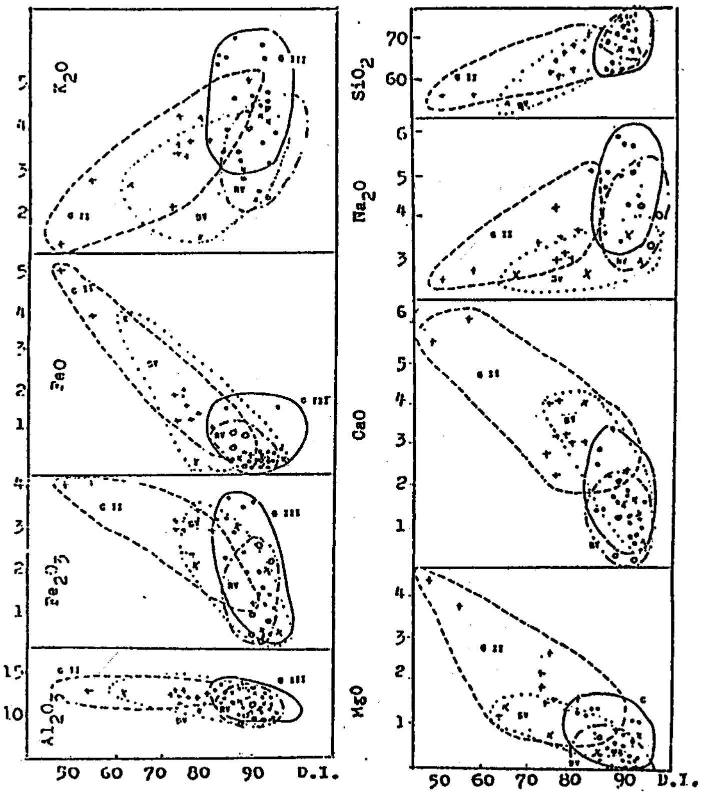

Fig. 9: The plot of the different oxide percentages against the D.I. values of the examined volcanics and plutonites.

TRACE ELEMENTS

To investigate the variation of trace element abundance with the calculated D.I., figure 12 is constructed for both SV-, and RV-volcanics. Zr, and Ba increase with increase in D.I. while Sr, Co, Ni, V, and Cr decrease.

Ramsy *et al.* [19] used data on the volcanics analysed from various tectonic settings to plot the important among their elements against the SiO_2-content (Fig. 13). The SV fall mainly in the field of immature island arcs, and active continental margins while the RV belong to the anorogenic terrains.

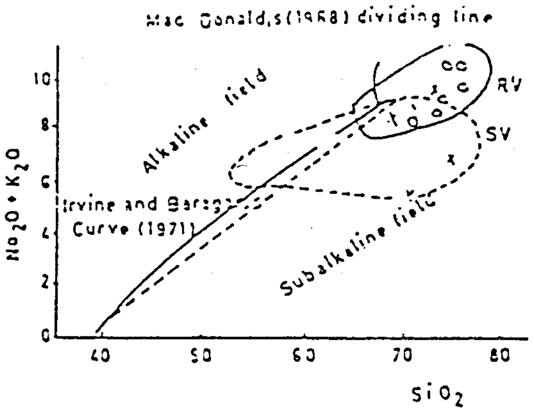

Fig. 10: Alkalies-silica diagram. The dashed line is McDonald's (1968) dividing line for Hawaiian tholeiitic and alkaline rocks. The solid curve is a line proposed by Irvin and Brager (1971) for making a general distinction between alkaline and subalkaline compositions. Plots are in weight percent.

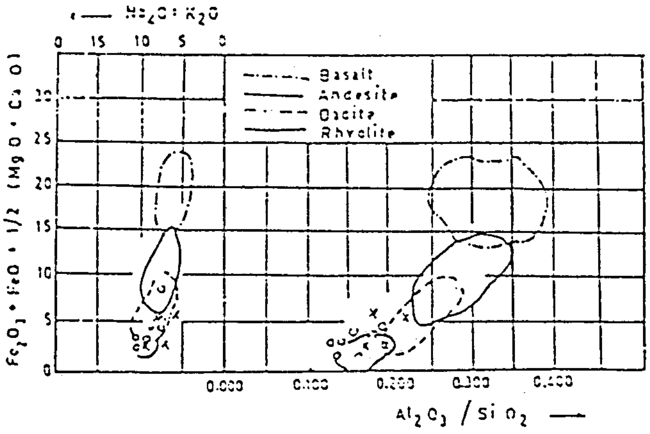

Fig. 11: Triaxial plot of Na_2O+K_2O versus Fe_2O_3 + FeO +1/2 (MgO + CaO), basicity index of church (1974) versus Al_2O_3/SiO_2 in weight percent for St. Catherine volcanics. Fields of variation of most common volcanic rocks are shown as designated by Church (1975).

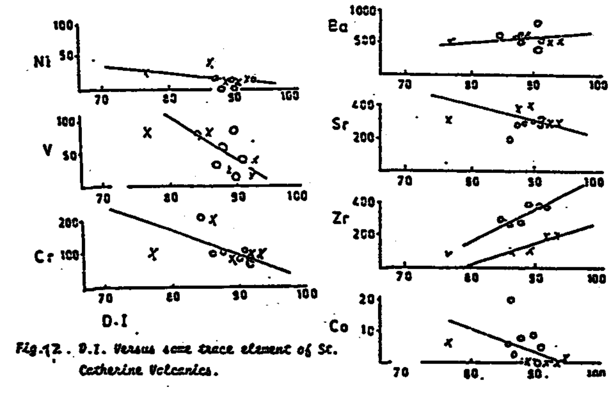

Fig. 12: D.I. Versus some trace element of St. Catherine Volcanics.

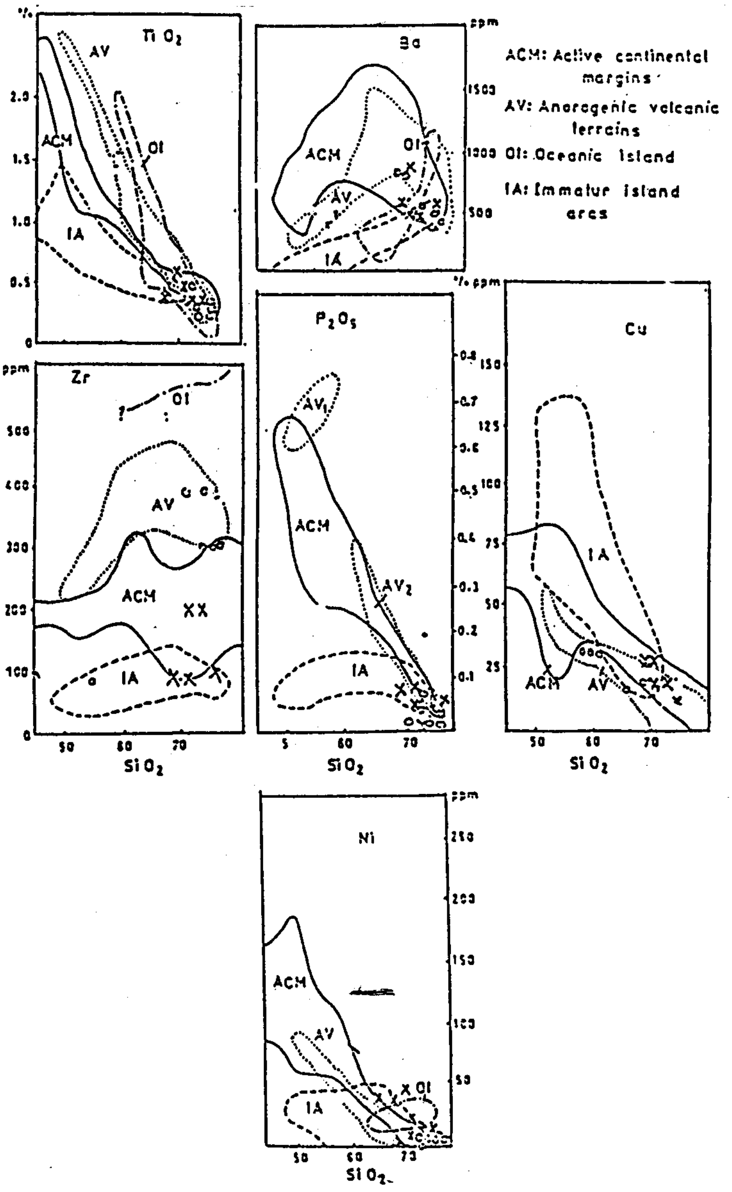

Fig. 13: Abundances of Ti O_2, Zr, P_2O_2, Ba, Ni and Cu in St. Catherine volcanics compared with average fields of magmas from various modern geotectonic environments (defined by Ramsay *et al.* (1981) after Ewart (1979 and 1981).

CONCLUSIONS

Although the average contents of major and trace elements show decrease or increase from the G-II-granites to the G-III-granites, yet it is not possible to relate the varieties of the two types, collectively, to one differentiation trend. Accordingly both granitic types are derived from different sources at different tectonic environments. The plots of the rift-related volcanics (RV) reveal trends always parallel to those observed for the examined G-III-granites.

The geochemical criteria strongly suggest the island-arc setting for the SV-volcanics, and compressional environment for the emplacement of the calc-alkaline (G-II-) granites (mostly suture related) while the most reasonable tectonic setting for the RV-volcanics and the alkaline (G-III-) granite is that of anorgenic or within plate.

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