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GEOLOGIC SETTING OF THE ST. CATHERINE BASEMENT ROCKS, SINAI, EGYPT

By

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الوضع الجيولوجي لصخور الأساس في سانت كاترين سيناء ـ مصر

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تغطي صخور القاعدة منطقة سانت كاترين (٩٠٠كم٢) . وتشمل هذه الصخور الرسوبيات القارية المتحولة في نطاق الحزام الجزري والرسوبيات المتحولة القديمة والصخور البركانية (أ س في) ، الجرانيت الكالس قلوي (جـ٢) ، الصخور البركانية (ارفي) والجرانيت (جـ٣) . وتكون الصخور البركانية (ارفي) والجرانيت (جـ٣) معقد حلقي بيضاوي الشكل غير كامل . ولقد تكونت الصخور البركانية (ا س في) ، الجرانيت (جـ٢) في بيئات جزر قوسية بينما تكون الجرانيت (جـ٣) والصخور البركانية (ارفي) خلال الألواح .

ولقد تكون معقد سانت كاترين الحلقي لطفح البازلت القلوي خلال صدع دائري ثم تلا ذلك طفح الرايوليت القلوي حيث تمت عملية تمثيل بينهما كونت صخور مماثلة للسيانيت في الجزء الجنوبي اما الجزء الشمالي فيتكون من السيانيت الأحمر الذي قطع بالجرانيت (جـ٣) فيما بعد .

Key Words: St. Catherine, Ring Complex, Volcanic Activity, Syenite-granite Magmatism

ABSTRACT

St. Catherine area, some 900 km in size, is dominated by basement rocks Encompassing old continental gneisses, metasediments, greenstone belt, calc-alkaline granites (G-II-granites), rift-related volcanics (RV), and anorogenic within plate granites (G-III-granites). The greenstone belt is composed of subduction-related volcanics (SV) intercalated with metasediments. These volcanics split into older group (moderately metamorphosed) and younger group (slightly metamorphosed). The calc-alkaline granites were formed during collision and partial melting of the lower crust. Probably mantle materials were incorporated in the melt.

The rift-related volcanics (RV), and the anorogenic granites form, in the central part of St. Catherine, an incomplete ring massif intruded by a granitic belt of younger age. The igneous activity and the structural development are related in space and time. The first event was the formation of the southern part of the ring fault along which alkalibasalts were erupted (rift-related old volcanics). This phase was followed by the eruption of alkalirhyolites and ignimbrites (rift-related young volcanics). Wide assimilation processes occurred where the alkalibasalts are converted into a black syenitoid rock. This later volcanic phase was the surface expression of an alkaline syenite-granite magmatism. The earlier member of these alkaline plutonites was alkalie-red syenite emplaced along the progressively formed northern part, of the ring fault. Crustal melting then increased and acidic members of red-granite, leuco-granite, and granophyric granite were successively emplaced, crossing the ring massif. These alkaline granitoids are anorogenic plutonites formed during hot spot and incipient rifting mechanism.

INTRODUCTION

St. Catherine province constitutes a part of the Precambrian Basement Complex of Southern Sinai (Fig. 1). Topographically, the area is mountainous, with 24 conspicuous peaks, the highest of which is Catherine peak (2637 m above sea level). The principle Wadis crossing the area run more or less in N-S, and E-W directions and drain to the Gulf of Suez and Gulf of Aqaba.

The area was early described by Barron (1907) who mentioned that pink granite is seen to occupy the whole of the country. Barthoux (1922), recorded abundant aplite dykes near the monastery. Hume (1934) described Feiran gneisses with intercalated less metamorphosed sediments, diorites intruding the gneisses, Feiran volcanics, riebeckite granite in Gabal

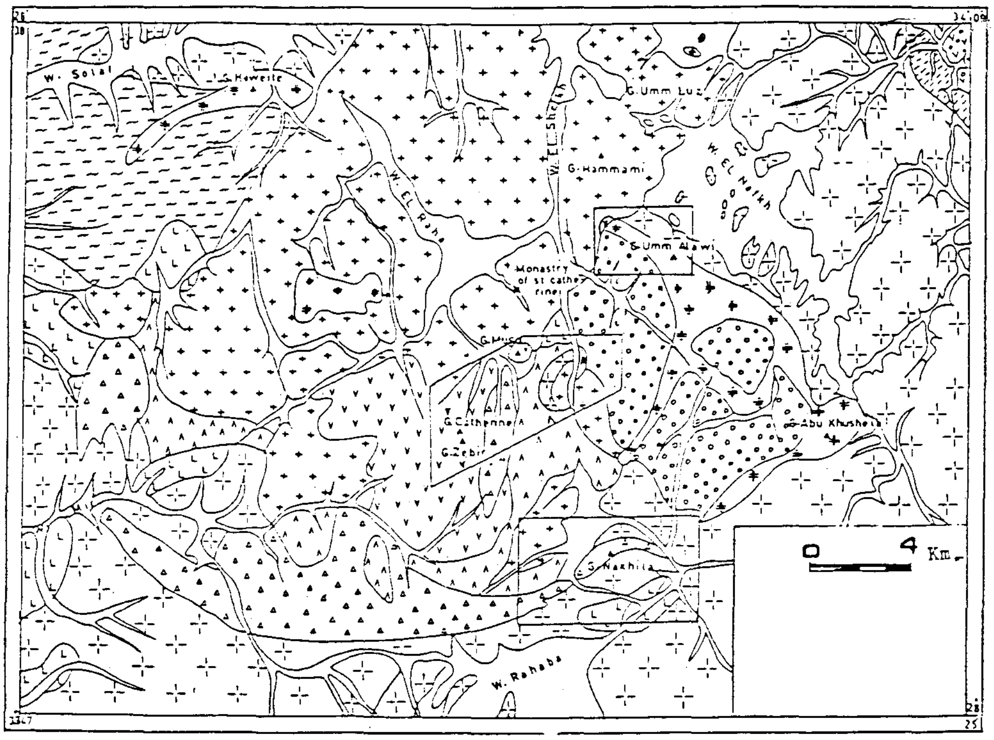
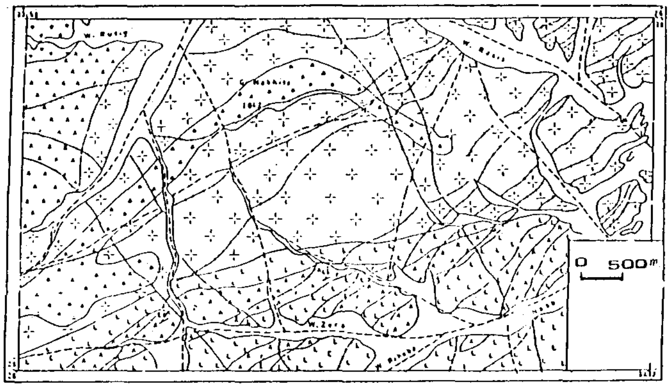


Fig. 1: Generalized geological map of St. Catherine area



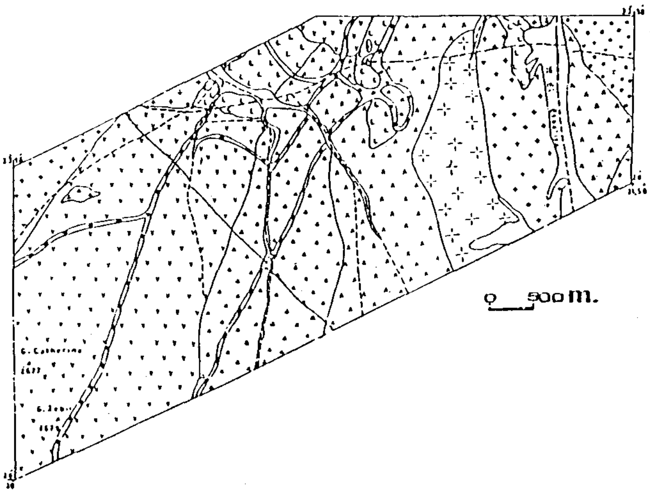


Fig. 2: Geological map of Gobal Nakhila area.

Fig. 3: Geological map of Gobal Catherine area

Musa, and two periods of dolerite dykes. The Feiran metamorphites were considered by Andrew (1938) as partly ortho-and partly para-gneisses. The investigations of Akaad (1959) and Akaad *et al.*, (1967) reveal that the Feiran gneisses suffered two stages of sodic metamorphism. El Shazly *et al.* (1964) constructed a geologic map of Sinai, from ERTS-1 satellite images, on which the Saint Catherine area is covered by geosynclinal sediments, and post orogenic plutonites.

Bogoch (1977) studied the Feiran gneisses and stated that they are of sedimentary origin. El-Gaby and Ahmed (1980) investigated the Feiran gneisses and Concluded that they represent a thick sedimentary succession with minor basic magmatic intercalations, that were folded into three anticlines, thrusted and metamorphosed into gneisses and migmatites and classified them into five formations. Shimron (1980) signifies a major ring dyke complex with central volcanic pile (caldera?) in St. Catherine. Henry *et al.* (1986) compiled a map on the scale 1:500,000 from Landsat satellite Imagery based on reflectance property. On this map, Saint Catherine area is covered by granodiorites, granites, volcanics, and metasediments. Mollat (1986) applied the thematic mapper imagery on the southern part of Sinai which includes St. Catherine area. The following colours are assigned, brown yellow (hornblende-alkali-granite), light lavender blue (diorite to granodiorite), olive green (Volcanics around the Monastery, composed of quartz-porphyrite, and rhyolite), and reddish brown (gneisses and schist).

GEOLOGY

Field mapping of St. Catherine area on the scale 1:40,000 is shown in Figure 1. Three selected segments were chosen for detailed mapping on the scale 1:10,000 (Figs. 2, 3 and 4). Field work reveals that the area is dominated by basement rocks lithostratigraphically arranged as follows:

IV. Incipient Rifting (Catherine ring complex)	IVB. Within plate syenite-granite spectrum (G-III-granites)	1. Granophyric granite 2. Leucocratic granite 3. Red granite 4. Syenites
	IVA. Rifting-related volcanics	1. (RYV) Rifting-related younger volcanics 2. (ROV) Rifting-related older volcanics
III. Suture-related plutonites	Calc-alkaline granites (G-II)	3. Quartz-monzonite 2. Granodiorite 1. Quartz-diorite
II. Island-arc mechanism	Greenstone belt	3. (SYV) Subduction-related younger volcanics 2. (SOV) Subduction-related older volcanics 1. Metasediments and conglomerates.
I. Craton	Old continental metasediments	Gneisses and schistose metasedimentary rocks

I. OLD CONTINENTAL METASEDIMENTS

These rocks form a part of the Feiran-Solaf gneiss belt which lies in the south western part of Sinai, stretching NW-SE for about 40 km. They are dark grey buff, banded with augens, crenulations and displacement of bands. The rocks show minor folding related to the major Solaf anticlinal fold plunging NE, described by El Gaby, and Ahmed (1980). Gneisses are intercalated and grade into schistose metasediments, and are cut by the G-II-granites, and multitudes of white and pale pink pegmatites. El Gaby and Ahmed (1980) stated that the preserved relics indicate that pelitic sediments were metamorphosed into biotite-gneiss, augen-gneiss and finally into granitic-gneiss.

II. GREENSTONE BELT

The greenstone belt includes metasediments and subduction-related volcanics (SV). The latter comprise two main groups; the moderately metamorphosed older group (SOV), and a younger slightly metamorphosed group (SYV). The first group was described by Shimron (1980) as Sa'al group while the second as Feirani group.

Metasediments

These forms an elongated and moderately elevated belt (3 x 1.5 km) of greenish grey to reddish grey colour. A conglomerate zone 5 to 10 m thick is observed at the base of these metasediments. The conglomerates are grey to reddish in colour, containing abundant pebbles and cobbles, stretched S 50°W in parts, and constitute metasediments and granites embedded in a siliceous matrix. The metasediments are intruded by phases of the (SOV), G-II-granites and dykes. The presence of these conglomerates refers to subaerial or shallow water continental depositional environment.

Subduction-related older volcanics (SOV)

This is a metamorphosed volcanic belt (1x0.3 km) exhibiting the mineral assemblage of amphibolite facies, overlying the metasediments and are of grey to reddish grey colour, porphyritic, and banded. Stern (1981) added the prefix old to the comparable meta-volcanics in the Eastern Desert of Egypt. He mentioned that these old meta-volcanics (OMV) are succeeded by a series of dominantly volcanogenic sediments, especially tuffaceous sandstones and breccias.

Subduction-related younger volcanics (SYV)

These are slightly metamorphosed volcanics showing the mineral assemblage of the green schist facies. Thickness reaches 200 m. and volcanic sheets strike N-S and dip 40 to 50 due W. They are strongly porphyritic. The SYV are intruded by the G-II, and the G-III-granites. The eruption of these volcanics and the deposition of the associated sediments are both cyclic. The SYV are comparable to the Dokhan volcanics in the Eastern Desert, which are calc-alkalic with mild tholeiitic tendency and represent a well developed island-arc with a thick continental crust (Basta, *et al.*, 1980). Stern *et al.* (1984) gave the term (YMV) for them (younger metavolcanics) and stated that they are a thick sequence of slightly metamorphosed (lower greenschist facies) intermediate to felsic volcanics.

The examined volcanic pile contains dominantly pyroclastics. According to Rittmann (1960), pyroclastics are more abundant in volcanic rocks of Island arcs and continental arcs than those from oceanic islands and ocean basins. Garcia (1978) stated that volcanic arcs are the suite of explosive activity, while volcanism in mid oceanic ridges and oceanic islands are mainly effusive with only minor fragmental deposits.

III. CALC-ALKALINE GRANITES (G-II-GRANITES)

A group of calcalkaline granites exhibiting the field characteristics of those described by Hussein *et al* (1982) as G-II-granites, covers a wide area in Saint Catherine, and includes quartz-diorite, granodiorite, and quartz monzonite (Fig. 1).

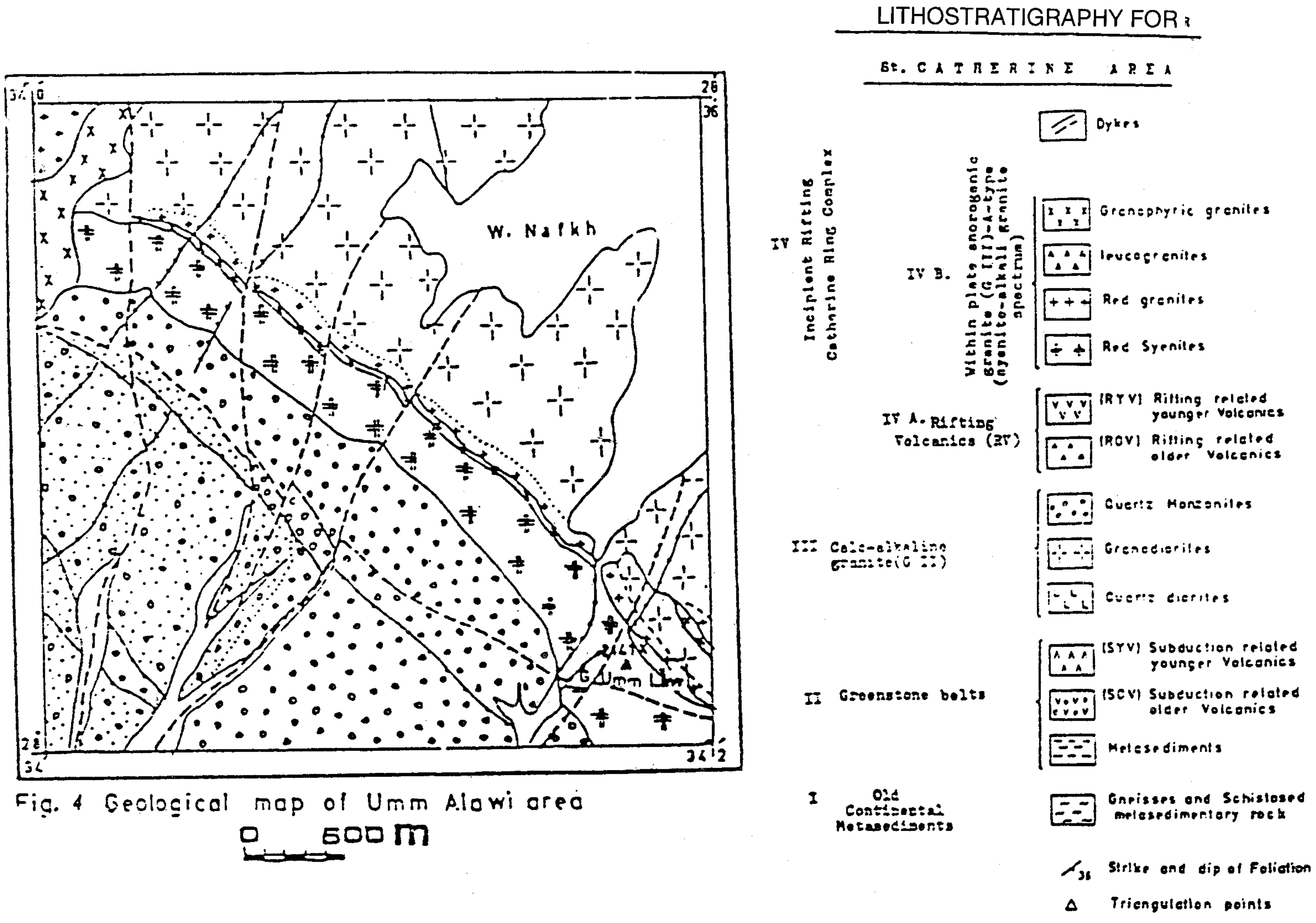


Fig. 4 Geological map of Umm Alawi area

Quartz-diorite occurs as an elevated oval shaped mass (1-3 km). It is greenish-grey, speckled with black dots (mafics) and exhibits onion weathering (0.5 - 1 m across). It intrudes the (SYV) Figure 2, and are intruded by the granodiorite (Fig. 1). Under the microscope, their plagioclases exhibit oscillatory zoning where the successive zones are not parallel to each other indicating mechanical movements during crystal-liquid equilibrium conditions (Fig. 5).

Granodiorite, the main dominant type recorded, is of light grey to pink colour, highly joined and forms characteristic boulders (1-2 m across). The different varieties of the granodiorite hold moderately assimilated rounded to subrounded basic xenoliths (10 to 15 cm across). Along Wadi El Riqueita and El Rasis they carry Cu-minerals associated with milky quartz veins, ranging in thickness from 0.5 to 1 m. The granodiorite is intruded by the quartz-monzonite.

Quartz-monzonite covers 35 km^2 and is grey, porphyritic, xenolithic (xenoliths are 5 to 30 cm across) and of lower relief with characteristic boulders due to weathering. It is traversed by the syenites and the red-granite of the G-III-group and intrudes the granodiorite (Fig. 1). Under the microscope microcline plates contain areas of orthoclase, still unconverted into microcline (Fig. 6).

IV. THE ST. CATHERINE RING COMPLEX

The ring complex of St. Catherine is a major ring structure, located in the central part of the southern Sinai. It is 28 km. In diameter and varies in width from 1 to 5 km., with the highest peak rising up to 2455m above sea level. The southern part of the ring massif is composed of black volcanic rocks (assimilated alkalibasalt), incorporated as xenoliths in the red alkalirhyolites, and syenites (Fig. 3), while the northern part of the ring massif consists only of syenite (Fig. 1).

The events of formation of this ring complex commenced with the eruption of alkalibasalt, while the rifting movement affected the area. This eruption took place along a major semicircular ring fault roughly oriented E-W at the southern part of the ring. Example of these eruption is that of Kibran described by Shimron (1980) as eruptions on E-W rift faults. As these earlier eruptions are related to rifting the name rifting related old volcanics and the symbol (ROV) are assigned to them. Bowden (1974) and Baily (1974) have suggested that periods of little or no horizontal plate displacement give rise to the formation of deep fracture which permit passive emplacement of mantle derived alkali magma. This basic magma is thought to provide the heat necessary for lower crustal anatoxis. A second phase of volcanic activity which yielded rhyolites, alkalirhyolites and rhyolitic ignimbrites was extruded along the same structural plane. The name rifting related younger volcanics and the symbol (RYV) is assigned to them. A notable reaction, assimilation, and digestion between the ascending alkalirhyolites and the engulfed alkalibasalts resulted in the formation of compositional shades of black syenitoid rock. These assimilated rocks still preserve their original black colour, and their primary folded banded structures (Fig. 7). The black alkalibasalts (ROV) intrude the subduction related younger volcanics (the SYV) at the northern part and the G-II-granites from the south and west, and are intruded by alkali-granite and syenites.

Microscopically, these rocks are porphyritic with phenocrysts of plagioclase, alkalifeldspar, and augite embedded in fine-grained black matrix. The plagioclase is calcic (labradorite, An_{60-70}), Figure 8. The porphyritic orthoclase crystals are surrounded by marginal parts representing progressively formed new zones (Fig. 9). In places, the newly formed orthoclase material crystallizes in the intervening areas between the mineral components, and captures them in a seemingly poikilitic texture (Fig. 10). Biotite is recorded forming flakes interstitially disposed between the plagioclase and augite crystals. Augite is converted into hornblende, rimmed by secondary biotite (Fig. 11). In some places, the amount of quartz notably increases where porphyritic quartz crystals are clearly seen and the rock approaches the composition of the quartz-syenite. In fact the term syenite is generally applied to a rock with dominant potash feldspar and less dominant mafic constituent. A rock of such composition would never be black unless the feldspar constituents are highly transparent like those syenites present in Greenland, where feldspars are highly translucent and even transparent and the rock attains the dark colour exhibited by its mafic content (Escher, and Stuart, 1976) which is not the case at St. Catherine. The resemblance in composition between these black rocks and syenite is the direct result of assimilation and metasomatic alterations which developed quartz, orthoclase, and biotite crystals in addition to the original black volcanic groundmass, the calcic plgioclase, and the augite.

The (RYV) occupy 40 km^2 at the central part of the Saint Catherine batholith. Bentor (1985) considered them as part of the younger volcanic series of the Arabo Nubian massif. The colour of these rocks is buff with black porphyritic riebeckite crystals. The volcanic pile reaches more than 1 km thickness with volcanic sheets dipping 20° to 30° due west. They engulf xenoliths of the (ROV) and are traversed by the G-III-granites. Columnar jointing (Fig. 12) is observed. The basal part of the (RYV) is occupied by a zone of conglomerates from 5 to 20 meters thick, and are generally of greenish grey colour and contain abundant pebbles and boulders (up to 90 cm across) from the underlying (SYV). The pebbles and the boulders are stretched in places where shear zones are recorded (Fig. 13). The general elongation is N 50° E. (RYV) are identified as formed of rhyolites and ignimberites.

Rhyolites are composed of quartz, and potash feldspar phenocrysts set in a quartzo-feldspathic groundmass containing riebeckite. Quartz phenocrysts are usually corroded and contain ovoidal quartzo-feldspathic blebs of the groundmass. Potash feldspars occur as perthite and less commonly as orthoclase. Perthite shows string-, ribbon-, and compound-types with Baveno twinning (Fig. 14 and 15), and is occasionally corroded against the groundmass. Plagioclase is less abundant and is albite-oligoclase (An_{8-16}). Riebeckite forms prismatic crystals as well as aggregates in the groundmass (Fig. 16).

Ignimbrites are intimately associated with alkalirhyolites and have wide range of size, exhibiting black clots of glassy material standing against black brownish matrix, characterized by the presence of flattened lenticular clots of dense glass (Fiamme).

Microscopically, the rock is vitrophyric, essentially composed of unsorted mixture of rock-, and crystal-fragments enclosed in glassy materials with perlitic texture. Rock fragments are rhyolites, while crystal fragments are K-feldspars, plagioclase, quartz, and ferromagnesians. They are broken due to explosive impact during turbulent motion at the surface. Crystals are rounded or irregular, embayed by the groundmass indicating high temperature conditions. They are commonly fractured due to strain set by contraction on cooling of the groundmass. Fiammes are observed in the groundmass. Fiammes are lenticular, not uncommonly curvlinear with crenulated margins. Crystals and rock fragments cause divergence and bending of the fiammes around them. This observation indicates plastic flow conditions. Fiammes are composed of two well defined zones distinguished from each other by slight differences in colour and degree of devitrification.

The eruption of the (RYV) was the surface expression of a syenite-granite magmatism. The earlier phase of this syenite-granite spectrum (syenites) was emplaced along the progressively developed ring structure (the northern part of the ring). The earlier member, the syenite is intruded by the later members, which form a mass crossing the ring in a NE-SW direction. The syenite-granite spectrum which is the plutonic expression of the crustal anatexis is named here collectively as G-III-granites or anorogenic within plate granites and have been found to constitute syenite, red-granite, leucocratic granite, and granophyric granite. The syenites form the northern ring massif and part of the southern massif with highest peak rising to 1867 m., in addition to occurrences in the southern part of the ring massif and in the central part intruding through the G-II-granites. Syenites are coarse-grained, porphyritic, with buff colour carrying xenoliths of the (ROV). They intrude the (RYV) and are invaded by red-, and granophyric-granites.

The red-granites form a pink to red belt 240 km^2 in area extending in NE-SW direction. They form conspicuous topographic features rising up to 2005 m above sea level. The mass exhibits hollow weathering and cavities (Fig. 17) and is dissected into blocks by several faults and intersecting systems of joints (Fig. 18), along which some quartz veins occur. Red-granites intrude the (SOV), granodiorites, quartz-monzonites Figure 1, (RYV) Figure 3 and are poorly traversed by dykes. A phenomenon which may indicates a younger age for the red-granites. Under the microscope, replacement by secondary albite is observed in the perthite plates where patch perthite is developed (Fig. 19). Vein like perthite and embayments of secondary albite are also recorded (Fig. 20). Perthite plates are twinned according to the Carlsbad law (Fig. 21) which refers to crystal-liquid equilibrium conditions (Wallace, 1956).

The leucogranites (Fig. 3) are white to yellowish white of equigranular texture, showing the same field relations as the red-granites. They are believed to be formed by metasomatic alterations of the host red granites. Always they associate the red granites and show gradational metasomatic contacts with them (Fig. 22). These rocks are similar in features to those recorded in the alkaline white granite (apogranites), Igla El Ahmar area, Eastern Desert, by Abdel Makasoud and Khalaf (1988). Eyal *et al.,* (1980) noticed the phenomenon of metasomatism in St. Catherine, applied it into the whole area and divide it into 3 distinct petrographic zones (A, B and C). Zone A is the original intrusive rock while zone B is the product of the reaction of alkaline rich solution and zone C is transitional. Soliman (1985) mentioned that albitization is related to magmatic and/or post-magmatic processes. In the early stages, the granitic mineral assemblages are highly replaced by albite, while the original texture is well preserved. In an advanced stage, the rock forming minerals are largely replaced by albite resulting in the development of albite and quartz.

The granophyric granites (Fig. 4) are of red and buff colours, forming dyke-like masses, reaching in length up to 5 km and up to 0.1 km in width. The granophyric granites intrude the granodiorites, quartz-monzonites, and the red granites (Fig. 23). Quartz in the granophyric granites frequently reacts with the alkalifeldspar plates forming graphic texture at their boundaries (Fig. 24). Two phases of perthite are recorded where the newly formed phase replaces the older one, forming embayments. Secondary albitization is also recorded in the granophyric granites with replacement patch-perthite, hair-pherthite (Fig. 25), and two sets of parallel spinifex quartz interesecting at an angle (Fig. 26) are recorded.

MODAL ANALYSES OF SAINT CATHERINE GRANITES

Modal data of the examined granites are shown in table 1. Using the classificational diagrams of the IUGS (1973), and Streckeisen (1976) figures 27a and 27b, the G-II-type is shown to comprise quartz-diorites, granodiorites, and quartz-monzonites, while the G-III-type comprises quartz-syenite, granites, and alkalifeldspar-granites. In addition the G-III-granites plot in the field of the A-type (rifting-related granites) on the diagram, of Lameyre and Bowden (1982), Figure 27c.

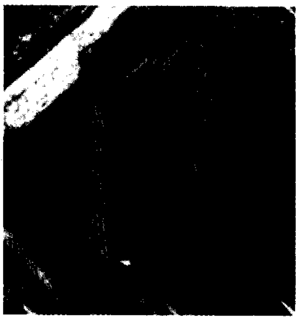
CONCLUSIONS

In Saint Catherine, an old cratonic mass consisting of gneisses and metasediments was subjected to collision with an oceanic crust where volcanics related to subduction mechanism were erupted during two main episodes. The abbreviations; SOV for subduction-related old volcanics (moderately metamorphosed) and SYV for the young episode (slightly metamorphosed) are advanced. The dominant rock variety is mostly rhyolite where the volcanics forming the arc have the opportunity to differentiate during passing through a thick continental crust and to be mixed with crustal materials.

Partial melting of the lower crust probably with some additional material from the mantle produced a multiphased granitic mass where quartz-diorite, granodiorite, and quartz-monzonite were emplaced successively. The copper mineralization (at El Riqeita) has shown to be, geochemically unrelated to the host granodiorite.

The development of the major ring complex of Catherine commenced by large scale rifting accompanied with alkalibaslt eruption which is named by the present authors as rift-related old volcanics (ROV). Bowden (1974) mentioned that anorogenic magmatism coincides with periods of little or no horizontal plate displacement where continental crustal extension gives rise to the development of deep fractures which permit passive emplacement of mantle derived alkalibasaltic magma. The southern part of the ring was firstly developed and constitutes the main fracture zone, favourable for the ascent of the firstly formed magma phase, related to rifting (the alkalibasalt). Subsequent phase of alkalirhyolite and ignimberites was extruded. The name rift-related young volcanics is assigned to them (RYV). According to Condie (1975) later volcanic members, related to rifting, show enrichment in alkalies with high SiO_2-content and alkalirhyolites are highly expected. The eruption of the (RYV) took place along the same structural planes.

Wide assimilation occurred between the earlier waves of the alkalirhyolites (gaseous phase enriched in alkalies) and the alkalibasalt (the ROV). Concerning the low melting temperature of the alkalirhyolite with respect to the assimilated alkalibasalt, the process of assimilation has to be mainly through ionic diffusion mechanism, between hot acidic magma and cold basic blocks where complete digestion and oblitration of the primary structures are not highly expected. Primary folds and Wrinkles of the black (ROV) lava are partially preserved in the red alkalirhyolite host. The metasomatism has converts the bulk of the ROV into a rock resembling quartz-syenite in composition.



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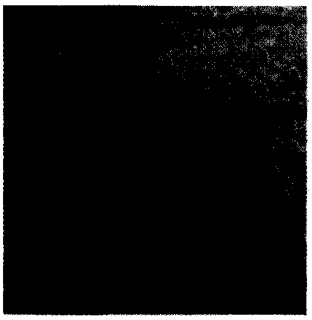

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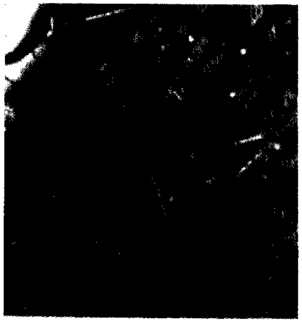

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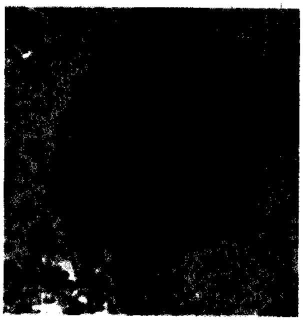

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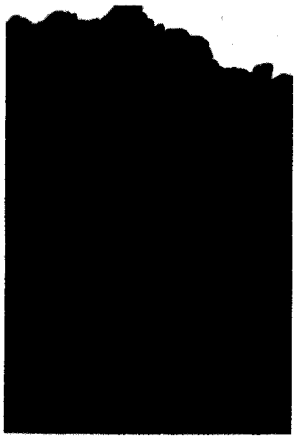

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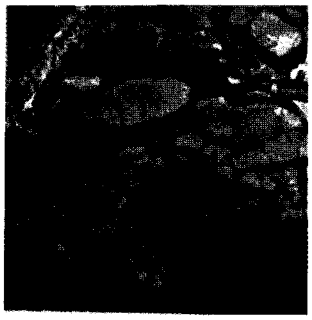

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Fig. 5: Oscillatory zoning in plagioclase. The successive zones are not parallel indicating mechanical movement during crystalization. G-II-granite. C.N., X 70.

Fig. 6: Microcline plate containing areas of orthoclase. G-II-granite. C.N., X 70.

Fig. 7: Primary folded structure of assimilated black volcanics in an alkalirhyolite host.

Fig. 8: Calcic-plagioclase, showing high extinction angle. The ROV. C. N., X 70.

Fig. 9: Porphyritic orthoclase crystal surrounded by a marginal part representing progressively formed new zone. The ROV. C. N., X 70.

Fig. 10: Orthoclase crystallizing in the intervening spaces of the volcanic groundmass. The ROV. C.N., X 70.

Fig. 11: Augite crystal converted into hornblende, rimmed by secondary biotite, the ROV. C. N., X 70.

Fig. 12: Columnar jointing in alkalirhyolites (RYV).

Fig. 13: Volcanic conglomerates at the basal part of the (RYV), showing stretched pebbles and boulders.

Fig. 14: Ribbon-perthite showing Baveno-twining. Rhyolite. C. N., X 70.

Fig. 15: Compound-perthite showing vein-, and string- types. Rhyolite. C. N., X 70.


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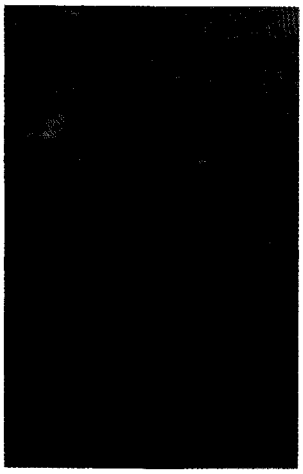
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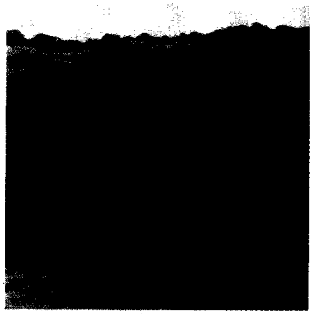
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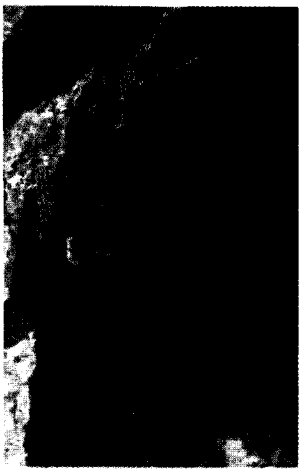
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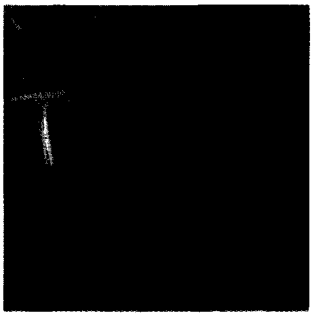
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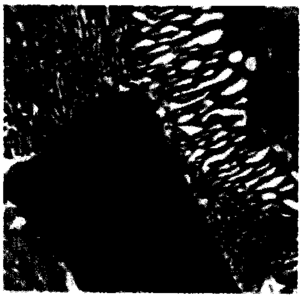
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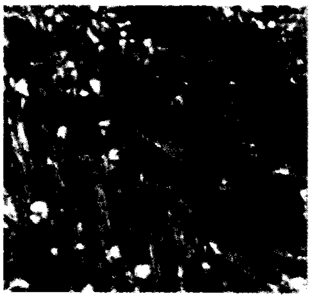
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Fig. 16: Aggregate of the mafic mineral riebeckite. Alkalirhyolite. C. N., X 120.
Fig. 17: Hollow weathering and cavities. G-III-granite.
Fig. 18: Vertical and horizontal joints dissecting the G-III-granite into blocks.
Fig. 19: Perthite plate replaced in parts by albite. G-III-granite. C. N., X 70.
Fig. 20: Perthite plate embayed by secondary albite. G-III-granite. C. N., X 70.
Fig. 21: Perthite crystal twinned according to the Carlsbad law. G-III-granite. C. N., X 70.
Fig. 22: Grdational metasomatic contact between leucocratic - granite and red-granite.
Fig. 23: Granophyric-granite intruding red-granite.
Fig. 24: Graphic texture in the granophyric-granite. C. N., X 70.
Fig. 25: Hair-like perthite. Granophyric-granite. C. N., X 70.
Fig. 26: Two sets of parallel spinifex quartz interesecting at angle. Granophyric-granite. C. N., X 70.

Table 1
Modal analyses of St. Catherine plutonic rocks

Rock type	Sample No.	Quartz	alk-felspar	Plagioclase feldspar	Hornblende	Biotite	Accessories	C. I.	Mafics	Symbol used for plotting
Quartz diorita	1	10.08	-	59.67	23.70	5.07	1.48	10.25	20.77	Δ
	2	11.18	4.97	62.36	18.51	6.24	1.74	21.49	19.75	
	aver.	10.63	2.47	61.02	18.61	5.66	1.61	25.88	24.27	
Granodiorite	3	21.98	18.17	45.59	3.12	8.60	2.54	14.26	11.72	□
	4	21.33	15.79	44.54	7.10	9.51	1.73	18.34	16.61	
	5	22.20	19.50	53.19	1.20	3.15	0.76	5.11	4.35	
	6	20.12	16.21	51.28	2.33	4.35	5.71	12.39	6.68	
	aver.	21.41	17.42	48.65	3.43	6.40	2.69	12.52	9.83	
Quartz Monzonite	7	16.24	44.98	28.14	3.19	6.01	1.44	10.64	9.20	▲
	8	19.64	45.41	26.33	1.95	4.63	2.04	8.62	6.58	
	9	16.71	43.78	25.33	2.11	8.06	4.01	11.18	10.17	
	10	15.32	47.73	29.66	2.21	4.01	1.07	7.29	6.22	
	aver.	19.96	45.48	27.37	2.37	5.68	2.14	10.19	8.05	
Quartz Syenite	11	12.99	63.99	16.63	-	4.51	1.88	6.39	4.51	+
	12	10.80	64.88	17.10	5.58	-	1.64	7.22	5.58	
	13	11.40	63.6	15.92	-	7.02	2.06	9.00	7.02	
	14	12.40	61.15	17.90	-	6.80	1.75	8.55	6.80	
	aver.	11.90	63.41	16.89	1.40	4.58	1.82	7.80	5.98	
Biotite Cranite	15	45.82	46.19	2.16	-	5.15	0.68	5.83	5.15	▬
	16	44.24	49.36	3.53	-	2.56	0.31	2.87	2.56	
	17	40.49	46.69	3.82	-	6.59	2.41	9.00	6.59	
	aver.	43.52	47.41	3.17	-	4.77	1.13	5.90	4.77	
Adamellite	18	23.03	26.11	39.95	-	10.79	0.12	10.91	10.79	○
	19	20.28	25.71	40.46	-	11.05	2.5	13.55	11.05	
	aver.	21.65	25.91	40.21	-	10.92	1.31	12.23	10.92	
Leucogranite	20	39.74	41.78	14.53	-	-	3.05	3.95	-	•
	21	40.88	43.26	13.63	-	-	2.23	2.23	-	
	22	39.32	44.28	12.20	-	-	4.20	4.20	-	
	23	40.51	43.10	15.34	-	-	1.05	1.05	-	
	aver.	40.11	43.11	13.92	-	-	2.86	2.86	-	
Granophyric Granite	24	25.2	44.30	21.02	5.03	3.4	1.05	9.48	8.43	X
	25	24.52	45.31	20.04	3.10	4.81	2.22	10.13	7.01	
	26	26.68	43.3	22.01	2.10	5.30	0.01	7.41	7.40	
	aver.	25.47	44.5	21.02	3.41	4.51	1.09	9.01	7.92	

The eruption of the (RYV) was the surface expression of the syenite-granite magmatism. the earlier phase of this syenite-granite specturm (syenite) was emplaced along the progressively developed ring structure (northern part of the ring). The earlier member, the syenite is intruded by the later members, which form a mass crossing the ring in a NE-SW direction. The syenite-granite spectrum which is the plutonic expression of the crustal anatexis is named here collectively as G-III-granites or anarogenic within plate granite and have been found to constitute syenite, leucocratic-granite, and granophyric-granite.

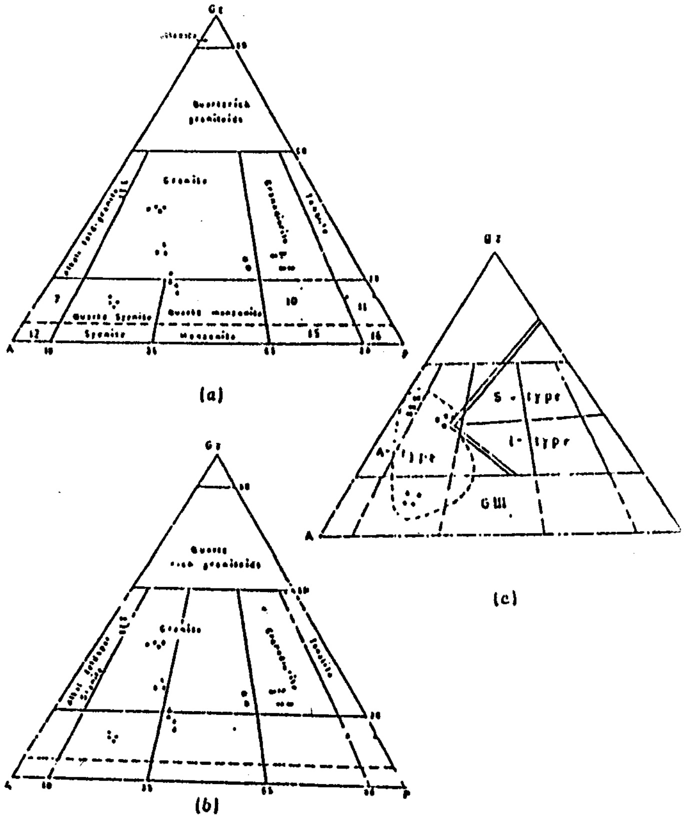

Fig. 27: The plot of Modal data of Saint Catherine plutonites on the Q-A-P diagrams of the IUGS, 1973 (a), Streckeisen, 1976 (b), and Lameyrl and Bowden, 1902 (c).

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