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Petrogenesis of the Alkaline Basalts, West Shalatein, Egypt: Evidence from Clinopyroxene Chemistry

Abstract: The Paleogene volcanic and subvolcanic alkaline basalt rocks of the west Shalatein comprise mainly Olivine-rich and olivine dolerite and/or basalt and normal basalt. The pyroxenes of the ultrabasic and basic rocks follow the augite-diopside-hedenbergite fractionation trend which is significant for the undersaturated rock suites with low silica activity.

The studied basalts are characterized by the presence of very peculiar zoned clinopyroxenes of megacrysts and groundmass grains. This pyroxene exhibit a clear decrease of Si, Mg, Ca and Cr from cores to rims. The Ti and Al content increases in pyroxenes with crystallization, but the coprecipitation of other Ti- and Al-bearing phases deplete the pyroxenes of outer rims as well as the groundmass in these elements in the later stage of fractionation. The incorporation of both Ti and Al into the pyroxene lattice is indicative of non-equilibrium crystallization (e.g. sector zoning).

The clinopyroxenes exhibit a trend of fractionation analogous to that of the non-orogenic, intraplate-type basalts from undersaturated alkaline suites. Cr-bearing cores of clinopyroxene reveal that the present basalt were derived from deep-seated mantle source magma under early high pressure and low fO_2 conditions.

Keywords: Egypt, West Shalatein, Basalts, Petrogenesis, Chemistry, Clinopyroxene.

Introduction

The basaltic rocks of West Shalatein (about 20 km²), on the Red Sea coastal plain (Fig. 1) are part of the Paleogene volcanic and subvolcanic rocks of Egypt. They consist of olivine-rich and/or olivine dolerites to olivine and/or normal basalts that erupted during Middle Eocene and re-activated in Late Oligocene (Abdel-Karim, in prep.).

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النشأة الصخرية للبازلت القلوي بغرب شلاتين بمصر :

دلائل من كيميائية البيروكسين المائل

عبدالعال محمد عبدالكريم و جابور دوشي

المستخلص: تصنف الصخور البركانية بمنطقة غرب شلاتين، بجنوب الصحراء الشرقية المصرية بانها تابعة لحقب الباليوجين، تتضمن هذه الصخور الدوليرايت والبازلت الأوليفيني أو الغنثيني فيه مع البازلت العادي . وتتميز هذه الصخور بوجود بلورات بوفيرية كبيرة تنطقية وأخرى صغيرة مغموسة في الأرضية من معدن البيروكسين المائل . ويهدف البحث الحالي أساسا إلى إستخدام 27 تحليل كيميائي بطريقة الميكروبروب الثاقب لمعدن البيروكسين المائل في دراسة نشأة هذه الصخور .

وقد أثبتت الدراسة التفصيلية للبيروكسين المائل، أن هذه الصخور تتبع تمايز سلسلة معادن الأوجايت ، دايبسايد ، هيدنبرجايت، المميزة للصخور الغير مشبعة السيليكا . كما تتميز بلورات هذا البيروكسين بنقص واضح في عناصر السيليكون والماغنسيوم والكالسيوم والكروميوم يتدرج من مركزها إلى الحواف . وتزيد نسب كل من التيتانيوم والألمنيوم مع زيادة عملية التبلر، مما يؤدي إلى نقص ترسيب الأطوار الحاملة لهذين العنصرين في المراحل النهائية للحواف الخارجية للبلورات البوفيرية وبلورات الأرضية في أثناء مراحل التمايز النهائية . ويمكن الإستدلال على عملية التبلر الغير متوازنة هذه، بعملية ملئ كل من التيتانيوم والألمنيوم للفراغات البلورية للبيروكسين والتي تظهر في صورة تنطق قطاعي مسنن في هذه البلورات .

كما دلت الدراسة على ان هذا البيروكسين يشبه بيروكسين الصخور البازلتية القلوية الغير مشبعة المتكونة داخل الألواح غير المصاحبة للحركات الأوروجينية . وتشير مراكز البلورات الحاملة لعنصر الكروميوم لهذا البيروكسين أن صخور البازلت الحاوية له قد إشتقت من مصدر عميق للصهير يقع في وشاح الأرض ، وأن هذا المصدر قد تميز في بادية تكونه بحالات من الضغط العالي وهروب منخفض للأكسجين .

كلمات مدخلة: مصر ، غرب شلاتين ، بازلت قلوي ، النشأة الصخرية ، كيمياء ، البيروكسين المائل.

Detailed investigations of the crystal chemistry of the pyroxenes in conjunction with experimental studies recognized their importance as petrogenetic indicators of the bulk chemistry, fO_2 , mineral paragenesis and cooling rate of their host rocks (Cameron and Papike, 1981). They also elucidate the composition of calcic pyroxenes from basalts belonging to different tectonic settings (Nisbet and Pearce, 1977; Leterrier *et al.*, 1982).

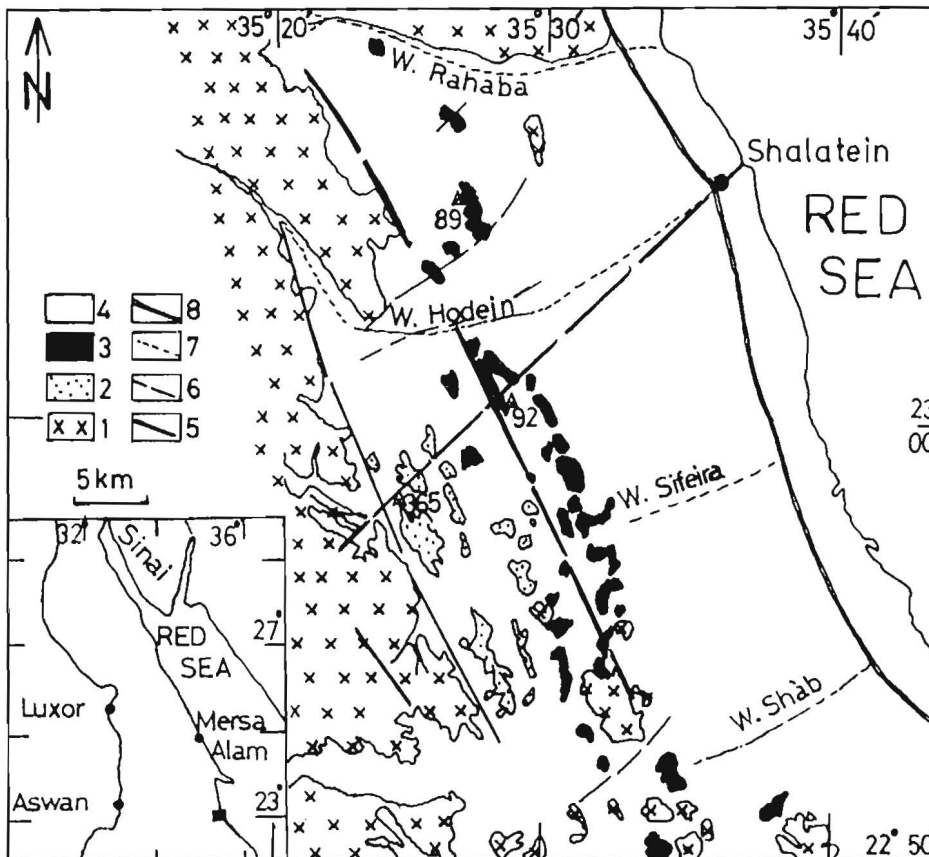


Fig. 1: Location map of the alkaline basalts of west Shalatein, south Eastern Desert, Egypt. 1=basement rocks, 2=Wadi deposits, 3=major faults, 4=Asphaltic road.

The present study contributes to use of clinopyroxenes in the petrogenesis of basaltic rocks from West Shalatein in order to follow the course of fractionation and its implication on the nature of the melt and the tectonic setting of the host rocks. The use of clinopyroxenes as indicators in the Egyptian volcanics was presented and discussed by some workers (e.g., Basta and Hafez, 1985; Abdel-Kader, 1995; Hafez and Abdou, 1989; Sourour, 1997).

Twenty seven chemical analyses for zoned clinopyroxenes were determined using JEOL Superprobe 733 microprobe under operating conditions of 15 kv accelerating voltage and 36 nA beam current with natural and synthetic standards correlation on-line 2AF program.

Petrography

Microscopic investigation of the Tertiary basalts of the west Shalatein indicates that they are mostly olivine-rich, olivine- and normal basalts and/or dolerites. They generally have a holocrystalline porphyritic texture with euhedral olivine,

clinopyroxene, plagioclase and opaques. These minerals occur as glomerophytic or seriate clusters of an individual mineral or group of the minerals. The groundmass consists of a plexus of plagioclase laths, clinopyroxene and olivine granules, small stumpy prisms and granules of Fe-Ti oxides, nepheline, apatite and interstitial analcime and glass. Groundmass textures are variably intergranular, intersertal and hyalopelitic textures.

Olivines are often fresh and zoned, range between $Fo_{87} Fa_{13}$ and $Fo_{56} Fa_{44}$. Plagioclase are zoned from $An_{75} Ab_{25}$ to $An_{16} Ab_{84}$.

Clinopyroxenes are present as megacrysts embedded in a fine-grained groundmass composed of

the other phases together with a finer clinopyroxene generation. They are often zoned (Fig. 2a), but few prismatic megacrysts (1.7x3.5 mm) and fine crystals of the groundmass generation (0.05-0.1 mm) display only cryptic chemical zoning as indicated by the microprobe scans (Fig. 2b, c). Sector zoning in some clinopyroxene megacrysts is rarely recorded (Fig. 2d). Generally, the cores of the zoned clinopyroxene crystals are colourless augite followed by brownish rims of titanaugite forming concentric zoning. Dobosi *et al.* (1991) and Deer *et al.* (1992) mentioned that zoning is very common in Ti-bearing augite of the alkaline volcanics. On the other hand, clinopyroxene from tholeiitic volcanics is usually unzoned, as the case of the Bushveld Igneous Complex in South Africa.



Fig. 2: Compositional type back scattered electron images of the clinopyroxenes. a) Zoned diopside megacryst in olivine basalt, b) Cryptic zoned megacryst of diopside in olivine-rich dolerite, c) Cryptic zoned groundmass grain of hedenbergite, d) Sector zoned megacryst with augitic core and hedenbergitic rim in olivine dolerite.

Pyroxene Chemistry

Results of the electron microprobe of 27 analyses of clinopyroxene from the studied basalts are reported in Table 1. The analyses includes five spots in selected fresh megacryst in olivine-rich

dolerite, three spots in a megacryst in olivine-rich basalt; five spots in a megacryst in each of olivine dolerite, olivine basalt and normal basalt, two spots in a groundmass crystal. In all crystals core, intermediate zone and rim composition were determined for zoned mineral grains.

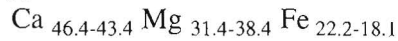
i) Composition and zoning

The clinopyroxene in olivine-rich dolerite and basalt are augite and diopside with the following composition:

The clinopyroxene cores:

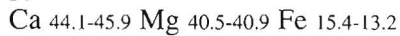


The clinopyroxene rims:

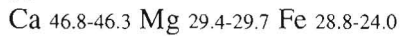


The clinopyroxene in olivine dolerite and basalt are augite and diopside and minor hedenbergite with the following composition:

The clinopyroxene cores:

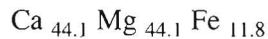


The clinopyroxene rims:

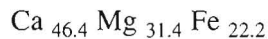


The clinopyroxene in normal basalt are diopside and minor hedenbergite with the following composition:

The clinopyroxene core:

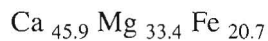


The clinopyroxene rim:

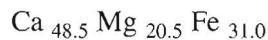


The clinopyroxene of the groundmass is hedenbergite with the following composition:

core:



rim:



The clinopyroxene analyses from all basalt types indicate augitic composition with the increase of the ferrosilite component from cores to rims as a result of relative Fe-enrichment with fractionation. Following the classification after Morimoto (1988), the present clinopyroxenes are diopside with minor augite and hedenbergite (Fig. 3). microprobe traverse in one zoned clinopyroxene megacryst (Fig. 4) shows that liquid enrichment in Fe with the advance of crystallization is also accompanied by the increase of Ti, Al, Mn and Na towards the rims. The titaniferous nature of the rims is obvious from the TiO₂ content (1.00-2.43 wt.%) as compared to those from cores (0.81-1.71 wt%). Clinopyroxene from the groundmass has highest TiO₂ content (3.41-2.71 wt%). In Eastern Desert of

Egypt, Basta and Hafez (1985) and Sourour (1997) reported clinopyroxenes from some Precambrian alkaline volcanics with average TiO₂ contents of 2.58 wt% and 1.82 wt%, respectively.

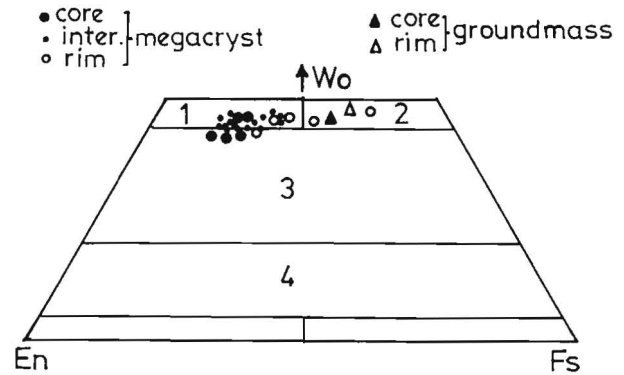


Fig. 3: Classification of analyzed pyroxenes on the En-Wo-Fs diagram of Morimoto (1988). 1=Diopside; 2=Hedenbergite; 3=Augite; 4=Pigeonite

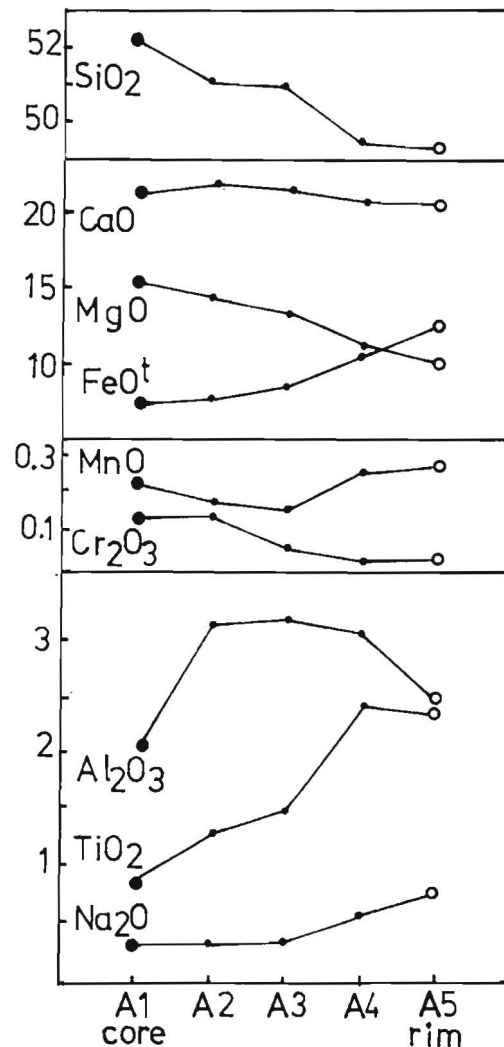


Fig. 4: Microprobe traverse through clinopyroxene megacryst.

Figure 4 exhibits a clear decrease of Si, Mg, Ca and Cr from cores to rims in harmony with their analogy from other alkaline suites (Dobosi, 1987; Embey-Isztin *et al.*, 1993). In the Eastern Desert of Egypt, the same features were recorded from clinopyroxenes of some alkaline rocks from Muhagara and Sheikh Salem volcanics (Basta and Hafez, 1985; Sourour, 1997).

Both megacrysts and groundmass grains can be zoned. Megacrysts generally have a continuous increase of Fe, Ti and Al, and decrease of Si, Mg, and Cr from cores to rims, but discontinuous or reverse changes also occur. Augitic cores are common in the pyroxene megacrysts (Analysis A1, B1, C1) of the present basalts. These cores are dark grey in the backscattered electron images (Fig. 2a, b, c) and are higher in Si, Mg and Cr, and lower in Fe, Ti and Al than the outer light grey mantle of the crystals.

The groundmass grain generally have a strong increase of Fe, Mn and Na and a decrease Si, Mg and Cr from core to rim analogous to the megacrysts, but both Al and Ti contents show reverse changes. The groundmass has higher Ti, Al, Fe, Mn and Na contents and lower Si and Mg contents compared with the megacrysts suggests the advance of their fractionation.

Fe³⁺ in the analyzed clinopyroxene megacryst (sample V, Table 1) range from 0.011 core to 0.027 rim rise in the groundmass generation from 0.019 core to 0.070 rim.

Since Na has 0.024-0.083 cations which is much higher than the normal value of augite (0.005) suggesting Na substitution in M2 octahedral sites. Generally, variations of Si⁴⁺ and other substituting cations support the aspect of chemical zoning and not corona or reaction rim.

ii) Pyroxene fractionation index

The use of the pyroxene fractionation index (e.g., Fe/(Fe+Mg) ratio) is very important for the understanding of the magmatic evolution of basic magmas since this index exhibits very sensitive correlation with elements concentrated in the melt (Dobosi, 1987; Carman *et al.*, 1984).

Table 1 shows the continuous increase of Fe/(Fe+Mg) ratio from cores to rims of the megacrysts. The early crystallized pyroxene megacrysts of olivine-rich dolerite and basalt

(average: 0.23 core and 0.44 rim) are generally high in Fe/(Fe+Mg) ratio relative to that of the noraml basalt (0.28 core and 0.63 rim). The groundmass generation has an intermediate value of the Fe/(Fe+Mg) ratio (0.38 core and 0.60 rim) compared with that of the megacrysts. Moreover the Fe/(Fe+Mg) ratio gradually increase from olivine-rich dolerite to normal basalts, indicating the progress of clinopyroxenes fractionation. These vaules are analogous to that of the alkaline suits (Gibb, 1973).

Clinopyroxenes from tholeiitic basic volcanics have lower Fe/(Fe+Mg) ratio, e.g. 0.33-0.44 (Bendarz and Schmincke, 1994). In Egyptian Shield, the same results has been recorded by Hafez and Abdou (1989) who concluded that the Fe/Fe+Mg of the normally zoned clinopyroxene from Abu el Darag alkaline basalts increase from 0.23 (core) to 0.26 (rim).

The variation of some elements against the Fe/(Fe+Mg) ratio is shown in Fig. 5. It is clear from this figure that both Na and Mn increase while Cr decreases with fractionation of pyroxene. The early crystallized diopsides of the present basalts contain 0.03-0.26 wt% Cr₂O₃, but their Cr content strongly decreases with fractionation (Fig. 5), and pyroxene having a Fe/(Fe+Mg) ratio less than 0.46-0.33 do not contain detectable Cr. The crystallization of diopside, magnetite and a little chromspinel rapidly impoverishes the melt in chromium.

The variation of Mn in pyroxene follows the Fe variation. MnO increases from 0.16-0.36 wt.% in diopsides to 0.36-0.41 wt.% in hedenbergite, while augites contain only 0.17-0.26 wt.% MnO.

Both Ti and Al tend to increase in the early and middle crystallized pyroxene megacrysts with fractionation. This is consistent with the results of Sack and Carmichael (1984) who have established that decreasing temperature and increasing substitution of Fe²⁺ for Mg enhance solubility of pyroxene solid solution. But both Ti and Al decrease sharply in the late stage pyroxenes and groundmass with fractionation (Fig. 5). The decrease of these elements is due to the crystallization of other Ti- and Al-bearing phases such as titanomagnetite and plagioclase. The precipitation of these phases impoverishes the melt in Al and Ti. A similar variations was described by Gibb (1973) and Dobosi (1987).

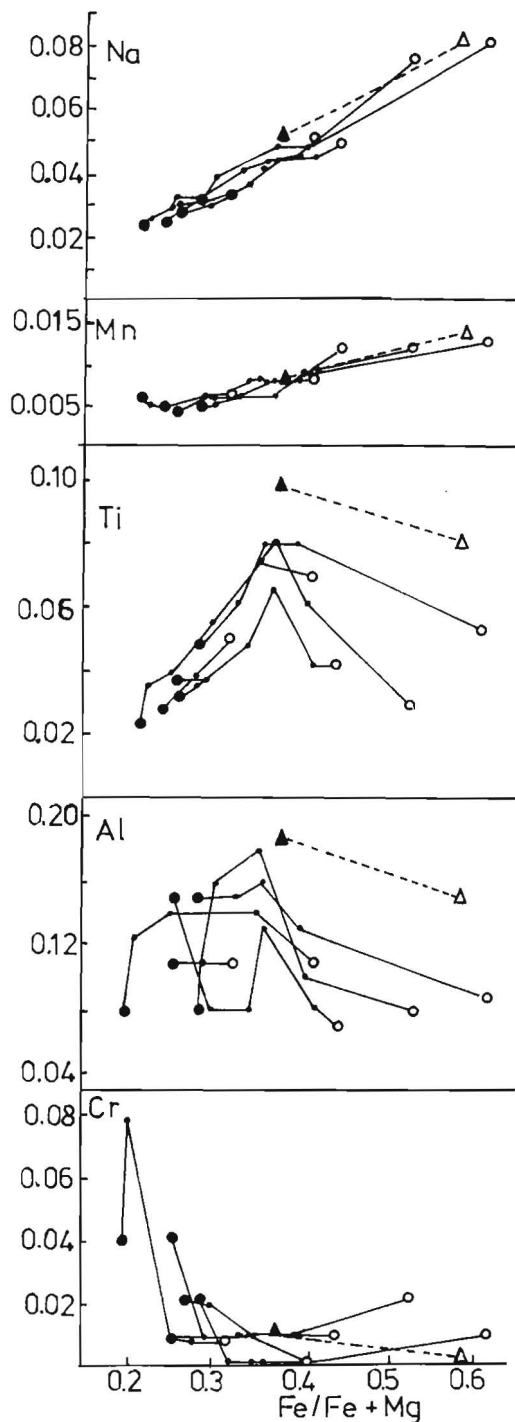


Fig. 5: Variation of some elements vs. $Fe/Fe+Mg$ of the clinopyroxenes from Shalatein basalts.

Magmatic Evolution

i) Magma type and fractionation

Figure 6 illustrates the pyroxene data plotted on the Ti versus $(Ca+Na)$ diagram of Leterrier *et al.* (1982). In this figure the analyzed pyroxenes from west Shalatein basalts plot in the alkaline field except a few analyses fall in the non-alkalic

(tholeiitic) field. Basta and Hafez (1985) reported that the Mohagara volcanics of Wadi Ghadir area contain some clinopyroxene megacrysts of alkaline affinity. The same results were recorded by Hafez and Abdou (1989) for the Abu el Darag basalts on the Gulf of Suez.

TiO_2 content of the clinopyroxene, however, depends on the crystallization temperature (Yagi and Onuma, 1967); the early crystallized megacrysts of alkaline basalts have low TiO_2 content, and their TiO_2 increase with further crystallization. This may explain why, some early crystallized megacrysts of the west Shalatein basalts plot in the field of non-alkalic basalts. The cores of some megacrysts are considered as high pressure phases by their higher octahedral alumina content (analysis B1, D1, E1), because the composition of the clinopyroxenes strongly depends on pressure, such high pressure pyroxenes have diagnostic value in pyroxene discrimination.

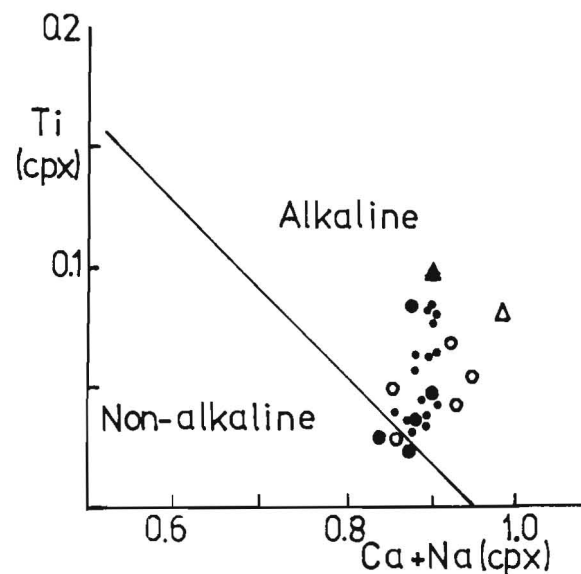


Fig. 6: Plot of Ti vs. $Ca+Na$ diagram of Leterrier *et al.* (1982) for the clinopyroxenes from Shalatein basalts.

Figure (7) also indicates an alkaline fractionation trend of the studied basalts which is analogous to that of the alkaline undersaturated suites from Tenerife, Canary Island (Scott, 1976) and from Mecsek Mountains, Hungary (Dobosi, 1987), but different from that of the tholeiitic Skaergaard suite (Wager and Brown, 1967). Fractionation parameters ($Fe/Fe+Mg$) also support this conclusion.

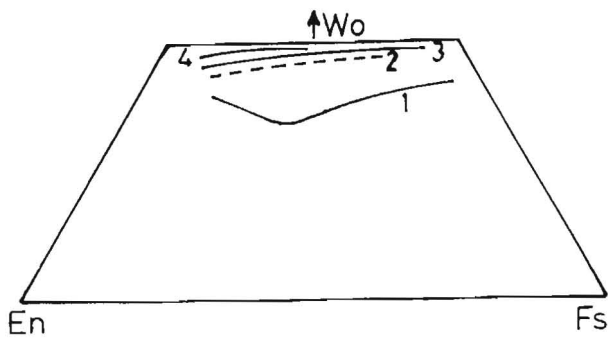
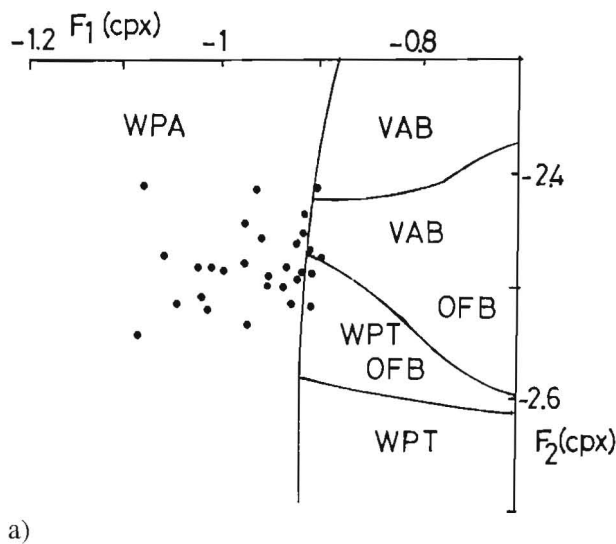


Fig. 7: Pyroxene fractionation trends in En-Wo-Fs diagram. 1=Skaergaard intrusion, Greenland (Wager and Brown, 1967), 2=Shalatein basalt (Present work); 3=Mecsek Mts., Hungary (Dobosi, 1987), 4=Tenerife, Canary Islands (Scott, 1976).

ii) Tectonic Setting

The plot of $F_1 - F_2$ and MnO-TiO₂-Na₂O diagrams of Nisbet and Pearce (1977) for the clinopyroxenes of basalts allows the identification of their tectonic settings. On these diagrams, the pyroxenes fall in or around the field analogous to the pyroxene of the within plate alkaline (WPA) basalts (Fig. 8). The separation of the pyroxenes of the WPA basalt group from the other magma types is based on the value of TiO₂, CaO and Na₂O; thus pyroxenes of the alkali basalts having greater concentrations of these oxides can be distinguished from the other magma types.



a)

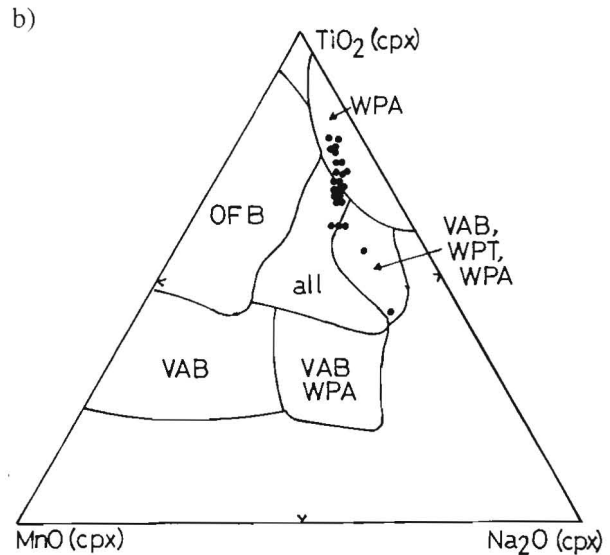


Fig. 8: Plot of the clinopyroxenes from Shalatein basalts on: a) discriminant functions F_1 vs. F_2 and b) MnO-TiO₂-Na₂O diagram after Nisbet and Pearce (1977). WPA= within plate alkaline, WPT=within plate tholeiite, OFB=ocean floor, VAB=volcanic arc basalts.

Moreover, on the Ti+Cr versus Ca diagram of Leterrier *et al.* (1982), the present clinopyroxene fall in the field of pyroxene of non-orogenic affinity (Fig. 9). The enrichment of both Ti and Fe is common through the course of fractionation which is in agreement with the data given by Nisbet and Pearce (1977). Similar trends of enrichment are recorded in the clinopyroxenes from other Egyptian alkaline rocks (Basta and Hafez, 1985; Sourour, 1997).

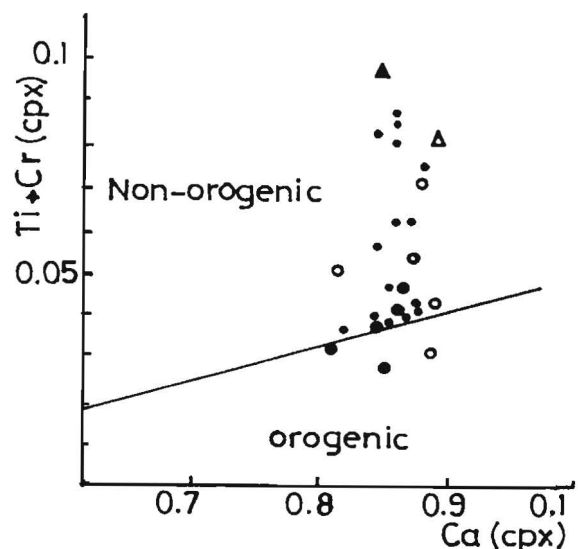


Fig. 9: Plot of Ti+Cr vs. Ca diagram after Leterrier *et al.* (1982) for the clinopyroxenes from Shalatein basalts.

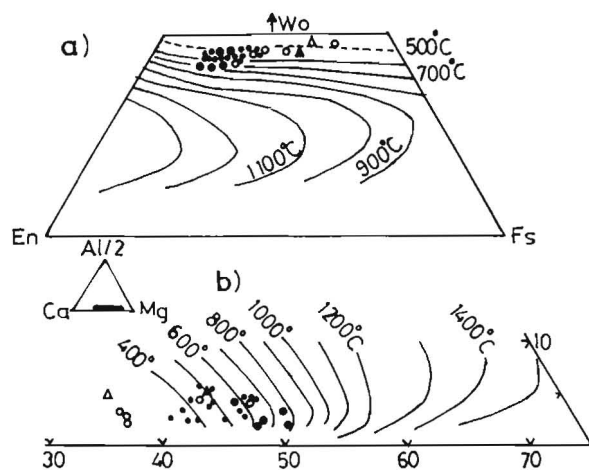


Fig.10: Geothermometric data of the analyzed clinopyroxenes after: a) Lindsley (1983); b) Nickel *et al.* (1985).

iii) Geothermobarometry and Oxygen Fugacity

It is possible to characterize the conditions of crystallization: temperature, pressure, and oxygen fugacity (fO_2) of the coexisting clinopyroxenes in the present basalts, from their mineral chemistry.

The analyzed pyroxenes plot in the diopside-hedenbergite field (Fig. 3), which indicate their crystallization under high temperature (900°C), since the hedenbergite-diopside inversion temperature is lower than 925°C.

Using the graphical thermometer developed by Lindsley (1983) and Nickel *et al.* (1985) for the clinopyroxene, the studied diopside reached equilibrium at temperature around 800-850°C in the cores, 600-500°C at the rims. Hedenbergites in the groundmass equilibrium and at a temperature less than 600°C for the core and less than 500°C for the rim (Fig. 10).

The relative amounts of Al in clinopyroxenes are considered to reflect varying crystallization pressure in the host magma (Wass, 1979). Huckenholz (1966) and Dobosi (1987) concluded that sometimes the cores of clinopyroxene megacrysts in the alkaline suites represent high-pressure phases. They gave a clinopyroxene composition analogous to that of the present alkaline basalts and reported that Cr played an important role since the element is early captured in the mineral core from alkaline olivine basalts of Hocheifel (Germany) and Velence (Hungary) which contain 0.17-0.60 wt.% Cr_2O_3 . The cores of diopside from west Shalatein basalts contain 0.13-0.26 wt.% Cr_2O_3 (Table 1). Plot of Al^{iv} versus Al^{vi} is an excellent pressure parameter in clinopyroxenes (Fig. 11). Values of Al^{iv} usually dominate at rims indicating drop in pressure (Table

1). It is believed that at the cores forming at higher pressure Al substituted in the octahedral M1 site instead of tetrahedral sites.

The Al^{iv}/Al^{vi} ratio calculated for the analyzed pyroxenes indicates that these minerals crystallized at relatively low pressure since their Al^{iv} always exceeds by far than their Al^{vi} . Wass (1979) noticed that with increasing pressure, Al^{iv}/Al^{vi} ratio would decrease. In the analyzed crystals, this ratio decreases considerably in the core, indicating that the rims formed at lower pressure.

It is evident that the cores of the clinopyroxene megacrysts crystallize at highest pressure followed by the rims and finally the groundmass at lowest pressure conditions (Fig. 11a). This conclusion is also consistent with that given by Embey-Isztin *et al.* (1993) and Sourour (1997). Such results indicate that crystallization of clinopyroxene took place under mantle conditions.

The distribution of Fe^{2+} and Mg^{2+} between M1 and M2 sites can be partly a function of temperature and pressure. These elements may behave more like small cations at low temperature-high pressure, and more like large cations at high temperature and low pressure; but crystal structure studies show that the present pyroxenes have a strong qualitative basis.

Mg^{2+} varies between 0.35 and 0.85 being usually more concentrated in the core (0.74-0.85). This element has been completely assigned to the M1 site in the analyzed pyroxenes. Moreover, the presence of maximum amount of Mg in the M1 site requires that there be a minimum amount of Al^{vi} , Fe^{3+} , Ti^{4+} , Cr^{3+} and Fe^{2+} so that Mg^{2+} can all be accommodated in M1 suggesting, again, crystallization under high pressure cores and low pressure rims, respectively.

The variation of $Fe/Fe+Mg$ ratio and the values of Fe^{3+} in the clinopyroxene from core to rim indicate that the initial fO_2 in the magma was low and increased rapidly in contrast with the tholeiitic magmas (Gibb, 1973). Crystallization of olivine, early formed plagioclase and clinopyroxenes occurred at low fO_2 and almost no Fe^{3+} enters the clinopyroxene structure (Cameron and Papike, 1981). Consequently, Fe^{3+} incorporates Ti to form Ti and Fe bearing phase (e.g. titanomagnetite) probably when the $Fe/Fe+Mg$ ratios become >0.35 . Restriction of this magnetite to the outermost rims of the clinopyroxene, as well as in the groundmass, supports the increase of fO_2 with fractionation.

Figure (11b) shows the introduction of Fe^{3+} in the structure of pyroxenes, using the charge-deficiency versus charge-excess (Schweitzer *et al.*, 1979). It is

evident that all analyses of rims and some of intermediate zone of crystals are located above the line $Fe^{3+}=0$ indicating the partial involvement of ferric iron in the crystal structure and reflecting a higher fO_2 for the outer rims as well as the groundmass compared to the cores in the environment of crystallization.

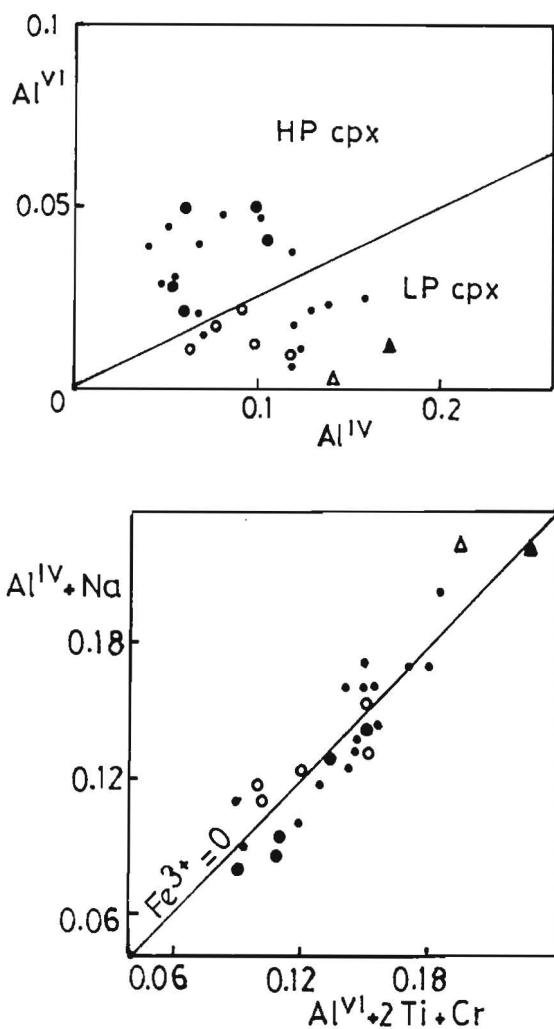


Fig. 11: Plot of the analyzed clinopyroxenes on: a) Al vs. Al diagram. Fields of low- and high-pressure cpx are from Aoki and Kushiro (1968) and Wass (1979). b) charge deficiency vs. charge excess (after Schweitzer *et al.*, 1979).

Discussion and Conclusion

The mineralogy of west Shalatein basalts as well as the chemistry of their clinopyroxene reveal that they belong to the alkaline undersaturated igneous suites. The composition of the parental magma was close to the composition of alkali basalts. They differentiate into olivine-rich dolerite and basalt,

olivine dolerite and basalt and normal basalt. The present basalts are characterized by the presence of peculiar megacrysts of zoned augites, diopsides and hedenbergites that follow forsteritic olivine and continued with basic plagioclase and titanomagnetite.

The nearly continuous change of the pyroxene chemistry emphasizes the optical concentric and sector zoning of this mineral. Cores are enriched in Si, Mg, Cr and Ca, whereas the rims are rich in Ti, Fe and Mn.

The clinopyroxenes exhibit a trend of fractionation analogous to that of alkaline suites. $Fe/Fe+Mg$ ratio, Al^{VI}/Al^{IV} in addition to Fe- and Ti-enrichment and depletion of Cr in the clinopyroxene from cores to rims reveal early high-pressure crystallization conditions at growing fO_2 . Both Ti and Al tend to increase in the early and middle crystallized pyroxene megacrysts with fractionation, then decrease sharply in the late stage pyroxenes as well as groundmass, due to the crystallization of other Ti- and Al-bearing phases (e.g. titanomagnetite and plagioclase). The precipitation of these phases deplete the melt in Al and Ti and increase the fO_2 with fractionation.

The FeO^I/MgO ratio in the studied basalts characterized by 0.46-0.68 core and 0.82-2.99 rim which indicate their crystallization from primitive mantle. Table 1 exhibit that the differences between cpx and liquid ratios is not very high and $FeO^I/MgO(cpx)$ never exceeds 0.70 for megacrysts which is typical for primitive magmatic melt.

Pyroxene of the present rocks are analogous to that of the non-orogenic, within plate alkaline basalts. Green and Ringwood (1967) indicated that alkali basalts and undersaturated melts are generated deeper in the mantle than the silica saturated one. The high-pressure nature of the clinopyroxene cores suggests primitive alkaline melt generated at depth of about 25-30 kbar and at temperature of 1200-1300 °C in the garnet peridotite mantle (Green, 1973, Ulmer *et al.*, 1989). Slight peralkalinity of the late clinopyroxenes as well as the groundmass (acmite up to 4.8 mole%) in the west Shalatein basalts, in addition to deficiency in silica and the present of some crustal xenoliths contamination of the ascending potassic melt with silicic continental materials is effective. These features are probably related to the major tensional tectonic regime prior the development of the Red Sea.

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