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# THE GRANITIC ROCKS AND THE DEVELOPMENT OF THE CONTINENTAL CRUST [1]

by

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(10 figures)

**RESUME.-** L'origine des granites a depuis longtemps fait l'objet de discussions controversées parmi les géologues, quant à leur région-source, à leur origine et à leur mode d'évolution. De nombreuses classifications en ont résulté.

La complexité pétrogénétique des granites est illustrée dans ce travail à partir de trois exemples de massifs situés dans des contextes géotectoniques totalement différents :

1. Les enclaves plutoniques (gabbro → granite alcalin) dans les laves de l'**île de l'Ascension** reflètent la possibilité de générer de petits volumes de roches acides en milieu océanique par différenciation de magma basique.
2. Les granites alcalins de l'**Archipel des Seychelles** (Océan indien) proviennent de la différenciation d'un magma mantélique qui a néanmoins incorporé du matériel de la croûte continentale supérieure dans une proportion relativement faible, reflétant la situation géotectonique du complexe : un bombement épeirogénique antérieur à une fragmentation continentale.
3. Les roches acides charnockitiques associées aux complexes anorthositiques du **Rogaland (Norvège méridionale)** correspondent au liquide résiduel de la différenciation des anorthosites fortement contaminé par du matériel de la croûte inférieure (faciès granulite) lors du développement orogénique.

**ABSTRACT.-** Granites have been subject to many controversies with respect to their source, mode of origin, subsequent evolution and, consequently, with regard to their classification. Indeed, the nomenclature of granites s.l. depends on the criteria used to classify these rocks : chemical composition (aluminous, calc-alkaline or alkaline granites) and/or geotectonic situation (orogenic versus anorogenic granites). These controversies reflect primarily the multiplicity of processes generating granitic rocks but also the intimate interdependance between the scientific approach and the researcher's ideas.

To illustrate the complexity of granite petrogenesis, different examples are studied.

1. The possibility of generating small volumes of acidic rocks in an oceanic environment has recently been demonstrated for the Kerguelen syenitic-granitic ring complexes (Dosso *et al.*, 1979 ; Dosso & Murphy, 1980) and for the alkaline acidic plutonic enclaves in the **Ascension island** lavas. In both cases, continental contamination is obviously absent as is confirmed by the Pb, Sr and Nd isotope compositions. These granitic differentiates could be considered as "sialic nuclei" constituting a picture of a first proto-continental stage.
2. The main islands of the **Seychelles Archipelago** (Indian Ocean) are mainly composed of granitic rocks of Precambrian age ranging in composition from a biotite-hornblende type to a slightly alkaline type. More basic rocks, of gabbroic to dioritic composition, occur only as dark fine-grained enclaves. Both petrography and trace element geochemistry indicate the alkaline character of these granites and also show that the different facies could belong to a single magmatic differentiation suite. Pb isotope compositions of whole rock samples and K-feldspars point to a mantle origin for the parental magma but indicate, on the basis of the relatively high $^{207}Pb/^{204}Pb$ ratios, that these rocks have been slightly contaminated by upper crustal material. This interpretation is compatible with Sr initial isotopic compositions and with the initial $\epsilon_{Nd}^{BE}$ values. The process of interaction between mantle derived magma and the continental crust was not very important which could reflect the geotectonic situation, namely epeirogenic doming prior to continental break-up. In contrast with the active processes of oceanic crust genesis, this kind of neoformed granites could contribute by means of a pulsing accretion processes to a more extensive continental crust.

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3. Granitic rocks of orogenic zones, on the contrary, may be entirely generated by the reworking of crustal material, i.e. muscovite leucogranites (Didier & Lameyre, 1969) or S-type granites (Chappelland White, 1971). Nevertheless, in the deep continental crust, large volumes of mantle derived basic rocks of anorthositic-gabbroic composition contribute to an increased crustal volume. Acidic rocks of charnockitic type are commonly associated with anorthosites : these correspond to the residual liquid of the anorthosite differentiation which is contaminated to a major degree by material from the granulite facies of the lower crust during the deformation process (De Waard *et al.*, 1974 ; Duchesne & Demaiffe, 1978 ; Demaiffe & Hertogen, 1981).

## INTRODUCTION

The origin of granitic rocks has always been subject to a lot of debates, and, as a conclusion of "The Granite Controversy", Read (1957) stated that "there are granites and granites . Since then, it has been shown by experimental petrology that under natural conditions the two main processes leading to granite formation are feasible : differentiation from basic magmas (Bowen, 1928) and partial melting (i.e. anatexis) of continental crustal rocks (Winkler & von Platen, 1958). At those times however, very few geochemical and isotopic data have been obtained on granites. In the 1970's, a lot of work by experimental petrologists and geochemists has been devoted to the plate tectonics theory. As the 1970's have been considered as "Decade of basalts" (Hart & Allegre, 1980), it seems that the 1980's could be called the "Decade of granites". Indeed, in the new IUGS-IUGG "Lithosphere" program, Price & Flynn (1981) stated that "none problem is more pressing or more important than clarifying the nature, origin and evolution of the continental lithosphere". Moreover, a special issue of The Journal of Geophysical Research (nov. 1981) on "Granites and Rhyolites" has already been published.

## NOMENCLATURE

To study the acidic rocks, either plutonic or volcanic, it is necessary to have good bases for classification. Unfortunately, for the granites, we have no classification scheme like the Yoder and Tilley (1962) tetrahedron of the basaltic rocks. So, besides the classical Quartz–Alkali feldspar – Plagioclase triangle (Streckeisen, 1975), the nomenclature of granitic rocks depends on the criteria used to classify the rocks.

- **chemical and/or mineralogical composition** : the critical parameter $Al_2O_3/Na_2O + K_2O + CaO$ is the basis to define three main granitic types : aluminous, alkaline and peralkaline.
- **nature of the source material** : two main types of granites have been defined by Chappell & White (1974). S-type granites derived by partial melting of sedimentary source material and I-type granites which have igneous precursors. An A-type has recently been added to account for the alkaline anorogenic granites (Bowden, pers. comm.).
- **geotectonic environment** : orogenic versus anorogenic (or cratonic) granites (Lameyre *et al.*, 1974).

In recent papers, Lameyre (1980), Lameyre & Bowden (1982) have shown that the modal QAP diagram (fig. 1) is very useful to distinguish the various granitic series if one takes into account the associated intermediate and basic rocks. In fact, this diagram links the classical modal classification to the other approaches described above.

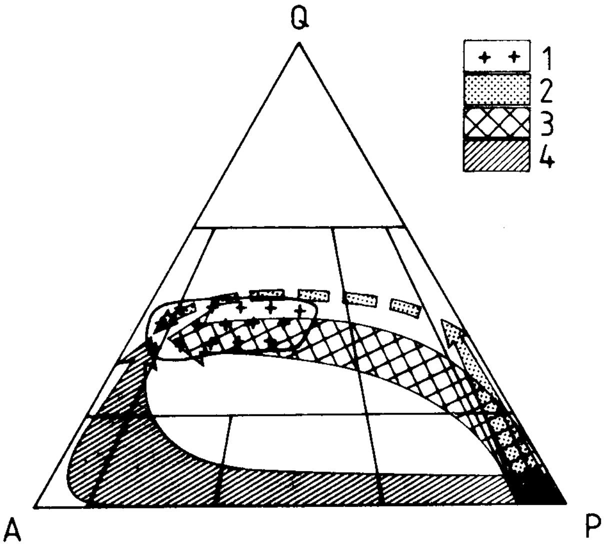


*Figure 1.– QAP diagram showing the four main plutonic series (from Lameyre, 1980).*
*1. Anatectic granites; 2. Tholeiitic series; 3. Calc-alkaline series ; 4. Alkaline series.*

## PETROGENESIS OF GRANITES

Although the classification scheme proposed by Lameyre & Bowden (1982) constitutes a good framework to study the granitic rocks, it is clear that the granite petrogenesis is a much more complex problem than the basalt petrogenesis. To illustrate this complexity, we have taken three different examples of granitic rocks from very different geologic situations which are examined from both petrographical and geochemical (trace elements and isotopes) viewpoints.

## OCEANIC ENVIRONMENT

It is well known since a long time that small volumes of acidic rocks can be generated by magmatic differentiation starting from a basaltic magma of alkaline type. Indeed, trachytes and alkaline rhyolites (comendites and pantellerites) have been reported from numerous oceanic islands (Bouvet, Iceland, Ascension,...) (see Bowden, 1974 ; Baker, 1973). In general, Nd, Pb and Sr isotope geochemistry of these rocks point to a direct mantle origin which is obvious since there is no continental crust in those areas.

Plutonic acidic rocks in oceanic domains are still more scarse ; except the trondhjemites (= oceanic plagiogranites of Celeman & Peterman, 1975) known to be associated with the ophiolite complexes (Coleman, 1977 ; Allègre *et al.,* 1973), most of the islands (Rockall, Madagascar,... ) where acidic rocks have been found were interpreted as continental fragments (Scrutton, 1976).
Nevertheless, two occurrences of plutonic acidic rocks in oceanic environment merit further examination.

### ASCENSION ISLAND

Since the classical works of Darwin (1876) and Daly (1925), Ascension Island is well known for its alkali basalt-hawaiite-mugearite-benmoreite-trachyte-alkali rhyolite series which is now regarded as the common association of oceanic volcanic islands. Moreover, Ascension Island is famous for the numerous **plutonic xenoliths** found in the lavas and the tuffs. These xenoliths cover a wide range of composition from basic (gabbros of cumulate origin) to acidic types (monzodiorites and granites). The petrography of the acidic xenoliths shows their alkaline nature : presence of riebeckite-arfvedsonite, aegyrine, hypersolvus feldspar and alyite or vlasovite (rare potassium or sodium zirconosilicate, van Tassel, 1952).
A schematic representation of the geological situation of Ascension Island is shown in figure 2.

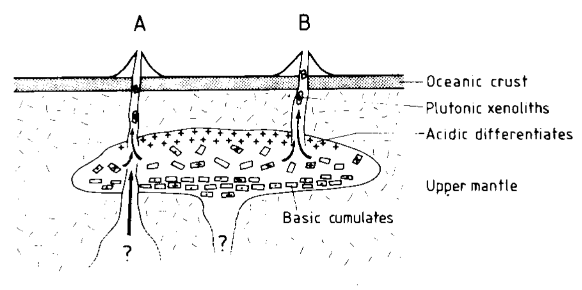


*Figure 2.- Schematic representation of the geological situation of Ascension Island.*

*A. Two magmatic events*
*The xenoliths are fragments of a previously consolidated magmatic chamber which has been sampled by the lavas generated later.*

*B. Single magmatic event*
*The xenoliths and the lavas are subcontemporaneous ; they both result from a single differenciation event.*

Major and trace elements compositions of the lavas and the xenoliths are largely overlapping which could indicate that the latter are the subvolcanic equivalents of the various terms of the volcanic differentiation sequence (Cauet, 1979) as it was already suggested by Tilley (1950) and Roedder & Coombs (1967). This is confirmed by the isotopic data. The basic lavas (basalts and hawaiites) and the basic plutonic xenoliths (gabbros, diorites, monzodiorites) have the same range of Sr isotopic composition (fig. 3) : the $^{87}Sr/^{86}Sr$ ratios are in the range 0.7028 - 0.7035 on the lower side of the oceanic island basalt range (0.7028 - 0.7075 ; Hofmann & Hart, 1978). The differentiated alkaline rich lavas (trachytes and rhyolites) and xenoliths (alkali granites) have usually higher $^{87}Sr/^{86}Sr$ ratios up to 0.712 which could result from extreme Rb enrichment and Sr depletion (Rb/Sr ratios as high as 50) due to compositional zonation of the magma chamber in the late stages of the differentiation process (Hildreth, 1979, 1981). These high values could also result from the contamination of the Sr depleted late stage magmatic liquid by oceanic sediments.

The Pb isotopic compositions (Weis, 1983) also show a close similarity between lavas and xenoliths (fig. 4) : most of the lavas (except a basaltic tuff) and the xenoliths (except the gabbroic ones) have a narrow range of isotopic composition : $^{206}Pb/^{204}Pb$ : 19.298 to 19.748, $^{207}Pb/^{204}Pb$ : 15.548 to 15.642 and $^{208}Pb/^{204}Pb$ : 38.787 to 39.379. These data are comparable to those of other oceanic island basalts (see an excellent review in Sun 1980) ; in the $^{207}Pn/^{204}Pb$ versus $^{206}Pb/^{204}Pb$ diagram, they plot to the right of the geochron and the lavas define a linear trend whose slope corresponds roughly to an age of 1 b.y.
In the modified concordia diagram (Ulrych, 1967), two distinct straight lines (i.e. discordia chords) passing through the origin can be drawn which points to the existence of two recent, and distinct, magmatic differentiation suites. This indicates the existence of at least two different source-regions in the upper mantle beneath Ascension Island which, in turn, confirms the presence of local heterogeneities in addition to the regional ones. Recent Nd isotope studies confirm these deductions. Indeed, the mean $\epsilon^{BE}_{Nd}$ values for four lavas covering the whole range of petrographical type is 11.0 ± 1.4 and for four xenoliths 9.4 ± 0.8.

### KERGUELEN ARCHIPELAGO

On Kerguelen, plutonic rocks, gabbros to alkali granites with predominant quartz syenites intrude, as ring complexes, a series of basaltic flows (Dosso *et al.,*

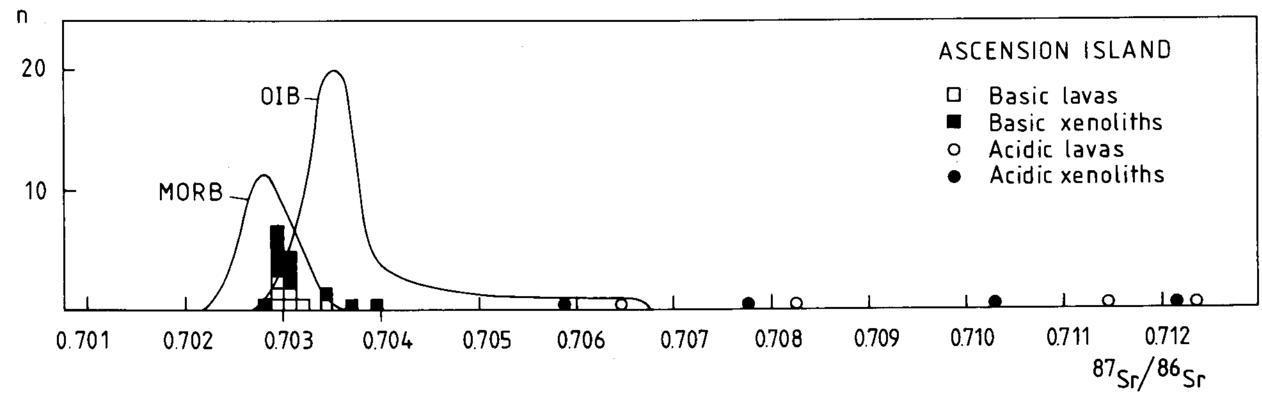


*Figure 3.- Sr isotopic composition of the lavas and their plutonic xenoliths of Ascension Island. Comparison with the mid-ocean ridge basalts (MORB) and the oceanic island basalts (OIB) (from Hofmann and Hart, 1978).*

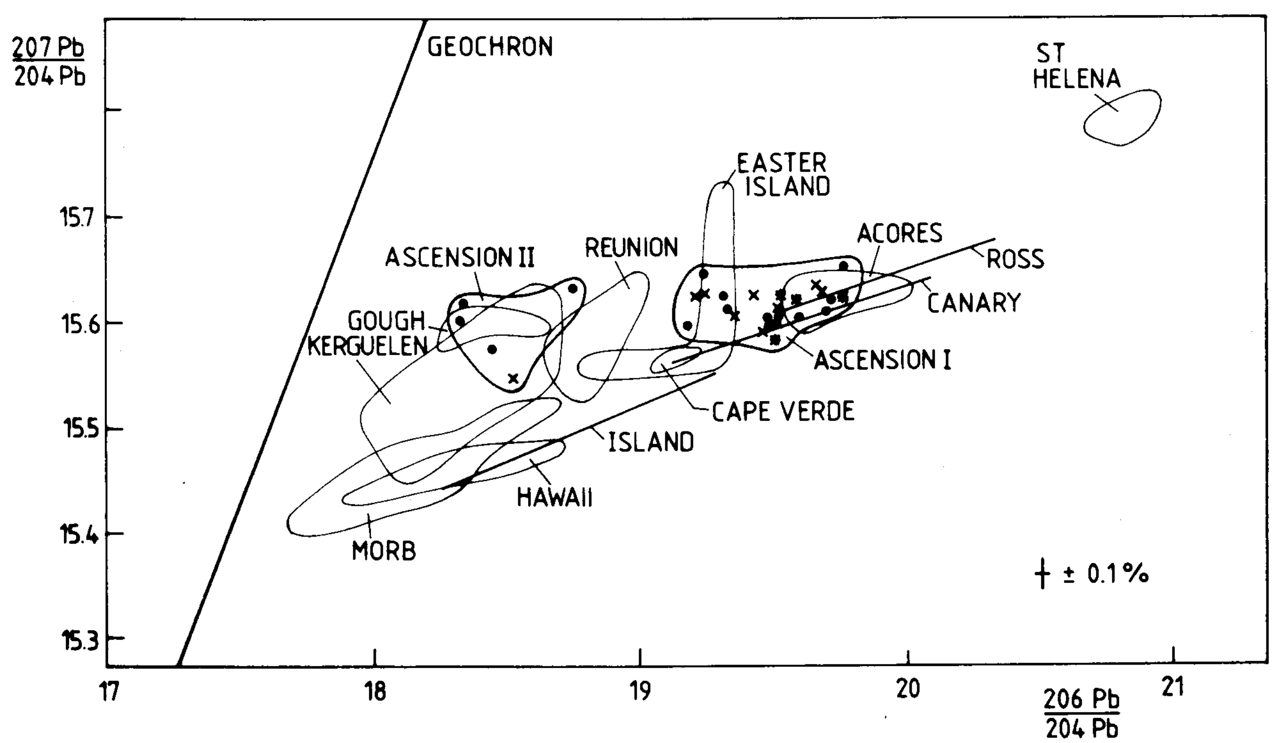


*Figure 4.- $^{207}Pb/^{204}Pb$ - $^{206}Pb/^{204}Pb$ diagram for the lavas (x) and the xenoliths (●) of Ascension Island. Comparison with the date (✱) analysed by Sun (1980).*

1979). The petrology and chemical composition of these plutonic rocks are comparable to those of oceanic island lavas of alkaline affinity. The Sr isotopic composition shows a close grouping of values at about $^{87}Sr/^{86}Sr$ = 0.7057 (Dosso *et al.*, 1979) ; in the Pb-Pb diagram, the data points define a linear array as most other oceanic islands do. Recent Nd isotopic data (Dosso & Murthy, 1980) confirm an upper mantle origin for these rocks which may be derived from an enriched mantle source without any incorporation of old continental material.

In conclusion, both the acidic plutonic xenoliths of Ascension Island and the syenitic to granitic ring complexes of Kerguelen archipelago confirm the possibility of generating acidic rocks by differentiation of a basic magma originated in the undepleted, or even enriched, oceanic mantle (source of the OIB) without any crustal influence. These granitic differentiates, which nevertheless do not constitute large volumes, could be considered as "sialic nuclei" constituting a picture of a proto-continental stage of the evolution of the earth.

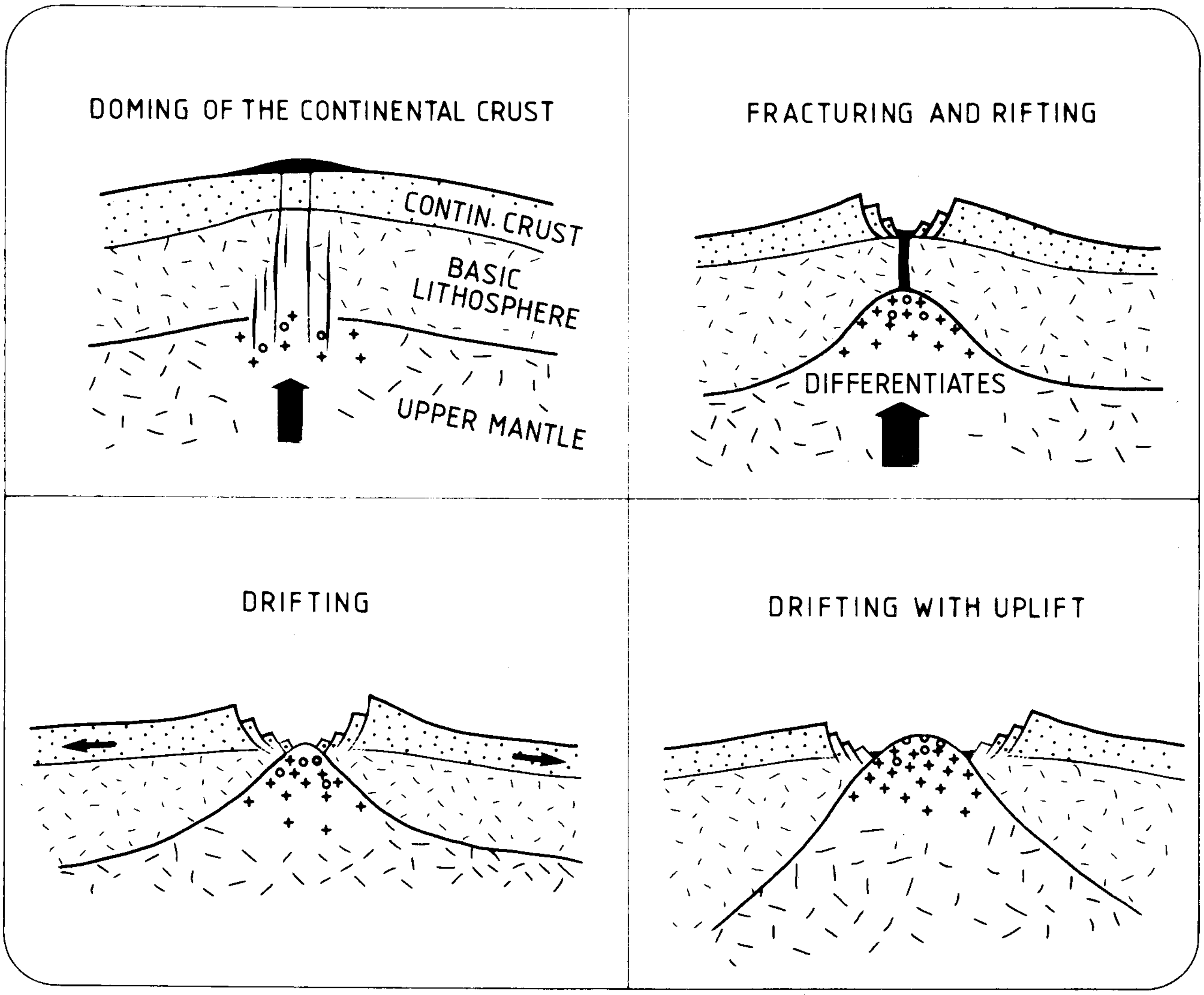


*Figure 5.- Schematic evolution of the Seychelles archipelago in a model of continental doming and rifting.*

## CONTINENTAL DOMING AND RIFTING

This type of geological environment is well known for the occurrence of intraplate magmatism mainly of alkaline nature and which includes kimberlites, carbonatites and alkali granites and syenites (Bowden, 1974 ; Sykes, 1978). These latter usually appear as subvolcanic cone-sheets and/or ring dikes complexes (Bowden & Turner, 1974 ; Bonin & Lameyre, 1978) which should be related, in the deeper part of the crust (or in the mantle ?) to a larger magmatic chamber generated during an epeirogenic doming of the crust.

Although situated in an oceanic domain, most of the islands of the **Seychelles archipelago** consist of precambrian granitic rocks (Wasserburg *et al.,* 1963 ; Michot & Deutsch, 1977).
Three types of granite have been recognized (Baker, 1963) : a slightly alkaline granite and a biotite-hornblende granite outcropping only on the main island (Mahé) and a biotite granite which occurs on the small western islands (Praslin, La Digue, Félicité). These granites include fine grained xenoliths exclusively of magmatic origin : light ones comparable to the biotite granite and dark ones of dioritic to gabbroic composition. The petrography (riebeckitic amphibole, hypersolvus alkali feldspar, fluorite, . . . ) and trace element geochemistry (K-Rb, REE ; Demaiffe *et al.,* 1981) point to the alkaline nature of the Mahé granites which are comparable to the granites of the plutonic anorogenic complexes (Bonin & Lameyre, 1978 ; Vidal *et al.,* 1979 ; Bowden, 1974). The different rocks of Mahé belong to a single magmatic differentiation suite. In view of its petrology, the biotite granite of Praslin could belong to the same suite as an extreme differentiation term but late hydrothermal fluids have obliterated its primary features.
A Rb-Sr whole rock isochron (Demaiffe *et al.,* 1981) based on 23 samples (16 granites, 2 light and 5 dark enclaves) gives an age of 705 ± 8 m.y. (2 $\sigma$) (fig. 6) in agreement with the previous determination of Wasserburg *et al.* (1963) : 681 ± 34 m.y. The Sr isotopic initial ratio is low : 0.70408 ± 18 (2 $\sigma$) which means that

an origin by crustal anatexis can be entirely ruled out. Nevertheless, the Pb isotopic compositions give even a more complex picture (Weis, 1982, inédit) (1). In the $^{207}Pb/^{204}Pb$ - $^{206}Pb/^{204}Pb$ diagram (fig. 7), two groups are clearly distinguished. The granites of Mahé constitute the first group ($^{206}Pb/^{204}Pb$ = 17.741 to 19.794, $^{207}Pb/^{204}Pb$ = 15.565 to 15.727 and $^{208}Pb/^{204}Pb$ = 37.694 to 40.044) ; these data define a good straight line whose slope corresponds to an "age" of 917 ± 74 m.y. but which has to be considered as a mixing line because

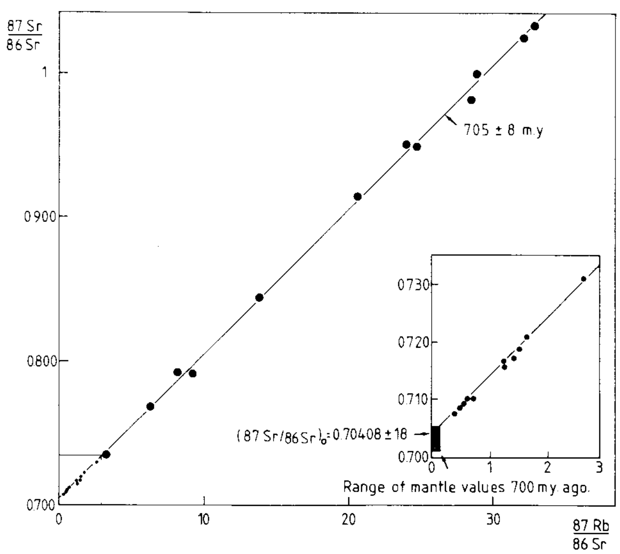

*Figure 6.- Rb-Sr whole rock isochron for the Seychelles granitic rocks and their xenoliths.*

of both the geochronological (U/Pb, zircon, Rb/Sr,...) and geochemical data. The biotite granites of Praslin, La Digue and Félicité are distinctly more radiogenic with $^{206}Pb/^{204}Pb$ up to 20.549 ; $^{207}Pb/^{204}Pb$ up to 15.918 and $^{208}Pb/^{204}Pb$ up to 42.218. These data also yield a good linear array (with a slope corresponding to an "age" of 1.320 ± 220 m.y.) which corresponds to a mixing line between a component comparable to the Mahé dark xenoliths and a more radiogenic one with upper crust isotopic and geochemical characteristics. This grouping is clearly confirmed by the K-feldspar Pb data (fig. 8). Indeed, the Praslin, La Digue and Félicité rocks have more radiogenic ratios than those from Mahé.

The $\epsilon_{Nd}^{BE}$ (705 m.y.) value for the Mahé rocks is 3.1 ± 0.5 and for the Praslin rocks 1.9 ± 1.6 (Weis & Deutsch, in press). This confirm thus very well the deductions based on the Pb data. In fact, the existence of these two groups of Precambrian granitic rocks, evidenced by their initial Pb and Nd isotopic compositions, leads to a reconsideration of the Sr isotopic data. The Mahé rocks alone define a whole-rock isochron giving 706 ± 12 m.y. ($2\sigma_M$ - MSWD 2.5) with an initial $^{87}Sr/^{86}Sr$ ratio of 0.70406 ± 22 i.e. values comparable to those obtained when all the samples are considered together. On the other hand, for the second

(1) WEIS, D., 1982. La géochimie isotopique du plomb total comme traceur pétrogénétique : méthodologie et exemples d'applications. Thèse Doct. (inédite). Univ. Libre de Bruxelles, 353 p.

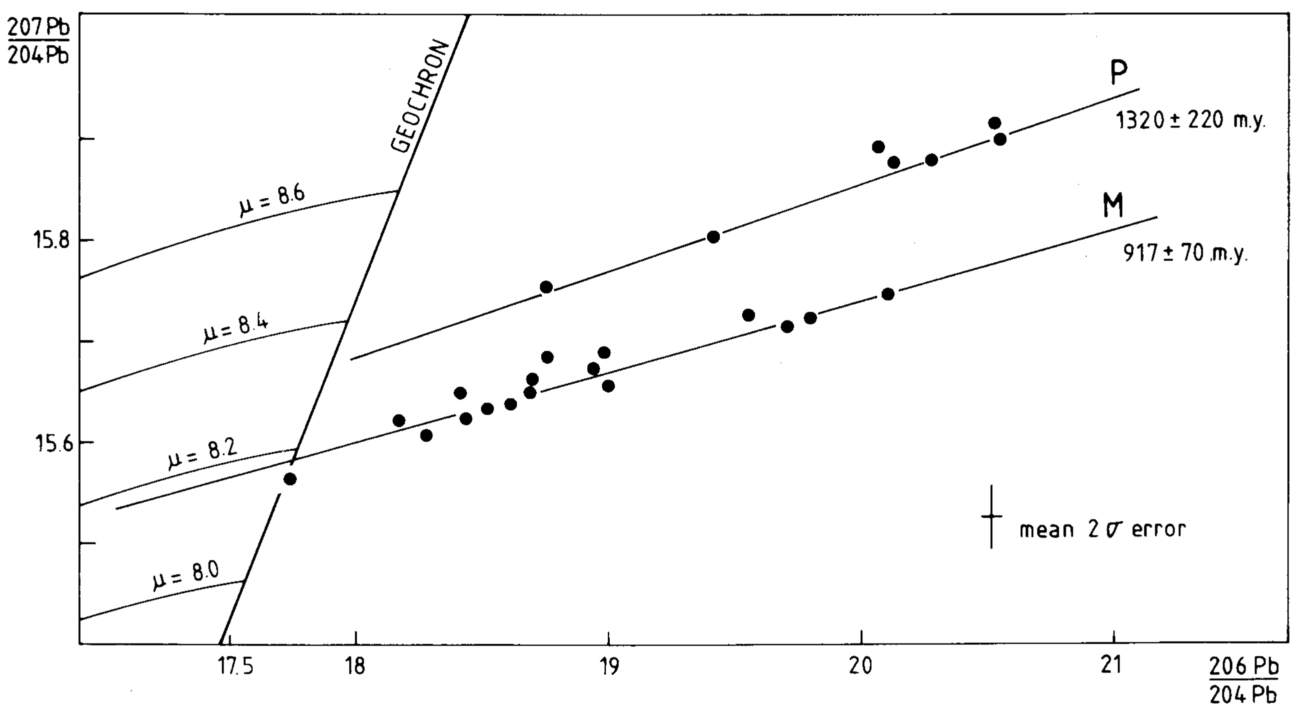

*Figure 7.- $^{207}Pb/^{204}Pb$ - $^{206}Pb/^{204}Pb$ diagram for the Seychelles whole rocks. M : rocks from Mahé ; P : rocks from Praslin - La Digue - Félicité.*

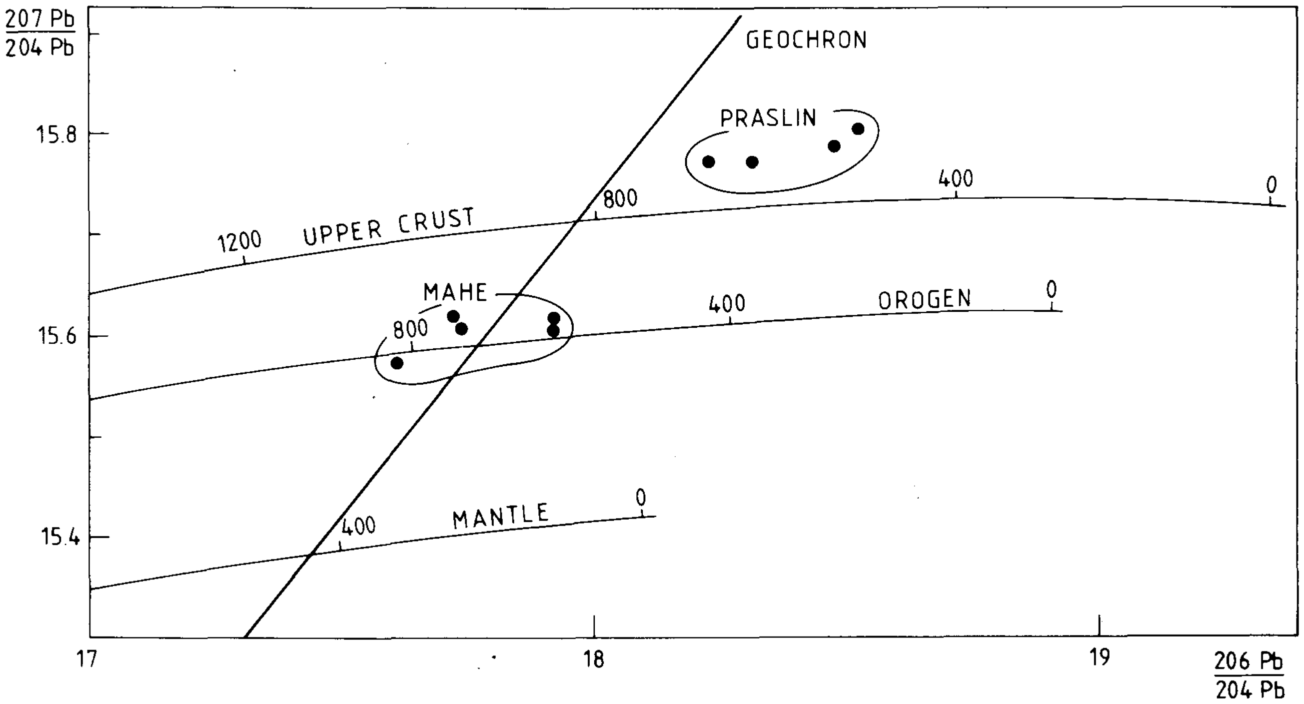


*Figure 8.- $^{207}Pb/^{204}Pb$ - $^{206}Pb/^{204}Pb$ diagram for the Pb isotopic composition deduced from K-feldspar. For comparison, the Pb isotopic evolution curves for the mantle, the upper continental crust and the orogen have been drawn from the "Plumbotectonics" model (Zartman and Doe, 1981). The evolution curve for the lower crust is not reported ; due to the regional U-depletion, this curve is situated below those of the mantle.*

group (Praslin, La Digue and Félicité), the age obtained is slightly younger (667 ± 19 m.y., MSWD 0.5) while the initial ratio is much higher at 0.7152 ± 48.

In conclusion, the granitic rocks of the Seychelles archipelago show alkaline affinities. The Mahé group of granites and xenoliths have an origin in a slightly depleted mantle source region but with little contamination resulting from old upper crustal derived material incorporation. The parental magma of the second group of rocks (Praslin, La Digue, Félicité Islands) has the same origin as those of the Mahé rocks. Nevertheless, there was more important interaction with a LILE enriched fluid phase during the final stage of the differentiation process.
Anyway, the interaction process between this mantle derived magma and the continental crust was not very important which could reflect the geotectonic situation, possibly an epeirogenic doming prior to a continental break-up (fig. 5). The generated granitic material can still be important in volume and contribute to extend significantly the continental crust by a process of pulsing accretion. The Seychelles magmatism does not appear to be linked with a major tectonic (i.e. orogenic) event and, in that sense, could be classified as an anorogenic magmatism.

## OROGENIC ENVIRONMENTS

It has been shown by detailed field work on migmatites (Mehnert, 1968) and by experimental petrology (see reviews in Winkler, 1976 and Wyllie, 1977) that some granitic magmas may be formed entirely by partial melting (i.e. anatexis) of continental crust material. These granites have chemical compositions close to the thermal minimum in the Qz-Ab-Or diagram : they usually have a rather high alumina content which is reflected by the presence of aluminous minerals (muscovite, garnet, cordierite, sillimanite, .s. .s). These granites have been called leucogranites (Lameyre, 1966) or S-type granites (Chappell & White, 1974). The origin of these rocks is also reflected by their isotopic compositions : the $^{87}Sr/^{86}Sr$ initial ratios are always high (> 0.720 and up to 0.780 ; Faure & Powell, 1972 ; Vidal, 1978 ; Allègre & Ben Ohtman, 1980) ; lead isotopic compositions of whole rocks and K-feldspars are all radiogenic (Michard-Vitrac *et al.,* 1980) ; the $\epsilon_{Nd}$ values for young orogenic granitoïds are often negative (- 5 to - 18 $^{o}/oo$ ;s Allègre & Ben Ohtman, 1980, McCullogh & Chappell, 1982).
In the deepest continental crust, i.e. under granulite facies conditions, acidic magmas are less abundant while basic to intermediate magmas giving rise to the rocks of the anorthosite-gabbro-norite suite constitute a major component of this deep continental crust (see Michot, 1952 and Michot & Michot, 1969, for a review of the **Rogaland Complex of South Norway)** (fig. 9). These magmas are mainly derived from the upper mantle : the Sr isotopic initial ratios are low (0.7035 to 0.7055 ; Duchesne & Demaiffe, 1978 ; Demaiffe & Hertogen, 1981) ; the $\delta^{18}O$ values fall in a narrow range close to

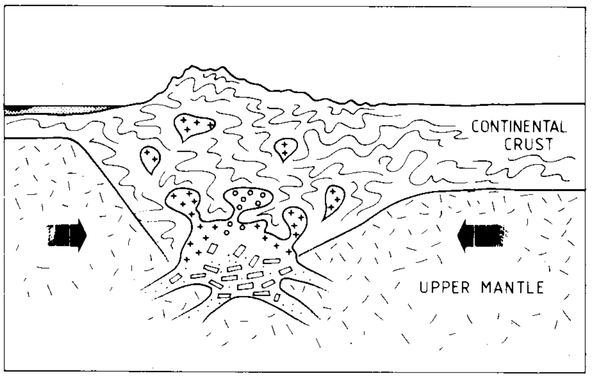


*Figure 9.- Schematic cross section of an orogenic zone with development of a deep-seated magmatism of anorthositic type.*

the mantle values : 5.4 to 6.5 °/oo (Demaiffe & Javoy, 1980). The lead isotopic compositions are also compatible with this interpretation (Weis, 1982 ; Weis & Demaiffe, 1983a). In the field, the large anorthosite massifs are commonly associated with smaller volumes of acidic material, mainly of charnockitic type. Detailed geochemical studies have shown that these charnockites may be considered as the residual liquid of the anorthosite differentiation process : they have REE distribution trends complementary to those of the plagioclasic cumulates (Demaiffe *et al.,* 1979 ; Demaiffe & Hertogen, 1981). Nevertheless, the isotopic compositions of the charnockites point to the existence of contamination processes of the mantle derived magmas generating the anorthosites with granulite facies gneisses of the metamorphic envelope (Weis & Demaiffe, 1983b). A detailed account of the Pb isotopic systematics of the Hidra anorthositic-charnockitic body giving quantitative estimation of the contamination is reported elsewhere (Weis & Demaiffe, 1983a).

In conclusion, acidic rocks in orogenic zones may be of various origin : pure anatectic melts related to high grade metamorphic rocks and migmatites or, in the deep crust, charnockites interpreted as the highly contaminated residual liquids of the anorthosite differentiation suite.

## CONCLUSION

Three different geodynamic occurrences of acidic plutonic rocks have been studied from both petrographical and geochemical (trace elements and isotopes) points of view : the plutonic xenoliths of the Ascension Island lavas (Atlantic Ocean), the granites of the Seychelles archipelago (Indian Ocean) and the charnockites associated with the anorthosites of the Rogaland Complex (SW Norway). These granites s.l. occur in very different geotectonic situations. The lavas of the **Ascension Island** are typical of oceanic island volcanic suites and have been related to an hot spot (or plume) magmatic activity with no connexion with any tectonic process. The plutonic xenoliths, including alkaline granitic varieties have been interpreted, on the basis of their petrology and Nd, Sr and Pb isotopic compositions, as the subvolcanic equivalents of the lavas which indicates the possibility of generating acidic rocks in oceanic domain, in small quantities indeed,sas the end product of a differentiation sequence starting from a basaltic magma. Obviously, this process occurs without any contamination by continental crust material.

The geotectonic situation of the **Seychelles granitic rocks,** at their time of formation in the late Precambrian, is difficult to assess since these rocks now occur, isolated, on the young (< 60 m.y.) seafloor of the Indian Ocean. Nevertheless, the petrological and geochemical features of these granites show that they are quite comparable to the alkaline granites of anorogenic complexes although they do not display the typical ring dike intrusion form characterizing these subvolcanic complexes (i.e. Nigerian Younger granites). One could suggest that the actual level of erosion is deeper for the Seychelles complex than for the Nigerian ring dikes and could correspond to the level of the magmatic chamber itself from which higher level intrusions originate. By analogy with the well known common association of the alkaline anorogenic magmatism and the epeirogenic doming (and sometimes later break-up) of continental lithosphere (Bowden & Turner, 1974 ; Bonin & Lameyre, 1978) it is proposed that the Seychelles granites could constitute a witness of a pre-Gondwanian continental drift of Pan-African age for which there are some paleomagnetic indications (Kröner, 1980 ; Mc Elhinny, 1980). In that respect and remembering the Nd, Pb and Sr isotopic compositions of the Mahé rocks compatible with a mantle derived parental magma (although slightly contaminated by crustal material), the Seychelles rocks could be compared with the alkaline granites occuring in the Arabian-Nubian massif in Sinaï (Bielski *et al.,* 1979 ; Eyal *et al.,* 1981) and in the Arabian shield (Fleck *et al.,* 1980).

**The Rogaland anorthosito-charnockitic complex** was emplaced in the deep zones of the continental crust during an important tectono-metamorphic event, the Sveconorwegian (i.e. Grenvillian) orogenesis. In the roots of this orogen, important transfers of material occur both vertically (intrusion of magmas) and laterally (nappe formation in the gneissic envelope) which favors migration and exchange of elements. During the emplacement of the magmatic complexes, two important processes develop altogether : fractional crystallization of a mantle derived magma generating plagioclasic cumulates (anorthosites and leucnorites) and progressive contamination, by the surrounding granulitic gneisses, of the residual liquid which gives rise to highly contaminated charnockitic differentiates.

In conclusion, it appears that the interactions between the two main reservoirs from which magmatic rocks can be derived, namely the upper mantle and the continental crust, are highly dependent of the geotectonic position at the time of magma genesis.

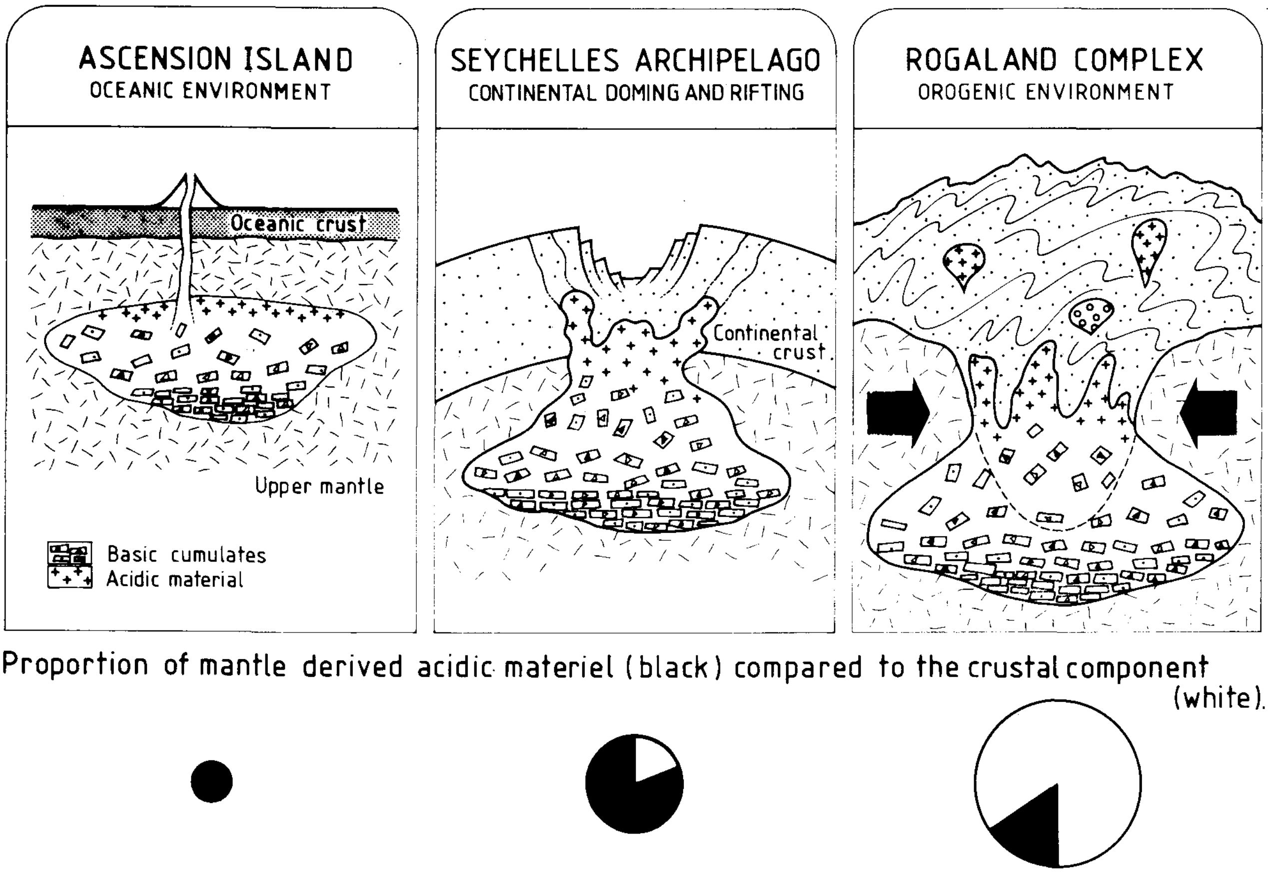


*Figure10.- Synthetic models for the development of acidic rocks in the 3 geological environment reported in this paper. The circle dimension is related to the volume of generated material.*

Three different examples we have synthetically presented in this paper are summarized in figure 10 which shows how much contamination can be expected in each case compared to the relative production of granitic material from the differentiation of a mantle derived magma. It is clear that the geological conditions which corresponds to the best mixing situations are those related to the development of large orogenic belts. This kind of environment on the other hand appears as the special one where sialic anatexis and granitic regeneration are best expressed.


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