Petrology of the Cenozoic alkali basalts in the central Chugoku district,Southwest Japan: implications for their origin and evolution

氏　　名	宿 野 浩 司
生 年 月 日	
本　　籍	岡山県
学 位 の 種 類	博士(理学)
学 位 記 番 号	博甲第325号
学位授与の日付	平成11年9月30日
学位授与の要件	課程博士(学位規則第4条第1項)
学位授与の題目	"Petrology of the Cenozoic alkali basalts in the central Chugoku district, Southwest Japan:implications for their origin and evolution(西南日本，中国地方の新生代アルカリ玄武岩：マグマ進化について)"
論文審査委員(主査)	荒井　章司(研究科・教授)
論文審査委員(副査)	佐藤　努(研究科・助教授) 田崎　和江(理学部・教授) 石渡　明(理学部・助教授) 氏家　治(富山大学理学部・教授)

学 位 論 文 要 旨

Abstract

Cenozoic alkali basalts in the central Chugoku district indicate primary chemical characteristics. They were produced by the mantle upwelling from the deep mantle. These alkali basalts form several monogenetic volcano clusters and their chemical trends in each cluster are divided into two types on the FeO*/MgO-SiO_2 wt % diagram. One trend (= Fe-rich trend) can be produced by a fractional crystallization of olivine and clinopyroxene. The other trend (= Si-rich trend) can not be explained by fractional crystallization with subtraction of any possible mafic minerals. On the other hand, these alkali basaltic magmas were possibly produced from a mixture between an enriched mantle source from the mantle plume and a subduction-related mantle source in the trace element chemistry. Heterogeneous mantle which were formed by previous arc magmatism or addition of slab components may have occurred beneath the central Chugoku district. The primary magmas produced from such hybrid sources possibly underwent magma-mantle interaction with subsequent fractionation. The magma-mantle interaction with subsequent crystal fractionation can explain the chemical trends of most of the basaltic rocks in the central Chugoku district. The wide variations of primary magmas are expected for some of the basaltic rocks in the central Chugoku district. The magma-mantle interaction possibly caused the formation of such wide variations of the primary magmas.

Introduction

Cenozoic alkali basaltic rocks are widely distributed in the central Chugoku district, Southwest Japan, forming several monogenetic volcano clusters. These volcanic clusters can be divided into

several zones parallel to the elongation of the Southwest Japan arc; the San-yo, Sekiryo and San-in zones and the Oki islands from the Pacific side continent-ward. The basaltic rocks in the central Chugoku district indicate undifferentiated characteristics and are considered to be produced in the upper mantle. The documented melting experiments suggested that these basaltic magmas were produced from the mantle upwelling from the deep mantle with a center in the Japan Sea coastal region (Iwamori, 1991). The magmatic evolutions of the basaltic rock in the central Chugoku district were discussed, based on the bulk rock and mineral chemistries.

Olivine-spinel compositional relationships

Restites of these basaltic magmas are estimated by compositional relationships between Fo content of olivine and Cr# (= Cr/(Cr + Al) atomic ratio) of chromian spinel. Each cluster has characteristic restite type with different refractoriness: lherzolite (Cr# < 0.5) for the Tsuyama (5 Ma), Kibi (9 Ma) and Sera (9 Ma) volcano clusters in the San-yo zone, lherzolite to harzburgite (Cr# = 0.2-0.6) for the Kuroiwa-Kogen (5 Ma), Yokota (1 Ma) and Hiba (11 Ma) volcano clusters in the Sekiryo zone, lherzolite (Cr# < 0.4) (11 Ma) and harzburgite (Cr# = 0.5-0.6) (1 Ma) for the Matsue volcano cluster and harzburgite (Cr# = 0.5) for the Kurayoshi volcano cluster (5-1 Ma) in the San-in zone, and lherzolite (Cr# < 0.5) for the Oki-Dogo volcano cluster (4-0.5 Ma) in the Oki islands. The regional distribution of possible mantle restites suggests that the relatively depleted restite (the Yokota cluster) is surrounded by the relatively fertile mantle restites. The temporal variation of Cr# of spinel coexisting with Mg-rich olivine is recognized and suggests that the refractoriness of possible resites sometimes tends to increase with time. The restites for the basalts of 1 Ma in age from the Matsue and Yokota clusters, which are located near the center of mantle upwelling, indicate relatively depleted characteristics. The change of possible restites through space and time may be responsible for the repeated basaltic volcanism in the Southwest Japan due to mantle upwelling.

Polygenesis of clinopyroxenes and magma evolutions

There are polygeneitic clinopyroxenes in the silica-undersaturated alkali basaltic magmas of the Tsuyama and Kibi volcano clusters in the San-yo zone. They exist as phenocrysts or xenocrysts and have strong zonal structures. The strongly zoned clinopyroxene grains have optically distinct cores, which are greenish in color and called the green-core clinopyroxenes. They show variable chemical characteristics and are divided into two groups; one is high in total Tschermak's components (high-Ts group) and the other is low in them (low-Ts group). The genuine clinopyroxene phenocrysts are titanaugite and are possibly high pressure precipitates near the mantle/crust boundary. The high-Ts group green-core clinopyroxenes may have been crystallized from evolved alkaline basaltic magmas which stagnated near the mantle/crust boundary. The low-Ts group green-core clinopyroxenes may be either precipitates from melts produced from a metasomatized mantle or reaction products between a basaltic magma and crustal materials, e.g., crustal assimilation. Anyway, these green-core clinopyroxene

are considered to be accidental fragments trapped from the wall rocks as xenocrysts. The existence of these green-core clinopyroxenes indicates that the underground rocks of these areas, particularly the rocks in the uppermost mantle or lower crust, may have been influenced by the precursory alkali basaltic magmatism such as generation of cumulates, mantle metasomatism or crustal assimilation processes.

Petrogenesis

The chemical trends of the basaltic rocks in each cluster of the central Chugoku district are divided into two types on the FeO*/MgO-SiO_2 wt % diagram. One trend (= Fe-rich trend) shows a slight increase of SiO_2 with an increase of FeO*/MgO ratio, similar to a tholeiitic trend. The other trend (= Si-rich trend) shows an increase of SiO_2 with a slight increase of FeO*/MgO ratio, similar to a calc-alkaline trend. Most of the Fe-rich trends can be produced by a fractional crystallization of olivine and clinopyroxene. However, the Si-rich trends can not be explained by fractional crystallization with subtraction of any possible mafic minerals. Magma-mantle interaction processes are necessary for the formation of the Si-rich trends. On the other hand, these alkali basaltic magmas were possibly produced from a mixture between an enriched mantle from the mantle plume and a subduction-related mantle in the trace element chemistries. Heterogeneous mantle occurred beneath the central Chugoku district. This heterogeneous mantle may have been formed by arc magmatism which converted a pre-existing mantle to an arc-type mantle, or by addition of fluid released from the subducted slab. The varied mantle have been settled by migration of convective mantle wedge beneath the central Chugoku district. The basaltic rocks in the Sekiryo and San-in zones, the coastal region of the Japan Sea, show arc-like signature, whereas the basaltic rocks in the Sanyo zone and Oki-Dogo show OIB-like signature. The basaltic rocks in the Sekiryo and San-in zones can be produced by mixing of a magma from the enriched mantle source and a magma from the arc-type mantle source with depletion of Nb and enrichment of the other incompatible elements. The basalts in the San-yo zone and Oki-Dogo can be produced by mixing of a magma from the enriched mantle source and a magma from a depleted MORB-type mantle weakly metasomatized by fluid released from the subducted Pacific plate (Nakamura et al., 1989). The primary magmas thus produced possibly underwent some magma-mantle interaction and they subsequently fractionated olivine and clinopyroxene. The magma-mantle interaction with subsequent crystal fractionation can explain the chemical trends of most of the basaltic rocks in the central Chugoku district. The wide variations of primary magmas are expected for the rocks in the Sekiryo and San-in zones. The magma-mantle interaction possibly caused the formation of such wide variations of the primary magmas. The younger basaltic magmas (1 Ma) are rich in LILE and REE relative to the older basaltic magmas in the Sekiryo and San-in zone. The effect of the slab components is possibly larger in the younger ones than the older ones in the coastal region of the Japan Sea. The Philippine Sea plate reached beneath the Japan Sea coastal region in Quaternary, and has been adding slab components to overlying mantle source then. The degree of melting for the younger basalts may have been promoted by the addition

of the slab components in the coastal region of the Japan Sea. The voluminous Quaternary andesitic to dacitic magmas erupted in the coastal region of the Japan Sea. They were considered to have been produced by the partial melting of the subducted Philippine Sea plate (Morris, 1995). The heat from the mantle upwelling producing the basaltic magmas in Southwest Japan have possibly enhanced the melting of the subducted Philippine Sea plate.

Conclusion

The Cenozoic alkali basalts in the central Chugoku district were possibly produced by several complicated processes; (1) upwelling of enrich mantle plume from the deep mantle, (2) two types of mixing of melts from some kinds of mantle sources; (a) mixing of a magma from an enriched mantle source from the mantle plume and a magma from an arc-type mantle source produced by previous arc magmatism and (b) mixing of a magma from an enriched mantle source from the mantle plume and a magma from a depleted-MORB type mantle source metasomatized by fluid released from the subducted Pacific plate, (3) contamination of fluid released from the subducted Philippine Sea plate, possibly enhancing the degree of melting, and (4) magma-mantle interaction to produce wide variation of primary magmas. On the other hand, the upper mantle or lower crust may have been partly modified by precursory alkali basaltic magmatism and the modification of the upper mantle or lower crust may have been responsible for the formation of the green-core clinopyroxenes.

学位論文審査結果の要旨

宿野浩司君の提出論文について，８月２日の第１回審査委員会に引き続き，８月５日に公開発表会，第２回審査委員会を行い以下の結論を得た。

本論文は西南日本に分布する新生代の玄武岩類(主としてアルカリ玄武岩)の成因を野外での産状，顕微鏡観察による記載岩石学，鉱物の化学組成，岩石の主要および微量元素，同位体組成などの情報を総合して論じたものである。目覚ましい成果として以下の３点をあげることができる。(1)アルカリ玄武岩の組成変化に，Si-rich trendとFe-rich trendの２つが存在することを見いだし，それぞれかんらん岩／メルト相互反応，結晶分化作用によるものであることを明らかにした。(2)かんらん石－スピネルの化学組成の関係を用いて単成火山ごとに，溶け残り岩を推定し，溶け残り岩の空間的・時間的な変化を明らかにした。(3)この結果およびマグマの組成からマグマ源のマントル組成を推定し，西南日本弧の新生代のマントルでの出来事を明示した。

宿野君は几帳面に蓄積されたデータから慎重に結論を出すという態度を一貫してとっている。このため本研究は極めて重厚なものとなっている。モデリングや解釈の面でやや大胆さを欠いているきらいはあるものの，本研究で得られた上記の成果は，マグマ成因論および日本列島の発達史などに重要な進歩をもたらすものである。従って，宿野浩司君の論文は博士(理学)の学位を与えるのに十分値するものである。