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# Petrogenetic processes, crystallization conditions and nature of the Lower-Oligocene calc-alkaline spessartitic lamprophyres from Kal-e-kafi area (East of Anarak, Isfahan province)

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## Introduction

Lamprophyres are mesocratic to melanocratic igneous rocks, usually hypabyssal, with a panidiomorphic texture and abundant mafic phenocrysts of dark mica or amphibole (or both) with or without pyroxene, with or without olivine, set in a matrix of the same minerals, and with alkali-feldspar restricted to the groundmass (Woolley et al., 1996). Lamprophyres are frequently associated with orogenic settings and a mantle modified by dehydration of subducted slab (Gibson et al., 1995).

Small outcrops of lamprophyres with Paleozoic to Oligocene age are reported from the central parts of Iran (Torabi 2009 and 2010). The primary magmas of these lamprophyres were derived from decompression melting of the mantle induced by a tensional regime of continental crust (Torabi, 2010). Bayat and Torabi (2011) called the western part of the CEIM (Central-East Iranian Microcontinent) (Anarak to Bayazeh) a "Paleozoic lamprophyric province" and suggested that the lamprophyre magmas were formed by subduction of Paleo-Tethys oceanic crust from the Early to late Paleozoic which resulted in the mantle metasomatism and enrichment.

Lamprophyric dykes and stocks of the Kal-e-kafi area (Central Iran, Northern part of Yazd Block) cross-cut the Eocene volcanic rocks and other older rock units such as Cretaceous limestone. These lamprophyres are mainly composed of hornblende (magnesio-hastingsite), clinopyroxene (diopside) and plagioclase (labradorite to bytownite) as phenocryst, in a matrix of fine to medium grained of the same minerals and orthoclase, apatite, magnetite, chlorite and epidote.

In this paper that is a report on the first study on the calc-alkaline lamprophyres of Central Iran, the petrography and mineral chemistry of calc-alkaline lamprophyric dykes of the Kal-e-kafi area are discussed.

## Materials and methods

Chemical composition of minerals were conducted at Kanazawa University (Kanazawa, Japan) using the wavelength-dispersive electron probe microanalyzer (EPMA) (JEOL JXA-8800R), with 20kV accelerating potential, 20 nA beam current and a counting time of 40 seconds. Natural minerals and synthetic materials were used as standards. The ZAF program was used for data correction. The $Fe^{3+}$ content of minerals was estimated by stoichiometry. The Mg# and Fe# were calculated as $[Mg/(Mg+Fe^{2+})]$, and $[Fe^{2+}/(Fe^{2+}+Mg)]$ atomic ratio of minerals, respectively.

Trace element values of phenocrystic clinopyroxene, amphibole and plagioclase were analyzed by LA-ICP-MS (laser ablation-inductively coupled plasma-mass spectrometry) using an ArF 193 nm Excimer Laser coupled to an

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Agilent 7500S at the Earth Science Department of the Kanazawa University (Japan). The diameter of the analyzed points was 60 micrometers for clinopyroxene and 120 micrometers for amphibole and plagioclase.

Mineral abbreviations are adopted from Whitney and Evans (2010).

## Results and Discussion

Lamprophyres of the Kal-e-kafi area (Central Iran, West of Yazd Block) are exposed as dykes and stocks which cross-cut the Eocene volcanic rocks and other older rock units such as Cretaceous limestone. Field studies indicate that calc-alkaline lamprophyric dykes of the Kal-e-kafi (east of Anarak) are younger than the other igneous rocks.

According to the results of petrography and mineral chemistry, the mesocratic lamprophyres of Kal-e-kafi area are calc-alkaline spessartite.

Unique values of $Al_2O_3$ and $TiO_2$ associated with oscillatory zoning of clinopyroxenes reveal the crystallization of clinopyroxenes during ascending of magma.

Plagioclase phenocrysts are labradorite to bytownite in composition and the plagioclases of matrix are labradorite. Chemical composition diversity of plagioclase indicates the fractional crystallization of these lamprophyres.

Amphibole thermometry estimate average temperature of 860°C and barometry by Anderson and Smith (1995) shows 1.5 to 3 kbars pressure. Clinopyroxene thermobarometry calculate 1150 °C temperature and pressure between 2 to 5 kbars.

The geochemical features and thermobarometry of the Kal-e-kafi spessartite minerals suggest that the primary lamprophyric magma was derived from partial melting of a lithospheric mantle spinel lherzolite. Changes in values of pressure, water content, and Oxygen fugacity during magma ascending lead to oscillatory zoning minerals.

Based on the mineral chemistry, it can be concluded that the Kal-e-kafi lamprophyres were formed in a subduction-related environment by a calc-alkaline magmatism.

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