

SHORT COMMUNICATION

EXTREMELY IRON-RICH OLIVINES FROM FERROSyenITES OF THE PRAKASAM DISTRICT, ANDHRA PRADESH WITH PETROGENETIC COMMENTS

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Though fayalite + quartz association is common in a variety of rocks, it is extremely rare with orthopyroxene and virtually non-existent with orthopyroxene + garnet. Hence the fayalite-ferrosilite-ferrohedenbergite-(almandine-rich)garnet-quartz-bearing ferrosyenites in the Prakasam district (A.P.) are deemed as singularly exceptional and amazingly unique (Leelanandam, 1993a). The main purpose of this communication is to present electron microprobe analyses of the extremely iron-rich olivines ($Fa_{97.29} - Fa_{99.78}$) from these unusual rocks and to comment on the relevant petrogenetic implications.

Introduction

In the Prakasam district, ferrosyenites principally occur (Prasad Rao et al. 1988): at Errakonda and Obachettipalem, close to and in between the Chimakurti gabbro-anorthosite and Uppalapadu alkaline plutons (Krishna Reddy et al. 1998); and also, at Gokanakonda near the Boggulakonda gabbro and Settupalle alkaline plutons (Srinivasan and Natarajan, 1990). Olivine is scarce in many samples and they were referred to as "hornblende-orthopyroxene-syenites", in the early stages of our study of the Uppalapadu pluton (Leelanandam and Krishna Reddy, 1981); a generalized description of the field setting of the plutons is given in Leelanandam (1989).

Petrography

Olivine is commonly rimmed by orthopyroxene, clinopyroxene, (secondary) amphibole or symplectic garnet; overgrowths of olivine around clinopyroxene, and (altered) inclusions of olivine in poikilitic plates of amphibole are not uncommon. The mineral is often heavily cracked and the fractures are occupied by secondary amphibole, or are filled with magnetite; it is rarely pseudomorphed, though not completely, by orange-red iddingsite and magnetite, and is rimmed or replaced by grunerite. Apatite, a dominant accessory, is often euhedral and tends to occur in the vicinity of, and as inclusions in, olivine and more commonly in

Fe-Ti oxides. In many but not all garnet-bearing varieties, and also in some orthopyroxene-rich types, olivine is practically absent. Figures 1-4 portray some of these textural features, which were not highlighted in the earlier publications (Leelanandam, 1993a, 1993b, 1994).

Mineral Chemistry

Representative microprobe analyses of the olivines from the ferrosyenites of the Prakasam district are presented in Table 1. The striking feature is the extreme Fe-enrichment and highly restricted range of compositions ($Fa_{97.29} - Fa_{99.78}$) of the olivines suggesting an unusually high degree of fractionation in the magmas. While the variation in FeO (65.94-67.27%) and MgO (1.08-0.09%) contents is minimal, variation in MnO (2.02-4.67%) is rather significant in the analyzed olivines; CaO is practically nil (0.02-0.05%) and there seems to be no need to determine it besides TiO_2 , Al_2O_3 , Na_2O and K_2O (see Table 1).

Discussion

The olivines exhibit no perceptible compositional zonation, but show rare inter-grain variation. X_{Mn} is always far greater than X_{Mg} in all the fayalites with vague negative correlation suggesting Mg-Mn substitution. The "drastic" variations in MnO contents of the samples ST 16 (2.58-4.67%) and CK 33 (2.02-3.47%) do not go unnoticed (anal. 9-11, and 5&6 in Table 1), though the totals FeO + MnO are substantially the same in both the samples (69.71-70.72% in ST 16, and 69.65-69.41 in CK 33). In the sample ST 16, it is the significant drop in the insignificant MgO (0.18 - 0.09%), which is instrumental in shooting up the Fa value tremendously; hence the highest Fa value ($Fa_{99.78}$) is encountered in it, though its X_{Fe} (93.11) is lowest and X_{Mn} (6.67) is the highest for the entire group. A value of $Fa_{99.58}$ is earlier reported for the same sample ST 16 by Srinivasan and Natarajan (1990). The lowest $Fa_{97.29}$ reported here for the Prakasam district olivines is higher than the highest $Fa_{96.39}$ recorded by Ratnakar et al. (1996) for the Sivamalai olivines. As

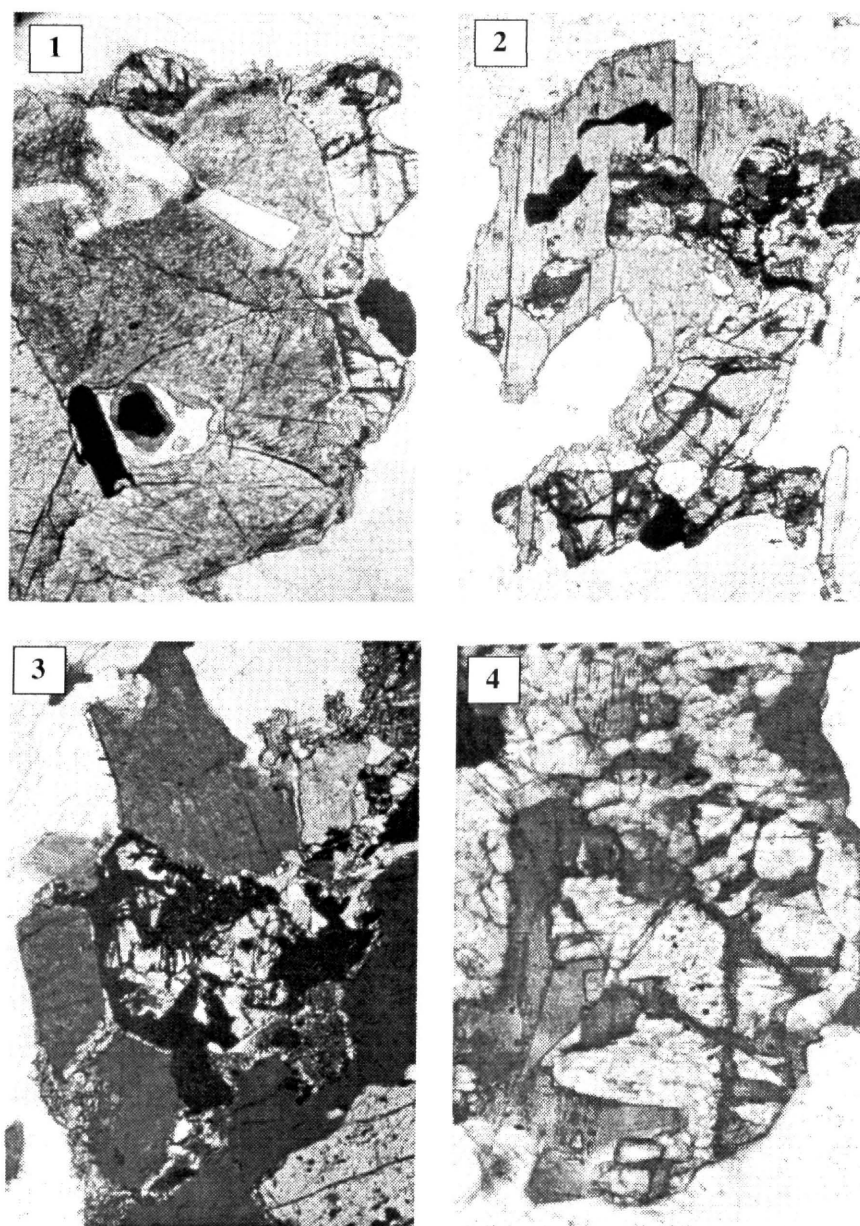


Fig.1. Olivine, fractured and filled with amphibole, is moulded on very coarse dirty-looking clinopyroxene. Note the amphibole rim around ore in feldspar. See also Figs.1&2 in Leelanandam (1993a), and Fig.6 in Leelanandam (1994). Sample CK 42B, PPL. Width of view is 1.0 mm. **Fig.2.** A large amphibole plate contains altered inclusions of olivine. The big olivine crystal (with fractures) contains a thin rim of clear orthopyroxene and an inclusion of apatite. Note the apatite rods in the vicinity. See also Figs.4-7 in Leelanandam (1993a), Figs.4&5 in Leelanandam (1993b), and Fig.5 in Leelanandam (1994). Sample CK 45, PPL. Width of view is 0.9 mm. **Fig.3.** Approximately euhedral olivine (extremely pseudomorphed by magnetite) is surrounded by coarse subhedral amphibole crystals, simulating a 'cumulate' texture. The "wormy" area adjacent to olivine contains spongy garnet. Sample CK 33, PPL. Width of view is 0.7 mm. **Fig.4.** Part of olivine crystal showing wide fractures filled with (brown) amphibole, while (green) amphibole fringes around olivine (towards right) with intervening orthopyroxene (lower side). Sample CK 43, PPL. Width of view is 0.2mm.

far as the writer is aware, the most Fe-rich olivine so far reported in a comparable rock suite is $Fa_{98.0}$ (Young and Cuthbertson, 1994), though pure fayalite (Fo_0) is not unknown from other rock groups. Hence the Fa values of

olivines from the Prakasam district ferrosyenites are the highest recorded to-date in this category.

A survey of the world literature suggests that ferrosyenites may principally, but not exclusively, represent

Table 1. Electron microprobe analyses of olivines

Sample No	CK 45			CK 43	CK 33*		CHK 3*	S 28	ST 16		
Anal No	1	2	3	4	5	6	7	8	9	10	11
	(av 3)@	(1/2)	(1/3)\$	(1/5)	(1)	(1/4)	(av 7)	(av 3)	(1/2)	(av 6)	(1/4)
SiO ₂	29 80	28 95	29 33	29 63	29 12	29 94	30 29	29 97	30 16	29 48	29 71
TiO ₂	0 01	0 01	0 03	0 00	0 01	0 01	0 01	0 00	0 00	0 00	0 00
Al ₂ O ₃	0 00	0 00	0 04	0 00	0 02	0 00	0 01	0 00	0 13	0 17	0 00
FeO [†]	66 64	67 19	67 03	66 74	67 63	65 94	67 27	66 56	67 13	66 17	66 05
MnO	2 21	2 18	2 37	2 23	2 02	3 47	2 48	3 66	2 58	3 90	4 67
MgO	1 08	0 93	0 86	1 05	0 64	0 60	0 26	0 16	0 18	0 12	0 09
CaO	0 02	0 04	0 02	0 04	0 04	0 05	0 03	0 02	0 03	0 03	0 04
Na ₂ O	0 01	0 02	0 03	0 02	0 01	0 06	0 03	0 02	0 07	0 04	0 04
K ₂ O	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00
Total	99.77	99.32	99.70	99.70	99.47	100.09	100.38	100.40	100.27	99.93	100.60
Number of cations on the basis of 4 oxygens											
Si	1 0028	0 986	0 9929	0 9993	0 991	1 0064	1 0146	1 0075	1 0117	0 9977	1 0001
Ti	0 0001	0 000	0 0008	0 0000	0 000	0 0003	0 0003	0 0000	0 0000	0 0000	0 0000
Al	0 0000	0 000	0 0015	0 0000	0 001	0 0000	0 0004	0 0000	0 0051	0 0069	0 0000
Fe	1 8756	1 914	1 8975	1 8826	1 924	1 8534	1 8842	1 8711	1 8834	1 8732	1 8594
Mn	0 0630	0 063	0 0679	0 0637	0 058	0 0988	0 0702	0 1042	0 0732	0 1118	0 1332
Mg	0 0540	0 047	0 0433	0 0530	0 032	0 0300	0 0129	0 0082	0 0089	0 0063	0 0043
Ca	0 0007	0 001	0 0007	0 0014	0 001	0 0020	0 0012	0 0006	0 0011	0 0012	0 0015
Na	0 0009	0 001	0 0017	0 0011	0 001	0 0042	0 0020	0 0013	0 0044	0 0029	0 0026
K	0 0000	0 000	0 0000	0 0000	0 000	0 0000	0 0000	0 0000	0 0000	0 0000	0 0000
	2 9972	3 013	3 0062	3 0010	3 009	2 9952	2 9857	2 9929	2 9877	3 0001	3 0010
Atomic percentages											
Fe(X _{Fe})	94 13	94 57	94 46	94 16	95 53	93 50	95 77	94 33	95 82	94 07	93 11'
Mn(X _{Mn})	3 16	3 11	3 38	3 19	2 88	4 98	3 58	5 25	3 72	5 61	6 67
Mg(X _{Mg})	2 71	2 32	2 16	2 65	1 59	1 52	0 65	0 42	0 46	0 32	0 22
Fa#	97 20	97 61	97 76	97 26	98 36	98 40	99 33	99 56	99 52	99 66	99 76
Fa	97.29	97.68	97.84	97.35	98.41	98.48	99.35	99.59	99.55	99.68	99.78

The numbers given in the fourth decimal place for the cation values in the structural formulae have no significance

* - from Errakonda and rest from Gokanakonda, @ - average of 3 analyses, \$ - selected best analysis out of 3

Fa# = Fe / (Fe+Mg), Fa = (Fe+Mn) / (Fe+Mn+Mg)

either residual liquids (after the formation of gabbros and anorthosites) from a mantle derived basaltic melt, or liquids formed by partial melting of lower crust adjacent to hot mafic magmas. Significant negative Eu anomaly and pronounced Sr depletion in ferrosyenites are often cited as hallmarks for their residual melt origin. However, it is ingeniously argued that the absence of these features in some cases (*see* Scoates et al. 1996) cannot be taken as evidence against direct petrogenetic relationship between ferrosyenites and gabbros/anorthosites (even if they exhibit large isotopic discrepancies). Trace element (including REE) and isotopic evidences, by themselves, cannot readily demonstrate or preclude a direct comagmatic relationship between gabbro and ferrosyenite; for a full discussion, *see* Mitchell et al (1996) and Vander Auwera et al. (1998), and references therein.

In the Prakasam district, ferrosyenites are juxtaposed against gabbros, and are intrusive into the border zone gabbro-norite of the Chimakurti pluton and also into the country rocks (Prasad Rao et al. 1988; Rao, 1993). The absence or rarity of transitional rocks such as monzogabbro, ferrodiorite, monzodiorite, monzonite and monzosyenite is strikingly conspicuous, and the exact gradation between the gabbro and ferrosyenite units (for a continuous differentiation model) is nowhere witnessed until now. It is not clearly understood what the intimate spatial association between the gabbro and ferrosyenite units actually means, because a 'cospatial' relationship is often (but not always) construed for a 'coeval', 'cogenetic' and/or 'comagmatic' relationship. It is instructive to note that the Rogaland (southwest Norway) monzonitic rocks are coeval and intimately related to, but not comagmatic with, anorthosites

(Duchesne et al 1989), and that the jotunite-syenite series of the San Gabriel Mountains (California) is 'cogenetic and coeval with the anorthosite series, but not comagmatic' (Ekstrom et al 1994)

In the Prakasam district, ferrosyenites are devoid of enclaves of gabbro, and also of the distinctive oxide- and apatite-rich 'horizons', some ferrosyenites are unusually rich in amphibole and occur as xenoliths in hornblende syenite (*see* Figs 1 and 2 in Leelanandam and Krishna Reddy, 1981), unambiguous dykes of ferrosyenite are not so far observed in gabbros, textural characteristics of the co-spatial gabbros and ferrosyenites (with disparate mineralogies) are distinctly dissimilar. Expectedly, a profound chemical hiatus persists between the corresponding minerals from the two units in consonance with the remarkably wide compositional gap between them. More importantly, the mineral assemblages and P-T estimates indicate that the ferrosyenites (with Fe-rich orthopyroxene) were emplaced at lower crustal (deeper) levels at higher pressures and recrystallized under granulite facies conditions (Leelanandam, 1993b), while gabbros (with olivine + plagioclase cumulates) were emplaced at mid-crustal (shallower) levels at moderate pressures and crystallized without being metamorphosed. Though reasonable, it is not justifiable to visualize a direct comagmatic relationship between the two units, especially in the absence of any compelling isotopic and trace elemental data. However, such a relationship is either expressed or implied in the earlier publications of the author [*see* Leelanandam (1994) and references therein]. A residual melt, rather than crustal melt, origin is favourably preferred because the ferrosyenites (1) contain relics of inverted pigeonite indicating extremely high initial crystallization temperatures (> 1000°C) consistent for the mantle derived melts, (2) have compositions which are no way similar to those normally obtained by crustal melting, and, (3) indicate their formation under strange and stringent reducing conditions uncommon during melting of crustal material. Curiously, no ferrosyenites are encountered in the vicinity of, or within, the Pasupugallu gabbro-anorthosite pluton (Jyothender Reddy, 1989) which is as vast as, and close to, the Chimakurti pluton (*see* Fig 1 in Prasad Rao et al 1988).

The alkaline rocks of Uppalapadu, which were

recrystallized under amphibolite-granulite facies conditions (Czygan and Goldenberg, 1989), exhibit prominent gneissosity (Prasad Rao et al 1988) and are co-folded along with the host quartzites of the khondalitic group (Rao, 1993). The presence of noritic gabbro and gabbro dykes within the Uppalapadu pluton suggests that "nepheline syenite is older to gabbro" (Prasad Rao et al 1988). At the western margin of the Chimakurti pluton, a septum of metapelitic country rock (with refractory minerals and fossil osumulite) separates gabbros from ferrosyenites which are proximal to, but not comagmatic with, the alkaline rocks of Uppalapadu (*see* Fig 1 in Leelanandam and Krishna Reddy, 1981). These observations allow us to tentatively speculate that the ferrosyenites and alkaline rocks are older (and probably coeval), and are later intruded by the younger gabbro-anorthosite pluton. Implicit in this interpretation is the assumption that the ferrosyenites are crustal or independent melts, but not residual melts. If that were to be so, then the co-spatial gabbros and ferrosyenites are not comagmatic and not even coeval. The absence of gabbros (at the present level of exposure) in the vicinity of Sivamalai ferrosyenites [which contain spectacular fossil pigeonites (Babu and Leelanandam, 1993, Leelanandam, 1993b), which have an affinity to the "granulites of the country rocks", and which are in close proximity to the "metamorphosed" alkaline rocks (Czygan and Goldenberg, 1989)] is a pointer in this direction, and suggests that gabbros play no parental role in the genesis of ferrosyenites. The available evidences from the Prakasam district seem to comply with this new interpretation, but its validation by systematic isotopic and geochronological studies is absolutely mandatory. Until such time, the problem whether the ferrosyenites of the Prakasam district represent residual, crustal or independent melts remains open.

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