FASSAITE FROM MADAGASCAR

H.H. MAJMUNDAR *

Appalachian State University, Boone, N.C. 28607

Eighteen samples of fassaite from extreme S.E. Madagascar were separated from the phlogopitic, feldspathic, and scapolitic pyroxenites. These pyroxenites (Precambrian) occur in association with charnockites and are considered to be metamorphosed sedimentary rocks (Lacroix 1941, de la Roche 1956, 1958). Fassaites have never been reported from Madagascar, and in other parts of the globe also, they are very limited in their distribution and therefore, I wish to report their optical, chemical and *x*-ray data.

X-ray powder diffraction data obtained with both, Cu*Ka* and Fe*Ka* radiation, are in good agreement with data given by Clark (1946) and Sakata (1957).

Partial chemical analyses were done spectrographically using an Applied Research Laboratories' Quantometer. Synthetic standards were prepared by mixing pure chemicals in approximately the same amounts expected in the natural samples of fassaite. The standards and samples were prepared for analysis by fusion technique using lithium carbonate and boric acid. All the analyses were done in quadruplicate and the averages are given. The results are reported in Table 1.

These fassaites are light to dark green to greenish black in color. Fassaites from phlogopitic and scapolitic pyroxenites are nonpleochroic, pleochroic varities occur in feldspathic pyroxenites. The density and optical properties are listed in Table 1 along with the partial chemical analyses. These results are in excellent agreement with the data published by Tilley (1938), Knopf & Lee (1957), and Rajasekaran (1960).

Trace elements were determined spectrographically by the methods described by Black (1952) and Mitchell (1948) using Jobin et Yvon quartz prism spectrograph. The measurements of line densities were made with the A.R.L. Spectroline Scanner. Samples and synthetic standards were mixed with graphite (1 : 1) using 0.02% La_2O_3 as an internal standard. A water-cooled Stallwood jet of CO_2 was used to improve precision. Johnson-Matthey "Specpure" chemicals were used to prepare standards. The data obtained are given in Table 2. Sample 18 was analyzed

* Present address : Division of Mines and Geology, Ferry Building, San Francisco California 94111.

TABLE 1. PARTIAL CHEMICAL ANALYSES AND OPTICAL PROPERTIES OF FASSAITE FROM S. E. MADAGASCAR

	1 Rano-piso	2 Mafile-fy	3 Beam-ping-aratra	4 Beam-ping-aratra	5 Beam-ping-aratra	6 Ambo-taka	7 (Un-known)	8 Ambia	9 Beam-ping-aratra
SiO_2	44.30%	44.00%	42.30%	42.60%	41.10%	42.30%	41.60%	44.20%	41.50%
Al_2O_3	10.10	7.40	8.85	8.20	11.10	7.70	11.35	7.00	8.85
Fe_2O_3 [1]	5.15	5.00	7.50	7.10	5.00	11.80	6.10	3.30	15.60
CaO	25.20	25.10	23.90	24.60	25.00	24.41	24.73	24.70	23.50
MgO	14.80	15.40	15.50	14.40	14.35	12.00	14.00	17.20	9.00
MnO	0.04	0.33	0.10	0.09	0.10	0.40	0.05	0.14	0.26
TiO_2	0.42	0.43	0.38	0.36	0.67	0.24	0.58	0.30	0.18
Na_2O	0.61	0.61	0.35	0.27	0.56	0.60	0.66	0.45	0.64
γ	1.709	1.706	1.709	1.709	1.710	1.718	1.709	1.701	1.729
α	1.682	1.678	1.682	1.682	1.682	1.693	1.681	1.672	1.700
γ-α	0.027	0.028	0.027	0.027	0.028	0.025	0.028	0.029	0.029
$2V(+)$	58.5°	58°	59°	59°	58.5°	60°	59°	57.5°	61°
$Z\Lambda c$	39°	40°	40°	40°	39°	42°	40°	38°	43°
D	3.312	3.311	3.301	3.300	3.300	3.390	3.300	3.285	3.600

	10 Ambo-alengo	11 Androy Mandra-reen	12 * Ambo-taka	13 Anara	14 Anara	15 Ambin-dendra-kemba	16 Rano-piso	17 Mafile-fy	18 * Mafile-fy
SiO_2	41.20%	43.30%	43.52%	43.10%	41.28%	41.25%	44.00%	44.50%	42.30%
Al_2O_3	7.45	7.10	7.44	9.30	10.15	10.10	6.75	9.20	9.88
Fe_2O_3 [1]	23.00	12.80	12.97	5.10	5.60	5.60	7.15	5.00	9.00
CaO	23.60	24.30	24.51	24.73	24.40	24.40	25.70	23.40	24.20
MgO	3.60	9.50	9.51	13.10	16.85	17.00	13.10	13.20	10.53
MnO	0.40	0.12	0.31	0.08	0.06	0.10	0.09	0.32	0.43
TiO_2	0.58	0.76	0.33	0.65	0.74	0.73	0.59	0.33	1.62
Na_2O	0.68	0.52	0.44	0.77	0.86	0.85	0.57	0.62	0.53
γ	1.743	1.722	1.724	1.707	1.708	1.707	1.711	1.707	1.720
α	1.724	1.699	1.700	1.680	1.680	1.679	1.684	1.680	1.695
γ-α	0.019	0.023	0.024	0.027	0.028	0.028	0.027	0.027	0.025
$2V(+)$	59°	60°	60°	58.5°	58.5°	58.5°	59.5°	58.5°	59.5°
$Z\Lambda c$	45°	41°	42°	40°	40°	39°	40°	41°	41°
D	3.489	3.391	3.382	3.295	3.300	3.300	3.310	3.312	3.345

Sample Nos. 1-8 phlogopitic pyroxenites; 9-12 feldspathic pyroxenites; 13-18 scapolitic pyroxenites.

* Analyzed 16 times. [1] Total Fe quoted as Fe_2O_3.

TABLE 2. TRACE ELEMENTS IN FASSAITE FROM S. E. MADAGASCAR

Element	1	2	3	4	5	6	7	8	9
Ag	<1ppm	<1ppm	—	—	<1ppm	<1ppm	<1ppm	<1ppm	<1ppm
B	26	110	212	110	97	58	100	10	291
Ba	30	35	82	45	33	47	56	83	113
Be	9	17	258	194	105	246	17	9	345
Co	65	200	98	78	61	71	68	66	124
Cr	57	78	114	89	123	66	118	72	102
Cu	23	10	145	121	32	133	19	76	184
Ga	12	7	24	12	8	10	14	9	29
Mn	547	1895	2845	1490	1250	3390	677	2135	6460
Mo	—	<10	Tr	Tr	—	—	—	—	<10
Ni	50	84	80	61	34	37	50	60	99
Pb	6	3	59	163	10	4	7	9	36
Sn	60	44	2670 *	1805 *	234	610	71	61	2000 *
Sr	33	30	420	178	120	52	470	75	610
Y	1770	1455	1450	2000	425	1115	2245	2095	768
Yb	5	4	16	11	7	6	6	6	11
Zn	230	191	337	458	324	273	267	274	544

Element	10	11	12	13	14	15	16	17	18
Ag	3ppm	<1ppm	1ppm	<1ppm	<1ppm	<1ppm	<1ppm	<1ppm	<1ppm
B	46	35	85	54	77	50	102	79	26
Ba	48	37	28	40	41	718 *	43	137	70
Be	14	9	125	7	8	4	10	19	11
Co	103	88	84	61	62	58	83	212	81
Cr	321	418 *	104	115	108	119	76	72	187
Cu	215	20	12	14	19	21	45	12	41
Ga	27	15	21	8	8	15	20	66	11
Mn	6875	1032	2520	502	416	247	1130	114	3910
Mo	—	<10	<10	—	—	—	—	<10	<10
Ni	115	140	42	40	46	41	63	39	28
Pb	17	3	—	3	6	38	14	5	10
Sn	188	39	448	10	68	49	89	52	104
Sr	692	91	150	148	154	2350 *	329	76	125
Y	2075	2700 *	1115	429	2470 *	1370	2270	1720	5410 *
Yb	7	5	7	5	5	7	6	5	7
Zn	724	437	333	368	300	179	438	210	882 *

Notes: All the analyses were done in triplicate and the average is given (except for samples 12 and 18, which were analyzed 16 times.

* For these high values, a control was kept by exciting those samples, various times, for independent elements.

Tr: means the element was present, but at a level below the lowest significant point on the working curve.

<: less than is used where concentration was below a measurable level.

—: signifies that the element was not detected.

16 times to determine the reproducibility and precision of the methods used. These results are recorded in Table 3. From this the analytical dispersion can be judged for the other analyses. The atom proportions (for 24 oxygen) are given in Table 3.

The most remarkable single characteristic of these pyroxenes is the high content of Al_2O_3 which distinguishes them from the common pyroxenes of the diopside-hedenbergite series. As a group, fassaites are distinguished from aluminous pyroxenes of the omphacite type by their lower silica percentages, omphacites having higher silica percentages (52-55.5 per cent). The fassaites have insignificant content of alkalis, whereas omphacites have a significant content of alkalis. In fassaite, the

TABLE 3. PRECISION DATA FOR SAMPLE 18

Element	Mean[1]	Relative Deviation[2]	Number of atoms		
SiO_2	42.30%	1.06%	Si	6.62	8.0
Al_2O_3	9.88	8.13	Al	1.38	
Fe_2O_3	9.00	11.06	Al	0.35	3.93
CaO	24.20	6.14	Fe	1.01	
MgO	10.53	2.66	Mg	2.33	
MnO	0.43	2.22	Mn	0.06	
TiO_2	1.62	7.30	Ti	0.18	
Na_2O	0.53	5.88	Ca	3.86	4.01
Ag	1 ppm	2.5%	Na	0.15	
B	26	12.2	O	24.0	24.0
Ba	70	6.6			
Be	11	5.8			
Co	81	2.9			
Cr	187	5.5			
Cu	41	2.3			
Ga	11	2.1			
Mn	3910	10.5			
Mo	—	—			
Ni	28	3.7			
Pb	10	14.8			
Sn	104	11.2			
Sr	125	10.1			
Y	5410	8.6			
Yb	7	1.5			
Zn	882	3.9			

[1] Bias-corrected mean of 16 determinations.
[2] Combined deviations of measurement and bias-correction, for single determinations.

major part of the aluminum replaces silicon, whereas in the omphacite, aluminum replaces silicon as well as the elements of the "Y" group (Mg,Fe,Mn, etc.) and at the same time calcium is replaced by sodium.

The general high level of trace elements in the samples of fassaites confirm the very complex paragenesis of the minerals of S.E. Madagascar (phlogopite, monazite, uranothorianite, cassiterite, spinel, rutile, ilmenite, magnetite, garnets, zircon, sphene, beryl, apatite, amphiboles, ortho-pyroxenes, feldspars, calcite, dolomite, scapolites, saphirine and various sulphide minerals) (Lacroix 1922, 1941 ; de la Roche 1956, 1958).

Acknowledgments

I wish to express my sincere gratitude to Dr. H. de la Roche, Assistant Director of C.R.P.G., C.N.R.S., Nancy, France, for providing the samples and use of the optical and chemical laboratory facilities at C.R.P.G., Nancy. I am also grateful to Professor C.G.I. Friedlaender, Department of Geology, Dalhousie University, Halifax, Nova Scotia, Canada, for permitting the use of the laboratory facilities for *x*-ray investigations during a period as a Special Lecturer in Geochemistry.

References

Black, I.A. (1952) : Application of the seidel transformation to the determination of intensity ratio by blackening curve separation : *Spectrochim. Acta* **4,** 519-524.

Clark, C.B. (1946) : X-ray diffraction data for compounds in the system CaO-MgO-SiO_2 : *Jour. Am. Ceram. Soc.* **29,** 25.

Knopf, A. & Lee, D.E. (1957) : Fassaite from near Helena, Montana : *Am. Mineral.* **42,** 73-77.

Lacroix, A. (1922) : *Minéralogie de Madagascar,* I, II, III, Challamel, Paris.

———— (1941) : Les gisements de phlogopite de Madagascar et les pyroxénites qui les renferment : *Ann. Géol. Serv. Min. Madagascar XI.*

Mitchell, R.L. (1948) : The spectrographic analysis of soils, plants and related materials : *Comm. Bur. Soil Sci., Tech. Comm.* **44,** 1-183.

Rajasekaran, K.C. (1960) : Fassaites from Sankaridrug and Tiruchengodu, Salem District, Madras, India : *Ind. Min.* **1,** 29-31.

Roche, H. de la (1956) : La géologie de l'extrême Sud-Est de Madagascar : *Bull. Soc. Géol.* France (6) **6,** 259-267.

———— (1958) : *Contribution à l'étude géologique du socle cristallin de Madagascar :* Thèse, Univ. de Nancy.

Sakata, Y. (1957) : Unit cell dimensions of synthetic aluminian diopsides : *Jap. Journ. Geogr. & Geol.* **28,** 161-168.

Tilley, C.E.(1938) : Aluminous pyroxenes in metamorphosed limestones : *Geol. Mag.* **75,** 81-86.

Manuscript received January 1970.