

lawsonbauerite await a full single crystal structure determination which we hope shortly to initiate using crystals from Iron Monarch.

Acknowledgements. The authors wish to thank Mr. Stuart McClure of CSIRO Division of Soils, Adelaide, for taking the SEM micrograph. Microprobe analyses were obtained in the Department of Geology, University Melbourne.

References

- Francis, G. and Segnit, E. R. (1981) Lepidocrocite from Iron Monarch, South Australia. *Austral. Mineral.*, **1**(36), 187–8.
- Hill, R. J. (1980) The structure of mooreite. *Acta Crystallogr.*, **B36**, 1304–11.
- Miles, K. R. (1954) *The geology and iron ore resources of the Middleback Range Area*. Geological Survey of South Australia, Bulletin, 33, 245pp.
- Pecor, D. R., Dunn, P. J., Kato, A., and Wicks, F. J. (1985) Shigaite a new manganese aluminium sulfate mineral from the Ioi mine, Shiga, Japan. *Neues Jahrb. Mineral., Mh.*, 453–7.
- Pilkington, E. S., Segnit, E. R., Watts, J., and Francis,

- G. (1979) Kleemanite, a new zinc aluminium phosphate. *Mineral. Mag.*, **43**, 93–5.
- Pring, A., Francis, G. L., and Birch, W. D. (1989) Pyrobelonite, arsenoklasite, switzerite and other recent finds at Iron Monarch, South Australia. *Austral. Mineral.*, **4**, 29–55.
- Gatehouse, B. M., and Birch, W. D. (1990) Francisite, $\text{Cu}_3\text{Bi}(\text{SeO}_3)_2\text{O}_2\text{Cl}$, a new mineral from Iron Monarch, South Australia: description and crystal structure. *Am. Mineral.*, **75**, 1421–5.
- Francis, G. L., and Birch, W. D. (1992) Namibite and nissonite, two unusual copper minerals and other recent finds from Iron Monarch, South Australia. *Austral. Mineral.*, **6**, 31–9.
- Segnite, E. R. and Francis, G. L. (1983) Secondary phosphate minerals from Iron Monarch South Australia. *Ibid.*, **1**(43), 243–50.
- Treiman, A. H. and Pecor, D. R. (1982) The crystal structure of lawsonbauerite, $(\text{Mn,Mg})_9\text{Zn}_4(\text{SO}_4)_2(\text{OH})_{22}\cdot 8\text{H}_2\text{O}$ and its relation to mooreite. *Am. Mineral.*, **67**, 1029–34.

[Manuscript received 16 September 1991]

© Copyright the Mineralogical Society

KEYWORDS: shigaite, Iron Monarch, South Australia, hydrated manganese aluminium sulphate, powder X-ray diffraction data, chemical analyses.

South Australian Museum, North Terrace, Adelaide, South Australia 5000, Australia.

CSIRO Division of Soils, Private Bag No. 2, P.O. Glen Osmond, South Australia 5064, Australia.

Museum of Victoria, 285 Russell Street Melbourne, Victoria 3000, Australia.

A. PRING

P. G. SLADE

W. D. BIRCH

MINERALOGICAL MAGAZINE, SEPTEMBER 1992, VOL 56, PP. 419–422

The occurrence of daqingshanite-(Ce) in the Nkombwa Hill carbonatite, Zambia

DAQINGSHANITE-(Ce), $(\text{Sr,Ca,Ba})_3(\text{Ce,Lu})_2(\text{PO}_4)_3(\text{CO}_3)_{3-x}(\text{OH,F})_x$, was first found in 1976 in the margin of an altered pegmatite dyke in the Mont Saint-Hilaire alkaline intrusive complex, Quebec, Canada; and was recognised as a potential new species (Chao and Baker, 1979; Horváth and Gault, 1990). Daqingshanite was also identified in 1980 in low-grade meta-dolomite in the footwall zone of the Proterozoic Bayan Obo iron ore–rare earth element (REE) deposit in China and was subsequently described as a new species with the ideal formula $\text{Sr}_3\text{RE}(\text{PO}_4)_3(\text{CO}_3)_3$ (Yin-

chen *et al.*, 1983; Shigley, 1984). At Bayan Obo there may be some genetic links with carbonatite dykes. During a mineralogical study of the Nkombwa Hill carbonatite complex in northern Zambia, the present authors discovered daqingshanite in magnesiocarbonatite (Woolley and Kempe, 1989).

The Nkombwa Hill carbonatite (Turner *et al.*, 1989) is a 700 m wide and 1200 m long oval plug of dolomite carbonatite and subsidiary ferrocarnatite occurring in northern Zambia as part of the late Proterozoic North Nyasa alkaline province

(Bloomfield, 1970). Daqingshanite has been identified within sheets of altered magnesio-carbonate cutting dolomite carbonatite at two localities in the northwest sector of the intrusion where it is associated with monazite-rich bands which are a few centimetres thick and extend for several metres.

Daqingshanite comprises approximately 20% of the rock and occurs as off-white, platy crystals, up to 3 mm in size, set in a matrix of dolomite which is sometimes clouded with goethite (Fig. 1). Clustered tabular grains of baryte microcrystalline aggregates of monazite and quartz are the other major components with isokite (Deans and McConnell, 1955), apatite and strontianite as rare accessory phases.

The platy crystals of daqingshanite often have rounded edges and sometimes occur as rhombohedra (Fig. 1). Optically it is difficult to distinguish from dolomite as it is colourless in

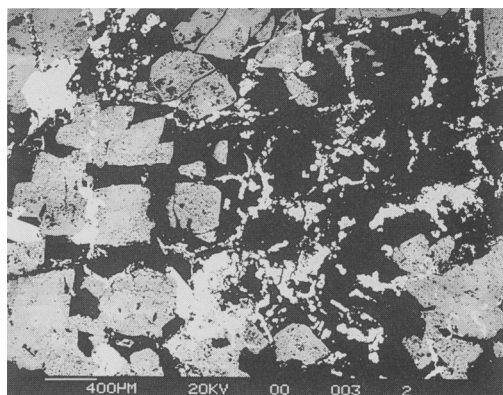


FIG. 1. Backscattered electron photomicrograph of daqingshanite-(Ce) magnesio-carbonatite (ZNK-14): platy crystals of daqingshanite (grey); dolomite (black); tabular baryte (white); microcrystalline aggregates of monazite (white).

unpolarised light, uniaxial negative and has a high birefringence. The optical and physical properties of the daqingshanite have not been investigated in detail.

Distinct C-O (CO_2) and P-O (PO_4) absorption bands can be seen on the infrared spectrum (Fig. 2), but it is clear from the indistinct H_2O absorption band that there is little OH substitution for carbonate. In contrast the Bayan Obo daqingshanite has a pronounced H_2O absorption band (Yingchen *et al.*, 1983).

X-ray powder photographs of daqingshanite removed from a polished thin section were made using a Debye-Scherrer camera and Ni-filtered $\text{Cu-K}\alpha$ radiation. There is good agreement between the Nkombwa and Bayan Obo XRD data except that the $d(\text{obs})$ 1.701 for the Nkombwa daqingshanite appears to be significantly stronger than for the equivalent $d(\text{obs})$ 1.690 of the Bayan Obo sample (Table 1).

Energy-dispersive electron microprobe analysis using techniques described in detail by Styles and Young (1983) together with wavelength-dispersive microprobe analysis for fluorine and chlorine is reported in Table 2. Variations within and between grains were detected but no systematic zoning was recognised. The Nkombwa daqingshanite contains more strontium with correspondingly lower calcium and barium than the Bayan Obo daqingshanite. $\text{Sr}/(\text{Sr} + \text{Ca} + \text{Ba})$ is 0.9 for Nkombwa compared with 0.5 for Bayan Obo. The light rare earth elements (La, Ca, Pr, Nd) predominate over the heavy rare earth elements in both examples of daqingshanite but the total amount of the rare earth elements is higher in the Nkombwa daqingshanite whilst F and (OH) are lower. As CO_2 and H_2O^+ were not determined in the Nkombwa daqingshanite, empirical formulae were calculated assuming the presence of three (CO_3^{2-} , F^- , OH^- , Cl^-) anions and assigning 7 oxygens to the remaining cations. This gives formulae of $(\text{Sr}_{2.69}\text{Ca}_{0.11}\text{Ba}_{0.20})_{\Sigma 3.0}$

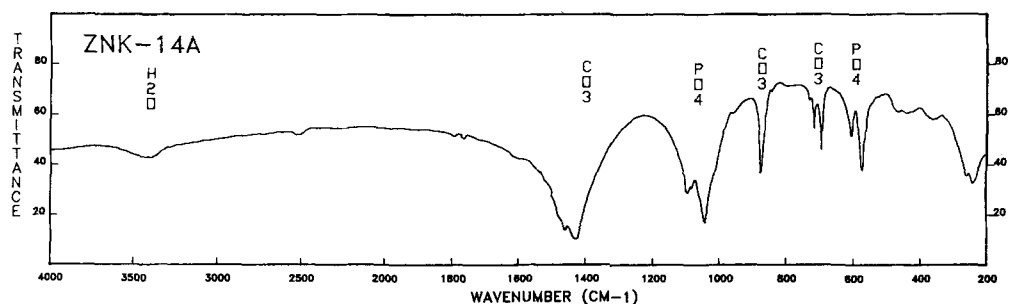


FIG. 2. Infrared absorption spectrum of Nkombwa daqingshanite.

Table 1. Daqingshanite X-ray powder data

Nkombwa, Zambia		Bayan Obo, China ⁽¹⁾	
d (obs)	I ⁽²⁾	d (obs)	I/Io ⁽³⁾
10.400	VVW	—	—
6.340	VW	—	—
5.030	M	5.020	3
4.080	MW	4.060	1
3.940	S	3.950	6
3.170	VVS	3.160	10
3.060	MS	—	—
2.890	W	2.890	1
2.520	MS	2.520	7
2.340	VW	2.315	2
2.230	W	2.225	1
2.120	S	2.110	5
2.040	S	2.040	6
1.972	MW	1.964	3
1.948	S	1.941	6
1.902	M	1.895	4
1.892	—	—	—
1.835	W	1.828	1
1.806	MW	1.801	1
1.701	M	1.690	1
1.621	M	1.620	4
1.551	M	1.552	4
1.358	M	1.358	4
—	—	1.170	1
—	—	1.079	1
—	—	1.071	1
1.032	M	1.035	4

(1) Yinchen *et al.*, 1983. Debye-Scherrer camera, Mn filtered Fe K α

(2,3) Visually estimated (V = very; W = weak; M = medium; S = strong)

(La,Ce,Nd,Pr)_{1.02}(PO₄)_{0.99}(CO₃)_{3-x}(OH,F)_x for Nkombwa and (Sr_{1.61}Ca_{0.71}Ba_{0.67})_{Σ3.0}-(La,Ce,Nd,Pr)_{0.79}(PO₄)_{1.06}(CO₃)_{3-x}(OH,F)_x for Bayan Obo.

These results suggest that major substitution between Sr, Ca and Ba occurs in daqingshanite together with minor light REE and possibly total

Table 2. Daqingshanite chemical composition.

	Nkombwa, Zambia (ZNK-14)		Bayan Obo, China ²
	mean(n=10)	S.D. ¹	
La ₂ O ₃	10.22	1.07	7.88
Ce ₂ O ₃	12.24	0.28	10.16
Pr ₂ O ₃	0.83	0.27	0.68
Nd ₂ O ₃	1.71	0.39	1.59
Sm ₂ O ₃	<0.42	nd	0.11
Gd ₂ O ₃	<0.40	nd	0.12
ThO ₂	<0.22	nd	0.04
CaO	0.94	0.38	6.17
Na ₂ O	<0.16	nd	0.13
SrO	41.82	1.43	26.10
BaO	4.57	1.00	15.98
MgO	<0.12	nd	0.72
Al ₂ O ₃	<0.12	nd	0.18
P ₂ O ₅	10.50	0.44	11.73
F	0.29	nd	0.80
Cl	0.10	nd	nd
CO ₂	nd	nd	16.19
H ₂ O ⁺	nd	nd	0.68
Total	83.22	nd	99.26
Number of ions on basis of 7 oxygens			
La	0.42	0.04	0.31
Ce	0.50	0.01	0.40
Nd	0.03	0.01	0.03
Pr	0.07	0.01	0.06
Sm	nd	nd	0.00
Gd	nd	nd	0.00
Th	nd	nd	0.00
Ca	0.11	0.05	0.71
Na	nd	nd	0.03
Sr	2.69	0.05	1.61
Ba	0.20	0.05	0.67
Mg	nd	nd	0.11
Al	nd	nd	0.02
P	0.99	0.02	1.06
Total	5.01	0.03	5.01
ΣSrBaCaNa	3.00	0.05	3.01
REE	1.01	0.03	0.79

¹ S.D. : standard deviation

² Yingchen *et al.*, 1983

nd not determined

REE variation. Analyses of the Bayan Obo daqingshanite was performed on a mineral concentrate by wet chemical (?) methods and gas

chromatography, so direct comparison with out electron microprobe data should be made with caution.

Acknowledgements. This study forms part of a project on African carbonatites funded by the Overseas Development Administration, UK. Improvements to the manuscript were suggested by F. Wall and J. F. W. Bowles. Permission to publish was granted by the Director, British Geological Survey (NERC) and the Chief Geologist, Minex Department, ZIMCO.

References

- Bloomfield, K. (1970) Orogenic and post-orogenic plutonism in Malawi. In *African Magmatism and Tectonics* (T. N. Clifford and I. G. Gass, eds.) Edinburgh, Oliver and Boyd, 119–55.
- Chao, G. Y. and Baker, J. (1979) What's new from Mont Saint-Hilaire? *Mineral. Record*, **10**, 99–101.
- Deans, T. and McConnell, J. D. C. (1955) Isokite, CaMgPO_4F , a new mineral from Northern Rhodesia. *Mineral. Mag.*, **30**, 681–90.
- Horváth, L. and Gault, R. A. (1990) The Mineralogy of

- Mont Saint-Hilaire, Quebec. *Mineral. Record*, **21**, 281–359.
- Shigley, J. E. (1984) Daqingshanite (New Mineral Names: abstr.) *Amer. Mineral.*, **69**, 811.
- Styles, M. T. and Young, B. R. (1983) Fluocerite and its alteration products from the Afu Hills, Nigeria. *Mineral. Mag.*, **47**, 41–6.
- Turner, D. C., Anderson, L. S., Punokollo, S. N., Sliwa A., and Tembo F. (1989) Igneous phosphate resources of Zambia. In *Phosphate deposits of the World, Volume 2: Phosphate Rock Resources* (A. G. Northolt, R. P. Sheldon, and D. F. Davidson, eds.) Cambridge, Cambridge University Press, 247–57.
- Woolley, A. R. and Kempe, D. R. C. (1989) Carbonatites: nomenclature, average chemical compositions, and element distribution. In *Carbonatites* (K. Bell, ed.), Unwin, London, 1–14.
- Yingchen, R., Lulu, X., and Zhizhong, P. (1983) Daqingshanite—a new mineral recently discovered in China. *Geochemistry (China)*, **2**, 180–4.

[Manuscript received 4 July 1990;
revised 13 January 1992]

© Copyright the Mineralogical Society

KEYWORDS: Zambia, Nkombwa Hill, carbonatite, daqingshanite-(Ce)

*British Geological Survey, Keyworth,
Nottingham NG12 5GG, UK*

*MINEX Department, ZIMCO Ltd.,
P.O. Box 30090, Lusaka, Zambia*

J. D. APPLETON
D. J. BLAND
P. H. NANCARROW
M. T. STYLES
S. H. MAMBWE
P. ZAMBEZI

MINERALOGICAL MAGAZINE, SEPTEMBER 1992, VOL 56, PP. 422–425

A new mantle xenolith locality from southern Ethiopia

ULTRAMAFIC xenoliths are found in basanite and nephelinite lava flows and pyroclastic rocks of probable late Pleistocene age south of Mega, in the Sidamo Region of southern Ethiopia, close to the Kenya–Ethiopia border line (Lat. 3°55'N, Long. 38°15'E) in the Anza graben (Fig. 1). The xenoliths, first reported by Jelenc (1966), comprise crustal granite and gneiss, and abundant ultramafic inclusions, up to 40 cm in diameter, and are sub-rounded ovoidal to angular. The host rocks also carry rarer feldspathic and pyroxenitic nodules as well as megacrysts, mainly of anorth-

oclase, clinopyroxene and amphibole. The first chemical data of the ultramafic xenoliths and host rocks are presented here.

Host rocks

The nephelinite and basanite host rocks show a porphyritic texture of olivine phenocrysts and Ti-augite microphenocrysts set in a groundmass of olivine, Ti-augite, plagioclase, opaques, subordinate nepheline and glass. Elongate vesicles with a