most of those reported by the above authors. The composition of the plagioclase from the above analysis ($Ab_{48}An_{50}Or_2$) falls on the boundary of andesine–labradorite. However, the MgO percentage of this analysis is larger than those of andesine and labradorite reported by Deer et al. (1963), who pointed out that Mg could substitute for Ca in the anorthite molecule. The larger MgO percentages for ilmenite and plagioclase of the Deer Park grey basalt is consistent with the analysis of the rock itself, which indicates 9.70 MgO, 7.80 CaO, 6.80 FeO, and 3.42% Fe_2O_3.

The vesicles form early in the cooling history of the lava flow as a result of the release of volatiles, which assist the movement of residual liquids and facilitate crystallization of minerals in the vesicles. This feature was less extensive in the Deer Park basalt than in the Portland alkali basalt and in the Cosgrove leucitite, since vesicle formation and mineral crystallization was less developed in the former. The differences in mineral assemblages and in vesicularity of the rocks reflect the differences in the composition of the original magma, the residual liquids, and the volatiles.

The equilibrium diagram of plagioclase feldspars indicates a crystallization temperature of 1285 °C for the andesine–labradorite ($Ab_{48}An_{50}Or_2$) from Deer Park. This temperature, however, would be applicable to a volatile-free system and, for the vesicle minerals of the grey basalt, a temperature range of 700 to 900 °C, similar to that suggested for Cosgrove leucitite (Birch, 1980), is probably more reasonable.

REFERENCES

Birch, W. D. (1979) Austral. Mineral. 27, 131–2.
——(1980) Mineral. Mag. 43, 597–603.
——(1982) Austral. Mineral. 37, 195–8.
Cole, W. F., and Lancucki, C. J. (1975) Proc. Int. Clay Conf., Mexico City, 35–43.
Coulson, A. (1938) Proc. R. Soc. Victoria, 50, 251–7.
Deer, W. A., Howie, R. A., and Zussman, J. (1963) Rock Forming Minerals, 4. Longmans, Green and Co. Ltd., London, 108–29.
——————(1967) Ibid. 5, 28–33.
Reynolds, A. H. (1972) Proc. 6th ARRB Conf. 6(5), 124–38.
Spencer-Jones, D. (1967) Geological Survey of Victoria. Bulletin No. 59, Geology of Melbourne District, Victoria, 62.

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The composition of sphalerites from Ishiagu, E. Nigeria

A NUMBER of sphalerite samples have been collected from Quarries 1 and 2 (fig. 1) at Ishiagu, about 80 km SSE of Enugu. The sphalerite occurs with galena and minor pyrite in a gangue of siderite and quartz, in steeply dipping veins which follow fault zones trending approximately N40° W. Previous reconnaissance work on the deposits (Cotsworth, 1949; McConnell, 1949; Bogue, 1952; and Farrington, 1952) did not involve any detailed mineralogy. The purpose of this note is to present new analyses for both major and minor elements in the sphalerite, and to discuss possible indications of the temperature of formation.

Geology and physiography. The geology of the Ishiagu region is shown in fig. 1. The geology of the area, which lies between 30 and 100 m o.d. and is covered by tropical rainforest, is dominated by the Asu River Formation, which consists of carbonaceous shale with sandstone lenses of Albian age. The Ezeaku Shale Formation (Turonian) has a basal sandstone unit which lies unconformably above the Asu River Formation. The former now occurs in the NW and SE of the area, on the limbs of a gentle anticline which trends NE. An alkaline dolerite sill is intruded into the Asu River Formation (Ezepue, 1979) and forms the principal host to the mineral veins. Two sets of steeply dipping faults cut the sill, striking at around N30° W and N50° E. Only the former carries mineralization.

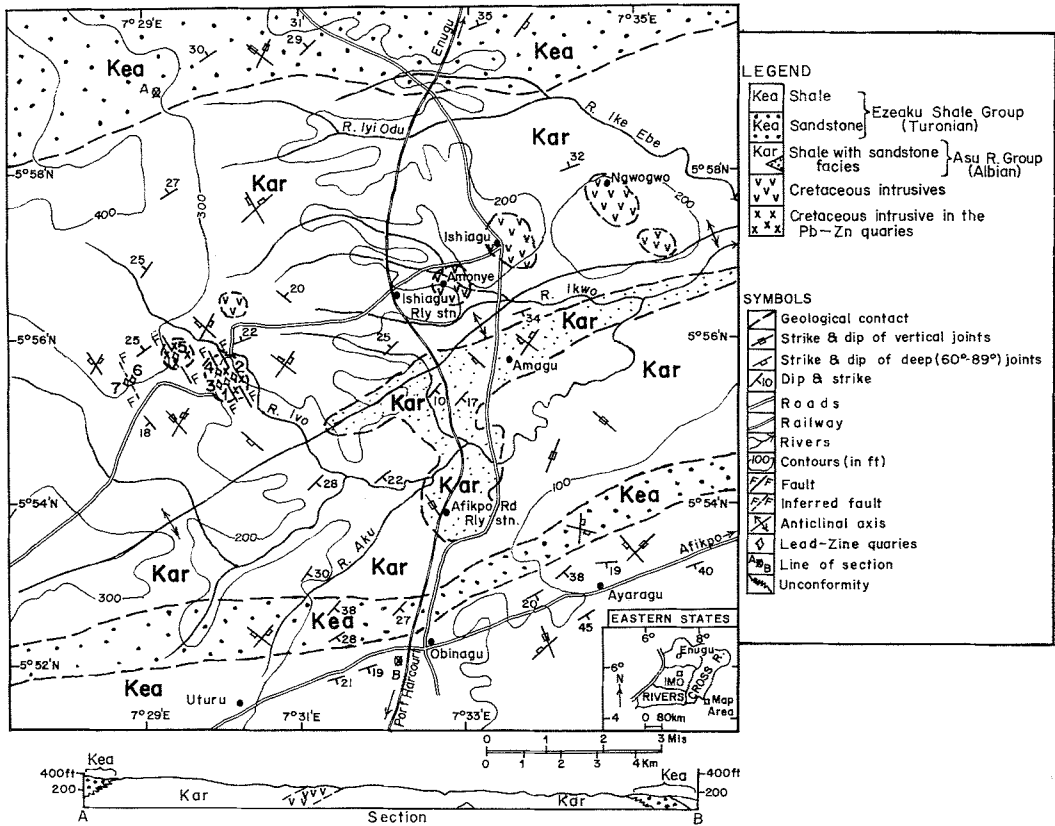Composition of the sphalerites. Five samples were

FIG. 1. Geological map of the Ishiagu lead-zinc district.

chosen to represent the material seen in the field. These have been analysed for Zn, Fe, Mn, and S using a Geoscan electron microprobe fitted with a Link Systems ED spectrometer. Other elements were analysed in bulk samples using pressed powder discs in a Philips PW1450 XRF.

The Ishiagu sphalerite shows a range of colours, from yellow to pale brown to dark brown, occurring usually as anhedral to subhedral crystals in monomineralic bands, or in bands with galena with or without pyrite. Some bands are finely granular. In transmitted light distinct colour zoning is apparent, of a style considered to be typical of low-temperature sphalerites (Mincheva-Stefanova, 1974).

A number of spot analyses (53) have been made of the different colour bands using the electron microprobe. The results are summarized in Table I, with the bulk sample trace element analyses for each sample, determined by XRF. The averaged analyses are close to a metal to sulphur ratio of unity, but generally have a slight excess of sulphur,

as might be expected in view of the presence of pyrite and galena in the veins.

In the lower part of Table I, the average values for Fe in the light-brown (LBZ), yellow-brown (YBZ), and red-brown (RBZ) zones are shown, with the mean value for each type of band. There would seem to be small but systematic changes in the Fe-content between bands. Mn was looked for by both analytical techniques, but not found (detection limits: EMPA 0.15 wt. %, XRF 10 ppm), so cannot contribute significantly to the colour zoning. It is not possible to assess from the present data whether any of the trace elements plays a significant part in the zoning; they are all below or very close to the detection limits of the energy dispersive spectrometer.

The levels of iron in the Ishiagu sphalerites (ave. 0.9 wt. %) are small compared with the 26 wt. % Fe considered by Kullerud (1953) and Deer et al. (1962) to be capable of replacing Zn in high-temperature, iron-rich environments. However, the levels found at Ishiagu are very similar to low-temperature

TABLE I. *Average electron microprobe and XRF analyses of sphalerites from Ishiagu*

Sample	E1	E2	E3	E4	E5	
Zn	65.7	65.7	66.1	66.0	65.9	
Fe	1.1	1.3	0.8	0.7	1.1	
S	33.3	33.1	32.9	33.2	33.2	
Ag	46	42	28	95	28	
Cd	3325	2950	3400	2775	4425	
Sn	35	n.d.	n.d.	48	148	
In	n.d.	12	7	15	27	
Ge	195	120	95	228	100	
Total	100.5	100.4	100.2	100.2	100.7	
	Cations per ten sulphurs					
Zn	9.67	9.74	9.85	9.74	9.73	
Fe	0.19	0.22	0.14	0.13	0.19	
Cd	0.03	0.03	0.03	0.02	0.04	
Total	9.89	9.99	10.02	9.89	9.96	
	Iron in different colour zones					Mean
LBZ	0.9(4)	0.8(5)	0.5(5)	0.5(9)	0.8(2)	0.6
YBZ	1.2(2)	1.7(1)	1.0(1)	0.8(4)	0.9(2)	1.0
RBZ	1.2(7)	2.3(2)	1.0(3)	1.1(3)	1.4(3)	1.3
Spots	13	8	9	16	7	

Notes. 1. Zn, Fe, and S in wt. %. Electron microprobe spot analyses. The total number of spots analysed for each sample is shown at the foot of the Table, and for each colour band in brackets after the average values.

2. Ag, Cd, Sn, In, and Ge in ppm. XRF bulk analyses. n.d. means not detected. In addition the following elements were looked for but not found: Nb, Sb, Zr, Rb, Cu, Ni, Cr, Ce, Nd, V, Ti, La, Ba, Se, Tl, As, Ga, Mn, Bi.

3. Only Cd from the minor elements is included in the calculation of cations per ten sulphurs; the total contribution of the other trace elements is less than 0.003 per ten sulphurs.

4. Analyst: M. C. Ezepue.

TABLE II. *Comparison of trace element data*

	E/H	Ag	Cd	Sn	In	Ge	Mn
Ishiagu	E	48	3355	46	12	144	n.d.
Mississippi Valley	E	25	—	—	n.d.	101	50
SE Missouri	E	34	—	—	8	110	—
Illinois–Kentucky	E	—	6900	—	n.d.	—	—
Abakiliki (Nigeria)	E	12	7000	—	n.d.	250	300
Halkyn	E	67	7500	—	12	162	n.d.
N. Pennines	E	160	—	—	36	185	n.d.
Cornwall	H	—	—	156	236	—	2440
La Villeder (France)	H	300	—	200	300	n.d.	2000
Panasqueira	H	250	—	400	200	n.d.	2000
Liruei (Nigeria)	H	—	7000	—	700	n.d.	2000

Data from El Shazly *et al.*, 1957, and Hall and Heyl, 1968.
E means epithermal and H means hypothermal.

deposits (50–200 °C) of the Gringuro Band (0.2–1.6% Fe, 36 samples) and Kanizawa (0.3–2.4% Fe, 29 samples) (Hattori, 1975), from Western Canada (0.9–5.0% Fe, 20 samples; Evans et al., 1968) and from the epithermal deposits of the Upper Mississippi Valley, Illinois–Kentucky district and SE Missouri (1.4, 2.5, and 0.5% Fe respectively; Hall and Heyl, 1968).

The trace elements found in the Ishiagu sphalerites are compared with data from other epithermal and hypothermal deposits in Table II. The data indicate that the trace elements of the Ishiagu sphalerites are similar to epithermal deposits elsewhere. The epithermal deposits have low Ag, In, Mn, and Sn, but higher Ge than the hypothermal deposits (Fleischer, 1955). Cd levels are erratic. However, the data are still scanty and many factors other than temperature may affect the trace element levels.

REFERENCES

Bogue, R. G. (1952) Unpubl. Geol. Surv. (Nigeria) Rept. no. 1016.
Cotsworth, T. H. G. (1949) Unpubl. Rept. no. E/182/1, Mines Dept., Enugu.
Deer, W. A., Howie, R. A., and Zussman, J. (1962) Rock Forming Minerals, 5. Longmans, London.
El Shazly, E. M., Webb, J. S., and Williams, D. (1957) Trans. Inst. Mining Metall. 66, 241–71.
Evans, T. L., Campbell, F. A., and Krouse, H. R. (1968) Econ. Geol. 63, 349–59.
Ezepue, M. C. (1979) Unpubl. Ph.D. thesis, University of Manchester.
Farrington, J. L. (1952) Econ. Geol. 47, 583–608.
Fleischer, M. (1955) Ibid. 50th Anniv. Vol. 970–1024.
Hall, W. E., and Heyl, A. V. (1968) Ibid. 63, 655–70.
Hattori, K. (1975) Ibid. 70, 677–93.
Kullerud, G. (1953) Norsk Geol. Tidskr. 32, 61–147.
McConnell, R. B. (1949) Unpubl. Geol. Surv. (Nigeria) Rept. no. 408.
Mincheva-Stefanova, Y. (1974) Minerogenesis, Sofia, 171–88.

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Comments on the validity of badenite and epigenite

IN a recent review of the literature, JCPDS, the international centre for diffraction data, has been unable to find X-ray powder diffraction data for either badenite or epigenite. These are the only sulphides given species status by Fleischer (1980) where no powder diffraction data has been found. Palache et al. (1944) consider that badenite needs confirmation and epigenite needs further study. Neither of these minerals are given species status by Strunz (1970) and badenite is not given species status by Embrey and Fuller (1980). Since the original descriptions of badenite in 1900 and epigenite in 1869 no further descriptions have been found by the author. From X-ray powder diffraction data of epigenite (Royal Ontario Museum specimen M11582) from the type locality, Berry and Thompson (1962) indicate its similarity to tetrahedrite.

The chemical formula of badenite given in Palache et al. (1944) as $(Co,Ni,Fe)_3(As,Bi)_4$? is different from that given by Dana and Ford (1909) as $(Co,Ni,Fe)_2(As,Bi)_3$. The chemical analysis given

has 61.54 As, 4.76 Bi, 0.27 S, 20.56 Co, 7.39 Ni, 5.98 Fe, and 100.50% total. This chemical analysis may be calculated into a chemical formula of $(Co,Ni,Fe)(As,Bi,S)_{1.47}$. Since the atomic size of Bi is significantly greater than As, Bi is highly unlikely to substitute for As. If Bi occupies a discrete crystal structure site then the chemical analsis may be calculated into a chemical formula of $(Co,Ni,Fe)_{25.5}(As,S)_{36.5}Bi_{1.0}$. Such a chemical formula is unlikely due to the high ratios involved. The binary alloy diagrams given by Hansen and Änderko (1958) do not show intermediate compounds between FeAs and $FeAs_2$, CoAs and $CoAs_2$, and NiAs and $NiAs_2$. Neither does the investigation of a natural Ni–Co–As assemblage by Misra and Fleet (1975). Therefore both the metal:non-metal ratios of 3:4 and 2:3 are unlikely in these chemical systems. Calculations show that a mixture of 5% bismuth, 55% safflorite ($CoAs_2$), and 40% modderite (CoAs) would fit the chemical analysis of badenite.

The chemical formula of epigenite given in