

## THE CONCENTRATION OF COPPER, LEAD AND ZINC IN SEDIMENTS IN WOOKEY HOLE CAVE, SOMERSET

by  
R. D. STENNER

### SUMMARY

The River Axe in Wookey Hole Cave drains a large area of Central Mendip. Three of the tributary streams enter St. Cuthbert's Swallet after flowing through disturbed land, where lead mining was carried out from pre-Roman times until the early twentieth century (Gough 1967). Analyses of sediments collected from an excavation in the Fourth Chamber of Wookey Hole were compared with those from elsewhere, to permit an assessment to be made of the extent and magnitude of contamination by the former lead industry.

### EXPERIMENTAL

Samples of sediments were collected from the excavation of a Romano-British cemetery in the Fourth Chamber of Wookey Hole in August 1973, 1974 and 1975. Other samples were from the first five chambers and the passage, now closed, from Wookey Hole Nine to the surface. Samples were also collected from St. Cuthbert's Swallet and three other Mendip caves. From other surface sites a further 150 samples were taken, to provide more comparative data, which were all analysed using identical procedures.

The samples were dried, screened, digested with nitric acid and analysed for copper (Cu), lead (Pb) and zinc (Zn) by atomic absorption spectrophotometry. Full practical details of this method will be presented in a future publication (Stenner 1978). In 90 samples analysed in duplicate the mean of each metal had a Standard Error of approximately 5.5%. The maximum enhancement of lead by calcium was 50 parts per million (p.p.m.). The three sets of results from the Wookey Hole Fourth Chamber excavation were compatible with one another and a summary of these results is presented in Table 3.

TABLE 3

Thickness of sample analysed cm. (approx.)	Thickness of deposit, cm.	Description of deposits	Metal concentration, p.p.m.		
			Cu	Pb	Zn
		Surface			
1 _____ )	8 (approx)	soft, unstratified	18	7200	1100
_____ )					
2 _____ )	7 (approx)		25	11000	1600
_____ )					
0.9 _____ )	15 approx.	hard, stratified,	71	26000	1600
0.8 _____ )			38	24000	2100
1.6 _____ )		29	5200	1800	
0.5 _____ )		many strata containing	38	5100	1700
0.9 _____ )		charcoal or	37	4800	780
0.6 _____ )		bone fragments	31	3600	860
0.5 _____ )			34	5100	1500
_____ )					
5 _____ )			53	4700	680
4 _____ )			50	3000	820
_____ )	15	compact, unstratified	36	480	760
2 _____ )					
_____ )	15		75	750	1050
2 _____ )					
_____ )	16	muddy gravel	28	1100	810
2 _____ )					
		bed rock.			

The concentration of copper, lead and zinc in sections through a mud bank in the Fourth Chamber of Wookey Hole containing archaeological material, given by samples collected in August 1973, 1974 and 1975.

## DISCUSSION

Table 3 shows conclusively that the higher levels of lead in Wookey Hole Cave sediments are un-natural and are a consequence of the lead

industry. Analysis of sediments from St. Cuthbert's Swallet also led to the conclusion that the high level of lead contamination was un-natural and was the result of pollution by the lead industry (Stenner 1978).

The analysis of nine samples from the river bed in Wookey Hole Chambers 1 to 5 gave figures similar to the soft unstratified deposits in the Fourth Chamber, set out in Table 3. The mean was 8,500 (S.D. 2,400) p.p.m. Pb. Eight samples from stream passages in St. Cuthbert's Swallet had a mean for Pb of 31,000 (S.D. 15,000) p.p.m., while eight samples from the three feeder streams to the swallet had a mean for lead of 44,000 (S.D. 8,000) p.p.m. Further down the Axe at Loxton four samples from the river bed contained a mean of 90 p.p.m. Pb.

The analysis of 16 samples from caves with no known association with contaminated streams gave figures for copper, lead and zinc of 22 (S.D. 9), 140 (S.D. 90) and 170 (S.D. 120) p.p.m. respectively. These figures suggest that the sediments in St. Cuthbert's Swallet and Wookey Hole, which pre-date the lead mining industry, do indeed contain more lead than other similar cave streams. Values for Pb lay within the range 300 to 900 p.p.m., with the exception of the deepest sample from Wookey Hole Four, shown in the Table. This sample was slightly contaminated by drainage from upper levels.

Of 120 soil samples analysed 61 contained less than 500 p.p.m. and only six contained more than 5,000 p.p.m. Pb. The samples included many from intensively mined land and this serves to emphasize the unusual magnitude of the levels found in the sediments in the streams which sink into St. Cuthbert's Swallet. This swallet has a catchment of 1.2 km<sup>2</sup>. compared with the total revised area of 46.2 km<sup>2</sup>. for Wookey Hole (Smith and Drew 1975). The swallet thus contributes only a small fraction of the total flow from the resurgence. The possibility of sediments being carried by water percolating through intensely mineralized rock and old workings was considered. However the poor ability of small streams to transport sediments must be contrasted with the high transport potential in St. Cuthbert's stream, with its notably fast flow-through time to Wookey Hole (Atkinson, Drew with High 1967). The well-documented lead pollution at Wookey Hole caused directly by the operations at St. Cuthbert's Leadworks were another consideration (Gough 1967). The author's opinion is that the facts are consistent with a hypothesis, that the lead which contaminates the Wookey Hole sediments was transported via St. Cuthbert's Swallet.

#### ACKNOWLEDGMENTS

The author wishes to thank the Royal Society for sponsoring his research and his supervisor, Dr. G. Nickless, for the necessary practical facilities and valued critical advice. He also wishes to thank Dr. W. I. Stanton, Dr. E. K. Tratman and the management of Wookey Hole Caves for making it possible for him to collect samples from within the cave.

## REFERENCES

- ATKINSON, T. C., 1967 Mendip Karst Hydrology Research Project, Phases  
DREW, D. P. with HIGH, C. 1 and 2. *Wessex Cave Club Occ. Publ. Ser. 2 (1)*.
- GOUGH, J. W. 1967 *The Mines of Mendip*. 2nd Ed. David and Charles.
- SMITH, D. I. and 1975 Limestone and Caves of the Mendip Hills. David  
DREW, D. P. (Eds.) and Charles, 183 and 200.
- STENNER, R. D. 1977 The concentration of some heavy metals in sedi-  
ments in some Mendip Caves and an assessment of  
the significance of un-natural contamination. *Proc.*  
*7th. Internat. Cong. of Speleology, Sheffield, Eng.*,  
183-4.
- 1978 (In preparation).