A NOTE ON FRESHWATER RESEARCH IN CHINA, WITH SOME OBSERVATIONS ON THE ALGAE FROM DOUPE POOL, GUIZHOU PROVINCE

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Introduction

This article provides insights into a particular aspect of freshwater research in China and its wider implications for western researchers. China's research activities, although extensive, are the least known of all the world's major countries. This results from two factors. The written Chinese language with its thousands of characters is known to few western researchers, and although most Chinese research papers provide an English summary, the important detail is inaccessible to most researchers, as indeed are the journals themselves. The second important factor is that China was effectively isolated from the west for a period of some thirty years, from the 1950s until the early 1980s. However, there was collaboration with the Soviet Union and Russian became a second language for most Chinese academics during that period. Few academics knew any English, and even today it is the younger researchers who tend to have a better command of that language.

After two years preparation and paperwork, the senior author was granted permission to visit the algology section of the Department of Botany, Nanjing University, in 1982. As far as we are aware this was the first official research visit by a British biologist to Nanjing since the 1950s. Allan was treated with great courtesy and the visit was profitable, resulting in two publications.

More recently, Allan has collaborated with Professor Zhang Zhaohui from Guizhou Normal University to investigate the travertines of China. At the time of writing, foreign researchers with an official invitation can visit China. In the UK, exchange visits are encouraged and the Royal Society, with the National Natural Science Foundation of China, operates several schemes allowing funded visits of up to a year. We participated in such a scheme to conduct field investigations in the provinces of Guizhou and Sichuan in central China (see Fig. 1). Our aims were to investigate the aquatic flora of their travertines, and seek evidence of recent environmental change. We also undertook a comprehensive review of the Chinese deposits to enable us to determine the present state of knowledge and plan future projects.

Over the past 20 years there have been great changes in Chinese research activities. This became apparent from our review. We found that, except for one, all significant papers relating to Chinese travertine were published after

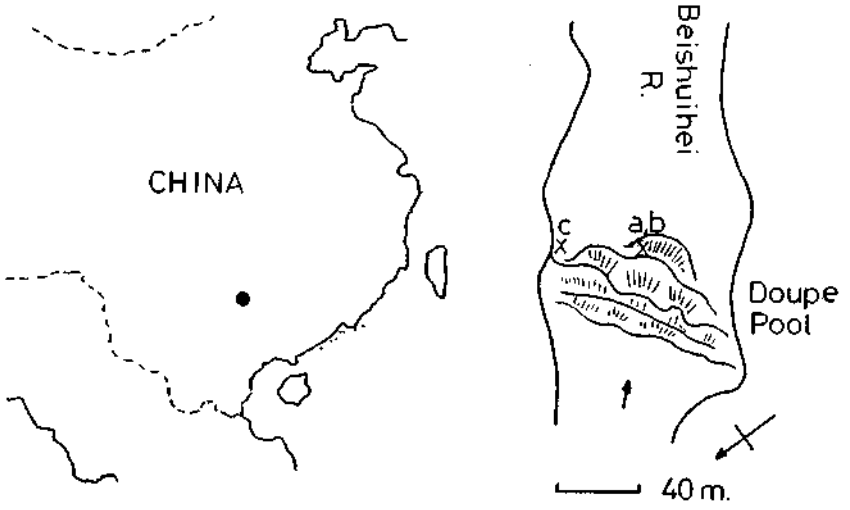

FIG. 1. Location of the Beishuihei River in China (left) and plan of Doupe Pool Waterfall (right), with locations of sampling sites (a), (b) and (c).

Table 1. Numbers of significant research papers on Chinese travertines.

Period	West only	China + West collaboration	China only	Totals
Before 1981	1	0	0	1
1981-1990	2	0	7	9
1991-2000	0	6	17	23

1981 (Table 1). During 1981-1990 there were nine papers but no Chinese-Western collaborations. During 1991-2000 the total was 23 and one-quarter of them were Chinese-Western collaborations. Some of these papers include observations that are not found anywhere in the western literature. If representative of the whole of Chinese freshwater research, there has been a huge upsurge in the past 20 years which is likely to be sustained and of increasing importance to western freshwater biologists.

Travertines are freshwater carbonate deposits accumulating in hard-water springs and rivers. In some areas they develop rapidly, forming picturesque cascades and magnificent travertine-dammed lakes. Some of China's most famous tourist sites are the result of travertine formation (Figs 2 and 3).

The travertine-depositing environment is a unique fast-flowing ecosystem inhabited by specialist plants and animals (e.g. Durrenfeldt 1978; Pentecost

1992). Algae and bryophytes are particularly significant as they aid deposition by trapping carbonate particles and precipitate some carbonate through their photosynthesis. Travertines are often brightly coloured by the growth of algae. For example, the famous deposits of Huanglong (Yellow Dragon) are coloured by diatoms. In sites where such waters have become polluted, the plants have been lost and travertine formation has ceased (Golubic & Fischer 1975).

If serious pollution affected the Chinese sites their beauty would be destroyed. It is therefore important to record their present unpolluted state and implement environmental management policies. Fortunately the Chinese are well aware of the sensitivity of these ecosystems, but a rapidly expanding tourist industry can result in unexpected problems. For example, the surge of tourists to the Pamukkale travertine terraces in Turkey led to water-pollution events that spoilt parts of the terrace and threatened groundwater quality. It is therefore important to record conditions before such events occur, and then monitor to detect early signs of change. We report here on some results from our expedition to the Guizhou travertines where, as far as we know, no previous algological work has been undertaken.

Freshwater algae of the Doupe Pool travertine

Situated on the Beishuihei River in Guizhou Province (26°08'N, 105°36'E; altitude 590 m), Doupe Pool is one of China's most spectacular waterfalls. At 105 metres wide and 21 metres high it is one of the widest travertine-depositing cascades in the world (Figs 1-3). For ease of access we chose this site in preference to the larger Huangguoshu Falls *c. 2* km downstream (see Fig. 3). The Beishuihei River is large and fast-flowing even during the dry period, when we visited the site. We did not undertake water analyses but Yang et al. (1985) found a pH of 7.4, a calcium concentration of 3.1 milliequivalents per litre and 3.26 milliequivalents per litre alkalinity. Mean annual air temperature and precipitation are 16°C and 1200 mm respectively. Rainfall is seasonal and highest in the summer.

We took representative samples of the travertine during April 1999. About half of the cascade surface is covered with the travertine-depositing moss *Hydrogonium williamsii* (Broth.) P. C. Chen. Algae were investigated from three sites: (a) the nodular travertine surface near the base of the cascade and exposed to the full force of water, (b) adjacent growths of *H. williamsii*, and (c) growths of *H. williamsii* from a more sheltered site at the northern end of the falls (Figs 1 and 2).

From our collections we identified as far as possible all freshwater algae that were present. For diatoms, relative abundance was obtained from a large cleaned sample (N = 400 frustules). For the remainder we used a more crude ranked abundance scale (Table 2).

FIG. 2. Doupe Pool Waterfall on the Beishuihei River, looking west. The black arrow on the left indicates positions of sampling sites (a) and (b); the white arrow on the right indicates the position of site (c).

FIG. 3. *Above:* Huangguoshu Waterfall on the Beishuihei River, *c.2* km downstream from Doupe Pool. 74 m high and covered with travertine, the falls attract millions of visitors each year. *Below:* Doupe Pool area; a travertine cave surrounded by mosses, and a pot-hole (foreground) eroded in the travertine.

Table 2. Freshwater algae found at three sites (a, b, c) at Doupe Pool Waterfall on the Beishuihei River, China, and their distribution on travertines elsewhere in the world (C.Am = Central America, N.Am = North America). At Doupe Pool, the percentages of specific diatoms are given when these equal 1% or more; + indicates present at below 1%. For other algae the relative abundances are expressed as Abundant, Frequent and Rare.

Taxon	Site (a) on nodular travertine	Site (b) on *Hydrogonium*	Site (c) on *Hydrogonium*	Elsewhere in the world
CYANOBACTERIA				
Chroococcus helveticus	—	—	Frequent	Europe
Phormidium incrustatum	Rare	—	—	Cosmopolitan
Schizothrix fasciculata	Abundant	—	—	Cosmopolitan
CHLOROPHYTA				
Cladophora sp.	Frequent	—	—	Cosmopolitan
Closterium striolatum	—	—	Rare	
DIATOMS				
Achnanthes minutissima	67%	77%	42%	Cosmopolitan
Anomoeoneis cf. *brachyseira*	—	—	4%	
Cocconeis pediculus	+	+	+	Europe
Cocconeis scutellum	—	+	—	
Cymbella laevis	17%	11%	38%	Europe
Cymbella lanceolata	—	—	1%	Europe, N.Am
Cymbella minuta	1%	+	1%	Europe, Asia
Cymbella cf. *pusilla*	+	—	—	
Cymbella subaequalis	—	+	—	Europe
Cymbella tumidula	+	—	—	
Denticula elegans	—	+	+	Cosmopolitan
Diatoma vulgare	—	+	—	Europe
Diploneis oblongella	—	1%	—	Europe, C.Am
Eunotia arcus	—	—	1%	Europe, Asia
Fragilaria capucina var. *vaucheriae*	2%	1%	+	Europe
Gomphonema angustum	+	+	1%	Europe, C.Am
Gyrosigma acuminatum	—	+	—	Europe
Navicula cryptotenella	6%	2%	6%	Europe, N.Am
Nitzschia sinuata	1%	+	1%	Europe
UNIDENTIFIED	5%	6%	4%	

Only one cyanobacterium is common, *Schizothrix fasciculata,* well known in other regions of the world for its nodular, heavily calcified colonies growing in turbulent water (Pentecost & Whitton 2000). Green algae are poorly represented and the occurrence of the desmid *Closterium striolatum* is unexpected, as in Europe it is a species normally associated with acidic boggy areas.

Diatoms are abundant in all three sites. Numerically the most important is *Achnanthes minutissima*, a ubiquitous species of clean fast-flowing streams worldwide. We previously found this to be subdominant on the Sichuan travertines (Pentecost & Zhang 2001) and it occurs on most of the European deposits, sometimes growing endolithically. *Cymbella laevis* is subdominant at Doupe Pool. Interestingly, in our Sichuan sites, this species is absent but the morphologically similar *C. delicatula* is dominant at two of those sites. *Cymbella laevis* has also been found in large numbers on the Lorraine travertines (Iserentant 1988) and is a diatom of calcareous mossy streams generally. *Fragilaria capucina* var. *vaucheriae, Gomphonema angustum* and *Navicula cryptotenella* are other frequently recorded species known from European deposits. The flora is one of an unpolluted but weakly mesotrophic and calcareous water.

Of the 19 diatom species that we have identified, all but four are known from travertines in other parts of the world and we suspect that many of them are cosmopolitan (see Table 2). There are, however, several common European travertine diatoms yet to be found on Chinese deposits, such as *Amphora ovalis, Caloneis bacillum, Navicula cari* and *Rhopalodia gibba.*

It is interesting to note that the bryophytes at site (b) have a flora that is similar to that of the bare travertine rock at site (a) nearby (the percentage similarity is 81%), whereas the two bryophyte sites, (b) and (c), where the degree of water impact differs, are less similar (59%).

While the pioneering work on the Chinese freshwater diatom flora was undertaken by-European algologists early in the 20th Century (e.g. Skvortzow 1938) much regional work is currently underway at the Institute of Hydrology at Wuhan. For example, a diatom flora of Xizhang (Tibet) has been published recently (Zhu & Chen 2000) and others are expected to follow. We await great developments in Chinese algology during the next few decades and we thank the Royal Society and National Natural Science Foundation of China for a successful collaboration allowing research groups such as ours to participate in new and often pioneering work in this great and fascinating country.

References

Durrenfeldt, A. (1978). Untersuchungen zur Besiedlungsbiologie von Kalktuff faunistosche, okologische und elektronenmikroskopische Befunde. *Archiv fiir Hydrobiologie Supplementebande* 54, 1-79.

Golubic, S. & Fischer, A. G. (1975). Ecology of calcareous nodules forming in Little Conestoga Creek near Lancaster, Pennsylvania. *Verhandlung der Internationalen Vereinigung fiir Theoretische und Angewandte Limnologie* 19,2315-2323.

Iserentant, R. (1988). Les diatomees d'un travertin de Pente (<Cron>) en

Lorraine. *Memoires de la Societe Royale de Belgique* 10, 17-25.
Pentecost, A. (1992). Travertine: life inside the rock. *Biologist* 39, 161-164.
Pentecost, A. & Whitton, B. A. (2000). Limestones. In *The ecology of Cyanobacteria* (eds B. A. Whitton & M. Potts), pp. 257-279. Kluwer, Amsterdam.
Pentecost, A. & Zhang, Z. (2001). The travertine flora of Jiuzhaigou and Munigou, China and its relationship with calcium carbonate deposition. *Cave and Karst Science* (in press).
Skvortzow, B. W. (1938). Diatoms from Chengtu, Szechuan, Western China. *Phillipine Journal of Science* 66, 479-496.
Yang, H., Zhu, W. & Huang, R. (1985). Research on travertine formation in the rivers of Giuzhou. In *Karst landforms and caves*, pp. 39-47. Science Press, Beijing.
Zhu, H. & Chen, J. (2000). *Bacillariophyta of the Xizhang Plateau.* Science Press, Beijing.