Results of the Preliminary Monitoring Network of Cango Caves (Outdshoorn, South Africa)

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Abstract

Cango Cave is the most important show cave in Africa with some hundreds of thousand visitors per year, and is presently monitored to ascertain its visitors' capacity. A simple monitoring network has been installed in September 2000 to be operated for one year. It consists of 15 rugged data loggers distributed along the cave. Air and water temperature, carbon dioxide concentration, and relative humidity are measured and the values are transferred periodically by a shuttle into a computer outside the cave. The first results are here reported. Later, a totally automatic monitoring network will be installed after the results of the first simple network are achieved. In addition to the parameters measured by the first simple network, also air current and water level will be included in the automatic one.

Introduction

Cango Cave was discovered in 1780 by a Hottentot herd-boy working in Van Zyl's farm. During the XVIII century no records of the number of visitors are available but, on account of the travel difficulties, the figure should be of the order of hundreds. In 1914 it was 1352, in 1930 11,457; around 50.000 in 1955; around 100,000 in the '60s; 228,600 in 1990 (CRAVEN, 1994) and around 250,000 from 1995 to present. The cave was the object of a long series of regulations for its preservation, which were more or less successful. Finally, on 31 August 1938 the cave was proclaimed a Historical Monument because of its natural and scientific value. A rather complete descriptions of the cave and its surroundings was published recently by Martini (2000).

The section normally visited by tourists is known as Cango I and extends about 600 m from the entrance; another section follows, Cango II, for about 400 m. The whole cave morphology is essentially horizontal and the cave develops at the same fossil level. To proceed any further than the end of Cango II it is necessary to reach a lower level (about 20 m below) still active with a streamlet (the Sump). Normally this level is totally flooded and the access to Cango III is possible only after lowering the water level by a pump. The flooded part is 179 m long and the Cango III can be reached by climbing up to the same level of the previous sections of the cave (Fig. 1).

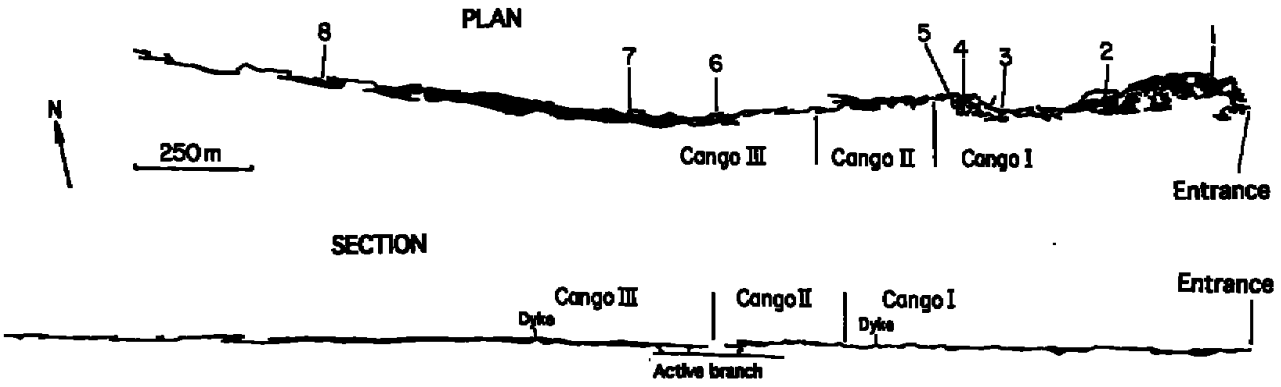

Fig. 1 - The Cango Cave: 1) Van Zyl's Hall, 2) Grand Hall, 3) Japanese Umbrella, 4) Devil's Workshop, 5) Banqueting Hall, 6) Krakatoa Chamber, 7) Stonehenge, 8) Isolation Chamber (After Crombie et al., 1978).

In 1995 the University of the Free State, Bloemfontein, carried out a scientific study which resulted in a report (GROBBELAAR et al., 1996). Such a report covers different issues both on the external environment and on

the cave itself. Data on average CO_2 concentration, air temperature and relative humidity for some months are given.

In April 2000 a series of spot measurements of air temperature and relative humidity along the whole cave, from the entrance to "Isolation Chamber" in Cango III (some 1700 m from the entrance) were obtained. Since the last days of August 2000 a preliminary monitoring network was installed.

Measurements

Spot measurements

From 3 to 7 April 2000 a number of measurements of air temperature and relative humidity have been carried out along the cave. Obviously such measurements were assumed only to have an idea of the distribution of these parameters. A good agreement within 0.1°C was found between measurements performed with different portable instruments (i.e. Airflow and Thermo). The results are reported in Table 1.

Table 1 - Spot measurements (3-7 April 2000)

POSITION	DISTANCE FROM THE ENTRANCE (m)	TEMPERATURE (°C)	RELATIVE HUMIDITY (%)
Outside	0	13.3	59.8
Entrance	5	18.4	75.1
"Museum"	30	19.7	74.2
Fern garden	40	19.9	78.2
"	63	19.5	77.6
Van Zyl's Hall	84	19.2	81.6
Botha's Hall	170	19.2	84.5
Devil's face	194	19.3	86.7
Bridal chamber	220	19.7	88.6
Fairy palace	255	19.3	88.2
	265	20.5	88.7
Drum Room	280	19.9	88.7
Entr. Grand Hall	294	19.3	88.8
Lot's chamber	350	19.2	89.6
Nylon stockings	396	18.5	89.8
Gen. Smythe's ladder	440	18.1	90.0
Crystal chamber	473	18.3	90.0
Lumbago Walk	485	18.6	90.6
Crystal palace	520	19.6	90.1
King Salomon's mine	550	19.6	90.0
Above Iron ladder	558	20.3	89.9
Ice chamber	576	20.0	89.7
Devil's workshop	635	19.5	85.7
"Transformers"	640	18.5	85.7
Sump	1040	18.4	-
Alpine room	1730	18.2	87.4

The peaks of air temperature may be due to both local perturbations by tourists and an air circulation cell originated by some unknown passages of the cave. The data obtained by the monitoring network over an extended time interval will confirm or exclude such a hypothesis.

In Cango 1, in addition to the data obtained along the walkways, other relative humidity measurements were carried out in some passages far from such walkways and confirmed that the relative humidity was always less than 100%. A measurement of the water temperature of the stream at the end of Cango 2 gave a value of 18.2°C, i.e. 0.2°C below the corresponding air temperature.

When the water level in the Sump between Cango II and III was lowered in order to negotiate the flooded passage, a distinct noise, due to the air blowing from Cango III, was heard for some minutes, confirming that this section of the cave is normally sealed with respect to Cango II.

Preliminary Monitoring Network

A simple monitoring network was designed to be operated for one year. It is constituted by 15 data loggers distributed along the cave, which record temperature (T) at 6:00, 12:00, 18:00 and 24:00 of every day. Some of them record also the relative humidity (RH) and one the water temperature. Sensors for CO_2 were installed in fours stations and their outputs are transmitted to a data logger in the entrance for easy data retrieval.

Data are transferred periodically by a shuttle into a computer outside the cave. The layout of this network is summarised in the Table 2.

On 25 August 2000 this preliminary monitoring network was set into operation. Unfortunately the humidity sensors did not perform correctly because of the saturation of the capacitive sensor when some condensation occurred on them notwithstanding the result of the spot measurements were always below 100%. For this reason only Station 2 (Van Zyl's Hall) recorded acceptable relative humidity values for a couple of months before moving out of range for about one month; successively acceptable values were recorded again. This inconvenience, due to condensation, must be taken into account when automatic monitoring networks are operated.

Table 2 - Layout of the preliminary monitoring network.

POSITION	PARAMETERS	*FrEquency of discharge*
0-Outside	T, RH, Atm. Press.	One month
1-“Washrooms”	T	1 month
2-Van Zyl’s Hall	T, CO_2	1 month
3-Botha Hall	T, RH	1 month
4-The Vestry	T, RH	1 month
5-Drums Room	T, RH, CO_2	1 month
6-Lot’s Chamber	T	1 month
7-Gen. Smythe's Ladder	T, RH	1 month
8-Crystal Palace	T	1 month
9-Ice Chamber	T	1 month
10-“Transformers”	T	1 month
11-Cango 2: Broken stalagmite	T, RH	1 month
12-Cango 2: Sump	T + T water, CO_2	1 month
13-Cango 3: Base Camp	T, CO_2	3 months
14-Cango 3: Alpine Room	T	3 months
15-Cango 3: Isolation Chamber	T, RH	3 months

First Results of the Preliminary Monitoring Network

Presently, the temperature recorded from August 25, 2000 to January. 30, 2001 is available. There are a few gaps, only, due to temporary problems of some sensors. The data are reported in Fig. 2. The range of air temperature within the cave is about 2°C, by increasing steadily from 18 °C in Cango 3 to about 20°C at the entrance with three exceptions.

Station 7 "Gen. Smythe's Ladder" and 6 "Lot’s Chamber" have an average temperature which is from 0.1 to 0.2 °C less than the expected value according the steady increase quoted above; station 4 " The Vestry", which is rather close to Station 3 "Botha's Hall", has a value 0.26 °C lower than the latter.

In this last case the difference could be due to the evaporation latent heat because in the Vestry there are some small ponds while the area close by is drier. The explanation of the difference observed in Stations 6 and 7 is less evident because it could be due both to the same mechanism of Station 4 and to some hypothetical air flow from inner passages still unknown. When the data, recorded during at least one year, will be available, a more founded explanation would probably be obtained.

The abnormal fluctuation of Station 12 "Sump" is an artefact due to some local disturbance (works, heat released by instruments) in a rather small volume.

CO_2 concentrations are available from December 5, 2000 to January. 30, 2001.

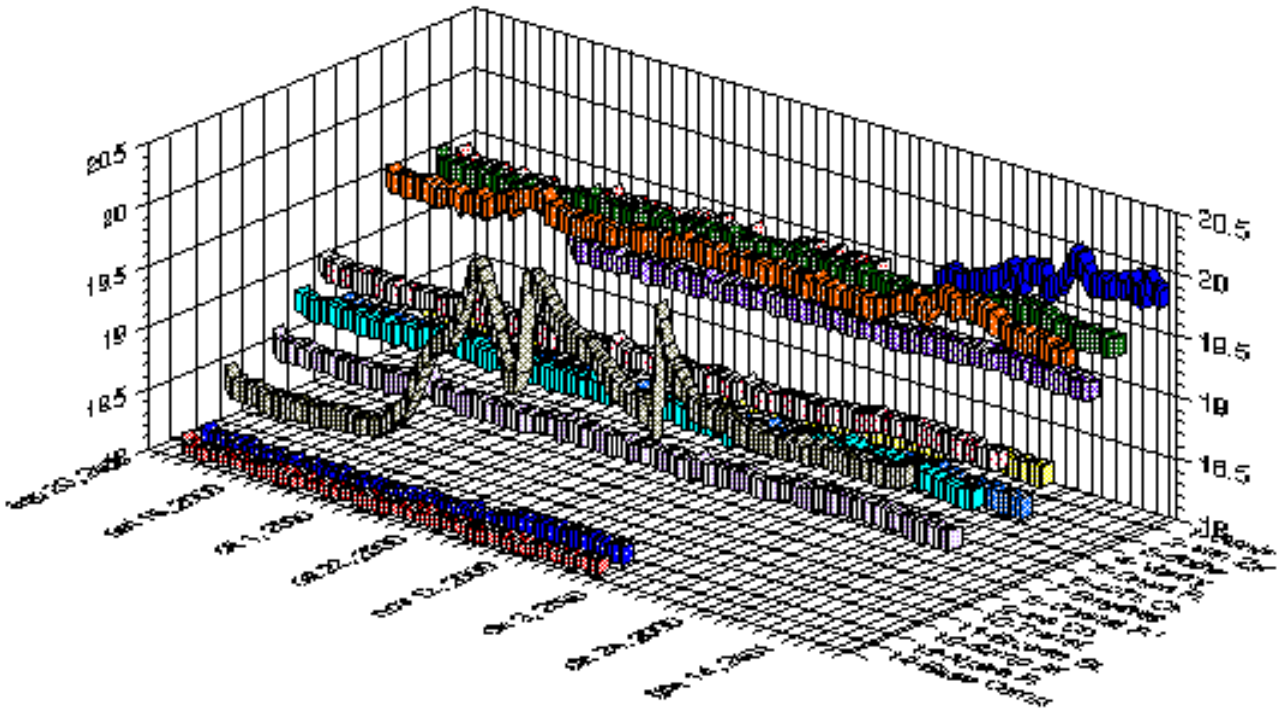

Fig. 2 - Air temperature distribution in Cango Cave from August 25. 2000 to January 30. 2001.

Discussion

Temperatures

In addition to the data reported in the previous section, an additional set is available. From September 1 to 3, 1956 the Cave Research Sub-Committee of the Cape Section of the South African Spelaeological Association made some meteorological observation at the Cango Cave (DU PLESSIS, 1958a).

The readings were obtained by the following unstandardised instruments:

Max and Min thermometers, accuracy approximately 0.6°C;

Wet and dry-bulb thermometers, accuracy approximately 0.3°C;

Soil thermometers, accuracy approximately 0.2°C.

In Table 3 a comparison between these measurements and those obtained by the monitoring network operating at present, are reported. This comparison is obviously indicative only, because the stations are not really identical but refer to sites very close by. By taking into account the accuracy of the thermometers it can be assumed that the increase of temperature in the stations here considered, if any, is not greater than some tenth of °C in about half a century.

It is noteworthy to recall here that in March 1896 air temperatures ranging "from 65 to 66°F" (18.3 to 18.9°C) were recorded in Cango cave. Since values are given as a whole number of °F, it may be attributed an approximation of about ± 0.5°C (CORSTORPHINE G.S., 1897).

Table 3 - Air temperature measurements in 1956 and 2000.

STATION	°C (Sept. 1956) (± 0.3)	°C (Sept. 2000) (± 0.2)
5/6 - Drum Room /Lot's Chamber	18.7	18.6 ÷ 19.6
10 - Transformers	17.8 ÷ 18.6	18.6

CO_2 concentration

As it was reported above, fours sensors for CO_2 were installed in stations: 2-Van Zyl's Hall; 5-Drums Room; 12-Cango 2: Sump and 13-Cango 3: Base Camp. Unfortunately the sensor of station 12 did not worked properly due to a power supply problem. The values of CO_2 concentration are plotted in Fig. 3 together with the daily number of visitors.

The values measured in Van Zyl's Hall started from around 3000 ppm in the first part of December, increasing to nearly 5000 ppm at the beginning of January and decreasing slowly to 4000 ppm successively. In the Drum Room the behaviour is similar with a starting value around 4500 ppm and a maximum around 8000 ppm about one week later than that observed in Van Zyl's Hall. In Cango 3, Base Camp, i.e. just after the sump that divides Cango 3 from Cango 2, the values are constantly around 9500 ppm. Such a constant value over the whole period is an artefact due to values out of range (0-10,000 ppm) in agreement with the values ranging from 12,500 to 16,300 reported by Maxwell (1980). In the future the sensor in Cango 3 will be substituted in order to cover a wider range.

The measurements carried out in 1995 by the University of the Free State, (GROBBELAAR et al., 1996) reported values in good agreement with those reported above. In particular the daily fluctuation due to the presence of visitors is identical with a range of few hundreds of ppm.

The peak of the number of visitors, around 2500 persons per day, is nearly one week before the maximum of CO_2 concentration observed in Van Zyl's Hall.

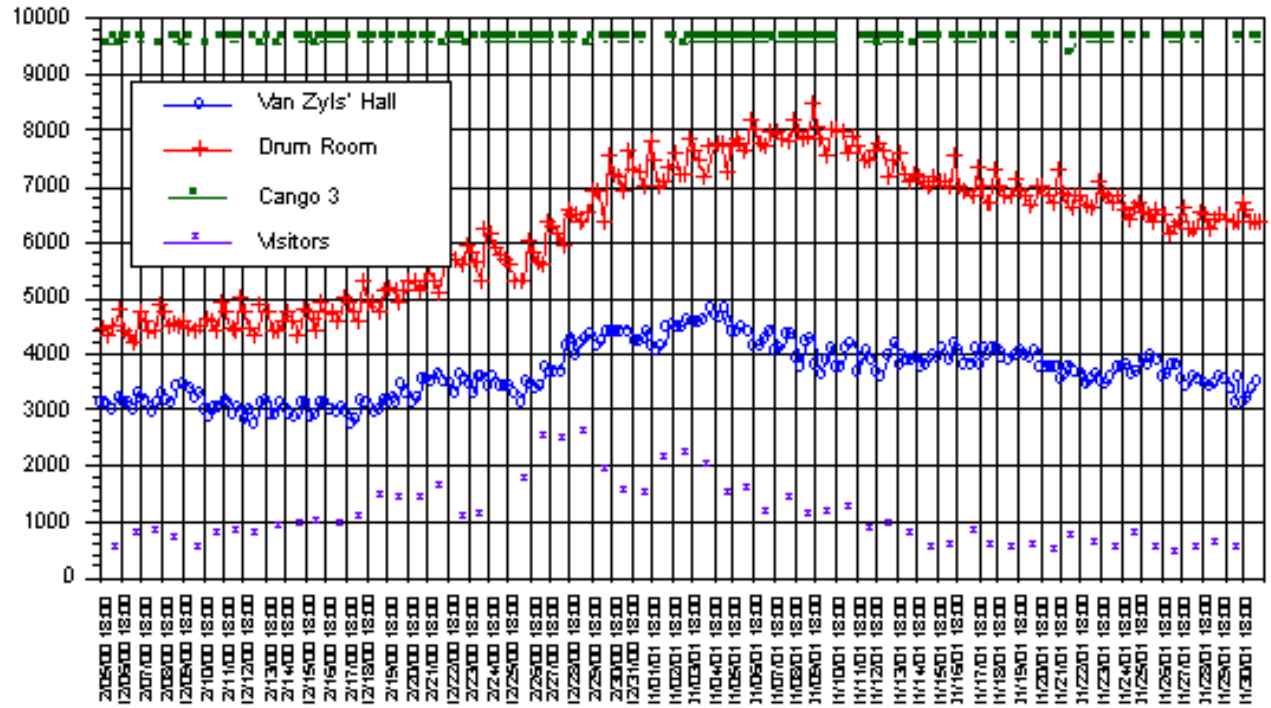

Fig. 3 - CO2 concentrations (ppm) Cango Cave from December 5. 2000 to January 30. 2001. The daily number of visitors is also report

Conclusions

The data obtained up to now allow drawing some preliminary conclusions, which should be confirmed or modified when a whole set of data ranging over at least one year interval will be available.

Temperatures

The first measurements were recorded in Cango Cave in 1896 (CORSTORPHINE G.S., 1896) when the global number of visitors from its development as a show cave was around few thousands people. Same values were obtained when the South African Spelaeological Association carried out some measurements in 1956 (DU PLESSIS, 1958a) and the visitors reached about 900,000; from that time to now other 7 millions people visited the cave. As it was reported above, the increase of air temperature during this time interval, if any, is not greater than some tenth of °C.

This fact means that the visitors capacity (CIGNA & FORTI, 1989) of Cango Cave was reasonably not exceeded notwithstanding management criteria (light, entertainment, etc.) not optimised from the point of view of the environmental impact.

The temperature measured in Cango 3, where the impact of visitors is absolutely negligible (few tenth of persons since its discovery) may be assumed as an undisturbed value not affected by any external influence (seasonal variation, visitors).

The average increase observed by moving from the inner stations to the entrance is probably due mainly to the influence of the seasonal variation from outside. The exceptions to such an increase found in stations 7-Gen. Smythe's Ladder, 6-Lot's Chamber and 4-The Vestry, could be due to either the evaporation latent heat or some hypothetical air flow from inner passages still unknown, as it was reported above.

When data sets ranging over one year will be available, the propagation velocity of the seasonal heat wave inside the cave could be evaluated and provide some more information on the real cause of such exceptions.

CO_2 concentration

The evaluation of the data shows that the main source of CO_2 in the cave is the natural process of oxidation of the organic matter in the percolation water (BOURGES et al., 1998) while the amount of CO_2 released by visitors is at least one order of magnitude lower. This fact is confirmed by the measurements carried out by GROBBELAAR et al. (1998) when the increase due to the visitors was around some hundreds of ppm against a background of some thousands. In addition the CO_2 concentration increases in the inner part of the cave reaching a value above 10,000 ppm in the confined section of Cango 3 where the visitors have no influence at all.

Final remarks

The different appearance between the first halls of the Cango Cave and the inner parts is quite evident because the formations and the rock surface of the former are somewhat corroded while in the inner parts the formations are still growing.

Such a difference has been attributed to the use of the cave as a show cave. The results obtained in the first months of operation of the preliminary monitoring network do not support the conclusion that the CO_2 released by tourists could affect the chemical equilibrium concerning the formations. In fact the CO_2 released by natural oxidation process of organic matter in the percolation water is much larger than the CO_2 released by visitors.

In any case, it must be pointed out that, if the corrosion of the formations and the rock surface would be recent, the rock painting discovered by the Abbé Breuil in 1929 (CRAVEN, 1988) would have totally disappeared notwithstanding any possible restoration occurred in the meantime. The corrosion of formations must therefore be attributed mainly to natural causes as the decomposition of guano (CRAVEN, 1994). In fact the "dirty yellowish brown colour" observed by a visitor in the XIX century (DU PLESSIS, 1958b) was due to such a corrosion and was already present when the number of visitors was absolutely too small to produce any impact.

On the other hand, the plastic closure of the cave entrance installed on the gate might have modified the air circulation; the first halls could now act as a "warm trap" with a consequent increase of thetemperature in this section. When more data from the preliminary monitoring network will be available a firmer conclusion concerning this point could be drawn.

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