Geological Society of Malaysia Annual Geological Conference 2002
May 26 – 27, Kota Bharu, Kelantan, Malaysia

Estimating limestone dissolution rates in the Kinta and Lenggong valleys using the micro erosion meter: a preliminary study

Ros Fatihah Muhammad & Yeap Ee Beng

Department of Geology, University of Malaya
50603 Kuala Lumpur, Malaysia

Abstract: Limestone dissolution rates have been measured using micro erosion meter in the area of Kinta and Lenggong valleys. Limestone samples in the form of tablets are used with the micro erosion meter which measures the lowering of the tablets' surface after being exposed in certain environments of erosion. The samples are left in three different conditions in the field: in running streams, in stagnant pond water and exposed to the subaerial condition.

Thirty one (31) samples were left to be dissolved and due to the time constraint, the last measurements were taken after 5 to 14 months in the field. The results obtained showed that the rates for each tablet are highly variable with the range of about 1.830 to 0.005 mm/yr. More reliable results are considered representative of dissolution rates in/under running water and stagnant water environment, with values of 0.369 and 0.244 mm/yr, respectively. Depositions are also common on some sample surfaces, believed to be due to the airborne dust and material from quarrying activities in the study area. Growth of mosses on the samples left in the subaerial condition is also common. For these samples, the erosion rate could not be obtained.

INTRODUCTION

Dissolution of limestone occurs under various hydraulic conditions e.g. laminar or turbulent flow and also with respect to the interaction of karst water with CO_2 which delivers the chemical energy driving karst processes (Dreybrodt & Eisenlohr, 2000). The degradation of carbonate terrains is mostly chemical and depends on the amount of precipitation, the water composition, the runoff rate etc. (Kukal, 1990).

Various methods of estimating the rate of karst denudation show variable results. Important data from the literature compiled by Kukal (1990) shows that the rates of dissolution is highly variable in different regions in the world. The tropical areas show a range of between 15 to 99 mm/ka. In Ireland, using the MEM (micrometer erosion meter, see below), Williams (1966) obtained values ranging from 3-6300 mm/ka and concluded that karst degradation was highly selective. Sweeting (1972) claims that mean dissolution rates of limestone is between 15 and 100 mm/ka.

MEM data derived from a subaerial surface site in north Yorkshire, UK, indicate current rates of erosion of the order of 0.01 – 0.05 mm a year (Trudgill, 1989) and Trudgill also concluded that rates are both higher and lower than this under acid and alkaline soils respectively. Stephenson and Kirk (1996) have measured erosion rate of shore platforms in South Island, New Zealand, using the MEM on two data sets: one was taken after 2 years and the other 20 years and concluded that extrapolation of short term MEM data is acceptable in certain environment. They also came up with the average annual lowering rate of 1.10 mm/yr for limestone platforms and 1.48 mm/yr mudstone platforms.

METHODOLOGY

In order to obtain estimation of rate of limestone dissolution in this research, direct measurement of surface lowering by a micrometer gauge were carried out. The micro erosion meter (MEM) was developed by High & Hanna (1970 in Ford & Williams, 1989) and improved by Coward (1975) and Trudgill *et al.* (1981).

This instrument consists of a probe connected to a micrometer gauge and fits precisely into stainless steel studs set into the rock surface (Figs. 1 and 2). Selected points in this surface can be repeatedly measured for erosional lowering. Results are accurate to the nearest 0.001 mm. For each MEM, there are 14 points that can be measured on the limestone surface. However, due to uneven surface of the tablet, the meter gauge could not take any measurements on certain points. Normally it is because parts of the sample surface are either too low and do not touch the reading point or are too high. So, not all 14 points have reading from the tablets. Any reduction in the reading indicated surface lowering or denudation, whereas any increment indicates deposition on the surface.

There are two methods of fixing the template to get both under water and sub-earial condition of denudation.

1. On limestone tablet from the same area where erosion rate were calculated.
2. On limestone bedrock it self, in subearial environment.

For the first method, limestone tablets with flat and jagged surface were collected from a dimensional rock factory. These rock samples are from limestone hills in the Kinta Valley and Lenggong, Perak. To obtain results from various environments of denudation, the limestone tablets were placed in three conditions:

1. In running streams in and outside caves.

2. Stagnant water in ponds.
3. Exposed to the air.

The size of the tablet varies since it requires only a triangular area of 12-200 cm^2 to be fixed with the MEM. The end of each leg has been machined differently, one has a cone shaped depression, one has a v-notched depression and the third is flat. Tablets with even or uneven surfaces were collected from a marble factory and quarry with the certainty that they are from limestone hills around Kinta Valley. In the Lenggong area, limestone blocks from an old quarry were used to get the rate from that area. These tablets were drilled to make three holes to be fixed with the studs. Strong and water resistant glue was used to ensure they would last in water for a period of time. Reading at each point was recorded before placing them in the field. These tablets were then placed in ponds at the foot of the hills or in running streams near or in caves. Temperature of air and water were recorded. Where possible, the velocity of stream were calculated. The pH and chemical properties of each water sample were analysed using the Atomic Absorption Spectrometer. Five elements of Ca, Mg, Fe and Mn were analysed.

For the second method, the suitable sites were selected. Holes were drilled directly on the limestone surface. The studs were fixed with glue, each point was measured and then left in place for a few months. A standard measurement was taken before and after each reading is taken. Any difference in the standard reading was added or deducted to make sure that a similar standard was obtained throughout the whole experiment.

The writers were advised by Prof Derek Ford that for tropical areas, the samples should be in the field for at least 6 months. Due to time constraint in the field, the final measurements were made after periods ranging from 5 to 14 months for each tablet. All of them however, have been left in the field for continued dissolution. However, frequent visits (every two to three months) were made to make sure the tablets are in fine condition. Some tablets which were put in streams or even ponds are easily buried under sediments. Frequent visits allow the writer to make sure the samples are not lost, though in some cases heavy rains have temporarily drowned the samples. Measurements as well as water samples were taken on almost every visit to make sure that any changes in the weather, such as heavy rain which have an effect on the pH, are considered in calculating the dissolution rates.

RESULT

The samples are divided into three categories depending on the type of location they were placed. Readings of the lowering of the limestone surface were measured and any point which shows reading increment (deposition) is also recorded but they are not used in calculating the erosion rates. Rates are calculated based on the average of the reductions in the readings using the Microsoft Excell Programme. They are then extrapolated to a value for a one year period. The rates here are presented in mm/ka. The results of each tablet and their environment of location are shown in Table 1.

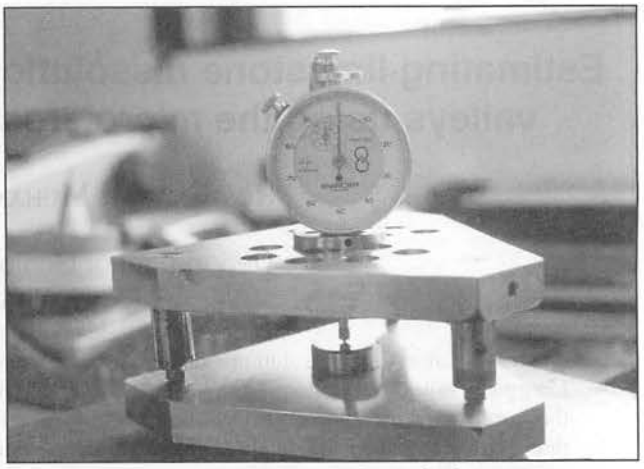

Figure 1. Micro erosion meter consists of micrometer gauge, a template and a standard plate.

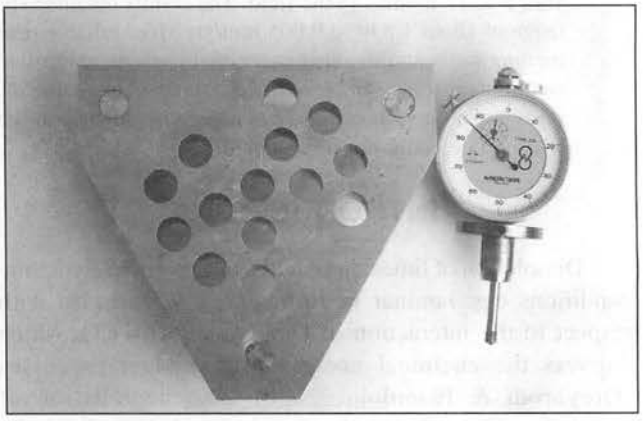

Figure 2. Micro erosion meter template with 14 holes which are then traced on limestone tablets as measurement points.

DISCUSSION

From the results shown in Table 1, we can deduce that the denudation rate of each point in certain samples showed enormous differences. This was even observed for points of the same sample. As stated earlier, some samples which were left especially in fast running water in streams are exposed to the possibility of being hit by the pebbles and sand carried by the current. This, in the writers' opinion has contributed to the very large difference of rates in certain samples.

Besides this, where lichen and moss growth were hardly present, deposition still occurs in some samples. Being in the environment where limestone is being quarried, we are of the opinion that material from quarries, especially in the form of dust, is well distributed throughout the area. Besides that, air-borne dust from the nearby PLUS highway is believed to have contributed to the deposition on the tablet surface. Elsewhere, lichen and moss growth have prohibited the erosion rate of being calculated. However,

Table 1. Estimated limestone dissolution rate in Kinta and Lenggong valleys.

Location	Air/Water Temperature (°C)	Water pH	Ca (ppm)	Duration in the field (days)	Estimated Rate mm/ka
a. Ponds					
1.Alpha Mar*	27	6	52,58,57,74	146	316
2.Quarry Per+	26	6	76,63	308	202
3. Nat Steel*	30.5	6	52,38,60	154	32
4. KLT1	26	7	47,40	304	221
5. KBB+	22	6.5	42,49	154	54
6.NF5B+	22	7	44,53	308	5
7.Tambun*	27	6.5	84,60	160	91
8.Terendum@	27	6	60,63	-	-
9.Mes 1+	26.5	6	24,35	154	969
10. Sunway+	31	5	17	334	224
b. streams					
11.T-Gra Fl+	27.5	5	17,20	350	369
12.T-Gra^	27.5	5	17,19	350	310
13.GT2 (a)*	26	6	36	145	443
14.GT2 (b) Fl*	26	6	36,33	145	416
15.GT3 (2)+	25.5	6	36,40	371	150
16.Mes (2)+	26.5		2.4	274	310
17.GT1@	26	6	31,29,29	-	-
18.GBC (Leng)^	29	-	-	202	1026
19.GRunC^	26.5	-	-	202	276
20.GT3 (1)+	26	6	37	441	107
21. Lang^	28.5		38,31,32	154	344
c.Bedrock					
22.NF3^	25	-		309	114
23.NF1^	25	-		309	45
24.NF2*	25	-		309	-
25.NF4KB*	25	-		310	578
26.NF5TP*	25	-		308	872
27.NG1*	25	-		333	1818
28.NG2*	25	-		333	1835
29.NG3*	25	-		333	840
30.Lan1^	25	-		196	133
31.Lan2^	25	-		196	245

Note: + evenly distributed rate; ^ variable; *highly variable; @ covered with mud, rate could not be obtained

acidic condition provided by the moss layer is believed to assist the erosion under the cover. Hence, samples are left to be dissolved further. So far, observation on the water temperature, pH and chemical constituents show no significance effect on the rate of dissolution.

The results obtained showed that the rate for each of the tablets are highly variable with tÄ¯ range of about 1.830 to 0.005 mm/yr. However, samples which were located in the calm environment of a pond e.g away from the busy roads and active Sunway Quarry, for example, have shown rather uniform distributed rates. Samples in the Granite-Tempurung contact, though very near to the highway were located in fast running streams and free from pebbles movement also show a rather uniform rate. These results are considered representative of rates for standing pond water (224 mm/ka) and running water environment (369 mm/ka) respectively. As for the bedrock surface, though deposition on the surface was unavoidable, readings of 45 to 245mm/ka (with the average of 134 mm/ka) are taken to be the representative of such environment.

CONCLUSIONS

Some conclusions deduced from the study are as follows:

1. Dissolution rates on the limestone in the Kinta Valley are highly variable.
2. Airborne dust from quarries and highway traffic are believed to have been deposited on some sample surfaces and gives increments to the readings. Such condition is also observed where lichen and mosses are present and where they grow.
3. Estimated limestone degradation rates for standing water, running water and under subaerial condition are 224 mm/ka, 369 mm/ka and 134 mm/ka respectively.

REFERENCES

COWARD, J.M.H., 1975. *Paleohydrology and streamflow simulation of three karst basins in southeastern West Virginia.* PhD thesis, McMaster University, Canada.

DREYBRODT, W. & EISENLOHR, L., 2000. Limestone dissolution rates in karst environments. *In*: A.B. Klimchouk, D.C. Ford, A.N. Palmer and W.Dreybrodt (Eds.), *Speleogenesis: Evolution of Karst Equifers*, 136-148.

FORD, D.C. & WILLIAMS, P.W., 1989. *Karst Geomorphology and Hydrology*, Unwin Hyman, London, 601p.

KUKAL. Z, 1990. The Rate of Geological Processes. *Earth Science Reviews, 28.* Elsevier.

STEPHENSON, W.J. & KIRK, R.M., 1996. Measuring erosion rates using the micro-erosion meter: 20 years of data from shore platforms, Kaikoura Peninsula, South Island, New Zealand. *Marine Geology 131*, 209-218.

SWEETING, M.M., 1972. *Karst Landforms.* Macmillan, New York, 362p.

TRUDGILL, S.T., 1989. Limestone weathering under a soil cover and the evolution of limestone pavements, Malham district, north Yorkshire, UK. *In*: Paterson, K. and Sweeting M.M. (eds.) *New Directions in Karst. Proceedings of the Anglo-French Symposium*,1983, 461-472.

TRUDGILL, S., HIGH, C.J. & HANNA, F.K., 1981. Improvements to the micro-erosion meter. *Brit.Geom. Res. Gp. Tech. Bull. 29*, 3-17.

WILLIAMS, P.W., 1966. Limestone pavement with special reference to western Ireland. *Inst. Brit. Geograph. Trans., 40*, 155-172.