Annales de la Société Géologique de Belgique, T. 102 - 1979, pp. 53 - 57 décembre 1979

WEATHERING AND SOLUTION OF THE MELINAU LIMESTONES IN THE GUNONG MULU NATIONAL PARK, SARAWAK, MALAYSIA

by

M. M. SWEETING[1]

(2 figures, 3 tables)

RESUME.- Pendant une campagne d'un an dans le Parc National de Gunong Mulu, des observations du contenu soluble d'eaux diverses ont été effectuées. Le débit des cours d'eau était beaucoup plus variable que prévu à une latitude équatoriale (4° N). Les précipitations atteignaient environ 5000 mm au camp de base, et davantage en montagne. Malgré des concentrations d'éléments solubles relativement faibles dans les eaux des grottes et des rivières, les précipitations élevées et la percolation rapide des eaux expliquent la dissolution très forte des calcaires (jusqu'à 180 mm par 1000 ans). Ce chiffre est confirmé par des expériences faites au moyen de plaquettes de roches, placées dans le sol et dans les cours d'eau pendant à peu près 6 mois, et pesées avant et après; elles révèlent une dissolution très active.

Les calcaires de Melinau sont d'âge oligo-miocène. Ils sont très résistants, compacts et extrêmement uniformes. Ces caractères justifient en partie la subsistance de pinacles impressionnants d'une cinquantaine de mètres de haut, avec des " rillenkarren " longs de plusieurs mètres.

ABSTRACT.- Observations of solute content of different waters in the Gunong Mulu National Park were made during a year's project here. The regime of the rivers was much more variable than expected for the Equatorial latitude (4° N). The rainfall at the base camp averaged about 5000 mm, with higher values in the mountains. Despite relatively low solute contents in the cave and river waters, the high rainfall and rapid throughput of the waters indicate a very high solution rate of the limestones - up to 180 mm per 1000 years. This figure is corroborated by experiments with weighed rock tablets which were inserted into the soil and into the rivers for about 6 months, and which showed very active solution.

The Melinau Limestones are of Oligo-Miocene age and are very strong, compact and extremely uniform. The strength partly accounts for the survival of impressive pinnacles up to 50 m high with rillenkarren several metres long.

This short paper discusses some of the work done by the Royal Geographical Society's Expedition, 1977-78, in the new Gunong Mulu National Park in Sarawak. The area is situated close to the border with Brunei in north Borneo at about latitude 4° N; it is therefore in a truly Equatorial climate and is covered with rain forest (fig. 1). The rainfall at the base camp at Long Pala was voer 5000 mm per year; rain fell generally throughout the year but the following table 1 showing the flow of the Melinau river indicates that relatively dry spells do occur, the low flow months being August/September in particular (WALSH, 1978).

The area of the National Park is about 200 sq. miles (500 km^2) and it comprises diverse relief which rises from under 100 m in the western part to over 2400 m at the summit of Gunong Mulu. The most abundant rocks are the Mulu Formation which form much of the eastern area of the Park; the Mulu Formation is of Palaeocene age and is made up of slightly metamorphosed sandstones and shales over 4000-5000 m thick. These beds dip generally to the west (often steeply up to 70°-80°), and are succeeded generally conformably by the Melinau Limestones which are of late Eocene to Miocene age; the limestones dip steeply westward off the Mulu axis and are over 2000 m thick. The limestones are extremely massive and relatively uniform, behaving virtually like a single facies (ADAMS, 1965). They are greyish to white, fine grained and micritic with many foraminifera; they are also massively bedded and well-jointed. In places the limestone has been recrystallised to give the appearence of a marble, and in sections in the

1 School of Geography, University of Oxford. Mansfield Road, Oxford, OX1 3 TB.

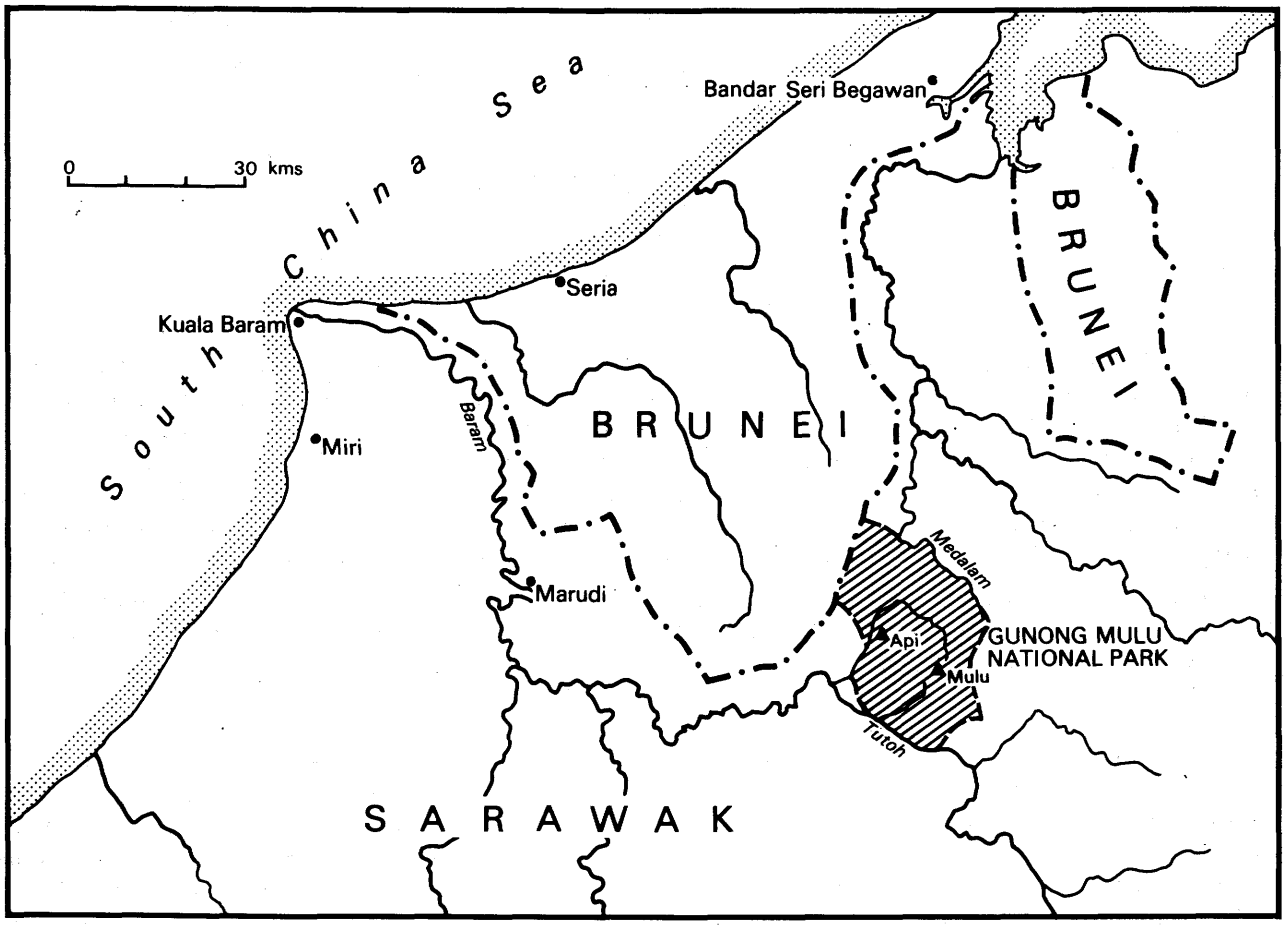

Figure 1.- The situation of the Gunong Mulu National Park. Map based on work by M.J. DAY

caves it can be seen to be quite variable. The limestones form a conspicuous ridge running NNE-SSW through the National Park and on the west side of high ground on the Mulu formation (fig. 2).

The Melinau limestones are quite hard, giving a rebound value of 56.4 on the Schmidt Hammer test scale; the Carboniferous Limestone in N.W. Yorkshire in Northern England has a rebound value of about 58 (DAY & GOUDIE, 1977); Dr. Michael DAY looked at the Melinau Limestone to see if it was in any way case-hardened; he found that this was not so - the outer weathered part of the rock surface giving a lower reading than the inner non-weathered rock (DAY, in press). The hardness of the limestones is reflected in the height of the limestone ridge - over 1500 m in Gunong Api - and its occurrence in massive cliffs, especially where the allogenic rivers, Melinau and Melinau Paku, cut through it, (fig. 2) - even though "immunité karstique" may play a part.

The solute contents of different waters in the area have been determined; the limestone and cave waters have been examined in particular. Table 2 compiled by R.P.D. WALSH and M. LAVERTY, summarises these results and it is important to remember the high annual rainfall of the region. Thus it can be seen apart from some of the cave waters and cave drips, concentrations of calcium and magnesium in the waters are rather low; this partly is explained by the high rainfall and runoff and the rapid through-put of water through the soil and rocks. The work of R.P.D. WALSH & M. LAVERTY suggests that the rate of dissolution of the Melinau Limestone is of the order of 181-200 mm per 1000 years, which is a relatively high figure.

These figures have been corroborated by the results obtained from the weight loss of rock tablets inserted into different environments in the area; many of these tablets are still in place, but a certain number were removed after eight months. The following table 3 shows the percentage weight loss in the various environments of weighed oolitic limestone tablets (from the Jurassic series in England), and which had been left

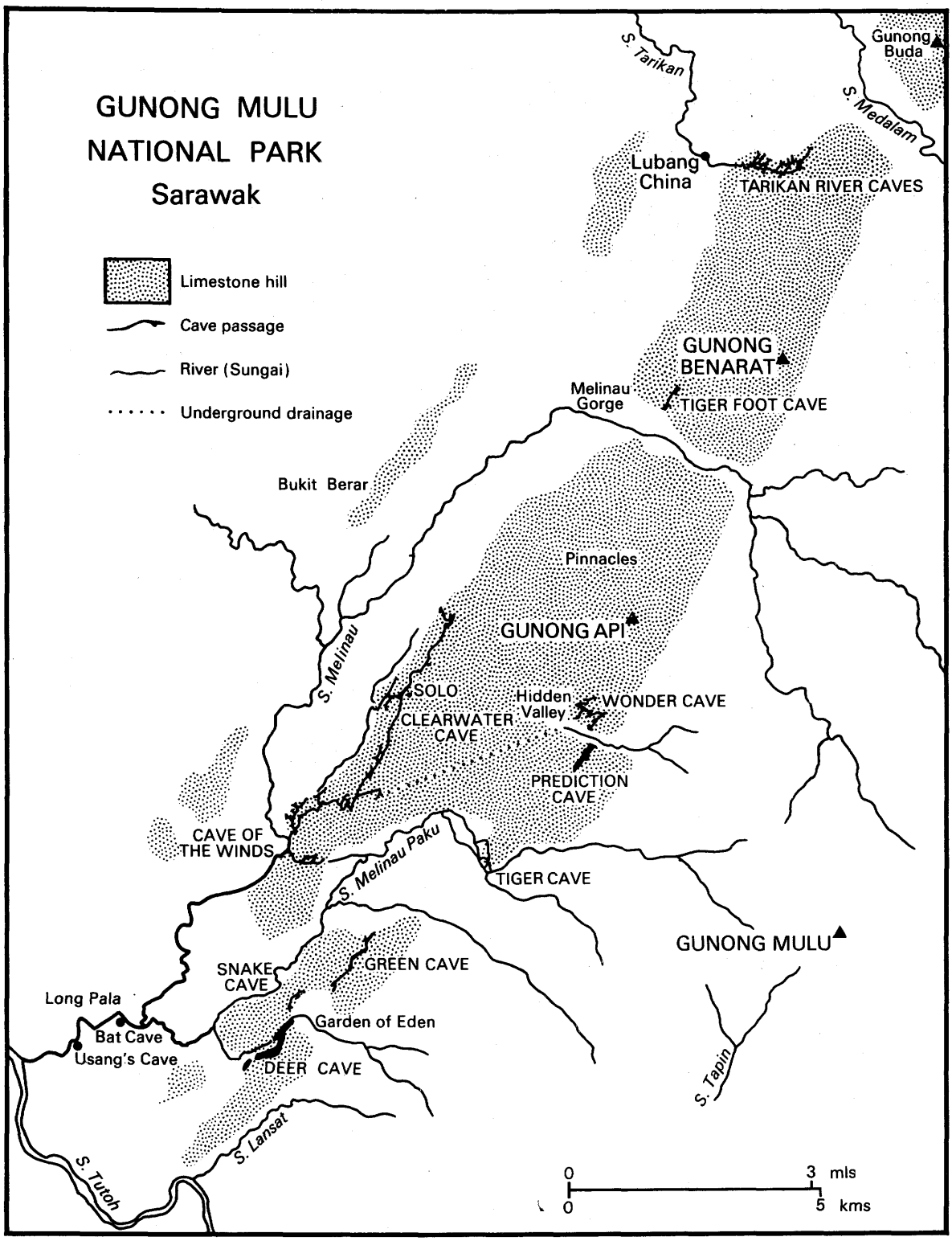

Figure 2.- Location map based on work by A.C. WALTHAM

Table 1.- Summary of River flow statistics of the Melinau River System at R.G.S. Base Camp, Mulu, August 1977 - August 1978 (From R.P.D. WALSH).

	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	YEAR SEP 1977-AUG 1978
Mean Flow (Cusecs)	585	189	723	1846	1878	885	1309	645	798	1512	871	1195	177	1001
Peak Flow (Cusecs)	4114	650	3654	> 6200	4425	4344	5905	1871	4037	4425	5262	4286	724	> 6200
Minimum Flow (Cusecs)	139	54	54	170	340	293	330	202	178	194	178	243	70	54
Floods > 4000 cusecs (Days)	1	0	0	4	1	1	1	0	1	2	1	1	0	12
Runoff (inches)	6.76	2.11	8.36	20.65	21.70	10.23	13.60	7.46	8.93	17.47	9.74	13.81	2.04	136.10"
Rainfall (inches)	10.06	3.88	21.54	28.59	12.79	17.19	15.80	12.87	23.89	28.62	15.62	14.20	5.29	200.27"

*Table 2.- Chemical concentrations of River waters in the Mulu Area **

Geology and Environment	Calcium Hardness ppm $CaCO_3$	Magnesium Hardness ppm $CaCO_3$	Soluble Silica ppm	Specific Conductance µmhos	Chemical Concentration (Solutes + Colloids) mg/l
Streams of the Mulu Formation	0 - 9	1 - 9	6 - 9	9 - 25	40 - 45
Streams of the Limestone Mountains	88 - 138	4 - 9	0.2 - 3	195 - 290	100 - 170
Streams composed of Limestone water and Sandstone streamwater passing underground through the limestone belt	30 - 78	2 - 18	2.5 - 10	80 - 180	105 - 120
Streams of the Alluvial Plain and Limestone Residuals (Berar, Pala & Alluvial Gullies)	70 - 80	9 - 13	2.5 - 3.0	150 - 175	105 - 120
All Environments : the Melinau River Catchment (100 sq. miles)	52 - 62	4 - 15	4.5	120 - 145	83 - 100

* All concentrations are much lower at higher flows
* Data from R.P.D. WALSH & M. LAVERTY.

inserted from January 1978 to the end of August 1978.

Table 3

	No of samples recovered	Average percentage weight loss.
1. In Melinau river at Long Pala, Base camp raft.	2	5 - 9 o/o
2. In soil behind base camp	14	3.9 o/o
3. In litter at base camp	16	1.42 o/o
4. In free air in forest	16	0.487 o/o
5. In free air at base camp (cleared forest	9	0.24 o/o

Some determinations of CO_2 in the soil were also made, and gave the following results :

Depth	On alluvial terraces	In limestone soil by foot caves
10 cm	0,7 o/o	0.45 o/o
25 cm	0.8 o/o	0,65 o/o
50 cm	0,8 o/o	0,65 o/o

The intensity of weathering suggested by the solute through-put and the weight loss experiments, is seen in the rugged landforms of the Melinau limestone. Solution along joints and beddings-planes produces an intensely irregular landscape with deep clefts along the joints. This highly fissured country reaches its greatest expression in the occurrence of deeply furrowed pinnacles of bare limestone over 30 m high, with equally deep clefts between. The most well studied group of pinnacles are those which lie in a shallow valley at about 1200 m of the northern slopes of Gunong Api, fig. 2; but other similar groups of pinnacles occur elsewhere on the limestone mountains, notably on the southern slopes of Gunong Benarat. The group at the north end of Gunong Api seem to occur in particularly hard limestone (SCHMIDT HAMMER rebound test by M.J. DAY gave a value of 61.5) and this may be one factor in their development. Many members of the expedition studied these pinnacles which will be the subject of further articles.

Thus these first results illustrate the highly dynamic and solutional environment of the Melinau limestones in the Gunong Mulu National Park. This is also borne out by the occurence in the Park of some of the largest river caves in the world (WALTHAM & BROOK, 1978). The geomorphology team are indebted to the administrative members of the Expedition for help in the smooth running of the field work. We also acknowledge a grant from the Royal Society towards the cost. I was the coordinator of the geomorphological work and am grateful in particular to Dr. M.J. DAY, Dr. R.G. LEY, R.P.D. WALSH and to J. OWENS, for these results.

DISCUSSION

M. R. MAIRE :

En Nouvelle-Bretagne ont été obtenus des chiffres de vitesse d'ablation fort semblables à ceux que vous citez : 100 à 20 mm par millénaire, pour des précipitations annuelles de 5 à 9 m. Il semble que les conditions climatiques de ces régions soient vraiment optimales en matière de karstification.

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