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POTASSIUM – ARGON DATES AND PRE-WÜRM GLACIATIONS OF MOUNT GILUWE VOLCANO, PAPUA NEW GUINEA

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With 3 Figures

ABSTRACT

A series of K-Ar dates from Mt Giluwe volcano is reported and its relevance to the Quaternary history of the volcano is discussed. The period between about 380 000 and 220 000 years BP seems to have been one of major volcanic activity. During the volcanic activity there were periods of ice cover probably of short duration. The oldest evidence of glacial action predates a lava flow dated at between 340 000 and 380 000 years. At about 290 000 years an ice cap of a thickness of at least 100 m covered the summit area and one or a series of subglacial eruption(s) led to the formation of palagonitic breccia. This event was probably associated with a complete melting of the ice since it was followed almost immediately by the eruption of a thick sequence of normal lava flows which range in age from about 289 000 years to about 220 000 years. Subsequent volcanic activity was less significant and no dates are available on this.

KALIUM-ARGON DATIERUNGEN UND PRÄ-WÜRM VEREISUNGEN AM MOUNT GILUWE, PAPUA NEW GUINEA

ZUSAMMENFASSUNG

Eine Reihe von K-Ar Datierungen vom Mt. Giluwe wird mitgeteilt, und ihre Bedeutung für die quartäre Geschichte des Vulkans wird diskutiert. Der Zeitraum von etwa 380 000 bis 220 000 Jahren ist durch starke vulkanische Aktivität gekennzeichnet. Im gleichen Zeitraum konnten aber auch Phasen der Eisbedeckung nachgewiesen werden. Der älteste Nachweis für eine Vereisung des Mt. Giluwe ist eine von einem basaltischen Lavastrom überlagerte Moräne. Das Alter dieser Lava und damit das Mindestalter der Moräne ist 340 000 – 380 000 Jahre. Vor etwa 290 000 Jahren bedeckte ein Plateaugletscher von mindestens 100 m Mächtigkeit das Gipfelgebiet, und eine oder eine Reihe von Eruptionen unter dem Eis führten zur Bildung von Palagonitbreccie. Diese Eruptionen verursachten wahrscheinlich ein vollständiges Schmelzen des Gletschers, denn fast „unmittelbar" anschließend folgte die Eruption von normalen basaltischen Lavaströmen, deren Alter zwischen 289 000 und 220 000 Jahren liegt. Die darauffolgende vulkanische Aktivität war weniger bedeutungsvoll und keine Datierungen sind vorhanden.

INTRODUCTION

The Pleistocene history of the Papua New Guinea highlands is closely linked with the development of the highland volcanoes, a group of some 15 major volcanic centres covering much of the area between latitudes 5° and 7° S and longitudes 142° 30′ and 145° E. These volcanoes are considered to be Pleistocene in age since some of their lava flows and ash deposits overlie Pliocene sediments. A small number of K-Ar dates are also available and support this conclusion. The oldest dates are 1.1 million years from Kara Plug south-west of Mt. Ialibu (Bain *et al.* 1975) and 0.85 million years from Mt Iume north-west of Tari (Williams *et al.* 1972). Considerably younger are two dates from Mt Hagen volcano and one from Mt Karimui volcano which are 0.218, 0.204 and 0.202 million years respectively (Page and Johnson, 1974). Little is known about the stratigraphic and geomorphic significance of these dates.

Dating of lavas in the highlands could provide a useful stratigraphic record if lavas in stratigraphically important positions could be dated. One such area is the Mt Giluwe volcano where a reconnaissance study by D. H. Blake and the author revealed that volcanic activity alternated with glacial ice cover (Blake and Löffler, 1971; Löffler, 1972). In addition, the volcanic activity led to the formation of the Kaugel intramontane basins and the ages of the lavas causing ponding of the basins would give important insights on the development of the landforms.

GENERAL SETTING

In spite of its uniform appearance as a large almost symmetrical dome, Mt Giluwe is a complex multivent volcano with numerous eruptive sites over its entire area (fig. 1). It is built up of a succession of thin mainly outwardly dipping lava flows which probably followed one annother in relatively quick succession since there is no soil or weathered horizon developed between the individual flows (Blake and Löffler, 1971).

The lavas are nearly all olivine basalts with abundant phenocrysts of plagioclase, clinopyroxene and olivine. One exception is a small andesitic cumulo dome near the main summit ridge. All lavas are chemically rich in potassium. The summit area of Mt Giluwe has been extensively modified by glacial action down to about

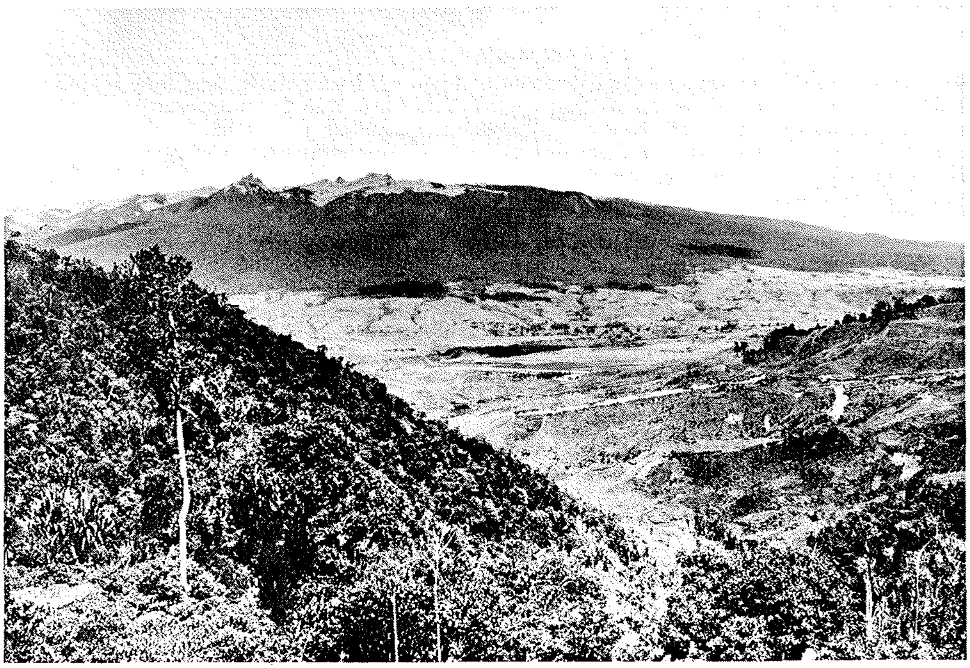

Fig. 1: General view of Mt Giluwe volcano seen from the north from a distance of about 25 km. The grass covered summit area approximately coincides with the extent of the last glaciation.

3200 m, the lower limit of a more or less continuous ice cap. Below this several valley glaciers diverged from the ice cap and descended further down to between 2750 and 3000 m (fig. 2). The glacial landforms are all exceptionally well preserved. It is now well established from C^{14} dates from Mt Wilhelm and Mt Giluwe (Hope, 1973; Hope and Peterson, 1974; Löffler, 1977) that this last glaciation was contemporaneous with the last glaciation of the northern hemisphere and that the recession of the ice began at about 12000 years BP. By 9000 years BP the mountain peaks of Papua New Guinea were completely free of ice.

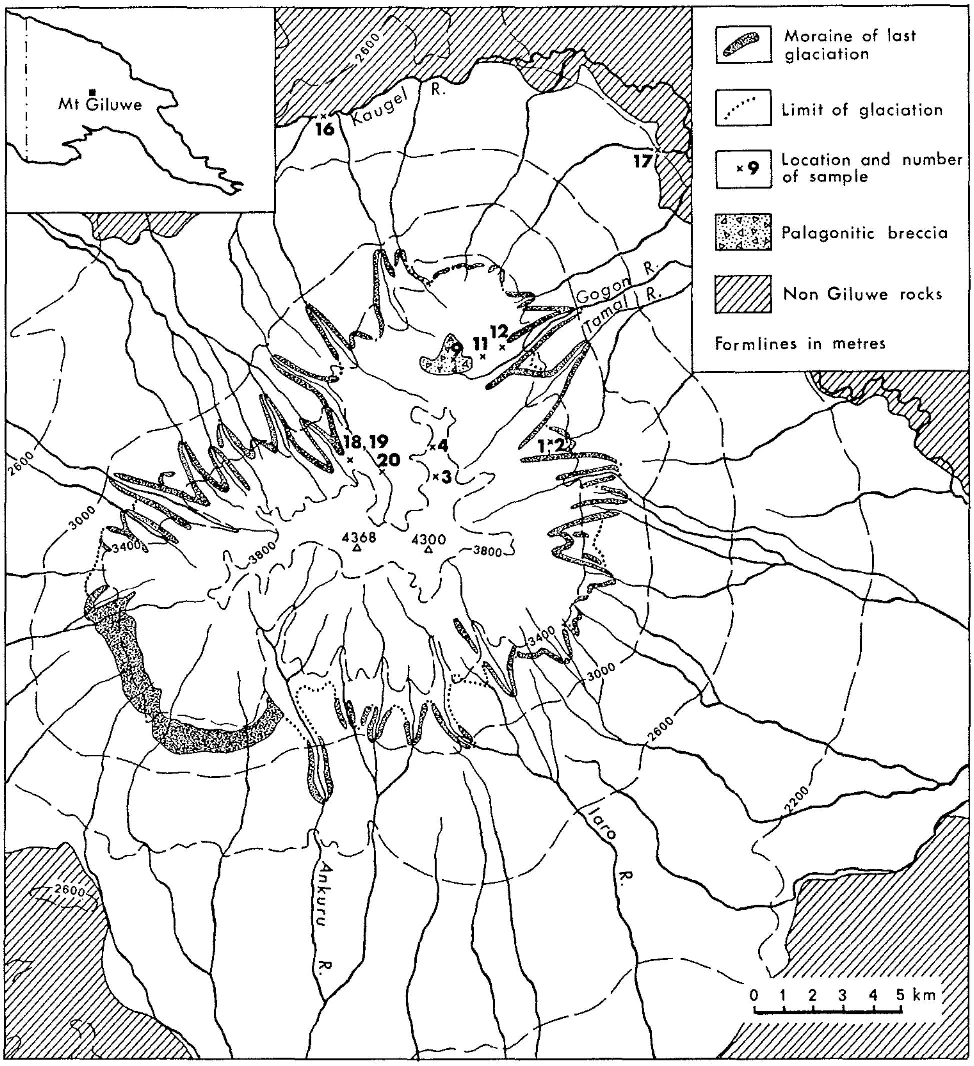

Fig. 2: Volcanic and glacial landforms of Mt Giluwe with locations of samples.

EVIDENCE OF GLACIAL ACTIVITY PRIOR TO THE LAST GLACIATION

It is always difficult and often impossible to find traces of older glaciations in areas where the glaciers only covered isolated mountain peaks and did not extend into a foreland or develop extensive ice sheets. The reason for this may be that the high rates of erosion on the mountains usually obliterate any traces of the former ice cover or as pointed out by Galloway *et al.* (1972) because the last glaciation had a more severe climate than its predecessors but was of shorter duration which would not have permitted the larger glaciers and continental ice sheets to develop to the maximum extent while the smaller mountain glaciers would have grown quickly to their maximum size covering the areas of previous glaciations. In addition glaciers could develop in marginal situations where no ice cover had been present previously. Another hypothesis for the lack of evidence for older glaciations, particularly in the New Guinea situation, has been that it was only shortly before or during the last glaciation that the mountains were uplifted high enough to be affected by glaciation (Verstappen, 1964). Be that as it may there is one landform type, the volcano, where the likelihood of preservation of older glacial evidence is relatively great, because volcanism and glacial activity may alternate and traces of glaciation may be either

Fig. 3: Palagonitic breccia on ridge crest in Gogon valley forming castellated crags. The breccia is overlain to the east (left) by a series of steeply dipping normal lava flows. Sample 9 is from base of palagonite, 11 from lowermost lava flow. 12 is from lava higher up the sequence and is outside the picture.

buried under lava flows or preserved as palagonite which forms when magma erupts and is drastically chilled and explodes to form a breccia. Both kinds of evidence have been found on Mt Giluwe and have been reported by Blake and Löffler (1971) and Löffler (1972). It was the main aim of the subsequent work to establish a radiometrically controlled stratigraphic base for these events.

The two main findings for older glacial activity were palagonitic breccia which almost certainly erupted under an ice cover in the upper Gogon valley on the eastern slopes of Mt Giluwe (fig. 3) and moraine material overlain by lava in the headwaters of the southernmost tributary of the Tamal River. Both localities are situated inside the limits of the last glaciation. Initially there was some doubt whether the morainic material underlying the lava flow was in fact a glacial deposit and not merely volcanic rubble and scoriaceous lava that preceded the ejection of the lava flow. However, further examinations have shown that a morainic origin is more likely than a volcanic: the deposit consists of rounded boulders of lava enclosed in a clay and silt matrix which is indicative of a moraine deposit and is usually not present in scoriaceous lava or volcanic rubble. This more extensive examination also revealed that the moraine material was overlain by finely bedded silt and clay deposits accumulated in a shallow lake basin that had probably formed behind a terminal moraine immediately downslope.

DATING OF LAVAS

Twenty rock samples from lavas in stratigraphically significant positions were submitted for K-Ar datings but only 12 of these proved suitable for dating. The results of the dating are listed on table 1 and the locations of the rocks are shown in fig. 2.

In cases where a simple stratigraphic relationship between lava flows is present the results are consistent with this evidence. For instance, the youngest lavas dated either form the top layers of the summit ridge (3, 4, 18, 19) or occur as the upper layers on ridge crest on the flanks of the volcano (12). The older lavas were found in or near valley floors clearly underlying the lavas on the ridge crests (1, 2, 20). The relationship of 16 and 17 to the other dated lavas is not known since they occur in isolation near the outer margin of the volcano. These were collected in order to establish some radiometric control on the history of the Kaugel Basin and are mainly relevant in relationship with 13, 14 and 15 which proved unsuitable for dating. However, 17 can probably be regarded as giving a maximum age for the development of the basin since it underlies the basin sediments.

The isotopic ages obtained from lavas 1 and 2 and 9, 11 and 12 are of particular interest. Lavas 1 and 2 overlie the moraine material in the southern tributary of the Tamal River and are also the oldest dated lavas found so far on Mt Giluwe. The results of the datings are not statistically different but that for 1 ist the more precise date because of the lower atmospheric contamination in the sample. The close agreement between the two results and between the duplicate analyses increases the probability that 340 000—380 000 years is the age of the extrusion of the lava[1] and this is the minimum age for the moraine material.

[1] Samples 1 and 2 were dated before the Australian Mineral Development Laboratories received a high purity Ar^{38} tracer and the error is therefore considerably greater than for the subsequent samples. It is hoped to collect more material from the site to obtain greater precision for this important event.

Table 1: Potassium-argon dates on whole rock lavas from Mt Giluwe

Sample No.	K %	* Ar^{40}/K^{40}	Ar^{40} atm. (%)	Age (x 10^6 y)
1	2.03	0.00001967	39.9	0.337 ± 0.120
	2.03	0.00002021	33.6	0.346 ± 0.120
2	2.04	0.00002225	90.7	0.381 ± 0.120
	2.04	0.00002230	88.3	0.382 ± 0.120
		0.00002161	88.3	0.370 ± 0.120
3	1.99	0.00001414	91.1	0.242 ± 0.012
	1.99			
4**	1.99	0.00002422	74.2	0.414 ± 0.015
	1.98	0.00001211	83.8	0.207 ± 0.015
		0.00001973	76.2	0.338 ± 0.012
		0.00001308	83.1	0.224 ± 0.015
		0.00001275	81.5	0.218 ± 0.020
9	2.23	0.00001725	96.5	0.295 ± 0.020
	2.24	0.00001631	96.7	0.279 ± 0.020
11	2.30	0.00001688	94.9	0.289 ± 0.025
	2.31			
12	2.19	0.00001287	72.8	0.220 ± 0.015
	2.20			
16	2.08	0.000014930	69.2	0.256 ± 0.012
	2.09	0.000015878	75.8	0.272 ± 0.012
17	2.06	0.000013829	73.3	0.237 ± 0.010
	2.06			
18	1.89	0.000012709	89.1	0.218 ± 0.022
	1.91			
19	1.92	0.000012727	76.8	0.218 ± 0.013
	1.92			
20	2.38	0.000013883	96.2	0.238 ± 0.024
	2.37			

* Denotes radiogenic argon.
Constants used: $K^{40} = 0.0119$ atom %
$\lambda\beta = 4.72 \times 10^{-10}\ y^{-1}$
$gz = 0.584 \times 10^{-10}\ y^{-1}$

** Sample 4 was analysed five times and the spread of results was from 400000 to 200000 years. If the analytical data are plotted on an argon "isochron" diagram based on all samples dated (Ar^{40}/Ar^{36} vs K^{40}/Ar^{36}) it becomes apparent that the last two results of analysis are closest to the "isochron" drawn through the other sample points. The ages of 0.224 ± 0.0015 and 0.218 ± 0.020 × 10^6 are therefore the most probable ones although there is no apparent justification for the rejection of the other analyses (Dr. Webb, pers. comm.). Since the stratigraphic position of the lava is equivalent to samples 3, 18 and 19 an age of 220000 years can be regarded as correct.

Samples 9, 11 and 12 are important in relation to the eruption which led to the formation of the palagonitic breccia in the upper Gogon valley. Sample 9 was collected from within the palagonitic breccia. The results of the duplicate analyses of 9 are not significantly different and both are within the range of error and 280000—290000 years BP can be regarded as the age of the extrusion of the palagonite.
Surprisingly the lava flow directly overlying the breccia (11) proved to be of the same age but there was a substantial time difference between it and a flow (12) occurring some 800 m higher up in this sequence of normal lava flows.

DISCUSSION

The formation of Mt Giluwe volcano probably goes back into the mid Pleistocene. The oldest rocks dated have ages of between 340000 and 380000 years and these overlie moraine deposits formed during a preceding glaciation. This indicates that at this time Mt Giluwe and probably most of the mountains in the vicinity must have reached altitudes similar to the present ones in order to be affected by glaciation. The hypothesis that the New Guinea mountains escaped earlier glaciations because they were not high enough (Verstappen, 1964) is therefore highly unlikely. The period following this must have been one of considerable volcanic violence with the eruptions of innumerable lava flows following in quick succession. A significant break seems to have taken place about 290000 years ago when the palagonitic breccia was formed in the upper Gogon. An ice cover of at least 100 m thickness must have been present at the time (Blake and Löffler, 1971) again an indication that Mt Giluwe must have reached altitudes similar to the present ones. The extrusion of the palagonite was almost "immediately" succeeded by the eruption of normal lava flows. This succession is several hundred metres thick and ranges in age from 289000 years to 220000 years. The youngest dated flow of this sequence is of similar age to the uppermost lava flows on the summit ridge and this seems to mark the end of the major effusion of lavas on Mt Giluwe. Apart from numerous parasitic cones, which erupted on the flanks and footslopes, later volcanic activity was restricted to the eruption of lavas on the main and east peaks and to the formation of a small andesitic cumulo dome near the main summit ridge. No dates are available on these events since the collected material proved unsuitable for dating but stratigraphic evidence suggests that the extrusion of lavas from the main and east peaks took place during the last glaciation and the formation of the cumulo dome during the deglaciation (Blake and Löffler, 1971). Little can be said as yet about a possible correlation of the glacial events in the New Guinea mountains and other parts of the world except that the dates are not inconsistent with the paleotemperature curve of Emiliani (1970) which shows a distinctive temperature low at about 280000 years ago and the glacial record of New Zealand where the Waimaungan glaciation appears to have ended at about 250000 years ago (Fleming, 1975).

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REFERENCES

Bain, J. H. C., D. E. Mackenzie and R. J. Ryburn, 1975: Geology of the Kubor Anticline — Central Highlands of Papua New Guinea. Aust. Bur. Miner. Resour. Bull. 155. 106 p.

Blake, D. H., and E. Löffler, 1971: Volcanic and glacial landforms on Mount Giluwe, Territory of Papua and New Guinea. Bull. Geol. Soc. Am. 82: 1605—1614.

Emiliani, C., 1970: Pleistocene paleo-temperatures. Science 168: 822—825.

Fleming, C. A., 1975: The Quaternary record in Australia and New Zealand. Bull. R. Soc. N. Z., *13*: 1—20.

Galloway, R. W., G. S. Hope, E. Löffler and J. A. Peterson, 1973: Late Quaternary glaciation and periglacial phenomena in Australia and New Guinea. Palaeoecology of Africa and the Antarctic *8*: 127–138 (Ed. E. M. von Zinderen Bakker), Cape Town.

Hope, G. S., 1973: The vegetation history of Mt Wilhelm, Papua New Guinea. Ph. D. thesis, Aust. Nat. Univ., Canberra, 460 p.

Hope, G. S. and J. A. Peterson, 1974: Glaciation and vegetation in the high New Guinea mountains. Bull. R. Soc. N. Z. *13*: 155–162.

Löffler, E., 1972: Pleistocene glaciation of Papua New Guinea. Z. Geomorph. N. F. Suppl. *13*: 33–58.

Löffler, E., 1977: Geomorphology of Papua New Guinea. Aust. Nat. Univ., Press, Canberra. 190 p.

Page, R. W. and R. W. Johnson, 1974: Strontium isotope ratios of Quaternary volcanic rocks from Papua New Guinea. Lithos *7*: 91–100.

Verstappen, H. Th., 1964: Geomorphology of the Star Mountains. Nova Guinea, Geology *5*: 101–158.

Williams, P. W., I. McDougall and J. M. Powell, 1972: Aspects of the Quaternary geology of the Tari-Koroba area, Papua. J. Geol. Soc. Aust. *18*: 333–347.

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