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K-Ar AGES AND GEOLOGICAL RELATIONS OF PLUTONIC ROCKS IN NEW BRITAIN

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CONTENTS

SUMMARY

New Britain exhibits many characteristics of island-arc tectonism. Strongly folded and faulted basic to intermediate lavas and volcaniclastic sediments of Eocene age form the earliest recognized basement rocks of the island. In the late Oligocene, island-arc activity recommenced, but was mainly confined to central and eastern New Britain. Limestone deposition over much of the island in the early part of the Miocene was followed by further volcanism in the late Miocene to Pliocene.

Intermediate and basic intrusives complexes were emplaced into the Eocene to Oligocene volcanic formations, and were overlain by lower and middle Miocene limestone sequences. K-Ar mineral and whole-rock ages on these bodies are quite consistent with this geological control and reveal two groups of ages: one at 27 to 29 m.y. (mid Oligocene), the other at 22 m.y. (late Oligocene to early Miocene). In the Gazelle Peninsula, a single tonalite body dated at 14 m.y. is distinctly younger than all the other intrusives.

INTRODUCTION

New Britain is a long (500 km) narrow (40-100 km) arcuate island that lies between mainland New Guinea and the northwest-trending Solomon Islands/New Ireland chain (Plate 1).

Between 1967 and 1969, regional geological mapping on a scale of 1:250 000 was conducted jointly by the Bureau of Mineral Resources and the Geological Survey of Papua New Guinea. Specimens for geochronological investigation were collected from most of the largest intrusive bodies which crop out widely in the island's mountainous interior. This paper presents the results of this work, which has employed the K-Ar dating technique on both separated minerals and whole rocks. The opportunity has also been taken to include a summary of the geology of New Britain, pending a detailed account (Ryburn, MacKenzie & Johnson, in prep.).

Much of the stratigraphic sequence has been dated by foraminifera (Binnekamp, 1971, 1973) using the scheme of Clarke & Blow (1969) for correlation between the East Indies letter stages (larger foraminifera), planktonic foraminiferal zones, and Tertiary epochs. The geology of the Gazelle Peninsula (at the northeastern end of New Britain, Plate 1) has been described in detail in an unpublished report (Macnab, 1970), and the 1:250 000 geological map of that area is now available (Davies, 1973). Maps on the same scale covering the rest of the island will be published shortly (Ryburn, in press, a, b, & c).

GEOLOGICAL RELATIONS

New Britain lies within the belt of strong seismicity and volcanism bordering the Pacific Ocean. Like many of the islands or groups of islands on the western Pacific margin, it is an active island arc, with a history of episodic volcanism and tectonism spanning most of the Cainozoic. The main body of the island is essentially a geanticline that exposes faulted and tilted upper Oligocene volcanics and associated sediments, intruded by dioritic plutons. This igneous basement is partly mantled by extensive Miocene limestone, and by Upper Tertiary volcanics and sediments. Quaternary volcanoes, some of which are active, are situated along the northern side of the island and at its eastern and western end. A deep submarine trench (New Britain Trench) parallels the south coast, and a tabular zone of earthquake foci (Benioff zone) dips steeply northwards beneath the islands from the vicinity of the trench (Denham, 1969; Johnson, MacKenzie, & Smith, 1971).

The oldest rocks recognized are the upper Eocene Baining Volcanics (Macnab, 1970), which are exposed in central and eastern New Britain (Plate 1). These are essentially a thick inhomogeneous pile of calc-alkaline volcaniclastic rocks, lavas, and hypabyssal intrusives, which probably accumulated directly on oceanic crust as an embryonic island arc. The lavas are predominantly basalts and andesites, but much of the formation consists of pyroclastic and epiclastic rocks including volcanic rudites, arenites and lutites. Many of the abundant volcanic rudites (mostly breccias) appear to be the products of submarine eruptions (Macnab, 1970). Benthonic foraminifera of upper Eocene age (b stage) occur mainly in sparse but widespread small limestone lenses or in limestone clasts associated with the volcanic rudites. The formation is indurated, extensively faulted, and generally highly tilted. Most rocks have suffered low-grade metamorphism with variable degrees of alteration to albite, chlorite, epidote and, in some instances, prehnite. Biotite and hornblende schists occur locally in the centre of the Gazelle Peninsula.

Unconformably overlying the Baining Volcanics in central and eastern New Britain are less voluminous volcanics of upper Oligocene (lower e stage) age (Merai Volcanics in eastern New Britain, Kapuluk Volcanics in central New Britain). These are lithologically similar to the Baining Volcanics but are less indurated, less jointed, less steeply dipping, and apart from zeolitization are unaltered. Although marine limestone and carbonate detritus are more common in parts of these formations than in the Baining Volcanics, other parts contain silicified tree trunks in tuff and thin coal seams in epiclastic sediments.

The intrusive rocks whose K-Ar ages are reported in this paper are widely distributed in the upper Eocene and upper Oligocene volcanic formations. The larger plutons, up to 15 km across, are mostly complex bodies of tonalite, gabbro, and diorite; less commonly granodiorite, monzonite, and adamellite. Most rocks appear to be normal calc-alkaline types, but high-potassium calc-alkaline varieties are also known from parts of the Gazelle Peninsula (Macnab, 1970). In many areas the Baining Volcanics are hornfelsed adjacent to the larger plutons; related porphyries and microplutonic rocks are common as small stocks and dykes intruding the volcanic formation. Copper mineralization is associated with the intrusives at a number of localities, the most notable being the porphyry copper prospect at Plesyumi (Lae River in Plate 1) in central New Britain (Titley & Bell, in press).

An upper limit to the age of the intrusives is provided by the Yalam Limestone (Macnab, 1970), which accumulated over large areas of New Britain in the lower and middle Miocene (upper e and f stages). Slow regional subsidence allowed the growth of a thick (up to 1500 m) blanket of reef and inter-reef limestone with no contamination from volcanism and little detritus from terrestrial sources, except at the base. With possible exception in western New Britain, the Yalam Limestone rests unconformably on the older volcanics and intrusives on an irregular erosion surface. The lower parts of the limestone are diachronous and range from earliest Miocene (early upper e stage) in western New Britain to late middle Miocene (upper f stage) in the Gazelle Peninsula; its upper parts are poorly dated and may extend into the upper Miocene in some areas.

Following this period of volcanic and tectonic quiescence in the Miocene, volcanism resumed in the late Miocene or early Pliocene. Subaerial pyroclastics, andesitic and basaltic lavas, and intercalated tuffaceous marine sediments of late Miocene to Pliocene age (Sigule Volcanics) crop out in the eastern Gazelle Peninsula, while parts of the southwestern Gazelle Peninsula and the Wide Bay/Open Bay Isthmus are covered by equivalent marine and fluviatile tuffaceous sediments (Sinewit Formation) with a basal ash-flow unit (Mevlo Member). In central New Britain, similar highly tuffaceous sediments (Kapiura Beds), now elevated by up to 600 m, are probably of late Miocene to Pliocene age, and, in western New Britain, volcaniclastic marine and terrestrial sediments (Aria Beds) are of Pliocene age. In some areas farther removed from the sources of volcanism, soft calcareous lutites with interbedded limestone lenses were deposited in the late Miocene to Pliocene (Plate 1).

The present regime of volcanism, uplift, and faulting appears to have commenced in the late Pliocene or early Pleistocene. The volcanoes (Plate 1) are mostly central-type stratovolcanoes. Lavas include tholeiitic high-alumina basalt, large volumes of andesite, dacite, and minor rhyolite (Johnson et al., 1971, 1973). Uplift has mostly taken the form of broad anticlinal arching of the axis of New Britain (up to 200 m a.s.l.) with minor superimposed faulting. However, in eastern New Britain, the island is intersected by major northwest-trending faults which are probably related to those of the Solomon Islands/New Ireland chain (Coleman, 1970). Pleistocene fanglomerates occur on the northeast side of two of these faults (Plate 1). The southern coast of New Britain is fringed by uplifted Quaternary coral reefs up to 200 m above sea level. Swampy alluvial plains on the northern coast may indicate subsidence.

GEOCHRONOLOGICAL METHOD

In common with most heavily vegetated tropical environments, outcrop is largely confined to stream-beds and is generally rather weathered. The freshest rock material is found in stream boulders, which also provide a reasonable representative sample of the hard rocks exposed in the catchment area. All of the dated intrusive rocks were selected from stream or river boulders, after a careful examination of the rock types presented in the float; most were collected in streams of limited catchment area, and can be confidently related to the mapped intrusive bodies.

Most of the samples used in this study are of tonalitic to gabbroic composition. The dating was undertaken by the K-Ar method using separated biotite and hornblende, and one whole-rock sample. Potassium values were measured in duplicate by flame photommetry (Cooper, 1963), and argon analysis, in a Reynolds-type mass spectrometer, employed the isotope dilution techniques previously described by McDougall (1966). The physical constants used in the age calculations are: $\lambda_\beta = 4.72 \times 10^{-10}\ yr^{-1}$; $\lambda_e = 0.585 \times 10^{-10}\ yr^{-1}$; $K^{40}/K = 1.19 \times 10^{-2}$ atom percent. The precision quoted for each age represents two standard deviations and is based on the accumulated errors of each measurement in the age determination (McDougall, Polach, & Stipp, 1969).

THE INTRUSIVE ROCKS AND THEIR AGES

Of the twelve dated specimens, ten are medium to coarse plutonic rocks derived from six separate plutons; the other two are porphyritic rocks which cannot be related to any mapped intrusive body, but are probably representative of the numerous small stocks and dykes which invade the volcanic basement. The larger plutons are complex bodies which intrude the upper Eocene Baining Volcanics, or, in central New Britain, the upper Oligocene Kapuluk Volcanics. Plutonic rocks are unconformably overlain by the lower to middle Miocene Yalam Limestone in the northwest Gazelle Peninsula and in the Ala River area (small limestone outliers not shown on Plate 1). A similar relation may be inferred in some other areas (e.g. the Sai and Torlu Rivers) where it is probable that the coarse-grained plutonic rocks were once overlain directly by the Yalam Limestone.

TABLE 1

AMD No.	Field No.	Grid Reference*	Locality	Lithology	Mineral	K%		Radiogenic Ar^{40} $\times 10^{-6}$ SCC/gm	100x $\frac{\text{Radiogenic } Ar^{40}}{\text{Total } Ar^{40}}$	Calculated Age m.y.
GA5477	P1347	399500E	Rapmetka River Gazelle Peninsula	Tonalite	Biotite	7.380 7.400	7.390	4.055	76.1	13.7 ± 0.2
					Hornblende	0.251 0.251	0.251	0.142	36.3	14.1 ± 0.4
70-6015	54NG2548A	359000E 9449300N	Sai River - south branch	Diorite	Hornblende	0.371 0.375	0.373	0.381	50.1	25.5 ± 0.7
70-6016	54NG2548B	"	"	Tonalite	Biotite	6.832 6.939	6.886	7.456	85.3	26.9 ± 0.6
					Hornblende	0.440 0.445	0.443	0.422 0.431	52.3 51.9	23.8 ± 0.7 24.3 ± 0.5
70-6017	51NG2661A	265000E 9384800N	Ala River in Uasilau area	Tonalite	Biotite	6.816 6.888	6.852	7.584	77.7	27.5 ± 0.6
					Hornblende	0.368 0.375	0.372	0.407	37.7	27.3 ± 0.9
70-6018	51NG2661C	"	"	Tonalite	Hornblende	0.377 0.342	0.340	0.385	42.2	28.2 ± 0.7
70-6019	51NG2662A	264300E 9382700N	"	Tonalite	Hornblende	0.260 0.264	0.262	0.302	39.9	28.7 ± 0.8
70-6020	51NG0053F	264600E 9386000N	"	Tonalite	Hornblende	0.231 0.233	0.232	0.268	25.7	28.7 ± 0.9
70-6021	51NG2551A	246200E 9349000N	Ania River	Diorite porphyry	Hornblende	0.144 0.144	0.144	0.142	22.5	24.5 ± 0.7
70-6022	51NG2552A	238800E 9348400N	Wala River near Ainbul	Hornblende-augite-hypersthene gabbro	Whole rock	0.138 0.137	0.138	0.164	27.2	29.6 ± 0.9
70-6023	51NG2548	231700E 9342800N	Lae branch of Metelen River	Quartz-biotite-hornblende mangerite	Biotite	7.927 7.927	7.927	7.016	70.4	22.1 ± 0.3
					Hornblende	0.402 0.402	0.402	0.355	28.1	22.0 ± 0.6
70-6024	51NG2556	175500E 9373900N	Kori River above junction with Ishmi Creek	Tonalite	Hornblende	0.328 0.331	0.330	0.292	36.6	22.1 ± 0.4
70-6025	54NG2546A	386000E 9397800N	Mogigi River - east branch	Hornblende andesite porphyry	Hornblende	0.576 0.575	0.576	0.661	68.3	28.6 ± 0.7

Constants used $\lambda_\beta = 4.72 \times 10^{-10} yr^{-1}$; $\lambda_e = 0.585 \times 10^{-10} yr^{-1}$; $K^{40}/K = 1.19 \times 10^{-2}$ atom percent.

* Grid reference in terms of metric grid as shown on 1:250 000 geological sheets only

The largest plutons are composed mainly of tonalite, diorite, and gabbro with less abundant granodiorite and adamellite, and rare monzonite and mangerite (petrographic classification of Johannsen, 1931). Orthoclase-bearing varieties are more abundant in the southern Gazelle Peninsula where Macnab (1970) recognized a distinct group of high-potash calc-alkaline plutons. Smaller plutons, such as the dated gabbro body in the Wala River (Plate 1), may be largely one rock type.

The K-Ar ages of all specimens are given in Table 1. With the exception of one sample the age measurements on hornblendes, biotites, and one whole-rock sample lie within the age range, 22.0 to 29.6 m.y. Although these should be regarded as minimum values, the concordance of ages from a given intrusive and the generally good agreement between biotite-hornblende pairs from an individual sample suggest that the ages are geologically meaningful and that they represent a period of major plutonic emplacement from mid-Oligocene to earliest Miocene, using Berggren's (1969) time-scale.

Four separate specimens of tonalite were dated from the Ala River pluton and the K-Ar ages are quite consistent at about 28 m.y. The gabbro body in the Wala River (whole-rock sample) and a hornblende andesite porphyry from the Mogigi River yield similar ages. The ages for the other bodies are significantly younger at around 22 to 25 m.y., and suggest emplacement and cooling of these bodies in the late Oligocene to early Miocene. The 22 m.y. age from the Lae River pluton is especially interesting, for the porphyry-copper mineralization is associated with younger porphyries intrusive into this body (Titley & Bell, in prep.). This date is a maximum for the age of mineralization, which, although no younger than Pliocene on stratigraphic evidence, is nevertheless unlikely to be more than a few million years younger than the age of the 22 m.y. host intrusive.

By far the youngest dated specimen (GA5477) is a tonalite from the Rapmetka River in the centre of the Gazelle Peninsula; it has concordant hornblende and biotite ages of about 14 m.y. The result is in accord with the age of the overlying Yalam Limestone, which in this area is no older than upper f stage (Binnekamp, 1971, 1973), and therefore probably no older than 10 to 12.5 m.y. (McDougall & Page, in press).

The late Oligocene to earliest Miocene ages of most of the New Britain rocks suggest that they may be the deep-seated equivalents to the biostratigraphically dated Kapuluk and Merai Volcanics, a conclusion which is consistent with the limited petrographic data (Ryburn et al., in prep.). In the Ala River and Lae River plutons there are enclosed bodies of igneous breccia, porphyry, and pyroclastic rocks which indicate near-surface emplacement. Possibly these bodies are diatremes or cauldron subsidence structures in magma chambers beneath volcanoes that once fed the Kapuluk and Merai Volcanics.

DISCUSSION

The K-Ar age results for eight separate intrusive bodies in New Britain are internally consistent, are in good agreement with the geological age constraints, and are thus believed to indicate reliable minimum ages of igneous emplacement. Three groups of ages are found: (i) the oldest, mid-Oligocene group, at 27 to 29 m.y., in the Wala River and Ala River, and possibly those in the Ania and Sai River regions; (ii) a late Oligocene or early Miocene group in the Kori River and Lae River are 22 m.y. old; (iii) the only intrusive body dated from the Gazelle Peninsula area is distinctly younger than all the other bodies at 14 m.y. (mid-Miocene).

Thus, most of the plutonic activity known in New Britain appears to have occurred in the latter part of the Oligocene. No early Tertiary or earlier plutonism is known.

The evidence now available from isotopic dating studies on mainland New Guinea and New Britain (Page & McDougall, 1970; 1972; Page, in prep.; Hutchison & Norvick, in prep.) strongly suggests that mid-Tertiary and later plutonism has occurred in at least three distinct episodes; the New Britain plutonism dated in this paper took place during the second, i.e. between the late Eocene to early Oligocene activity (35 - 40 m.y.) in the Torricelli Mountains (north New Guinea) and the extensive mid-Miocene plutonic belt (12-15 m.y.) in the central New Guinea Highlands. The episodic nature of the plutonic activity implies corresponding tectonic episodes; for example, in the mid-Miocene plutonic belt in the New Guinea Highlands, a collision process between the northward-moving Australian Plate and a mid-Tertiary 'Pacific island arc' has been invoked as a triggering mechanism for the plutonic activity (Dewey & Bird, 1970; Page, in prep.). It is feasible that New Britain represents the eastern extension of such an island arc, one which was active in the latter part of the Oligocene. Isotopic dating of intrusive rocks from the Huon

Peninsula and Adelbert Ranges on the north New Guinea mainland, and their comparison with the New Britain age results will enable a more complete evaluation of the continent/island-arc collision hypothesis in this part of the southwest Pacific.

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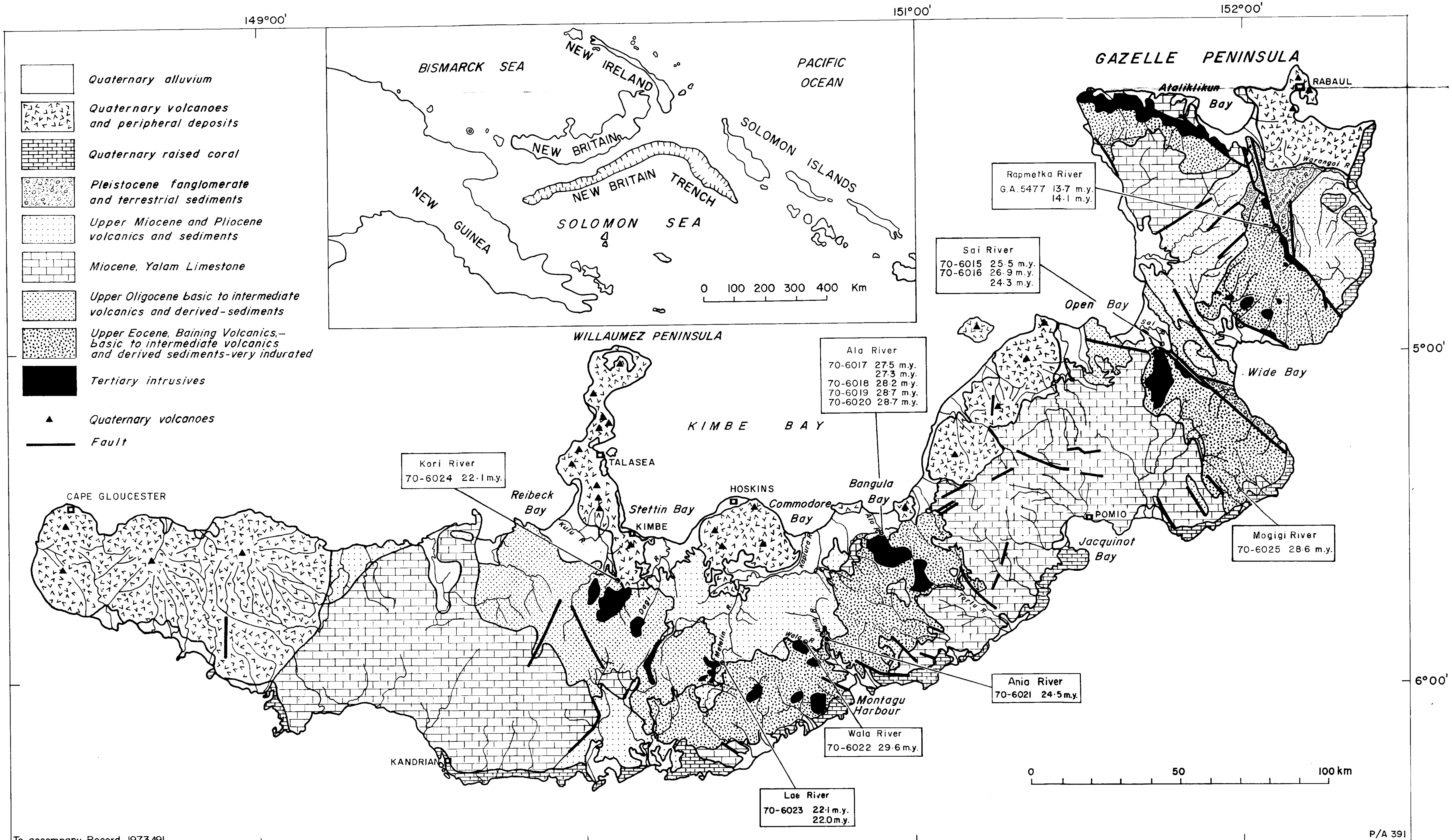

PLATE I - SIMPLIFIED GEOLOGICAL MAP OF NEW BRITAIN SHOWING LOCALITIES AND CALCULATED AGES OF DATED SPECIMENS