RATES OF DIASTROPHIC MOVEMENT DURING THE QUATERNARY IN INDONESIA[1])

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ABSTRACT

Quaternary folding, faulting, tilting, uplift, and subsidence for several localities in Indonesia yield the following information with regard to rates of diastrophic movement.

In the mobile regions the average rate of uplift with or without attendant folding amounts to 0.5 to 1.0 mm/yr. Subsidence occurs at rates of 2.0 mm/yr. As expected, diastrophic movements in the continental areas are much slower and are measured in hundredths of a millimeter annually. Wrench faulting possesses most rapid movements; rates of strike-slip movements are at least 5 mm/yr.

It was also found that observation on deformational phenomena for, shorter periods yields anomalously high values of diastrophic rates. This evidence is in accordance with the spasmodic nature of diastrophism which is also reflected by the occurrence of multiple elevated terraces.

INTRODUCTION

Radiometric ages for Quaternary deposits of Indonesia are scarce, a few are know from alluvial tin deposits in Billiton (Gentner & Zähringer, 1960). Quaternary ages are better documented in neighbouring areas like Brunei (Wilford et al., 1966; Wilford, 1967).

In the present study rates of Quaternary tectonic movements have been deducted by the application of general stratigraphic and semi-quantitative methods. Pleistocene vertebrate stratigraphy has been adequately established in Java by investigations of von Koenigswald and others (see van Bemmelen, 1949), and subdivision into Lower, Middle and Upper Pleistocene can easily be made. Furthermore the percentage method may be employed which deals with fossil coral or mollusc assemblages. For instance, a fossil coral association containing more than 70% living species indicate a Pleistocene age or younger. This method is also explained by van Bemmelen (1949). Horizontal to slightly tilted reef-terraces, erosion levels, and elevated marine sediments are also considered to be of Quaternary age. These features may also yield information on rates of movement.

A number of geologists familiar with European glacial chronology tried with dubious result to correlate morphologic and related stratigraphic levels with the established glacial chronology (e.g. Smit Sibinga, 1948). This method may well be applied in the stable parts of the archipelago, but the extreme mobility of the majority of the Indonesian islands must have distorted evidences of various Pleistocene eustatic movements. Moreover volcanic activity may add to the confusion by shoaling adjacent sea floors or by forming depositional lahar terraces (van Bemmelen, 1949).

Through comparison with coastal areas in other countries the present author (1968a) dated the post-glacial "Daly levels" of higher sea stands occurring at elevations of 0.5-1 m, 1.5-2 m, and 5 m respectively, as 3,500 years, 5,000 years, and 6,000 years old. These levels are generally well developed along limestone coasts and they may be represented by abrasion terraces or sea level notches. Absence of one or two of these levels in a calcareous sea cliff which has at least one recognizable "Daly level" has been assumed to indicate crustal movements that

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precluded the formation of the missing levels. This method was used to estimate the rate of uplift in the Tukangbesi Island group, southeast of Sulawesi (Tjia, 1968b).

Historically recorded diastrophisms furnish most reliable data on rates of tectonic movement. Earth movements, however, are usually spasmodic rather than continuous. Shorter periods of observation often yield extremely high rates of diastrophism, many examples of which are listed in Table I. For instance, coastal changes in the period 1866-1907 in the group of islets off the north coast of Central Java imply subsidence amounting to 70-150 mm/yr (Niermeyer, 1908), whereas the maximum rates of subsidence in the Moluccas, an area regarded as extremely mobile, appear to be approximately 3 mm/yr during the last 300 years (van Bemmelen, 1949, p. 380). An other example is the 1891 – earthquake of Sumatra, when right lateral dislocation along the Semangko fault zone amounted to 1230 mm and was achieved during that single event.

Rutten (1938) found that denudation rates in the tropics, like in Java, average 1 mm anually. Although the present writer admits the reality of rapid downwearing in Indonesia, yet for the time being estimates of rates of subaerial diastrophism do not include the effect of denudation.

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RATE OF QUATERNARY DIASTROPHIC MOVEMENTS

In Table I are listed known or estimated rates of uplift, of subsidence accompanied or unaccompanied by either warping or folding, and of strike-slip faulting. In most cases the original observations from which the rates have been derived, are not mentioned if these have already been recorded by van Bemmelen (1949). The rates of tectonic deformation have been calculated from the elevations of Quaternary rocks, abrasion levels, and their absolute age. Where ages are unknown, a value of 1,000,000 years has been assumed for that particular feature. In other words, the present estimates of diastrophic movements are generally too low. On the other hand these average values of rates of movement seem to be rather reliable if compared with those listed in Table II.

Figure 1 shows the locations and rates of tectonic movement of various diastrophic phenomena in the

TABLE I

Evidence for Quaternary Deformation

Locality	Amount and type of displacement	Age and remarks	Rate in mm/y
Simalur Island	U 100m coral	L. Pleist.(?)	.1
Sumbawa	U 605m coral	,,	.6
Sumba	U 470m coral	,,	.5
Sawu Island	U 300m coral	,,	.3
Roti Island	U 444m coral	,,	.45
Timor, S.W.	U 520m coral	,,	.5
Timor, Central	U 765m coral	750,000 y	1.0
		Percentages	
Timor, East	U 700m coral	L. Pleist.(?)	.7
Lomblen Island	U 250m coral	,,	.25
Pantar Island	U 400m coral	,,	.4
Alor Island	U 700m coral	,,	.7
Wetar, West	U 600m coral	,,	.6
Wetar, East	U 820m coral	,,	.8
Romang Island	U 535m coral	,,	.5
Dai Island	U 620m coral	,,	.6
Babar Island	U 795m coral	,,	.8
Molu Island	U 231m coral	,,	.25
Kai Major, South	U 600m coral	,,	.6
Kai Major, North	U 340m coral	,,	.35
Tajandu Island	U 300m coral	,,	.3
Kur Island	U 450m coral	,,	.45
Kasui Island	U 320m coral	,,	.3
Gorong Island	U 320m coral	,,	.3
Ceram, East	U 400m coral	,,	.4
Ceram, West	U 1200m peneplain	,,	1.2
Ambon Island	U 480m coral	,,	.5
Haruku Island	U 348m coral	,,	.35
West Irian, N.W.	U 300m coral	,,	.3
Geelvink Bay, Irian	U 500m coral	,,	.5
Kofiau	U 250m coral	,,	.25
Halmahera, S.E.	U 260m coral	,,	.25
Halmahera, N.E.	U 200m coral	,,	.2
Halmahera, N.	U>100m coral	,,	>.1
Halmahera, W.	U 350m coral	,,	.35
Mangole Island	U 100m coral	,,	.1
Taliabu Island	U 20m coral	,,	.02
Maju Island	U 210m coral	,,	.2
Sulawesi, North	U 1000m coral	,,	1.0
	U 550m coral	,,	.55
Sulawesi, East	U 700m coral	,,	.7
	U 400m coral	,,	.4
Sulawesi, Central	U 815m coral	,,	.8
Sulawesi, S.W.	U 300m coral	,,	.3
Sulawesi, S.E.	U>500m coral	,,	>.5

TABLE I (continued)

Locality	Amount and type of displacement		Age and remarks	Rate in mm/y
Togian Islands	S	40m coral	20,000 y, Umbgrove (1947)	-2.0
Peleng Island	U	250m coral	L. Pleist.(?)	.25
Muna Island	U	425m coral	„	.4
Buton Island	U	703m coral	M. Pleistocene Percentages	1.0
Kalao Island	U	518m coral	L. Pleist.(?)	.5
Maratua Atoll	S	>529m coral	Pleistocene Kuenen (1933)	> -.5
Bawean Island	U	40m coral	L. Pleist.(?)	.04
Java, West	U	400m peneplain	M. Pleist.	.8
Billiton	U	25m terrace	Pleistocene Osberger (1962)	.05
Bangka	U	18m terrace	„	.02
Sumatra, South	U	100m beach sed.	L. Pleist.(?)	.1
Sumatra, North	U	200m marine sed.	„	.2
Brunei	U	1000m erosion surface	L.-M.Pleist. Wilford (1967)	1.1
Kutei, Kalimantan	U	90m terrace	Holocene, de Sitter (1948)	4.0
Tijger Atoll	S	2000m coral slope	Pleistocene, Umbgrove (1949)	-2.0
Tukangbesi area	S	1000m coral slope	Pleistocene, Kuenen (1933)	-1.0
Wangi-wangi Is.	U	8m Daly level	6,000 y	1.5
Kaledupa Island	U	5m Daly level	6,000 y	.9
Tomea Island	U	5-8m Daly level	6,000 y	1.5
Obi Major, West	S	1m fortress	300 y	-3.0
Babo, West Irian	S	510m Quat. sed.	L. Pleist. (?)	- .5
Madura Strait	S	108m paralic sed.	U. Pleistocene	- .5
Sunda Strait	S	1000m bathymetry	L. Pleist. (?)	-1.0
Kendeng, East Java	F	180m sediments	M. Pleistocene Vertebrates	.4
	F	250m sediments		.5
Rembang, East Java	F	300m sediments	„	.6
Sulawesi, South	F	130m sediments	L. Pleist.(?)	.13
Semangko fault	W	?	4-5 M.y., Katili & Hehuwat (1967)	5-7
Lembang fault	W	140m offset	3,000-6,000 y, Tjia (1968c)	30.0

U : uplift and tilting S : subsidence
F : uplift accompanying folding W : wrench faulting

Indonesian archipelago during Quaternary time.

Table I gives the following general picture of diastrophic rates during the Quaternary of Indonesia.

1. In the mobile areas, especially in the belts of pronounced negative, isostatic gravity anomalies, rates of uplift range between 0.2 and 1.5 mm/yr, and for the majority of cases between 0.5 and 1.0 mm/yr. The high rate of uplift indicated by the Holocene terraces in Kutei, East Kalimantan, may be due to incorrect age estimation or to the short period of observation. Subsidence has occurred at rates of 0.5 to 3.0 mm/yr, with a mean value around 2.0 mm/yr.

2. In the same mobile belts uplift accompanying folding amounts to approximately 0.5 mm/yr.

3. Wrench faulting as exemplified by the Semangko fault zone, Sumatra, and the Lembang Fault in West Java is 5-7 mm/yr and 30 mm/yr respectively. The last value may again be influenced by the shortness of period of observation, which is only 3,000 to 6,000 years.

4. Uplift in the stable continental areas appears to occur at rates measured in hundredths of a millimeter each year.

The rates of movement cited above correspond with values of rates recorded in other mobile areas as is shown in Table II.

TABLE II

Rates of Quaternary Deformation Outside Indonesia

Data from various papers published in the J. Geosci. Osaka University, vol. 10, N. Ikebe (ed., 1967)

Locality	Type and rate of deformation	Measured during	Authors
Kanto, Japan	Warping .9-1.3 mm/y Tilting .1'/1000 y	Quaternary	A. Sugimura
Tokyo Bay, Japan	Subsidence 1.0 mm/y	Quaternary	A. Sugimura
Kinki, Japan	Uplift and folding $>$1.0 mm/y	Quaternary	K. Huzita
Osaka Bay, Japan	Subsidence ± 1.2 mm/y	Quaternary	K. Huzita
New Zealand	Uplift and folding 4.0 mm/y Tilting .03°/100 y	6,500 y	H.W. Wellman
Alaska	Uplift of terraces .9 mm/y Uplift along fault 7.0 mm/y Subsidence, average 10.0 mm/y	4,500 y 7,650 y 230 y	G. Plafker & M. Rubin
Atera fault, Japan	Strike slip 5 mm/y	28,000 y	A. Sugimura

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