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NEOTECTONIC SIGNIFICANCE OF THE CHIMEI FAULT IN THE COASTAL RANGE, EASTERN TAIWAN

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ABSTRACT

Two of the major tectonic breaks in the Coastal Range are the Longitudinal Valley fault and Chimei fault. The Longitudinal fault acts as a plate boundary separating the Asian continent from the Philippine Sea plate. The Chimei fault splits the Coastal Range into northern and southern blocks. Characteristic features of block-movement of the Coastal Range can be estimated by analyzing the altitudes of the deformed Neogene strata, those of stream and marine terraces and those of triangulation bench marks. The elevational variations of terraces indicate that the southern block has been tectonically more active than the northern one. There are a number of Holocene raised coral reefs and marine terraces on the coastal side of the Range. Radiocarbon dates of raised reef corals and drift-woods from these terraces show that the average uplift rate of the southern part (Fukang- Tuluan) is 14 mm/yr, and the northern part (Pahsientung- Chengkung) 5-9 mm/yr.

INTRODUCTION

After having evolved at the western edge of the Philippine Sea plate, the volcanic arc system of the Coastal Range has gradually approached the Asian continental margin. In late Pleistocene, all of the Coastal Range overrode on the continental slope and shelf, causing the Neogene volcanic rocks and its overlying sedimentary rocks in the Coastal Range to be severely deformed. Two of the major tectonic elements in this area are the Longitudinal Valley suture and the Chimei fault. Previous studies revealed that the former is a left-lateral fault, and the latter, an active, northwest-verging thrust-fault which formed at about 0.5 Ma., extending from Fengpin, through Chimei to Juishui and joining the Longitudinal Valley. It splits the Coastal Range into northern and southern blocks.

In the present study, evidence of neotectonic movements in the Range have been monitored from (1) the folding and faulting of Neogene strata, (2) the altitudes of stream and marine terraces, and (3) the retriangulation results.

Folding and Faulting of Neogene Strata

The lithostratigraphic units in the Coastal Range include the Tuluanshan (Chimei Complex), Kangkou Limestone, Fanshuliao and Paliwan Formations (Chang, 1968; Teng, 1979; Chen and Wang, 1988). The Fanshuliao Formation, the older sedimentary rocks in the Coastal Range is mainly exposed to the east of the Longitudinal Valley fault. The oldest volcanic rocks of the Chimei Complex are exposed to the south of the Chimei fault which has been activated due to the consecutive NW-SE compression.

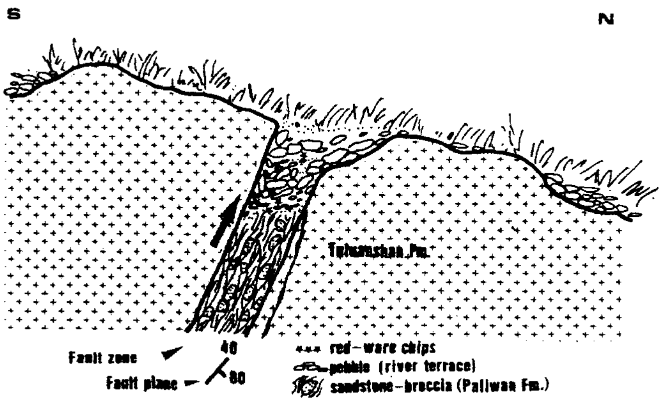

Figure 1. The Chimei fault has displaced a Holocene stream-terrace near Fengpin. The stream terrace contains some red-ware chips.

The volcanic and sedimentary sequences in the Taiyuan basin are exposed to the east of the Longitudinal Valley fault. The volcaniclastic sequence of the Tuluanshan Formation, having a thickness of about 1000 m, is overlain by a sedimentary sequence of the Fanshuliao and Paliwan Formations. The sedimentary sequences consisting of 4000 m thickness of turbidite sediments were deposited in a deep sea at a probable depth of more than 1000 m. Because the volcaniclastic sequence in this area are more than 1,000 m above sea-level at present, the volcaniclastic sequence to the east of the Longitudinal Valley fault might have been elevated more than 6,000 m since late Pleistocene (ca. 0.5 Ma.) to present. The minimum uplift rate of this area is therefore estimated to be about 12 mm/yr. By the Chimei thrust, the Chimei Complex (ca. 17 Ma. or older) came to rest on the Pleistocene sedimentary rocks (Wang,1973; Yang *et al.*, 1989). The vertical slip has been many thousands of meters since late Pleistocene. Figure 1 shows that the fault has further displaced a Holocene stream terrace near Fengpin, with relative height of 10 m above the stream bed, which contains some red-ware chips and is probably 5,000 yr. BP or younger, since the first appearance of red-ware is at about 5,000 yr BP in eastern Taiwan. This fact indicates that the Chimei fault is an active fault.

THE ALTITUDES OF TERRACES

The geomorphological development of stream and marine terraces is different between the northern and southern Coastal Range. Therefore, the study area can be divided into three topographic units trending west to east, namely, the Longitudinal Valley, the mountain area and the coastal aera.

(1) The Longitudinal Valley

Development of stream terraces in the northern part (from Hualien to Juishui) are meager, but very conspicuous in the southern part (from Juishui to Taitung) (Hsu, 1955). The altitudes of stream terraces in these two parts are different. More specifically, there are four prominent steps of stream terraces in the southern part whereas there are only two in the northern part. The terraces of the Hsiukuluan and Peinan rivers in the southern Longitudinal Valley can be divided into several steps covered with lateritic or non-lateritic soil (Yang, 1986). Furthermore, the lateritic stream terraces at Wuho and Peinanshan, have alrealy been deformed. The C-14 dating of a driftwood sample (NTU-1029) from the Wuho terrace indicates an age greater than 50,000 yr BP (Table.1).

Table 1. The radiocarbon dates and altitudes of raised coral reef and drift-wood samples from the Coastal Range

Sample Locality	Sample number	C-14 age yr.BP	Altitude + m	Eustatic sea-level	Minimun uplift	
Fukang	NTU-1082	3630±50	40 m	0 m	40 m	@
Heifachiao	NTU-1069	2820±50	40 m	0 m	40 m	@
Yuchiao	NTU-1077	7690±60	1 m			@
Chihtien (Chengkung)	NTU-1106	3380±50	15 m	0 m	15 m	@
	NTU-1187	5550±50	20 m	0 m	20 m	@
Wuho	NTU-	>50000	80 m			@
Pahsientung		4970±250	36 m	0 m	36 m	#
		5340±260	36 m	0 m	36 m	#
		5240±260	36 m	0 m	36 m	#
Shihtiping	A	3690±100	26 m	0 m	26 m	*
	B	3930±100	26 m	0 m	26 m	*
	26MA	3560±100	26 m	0 m	26 m	*
	26MB	3760±100	26 m	0 m	26 m	*
	6M	980±80	6 m	0 m	6 m	*

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#Sung, W. H. (1969)
*Lai, C. K. (1987)

Comparison of the relative height above stream bed indicates that the stream terraces in the southern part are apparently higher than those in the north. The higher steps of the terraces are also well developed and widely distributed in the southern part. It is therefore evident that the southern part of the Longitudinal Valley has been tectonically more active than the northern part.

(2) Mountain area

The drainage systems north of the Chimei fault include the Shuilien, Fanshuliao, Tingtzulou and Paliwan rivers, and those of the southern part include the Hsiukuluan and Mawuku rivers. Well developed, higher-stepped stream terraces are distributed mostly in the southern Coastal Range. In the northern part, there are generally three to four steps of stream terraces. For example, four steps of stream terraces exist along the Shuilien river with relative heights of 17-22 m, 10-12 m, 5-8 m and 2-5 m above the stream bed, respectively (Figure 2). However, detailed mapping shows

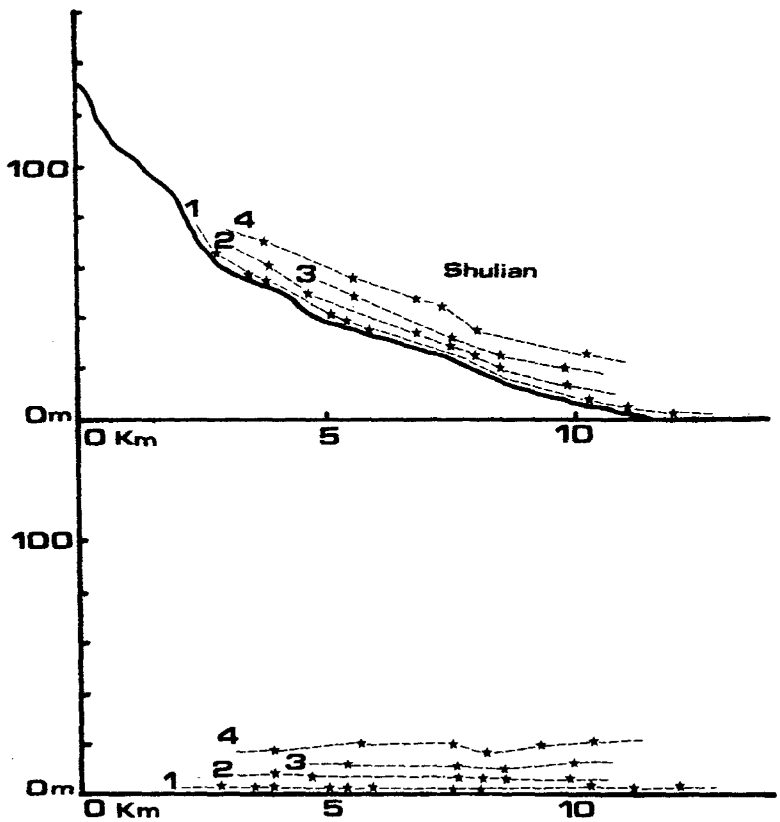

Figure 2. Four steps of stream-terraces along the Shuilian-chi with relative heights of 2-5 m, 5-8 m, 10-12 m, and 17-22 m above stream bed, respectively.

seven to eight steps of stream terraces in the south. For example, seven steps of stream terraces exist along the Mawuku river with relative heights of 2-5 m, 7-12 m, 10-22 m, 24-33 m, 33-48 m, 56-58 m and 70-75 m above the stream bed (Figure 3). Along the Hsiukuluan river, there are eight steps of stream terraces with relative heights of 5-8 m, 8-10 m, 20-30 m, 45-60 m, 74-82 m, 116-122 m, 142-148 m and 167-169 m above the stream bed (Figure 4). The highest step here reaches a maximum elevation about 170 m above the stream bed. The recent and Pleistocene terraces are generally higher in the southwestern part and become lower and lower toward the eastern and northern parts (Yen, 1967).

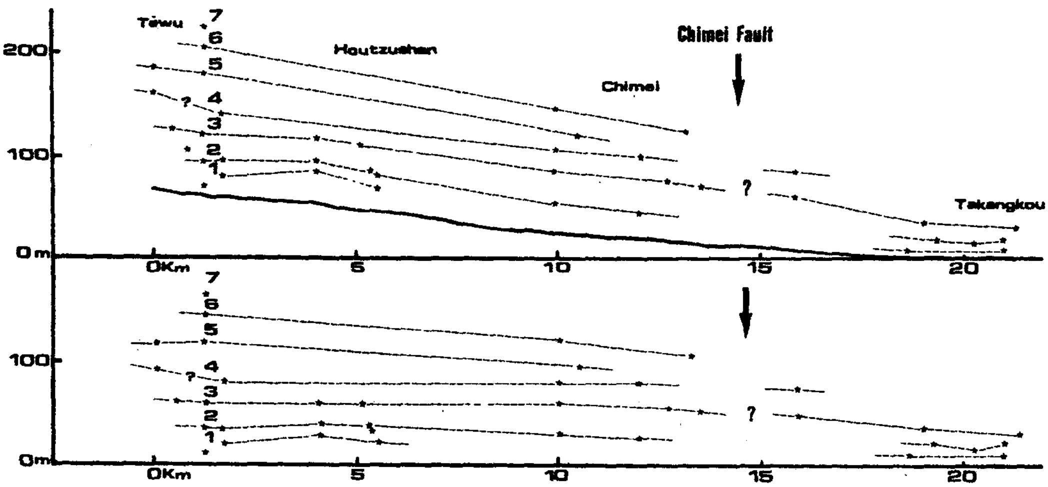

Figure 3. Seven steps of stream-terraces along the Hsiukuluan-chi with relative heights of 5-8 m, 8-12 m, 20-30 m, 45-60 m, 74-82 m, 116-122 m, and 142-148 m above stream bed respectively.

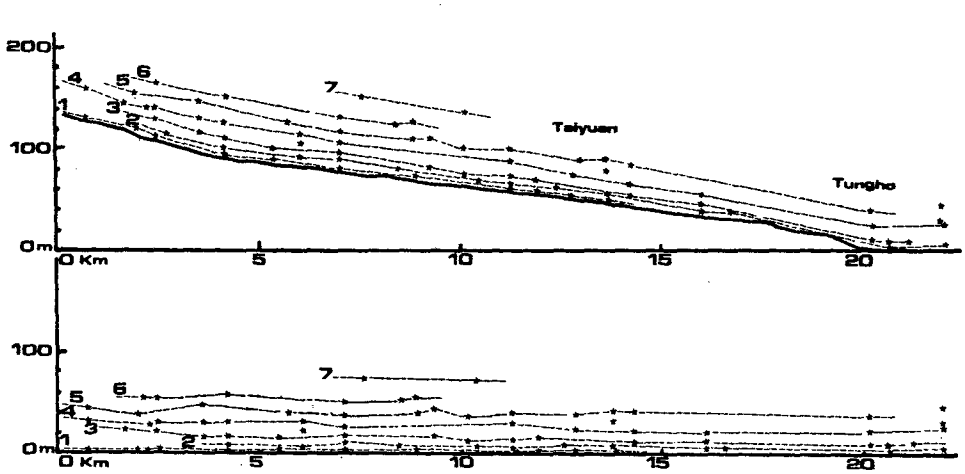

Figure 4. Seven steps of stream-terraces along the Mawuku-chi with relative heights of 2-5 m, 7-12 m, 10-22 m, 24-33 m, 56-58 m, and 70-75 m above stream bed respectively.

(3) Coastal area

The marine terraces north of Fengpin form only three inconspicuous steps, about 5-12 m, 17-25 m, and 25-35 m above sea-level, respectively, but in the south there are three conspicuous steps, about 6-15 m, 20-30 m and 45-50 m above sea-level, respectively (Shih *et al.*, 1988; Lai, 1987). It seems that the marine-terrace systems in the southern part are relatively higher than those in the northern part, although there are not sufficient data yet to correlate them. Therefore, only the average uplifting rates of the southern Coastal Range, where we have more age data, are discussed in this study.

The dates of coral and driftwood samples, obtained in this study and others, are summarized in Table. 1. The samples were collected from Pahsientung, Shihtiping, Chihtien, Yuchiao, Heifachiao, and Fukang areas. The field occurrences have been described in detail as shown in the following.

(a) Fukang section (Figure 5)

The altitudes of raised reefs in the Fukang area are quite varied from 40 m to 0 m above sea-level and covered by wide patches of coral growth. The coral reefs are mainly made up of domal or massive corals encrusting on the hard substrata. They are generally small coral knobs on top of these fringing reefs. The landscape of a raised-reef is comprised of a marine terrace and a gentle slope about 30-50 m above sea level (Figure 5). A coral sample (NTU-1082) collected from the marine terrace about 40 m above sea-level, is 3,630 + 300 yr BP in age by C-14 dating (Table 1). Topographically, this terrace has a smooth lateral extension of about 1,000 m, and obviously occurs as a reef-flat. Thus the shoreline angle of this reef-flat about 50 m above sea- level may represent the high-tide sea-level. Therefore, the average uplifting rate at Fukang is about 14 mm/yr for the past 3,600 years.

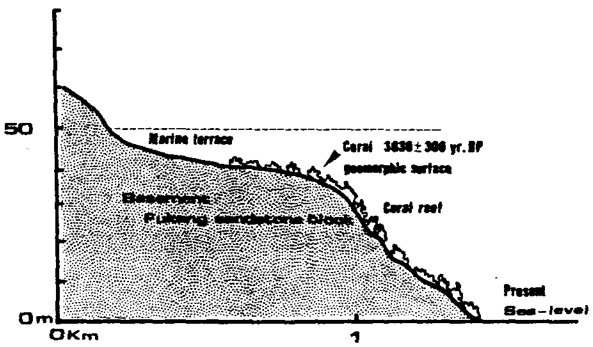

Figure 5. The uplifted coral-reefs in the Fukang area are quite varied from 0 m to 40 m above sea-level. The altitude of marine terrace is from 40 m to 50 m above sea-level.

(b) Heifachiao section (Figure 6)

Heifachiao is located about 1 km north of Fukang. A marine terrace, 40-25 m in altitude, is covered by well-sorted beach sand intercalating many marine shell-debris and red-ware chips (Figure 6). From the characteristic features of the red-ware, it may be dated to be 5,000 yr BP or younger in age (Liu Y. C.,1989). A marine shell sample (NTU-1069) collected from the beach-sand bed about 40 m in altitude gives an age of 2,820±50 yr BP by C-14 dating (Table 1). It is interesting to find that the average uplifting rate of the area is again about 14 mm/yr.

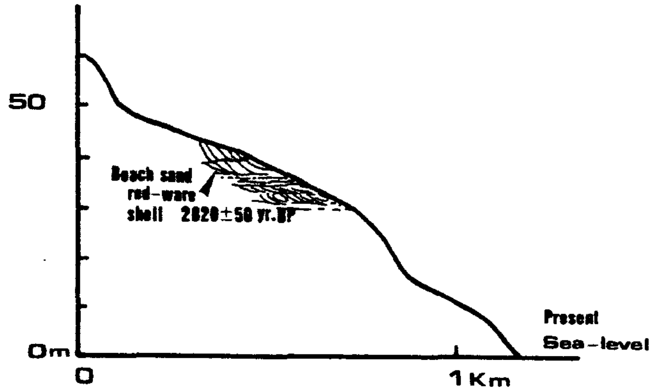

Figure 6. The marine terrace in the Heifachiao area, about 25-40 m in altitude, is composed of well-sorted sands and many of shell-debris and red-ware chips.

(c) Yuchiao section (Figure 7)

Yuchiao is located about 7 km north of Heifachiao. Submarine-slumping beds exposed at 0 m - 8 m in altitude, mainly consist of deformed semi-consolidated sediments with marine shell-debris and driftwood (Figure 7). A driftwood sample (NTU-1077) was collected from the above beds, which gives an age of 7,690 + 60 yr BP by C-14 dating (Table 1). Because the water depth is difficult to estimate by the sedimentary features, the uplifting rate cannot be calculated for this side.

At another location, there are loose sands and gravels unconformably underlain by slumping beds or alternated sandstone/shale strata of the Paliwan Formation (Figure 7). The marine-terrace sediments comprise 8 m- 45 m of sands/gravels which are generally characterized by parallel-laminated and unidirectional cross-bedded structures. The facies association is believed to reflect a shoreface environment. Here, the marine terraces can be divided into three steps of about 8 m-10 m, 20 m-30 m, and 35 m-45 m above sea-level.

The highest marine terrace at this side is overlain by an alluvial fan whose shape is similar to a segment of a cone (Figure 7). The deposits are composed mainly of andesitic sediments, and are generally lenticular in shape intercalated with poorly-sorted sands and gravels deposited probably from a low-viscosity flow. In the lower part of the alluvial fan, there are well-sorted beach-gravels about 2 m thick. In the rounded andesitic gravels with some slumping beds, we found some angular red-painted ware chips. According to the archaeologic studies, there were red- painted wares found (Liu, 1989; Chang,1969) in the Fengpitou Culture (2,400 - 3,500 yr BP). Since the age of the first- appearance of red-painted ware in Taiwan is at about 3,500 yr BP, the beach gravels might be deposited at similar age or later. If this is correct, the minimum average uplifting rate for this point is estimated to be 14 mm/yr.

If the uplifting rate in the Holocene is constant, the submarine slumping bed may originally have been deposited at a depth of about 100 m below sea-level. Facies patterns in this section are dominated by a gradational shallowing-upward sequence which is considered to reflect rapid uplifting.

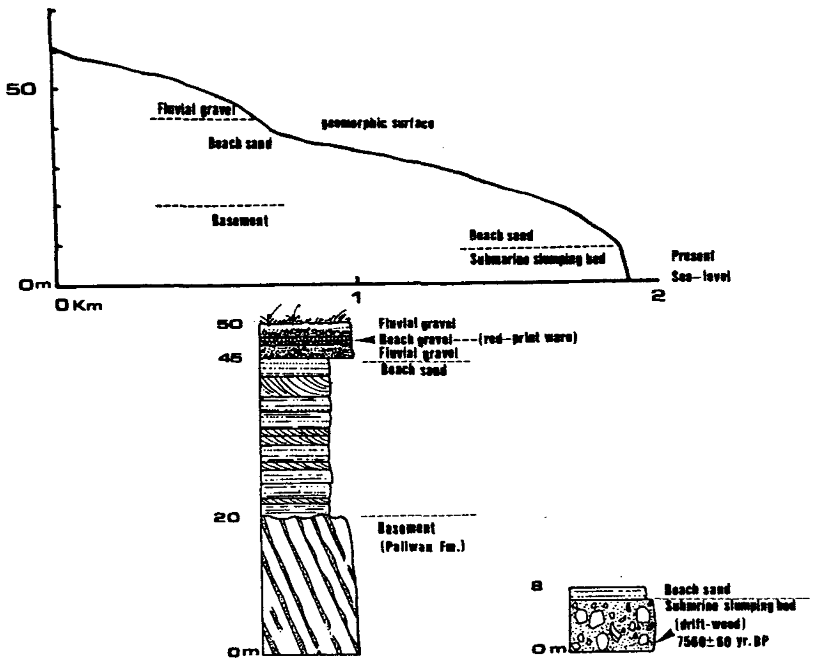

Figure 7. The marine terrace in the Yuchiao area, about 8-45 m in altitude, is composed of well-sorted marine sands. A part of basement of the marine terrace is a submarine slumping bed which consists of poorly-sorted sands/gravels, shell-debris and drift-wood.

(d) Chihtien section (Figure 8)

The Chihtien area is located about 1 km north of Chengkung. The landscape at this location characterized by a marine terrace about 30 m above sea-level and a raised coral reef forming a slope of 10 m-25 m in altitude below the marine terrace (Figure 8). The coral reef consists mostly of aggregates of coral knobs which are made of domal and massive corals. Most of the coral-algal reef is found seaward of a reef-crest, growing on an irregularly sloping ramp called the reef front (James, 1983). Thus, the environment of the coral reef in Chihtien may have been such a reef front, and the marine terrace (20 m-30 m in altitude) may correspond to a reef crest nearly growing to sea- level. The altitude of shoreline angle of the marine terrace about 30 m in altitude may represent the high-tide sea-level at that time.

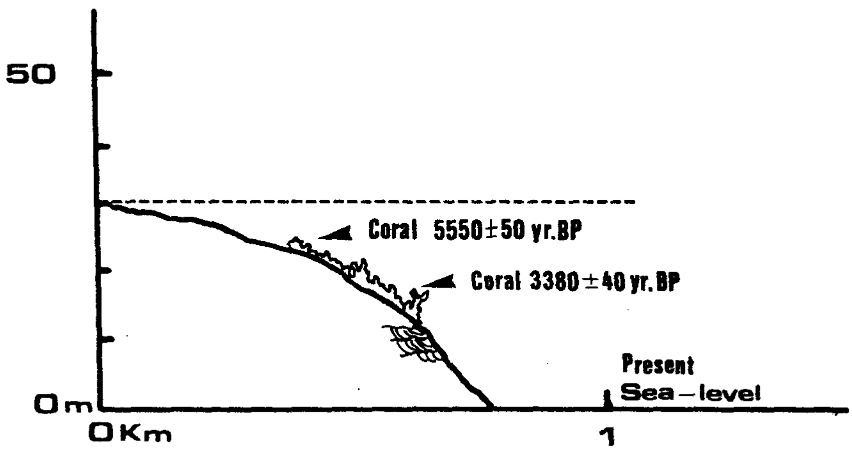

Figure 8. The uplifted coral-reefs from which we collected samples in the Chihtien area are quite varied from 10-25 m above sea-level. The altitude of marine terrace is about 30 m above sea-level.

A coral sample (NTU-1106) which was collected from a slope of 20 m in altitude gives an age of 5,550±50 yr BP, and another sample from 15 m in altitude gives an age of 3,380±40 yr BP by C-14 dating (Table 1). Therefore, the average uplifting rate in Chihtien is about 5 mm/yr.

(e) Pahsientung section

The Pahsientung cliff, as a wave-cut cliff, has many sea- caves at various altitudes: 26 m, 30 m, 44 m-47 m, 66 m, 77 m, 112 m and 130 m above sea-level (Sung, 1969; Lai, 1987; Shih *et al.*,1988). In one of the sea-caves, the Tsauintung (36 m in altitude), marine sands were found covering the cultured materials (the Changpin Culture) which was about 5,000 yr BP (Sung,1969) (Table 1). The average uplifting rate in the Pahsientung area is therefore about 7 mm/yr.

(f) Shihtiping section (Figure 9)

The highest-step marine terraces in the Shihtiping area are 15 m-30 m above sea-level, and are covered by coral reefs and beach sands/gravels. The highest point of the marine terraces about 30 m in altitude may represent the high-tide sea-level. Some coral samples were collected from a marine terrace about 26 m in altitude by Lai (1987), which were dated at around 3,560±100 to 3,930±100 yr BP in age (Table 1). Therefore, the minimum average uplifting rate here is about 8 mm/yr.

According to the above uplifting rates of the marine terraces, it is evident that the southern part of the Coastal Range from Fukang to Tuluan has been uplifted faster than the northern part from Chengkung to Shihtiping. The different uplifting rates in the southern Coastal Range may be ascribed to the fact that the southern part belongs to the hanging wall of the Chimei fault.

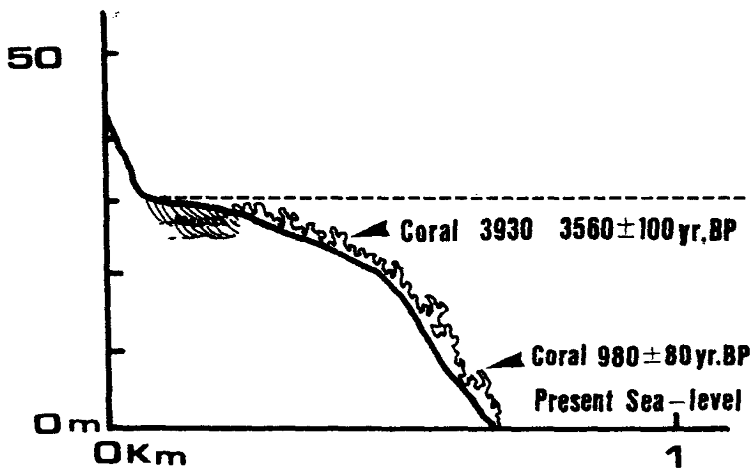

Figure 9. The uplifted coral-reefs in the Shihtipin area are quite varied from 0-26 m above sea-level. The altitude of marine terrace is about sea-level.

RE-TRIANGULATION RESILTS

Almost all the geodetic stations which were displaced north- northeastward during the last 66 years (1914-1979) are located in the northern Coastal Range and all the stations displaced west-northwestward are in the southern Coastal Range (Biq, 1984). Abrupt change in the displacement directions occurs across the Chimei fault.

Based on the results stated above, it is apparent that the northern and southern Coastal Range have different trends in neotectonic movement. The 15 geodetic stations which are located in the northern Coastal Range, the direction of displacement is 11 degrees in northeast (Figure 10). The average horizontal displacement for the past 66 years is 5.5 cm/yr for the area north of the Chimei fault. The southern Coastal Range is overriding on the Central Range and the northern Coastal Range along the Longitudinal Valley and Chimei faults, respectively. In all of the 26 geodetic stations which are located in the southern Coastal Range, the average direction of displacements is N22E (Figure 10). The average horizontal rate of their displacement is 5.1 cm/yr. It also shows that the difference in the directions of displacement between the northern and southern Coastal Range is as large as 33 degrees. Yu's geodetic data (Yu, 1989; Yu, *et al.*, 1982, 1986) has also shown similar results.

CONCLUSIONS

Judging from the C-14 dates of the Holocene raised coral reefs and depositional marine terraces below 100 m above sea- level, the uplifting rates of stream and marine terraces of the southern part of the Coastal Range are higher than the northern part. In other words, the southern part (Fukung-Tuluan) is tectonically more active than the northern part (Chengkung- Shihtiepin). Furthermore, observation on the exposure level of the folded and faulted Neogene strata indicates that, the western part of the southern Coastal Range has been uplifted faster than the eastern part during the late Pleistocene. The different uplifting rate may be due partly to the fact that the southern segment of the Coastal Range belongs to the overriding block of the Chimei fault in eastern Taiwan, and partly to the fact that the very center of the arc-continent collision has migrated southward.

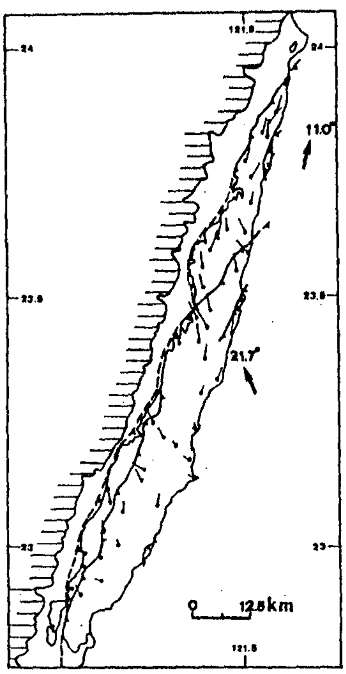

Figure 10. Map of the Coastal Range, eastern Taiwan, showing horizontal displacement indicated by re-triangulation changes between the 1914-1921 and 1976-1979 surveys (after Biq,1984).

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REFERENCES

Biq, Chingchang (1984) Present-day manner of movement of the Coastal Range, eastern Taiwan, as reflected by triangulation changes: *Mem. Geol. Soc. China*, **6**, 35-40.

Chang, L. S. (1968) A biostratigraphic study of the Tertiary in the Coastal Range, eastern Taiwan, based on smaller foraminifera. (II. Northern Part): *Proc. Geol. China*, **11**, 19-33.

Chang, K. C. (1969) Fengpitou, Tapenkeng, and the prehistory of Taiwan: *Newhaven*, 279p.

Chao, C. T. (1984) Sea-level changes of East China since 20Ka (in Chinese): *Studies of revolution of Chinese coast, Fuchien Scientific Technology press*, p.194.

Chen, W. S. (1988) Tectonic evolution of sedimentary basins in Coastal Range, Taiwan: *Ph. D. thesis, Inst. Geol. Natl. Taiwan Univ.*, Taipei, Taiwan, 304p.

Chen, W. S. and Wang, Y. (1988) Development of deep-sea fan systems in Coastal Range basin, eastern Taiwan: *Acta Geol. Taiwanica*, 26, 37-56.

Hsu, T. L. (1955) On the geomorphic features and the recent uplift movement of the Coastal Range, eastern Taiwan: *Bull. Geol. Sur. Taiwan*, 7, 51-62.

Lai, C. K. (1987) The study of marine terrace from Chengkung to Fengping, Coastal Range, Eastern Taiwan: *MS. thesis, Inst. Geography Natl. Taiwan Univ.*, Taipei, Taiwan, 111p.

Liu, Y. C. (1989) Disscusion of Fengpitou Culture and the chronological problem of Peinan Culture: (In press)

Peng, T. H., Li, Y. H. and Wu, Francis T. (1977) Tectonic uplift rates of the Taiwan island since the early Holocene: *Mem. Geol. Soc. China*, **2**, 57-69.

Shih, T. T., Teng, K. H., Hsu, M. Y. and Yang, G. S. (1988) A geomorphological study of marine terrace in Hutung Coast of Taiwan: *Geographical Research*, **4**, 1-50.

Sung, W. H. (1969) Changpinian: A newly discovered preceranic culture from the agglomerate caves on the easter coast of Taiwan: *News letter of Chinese ethnology*, **9**, 1-27.

Teng, L. S. (1979) Petrographical study of the Neogene sandstones of the Fanshuliao Formation, northern Coastal Range, eastern Taiwan. (I. Northern Part): *Acta Geol. Taiwanica*, **20**, 129-155.

Wang, Y. (1973) Wall rock alteration of Late Cenozoic mineral deposits in Taiwan: Geologic settings and field relations: *Proc. Geol. Soc. China*, **16**, 145-160.

Yang, G. S. (1986) A geomorphological study of active faults in Taiwan: Especially on the relation between active faults and geomorphic surfaces: *Ph. D. thesis, Inst. Geography Culture Univ.* Taipei, Taiwan, 178p.

Yang, T. Y., Liu, T. K. and Chen, C. H. (1988) Thermal event records of the Chimei Igneous Complex: Constraint on the ages of magma activities and the structural implication based on fission track dating: *Acta Geol. Taiwanica*, **26**, 237 -246.

Yen, T. P. (1967) A geologic consideration on the basic and ultrabasic plutonic rocks of the Coastal Range, eastern Taiwan: *Proc. Geol. Soc. China*, **10**, 25-39.

Yu, S. B. and Tsai, Y. B. (1982) A study of microseismicity and crust deformation of the Kuangfu-Fuli area in eastern Taiwan: *Bull. Inst. Earth Sci., Academia Sinica*, **2**, 1-17.

Yu, S. B. and Lee, C. (1986) Geodetic measurement of horizontal crustal deformation in eastern Taiwan: *Tectonophysics*, **125**, 73-85.

Yu, S. B. (1989) Crustal deformation in the Longitudinal Valley area, eastern Taiwan: *Ph. D. thesis, Inst. Geophysics Natl. Central Univ.*, Chung-li, Taiwan, 117p.

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海岸山脈奇美斷層新期構造的地質意義

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摘 要

花東縱谷斷層與奇美斷層是海岸山脈兩條最重要的構造線。花東縱谷斷層是分開歐亞板塊與菲律賓海板塊的界線（亦爲中央山脈與海岸山脈的界線）。奇美斷層則將海岸山脈分爲南北兩個地塊。本研究乃依據新第三紀岩層變形及出露高度，河階及海階的對比及碳十四定年資料與三角點測量的結果來推論海岸山脈地塊活動的情形。由河階與海階的上升高度顯示南段海岸山脈地塊在全新世之後的上升速率較北段爲快。另一是由珊瑚的碳十四定年結果顯示南段海岸山脈南側（富岡--都鑾）的上升速率(每年14公釐)較北側（八仙洞--成功）的上升速率（每年5-9公釐）爲快。由目前三角點測量結果指示北段海岸山脈平均每年以5.5公分的速率向北11度東方向移動。而南段海岸山脈則以每年 5.1公分的速率向北22度西的方向移動。