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序

地層是個既古亦新的研究課題，且是現代地質學的基礎。從事地層學的研究一方面可瞭解地球的發展史，他方面亦有助於闡明古地理環境變遷以及大地構造諸問題，與國土建設和資源開發亦都息息相關。

台灣位於歐亞大陸與菲律賓海兩板塊之交界處，亦是周邊盆地，因此地層的沈積極端複雜與多變，在此環境背景下更突顯地層研究的重要性。台灣的經濟發展快速成長，工程建設逐年增加，工程規劃設計所需之地質資料也跟著大幅增加，這需要很多地質人員的配合參與，無形中也帶動地層的調查、研究檢討和改進。本所有感於新地層資料的不斷增加，以及對一些地層對比問題缺乏一致的看法，需要藉共同討論以取得共識，乃於民國78年9月22至23日舉辦第一次「台灣地層研討會」，當時會獲得全國地質界的熱烈支持和響應，足見該研討會主題的正確與符合當前之需要。

在上次研討會的激勵之下，如今已事隔兩年，對於台灣地區的地層研究又已累積不少資料和心得，在自然需求之下復於民國80年9月26至27日舉行第二次地層研討會。此次研討會共計宣讀論文二十二篇，外加一篇學術壁報，與會人數一百餘，討論至為熱烈，並對會後之研究方向提出諸多寶貴意見。本論文集係將其中十七篇整理編印成册，供地質界同仁研究之參考，在此謹向提供論文及與會之諸位學者專家深表謝忱。

經濟部中央地質調查所

所長　黃敦友

中華民國八十一年六月

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DEPOSITIONAL ENVIRONMENTS OF STRATA IN TAIWAN

T. P. Yen[1]

INTRODUCTION

The purpose of this paper is to discuss depositional environments of the strata in Taiwan, and only the general features of them will be taken into consideration. Small, local depositional environments and detailed variation of environments will not be touched here. Because the Neogene and Quaternary strata of Taiwan have extensively been studied and many stratigraphic data and geologic maps are available, the depositional environments of these strata will be more easily inferred than those of the Paleogene and older strata. The weight of this study, therefore will be put on the Paleogene and older strata.

Generally speaking, the older the ages of strata, the strata are more limited in their exposures. Therefore, depositional features of strata like depositional environments and processes are also much more difficult to study. Moreover, data of strata are generally different in quantity and quality from area to area, and from younger to older strata. Keeping these two points in mind, we are going to discuss depositional environments of the Taiwan strata.

STUDY ON DEPOSITIONAL ENVIRONMENTS

The classification of depositional environments seems to have several ways. Some of them are as follows:

(1) Classification is based only on depositional environments.
(2) Classification is based on both depositional environments and processes.
(3) Classification is based on movements of plate which yield depositional environments.

The classification based only on depositional environments is as follows:

(A) Mega-environments
  (a) Continental platform
  (b) Geosyncline
  (c) Oceanic floor
(B) Regional environments

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(a) Land
alluvial plain, lake, desert, glacier
(b) Land and Sea
shore-beach, delta
(c) Sea
shallow sea (continental shelf) 0-200 m deep
bathyal sea (continental slope) 200-2000 m
abyssal sea (ocean floor) 2000 m and more

The classification based on movements of plates is as follows:

(a) divergence
rift, trough, basin, ocean
(b) convergence
trench. trough, back arc basin
(c) strike-slip fault
basin
(d) intraplate
continental platform, ocean floor.

Depositional environments are usually interpreted or discussed based mainly on lithic and stratigraphic features of strata. These features are direct data and can be used for interpretation of both depositional environments and processes. The lithic and stratigraphic features of strata may include the following items:

(1) Distribution of strata (geologic map, well log, geophysical data).
(2) Rock types and lithofacies change.
(3) Thickness and variation of thickness.
(4) Stratification type (alternation type, monolithic type, etc.)
(5) Sequence (coarsening or fining sequence, cyclic sequence).
(6) Sedimentary structure.
(7) Fossils and biofacies change.
(8) attitude of strata (original, primary, secondary).
(9) Source area of sediments and its geology.
(10) Formation, transportation and deposition of sediment materials.

Except for data of strata, other geologic data like magmatism, metamorphism, tectonism, etc., geochemical data and geophysical data also will provide valuable informations to study of dpositional environments.

STRATA OF TAIWAN

Many studies on the strata of Taiwan have been carried on since early, and abundant reports and publication are available. Besides, not a few geologic sheet maps and several geologic maps of the whole Taiwan have

been published. The general features of depositional environments of the Taiwan strata, therefore, can be inferred to some extent based on these available publications. However, if we want to study depositional environments more detailedly, we will find that the available existing data are still not enough to do such studies. This trouble will occur often in studying the Paleogene and older strata.

Here we will briefly review only some lithic characters of the Taiwan strata. The detailed description of the strata can be referred to many published papers.

Late Paleozoic with/without early Mesozoic

(1) Central Rage (Nanao zone)

The rock types include sandstone-shale with basic volcanics and limestone, limestone with basic volcanics, sandstone and shale, arkose-sandstone, and sandstone-shale with basic volcanics. The total thickness is ca. 6000m.

(2) Southwest Taiwan (underground, Chiali zone)

The known rocks include limestone and chert. The thickness is more than 800m.

Early to middle Mesozoic

The middle Mesozoic shale beds with sandstone were found several places in the Tananao Schist terrain, but the metamorphic grade of the shales seems to be lower than the Tananao Schist. The modes of occurrence and rock characters of the Mesozoic rocks have yet been studied in detail and systematically, but some suggest that the rocks form melange with the Tananao Schist. The intimate occurrence of the Mesozoic rocks with the Paleozoic rocks should be studied from the standpoints of paleontology, metamorphism and tectonism.

At presnt, the relations in mode of occurrence between the Paleozoic and Mesozoic strata will be inferred as follows:

(1) Cover type: Mesozoic strata cover Paleozoic ones.

(2) Mixed type: Paleozoic strata were emplaced into Mesozoic ones by deposition (as slumping, sliding, etc.)

(3) Tectonic type: Paleozoic strata were emplaced on/under Mesozoic ones tectonically, or Mesozoic strata were emplaced on/under Paleozoic ones tectonically.

(4) Combined type: Combination of two or three types.

Late Mesozoic

The known localities of the possible late Mesozoic strata are still few.

Some are known on the surface and some from underground.

(1) Cantral Range (Pihou, Tafun, Litao formations)

The rocks include conglomerate-sandstone-shale-limestone (lower part, ca 1500m thick) and sandstone-shale (upper part, ca 1400m thick).

(2) Hsuehshan Range (Chungling, Sihtsun formations)

The rocks are shale with sandstone. Part of the rocks could belong to Mesozoic rocks.

(3) Peikang (underground)

The rocks are arkose, wacke and shale with fossils of mollusca and Belemnite (Aptian-Albian).

(4) Penghu (underground)

Arkose, sandstone, siltstone, and porphyrite are the main rock types.

(5) Pakuashan (underground)

The rocks are sandstone and wacke.

Early to middle Eocene

The Eocene strata seem to cover the whole Taiwan, and their rock facies can be divided as follows:

Hsuehshan Range facies: conglomerate-sandstone-shale; ca 700m+thick

Yushan facies: shale and sandstone with porphyrite, basalt; ca600m+thick.

Central Range facies: shale with sandstone, limestone, basalt; ca500m+thick.

Table 1. Lithic character

	Northern Taiwan					Southern Taiwan				
	West belt	Slate belt: Hsuehshan	Slate belt: Central R.	Schist belt	East belt	West belt	Slate belt	Schist belt	East belt	
L. Paleoz. E. Mesoz.				ss-sh-ls -bv-av		ss-ls sh (under-ground)		ss-sh-ls bv		NA (m)
M. Mesoz. ?				ss-sh				ss-sh		
L. Mesoz.	ss-sh por (under ground)	sh silt	sh ss-por	pluto			sh-ss			TP (m)
E. - M. Eocene	ss-sh-cong pluto	ss-sh cong pluto	sh-ss-bv por	pluto		pluto	sh-ss-ls-bv-por			PL (m)
L. Oligo. Miocene	ss-sh-bv	ss-sh	sh-ss		agglo-ls -and	sh-silt-bv	sh-ss		agglo-ls-and	CR
Pliocene	ss sh bv				sh-ss-cong ls-agglo -and	sh-silt			sh-ss-cong -ls-agglo -and	TW
Quaternary	sd-cl-gr and.	sd-cl-gr	sd-cl-gr	sd-cl-gr	sd-cl-gr	sd-cl-gr -ls	sd-cl-gr -ls	sh-cl-gr	sd-cl-gr -ls	

NA: Nanao unconformity; TP: Taiping unconformity; PL: Puli unconformity; CR: Coastal Range unconformity.

TW: Taiwan unconformity; pluto: plutonism; m: regional metamorphism; ss: sandstone; sh: shale; por: porphyrite; undergr: underound; cong: conglomerate; bv: basic volcanic rock; and: andesite; cl: clay; gr: gravel; silt: siltstone; and: andesite rock.

West Taiwan (underground): conglomerate-sandstone-shale.
Toward east, the rock facies of the Eocene strata vary from Hsueshan Range faciest hrough Yushan facies to Central Range facies.

Table 2. Depositional environments

	Northern Taiwan					Southern Taiwan				
	West belt	Slate belt: Hsuehshan	Slate belt: Central R.	Schist belt	East belt	West belt	Slate belt	Schist belt	East belt	
L. Paleoz. E. Mesoz.?				shall bthy (geosyncl)		shall-bthy (geosyncl) undergr		shall-bthy (geosyncl)		NA
M. Mesoz. ?				shall ?				shall ?		
L. Mesoz.	shall (undergr)	shall-bthy	shall-bthy				shall-bthy			TP
E. - M. Eocene	shall delta	shall delta	shall-bthy (delta ?)				shall-bthy			PL
L. Oligo. Miocene	shall (shelf) deltas	shall (shelf)	bthy (trough)		bthy submarine volcanoes	bthy slope	bthy slope		bthy submarine volcanoes	CR
Pliocene	hall (shelf)				shall-bthy trough→ delta	bthy-shall slope			shall-bthy trough→ delta	TW
Quaternary	land (pl)	land(mts)	land(mts)	land(mts)	land(mts-pl)	land (pl)	land(mts)	land(mts)	land (mts-pl)	

shall: shallow; bthy: bathyal; geosyncl: geosyncline; undergr: underground; mts: mountains; pl: plain; L: late; E: early; Paleoz: Paleozoic; Mesoz.: Mesozoic.

Table 3. Depositionsl environments (summary)

Age	NW Taiwan	SW Taiwan	Central Range	E Taiwan	Ma
Late Paleozoic ±Early Mesozoic	Geosyncline (whole Taiwan) (shallow-bathyal) Regional metamorphism			(Chiali zone) (Nanao zone)	240 180 NA
	LAND				
Early to middle Mesozoic	Local basins (shallow) ? ?				
Late Mesozoic	Local basins (shallow)				TP
Early to middle Eocene	Deltaic deposits (whole Taiwan) (from W to E, shallow to bathyal)				PL
	LAND				
Late Oligocene	Basin on shelf	Basin on slope	Trough canyon or slope	Volcanic arc	
Miocene	LAND			LAND	CR
Pliocene	Basin on shelf	Basin on shelf-slope		Deltaic dep. on volcanic arc	
	LAND				TW
Quaternary	Alluvium, terrace deposit, deltaic deposit, corals, laterite, etc.				

NA : Nanao; TP : Taiping; PL : Puli; CR : Coastal Range; TW : Taiwan (movement/unconformity).

Late Oligocene to Miocene

The strata of this age are known in the Hsueshan Range (ON fm) and in the Central Range (NO fm).

ON fm: Shale with sandstone; late Oligocene strata with/without Miocene strata; ca. 700m thick.

NO fm: Shale with sandstone; Miocene strata with/without Oligocene strata; ca 1000m thick.

Miocene to Pliocene

The Miocene to Pliocene strata are distributed in west zone and east zone, but the lithic characters are very different between the two zones.

West zone: In the Miocene strata, some are missing, showing an unconformity.

northern part: sandstone-shale alternation with basalts, coal seam, early Miocene to Pliocene, ca. 6000m thick.

southern part: shale with siltstone, late Miocene to Pliocene, ca. 3000m thick.

East zone: Between the lower and upper parts, there is an unconformity.

lower part: andesitic agglomerate, Miocene or/and older, ca 1500m thick.

upper part: shale-sandstone-conglomerate, Pliocene to pleistocene, ca 3000m thick.

Quaternary

Most of Taiwan became land. The Quaternary rocks are represented by sandstone-shale-conglomerate (Cholan Fm, Toukoshan Fm) and sand-clay-gravel-lateritic soil-coral (Alluvium and Diluvium). The total thickness will attain 3000m or more.

DEPOSITIONAL ENVIRONMENTS

Late Paleozoic with/without early Mesozoic

Taiwan might have been situated in a part of long and large geosyncline (or trough) developing along the margin of the late Paleozoic Asia continent. The strata may be divided into two zones, namely the Chiali zone in continental side and the Nanao zone in ocean side. The rocks of the Nanao zone show eugeosynclinal lithic characters. The Chiali zone seems to be buried under western Taiwan and its rocks are still not clear. After deposition of the strata, a regional metamorphism started to take place, immediately in the Chiali zone and some later in the Nanao zone (Jahn, 1991, personal communication).

Early to middle Mesozoic

Few middle Mesozoic rocks including dinoflagellata have been reported to occur in the Tananao Schist terrain, but the metamorphic grade of the rocks seems to be lower than the Tananao Schist. The Mesozoic strata in the Tananao Schist terrain have yet been studied in detail and systematically, so the depositional environments of the Mesozoic strata are at present difficult to infer.

During Mesozoic, east Asia and west margin of the Pacific Ocean (or Kula plate?) have been subjected to several significant crustal movements as the Indochina movement, Yenshan movement, etc., so the depositional environments also have been subjected to many changes.

Late Mesozoic

The late Mesozoic strata generally cover the Tananao Schist and their metamorphic grade is lower than the Tananao Schist. The strata seem to be deposited in shallow basins. After deposition there took place a crustal movement (Taiping movement).

Early to middle Eocene

The Eocene strata cover the whole Taiwan widely and form a large-scale delta. Toward east lithic facies become fining. After deposition of the strata a crustal movement took place (Puli movement).

Late Oligocene to Pliocene

During late Oligocene the strata are distributed widely, but depositional environments are different from area to area. The strata in NW Taiwan were deposited on continental shelf; those in SW Taiwan on continental shelf and slope; those in NW slope of the Central Range in trough; and those in SW and SE parts of the Central Range in continental slope and submarine canyons. In west Taiwan some of the Miocene strata are missing, showing an unconformity. The Coastal Range consists of volcanic arc islands covered unconformably by Pliocene to Pleistocene sandstone-shale-conglomerate beds, some of them show deltaic features.

Quaternary

In Quaternary most of Taiwan became land, so the sediments show marine, marine-land and land facies. They form diluvium, alluvium, coast-beach deposit, etc. Northern Taiwan occupies the Western end of the Ryukyu arc system. The Coastal Range forms part of volcanic arc island chains developing in western margin of the Philippine Sea. The Central Range extends southward to Mindoro-Palawan arc system. Southwest Taiwan is connected with continental shelf and slope of the South China Sea, namely occupies the northeast part of rifted South China Sea.

臺灣地層之沈積環境

顏 滄 波[1]

節 要

古生代後期至中生代初期：臺灣可能位於古生代後期亞洲大陸緣邊部之大規模舟狀盆地（如地槽）之一部分。地層似可分爲兩帶，卽西側的佳里帶與東側的南澳帶。地層沈積後佳里帶在三疊紀而南澳帶在侏羅紀受到廣域變質作用，部分地區似成爲陸地。

中生代中期至後期：因地質資料尙缺少，不易推測其沈積環境，但可能有若干局部性淺盆地的發育。其後太平運動發生，成爲陸地。西太平洋大陸緣邊部在中生代有較大的地殼變動如印支及燕山運動等沈積環境也隨着變化。

始新世前期至中期：全地區由一個大規模三角洲覆蓋，岩性由西而東漸變爲細粒。地層沈積後埔里運動發生而成爲陸地。

漸新世後期至上新世：在各地的沈積環境出現差異，表示沈積區有小規模化的傾向。西北部主爲大陸棚；西南部主爲大陸坡；中央山脈西坡呈舟狀海盆；中央山脈南部呈大陸坡並有海谷；海岸山脈區爲火山島弧，而在上新世三角洲相當發育。

第四紀：臺灣地區大部分已陸化，因此第四系大都爲陸相沈積物。臺灣北部爲琉球島弧系的西端；海岸山脈爲菲律賓海西緣的一火山島弧；中央山脈南伸至呂宋島西方 Mindoro-Palawan 島弧系；臺灣西南部爲南海大陸棚及海盆之一部分。

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澎湖羣島地層劃分與地質構造上一些問題的檢討

陳　培　源[1]

節　　要

本文是對澎湖羣島之地層與地質作一般之檢討，表示本人觀感。澎湖羣島地層依據林朝棨（1957,1963）之劃分，雖大體上尚可接受，但仍有問題未解。為澎湖地層之主體之澎湖羣之年代，近年已依定年資料由第四紀更正為中新世。而在對比上尚頗多問題，本文指出其中易引導錯誤與困難之可能原因。

澎湖羣由數玄武岩熔岩流和間夾的沉積層交間而成，各層接觸面之間均應有一地層不連續之間歇面之存在，因短暫之火山噴發期之後有漫長之「間火期」之存在，使地面岩層經歷一段侵蝕時期。在頂部柱狀玄武岩層的底下，有廣泛的紅土化岩層的存在，即屬其中之一最顯明的不整合面，當此時期在沼澤中及淺水中之沉積物則產生泥煤與無紅土化之沉積岩。澎湖羣玄武岩除熔岩流之外也有岩脈和岩床等侵入岩體，部分岩床型玄武岩也有被誤認為熔岩流，而造成對比上淆混之可能。沉積岩也含有連續性甚短之局部沉積，造成對比上的不確定性。沉積岩之組成絕大部分非當地材料，其來源可能與臺灣中新世沉積物相似，都來自西北方大陸方面，並混雜有不同時代之碎屑物質。火山碎屑物質在澎湖羣中只占少數之局部沉積。粘土中常含有蒙脫石應為玄武岩風化分解和淋積的物質而非由火山灰轉變之產物。澎湖地區第四紀地盤之升降和澎湖羣中岩層之變位和褶皺以及火成活動可能南海擴張、臺灣之蓬萊運動以及東亞新構造運動都有關連。

本文提出一修正之澎湖地層層序表，其中也包括由鑽井中所見之地下岩層在內。

緒　　言

澎湖地層之分層以林朝棨（1957,1963）之分劃較爲詳細，林氏於1957年分爲七層（表一），其後於1963年又列出四地文期，並將晚全新世地層細分爲數層（表二）

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。一般言之，漁翁島羣應爲澎湖地層之主體，佔地層總厚度之百分七十以上。

林朝棨之漁翁島層在1963年又重分爲十一層（表二）。他認爲共有四層玄武岩流和四層沉積岩層交間而成，在中間又間夾兩層紅色岩層。但澎湖各島岩層之位態均近於水平，傾斜度甚小，在各地剖面上能見到玄武岩層多僅一層至兩層，少有同地能見到三層的例子，故在野外對比上疑問重重，探其困難原因，可能受有下列諸因素的影響。

表一　林朝棨1957年之澎湖羣島層序表

時代	地層	與臺灣對比
上完新世	G. 海濱堆積物砂丘砂及表土（含貝塚層）	
下完新世	F. 湖西統：4.黃褐色砂質泥層50～70cm（含貝塚）；3.褐色及灰色砂質泥層 80cm；2.黃灰色海貝層 2.5cm；1.褐色砂層及泥層 +2.5cm	花蓮統（FT層）
上更新世	E. 小門嶼統：2. *Baculogypsina* 石灰岩 20m；1. 鐵質石英砂層或砂層泥層互層 15m	米崙統（LT層）
中更新世	D. 赭土層 2～3 m	（LH層）
下更新世 上鮮新世	C. 漁翁島羣：7.粗粒玄武岩；6.柱狀及板狀玄武岩；5.上部灰砂層；4.多孔質玄武岩；3.中部灰砂層；2.多孔質玄武岩？（上部）；1.東嶼坪層（及馬公自來水井下部）下部	頭嵙山統
中生代	B. 花嶼羣：3.石英脈；2.矽長斑岩；1.玢岩	
?	A. 千枚岩類	

㈠玄武岩流和沉積層之數目在各地不一，二者都有尖滅或局部發育之現象，各層厚度在各地也常有變化。

㈡沉積層之位置不固定，部分是地表河流與湖沼之局部沉積，在二玄武岩層之間也非必定間夾有沉積岩。

㈢各層無一定標準的岩性和成分，有橫的側向遞變的現象。

表二　林朝棨1963年之澎湖羣島層序表

A.　「第四紀」層序表

D　北濱期
現海中沉積，現海濱沉積層
，現珊瑚礁及新期砂丘砂層

（中嶼島期貝塚）
隆起海岸珊瑚角礫層及有孔蟲層

沉水化石珊瑚礁

C　花蓮期
（沙港期貝塚）
（良文港期貝塚）
沙港礫石層
沙港含海化石砂層
舊期砂丘砂層與低位海階沉積層

湖西層

B　米崙期
小門嶼層及新期紅土層

A　頭嵙山期至臺南期
漁翁島羣
上部層
中部層
下部層
底部層
基盤岩類（花嶼羣）

B.漁翁島羣層序表

上部層
10上部緻密玄武岩流
9最上部沉積岩段
8下部緻密玄武岩流

中部層
7紅色粘土及紅色頁岩段
6紅色粘土及火山碎屑岩段

下部層
5上部沉積岩段
4上部多孔質玄武岩流
3中部沉積岩段
2下部多孔質玄武岩流

底部層
1.下部沉積岩積

㈣後期的地塊運動，使岩層有被切斷、傾側，及升降等之變動；在地面位置相當，未必是對等的層次。

㈤海島已經長期之侵蝕，漁翁島羣之頂部甚少有較新地層之覆蓋，各地露出岩柱之頂部應有缺失。

㈥人的因素：不同的認定。

以下是本人最近在澎湖羣島考察的觀感，對於地層和構造所作的檢討和建議。

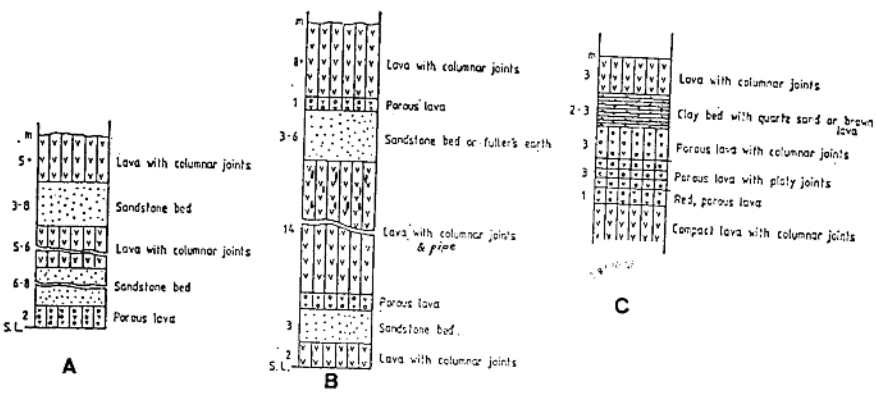
地層剖面舉例

西嶼外垵剖面

西嶼是澎湖本島西邊的最島嶼舊名漁翁島，漁翁島羣之最廣闊之剖面見於該島之西海岸，標準露頭見於赤馬至內垵之間，此處沉積岩（砂頁岩）最大厚度可達三十餘公尺，頂上柱狀玄武岩層厚達10～15公尺，造成沿岸壁立之海崖在附近大菓葉舊採石場中亦可見一列壯觀之柱狀矗立的玄武岩層。

以下是作者在外垵東北方所測的剖面，並與顏（1987）及莊（1988）二位所繪該地區之層序剖面作一比較。

作者所測層序由上而下是	厚度（公尺）
1.有柱狀節理之緻密玄武岩	>8
2.岩渣狀多孔玄武岩	0.3
3.塊狀熔岩	1～1.5
4.含小氣孔之杏仁狀玄武岩	1.0
……假整合……	
5.泥炭質泥土	0.2
6.灰色砂質粘土	3.0
7.灰褐色細砂質至粉砂質頁岩	5.0
8.黃色砂岩	2.0
9.砂頁岩與細砂岩互層	5.0
10.深灰色薄層頁岩	4.0
11.底下崖錐掩蓋。	



圖一　西嶼外坎(A)、虎井嶼(B)、與西嶼龜山(C)之層序柱面圖（顏，1987；莊，1988）。