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2006 年 3 月 22 -26 日
地質考察：

台灣東部海岸地質

Field Excursion Guidebook

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會後野外地質考察行程表

東台灣大南澳雜岩及現代增生造山帶野外地質行程

第一天 （**3 月 22 日，週三**）

STOP	1	東澳粉鳥林角閃岩。
STOP	2	南澳北溪源頭山花崗岩及補虜岩。
STOP	3	南澳北溪源頭山花崗岩及補虜岩。
STOP	4	和仁開南岡片麻岩。
		宿花蓮 東岸商務旅館 03-8332889。

第二天 （**3 月 23 日，週四**）

STOP	5	中橫白沙橋溪畔花崗岩及接觸帶。
STOP	6	中橫慈母橋大理岩、綠色片岩、黑色片岩、石英片岩。
STOP	7	白楊步道剖面大理岩、綠色片岩、黑色片岩、石英片岩、變質燧石。
STOP	8	天祥變質混雜岩。
STOP	9	九曲大理岩峽谷。
STOP	10	太魯閣國家公園。
		宿花蓮 東岸商務旅館 03-8332889。

第三天 （**3 月 24 日，週五**）

STOP	11	海岸山脈嶺頂都巒山火山碎屑岩。
STOP	12	橄子樹八里灣濁流岩。
STOP	13	石梯坪都巒山火山碎屑岩及上升海蝕平台。
STOP	14	穿越海岸山脈：奇美火成雜岩、秀姑巒溪曲流及濁岩。
STOP	15	奇美斷層。
		宿台東 福康旅館 089-355811。

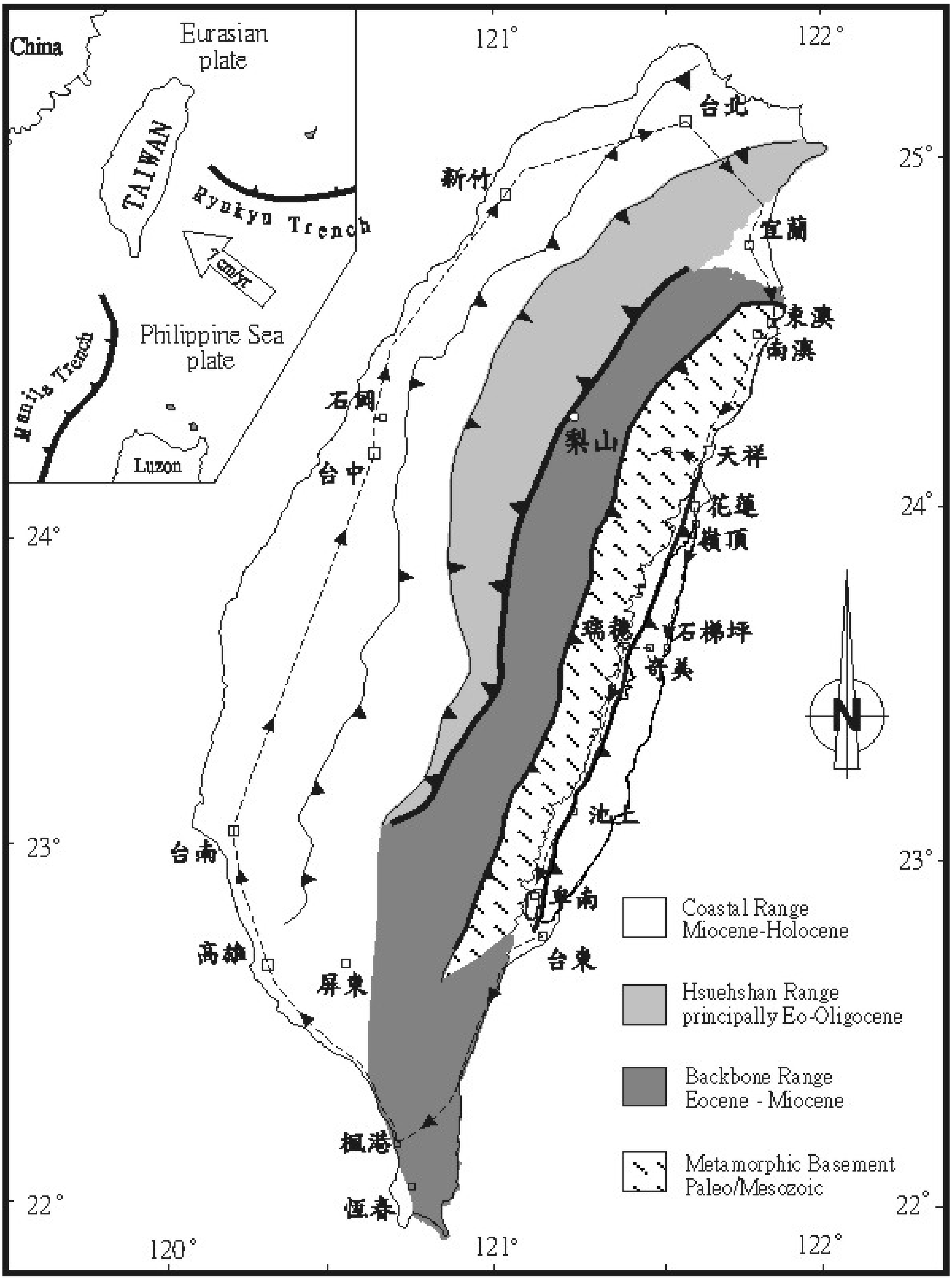
第四天 （**3 月 25 日，週六**）

STOP	16	台東利吉混雜岩。
STOP	17	台東大橋外來岩塊。
STOP	18	小野柳外來岩塊。
STOP	19	太麻里中央山脈南端地質構造。
		宿台南 朝代大飯店 06-2258121。

第五天 （**3 月 26 日，週日**）

STOP	20	成功大學地球科學系 06-2757575 *65400。
STOP	21	集集大地震地表破裂－阜豐橋、石岡水壩。
		宿台北 中央研究院學術活動中心 02-27852717。

Road map of the field trip



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Objective of the field excursion

The purpose of the field trip is to provide an opportunity for our mainland colleagues to visit a very young orogen of Taiwan and see how an active tectonic regime is in operation. The orogenic processes are possibly on one hand related to subduction of a continental margin in association with the subduction of the South China Sea plate (model of Lin, 1998), and are, on the other hand, certainly connected with the interaction between the Luzon Arc (吕宋岛弧) and the Asian continental margin. For those who are more familiar with the tectonics of the Central Asian Orogenic Belt (中亞造山帯) and the Tibetan Plateau-Himalayas (青藏-喜馬拉雅山), the language of "arc-continent collision" commonly used in Taiwan is probably more appropriately replaced by "accretion of the Luzon arc to the Asian continental margin". Nevertheless, this may be a semantic problem to some, but the real scientific content of our field excursion is more important.

In the five days to come we will visit two geological entities – a continental margin and an island arc. The part of continental margin to be examined was composed of shelf clastic and carbonate sediments as well as submarine volcanic rocks and other trench sediments. They were deeply buried, metamorphosed and then exhumed in response to the accretion of the island arc. The elevated continental margin forms the present spectacular Central Range (中央山脈), with the highest peak (Yushan) standing about 4 km tall. The island arc (Luzon Arc) constitutes the principal part of the Coastal Range (海岸山脈) of eastern Taiwan. The Coastal Range is nearly N-S trending, separated from the Central Range by a narrow corridor called the Longitudinal Valley (花東縱谷). The Coastal Range is in fact a mini-scale accretionary orogen, and its accretion to the Asian continental margin can be regarded as the initial stage of the continental growth. Consequently, understanding the actual tectonic style and its operation in Taiwan becomes very important for all of us to comprehend the orogenic processes in more ancient orogens.

The Tananao Schist Complex (大南澳片岩) or the Tananao Metamorphic Complex – Introduction

The Taiwan mountain belt is produced by the late Tertiary convergence between the Eurasian plate and the Philippine Sea plate. The convergence resulted in accretion of a small island arc onto the Asian continental margin. This is an actual model for the formation of juvenile terranes in the Central Asian Orogenic Belt. Because the convergence is oblique, the collision propagates southward and results in younger collisional features in deformation, metamorphism, and exhumation. The geology of Taiwan can be divided into six N-S trending tectonostratigraphic units (Ho, 1988): from west to east, the Coastal Plain, the Western Foothills fold-and-thrust belt, the Hsuehshan Range slate belt, the Backbone Range slate belt, the Tananao metamorphic complex, and the Coastal Range (Fig. 1). The Western Foothills, the Hsuehshan and Backbone Range slate belts, and the Tananao metamorphic complex belong to the late Tertiary accretionary prism, which exhibits increasing degree of deformation and metamorphism toward the east.

The Tananao metamorphic complex is exposed mainly in the eastern frank of the Central Range. It is essentially composed of metasedimentary and metavolcanic rocks with subordinate amounts of granitoids, amphibolites, and serpentinites. All these rocks are

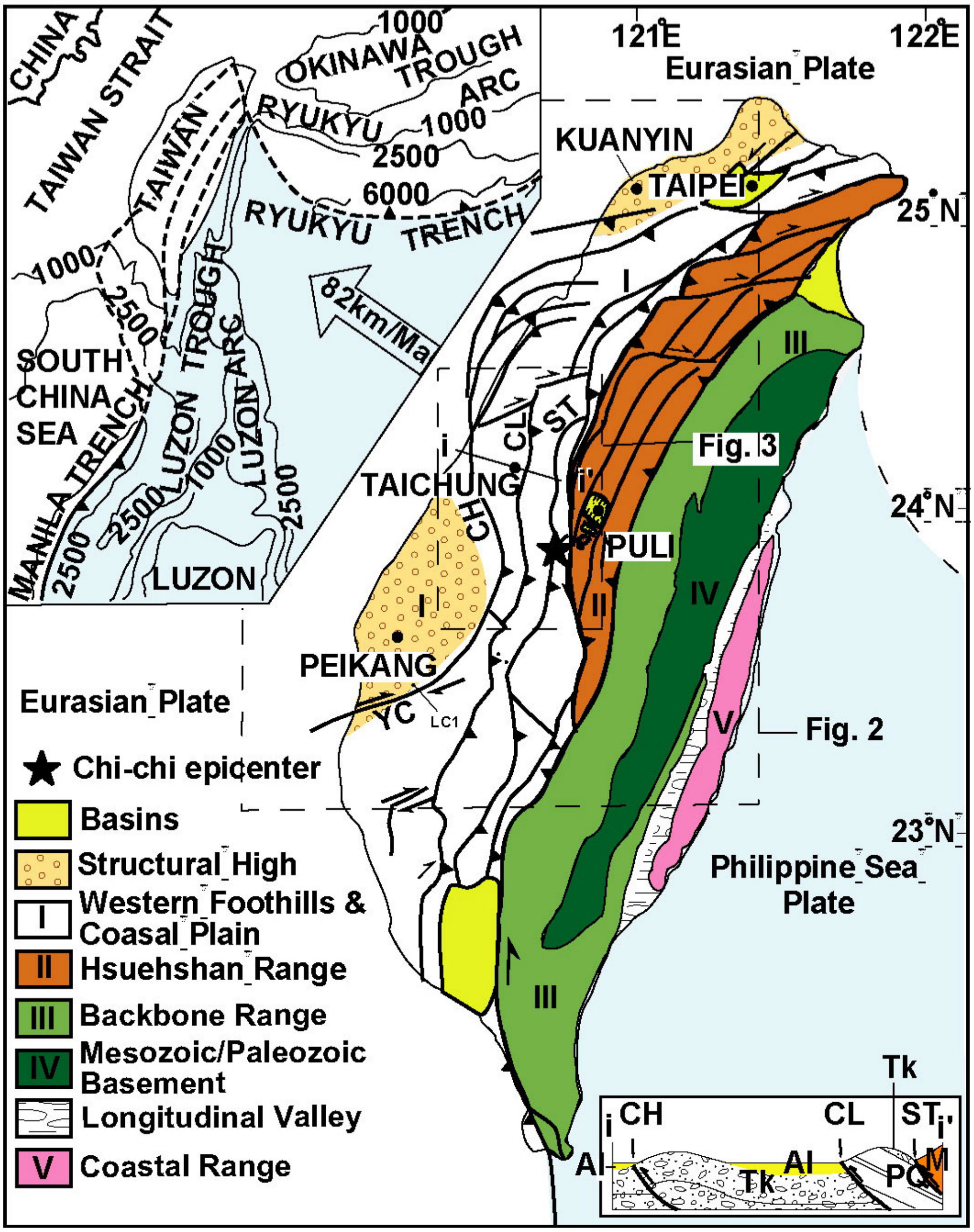


Fig. 1. Tectonic division of Taiwan and an E-W cross-section

grouped on the legend under the general stratigraphic term “Tananao Schist”. Three varieties, black or pelitic schist, greenschist, and siliceous schist are by far the dominant rock types in this belt (Yen, 1954).

Based on the paleontological evidence, Sr isotopic stratigraphy and Pb-Pb isostope dating, the initial carbonate (now marble) deposition and disgenesis took place in the late Permian (about 250 Ma; see e.g., Jahn et al., 1992). The associated pelitic schist, greenschist and siliceous are generally assigned as late Paleozoic to Mesozoic. These rocks has been intruded by late Cretaceous granitoids with crystallization ages ranging from 80 to 90 Ma (Jahn et al, 1986, 1990; Lan et al., 1990; C. H. Lo, 1990; Yui et al., 1993) which overlap with the most important circum-Pacific thermal event known in the Cathaysian foldbelts as late Mesozoic Yanshan Orogeny.

The metamorphosed mafic and ultramafic rocks in the Suao-Nanao area include amphibolites and serpentinites. They are dismembered ophiolites (Lan and Liou, 1981, Ernst et al., 1981). These rocks occur as enclaves within gneiss, marble and pelitic schist of the Tananao Schist. The contact relations between the amphibolites and the country rocks have been described to be concordant or tectonic. In the Nanao area, for example, the amphibolites are intruded by granitoid. In addition, rodingite occurs as lenses at the contact between serpentinites and amphibolites, or as tectonic inclusions within serpentinites. The principal constituent minerals of rodingite are diopside, tremolite-actinolite, hornblende, anthophyllite, chlorite, white mica, and plagioclase (Lan and Liou, 1981; Yui, et al., 1987).

The ultramafic rocks of the Central Range (mainly harzburgite, with minor lherzolite) are highly serpentinized. Relict primary minerals include cpx, chromite, picotite, and Ti-and Cr-rich magnetites. The bulk rock lithology and chemical compositions of these rocks are similar to Alpine peridotites.

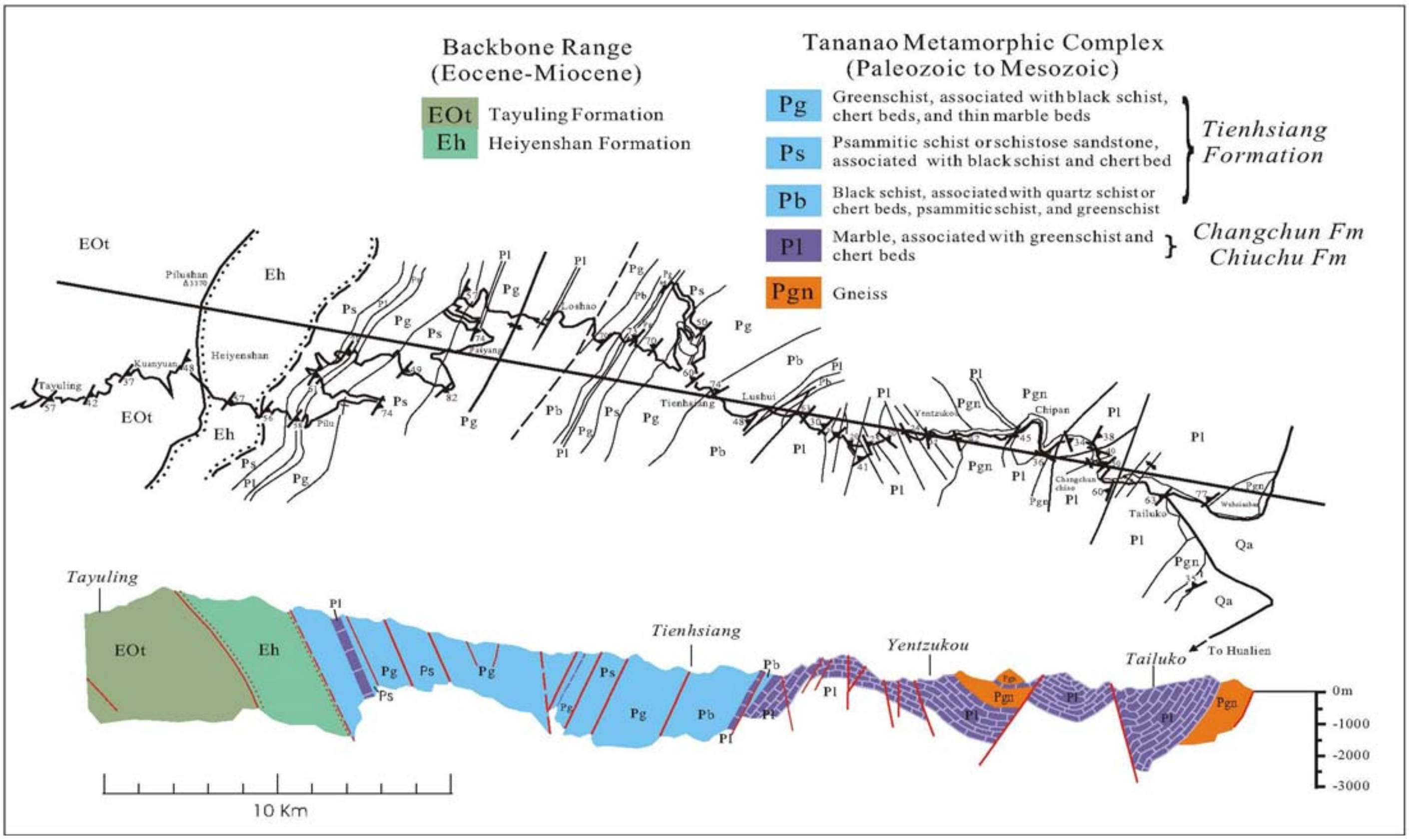


Fig. 2. Geologic road map of the eastern part of the Central Cross-Island Highway (After Chen, 1979)

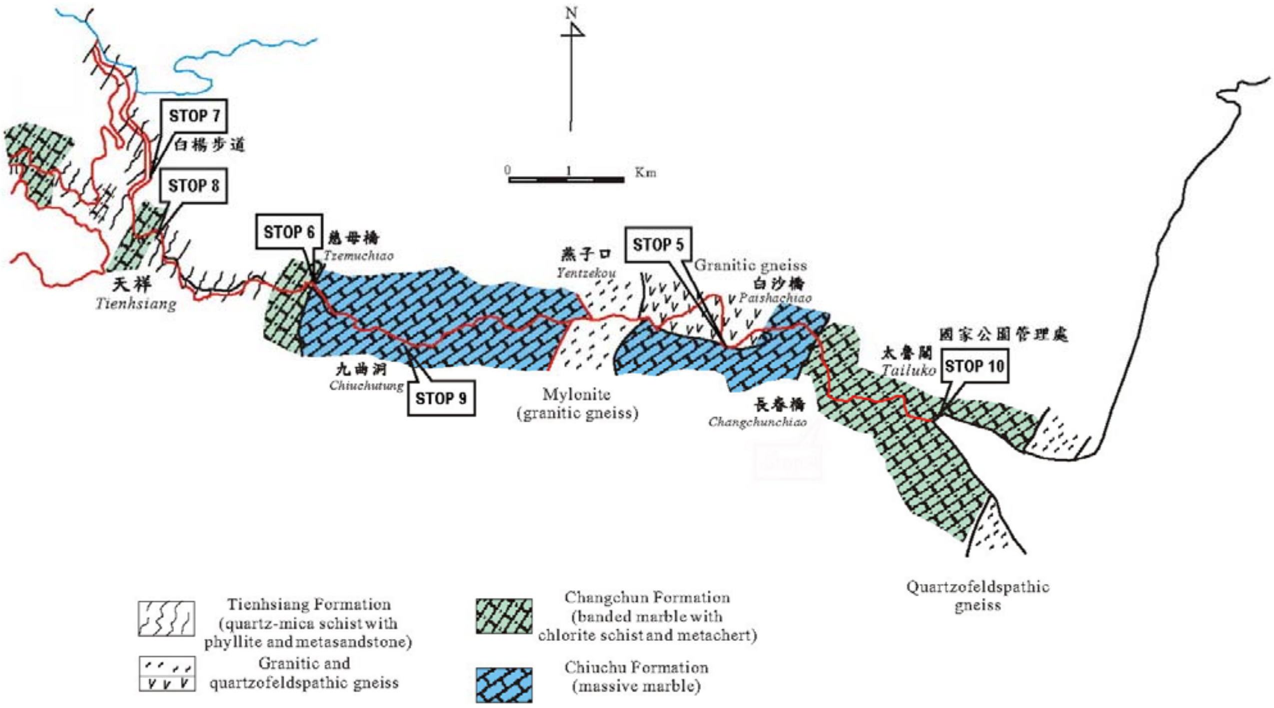


Fig. 3. Geologic road map with marked field trip stops from the Tailuko to Tienhsiang area.

Geologic Background of the Pre-Tertiary Tananao Basement Complex

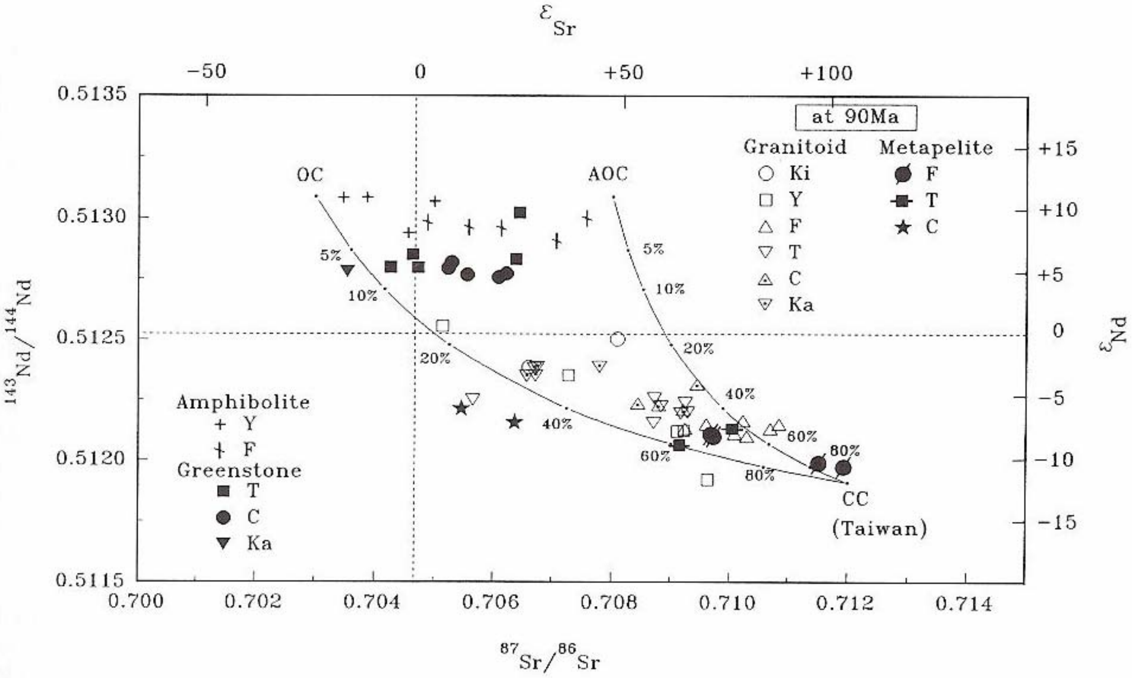
A. Stratigraphy

The age of the basement rocks was assigned to be pre-Tertiary. The metamorphic complex is commonly divided into two belts – Tailuko and Yuli. **The Tailuko Belt** comprises the following lithological units (Wang-Lee, 1979):

1. Kainangang (Kanagan) Formation 開南崗層 – granitic gneiss and schists. Protoliths considered to be arkosic to greywacke sandstones, or assemblage of ss+sh+ls.
2. Jiuchu Formation 九曲層 - massive marble; in places, interlayered with granitic gneisses. The contact between gneiss and marble is “intrusive” or “tectonic” as a fault plane with mylonitization.
3. Changchun Formation 長春層 – greenstones, thin layers of marble, Ca-rich quartzite, quartz schist, metachert; minor chloritoid rock, Mn-rich rock and serpentinite. This formation may represent an accretionary prism.
4. Tienhsiang Formation 天祥層 - mica-quartz-schist and phyllite are the principal constituents. Black schist, metasandstone, metaconglomerate also occur; exotic blocks include ss, greenstone, amphibolite, and marble; but not granitic gneiss. Meta-sandstones often deformed into boudined or lensoid structure.

The Tailuko Belt (太魯閣帶) was intruded by late Cretaceous granitic rocks at about 90 Ma (Jahn et al., 1986). The most representative is the Yuantoushan and Chipan granites. Geochemical studies indicate that the intrusive granitoids are dominantly granodiorite to quartz monzonite (adamellite). Most show A/CNK ranging from 0.95 to 1.6 and display REE patterns typical of granitic rocks. The Yuantoushan granite is metaluminous and of I-type; whereas the Chipan granite show A/CNK = 0.96 – 1.2, The calc-alkaline affinity of trace element data suggest that they were produced in a subduction-zone environment

(Lan et al., 1996). Sr-Nd isotope compositions of the granites and granitic gneisses are summarized by Lan et al. (1995).
Legend



Abbreviations: Ki = Kiyoku (Chiyaogu), Y = Yuantoushan, F = Fanbaochienshan, T = Tachoshui, C = Chipan, Ka = Kainangan.

The Yuli Belt (玉里帶) is composed of black schist, greenschist, blueschist, and mafic and ultramafic blocks. The Tailuko and Yuli belts have been thought to be paired metamorphic belts, with the Yuli Belt as the high pressure belt and the Tailuko Belt as the high temperature counterpart. However, this interpretation is still controversial.

Fossils in the metamorphic complex are rare. A few Permian fusulinids and corals (Yen et al., 1951; Yen, 1953) were found in the Changchun Formation, and middle Jurassic to early Cretaceous dinoflagellates (Chen, 1989) were recovered from the the Tienhsiang Formation. Stratigraphic correlation is difficult, if not impossible. However, the ages of intrusive granites have been well determined by U-Pb zircon dating (Jahn et al., 1986; Fig. 4 of this guidebook) and the depositional ages of the marble sequence were constrained to the late Permian (ca. 250 Ma) by Pb-Pb dating and Sr isotope compositions (Jahn et al., 1984, 1992).

B. Metamorphism

Most of the rocks have greenschist facies mineral assemblages. Rocks near the granitic intrusions may contain amphibolite facies minerals. The fragmented ophiolitic rocks were interpreted as the result of late Cretaceous and mid-Miocene subductions (Liou and Ernst, 1984). The P-T conditions as revealed by the Chipan granitic gneiss and Kainangang foliated gneiss indicate three episodes of metamorphism – the first stage at 2 kb and ca. 500°C, the second at 5-7 kb and 650-700°C, and the third stage at 4 kb and 450°C. The principal tectonothermal events of the island or Taiwan were established by

Jahn et al. (1986) and Lan et al. (1996; see Fig. 5 of this guidebook). A more detailed recount of the tectonothermal events is given in the appendix (Lan et al., 1996).

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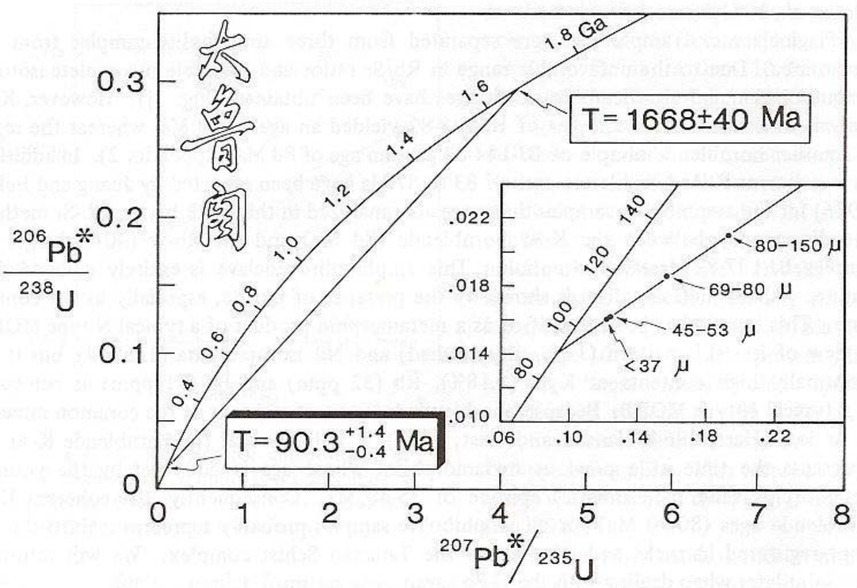

Fig. 4. U-Pb concordia diagram for granite sample BJ-123-82 from Chipan, Tailuko area. The discordia has a MSWD = 0.46.

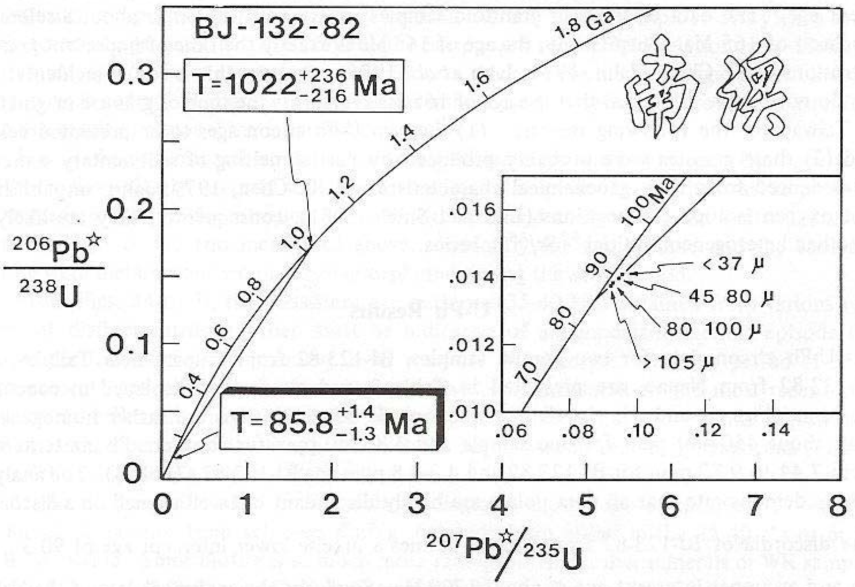

Fig. 5. U-Pb concordia diagram for granite sample BJ-132-82 from Nanao (NSWD = 0.11).

Fig. 4. U-Pb ages of the Chipan (Tailuko) and Yuantoushan (Nan'ao) granites from the Tailuko Belt (data from Jahn et al., 1986).

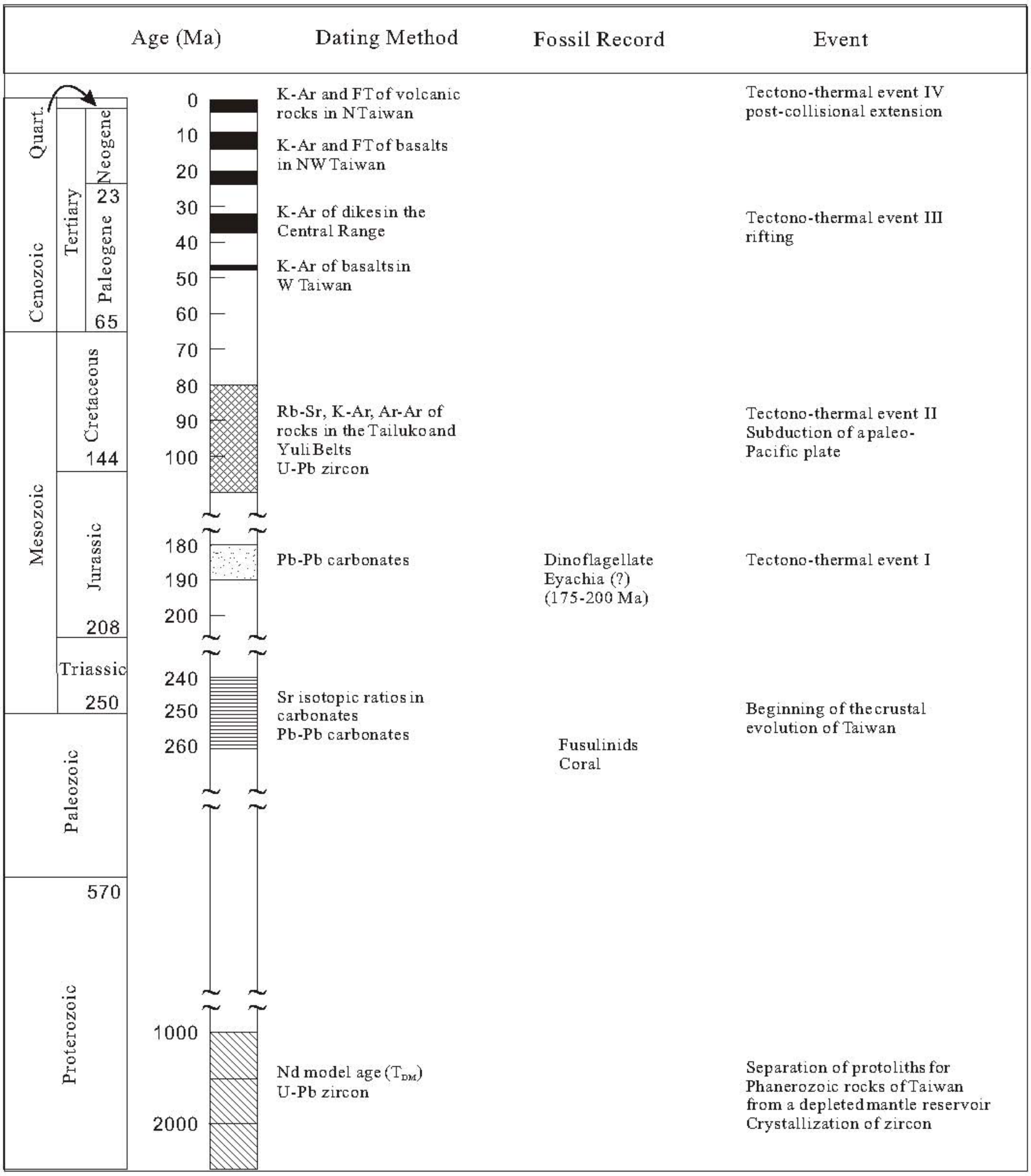

Fig. 5. Summary of important tectono-thermal events in Taiwan (Lan et al., 1996)

C. Structure Characteristics

Most deformation structures, such as foliations and lineations, were interpreted to have resulted from the late Tertiary tectonic event that exhumed the Tananao metamorphic complex (e.g., Stanley et al., 1981; Chan, 1990; Faure et al., 1991; Clark et al., 1992; Byrne, 1995). In the Tailuko region, the structures are characterized by a gently to moderately dipping foliation and a NE-plunging stretching lineation. Lu and Wang-Lee (1986) documented sheath folds with NE-plunging fold axes in schists and marbles. Abundant shear structures, such as S-C fabrics in the granitic rocks, indicate a top-to-the northeast sense of shear.

D. Tectonic Models for Mesozoic evolution

The Mesozoic tectonic evolution of the basement has been debated for years due to the limited number of constraints. Two types of tectonic model have been proposed: a subduction type (Yui et al., 1988; Fig. 6A) and a collision type (Wang-Lee and Wang, 1987; Fig. 6B).

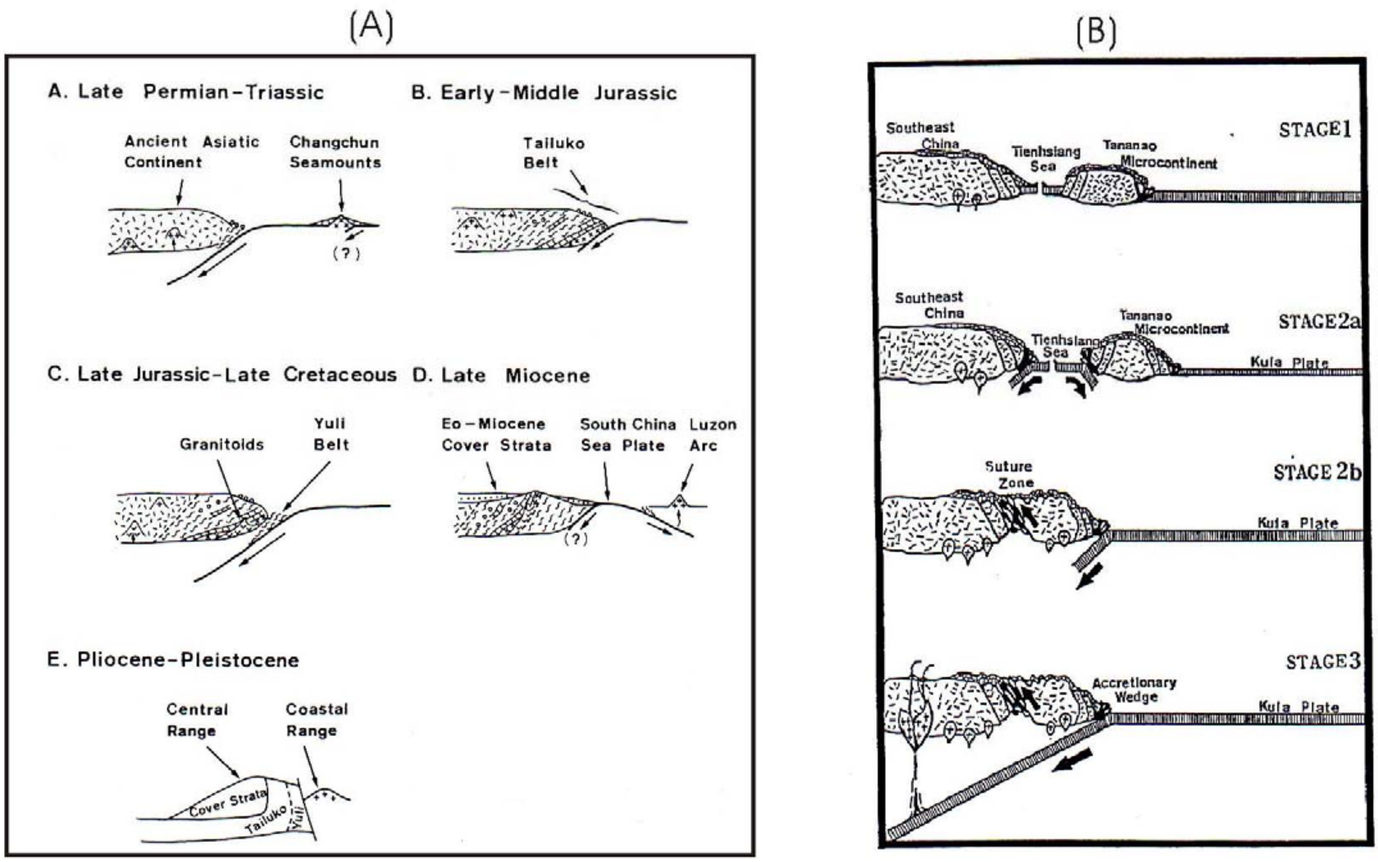

Fig. 6. Two proposed tectonic models for the evolution of the Tananao metamorphic complex. (A) subduction model of Yui et al.(1988) and (B) collision model of Wang-Lee and Wang (1987).

E. Cenozoic Exhumation Model

The basement complex was covered by young sediments during the Cenozoic rifting. Due to the arc-continental collision (or the accretion of the Luzon arc) since the Plio-Pleistocene, the basement rock began to be exhumed. Several mechanisms have been postulated to account for the exhumation (mountain building) process (Fig. 7): a critical wedge model (e.g., Davis et al., 1983), a discrete sequential thrusting model (Hwang and Wang, 1993), a lateral extrusion and normal faulting model (Byrne, 1995; Crespi et al., 1996), a lithospheric collision (Wu et al., 1997) and a subduction and extrusion model (Lin et al., 1998).

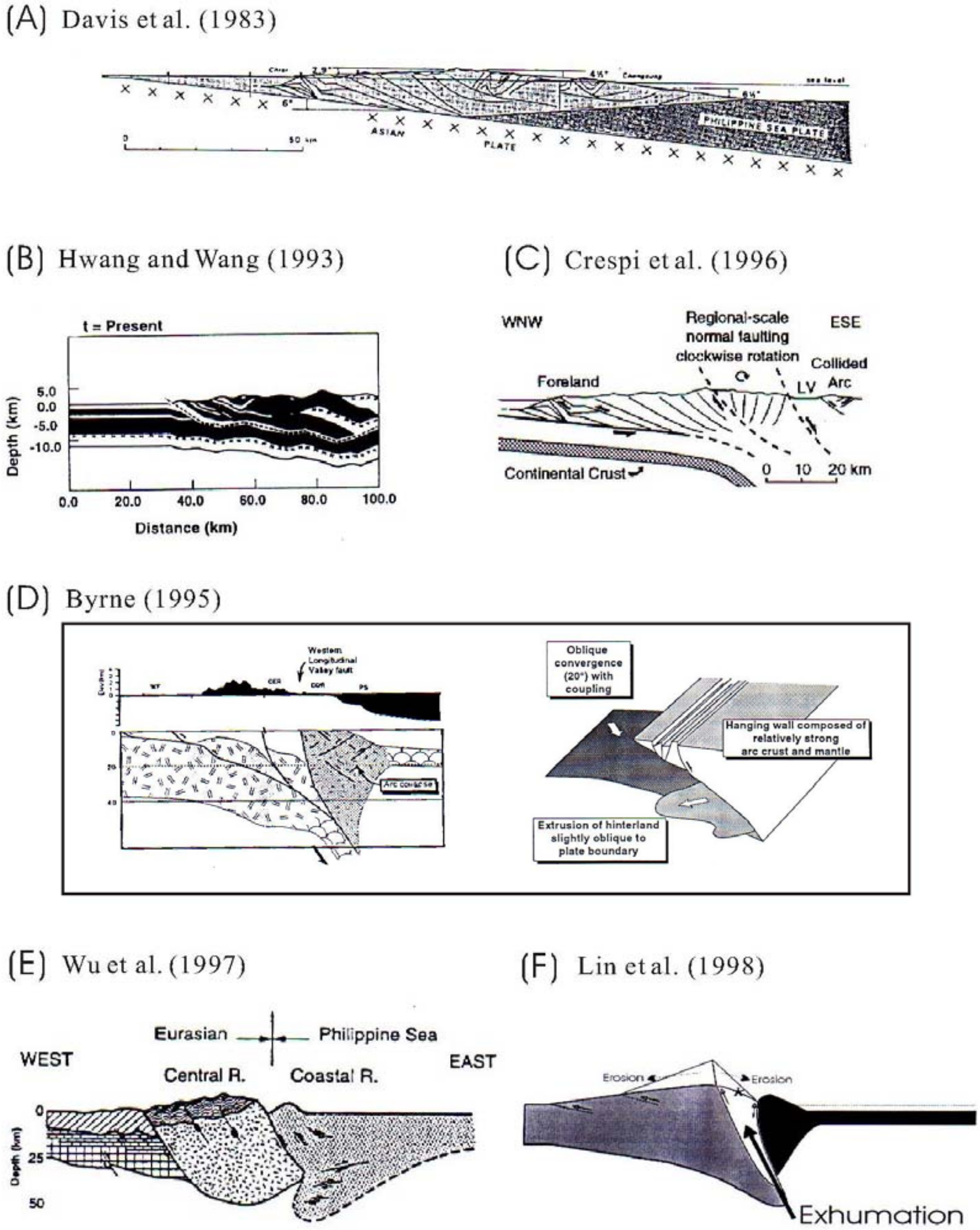

Fig. 7. Models for the regional tectonics of the Taiwan mountain belts.

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The Coastal Range (海岸山脈)

The Coastal Range comprises rocks of the pre-collisional Luzon arc-trench system and overlying syn-collisional orogenic sediments. The Coastal Range was first mapped by Hsu (1956), who described its main stratigraphic sequences. The basement of the sequence is constituted of a volcanic arc-derived Tuluanshan Formation (都巒山層) associated with a Miocene igneous complex (Ho, 1969). Sporadic reefal coral limestones forms the topmost part of the Tuluanshan Formation (大港口層). The limestones formed at the Mio-Pliocene boundary, and it is overlain by a thick marine detrital sequence called the Takangkou Formation (Hsu, 1956). According to Teng and Chen (1988), the upper Miocene-lower Pliocene sediments are derived from the erosion of a volcanic arc and the material of the upper part of the sequence may have originated from continent of Taiwan. In ascending order, from late Miocene to Pleistocene, they are the Fanshuliao Formation (番薯寮層), the Lichi Melange (利吉層), the Paliwan Foramtion (八里灣層), and the Pinanshan Conglomerate (卑南山礫岩). A hypothesized stratigraphic relationship between the individual formations is illustrated in the figure below.

The presence of a significant amount of fine-grained continent-derived detritus in the lower Pliocene Fanshulio deposits shows that the arc moved sufficiently close to receive sediment from the continent. The influx of voluminous coarse-grained continent-derived sediments in the Upper Pliocene Paliwan Formation demonstrates that the continental margin was rapidly uplifted to from high mountains (Teng and Chen, 1988).
The upward increase in grain size, metamorphic grade and accumulation rate of the continent-derived Luzon arc toward the continent but also the progressive uplift and unroofing of the collisional orogen.

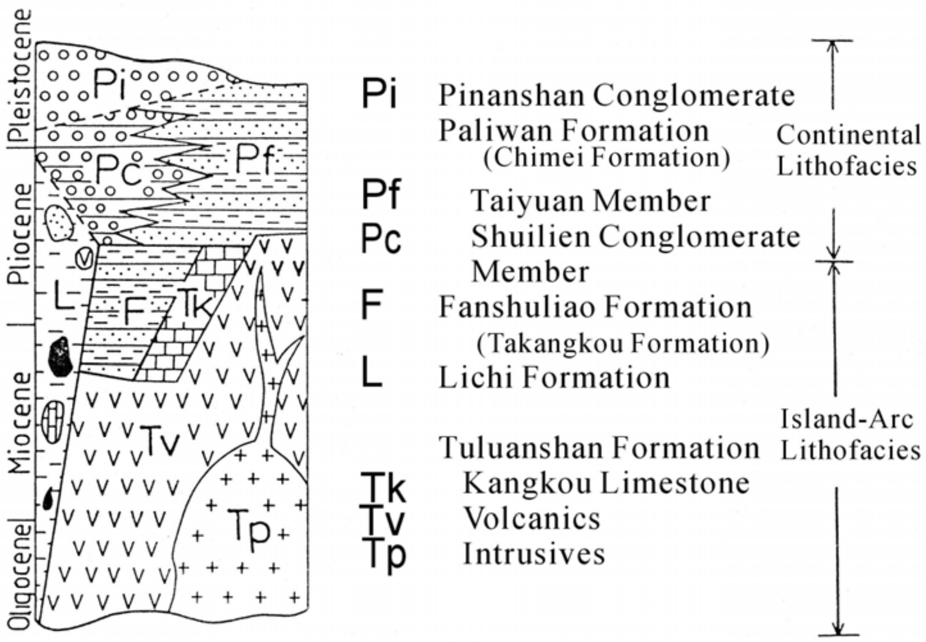
The Lichi Formation (or Lichi Mélange) forms a narrow belt along the western part of the southern Coastal Range, extending from Taitung northward for a distance of about 70 kilometers with widths ranging from 1-3 km. This formation is largely a chaotic mélange although locally it contains stratified mudstone and pebbly mudstone interlayers. However, most of the mélange is composed of disturbed dark gray, scaly mudstone matrix, peppered with abundant exotic blocks and fragments. The most striking components of the exotic blocks are mafic and ultramfic rocks, which are collectively called “East Taiwan Ophiolite” (Liou and Ernst, 1979). Teng and Lo (1985) proposed that the Lichi deposits were accumulated continually from the late Oligocene to early Pliocene.

Stratigraphic relationship between different formations and terms used in the literature. Note the equivalence between:

***Paliwan Fm* (八里灣) = *Chimei Fm* (奇美)**

***Fanshuliao Fm* (番薯寮) = *Takangkou Fm* (大港口)**

***Tuluanshan Fm* (都巒山) *includes the Kangkou Limestone* (港口)**



Stratigraphic scheme and petrotectonic associations of the Coastal Range (after Teng, 1988).

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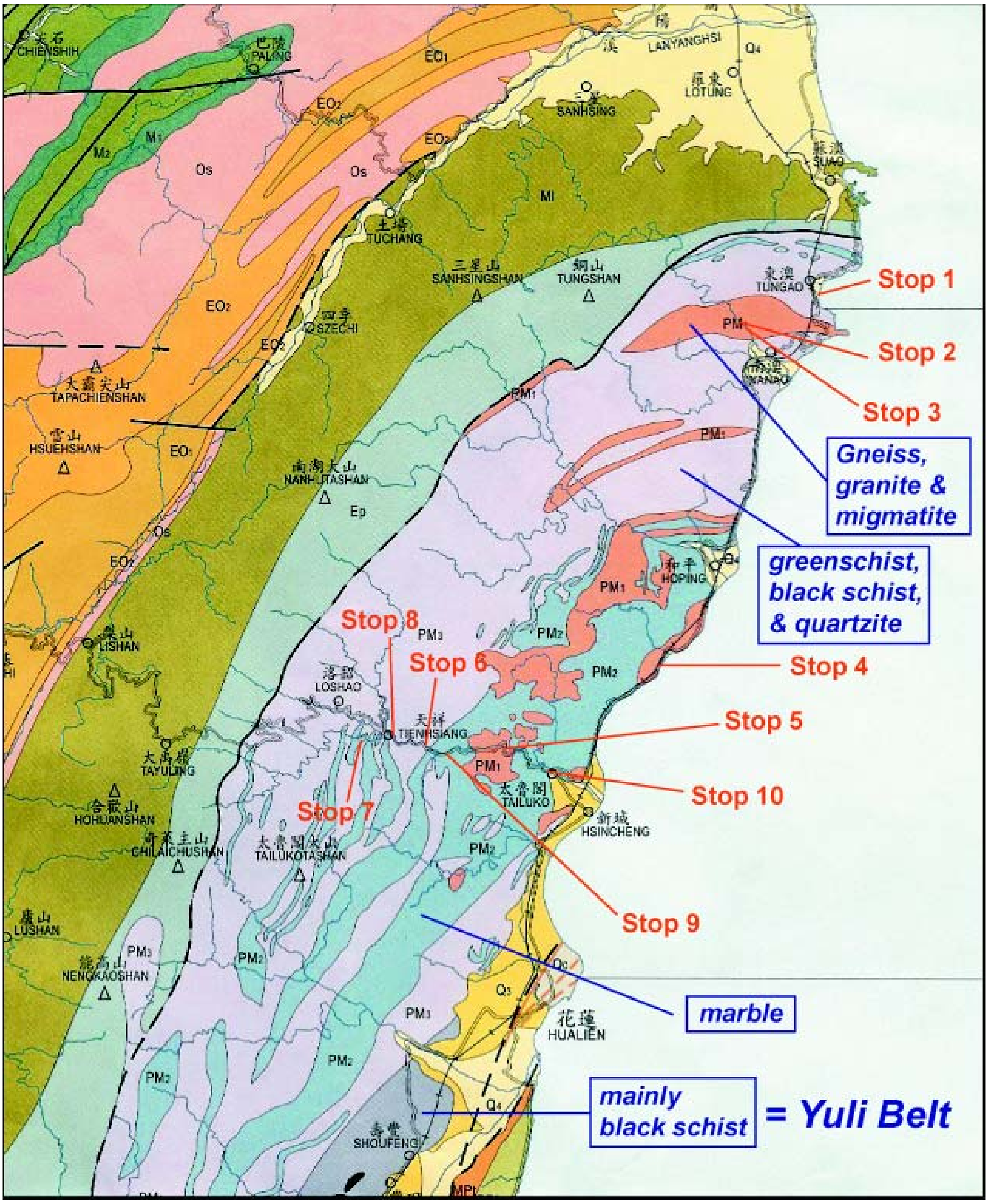
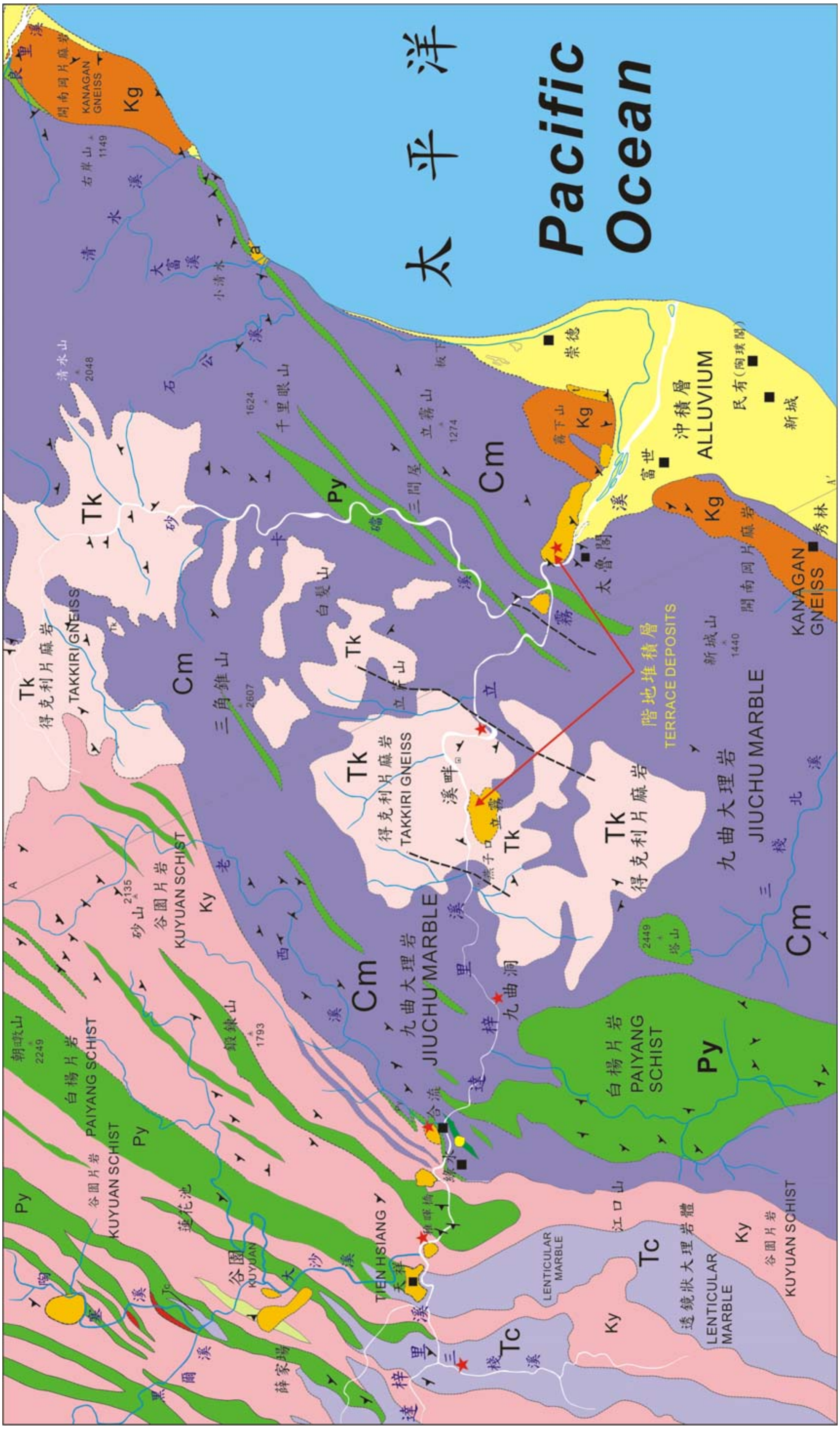
Brief description of stops

Field trip to the Tananao Complex





太平洋
Pacific Ocean
沖積層
ALLUVIUM
階地堆積層
TERRACE DEPOSITS
Kg
閣南岡片麻岩
KANAGAN GNEISS
Tk
得克利片麻岩
TAKKIRI GNEISS
Cm
九曲大理岩
JIUCHU MARBLE
Py
白楊片岩
PAIYANG SCHIST
Ky
谷園片岩
KUYUAN SCHIST
Tc
透鏡狀大理岩體
LENTICULAR MARBLE
TIEN HSIANG
天祥
九曲洞
三角錐山
2607
千里眼山
1624
立霧山
1274
清水山
2048
太魯閣
新城
秀林
崇德
富世
民有(陶璞閣)

Day 1 (Wednesday, 22 March, 2006)

Stop 1. Fenniaolin Amphibolite (Tungao). Continuous outcrops of amphibolite, black schist, greenschist, and serpentinite are well exposed along the coast SSE of Tungao.

Stop 2. Nanao Beixi (northern tributary of the Nanao River) **–** Yuantoushan granite and amphibolite enclaves.

Protoliths of UHP eclogites and country gneisses (similar to Dabieshan) in the future?

Stop 3. Nanao Beixi (northern tributary of the Nanao River) **–** Yuantoushan (源頭山) granite, amphibolite enclaves and mafic dikes.

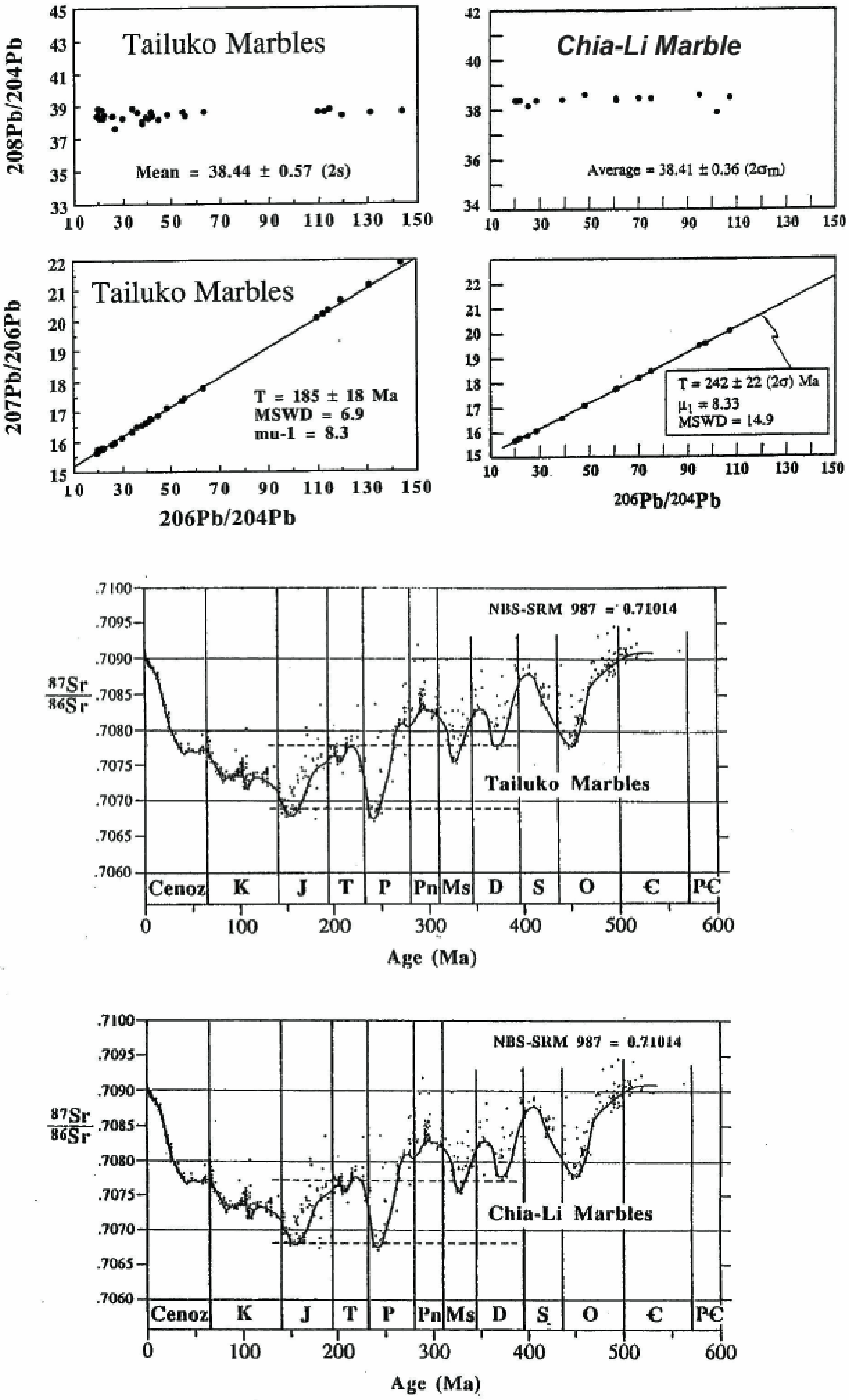
Stop 4. Hojen (or Heren) – the Kainangang (Kanagan；開南岡) Gneiss

Day 2 (Thursday, 23 March, 2006)

Stop 5. Central Cross-Island Highway – Chipan (Xiban, 溪畔) Granite at Baishachiao. A contact zone between granite and marble is observed.

Stop 6. Central Cross-Island Highway, at Tsimu (Cimu) Bridge – marble, greenschist (chlorite schist), blackschist (graphite schist) and quartzite are observed. The marble was first dated at ca. 165 Ma using the Pb-Pb isochron method (Jahn, 1988, Nature, 332:429-432). This age was later updated to 180 Ma with supplementary data (Jahn and Cuvellier, 1994, Chem Geol, 115: 125-151). Sr isotope compositions suggest that the carbonate protolith (limestone) was deposited at about 250 Ma.

Pb-Pb isochron ages and Sr isotope compositions of the Tailuko and Chia-Li marbles (Jahn, 1988; Jahn et al., 1984, 1992).

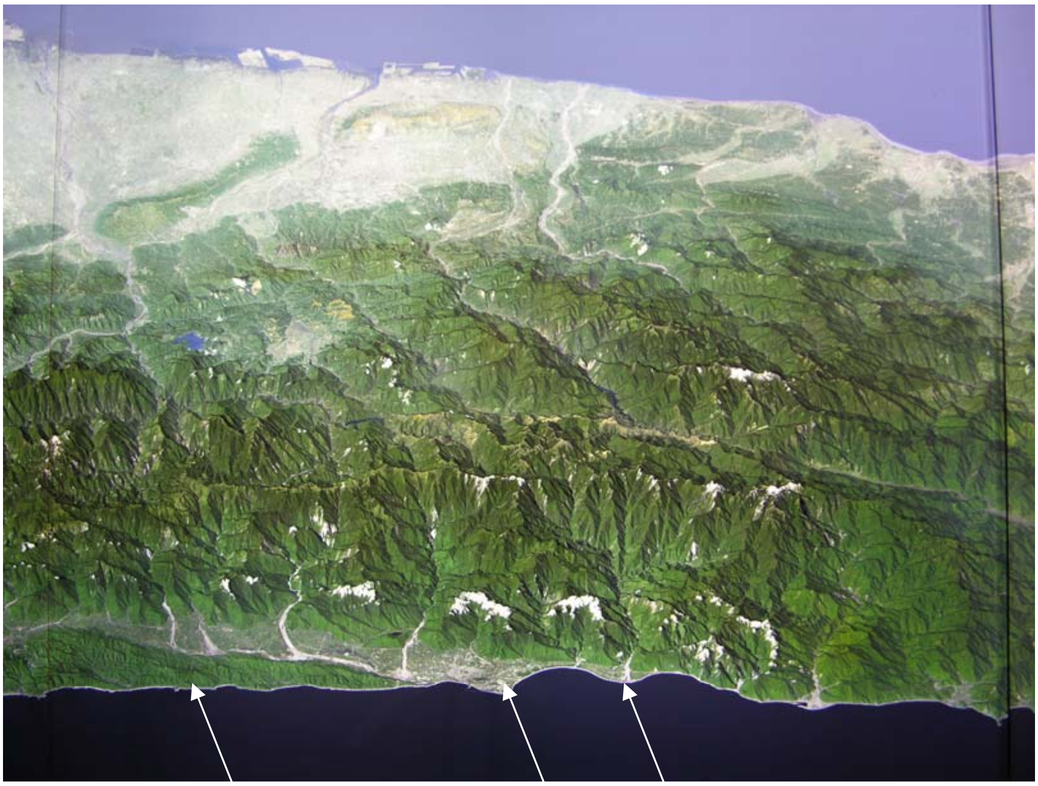


Stop 7. Baiyang Trail (白楊步道) cross-section, exposing marble, chlorite-schist, graphite-schist, quartz-mica-schist, and quartzite

Stop 8. Tianxiang (天祥) **–** complex metamorphic rock assemblage, including marble, greenschist, balckschist, chert, quartzite, etc.

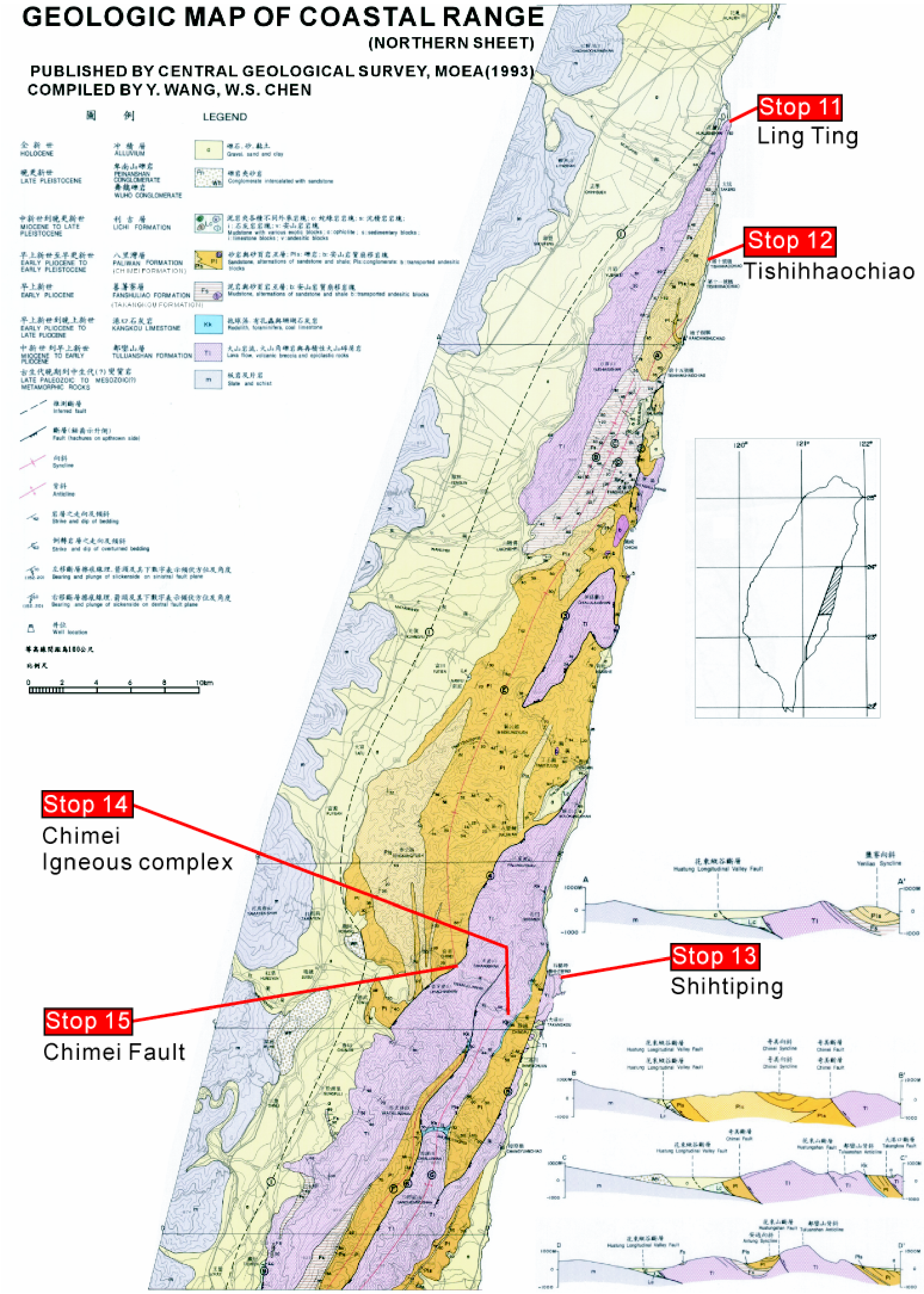
Stop 9. Jiuqu (Nine-turn) Tunnel (九曲洞) – A spectacular deep canyon in the Tailuko marble terrane.

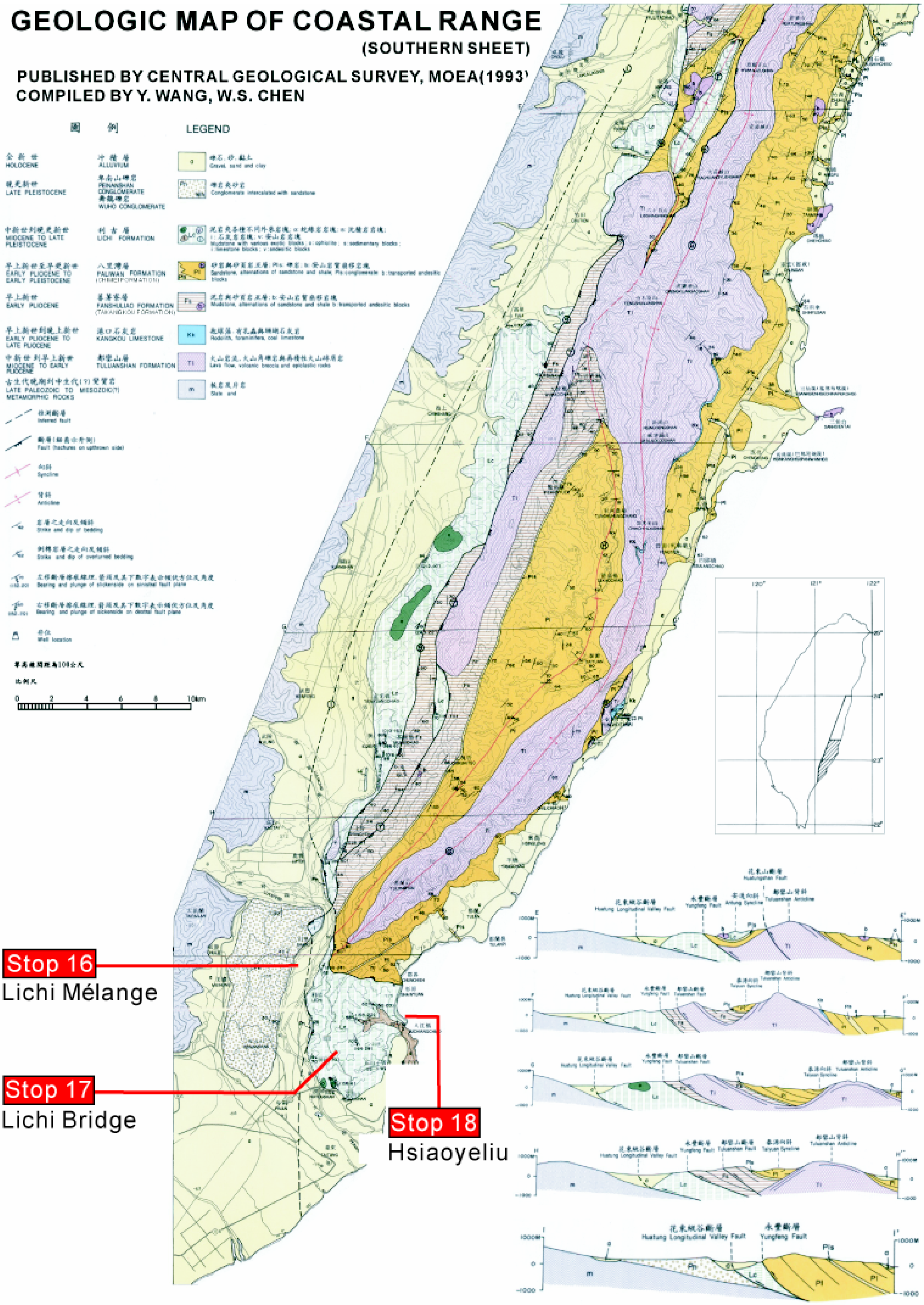
Stop 10. Tailuko National Park



海岸山脈　　　　　花蓮市　　立霧溪（太魯閣）

Field trip to the Coastal Range



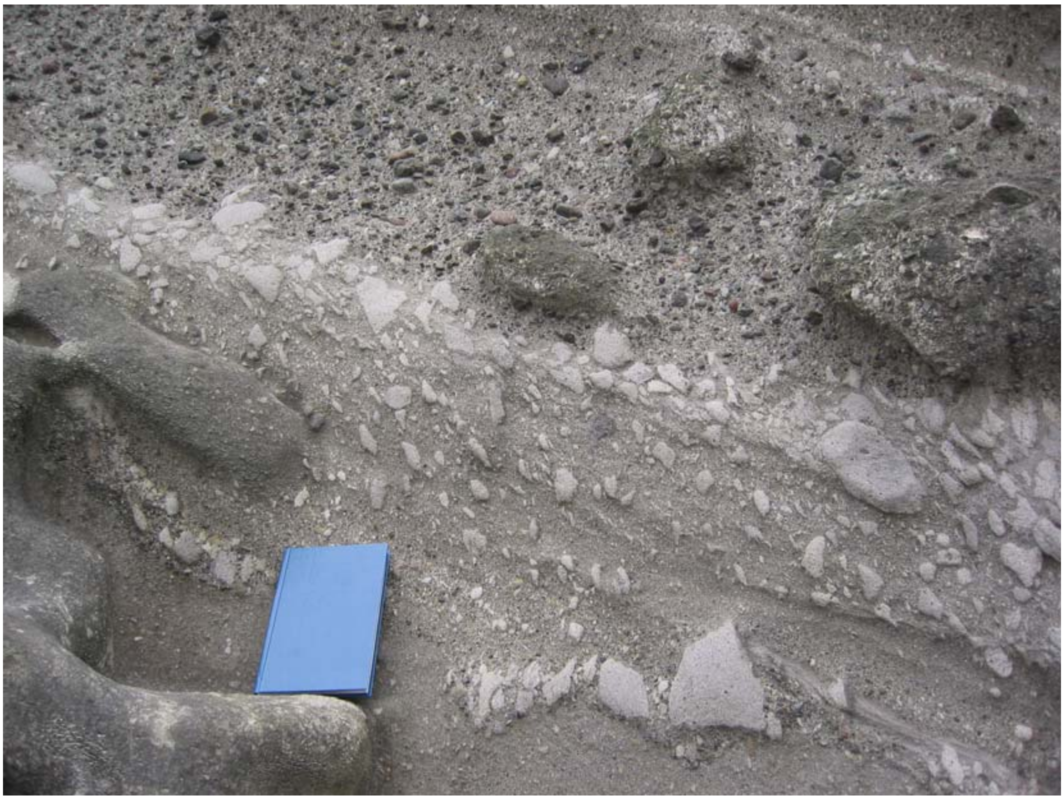

GEOLOGIC MAP OF COASTAL RANGE
(SOUTHERN SHEET)
PUBLISHED BY CENTRAL GEOLOGICAL SURVEY, MOEA(1993)
COMPILED BY Y. WANG, W.S. CHEN
LEGEND
Stop 16
Lichi Mélange
Stop 17
Lichi Bridge
Stop 18
Hsiaoyeliu

Day 3 (Friday, 24 March, 2006)

Stop 11. Lingting (嶺頂): northern tip of the Coastal Range showing continuous coastal exposure of the volcani-pyroclastic rocks of the Miocene Tuluanshan Formation.

Stop 12. Ganzishu (橄子樹 = No. 10 Bridge): turbidite of the Paliwan Formation. Thick-bedded conglomerate layers (belonging to the Pleistocene Shuilien Conglomerate) are well exposed along the river gorge wall.

Stop 13. Shihtiping (石梯坪): an uplifted marine terrace composed of pyroclastic flows, ignimbrite and volcanic breccias. It is capped with Holocene coral limestone. Also observed is white intermediate to acid tuff composed of welded volcanic glass shards and mafic minerals of pyroxene, hornblende, and opaque minerals.



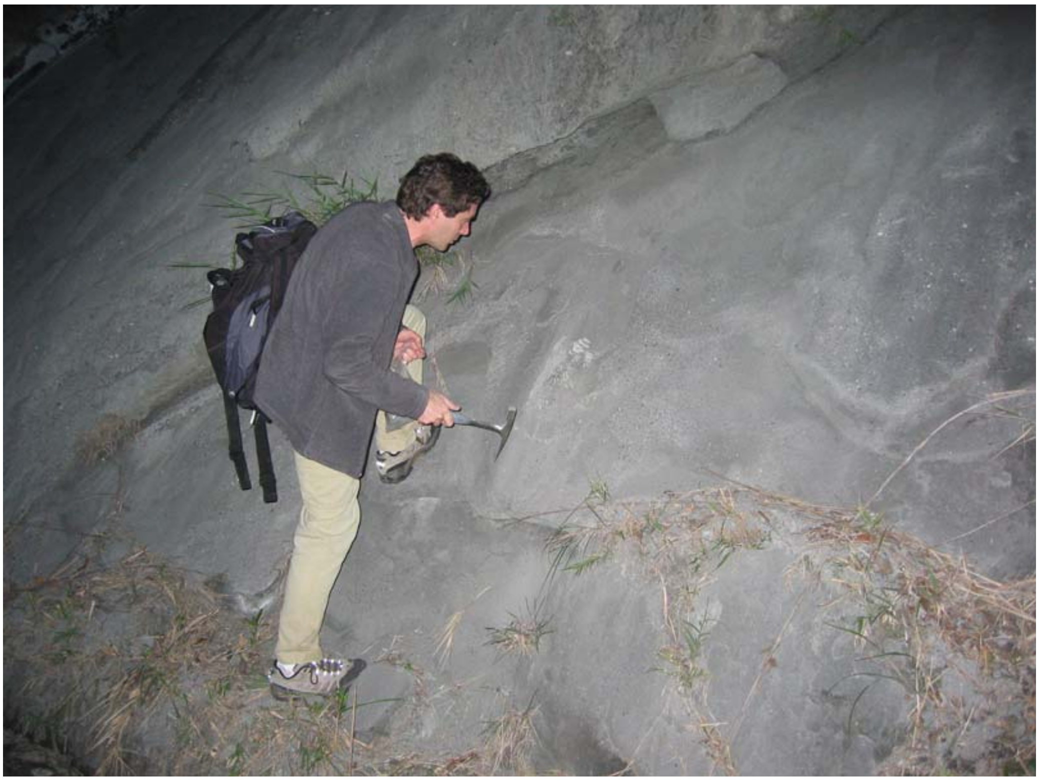
Stop 14. Takangkou to Juisui (Coastal Range Transect). Takangkou (Big Harbor, in Chinese): diabasic rocks of the early Miocene "Chimei Igneous Complex" can be observed on the roadside.

Andesite flow cut by the Shiukuluan River.

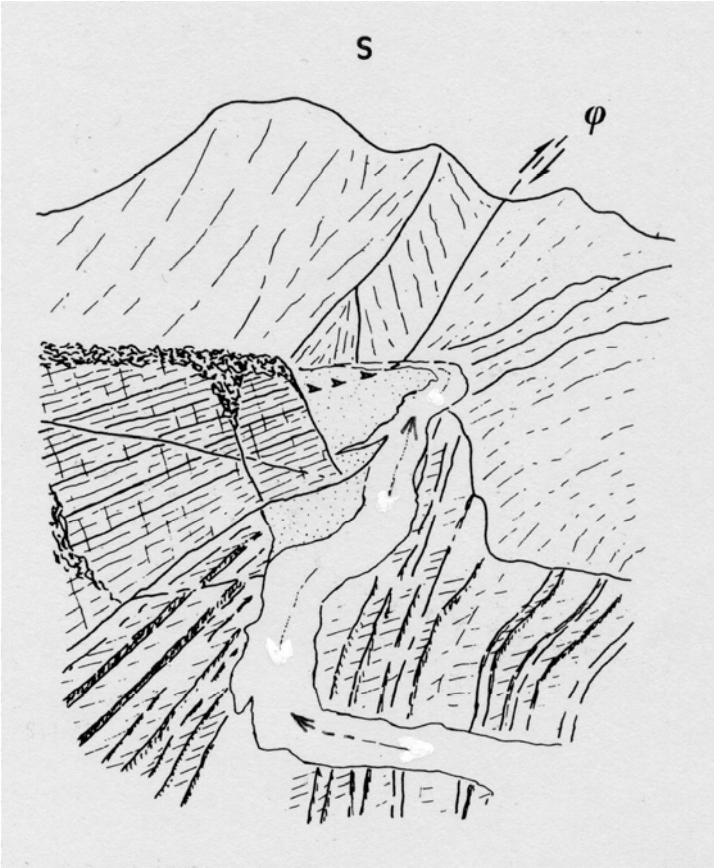
Chimei Village (奇美村): major tectonic contact between the pyroclastic rocks of the Miocene Tuluanshan Formation and the turbidite of the Pleistocene Paliwan Formation along the Shiukuluan River Bank. The former was ovrthrust onto the latter with vergence towards WNW. The shear zone with crenuation cleavages are well exhibited.

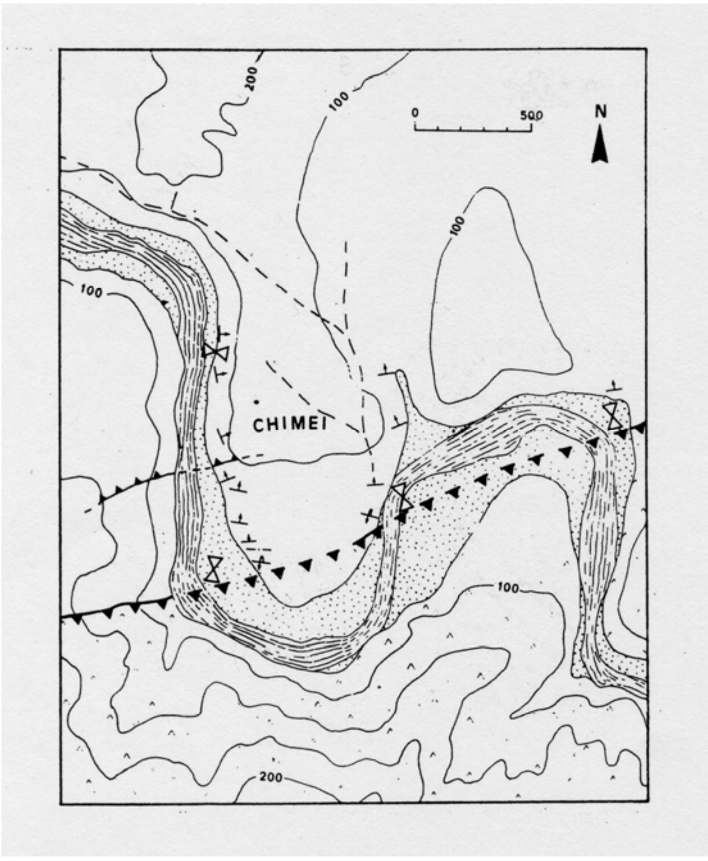
Contact between shale and pyroclastic deposits.

Shale of the Paliwan Formation



Stop 15. The Chimei Fault.





Day 4 (Saturday, 25 March, 2006)

Stop 16. The Lichi Melange.

The Lichi Melange is widely distributed in the southern part of the Coastal Range. It also extends northward along the western margin of the Coastal Range to Lehe (樂合), forming a narrow band of 1-3 km wide and 70 km long. The type locality if at Lichi Village near Taitung. The mélange is composed of thick mudstone, mixed with a variety of exotic blocks. Badland topography is the most characteristic of the Lichi Melange. According to the drilling data of the Chinese Petroleum Company, the thickness of the mélange is greater than 1 km (Meng et al., 1965). The exotic blocks are mostly ophiolitic fragments and sandstone. Other lithological varieties include greywacke, shale, limestone, conglomerate and andesitic agglomerate. The most distinguished exotic block is the so-called East Taiwan Ophiolite (ETO; Liou et al., 1977). The ETO comprises all the components for a typical ophiolite sequence – peridotite, gabbro, serpentinite, diabiasic dike, plagiogranite, basalt and red clay. Paleontological studies indicate that the mélange contains microfossils of ages ranging from Oligocene to Middle Pliocene (time span of ca. 30 Ma). Based on the youngest fossils, the deposition of the Melange is commonly assumed to begin in the Middle or Upper Pliocene (ca. 3 Ma).

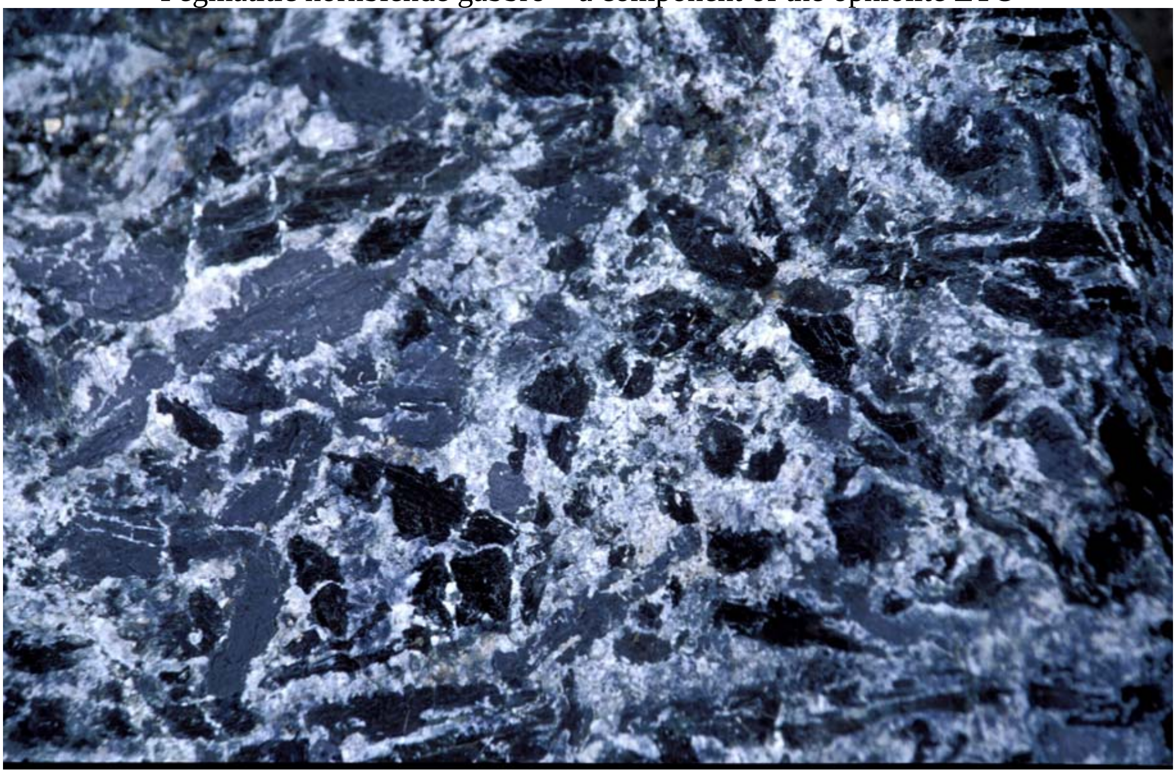
Lichi Melange at the type-locality of Lichi Village

Spectacular bad-land topography

Lichi Melange contains numerous exotic blocks (here, mainly sanstone). Locality: Yongfeng

Pillowed lava (occurrence at Jiawu Stream):

Pegmatitic hornblende gabbro – a component of the ophiolite ETO



Major rock types of the East Taiwan Ophiolite - pillow lava (glassy basalt), pegmatitic gabbro, serpentine, hornblendite, plagiograinte, and red clay.
Glassy basalt, hornblendite, gabbro, and plagiogranite.

Red clay from the Jiawunanxi (嘉武南溪)

Stop 17. Exotic Blocks near the Taitung Bridge (now called the Lichi Bridge).

Stop 18. Hsiaoyeliu (= Fugang Sandstone) - a huge exotic block (a few km long) of overturned Miocene sandstone enclosed in the Lichi Mélange. Sedimentary structures show rapid deposition and high energy shallow marine depositional environment.

Reverse bedding

Stop 19. Taimali (太麻里) – Impressive folding of lowly metamorphosed lithologies – including meta-sandstone, phyllite, and slate (called the Lushan Formation) in the southern end of the Central Range. The deposition age is Miocene.

Day 5 (Sunday, 26 March, 2006)

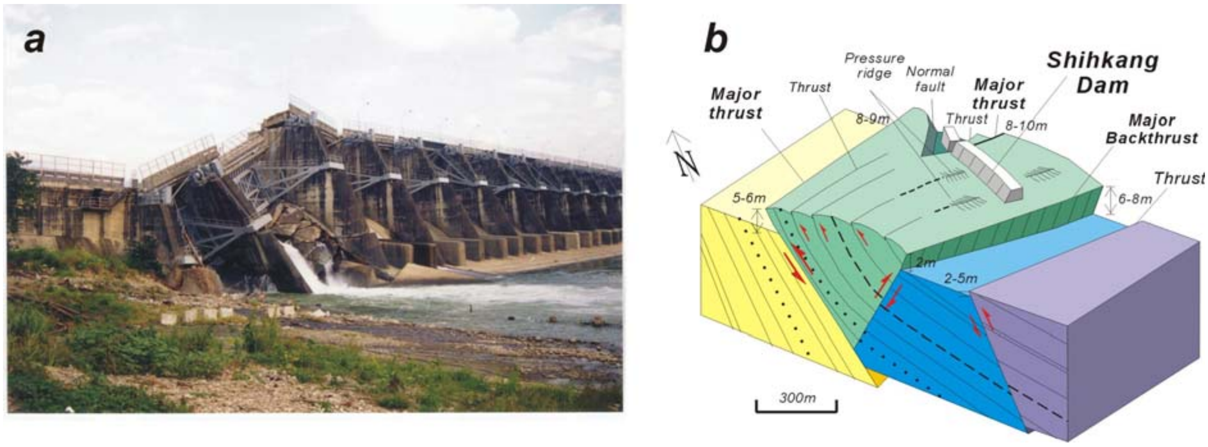
Stop 20. Visit to the Department of Earth Sciences, National Cheng Kung University.

Stop 21. Beifeng Bridge and Shigang Dam – sites of great damage caused by the Chi-Chi Earthquake **(集集大地震)** on 21 September, 1999.

A large earthquake (Richter scale $M_L = 7.3$) occurred in west-central Taiwan in Nantou County at 01:47 AM on September 21, 1999. This is the most devastating earthquake in the history of Taiwan. The epicenter was near the small town of Chichi (23.85°N, 120.82°E), and the focal depth is about 8 km. The focal mechanism of the mainshock indicates a thrust fault with a NNE trend. The rupture took place mainly along 80 km north-south stretch of **the Chelongpu Fault (車籠埔斷層).** The casualties include 2489 deaths, 50 missing, and 11465 injured. More than 10,000 houses and buildings destroyed. The total financial losss was estimated about 14 billions NT dollars. There has been a strong aftershock sequence. The Central Weather Bureau reported 5 events with magnitudes M6.0 or greater. There was a large aftershock (M6.8) that appears to be on a separate fault to the east. The large aftershock of September 26 (M6.8) caused deaths and damage in Meishan.

Stop 21a. Shihkang Dam (石岡壩)

In Shihkang, a system of multiple thrusts and a major backthrust slipped during the earthquake. First, to north of Shihkang in the Ta-Chia Chi, two thrust faults ruptured across the northern part of the Shihkang Dam. A major thrust, linked to the main thrust at the Pifeng Bridge to the west, exhibited a large vertical displacement of 8-10 m (according to the offset of the dam crest). The Shihkang Dam is located at the bottom of a triangular zone, of which two edges were formed by a major thrust and a backthrust. The thrust and the backthrust extend to the south of the Pifeng Bridge area and gradually increase in displacement on both sides of the Shihkang Dam. At least two major thrusts have been found to be closely associated with the destruction of the dam (Chen et al., 2000; Lee et al., 2001). The N-S trending main body of the dam was deformed to a gentle anticline. This N-S to NNW-SSE compression was also reflected by a series of pressure ridges at the foot of the dam.

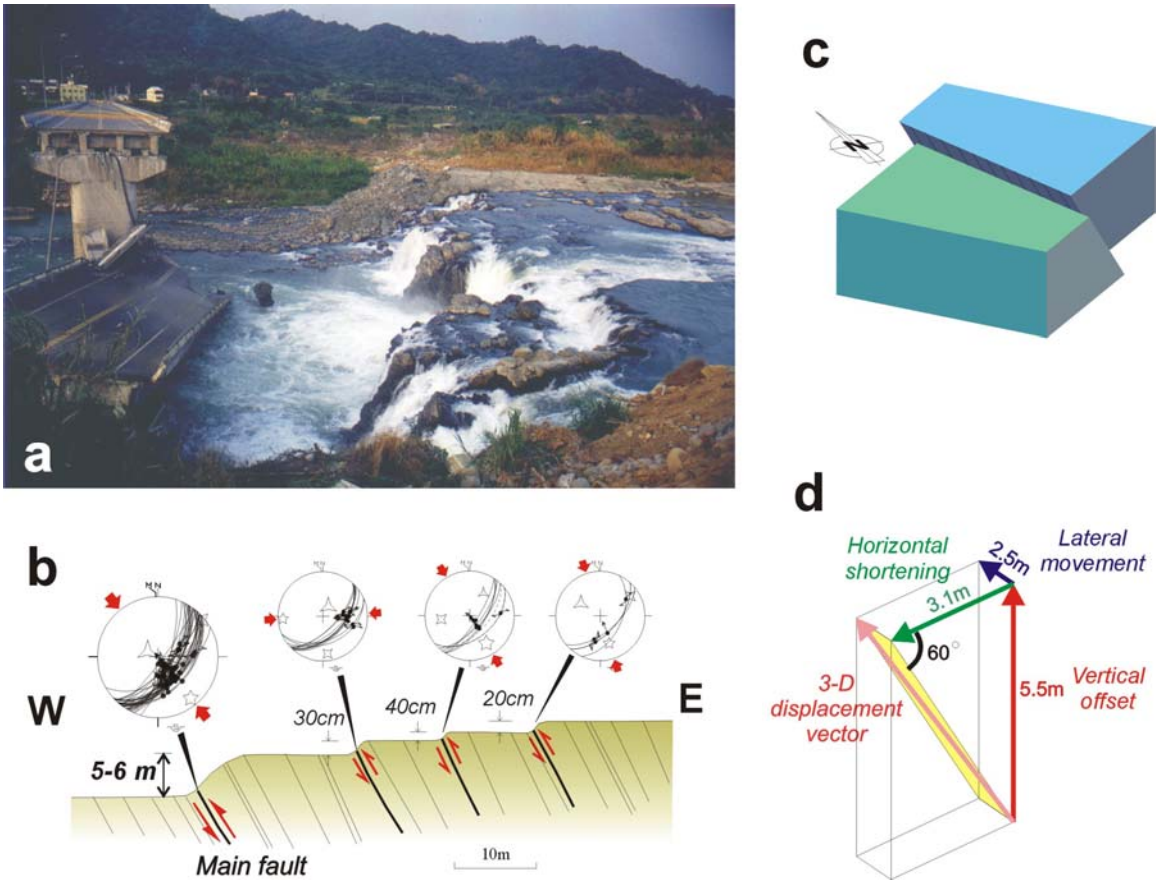


Complex deformation and fault system in the Shihkang Dam area. (a) Photograph of the Shihkang Dam showing the breaks of the dam body with a vertical offset of 8-10 meters. (b) A 3-D block-diagram of the deformation in the Shihkang Dam area. The Shihkang Dam is located on the pop-up fold lifted by thrust and backthrust. At least two thrusts situated on the northern end of the dam have broken the dam. The rest of the dam body has been folded and several different scales of pressure ridges can be observed along the foot of the dam.

Stop 21b. Pifeng Bridge (埤豐橋)

On the western side of the northern segment near the Pifeng Bridge, the surface rupture extended across the active channel of the Ta-Chia Chi (大甲溪) and formed a spectacular waterfall 5-6 m high. At least three other 20-40 cm high minor thrusts were also located in the hanging wall of the main surface rupture (i.e., the waterfall). These faults cut 50°-60°-dipping strata of the Chinshui Shale (錦水頁岩) parallel to the bedding or at a small angle of 10-20 degrees.

Slickenside lineations on the fault planes were observed on the exposed ruptures in the fine-grained sandstone bedrock of the Chinshui Shale. The fault striations revealed dip-slip movements with minor lateral slip for both the main fault and the minor faults. Stress tensor inversions indicate NW-SE directed compression on a NE-SW trending reverse fault dipping to the southeast. The stress tensor is generally consistent with the focal mechanism of the main shock of the earthquake (Chung and Shin, 1999; Ma et al., 1999; Kao and Chen, 2000). Note that it is in a good agreement with the focal solution of the northern sub-event of the main shock (Kao and Chen, 2000). However, a 15-20 degrees clockwise change in the trend of the maximum principal compressive stress direction occurs between the earthquake focus located 50 km to the south and at the Pifeng Bridge site. Slip on the main thrust can be illustrated by a 3-D displacement vector with a vertical offset of 3.5 m, a horizontal shortening of 2.0 m, and a small amount of left-lateral strike-slip of 0.6 m. The main fault in the Pifeng area strikes N40°E and dips to the east at about 60°; the hanging wall block of the fault moved in the direction of N320°E.



Kinematics analysis and reconstruction of the movement of the fault in the Pifeng bridge area along the Ta-Chia Chi, near Shihkang. A multi-fault system has been found on the riverbeds and clear striations have been observed on the fault planes and have been measured in order for the kinematics analysis. 3-D reconstruction of the displacement vectors shows that the main fault can be represented by a west-vergent reverse fault (strikes N30°E, dips 60° to SE) with a minor left-lateral strike-slip component.

End of the field excursion

Good bye
Au revoir
明年再見

(Guidebook prepared: 15 March 2006, Taipei)