Geol. Soc. Malaysia, Bulletin 6, July 1973; pp. 27–42.

The Manila Trench — West Taiwan Foldbelt: A Flipped Subduction Zone

RICHARD W. MURPHY[1]

Abstract: The Manila Trench—West Taiwan Foldbelt is an anomalous west-facing island arc segment of the western Pacific. It is postulated to be a young, east—dipping subduction zone which flipped in Pliocene time from a former west—dipping position on the east side of Luzon and Taiwan, where it probably formed a continuous subduction zone with the Ryukyu and Philippine Trenches.

The eastward dip of the Manila Trench is supported by the published work of Ludwig, Hays, and Ewing. Its continuation into western Taiwan is inferred from topographic alignments, published cross sections, and the probable eastward dip of the seismic focal plane. The hypothesis of flipping is introduced to explain the geologic characteristics of the structural belts of Taiwan and the apparent offset between the northern end of the Philippine Trench and the southern end of the Manila Trench. The time of flipping is inferred from tectonic events dated by surface geological means.

The northern termination of the subduction zone is a trench-to-trench transform between northernmost Taiwan and Yonaguni Island of the southwest Ryukyu Islands. The southern end is also a trench-to-trench transform expressed at the surface by left-lateral wrench faulting west of Atimonan, at the northern end of the Bondoc Peninsula.

The Central Taiwan Range is considered to be a fossil Upper Cretaceous subduction zone containing oceanic sediments of Late Paleozoic to Cretaceous? age. It is flanked on the west by a Paleogene continental rise flysch prism, deposited when subduction was dormant or had shifted to the east, and on the east by a Neogene andesitic island arc complex, which prior to flipping overlooked a west-dipping subduction zone on the Pacific side.

INTRODUCTION

The central western Pacific Ocean is dominated by a series of west-dipping subduction zones with accompanying island arcs which are convex toward the ocean. The only significant exception to this generalization between Halmahera and Kamchatka is the 900 km long segment between northeastern Taiwan and the northern end of the Philippine Trench (Fig. 1). In this segment the island arc features are straight or convex toward the west, and the associated trench lies on the western side of the island arc (Ludwig, *et al.*, 1967; Hayes and Ludwig, 1967; Ludwig, 1970; Biq, 1960; 1965).

The purpose of this paper is to document this reversal of subduction asymmetry and to relate it to the outcrop geology of Taiwan, the southwestern Ryukyu Islands, and Luzon. The thesis is developed that regional geology can be explained by the postulation of a Pliocene flip of a formerly west-dipping subduction zone located on the east side of Taiwan and Luzon and shift to its present position on the west side of the island arcs. A flip of a subduction zone (McKenzie 1969; Roeder *in* Dickinson, 1970) occurs when the sense of subduction reverses in a short period of time: i.e., a west-dipping subduction zone flips to an east dip.

The evidence in the Luzon part of the study area includes bathymetry, seismic reflection profiles, and seismic refraction profiles, whereas the evidence in the Taiwan-Ryukyu region is from seismicity and outcrop geology.

[1] Esso Exploration Inc., 170 Grange Road, Singapore 10.

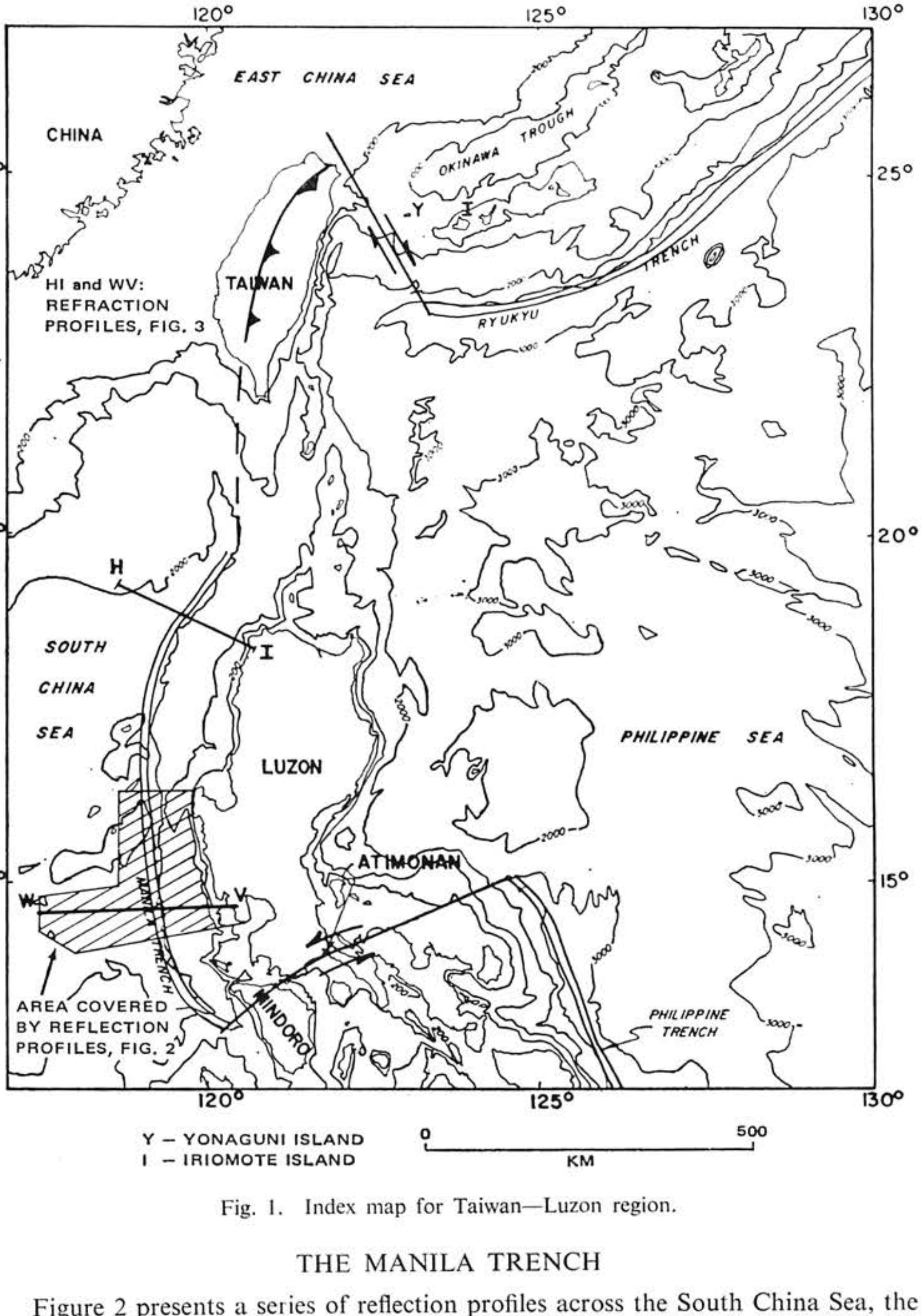

Fig. 1. Index map for Taiwan—Luzon region.

THE MANILA TRENCH

Figure 2 presents a series of reflection profiles across the South China Sea, the Manila Trench, a bordering ridge, the West Luzon Trough and the upper continental slope of West Luzon (Ludwig, *et al.*, 1967). The profiles show the anticipated sequence

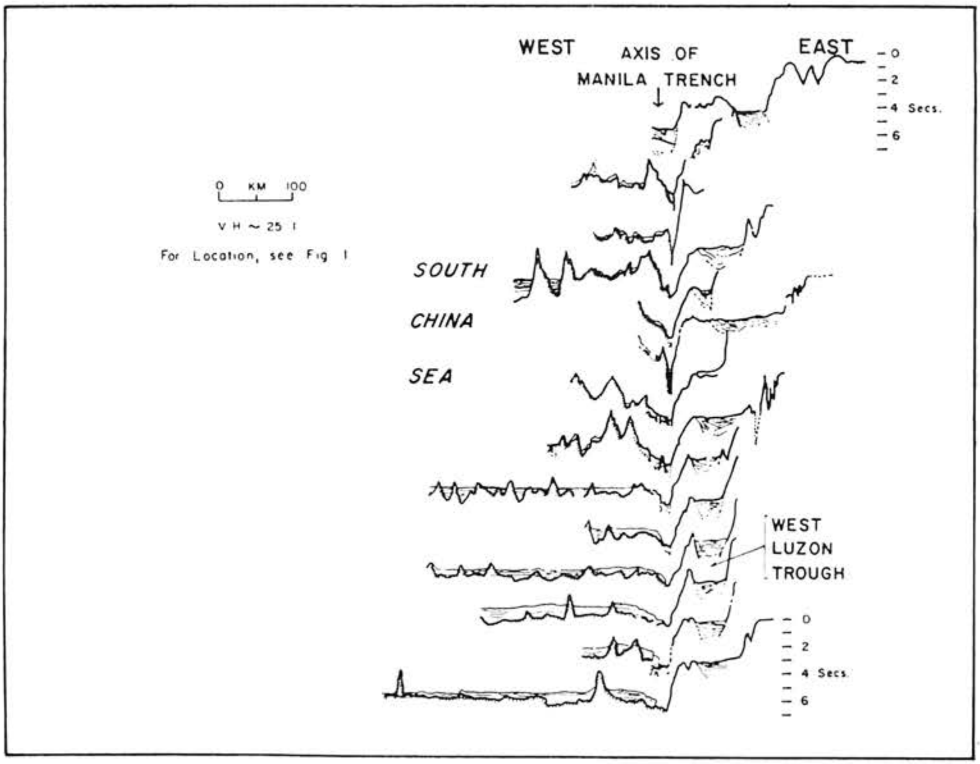

Fig. 2. Seismic reflection profiles across the Manila Trench (Ludwig, Hayes, and Ewing, 1967)

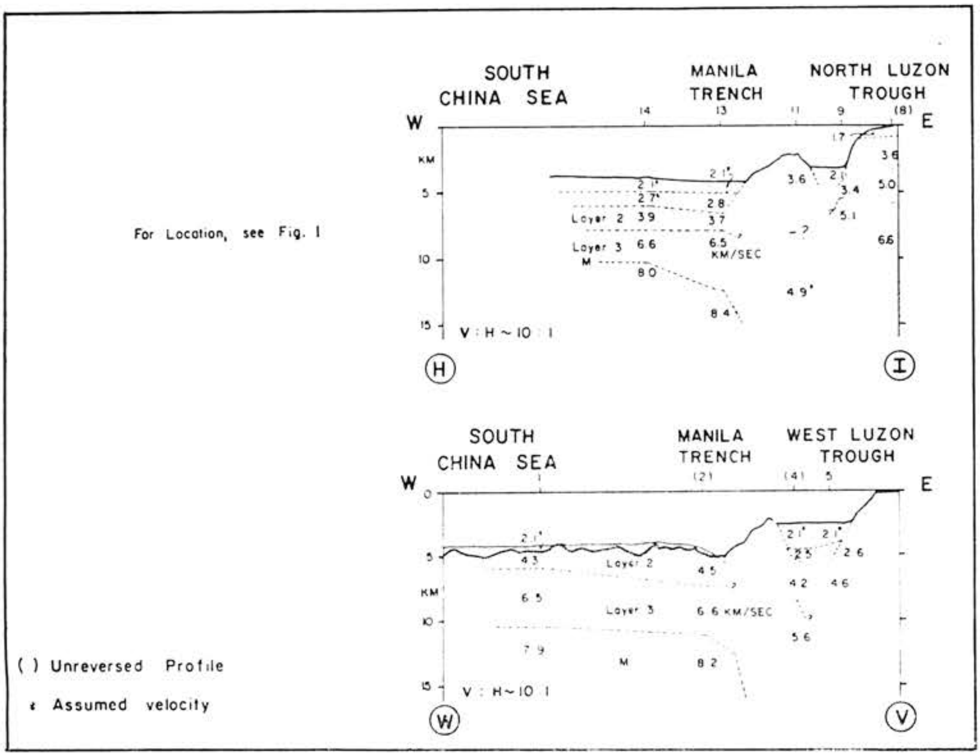

Fig. 3. Seismic refraction profiles across Manila Trench (Ludwig, 1970).

for an east-dipping subduction zone. The asymmetric trench profile is flanked on the west by relatively old oceanic crust of the South China Sea. The irregular oceanic topography has been partially buried by sedimentary thickness up to 1,200 m. At the outer trench wall the South China Sea crust and its sedimentary mantle are faulted down toward the trench in a series of step-like normal faults.

The relatively steep inner wall of the trench is acoustic basement and forms part of a submarine ridge which flanks the long graben-like West Luzon Trough. This profile is virtually identical with scores of others which have been published from other trenches of the western Pacific except that the polarity is reversed.

The seismic refraction profiles shown in Figure 3 (Ludwig, 1970), are likewise compatible with an east-dipping subduction zone. Normal oceanic crust of the South China Sea is seen to terminate at the Manila Trench in the exact manner of mirror-image subduction zones bordering the east sides of the Kurile, Japan, Ryukyu, Mariana, and Philippine Islands.

Evidence from Seismicity

Modern studies of seismicity of the Philippine Islands between northern Luzon and Mindanao have not yet appeared in print, but observation of published seismic maps (Baranzangi and Dorman, 1969; ESSA, 1970) reveals for northern Luzon

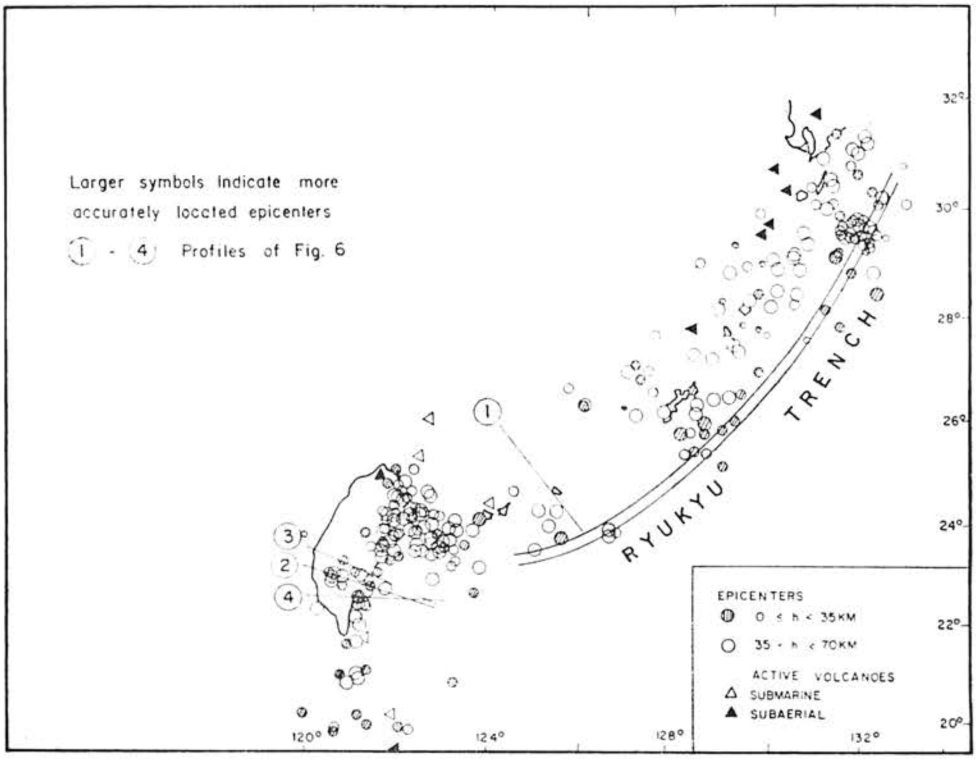

Fig. 4. Map of shallow-focus earthquakes in the vicinity of Taiwan and the Ryukyu Trench (Katsumata and Sykes, 1969).

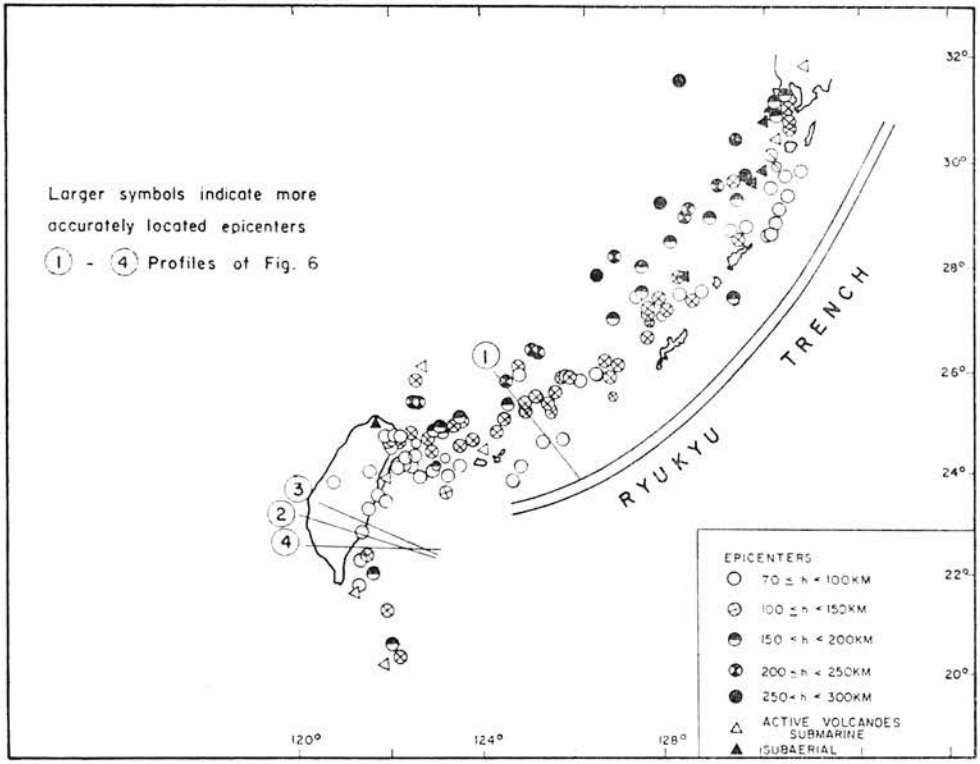

Fig. 5. Map of intermediate-focus, earthquakes in the vicinity of Taiwan and the Ryukyu trench (Katsumata and Sykes, 1969).

a diffuse pattern of shallow and intermediate-depth earthquakes. A dipping plane or zone of focal depths is not apparent.

Katsumata and Sykes (1969) have published their study of earthquakes in the Ryukyu-Taiwan region for the period 1934–1967. The epicenter maps of Figures 4 and 5 and the vertical sections 1 and 2 in Figure 6 show their results.

No earthquakes deeper than 300 km were found, and the intermediate-depth earthquakes are nearly all confined to the Ryukyus. Taiwan was practically free from seismicity of focal depth greater than 100 km during the study period.

Vertical profile 1 (Figure 6) shows that the earthquake hypocenters beneath the southern Ryukyu Islands fall within a west-dipping Benioff zone. A focal mechanism study shows overthrusting toward the ocean, which is expected at shallow depths in a subduction zone. No such pattern is discernible in profile 2 across southern Taiwan. Furthermore, a focal mechanism study (Number 11 of Katsumata and Sykes) indicates left-lateral wrench faulting.

Profiles 3 and 4, from an earlier study by Lee (1962), also indicate that seismicity beneath Taiwan is shallow and diffuse. Lee interpreted the data to show an east-dipping Benioff zone, but the scatter is large.

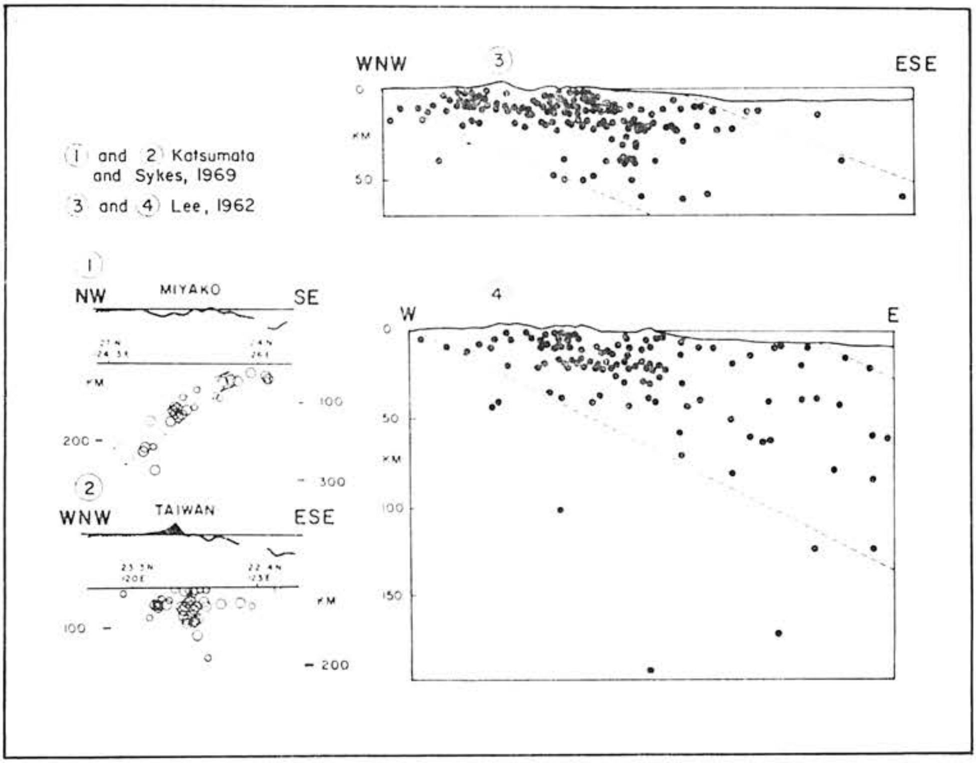

Fig. 6. Profiles of earthquake hypocenters across Ryukyu trench and Taiwan. Profiles 1 and 2 from Katsumata and Sykes (1969), 3 and 4 from Lee (1962). See figures 4 and 5 for location of profiles.

Evidence from Outcrop Geology

Taiwan

Taiwan is composed of a metamorphic core surrounded by thrust-faulted Tertiary sedimentary rocks (Figures 7 and 8). The dominant thrusting direction is westward and is expressed in the West Taiwan Foldbelt, where calculations from fold dimensions and thrustfault repetition yield a figure of at least 80 km westward transport.

A geologic cross section from the China mainland across Taiwan to the Philippine Sea (Figure 8) reveals the following belts of contrasting stratigraphic and structural character.

1. *China mainland.* South China contains a Caledonian crystalline core overlain by deformed postorogenic sedimentary rocks and severely affected by a Cretaceous magmatic episode. Extensive sheets of thick Cretaceous rhyolitic volcanics, deposited in a continental environment, are associated with widespread stocks of comagmatic granites. Post-Cretaceous rocks are in general thin and nonmarine. In the Penghu Islands, drilling has revealed thin Neogene marine sequences overlying Mesozoic basement.

2. *West Taiwan Foldbelt.* Continental crust of the China mainland underlies the coastal plain of western Taiwan, but the foothill zone comprises multiple thrust sheets

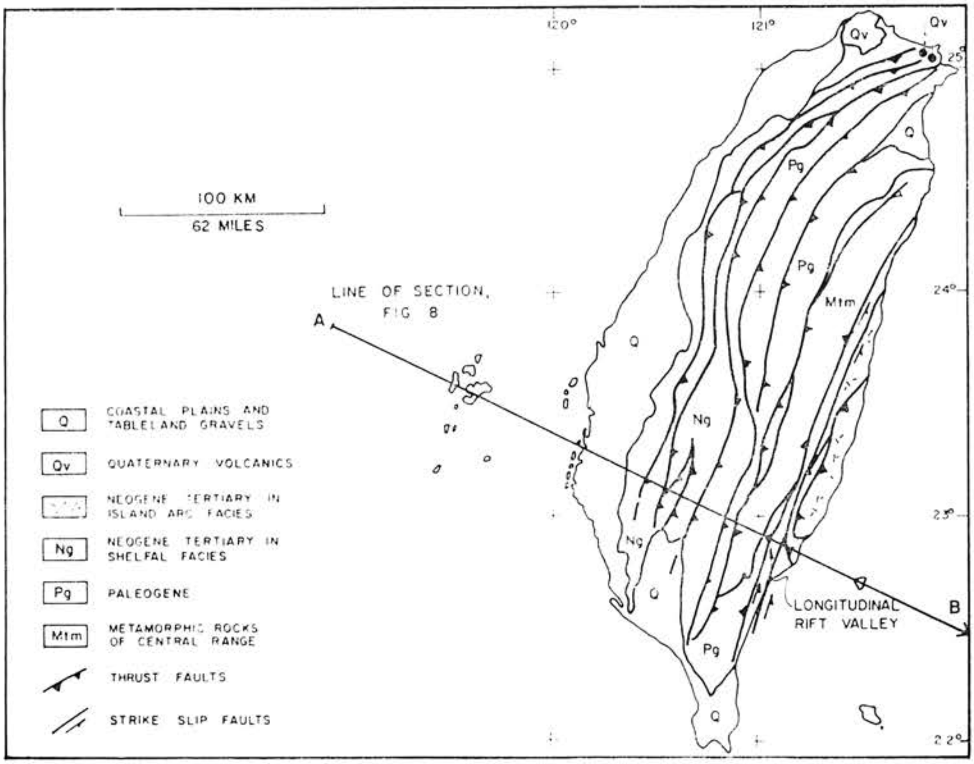

Fig. 7. Geologic Map of Taiwan (adapted from Ho, 1967).

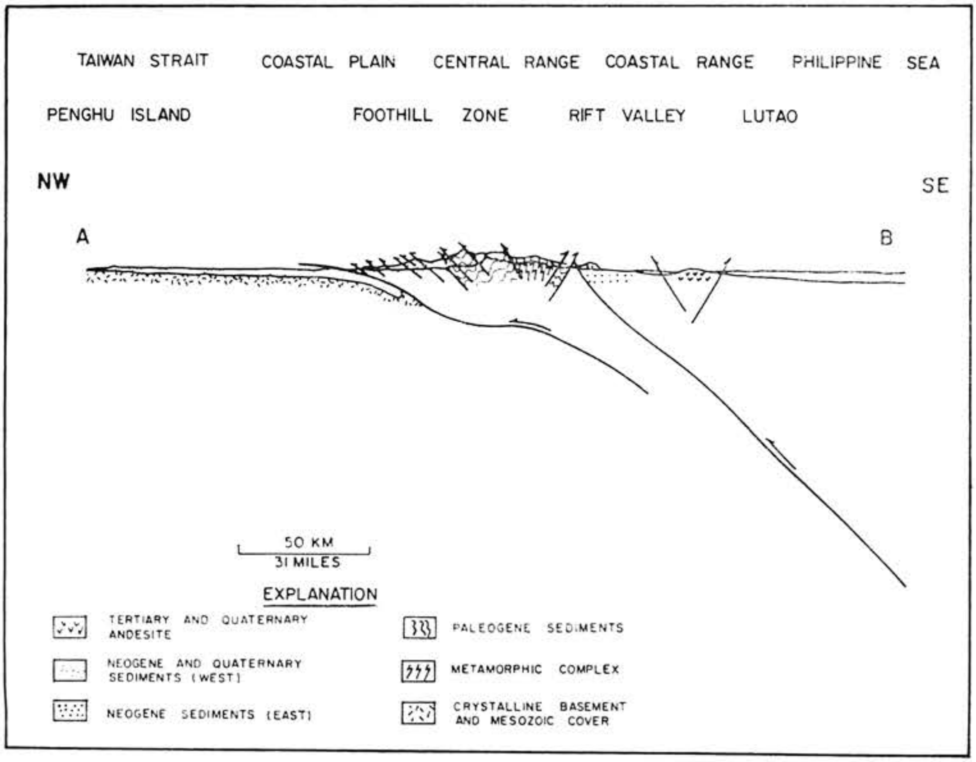

Fig. 8. Schematic Structural profile from the China mainland across Taiwan to the Philippine Sea (Biq, 1960). See Figure 7 for line of sections.

of Neogene terrigenous sedimentary rocks. The Neogene is essentially nonvolcanic and was derived from a continental provenance located to the west and possibly north (Schreiber, 1965). Parts of the thrust belt contain detached thrust masses interpreted as gravity slides by Ho (1967), Meng (1967a, 1967b) and Biq (1966, 1969).

The Neogene sedimentary rocks attain thicknesses of up to 5,000 m without a significant internal unconformity between Lower Miocene and Lower Pliocene beds. Three transgressions and three regressions are recorded, and transitional members between all facies are preserved. An unconformity occurs at the top of the Lower Pliocene Chinshui Shale, above which are found the increasingly coarse molasse-type sediments of the Cholan and Toukoshan Formations. Pleistocene beds are involved in the thrusting.

3. *Western Central Ranges*: A thick sequence of Paleogene flysch is thrust-faulted over the eastern edge of the Neogene outcrop belt. The flysch is predominantly dark gray argillite and slate, but also contains quartzitic and conglomeratic sandstone, limestone lenses, and minor submarine volcanics. Planktonic and benthonic foraminifera have proven a Latest Cretaceous to Oligocene (Aquitanian?) age for the unit. The sandstone content decreases from west to east, suggesting a western source.

The Paleogene is thrust-faulted over the western foothills and is in turn itself overridden by the metamorphic rocks of the Eastern Central Range.

4. *Eastern Central Range*: Schists, gneisses, crystalline limestones, and various igneous intrusions form the central core of Taiwan. Fusilinids from the limestone prove that at least part of the sequence is Permian in age. A paired metamorphic belt has been identified (Yen, 1963) with a high-temperature assemblage in the west and a low-temperature, high-pressure blueschist assemblage in the east. The blueschists record a fossil subduction zone with the upper, high temperature, plate in the west and the lower, high pressure, plate in the east.

The age of the rocks involved and the time of metamorphism are as yet unresolved. There are only three published radiometric age determinations from the zone (Yen and Rosenblum, 1964). Of the three determinations, all K/A, one is considered unreliable and the other two suggest two times of quartz diorite intrusion: 86 ± 5 MY and 33 ± 2 MY. The age of this belt will be discussed further below.

5. *Rift Valley*: The longitudinal rift valley (Figure 7) is bordered on the west by upthrust metamorphic rocks of the Eastern Central Range together with slivers of Paleogene flysch. Lying to the east are the Neogene volcanogenic sedimentary rocks of the Eastern Coastal Range. Both borders are long, straight faults along which an earlier thrusting phase has been replaced by recent left-lateral strike-slip faulting (Ho, 1967; Hsu, 1956).

6. *Coastal Range*: A thick, chaotic series of Lower Miocene to Pliocene andesitic volcanogenic rocks in island arc facies form the easternmost structural unit of Taiwan. Westward-directed thrusts and olistostromes of Pliocene and Early Pleistocene age are described by Biq (1965).

7. *Philippine Sea*: A narrow eastern Taiwan shelf drops off quickly to normal oceanic crust of the Philippine Sea (Murauchi, *et al.*, 1968). There is no trench at this latitude, but a chain of modern volcanoes extends northward from northern Luzon at least to the latitude of Lutao, off southeastern Taiwan.

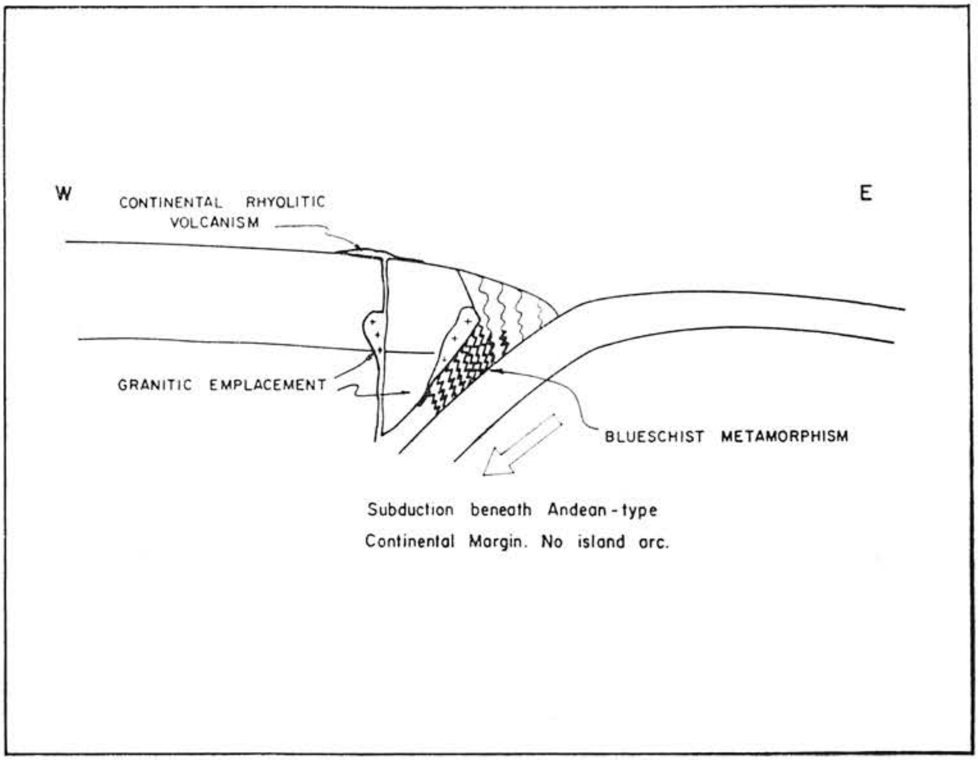

Fig. 9. Evolution of Taiwan, Late Cretaceous

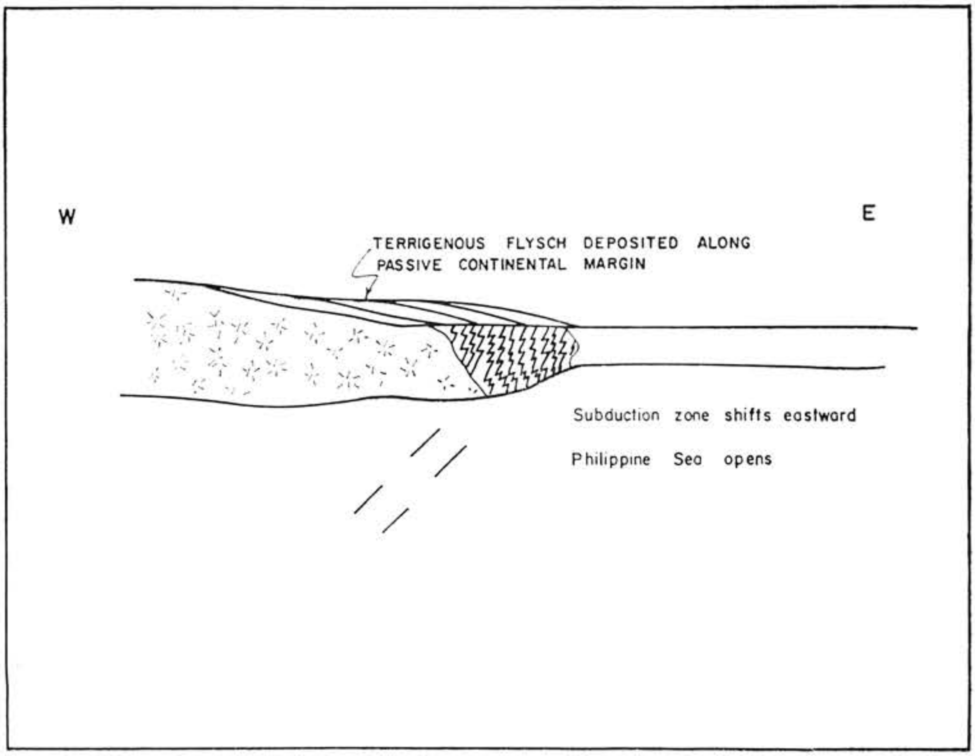

Fig. 10. Evolution of Taiwan, Paleogene.

Evolution of Taiwan

A tentative reconstruction of the evolution of Taiwan is presented in Figures 9–13.

1. *Late Cretaceous*: An Andean-type subduction zone is believed to have been operating at the eastern margin of the Asian continent in Late Cretaceous time. Rhyolitic volcanism and granitic emplacement within the continent accompanied subduction at the continental edge. Blueschist metamorphism took place at depth within the trench.

The evidence for the age of subduction is not conclusive, nor is it all presented in this paper. Analogy with better-documented contemporaneous subduction zones further north in Japan has been employed. The 86 MY radiometric age date is thought to be most representative of time of intrusion into the upper, high temperature plate of the paired metamorphic belt. The Permian limestone masses in the upper plate may have been oceanic islands which descended partway into the trench and were subsequently exhumed during inversion.

2. *Paleogene*: During the Paleogene (probably commencing in latest Cretaceous time) subduction at the eastern border of the continent ceased. The subduction zone presumably shifted to the east in front of an eastward-migrating island arc-marginal basin system. The mechanism involved may have interarc spıeading in the sense of

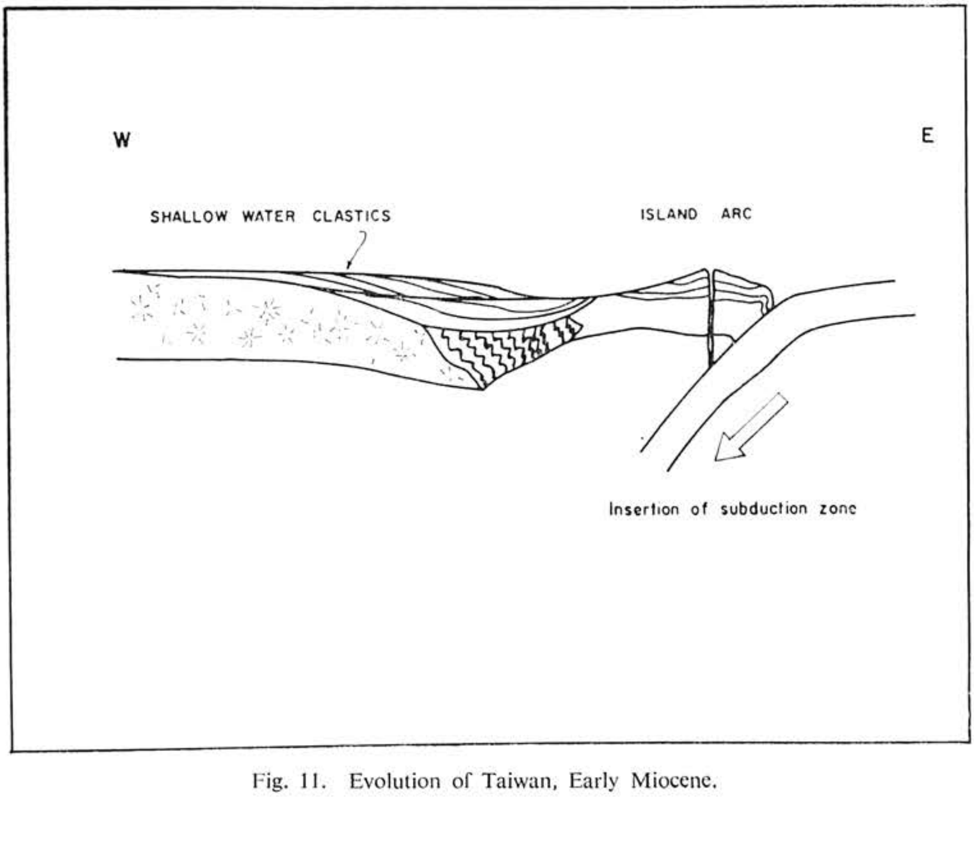

Fig. 11. Evolution of Taiwan, Early Miocene.

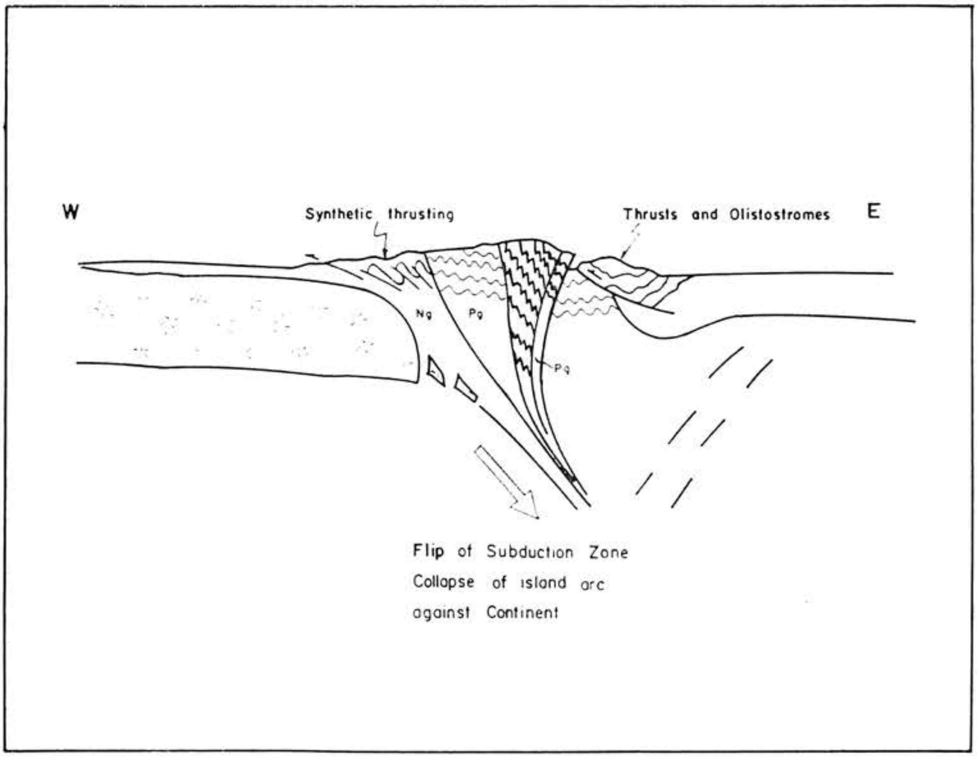

Fig. 12. Evolution of Taiwan, Middle Pliocene

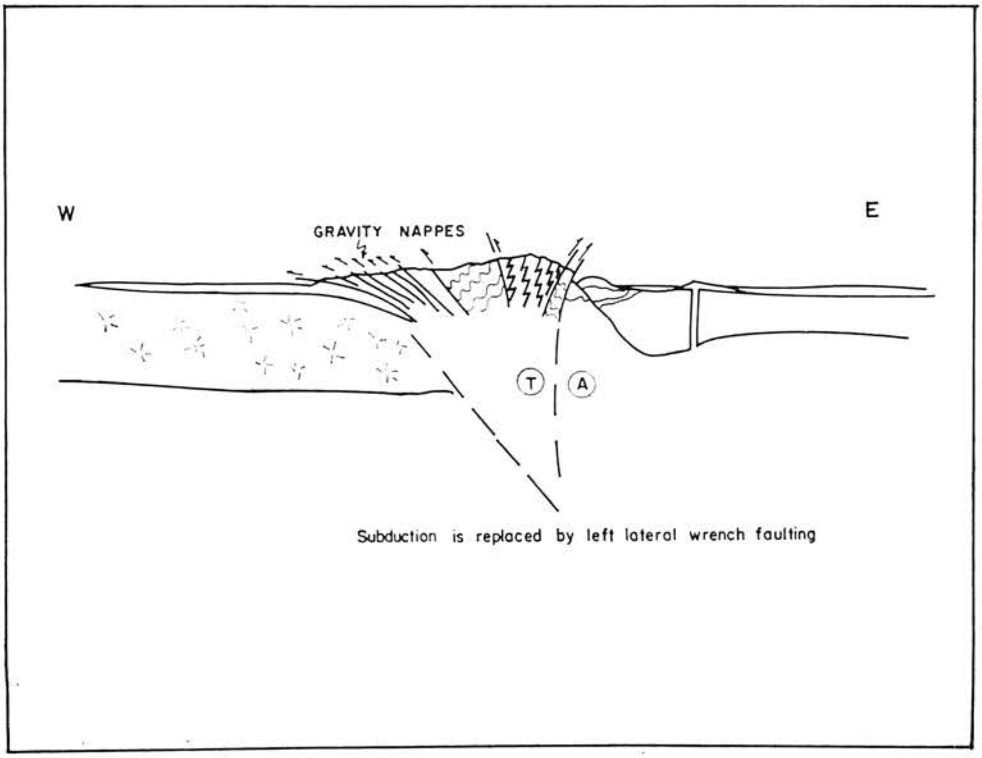

Fig. 13. Evolution of Taiwan, Recent.

Karig (1971) or asymmetric spreading behind an island arc (Temple and Nelson, in press). The Philippine Sea probably opened at this time behind the island arc.

The continental margin became a passive one with prisms of terrigenous flysch clinoforming out into the deep water of the newly-formed Philippine Sea. The fossil subduction zone became buried by flysch.

3. *Early Miocene*: A new pattern of subduction broke through in Early Miocene time, severely altering the entire paleogeography of Southeast Asia. In the Taiwan-Phillipine region, the new pattern was dominated by a west-dipping subduction zone located just east of the Asian mainland (Jahn, 1972). In contrast to the Upper Cretaceous subduction zone, an island arc was coupled with the new trench. The record of this island arc is now found in the andesitic volcanic and pyroclastic rocks of the Coastal Range of Taiwan.

Simultaneous with renewed subduction, a clastic wedge spread eastward from the Asian continent into the shallow water of the newly-formed marginal sea.

Subduction probably continued at a slow rate from Early Miocene until Pliocene time. The subduction zone was nearly stationary, because a wide marginal basin was not opened up between the island arc and the continent. Movements on the shelf were minimal, except for slow subsidence, permitting an accumulation of 5,000 m of shallow water sediments without a significant internal unconformity.

4. *Middle Pliocene*: Commencing in Middle Pliocene time, which is marked on Taiwan by the unconformity at the top of the Chinshui Shale, subduction "flipped" to the west side of Taiwan. Continuing through the Pliocene and culminating within Pleistocene time, thrusting toward the continent piled up the great thrust sheets of the Central Ranges and initiated the downslope sliding of gravity nappes in the western foothills. Thrusting toward the continent was "synthetic" to the sense of subduction (Roeder, D.H., "Subduction and Orogeny", in preparation) in that near-surface compression was parallel to and in the same direction as subduction. The rear flank of the thrust belt is marked by upthrusts which were antithetic to the sense of subduction.

At the same time the old island arc of Neogene age collapsed against the Central Range, obliterating traces of the narrow marginal sea. Landward thrusting and olistostrome slumping brought the island arc facies into contact with the metamorphics of the central Taiwan core.

Only a limited amount of subduction of a continental crust under the oceanic upper plate was possible. Most of the compression was taken up by thrusting. The present high altitude of the core of Taiwan (4,000 m) may be a crustal block forced upwards because it could not be subducted.

5. *Recent*: Compressional deformation has essentially ceased on Taiwan (Biq, 1971) and relief is being sought by horizontal movement between blocks. The left-lateral wrench faulting along the Eastern Longitudinal Valley is also thought to be coupled in some manner not yet understood with the end of compressional deformation on Taiwan.

Terminations of the Trench-Foldbelt

If the West Taiwan Foldbelt and the Manila Trench do indeed represent a flipped subduction zone which was formerly continuous with the Ryukyu Trench and the

Philippine Trench, then there might be some surface evidence of horizontal movements at their northern and southern ends. The apparent offsets (Figure 1) are about 300 km right laterally between Taiwan and the southern Ryukyus and about 500 km left laterally between the Manila Trench and the Philippine Trench.

Evidence supporting right lateral offset between Taiwan and the southern Ryukyus is provided by the Yaeyama sandstone outcrops on the islands of Yonaguni and Iriomote in the Yaeyama Retto of the southern Ryukyus (Fig. 1). The sandstone, which is up to 1000 m thick, is lithologically identical with Miocene sandstones exposed in northwestern Taiwan. Its age has been given as probably Lower Miocene (Burdigalian) (Hanazawa, 1936) based on *Operculina* and *Astriclypeus*. There is no apparent source for the quartzose sandstone of the Yaeyama Formation. The southern Ryukyus are separated from the shelf of the East China Sea by the Okinawa Trough, with water depths of over 2000 m. The Yaeyama Formation on Yonaguni lies 120 km east of equivalent sandstone outcrops of Taiwan and the same beds on Iriomote are separated from Taiwan by 200 km. Allowing for tectonic transport of the Miocene formations on Taiwan during thrusting, there still seems to be about 100 km offset between the Lower Miocene outcrop belts of Taiwan and the southern Ryukyus. The time of right-lateral movement can only be given as post-Early Miocene. It is suggested here that the offset occurred as a consequence of the flip of the subduction zone.

Figure 1 also shows apparent offset of 500 km between the northern end of the Philippine Trench and the southern end of the Manila Trench, as expressed by bathymetric contours. A line connecting these points passes through the center of a broad zone in which several apparent left lateral offsets occur in the Philippine geology. The most obvious is the great westward bend of the island of Luzon at 14° north latitude. The bend is expressed as an *en echelon* pattern of uplifted deformed belts: Albay, Bondoc, and the Sierra Madre. Just west of Atimonan (14°N, 121° 55′ E) is a six-kilometer left-lateral offset mapped on air photos by S.L. Rieb in 1964 (Visayan Exploration Co., unpublished map). The piercing points (in the sense of Crowell, 1962) are Oligocene and Early Miocene in age, but Pliocene beds abut against the surface trace of the fault and seem to be involved.

None of the apparent horizontal movements is conclusive proof of strike slip faulting or of a flip of the nearby subduction zone. It is not even necessary that a flipped subduction zone be expressed by surface wrenching. Nevertheless, these additional pieces of information fit nicely with the hypothesis of flipping.

Possible Cause of Flipping

In Figure 14 a highly speculative suggestion is made that the Pliocene flip of the subduction zone discussed in this paper may be correlated with two other contemporaneous crustal events. A southeastward shift of the Ryukyu Trench and opening of the Sulu Sea in a northeastward direction may have occurred at the same time. As a relief from the space problem thereby createa, the sense of subduction flipped from west-dipping to east-dipping, the surface trace of the zone shifted from the east to the west sides of Luzon, and the old oceanic crust of the South China Sea began to be consumed in the new trench. The West Taiwan Foldbelt is in this view simply a compressional wedge piled up on continental crust and is the northern analog of crustal consumption in the Manila Trench.

The Ryukyu Islands in their present position are thought to be a Pliocene to Recent feature, which would explain their lack of deep focus earthquakes. The East

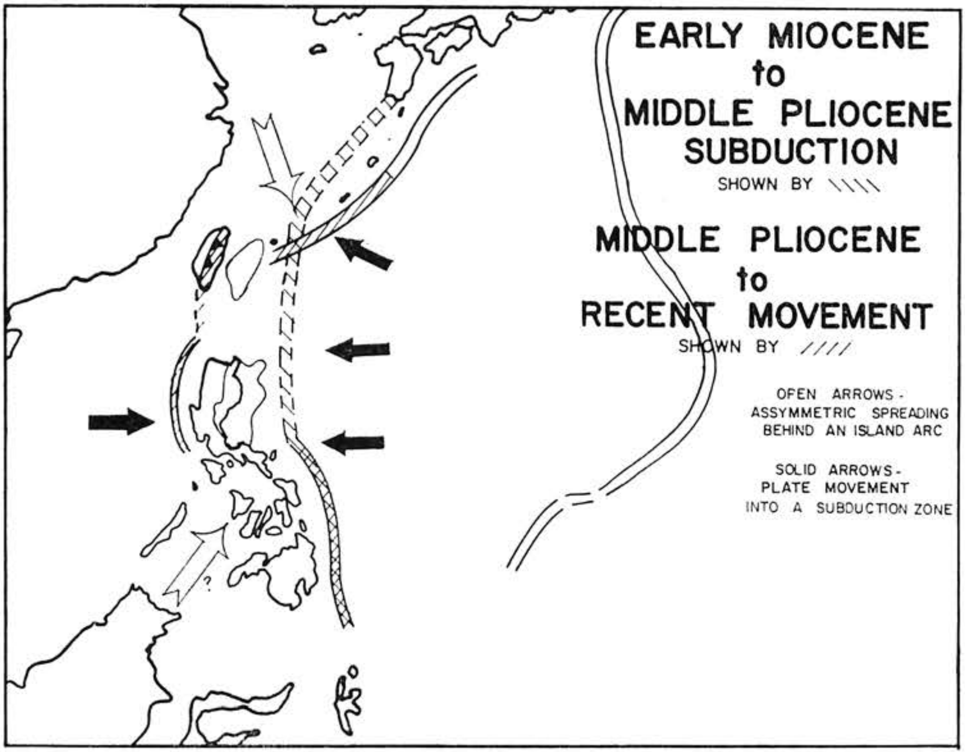

Fig. 14. Map suggesting flip and shift of the central portion of the Ryukyu—Philippine trench.

Taiwan Rift is a left-lateral wrench in some way tied to the termination of compression in the West Taiwan Foldbelt. The Palawan-Busuanga-Cuyo-Western Mindoro block is a nematath which has been brought northeastward into contact with previously existing island arc elements of the central Philippines.

ACKNOWLEDGEMENTS

I would like to thank Esso Exploration Inc. for permission to publish this paper and Esso Production Research Co. for permission to draw upon unpublished reports. Thanks also go to my Esso colleagues in Singapore whose many suggestions clarified the thought and expression considerably. Special thanks are owing to D.H. Roeder for critical reading of the manuscript and to Dennis Taylor for the suggestion that the present elevation of Taiwan may be due to the indigestibility of continental crust in the subduction zone.

REFERENCES

ANONYMOUS, 1970. World Seismicity 1961–1969: ESSA (map).

BARAZANGI, M., and DORMAN, J., 1969. World seismicity maps compiled from ESSA, Coast and Geodetic Survey, epicenter data, 1961–1967: Seismol. Soc. America Bull., v. 59, no. 1, p. 369–380.

BIQ, C.C., 1960. Circumpacific tectonics in Taiwan: Intern. Geol. Congr., XXI Session, Norden, Pt. XVIII, p. 203–214.

———, 1965. The East Taiwan Rift: Petroleum Geology Taiwan, no. 4, p. 93–106.

———, 1966. Tectonic styles and structural levels in Taiwan: Geol. Soc. China, Proc., no. 9, p. 3–9.

———, 1969. Role of gravitational gliding in Taiwan tectogenesis: Geol. Survey Taiwan Bull., no. 20, p. 1–39.

———, 1971. Some aspects of post-orogenic block tectonics in Taiwan: Recent crustal movements, Royal Soc. New Zealand Bull., no. 9, p. 19–24.

Crowell, J.C., 1962. Displacement along the San Andreas fault, California: Geol. Soc. America Spec. Paper 71, 61 p.

DICKINSON, W.R., 1970. The new global tectonics: Geotimes, v. 15, no. 4, p. 18–22.

HANZAWA, SHOSHIRO, 1936. Topography and geology of the Riukiu Islands: Tohoku Univ. Sci. Reports., 2nd. ser. (geology), v. 17, no. 5, p. 1–61.

HAYES, D.E., and LUDWIG, W.J., 1967. The Manila Trench and West Luzon Trough—II. Gravity and magnetics measurements: Deep-Sea Res., v. 14, p. 545–560.

HO, C.S., 1967. Structural evolution and major tectonic forms of Taiwan: Geol. Soc. China Proc., no. 10, p. 3–24.

HSU, T.L., 1956. Geology of the Coastal Range, Eastern Taiwan: Geol. Surv. Taiwan Bull., no. 8, p. 39–63.

JAHN, BOR-MING, 1972. Reinterpretation of geologic evolution of the Coastal Range, East Taiwan: Geol. Soc. America Bull., v. 85, p. 241–248.

KARIG, D.E., 1971. Origin and development of marginal basins in the Western Pacific: J. Geophys. Research, v. 76, no. 11, p. 2542–61.

KATSUMATA, MAMORU, and SYKES, L.R., 1969. Seismicity and tectonics of the Western Pacific; Izu-Mariana-Caroline and Ryukyu-Taiwan regions: J. Geophys. Research, v. 74, no. 25, p. 5923–5948.

LEE, C.N., 1962. Distribution of earthquake foci in the Taiwan region and its tectonic significance: Geol. Soc. China Proc., no. 5, p. 109–118.

LUDWIG, W.J., 1970. The Manila Trench and West Luzon Trough—III; Seismic refraction measurements: Deep-Sea Research, v. 17, p. 553–571.

———, HAYES, D.E., and EWING, J.I., 1967. The Manila Trench and West Luzon Trough—I; Bathymetry and sediment distribution: Deep-Sea Research, v. 14, p. 533–544.

MCKENZIE, D.P., 1969. Speculations on the causes and consequences of plate motions: Roy. Astron. Soc., Geophys. J., v. 18, no. 1, p. 1–32.

MENG, C.Y., 1967a. Lateral movement in the northern half of Western Taiwan; Proceedings of the Third Symposium on the Development of Petroleum Resources of Asia and the Far East; Mineral Resources Development Series, No. 26, v. 1, p. 181–186.

———, 1967b. The structural development of the southern half of Western Taiwan: Geol. Soc. China Proc., no. 10, p. 77–82.

MURAUCHI, SANADORI, *et al.*, 1968. Crustal structure of the Philippines Sea: J. Geophys. Research, v. 73, no. 10, p. 3143–3171.

ROEDER, D.H., *in preparation*, Subduction and Orogeny.

SCHREIBER, ALFRED, 1965. On the geology of the Cenozoic geosyncline in middle and northern Taiwan (China) and its petroleum potentialities: Petroleum Geology, Taiwan, no. 4, p. 25–87.

TEMPLE, P.G., and NELSON, T.H., *in press*, Mainstream Mantle Convection.

YEN, T.P., 1963. The metamorphic belts within the Tananao Schist Terrane of Taiwan: Geol. Soc. China Proc., no. 6, p. 72–74.

———, and ROSENBLUM, SAM, 1964. Potassium-Argon ages of micas from the Tananao Schist Terrane of Taiwan—A preliminary report: Geol. Soc. China Proc., no. 7, p. 80–81.

Notes added by author

Since the preparation of this paper, three pertinent articles concerning the tectonics of Taiwan have come to my attention (Biq, 1971; Chai, 1972; and Jahn, 1972). In each of these paper the tectonics of Taiwan is reassessed in terms of plate tectonics. Chai and Jahn offer plate tectonic models substantially different from the one proposed in this paper. I see no reason to change my interpretation at this time, but I freely admit that we need to assemble more "hard" data before we can adequately interpret the development of this region.

Biq Chingchang, 1971, A fossil subduction zone in Taiwan: Proceedings Geol. Soc. China, No. 14, p. 146–154.

Chai, Bruce H.T., 1972, Structure and tectonic evolution of Taiwan: Am. J. Science, vol. 272, p. 389–422.

Jahn, Bor-Ming, 1972, Reinterpretation of geologic evolution of the Coastal Range, East Taiwan: Geol. Soc. America, Bull., vol. 83, p. 241–248.

July 6, 1972