CHAPTER II

REVIEW ON TECTONIC SETTINGS OF JAPAN

Japan forms part of festoon islands in the northwestern Pacific off the Asiatic continent. Geographically, it comprises four main islands, Hokkaido, Honshu, Shikoku, and Kyushu, including many other subordinate islets, which are arranged in an arc shape stretching from northeast to southwest. As quoted by Isozaki (1996), presently Japan is tectonically situated in the boundary zone among at least four plates, namely Eurasian plate on the northwest, North American plate on the northeast, Pacific plate on the southeast, and Philippine Sea plate on the southwest (Fig. 2.1). All the time since their births, at least the beginning of Phanerozoic (Ogawa *et al.*, 1997), these plates have moved against one another with different rates and directions, creating then five island arcs of Japan, viz. Kurile, Northeastern Japan, Izu-Bonin, Southwestern Japan, and Ryukyu arcs. These island arcs represent the complex patterns common in the western-Pacific region. Except for the Izu-Bonin, which forms an intra-oceanic arc, the rests form parts of active island arcs between Eurasian continent and Pacific ocean, and Eurasian continent and Philippine Sea where the oceanic plates are currently subducting westward or northwestward beneath an Eurasian plate (Isozaki, 1996). Two back-arc basins, Japan Sea and Philippine Sea, exist behind the subduction zone of Pacific plate that move under Eurasian and Philippine Sea plates. Within these two basins, there are some remnants which were thought to be relicts of the opening of the seas in late Tertiary time (Isozaki, 1996). In addition to the above subductions, another new, weakly developed convergent boundary extends along the eastern margin of the Japan Sea, from Sakhalin to central Honshu, and along the western boundary of the Fossa Magna. Along this boundary, the Eurasian plate is subducting eastward beneath the North American plate. Ongoing subduction processes along these convergent plate margins add materials to and

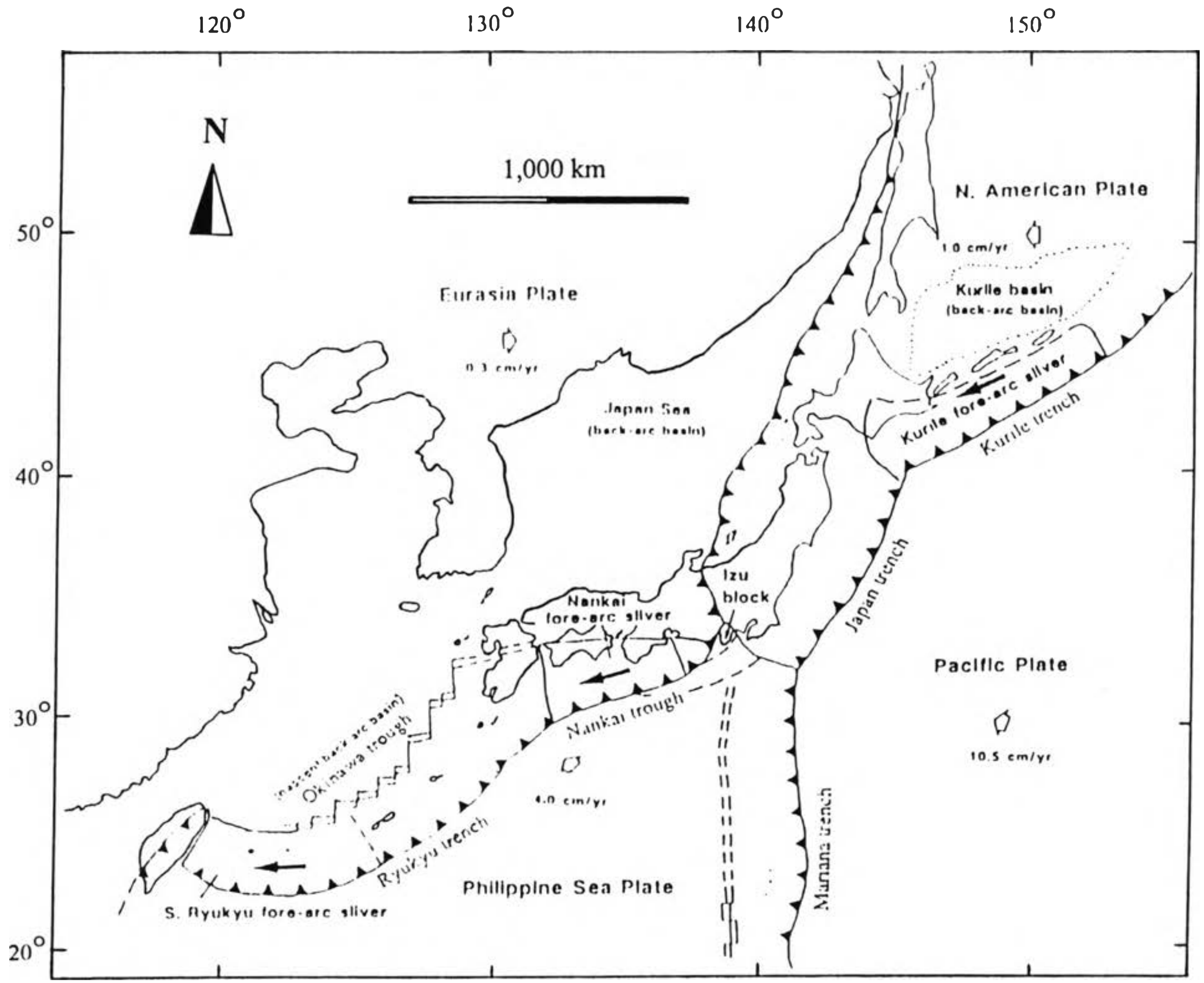

Figure 2.1 Map showing major plates and their interactions around Japanese Islands (Isozaki, 1996)

modify tectonic features of the Japanese islands, which are overall widening oceanward. These show that the present-day tectonic framework of Japan is the product of a long-term interaction among the above plates.

2.1 Geotectonic Subdivision of Japan

The Japanese Islands were subdivided geotectonically by Isozaki in 1996 into 12 units based on accretion tectonics, and it contrasts strikingly with previous schemes (e.g. those of Zang, 1985 and Taira *et al.*, 1989) based on geosyncline tectonic, continent-continent collision-related tectonics, or terrane tectonics. According to him, most of the Japanese geotectonic units are composed of Late Paleozoic to Cenozoic accretionary complexes and their high-P/T metamorphic equivalents, except for two units, Oki and Hida, that represent fragments of the Precambrian cratons detaching from mainland Asia in the Tertiary period (Fig. 2.2).

This new geotectonic subdivision can be grouped into four sections based on structural domains including Southwestern Japan, the Ryukyus, Northeastern Japan, and Eastern Hokkaido (Isozaki, 1996). All 12 geotectonic units were encountered in Southwestern Japan, five of which exist along arc equivalents in the Ryukyus. Northeastern Japan contains nine while eastern Hokkaido has only three of these 12 units.

In Southwestern Japan, the Cenozoic volcano-sedimentary covers are thinner than those in other domains due to the rapid uplift in the Quaternary allowing extensive exposures of Late Paleozoic to Mesozoic accretionary complexes and their metamorphic equivalents. The Ryukyus and Northeastern Japan can be essentially treated as lateral extension of Southwestern Japan. However, these two domains were considerably modified and dislocated by secondary tectonism including movement of

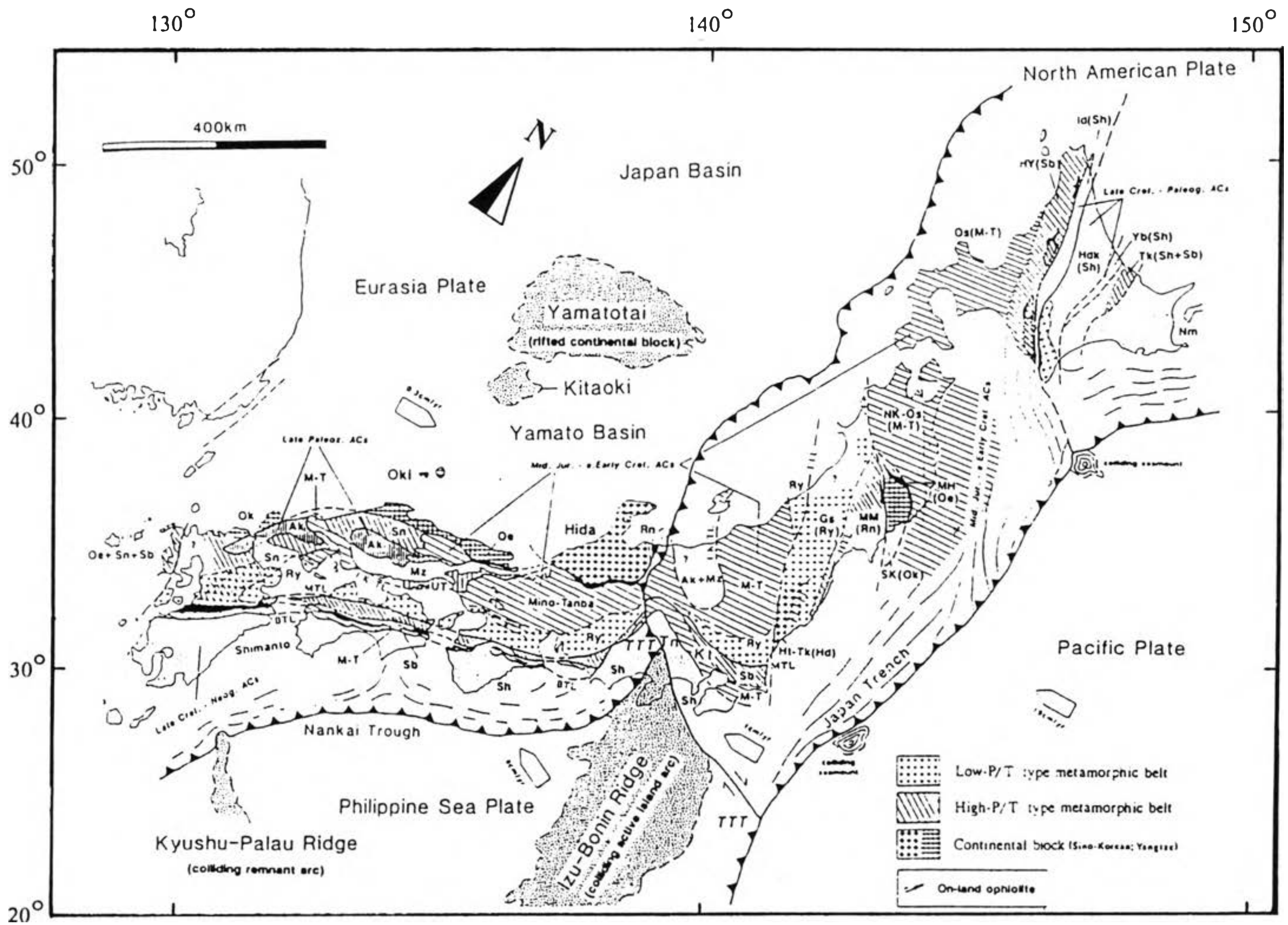

Figure 2.2 Map showing the new geotectonic subdivision of Japanese Islands (Isozaki, 1996).

fore-arc sliver, back-arc spreading, and arc-arc collision. The island of Hokkaido is characterized by a unique setting with an arc-arc collision between the Northeastern Japan and Kurile arc, and the eastern Hokkaido is believed to belong to Kurile arc. The Izu-Bonin Islands were not described as they form a young island arc of intra-oceanic nature and have lesser significance to the primary orogenic framework along the Asian continental margin. For convenience, the term "belt" was used herein to describe the distribution of geotectonic units in two dimensions. When a three-dimentional geotectonic entity is to be described, non-genetic terms like unit, body, block, complex, and nappe were adapted.

2.1.1 Southwestern Japan

All 12 distinct geotectonic units exist within southwestern Japan (Fig. 2.3). They are generally E-trending and show zonal arrangement. These units, from oldest to youngest are: a 2.0 Ga-250 Ma gneiss complex, a 230 Ma intermediate pressure type metamorphic complex, a 580-450 Ma ophiolite, a 400-300 Ma high-P/T schist, a 250 Ma accretionary complex, a 230-200 Ma high-P/T schist, a 180-140 Ma accretionary complex, a 120-100 Ma low-P/T metamorphic complex, a 100 Ma high-P/T schist, an 80 Ma accretionary complex, and a 40-20 Ma accretionary complex. These units distribute in 15 belts, that are, from Japan Sea side to the Pacific side: 1) Oki belt, 2) Hida belt, 3) O-eyama belt, 4) Renge belt, 5) Akiyoshi belt, 6) Sangun belt, 7) Maizuru (+Ultra-Tanba) belt, 8) Mino-Tanba belt, 9) Ryoke belt, 10) Sanbagawa belt, 11) Northern Chichibu belt, 12) Kurosegawa belt, 13) Southern Chichibu belt, 14) Northern Shimanto belt, and 15) Southern Shimanto belt. Repeated occurrence of the same unit in more than two belts causes a mismatch in the number of belts and geotectonic units.

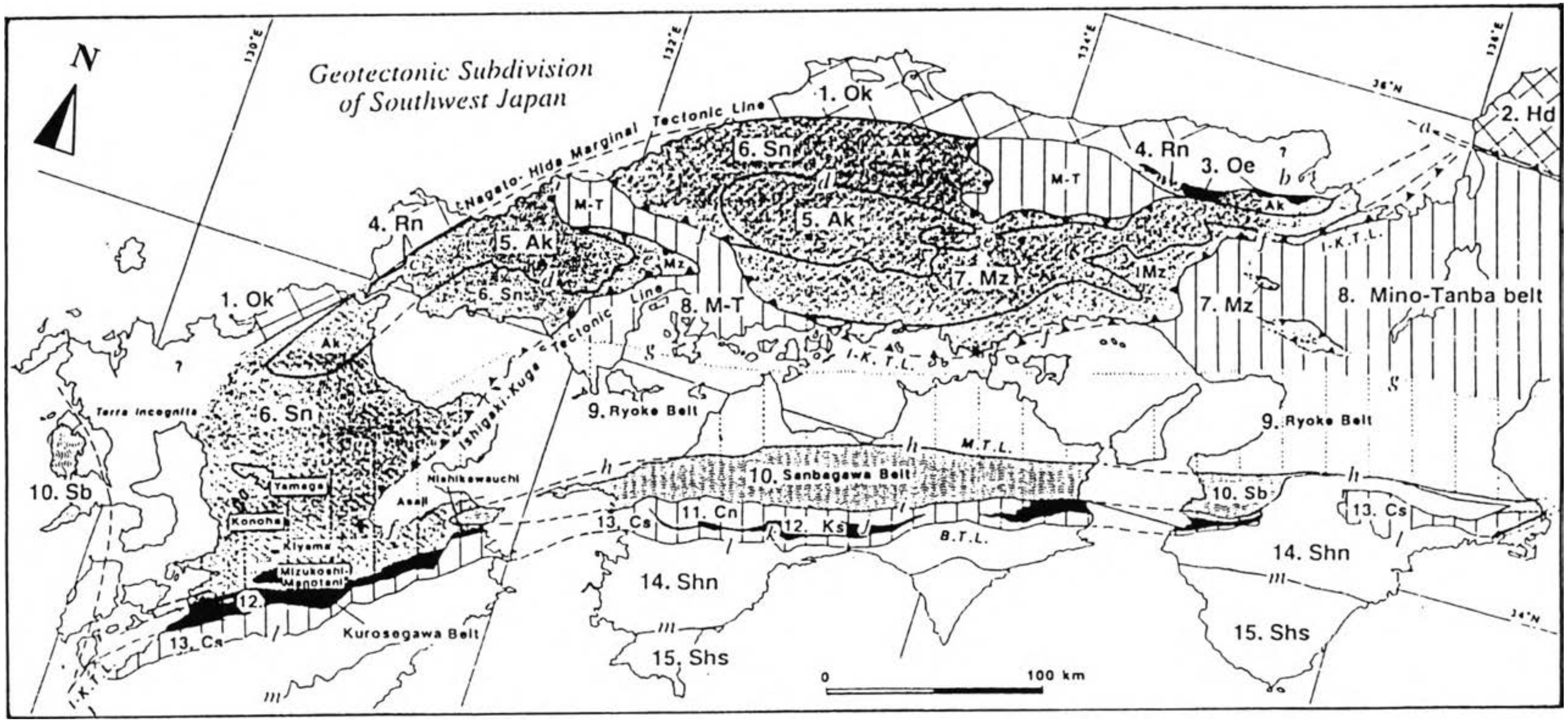

Figure 2.3 Map showing the geotectonic subdivision of Southwestern Japan (Isozaki, 1996).

The three belts along the Japanese Sea side, Oki (Ok), Hida (Hd), and O-eyama (Oe) belts, are intimately linked to Precambrian crusts in nature, and they form the core of the Phanerozoic orogen in Southwestern Japan. On the contrary, the other 12 belts surrounding the above three belts represent zones of subduction-related accretionary growth that account for the 450 million year-long widening and thickening of Southwestern Japan.

The Oki belt of continental affinity is, at present, isolated from mainland Asia, as it was rifted and detached by the Miocene opening of a back-arc basin, the Japan Sea (Isozaki, 1996). Judging from the lithologic and chronologic similarity to the Precambrian rocks of the Sobaesan massif in South Korea, the Oki belt is regarded as an eastern extension of the Yangtze (South China) craton (Isozaki and Maruyama, 1991).

The kyanite-bearing Hida metamorphic rocks are regarded as the northeastward-extension of the ultrahigh- to high-pressure metamorphic rocks along the Qinling-Dabie suture (230 Ma continent-continent collision zone) in central China between the Yangtze and Sino-Karean (North China) blocks (Maruyama *et al.*, 1994). The unique occurrence of Middle to Late Paleozoic shelf strata with Boreal fauna in the periphery of the Hida belt (Igo, 1990; Kato, 1990) suggests a strong link between the Hida belt and Sino-Korean block. The present position of the Hida belt in the central part of Japan is due to later across-arc contraction and juxtaposition (Komatsu, 1990), and the primary contact with the Oki belt (the Yangtze block) had been lost.

The 450-580 Ma ophiolite of the O-eyama belt along the southern margin of the Oki belt is the oldest oceanic material in Japan (Isozaki, 1996). Its eastward extension in Northeastern Japan, in the Miyamori-Hayachine belt, has covered by mid-Paleozoic sedimentary rocks of continental shelf facies (Ozawa, 1988). The occurrence of the medium-pressure type amphibolite in the O-eyama belt probably suggests its movement in the 250 Ma collision event (Isozaki, 1996).

The belts 4-15 listed below are zones of subduction-related accretionary growth that practically account for the 450 million years long orogenic widening and thickening of Southwestern Japan together with underlying granitic batholiths emplaced later. These accretionary complex belts, including metamorphosed equivelents, were successively added to the southeastern margin of the continent, in particular around the Yangtze block. It is noteworthy that the timing of accretion is generally getting younger oceanward from the 400 Ma meta-accretionary complex to the Miocene accretionary complex, and that the age of the subducted oceanic plate responsible for accretion has been considerably variable, from about 160 million years old for the Jurassic accretionary complex to almost zero for the Southern Shimanto accretionary complex.

Renge belt (Rn) is a belt of 400-300 Ma high-P/T schists and associated serpentinite. The highest metamorphic grade reaches the high-P amphibolite facies through glaucophane schist facies. The protolith is an accretionary complex of unknown age composed of greenstones, siliciclastics and chert.

Akiyoshi belt (Ak) is a belt of Late Permian (250 Ma) accretionary complex composing of oceanic greenstones, mostly of oceanic island basalt origin, chert, reef limestone, and terrigenous clastics. This unit suffered from low-grade regional metamorphism up to the lower greenschist facies at 220 Ma.

Sangun belt (Sn) is a belt of 230-210 Ma high-P/T schists. The highest metamorphic grade reaches the high-P amphibolite through the glaucophane schist facies. The protolith is an accretionary complex, probably containing a part of the 250

Ma Akiyoshi accretionary complex. Neighboring schist unit with problematic 200-180 Ma ages is also included here.

Maizuru belt (Mz) is a belt of Middle-Late Permian accretionary complex with 280 Ma ophiolite. The unit, sometimes discriminated as the Ultra-Tanba belt, is included here. The ophiolite suite is dismembered but its primary thickness is estimated to be about 25 km.

Mino-Tanba belt (Mt) is a Jurassic accretionary complex with a minor amount of latest Triassic and earliest Cretaceous parts (200-140 Ma). This unit is composed of oceanic greenstones of oceanic island basalt origin, deep-sea pelagic chert, reef limestone, and terrigeneous clastics. Secondary mixed accretionary complex (olistrostromes and melanges) occur commonly. This unit is tentatively subdivided into three parts: (1) Early Jurassic part that accreted at 200 Ma and metamorphosed at 170 Ma, (2) Middle Jurassic part that accreted at 170 Ma and metamorphosed at 140 Ma, and (3) Late Jurassic part that accreted at 140-150 Ma and metamorphosed at 120 Ma.

Ryoke belt (Ry) is a 120-100 Ma low-P/T metamorphic rocks and associated granites. The highest grade includes silimanite-bearing gneiss. Protolith is mostly composed of Jurassic accretionary complex with lesser amount of the pre-Jurassic accretionary complex and sediments. Ages of granites are in the range of 120-70 Ma with eastward younging polarity along the Southwestern Japan arc.

Sanbagawa belt (Sb) is a belt of high-P/T metamorphosed Early Cretaceous accretionary complex that is well known as the Sanbegawa schists. The highest grade reaches the high-P amphibolite facies and radiometric ages concentrated in 100-80 Ma. The high-P/T Sanbegawa belt and the low-P/T Ryoke belt form pair metamorphic belts.

Northern Chichibu belt (Cn) is a Latest Triassic to Middle Jurassic accretionary complex equivalent to the older part of the Jurassic accretionary complex in the Mino-Tanba belt. This unit is regarded as forming a tectonic outlier of the Jurassic complex of the Mino-Tanba belt.

Kurosegawa belt (Kr) is a belt of fault-bounded mixture of the pre-Jurassic elements. Components of the above mentioned O-eyama, Renge, Akiyoshi, Sangun, and Maizuru belts occur chaotically as slivers, lenses and/or blocks of various sizes and shapes, enveloped within serpentinite matrix. As a whole, this unit represents a tectonic outlier of the pre-Jurassic rocks, which occurred on the Asian continental side.

Southern Chichibu belt (Cs) is a belt of Early Jurassic to earliest Cretaceous accretionary complex that equivalent to the younger part of the Jurassic accretionary complex in the Mino-Tanba belt and partly that in the Northern Chichibu belt.

Northern Shimanto belt (Shn) is a belt of Late Cretaceous scarcely metamorphosed accretionary complex composing mostly of oceanic rocks. Sporadically intervened are thin tectonic slices of melanges that include oceanic greenstones and bedded chert within scaly argillaceous matrices.

Southern Shimanto belt (Shs) is a belt of Paleogene and Miocene little metamorphosed composing mostly of terrigenous clastic rocks. A minor amount of tectonic melanges occur in this belt.

Most of the geotectonic boundaries in Southwestern Japan are demarcated by low-angle thrust. There is only the boundary between Mino-Tanba and Ryoke belts that is found to be the high-angle normal fault whereas that between Sangun and Maizuru belt is still not examined.

2.1.2 The Ryukyus

On the basis of strong similarlity of components, the Ryukyu Islands are basically regarded as the southwestward-extension of Southwestern Japan (Fig. 2.4). This domain is clearly separated from Southwestern Japan by a N-trending transverse fault, right-lateral off-set of the Late Cretaceous high-P/T unit in west Kyushu.

Geological information on the Ryukyu Islands is limited by the lack of exposures but some geotectonic units are well correlated with those in Southwestern Japan. Most of the units in this domain are composed of Late Paleozoic and Mesozoic accretionary complexes and their metamorphic equivalents. There is no geotectonic unit with continental affinity in this domain except Early Paleozoic ophiolite in western Kyushu.

The geotectonic units known from the Ryukyus are listed below as the equivalent of those from Southwestern Japan. For convenience, the numbers and symbols that were used for units in Southwestern Japan are also used to describe units in the Ryukyus: 3, metagabbro from Namo point, 450-580 Ma ophiolite (=Oe); 6, Tomuru metamorphic rocks, 220 Ma high-P/T schists (=Sn); 8, Fusaki Formation, Jurassic accretionary complex (=MT); 10, Yuan Formation and Takashima schists, Early Cretaceous accretionary complex and 60-90 Ma high-P/T metamorphic equivalents (=Sb); 14, 15, Kunchan Group, Cretaceous and Paleogene accretionary complexes (=Sh).

The only two belt boundaries have been examined on land in the Ryukyus, that are boundary between belts 6 and 8 (Sn/MT) which is low-angle thrust, and boundary between belts 10 and 14 (Sb/Shn) which is high-angle fault.

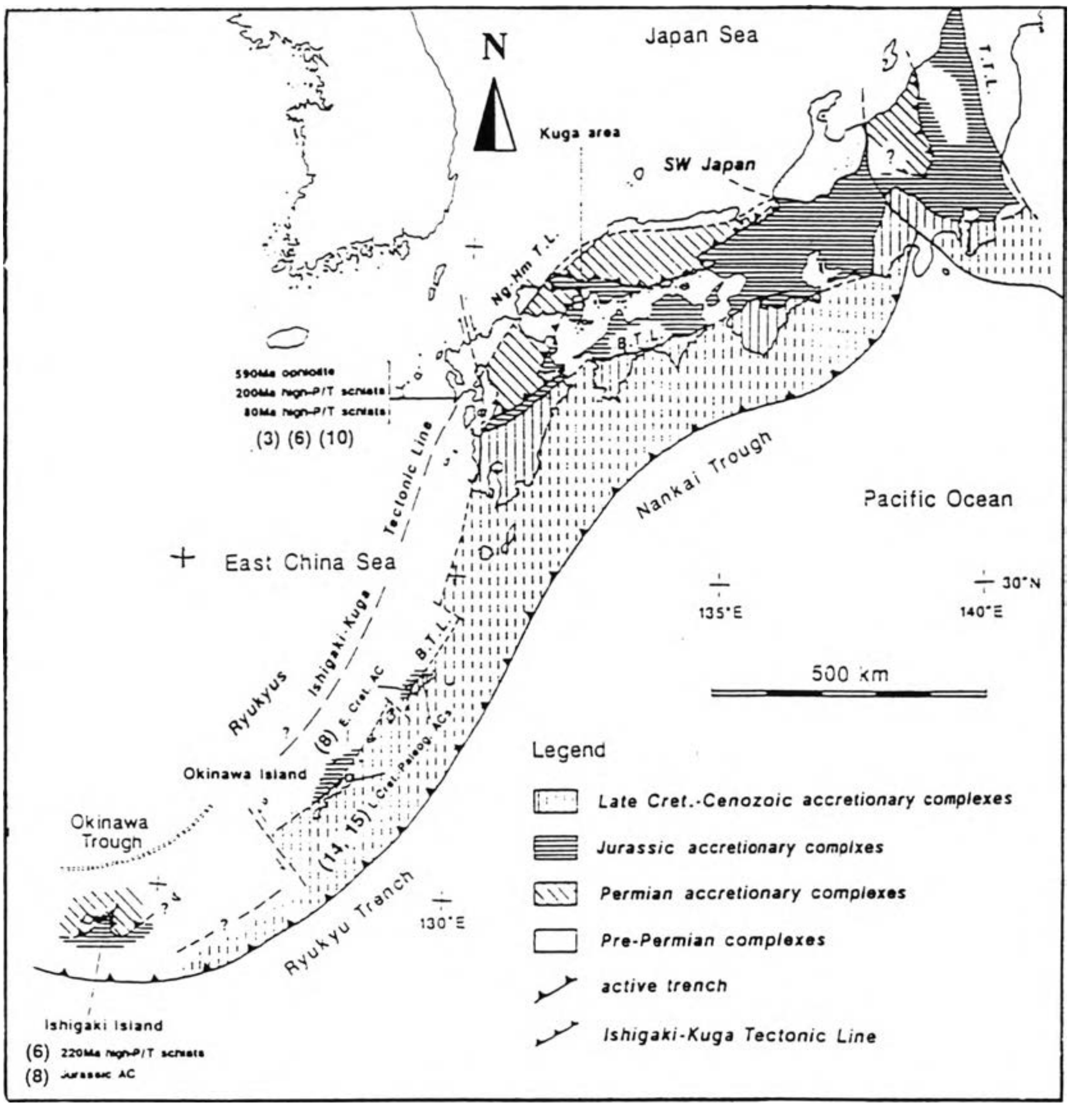

Figure 2.4 Map showing the geotectonic subdivision of the Ryukyus (Isozaki, 1996).

2.1.3 Northeastern Japan

Northeastern Japan comprises northeastern Honshu and the western Hokkaido, and is separated from Southwestern Japan by a left-lateral strike-slip fault called Tanakura tectonic line (T.T.L.), and from eastern Hokkaido by a N-trending fault in central Hokkaido, respectively (Fig. 2.2). Northeastern Japan is also characterized by an apparent zonal arrangement of several geotectonic units on the surface (Figs. 2.5 and 2.6). This domain has been intensely modified by secondary tectonism, in particular by left-lateral strike-slip faults, relevant to the Miocene opening of the Japan Sea. This faulting leads to uncertainty in the primary geometry and nature of contact among the component units. However, a comparison with Southwestern Japan can help in the reconstruction of primary features of this domain. Geotectonic units of Northeastern Japan are briefly explained in comparison to those of Southwestern Japan.

As well as the Oki, Hida, and O-eyama belts in Southwestern Japan, the three belts in Northeastern Japan, that are Southern Kitakami, Hitachi-Takanuki, and Miyamori-Hayachine belts, also show strong continental affinities. The rests are accretionary-complex units which later accreted to Northeastern Japan.

Southern Kitakami belt (SK) including 440 Ma granite and Gneiss, 350 Ma and 250 Ma granites (=Ok) with middle to Late Paleozoic sedimentary covers is characterized by marine fauna of Australian (Gondwana) affinity (Kawamura *et al.*, 1990; Kato, 1990). Hitachi-Takanuki belt (Ht-Tk) comprises 250 Ma medium-P metamorphics. The protoliths include Late Paleozoic sedimentary rocks accumurated on the continental shelf and volcanic rocks of bimodal characteristics (=Hd). Granite-related thermal overprint occurred regionally at 110 Ma which is correlated to the Ryoke metamorphism in Southwestern Japan (=Ry). Miyamori-Hayachine belt (MH)

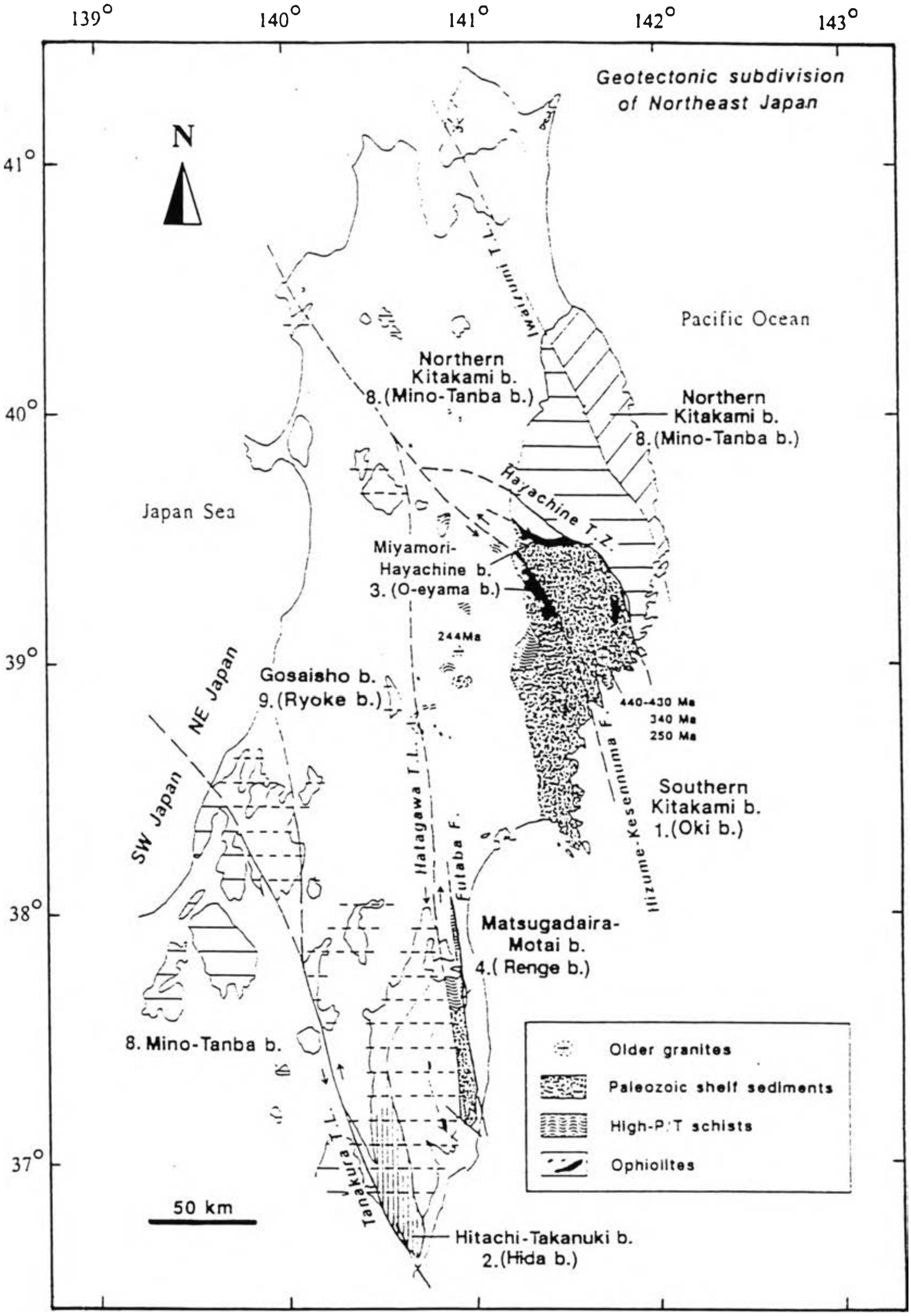

Figure 2.5 Map showing the geotectonic subdivision of Northeastern Japan (Isozaki, 1996). Names in parentheses indicate correlative units in Southwestern Japan.

is composed of 450 ophiolite (=Oe) with Paleozoic sedimentary covers. Matsugadaira-Motai belt (MM) comprises 300-400 Ma high-P/T schists (=Rn).

Northern Kitakami-Oshima belt (NK-Os) includes of Jurassic accretionary complex (=MT) and Early Cretaceous accretionary complex (=Sb). Gosaisho belt (Gs) is composed of 110 Ma low-P/T metamorphic rocks and granites (=Ry). Protoliths include components of the Jurassic accretionary complex (=MT). Sorachi-Yezo belt (SY) is composed of Early Cretaceous accretionary complex and 100 Ma high-P/T (Kamuikotan) schists associated with (Horokanai) ophiolite (=Sb). Idonnappu belt (Id) is composed of Early to early Late Cretaceous accretionary complexes (=Sh). Hidaka belt (Hdk) is composed of Late Cretaceous to Paleogene accretionary complexes (=Sh) which were partly metamorphosed into low- to medium-P type metamorphics associated with 50 Ma migmatite-granite.

The geotectonic boundaries between these units in Northeastern Japan are listed below:

(i) boundary between Ht-Tk and SK is unknown;

(ii) boundary between SK and MH is vertical fault but primarily low-angle thrust (western margin of the Hayachine tectonic zone);

(iii) boundary between MH and NK-Os is vertical fault but primarily low-angle thrust (eastern margin of the Hayachine tectonic zone);

(iv) boundary between Ht-Tk and Gs is an E-dipping low-angle fault probably activated before the intrusion of the Cretaceous granite;

(v) boundary between Gs and MM is left-lateral strike-slip fault;

(vi) boundary between MM and NK-Os is left-lateral strike-slip fault;

(vii) boundary between NK-Os and SY is unknown;

(viii) boundary between Id and Hdk is an E-dipping low-angle thrust on the surface that translates into a low-angle one in deeper level.

The zone between boundaries (ii) and (iii) has been traditionally called the Hayachine tectonic zone because serpentinized ophiolite occurs in an apparently narrow belt. The faults (v) and (vi) are the typical examples of sinistral strike-slip faults as well as the Hizume-Kesennuma tectonic line that activated during the Miocene opening event of the Japan Sea along its eastern margin. These faults clearly cut the primary sinuous boundary faults such as the faults (ii) and (iii). The fault (viii) represents another example of the secondary modification upon the primary structure, and this fault has been activated probably by ongoing westward collision of the Kurile fore-arc sliver.

2.1.4 Eastern Hokkaido

Eastern Hokkaido has a rather complicated tectonic history compared to the other domains of Japan, probably reflecting its peculiar geotectonic condition, sandwiched between two Cenozoic back-arc basins, Japan Sea and Kurile basin (Fig. 2.1). The boundary between Northeastern Japan including western Hokkaido and eastern Hokkaido is inferred in central Hokkaido in the name of the Tokoro or Shibetu fault, however, its precise position, geometry, and nature are unknown owing to thick Quaternary covers in between. There is no Paleozoic and Early Mesozoic unit in eastern Hokkaido, and this implies a unique geohistory for this domian. Three geotectonic units are recognized in Eastern Hokkaido (Fig. 2.6), that are Yubetsu belt (Yb) which is Cretaceous accretionary complex (=Sh); Tokoro belt (Tk) which is Cretaceous accretionary complex and high-P/T metamorphic equivalents; and Nemuro belt (Nm) which is Cretaceous-Tertiary shelf sequences with unknown basement probably composed of Mesozoic-Cenozoic crystalline rocks of arc affinity.

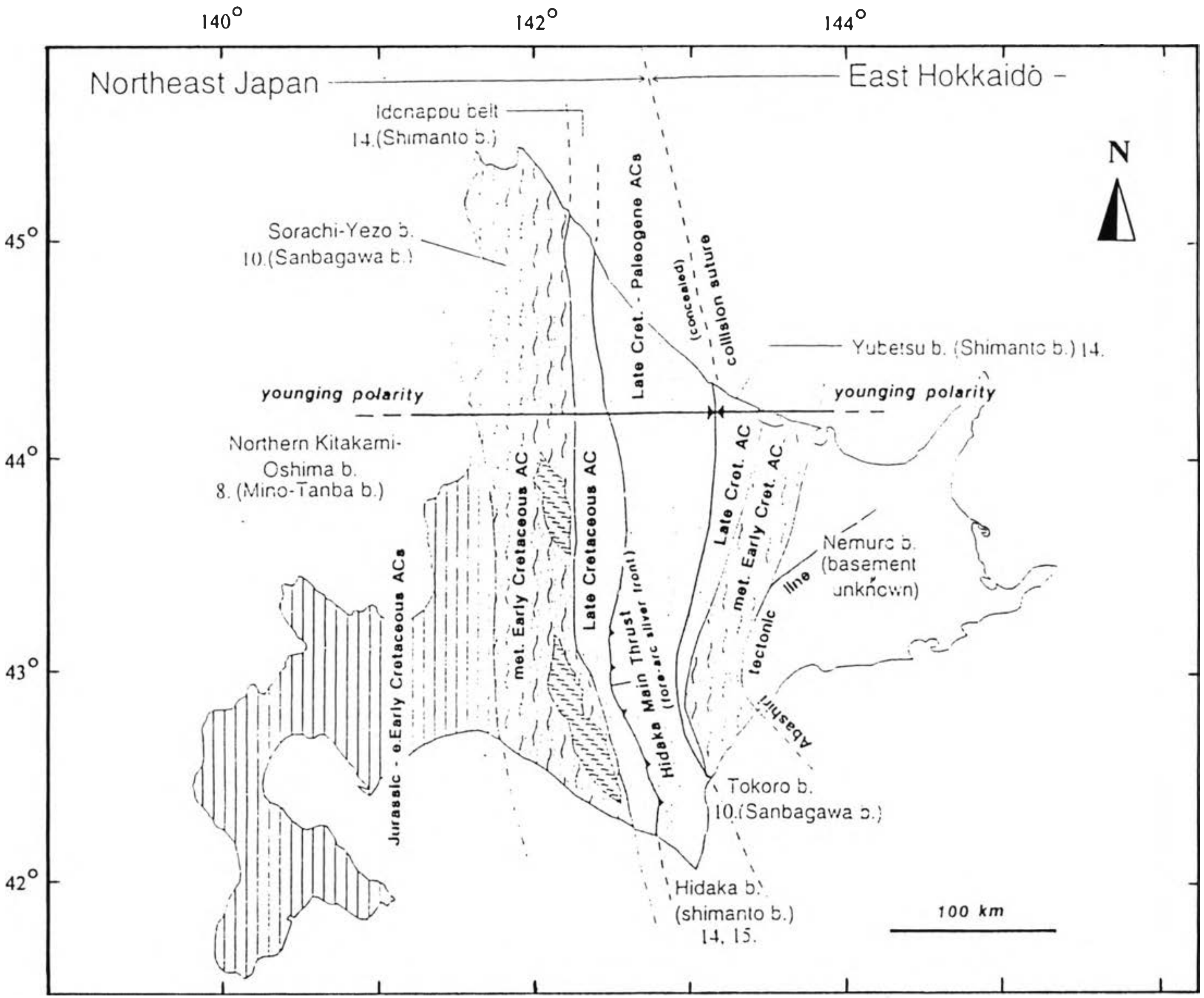

Figure 2.6 Map showing the geotectonic subdivision of Hokkaido (Isosaki, 1996).

These three belts are separated from each other by the N-trending faults. The fault between Tokoro and Nemuro belts has a strike-slip nature and is called the Abashiri tectonic line. This fault has activated in a right-lateral manner during the opening event of the Kurile back-arc basin.

2.2 Geotectonic History of Japan

The time-space relationships among the orogenic units described here suggest that the Japanese Island have grown oceanward by almost 400 km across the arc since Middle Paleozoic. The history bagan with rifting of the supercontinent in the late Neoproterozoic (Isozaki, 1996; Maruyama *et al.*, 1997), and was followed by a tectonic inversion shifting from an extensional regime to a convergent regime around 500 Ma. Since then, an oceanic subduction-related accretion regime has persisted, and is responsible for the oceanward growth of the islands. Figure 2.7 summarizes this history from the birth of the islands at 700 Ma to their separation from Asia in the Miocene. Most of the descriptions below were picked up from Isozaki (1996).

2.2.1 Birthplace of proto-Japan

The Oki belt in Southwestern Japan and the Southern Kitakami belt in Northeastern Japan represent parts of the core of Japan, which began as a segment of the Yangtze continental margin. In addition, a fragment of the Sino-Karean continental block also participated in the orogenic growth of Japan after the 250 Ma collisional event. These two continental blocks, particularly the Yangtze block, have played the most important roles in constraining the configuration of the Japanese Phanerozoic orogen.

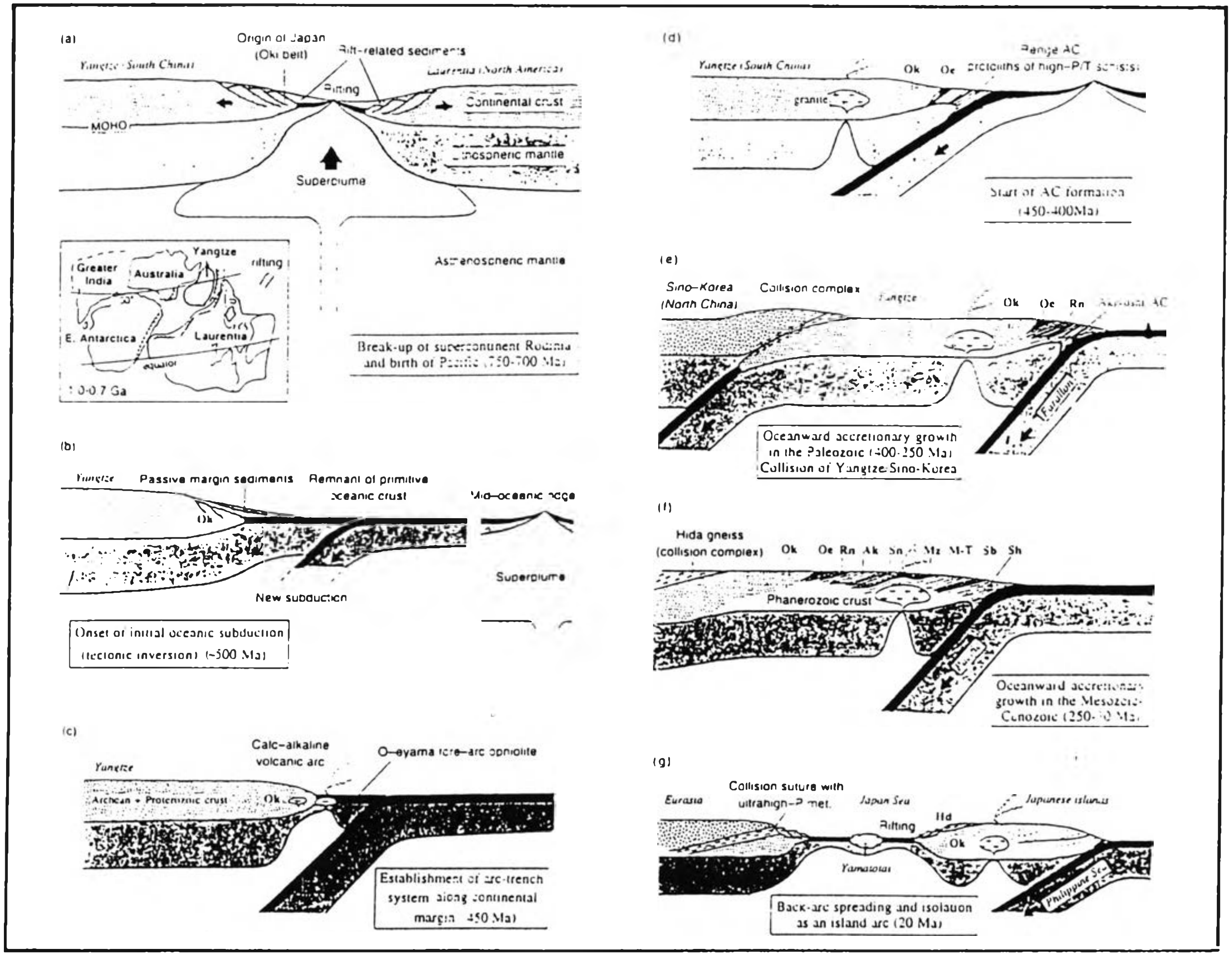

Figure 2.7 Cartoons showing 700 million years of geotectonic evolution of Japanese Islands (Isozaki, 1996).

The relation of Yangtze and Sino-Korean continental margins to proto-Japan goes back to nearly 750-700 Ma when it was believed that the supercontinent Rodinia started rifting apart. Judging from the patterns of radial dyke swarms and rifted basins, the breakup of Rodinia was probably started by a superprume rising to the surface from the mantle/core boundary. As a result, the proto-Pacific ocean was born in 750-700 Ma by the rifting of Rodinia, and several continental fragments including the Yangtze and Sino-Korean blocks were then dispersed in various directions (Fig. 2.7a). Due to the similarities in Neoproterozoic to Cambrian stratigraphy, the rifted Yangtze margin is probably a conjugate block of the Australia and/or Laurentia (North America). For the paleoposition of the Sino-Korean block, with respect to Rodinia, it still remains highly enigmatic. The birthplace of Japan was probably located somewhere in the northern periphery of Rodinia in mid-latitudes at about 700 Ma. Most of the dispersed continental fragments once again assembled to form another (semi-)supercontinent, Gondwanaland, at about 500 Ma. However, some large blocks such as Laurentia, Siberia, and Baltica were isolated from the supercontinental mass. In the same way, the absence of evidence for late Neoproterozoic to Cambrian collision in China suggests that both the Yangtze and Sino-Korean blocks, including proto-Japan, were also isolated from Gondwanaland, although Early to Middle Paleozoic faunal provincialism suggests that the Yangtze block, including proto-Japan, and Australia were close neighbors.

Due to limited exposure and later tectonic modification in Japan, there is little evidence to conclude that continental rifting, such as extensional fault system, rift-related bimodal volcanism, and rift-related sedimentary sequences, were active at this time. Stratigraphical and paleontological information suggest that the small distribution of Early to Middle Paleozoic (Ordovician to Devonian) terriginous clastic/carbonate sequences in the periphery of the Hida, Hitachi-Takanuki, Southern

Kitakami, Mutsukadaira-Motai, and Kurosegawa belts all represent remnants of continental shelf facies accumulated along the rifted Proterozoic continental margins.

2.2.2 Inversion from passive to active margin

With the exception of Precambrian gneissic clasts in younger sediments, the oldest unit of oceanic affinity in Japan is the 580 Ma ophiolite in the O-eyama belt, Southwestern Japan. Its occurrence in the periphery of the Oki belt (ancient Yangtze margin) suggests that this unit is a remnant of proto-Pacific ocean crust. The O-eyama ophiolite and its equivalent in the Miyamori-Hayachine belt in Northeastern Japan have a bimodal distribution of radiometric ages, one at 580 Ma and another at 480-450 Ma. Distribution of the oldest ophiolite in Japan was explained by Isozaki and Maruyama (1991) as below.

The tectonic history of the O-eyama ophiolite is two-fold: (i) following rifting with the emplacement of nascent oceanic crust, a MORB-like oceanic crust formed at the proto-Pacific mid-oceanic ridge around 580 Ma (Fig. 2.7a); and (ii) these rocks were then intruded around 450 Ma by calc-alkaline volcanism of arc affinity when a new intra-oceanic subduction was initiated (Figs. 2.7b-c).

O-eyama is regarded as the only example of a fore-arc ophiolite in Japan, while other ophiolitic rocks are regarded as accreted fragments of ancient seamounts, rises, and plateaus. Between 580 Ma and 480 Ma, tectonics in proto-Japan changed noticeably from rift/ridge-related extension to subduction-related compression, and passive margins changed rapidly to active margins. The tectonic inversion probably corresponds to global plate reorganization, in particular to the opening of the proto-Atlandtic ocean on the oposite side of the globe. Accretion of the O-eyama ophiolite can be explained by either of the following two mechanisms: (i) initiation of a landward dipping subduction zone within the primary oceanic crust (Figs. 2.7b-c); or (ii) collision of an island arc system from the ocean side and a reversal of subduction polarity.

2.2.3 Accretionary growth of the Japanese Islands

After the tectonic inversion around 500 Ma, proto-Japan bagan a state of accretionary growth that persists today. Within 50 million years after initiation of intra-oceanic subduction, the arc-trench system featured accretionary complexes, high-P/T schists, and granitic batholiths (Figs. 2.7d-e), in the Renge and Kurosegawa belts of Southwestern Japan and in Southern Kitakami and Matsukadaira-Motai belts of Northeastern Japan. In particular, the oldest accretionary complex in Japan is the protolith of the 450-400 Ma high-P/T schists. The high-P/T schists and coeval granitic rocks are elements of a paired metamorphic belt, with a high-P/T belt on the ocean side and a low-P/T belt on the continent side.

Following the oldest 450 Ma unit, Late Paleozoic, Mesozoic, and Cenozoic accretionary complexes were formed through subsequent subduction. At least several major oceanic plates have subducted beneath the Yangtze margin, leaving more than 10 distinct accretionary complex belts. Numerous oceanic fragments derived from subducted oceanic plates, including deep-sea sediments and seamount-derived basalts/reef limestone, were accreted to Japan.

Accretionary growth of Japan has not apparently been developed continuously. However, including the youngest accretionary complex, now under construction along the Nankai trough off Southwestern Japan, the total accretionary growth is nearly 400 km in across-arc width (Fig. 2.7f), not taking into account the material loss by subduction-erosion. Thus, the overall accretionary complex-dominated orogen in Japan has grown oceanward for almost 400 km during the 450 million years.

It was only 20 million years ago when the Japanese Islands obtained their present configuration through back-arc spreading (Fig. 2.7g). However, the accretionary growth of the Japanese Islands will likely continue until other continental blocks, such as Australia or North America, collide against Asia to form a future supercontinent.

2.2.4 Remnant of continent-continent collision

While most of the geotectonic units in Japan are the results of Oceanic subduction, the Hida and Hitachi-Takanuki belts are remnants of continent-continent collision. At about 250 Ma, the Yangtze and Sino-Korean blocks collided along the Quiling-Dabie suture, generating an ultrahigh-P metamorphic belt, best preserved in the Dabie mountain and Shandon province in China (Fig. 2.8). The region of ultrahigh-P metamorphism appears to be restricted to the central part of the 3,000 km long suture, suggesting that a promontory collision may have locally generated ultrahigh-P conditions. East of the Shandon peninsula, the coeval 250 Ma regional metamorphism is detected in the Hida and Hitachi-Takanuki belts in Japan, they are characterized by medium-P-type metamorphism. Although these belts lack ultrahigh-P metamorphism, from a geographical viewpoint, they may also correspond to an eastern extension of a collision-related metamorphic belt, including the Imjingang and/or Ogchon zone(s) in Korea. The Hida belt and its equivalent occur at the eastern terminal of the suture. Data from this belt indicate a decrease in grade and magnitude of a collision-related metamorphic belt. After 250 Ma, accretionary growth in Japan radiated from a core that composed of the amalgamated Yangtze and Sino-Korean blocks.

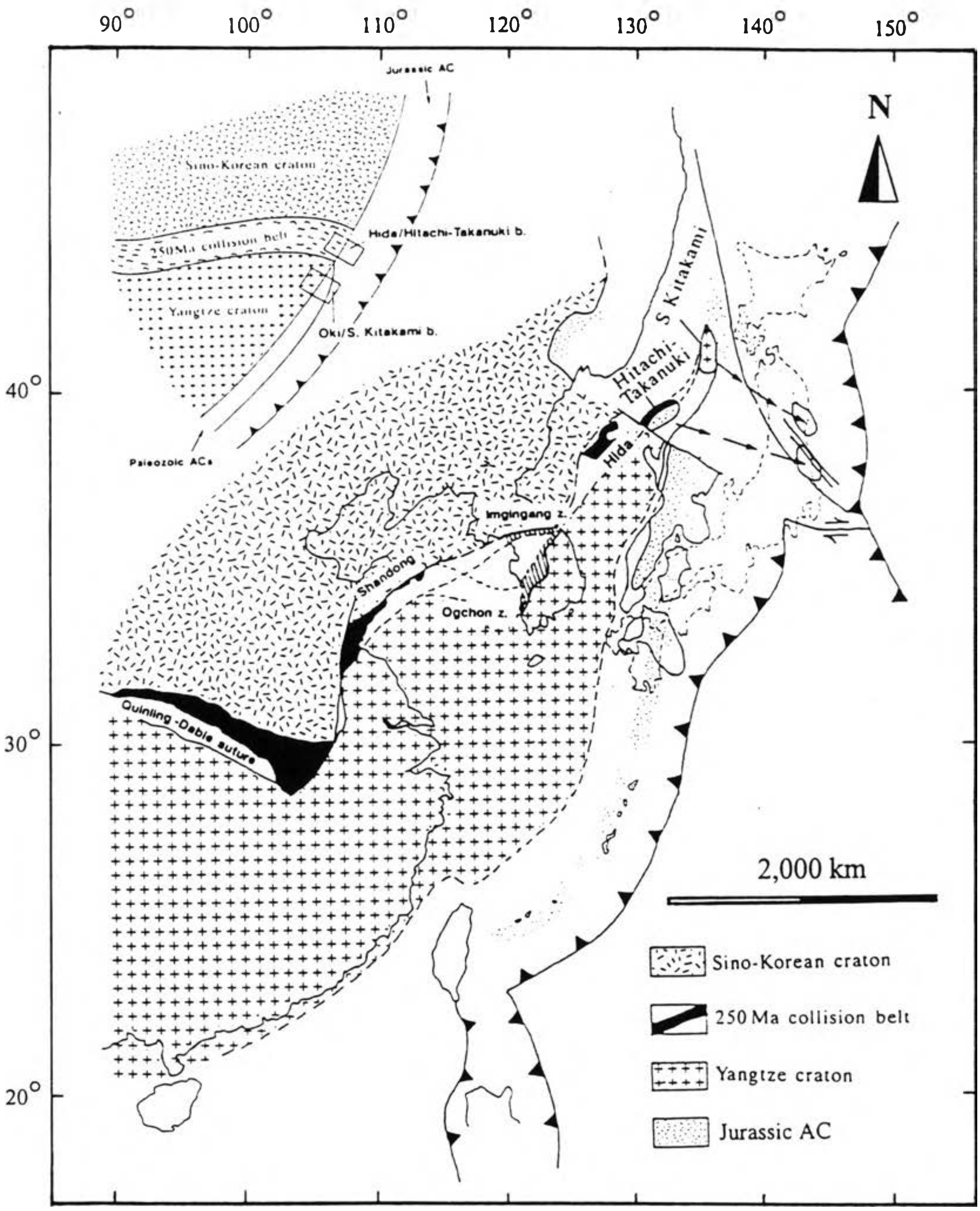

Figure 2.8 Tectonic framework of 250 Ma East Asia showing a continent-continent collision between the two Precambrian cratons, Sino-Korean and Yangtze blocks (Isozaki, 1996).