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GENERAL STRATIGRAPHY OF KOREA

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ABSTRACT

Regional unconformities have been used as boundaries of major stratigraphic units in Korea. The term "synthem" has already been propsed for formal unconformity-bounded stratigraphic units of maximum magnitude (ISSC, 1974). The unconformity-based classification of the strata in the cratonic area in Korea comprises in ascending order the Kyerim, Sangwŏn, Josŏn, Pyŏngan, Daedong, and Kyŏngsang Synthems, and the Cenozoic Erathem. The unconformites separating them from each other are either orogenic or epeirogenic (and vertical tectonic). The sub-Sangwŏn unconformity is a non-conformity above the basement complex in Korea. The unconformities between the Sangwŏn, Josŏn, and Pyŏngan Synthems are disconformities denoting late Precambrian and Paleozoic crustal quiescence in Korea. The unconformities between the Pyŏngan, Daedong, and Kyŏngsang Synthems are angular unconformities representing Mesozoic orogenies. The bounding unconformities of the Kyŏngsang Synthem involve non-conformable parts overlying the Jurassic and late Cretaceous granitic rocks.

INTRODUCTION

The Japanese Islands in the continental margin has been highly mobile throughout its detectable geologic history since the Silurian Period. The region comprising Korea and northern China, on the other hand, was generally stable during the late Precambrian and the Paleozoic times, but the Mesozoic Era was a time of crustal mobility even for this region as evidenced by thick non-marine sedimentary and volcanic sequences that were repeatedly deformed and intruded by granites. To denominate such a remobilized cratonic area as this region, the terms "heterogen" (T. Kobayashi, 1953, p. 155) and "paraplatform" (Huang, 1963) were coined.

In Korea, there are two geosynclinal areas, namely, the Okchŏn trough (which had shown truly geosynclinal characters during the late Paleozoic-Jurassic time according to Chang, 1972) in southern Korea and a Permian extension in the northeastern corner of Korea of the Paleozoic Mongolian geosyncline (Noda, 1956). These intracratonic highly-mobile zones, not found in the other part of the Korea N. Chinese region, reflect proximity to the Japanese area near a plate boundary. This synoptic classification of strata in Korea represents the wider area of Korea having cratonic characters; the still-debated reconstructions of the stratigraphy of the geosynclinal areas are not included in this synopsis.

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PRECAMBRIAN EONOTHEM

Sub-Sangwŏn Precambrian

One of the most prominent stratigraphic boundary in Korea and China is the unconformity between the late Precambrian Sangwŏn (or the Sinian s. l. in China) Synthem and the sub-Sangwŏn rocks (metasedimentary rocks and granite gneisses). The sub-Sangwŏn metasedimentary rocks were collectively called the "Kyerim System" in Korea (Nakamura and Matsushita, 1940). The sub-Sangwŏn metasedimentary rocks in Korea are assigned to the Yŏnchŏn and the Machŏnnyŏng Supergroups.

The Yŏnchŏn Supergroup (originally "Rensen System" by Kawasaki, 1918) is older than the associated complex of gneiss and granite which is dated as about 2000 m. y. B. P. based on Rb-Sr and U-Pb data (Hurley et al, 1973; Gaudette and Hurley, 1973). It comprises the oldest known sedimentary rocks in Korea. Its type area is between Seoul and Yŏnchŏn, Kyŏnggi-do, middle Korea. The type Yŏnchŏn consists of mica-schist (bearing kyanite, andalusite, sillimanite), phyllite, amphibolite (derived mainly from basic volcanics), (garnetiferous) hornfelses, and marble. This Supergroup extends to the western part of Chungchŏng-do, where it consists of mica-schist, quartzite, and limestone, and contains minable deposits of iron-formation and graphite. It's thickness is enormous, the base being unknown. It is notable that the Yŏnchŏn Supergroup contains considerable amount of organic graphite, iron-formation, quartzose sandstone, and limestone, none of which is characteristic of the oldest strata of the earth. It is also notable that the Supergroup contains abundant amphibolite.

The Machŏnnyong Supergroup (originally "Machonnyong series" by Kawasaki, 1916) is more calcareous and less metamorphosed than the Yŏnchŏn Supergroup, and isolated from the latter by granite gneiss. It occurs in northeastern Korea forming the Machŏnnyŏng range whose divide serves as the the administration boundary between the Hamgyŏngnam-do and Hamgyŏngbuk-do. Its lithologic succession is as follows (based on Kinosaki, 1932, in Asano *et al*, 1967, p. 98).

Table 1.

(5) Quartzite and feldspar schist	4, 000m
(4) Mica schist	1, 200m
(3) Dolomite and limestone (*Collenia*)	3, 000m
(2) Dolomite and limestone (magnesite)	3, 000m
(1) Dolomite and limestone (graphite schist, etc.)	1, 500m
Total thickness	12, 700m

The Iwŏn igneous group that intruded the Machŏnnyŏng Supergroup is dated based on K-Ar data as about 1, 700 m. y. B. P. (Polevaya *et al*, 1961; Masaytis, 1962) or as 1, 200 m. y. B. P. and younger (Kropotkin, 1969). Apparently, multiple overprintings of younger igneous and metamorphic events complicated these age data. What appears certain and significant is that the granitic rocks of about 2, 000 m. y. B. P. prevalent not only in southern but also in northern Korea (Masaytis, 1962) did not affect the Machŏnnyŏng Supergroup. Accordingly, it is very probable that the Machŏnnyŏng is unconformably above the Yŏnchŏn, although their relation is not directly observable due to isolation.

The Yŏnchŏn and the Machŏnnyŏng are lithologically and in the degree of deformation very comparable respectively with the Taishan and the Wutai "Systems" in North China. The Taishan comprises the oldest rocks in China, older than 2, 400 m. y. B. P. (Mu *et al*, 1963). The long sustained view that the Yŏnchŏn is older than the Machŏnnyŏng is in conformity with the known general lithogenetic history of the Precambrian Erathem that carbonates are more abundant in the younger deposits and the basic volcanics are more abundantly associated with the older deposits.

Sangwŏn Synthem^{+}

Deformed but only slightly metamorphosed late Proterozoic Sangwŏn Synthem ("Syogen system" by Nakamura, 1926) occurs in North Korea with a parallel distribution with the overlying Cambro-Ordovician Josŏn Synthem. The type area is the Hwangju-Haeju area, middle Korea, where its lithologic succession is as follows (based on Matsushita, 1940, in Asano *et al*, 1967, p. 100):

Table 2.

Kuhyŏn Group	slate	370m	
	tilloids	900m	
	slate & quartzite	250–1500m	
	sandy limestone	50–330m	
	slate	250–450m	1,820–3,550m
unconformity			
Sdang'u Group	limestone	450–600m	
	dolomite	250–540m	
	limestone	700–1100m	1,400–2,240m
Jikhyŏn Group	calcareous phyllite	625+m	
	quartzite	1000m	
	slate	500–1800m	
	feldsparthic quartzite	600–1000m	
	(base has not been observed)		2,745–4,425m+

The upper boundary of the Sangwŏn Synthem is a disconformity or a "very slight" angular unconformity between it and the overlying Josŏn Synthem. The unconformable relation is said to be detectable only by a detail work (Kobayashi, 1966b). Since a similar unconformity exists between the Sadang'u and the Kuhyŏn Groups, the Haeju (for the composite of the Jikhyŏn and the Sadang'u Groups) and the Kuhyŏn Subsynthems are here proposed.

In China, the equivalent of the Sangwŏn Synthem is the widely distributed "Sinian System" (Grabau, 1922). The equivalent in China of the Haeju Synthem is called the Huto System (Willis and Blackwelder, 1904). The Sinian, s. str., corresponds to the Kuhyŏn Subsynthem in North Korea.

A reasonable consensus of the radiometric age of the base of the Sinian, s. lato, in China (i. e., the Sangwŏn Synthem) appears to be 1300 m. y. B. P. (Li, 1965, p. 1671).

⁺Stratigraphic term for a major unconformity-bounded unit (ISSC, 1974).

Collenia limestones reportedly occur in the lower part of the Kuhyŏn Subsynthem (Matsushita, 1941, in Asano *et al*, 1967) and in the upper part of the Sadang'u Group (Matsushita according to Nakamura et al, 1957, p. 7) in the NE. vicinity of Pyŏngyang, N. Korea.

PALEOZOIC ERATHEM

Josŏn Synthem

The Josŏn Synthem (Cambrian-M. Ordovician) unconformably overlies the Sangwŏn Synthem or other Precambrian rocks. The upper boundary of this Synthem is the disconformity representing the late Ordovician- early Carboniferous hiatus that forms a very conspicuous stratigraphic boundary in Korea- N. Chinese region.

The Josŏn Synthem is composed of limestone, dolomite, shale, and sandstone, and yields trilobites. brachiopods, gastropods, and pelecypods. Nautiloids and conodonts are locally abundant in the Ordovician strata. Fossils are generally so scanty that most proposed biozones based on them are only in preliminary from. Deformation combined with very slight metamorphism has hampered the stratigraphic reconstruction of the Josŏn Synthem.

Dividing the Synthem into the Cambrian and the Ordovician Systems based on its fossils is the only regional stratigraphic boundary possible to recognize within the Synthem throughout its extent over the Korean areas of its distribution. The Synthem consists generally of alternating carbonate and clastic strata but predominantly of carbonates. The Synthem is generally divided into two lithostratigraphic units: the basal clastics (Yangdŏk Group) and the remainder ("Great Limestone" Group). No unconformities have been found within the Synthem.

The lowest fossiliferous sequence of the Josŏn Synthem in Korea is found in Munsanri area, N. Korea, i. e., near the border of Junghwagun, Pyŏngannam-do and Hwangju-gun, Hwanghae-do on the basis of which the (basal Cambrian) Munsanri Stage is recognized. The type Munsanri Stage is overlain by "*Redlichia* shale" and disconformably underlain by the Kuhyŏn Subsynthem.

The Munsanri Stage is divided into the upper part(quartzite), about 150m thick, and the lower part(shale), 10m or thicker. Kuhyŏn rocks are locally found as pebbles in the the base of the Stage. The shale yielded species of *Obolopsis, Hyolithes, Lusatiops,* and *Aluta* (Kobayashi, 1966, p. 218). These are endemic species not allowing interregional correlation. But, it is certain that they are older than the age of *Redlichia* (early Cambrian). The Munsanri Stage occurs limitedly; otherwise its equevalent is an unfossiliferous quartzitic facies.

There are two major distributions of the Josŏn Synthem: one in Kangwŏn-do, S. Korea, and the other in Pyŏngannam-do, N. Korea. The Daegi-Dongjŏm area in Kangwŏn-do has been most studied and has the following lithostratigraphic sequence.

Table 3

Lower and Middle Ordovician	Duwibong Fm.	Limestone	50m
	Jikunsan Fm.	Shale	40m
	Makgol Fm.	Limestone	300m
	Dumugol Fm.	Shale, limestone	150m
	Dongjŏm Fm.	Sandstone	40m
Cambrian	Hwajŏl Fm.	Limestone, shale, sandstone	200m
	Sesong Fm.	Shale	50m
	Daegi Fm.	Limestone	300m
	Myobong Fm.	Shale	150m
	Jangsan Fm.	Sandstone (pebbly)	150m
		Total thickness	1,430m

Redlichia saitoi was collected from both the Myobong Formation and the "*Redlichia* shale" above mentioned. Although, at present there is no way to know what part of the Jangsan Formation corresponds to the Munsanri Stage, it appears certain that the Josŏn Synthem in general ranges down to the very lower part of the Cambrian System.

The type Dumugol Formation yielded Tremadocian and Arenigian megafauna according to T. Kobayashi (1966a), but yielded only Arenigian conodonts according to Lee and Lee (1971). In any case the base of the Dongjŏm quartzite is the most reasonable boundary in this area between the Cambrian and the Ordovician Systems if we adopt the base of the Tremadocian as the base of the Ordovician System.

The Jikunsan and the Duwibong Formations are locally quite fossiliferous in contrast to the largely barren Makgol Formation. According to T. Kobayashi (1966a), fossils from these formations include genera of the Black-Riverian and the Trentonian Stages of N. America, the Llandeilian and the Caradocian Stages of western Europe, and Toufangian Series of N. China. As the boundary between the Llandeilian and the Caradocian is regarded as the boundary between the Middle and the Late Ordovician Epochs, the top of the Josŏn Synthem is as young as the last of the Middle Ordovician Epoch or even as the early Late Ordovician Epoch.

In northern Korea and China, the Sangwŏn and the Josŏn Synthems form a distinct mega-unit showing a certain unity in distribution, degree of deformation, and also in lithofacies. Therefore, this unit was called the Naknang System (Nakamura, 1927). In view of the fact that the Naknang is bounded by profound regional unconformities it should be called the Naknang Supersynthem. A.W. Grabau was once of the view that the scope of the Paleozoic might include his Sinian (Sangwŏn Synthem) (Asano *et al*, 1967. . 88).

Pyŏngan Synthem

The Pyŏngan Synthem (upper Carboniferous-Permian) is bounded by a disconformity between it and the underlying Josŏn Synthem, and above by an angular unconformity between it and the overlying Daedong (U. Triassic -L. Jurassic) Synthem representing the Songrim orogeny.

The Pyŏngan Synthem is composed of shale, sandstone, limestone, conglomerate, chert and coal (anthracite). The sequence generally coarsens upward and shows a steady regressive facies succession. Its major distributions are in Pyŏngannam-do and Kangwŏn-do like those of the Josŏn Synthem, where both Synthems show closely parallel distribution.

In Pyŏngyang coalfield (the type area of the Synthem), the Synthem is subdivided (in descending order) as follows (Nakamura, 1957).

Table 4

Taejawŏn Formation (500m+)	Light gray ss. ……………………100m Red shale and ss. …………200+m Ss. and variegated shale with basal conglomerate ……… ……………… ….. 150-200m
Kobangsan Formation (500m)	Variegated sh., gray sh. and whitish quartzose sandstone sometimes with small pebbles of quartzite. Gray shales yield rich flora including *Gigantopteris* and *Lobatannularia*.
Sadong Formation (350m)	Upper Member (200m) Dark gray sh. and gray ss. with major coal seams. This member yields very copious flora with abundant "Arcto-Permo-Carboniferous" elements such as *Callipteris*, *Lepidodendron*, *Sigillaria*, *Stigmaria*, *Calamites*, *Odontopteris*, etc. Lower Member (150m) Dark gray sh., ss., ls., and chert. Fusulinids including *Pseudoschwagerina*, *Triticites*, *Fusulina*, and *Fusulinella*, brachiopods including *Productus*, corals, gastropods, and land plants including *Neuropteris pseudovata* were yielded.
Hongjŏm Formation (250m)	Reddish or greenish sh., light gray ls., and chert. Fusulinids including *Fusulina*, *Fusulinella*, *Profusulinella*, *Pseudowedekindellina*, *Aljutovella* occur. (The latter two are the basal Moscovian genera.) Brachiopods (*Productus*, *Spirifer*, etc.), corals, gastropods, and land plants (*Neuropteris gigantea* etc.) were yielded.

Although there are local exceptions, this classification is so far the best plan for subdividing the whole Pyŏngan Synthem in Korea. The Hongjŏm is a marine facies. The lower member of the Sadong Formation is a mixed facies. The rest is terrestrial. The Hongjŏm is characterized by the variegated red rock color. The Sadong is characterized by the dark gray rock color due to carbon pigments and by the important anthracite beds in its upper member. The Kobangsan is characterized by the whitish quartzite member at its base. The Taejawŏn is characterized by the distinctly green and red rock colors.

Formerly, the Synthem was believed to range up to the Early Triassic age. But, a recent concensus is that its top is very close to that of the Permian System. The Taejawŏn Formation is barren, but its correlative in South China reportedly yielded Late Permian fusulinids, ammonites, etc. No positive Triassic fossil has ever been found in this Synthem.

MESOZOIC ERATHEM

There is no record of orogenies during the

Table 5 Correlation of Permo-Carboniferous stratigraphic units in Korea and N. China.

CHRONOSTRATIGRAPHIC UNITS (& Fusulinid zones)		NORTH CHINA	KOREA	LITHOSTRATIGRAPHIC UNITS & Fusulinid zones: Pyŏngyang coalfield (N. Korea)	Yŏngwŏl coalfied (S. Korea)	Samchŏk coalfield (S. Korea)
PERMIAN		SHIHCHIENFENG SERIES (400m+) ss. sh.	TAEJAWŎN SERIES (GREEN SER.)	Taejawŏn Formation ss. sh. cg. (650m+)		Donggo Formation ss. cg. sh. (500m+)
PERMIAN		SHIHOTSE SERIES (400m) ss. sh.	KOBANGSAN SERIES	Kobangsan Formation (500m) sh. ss. cg.		Kohan Fm. (80m) sh. ss. Dosagok Fm. (230m) ss. cg. sh. Hambaek Fm. (250m) ss. sh.
PERMIAN		SHANSI SERIES (70m) sh. ss. coal	SADONG SERIES UPPER	Sadong Formation Upper (200m) sh. ss. coal	Mitan Formation sh. ss. coal	Jangsŏng Formation (110m) sh. ss. coal. (hiatus?)
	URALIAN	TAIYUAN SER. (100m) ss. sh. ls. *Pseudoschwag. Z.* *Triticites Z.*	SADONG SERIES LOWER	Sadong Formation Lower (150m) sh. ss. ls. *Pseudoschwagerina Z* *Triticites Z.?*	Bamchi Fm. *Pseudoschwag. Z.*	Kŭmchŏn Fm. (120m) sh. ss. ls. chert
CARBONIFEROUS	MOSCOVIAN	PENCHI SERIES (200m~20m) sh. ss. ls. *Fusulina-Fusulinella Zone*	HONGJŎM SERIES	Hongjŏm Formation (250m) sh. ls. chert *Fusulina-Fusulinella Zone*	Pangyo Fm. *Fusulina-Fusulinella Zone*	*Fusulina-Fusulinella Zone*
CARBONIFEROUS	MOSCOVIAN	*Eostaffella subsolana Zone*	HONGJŎM SERIES	*Profusulinella-Pseudowedekindellina Zone*	(basal cg.)	*Eostaffella subsolana Zone*
		hiatus				

Sangwŏn (Sinian, s. lat.) time and the Paleozoic Era in Korea and North China. There are several conglomeratic horizons in the Permian Kobangsan and Greenstone Seires particularly in southern Korea but these are related to orogeny in the Japanese area. The Mesozoic Era, on the contrary, is the time of a continual tectogenesis in East Asia. The Mesozoic synthems in Korea are bounded by unconformities caused by orogenies, severe vertical tectonics, and associated igneous activities. The widespread Mesozoic emergence of Korea and China, and the related great volume of continental sedimentary and volcanic deposits are notable.

Daedong Synthem

The boundary between the Pyŏngan and the Daedong Synthems is an angular unconformity representing the Early and Middle Triassic hiatus in Korea. The Songrim disturbance (Kobayashi, 1930) that produced this unconformity is an early major phase of the Mesozoic tectogenesis in Korea. The Songrim disturbance must have started at the beginning of the Triassic Period if the deposition of the Pyŏngan Synthem was terminated due to the earliest effect of that movement. In Japan, the equivalent movement of the Songrim orogeny is called the Akiyoshi orogeny which had its paroxism in mid-Triassic time (Takai *et al*, 1963,

p. 77).

The Songrim orogeny was accompanied by granite intrusions that are radiometrically dated by Masaytis (1962) and Polevaya *et al* (1961) as ranging 224–181 m.y. B.P. (earliest Triassic to mid-Liassic) but are largely concentrated within the range of the early to middle Triassic span. It is difficult to know when the paroxismal stage of the Songrim disturbance occurred in Korea, but its Middle Triassic age is obvious as the Daedong Synthem, nonmarine molasse-type deposits, began to accumulate during early Late Triassic time.

The Daedong Synthem is distributed in Nampo, Kimpo, Mungyŏng, Yŏngwŏl, and Pyŏngyang areas. The Daedong Synthem in Nampo area, Chungchŏngnam-do, S. Korea, is so far known to have the most complete sequence and to represent the earliest and the latest times of the deposition of the Daedong Synthem in Korea. The Synthem in Nampo area is subdivided as follows (in descending order) (Shimamura, 1931; Son *et al*, 1967).

Sŏngjuri Fm.……sandstone, shale	…………600m
Baekunsa Fm.……shale (anthracite, plant fossils)	………650m
Kaehwari Conglomerate Fm.	……………70m
Amisan Fm.……shale, sandstone (anthracite, plant fossils)	……………750m
Wŏlmyŏngsan conglomerate Fm.	…………350+m
Table 6	Total thickness 2420+m

At least two sedimentary cycles commencing with basal conglomerate formations (e. g. the wŏlmyŏngsan and the Kaehwari Conglomerate Formations) are recognized in this sequence. They correspond to the post-or late orogenic phases of the Songrim orogeny.

The Tongjin Formation, about 800m thick, is the lower part of the Daedong Synthem in Kimpo area, near Seoul. This Formation is notable because it yielded from its upper part Estherian species, *Cycloestheroides coreanica* and *Euestheria kawasakii*, both of which occur in the upper part of the the upper Carnian Yamanoi Formation in Asa area, Yamaguchi Prefecture, SW. Japan. The plant fossils contained in the Tongjin Formation are much in common with both the Amisan and the Baekunsa Formations. Therefore, the lower part of the Daedong Synthem in the Nampo and the Kimpo areas is assigned a Carnian age.

In Japan, a great mid-Liassic (mid-Pliensbachian) floral change (from *Dictyophyllum* to *Onychiopsis* suites) has been recognized; the flora preceding this change is called the Rhaeto-Liassic flora. E. Takahashi (1973) noted the following plant species of the Daedong Synthem in the Mungyŏng, Yŏngwŏl, and Pyŏngyang areas which are younger than the Rhaeto-Liassic elements: *Coniopteris hymenophylloides, Eboracia lobifolia, Cladophlebis argutula, Nilssonia nipponensis, Pterophyllum propinquum, Podozamites reinii, Xenoxylon latiporosum*, etc. He tentatively allocated the lower and the upper parts of the Daedong Synthem in the Pyŏngyang area to the upper Liassic and the Dogger, respectively. Apparently the maximum age range of the Daedong Synthem is from late Triassic to Liassic or even possively to early middle Jurassic. It must be noted that accumulation of the Daedong Synthem both began and ceased earlier in one basin and later in another basin.

Kyŏngsang Synthem

In Korea, the Cretaceous and younger strata are gently folded and distributed very differently from the older strata which are strongly folded due to the Daebo orogeny (E. Konno, 1928), the middle and late Jurassic paroxismal phase of the Mesozoic tectogenesis. Since the earliest part of the Kyŏngsang Synthem is of earliest Cretaceous age (see below) and the latest part of the Daedong Synthem is of early middle Jurassic age, the

Daebo orogeny must have occurred within the range of the middle and late Jurassic Epochs. The K-Ar datings of the Jurassic granites in Korea ("Daebo granite") are distinctly within the range of 170–150 m.y. B.P. (Middle Jurassic-early Late Jurassic) with very minor scattered exceptions (Kim, 1971; Polevaya, 1961).

The Daebo orogeny was the greatest crustal movement in Korea since the Sangwŏn (Sinian, s.l.) time. The associated Daebo granite is more extensively distributed in southern Korea, i.e. in the Okchŏn (tectonic) zone, than in northern Korea. The "schistose granite" widely distributed in Jŏnla-Do is obviously a part of the Daebo granite as disclosed by radiometric datings; the gneissosity of the "schistose granite" was resulted from syn-orogenic emplacements. In the Nampo area, the basal part of the Daedong Synthem was migmatized during the Daebo orogeny.

A major sedimentary basin, Kyŏngsang basin, had its center in southeastern Korea, where three subbasins are recognized, namely, the Nakdong, the Sinla, and the Yŏngyang subbasins. The Kyŏngsang Synthem is a major unconformity-bounded unit consisting in Korea of non-marine sedimentary and volcanic layers of about the whole span of the cretaceous system. In the southeastern Korea, this synthem is subdivided in ascending order into the Sindong, the Hayang, and the Yuchŏn Groups, respectively corresponding to three sedimentary-volcanic phases of the development of the Kyŏngsang Synthem in the Kyŏngsang basin: namely, (1) pre-volcanic, (2) sparsely volcanic, and (3) climactic volcanic. The generalized significant features of each groups are tabulated as follows.

Table 7

	Stratigraphic units		Thickness	Sedimentary rocks	Volcanic rocks
Silla (← Former boundary)	Yuchŏn Group	Yŏngnam Supergroup	2000m or more	Minor amount of volcaniclastic cg. ss. sh.	Enormous amount of lava and pyroclastics. above: rhyolite, dacite below: andesite
Silla	Hayang Group	Yŏngnam Supergroup	Maximum 5300m	Abundant non-volcanic and volcaniclastic sh. ss. cg. (ls.)	Sparse volcanic layers (basalt and andesite)
Nakdong	Sindong Group		Maximum 3500m	non-volcanic ss. cg. sh. (ls.)	No volcanics

	Main loci of deposition and emplacement	Basin development	Volcanic history
Yuchŏn group	Sinla subbasin	End was marked by intrusion of Bulguksa granite. Climactic volcanism.	Late phase: acidic pyroclastics dominated. Early phase: intermediate lava dominated.

Hayang Group	Kyŏngsang basin	Eastward extension of Kyŏngsang basin (births of Sinla & Yŏngyang subbasins)	Intermittent volcanisms (basic to intermediate lava) in sedimentary basin. Volcanism starts.
Sindong Group	Nakdong subbasin	Local subsidence of an elongated piebmont basin (Nakdong subbasin)	No volcanisms in sed. basins and near-by source area

Table 7 cont'd.

	Sedimentary tectonics
Yuchŏn Group / Hayang Group	Laterally discontinuous lithologic bodies, highly variable lithofacies change, differential subsidence between blocks, abrupt differential sedimentation, highly variable paleocurrents, unstable depositional sites, etc.
Sindong Group	Relatively stable.

Table 7 cont'd

	Depositional environment
Yuchŏn Group	Local fluvial sedimentations in volcanic piedmont (interlayered volcanics and conglomerate), floodplain (redbeds), and ponds (gray sh. and marl).
Hayang Group	Lake (massive mudstones) and floodplain (red sh.) (medium gray or dark greenish gray sandstone and shale of great thickness are lacustrine.)
Sindong Group	Piedmont (boulder cg.), floodplain (red sh. and fine-grained and bedded ss.), and swamp (coaly sh. and marl).

Table 7 cont'd

	Fossils and geologic age
Yuchŏn Group (upper Cretac.)	K-Ar age of Bulguksa granite that intruded at the termination of Kyŏngsang deposition ranges 68 to 88 m.y. B.P.; never younger than the end of the Cretaceous.
Hayang Group (upper Cretaceous)	Crustacea *Euestheria kyongsangensis medialis* *E. kyongsangensis pausilineata* Mollusca *Thiara (Siragimelania) tateiwai* *T. (S.) japonica* *Trigonioides pausisulcatus pausisulcatus* *T. matsumotoi*, *Nipponоnaia (?) obsoleta* Vascular plants correlated with Gyliak flora (Cenomanian-Turonian based on ammonites) and "Late Cretaceous" Asuwa flora in Japan
Sindong group (lower Cretaceous)	Crustacea *Estherites imamurai* *Euestheria kokurensis* *E. kyongsangensis* *Palaeolimnadiopsis kantoensis* *Sinoestheria tsaidamensis* *Bairdestheria hungshuikouensis* Mollusca *Viviparus (Sinotaia ?) onogoensis* *Brotiopsis wakinoensis* *Corbicula coreanica* *Nakamuranaia chingshanensis* *Plicatounio naktongensis* *Trigonioides kodairai* *Nipponоnaia wakinoensis* Vascular plants correlated with Ryoseki flora in Japan. Geologic age Common molluscan fauna supports correlation with Wakino Subgroup (inner belt of SW. Japan) and Ryoseki Group (outer belt of SW. Japan).

The Ryoseki Group conformably overlies marine beds bearing Tithonian ammonites.

Table 7 cont'd

The Sindong Group is a post-orogenic deposit, the source area to the northeast being the Okchŏn orogen that was intermittently uplifting during the Sindong sedimentation. Its distribution is confined to the Nakdong subbasin, an elongated intermontane sedimentary trough in the western part of the Kyŏngsang basin. The boundary between the Sindong and the Hayang Groups is a facies boundary between the "black shale"-dominant Jinju (Dongmyeong) and the red-banded Chilgok Formations, and is visible only in the western part of the Kyŏngsang basin.

The Hayang Group is characterized by sparsely distributed volcanic layers (lava and tuff) and consists mostly of clastics. During the time of the Chilgok Formation volcanism started in the Kyŏngsang basin concomitantly with the births of the Sinla and the Yŏngyang subbasins in which unstable sedimentations with shifting facies variations started to take place. In the Nakdong subbasin the Hayang Group gradually deposited on the Sindong Group. But, in the other parts of the Kyŏngsang basin, the basal part of the Hayang Group unconformably overlies the gneiss and granite of older ages. The base of the Hayang Group marks a significant stratigraphic boundary.

The division into the former Nakdong (Rakudo) and the Silra (Shiragi) Groups since Tateiwa (1929) is possible in the limited area where the Sinla Conglomerate Formation and its approximate equivalent occur. But the division into the Sindong and the Hayang Groups works throughout the whole Kyŏngsang basin.

The Yuchŏn Group is the upper part of the Kyŏngsang Synthem, occurring only in the Sinla subbasin, and composed dominantly of volcanic layers (intermediate to acidic lavas, acidic tuff and ash-flow tuff) and subordinately of the associated sedimentary rocks. The base of the Yuchŏn Group is marked in many places by local unconformities and shows in some places an intertonguing relationship with the underlying Hayang Group. It is evident that the base of the Yuchŏn Group is highly heterochronous. To differentiate between the Hayang and the Yuchŏn Groups is very difficult when they are intertonguing each other as in the vicinities of Daegu and when the Yuchŏn Group contains abundant sedimentary rocks as in the eastern vicinity of Namhae.

It is therefore justified that the Hayang and the Yuchŏn Groups constitute the Yŏngnam Supergroup which in the Kyŏngsang basin (the type area of the Supergroup) is a syn-volcanic deposit. Actually the Yŏngnam Supergroup in many parts of Korea directly overlies the pre-Kyŏngsang basement.

Tateiwa's (1924) Bukkokuji (meaning Bulguksa) "Series" consists of the granitic and associated hypabyssal rocks (here called the Bulguksa igneous group) and also rhyolitic rocks. Both are apparently comagmatic and generally occupy the same emplacement loci. Regardless of their genetic association, the volcanic component has here been incorporated to the Yuchŏn Group.

The volcanic sequence of the Yŏngnam Supergroup is characterized by a systematic change from basic through intermediate to acidic compositions. And, the development of the Kyŏngsang basin was terminated by the prevalent emplacements of the Bulguksa granite, an important source of ore deposits in Korea.

The moot questions of correlating the Kyŏngsang strata between sedimentary subbasins within the large Kyŏngsang basin has now been finally answered. A high, "Chŏngsong ridge", existed between the Sinla and Yŏngyang subbasins. The recognition of the Kisadong Formation of the Hayang Group (Chang, 1975) straddling over the Chŏngsong ridge was key to work out the stratal

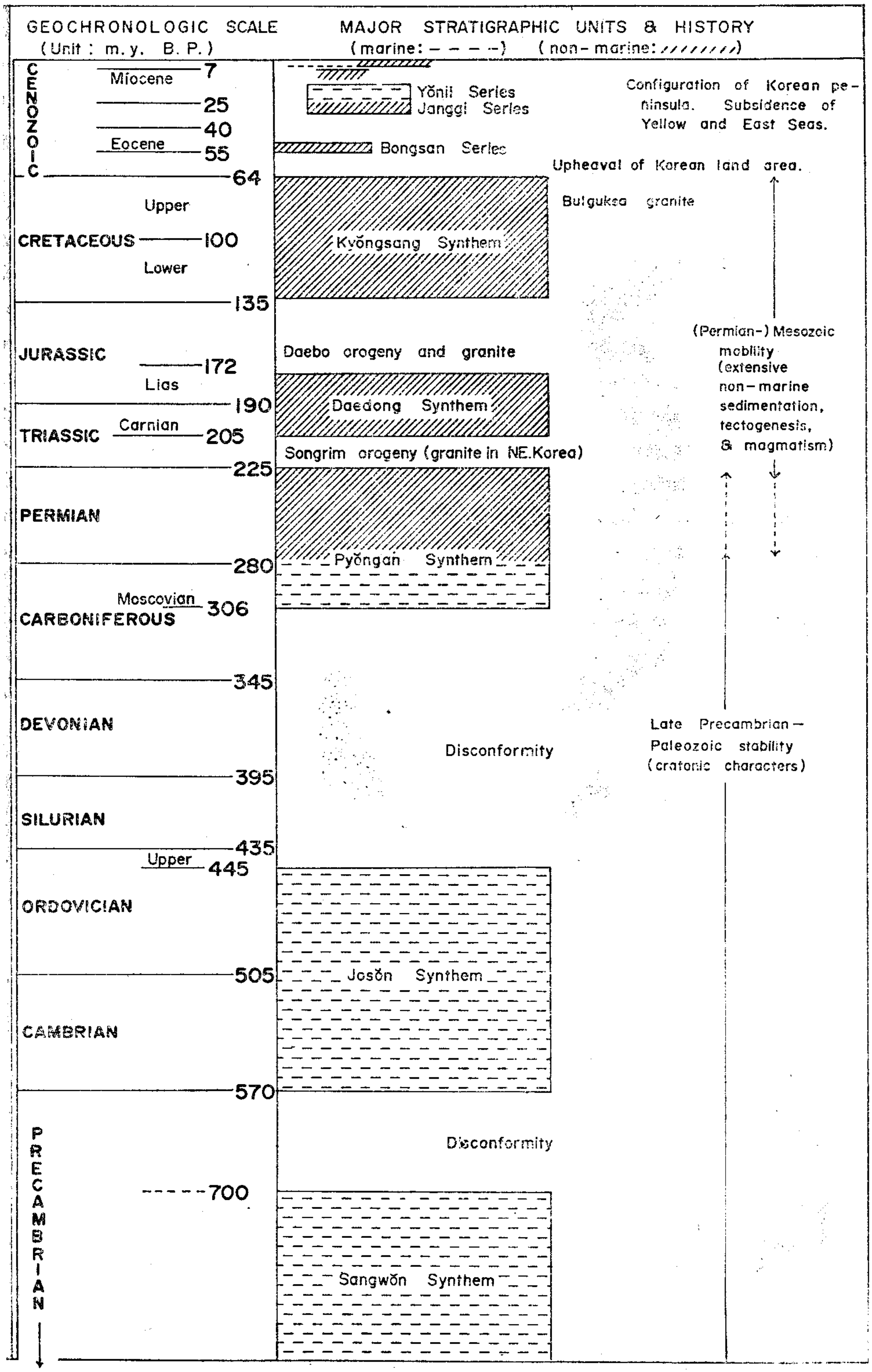

Fig. 1 Outline of the Stratigraphy of Korea

correlation between these subbasins. Likewise, the recognition of the Kumidong Formation of the Hayang Group was the key to work out stratal correlation between the Nakdong and the Sinla subbasins and between the Dopyŏng and the Milyang blocks of the Sinla subbasin (Chang, 1975).

CENOZOIC ERATHEM

Cenozoic strata are scanty in Korea denoting prevailing emergence of the Korean peninsula during the Cenozoic Era. Obviously, the early Cenozoic uplift followed the late Cretaceous emplacements of the Bulguksa granite. The Tertiary strata in Korea are scatteringly distributed only along the coasts of the Peninsula: the Miocene strata along the east coast and the Upper Eocene non-marine deposits(Takai, 1935) confined to two small areas along the west coast of northern Korea.

Extensive Cenozoic deposition has been taking place under seas surrounding the Korean peninsula. Recognizing regional unconformities dividing the Cenozoic strata in and near Korea into unconformity-bounded units will be possible when submarine records will have been restored.

The Tertiary strata distributed along the east coast of Korea are exclusively of Neogene age and are especially noteworthy because of their genetic relationship with the development of the East Sea basin and the configuration of the east coast of the Korean peninsula. As shown in table 9 the Miocene sequences consist of alternating volcanic and clastic rocks which contain copious vascular plants. Their ages are nearly exclusively within the range of the early and middle Miocene Agesas determined by floral correlation with the Miocene in Japan, the ages of which are known by means of marine fossils (Huzioka, 1972).

Table 8

	Kyŏngwŏn area, Hamgyŏngbuk-do	Kilju-myŏngchŏn area, Hamgyŏngbuk-do	Tongchŏn area Kangwŏn-do	Yŏngil bay area Kyŏngsangbuk-do
Middle Miocene	{*Kogŏnwŏn flora* sh. coal ...... unconf.	Myŏngchŏn group 1800m {ss. basalt sh. *Hamjindong flora* cg. ss. .... unconf.	{*Tongchŏn flora* cg. ss. sh. coal ...... unconf.	Yŏnil group 800m {sh. *Yŏnil flora* cg. ss. .... unconf. .... Bŏmgokni group 450m {andesite, perlite volcanic breccia .... unconf. ....
Early Miocene	{ss. sh. coal cg. trachyte, andesite. ...... unconf.	Yongdong group 1000m {basalt, ss. *Yongdong flora* ss. sh. .... unconf.		Janggi group 1700 m {basalt ss. sh. coal basalt ss. sh. coal *Kŭmgwangdong flora* andesite, trachyte cg. .... unconf. ....

According to Huzioka (1972), the floras of the Kŭmgwangdong Formation and the Yongdong Group are correlated with each other and also with the Early Miocene Aniaian flora in Japan; the Kogŏnwŏn, the Tongchŏn, and the Kungshim floras are correlated with each other and also with the early Daijiman (early middle Miocene) flora in Japan; and the Yŏnil and the Hamjindong floras are correlated with each other and also with the Late Daijiman (late middle Miocene) flora in Japan. In table 8 the early middle Miocene age of the Bŏmgokni Group is tentative. The "earliest Miocene" Ainouran of Japan has no coeval strata in Korea.

The Early Miocene and the early middle Miocene strata in Korea are largely non-Marine deposits intercalated with coal seams and volcanic rocks. The late middle Miocene strata, on the other hand, are largely marine and scarcely include volcanic rocks. According to Huzioka (1972, p. 1; p. 33), the early Miocene floras consist of woody species similar to the modern cool temperate forests of East Asia but the early middle Miocene floras in Korea show a warmer climatic condition in floral composition. This climatic change may have been caused by the invasion of the warm sea-water in the East Sea area, which in turn may have been caused by an extensive subsidence of that area.

SUMMARY

The role of unconformities in subdividing the geologic column of Korea has been conventionally regarded important. Since many of major unconformity-bounded units in Korea are recognized also in North China, their importance is virtually justified. The stratigraphy of the cratonic part of Korea except the areally minor geosynclinal parts is summarized as follows with emphasis on the stratigraphic importance of unconformities:

Cenozoic Erathem
················unconformity················
Kyŏngsang Synthem
(Cretaceous)
················unconformity················
Daedong Synthem
(U. Triassic-L. Jurassic)
················unconformity················
Pyŏngan Synthem
(U. Carboniferous-Permian)
················unconformity················
Naknang Supersynthem {
Josŏn Synthem
(Cambrian-M. Ordovician)
················unconformity················
Sangwŏn Synthem { Kuhyŏn Subsynthem
··· unconformity ·········
Haeju Subsynthem }
}
················unconformity················
Kyerim Synthem

韓半島層序概要

章　基　弘

韓國의 大單位地層들은「系」혹은「層群」으로 불리워 왔으나 廣域不整合을 그 上下面으로 하는 것이 가장 基本的인 特徵이므로 SYNTHEM(間系)이란 單位名이 適當하다. 韓半島는 그 面積의 大部分이 準剛塊的 性格을 띄고 있는데 그러한 地域에 發達된 地層을 大不整合에 基準하여 分類하면 詳原, 朝鮮, 平安, 大同 및 慶尙의 諸間系들이 認定된다. 이들 사이의 不整合들은 造山運動에 基因한 것과 造陸運動 (및 垂直造構造)에 基因한 것으로 나눌 수 있다. 詳原間系와 先詳原基盤累層(basement complex)과의 境界는 確然한 無整合(noncomformity)이다. 詳原, 朝鮮, 및 平安 間系들 사이의 不整合은 先캠브리아 永代後期 및 古生代 동안 이들이 分布하는 地殼部分이 安定을 유지하였음을 表象하는 非整合(disconformity)들이다. 平安, 大同, 및 慶尙間系들 사이의 不整合은 中生代造山運動들을 代表하는 傾斜不整合들이다. 慶尙間系 上下의 不整合들은 곳에 따라 (주라紀 中期내지 後期 및 白堊紀 末期의 花崗岩들 위의) 無整合이다.

漣川 및 摩天嶺 累層群들은 花崗岩質岩을 사이에 두고 서로 떨어져 있어 相互 關係가 直接으로 表示되어 있는 곳은 없으나, 그 變形變成의 程度와 岩質이 현저한 差異를 나타냄에 비추어 서로 時代를 달리할 可能性이 크다는 생각은 오래 전 부터 있었다. 南韓의 片麻岩類에 대한 가장 確實性있는 放射能 年齡測定値가 20億年前 內外라는 近來의 資料는 漣川累層群을 包含하는 韓半島의 最古期 基盤累層을 가장 廣域的으로 變成·花崗岩化 시킨 時期가 바로 그 때임을 意味하는 것으로 생각된다. 이에 反하여 摩天嶺累層群 發達末期 또는 直後에 貫入한 것으로 생각되는 利原火成岩群의 放射能 年齡値는 10數億年前으로 測定되어 있다. 이러한 絕對年齡資料들은 漣川累層群이 摩天嶺累層群보다 古期라는 見解를 뒷받침한다. 摩天嶺累層群의 對比層이 南韓에서는 發見되지 않는 事實은 詳原間系 또한 南韓에서 發見되지 않는다는 事實과 더불어 注目을 要한다.

詳原間系의 祠堂隅層群과 駒峴層群 사이에 있는 平行不整合은 詳原間系와 朝鮮間系 사이에 있는 平行不整合 못지않게 큰 것이나, 後者는 先캠브리아 永代層과 顯生永代層을 갈라놓는 重要한 구실때문에 重要視되어 왔다. 詳原間系는 中國의 廣意의 震旦系(Sinan)에 對比된다. 標式震旦系의 基底의 年齡은 13億年前으로 測定되어 있다. 中國 北部와 北韓에 있어서 詳原間系와 朝鮮間系는 그 分布가 흔히 並行하고 構造的으로 흡사하며 岩質에도 共通點이 많아 하나의 大單位地層(「樂浪系」)으로 간주된 일까지 있다.

朝鮮間系 基底에서 化石이 産出된 곳으로는 北韓의 文山里 附近이 있는데 이곳에서는 캠브리아紀 初期中 比較的初期의 것으로 認定되는 化石群이 産出되었다. 朝鮮間系의 層序가 比較的 잘 硏究된 곳은 江原道 大基-銅店 地方인데 이곳의 最上位層인 織雲山層 및 斗圍峰層에서는 유럽의 Llandeilian 階 및 Caradocian 階와의 共通屬으로 는 認定된 化石들이 産出되었다. Llandeilian 과 Caradocian 의 境界를 가지고 오르드뷔스紀의 中部와 上部의 境界를 삼 慣例에 따르면 朝鮮間系는 그 時代가 캠브리아紀와 오르드뷔스紀 中期(後期의 前期에까지 ?) 걸친다고 보게된다

朝鮮間系가 여러번의 海浸과 海退를 反影하고 있음에 反하여 平安間系는 하나의 큰 海退形斷面을 이룬다. 朝鮮間系의 岩質地層單位들이 局地的임에 反하여 平安間系의 紅店, 寺洞, 高坊山, 및 綠岩의 諸層들은 널리 認定되며 時間地層單位로도 使用이 可能하다. 紅店層 혹은 紅店統은 海棲化石을 多産하는데 이들은 本層의 堆積이 石炭紀 Moscovian 階 初에 始作되었음을 가리킨다. 綠岩統 혹은 太子院統은 化石이 極히 希貴하여 時代決定이 어려우나, 中國南部에 있어서는 그 對比層에 海成層이 협제되어 있고 페름紀 後期의 標準化石들이 産出되었다. 平安間系가 三疊系의 一部를 包含한다는 증거는 發見되지 않는다.

先캠브리아後期와 古生代 동안 韓半島와 中國北部에는 造山運動이 없었으나 中生代에는 이곳에 여러번의 變動期가 있었고 韓半島에는 두번의 絕頂期가 있었다. 平安間系는 三疊紀 前半期間에 있은 松林造山運動으로 因하여 褶曲되었으며 半島北東部에는 造山運動에 수반된 花崗岩 貫入이 있었다. 그 放射能 年齡値는 2億2千萬年 내지 1億8千萬年 前이나 測定値의 大多數는 三疊紀 前半期에 集中된다.

松林運動은 南韓보다 北韓에서 격렬하였으나 주라紀의 大寶造山運動은 北韓보다 南韓에서 偉勢를 떨쳤던 것으로 나타난다. 大寶運動에 수반된 花崗岩의 放射能年齡値는 1億7千萬年 내지 1億5千萬年前(주라紀中期 내지 後期의 初期)이다. 大同間系는 松林運動以後 大寶運動以前 期間中에 堆積된 地層이다. 大寶運動 以後 白堊紀 동안에 걸쳐 慶尙間系가 堆積되었다. 韓半島에 있어서 페름系와 中生代層은 沃川流動帶의 地層을 除外하고는 모두가 陸成層이다.

慶尙間系의 堆積後期에는 堆積盆地에 대규모의 火山岩噴出이 있었고 이어 (白堊紀末에는) 대규모의 花崗岩 貫入이 있었다. 이어 (新生代初에는) 堆積盆地의 消滅을 가져온 地盤의 隆起運動이 일어났는데 東海와 黃海의 沈降運動, 따라서 半島의 形成은, 이와 同時이거나 後續한 現象일 것이다. 中新世層이 東海岸을 따라 分布함을 보아 中新世末에 半島의 傾動運動과 同時에 東海의 加速的 沈降이 있었던 것으로 생각된다.

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