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Summary of the Geology of South Korea

1. GEOLOGICAL PROVINCES OF SOUTH KOREA

Tectonics of South Korea was elaborated by T. Kobayashi (1953) and later revised by O. J. Kim (1970). South Korea is geologically bound to North Korea by the Chugaryeong rift valley of N–NE trend.

The Ogcheon geosynclinal zone (orogenic zone) runs diagonally in NE–SW direction as the Sinian direction across South Korea having breath of 60–70 km in the mid-central region. The Gyeonggi massif is situated to the northwest side of and the Yeongnam massif to the south-east side of Ogcheon zone. To the southeast of the Yeongnam massif is there the Gyeorgsang sedimentary basin which connects to the south-western parts of the Ogcheon zone around the southwestern tip of Korea Peninsula. Few Tertiary sediments crop out in few isolated areas (see Fig. 2).

On the basis of tectonics and geology, South Korea can be divided into four geological provinces and their major geology are summarized as follows;

Gyeonggi massif – – – Rocks of the Precambrian Yeonchon system, as well as the Younger Jangrak and Chunsong groups and the associated granite gneisses are widely distributed in the Gyeonggi massif. The Mesozoic Daebo granite is widespread across the Peninsula in the Sinian directon.

Yeognam massif – – – The Precambrian Yeongnam aond Yulri Systems, granite gneisses, and Mesozoic Daebo granite are widespread. The Daebo granite is aligned in the Sinian direction, but not so clearly as in the Gyeonggi massif.

Ogcheon geosynclinal zone – – – This geosynclinal zone is within the Gyeonggi–Yeongnam massif. Paleozoic to Mesozoic sedimentary formations are distributed in the northeasten neogeosynclinal zone, and the Precambrian Ogcheon system is present in th southwestern paleogeosynclinal zone. The Jurassic Daebo and late Cretaceous Bulgugsa granites are scattered in both zones.

Gyeongsang sedimentary basin – – – Cretaceous terr estial sedimentary formations associated volcanic flows and tuffs are present, and the late Cretaceous and pale-

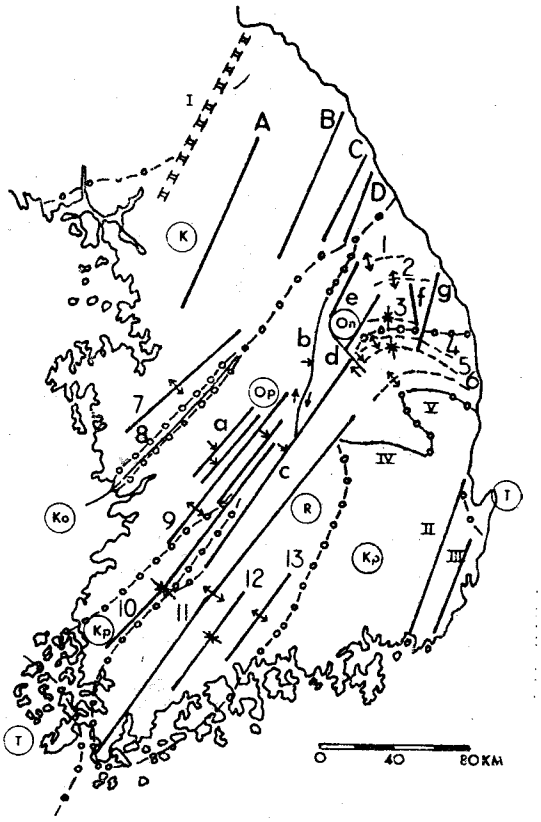

FIG. 1–Geologic provinces and tectonic map of South Korea.

Provinces (circled letters): *K*, Kyonggi land; *R*, Ryongnam land; *Op*, Okchon paleogeosynclinal zone; *On*, Okchon neogeosynclinal zone; *Kp*, Kyongsang proper basin; *Ko*, Kyongsang trough in Okchon zone; *T*, Tertiary basins.

Pre-Triassic faults: *A*, Pyunggang fault; *B*, Inje fault; *C*, Hyonri fault; *D*, Changchon fault.

Triassic deformation: *1*, Jongson syncline; *2*, Jungbongsan anticline; *3*, Hambaek syncline; *4*, Sobaeksan anticline; *5*, Yulri syncline; *6*, Andong anticline.

Jurassic deformation: *7*, Charyong anticline; *8*, Kongju syncline; *9*, Okchon anticline; *10*, Yongdong syncline; *11*, Dukyusan anticline; *12*, Kure syncline; *13*, Jirisan anticline; *a*, Okchon thrust; *b*, Bonghwajae thrust; *c*, Jomchon thrust; *d*, Danyang fault; *e*, Pyongchang fault; *f*, Samchok fault; *g*, Osipchon fault.

Cretaceous-Tertiary deformation: *I*, Chugaryong rift; *II*, Yangsan fault; *III*, Tongrae fault; *IV*, Andong thrust; *V*, Ilwolsan thrust.

* This paper was prepared for the participants of the 7 th meeting of IGCP/CPPP in Korea, 1977, compiled by the organizing committee and KIGAM

ogene Bulgugsa granite intrudes randomly into the sedimentary rocks in the basin.

Tertiary basins - - - Neogene sedimentary formations and the associated basaltic flows and tuffs are present in the small Tertiary basins and in Cheju Island off the south end of the Peninsula. Granites also crop out there, and some has been dated as paleogene granites.

II. SUMMARY OF THE GEOLOGY OF SOUTH KOREA

1. General Stratigraphy

The geology of South Korea is relatively well understood except Precambrian stratigraphy.

Professor C. H. Cheong (1956) had summarized the geological sequences of Korea from the data available done by many previous geologists. The sequences thus assimilated has been standard and is generally being accepted until very recent. Professor O. J. Kim in collaboration with his colleagues and assistants has been very intensively studying on the Precambrian stratigraphy and the Mesozoic granites (it has been known in Korea as younger Granites).

He established the Precambrian stratigraphy (some of them is under till debate!) and differentiated the gran ites into Jurassic and Cretaceous ones although all younger granites were previously considered to be Cretaceous in age (Refer to the attached geologic map Fig. 2). Recently Professor Y. J. Lee (1976) has dated the Tertiary granite which was predicted many years ago to exist in S. Korea by O. J. Kim.

It must also be mentioned that the undifferentiated "Granite Gneiss System" was misused previously as a general term compromising granite gneisses known as "Gogurian granite" of Precambrian age.

Recently two granite gneisses of middle and late Precambrian age were identified and many Precambrian schist formations were differentiated which were previously thought to be the granite gneiss. These facts were the basis of establishing precambrian stratigraphy.

The geological sequence of South Korea which was summarized by prof. C. H. Cheong and O. J. Kim is tabulated in table 1. The most controversial problem among geological sequences of S. Korea has been concentrated in the Ogcheon System. The system was originally thought to be Precambrian (Nakamura. 1923), but later was considered to be metamorphosed Paleozoic and/or Mesozic formations by many workers. Professor O. J. Kim (1968) has, however, reiterated that the Ogcheon system belonged to the late precambrian which has been supported by many geologist since then.

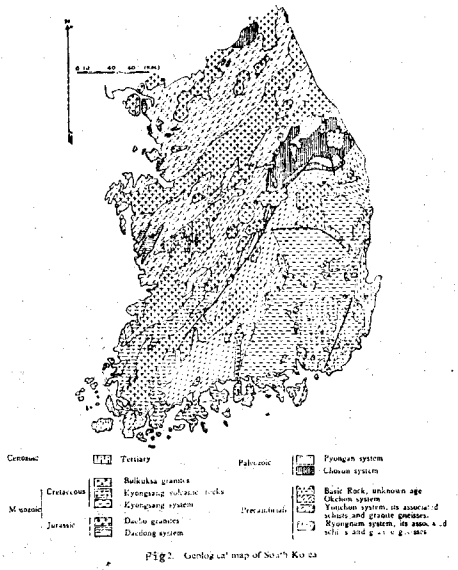

Fig 2. Geological map of South Korea

2. Precambrian Geology

a. Geology

The Precambrian geology of South Korea has not been well studied so as to formulate it in a way that all the Precambrian students can agree. There are, at present, many discrpancies in opinion in regard to the stratigraphy, age and geological structure, yet nobody has ever described it systematically except few short articles and oral discussions. It must be mentioned that the following descriptions on the Precambrian geology are strictly of personal opinion of O. J. Kim, so that thet they are not only standard ones all Precambrian students in Korea will agree, but also some parts would even be denied by other students.

b. Gyenggi-Yeongnam Province

The province was previously separated, but now grouped together because of the fact that (1) the Gyeonggi and Yeongnam massifs are located in opposite side of the Ogcheon zone, (2) the geology and tectonics of both massifs are similar and can roughly be correlated, and (3) the massifs acted as a basement of the Ogcheon geosyncline.

Prominent in the province are Precambrian schists and

Tab. 1. The Geological sequence of South Korea

Age		System	Series
Cenozoic		Quaternary	basalts
		Tertiary	Yeonil
			Janggi
			granites (Bulgugsa granites) volcanics
Mesozoic	Cretaceous	Gyeongsang	Silla
			Nakdong
			Granites (Daebo granites)
	Jurassic	Daedong	Chungnam, Dansan, Bansong
	Triassic	Pyeongan	Nokam
Paleozoic	Permian		Kobangsan
	Carboniferous		Sadoog
			Hongjom
	Devonian		absent
	Silurian		
	Ordovician	Chosun	Great Limestone
	Cambrian		Yangdeok

Late Precambrian	Sangwon system (in North Korea)	Ogcheon System	Kunjasan	
			Hwanggangri	
			Changri	
			Munjuri	
			Hyangsanri	
	granite gneiss		?	granite gneiss
Mid to late Precambrian	Chunchon system: Chungsung group		Kemyongsan	Yulri system: Taebaeksan
				granite gneiss
	Jangraksan group			Kosonri
				Kakhwasa
	Granite gneiss			granite gneiss
Early to middle Precambrian	Yonchon system: Yangpyong complex			Ryongnam system: Wonnam
				Kisong
	Sihung complex			
	Puchon complex			Pyonghae

paragneisses; which were intrude by Precambrian granite gneisses and Jurassic Daebo granites.

1) Gyeonggi Massif

In the southwestern half the Gyeonggi massif (plate 1), a north-western half, Precambrian formations are differerentiated into the Yeoncheon System and the Chuncheon System (O. J. Kim, 1973).

Yeoncheon System is overlain unconformably by the Chuncheon System. Both Systems are highly metamorphosed and show generally amphibolite facies and metasomatized in parts.

These systems are differentiated as follows:

Granite gneiss

Late Precambrian

Chuncheon System { Chunsong Group / Jangrak Group

~~~~~granite gneiss, unconformity~~~~~

Early - middle Precambrian

Yeoncheon System { Yangpyeong Group / Sihung Group / Bucheon Group

The Precambrian geology in the northeastern parts of the Gyeonggi massif has not been studied, but the rock unit varies considerably, yet granitic gneiss is predominant.

Yeoncheon System - - - The system is distributed in the southwestern parts of the Gyeonggi massif and extends both north-northwest and northeast from Seoul, the capital city (refer to plate 1).

The excursion to the Precambrian terrain toward Chuncheon is to inspect the system until a town of Gapyeong that is more than two third of the entire route, and the rest is going to visit the Chuncheon system. The Yeoncheon system is divided into three metamorphic complexes:

The Bucheon group, the Sihung group and the Yangpyeong group in ascending order. The Bucheon group is exposed in a low land along the west coastal area and composed mainly of biotite-quartz-feldspar schist and gneiss which are interbedded by quartzite and quartz sericite schist. The upper boundary of the group with the Sihung group is marked by the limestone bed which is discontinuous but persistant in areal distribution.

Near the upper boundary develops there a prominant graphite schist which had been and/or is being mined for the crystalline graphite.

The Sihung group is designated as to comprise all the metamorphic complex bound by the limestone bed at the base and by the Daesongri quartzite bed at the top, and is differentiated into the four subgroups; S_1 to S_4. The S_1 is composed of biotite-quartz-feldspar schists and gneiss, S_2 garnet-bearing porphyroblastic to banded biotite-quartz-feldspar schist and gneiss, S_2 banded gneiss and biotite-quartz-feldspar schist intercalated occasionally by limestone lenses, and S_4 chlorite schist which may represent a sort of retrogressive metamorphic facies of the S_3.

The Yangpyeong group is composed of the Daesongri quartzite and banded gneiss and expose in the areas along the south Han River. The structure of the Yeoncheon system is so much complicated that even a generalization is almost impossible. The foliation generally strikes north-northwest in the western side of while no rth-northeast in the eastern side of the city. Isoclinal, overturned folds are numerous and major faults are also parallel to the foliation of the Ogcheon System.

Chuncheon System - - - The system is mostly distributed overlying unconformably the Yeoncheon system in the south of Chuncheon the capital of Kangweon-do.

The system will be visited in the later course of Seoul-Chuncheon excursion. The Chuncheon System is div ided into the Jangrak group, the lower member and the Chunsong group, the upper member.

The Jangrak group consists mainly of quartzite at the base which is a ridge maker the south of Gapyeong and cut off by the Kyonggang fault at the north of Gapyeong and the upper biotite schist which is intercalated by limestone beds. The Chunsong group is differentiated into the few formations, the Euiam quartzite is well exposed in the Euiam dam site and makes a prominant ridges circling around in the south of Chuncheon. The middle augen gneiss is well exposed on the road cuts south of Chuncheon where two stops will be made. The upper banded gneiss ar d augen gneiss are mostly metasomatized by k-feldspar (mostly microcline) in the central parts of the area exposed.

The Jangrak and Euiam quartzites represent unconformities between the Yeoncheon and Chuncheon system and between the Jangrak and Chunsong and Chunsong groups respectively. These groups appear as a nearly circular basin in the south of Chuncheon although the Jangrak group is cut by the Mogok fault in the halfway around
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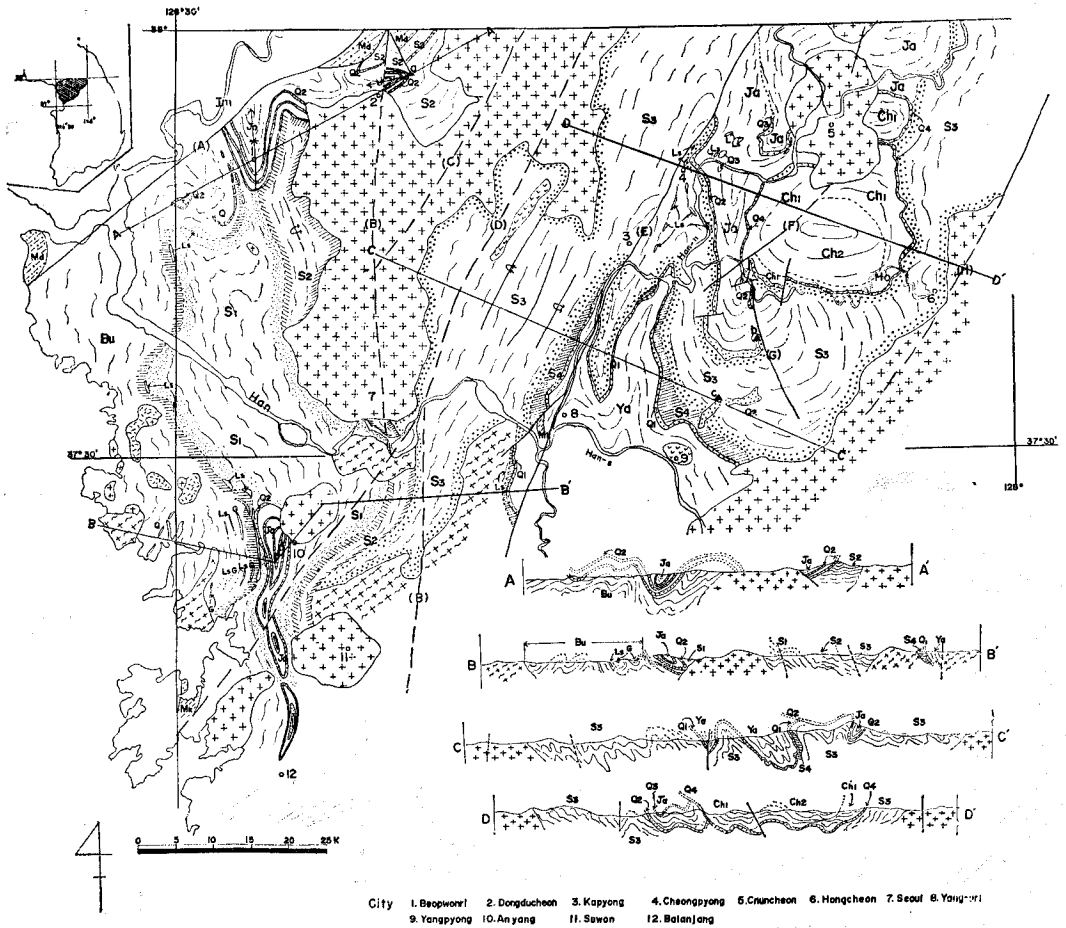
GEOLOGIC MAP OF THE NORTHWESTERN AREA OF KYONGGI MASSIF



City 1. Beopwonri 2. Dongducheon 3. Kapyong 4. Cheongpyong 5. Cruncheon 6. Hongcheon 7. Seoul 8. Yangju
9. Yangpyong 10. Anyang 11. Suwon 12. Balanjang

Mt. a. Soyosan b. Sorisan c. Yongmunsan d. Suamsan

River Im: Imjin R. Han: Han R. (-n-north Han R. -s-south Han R.) He: Hongcheon R.

Fault (A) Imjinkang f. (B) Dongducheon f. (C) Pocheon f. (D) Wangsukcheon f.
(E) Kyongkang f. (F) Bansanri f. (G) Mogok f. (H) Inje f.

REGEND

Cretaceous	Mx	Red Beds.
Jurassic — Intrusion	Jg	Deebo Granite
	My	Conglomerate, Sandstone, Slate & Anthracite Beds
Pre-Jura.	Rhyolite, partly flow	
Middle to early late Pre-Cambrian — Intrusion — Jangsan Group	Ch2	Banded Gn., Augen Gn. partly K-metasomatized
	Ch1	Chlorite Sch., Augen Gn. include Limestone lenses
	Q4	Eam Quartzite include Limestone lenses
Jangsan Group	Jb, Q3	Biotite Sch. & Quartzoic Gn. include Limestone lenses & Quartzite (Kalbongsan Qzt)
	Q2	Jangraksan Qzt. interbedded by Sericite-Qz. Sch. & occasionally banded Biot. Sch.
Age unknown — Intrusion		Gabbro & Peridotite
		Gr. Gn. Migmatite in parts
Early Pre-Cambrian — Kyonggi Metamorphic Complex — Yangpyong Group — Intrusion	Ya	Banded Gneiss
	Q1	Daesangri Quartzite
Sakhung Group	S4	Chlorite Schist
	S3	Banded Gn. & Biot-Qz-Feld Sch (occasionally include Garnet) with Limestone lenses
	S2	Garnet-bearing, porphyroblastic to banded Biot-Qz-Feld. Sch. & Gr
	S1	Biot.-Qz.-Feld Sch & Gr
Buchon Group	Ls	Limestone & Lime-Silicate
	G	Graphite Schist
	Pu	Biot-Qz.-Feld. Sch. & Gn. interbedded by Quartzite & Sericite beds

General trend of Schistosity

Fault (broken lines indicate inferred fault)

Overturned Anticline

Overturned Syncline

the basin.

2) Yeongnam Massif

In the Yeongnam massif, a southern half of the Gyeonggi-Yeongnam land, the Precambrian formations were differentiated as follows:

Mid. late Precambrian		Taebaegsan Series
	Yulri System	Gosenri Series
		Gaghwasa Series
Early-	Yeongnan System	
Mid. Precambrian		Weonnan Series
		Giseong Series
		Pyeonghae Series
	Yeongnam System	

Pyeonghae Series; The series is highly metamorphosed granitic gneisses which are intercalated within thin marble lenses, and distributed in Pyeonghae, southeastern coastal region.

Giseong Series; The series is of metavolcanics and overlies unconformably the Pyeonghae series at the north and northeast of Pyonghae.

Weonnam Series;-The series is composed, in ascending order, of the Weonnam, the Dongsugol, the Janggun limestone and the Dueumri formations and overlies unconformably the Giseong series.

The Weonnam series is composed of granitic gneisses intercalated with thin limestone lenses and biotite-quartz schist; the Dongsugol formation of phyllites; the Janggun limestone of limestone; and the Dueumri formation of phyllite and sericite schist. The Weonnam Series is distributed along the Deogyu mountain chain across diagonally the Yeongnam province.

Yulri System; The system overlies the Weonnam System uncoformably and is intruded by the granite gneiss. The system can be, in ascending order, divided into the Gaghwasa, the Goseonri, and the Taebaegsan series. The former two was differentiated by C. M. Son(1963), and the latter used to be considered synonymous with the former two series. Entirely different lithology, grade of metamorphism and structural relationship are suggestive of different formation and unconformable relationship is expected between the two formations and the upper one. The system is, as a whole, composed of chlorite schist, biotite schist, quartzite, limestone lens, and sericite-chlorite schist. Grade of metamorphism is in genrally getting weaker toward the upper formation.

Schistosities of Precambrian formations in the Yeongnam massif are diverse, but predominant is the northeast to northwest in the Yeongnam zone, which is oblique to the trend of Ogcheon geosynclinal zone and distribution of Jurassic Daebo granites, and which is probably of pre-Triassic in age.

c. Ogcheon geosynclinal zone

The zone was previously divided into the metamorphosed and nonmetamorphosed zones. It was thought that the Ogcheon System was distributed in the former zone and the non-metamorphosed Paleozoic to Mesozoic sedimentary formations in the latter zone, and both zones were originally of same formations, but show difference in a grade of metamorphism (Kobayashi 1953, C. M. Son 1969). However, the both zones are bound by upthrust and shear fault, which were not recognized by the previous workers, so that the lithology and structure are discontinuous in both zones (O, J, Kim 1973).

The Ogcheon systems in the erstwhile metamorphosed zone is definitely Precambrian in age although few geologists had thought to be metamorphosed late Paleozoic to early Mesozozoic sediments. The difference in the geology and tectonics in both zones is due to the fact that Ogcheon geosyncline had been shifted or migrated and effected by different orogenies through out the geologic time. Thus, O. J. Kim (1970) designated the so called metamorphosed zone as "paleogeosynlinal zone" and non-metamorphosed zone as "neogeosynclinal zone".

The paleogeosynclinal zone is consisted of the Ogcheon System of late Precambrian age and the Jurassic Daebo granites, and the neogeosynlinal zone of post-Cambrian sediments. Only the Ogcheon System is dealt in this chapter. The stratigrapy and lithology of the Ogcheon System established by O. J. Kim et al(1969) are tabulated below.

Ogcheon System	Major rock types
Gunjasan Series	pebble-bearing siliceous rock, in part slightly calcarious.
Hwanggangri Series	pebble-bearing slaty to phyllitic rock
Changri Series	limestone, black slate
Munjuri Series	phyllite, limestone lenses
Hyangsanri Series	quartzite, dolomite
——— ? ———	
Gyemyeongsan Series (undifferentiated)	this must be separated from the Ogcheon sysetm, although it has been regarded as the Ogcheon system up to now.

Two uncoformities were recognized between the Changri and the Hwanggangri series, and between the Hwanggangri and the Gunjasan series. Pebbles in the Hwanggangri series are of various kinds mainly of granite gneiss, quartzite, and phyllite, and in rare occasions limestone and granite.

Scattering various sizes of pebbles in fine matrix is suggestive of tillite deposits, (O. J. Kim 1971) which was supported later by Reedman et al (1975). The pebbles of the Gunjasan series are also of many varieties, of which calcite pebbles of nodules are worthwhile to mention.

Some of calcite pebbles are not metamorphosed whereas others are entirely altered to amphiboles leading reaction rim like feature around their peripheral. This feature led some geologist to interprete in such that the amphibole pebbles were derived from hornblendite which penetrates elsewhere into the Cambro-Ordovician Great Limestone Series. Consequently it was thought by these geologists that the Gunjasan is thought to be silicified Hwanggangri series and that the Gunjasan and the Hwanggangri seies were post-Ordovician in age. The hornblendite is though by O. J. Kim to be Jurassic in age. In general the Ogcheon System is thought to be late Precambrian in age might be equivalent to the Sinian System in China. The geological sequences and ages of the Ogcheon system done by the all geologists are summarized as following table 2.

Tab. 2. Correlation chart of the Ogcheon System

	M. S. Lee et al	O. J. Kim (1968, 70)	D. S. Lee (1971)	Reedman et al (1973)
Mesozoic Age unknown Ogcheon System	Munjuri Hwangangri Myongori Buknori		Hwanggangri	
Camb–Ord	Daehyangsan Hyangsanri Kyemyeongsan —Unconformity?	Great Limestone Series	Ogcheon group: Changri, Munjuri, Daehyangsan	Great Limestone series Chungju group: Kyemyeongsan, Daehyangsan
		fault	?	?
late Precambrian		Ogcheon System: Gunjasan, Hwanggangri, Changri, Munjuri, Daehyangsan, Kyemyeongsan	Kyemyeongsan	Ogcheon Group: Munjuri, Hwanggangri, Myongori, Bukno ri, Seochangri, Kounri

D. S. Lee had agreed with O. J. Kim in the geological sequence, but put the system into Cambro-Ordovician age and even into Mesozoic after the aud others had discovered *Archaeocyatha* from the Daehyansan formation in 1970.

Reedman et al. had followed the geological sequence set up by M. S. Lee et al. in 1965, but set up newly the Chungju group which comprises the same formations of M. S. Lee but reversed geological sequence. This was probably done so after the fossil *Archaeocyatha* was taken into the consideration.

Recently young geologists have expressed some different idea (oral communication,) which O. J. Kim thinks to be worthwhile to mention, as follows:

Camb.		Daehyangsan
Precambrian	Ogcheon system	Gunjasan Hwanggangri Changri Munjuri Kyemyongsan

The idea has been conglomerated by the Ogcheon system of O. J. Kim and a part of the Chungju group of Reedman et al.

d. Precambrian Granite Gneisses

Precambrian granite gneiss was recognized to intrude into the Yeoncheon system in the Gyeonggi massif and into the Yulri System in the Yeongnam massif, but, no relationship has been detected in the Ogcheon System. No age determination has been carried out so that it has not been known whether these two granites were same in age.

From geological viewpoint, however, two granite gneisses can be separated; post Yeoncheon to pre-Chuncheon and post-Yulri to pre-Taebaeksan. The former is perhaps older than the latter and they are correlated respectively to mid-Precambrian and late-Precambrian in age.

Correlation of Precambrian systems:

The Precambrian systems in central Korea so far described can tentatively by correlated as Table 3.

Tab. 3. Correlation chart of Precambrian systems in South Korea.

age \ area	Gyeonggi massif		Ogcheon palaeogeo-synclinl zone		Yeongnam massif	
Late Precambrian	Sangweon system (in North Korea)		Ogcheon system	Gunjasan Hwanggangri Changri Munjuri Hyangsanri		
	granite gneiss				granite gneiss	
Mid to Late Precambrian	Chuncheon System	Chunsongi group Jangraksan group	Gemyeongsan		Yulri system	Taebaeksan Granite gneiss Kosonri Kakhwaasa
	Granite gneiss				granite gneiss	
Early to mid Precambrian	Yeoncheon System	Yangpyong complex Sihung complex Bucheon complex			Yeongnam System	Weonnam Kisong Pyeonghae

e. Tectonics and Related Granites

In the Gyeonggi massif area two great unconformities were recognized (O. J. Kim, 1973) and three uncoformities were also identified in the Yeognam massif area (O. J. Kim et al, 1963) as shown in the table 1. The metamorphic rocks separated by these unconformities shown a different degree of metamorphism and a different attitude of deformation. Thus, the periods in which the metamorphism and deformation took place in these areas can be categorized into two or three periods (O. J., Kim, 1972). Nevertheless, it is uncertain as to their exact ages of episodes and whether or not they could exactly be correlated each other in both Precambrian terrains. This is the reason why the geologic structure of both Precambrian terrains is grouped as Pre-Trassic in age, because the structural breaks in Korea are definitely known to have occurred in the end of Triassic (Songrim Disturbance), late Jurassic (Daebo Orogeny), late Cretaceous (Bulgugsa Distubance) and mid-Tertiary (Yeonil Disturbance).

It must be mentioned that there is a great hiatus in the periods from late Ordovician to early Carboniferous when no deposition took place at least in south Korea.

It has been well studied and concluded the structural relatioship between the two systems above and below the great hiatus is parallel unconformity due to the ep-

eirogenic movement. The great limestone series, the lower system and the Pyeongan system the upper one well coincide structurally in spite of the fact that some local clinounconformity has been observed. Thus, the systems of both above and below the great hiatus did not effected differently by the following tectonic movements.

This is the reason why the great hiatus is eliminated from the following tectonic events. The generalized structural pattern is shown in the fig. 1.

1) Pre-Triassic deformation

In the Gyeonggi massif the foliation of the metamorphic complex within the same system as well as in the different systems bounded by unconformities is so diverse that generalization can not be drawn. However, the prevailing ones trend NNE-SSE direction in the western parts and NNE-SSW direction in the central to eastern part of the massif. Four major faults trends to NNE-SSW direction but cut by the Daebo granite at their southwestern ends. There is no evidence that the foliation of the complex had been effected by the intrusion of the Daebo granite. In the Ryongnam massif the foliation is also very diverse, but changes to nearly NE-SW direction toward the southwestern parts and cut slight obliquely by the Jeomchon thrust.

2) Triassic deformation (Songrim Disturbance)

In the Ogcheon Neogeosynclinal zone at east central region of South Korea, Paleozoic and Triassic sedimentary formations are folded and the axis of folds trend west-northwesterly.

This deformation is thoughful to be caused by the Songrim disturbance at the end of Triassic period, since the Jurassic sediments in the area have not been affected by this deformationl movement.

The western end of those folds are bent the NE-SW Sinian direction of Jurassic age. In the northeastern portion of the Yeongnam massif the trend of the Sobaeksan anticline, Yulri syncline and Andong anticline is WNW in general, but it is guessed that they were modified by the Triassic deformation although they might be originally Precambrian structures.

3) Jurassic deformation (Daebo Orogeny)

The Jurassic deformation caused by the Daebo orogeny was taken place and continued from early Jurassic to early Cretaceous (this was known from the age dating of the Daebo granites). This orogeny is the biggest one in Korea and some of the procceding formations were severely folded and faulted. The nature of the Daebo orogeny is manifested by the distribution of the Jurassic Daedong sedimentary formations and the alignment of the Daebo granites which are well cropped out along Sinian direction in the Ogcheon geosynclinal zone and its adjacent Precambrian terrains.

As shown in the tectonic map, four anticlinoriums and three synclinoriums run alternately from the southern border of the Gyeonggi massif to the Yeongnan massif through the Ogcheon zone.

The Ogcheon thrusts are in the Ogcheon zone, the Bonghwajae thrust bounds the Ogcheon Paleogeosynclinal zone and Neogeosynclinal zone, and the Jeomcheon thrust joined by the Bonghwajae thrust bonds the Ogcheon zone and the Yeongnam massif in the southwest. These anticlinoriums constitute major mountain ranges the younger sediments of Jurassic and Cretaceous periods scatter in the few isolated locations in the synclinorium areas.

4) Late Cretaceous to early Tertiary deformation (Bulgugsa Disturbance)

Only minor folds are observed in the Cretaceous Gyeongsang sedimentary basin although the sedimentary formations in the basin show homoclinal structure to the southeast in general. The fragmentation of the basin caused by the post-Bulgugsa disturbance resulted in forming of the upthrust at Andong and Ilweolsan which bound the Precambrian basement and the Cretaceous sediments. Along the Chugaryeong rift valley exturuded the Cenozoic basalt flows which cover even the old river beds (this basalt might be early Quaternary in age). High heat flows are checked along the Yangsan and Tongrae faults (Chang, 1970).

5) Mid-late Tertiary deformation (Yeonil Disturbance)

The disturbance has been known to exist in the middle to late Tertiary period in which basaltic and rhyolitic volcanism had taken place and minor deformation was associated in the Tertiary formations. This is known as the Yeonil Disturbance.

6) Associated granites

The granites of various geologic time are closely associated with the orogenies in Korea. The ages and the occurrence of the Precambrian granites are not certain

although they are relatively estimated as shown in the table 1. The Jurassic Daebo granites, syntectonic plutons of the Daebo orogeny, intruded along the Sinian direction in the cores of the Ogcheon folded mountain belts and in the Gyeoggi-Yeongnan Precambrian land massses (Refer to the geologic map).

At the end of Cretaceous and probably extended into early Tertiary, the Bulguksa granites and the associated acidic intrusive intruded in the Gyengsang basin area and the adjacent Ogcheon zone as small stocks without any pronouncing deformation. Y. J. Lee (1976) had dated three Paleocene granites in Ulsan area and O. J. Kim et al two Eocene granites in Pohang area (1976, unpublished.).

The granites of the Post-Chosun (mid-Paleozoic) and the Songrim disturbance (late Triassic) are expected to exist. In fact granites of these periods were reported in North recently but not discovered in South Korea thus far.

The relation of the plutons to various orogenies in South Korea is summarized in the table 4.

Tab. 4. Orogenies and associated Igneous Rocks in South Korea.

Orogeny	Periods	Granites	Other Igneous Rocks
Yeonil disturbance	Mid-late Tertiary	?	basalt, rhyolite, andesite and associated tuffs
Bulgugsa disturbance	late Cretaceous early Tertiary	Bulgugsa granite	rhyolite, andesite, basalt and associated tuffs
Daebo orogeny	Jurassic-early Cretaceous	Daebo granites	hornblendite, andesite
Songrim disturbance	late Triassic	Known in N. Korea	
Post-Chosun disturbance	late Ordo. -early Carb.	Konwn in N. Korea	
Post-Sangweon disturbance	end of Precambrian	granite gneiss	
Taeback (Chunsong) disturbance	early-late Precambrian (?)	granite gneisses,	amphibolite (?)
Yeongnam (Jangrak) orogeny	early-mid Precambrian (?)	granite	serpentinite (?)

(Compiled by O. J. Kim)

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3. Paleozoic Erathem

a. Introduction

The Paleozoic sediments in Korea have been represented by the lower Paleozoic Chosun Supergroup and the Upper Paleozoic Pyeongan Group, the former comprises the Cambrian and Middle Ordovician Systems, and the latter Upper Ca rboniferous, Permian and Triassic Systems. Both the sedimentary sequences are closely related each other in their geographic unconformably.

Any strata of upper Ordovician to lower Carboniferous Systems have not been confirmed yet, although some fossils of Silurian and Devonian have been reported.

b. The Cambro-Ordovician Strata.

(Chosun Supergroup)

The Cambro-Ordovician Chosun Supergroup is widely distributed in the so-called limestone plateau in Gangweon-do in middle-east Korea and in another bigger limestone plateau in northwest Korea. The Latter, which has been in accessible for many years, is about four times wider than the former in area. There are many other scattered patches of the Chosun Supergroup in the northern part, and several patches in southern part of Korea.

The Chosun Supergroup was first designated by Inoue (1970) and has been divided into two parts by the lithology, namely, the Yangdeog Group and the Great Limestone Group. These two groups have been named by the unknown geolgist about 1915. These groups are conformable each other.

Recently Cheong(1969) divided the Supergroup into two groups by the geologic age, namely, the Cambrian Samcheog Group and the Ordovician Sangdong Group, and more recently the Supergroup has also been subdivided by Cheong et al. (1973) into four Series, the Iyeonnae, Homyeong, Mungog and Yemisan Series.

First two series are included in the Cambrian and the last two in the Ordovician respectively. Subdivisions and groupings of the Supergroup as well as the stratigraphical correlation with Europe and North America are shown on the table 5. In this explanation the stratigraphy will be described in order of the classic division.

1) The Yangdeong Group

The Yangdeog Group overlies unconformbly the Precambrian granitic gneisses in most places, but contacts with the metasediments in other areas. In S. Pyeongan-do of North Korea, the Yangdeog Group is underlain by the limestone-rich Proterozoic Sangweon System though the northern margin the group overlies the granitic gneisses by thinning out of the Sangweon System toward north.

The Yangdeog Group is divided into the Jangsan quartzite and the Myobong slate in Gangweon-do, South

Korea. The Jangsan quartzite consists linly of white quartzite and is often associated with conglomeratic qartzites. The formtion varies in thickness from 50 to 200 metres. No fossil has been known in the formation yet, but in consideration of the stratigraphic relation with sub-and superjacent strata, it is certain that it is of early Cambrian in age.

The overlying Myobong slate, which is predominated by greenish grey slates, follows the Jangsan with alternation zone of quartzite and slate at the base. The average thicknesss of this formations is about 200 metres. In the formation Kobayashi (1966) has recognised four fossil zones as follows in ascending order; *Redlichia* Zone, *Elrathia* Zone, *Mapania* Zone and *Bailiella* Zone and these faunas are indicative of early Cambrian to early Middle Cambrian in age.

2) The great Limestone Group

The Great Limestone Group, distributed in Gangweon-do is also a thick sequence of the limestone-rich sediments as the case of the group in northern Korea.

The group in Samcheok district has been divided into eight lithologic units as shown on the table 5. The lowermost part of the group, the Daegi Formation, consists mainly of white limestone beds with about 350 metres thick. Above the formation lies the Sesong, which is composed of dark grey to dark greenish grey slate and siliceous rocks. The formation is so very thin, reckoned about 20 metres, that can not be easily traced.

The Hwajeol Formation overlies the Sesong slate conformably and is characterized by the vermicular limestone, showing a peculily weathered "worm-eaten" surface. It is about 300 metres in thickness. The Hwajeol Formation is overlain by the Dongjeom quartzite, which is composed chiefly of dark grey and light grey quartzites with variety of 5 to 50 metres in thickness. The base of the formation seems to in accordance with the base of the Ordovician System. The Dumugol shale overlies the Dongjeom quartzite conformably and it consists mainly of light greeish grey shales with numerous limestone beds. It is estimated at about 160 to 200 metres.

The Maggol and the Duwibong limestones consist mainly of bluish grey limestones, and fossilliferous shale bed, the Jigunsan shale, is intercalated between the two limestones.

Fossil *trilobites, cephalopods, brachiopods, gastropods, pelecypods and graptolites* have been found from the limestones of the Great Limestone Group. The Group in Samcheok area has been classified into 16 fossil zones through these macrofossils (Kobayashi, 1965) and correlated with the corresponding strata in Europe and North America as well as those of other regions.

Recently a number of conodont microfossils have been found from upper Cambrian to middle Ordovician form ations. These conodonts show nearly the same divisions of the group with a minor discordance compared to the division disclosed by the macrofossils. Especially conodont studies suggest that the base of the Ordovician in Samcheok area may not accord with the base of the Dongjeom quartzite, but may lie in upper part of the Hwajeol Formation, and that the Dmugol shale is not of Tremadocian but of Arenigian in age.

The Great Limestone of western Yeongweol area is so different from those of Samcheok area including the Baegunsan syncline basin that it cannot be lithologically correlated.

The Former is divided into five formation as follows-in ascending order, the Sambangsan Formaton, the Machari Formation, the Mungog Formation and the Yeongheung Formation. It has been also classified into 10 fossil zones. More recent study on conodonts indicates that the Mungog Formation is not correlated with Maggol Formation in Samcheok area because its conodont fauna is of upper Tremadocian in age.

c. Middle Paleozoic Strata

Some Silurian fossils such as *Halysites* and *Favosites* have been reported from the limestone pebbles in basal conglomerates of the Jurassic strata in the vicinity of Gyeomipo, northern Korea. This fact indicates that the Silurian sediments had been deposited, though no outcrop has been found yet.

Disphyllum and *Phillipsastraea* have been described from the Cheonseongri Series distributed in Suncheon-gun, S. Pyeongan-Do, Northern Korea. This series has been known to be the Devonian strata. But the age of the fossils, especially of *Dispyllum*, may be of Carboniferous. Another *Disphyllum sp.* has been known from the Danyang coalfield, South Korea. Recently a paleontological study of the Danyang coalfield reported fusulinids from the limestone bed from which the *Disphyllum* was found (Cheong, 1971). The fusulinids are of Car-

boniferous, therefore it seems to be clear now that the *Disphyllum*-bearing limestone bed is not of Devonian but of Carboniferous as indicated by the microfossils.

Some sequences in Ogcheon Geosyncline are thought to be of middle Paleozoic in age by some geologists. Their conclusions are deduced from their field observations. Paleontological or chronological data are needed to back up their opinions.

d. The Carboniferous-Triassic strata (Pyeongan Group)

The Carboniferous-Triassic Pyeongan Group is distributed, exclusively overlying the Cambro-Ordovician strata unconformably.

The Pyeongan Group was first named by Korea (1924) and has been divided into four formations (series in traditional term) by lithology, especially charactrized by colour; the Hongjeom, the Sadog, the Gobangsan and the Nogam formation in ascending order (see table 5).

The lowermost Hongjeom Formation overlies the Cambro-Ordovician Chosun Supergroup unconformably. The main rocks of the formation are slightly metamorphosed green, red, gray or mottled sandstones and shales with several light coloured limestone beds. The limestone beds are fossilliferous with primitive fusulids, other foraminifers, corals and brachiopods. Fusulinids indicate the age of the formation to be Moscovian of middle Carboniferous. The formation is about 200 metres thick in average. Recently the formation in Samcheok and Danyang district was renamed the Manhang Formation by Cheong (1969).

The overlying Sadog Formation is characterized by somewhat metamorphosed gray to dark gary sandstone (subgraywacke), shales, coaly shales, coal beds and dark gray limestone beds.

Limestones are intercalated in the lower part and three of more coal beds are in the upper part of the formation. The upper part of the formation is made of a megacyclothem, which may be split into four or more cyclothems of 20 to 50 meters each in thickness, comprising a sandstone bed at the bottom and shale-coal-shale sequence on the top of each cyclothem. The third cyclothem above the bottom of the megacyclothem includes the main coal bed, which is the important anthracite producer in Korea. The limestones are also fossiliferous with many fusulinids, other foraminifers, corals, brachiopods, crinoids and conodonts. Cheong (1969) reported through the detailed fusulinids work, that the limestone bed in the lower part of the formation in the Samcheok and the Danyang Coalfields contain upper Moscovian fusulinids, while the corresponding part in Yeongweol Coalfield include the Sakormaian fusulinids.

Abundant plant fossils have been described from black shales of the formation. Kawasaki (1927, 31, 34, 39) has described one hundred and fifteen species referable to fourty six genera. Important genera are as follows; *Annularia, Calamites, Cordaites Lepidodendron, Sigillaria, Neuropteris, Sphenophyllum, Pecopteris and Taeniopteris.* The formation is about 150m in average thickness. Cheong (1969) divided the formation in Samcheok and Danyang area into two formations, the lower Gum cheon and the upper Jangseong Formation.

The Gobangsan Formation locally overlies the Sadong Formation unconformably, but in most contacts the latter grades into former with increasing grain size. The lower part of the Gobangsan Formation is composed mainly of white quartzites, intercalating some black shales. The milky white quartzite marks conspicuous cliffs above the shale dominant Sadong Formation. The middle and the upper parts of the formation include grey, green to red sandstones with intercalations of green, red to dark grey shales. The formation is also rich in plant fossils. Characteristic fossils of the floral assemblage include *Annularia, Lobatannularia, Sphenophyllum, Neuropteridium, Gigantopteris, Chiropteris and Tingia.* Age of the Gobangsan Formation has been yet in a controversy. The Gobangsan flora was considered by Kawasaki to be Triassic but Kobayashi (1952) expressed his opinion that the flora was mainly late Permian in age. Recently Cheong (1969) reported that the lower part of the formation is of Permian while the middle and the upper part may be of Triassic in age. The formation varies in thickness from 500 to 1000 metres. Cheong (1969, 71) divided the formation into three lithologic unit, namely the lower Hambaeg Formation, the middle Dosagog Formation and the upper Gohan Fomation (see Table 5).

Above the Gobangsan Formation lies the Nogam Formation. The formation is composed mainly of green arkose sandsone with some conglomerate beds. Any distinct fossils have not been known yet in the formation, so

Tab. 5. Stratigraphic Division and Correlation of the Paleozoic Systems in Samcheok area South Korea

Geologic Age		Standard Section of Europe	Important fossils and fossil zones	Stratigraphy in Samcheok district		Newly proposed Stratigraphic Division by Cheong (1969) & Cheag et al (1973)		Correlation with North America
Triassic	Early & Mid.	Scythian to Ladinian (?)		Pyeongan Group	Nogam Formation	Hwangji Group	Donggo Formation	Lower to middle (?) Triassic
							Gohan Formation	
			Lobatahnularia				Dosagog Formation	
Permian	Middle	Tartarian	Neuropteridi		Gobangsan Formation	Cheolam Group	Hambaeg Formation	Ochoan
		Kazanian	Desmopteris					Guadalupian
	Early	Kungurian	Gigantopteris					
		Artimskian	Tingia				Jangseung Formation	Leonardian
		Sakmarian	Annularia, Calamites					
Carboniferous	Late	Stephania – Gzhelian	Cordaites, Lepidodendron		Sadong Formation			Wolfcampian
			Sigillaria, Neuropteris					Vergillian
			Sphenophyllum					Missourian
		Westphalian – Moscovian	Taeniopteris			Gomog Group	Geunchecn Formation	Desmoinesian
			Fusulina Neostofella Fusulinella					
			Pseudostaffela Beedeina Eostaffela		Hongieom Formation		Manhang Formaton	Atokan
		Namurian						Morrowan
Silurian to Lower Carboniferous								
Ordovician	Late	Ashigillian						Cincinnatian
	Middle	Caradocian	Actnoceroides, Phragmodus	Toseon Soperoroup	Duwibong Ls	Sangdong Group	Yemisan Series	Champlainian – Mohamkian
		Llandeilian	Orthoceroides, Eoplacognathus		Jigunsan Shale			Champlainian – Chazyan
		Llanvirnian	Clarkella, Polycaulalus	Great Mimestone Group	Maggol Ls			
	Early	Arenigian	Protopliomerops, Oistodus Scolpodes Asaphellus Scandodus		Dumugol Shale		Mungog Series	Canadian
		Tremadocian	Pseudokainella		Donieom Quartzite			
Cambrian	Late	Lingula flags	Eoorihis, Chosonodina Dietyites, Kaolishania, Furnishina Chuangia Prochuangia, Proconodontus		Hwajeol Formation	Samcheog Group	Homyeong Series	Croixian
	Middle	Menevian	Drepanura, Stephano cam		SesongSlate			Albertan
			Olenoides Solenoparia Megagraulos	Yanodug Group	Daegi Formation		lyeonnae Series	
	Early	Harlechian	Bailiella Mapania Elrathia Rodilichia		Myodog Slate			
					Jangsan Quartzite			Waucodan
pre-Cambrian				Taebaegsan Series				

that the age of the formation can be clarified. It seems, however, that the formation may be Triassic, because it is partly covered with the Jurassic sediments uncoformably. The formation is about 400 metres thick in the Samcheock coalfield, but in the Jeongseon coalfield it attains about 2,000 meters in thickness. (Compiled by H. Y. Lee)

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4. The Mesozoic Erathem

a. Daedong Group

Due to the disturbance following the deposition of the upper Pyeongan Group, the Daedong Group is shown of entirely different distribution from that of the Pyeongan System. The Daedong System is found as several small isolated patches, widely scattered in Korean Peninsula. In South Korea, it is distributed most widely Chungcheongnamdo.

The Systems is made up of entirely terrigeneous sediments and contain several coal seams. In Pyeongan coal field (North Korea), where its stratigraphy has been studied in detail, it is divided into two, Seonyeon(lower) Series and Yugyeong(upper)Series. Its age is recognized to be early to middle Jurassic from the studies of its organic remains.

b. Myogog Formation

Though this Formation is found only in small patch at a small village in Gyeongsangdo, it is fairly important for understanding the Korea upper Mesozoic history. This Formation consists also of terrigeneous sediments and is unconformably overlain by the adjacent Gyeongsang Group.

It yields several non-marine mollusca such as trigoniodid (*koreb nahacheongi*), unionids (*nagd on gia leei, cuneopsis?*) viviparid garstropods and some of the upper Jurassic flora. Its age is recognized of post-Daedong and pre-Gyeongsang, maybe upper Jurassic from the studies of its organic remains.

From the fact of its presence, the so-called Daebo movement must be regarded to be divided into two,

that is, one is of pre-Myogog, and the other of post-Myogog and pre-Gyeongsang.

C. Gyengsang Group

The Gyeongsang Group is distributed widely in southern part of Korea and found also in small patches in other areas. In a few places it overlies unconformably on the Daedong System or the Myogog Formation, but generally lies upon older rocks, and is intruded by late Cretaceous plutonic rocks (Bulgugsa granite).

The Group consists of mostly terrigeneous clastic sediments and pyroclastics. Mudcracks, ripple marks and rain prints commonly appeared in these rocks show the shallow water conditions of sedimentation.

It is divided into Subgroups as follows,

Bulgugsa granite

..... intrusion .....

2) Silla Subgroup: mudstone, siltsone, shale, sandstone, conglomerate, and prophyrite: about 350m in thickness.

..... conformity .....

1) Nagdong Subgroup conglomerate, conglomeratic sandstone, sandstone. mudstone, siltstone, marl and coal: about 4500m in thicknesss.

..... unconformity .....

pre-Gyeongsang rocks

1) Nagdong Subgroup: The Subgroup shows a zonal distribution in north-northeasterly directions in the west of the main Gyeongsang basin. It consists of chiefly coarse terrigeneous clastics and subordinately of fine clastics, and in lower horizons a few of thin coal seams of low quality. The fine sedimentary rocks are frequently reddish in color.

The animal remains include non-marine forms, among which trigoniodiods (*trigonioides, nipponoaia*) unionids (*plicatounio, schistooesmus, nag do ngia*) viviparids and BROTIOPSIS are prominent. Addition to these, ostracodes and estherids are also not so rare. It is notable that the type-localites of the type-species of the genera, *trigonioides, plicatoun io* and *nagdongia* are in the lower part of this Subgroup. The fossil plants, which occur in the lower and middle parts of the Subgroup, are Filicales (*adiantites, coniopteris, onychiopsis*), Equisetales (*equisetum*), Cycadeceas (*dictyozamites, podozamites*) and Ginkgoacae (*ginkgodium*),

These fossils indicate that the Subgroup is approximately of lower Cretaceous (Neocomian).

2) Silla Subgroup: The Silla Subgroup overlies conformably upon the lower Nagdong Subgroup and is bounded thick conglomerate fromation the latter. It is made up of mudstone, siltstone, conglomerate, prophyrite and tuff.

The lower part of the Subgroup is chiefly reddish beds and the upper one principally of porphyrite with some tuff and terrigenous sedimentary rocks. As a whole this Subgroup is of finer-sediments than the lower Nagdong Subgroup.

The animal fossils are non-marine forms, such as trigoidids, thiararids (*thiara*), ostracods and estherids. The plant fossils are poorly preserved.

The organic remains indicate that the Silla Subgroup is roughly of upper Cretaceous (Turonia-Coiacian). (Compiled by Seong Yong, Yang)

d. Igneous Activities in South Korea

1) Classification

In south Korea the surface of about 48 percent is underlain by igneous rocks (Fig. 3 and Fig. 4).

These occurrencs can be classified into the following five age-categoried igneous activities of their tectonic relations and their isotopic ages (Fig. 5).

1. "Late Triassic activity" related to Songrim disturbance
2. "Early Jurssic to Early Cretaceous activity" related to Daebo Orogeny.
3. "Late Cretaceous to Early Tertiary activity" related to Bulgugsa disturbance
4. "Middle Tertiary activity" related to Yonil disturbance
5. "Plio-Pleistocene activity" related to the Circum-East Sea (East Sea-Japan Sea) volcanism.

Of these, the igneous rock of the late Triassic age have not been clearly conformed yet, and their existance is at the stage off discussion.

2. Late Triassic activity.

Songrim disturbance has been thought to be a cause of an igneous activity in Pre-Jurassic deformation (O. J. Kim, 1975) because the disturbance took place at the end of Triassic in the South Korea, especially in the Hambaegsan area, and some granites of this period were reported in the north Korea. However, the present writer

Tab. 6. Igneous Activities in the Evolution of the Middle Ogcheon Geosyncline. (D. S. Lee, 1971)

Geologic time	Sequence	Stage of tectonic activities	Representative trend(s)	-Zone	Rock type
CRETACEOUS	11	Post tectonic	N-S, NW-SE	whole area	Porphyries and granophyre
	10	〃	NE-SW and massive	C	Granophyre
	9	〃	NE-SW	C	Perthite-granite (C-Zone younger)
	intru.				
	8	〃 (Younger volcanism)	N-S, massive	C, SE	Tuff, rhyolite with terrigenous sedim ents: shale, sandstone, conglomerate tc.
	7	〃 (Older volcanism)	NW-SE	C	Andesite flow
	unconf.				
JURASSIC	6	Late-tectonic	NE-SW	C	Tuffs, intercalated in Cretaceous sediments (Gyeongsang System)
	unconf				
	5	〃	NE-SW	C	Granodiorite-adamellite (C-Zone older)
			NE-SW	NW	Gabbro-tonalite-granodiorite-adamellite Complex
	intru.				
	4	Syn-tectonic	NE-SW	SE	Migmatite, schistose granite and granite gneiss
	3	*Embryonic state of tectonic activity	NE-SW	C	Tuffs and basalt intercalated in Jurassic sediments (Daedong System)
	unconf.				
PRE-JURASSIC	2	Pre-tectonic	NE-SW, NW-SE	C, NW	Amphibolite and meta-volcanics in Changri Group
	?				
	1	〃	NE-SW, Nw-SE	C, NW	Rhyolite and acidic tuffs in Gyemyeongsan Formation

prefers to refer a volcanic activity rather than plutonic one in the south Korea, because Bansong Formation which is distributed along the southeast side of the Ogcheon Zone was deposited from late Triassic to middle Jurassic (T. Kobayashi 1953, and S. H. Um et al., 1972) and it includes volcanic material in its lower part. The volcanic material is mostly andesitic, basalic and liparitic lavas and tuff layers. In other view point, the meta-volcanic rocks in Majonri Fomation of an upper member of Ogcheon Group can be considered to be correlated to the igneous products of the late Paleozoic age (D. S. Lee, 1971).

3. Early Jurassic to Early Cretaceous activity

The Jurassic deformation caused by the Daebo Orogeny taken place and continued from early Jurassic to Cretaceous. This orogeny is the strongest one in Korea and some of the pre-existed formations were severely folded and faulted. The nature of the Daebo Orogeny is manifested by the features of preceded sedimentary formations, such as Ogcheon Group, Chosun Supergroup, Pyeongan Group and Daedong Group, and the alignment of granite batholiths (named as Daebo Granite) which well crop out along the Ogchon Synclinal zone and its adjacent Precambrian terrains.

As shown in in the Fig3, the Daebo Granites covers roughly whole area of South Korea except the Gyeongsang Basin which occupies the south-eastern part of Korea. The igneous activities in this period were analysed in the middle of Ogchen geosynclinal zone (D. S. Lee, 1971). According to the study, three phases of igneous activities were recognized in this period. The early two phases belong to Syntectonic and the last phase to Late -tectonic of the Daebo Orogeny as shown in Table 6. The early phase 1* is the transitional stage from the pre-tectonic to the Syntectonic and yielded some volcanic rocks. The phase* is mostly metasomatic plutonism

and its plutons are aligned along the southeastern margin which was highly metamorphosed and they consist mainly of schistosed or porphyroblastic adamellites to granodiorites, and migmatites to granitic gneisses. The phase 3* is the most active plutonism and produced large-sized batholithic granite plutons associated with small dioritic and gabbroic stock, paralleled to the Sinian direction along the cores of the Ogcheon folded mountain belt and the Gyeonggi-Yeongnam Precambrian land mass (Fig. 3).

* The phase 1, 2 and 3 are correspond to Sequence 3, 4 and 5 in Table 6 respectively.

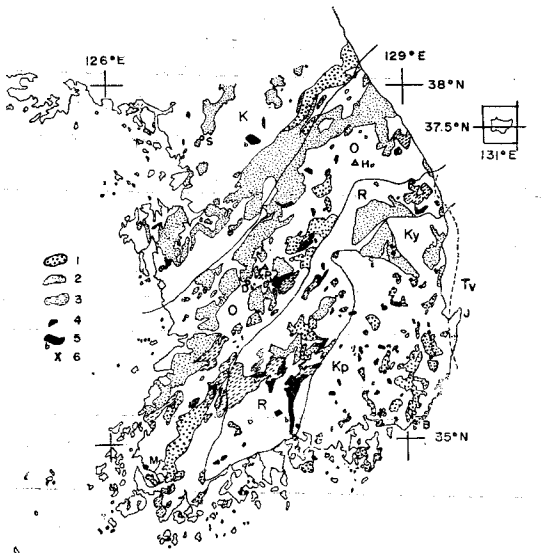

Fig.3. Distribution of plutonic rock with major petrographic provinces in S. Korea. K: Gyeonggi land, R: Yeongnam land, O: Ogcheon Zone, Kp: Gyeongsang proper basin, Ky: Yeongyang basin, Tv: Neogene alkali volcanic province, H: Hambaegsan region, P: Pibanryong region, S: Seoul, D: Daejon, B: Busan, M: Mogpo, J: Janggi cape, 1: Cretaceous granite, 2: Jurassic granite, 3: Jurassic schistosed granite, 4: Intermediate rock, 5: Mafic and meta-mafic rocks, 6: Peridotite.

ted.

C. K. Won, (1968) who described the Cretaceous igneous activities in Gyongsang basin pointed out the activities as an igneous cycle and divided them into four phases; (1) the volcanic, (2) the andesitic hypabysal intrusion, (3) the plutonic intrusion and (4) the dike rock intrusion, in descending order in age.

The similar cyclic rock sequence has been recognized in Ogcheon zone and suggested a volcano-plutonism connecting the phase (1) and the phase (3), or the phase (2) and the phase (3).

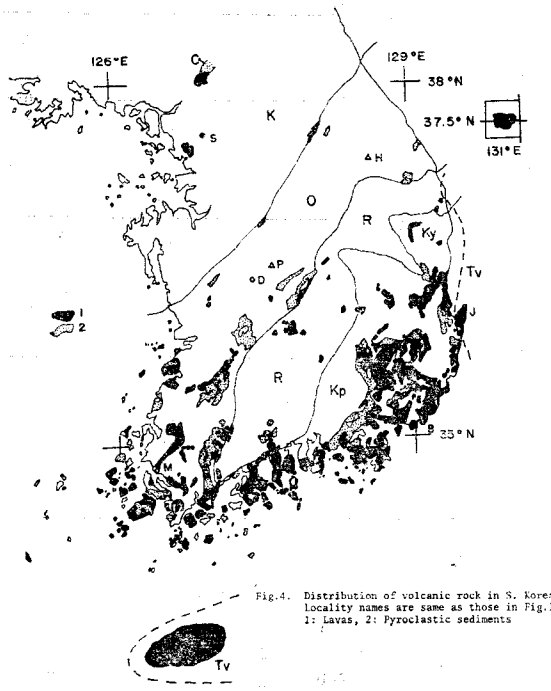

Fig.4. Distribution of volcanic rock in S. Korea. Locality names are same as those in Fig.1 1: Lavas, 2: Pyroclastic sediments

4. Late Cretaceous to Early Tertiary activity

The igneous activities in this period were taken place chiefly in the Gyeongsang basin and subordinately in the Ogcheon zone and the Gyeonggi-Yeongnam land relating to the so-called "Bulgugsa disturbance" The deformation shows only minor folding, rather gentle warping in the basin. The block movement caused fragmentation by post-Bulgugsa disturbance resulted in forming of upthrust along the northern margin of the basin at the contact with the Precambrian basement. In this period, Chugaryeong rift valley in Gyeonggi mass, and several fault systems, directed in NNE to SSW, near the southeast coast of the Gyeongsang basin were resul-

The volcanic phase was initiated at the time of deposition of Silla Conglomerate, a base of Silla Subgroup. It is subdivided into three units; the Hagbong lava flows of porphyrite and andesitic basalt and tuffaceous explosion, the Chaeyagsan lava flows of prophyrite and andesitic basalt, and the Jayangsan lava flow of propyrite and pyroclastic explosion.

The hypabyssal andesitic intrusions are also subdivided into three; andesite intrusion, trachy-andesite intrusion and rhyo-dacite or felsophyre intrusion descending order in age.

Plutonic intrusion covers the middle and east parts of the Gyeongsang basin, the middle and the southwest

end of the Ogcheon Zone, east coast of the Gyeongi land, and middle and southeast corner of the Ryongnam land. The plutons in the Gyeongsang basin were controlled in their emplacements to the directions of NE, N 20°E, N30°W and N60°W, and are mostly stocks and batholiths.

Petrographically, the stocks are homogeneous throughout the rock body, while the batholiths are commonly heterogeneous, forming igneous complex. The plutons in this period consist mainly of granite to adamellite and are higher in alkali-content than the granite plutons of the older period. Anorthosite, hornblendite and diorite are associated with this activity.

Dike rock intrusions in the late stage of this period occured in the whole area through weak zones, especially in the Gyeongsang basin and in the middle part of the Ogcheon Zone. Dikes are commonly granophyre, felsite, pegmatite, porphyries and lamprophyre.

Recently, three granite masses cropped out at an east coast, near Ulsan City were reported to be Tertiary granites by K-Ar age dating which is shown a range of 58 to 63 m.y. (Y. J. Lee and Y. Ueda, 1976).

5. Middle Tertiary activity

A clinouncoformity has been known to exist between the lower Miocene; namely the Janggi Formation, and the upper Miocene; namely the Yeonil Formation. The unconformity indicates a geologic disturbance at the middle time of the Tertiary period and C. M. Son (1969) named it as "Yeonil disturbance". In the Eoil basin, near the Pohang city, basalt flows and tuff layers in the lower part of Yeonil Formation illustrate this activity.

6. Plio-Pleistocene activity

The Plio-Pleistocene igneous activity has been found in Jeju and Ulnung volcanic islands in South Korea and it includes the area near Pohang City and its adjacent small exposures consisted of basaltic rocks. The islands and the areas correspond to the western border Zone of the so called "Circum East Sea (East Sea) alkali rock province". The province extends further to North Korea and toward south and southeast to north coast of Kyushu and Inner coastal zone of Japanese Island Arc. Chugaryong rift valley was also included in this period.

In Jeju Island, five eruption cycles were recognized by Won(1976). Each cycle starts from basalt flowing and ends to pyroclastic explosion through trachyte or trachy-andesite eruption.

In Ulnung Island, A. Harumoto (1970) also summarized the volcanic sequence into five events, from the flows of vast quantities to the end of parasitic eruption of trachy-andesite, though the dike intrusions of trachyte and phonolitic dikes, lava-effusive activities of central vents of trachyte and phonolite, and intra-caldera lava eruptions of leucite-bearing trachy-andesite.

In the Chugaryong rift valley, three volcanic events were counted (D. S. Lee, 1977), starting from olivine-free basalt flow and ending to large amount of olivie

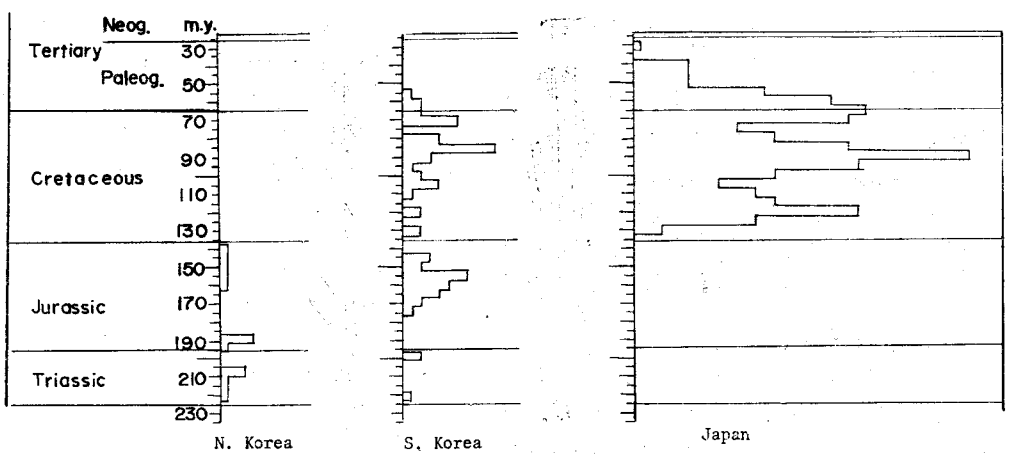

Fig.5. Isotopic age distribution of Triassic to Paleogene igneous rocks in Korea compared with the distribution of Japanese granites.

bearing basalt lava overpuring to form broad basalt plateau, in the intermediate time, vast amount of rhyolitic to andesitic material flowed out along the valley and resulted pyroclastic plateaus.

In Pohang area, some of basalt sheets were intruded into Gampo Tertiary Formation, and olivine basalt and pyroxene basalt flows of the Pleistocene were recognized by I. Tateiwa (1924).

(Compiled by D. S. Lee)

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5. CENOZOIC ERATHEM

a. Introduction

In Korea the Tertiary strata are sporadically distributed along the eastern coast of the Korean Peninsula and are divided into several small sedimentary basins, i. e., the Bugpyeong, the Yeonghae, the Pohang, the Eoili and the Ulsan basin (Fig. 6). Most of the Tertiary sedimentary rocks in Korea were deposited during the Miocene Epoch, and the uppermost parts of the Pohang and Bugpyeong sequences and Seoguipo Formation of Jeju Island are Pliocene in age. No Paleogene strata have been found in southern Korea. Each sedimentary basin is briefly described below.

b. Geology and Paleontology

The Bugpyeong Basin

This basin comprises the Bugpyeong Formation and the Bugpyeong Conglomerate. The lower Bugpyeong Formation, which rests uncoformably on Ordovician limestone, is largely composed of mudstone with intercalation of thin lignite coal seams in the middle part. The upper and lower parts of the formation yield three species (in two genera) of planktonic, 17 species (in 14 genera) of benthonic foraminifera and some molluscs, which allow correlation with Pohang Formation of the Pohang basin. These sediments were deposited in deltaic to estuarine environment. The non-marine Bugpyeong Conglomerate, which overlies the Bugpyeong Formaton unconformably, is made of poorly consolidated conglomerate and sandstone. The occurrence of pollens diatoms indicates that the age of the Bugpyeong Conglomerate is Pliocene, and that a mild-temperate condition prevailed on land during deposition of the conglomerate.

Yeonghae Basin

Tertiary strata in the Yeonghae Basin are named as the Yeonghae Group, which is divided into the Dogog-dong Formation, the Yeonghae conglomerate and the Yeongdong Formation in ascending order. Even the lower two formations are poorly fossiliferous, some plant remains indicate that they are to be terrestrial deposits. But the upper part of the Yeongdong Formation consits of marine sediments yielding 17 species (in 8 genera) of arenaceous foraminiferas, which indicates that shallow environments prevailed at the time of deposition.

Kim(1970) correlated the Yeongdong Formation to the Idong and Pohang Formation.

Pohang Basin

The Tertiary strata in the Pohang Basin rest unconformably on the Cretaceous rocks and are divided into two groups: the Yangbug Group and the Yeonil Group. The Yangbug Group, referred to the early Miocene, consists of non-marine sedimentary rocks intercalated with tuffs and volcanic lavas. The Yeonil Group is made of both marine and non-marine sedimentary rock, while volcanic rocks are rare.

Although the Yeonil Group is generally considered to lie stratigraphically above the Yangbug Group, contacts between both groups are rarely found in the field.

The Yangbug Group distributed in the southeastern area of the Pohang basin has been divided into several formations (Kim, Cheong and Kim, 1975). The sequence is briefly described as follows:

Beomgogri Formation: Andesite, grey andesitic tuff, white tuffaceous sandstone and grey shale intercalated with lignite coal seams. Bangsanri perlite in the lower part of this Formation. Upper basaltic tuff: gray basaltic tuff, sandstone and shale, plant fossils in the shale part. Geumori trachytic tuff: White trachytic tuff, sandstone and thin lignite coal seams. Geumori Formation: Sandstone, shale, conglomerate, tuff and lignite seams. Middle basaltic tuff:Basaltic tuff with intercalation of dark gray shale, sandstone and thin lignite coal seams. Upper coal-bearing formation: Sandstone, pebbly sandstone, conglomerate, shale and gray basaltic tuff. Several lignite coal seams of less than I in thickness. Plant fossils such as *Sequoia langsdorfi*, *Fagus untipofi*, etc. in shale and basaltic tuff. Lower basaltic tuff:Gray basaltic tuff, sandy shale and thin lignite seams.

Upper coal-bearing formation: Sandstone, shale, white tuff, conglomerate and several lignite coal seams. Cross-bedding common. plant fossils. Geumgwangdong Formation: Dark gray shale intercalated with sandstone and thin coal seams. Abundant plant Fossils.

Nuldaeri trachytic tuff: white to light brownish tuff with thin beds of sandstone, shale and conglomerate. Silisified woods. Plant fossils in shale part.

Janggi conglomerate: Conglomerate, sandstone, dark gray shale and thin lignite coal seams. well rounded pebbles in conglomerate. Although the total thickness of all the formations exceeds 2, 000m, individual members are laterally impersistent and in any localities several members are usually absent.

The Yeonil Group is divided into six formations: The Seoam Conglomerate, the Songhagdong, the Daegog, the Idong, the Pohang and the Umogdong Formation in ascending order. The geologic age of these formations, exclusive of the Umogdong Formation of Pliocene age, ranges from Middle to Late Miocene. The stratigraphic units are summarized as follows Umogdong Formation: Light gray finegrained sandstone intercalated with a pebble-bearing sandstone in the lower and with a gray mudstone bed of nearly ten meters thick in the middle part of the Formation. plant fossil. Pohang Formation: Light brown shaly mudstone intercalated with thin sandstome beds. Light gray fine-grained sandstone at the base. Abundant foraminifers in middle part. Marine molluscs and plant remains in marly concretions.

Idong Formation: Light brown mudstone with abundant concretion of marl. Fish remains and molluscs in the concretions. Clay mudstone intercalated with a gypsum bed. Fossil whale bones in the gypsum bed. Abundant-foraminifers.

Daegog Formation: Light brown mudstone in the layer; light brown siltstone with a light gray sandstone lens in he middle; and light gray fine-grained sandstone in the upper part. Abundant foraminifers in lower and middle part.

Songhagdog Formaton: Alternation of cross-bedded light-brown sandstone, siltstone and shale intercalated with conglomerate; radiolaria-bearing light brown mudstone in the lower. Foraminifers in upper part. Molluscs and corals common.

Seoam Conglomerate: Conglomerate with intercalation of sandstone and shale. Rounded and subrounded pebbles in conglomerate with about 10 to 30 cm in diameter, consisting of black shale, quartz porphyry, and granite in the lower, and sandstone and shale wih lenticular shape in the upper part. Marine molluscan fossils in upper and blackish water shells in the lower.

This Yeonil Group has been divided into three biostratigraphic zonules; namely, Radiolaria zonule, Turborotalia bykovae zonule (with two subzonules of T. bykovae-T. scitula praescitula and T. bykovae-Globigerina trilocularilocularis) and T. scitula zonule (Kim, 1965).

Eoil Formation

The Tertiary strata of the Eoil Basin is divided into three Formation; The Eoil Formation, Hyodongri Volcanics and Gampo Conglomerate. Gampo Conglomerate is composed of conglomerate, sandstone, shale and tuff. plant fossils indicate that this Formation has been deposited in the fresh-water environment. Hyodongri volcanics are mainly trachyte and andesite. The Eoil Formation is composed of sandstone, shale, conglomerate, tuff and basalt flows and it yields the Vicarya-Anadara assemblage which is closely composed with the early mid-Miocene faunas found at a number of localities in Japan.

Ulsan Basin

The Tertiary deposits of the Ulsan Basin which was formerly called the Jeongjari conglomerate has recently been renamed the Hwabongri Formation (Kim, 1970). The Formation contains a marine fauna including molluscs and benthonic foraminifers and is correlated to the Idong and Pohang Formations of the Yeonil Group.

Seoguipo Formation

The Seoguipo Formation is distributed at Seoguipo village, the southern midle coast of Jeju Island. The Formation measures about 50 meters in thickness and consists of light gray to brown fine to medium grained sandstone, sandy shale. The Formation has three molluscan fossil zones and three diatoms. The geological age of the Formation is to be Pliocene and the sediments were deposited in the lithoral zone of a shallow warm open sea.

c. Correlation

The correlation of the Tertiary strata in Korea is as Table 7. (Compiled by B. K. Kim)

Table 7. Correlation of Tertiary Strata

Geologic Age		Venezuela Blow (1959)	Saito (1963)	Akita (JAP.)	S. KOREA, KIM (1965)		S. KOREA, KIM(1970)				S. Korea Kim (1965) Seogwipo	N. KOREA Gilju-Myeongcheon Kanehara (1935)
							Bugpeang	yeonghae	Eoil	Ulsan		
PLIOCENE					Oomogdong F.		Bugpeyeong C.C.				Seogwipo F.	
MIOCENE	SARM.	G. bulloides zone		Funakaw Kitkura	Tbl. scitula scitula zonule	Pohang Form.	Bugpyeong F.	Yeonghae Group	Yeongdong Form.	Hwabongri Form.		Bankodo Form.
	TORTONIAN	Sphaeroidinellopsis seminulina zone	→									
		Glt. menardi/ G. nepenthes zone	→									
	HELVETIAN	G. mayeri zone	→	Onnagawa	Tbl. bykovae zonule	Eedong F.						
						Daegog F.			Yeonghae Conglo.			Kantindong Form.
	BURDIGALIAN	G. foshi zone	Glt. bykovae zone		Radiolaria zonule	Songhag Dong F.			Dogogdong F.			
			→	Nishikurosawa		Seoam Cong.						
	AQITANIAN	G. insueta zone			Vicarya collosa japonica zone	Janggi Series						
		Catapsydrax stainforth zone							Eoil Form.			Heirokudo Form.
		C. dissimilis zone							Gampo conglo. Form.			
		Tocuyo Form.										
		Pozon Form.										

Glt. *Globorotalia*, Tbl: *Turborotalia*, G: *Globigerina*.

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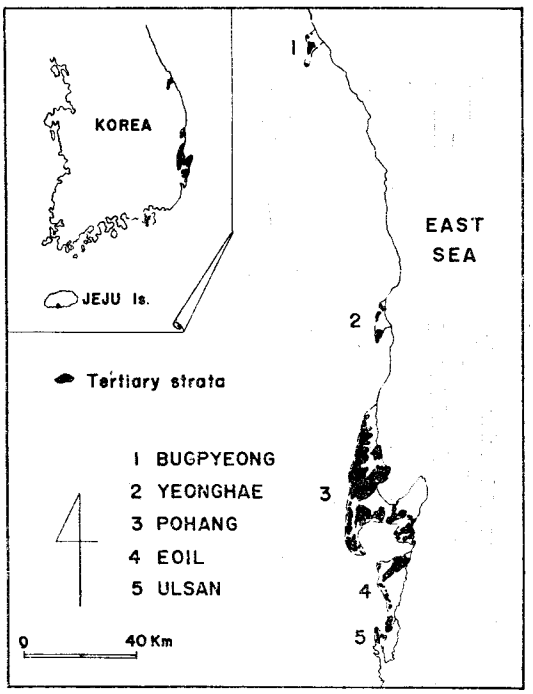
Fig. 6 Map showing the distribution of Tertiary rocks in Korea



6. SOME FEATURES RELATED TO PLATE TECTONICS

Among few geologists in Korea, two schools of thoughs exist in regard to the application of plate tectonics to the explanation of the geology and tectonics of Korea. One school postulates a subduction at the continetal margin of the peninsula, while the other visualizes an obduction beneath it. These ideas are summarized below.

Park and Kim (1971) postulated that a subduction along the margin of the Pacific Plate might have accelerated the compressional strain on the peninsula along its east coast, and uplift of the east coast might have been the result. Park and So (1972) illustrated the numerous similarities between the Ogcheon System and recent island arcs, and insisted that lithology, metamorphic facies, geological structure, genesis of ore deposits, and the generally elogated distrbuion of the component rocks of the Ogcheon System all pointed to an island arc origin. Lee (1972 and 1974) also discussed some characteristic features such as metamorphism, heat flow and magmatism and then postulated that these features might be related to plate tectonic processes.

Contrary to the ideas described above, Workman (1972) proposed that the Mesozoic granites of Korea might lie along a Mesozoic thermal rise which might be a lithospheric plate source.

Uyeda and Miyashiro (1974) state the mid-ocenic Kula-Pacific Ridge probably collided with Japan and then descended beneath it in late Cretaceous time. As show in Figure 7 (after Uyeda and Miyashiro) the Kula-Pacific Ridge underthrusted beneath the Asiatic continent with very small dip with which thermal effect reduced the thickness of the continental plate above, caused extensive volcanism, and in turn the continental plate above had been broken by tensional force causing Japanese Islands drifted toward south and leaving the newly opened East Sea (Japan Sea) behind.

Let us have little time to discuss the prominant geological features such as metamorphic facies, heat flow, and magmatism and volcanism which Lee had put much emphasis on interpretation of geological features of Korea by applying the plate tectonic concept to them, and then summarize whether or not the features could be explained by the plate tectonics ideas.

Metamorphic facies

The Korea Peninsula is a part of the Asian continent and consists of Precambrian metamorphic basement rocks over more than half of the land. Lee (1972) stated that the basement is marked by low-pressure/high-temperature metamorphic facies is overlain by metamorphic rocks of high-pressure/low-temperature facies (he meant the latter presumably representing the rocks of the Ogcheon System).

He related the paired metamorphic belts in Japan to the Korea which changes in ages from Triassic in the north to Cretaceous in the south. It is, however, very doubtable that a such correlation is sound.

Park and So (1972) also applied the paired metamorphic belt concept, postulated for Japan by Miyashiro (1973), to the Korean Peninsula, but this may not be a valid comparison.

In most cases the age of deformation and metamorphism of the Precambrian basement and the overlying Og-

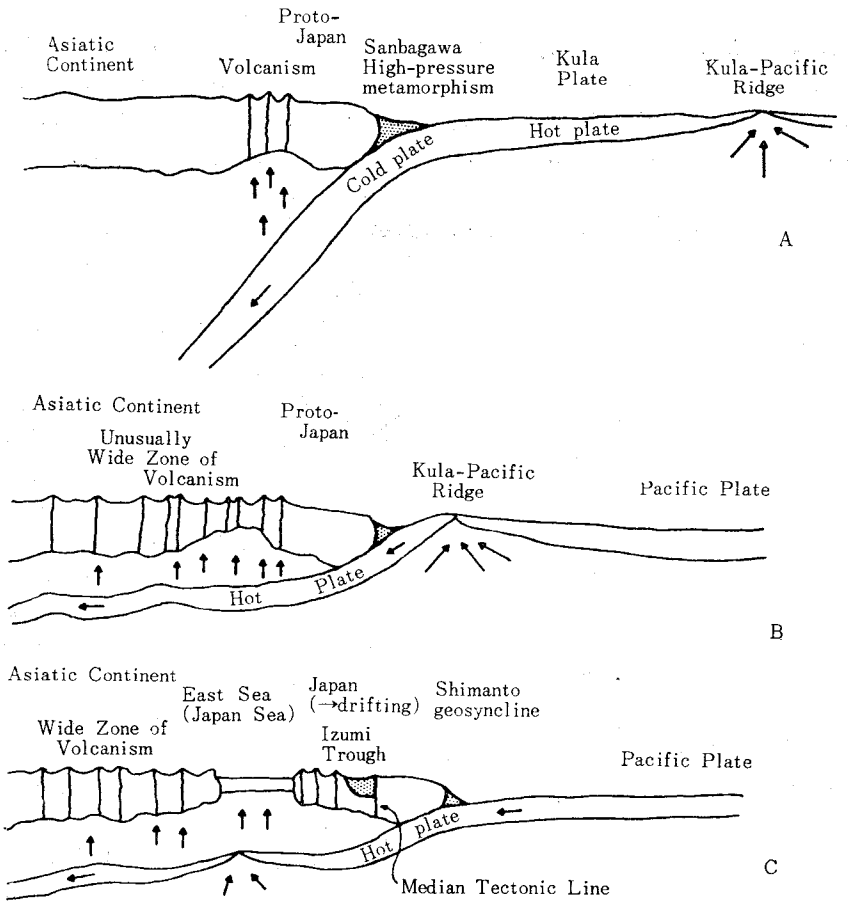


Figure 7 Schematic diagrams showing the supposed sequence of events related to the submergence of the Kula-Pacific Ridge (not drawn to scale) (after Uyeda and Miyashiro, Fig7, 1974).

A. 120 m.y. ago. The ridge is approaching the Asiatic continent. The rapid underthrusting of the cold plate causes the Sanbagawa high-pressure metamorphism in the subduction zone with the Ryoke metamorphism on the continental side.

B. 90 m.y. ago. The ridge is so close to the continent that high-pressure metamorphism is no longer taking place. The light, hot Kula plate is underthrust with a very small dip. Its thermal effect reduces the thickness of the continental plate above and causes extensive volcanism.

C. 70 m.y. ago. The ridge is submerged beneath the continental plate. Its thermal effect further reduces the thickness of a part of the continental plate, which eventually is broken by tensional force. The oceanic-side fragment of the continental plate drifts away to form the Japanese Islands, leaving the newly opened Japan Sea behind. The same system of tensional force produces the Izumi Trough in Japan, where sandstone formations as thick as 10 km are deposited.

cheon system dates from Precambrian times, having occurred on several different occasions throughout the geologic time even Ogcheon system does not reveal blue schist facies, hence, the paired metamorphic belt idea is not applicable to the metamorphic complexes of Korea.

The metamorphic facies are so diverse and superimposed one after another that it is too early to generalize the facies series, as was done by Lee (1974). This warirer does not hesitate to state that the difference in metamorphic facies is not related to plate tectonic processes, because study of the Precambrian metamorphic complex in Korea is an early stage, and its evolution with regard to deformation and metamorphism is presently beyond our capabilty to visualize.

Heat flow

Eighteen heat flow values measured by the Geological Survey of Korea showed an overall average of 1.7 HFU (Chang et al. 1970). Anomalously high heat flow values of over 2 units appear in the southeastern parts of the peninsula, to the east of the Yangsan Fault (Fig. 1). Uyeda and Horal (1964) reported high values of 2 to 3 HFU on the eastcoast of Korea. All these high values seem to be south-western extension of heat flow values in the East Sea (Japan Sea).

The data accumulated so far not sufficient to conclude

whether or not the heat flow values are the result of a submerging oceanic slab, as advocated by Lee(1974), or the result of the southward drift of the Japan island are from the Asian continent, as advocated by Uyeda and Miyashiro (1974).

A north-northwest trending (Korean direction) fault has been detected in the East Sea (Japan Sea) off the Korean coast. The high heat flow is probably related to faults, but the origin of such faults is not known so far. However, it seems more logical to conclude that the high heat flow may be related to south drift of Japan leaving East Sea (Japan Sea) behind with thin continental crust and tension cracks.

Magmatism and volcanism

It has been observed that the ages of granites in Korea get progressively younger toward the south (O. J. Kim, 1971). Triassic and older granites are known to occur in a few places in North Korea, Jurassic to early Cretaceous granites in mid-peninsula, and late Cretaceous to Paleogene granites in the south. The explanation of this arrangement of granites has not been determined, but it might be assumed to be related to plate tectonic activity where a descending Kula plate subducted beneath the Asia continent during late Paleozoic to Mesozoic time and the Kula-Pacific Ridge underthrusted very gently northwards, during late Mesozoic as shown in Figure 7. Uyeda and Miyashiro estimated the time of the Kula-Pacific submergence approximates 80-90 m. y. B. P. but the time lasted until early Paleogene which was induced by the ages of Paleogene granites in Korea. It might be explained that the Triassic to early Cretaceous graintes were originated during the period of the Kula-plate submergence and the late Cretaceous to Paleogene granites during the period of the Kula-Pacific Ridge submergence.

As shown in Figure 2. andesitic volcanic rocks are distributed throughout the southern part of the Gyengsang Basin and basaltic and rhyolitic volcanics in the Tertiary basin in the southeast corner of the peninsula. Basaltic volcanic rocks are found on Cheju and Ulnung islands which lie some distance off the south and east coasts of the peninsula respectively. Petrochemical study of these volcanic rocks has not been fully done, so it is not yet possible to relate them to the mechanics of plate tectonics; but the disposition of the volcanic rocks may relate to such activity.

Some basic rocks are distributed in the Ogcheon Paleogeosynclinal Zone and in southern parts of the Yeongnam Massif. The writer a study revealed that these basic rocks do not look like ophiolite in either lithology or occurence. It is quite reasonable to guess that these rocks are intrusives and extrusives come through the tension fractures created by the submergence of Kula-Pacific Ridge beneath the Asiatic continent as suggested Uyeda and Miyashiro.

(Compiled by Ok Joon Kim)

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