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Upper Mesozoic Stratigraphic Synthesis of Korean Peninsula

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ABSTRACT : The Cretaceous and the Upper Jurassic strata of the Korean Peninsula, entirely of continental facies, form a sedimentary mega-unit subdivided into three unconformity-bounded units. The lower, Upper Jurassic-early Lower Cretaceous unit (Jasong Synthem) occurs profusely in North Korea and is characterized by volcanic rocks of intermediate to acidic, calc-alkaline to alkaline compositions; but strata of this unit is very rare in South Korea. The middle, Hauterivian-Lower Albian unit occurs commonly in the Korean Peninsula, but some alkaline-subalkaline basalt and andesite occur only in South Korea. A recently obtained U-Pb isochron age about 113.6 Ma (Chang *et al*, 1998) from the zircon grains of the Kusandong Tuff in the uppermost part of the Haman Formation has thrown much light on the age of this unit. The stratotype of this Hauterivian-L. Albian unit is the Sindong and Hayang Groups of the Kyongsang Basin, where the unit is about twice thick and has more conglomerates than in sedimentary basins in North Korea. The unit shows various sedimentary cycles in different basins showing that the cyclicity is controlled by local crustal motion. The upper, Upper Albian-Upper Cretaceous unit is abundant in South Korea with prolific volcanic rocks which are intermediate to acidic and notably calc-alkaline. In North Korea, however, this unit occurs in only one locality without volcanic rocks and is not voluminous. The distribution of these three unconformity-bounded units shows a stepwise younging toward the Pacific Ocean: the lower unit occurs mainly in N Korea, the middle unit occurs in both N and S Korea, and the upper unit occurs mainly in the southern part of S Korea. The Cretaceous sedimentary basins of S Korea were genetically controlled by paralleling sinistral strike-slip faults parallel to the Pacific margin.

INTRODUCTION

When the senior writer wrote a chapter on the Cretaceous System of Korean Peninsula (Lee *et al*, 1987), the content on the North Korean Cretaceous was based on the publications from N Korea as the territory has been unaccessable for a geological field work by the residents of South Korea for more than a half centry. His further pursue for a synthesis of the Cretaceous of Korea has led to a co-work with N. I. Filatova who visited N Korea for one month every year during the years 1986-1990 for the upper Mesozoic geological field works. This paper is the outcome of the co-work.

GEOLOGIC SETTING

Due to the mid-Jurassic tectono-magmatisms, the Mesozoic sequence of Korean Peninsula is divided into the lower and the upper parts. The collision of the Yangzi craton against the Sino-Korea craton occured during the lower Mesozoic in Korea, but the process concluded in Korea prior to the advent of the Cretaceous Period (Chang, 1997). Korea was a part of the East Asian land-mass in the upper Mesozoic, where extensive crustal upheaval and substancial non-marine sedimentation took place. During the Cretaceous Period, Korea was invloved in an extension-dominant tectonic environment and, in particular, S Korea was involved in a series of sinistral strike-slip tectonics that controlled basin genesis and development (Chang, 1987; 1994; 1997).

Facies geometry and paleocurrent patterns suggest that the Cretaceous sedimentary basins of S Korea were intermontane grabens and semi-grabens, the sedimentary material being derived from intergraben areas (Chang, 1988). Fault-controlled basin genesis is typical of all the upper Mesozoic sedimentary basins in the Korean Peninsula. The Kyongsang (Gyeongsang) Basin experienced fluvio-lacustrine deposition throughout its history,

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with material derived from the lower Mesozoic Okchon Orogen to the northwest and, from the east, the Permo-Jurassic accretionary complex of Japan which was then adjacent to the Kyongsang Basin (Chang, 1985; 1988; Chang *et al.*, 1990). The Kyongsang Supergroup is the Cretaceous basin-fill in the Kyongsang Basin, and it yielded fossils and sedimentary features of exclusively continental origin; no marine fossils have been found (Chang, 1967a; 1967b; 1977; 1978). The non-marine origin is true to all upper Mesozoic basins of Korean Peninsula.

The upper Mesozoic strata of Korea are divided into two regional unconformity-bounded units: the Jasong (U Jurassic-lowermost Cretaceous) and the Kyongsang (Cretaceous) Synthems, the latter again divided into two unconformity-bounded units or subsynthems (Chang, 1975a; 1975b). In Korea and the vicinity, the Cretaceous System is stratigraphically inseparable from the U Jurassic. For a review of the upper Mesozoic history of the whole Korean peninsula, we attempt here to draw a picture by comparing N and S Korea. For S Korea, mainly the data of the Kyongsang Basin are used to represent the upper Mesozoic geology of S Korea.

SEDIMENTARY BASINS IN N KOREA

The upper Mesozoic strata of N Korea occur in isolated grabens and semi-grabens bounded by strike-slip and normal faults. Some of the faults may be of syndepositional just like many such cases in S Korea, but some of them must be post-depositional Cretaceous?-Cenozoic faults as strongly deformed rocks occur along the faults often accompanying cataclasite and mylonite and even showing secondary foliation with the appearance of chlorite and sericite. Notable is the relative abundance of the strata belonging to the Jasong Synthem in N Korea. The overlying L Cretaceous unit is less abundant. The U Cretaceous strata are very rare, in only one locality (Figs. 1 and 2).

U Jurassic-early L Cretaceous (Jasong) Unit

This unit here yielded abundant U Jurassic-Neocomian plant fossils (Pak, 1975; 1984). The unit also yielded the *Eosestheria middendorfii-Lycoptera middendorfii-Ephmeropsis trisetalis* fauna, known to occur in the U Jurassic of Mongolia, Zabaikal and East China, and also in the L Cretaceous of Mongolia, Russian maritime and NE China (Jon, 1987; Chinese Acad. Geol. Sciences, 1975).

The Jasong Synthem occurs in the following major localities in N Korea:

(1) Daedonggang Basin (Fig. 1, loc. 4): The Jasong Synthem, about 1550 m. thick, is subdivided into 3 groups, in ascending order as follows:

The Chimchon Group, about 300~400 m thick, is composed of sedimentary and pyroclastic rocks: conglomerates, sandstones, siltstones, tuffaceous sandstones and tuffs. The tuffs of intermediate composition predominate with basaltic, andesitic, and andesite-dacitic pyroclasts ranging in size several mm to 2~3 cm across. Subordinately, acidic tuffs also occur. The mylonitized clasts of the Lower Jurassic Songnimsan Series were identified (by N. I. Nadezhda), which indicates a tectonism before the accumulation of the Chimchon Group.

The Daebosan Group, conformable on the Chimchon Group, is a volcanic association, about 800 m thick. Near Pyongyang, 5~10 dark-grey andesitic lava flows (130~170 m thick) occur at the base of the Daebosan Group. Overlying are intercalated medium- to course-grained tuff layers mainly of andesitic composition with subordinate amount of dacitic tuffs. The upper part of the Daebosan Group consists of the rhyolitic lava-flows and numerous extrusive domes with rhyolitic breccia.

The Mangyongdae Group, about 350 m thick, consists of tuffaceous sandstones, acidic tuffs and conglomerates.

(2) Jaeryonggang Basin (Fig. 1, loc. 5): The Chimchon Group is missing, and the Daebosan Group composed of lavas and tuffs rests unconformably on the L Jurassic Songnimsan Series. The Daebosan Group here includes the volcanic association ranging from basalt to rhyolite, dominated by andesites and dacites. The volcanic bombs and tuffs of basaltic and andesitic composition prevail in the basal part, and the lapilli of dacitic composition are widespread in the top of the sequence. The youngest acidic shallow intrusive bodies and extrusive domes occupy the central and peripheric parts of the cauldrons. Thus, the Daebosan Group here shows a typical volcanic compositional sequence

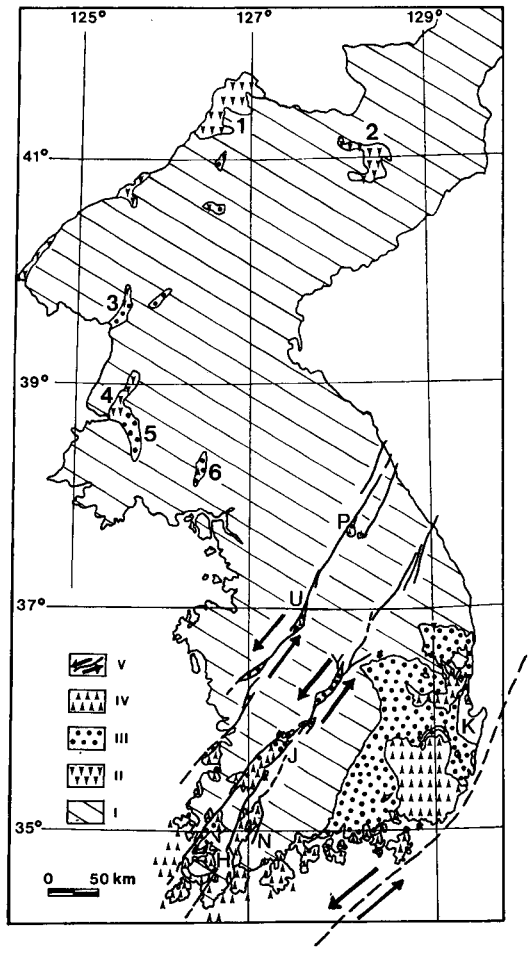

Fig. 1. Upper Mesozoic sedimentary basins of Korean Peninsula showing basin-fills by age. I: basement (Precambrian-Jurassic); II: Upper Jurassic-early Lower Cretaceous strata (Jasong Synthem); III: Hauterivian-Lower Albian strata (Lower Kyongsang Synthem); IV: Upper Albian-Upper Cretaceous strata (Upper Kyongsang Synthem); V: Cretaceous faults with arrows showing sinistral motions. K: Kyongsang Basin; Y: Yongdong Basin; J: Jinan Basin; N: Nungju Basin; H: Haenam Basin; P: Pungam Basin; U: Umsong Basin. 1: Amnokgang Basin; 2: Hochongang Basin; 3; Daeryonggang-Chongchongang Basin; 4: Daedonggang Basin; 5: Jaeryonggang Basin; 6: Yesonggang Basin.

as in the Pyongyang area.

The overlying sedimentary (partly tuffaceous) sequence, a correlative of the Mangyongdae Group, has a very limited distribution here.

(3) Daeryonggang Basin along the Daeryonggang fault zone near Anju city (Fig. 1, loc. 3): Containing distinctly mafic volcanic rocks, the Bongsu Group, 600~900 m thick, corresponds to the Chimchon, Daebosan and Mangyongdae Groups together. The lower part of the Bongsu Group consists of conglomerates, sandstones and mudstones with pyroclastic admixtures. The middle part is composed of dark-green and grey violet basalts and andesitic basalt as well as basic tuffs. The basalts contain the phenocrysts of plagioclase, olivine, clinopyroxene, rare hornblende and ore minerals. The upper part of the group consists of sedimentary (partly tuffeceous) rocks including acidic tuff layers.

(4) Amnokgang Basin near Unbong and Jasong cities (Fig. 1, loc. 1): The Sinuiju Group, about 2000 m thick, consists of (tuffaceous-)sedimentary and effusive rocks. The group shows numerous ring-shaped volcanic structures of the central type having different size (up to 20 km in diameter). The lower and upper parts of the Sinuiju Group are (tuffaceous-)sedimentary rocks while the middle part is volcanic rocks. The lower part of the group includes red, grey and green conglomerates, sandstones, mudstones and sometimes thin coal beds. The pyroclastic component is predominantly andesitic. The middle volcanic part forms a homodromous sequence from andesitic basalts and andesites in the lower part to dacites and rhyolites (lava-flows and massive bodies) at top. The upper part of the Sinuiju Group consists of alternated grey, green, rarely reddish sandstones, mudstones and conglomerates with coal layers and acidic pyroclasts.

(5) The Hochongang Basin near Kapsan city (Fig. 1, loc. 2): A volcanic sequence from andesites, dacites to rhyolites occurs here.

The Jasong Synthem of N Korea is relatively widespread, and is characterized by comprising basalt-andesite-dacite-rhyolite associations of calc-alkaline and alkaline compositions. The REE abundance and other geochemical signatures of the volcanics of this unit are similar with those of the Andean volcanic belt and other subduction-related continental-marginal volcanic belt (Filatova, 1995).

The three successive volcanic stages of this unit in N Korea exhibiting a typical compositional cycle inherent to the development of a volcanic belt are: (1) the lower, clastic-pyroclastic deposits, (2) the middle, thick volcanic association showing thorough differentiations, which is the main mag-

matic episode, and (3) the upper, alternated sedimentary and pyroclastic rocks, the latter representing the terminal eruptive episode leading to the extinction of the N Korean volcanic belt.

The U Jurassic-early L Cretaceous volcanic belt of N Korea extends to NE China (Wang *et al.*, 1985). In the Inner zone of SW Japan, the Tithonian-Valanginian sedimentary sequences of W Chugoku (Toyonishi Group) and central Honshu (Itoshiro Subgroup of Tetori Group) show no volcanisms but regressive phases from shallow-marine or brackish facies below to fluvio-lacustrinel ones above (Kimura, 1991; Sakai and Okada, 1997).

L Cretaceous (Hauterivian-L Albian) Unit

The N Korean Cretaceous System that unconformably overlies the Jasong Synthem is characterized by lacking contemporaneous volcanic component. Sometimes the Cretaceous strata are erroneously described as tuffaceous (Paek *et al.*, 1996), but the volcanic components in the sandstones and conglomerates are reworked volcanic debris of acidic and andesitic compositions derived from the eroded Jasong Synthem. The co-existance of well-rounded and acute-angular sedimentary fragments is notable as it either imply two provenances or different length of transportation.

The Hauterivian-L Albian unit contains bivalves, gastrapods, ostracods, estheriids, fishes and plant fossils. Notable is the occurrence of *Clypeator jiuquanensis*, a Hauterivian-Barremian charophyte (Paek *et al.*, 1996). Flora includes *Equisetites naktongensis*, *Brachyphyllum ningshiaense*, *B. japonicum*, *Manica foveolata*, *M. papillosa*, *M. da- latzensis*, *Onychiopsis elongata*, *O. mantelli* etc. characterizing the Upper Cretaceous (Paek *et al.*, 1996).

(1) The Daedonggang-Jaeryonggang Basin: The Hanbongsan Group, 3000~4000 m thick, unconformably rests on the U Jurassic-Neocomian strata, and contains numerous volcanic fragments derived from the Daebosan and Mangyongdae Groups. The lower part of the Hanbongsan Group consists of red and grey conglomerates, sandstones, mudstones with limestone layers. The middle part includes conglomerates in the below and alternation of sandstones, siltstones and mudstones in the above. The upper part is composed of conglomerates, sandstones and mudstones below and red, green and grey sandstones, siltstones, mudstones with limestone layers above.

(2) The Daeryonggang Basin: Unconformably overlying the Bongsu Group, the Bakchon Group, about 2000~2500 m thick, comprises red conglomerates that pass upward into alternated conglomerates, sandstones and siltstones in the upper part of the group, which is intercalated with grey and black argillites, siltstones, sandstones and rarely limestones.

(3) The Amnokgang Basin: The Bongchonbong Group, about 1800 m thick, comprises thick (about 300 m) basal conglomerates and two levels of conglomerates in the middle and upperr parts. Black siltstones and fine sandstones occupy two levels: above basal conglomerate and at the top. Sedimentary cycles are similar with those of the Daedonggang-Jaeryonggang Basin.

U Cretaceous Unit

The Bonghwasan Formation in the Yesonggang(river) graben is the only U Cretaceous strata in N Korea. The formation, about 424 m thick, consists of sandstone, mudstone and rarely conglomerate: the basal part, about 80 m thick, comprises grey fine clastics while the above comprises reddish coarser clastics. The Upper Cretaceous age is based on plant fossils (Pak, 1989; Paek *et al*, 1993; 1996) including *Frenelopsis parceramosa*, *Brachyphyllum ningshiaense*, *Platanus embicola*, *P. cuneifolia*, *P. nobilis*, *P. raynoldsii*, *Dalbergites.* sp. *Trochodendroides arctica*, *Populites pseudoplatanoides*, *Pseudoaspidiophyllum* cf. *longifolium*, *Dalbergites* sp., *Quercus* sp., *Salix* sp. etc.

Besides ostracods, bivalves and charophytes, the Bonghwasan Formation yields the foot prints of several species of the carnivorous dinosaurs belonging to the Tyrannosauridae, Iguanodontidae and Anchisauripodidae families of Theropoda (Paek *et al*, 1996). The stratigraphic relation between the Bonghwasan Formation and the underlying unfossiliferous Sansongri Formation is reportedly conformable (Paek *et al.*, 1996).

KYONGSANG BASIN, S KOREA

The largest upper Mesozoic sedimentary basin

Table 1. Upper Mesozoic unconformity-bounded units of Korea with examples from Kyongsang Basin, SE Korea, and N Korean basins: D-J: Daedonggang-Jaeryonggang; Y: Yesonggang.

unconformity-bouded units, whole Korea	Kyongsang Basin	Northern Korea
UPPER KYONGSANG SUBSYNTHEM (mid-K-UK-Paleocene)	Yuchon Volcanic Group	Bonghwasan Fm., Y Basin
LOWER KYONGSANG SUBSYNTHEM (LK-mid-K)	Hayang Group (Aptian-L Albian) Sindong Group (Hauterivian-Barr.)	Hanbongsan Group, D-J Basin
JASONG SYNTHEM (UJ-LK)	Myogok Formation	Chimchon, Daebosan and Mangyongdae Fms., D-J Basin

in the Korean Peninsula, the K Basin in Southeast Korea is here used to represent all the coeval sedimentary basins of S Korea in this comparative stratigraphic study with the U Mesozoic sedimentary basins of N Korea. The stratigraphic scheme with three unconformity-bounded units as adopted here owes much to the detailed study of the K Basin in the past years (Chang, 1966; 1967b; 1975a; 1977; 1978; Chang *et al.*, 1984; 1997; Chang and Park, 1995) but has been reinforced, of course, by a comprehensive study of major U Mesozoic basins of the whole Korea.

The Sindong, Hayang and Yuchon Groups (Table 1) constitute the K Supergroup, the sediment fills of the K Basin. The K Supergroup yielded only the terrestrial fossils: leaves and stems of plants, fresh-water shells, estheriids (conchostracans), insects, tortoise, dinosaurs (both bones and footprints), bird tracks and charophytes, a sort of fresh-water algae. Channelings or channel beds (often with "shale pebbles"), poor sorting, mica flakes and the prevalent red rock color of the clastic rocks are additional lines of evidences for the continental environment of K Supergroup (Chang, 1967b; Chang *et al.*, 1982). The occurrences of caliche beds and calcareous nodules suggest temporary aridity over floodplains. Marls, usually less than 1 m thick, are the sediments of swamps and temporary lakes; thick black shale sequences yield lacustrine-paludal fossils.

Myogok Formation (U Jurassic and/or early L Cretaceous)

The U Jurassic-early L Cretaceous Myogok Formation crops out in a very limited area in the northern part of the K Basin, which implied that the K Basin started with the deposition of the Myogok Formation. The formation, about 70 m thick, is composed of sandstone and black shale. The strata are folded by the "Nakdong Disturbance"(Cheong and Lee, 1966) probably of Valanginian age. The geologic age of the Myogok Formation has been known as either the U Jurassic based on the fossils of fresh-water molluscs (Yang, 1984) and pollens or as the lowermost Cretaceous based on fossil flora and pollens (Chang and Yang, 1970; Chun *et al.*, 1991).

Sindong and Hayang Groups (Hauterivian-L Albian)

In the middle L Cretaceous (Hauterivian-Barremian) time, a NNE trending trough called the Nakdong Trough was formed in the western part of the K Basin, in which the Sindong Group, 2,000 to 3,000 m thick, composed of sandstone, shale, conglomerate and marl was deposited. The major source area was located to the WNW as indicated by paleocurrent analysis (Chang, 1988); it was intermittently rising as recorded in sedimentary megacycles.

The Sindong Group yields in its lower part an esteemed guide taxon of charophyta, *Clypeator jiuquanensis* (Seo, 1985), which is known to range Hauterivian to Early Barremian (Wang and Lu, 1982). Based on this discovery, it is judged that the Sindong Group began to accumulate in the Hauterivian age. The middle part of the Sindong Group yields the famous *Trigonioides-Plicatounio* assemblage that allows correlation with same biozone in Japan and China (Kobayashi and Suzuki, 1936; Chen, 1988; Yang, 1974).

An abrupt expansion of the basin toward E to NE brought to the deposition of the Hayang Group over the whole K Basin. The group, 1000 to 5000 m thick, is composed of shale, sandstone, conglomerate and intra-basinal volcanic rocks. Paleocurrent

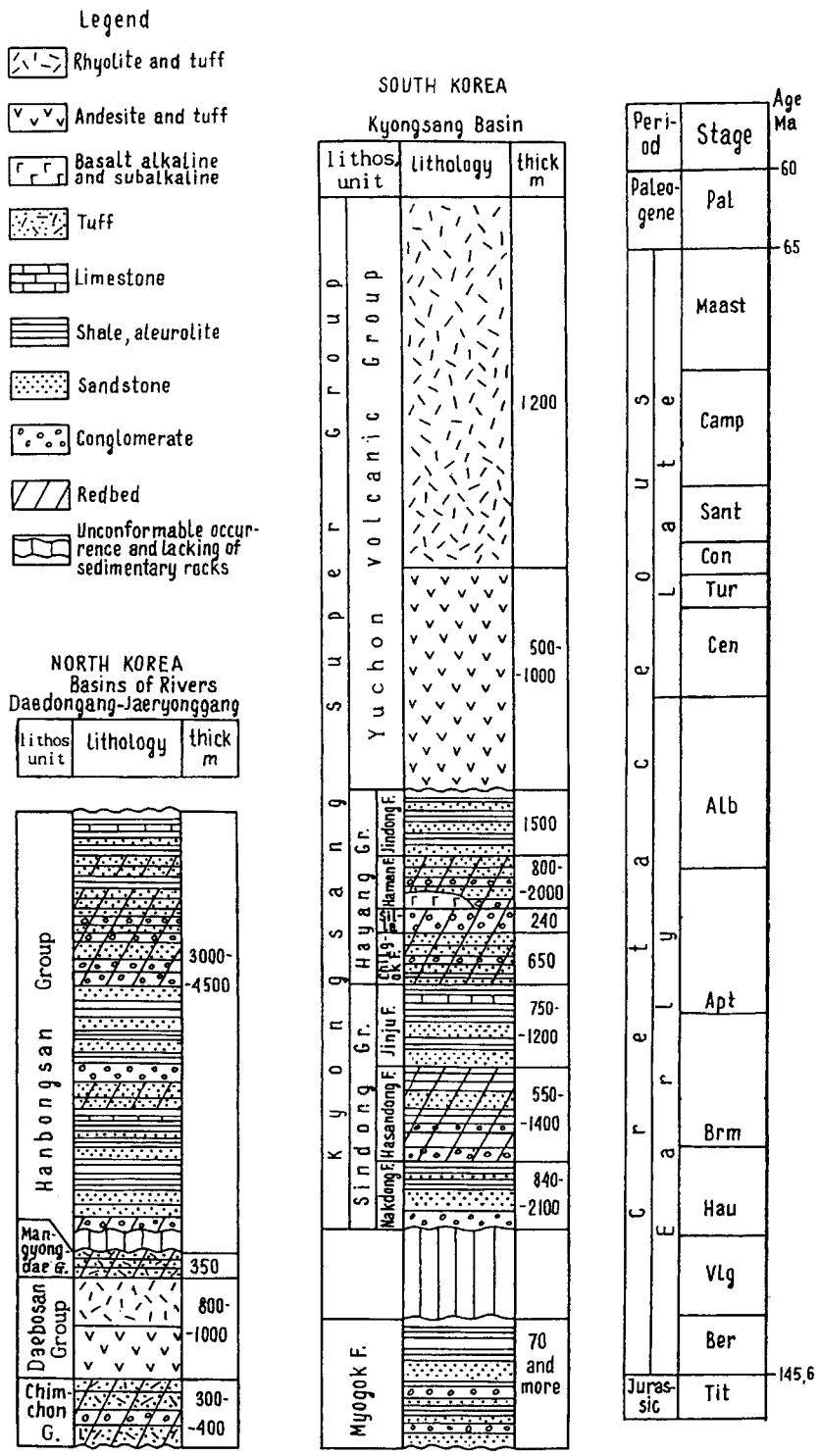

Fig. 2. Highly simplified geological columnar sections representative of basins in northern and southern parts of Korean Peninsula.

and facies analyses indicate a dominant clastic source area to the east: somewhere in the present East Sea (Japan Sea) (Chang, 1988; Chang *et al.*, 1990). During the sedimentation of the Hayang Group, the K Basin was ruled by WNW-trending growth faults that divided the basement of the basin into smaller crustal blocks. Syndepositional block movements and related sedimentation yielded abrupt lateral lithologic and thickness changes causing difficulties in intra-basinal correlation (Chang, 1975a; Chang, 1987; Chang and Park, 1995).

Recently, an U-Pb CHIME isochron, about 113.6 Ma, has been obtained from the zircon grains of the Kusandong Tuff in the top Haman Formation of the Hayang Group (Chang *et al.*, 1998). It now appears that the boundary between the Haman and the Jindong Formations roughly corresponds to the Aptian-Albian transition, ca. 112 Ma. The Jindong Formation, a dark-gray silty facies 1500 m or more thick, is the youngest, lacustrine phase of the Hayang sedimentation.

The Sindong and Hayang Groups form a single sedimentary cycle in clasicity in the northern part of the K Basin, but in the southern part of the K Basin they are of two sedimentary cycles; the sedimentary cycles were not regionally but locally controlled by motions of crustal blocks. Even if an inter-local sedimentary cycle throughout the Korean Peninsula may have existed, the local tectonics appears prevailed.

The volcanic pebbles of the Hayang Group, derived from contemporaneous volcanic rocks, render a contrast with the pebble composition of the Sindong Group in which no volcanic pebbles are observed. Such a pebble compositions observed in the K Basin are not expected in the coeval basins of N Korea.

In the northern part of the K Basin, the Kumidong and Kisadong Formations of the Hayang Group bear conglomerates containing the pebbles of the Permian, Triassic, Jurassic and L Cretaceous cherts. The cherts of the pebbles are in lithology and fossil content very similar with the cherts of the Tamba-Mino-Ashio and Chichibu belts of Japan (Chang *et al.*, 1990), the latters being accretionary belts that must have been located adjacent to the K Basin in the Cretaceous.

The development of the K Basin during the Cretaceous is characterized by an abrupt east to northeastward basin migration from the Nakdong Trough to the whole K Basin in about the Neocomian-Aptian boundary time. Such a feature may be explained by a pull-apart model due to a sinistral strike-slip fault that might underlie the Korea Strait (Chang, 1994). The Korea-Taiwan Strait Fault, one of several paralleling major Cretaceous sinistral faults (Xu *et al.*, 1987), may well have pull-aparted for the genesis of K Basin. The U Cretaceous high-volcanism along the southern coastal area of Korea may have been also facilitated by the fault and its associated faults.

Yuchon volcanic group (U Albian-U Cretaceous)

The upper limit of this group is yet much uncertain awaiting detailed future works. But it appears differ from place to place within K Basin though it certainly goes up till the basal Cenozoic. This group composed of volcanic and some clastic rocks unconformably overlies the Hayang and Sindong Groups and the basement rocks. Though the unconformity represents a brief time span, it is obviously angular (Chang *et al.*, 1984). The group is subdivided into the andesitic lower part (Jusasan Intermediate-Volcanic Subgroup) and the acidic upper part (Unmunsa Acidic-Volcanic Subgroup). The Yuchon volcanics and the comagmatic plutonic rocks are distinctly calc-alkaline, suggesting its belonging to the subduction-related continental marginal volcanic belt (Kim, 1986; Chang *et al*, 1984).

The group occurs extensively in the southern part of the K Basin and laterally extends toward west beyond the basin. Thus, the correlatives of this group are widespread in the southern part of S Korea, particularly along the Korea Strait.

SEDIMENTARY BASINS ALONG OKCHON-TAEBAEKSAN BELT, S KOREA

During the Cretaceous, the sinistral strike-slip movements of the Yongnam, Okchon-Taebaeksan, and Kyonggi blocks yielded several elongated sedimentary basins along the Okchon-Taebaeksan block or belt. Most of the basins, bounded by one or two strike-slip faults, were formed along the both sides of the block (Choi, 1995; Choi *et al.*,

1995; Chun and Chough, 1992; Chun and Kim, 1993; Kim *et al.*, 1994; Chen *et al.*, 1995; Kim, 1996; Kim and Lee, 1986; Kim and Hwang, 1986; Lee and Paik, 1990). These reports reveal that each basin genesis started not coevally during the Cretaceous. The basin-forming strike-slip faults also served as outlets of the coeval volcanism yielding intertonguing sedimentary and volcanic layers. But, in most cases, the equivalents of the Yuchon Volcanic Group can be distinguished. In the far southwestern part of the Okchon-Taebaeksan belt, the equivalent of the Yuchon Group non-conformably overlie the pre-Cretaceous (mostly Precambrian) basement.

CONCLUDING REMARKS

The Jurassic-Cretaceous boundary in Korea is tectono-stratigraphically continuous leaving the Jasong Synthem to straddle the boundary. The overlying unconformity-bounded unit, the Kyongsang Synthem, is here proposed to be subdivided into two subsynthems: the Hauterivian-L Albian Sindong-Hayang Subsynthem and the unconformably overlying U Albian-U Cretaceous Yuchon Subsynthem. These synthems and subsynthems are applicable over the Korean Peninsula.

Related with these unconformity-bounded units are recognized four diastrophisms: mid-Jurassic Daebo Orogeny, ca.-Valanginian Disturbance (Nakdong Disturbance), sub-Yuchon Disturbance and the Bulguksa Disturbance coeval with the Bulguksa igneous activity in the Late Cretaceous. The Valanginian disturbance not only folded the U Jurassic-early L Cretaceous Jasong Synthem but caused a migration of the depocenter from the West Korea Bay Basin in NW Korea to the Kyongsang Basin in SE Korea. The mid-Albian sub-Yuchon Disturbance would be recognized not only in Korea but also inter-regionally through NE China and the Russian Far East (Kirillova, 1995). The Cretaceous and the Eocene igneous activities are separately emplaced in both time and space in the Kyongsang Basin, without magmatism in the Paleocene. The Cretaceous activity was throughout the Kyongsang Basin but the Eocene activity was confined in the eastern periphery of the Kyongsang Basin.

Throughout the Late Mesozoic history, a crustal unrest shown by sedimentation and volcanism propagated from N Korea toward the SE Korea. The Late Mesozoic sedimentary volume decreased upward in N Korea while it increased in S Korea; and, volcanisms were confined in the lower horizons (U Jurassic-early L Cretaceous Jasong Synthem) in N Korea while they increased upward in S Korea occurring mostly in the Yuchon Subsynthem.

The Hauterivian-L Albian unit occurs widely in S Korea; it is about twice thick in the K Basin compared with that of N Korean basins; conglomerates are also prominent in the K Basin. Compared to the prominence of the sedimentary volume, scarcity of volcanism is a salient feature of this interval. In N Korea, this unit is largely devoid of volcanic rocks. But, in S Korea, it contains volcanic rocks though not abundant. In the K Basin, basalt and andesite (Kim, 1982), which are notably alkaline and subalkaline, are intercalated in the Aptian-L Albian strata.

The Hauterivian-L Albian unit of N and S Korea is commonly non-marine polycyclic clastic sequence. Comparing the Hanbongsan Group of Daedonggang-Jaeryonggang Basin and the Cretaceous sequence of K Basin, the former shows three sedimentary cycles each with basal red conglomerates while the latter consists either of one cycle or two cycles depending on part of the basin. Therefore the sedimentary cycles are not reliable criteria of correlation because they are controlled by local crustal behavior of the non-marine basins.

In mid- to U Cretaceous time, volcanisms culminated as shown in the Yuchon Volcanic Group of K Basin and the equivalents in SW Korea. Concomitantly with the volcanisms, co-magmatic granites were emplaced in the sub-volcanic crust. The Yuchon volcanism and the associated plutonism continued throughout the U Cretaceous time, but the isotope ages show two distinct peaks: a minor U Albian-Cenomanian(ca. 105~90 Ma) peak and a major Campanian-L Maastrichtian) (ca. 83~70 Ma) peak (Shin and Jin, 1995a; 1995b). The two peaks for volcanic rocks and those for plutonic rocks are apparently coincident.

The basins and the basin-fills of this unit occur most commonly in the southern part of S Korea in a volcano-sedimentary belt parallel to WSW-ENE-running Korea Strait or the coast-line of the south-

ern coast of the Korean Peninsula. The mid- to U Cretaceous volcanic rocks were most vigorously erupted and emplaced in this volcanic belt, about 150 km wide.

The Yuchon Volcanic Group in K Basin is subdivided into the lower Jusasan Intermediate-Volcanic Subgroup and the upper Unmunsa Acidic-Vocanic Subgroup. The U Albian-Cenomanian peak of the isotope ages represents the Jusasan intermediate volcanism. The Campanian-L Maastrichtian peak appears to correspond the culminating phase of the Unmunsa acidic volcanism.

Several Cretaceous sinistral pull-apart basins were formed along the Okchon-Taebaeksan belt, which is a crustal block, particularly along the bounding faults of the both sides of block. In general, the basins started to form in different times of the Early Cretaceous Epoch. In the far southwestern part of the Okchon-Taebaeksan belt, however, basins started to form coincidently with mid- to Late Cretaceous volcanism. Here the Yuchon equivalent non-conformably overlies the Precambrian basement without intervening younger Cretaceous basins. In the Cretaceous Period, the Yongnam Block with the Kyongsang Basin was bounded by sinistral faults, suggesting a pull-apart origin of the basin (see Fig. 1).

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한반도 후기중생대층 층서종합

장기홍 · 나데즈다 필라토바 · 박순옥

요 약 : 한반도와 중국 동부에 있어서 주라계와 백악계의 경계는 해성층의 결여로 구획이 곤란하고 경계상하가 연속적 지층을 이루고 있어 상부주라-하부백악계로 파악된다. 이는 하나의 광역적 부정합간 지층단위이므로 자성속(慈城束)이란 지층명이 적당하다. 그 위의 백악계인 경상속(慶尙束)은 다시 두 개의 부정합간 단위로 분류되는데 경상분지의 신동층군과 하양층군을 대표로 하는 단위(Hauterivian-하부Albian)와 동분지의 유천화산암층군을 대표로 하는 단위(상부Albian-상부백악계)가 그들이다. 즉, 한반도 전역의 상부주라-백악계는 이들 3개의 부정합간 단위로 나누인다. 상부주라-하부백악계 하위의 부정합은 주라기 중기 내지 후기의 대보변동에 기인하고 동 단위 상위의 부정합은 재령강(載寧江)변동에 기인한다. 유천아속(亞束)(상부Albian-상부백악계) 하위의 부정합은 유천(楡川)변동에 기인하는 것으로 이는 러시아 북동부와 연해주 일대에도 널리 인정된다. 상위의 부정합은 신생대 초의 변동의 산물이다. 상부주라-백악계의 퇴적을 개관하건데 하부단위(자성속)는 북한에는 널리 분포하고 화산암이 많으나 남한에는 소규모의 묘곡층 등이 알려져 있다. 그 위의 중부단위(신동 및 하양층군 해당의 하부백악계)는 한반도 전역에 분산 분포하나 경상분지가 대표적으로 큰 분지이며 이곳의 층후는 북한의 배(倍)에 달하고 역암의 양도 훨씬 많다. 상부단위(유천아속)는 남한에는 널리 분포하고 화산암이 대부분이나 북한에는 예성강분지의 봉화산층군 밖에는 알려져 있지 않고 화산암이 없다. 중부단위의 경우 각 퇴적층은 현저한 주기성을 보인다. 이 주기성은 남한과 북한의 동시기 지층의 상호대비의 기준이 되지 못할 가능성이 있다. 경상분지의 하양층군이 보여주는 주기성은 국지적 지각의 지괴운동의 차이에 따라 분지의 남부와 북부가 현저히 다르다. 이 사실에 비추어 보면 멀리 떨어진 두 분지의 동시기 지층들은 기반지각의 국지적 개별적 운동에 따라 서로 다른 퇴적 주기를 보일 수 있다. 상부주라-백악계의 퇴적에는 대체로 보아 화산활동이 수반했다. 북한의 자성속에는 칼크-알칼리 및 알칼리 중성 및 산성의 화산암류가 수반했다. 남한의 하부백악계 상부에는 알칼리-준알칼리 현무암 및 안산암이 수반했다. 남한의 유천아속은 칼크-알칼리 안산암 및 유문암이 대부분이다. 3개 부정합간 단위의 분포양상을 개관하면 하부는 주로 북한에 분포하고, 중부는 남북한에 공통으로 분포하고 상부는 특별히 남한 남부에 주로 분포하여 시간의 경과에 따라 태평양 쪽으로 분포지대가 단계적으로 이동했음을 알 수 있다. 백악기 동안의 남한의 분지형성에 대하여는 북동향 주향이동단층들의 좌수향 운동에 크게 기인했을 것으로 해석했다.