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Block Tectonics of The Taebaegsan Basin and En Echelon Sedimentary Wedges of The Yeonhwa-Ulchin District, Mideastern South Korea

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Abstact: The major structures characteristic of the Taebaegsan sedimentary basin were regionally analyzed with special reference to its southeastern extension to the Yeonhwa-Ulchin district of economic interest in zinc-lead mineralization.

The basin geometry, basement setting, sedimentary components, and the characteristics of deformation and igneous activity of the Taebaegsan basin differ basically from those of the adjacent mobile belt of the Ogcheon geosyncline, although the latter affected the basin's western side considerably. The subrectangular shape of the Taebaegsan basin reflects the checkered pattern of basement-block arrangement, and the carbonate-dominated lithologic components of the basin-fill indicate a cratonic depositional setting, which is comparable to some of the North American mid-continental craton.

The Taebaegsan basin, however, has somewhat been less stable than the North American megacraton that is reflected in the former's thicker sedimentary fill and steeper faults of later deformation, showing a tendency to increase in thickness close to the basement-block boundaries, which may indicate contacts of possibly detached cratonic blocks of Precambrian age; these weak zones of block boundaries have been the loci of repeated sedimentation, deformation and related igneous intrusions.

A series of downthrown or uplifted tilted blocks, in which the Cambro-Ordovician sedimentary wedges and the late Cretaceous to early Tertiary igneous intrusives are involved, occurs intermittently across the Yeonhwa-Ulchin district in a noticeable pattern of en echelon type. These sedimentary wedges are correlated to the Cambro-Ordovician section of the Hambaeg syncline to the west in stratigraphy and lithology, and are considered to have resulted from the northeastern and/or northwestern cross-faulting of the pre-existing syncline belt of easterly trend, extended from the main portion of the Hambaeg syncline.

These structural junctions (or intersections) of the earlier syncline belt and the later cross-faults have been acted as a guide to ascending igneous materials and hydrothermal ore-forming fluids to form a zone of zinc-lead skarn deposits across the Yeonhwa-Ulchin district showing a stepwise recurrence of these deposits toward the east.

1. Geologic sequence of Taebaegsan basin

1.1. Introduction

The Taebaegsan region containing the Yeonhwa-Ulchin district in its southeastern margin consists of a Paleozoic-Mesozic sedimentary basin surrounded by several basement blocks of Precambrian metamorphic complex and associated Mesozoic igneous rocks. The basin underlies more than 6,500km^2 of an angularly shaped area, lying mostly in southern Kangweon-do, with extensions to the southwest into Chungcheong buk-do and to the southeast into Geyongsang buk-do.

The Cambro-Ordovician limestone sequence underlies much of the area (Fig. 1); however, most of the other geologic units in South Korea, including upper Carboniferous-Triassic coal-bearing formations of economic importance, also occur in the region. The Mesozoic and Tertiary sedimentary rocks underlie several small basins situated mainly along the structurally low western and eastern zones. Some of the most important tectonic events that affected the region included the Triassic Songrim disturbance, Jurassic Daebo orogeny and Cretaceous Bulgugsa disturbance, during which the region's major structures were developed and most of the

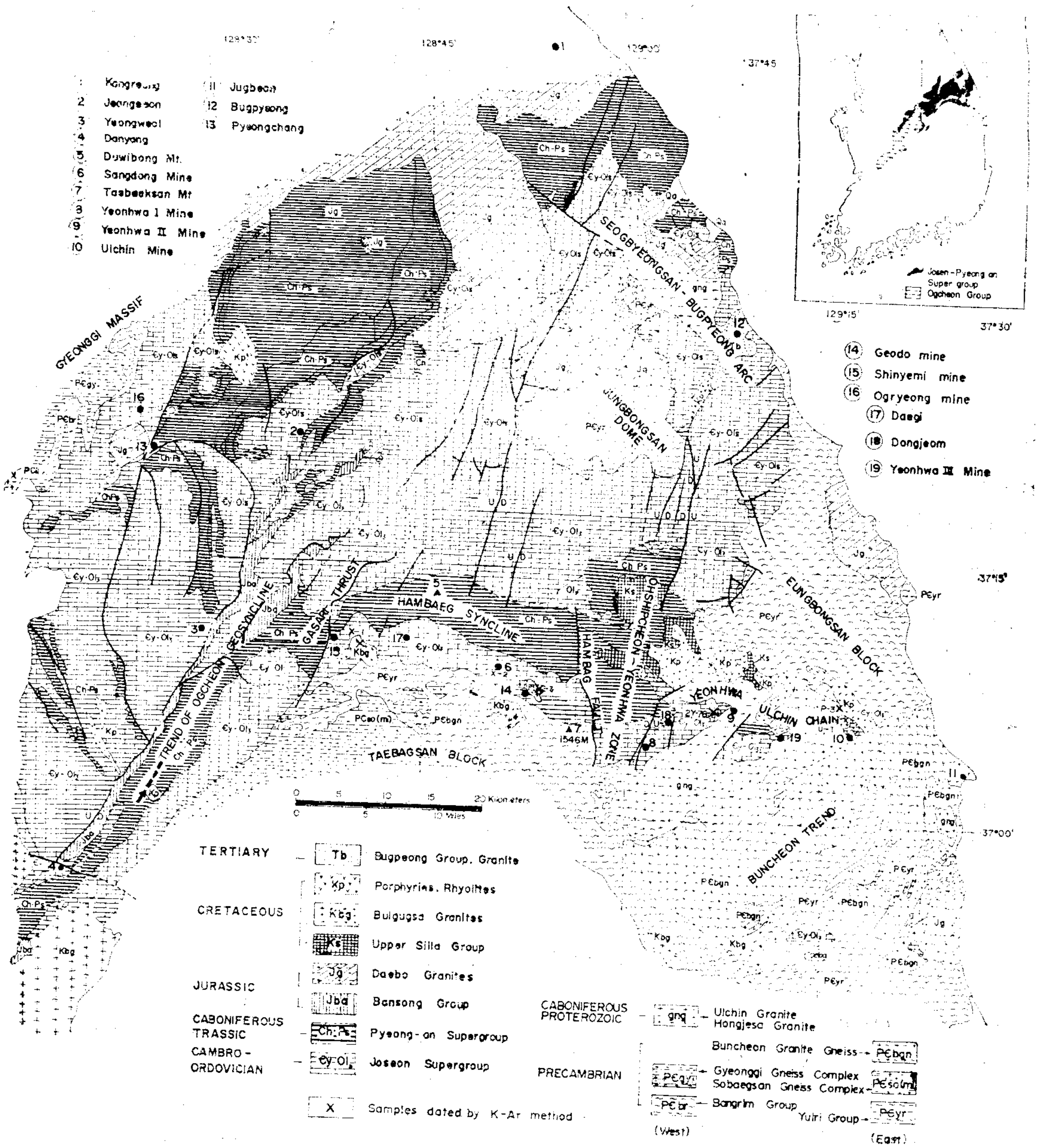

Fig. 1. Regional geology, major sturctures, and location of important metallic ore deposits in the southern Taebaegsan sedimentary basin (modified after Geological and Mineral Institute of Korea, 1973)

igneous rocks were emplaced.

A great hiatus in the mid-Paleozoic is a noticeable feature as shown by missing geologic records during late Ordovician through mid-Carboniferous periods. A granite intrusive in the Ulchin area, however, has an upper mid-Carboniferous K-Ar age (Yun, 1978a), which documents an earlier igneous episode. An

Tab. 1 Geologic sequence and major tectonic events

Geologic age	Stratigraphic unit	Igneous rock	Tectonic event
Tertiary	Bugpyeong Group	Ulchin Rhyodacite	
		Pungmun Granite	Yeonil Disturbance
		Rhyolite	
Cretaceous		Porphyry	
	Upper Silla Group	Bulgugsa Granite	Bulgugsa Disturbance
Jurassic	Bansong Group	Daebo Granite	Daebo Orogeny
Triassic		Lamprophyre	Songrim Disturbance
Carboniferous-Triassic	Pyeongan Supergroup	Ulchin Granite	Nonmarine sedimentation
Silurian-Devonian			Profound erosion
Cambro-Ordovician	Josean Supergroup		Marine sedimentation
Precambrian		Hongjesa Granite	
		Buncheon Granite Gneiss	
	Gyeonggi Gneiss Complex	Sobaegsan Gneiss Complex	
	Bangrim Group	Yulri Group	
	(west)	(east)	

occurrence of zinc-lead sulfide-bearing granite that crops out north of the Ulchin mine was found, by K-Ar dating, to be early Tertiary (52±1.6 m.y. Yun, 1978a), which is the youngest age of any granite reported in Korea.

A synopsis of stratigraphic sequence, igneous rocks and major tectonic events is given in table 1. Important geologic units and related events are briefly described as follows.

1.2 Precambrian basement

The Precambrian basement of schist and gneiss complexes exposed in the northwest, south and middle of the region is known as Gyeonggi Massif, Taebaegsan Block and Jungbongsan Block respectively (Kobayashi, 1953). In addition to these, another block to the east is called the Eungbongsan Block for the prominant Mt. Eungbongsan (Fig. 1).

The rocks of the eastern blocks, i.e. Taebaegsan, Jungbongsan and Eungbongsan, consist mainly of (1) metasedimentary sequence of mica schist, phyllite, metasandstone and intercalated limestone known as the Yulri Group (Kim and others, 1963); (2) granitic gneisses, which intrude the Yulri Group, known as the Sobaegsan Gneiss Complex (Geological and Mineral Institute of Korea, 1972) and Buncheon Granite Gneiss (Kim and others, 1963).

Precambrian granitic gneiss also occurs within a gneiss-granits complex, known as the Hongjesa Granites (Kim and others, 1963; Yun, 1967), surrounding the Yeonhwa-Ulchin sedimentary wedges. Some of the representative members of this complex include medium-grained granite gneiss, muscovite tourmaline pegmatite and coarse-grained granite. Samples of the granite gneiss and pegmatite were collected from under ground of the Dongjeom workings between the Yeonhwa I and Yeonhwa II mines; samples of coarse-grained granite were taken from a surface exposure, 6 km southeast of Dongjeom. The K-Ar ages of these three members were 1746 m.y., 1754 m.y. (early Proterozoic) and 730 m.y. (late Proterozoic) respectively (Yun, 1978a) indicating that at least two phases of Precambrian intrusive events were superimposed in this area.

The rocks of the western basement, known as the Gyeonggi Massif, are also schist and gneiss complexes. A small exposure of metasedimentary rocks associated with the Gyeonggi Gneiss Complex occurs near Pyeongchang. According to

Son and Cheong (1971), who named these rocks the Bangrim Group, the unit contains shale, phyllite, chlorite schist, mica schist, sericite schist and intercalated limestone of Precambrian age. The lithologies correlate well with rocks of the Yulri Group of the eastern blocks.

The Bangrim Group is intruded by a gneissic rock, called Noioonri granitic gneiss, which was considered by Son and Cheong (1971) to be post-Cambro-Ordovician in age. This is in keeping with the occurrence in many places of younger gneissic granites in older gneisses. For example, a younger member of Hongjesa Granites intrudes the lower part of Cambro-Ordovician in the Yeonhwa II mine area of the eastern block. The time-correlation of the younger units in Hongjesa Granites with the Noioonri granitic gneiss must await radiometric age dating.

Further descriptions of the extensive Precambrian rocks, which are as yet poorly understood, will not be attempted; however, lithologies of the Bangrim Group of the western basement are roughly comparable with those of the Yulri Group of the eastern basement. This implies that late Precambrian depositional environments in the west and in the east, before opening of the Taebaegsan basin, were similar.

1.3 Cambro-Ordovician Joseon Supergroup

The Cambro-Ordovician 1500 m thick sedimentary sequence, known as The Joseon Supergroup, was deposited unconformably on the Precambrian basement rocks. This Supergroup underlies nearly 70% of the Taebaegsan basin. Stratigraphic correlation of the rocks in the northwest (Jeongseon type), in the southwest (Yeongweol type) and in the south-southeast (Duwibong type) has been difficult and quite controversial (e.g. Kim and others, 1973; Son, 1973).

Some investigators (Kobayashi, 1960a, b) have suggested that the lithofacies and fauna display Hwangho affinities (North China type) in some areas and Yangstse affinities (South China type) in other areas, implying that two different types of environments were adjoining in the region. Complications are added by the tectonics of the Ogcheon Geosyncline[1] which affected the western region in which the Yeongweol-type sequence occurs. The Yeongweol sequence contains a fauna of Yangstse-type and is separated by major faults (e. g Gasari thrust) from the Duwibong sequence, which contains fauna of Hwangho-type. Further discussion of correlation problems will not be attempted here, but lithostratigraphic subdivision and detailed examination of the lower Duwibong sequence, based on the data including chemical and stable isotope analyses, will be spresented in a separate paper (Yun, 1978b). The lower members of this sequence are important host rocks of skarn ores in the Yeonhwa-Ulchin district and elsewhere in the region.

1.4 Carboniferous-Triassic Pyeongan Supergroup

By late Carboniferous time, the long continued mid-paleozoic stability of the crust was beginning to be broken, commencing with renewed sedimentation, deformation and igneous intrusion. About 1500m of upper Carboniferons-Triassic Pyeongan Supergroup, deposited during this time, rests disconformadly on the Cambro-Ordovician Joseon Supergroup along the axial zone of the previous basin.

The Pyeongan Supergroup is comprised of four groups, including the Hongjeom, Sadong, Gobangsan and Nogam in ascending order. The Hongjeom and Nogam Groups are characterized by their lithologic colors, reddish purple and green, respectively. The Sadong Group, with several anthracite coal beds, and

1. Regional metamorphic belt of Ogcheon Geosyncline (e. g. Kim, 1970a) trends southwesterly across the peninsula (see Fig. 1).

the Gobangsan group also with a few coal beds in some places, have been the major sources of fuel energy of the country.

The age of the Hongjeom Group previously was believed to be lower Permian. Cheong (1969), however, assigned it to the upper Carboniferous (Moscovian), based on fusulinids from the Samcheog coal field (area covering the Hambaeg syncline and its eastern extension within the Ohshipcheon shattered zone). He proposed an alternative classification of the Pyeongan Supergroup, subdividing it into three units of different age; these are the upper Caboniferous Gomog, Permian Cheolam and Triassic Hwangji formations.

The present worker is interested mainly in the Gomog system, because it is upper Carboniferous in age, close to the age of an upper mid Carboniferous granitic intrusive (297±9 m. y. old, in K-Ar age of biotite) occurring in the Ulchin district.

The Ulchin granite trends northwesterly, parallel to the Seogbyongsan-Bugpyeong igneous arc to the north where northwest-trending granitic intrusive rocks (gng) occur and a sedimentary basin of Gomog system (Ch-Ps) parallels the East Coast (Fig. 1). In view of the Carboniferous age of the Ulchin Granite, it is possible that the northern granites are not Jurassic, an age assigned without radiometric age dating (see 1 : 250,000 geologic map, Geological and Mineral Institute of Korea, 1973).

1.5 Traissic Songrim distusbance and Jurassic Bansong Group

The Songrim disturbance, which started in mid-Triassic time, was first recongnized at Songrim-ri, south of Pyeongyang, North Korea, where the rocks of late Triassic Formation (Kobayashi, 1930) rest on the Ordovician limestone with marked angular disconformity. In northern Korea the late Proterozoic and Paleozoic sedimentary strata, which form a thick cover upon the crystalline basement within the Pyeongnam basin, were intensely folded and faulted during the Songrim disturbance.

In southern Korea, however, the Songrim movements were much less intense than in the Pyeongnam basin. During this event the Joseon and Pyeongan Formations are believed to have been broadly tilted and folded along a west to west-northwest trend. This trend is best represented by the Hambaeg syncline developed between the Jungbongsan anticline to the north and the Sobaegsan anticline to the south (Kim, 1972).

No igneous phase of the Songrim disturbance has been recognized in South Korea, but some Triassic igneous rocks, ranging from gabbro and diorite to biotite granite, occur in northeastern part of North Korea (Geol. Survey Korea, 1972). A lamprophyre stock, 700 m wide in plan view, occurring at the Yeonhwa I mine is lower Triassic in age (213±4 m. y. old in K-Ar age of biotite, Yun, 1978a).

During the Songrim deformation in South Korea, which was characterized by gentle warping and uplift, the surface was eroded into a hilly terrain that surrounded a few elongate intermountain basins, in which the Bansong lake formed (Kobayashi, 1953).

Several narrow patches of northeast-trending Bansong formations occur in the western part of the region, resting unconformably on rocks of the Joseon and Pyeongan Supergroups. The Bansong sedimentary rocks were not affected by Songrim deformation but by a later event, the Daebo orogeny.

The Bansong Group was subdivided by Son and others (1967) into three units: a lower basal conglomerate, a middle dark-gray shale, and an upper arkosic sandstone. The units are comprised of typical fluviolacustrine deposits about 700 m in thickness. Cheong (1971) assigned a Jurassic age, based on plant fossils from the dark-gray shals.

1.6 Jurassic Daebo orogeny and Daebo Granites

Following the Songrim phase, crustal deformation intensified in the late Jurassic period and culminated in a great tectonic event known as Daebo orogeny (e.g. Kobayashi, 1953; Kim, 1971). During the Daebo orogeny, west to westnorthwest-trending broad folds of the Songrim phase were deformed to southwesterly-trending folds or to tightly folded and overthrust rocks in the western part of the region (Fig. 1).

The northeast trend of geologic units deformed by the Daebo orogeny is called the "Sinian direction." This Sinian direction dominates most structures of pre-Cretaceous rocks of the Ogcheon zone and its adjacent northwestern and southeastern massifs in which southwesterly elongate batholithic intrusives and related plutons are emplaced alternating with syntectonic metasedimentary belts of older age.

The batholithic granites and related plutons emplaced during the Daebo orogeny are referred to as Daebo Granites. According to Lee (1971) a series of Daebo Granites in the middle segment of the Ogcheno zone ranges from tonalite through granodiorite and adamellite to granite. According to Kim (1971), the K-Ar ages of Daebo Granites range from mid-Jurassic to early Cretaceous.

A biotite granite stock, intruded into limestone of unknown age near pyeongchang to the west of the region, was dated as mid-Jurassic, 164 ± 5m.y. by K-Ar methods (Yun, 1978a), indicating that the Daebo Granits invaded rocks along the western margin of the basin.

1.7 Cretaceous upper Silla Group

The upper Silla Group of late Cretaceous age is found in the Ohshipcheon shattered zone (Kobayashi, 1953) and in the northern border of the Yeonhwa-Ulchin zone, where several small basins formed on the eroded surfaces of pre-Silla rocks of mostly Paleozoic age.

The major exposures include the areas of Heungjeon, Donghwalri and Sagogri, from west to east, and the lithology of the group in each area is described and compared in table 2.

From table 2 the following points are significant:

1. The lithology of the group is characterized by basal conglomerate of basalt and andesite, and upper rhyolitic volcanic materials in general, implying that an igneous event was active during the Cretaceous time. There appears to be a change in type of volcanic materials from west to east; the western area is characterized by tuffaceous rocks, the eastern area is dominated by flows, and middle area by interbedded tuffs and flows.

2. Upper Silla sedimentary rocks rest on Triassic greenstone at Heungjeon, on Hongjesa Granite (younger unit?) at Donghwalri, and on Ordovician limestone at Sagogri. This implies that the eastern surface was on a more deeply eroded level than the western surface if all pre Silla rocks were flat before Silla sedimentation. This is consistent with many other facts which indicate a differential uplift of eastern crust relative to the west (this will be discussed in a later section on Yeonhwa-Ulchin zone).

1.8 Cretaceous Bulgugsa disturbance and Bulgugsa Granites

The various characteristics of the upper Silla Group mentioned above were believed to have related to the tectonic basining and sedimentation in the post-orogenic time (i.e. post-Daebo) when tension or block movements (as indicated by differential uplift) and accompanying igneous activity occurred. This tectonic movement is known as the Bulgugsa disturbance. Numerous exposures of granodiorite, granite, and their equivalent porphyries ranging in ages from mid-Cretaceous to early Tertiary occur in the region, particularly along the southern margin of the Hambaeg syncline and its Yeonhwa-Ulchin

Tab. 2 Lithological comparison of upper Silla Group in west and east

Heungjeon①, Ohshipcheon	Donghwalri②, Yeohwa II	Sagogri③, Ulchin
Heungjeon Formation:	Heungjeon Formation④:	Sagogri Formation④:
Tuff	Rhyolite	Rhylite
Tuffaceous sandstone	Tuff	Purple shale
	Tuff-breccia	Sandstone
Jeoggagri Formation:	Donghwalri Formation:	Coarse sandstone
Sandstone	Black shale	Purple shale
Reddish conglomerate	Gray conglomerate	Calc sandstone
—— Unconformity ——	Reddish conglomerate	Coarse sandstone
Triassic	—— Unconformity ——	Rhyolite
Nogam Series	Carboniferous	—— Unconformity ——
	to Precambrian	Ordovician limestone
	Hongjesa Granites	

① Geol. Invest. Conps, 1962.
② Yun. 1969.
③ Kim and Yoon, 1972.
④ Total thickness is 50m.

extension.

The most important igneous bodies include the Imog quartz monzonite, the Oepyeong granodiorite porphyry, the Yeonhwa II quartz monzonite porphyry and the Sagogri rhyolite, from west to east. According to Kim (1971), the Oepyeong stock is 107 m.y. old by K-Ar dating, and the Imog stock is 94 m.y. old. The Oepyeong stock is associated with skarn magnetite ore with chalcopyrite and Imog stock with skarn zinc ore. The Yeonhwa II quartz monzonite porphyry occurs as a sill and associated dikes relating closely to zinc-lead skarns, from which the K-Ar age of muscovite is 72.6 ± 2.2 m.y.-Late Cretaceous (Yun, 1978a). The Sagogri rhyolite occurs in basal horizons and also as top cover of the upper Silla Group of late Cretaceous age.

This is, however, only a small fraction of the vast array of Cretaceous igneous rocks which occur and widespread over South Korea. These rocks vary in composition from tonalite and granodiorite through adamellitic granite to granite porphyry known as Bulgugsa Granites (e.g. Tateiwa, 1924). The Bulgugsa Granite Series is most abundant in the Mesozoic Gyeongsang basin of southeastern peninsula. Some of the most important mineral deposits in Korea are related to this late Cretaceous to early Tertiary episode of igneous activity.

It is noteworthy that the Bulgugsa Granites are dispersed in an irregular fashion, whereas the Daebo Granites occur in area, elongate belt with a pronounced regional trend of Sinian direction. The reason for this difference may be attributed to the difference in regime of tectonic force under which they were emplaced; that is, the Bulgugsa Granites were accompanied by post-orogenic tensional and block movements and intruded between blocks randomly, whereas the Daebo Granites were emplaced between fold belts in most cases, during the orogenic compressive movement. However, even the Bulgugsa Granites apper to have been controlled by some pre-intrusive structures.

An elongate Tertiary sedimentary deposit occurs near Bugpeong, at a town on the East Coast, where the Ohshipcheon fault zone emerges from the East Sea (Fig. 1). On several Tertiary basins along the East Coast of the Korean peninsula, the Bugpyong Group unconformably overlies pre-Tertiary rocks of related ages, including Cambro-Ordovician limestone, Precambrian gneissic granite of Hongjesa type, and Cretaceous porphyry.

According to Kim (1970), the group consists of two formations: lower mudstone and coal beds of Miocene age, and upper conglomerate and shale of Pliocene age. Although the total thickness is only 110m, there is an unconformity between a lower marine formation and an upper non-marine formation. This implies that a minor disturbance existed during Miocene time which Son (1969) considered to be a late phase of the Yeonil disturbance. In view of the facts that the Miocene marine environment evolved to a Pliocene non-marine setting and that most Tertiary basins along the East Coast contain near-shore sea beds, the present location of the East Coast was probably established by Miocene time.

2. Major structures and tectonics

2.1 Relations between Ogcheon trend and Taebaegsan configuration

This section deals with the major structures developed in the Taebaegsan region and their tectonic relation to the Ogcheon fold belt. The region has been variously defined in tectonic terms by several workers, e.g. "non-metamorphosed Ogcheon geosynclinal zone" of Kobayashi (1953), "Ogchoen neogeosynclinal zone" of Kim (1970) and "intracratonic Ogcheon fold belt" of Fletcher (1976), who analysed exclusively structures of the middle segment of the Ogcheon belt proper.

The previous workers have treated the Taebaegsan basin as a northern segment of the Ogcheon fold belt, embracing the basin as a whole in their Ogcheon framework. It is true that the northeast trending thrust faults of Ogcheon direction pass through the Taebaegsan basin along its western side from southwest to northeast, truncating the west-northwest trending Hambaeg syncline (Fig. 1).

The main part of the basin to the east, however, is radically different from the Ogcheon zone proper, not only in metamorphic grade of the rocks but also in composition[2] (see Yun 1978 b), as well as in pattern of basement arrangement, geometry of the basin and its structural configuration. This discrepancy between the Ogcheon belt and the Taebaegsan basin poses a problem in that structures of the Taebaegsan basin may not be properly understood if they are considered within the framework of the Ogcheon fold belt.

2.2 Structural intersections

In terms of regional structure, the area is characterized by a checkered pattern of structural intersections dominated by northwestern and northeastern trends. The northwestern trends include: the west-northwest-trending Hambaeg syncline in the south; the northwest-trending major faults in both west and east (Fig. 2); and the northwest-trending Seogbyeongsan-Bugpyeong arc of elongate igneous intrusives and adjacent sedimentary trough to the north. The northeastern trends include: the northeast-striking Ogcheon zone of thrust faults in the west; and the north-northeast-striking Ohshipcheon-Yeonthwa zone of gravity faults in the east (Fig. 1).

The structural pattern is complicated by the further superposition of different zones of different ages. These relations, however, make it possible to untangle the strutural configuration in time and space. For instance, the north-northwest-trending Hambaeg syncline is bent southwestenly and truncated by the northeast-trending thrust faults of the Ogcheon belt at

2 The Taebaegsan Basin is dominated by carbonates and orthoquartzite of platform facies whereas the Ogcheon belt by graywacke suite (flysh) of geosynclinal facies.

its western edge. This indicates that the Hambaeg syncline is older than the Ogcheon thrust, which are considered to be formed by the Triassic Songrim disturbance (see 1, Fig. 2) and by the Jurassic Daebo orogeny, respectively (see 2, Fig. 2). The Hambaeg syncline lies between the Jungbongsan block to the north and the Taebaegsan block to the south, and extends to the Yeonhwa-Ulchin district on the east.

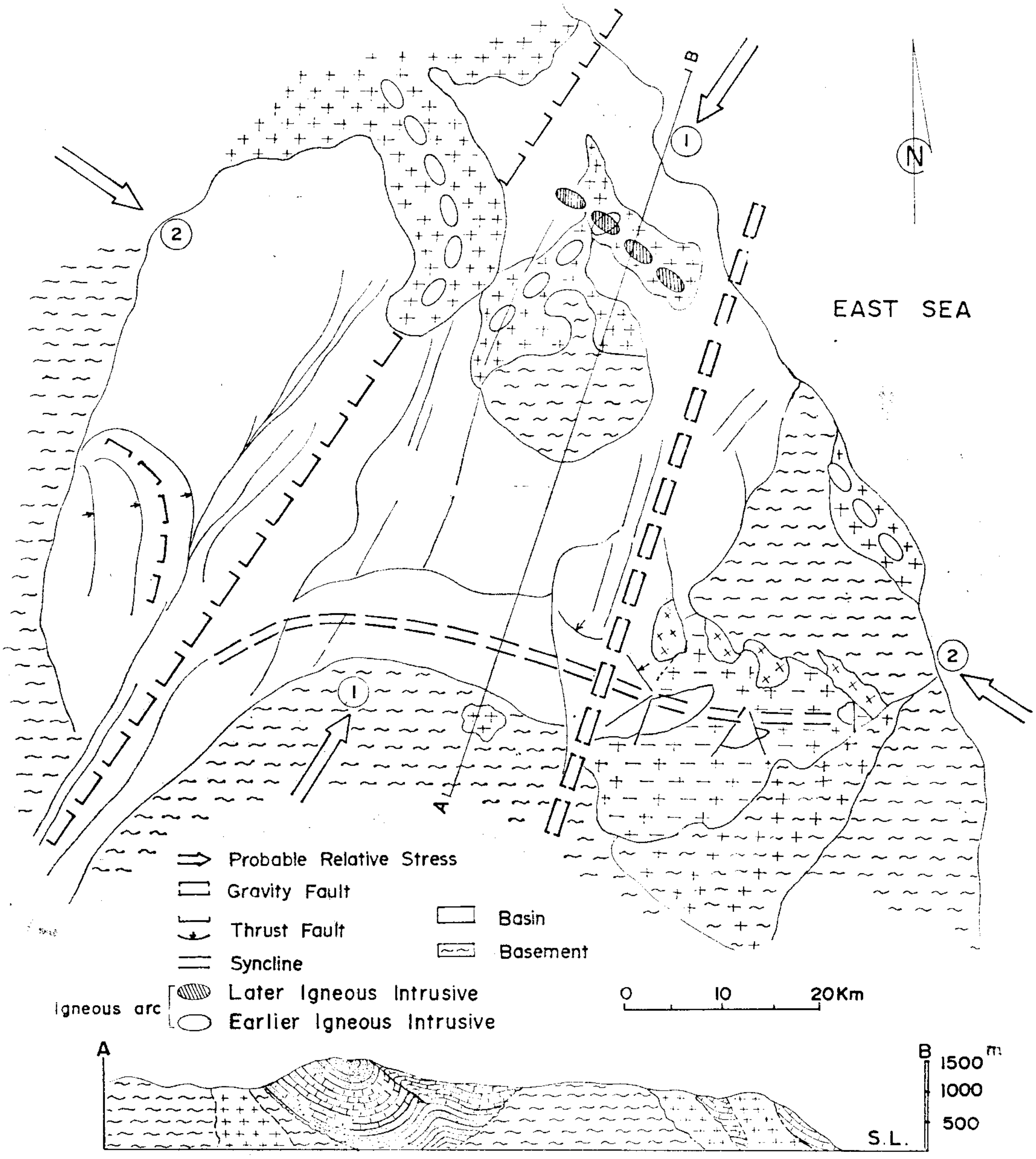

Fig. 2 Intracratonic sub-rectangular Taebaegsan Basin in which patterns of structral intersections occur that imply connection with underlying basement boundaries (conceived block contacts) has been existed.

The "Ohshipcheon shattered zone" of Kobayashi (1953), where the north-northeast-trending fault zone of graben type occurs, extends to the Yeonhwa area and further south as the Ohshipcheon-Yeonhwa zone of gravity faults (Fig. 2). The north-south zone cuts an east-west zone, and in the Yeonhwa I area, has produced a large intersection block of subrectangular shape (Fig. 1). This is defined as "Yeonhwa I block" which contains a mass of auxiliary faults and a number of zinc-lead orebodies of chimney type (e. g. Yun, 1978a).

In general, the northwest-trending structures appear to be earlier and are largely obliterated by the later northeast-trending structures, although a few exceptions are found, for instance, at the southern and northern segments of the Ogcheon belt. Thus, the structural superpositions and intersections of different trends and different ages are the fundamental aspects of the region's major structures.

2, 3 Intracratonic block tectonics

The basin geometry, basement setting, sedimentary components and characteristics of deformation and orogenic-igneous activities of the Taebaegsan basin differ basically from those of the adjacent mobile belt of the Ogcheon geosyncline. The subrectangular shape of the Taebae gsan basin reflects the pattern of basement-block arrangement, and the carbonate-dominated lithologic components of the basin-fill indicate a cratonic depositional setting rather than geosynclinal. Later tectonic deformation was characterized by a dominance of vertical movement involving high-angle faulting. Orogenic activity was less intense than that in the Ogcheon belt and an insignificant volume of discordant and concordant non-batholithic igneous intrusives occur mainly along the margin of basin fills.

All these features' characteristics of the Taebaegsan basin are comparable to those of the North American mid-continental craton, discussed by Krumbein and Sloss (1963) and Sloss (1964), although the former is far less than the latter in size. Therefore, the Taebaegsan basin can be considered as an "intramicrocratonic basin," somewhat less stable than those of the North American megacraton. The lower stability of the Taebaegsan basin is reflected in its thicker sedimemtary fill and moderately steep folds of later deformation, whereas the highly stable North American craton contains a generally flat-lying thin veneer of extensive sedimentary rocks without any significant orogenic disturbance.

The sedimentary fill of the Taebaegsan basin shows a tendency to increase in thickness close to the basement-block boundaries, indicating contacts of possibly detached cratonic blocks of Precambrian age (see Fig. 2). Above these block boundaries, the major folds and faults have been repeatedly superimposed, resulting in a subrectangular checked pattern on the surface. These weak zones of block boundaries have been the loci of repeated sedimentation, deformation and related igneous intrusion.

Several cycles of tectonic events, including sedimentation, deformation and igneous intrusion, appear to have been concentrated along these active basement boundaries. The tectonic attributes of the Taebaegsan basin, therefore, is referred to the type of "block tectonics." of E. Hills (1972, p. 342) who emphasized that "the effects of block tectonics are the formation of polygonal basins 'framed' by outcropping basement rocks but underlain by depressed blocks, and a notable tendency for the sedimentary filling of basins to increase very rapidly at the margin of the block...", a notion deduced from some aspects of the tectonics of Australia (Hills, 1946).

The important features significant to the Taebaegsan block-tectonics are summarized as follows.

1. The basement blocks of microcratons arrange themselves in a mosaic pattern, between which a sub-rectangular shallow basin has been developed; the central block (Jungbongsan dome) crops out in the middle of the basin so that active basin margins and their intersections form a sub-rectangular grid (Fig. 2).

2. The principal phase of sedimentation in the Taebaegsan basin was dominated by thick carbonate rocks and subordinate sandstones and shales, indicating a cratonic depositional facies.

3. The later phase of sedimentation, folding, faulting, and related igneous activitiy, tend to be concentrated along active zones of negative movements, below which concealed block boundaries can be postulated.

4. The faults developed in the basin are mostly of high-angle type and the thrust belts are relatively narrow in lateral displacement.

5. The western basement of the Gyeonggi massif and the eastern basements of the Taebaegsan block, Jungbongsan dome, and others, are roughly identical in lithology and stratigraphic succession.

These features imply that the Taebaegsan block-tectonics have been evolved in an intra-microcratonic setting, which was opened by the crustal fragmentation of a single Precambrian craton, adjacent to the Ogcheon geosyncline mobile belt. Under this regime of basement block-tectonics two sets of mutually discordant structural belts of T-shaped pattern could have developed either simultaneously or in sequence, under the combined influences of northwest and northeast trending tectonic movements (Fig. 2).

The basement block movements may have been vertical, lateral or diagonal in a limited extent of interspace. For instance, the general attitude of the basement blocks, together with the axial plane of the Hambaeg syncline, dip north, implying that movement of the southern block against the northern blocks deformed the basin fill during the Songrim disturbance. The Hambaeg axis is gently curved toward the north and the maximum curvature appears on its middle sector. The southward dislocation and downthrown faulting on its western and eastern portions at the contact with the Ogcheon zone and Ohshipcheon-Yeonhwa zone, respectively, are particularly evident, suggesting that both weak zones subsided relative to the central segment of the Hambaeg belt during times of the post-Songrim to Daebo orogeny.

2.4 The Yeonhwa-Ulchin en echelon chain of tilted blocks

A series of downthrown and uplifted fault blocks occurs intermittently across the Yeonhwa-Ulchin district (Fig. 3). The largest of these blocks, Yeonhwa I, occupies the western portion of the district. Here, the downthrown faulting of the Hambaeg belt is best demonstrated by the Hambaeg fault at the west limit of the district. This is a great fault, displaying a zone of strongly disturbed rocks more than 100m in width. It can be traced for 3000m on surface, and to a depth of 1500m underground (Kobayashi, 1953). It strikes north-northwest and is downthrown on the east side.

The Daehyeon fault, occurring west of the Yeonhwa I mine, strikes north-northeast which is diagonal to the Hambaeg fault (see Pl. 2 in Yun, 1978a). It is downthrown on its east side as well. The third one, however, the north-northwest-trending Dongjeom fault, is upthrown on its east side, opposite the western Hambaeg faulting. This means that the Yeonhwa I block was deeply subsided as a whole between these two boundary faults.

The Yeonhwa II mine area also is represented by a fault block bounded by the northeast-trending Seonweol fault, to which the quartz monzonite porphyry sill is related in the west,

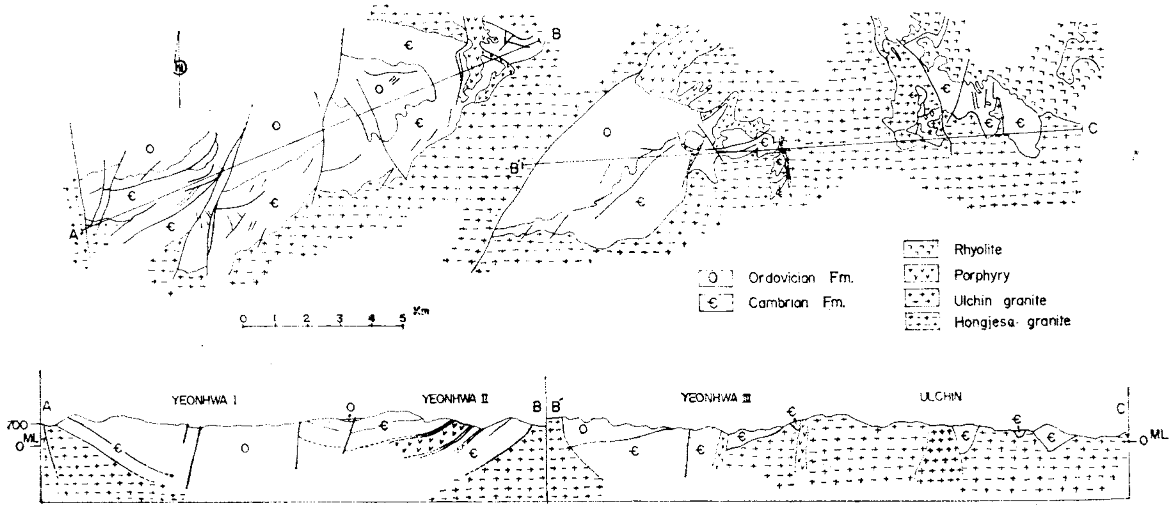

Fig. 3 The Yeonhwa-Ulchin en echelon chain of tilted wedges of the Cambro-Ordovician sedimentary rocks and associated igneous intrusives (a simplified version of Plate 2 in Yun, 1978a).
Geologic ages of igneous rocks: Hongjesa granite-upper Proterozoic, Ulchin granite-upper Carboniferous, Porphyry-upper Cretaceous, Rhyolite (and rhyodacite)-lower Tertiary.

and the Neobaeng-i fault of the same trend in the east, both of which are upthrown on their west sides; in other words, the western side of the block was subsided whereas its eastern side was uplifted, resulting in a westerly tilted fault block.

The Myobong block to the east is bounded by the Neobaeng-i fault, as mentioned above, on its western end, and the northwest-trending Deogpung fault on the eastern end, both of which are upthrown on their western sides. In the Ulchin area, the western block, in which the mine is located, appears to be upthrown on the west side of the northwest-trending Pungmoon fault.

As thoroughly examined above, the consistent nature of west-downthrows and east-upthrows of these fault blocks clearly indicates that the Yeonhwa-Ulchin setting is framed by a systematic step-faulting movement. Further complication of the block attitudes is accentuated by succeeding events of block movements and igneous intrusions. Therefore, the Yeonhwa-Ulchin district is defined as a tectonic belt characterized by an en echelon zone of tilted blocks of structural intersections. Based on a number of facts discribed above, the sequencial tectogenic development of the Yeonhwa-Ulchin setting is summarized as follows.

1. Folding of Cambro-Ordovician and Carboniferous-Triassic sedimentary rocks, with west-northwest-trending syncline axis as an eastern segment of Hambaeg syncline occurred during the Traissic Songrim disturbance(?).

2. Some time later, under radically changed deformational direction, i.e. northeast-trend of the Jurassic Daebo orogeny, weak undulational refolding of existing syncline began to down-buckle the cross-fold troughs with 11 to 12km of lateral interval; this is estimated from the distance between the present major blocks.

3. Strong cross-faulting of northeast or

northwest trend and subsequent igneous intrusions divided the synclinal belt into several intersecting blocks during succeeding periods of the Daebo orogeny. The uniformly monoclinal attitude of block arrangement and westward tilt of the blocks is thought to have shaped during this event.

4. Further disruption, tilting, uplift and readjustments partly modified the block attitudes during the later block movements and igneous intrusions of the Cretaceous Bulgugsa disturbance. The porphyritic quartz monzonite intrusion at Yeonhwa II and rhyodacite extrusion in the Ulchin area were involved in this event. The structural highs of the original syncline belt were removed by later advancing of surface erosion.

5. Continued uplift and further erosion largely removed the raised part of tilted blocks leaving only down-buckled segments of the original syncline belt during the post-Bulgugsa epeirogeny.

6. The eastward uplift of the tilted blocks in the district is also consistent with the regional eastward uplift of the peninsula itself that has long been accepted by most geologists (e.g. Kobayashi, 1953).

3. Conclusions

Although it is true that the northeast-trending Ogcheon fault zone passes through the Taebaegsan basin along its western side from southwest to northeast, the main part of the basin (to the east) is radically different from the Ogcheon zone proper (to the southwest) in geometry of the basin, in lithologic components of the sedimentary sequence and in principal trend of the structures.

The subrectangular shape of the Taebaegsan basin reflects a mosaic pattern of basement-block arrangement, and the carbonate-dominated lithology of the basin-fill indicate a cratonic depositional setting, rather than a geosynclinal one, for this basin. These features' characteristics of the Taebaegsan basin are comparable to those of the North American mid-continental craton, although the former is far less than the latter in size; hence the Taebaegsan basin can be considered as an "intramicrocratonic basin".

In terms of regional structure, the Taebaegsan basin is characterized by a checkered pattern of structural intersections of the predominant northwestern and northeastern folds and faults (see Fig. 2) below which contacts of detached cratonic blocks of Precambrian basement are postulaled. Several cycles of tectonic events, including sedimentation, deformation and igneous intrusion, have been concentrated along these active basement boundaries with a notable tendency for the sedimentary filling of basins to increase rapidly at the margin of the block; the tectonic attributes of the Taebaegsan basin is refered to the type of "block tectonics" of E. Hills (1972).

The ESE-trending Hambaeg syncline represents a typical tectonic-sedimentary belt developed on the basement boundary between the Jungb ongsan block and the Taebaegsan block, extending easterly to the Yeonhwa-Ulchin district, where it was cut by the northeastern and/or northwestern cross-faulting into several intersecting blocks down-buckled or uplifted; each of these tilted blocks contains a westerly plunging Cambro-Ordovician sedimentary wedge. The syncline of each sedimentary wedge converges to the east and dies out in the igneous block. The east-west trend of the original syncline axis appears to have shifted to a northeast direction during cross-faulting and block movements.

As appears in plane view (see Fig. 1), stepwise recurrence of these fault blocks toward the east, and westward tilting of individual blocks are the essential nature of their modes of occurrence. This recurring pattern appears to have resulted from the structural intersections of earlier synclines and later cross-faulting of roughly equal spacing.

These structural junctions, about which mineralized sedimentary wedges occur, are the loci of long-continued tectonic activity, leaving traces of by gone events of the district geologic evolution. It is, as a matter of course, postulated that these tectonic junctions wedged themselves deeply into the crust, and acted as a guide to ascending igneous materials and hydrothermal ore-forming fluids. A number of zinc-lead bearing skarn deposits of economic importance occurring through the district mostly are spatialy related to these deeply fissured and highly disrupted structural intersections.

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요 약

本硏究는 太白山堆積盆을 特徵짓는 主要構造를 廣域的으로 解析하였고 特히 이의 東南側으로의 連續體이며 經濟的으로 重要한 鉛, 亞鉛鑛化帶인 蓮花—蔚珍地域에 重點을 두었다.

太白山堆積은 그의 西緣部에 重複된 沃川地向斜運動의 影響을 받았음은 事實이나 그 堆積盆自體의 形態, 堆積成分및 變形과 火成活動의 特徵이 沃川地向斜帶의 그들과는 基本的으로 相違하다. 卽 準四角形인 그의 輪廓이 注目되며 東西方向인 咸白向斜와 石屛山—北坪弧가 南北方向인 沃川帶및 五十川—蓮花帶와 커다란 체크무늬로 交叉되어 中央에 中峰山塊를 끼고 있으며 이들 四大造構帶는 그下部에 各基盤岩塊의 分離境界面의 存在를 反影한다. 이들 境界面上部는 構造的弱帶로서 그위에 最深의 堆積層이 쌓였고 이로부터 멀어짐에 따라 堆積層厚는 減少한다. 따라서 太白山堆積은 先캠브리아 末로부터의 基盤岩의 地塊化와 造構運動史의 產物이며 그의 堆積成分은 選別度가 높은 砂岩(壯山珪岩)을 下部로 大部分 두터운 石灰質岩(大石灰岩統)을 主로하는 點은 이 堆積盆이 比較的 安定된 마이크로 크라톤의 모자익위에놓여있었음을 指示하며 이는 보다크고 安定했던 北美大陸內陸의 크라톤에 比較된다. 地塊運動과 構造交叉는 蓮花—蔚珍地域에까지 미쳤으며 이는 咸白向斜의 東方으로의 連續帶가 東北 또는 西南方向의 橫斷層에 依해 切斷된 猫峰—豊村層群과 이를 接觸貫入한 白堊紀末—第三紀初의 石英몬조니斑岩—流紋石英安山岩을 胚胎한 傾動地塊가 雁行狀으로 反覆露出됨으로서 나타나고, 이들 火成活動을 國內鉛·亞鉛總生產高의 85%를 占하는 大規模의 스카른 鑛化帶를 이루었다.

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