Coalfields of the Republic of Korea

Part 2

Geology of Macha-ri coalfield

Geology of Hambaek coalfield

Geology of Tangyang coalfield

GEOLOGICAL SURVEY BULLETIN 1041-C, D, E

Prepared in cooperation with the Korea Geological Survey under the auspices of the Economic Cooperation Administration

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By JOHN A. REINEMUND

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By KENNETH G. BRILL, Jr.

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COALFIELDS OF THE REPUBLIC OF KOREA

GEOLOGY OF MACHA-RI COALFIELD

By John A. Reinemund

ABSTRACT

For several years the Macha-ri coalfield of south-central Kangwŏn-do has been the second largest producer of coal in the Republic of Korea. More than 3 million metric tons of coal have been produced since mining was started in 1935. Practically all of this has been shipped to the nearby Yongwol powerplant by means of 7½-mile connecting aerial tramlines. As the main supplier of fuel to this plant, which is the chief souce of electric power for the Republic of Korea, the importance of the Macha-ri coalfield to the economy of the country is far greater than the size of the field would otherwise warrant.

The coal beds in the Macha-ri field are in the upper part of the Sa-dong formation of Pennsylvanian and early Permian age. They crop out in a narrow, northward-trending belt for nearly 4½ miles, and they dip westward at angles generally between 45° and 75°. The coal-bearing rocks are cut off on the west by the westward-dipping Macha-ri thrust fault which is closely parallel to the trend of the coal beds. This fault is the sole of a thrust plate, composed of Cambrian and Ordovician rocks, which has moved relatively eastward over the coal-bearing Sa-dong formation. During the thrusting, the coal beds were intensely faulted and folded, resulting in offset, duplication, coal gouge, and "pinch and swell" structure in the beds. There were probably three coal beds in the field that were continuous originally, individually as much as 10 feet in thickness, and several thin, discontinuous beds. The folding and faulting have resulted not only in the structural irregularity of these beds, but also in the disarrangement of the constituent layers in the beds and the pulverization of the high-quality coal.

Recent sampling and analysis show that the coal as now shipped from the Macha-ri field, without systematic beneficiation, has fixed carbon contents ranging from about 28 to 64 percent, ash contents ranging from about 28 to 62 percent, and heat values ranging from about 4,400 to 9,900 Btu. It is estimated that there is a reserve of about 28,287,700 metric tons of coal in the field, of which probably no more than half will be recovered.

INTRODUCTION

LOCATION OF AREA AND SCOPE OF REPORT

Located in the south-central part of Kangwŏn-do, the Macha-ri coalfield of Korea is about 125 miles east-southeast of the capital city of Seoul. The field takes its name from the town of Macha-ri which lies near its south end, in the east-central part of Puk-myon, Yongwol-gun. From Macha-ri the coal-bearing rocks extend northward about 4.3 miles into the southern part of Mitan-myon, P'yŏngch'ang-gun.

Ten miles south of Macha-ri by road is the town of Yongwol,[1] site of the steam powerplant operated by the Korean Electric Power Co. and terminus of a railroad from Chech'ŏn constructed in 1949–50. The location of the Macha-ri coalfield and its relation to Macha-ri, Yongwol, and adjacent political subdivisions are shown in figure 2.

This report summarizes the results of a study of the Macha-ri field by the Geological Survey which was made from September 1949 to March 1950, as a part of the program of the Economic Cooperation Administration and the Republic of Korea to increase the productivity of the coalfields. It presents data on the thickness, extent, and reserves of coal in the field; provides information on the structure and internal characteristics of the coal beds; and suggests procedures for future mine exploration.

PREVIOUS WORK AND ACKNOWLEDGMENTS

The Macha-ri coalfield was first mapped by geologists of the Chosen government fuel laboratory [2] about 1930. Additional detailed mapping of part of the field was done in 1933 for the Mitsui Mining Co.[3] Unpublished maps from these investigations were made available to the writer. The regional geology of the Yongwol-Macha-ri area was described by Yoshimura (1940), and brief examinations of the field were made by Hatae (1941a, 1941b) at about the same time.[4]

Information on the Macha-ri field was assembled by geologists of the U. S. Geological Survey in 1946 during the military occupation of Korea.[5] The work of these men has been helpful in the preparation of this report.

The writer wishes to express his appreciation to the many officials of the Korean Government and the Economic Cooperation Administration who made possible this study of the Macha-ri field, and to the 64th Engineering Topographic Battalion, Corps of Engineers, U. S. Army, for preparing the base maps used in this report. Thanks are also extended to the personnel of the Coal Branch, Division of Industry and Mining of the American Mission in Korea, and in particular to Claude Murphy, mining engineer assigned to the Macha-ri field, for their generous cooperation. The accommodations and information supplied by Tai Won Sun, manager, and Kim Chang Suo, chief of

[1] The Macha-ri field was formerly called the Yongwol (Neietsu) coalfield. Because it is closer to Macha-ri and is one of three coalfields in the vicinity of Yongwol, the name has recently been changed.

[2] Yong-pan, Kok-gang, Su-hyop, and Song-yo, undated, Geologic map of Neietsu (Yongwol) coalfield: Chosen Government fuel laboratory unpublished map, in files of the Korean Geological Survey.

[3] Nagabuchi, M., Nishiwaki, T., Kudooka, S., and Matsumo, G., 1933. Report on geology of Neietsu (Yongwol) coalfield: unpublished rept. from files of Mitsui Mining Co., Ltd., Tokyo, Japan.

[4] Hatae, Nobuhiro, 1939, Neietsu (Yongwol) coalfield: unpublished report in files of the Korean Geological Survey. (Japanese) Not available.

[5] Gallagher, David, and others, 1948, Mineral Resources of Korea—Coal: unpublished rept. in files of U. S. Geol. Survey, pp. 32–35.

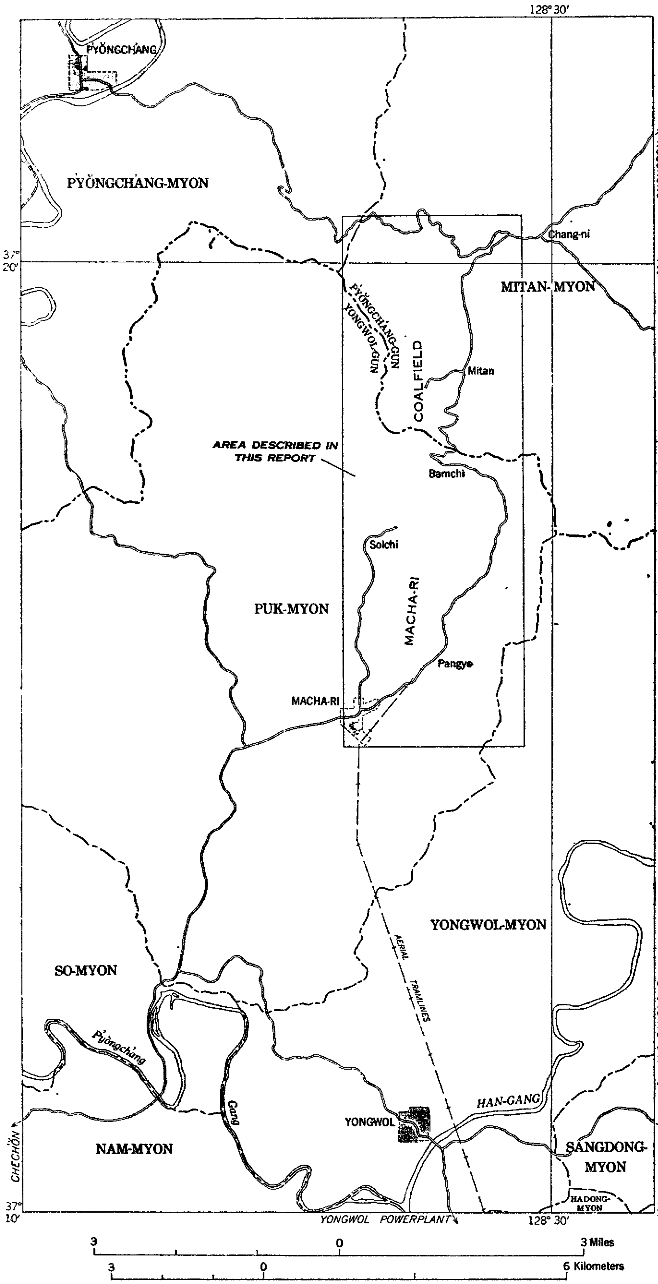


Figure 2.—Index map of the Macha-ri coalfield.

planning, as well as other officials of the Macha-ri Mines, have been most helpful. The writer especially wishes to express his appreciation for the services performed by Mr. Kwak Young Goo, technical assistant, and Shim Jai Won, driver, during the investigation.

GEOGRAPHY

TOPOGRAPHY

Characterized by steep-walled, narrow valleys and sharp sinuous ridges, the topography of the Macha-ri area is typical of the terrain in most of the eastern half of the Korean peninsula. Almost all the surface is steeply sloping, although locally in areas of easily eroded rocks the valley floors are wide enough to permit farming and the construction of villages. In areas where the rocks are resistant to erosion, most of the larger valleys are winding gorges with entrenched meanders and are poorly adjusted to the structure of the underlying rocks. Altitudes range from less than 800 at Macha-ri to more than 3,000 feet in the mountains near the northwest corner of the field. The outcrop of the coal beds ranges in altitude from about 900 near Pangyo to more than 2,200 feet northwest of Mitan. This outcrop is crossed by many deep valleys and sharp ridges, making it possible to mine much of the near-surface coal in the steeply dipping beds by tunnels into the valley sides and by opencuts on the ridge crests.

Remnants of stream terraces are present at two levels in the valleys of the Macha-ri area. Near the heads of the valleys the lower terraces are generally less than 15 feet, and the upper terraces less than 50 feet, above present stream level; downstream these terraces gradually increase in altitude relative to stream level, the lower terraces lying as much as 80 feet, and the upper terraces as much as 200 feet, above present drainage in the main valleys of the coalfield. The lower terraces have provided sites for the construction of miners' residences at Pangyo, Bamchi and Mitan. Most of these terraces are covered by deposits of clay, sand, and gravel as much as 40 feet thick, which were washed down from surrounding slopes or deposited by the streams when the valley floors were about the same altitude as the terraces.

Ridge crests in the region around Macha-ri show a marked accordance in altitude; if the present valleys were filled to the levels of the adjacent ridge crests there would result an old-age topography in which the highest ridges would be only hills. This accordance of crests, together with the widespread presence of entrenched meanders and the poor adjustment of drainage to rock structure, indicates that the present topography is a result of uplift and dissection of a surface of low relief. The steep-sided, narrow valleys indicate that the uplift has been fairly recent and downcutting by the streams has been rapid. Existence of the stream terraces at two levels indicates that downcutting was impeded twice while extensive widening and aggradation of the valleys took place. The streams of the area are now actively deepening their valleys and removing local accumulation of alluvium, probably as a result of recent renewal of uplift.

CLIMATE

The Macha-ri area, like most of Korea, has warm moist summers and cool dry winters. Information was collected from 10 weather stations in southern Korea during the period 1945–49 by the Central Meteorological Observatory, Ministry of Education, Republic of Korea, and assembled by the American Mission in Korea, Economic Cooperation Administration (1949, tables 20 and 21). These data show that the total mean precipitation in southern Korea for the months of June through September ranged from 23.1 to 44.2 inches, and the total mean precipitation for the months of October through May ranged from 13.6 to 17.7 inches during this 5-year period. The mean monthly precipitation ranged from 3.1 to 5.2 inches. These data are summarized in table 1, together with the mean annual temperatures for the same years. During 1949, when temperatures were about average for the period 1945–49, the range of temperatures in southern Korea was from a mean of 36° F in January to a mean of 79° F in August. These are figures which apply to southern Korea as a whole. Corresponding figures for the Macha-ri coalfield, if they were available, would probably show slightly greater precipitation and slightly lower temperatures as compared with the average conditions in southern Korea.

TABLE 1.—*Mean precipitation and temperature in southern Korea*

[Averages from 10 weather stations]

Year	Total mean precipitation				Mean monthly precipitation		Mean temperature	
	June-September		October-May					
	(mm)	(in)	(mm)	(in)	(mm)	(in)	(°C)	(°F)
1945	647.6	25.5	424.0	17.1	89.3	3.5	12.0	53.6
1946	848.0	33.4	423.8	16.7	106.0	4.2	12.9	55.2
1947	757.8	29.8	345.4	13.6	91.9	3.6	11.6	52.9
1948	1,122.0	44.2	449.5	17.7	131.0	5.2	13.2	55.8
1949	587.3	23.1	358.1	14.1	78.8	3.1	12.7	54.9

DRAINAGE

The Macha-ri area is drained by tributaries of the Han-gang which, at its nearest point, is about 2 miles southeast of Macha-ri. Drainage from the southwestern part of the field flows into the P'yŏngch'ang-gang, which joins the Han-gang at Yongwol (fig. 2). Streams in the northeast part of the field flow northward and eastward to join the Han-gang farther upstream.

From June to September, when the rainfall generally is more than 25 inches, rapid runoff resulting from steep slopes and sparse forests causes frequent flooding along the major streams. From October to May, when the total rainfall is generally about 15 inches, many small tributaries are dry. During these months the larger streams have small, but fairly constant, discharges which are sustained by springs, some along faults, some along contacts between beds of different permeability, and some along the bottoms of terrace gravel deposits. Water for domestic use comes from these springs and the streams they supply.

Extensive solution has occurred in the limestone beds along the east side of the coalfield, particularly along faults. Sinkholes, which are evidence of this subsurface solution, are present in limestone terrain throughout the Macha-ri area. Locally they have destroyed the surface drainage pattern as in the area northeast of Mitan (pl. 1). Ground water moving along faults has been found in the mine workings, but it has not seriously impeded mining activity because most of the workings are above the local stream level and above the water table. As mining is done at greater depths the flow of ground water into the workings will probably be more of a problem, because the mine areas are badly faulted.

LAND USE

The once heavy forests of the Macha-ri area, composed dominantly of pine and oak, are almost entirely gone. The local inhabitants, probably more than 25,000, of which more than 4,000 are employed at the mines, have stripped the hills of trees to obtain firewood, lumber, and mine timbers. In 1950 a good stand of timber remained on some of the higher ridges in the northwest corner of the field, and there was a reforested area of young trees on the mountain top east of Pangyo. The higher slopes and heads of valleys are generally brushy, but most of the lower slopes are bare.

Although the soil is very thin, the hillsides in the area are under intensive cultivation. Corn, cotton, wheat, barley, oats, millet, radishes, beans, peppers, cabbage, and other vegetables are grown on the slopes. Terraces and valley floors offer somewhat better soil. Rice paddies have been built on almost every square foot of terrace or bottom land that can be irrigated.

TRANSPORTATION

The Macha-ri coalfield may be reached by roads from Chech'ŏn and Yongwol to the south, from Chongson and Chang-ni to the northeast, and from P'yŏngch'ang to the northwest. These roads are shown in figure 2. They have crushed rock surfaces and are generally in good condition, but they may be temporarily impassable during the summer months because of flooding. The nearest railroad is at Yongwol, a branch line from Chech'ŏn constructed in 1949–50.

SEDIMENTARY ROCKS

SEQUENCE AND DISTRIBUTION OF FORMATIONS

The sedimentary rocks of the Yongwol-Macha-ri area have been described by Yoshimura (1940, p. 115–120), who grouped them into five formations belonging to the Chosen system of Cambrian and Ordovician age and two formations belonging to the Pyongan system of Pennsylvanian and Permian age. From oldest to youngest, the formations of the Chosen system have been named the Sambong-san, Macha-ri, Wagok, Moongok, and Yonghung. The Pyongan system consists of the Hongjom and the Sa-dong formations; the Sa-dong contains the coal beds and includes the youngest rocks in the Macha-ri coalfield. Except for the Moongok, which is exposed a short distance west of the mapped area, all these formations are present in the area shown on plate 1; their sequence, lithology, and thicknesses are summarized in figure 3.

Closely parallel to the northward-trending outcrop of coal beds in the Macha-ri field is the Macha-ri thrust fault, a structure which divides the area shown on plate 1 into two parts differing stratigraphically as well as structurally. With the possible exception of a small block of limestone that may belong to the Yonghung formation, the entire area west of this fault is underlain by rocks of the Sambong-san, Macha-ri and Wagok formations, comprising a thrust plate that has moved relatively eastward over the rocks east of the fault. The westward-dipping Macha-ri thrust fault is the surface along which this movement occurred. Duplicated by subsidiary thrust faults within the thrust plate, the Sambong-san, Macha-ri and Wagok formations crop out in almost parallel belts over most of the area west of this fault. East of the Macha-ri fault the entire area shown on the geologic map is underlain by rocks of the Yonghung, Hongjom, and Sa-dong formations. The Sa-dong crops out along the east side of the fault, and belts of outcrop of the Hongjom and Yonghung formations are farther east. Located in the upper part of the Sa-dong, the coal beds crop out in a narrow belt along the east side of the Macha-ri thrust fault; in many places the coal beds lie against the fault or are cut by it. The distribution of the geologic formations in the Macha-ri coalfield is shown on plate 1, and the relationship of the coal outcrop to the fault is shown on plate 2.

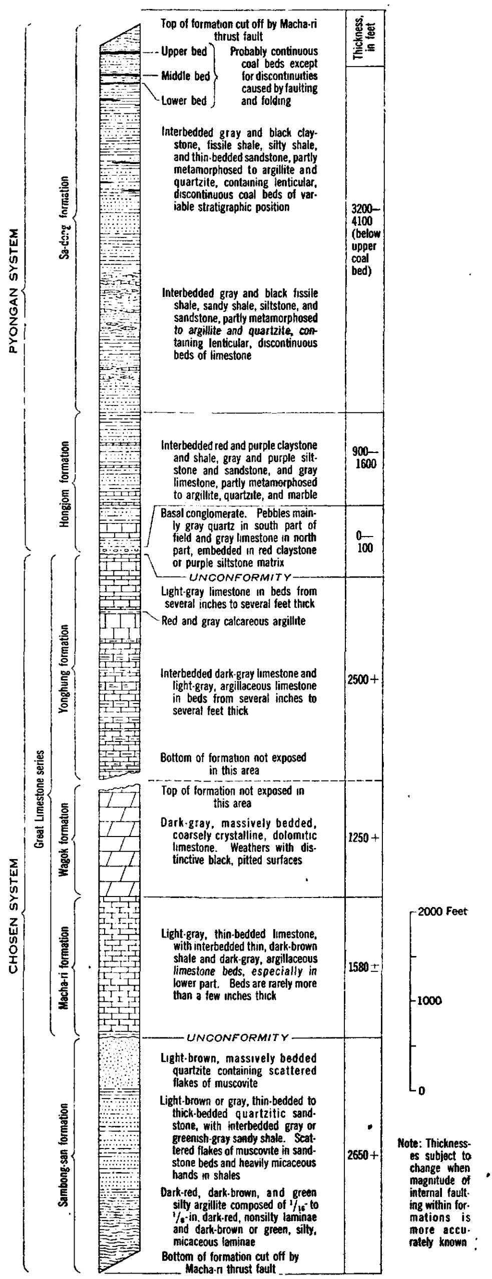


FIGURE 3.—Columnar section of formations exposed in the Macha-ri coalfield.

As the rocks of the Sambong-san and Macha-ri formations along the west side of the fault are more resistant to erosion than the rocks of the Sa-dong along the east side, there is usually an abrupt change in topography along the trace of the fault. This topographic change in the Bamchi area is shown in plate 5.

CHOSEN SYSTEM

The Chosen system in the Macha-ri area consists of clastic, non-carbonate sedimentary rocks in the lower part (Sambong-san formation) and limestone beds in the upper part (Macha-ri, Wagok, Moongok, and Yonghung formations), commonly called the Great Limestone series. A disconformity, not previously recognized, is at the top of the Sambong-san or between the non-carbonate and carbonate parts of the system. This disconformity is well exposed in a narrow valley about a third of a mile northeast of Solchi.

Yoshimura regards the lower part of the Chosen system, the Sambong-san formation, as of Middle Cambrian age; the limestone beds of the upper part of the system are believed to range in age from Middle or Late Cambrian (Nacha-ri formation) to Early or Middle Ordovician (Yonghung formation). The Cambrian and Ordovician boundary being indeterminate, Yoshimura calls the entire system "Cambro-Ordovician" in age. In view of the newly discovered disconformity at the top of the Sambong-san, the designation "Cambro-Ordovician" is reserved for that part of the Chosen system which is above the disconformity, the carbonate beds of the so-called Great Limestone series. The Sambong-san formation below the disconformity is here listed as being of Cambrian age (pl. 1).

The Chosen system in the Macha-ri area differs considerably in lithologic sequence and faunal assemblage from the Chosen system in the Okdong area east of Yongwol, described by Yoshimura (1940, p. 113–115), and in the Samch'ok coalfield farther east, described by Shiraki (1940). Although the same general lithologic division exists, the Chosen system east of Yongwol contains non-carbonate beds in the upper part and limestone beds in the lower part. Shiraki recognizes 20 faunal zones in the Chosen system of the Samch'ok field, ranging in age from Middle Cambrian to Middle Ordovician, but these zones have not been correlated with the faunal assemblage in the Macha-ri area. Emphasizing these differences, Yoshimura has named the Chosen system in the Macha-ri area the "Yongwol-type" Chosen system, whereas that east of Yongwol he calls the "Doodanvang-type."

SAMBONG-SAN FORMATION

The Sambong-san formation includes the oldest rocks exposed in the Macha-ri coalfield. As indicated in figure 3, it contains dark-red, dark-brown, and green silty laminated argillite in the lower part, grading upward into light-brown or gray quartzitic sandstone interbedded with gray or greenish-gray sandy shale. The argillite laminae are generally contorted in minute folds. At the top of the formation is a massive light-brown quartzite. This quartzite is exposed at several places along the west side of the Macha-ri thrust fault (pl. 1), and it also appears in narrow bands of outcrop along other thrust faults farther west. The remainder of the formation is present only in the northwest corner of the field where it is complexly folded and faulted. The base of the formation is cut off by the Macha-ri thrust fault and is not exposed in the Macha-ri area.

The lithology of the Sambong-san formation as shown in figure 3 differs from that indicated by Yoshimura. His report lists the successive members (from bottom to top) of the formation, as follows: limestone and interbedded shale, green and red argillite, light-brown quartzite, red and green shale, and light-brown quartzite. These members are shown as simple bands of outcrop in the northwest corner of the field. Their total thickness is listed as ±1,380 feet. As a result of the more detailed mapping possible during this investigation, it appears that the structure and outcrop pattern in the north part of the thrust plate are much more complex than previously thought. If these structural complexities are considered in interpreting the outcrop pattern, the succession of lithologic units in the Sambong-san formation is somewhat different. The only limestone noted in this area was a small patch along the Macha-ri thrust fault which had no continuity westward at the same stratigraphic position. Its relationship indicates that it is a block that was dragged into its present position along the Macha-ri thrust fault from some stratigraphically higher formation. It resembles limestone from the Yonghung formation, and has been tentatively identified as such (pl. 1). The true stratigraphic position of this limestone block is not known, but if it is a part of the Sambong-san formation it has been displaced by faulting and its true stratigraphic relationship has been obscured. The lithologic succession of the other members of this formation as described by Yoshimura is in agreement with the succession as shown in figure 3 if allowance is made for duplication of the members by thrust faulting, which is now known to exist within the thrust plate. The total thickness of this formation is now regarded as exceeding 2,650 feet.

It is probable that the thickness and lithologic succession of the Sambong-san formation as indicated here will be revised in the future when additional detailed mapping is done in the area northwest of the Macha-ri field. Until such mapping is done, the description of this formation presented here should be regarded as tentative.

On the basis of the trilobite fauna, Yoshimura indicates that the Sambong-san formation is probably of Middle Cambrian age. He lists the following fossils from this formation: *Ptychoparia* sp., *Anomocarella* spp., and *Megagraulos* spp.

GREAT LIMESTONE SERIES

MACHA-RI FORMATION

The Macha-ri formation consists of light-gray thin-bedded limestone having interbedded thin zones of dark-brown calcareous shale and dark-gray argillaceous limestone which are quantitatively more abundant in the lower part of the formation. Individual beds in the lower part range in thickness from ½ inch to several feet; in the upper part of the formation the beds are generally less than 6 inches thick. Most of the formation has a characteristic banded appearance resulting from the alternation of the light-colored beds and the relatively thinner dark beds. Where this formation borders the Macha-ri thrust fault the banding is accentuated in some places by seams of secondary dolomite which locally follow the bedding.

The Macha-ri formation crops out in northward-trending belts in the thrust plate west of the Macha-ri thrust fault. It has been strongly folded in many places within these belts, and there has apparently been a considerable amount of internal shearing along bedding surfaces and minor thrust faults within the formation, making it difficult to determine the true thickness. Yoshimura listed the thickness as ±350 feet; using the new topographic base for plate 1 as an aid in the calculation gives an estimate of thickness of about ±1,580 feet for this formation. This figure may be changed when more accurate information is available on the effects of faulting and folding within the formation.

Yoshimura apparently considers the Macha-ri formation as Middle to Late Cambrian in age. He recognizes two faunal zones within the formation characterized by the following fossils: upper zone, *Lopnorites*, *Glyptagnostus*, and *Olenus;* lower zone, *Tonkinella*, *Kootenia*, *Kogenium*, and *Manchuriella*.

WAGOK FORMATION

The Wagok formation is a massively bedded dark-gray, coarsely crystalline limestone, in part dolomitic. It weathers into large, rough blocks having black pitted surfaces. Over most of the outcrop area, along the west edge of the area shown on plate 1 it is intensely brecciated. It rests conformably on the Macha-ri formation. The top of the Wagok is exposed a short distance west of the area (pl. 1).

A 1,250-foot section of the formation is present in this area, including all but the top 200 feet. According to Yoshimura, the thickness of the Wagok ranges from 650 to 1,460 feet in the Macha-ri area.

No fossils were found in the Wagok during this investigation, and as far as the writer knows none have been reported.

MOONGOK FORMATION

The Moongok formation is not exposed in the area mapped during this investigation. Yoshimura has divided it into three lithologic units consisting of thin-bedded shaly, argillaceous limestone members at the top and bottom, and a thick-bedded, dolomitic limestone member in the middle.

Fossils reported by Yoshimura from this formation are: upper member, *Pomatotrema*, *Geragnostus*, *Shumardia*, *Asaphellus*, and a cheirurid; middle member, *Geragnostus*, *Lingulella*, *Apatokephalina*, *Geragnostus*, *Shumardia*, *Asaphellus*, and a cheirurid; and lower member, fossils not identified.

YONGHUNG FORMATION

A bed of red and gray argillite, ranging from 10 to 20 feet in thickness, is a conspicuous member of the Yonghung formation and was mapped in many places in the Macha-ri coalfield. This argillite marker, which is shown in the columnar section, figure 3, is about 600 feet below the top of the formation and divides it into two parts which differ lithologically. Above the marker the rocks are mostly light-gray limestone in beds generally between 2 and 6 feet thick. Below the marker the rocks are dark-gray limestone, in beds several feet thick, containing interbedded light-gray argillaceous limestone, only a few inches thick. The proportion of light-gray argillaceous limestone increases downward in the formation; the lower part probably grades into the top of the underlying Moongok. The contact between the Yonghung and Moongok formations may be present near the village of Chang-ni, near the northeast corner of the area shown on plate 1, but it was not observed during this investigation.

The Yonghung formation crops out in fault-bounded strips along the east edge of the coalfield and in blocks at the northeast corner of the field. Yoshimura estimated the thickness as about 1,300 feet. It now appears that this formation is probably about twice as thick as his preliminary estimate. A maximum thickness of about 2,500 feet is exposed in the area shown on plate 1, and this probably includes all the formation except 100 feet or less at the bottom.

Fossils are very scarce in the Yonghung formation. The list of those examined by Yoshimura is not available, but he apparently regards the formation as Early or Middle Ordovician in age.

PYONGAN SYSTEM

The Pyongan system, which includes rocks of Pennsylvanian, Permian, and Triassic ages, consists of four formations. From oldest to youngest these are called the Hongjom, Sa-dong, Kobangsan, and Nokam formations. Only the Hongjom and Sa-dong are present in the Macha-ri field. The Hongjom formation consists of a basal conglomerate overlain by intercalated beds of red and purple claystone and shale, gray and purple siltstone and sandstone, and gray limestone. This grades upward into the Sa-dong formation which contains interbedded gray and black shale, siltstone and sandstone, gray limestone, and coal. The contact between the two formations is the top of the highest redbed. Locally the rocks of both formations have been metamorphosed to argillite, quartzite, and marble, and the coal has been altered to anthracite or metaanthracite.

Rocks of the Pyongan system are widely distributed throughout Korea. Kawasaki (1940) and Hatae (1940) first classified the lower part of the system into the Hongjom and Sa-dong formations in P'yŏngan-namdo in northern Korea. These formations have been mapped and described in most of the anthracite fields of northern and southern Korea, and in the Macha-ri field by Yoshimura (1940, p. 118–120). As a result of these studies, the age of the Hongjom is established as Pennsylvanian, and the Sa-dong is regarded as Pennsylvanian and early Permian.

Partly because of lateral changes in texture and composition, and partly because of structural discontinuities, the lithologic units within the Hongjom and Sa-dong are not reliable units for field mapping. The Hongjom and Sa-dong must therefore be treated as formations, their upper and lower contacts being of greatest use and reliability in mapping. Accordingly they are listed as formations in this report, even though they have also been given the status of series by many geologists, because as lithologic units they are comparable with the formations of the Chosen system which have already been described.

The lithology and thickness of the Hongjom and Sa-dong formations are shown in figure 3.

HONGJOM FORMATION

At the base of the Hongjom formation is a conglomerate bed that is as much as 100 feet thick and lies unconformably on the limestone of the Yonghung. The best exposure of this bed is 1 mile northeast of Pangyo along the road to Bamchi (pl. 1). At that locality the bed is vertical and is 94 feet thick. It consists of crossbedded purple, red, and gray sandstone, that is fine grained to coarse grained, and in part micaceous and arkosic. Conglomerate lenses are present in the lower two-thirds of the bed, ranging from a few inches to several feet in thickness. The conglomerate lenses contain well-rounded pebbles of white quartz, gray quartzite, gray and red sandstone, and siltstone. The diameter of the largest pebble observed in this outcrop was 7¾ inches. This conglomerate bed was mapped at several other places in the field, but nowhere else was it as thick as at the above locality. At the north end of the field, on the road from Chang-ni to P'yŏngch'ang, this bed is 20 feet thick and consists of limestone pebbles, as much as 6 inches across, embedded in a red claystone matrix, and interbedded siltstone and sandstone.

Above the basal conglomerate member the Hongjom formation contains units of claystone, shale, siltstone, sandstone, and limestone ranging in thickness from 1 foot to almost 200 feet. The claystone and shale beds are generally red or purple, locally metamorphosed to argillite with the formation of secondary cleavage inclined to the bedding. Generally the siltstone and sandstone beds are gray or purple, in some places green or red; most of them are quartzitic. The limestone beds are mostly very light gray and contain an abundance of fossils; locally they are altered to marble. There is no regular succession of these lithologic units, although limestone is quantitatively more abundant in the lower part of the formation, siltstone and sandstone are most abundant in the middle part, and claystone and shale are most abundant in the upper part. A limestone unit ranging from 100 to 200 feet in thickness is present at about the same stratigraphic position over most of the field in the lower 400 feet of the formation. This member, which is shown in figure 3, is thick bedded and contains few fossils. Most of the other members of the formation are not sufficiently distinctive to be of aid in mapping.

The Hongjom formation crops out in two discontinuous, partly adjacent belts in the east part of the field where it has been duplicated by faulting and folding. Yoshimura lists the total thickness of the formation as about 1,950 feet. On the basis of information now available it appears that the formation ranges in thickness from about 900 to about 1,600 feet. This variation in thickness may indicate interfingering of redbeds at the top of the Hongjom with gray and black beds in the lower part of the Sa-dong.

The limestone of the Hongjom formation contains a fauna consisting of crinoids, gastropods, brachiopods, corals, and Foraminifera, including the Foraminifera *Textularia*, *Staffella*, and *Fusulinella*, according to Yoshimura.

SA-DONG FORMATION

The Sa-dong formation is composed mainly of gray and black claystone, shale, siltstone, and sandstone, locally metamorphosed to argillite and quartzite. In the lower 1,000 to 1,600 feet of the formation discontinuous, lenticular fossiliferous beds of limestone are present, ranging in thickness from 1 to 30 feet. The upper 1,000 to 1,200 feet contains fissile and carbonaceous shale, and coal beds as much as 12 feet thick. Discontinuous carbonaceous zones and coal beds as much as 18 inches thick are present at several stratigraphic positions in the middle of the formation. Shale and argillite are quantitatively most abundant in the lower and upper parts of the formation, and sandstone and siltstone are most abundant in the middle part. The general lithologic distribution of these different rock types is shown in figure 3. The top of the formation is cut off by the Macha-ri thrust fault and is not exposed in the Macha-ri coalfield.

The Sa-dong crops out in a single belt along the east side of the Macha-ri thrust fault. Because of its proximity to the fault, the formation has been subjected to intense shearing stresses which produced irregularities and discontinuities in the different lithologic units. Thus the coal beds in the upper part of the formation have a "pinch and swell" structure, and are abundantly contorted and offset as a result of folding and faulting accompanied by squeezing of the coal. Similarly, in many places the sandstone and limestone beds are faulted, folded, and pulled apart into discontinuous blocks around and between which the adjacent shale or argillite has been squeezed. The difficulties of tracing individual rock units in such a structural environment are increased by lateral changes in thickness and lithology of these units.

Because of the intense structural deformation within the Sa-dong, only approximate estimates of the thickness of the formation are possible at present. The best available evidence indicates that between 3,200 and 4,100 feet of Sa-dong is exposed in the Macha-ri coalfield. This probably includes all the formation except about 100 feet at the top which has been cut off by the Macha-ri thrust fault. Yoshimura's preliminary estimate for the total thickness of the Sa-dong formation was about 2,900 feet.

The Sa-dong is believed to be of Pennsylvanian and early Permian age on the basis of the fusulinids contained in the limestones of the lower part of the formation. These limestone beds contain an abundance of corals, brachiopods, and gastropods. The shale in the upper part of the formation contains crinoids, brachiopods, and pelecypods. Some shale beds in the middle and upper parts of the Sa-dong have an abundance of plant fossils (lepidophyta and arthrophyta). Plant fossils are distributed profusely throughout the light-gray claystone or argillite beds which underlie most of the coal beds. Yoshimura lists the fossils below from the Sa-dong formation.

Foraminifera: *Tetrataxis*
Textularia
Schwagerina
Pseudoschwagerina
Anthozoa: *Syringopora*
Brachiopoda: *Chonetes carbonifera* Keyserling
sp. A (N. spp.?)
sp. B (N. spp.?)
Productus manchuricus Chao
spp.
Linoproductus cfr. *simensis* Chao
Buxtonia cfr. *mapingensis* Grabau
Echinoconchus elegans (McCoy)
liangchowensis Chao
Dielasma sp.
Spirifer sp.
Squamularia asiatica Chao
Martinia semiglobosa Tschernyschew
Protoschizodus? sp.
Pelecypoda: *Aviculopecten manchuricus* Chao
spp.
Acanthopecten sp.
Entolium sp.
Pleuronectes sp.
Gastropoda: *Trachydomia* sp.

QUATERNARY SYSTEM

TERRACE DEPOSITS

Loosely coherent deposits of clay, sand, and gravel as much as 40 feet thick are present as terraces along the sides of many valleys in the Macha-ri area. These deposits are most extensive near Pangyo, Mitan, and Chang-ni (pl. 1). They consist of debris derived from rocks that crop out on ridges and valley slopes upstream. Most of the materials are poorly sorted; the constituent rock particles are angular, subangular, or subrounded.

The terraces of the Macha-ri region are remnants of alluvial stream deposits which were originally more extensive, probably covering most valley floors in the region before the valleys were cut to their present depth. As previously stated, these terraces record episodes when the downcutting of the valleys was temporarily interrupted and stream aggradation occurred. Similar river terraces are widely distributed in many parts of the world. It is generally assumed that the widespread changes in stream gradients required to produce most river terraces probably accompanied changes of sea level which occurred during the Pleistocene. The terrace deposits of the Macha-ri region are, accordingly, listed as Pleistocene although their precise age is not known.

ALLUVIUM

Most of the valley floors in the Macha-ri coalfield are covered with unconsolidated alluvial sand and gravel, but the only extensive deposits of alluvium are near Macha-ri, Mitan, and Chang-ni (pl. 1). These deposits are generally not more than a few feet thick. They contain larger boulders and less clay than the terrace deposits.

IGNEOUS ROCKS

In the coal-bearing zone of the upper part of the Sa-dong formation, along the Macha-ri thrust fault nearby, and in the overlying rocks of the thrust plate there are many small irregular felsitic intrusive bodies. These masses are most abundant in the badly faulted rocks immediately below the Macha-ri thrust where most of them are along faults; individual masses generally do not exceed a few feet in width and a few tens of feet in length. Earlier maps of the Macha-ri field show long, continuous dikes and sills near the coal beds along most of of the coal outcrop. Detailed mapping shows, however, that felsite is present only in scattered, discontinuous masses of extremely irregular shape and of such small size that only a few could be shown on plate 2. The largest of these masses is in the Sa-dong formation along the Macha-ri thrust fault in the Pangyo mine area. This sill-like body has the fault surface as its upper contact, as shown in plate 4. Other irregular intrusive masses are closely associated with the coal but have no apparent metamorphic effect on it (fig. 4).

The felsitic rocks of the Macha-ri field range in composition from syenite, consisting mainly of anorthoclase and accessory biotite, magnetite, apatite, and rutile, to andesite, consisting mainly of plagioclase and augite phenocrysts, rarely as much as ¼ inch across, in a fine-grained dark-green groundmass of hornblende, plagioclase, and magnetite. Preliminary examination indicates that the intrusive masses are generally either entirely syenitic or entirely andesitic; however, as the spatial and genetic relationship between the two intrusive types are not known, the intrusive rocks of the field are collectively listed as felsite on plate 2.

The intrusive masses along the Macha-ri thrust fault (pl. 2), as well as some other smaller masses in the mine areas, are syenite. Generally they are deeply weathered to a light-brown porous earthy material containing abundant sericite. A specimen of syenite collected from the largest intrusive mass in the field at the locality shown

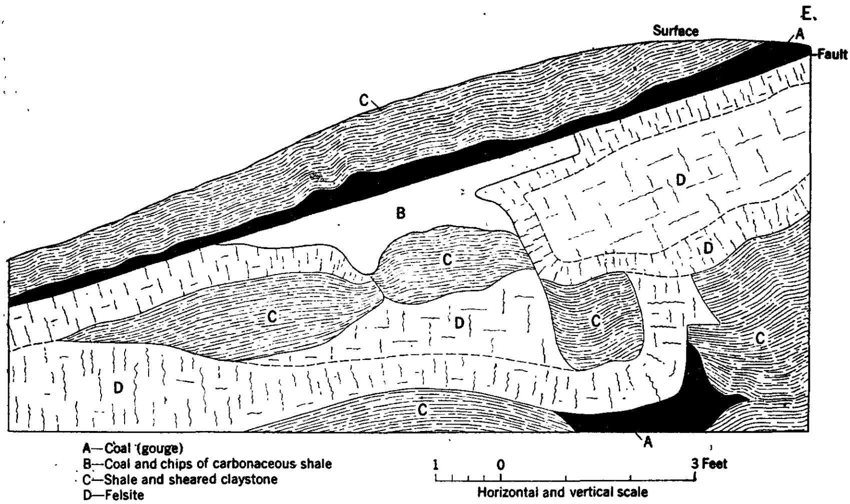


FIGURE 4.—Coal and felsite in Macha-ri fault zone, Pangyo mine area.

in plate 4 was studied and described by Mrs. Anna Heitanen-Makela as follows:

Coarse alkalie feldspar (anorthoclase) is the main constituent. It includes small altered biotite flakes, some magnetite grains, apatite prisms, and small areas consisting mainly of biotite and sericite (altered nephelines?). Biotites are partly altered to chlorite and include abundant small rutile needles, which are oriented parallel to the cleavage planes. Many biotites show pseudo-hexagonal shapes. Secondary biotite grows around the older flakes and fills the cracks in the feldspars.

Many small intrusive bodies in the mine areas as well as some dikes which were observed northwest of the area shown on plate 1 are of andesitic or basaltic composition. These are usually less deeply weathered than the syenite masses. A basaltic specimen from a 3-foot dike in the Solchi mine area is described by Mrs. Heitanen-Makela as follows:

Plagioclase (labradorite) and augite phenocrysts range from 1 to 3 mm. in length and are fairly abundant. The wholly crystalline fine grained groundmass consists of green to brown hornblende needles and tiny plagioclase laths. Small grains of magnetite and leucoxene are scattered through the rock.

Calcite is the most abundant secondary mineral. It replaces plagioclase phenocrysts together with sericite and augite phenocrysts with colorless hornblende and antigorite. In addition small calcite grains are scattered throughout the rock. Very little unaltered augite remains in the central parts of the areas which show external shapes of augite.

The intrusive masses of both rock types appear to be younger than the main thrust movements. The intrusive rocks along the Macha-ri thrust fault cut across from the footwall to the hanging wall of the fault in many places. Most intrusive masses are cut and offset by later normal faults of small displacement. The exact age of the intrusive rocks is not known. They may be of Cretaceous age, corresponding to intrusive rocks of the Upper Cretaceous Pulkuksa series, Kyongsang system, which are present in the Samch'ok coalfield. The relative age of the two intrusive types is not known, although it seems likely that the syenite may be a differentiation from the same magma that produced the more basic intrusive rocks.

STRUCTURE

MACHA-RI THRUST FAULT

As previously indicated, the Macha-ri thrust fault, one of the principal faults in east-central Korea, divides the Macha-ri area into two parts which differ in structure and stratigraphy. In the Macha-ri coalfield this fault is of economic importance, first because it cuts off the coal-bearing rocks on the west and thus forms the west limit of mining, and second because the structure of the coal beds is mainly a result of the thrusting that occurred along this fault.

The Macha-ri thrust fault was mapped by Yoshimura from the place where the P'yŏngch'ang-gang crosses it south of Macha-ri and west of Yongwol northward to a granitic area south of P'yŏngch'ang and northwest of the coalfield. This is a distance of more than 15 miles measured along the fault trace. Probably the fault extends farther south in the thrust belt west of the Tangyang coalfield. West of Yongwol the fault trends slightly east of north, changes to north near Macha-ri, and swings sharply toward the west as it passes beyond the northwest corner of the Macha-ri field. The fault dips westward throughout the area shown on plate 1. The dip averages about 50° near the Mitan mine, decreases to about 20° west of Pangyo, and then abruptly steepens to more than 70° east of Macha-ri. Precise dips of 45°, 35°, and 16° were measured at three places (pl. 1); elsewhere the dips could be only approximated.

The sinuous trace of the Macha-ri thrust fault (pls. 1, 2) is a result of the relatively low dip and the sharply dissected topography along the fault as already indicated in the Bamchi area (pl. 5). In a few places, offsets of a few feet, caused by later high-angle faults, were observed along the Macha-ri thrust fault. One such offset of about 10 feet in the fault surface in the Pangyo mine area is shown on plate 4.

The Macha-ri thrust fault is bordered on the west by limestone of the Macha-ri formation and quartzite or argillite of the Sambong-san formation. On the east side it is bordered by the coal-bearing zone in the upper part of the Sa-dong formation. The relationships of these formations on opposite sides of the fault are shown in the geologic sections (pl. 3). The greatest stratigraphic difference between rocks on opposite sides is northwest of the Mitan mine where the lower part of the Sambong-san formation is faulted against the upper part of the Sa-dong; the missing stratigraphic interval here totals at least 11,500 feet. This figure probably represents the minimum amount of displacement along this part of the fault. Considering the structure of the rocks on either side of the fault it seems likely that the displacement is considerably greater than this amount and that the movement along this part of the fault was mostly dip slip.

WEST OF MACHA-RI FAULT

West of the Macha-ri fault, the thrust plate of which it forms the bottom or sole is cut into northward-trending strips by similar thrust faults of lesser displacement and steeper dip. These subsidiary thrusts have about the same strike as the Macha-ri fault, and branch from it at depth. They have caused repetitions in the westward-dipping Cambrian and Ordovician rocks that compose the thrust plate; the faults generally dip more steeply than the beds. This pattern of narrow northward-trending thrust blocks is interrupted by transverse faults at the north end of the thrust plate, which were probably formed as a result of differential lateral movement within the plate. The structure of this part of the thrust plate is further complicated by folds which developed, in part at least, before the thrust faults were formed. As a result of this early folding, parts of different folds are now exposed on opposite sides of these transverse faults (pl. 3, *A–A'*). As previously pointed out in the description of the Sambong-san formation, this part of the field is much more complex than was formerly realized, and additional mapping northwest of the field is needed to determine the true significance of the structures in that area.

Within the thrust plate, the rocks have reacted differently to the compressive stresses that caused the thrusting. The most competent rock was the massive quartzite bed at the top of the Sambong-san formation, which generally resisted sharp folding but acted as a rigid support for parts of the thrust plate and subsidiary thrust blocks, and carried the overlying less competent rocks. The shale and argillite in the lower part of the Sambong-san and the thin-bedded limestone of the Macha-ri formation are incompetent rocks and yielded to the stresses by bedding-surface movements and by formation of sharp folds, as shown on section *C–C'*, plate 3. By contrast, the coarsely crystalline dolomitic limestone of the Wagok formation, reacting like a brittle substance, was brecciated and granulated instead of folded.

EAST OF MACHA-RI FAULT

Steeply dipping northward-trending faults, with displacements of hundreds of feet, have cut the area east of the Macha-ri thrust fault into wedge-shaped blocks. Most of these faults are continuous for long distances, are nearly vertical, and generally the west side is upthrown. The blocks bounded by these faults contain segments of large folds, having amplitudes of hundreds of feet, which were probably formed before the faulting occurred. These blocks also contain small folds, which usually trend obliquely to the faults bounding. Some of these small folds may have been formed by shearing stresses acting on the fault blocks during the period of faulting. The regional pattern of these large faults in the eastern part of the Macha-ri field, as well as the attitude of slickensides observed on some of the fault surfaces, indicates that the movements on these faults may have been dominantly strike slip.

The Bamchi fault (pl. 1) is one of the main faults in the eastern part of the field. Northwest of Mitan it forms the contact between the Hongjom and Sa-dong formations, cutting off the lower part of the Sa-dong and the upper part of the Hongjom. Near Mitan it truncates a series of folds which have duplicated and partly overturned the Hongjom beds north and east of Mitan; this fault and part of the series of folds are shown on sections *A–A′* and *B–B′*, plate 3. Northeast of Pangyo the Bamchi fault has duplicated the Hongjom formation as shown on section *C–C′*, plate 3.

At the south end of the Macha-ri coalfield the entire sequence of Sa-dong, Hongjom, and Yonghung formations is overturned toward the west. The north limit of this overturning is a northeastward-trending fault that starts near the Macha-ri thrust fault east of Macha-ri, trends obliquely across the strike of the beds, passes through Pangyo and Yobong, and joins the Bamchi fault east of Bamchi. North of this fault the beds are in normal position with the Sa-dong on top, dipping steeply westward. South of this fault they dip steeply eastward with the Sa-dong underlying the Hongjom, as shown on section *D–D′*, plate 3. The fault is along an axis of torsion in which the beds are wrinkled with small, closely spaced folds. South of the intersection of this fault and the Macha-ri fault, the coal-bearing upper part of the Sa-dong formation has been cut off, partly as a result of the overturning of the Sa-dong formation and partly because of the steepening of the Macha-ri thrust fault in this area.

At the north end of the coalfield is a group of transverse faults which cut and offset some of the northward-trending faults and folds previously described. These transverse faults are probably related to a major thrust fault believed to be present northeast of the area shown on plate 1.

In the folding and faulting that produced the present structures east of the Macha-ri thrust fault, the Yonghung formation responded competently with the formation of broad, open folds and few, but continuous, faults. The Hongjom formation, although less competent as a whole formed relatively simple structures because of the support afforded by the underlying Yonghung beds. By contrast, the Sadong formation was incompetent and was deformed into intricate discontinuous faults and folds resulting from this incompetence as well as from the proximity of the Macha-ri thrust fault. The outcrop belt of the Sadong formation as it appears on plate 1 is deceptive, for within this belt are many complex structures, some of which are shown on plates 2 and 3. Abrupt lateral and vertical changes exist in strike, dip, and displacement of faults and in attitude and amplitude of folds. Typical of the folding within the formation is the structure shown in plate 6, an exposure of thin-bedded sandstone at the Bamchi mine 1. The effects of such structural deformation on the coal beds in the upper part of the Sadong formation are discussed below.

STRUCTURAL CHARACTERISTICS OF COAL BEDS

The coal beds in the Macha-ri coalfield are intensely faulted and folded. The approximate outcrop of the center of the coal-bearing zone in the upper part of the Sa-dong formation and the position of the Macha-ri thrust fault are shown on plate 2; the more commercially important coal beds and their relationship to this fault are shown on plate 3. It will be noted that this zone of coal beds lies very close to the fault, that it dips westward beneath the thrust plate at angles generally slightly steeper than the dip of the fault, and that in many places the coal beds are actually in contact with the fault surface. Most of the contortions and complexities that exist in the coal beds are a result of their proximity to the Macha-ri thrust fault, for as the Cambrian and Ordovician rocks of the thrust plate were forced over the coal beds many faults and folds were formed in the relatively weak, incompetent coal and related shale of the upper part of the Sa-dong formation. Most of the faults and folds formed in this way trend about parallel to the Macha-ri thrust fault. Other structural complexities affecting the coal beds are faults trending obliquely to the coal-bearing rocks and resembling the high-angle continuous transcurrent-type faults that are present throughout the east part of the field. Some of these have caused offsets in the entire coal-bearing zone.

The principal faults and folds within the Sa-dong formation are shown on plates 2 and 3. There are many other structures that have important effects on the coal beds but are too small to be shown on these drawings. To plan mining operations efficiently in the Macha-ri coalfield it is necessary to recognize the existence and the effects of this minor, but important, faulting and folding in and near the coal beds.

EFFECTS OF FAULTING

Faults have caused thinning, thickening, duplication, and offsets in the coal beds. Some beds, several feet thick, have been thinned to several inches by faults which cut obliquely across the beds. Thus, in workings from slope 2 at the Pangyo mine, shown in figure 6, the so-called lower bed on level 3 contained about 42 inches of coal, whereas on level 6 this bed had been thinned to a few inches by faulting. The coal thus removed from a bed is usually dragged along the fault surface as gouge which is present along many faults in the Macha-ri field; some of the more evident concentrations of coal gouge are indicated on plate 2. A typical concentration along a low-angle thrust fault in the Pangyo mine area is shown in figure 4. In some places coal-gouge concentrations along faults have been mined, but generally they are too thin, impure, and discontinuous to be mined, and most of the coal gouge along faults is not recoverable.

Faults in the Macha-ri field also commonly follow the coal beds for considerable distances, in fact the writer has not observed a coal bed anywhere in the Macha-ri field that is not a locus of displacement. This localization of movement near and in coal beds is probably not just chance. Coal is an excellent lubricant, and stresses applied equally to a broad area would tend to be localized in a zone of easiest movement such as a coal bed. Such faults within the coal beds appear to be mainly responsible for the abrupt thickening and thinning that is so characteristic of the beds. In many places a coal bed changes in thickness abruptly from several feet to a few inches; a few feet beyond it may become thicker again just as abruptly. Such changes of thickness are shown in the photograph of a coal bed in the Bamchi 1 mine area, plate 7. Under these conditions it seems likely that the thicker parts of the bed are abnormally thick just as the thin parts are abnormally thin, and it is very difficult to make an accurate estimate of the original thickness of the coal bed.

Faults commonly offset and duplicate the coal beds in the Macha-ri field just as faults in the thrust plate have duplicated the Sambong-san formation and faults in the eastern part of the field have duplicated the Hongjom formation. Therefore in some mines the same coal bed has been found more than once in the same crosscut, and it has been assumed that there were more individual beds than actually exist, whereas if additional crosscuts had been driven it would have been apparent that one of the beds was simply a faulted segment of the other and had no lateral or vertical extension beyond the crosscutting fault. The entire coal-bearing zone has been duplicated by faulting west of Bamchi, as shown on section *B-B′*, plate 3. This is a large-scale example of the effect many faults have had on individual coal beds on a smaller scale, causing structural discontinuities in the coal beds and increasing the difficulties of mining.

EFFECTS OF FOLDING

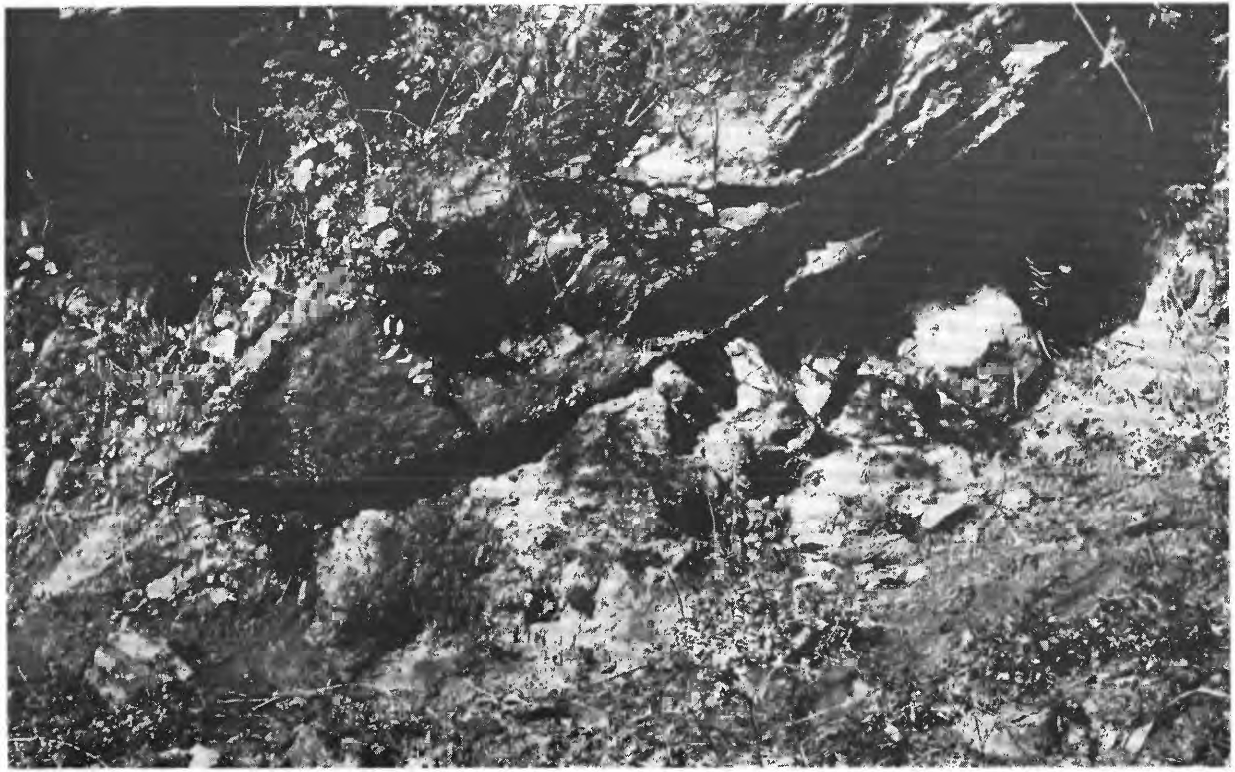
Folding has duplicated coal beds in many places in the Macha-ri field, and has also caused thickening and thinning of the coal beds. Most of the folds are small, but they increase the difficulty of mining and of determining the true thickness of the beds. Mine workings along the flanks of folds have disclosed coal that was abnormally thin, and workings along the crests and troughs of folds have discovered abnormally thick coal. In many places, crosscuts through folds have found coal beds duplicated at the same level. One of the best examples of the effects of folding is in a small opencut at Bamchi 2 mine where a 5-inch and a 24-inch coal bed have been duplicated. This fold appears to be cut off on the bottom just below the opencut by a thrust fault. A crosscut at the level of the opencut would show four coal beds, whereas a crosscut 50 feet below the opencut would show only two beds; the fold and consequent duplication of the coal beds have no continuation below the thrust fault.

An additional effect of the compressive stresses has been the squeezing of coal from the beds into cracks in the surrounding rocks. Where the beds have been strongly crumpled and brecciated it is common to find the coal as disconnected masses squeezed between and around blocks of shale. Such masses are shown in the wall of an opencut near the Kwang Kok slope, plate 8.

In summary, the regional structural patterns are duplicated and intensified in the relatively weak and incompetent coal and related shale beds in the upper part of the Sa-dong formation (pl. 1). Numerous faults and folds have been formed which have resulted in abrupt thickening and thinning of the coal beds as well as in duplication and offset in the beds, and in the formation of coal-gouge zones along faults.

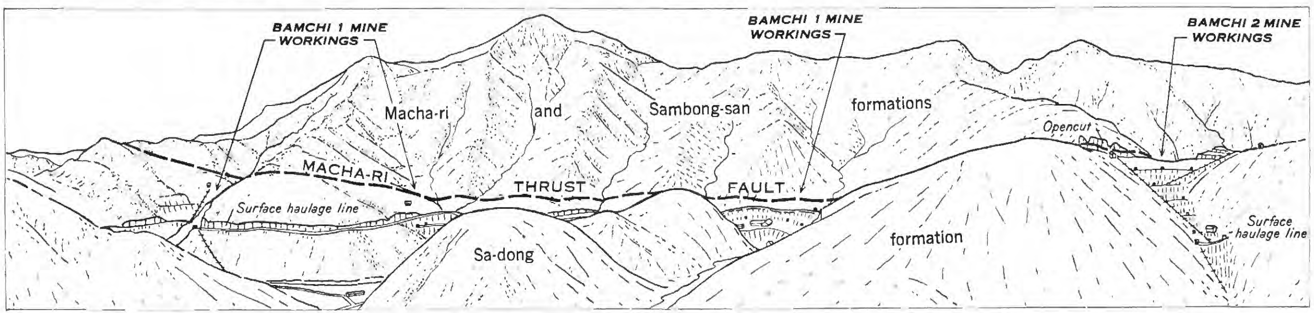
STRUCTURAL RELATIONSHIP OF COAL-BEARING ZONE TO SA-DONG FORMATION

When the trend of the coal beds in the Macha-ri field, as revealed by the outcrop pattern and the mine workings shown on plate 2, is compared with the structural trends of the underlying Sa-dong formation, a marked discordance is observed. The regional trend of the coal-bearing zone is closely parallel to the strike of the Macha-ri thrust



MACHA-RI THRUST FAULT IN PANGYO MINE AREA.

Limestone of Macha-ri formation resting on felsite intrusive body in upper part of Sa-dong formation. Near left edge of photograph, Macha-ri fault is displaced 10 feet by high-angle fault.



MINE WORKINGS AND MACHA-RI THRUST FAULT IN THE VICINITY OF BAMCHI.

View looking westward from hill northeast of Bamchi.

THIN-BEDDED SANDSTONE AND SANDY SHALE, SA-DONG FORMATION.

Exposure in cliff along tramway at Bamchi 1 mine.

OUTCROP OF COAL BED AT BAMCHI 1 MINE.

Exposure in cliff along tramway. Sheared claystone in both sides of bed.

COAL IN BRECCIA NEAR MACHA-RI THRUST FAULT.

View of wall of opencut near Kwang Kok slope. Coal squeezed between blocks of shale.

fault, but it truncates the smaller structures in the lower part of the Sa-dong. This discordant relationship is most clearly observed southeast of the Kwang Kok slope where intricate folds have brought sandstone beds from the middle of the formation up against the zone of main coal beds. The coal zone truncates these folds, and its relationship to these sandstone beds changes considerably through the length of the coalfield.

This discordant relationship is apparently a result of thrust movements in the coal and adjacent beds along many minor faults trending about parallel to the Macha-ri thrust fault. The cumulative effect of these many small thrust movements has been to drag the upper coal-bearing zone of the Sa-dong formation along for a short distance under the advancing thrust plate, causing this zone to truncate structures in the underlying Sa-dong as completely, but not as simply, as if the coal-bearing zone were separated by a single thrust fault from the rest of the Sa-dong. At the same time the parallelism of the minor folding and faulting in and near the coal beds with the Macha-ri thrust has imposed an apparent parallelism on the coal beds, even where they may have been previously divergent from the trend of the fault.

SEQUENCE OF DEVELOPMENT

The structural features observed in the Macha-ri area suggest the following sequence of structural events:

Late Triassic(?)

Formation of folds of large amplitude and lateral extent.

Late Jurassic(?)

Formation of high-angle transcurrent-type faults such as those in the eastern part of the field. Associated minor folding and thrusting.

Formation of major thrust faults such as those in the western part of the field with associated minor folding and continued movements on the high-angle faults. This and the previous step were probably going on simultaneously at different places.

Cretaceous(?)

Injection of felsite intrusive masses.

Tertiary(?)

Minor normal faulting, displacements small.

All these structural features affect the youngest sedimentary rocks in the Macha-ri field, the Sa-dong formation of Permian age. They also affect rocks of the upper part of the Pyongan system (Kobangsan and Nokam series) of Permian and Triassic ages, which crop out immediately north of the village of Chang-ni. Thus the only evidence available in and near the Macha-ri field indicates that the folding is not older than Late Triassic. In the Samch'ok field, where rocks of Triassic, Jurassic, and Cretaceous ages are present, the same sequence of structural events has been recognized and tentatively dated (Shiraki, 1940) as follows: Late Triassic, Late Jurassic, Late Cretaceous, and Tertiary (Miocene?). Because of the proximity of the Macha-ri and Samch'ok fields and the similarity in structural events, the same ages have been tentatively assigned to the Macha-ri field as listed above. All the steps in the structural sequence of this region have contributed to the high rank, poor quality, and structural complexity of the coal.

MINING DEVELOPMENT AND HISTORY

The mine workings in the Macha-ri coalfield have explored most of the coal outcrop north of Macha-ri. These workings are grouped in five areas known as the Pangyo, Solchi, Bamchi 1, Bamchi 2, and Mitan mines. Location of these mine areas and their relationship to the mining communities of Macha-ri, Pangyo, Solchi, Bamchi, and Mitan are shown on plate 1. The workings consist of tunnels and slopes, which explore the steeply dipping coal beds from the sides of the narrow valleys crossing the coal outcrop, and opencuts where the coal has been mined on ridge crests. Extent of the mine workings is shown on plate 2.

An electric railway haulage system (pl. 2) connects the coal tipple, which is located at the south end of the field near Pangyo, with the scattered mine workings. Individul workings are joined to the main haulage line by inclines. Most of the coal is transported to the tipple over this railway system; coal from the Mitan workings was being transported to the tipple by truck in 1949 pending completion of the north end of the haulage system. Two aerial tramways having a daily capacity of 1,600 metric tons and a length of about 7½ miles carry the coal from the tipple to the powerplant at Yongwol.

Although the existence of coal near Macha-ri has been known for many decades, possibly for many centuries, it was not until 1929 that systematic investigation of the field was undertaken. Information in the files of the Macha-ri Mine[6] shows that the Chosen Government fuel laboratory began a program of prospecting and mapping in that year to determine the extent and thickness of the coal beds. Exploration of the field began under Japanese direction in August 1935; the first workings were opened in the Pangyo mine area at the south end of the field. In 1936 the Macha-ri field was placed under control of the Chosen Electric Power Co. which was then constructing the steam

[6] Macha-ri Mines, 1949, The history of the Neietsu (Yongwol) coal field: unpublished pamphlet prepared by Macha-ri Mines staff, on file in mine office. (Korean)

powerplant at Yongwol. By 1938 the powerplant was completed and the two aerial tramlines were built, connecting the coal tipple at the south end of the field with the new plant. Mining was extended northward, workings were opened in the Solchi and Bamchi 1 mine areas. Production increased rapidly to fill the needs of the new powerplant which was the main source of electricity for southern Korea from 1938 until 1944. In 1944 the Yongwol plant was put on a standby basis as electricity became available from the Supung hydroelectric plant in northern Korea. Coal production at Macha-ri was curtailed, then stopped altogether in August 1945 when the war ended and the Japanese were expelled from the country.

Mining was resumed in April 1946 under the direction of the United States Army. The field was separated from the control of the Korean Electric Power Co., as the Yongwol plant was still on a standby basis, and placed under jurisdiction of Kangwon-do (province). In May 1948 the power supply from northern Korea was cut off. The Macha-ri mine were then put under control of the Department of Commerce of the Republic of Korea, and again began to supply fuel to the Yongwol plant, which regained its position as the principal source of electric power for southern Korea. Production of coal has steadily increased since that time, and mining has steadily spread northward in the field; more than half of the recent production has come from the Bamchi 2 and Mitan mines. Production started at the Mitan mine in 1948.

More than 3 million metric tons of coal have been produced from the Macha-ri field during its 15-year history. The yearly production is shown in table 2. These figures were taken from records in the files of the mine office at Macha-ri, except the figures for 1948–49 which were taken from data compiled by the American Mission in Korea (1949, tables 30a and 30b).

TABLE 2.—*Production from the Macha-ri coalfield*

	Metric tons		Metric tons
1936	5, 041	1944	249, 363
1937	71, 016	1945	109, 986
1938	182, 031	1946	22, 965
1939	294, 618	1947	76, 290
1940	387, 296	1948	150, 051
1941	422, 464	1949	271, 273
1942	447, 206		
1943	343, 085	Total	3, 032, 685

Although the individual yearly figures listed here for 1936–45 differ from the corresponding figures listed in the unpublished Gallagher report (see p. 3), the total production for this period is about the same. The Gallagher report shows 2,512,102 metric tons produced to the end of 1945, and the above figures show a total of 2,512,109 metric tons for the same period. In the 2 years 1948–49 the Macha-ri field was the second largest producing field in southern Korea, having a total production of about 421,000 metric tons during these 2 years as compared with a production of about 760,000 metric tons from the Samch'ok coalfield.

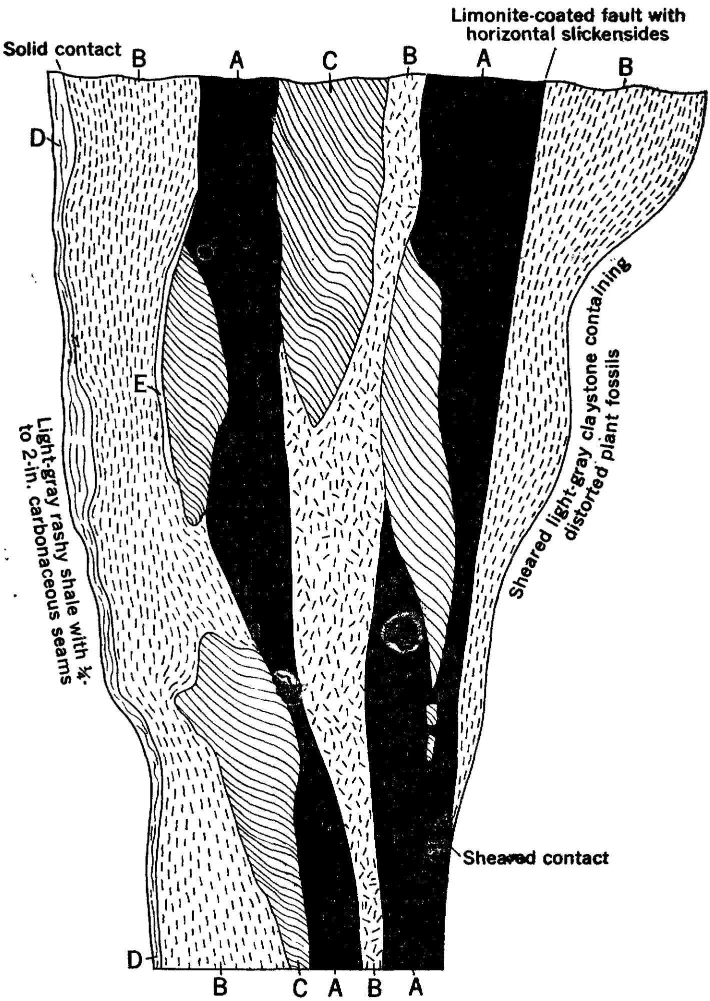
COAL

INTERNAL CHARACTERISTICS

The faulting and folding of the coal beds in the Macha-ri field have not only converted the coal to anthracite or metaanthracite, but they have also caused radical changes in the internal constituents of the coal beds and in their arrangement. Most coal beds are not homogeneous in composition or in quality of the coal, because they contain alternating layers of shale, shaly or bony coal of low heat value, and relatively good coal of higher heat value. These layers are normally parallel with the top and bottom of the bed, and the orderly arrangement of the different layers composing a bed makes it possible to exclude the impure layers by carefully mining only the desirable parts of the bed. In the Macha-ri field, however, the intense structural deformation has destroyed this orderly arrangement of layers within the coal beds just as it has caused radical changes in the form and distribution of the beds.

The constituents of coal beds in the Macha-ri field and their typical arrangement are shown in figure 5, which is drawn from a coal outcrop at Bamchi 2 mine. The shaly coal pods (*C*) represent an impure shaly coal layer in the original bed which has been broken by the faulting into scattered, disconnected pods. The flaky or rashy coal (*B*) represents original layers of considerably higher heat value, and the powder coal (*A*) represents original layers of the best coal in the bed. Scattered in all the constituent parts are quartz grains that came from quartz stringers similar to (*E*), most of which disintegrated during the faulting. This textural relationship is found nearly everywhere in the coal beds in the Macha-ri field, which indicates that under shearing stresses only the parts of a coal bed containing bony or shaly impurities retain enough coherency to form lumps.

In mining the coal it is generally impossible to separate the constituents, and it is usually necessary to extract the entire bed in order to obtain sufficient working room. Therefore much impure and undesirable material is included in the coal as mined, and this should be removed by cleaning. The correlation between grain size of coal and heat value, which results from the deformation of the beds, facilitates beneficiation by screening or gravity methods, and the quartz content of the beds should be removable by gravity separation methods.



A Powder coal containing a few scattered quartz grains

B Rashy or flaky coal containing scattered quartz grains. Orientation of flakes as indicated

C Shaly or bony coal pods with quartz stringers parallel to the shale partings. Orientation of partings as indicated

D Siderite

E Quartz

0 5 10 inches

Horizontal and vertical scale

FIGURE 5.—Textural detail of coal bed at Bamchi 2 mine.

It is not the purpose of this report to indicate the best methods of coal preparation; it is intended only to show the geologic reasons for the impurities in the mine-run coal and the need for beneficiation.

EXTENT AND THICKNESS

The entire outcrop of workable coal beds, as it is now known, is shown on plate 2. North of this there is no coal on the surface, but a heavy cover of talus conceals the bedrock over much of the area and it is possible that the coal beds continue beneath this talus and will be revealed by future prospecting. It is also possible that the coal beds continue farther northward at depth but have been cut off near the surface by faults. The coal beds appear to be thinning northward, however, and it is likely that any coal in this part of the field is thinner than in the areas of present mining. Southwest of Pangyo considerable prospecting has been done, but only thin shaly beds and coal gouge have been found. The coal has probably been cut off by the Macha-ri thrust fault in this part of the field. As the beds of the Sa-dong formation are overturned and dip steeply eastward in this area, as previously described, it is possible that the coal beds may be present near the Macha-ri fault at some depth below the surface, but this is not a certainty.

Mine workings and prospect trenches, shown on plate 2, have explored almost the entire length of the coal outcrop. Throughout this area there were originally only three economically important continuous coal beds, although there were also some relatively thin discontinuous beds at lower stratigraphic positions. The three main beds have been called the upper, middle, and lower beds. In all except the Mitan workings these three coal beds have been partly duplicated by faulting and folding, or by "false" beds in the form of coal-gouge zones. These duplications and coal-gouge zones have been mistaken for separate coal beds in many places, causing erroneous conclusions as to the total thickness of coal and the quantity of reserves. The stratigraphic positions of the coal beds are shown in figure 3.

For purposes of summarizing the data on thicknesses and reserves of coal, the Macha-ri field has been divided into three parts, differing somewhat in structure, thickness, and continuity of the coal beds. It is believed that these areas might best be explored as individual units in future mine operations, taking advantage of certain geographic features and existing mine workings, because they are separated by fault zones across which it would be difficult to maintain mine workings. The Mitan area, as listed in table 3, includes all the territory from the south end of the Bamchi 2 mine workings to the north end of the known coal outcrop; the Bamchi area includes that part of the field between the Solchi mine office, shown on plate 2, and the north end of the Bamchi 1 mine workings, and the Pangyo area includes the territory from Pangyo to the Solchi mine office.

The estimated thicknesses of the coal beds in the Macha-ri field are listed in table 3. These figures are, in part, actual measurements, and, in part, they are estimates based on measurements in adjacent areas with consideration given to probable lateral variations. The figures are believed to represent the average thicknesses for the beds within the indicated parts of the field. In preparing these figures, allowance has been made for abnormal thickness and thinness of beds, and for the duplications caused by faulting and folding throughout much of the field. Also, these thicknesses take into account the fact that, in general, only 50 to 75 percent of the material between the outer contacts of the beds is coal; the remainder is shale in the form of partings and detached blocks which have little value as fuel. Thickness of the discontinuous beds lower in the Sa-dong formation is not shown because these beds are generally thinner than 18 inches and are not considered economically important at this time.

TABLE 3.—*Thicknesses of coal beds in the Macha-ri coalfield, in meters*

[Estimated thickness indicated by asterisk. All others are actual measurements]

Coal bed	Pangyo area	Bamchi area		Mitan area	
	Pangyo north to Solchi mine office	Solchi mine area north of mine office	Bamchi 1 mine area	Bamchi 2 and Mitan mines	Area north of Mitan mine
Upper	2	1	2	1½	½*
Middle	2	2½*	3*	3	1½
Lower	1	½*	½	½	0*
Total	5	4	5½	5	2

COMPOSITION

During the investigation of the Macha-ri field in 1949, seven samples of coal were collected for analysis. Five of these were face samples collected in the underground workings, and two were samples of mine-run coal collected in the preparation and loading plant. These samples have been analyzed at the U. S. Bureau of Mines fuel testing laboratory, Pittsburgh, Pa. The location, chemical analyses, heat value, and specific-gravity determination for these samples are listed in table 4. The corresponding classifications for these coals have been determined by use of procedures outlined by the American Society for Testing Materials (1938), and are listed in the column on the right.

It is difficult to collect representative face samples in the Macha-ri field, because of the contortions and lack of homogeneity within the coal beds. Standard channeling procedure cannot always be followed where beds include scattered blocks of shale or other impurities which could readily be cleaned by selective mining or subsequent coal preparation, or where the coal has been squeezed from the beds into cracks in adjoining rocks. Furthermore the thicknesses of the beds change so abruptly that it is difficult to take a sample that is representative of the bed for any considerable distance. The following list describes the coal beds and the sampling procedure used in collecting samples 1 to 5 of table 4.

Sample	*Mine*	*Bed*	*Description*	*Thickness (feet)*	*Sampling procedure*
1	Mitan	Lower	Coal bed in fault zone, partly concealed by cave. Original bedding obliterated.	2	Channel, excluding "floating" shale block.
2	Mitan	Middle	Top, concealed by cave		
			Coal, concealed by cave	3	
			Coal, inaccessible	2	
			Coal	4	Channel.
			Shale, carbonaceous	1	
			Coal	1	Do.
			Shale, carbonaceous		
			Bottom		
3	Bamchi 1	Upper	Coal bed in fault zone, with thrust fault forming a smooth hanging wall. Coal squeezed between shale blocks. Original bedding obliterated.		Channel 6 feet long, excluding "floating" shale blocks.
4	Pangyo 6 (see fig. 6)	Upper	Top		
			Shale, carbonaceous		
			Coal	2	Channel.
			Shale, coaly	1	
			Coal	6	Do.
			Shale, carbonaceous		
			Bottom		
5	Pangyo 6 (see fig. 6)	Lower	Coal in shear zone, squeezed into cracks below bed. Average width 3½ feet.		Do.

In 1949, coal preparation before shipment to the Yongwol powerplant consisted of passing the coal over a 1-inch screen, handpicking the coarse material and then recombining the remaining coarse coal with the fine coal. Sample 6 is a composite of grab samples, spaced at 30-foot intervals, from the belt carrying the material that had passed through the screen. Sample 7 is a composite of grab samples of the coarser materials after handpicking. Comparison of these belt samples with the face samples indicates that this coal was below

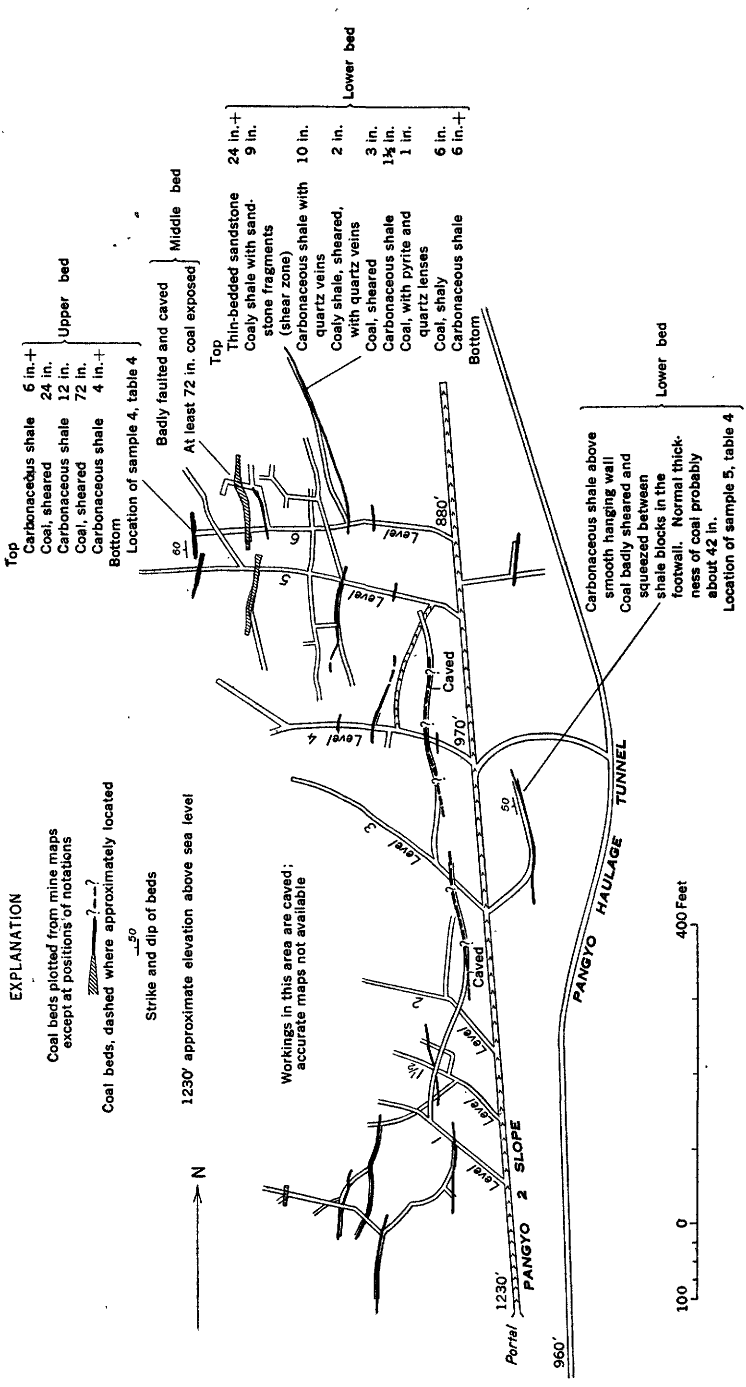


FIGURE 6.—Coal beds in workings from slope 2, Pangyo mine.

the average for the mine-run coal. Analyses of two mine-run car samples collected by Cheong Chang Hi in 1946, listed in the Gallagher report (see p. 3), gave the results listed below.

Moisture	3. 70	3. 39	Ash	34. 09	51. 15
Volatile matter	6. 08	3. 65	Sulfur	2. 03	. 25
Fixed carbon	56. 13	41. 81	Calories per kilogram	5, 232	4, 305

RESERVES

In computing the reserves of coal in the Macha-ri coalfield, the thicknesses of coal beds listed in table 3 have been used for each part of the field indicated in the table. The tonnages in each of the three parts of the field have been computed from the outcrop to sea level, assuming that the coal beds maintain their present dip and thickness to that depth. A small area between the Bamchi 2 and Mitan workings and another area between the Bamchi 1 and Bamchi 2 workings have been excluded because the rocks are so badly faulted in these areas that most of the coal is probably not minable.

The reserve estimates for the Macha-ri field listed in table 5 show: the estimated reserves in the three areas before mining was started; the estimated tonnages that have been mined and have been left as pillars, as beds too thin to be mined, or have been otherwise lost by caving and inefficient mining; and the remaining reserves after the tonnages mined and lost in mining have been subtracted from the original reserves. It is estimated that there is a total remaining reserve of about 28,287,700 metric tons in the field. Under the usual mining methods employed in anthracite fields elsewhere not more than 50 percent of the coal is recovered; the remainder is left as pillars or is too thin or too badly faulted to be extracted. Therefore it is probable that not more than half the remaining reserves are recoverable. The exact percentage of reserves that is ultimately mined will depend upon the mining conditions and the efficiency of the mining methods employed.

The reserves of coal in the Macha-ri field may be greater or less than indicated if the coal beds are found to increase or decrease in thickness as they become deeper. Also if the beds should become abruptly flatter with depth they may be cut off by the Macha-ri thrust fault and the reserves will be smaller. On the other hand, if they maintain their present average dip as far as sea level, or if they become steeper, they may be farther from the Macha-ri thrust fault at sea level and the structural complexities and mining problems may not be so great. The percentage recovery of reserves under these conditions may be somewhat larger. The reserves may also be increased by exploration north of the present known outcrop and south

Table 4. *Analyses of samples of coal from the Macha-ri coalfield*

[U. S. Bureau of Mines, H. M. Cooper, chemist. Form of analyses: A, air dried; B, as received; C, moisture free]

Sample No.	Location	Coal bed	Laboratory No.	Air-dry loss	Form of analyses	Chemical analyses									Heat value (Btu)	Specific gravity	Classification
						Proximate				Ultimate							
						Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulphur			
1	Mitan mine, level 2, middle bed, tunnel on south hill. End of first right crosscut.	Lower	D-36230	8.0	A	1.3	7.0	37.6	54.1	1.5	38.4	0.4	4.9	0.7	5,930	2.12	Anthracite.
					B	9.2	6.4	34.6	49.8	2.3	35.3	0.3	11.7	0.6	5,460	------	
					C	------	7.1	38.1	54.8	1.4	38.9	0.4	3.8	0.7	6,010	------	
2	Mitan mine, level 5, haulage tunnel on north hill. End of first left crosscut.	Middle	D-36231	2.1	A	2.2	4.8	57.7	35.3	1.7	56.8	0.5	4.6	1.1	8,920	1.93	Do.
					B	4.2	4.7	56.6	34.5	1.9	55.6	0.5	6.4	1.1	8,730	------	
					C	------	4.9	59.1	36.0	1.5	58.0	0.5	2.9	1.1	9,120	------	
3	Bamchi 1 mine, level 2, upper bed. End of main tunnel.	Upper	D-36232	2.0	A	1.4	5.8	43.2	49.6	1.5	43.1	0.5	4.0	1.3	6,800	2.05	Do.
					B	3.4	5.7	42.3	48.6	1.7	42.2	0.5	5.7	1.3	6,660	------	
					C	------	5.9	43.8	50.3	1.4	43.7	0.5	2.8	1.3	6,890	------	
4	Pangyo mine, slope 2, left turnoff 6. End of crosscut.	do	D-36233	1.4	A	1.7	4.8	64.6	28.9	1.7	64.9	0.5	3.6	0.4	9,980	1.86	Do.
					B	3.1	4.7	63.7	28.5	1.8	64.0	0.5	4.8	0.4	9,840	------	
					C	------	4.8	65.7	29.5	1.5	66.0	0.5	2.1	0.4	10,160	------	
5	Pangyo mine, slope 2, right turnoff 3. End of drift.	Lower	D-36234	1.5	A	1.3	4.9	37.7	56.1	1.3	37.4	0.4	4.6	0.2	5,780	2.14	Metaanthracite.
					B	2.8	4.8	37.2	55.2	1.5	36.8	0.4	5.9	0.2	5,690	------	
					C	------	5.0	38.2	56.8	1.2	37.9	0.4	3.5	0.2	5,850	------	
6	Preparation plant, composite sample of material less than 1 inch in diameter.	------	D-36235	5.0	A	1.2	6.0	38.3	54.5	1.4	38.3	0.4	4.6	0.8	5,940	2.12	Anthracite.
					B	6.1	5.7	36.4	51.8	1.9	36.4	0.4	8.8	0.7	5,650	------	
					C	------	6.1	38.7	55.2	1.3	38.8	0.4	3.5	0.8	6,020	------	
7	Preparation plant, composite sample of material less than 1 inch in diameter.	------	D-36236	2.4	A	1.2	6.0	29.4	63.4	1.2	29.6	0.4	3.7	1.7	4,530	2.24	Metaanthracite.
					B	3.6	5.8	28.8	61.8	1.5	28.9	0.4	5.8	1.6	4,420	------	
					C	------	6.0	29.8	64.2	1.1	30.0	0.4	2.6	1.7	4,590	------	

TABLE 5.—*Estimated reserves in the Macha-ri coalfield, in metric tons*

Area	Original reserves	Mined out and lost in mining (assuming loss equal to quantity mined)	Remaining reserves (only partly recoverable)
Mitan	10, 925, 700	345, 400	10, 580, 300
Bamchi	9, 559, 500	1, 027, 700	8, 531, 800
Pangyo	13, 763, 700	4, 588, 100	9, 175, 600
Total	34, 248, 900	5, 961, 200	28, 287, 700

of Pangyo, although it is unlikely that much coal exists in these areas.

The estimated reserves of coal in the Macha-ri field are less than previously has been thought. This does not alter the economic importance of the field as a supplier of the Yongwol powerplant, but it does emphasize the immediate need for greater efficiency in mining so that less coal will be lost.

LITERATURE CITED

Am. Mission in Korea, 1949, Republic of Korea statistical summation no. 12: Economic Cooperation Administration.

Am. Soc. Testing Materials, 1938. Standard specifications for classification of coal by rank: Am. Soc. Testing Materials Designation, D 388, p. 106.

Hatae, Nobuhiro, 1939, Stratigraphical division of the Heian system on fossil foraminifera: Jubilee pub. in commemoration of Prof. H. Yabe, Tohōku Imp. Univ., Sendai, Japan, v. 1, p. 551–562. (Japanese).

——— 1941a, Reconnaissance of the Neietsu (Yongwol) coal field, Kogendo: Chosen Geol. Survey, Misc. notes, no. 10, p. 26–28. (Japanese).

——— 1941b, Report on the inspection of Bunkei coal field in Keishohokudo and Neietsu (Yongwol) coal field in Kogen-do; Korean Mining, v. 8, no. 12, p. 10–12. (Japanese).

Kawasaki, Shigetaro, 1940, Geological age of the Heian system of Chosen: Jubilee pub. in commemoration of Prof. H. Yabe, Tohōku Imp. Univ., Sendai, Japan, v. 1, p. 1241–1251. (Japanese).

Shiraki, Takuji, 1940, Samchok anthracite field, Kangwŏn-do: Reports of the investigations of the coal fields in Korea, v. 14, p. 1–166. (Japanese). Translation by Yoo Dong Sop.

Yoshimura, Itiro, 1940, Geology of the Neietsu (Yongwol) district, Tyosen: Jour. Geol. Sci. Japan, v. 47, p. 112–122. (Japanese). Translation by Kwak Young Goo.

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Geology of Hambaek coalfield

By EWART M. BALDWIN

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GEOLOGY OF HAMBAEK COALFIELD

By Ewart M. Baldwin

ABSTRACT

The Hambaek coalfield is located in Kangwŏn-do and is a western extension of the better known Samch'ok coalfield. The coal is found within the Sa-dong formation of Pennsylvanian and Permian age in a broad eastward-trending basin. The Sa-dong formation is underlain by gneiss of Precambrian age, quartzite and shale of Cambrian age, a thick Cambrian and Ordovician limestone series, and the Hongjom formation of Pennsylvanian age, composed of argillite, quartzite, and limestone. The coal series is overlain by quartzite of the Kobangsan formation of Permian and Triassic age and in places to the east by the quartzite and argillite of the Nogan formation of Triassic age.

A late Jurassic orogeny caused north-northeastward-trending folds over the region. Slippage of the beds during the orogeny pulverized the coal. Faulting, which accompanied or perhaps in part followed folding, is represented by two sets of faults. The larger faults trend east-northeastward along the north edge of the basin. Another set of faults trends north-northeastward parallel to the axes of the tightly compressed folds.

The coal is anthracite with a heat value which ranges from 8,000 to 10,000 Btu. The ash content is generally high and ranges from 15 to 50 percent. Inferred coal reserves for the western part of the Hambaek field are about 31 million metric tons.

The coal outcrops are discontinuous around the edge of the basin because of faulting. Exploration by adits, trenching, and drilling have disclosed minable beds, none of which are known to be widespread. Mining is hampered by the pulverized coal and wall rock, and by discontinuity of the coal beds.

INTRODUCTION

LOCATION

The Hambaek coalfield is west of the Samch'ok coalfield in Chong Sun Gun and Yongwol Gun in Kangwŏn-do. The field is 28 miles northeast of the Tangyang field and 12½ miles east of the Macha-ri area (Andrews, 1956, p. 3). Yongwol, the site of a large powerplant, is the principal town in the vicinity and lies 12½ miles to the west of the Hambaek coalfield. Seoul, the capitol of the Republic of Korea, lies 93 miles to the west; the most direct route is by way of Chech'on, Wonju, and Ichon. Mining activities are predominantly in the west end of the coal basin at 37° 12′ N. lat. and 128° 42′ E. long.

The name Hambaek is derived from Hambaek-san, the highest peak in the Hambaek-san Range, which lies between the Hambaek coal area and the Samch'ok coalfield. The west boundary of the Samch'ok field is the Hambaek-san fault, a normal fault along which the vertical displacement has been about 5,000 feet (Shiraki, 1940). The area west of this fault is a broad westward-trending syncline. Although the entire area was included by Shiraki in the Samch'ok coalfield, the area west of the Hambaek-san fault will be referred to as the Hambaek coalfield. Between the Hambaek mines and the Samch'ok mines is an area containing potential coal reserves that may be exploited when made accessible by roads. The coal of the Hambaek field is of commercial interest because of its proximity to the Yongwol powerplant.

FIELDWORK AND ACKNOWLEDGMENTS

Fieldwork started in early September 1949, and was completed by the middle of November. The writer was accompanied and greatly aided by Yoo Dong Sop of the Korean Geological Survey. Lewis G. Nonini, Economic Cooperation Administration, provided helpful information on the Yomisan mine area.

Paik Dong Gil, chief of the Korean Geological Survey, assisted the investigation in many ways. Cheong Chang Hi of the Korean Geological Survey spent a short time with the writer in the field.

PREVIOUS WORK

Most of the geological investigations of Korean coal were conducted in neighboring regions that have a history of earlier production. Shiraki described the geology of the Samch'ok coalfield, including a reconnaissance of the Hambaek area (1940). Earlier he published a map of the coalfield (Shiraki, 1930). The eastern part of the coalfield was mapped by Shiraki in considerable detail, but the Hambaek region was mapped only in reconnaissance. Although coal was produced in the Samch'ok area in 1937 and shipped to Japan, little more than prospecting was done in the Hambaek region until 1948 when exploration began on a large scale. By late 1949 production was slightly more than 100 metric tons per day.

GEOGRAPHY

The Hambaek region has a maximum relief of about 2,500 feet. Tuwi-bong (4,765 feet), situated near the east edge, is the highest peak in the mapped area. It lies near the west end of the Taebaek-san Range. The hills in the western part of the mapped area rise about 1,500 feet above the valley floors. The region is deeply entrenched by streams which are still actively degrading. The slopes adjacent to the streams are steep although some of the slopes higher on the hills are more gentle. The higher hills composed of quartzite have characteristic talus slopes; nearly all slopes are covered by thick brush and young timber.

In general, the streams drain westward to the Han-gang. The stream draining the central part of the coal basin joins the Han-gang at Yongwol. A small part of the area near Chami-ni drains northward and then westward to the Han-gang and the south edge of the coalfield from the Sa-dong mine area to Yomisan drains southward to Sangdong Creek, an important tributary of the Han-gang.

The largest established village within the area mapped is Kilun-ni in the southwest corner at the Yomisan zinc mine. This village was the headquarters of the Hambaek coal mine until the establishment of a village in the creek bottom west of the junction of the Miryok and Bangje forks of the stream. The settlement is nearly continuous from the main forks of the stream below Kirun-ni to a point near the Hambaek American House. Sindong, the principal village in the vicinity, is situated just west of the mapped area. Chami-ni is a small village along the north edge of the mapped area. Most of the people live in the villages mentioned, but scattered farms are common in the western half of the area on the slopes of the hills. The eastern half is more rugged and sparsely populated. Dwellings are present in more favorable places along the lower slopes of the mountains and creek bottoms.

The region is accessible from Yongwol, which is about 20 miles by road to the west, or from the east coast by way of Sangdong, about 16 miles to the east. A railroad connecting Yongwol with other parts of the Republic of Korea was under construction from Chech'ŏn to Yongwol at the outbreak of hostilities in June 1950. A road has been completed from the Hambaek mine office to the Daijun area by way of the pass at the west end of Chigun-san. This road will be extended eventually to the Sa-dong coal mine area and perhaps beyond as development progresses. A narrow-gage railroad was under construction from Bangje to Dangok, and plans call for an extension by tunnel through the mountain to the Chigun and Daijun mine areas; this railroad may be extended as development progresses.

STRATIGRAPHY

The Hambaek mine area is located in the west end of a large syncline which plunges eastward at a low angle. Pre-Cambrian rocks of the Taebaek series are exposed both to the north and south of the syncline. The Chosen system which overlies the pre-Cambrian rocks is composed of a basal Cambrian quartzite, and overlying argillite, which together comprise the Yangdok series. Overlying this series is a thick limestone known as the Great Limestone series. The Pyongan system rests upon the Great Limestone series with questionable angular conformity and with a considerable lapse of time. The Hongjom formation of reddish-purple and greenish-gray argillite of Pennsylvanian age is the basal formation of the Pyongan system. The coal-bearing Sa-dong formation of Pennsylvanian and Permian age overlies the Hongjom formation. The Kobangsan formation of Permian or Permian and Triassic age is in the center of the syncline. It is a very resistant quartzite which makes up most of the prominent peaks of the area. The Nogam formation of Triassic age, the uppermost formation of the Pyongan system, is found in places in the center of the syncline to the east.

The Tae-dong system of Mesozoic age unconformably overlies the Pyongan system, and rocks of this younger system are present to the northwest of the Hambaek area but do not occur in the region mapped.

CHOSEN SYSTEM

The Chosen system is made up of the basal Cambrian Yangdok series and the Great Limestone series of Cambrian and Ordovician age. The Yangdok series is about 900 feet thick where it crops out along the south side of the Hambaek basin. It forms a prominent eastward-trending ridge a short distance south of the mapped area (pl. 10A). The upper part of the series contains shale which appears to be transitional between the basal quartzite and the overlying limestone series.

GREAT LIMESTONE SERIES

The oldest rocks mapped in the Hambaek mine area are beds of a thick limestone series bordering the north, west, and south sides of the coal outcrops. The Great Limestone series is composed predominantly of light-gray to light bluish-gray limestone although darker argillaceous limestone beds are present. Thin beds of quartzite and argillite are also present. The limestone series is the thickest unit in the region and in places probably exceeds 3,000 feet in thickness. The limestone is usually well bedded; the beds range from a fraction of an inch to several feet in thickness.

In the creek bed north of Miryok greenish-gray quartzite and dark-red argillite are present at the top of the limestone series. As these beds dip steeply with apparent conformity with the limestone series and appear to underlie the Hongjom unconformably, they are tentatively assigned to the Great Limestone series. Even though the Hongjom formation contains abundant purplish-red argillites, there is a difference in the color and texture of the beds near Miryok which, together with the attitude, suggests that these strata are a part of the Great Limestone series.

No attempt has been made to differentiate between members of the Great Limestone series in the Hambaek area. The limestone series yields marine fossils in places that have been dated as Middle Cambrian to Middle Ordovician; it is generally called Cambrian and Ordovician. (Shiraki, 1940.)

PYONGAN SYSTEM

The Pyongan system is made up of the Hongjom, Sa-dong, Kobangsan, and Nogam formations of late Paleozoic and early Mesozoic age. Although most of these formations were named and described during the studies of coalfields in northern Korea, they have been traced southward into the Hambaek and Samch'ok fields. The Hongjom formation consists mainly of a maximum of about 1,000 feet of red and green argillite, quartzite, and minor amounts of limestone which rests unconformably on the Great Limestone series. The coal-bearing Sa-dong formation which is about 500 feet thick rests conformably upon the Hongjom. Although Shiraki noted limestone, sandstone, and shale zones in the Sa-dong formation to the east (Shiraki, 1940), no limestone and only minor amounts of sandstone were present in the predominantly argillaceous beds in the Hambaek area. The Kobangsan formation conformably overlies the Sa-dong formation and is dominantly a coarse-grained quartzite more than 1,500 feet thick and composed of white quartz grains in a gray matrix. In the upper part some shale is present, and the formation grades into the greenish shale of the Nogam formation which is nowhere exposed in the mapped area but which is about 1,500 feet thick in the Samch'ok area.

HONGJOM FORMATION

The Hongjom formation in the Hambaek mine area forms a narrow belt along the southern part of the area; it crops out in a broader belt along the center of the syncline west of the Bangje fault and is preserved in a narrow belt along the northern part of the area where its outcrop pattern is restricted by faults.

The Hongjom formation rests unconformably upon the Great Limestone series although in many places the beds are nearly parallel (pl. 10*B*). The formation consists of alternating beds of quartzite argillite, and sandy argillite.

The basal beds of the Hongjom are quartzitic in most places. In the Macha-ri region 22 miles west, a basal conglomerate is present at the base, but in the Hambaek area a coarse-grained gritty quartzite is present. Along the north edge of the area east of Miryok the basal quartzite is thicker and contains small pebbles. The presence of quartzite float near this horizon indicates that the basal quartizite is present in widely separated parts of the field. The pebbles and coarse grains, which are composed of milky white quartz, in most localities are stained pink.

A prominent quartzitic member which is exposed behind the Hambaek American House west of the Bangje mine occurs near the middle of the Hongjom formation. This member is a coarse, gritty and, in part, feldspathic quartzite which may be traced to the south and east by intermittent outcrops and considerable quantities of float. A similar quartzite forms the dip slope on the north slope of Yomisan. This member may be traced northward across the valley. Thinner beds of quartzite, some having a greenish-gray matrix, are present in other parts of the Hongjom formation.

Hongjom, which means "red house," was derived as a formation name from houses in northern Korea built of the dominant reddish-purple rocks of the formation. Associated greenish argillite is interbedded with and grades into the reddish argillite. In many places the rock is mottled with both the reddish and greenish phase. The argillite beds have a set of closely spaced joints that causes it to break easily in platy pieces that may be utilized for roofing. In several places it was noted that the platy texture of the reddish and greenish Hongjom does not coincide with known bedding only a few feet above or below; in some of these places strikes and dips may have been taken upon this false bedding.

Limestone and dolomitic limestone are present in minor amounts in the Hongjom formation. Some of the dolomitic limestone contains relatively large irregular masses of chert which is light brown to flesh color. In some places during metamorphism the color of the limestone has been altered from medium gray to nearly white. The limestone beds, which generally do not exceed 10–15 feet in thickness, are evidently more abundant in the lower part of the Hongjom formation in the Hambaek area than in the upper part.

The argillaceous members of the Hongjom formation are cut by a very noticeable set of parallel shear joints that cut sharply across bedding. This type of jointing is more closely spaced in the Hongjom than in adjacent formations. Although shear jointing is not characteristic of the quartzite, large veins of comb quartz commonly an inch, and as much as 4 inches, in width are present. The limestone beds contain many calcite veins.

The maximum thickness of the Hongjom is nearly 1,000 feet where exposed west of Chigun-san but in the Tuwi and Sa-dong areas the formation is little more than 500 feet thick and contains a larger proportion of quartzite. The Hongjom is assigned to the Pennsylvanian by Shiraki (1940). No identifiable fossils were found in the formation in the Hambaek area although fragments of crinoid stems were observed.

SA-DONG FORMATION

The Sa-dong formation lies between the Hongjom and the thick Kobangsan. Because of its coal content, it is the most important formation in the coal-producing areas. The Sa-dong is made up of less competent shale and argillite than the underlying Hongjom and the overlying Kobangsan. For this reason, the present distribution of the formation results from the restriction by faulting and pinching during the diastrophism that occurred in the area. The outcrop of the Sa-dong is almost entirely missing along the north side of the Hambaek mine area (pl. 9). This formation is present in outcrops along the west edge and in a nearly continuous belt along the south edge. Because of faulting a full section of the Sa-dong is exposed in only very few places in the Hambaek area. The most complete section, although contorted and difficult to measure, is exposed in the pass at the west end of Chigun-san on the Bangje-Daijun trail. At this place only platy dark-gray argillite containing some coal shale is exposed. As the coal shale is less competent much of the adjustment during movement has been along these beds so that they are broken into small platy graphite-coated pieces of argillite.

No limestone has been observed within the Sa-dong formation in the Hambaek area although it is known to exist in places to the west. Some medium-gray thin-bedded quartzite is exposed within the Sa-dong in the creek bed in the Miryok region.

Coal shale is common within the Sa-dong, and impure coal beds are present. Several beds are known. In the Bangje mine area the coal now mined is in the upper few feet of the Sa-dong formation. In the Daijun area the coal is at the base of the formation. There may be some places in which the Sa-dong contains several minable beds and others in which there are no minable coal beds.

There appear to be 500 feet of Sa-dong beds in the west end of the field. However, at Tuwi the thickness of beds of the Sa-dong between the Kobangsan and Hongjom formations appears to be about 250–300 feet.

The Sa-dong formation has been assigned to the lower Permian by Shiraki (1940) on the basis of plant and animal fossils that occur in some areas. The U. S. Geological Survey recognizes the Sa-dong formation as Pennsylvanian and Permian age. Fusilinids, crinoid remains, brachiopods, and other forms are present. In some areas leaf imprints are abundant.

KOBANGSAN FORMATION

The Kobangsan formation is the thick ridge former that occupies the center of the large syncline and directly overlies the Sa-dong formation. The name Kobangsan is derived from a peak in northern Korea whose name means "mountain-making rock." The Kobangsan is composed of 1,500 feet or more of medium-gray coarse-grained quartzite and minor amounts of dark-colored fine-grained quartzite and dark-gray argillite. The rock is composed of coarse white angular grains of quartz with minor amounts of darker colored impurities in the matrix. The rock is well indurated and breaks cleanly across the grains when fractured.

The beds are generally 1 to 2 feet thick although some phases are more massive. Crossbedding is common. Shiraki (1940) states that the thickness is about 2,250 feet in some areas.

The rock is well jointed. Shear jointing is present although not as well defined as in the Hongjom. Closely spaced jointing in places resembles bedding. The deformation of the Kobangsan formation, which occupies the center of the Hambaek basin, is much more intense than that of the older formations exposed along the edges of the basin. The greater deformation is caused, in part, by two directions of folding. Closely folded strata whose axes trend northeastward plunge toward the center of the westward-trending basin. Along the periphery of the basin the cross folds tend to die out, but the strata are displaced by major faults. Drag folds are prevalent on the limbs of the tightly folded strata in the center of the basin.

No fossils have been found in the Kobangsan formation in the Hambaek region. It overlies beds of Permian age and underlies the Nogam formation of Triassic age. At present, the Kobangsan is considered to be Permian or perhaps in part Permian and Triassic. The transition between the Sa-dong and the Kobangsan formations is shown in the section below.

Transition between Sa-dong and Kobangsan formations

[The measured section starts with the coal bed at Bangje sublevel 1 and continues up the small draw immediately above the portal]

	Feet	Inches
Top of Kobangsan formation in this section:		
Quartzite, medium- to light-gray, some crossbedding, jointed as if near a fault, typical Kobangsan lithology	50	
Quartzite, light-gray, showing much milky quartz	20	
Quartzite, light-gray, crossbedded, relatively pure quartz-bearing rock	13	
Quartzite, medium-gray, medium- to coarse-grained, crossbedded, some beds 4–5 feet in thickness, typical Kobangsan lithology	25	
Quartzite, medium-grained	7	5
Quartzite	5	
Quartzite, medium-grained, strikes N. 12° W., dips 38° NE	14	
Quartzite, fine-grained	4	
Quartzite, medium-grained	4	6
Sandstone, dark, fine-grained, argillaceous beds	8	
Quartzite, medium-grained	2	4
Quartzite, dark-gray, fine-grained	4	5
Quartzite, dark-gray, medium- to fine-grained	4	6
Quartzite, dark-gray, medium- to fine-grained	5	
Argillite, dark-gray	6	
Quartzite, strikes N. 32° W., dips 20° NE	11	
Quartzite, gray	5	5
Partly covered	3	
Quartzite, medium-gray	1	5
Quartzite, dark-gray	3	5
Sandstone or quartzite, medium-grained, indurated; two beds	4	
Sa-dong formation:		
Argillite, dark-gray	7	
Argillite, indurated, massive, carbonaceous	6	
Shale, nearly black, massive carbonaceous	8	
Argillite, dark, massive	20	
Argillite, platy, imbricate; perhaps along plane of movement	4	
Argillite, dark-gray massive, plant-bearing in one bed	3	6
Argillite, dark-gray	3	6
Sandstone, and carbonaceous shale, badly deformed on slippage plane	4	
Sandstone, dark-gray, fine-grained	4	
Quartzite, like Kobangsan, relatively fine-grained		10
Argillite, black, massive	2	6
Covered by rock cribbing	4	
Shale, carbonaceous, with quartz veins	3	
Coal, over thickened lens owing to deformation	50	

ALLUVIUM

Coarse alluvium, overlain by sandy alluvium, covers the larger creeks; the coarse alluvium ranges in size from pebbles to boulders several feet in diameter. There are small quantities of alluvium upon some of the higher terraced slopes. Cliffs of the Kobangsan spall off to form long talus slopes which cover the bottoms of most of the small ravines draining peaks composed of quartzite of the Kobangsan formation.

Several areas which are not steep, such as the broad mountain top south of Bangje, have a thick mantle of soil which obscures much of the geology in this area.

IGNEOUS ROCKS

Igneous intrusions are sparse in the Hambaek mine area. Felsite and slightly more calcic intrusions are found in the Yomisan metal mine in the southwest corner of the area mapped. Shiraki mapped a granite porphyry intrusive body just south of the Yomisan mine. The large batholith which underlies much of the Republic of Korea is exposed about a mile to the south. This large batholith is assigned to the Cretaceous system, but the smaller intrusive bodies, such as the ones near the Sangdong tungsten mine and the Yomisan mine, may be Cenozoic in age as suggested by Shiraki (1940). They are mapped, though, as questionably Cretaceous as was done by Shiraki (1930) because of a lack of evidence.

A narrow dike composed of a light olive-green aphanitic igneous rock, generally less than 6 inches wide, was found in the Dangok mine workings 1. Small particles of coal occur as inclusions in this dike.

FAULTS

Formations of the Hambaek area are closely folded and faulted by the post-Tae-dong orogeny of Late Jurassic time. The Hambaek coalfield is situated in a large westward-trending syncline. Superimposed on the axis of this major feature are closely folded rocks in the center of the syncline whose axes generally trend between N. 20° E. and N. 40° E. The cross folds plunge toward the center of the basin. Drag folding is common within the Sa-dong and Kobangsan formations near the center of the basin where folding is more intense.

Bedding-plane slippage occurred during the intense deformation of the Pyongan system. There is a tendency for the overlying beds to move toward the crest of the anticlines during folding. Where the rocks are relatively homogeneous the movement is distributed throughout the mass. Of the rocks in the Pyongan system, the Kobangsan and Hongjom formations are relatively competent compared with the incompetent graphitic shale and coal beds of the Sa-dong formation. The deformation caused drag folds and bedding-plane slips within the coal series. This has resulted in the pulverization of the coal and the thickening of coal beds into pockets or lenses and also in the thinning of the bed. The thickening of the coal beds is to be expected along the axes of the northeastward-trending anticlines and synclines; thinning of the coal beds can be expected on the steeply dipping flanks.

In general, the largest and most persistent faults in the Hambaek area are found along the north side of the coal basin. These faults continue northeastward beyond the mapped area 1 (pl. 9). The strata are upthrown on the north side of the faults. Another set of faults lies parallel to the axes of the folds, in general, but in a few places cuts across the axes. The strata on the west side of these faults are generally upthrown, forming a consistent fault pattern. It is possible that there has been significant horizontal movement as well as the more obvious vertical movements.

POWERLINE FAULT

A major northeastward-trending fault separates the Great Limestone series and the Hongjom formation along the north-northwest side of the coal basin. An important powerline follows the fault through the area. The fault was traced from the main valley at the west edge of the map area to a point north of Chami-ni, a village northeast of Miryok. In places, the fault lies within the Great Limestone series where its exact position can only be approximated. Vertical displacement is about 1,000 feet with unknown horizontal displacement.

MIRYOK FAULT

The Miryok fault passes north of Miryok coal prospects and continues northeastward across the divide to the vicinity of Chami-ni. The fault joins the Chigun-san fault and, if projected northeastward, appears to intersect the Powerline fault. The Kobangsan formation on the south side has been downfaulted against the Hongjom formation, and the Sa-dong formation is missing in nearly all places except for the small Miryok coal area and a small area in a saddle at the top of the mountain east of Miryok. Several of the Miryok mine tunnels penetrate the fault zone of severely deformed rock adjacent to the zone. The throw is difficult to measure as it is a strike fault, and movement in some places may be nearly parallel to bedding. The throw is probably more than 750 feet where the Kobangsan formation is faulted on the north side against the Hongjom formation just east of Miryok.

BANGJE FAULT

The Bangje fault is one of the most important faults in the area. It extends from Miryok along the west side of the Bangje mine and southward through the saddle at the west end of Chigun-san. Beyond the saddle, this fault runs parallel to a creek to the south side of the map and was recognized during a reconnaissance where this creek joins the main drainage about 2 kilometers south of the map area. The Sa-dong formation is entirely missing on the west side which is the upthrown side. The fault, although in places parallel to the other faults to the east, cuts across several of the folds. In the area between Bangje and Kilun mine 2, the fault appears to follow the crest of an anticline, but south of Kilun mine 2, the fault again cuts across the folds. Thus the closely folded and northeastward-plunging Kobangsan and Sa-dong are in juxtaposition with beds of the Hongjom formation that, in general, dip northwestward. The throw is therefore differential in this area as is shown by the juxtaposition of Sa-dong and Hongjom in places and Kobangsan and Hongjom in other places. The Bangje fault is of major importance considering the position of the coal strata in the west end of the basin. The throw of the Bangje fault is difficult to measure, but in some places it is probably more than 1,000 feet.

There appear to be many small branch faults. One branch fault is near Bangje mine 1 and the sublevel. Two small displacements were noted between Bangje and Kilun. Another appears to duplicate the purplish-red and greenish-gray Hongjom exposed west of the Bangje mine.

The Great Limestone series is not exposed along this fault, but near Kilun, where the strata appear to be basal beds of the Hongjom formation, the Great Limestone series is believed to lie only a short distance below the surface.

CHIGUN-SAN FAULT

The Chigun-san fault, in general, lies parallel to the Bangje and Dangok faults. The strike trends nearly parallel to the strike of steeply dipping of the quartzite of the Kobangsan formation; consequently the throw is difficult to calculate. Meager evidence indicates that the fault is similar to the regional pattern in which the west side is thrown.

DANGOK FAULT

The Dangok fault, in general, lies parallel to the Bangje fault. The Kobangsan and Sa-dong formations on the west side have been uplifted, perhaps thrust eastward over nearly parallel beds of the Kobangsan (pl. 9). The Sa-dong formation has been exposed in the center of this faulted fold. The fault is present at the pass between Dangok and Daijun. It offsets strata of the Sa-dong between Daijun and Chigun mine areas with a throw of about 400–500 feet but the displacement is probably much greater near Dangok in the center of the syncline where it is probably more than 1,000 feet. The fault appears to dip steeply westward.

DAIJUN FAULT

Displacement just west of the Daijun mine area may be distributed over two or three small faults. The net displacement is an uplift of the west side of 200–300 feet. The larger of the faults lies parallel to the small creek that drains the south slope of Chigun-san. The Sa-dong formation appears to be thinner than normal just west of the Daijun fault and the area sloping westward toward the Bangje fault, but this apparent thinning is probably the result of the faulting.

TUWI FAULT

The Tuwi fault strikes northward about parallel to the faults already described which trend parallel to the axes of the folds. The Tuwi fault follows the west side of the creek on the west side of the Tuwi mine area. The Kobangsan formation on the east side has been downfaulted against the Sa-dong. Displacement is perhaps 200–300 feet. South of Tuwi, the fault appears to lie west of the creek valley, but north of Tuwi it appears to follow the trend of the valley to the top of the ridge and may cross the crest a short distance west of Tuwi-bong. Apparent thinning of the Sa-dong may be in part due to thrusting of the Kobangsan over the Sa-dong during deformation.

SA-DONG FAULT

The Sa-dong fault lies parallel to the Tuwi fault and separates the Tuwi and Sa-dong areas. The fault is crossed by the creek about one-half mile downstream from the mine opening, and just west of this point the stream turns westward (pl. 9). The Hongjom formation on the east is faulted against the Great Limestone series on the west. Although the writer did not trace the fault north or south, there is reason to believe that the Sa-dong fault intersects a more easterly trending fault to the south.

FAULT SOUTHEAST OF SA-DONG

A fault trends northeastward along the creek southeast of the Sa-dong area. The Hongjom formation which caps the ridge is repeated on the southeast side of the fault where it lies against the Great Limestone series. The fault which was recognized on a reconnaissance trip to the area southeast of Sa-dong trends about N.

50°–55° E. and, in general, is parallel to the Powerline and Miryok faults in the western part of the area.

The fault pattern within the Hambaek area suggests that other northward-trending faults will be found east of the Sa-dong mine area. The Hongjom and Sa-dong formations are exposed high on the mountain at the Sa-dong mine, and it is probable that they terminate against a fault with the dropped side on the east. Farther east, the trend may change but there is no reason to think that there will be fewer faults between the Sa-dong mine area and the Hambaek-san fault, forming the west boundary of the Samch'ok coalfield.

COAL

DISTRIBUTION AND CHARACTERISTICS

The coal beds in the Hambaek area are in the Sa-dong formation of Pennsylvanian and Permian age. The coal, which is anthracite, contains 45–80 percent fixed carbon, 15–50 percent ash, and about 5 percent volatile materials. The specific gravity ranges from 1.7 to 2.1 depending upon the amount and character of impurities; the heat value ranges from 8,000 to 10,000 Btu. Analyses of coal samples from the Hambaek and Samch'ok mines, which have been made by the U. S. Bureau of Mines, are given in table 1.

TABLE 1.—*Analyses of coal from Hambaek and Samch'ok mines*

[U. S. Bureau of Mines, H. M. Cooper, chemist. Form of analyses: A, air dried; B, as received; C, moisture free]

Mine	Hambaek						Samch'ok					
	Banje-Kilum			Dangok			Washed coal (head sample)			Run of the (tipple sample)		
Laboratory No.	D-19391			D-46294			D-20240			D-20226		
Air-dry loss	----					0.6	----			----		
Form of analyses	A	B	C	A	B	C	A	B	C	A	B	C
Proximate:												
Moisture	2.8	7.8	----	5.2	5.8	----	----	3.1	----	----	4.5	----
Volatile matter	4.9	4.6	5.0	5.6	5.6	5.9	----	3.0	3.1	----	3.6	3.8
Fixed carbon	53.7	51.0	55.3	66.7	66.2	70.3	----	79.8	82.4	----	76.5	80.1
Ash	38.6	36.6	39.7	22.5	22.4	23.8	----	14.1	14.5	----	15.4	16.1
Ultimate:												
Hydrogen	1.1	1.6	.8	1.5	1.6	1.0	----	----	----	----	----	----
Carbon	54.2	51.4	55.7	66.9	66.4	70.5	----	----	----	----	----	----
Nitrogen	.3	.2	.3	.2	.2	.3	----	----	----	----	----	----
Oxygen	5.1	9.6	2.8	8.6	9.1	4.1	----	----	----	----	----	----
Sulfur	.7	.6	.7	.3	.3	.3	----	.4	.4	----	.7	.7
Heat value (Btu)	8,040	7,620	8,270	9,910	9,850	10,460	----	11,810	12,190	----	11,310	11,840

The coal beds alternate with and grade both laterally and vertically into carbonaceous shale. There is no known single widespread bed of coal in the Hambaek field. Along the west edge of the field the coal is mined from the upper part of the Sa-dong formation; coal mined

A. View from pass between Bangje and Daijun, looking southward into southern part of Hambaek coalfield. High ridge in distance formed by Cambrian Yangdok series; valley on this side of high ridge underlain by Cambrian and Ordovician Great Limestone series; low ridge in center formed by Pennsylvanian Hongjom formation.

B. View looking northwestward across Powerline fault near west edge of Hambaek coalfield. Hongjom formation, which forms conical hill in center, faulted against Great Limestone series, which underlies ridges in background.

VIEWS OF YANGDOK AND HONGJOM FORMATIONS.

along the south side of the field is produced chiefly from the lowermost Sa-dong formation. Coal at the Dangok mine possibly occurs in the center of the formation, but its position is not definitely known. Although drill records indicate more than one bed of coal of minable thickness in certain areas, it is possible that adjacent areas contain no minable beds.

The coal in the Sa-dong formation probably accumulated in distinct beds with discernible partings at the time of deposition, but during subsequent deformation it was squeezed into pockets, the coal pulverized, and the original bedding obliterated. Although most of the thickening is at the axes of the anticlines and synclines, pulverized coal is present in all parts of the coal beds. Quartz and calcite veins are common impurities within the coal beds, in addition to the clay or shale constituents which form much of the ash content of the coal.

OUTCROPS

The coal beds seldom appear as outcrops. Faulting has restricted the area of the Sa-dong formation that is exposed along the north side near Miryok and in the Bangje-Kilun area. In the belt of Sa-dong formation between Kilun and the southwest exposure of the Sa-dong, the surface is covered largely by soil even where the faulting has not obscured the coal-bearing strata. Some graphitic shale beds are exposed southwest of Chigun-san, but trenching has failed to expose minable beds of coal.

Wherever the Kobangsan formation crops out higher on the mountain, the talus slope tends to obscure much of the Sa-dong formation. Most of the known coal beds have been discovered by trenching or drilling programs.

THICKNESS

The coal beds may have been of nearly uniform thickness when deposited. However, the intense deformation has pulverized the coal by differential movement of the hanging wall and the footwall. The coal beds are zones of weakness between more competent lithologic units. The coal has been squeezed into pockets resulting in abnormally thick deposits such as that found in the Bangje sublevel mine, thinning out to only a few inches in other areas.

The coal tends to grade into carbonaceous shale at the top and bottom of the beds so that in some areas the dimensions of the bed must be determined by ash content. Some drill holes cut the coal beds at an acute angle with the bedding planes and tend to give the impression of thicker coal than actually exists (pl. 9). Some coaly shale or coal of marginal quality may be included within the coal

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when interpreting the drill cores. There appears to be a tendency to overstate rather than minimize figures relating to the coal. Allowances were made for all these factors in calculating coal reserves.

DRILLING PROGRAM

The Korean Government financed a core-drilling program in the Hambaek coal basin during 1949–50. Holes were drilled in the Bangje-Kilun and Dangok areas. These drill holes are plotted on the geologic map (pl. 9), and they provide the only underground data available outside the mine workings. The equipment was designed for drilling less than 1,000 feet. Because of the pulverized coal, it was difficult to obtain the samples and the thickness was often determined by observing the cuttings during the drilling process. This was difficult to do because of the impure coal associated with the minable beds.

ESTIMATE OF RESERVES IN MINE AREAS

Estimated reserves of coal in the Hambaek coalfield are listed in table 2. Coal reserves were calculated for a distance of 1,650 feet (500 meters) down the dip from the outcrop in the deeper basins where the coal continues to a depth beyond which mining will not be practicable for some time. In shallower basins where the dips are seldom steep the depth of 1,650 feet was the base used in calculating reserves. So little coal has been produced from any of the mines, with the possible exception of Bangje, that production is negligible and was not subtracted from the total coal reserves.

TABLE 2.—*Inferred coal reserves in the Hambaek coalfield*

Mine	Area (square meters)	Thickness of coal (meters)	Reserves (metric tons)
Miryok	1,380,000	3	7,452,000
Bangje-Kilun	1,137,000	6	12,279,600
southern block	515,000	1.5	1,390,500
Dangok	984,750	2	3,545,000
Daijun	580,000	2.5	2,610,000
Chigun	540,000	1.5	1,458,000
Tuwi (west)	225,000	3	1,215,000
Tuwi (east)	425,000	1	765,000
Sa-dong (part)	142,000	1.5	383,400
Total			31,098,500

It should be emphasized that the reserves are calculated as inferred tonnage because there is insufficient information to justify more definite reserve figures. An average thickness was used which allows for both the areas of overthickening and those of little or no coal. The thickness of the coal beds in the Hambaek coal field cannot be measured in most places because of the intense deformation. Drilling data will furnish the only reliable figures for revising the data on the average thicknesses, and the calculation of coal reserves may be adjusted accordingly by increasing or decreasing the average thickness, other factors remaining the same. It should be emphasized that even under favorable mining conditions perhaps not more than 50 percent of the reserve will be recovered; this percentage may be lower if mining is done without efficient mining techniques and planning.

The Hambaek coalfield contains individual mine areas which are, with the exception of Bangje and Kilun areas, bounded by faults (pl. 9). The coal reserves are discussed in this report under individual mine areas. It seems advisable to treat Bangje and Kilun districts as a single coal area.

MIRYOK AREA

The Miryok mine area includes the outcrops of Sa-dong formation near Miryok and the area eastward to the Chigun-san fault. The east end of this block includes a large area where little data was gathered. The coal strata could not be observed because of their position beneath the Kobangsan, and along the north edge they have been cut out by the Miryok fault.

The coal at the Miryok workings is in a strongly deformed zone adjacent to the Miryok fault on the north side of the creek and the Bangje fault to the west. Mostly impure coal and coal shale has been found, and the outlook at Miryok is not promising. It is suggested that coal prospecting be conducted south of the creek, closer to the Bangje area. Drilling in the eastern part of the Miryok block may indicate a northward extension of the coal beds revealed in the drill holes east of the Bangje mine.

Some coal has been produced at Miryok. Coal exposed in the present cuts is little more than a yard thick; however, thicker coal is expected along the south side of the Miryok block where it is nearer the thicker Banje coal and for that reason an average thickness of 6½ feet is used for calculating reserves. Because dips of 30°–50° are common along the limbs of the structures, an adjusted average vertical thickness of 10 feet is used for computing reserves in the horizontal map area.

BANGJE-KILUN AREA

The Sa-dong formation is exposed along the east side of the Bangje fault at the Bangje and Kilun mine adits. The mines of this area consist of many short entries of which less than half are yielding or have yielded coal. The first appreciable production came from a pocket of coal about 50 feet thick at the Bangje mine 1. This pocket is located along a small fault (pl. 9). A new opening called the Bangje sublevel 1 was started beneath the original opening after caving of the original workings. Mining of this pocket continued during the fall of 1949.

The coal at Bangje probably extends northward into the hill. Drill records show that it is present to the east; in fact, more than one minable bed appears to be present as shown by drill records. The coal bed probably extends to the Kilun area to the south although it is interrupted by several small faults.

The Kilun opening 6 is directly across the creek from the Bangje sublevel. No coal had been found at the time of inspection late in 1949. Plans for a large-scale mining operation call for sinking a slope to tap coal to the east. Kilun 5 is located on the point overlooking the junction of the principal streams, but no coal is revealed in the workings. Kilun 3 is the next adit to the south from which some coal is produced. Kilun 1 yielded some coal, but the bed has been temporarily lost. Kilun 2 is about 1,300 feet to the south and is situated next to an adit, now caved, that was driven during the time of Japanese occupation. Kilun 2 contained only impure coal. Nearby drill hole 9 failed to disclose coal at a depth of 875 feet. There is no reason at present to assume that there is much coal to the south of the Kilun area. Therefore, the Bangje-Kilun area is arbitrarily divided, and less coal is calculated for the southern block.

Information contained in drill records indicates that two and possibly more minable coal beds are present east of Bangje, but it seems advisable to use a more conservative thickness than that shown in the drill records. An average thickness of 6½ feet for each of two beds is used which is adjusted to a vertical thickness of 10 feet for each due to dip of beds. A thickness of only 5 feet is used for coal in the southern block.

DANGOK AREA

The main drainage, the coal-bearing strata at Dangok, crosses about 1.5 miles east of the Bangje mine. The coal is restricted by the Dangok fault on the east and bordered by nearly vertical strata on the west. At the north end, the Sa-dong formation plunges beneath the Kobangsan; on the south the coal-bearing strata appear to extend through the pass to Daijun although there is a possibility that the coal is pinched out in the pass by the Dangok fault.

Rock formations dip steeply in the Dangok area and are greatly deformed. The best coal is exposed near the creek just east of Dangok opening 1, and the same pocket is presumably tapped by drill hole 6 where a thickness of 66 feet of coal was reported. However, the beds are so steep that the true thickness is unknown but presumably much less than the reported 66 feet. The coal is pulverized anthracite which, as in many of the pockets of coal, is caused by squeezing and flowage during deformation.

Dangok openings 1 and 2 showed some coal and much coal shale, but production to date has not been encouraging. One opening on the south side of the valley at the junction of the small stream with the main creek revealed coal which is presumably a continuation of that in the main Dangok openings. This adit has not been extended because of excessive water and caving ground, but coal of this bed can be reached by crosscuts from the Dangok-Daijun main haulage tunnel which is located a short distance to the west. Another short tunnel driven southeastward and a few feet from the Dangok-Daijun trail is headed directly for the Dangok fault and has found only coal shale.

Drilling of the Dangok area to date has been inconclusive because the vertical holes are nearly parallel to the strata. Drilling should be at a low angle to be approximately normal to the bedding. The evidence at hand does not indicate whether there is more than one minable bed of coal at Dangok. Deformation and drag folding which is common in the Sa-dong formation and which is expectable along the Dangok fault could account for the impression that there is more than one bed. The pocket of pulverized coal exposed is, no doubt, overthickened and thus true thicknesses are difficult to obtain. The coal in Dangok 1 is mixed with considerable coal shale.

If later evidence points to two beds of minable coal the reserves can be recalculated, but until the area is drilled there is no assurance that there are two beds of sufficient thickness to mine. Even though the coal is present as anticipated in the Dangok area, mining will be difficult because of pulverized ground along the Dangok fault. Timbers in Dangok 1 and 2 began to break less than a year after they were set because of loose ground along the Dangok fault. An average thickness of 6½ feet is used in computing reserves, for the coal is thought to continue to a depth considerably below 1,650 feet and no minable coal is believed to lie between the axis of the syncline and the Chigun-san fault.

DAIJUN AREA

The Daijun mine area is located on the south side of Chigun-san along the south side of the Hambaek coal basin. Coal at present is found in the basal part of the Sa-dong formation at Daijun 1 and other exploratory pits along the east side of the Daijun area. Nearly all of the adits start in the upper part of the Hongjom formation and intersect the overlying Sa-dong formation. Two coal beds were found in Daijun 1. The lower is about 2.6 feet thick, and the upper one, situated about 33 feet higher stratigraphically, is 5 feet thick. The lower bed may be too thin to mine in many places and perhaps should be minimized in estimation of reserves. It has not been possible to determine whether coal beds are located in the upper part of the formation as at the Bangje mine. Talus of the Kobangsan tends to obscure the upper part of the formation along the base of Chigun-san in many places.

The coal exposed in the Daijun area shows the same pulverization characteristic of other parts of the Hambaek coalfield owing to bedding-plane faulting. Many quartz stringers are present in Daijun 1 mine, but quartz is by no means restricted to the Daijun area. Although the coal dips from 30 to 40° northward into the hill, it is likely that the steeper dips exposed in the Kobangsan formation will be reflected at depth and dips of 50° or more may be expected where the Sa-dong formation extends beneath the mountain.

Many adits have been started on the east side of the hill facing the Chigun area. At the time of inspection all were started in the Hongjom and ranged from a mere beginning to about 250 feet in length. Several were far enough below the contact to require considerable tunneling in noncoal-bearing strata of the Hongjom before contacting the Sa-dong formation and coal. Most of them should intersect coal-bearing strata if extended far enough normal to the strike. There seems to be a substantial area of relatively low dipping Sa-dong rocks exposed in the Daijun area where mining should be easy.

Two beds, the upper one is 5 feet thick and a lower is about 3 feet thick, are present. Reserves are computed on this basis. The beds probably steepen at depth and will extend to a greater depth under Chigun-san than is practical to mine.

CHIGUN (JIKWOON) AREA

The Chigun area is located east of Daijun and east of the Dangok fault. The Chigun area is on the downthrown side of the Dangok fault. From the fault, the belt of Sa-dong strata extends eastward around the peak to the Tuwi mine. It should be emphasized that, although the belt of strata is continuous, there are many steep dips indicating local deformation such as drag folding. There were not many outcrops in the area, and most of the information about strata and structure was obtained by examining excavations. Coal has been found at Chigun 1 only. It is impure and of poor quality and offers little promise for future production.

At the time of inspection late in 1949, the area was being explored by means of three adits. Chigun 1 was started in the Hongjom formation and intercepted a coal bed about 5 feet thick in the base of the Sa-dong. This bed may be a continuation of the lower bed in the nearby Daijun area, and if so a thicker bed should be found about 33 feet stratigraphically above this bed. Chigun 2 was started west of 1, in the Sa-dong formation, but at the time of inspection had not disclosed coal. Chigun 3 is situated on a lower level along a road that connects it with the Tuwi area. It was also started in the Hongjom and had not yet reached the Sa-dong at the time of inspection.

The coal revealed to date has not been promising. It is expected that more coal will be found because minable coal is present on either side at Daijun and Tuwi. Present evidence indicates that 5 feet is a suitable thickness for calculating reserves.

TUWI AREA

The Tuwi mine area is situated between two small creeks that drain the slope of Tuwi-bong, the highest peak in the area. Tuwi is east of Chigun and connected by a road that was completed in 1950. There are many exposures of Hongjom and Sa-dong strata along this road.

The Sa-dong formation appears to be thin at the Tuwi mine where it is not more than 300 feet thick. In the small creek valley near Tuwi 5, the Kobangsan is faulted against the Sa-dong. The Hongjom is also much thinner here than elsewhere. It seems likely that this apparent thinning is due to initial deposition rather than thrust faulting.

Coal was found in Tuwi 1. A local resident stated that the coal was near the top of the Sa-dong formation and perhaps 16–23 feet thick. The thickness could not be checked because of the caved portal; it probably is a pocket, for such a thickness is unusual. Proximity of the overlying Kobangsan substantiates the conclusion that the coal is near the top of the formation. There are several openings below Tuwi 1. These are called openings 2 and 3 but at present extend only a few meters into the hill revealing no coal. There is no Tuwi 4. Tuwi 5, on the west side of the ridge, at the time of inspection had not disclosed coal. Three coal beds are said to be present, but it seems likely that not more than two are minable. The coal strata extends eastward to the Sa-dong area, but no coal has been found east of the creek that crosses the center of the Tuwi block. The Tuwi area appears to be favorably situated compared with the Sa-dong area. The dips are moderate, and coal appears to be present.

If there are two minable beds of coal at Tuwi the reserves will perhaps be greater than in adjoining areas. Reserves are estimated for two beds with thickness averaging 1.5 meters each in the west Tuwi block. Although thicker coal was reported, it is doubtful that such thickness extends throughout the area. No coal has been found in the area east of the creek and west of the Sa-dong fault; however, coal may be there, so a reserve was computed on the basis of coal 1 meter in thickness. This is subject to change when more data from drilling have been obtained.

SA-DONG AREA

The Sa-dong mine is located in a small valley near the head of the principal creek east of the Tuwi mine area. The strata are dipping steeply where exposed in this valley; they appear to project to a point high on the mountainside where they are cut off by another fault on the east. The Sa-dong area was visited twice, but only a few hours could be devoted to it. There are two short adits on the east side and two slightly longer adits on the west side of the creek. One of those on the east side now caved is said to have revealed good coal near the base of the formation; however, no coal was seen by the writer in any of the adits.

The area is closer to the Samch'ok coalfield than any other part of the Hambaek coalfield studied. With the present knowledge it seems reasonable to estimate tonnage computed on an average thickness of 1.5 meters until more exact information can be obtained by drilling or prospecting. The area included is small because the east edge was not determined. However, the coal strata are steeply inclined and crop out higher on the mountain where mining might be difficult. The coal will be difficult to mine in the Sa-dong area because of the Sa-dong fault zone and steeply dipping beds, and it seems better to concentrate exploration on the other more favorable areas first.

AREA BETWEEN KILUN AND DAIJUN

No coal has been produced from the southwest edge of the field although it has been prospected. The area between Kilun 2 and the crest of the hill to the south is covered by considerable soil. Beds of the Sa-dong formation crop out at two places, but faulting is common and probably even more complex in this area than indicated on the map. Impure coal has been found in the prospect that was opened in the small outcrop of the Sa-dong just west of the main Bangje fault. The coal was impure and less than 3 feet thick. It is doubtful if there is sufficient tonnage to warrant mining. The Hongjom formation underlies the thin coal bed which is evidently in the base of the Sa-dong formation. If future drilling or prospecting in the Kilun area indicates a southward continuation of coal, prospecting should be intensified in the area closer to the crest of the mountain.

South of the mountain crest is a section of nearly vertical Sa-dong strata bounded on the west by the Bangje fault and on the east by steeply dipping quartzite of the Kobangsan formation. Pulverized coal and coal shale are exposed at the mouth of a gulch from the west one-half mile south of the Bangje trail pass in the Bangje fault zone. There are other short adits to the south in the steeply dipping Sa-dong formation although most of them are caved. Drag folds are common, and the carbonaceous layers have acted as gliding planes during deformation. Deformation is such that mining would be even more difficult than is usual for the Hambaek coalfield. The Sa-dong formation dips at a low angle westward from the Daijun fault to form the eastern limb of the syncline. Several cuts expose coal shale, but no coal has been uncovered. The area west of the Daijun fault and east of the Bangje fault along the south side is not considered to be favorable for coal production.

LITERATURE CITED

Andrews, D. A., 1956, Coalfields of the Republic of Korea, Introduction: U. S. Geol. Survey Bull. 1041–A.

Shiraki, Takuji, 1930, Geological map of the Samch'ok coal field. [To accompany Shiraki, 1940.]

——— 1940, Samch'ok anthracite field, Kangwŏn-do: Reports of the investigation of the coal fields of Korea, v. 14, p. 1–166, (Japanese).

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Geology of Tangyang coalfield

By KENNETH G. BRILL, JR.

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COALFIELDS OF THE REPUBLIC OF KOREA

GEOLOGY OF TANGYANG COALFIELD

By Kenneth G. Brill, Jr.

ABSTRACT

The Tangyang coalfield was mapped during the fall of 1949 as one of the areas studied by the Geological Survey for the Economic Cooperation Administration in Korea.

The region contains rocks which range in age from pre-Cambrian to Late Jurassic or Cretaceous. Sedimentary rocks of Paleozoic and Mesozoic age rest unconformably on the pre-Cambrian igneous and metamorphic rocks. All are intruded by Upper Jurassic or Cretaceous igneous rocks.

The principal coal bearing formation is the Sa-dong formation of Pennsylvanian and Permian age, which contains three beds of anthracite coal. The coal-producing part of the field extends for a distance of about 15 kilometers through the Yongchun area and the Pobal, Taedae-ri, Kichon, and Rodong mining areas. Also, some coal is found in the Basong formation of Jurassic age. This coal is mined at Sapyong.

The inferred reserves of coal, calculated on a basis of reduction to a coal with 20 percent ash, are about 6 million metric tons above drainage and 20 million metric tons below drainage. In view of the thinness of the seams throughout their known extent in this field and the high percentage of shale in the coal beds, it does not seem likely that appreciable quantities of coal can be produced commercially from this field in the near future.

INTRODUCTION

The Tangyang anthracite coalfield extends for more than 25 kilometers in a northeasterly direction from the vicinity of Tangyang railroad station, Tangyang-gun, Ch'ŭngch'ŏng-pukto to the vicinity of the village of Wondong, Yongwol-gun, Kangwŏng-do (pl. 11). Tangyang station is located at longitude 128°18′6″ E. and latitude 36°54′ N., and Wondong is at longitude 128°31′ E. and latitude 37°10′ N.

The coal deposits of the southern part of the field were studied by Hatae,[1] who prepared analyses of the coal (table 3) and estimates of tonnage. Kobata (1942) published a generalized geologic map of the field, identified the sedimentary formations, and explained the structure of the region. The Day and Zimmerman report [2] gave

[1] Hatae, Nobuhiro, 1940, Report on Tanyang coalfield. Unpublished report transmitted to the Government General of Korea.

[2] Day and Zimmerman Inc., 1949, Rept. no. 5002 to his Excellency Syngman Rhee, President, on the condition, rehabilitation and further development of certain elements in the industry of the Republic of Korea. Transmitted by W. Findley Downs, President, Aug. 15, 1949.

estimates of the tonnage of coal in the southern part of the field.

The geology of the field was mapped by the writer during the fall of 1949 as a part of a project in which three coalfields in the vicinity of Yongwol steam powerplant were studied. The investigation was made for the Economic Cooperation Administration by the Geological Survey.

The area was mapped on aerial photographs made by the United States Army in 1947. The northern part of the field was mapped in detail, but the central and southern parts were mapped by less detailed methods. The northern part lies near the Yongwol powerplant which is the destination for the coal; for this part of the field a topographic map was prepared by the United States Army, 64th Engineer Base Topographic Battalion. Data obtained in the field were compiled on this map.

After the investigation showed that the northern part of the field was not favorable for future production of coal, the investigation was focused on the central and southern parts of the field. This latter area was mapped more rapidly and in less detail because of the approach of winter. The data obtained in the investigation of these parts of the field were compiled on the Japanese Imperial Land Survey topographic maps of Korea, scale 1:50,000, which have been revised and reissued by the United States Army Map Service.

The writer wishes to thank Cheong Chang Hi of the Korean Geological Survey, and Kim Kee Hwa, who acted as interpreters, translators, and field assistants. The writer is grateful for the many kindnesses received from these men. The Tangyang Mining Co. kindly provided a part-time guide in the field and made its production and drilling records available to the writer.

GEOGRAPHY

LAND FEATURES

The Tangyang coalfield lies on the northwest side of the Sobaek-san Range in the valley of the Han-gang. The relief in the field is about 800 meters, the highest point being Taewha-san, 1,027 meters above sea level. Hillsides are steep and, where not cultivated, are covered with brush, scrub pine, and hardwood timber.

DRAINAGE

The area is drained by the Han-gang and its tributaries. The Han-gang is 70 to 100 meters wide and has a gradient of about 2.4 meters to 10 kilometers. It is subject to sudden floods, during which the water level may rise 3 meters in a few hours. Most of the larger tributaries are spring-fed, permanent streams.

The course of the Han-gang is meandering, but the meanders are incised. The tributary valleys are mostly narrow and deep and have relatively steep gradients. Many of the larger tributary valleys show a local widening of the valley floor at an altitude of about 220 meters (pl. 11). Below and above this strath the valleys are narrow. The villages of Pobal-li, Taedae-ri, Kichon-ni, and Rodong-ri are situated on such straths.

The region on the west side of the Han-gang, northwest of the Tangyang mine office and southwest of the Sapyong mine, is underlain by limestone that has been recrystallized by igneous intrusions. In this region a karst topography has formed, and the drainage is mainly underground.

TRANSPORTATION

Tangyang station at the south end of the field is on a railroad which connects Seoul with Taegu on the Seoul-Pusan main line. During the fall of 1949 a spur line was being constructed from this railroad to the mining village of Sapyong. A dirt road with gentle grades extends the length of the field along the valley of the Han-gang between the towns of Yongwol to the north and Tangyang to the south and connects with the countrywide road network. There are no road bridges across the Han-gang. Vehicles must use a ferry at four different places between Yongwol and Tangyang. Four short roads connect the Rodong, Kichon, Taedae-ri, and Pobal mines with the main road. There are no other automobile roads in the area.

STRATIGRAPHY

The Tangyang coalfield lies near the northeast end of the Okchon (Yokusen) structural depression (Kobyashi, 1933) which is a broad belt of sedimentary strata trending in a northeasterly direction across the Republic of Korea. This depression was an area of sedimentation during much of the Paleozoic and early Mesozoic time. The Tangyang field contains strata from every Paleozoic and Mesozoic system except the Silurian, Devonian, and Cretaceous. The major stratigraphic breaks occur at the base of the Pennsylvanian and at the base of the Jurassic. Sedimentation seems to have been continuous throughout Permian and Triassic times. The generalized section below lists the stratigraphic units present in the field.

	Meters	Feet
Lower Jurassic:		
Tae-dong (Daido) [3] system:		
Bansong formation	700	2, 310
Angular unconformity.		
Triassic:		
Pyongan (Heian) system:		
Nogam (Ryokugan or Green) formation	500	1, 650
Permian and Triassic:		
Kobangsan (Kobosan) formation	500–600	1, 650–1, 980
Pennsylvanian and Permian:		
Sa-dong (Jido) formation	100	330
Pennsylvanian:		
Hongjom (Koten) formation	400–500	1, 320–1, 650
Disconformity.		
Cambrian and Ordovician:		
Chosen system:		
Great Limestone series	800–1, 000	2, 640–3, 300
Cambrian:		
Yangdok series	200	660
Unconformity.		
Pre-Cambrian: Igneous and metamorphic rocks.		

CHOSEN SYSTEM

The Chosen system is the thickest and one of the most widespread stratigraphic units in the north end of the Okchon depression. In the Tangyang field the Chosen system consists of the Great Limestone series of Cambrian and Ordovician age, underlain by the relatively thin Yangdok series of Cambrian age.

YANGDOK SERIES

The Yangdok series contains the oldest Paleozoic strata in the region. It is presumed to be of Cambrian age. It consists of fine- to medium-grained, grayish-yellow (5*Y*8/4) [4] or grayish-orange (10*YR* 7/4) quartzite. It is reported to be 200 meters thick (Kobata, 1942). The series presumably underlies the field at depth; however, its outcrop is several miles southeast of the outcrop of the coal beds, hence the series does not appear on the geologic map (pl. 11).

[3] Japanese stratigraphic names are given in parentheses. These names were proposed for the units; however, their Korean equivalents are now used by the Korean Geological Survey.

[4] The colors and numbers are from the Rock-color chart of the National Research Council, Washington, D. C., 1948.

GREAT LIMESTONE SERIES

The writer found no fossils in this series; however, Kobata states that *Maclurites* has been found in the upper part of the series near the town of Tangyang, and that the series ranges in age from Late Cambrian to Middle Ordovician.

The series crops out both northwest and southeast of the field. It lies in normal stratigraphic sequence on the southeast side, and on the northeast side has been brought up by faulting into contact with the Kobangsan, Nogam, and Bansong formations. The series consists chiefly of medium light-gray (*N* 6), medium-grained, massive limestone. Several thick beds of dark-red slate and argillite occur in the upper part of the series. In the north end of the field two such detrital layers are separated by beds of limestone with which they have gradational contacts. Southward in the field these detrital layers become more limy and are less easily distinguished from the rest of the series. Several stratigraphic units within the Great Limestone series have been named and are recognized in other areas; however, no attempt was made to subdivide the series in this area.

The thickness of the series was not measured; the width of outcrop indicates that the thickness is from 800 to 1,000 meters.

The limestone weathers into ridges having precipitous slopes. Few sinkholes are present except where igneous intrusions have recrystallized the limestone and made it more soluble. One area of karst topography lies on the north side of the Han-gang about 3.3 kilometers northwest of the Tangyang mine office.

PYONGAN SYSTEM

The Pyongan system is widely distributed in the Okchon depression and occurs also in the Pyongnam (Heian) depression (Kobayashi, 1933) in northern Korea. In the Tangyang field the Pyongan system consists of the Hongjom, Sa-dong, Kobangsan, and Nogam formations which range in age from Pennsylvanian to Triassic. These four formations are the principal strata in the field.

HONGJOM FORMATION

Sediments of Silurian, Devonian, and Mississippian age are absent in this region. In normal sequence the Great Limestone series is overlain by the Hongjom formation of Pennsylvanian age. Although the top of the Great Limestone series is weathered and in many places stained brown, there is no noticeable angular unconformity between this series and the Hongjom.

The Hongjom formation was named for the village of Hongjom in northern Korea by Yabe (1919). It consists of greenish-gray (5*G* 4/1 to 5*G*6/1) quartzite, argillite, and slate which weathers dark reddish brown (10*R*3/4), and light olive-gray (5*Y*5/2) phyllite, interbedded with lenses of white dolomitic marble. The red slate on the outcrop and the red soil which is derived from it make the formation easily recognizable.

The writer did not measure the thickness of the formation, but it is estimated to range from 400 to 500 meters. The formation has been folded isoclinally, and much slipping has occurred along the bedding planes; hence, its thickness is difficult to measure. The formation is resistant to erosion and forms hills and ridges, but these are not as prominent as those formed by the Great Limestone series or the Kobangsan formation.

Kobayashi (1933, p. 594) states that *Schwagerina princeps* occurs in the Hongjom formation in eastern Korea, which indicates that the formation is Permian in age. *Fusulina* sp. and *Fusulinella* sp. were collected by Hatae (1939) from limestone beds in the lower part of the Hongjom formation in the Macha-ri field. Fusulinids collected from this formation in the Tangyang field have the fusulinellid type of wall rather than schwagerinid type. This seems to corroborate Hatae's opinion and indicates, but does not necessarily prove, that the Hongjom in this area is no younger than middle Pennsylvanian.

SA-DONG FORMATION

The Sa-dong formation, the principal coal-bearing formation of the Republic of Korea, was named for the village of Sa-dong in northern Korea by Nakamura (1918). It consists of two unnamed members. The upper member is composed of interbedded dark-gray (*N* 3) and grayish-black (*N* 2) slaty shale, dark-gray (*N* 3) quartzite, and olive-black (5*Y* 2/1) argillite. The lower member is composed of dark-gray (*N* 5) crystalline limestone with stringers of white calcite interbedded with light olive-gray (5*Y*5/2) quartzite and gray argillite. The limestone member contains one to five beds of limestone each of which may have an average thickness of 2.5 meters. In the northern part of the field the limestone of the Sa-dong is less marbleized than that of the Hongjom formation, but in the southern part of the field neither is strongly marbleized and they are somewhat similar. The limestone member of the Sa-dong is an excellent marker bed and can be traced the length of the field, although in many localities it is concealed by slumping or cut out by faulting. Anthracite coal beds occur in the upper shale and argillite member. Commonly there are three beds 15 to 20 meters apart, the upper one of which lies 50 to 80 meters below the top of the formation. In most localities the upper bed is a meter or more in thickness, but in some places it is split by one or more beds of slate. The middle and lower beds usually average a few tens of centimeters in thickness and are also impure.

The upper member of the Sa-dong formation is an incompetent layer lying between two competent layers and, as a result, is strongly contorted by folding and thrust faulting. The true thickness of the formation was not measured, but it probably does not exceed 200 meters.

The Sa-dong formation weathers easily and, where it is steeply dipping, erodes to form saddles which lie between the high peaks formed by the overlying Kobangsan formation and the lower peaks formed by the underlying Hongjom.

Marine fossils are present in the limestone member at several localities. Hatae (1939) collected fusulinids from the Macha-ri area which were identified as *Schwagerina* sp. and *Pseudoschwagerina* sp. These seem to indicate that at least part of the formation is of Wolfcamp (Permian) age. The U. S. Geological Survey recognizes the Sa-dong formation as Pennsylvanian and Permian in age. The upper member of the Sa-dong contains fragments of plants.

KOBANGSAN FORMATION

The Kobangsan formation was named for exposures on Kobangsan in northern Korea (Tamura, 1917). It consists chiefly of thick-bedded medium-gray and grayish-white quartzite which weathers dark brown. Some beds are conglomeratic and contain small rounded quartz pebbles. Interbedded with the quartzite are relatively thin layers of dark-gray argillite and carbonaceous slate. Many veinlets of white quartz are present in the quartzite. Several thin beds of coal have been found in the lower part of the formation (Kobata, 1942). In a prospect pit about 500 meters south of the Taedae-ri mine, three thin beds of coal are exposed in an isolated outcrop of quartzite. The mine officials suggest that this is an exposure of Kobangsan coal. It is not of commercial grade, and as yet no coal has been mined from the Kobangsan in the field.

The writer did not measure the thickness of the formation; however, it is estimated to range from 500 to 600 meters.

The Kobangsan forms a prominent hogback with a steep side facing the Sa-dong outcrop. In many places an accumulation of talus composed of fragments of Kobangsan quartzite covers the coal-bearing beds of the Sa-dong formation. The Kobangsan is entirely nonmarine and is reported (Kawasaki, 1927, p. 1) to contain a mixed flora of Permian and Triassic age.

NOGAM FORMATION

The name Green or Nogam series was proposed by Kawasaki (1925) for exposures in northern Korea. The Nogam is the uppermost formation of the Pyongan system. It consists chiefly of light-green, dark-red, and light-gray fine-grained quartzite interbedded with argillite. The formation is easily recognized by the quartzite, from which the name was derived. The formation crops out in the middle part of the Tangyang field, but has been eliminated by faulting to the north and south.

The thickness was not measured, but the part of the formation that is preserved in the fault block along the Han-gang is about 500 meters thick.

The Nogam is not as resistant to erosion as the Kobangsan formation, but the quartzite beds form prominent hills. The formation is apparently unfossiliferous at all localities. Its age is established as Triassic because it overlies the Kobangsan and is overlain unconformably by the Bansong formation of Early Jurassic age.

TAE-DONG SYSTEM

The Tae-dong system is widespread in the Republic of Korea and was deposited in the Okchon depression and other basins of sedimentation. It also apparently overlapped the borders of the neighboring granitic highlands (Kobayashi, 1933, p. 596). In the northeastern part of the Okchon depression, in which the Tangyang field is located, the system is represented by the Bansong formation.

BANSONG FORMATION

The Triassic and Paleozoic strata were strongly folded and faulted by Late Triassic crustal movements. The Bansong formation rests with angular unconformity on the truncated Triassic and older strata. The Bansong can be divided into two distinct members in the Tangyang field. The lower member consists of a conglomerate containing rounded fragments of all the older geologic units in the region. The fragments are as large as 70 centimeters and predominate over the matrix which consists of a greenish-gray sandstone. The whole member weathers dark reddish brown (10*YR* 3/4). This conglomerate is 175–200 meters thick at the south end of the field and about 7 meters thick at the north end.

The upper member of the Bansong formation consists of dark carbonaceous shale and yellowish-gray sandstone. At least three beds of coal have been recognized in the upper member; two of these are being mined at the Sapyong mine. The top of the formation has been removed everywhere by faulting and erosion.

The writer did not measure the upper member, but is estimated to have a maximum thickness of about 700 meters.

The formation is entirely nonmarine, and its age has been established as Liassic (Early Jurassic) by plant remains (Kawasaki, 1925).

TALUS

Accumulation of talus is common on the steeper slopes. The cliffs formed by the Kobangsan formation yield a particularly thick talus of quartzite fragments. This quartzite does not weather readily and is commonly devoid of vegetation. In many places talus from the Kobangsan formation obscures the outcrop of the coal-bearing member of the Sa-dong formation and makes prospecting difficult. The large area mapped as talus on the west side of the Han-gang across the river from Wondong may contain landslide and slump blocks as well as talus.

ALLUVIUM

The largest deposits of alluvium occur in the flood plain of the Han-gang. They consist of silt, sand, and some gravel which form bars in the river and terraces on the banks. Probably the maximum thickness of these deposits is 8 meters. Most of the tributary valleys are narrow and steep and therefore contain relatively small deposits of alluvium; however, at the mouths of some of the larger tributaries there are relatively large areas of valley fill. The soil of the alluvial flats is the most fertile in the area and is cultivated intensively. The age of these deposits is probably Recent.

IGNEOUS ROCKS

Many dikes, sills, and irregular igneous rock bodies have intruded the region. The largest of these is a small stock about 2 kilometers in diameter which intrudes the Hongjom and Sa-dong formations. It lies on the south side of the divide between the Taedae-ri and Pobal mines. It is composed of light-gray granite porphyry containing large phenocrysts of pink potash feldspar.

Another large area of intrusive igneous rock lies on the north side of the Han-gang just south of the Sapyong mine. Here an irregularly shaped intrusion 1 to 2 kilometers in diameter has entered the Great Limestone series and Bansong formation. It is composed of grayish-yellow rhyolite porphyry containing small phenocrysts of quartz. Several rhyolitic sills occur in the valley of Taedae-ri creek between these two large intrusions. Many other rhyolitic and basaltic sills and dikes lie on the south side of the Han-gang within the large meander bend just northwest of the Tangyang mine office. These may be observed at the two tunnels and at other points on the new railroad grade, and in the cuts along the main automobile road for a distance of 1.5 kilometers north and 1 kilometer south of the mine office.

Several small dikes intrude a fault zone about 100 meters east of the main road, about 2.5 kilometers north of Tangyang railroad station.

Near the north end of the field a dikelike mass of finely crystalline biotite granite has been intruded along the Congsuwan fault 1 kilometer northwest of Wondong. The intrusion crops out along the same fault in the stream valley northeast of, and upstream from, the village. Along the south fork of this stream, about half a kilometer northeast of Wondong, a rhyolitic sill about 1 meter thick underlies the Sa-dong coal bed and is apparently the source of the numerous quartz veinlets that intersect the coal in this area.

Although many of the dikes are intruded along fault planes, the writer has seen no place where intrusive rocks have been faulted. Nearly all workers in the region agree that most of the faulting took place during the Jurassic period, and if this is true, the intrusions occurred later, probably during Cretaceous time. On the other hand Kobata (1942) states that the intrusive rocks are of Jurassic age and states that at one locality in the Tangyang field an intrusive rock body is intersected by a fault.

It is not unreasonable to assume that there was more than one period of intrusion in the region, which may account for the presence of more than one type of igneous rock.

STRUCTURAL FEATURES

The Tangyang field like the other major coalfields in the Republic of Korea lies in the Okchon depression. This depression, a structural rather than a topographic low, was an area of sedimentation in Paleozoic and Mesozoic time. It trends northeastward from the town of Kawanggi on the south coast to the town of Mukho on the east coast. It lies between two granitic structural highs. Kyonggi (Keiki) land (Kobayashi, 1933) lies on the northwest side of the depression and Yongnam (Reinan) land lies to the southeast.

The Tangyang field trends N. 30° E. The Paleozoic and Mesozoic strata in normal stratigraphic sequence dip northwestward off the pre-Cambrian core of the Sobaek-san range. The northwest side of the field is bounded by a thrust fault, or perhaps a series of en échelon faults, which have brought the Great Limestone series into contact with the Kobangsan, Nogam, and Bansong formations. According to Hatae (1940) this fault was named the Congsuwan fault by Yoshimura (pl. 11). This fault seems to dip northwestward at a relatively high angle except at the extreme north end of the mapped area where the dip is about 10° to 20° W.

Several high-angle thrust faults lie nearly parallel to the strike of the strata. Nearly all have the north or west side upthrown. Only the major ones are shown on the geologic map (pl. 11). The long fault which trends northeastward from the Duk Sang mine has been named the Surum-san fault. It crosses a spur on the east side of Surum-san and can be traced as far north as the Han-gang north of Sapyong. The writer, has named another one which is nearly parallel with the Surum-san, the Kichon fault. It is well exposed in the valley walls between the Tangyang mine office and the Kichon mine.

As a result of diastrophism the shale layers and other incompetent strata have been strongly deformed. This is particularly true of the upper member of the Sa-dong formation which consisted of shaly strata interbedded with coal beds and thin siltstone beds. This member lay between the limestone beds of the lower member and the quartzite beds of the Kobangsan formation. The limestone and quartzite tended to fold as a unit while the shale was contorted (figs. 7 and 8). In many parts of the field the Hongjom formation is also

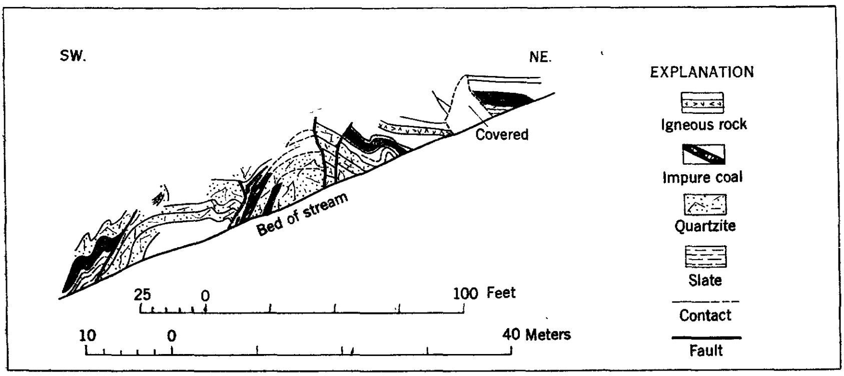

FIGURE 7.—Detail of Sa-dong formation 1.0 kilometer northeast of Wondong.

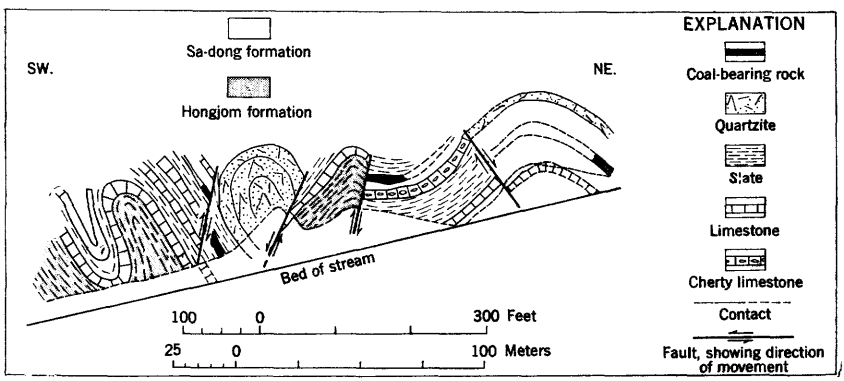

FIGURE 8.—Detail of coal outcrop 2.2 kilometers southwest of Yongchun.

strongly contorted. In the valley of the Han-gang east of the village of Wondong, it lies in isoclinal folds.

Widespread diastrophism occurred late in the Triassic period, at which time the Nogam and older formations were folded, tilted, and metamorphosed. The Bansong formation unconformably overlying the older formations is metamorphosed to a lesser degree than the older formations; hence, it is believed that the strata were further metamorphosed and faulted during the second period of diastrophism in Late Jurassic or possibly Early Cretaceous time (Kobayashi, 1933).

COAL

DISTRIBUTION

NORTH TANGYANG DISTRICT

For convenience of discussion the field may be divided into two parts, north Tangyang and south Tangyang; the line of separation is drawn arbitrarily where the Han-gang crosses the coal-bearing strata 1.5 kilometers southwest of Yŏngch'un.

The north Tangyang district was prospected by the Japanese in 1940. Many trenches and prospect pits were dug on the divides between the stream valleys. Further attempts to prospect or exploit the district were abandoned for nearly a decade.

The Macha-ri Mining Co., in 1949, at the suggestion of the Coal Branch of the Economic Cooperation Administration, opened several prospect adits 0.5 kilometer northeast of Wondong. A few tons of coal produced from one of these adits was shipped to the Yongwol powerplant; however, prospecting was stopped because the coal was strongly contorted by folding, faulting, and igneous intrusions (fig. 6).

Two core holes were drilled by the Macha-ri Mining Co. in this area. D. H. M1 (pl. 11) was abandoned at a depth of about 30 meters without having discovered coal. The cuttings indicate that the bedrock is dark-gray argillite and slate. D. H. M2 was abandoned before the bedrock was reached.

The coal beds in the vicinity of Wondong lie near the top of the limestone zone in the Sa-dong formation, whereas the coal beds in the southern part of the field lie considerably above the limestone zone. The proximity of the coal to the limestone may result from many small thrust faults which have eliminated the beds of argillite and slate. On the other hand these may be different beds of coal from those farther south, or the strata which lie between the coal and the limestone in other parts of the field may never have been deposited in this area.

Several prospect pits were dug by the Macha-ri Mining Co. on the south side of the Han-gang 550 meters south of Wondong. Fragments of coal were found in the float, but the bedrock was not reached.

Many Japanese prospect pits and trenches are present in the hills between Wondong and Yongchun. No coal was observed in either the pits or dumps; however, local farmers who dug the pits for the Japanese state that coal 2 meters in thickness was discovered in the hillside 1 kilometer north of Yongchun.

SOUTH TANGYANG DISTRICT

In the south Tangyang district coal has been produced from the Sa-dong formation in five mines and from the Bansong formation in one mine. From north to south the mines which have yielded coal from the Sa-dong formation are: Pobal, Taedae-ri, Kichon, Rodong, and Duk Sang. The Sapyong mine yields coal from the Bansong formation.

SOUTH YONGCHUN AREA

The south Yongchun area is at the northernmost end of the south Tangyang district. It lies between the Han-gang and the stream divide north of the Pobal mining area. Its north end is about 1.5 kilometer southwest of Yongchun. A few prospect pits and short adits have been dug, but no coal has been produced. Several coal beds appear to be present, but they are strongly folded and faulted (fig. 8).

A geophysical survey using self-potential was made in this area under the direction of the Tangyang Mining Co. The results of the survey have led the company to prospect this part of the field.

POBAL AREA

The Pobal mining area lies on both sides of an unnamed creek which flows through the village of Pobal-li. The mine consists of seven entries, six of which have disclosed coal. Adits 1 and 2 and the abandoned adit have caved (fig. 9).

Three beds of coal are present. The upper bed is reported to be 2 meters thick. The middle and lower beds are a few centimeters thick and are not mined. The middle bed is separated from the upper and lower beds by about 10 meters of shaly slate. Hatae (1939) states that the average thickness of the coal in the Pobal mining area is 4 meters. The Day and Zimmerman report, cited earlier, states that the average thickness is 7.5 meters. This figure represents the total thickness of three beds of coal in a core-drill hole located 700 meters southeast of the Pobal mine.

At the time of the writer's visit the only exposed face of coal was in the upper bed in adit 4 and, although the face was 2.5 meters wide, no more than 30 centimeters of coal was visible. This is probably one of the many places in the district where the coal is thin due to pinching of the beds. At other localities in the district the coal bed may be a meter or more in thickness.

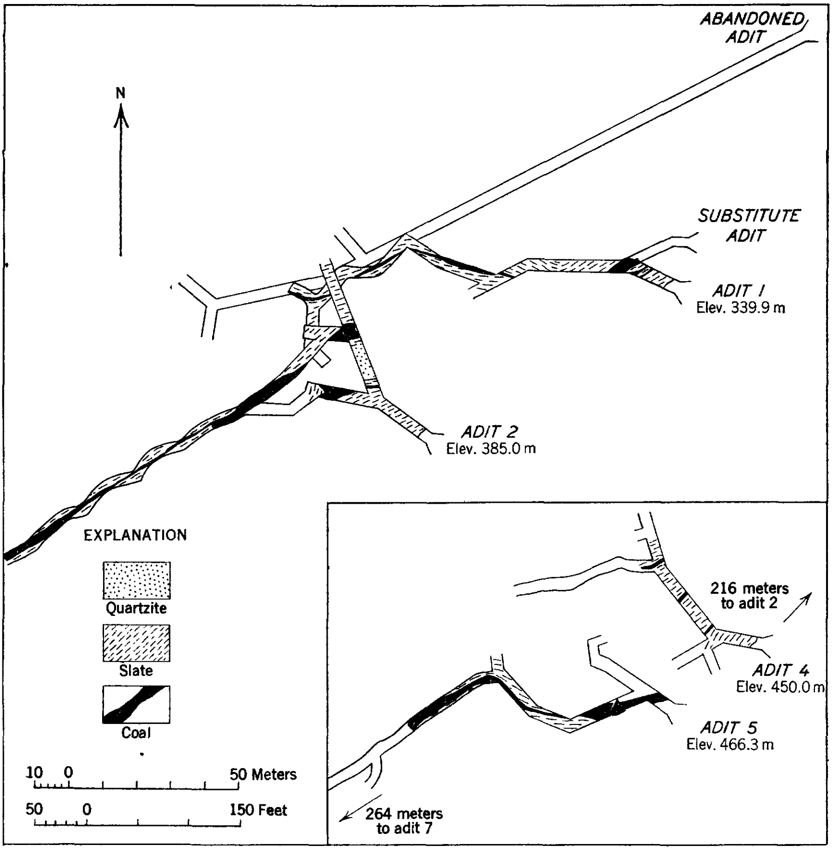

FIGURE 9.—Map of main workings, Pobal mine.

Much of the material classed as coal by the local miners is actually bituminous slate and fault gouge; this is attested by the fact that the coal shipped from the Tangyang field contains as much as 50 percent ash. Predicting reserves or production on the basis of total thickness, more than half of which must be discarded, is erroneous and misleading.

In some adits the miners measure the vertical distance from the top to the bottom of the beds rather than measuring the thickness normal to the bedding. Where the bed dips steeply, vertical measurements give exaggerated thickness to the coal.

Core holes 1, 2, 3, and 4 (fig. 10) were drilled in the Pobal area under the direction of the Tangyang Mining Co. Relatively great thicknesses of coal were penetrated in holes 1, 3, and 4 in which the coal is reported to be 15, 13, and 8 meters thick respectively. The writer did not see the cores, and it is possible that this is the true thickness of the coal. On the contrary this unusually great thickness might be

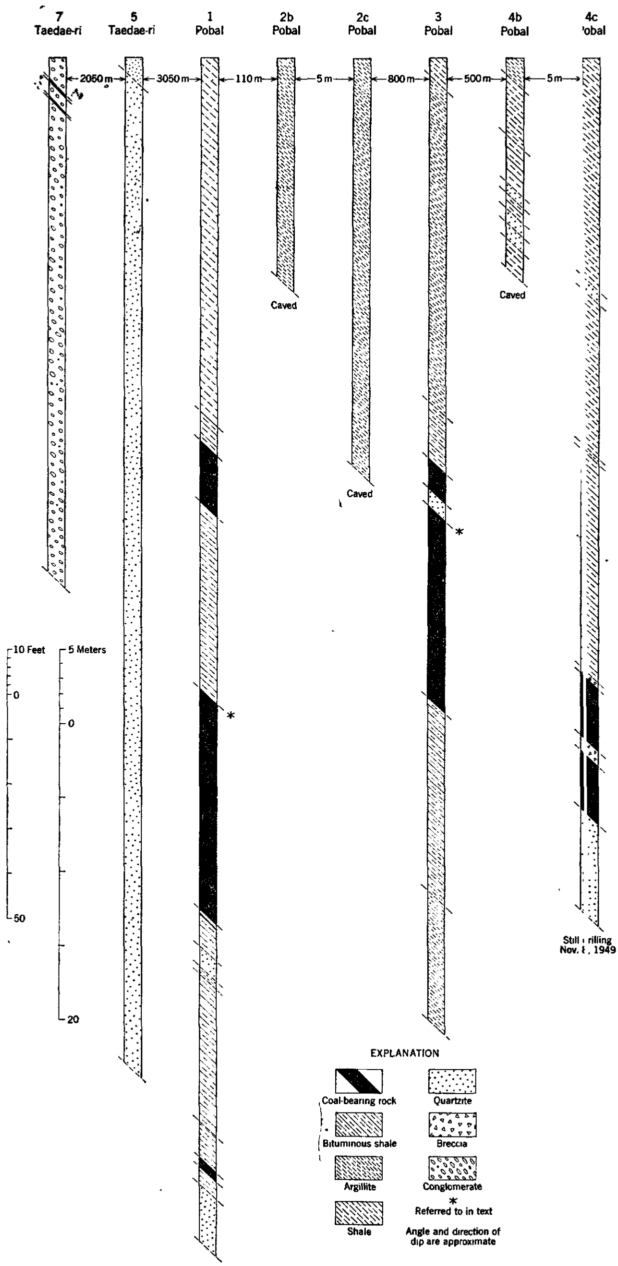

FIGURE 10.—Diagram showing logs of core-drill holes.

the result of the vertical drill hole passing through a coal bed which dips at a very high angle. It is possible also that a decimal point may have been misplaced, in which case the 15 and 13 meters of coal may be actually 1.5 and 1.3 meters. It is interesting to note that in Day and Zimmerman report that 1.5 meters of coal is present in the middle bed in drill hole 1. In the writer's opinion, an average thickness of 1 meter of coal for all three beds in this area is more nearly correct.

TAEDAE-RI AREA

The Taedae-ri mining area lies between the divides on both sides of an unnamed creek which flows through the Taedae-ri area. The mine, which lies on the hillside southwest of the creek, consists of six adits and several prospect pits.

Three beds of coal are present. The mine manager states that the thickness of the upper beds is 3.5 meters, the middle bed 1 meter, and the lower bed 0.5 meter. The middle bed is separated from the upper and lower beds by 10 to 15 meters of shaly slate. Hatae (1939) reported that the average thickness of the coal in this area was 4 meters.

According to the mine manager, the middle and upper beds were combined locally in the adit 4 and formed a bed 9 meters thick for about 30 meters. At the time of the writer's visit this pocket of coal had been mined out, and the combined thickness of the two seams was 1.8 meters.

Core-drill holes 5 and 7, which were drilled under the direction of the Tangyang Mining Co., did not disclose coal in appreciable quantities. In the writer's opinion the average thickness of the coal in the Taedae-ri area does not exceed 1 meter for all three beds.

The part of the area that lies on the northeast side of the creek is close to a large intrusion of granite porphyry which has altered the coal-bearing strata by contact metamorphism. It is probable that little coal will be found in this part of the area. Several prospect pits near the northeast edge of the valley floor are barren of coal.

KICHON AREA

The Kichon mining area lies between the divides on both sides of an unnamed creek which flows past the village of Kichon-ni and through the site of the Tangyang mine office. The mine workings consist of two extensive adits and several prospect pits on the north side of the creek and one adit and several prospect pits on the south side. At the time of the writer's visit all adits had caved in and were inaccessible.

Hatae (1939) presumed that this area was the most favorable in the field; hence, the Japanese government opened the mine and built a railroad grade to the mine portal. Hatae reported that the average thickness of the coal was 4 meters. An official of the Tangyang Mining Co. stated that three beds were present in the mine; of these the upper was 5 to 6 meters thick and the middle and lower were each 2 meters thick. The present writer believes that if such a remarkable thickness of coal had persisted for any great distance the Kichon mine would not have been abandoned. Furthermore during nearly 2½ years of operation the mine shipped only 2,346 metric tons of coal. These facts lead the writer to believe that the coal in the Kichon area is not much thicker than that in the rest of the field, about 1 meter.

The part of the area which lies on the south side of the creek passes close to a faulted area where there are felsite dikes and sills and is probably less favorable for coal production than the north side.

RODONG AREA

The Rodong mining area lies between the divides on both sides of an unnamed creek which flows through the village of Rodong-ri. The mine is on the hillside west of the creek, and consists of four adits and several prospect pits. Adit 1 and the abandoned entry have caved in (fig. 11).

Three coal beds are present; the middle and upper beds are thick enough to be mined. The middle bed, which lies about 20 meters stratigraphically below the upper, is 2.5 meters thick in adit 2 and is 15 centimeters thick in the level above. In adit 2 the coal is strongly deformed and probably has been increased in thickness by folding and slipping. At the time of the visit the only exposure of the upper bed was in this entry. The bed was about 1.5 meters thick and was contorted. Hatae (1939) reported an average thickness of 4 meters for all three beds of coal; however, an average thickness of 1 meter only seems justified by the evidence available at the time of this investigation.

The part of the area which lies on the east side of the creek is more strongly folded and faulted and probably contains less minable coal than the western part. Trenches dug by the Japanese in the hills west of the mine show no exposures of coal; however, coal may be present at depth. It will be noted from table 1 that more coal has been shipped from the Rodong mine than from any other mine in the field.

DUK SANG AREA

The Duk Sang mining area lies between the divides on both sides of an unnamed creek which flows through the village of Toksang-ri. The mine is located about 1 kilometer upstream from this village and about 1.5 kilometers east of the Tangyang railroad station. The mine is on the west side of the creek and consists of three short adits and several prospect pits. Coal has been found in two adits (fig. 12).

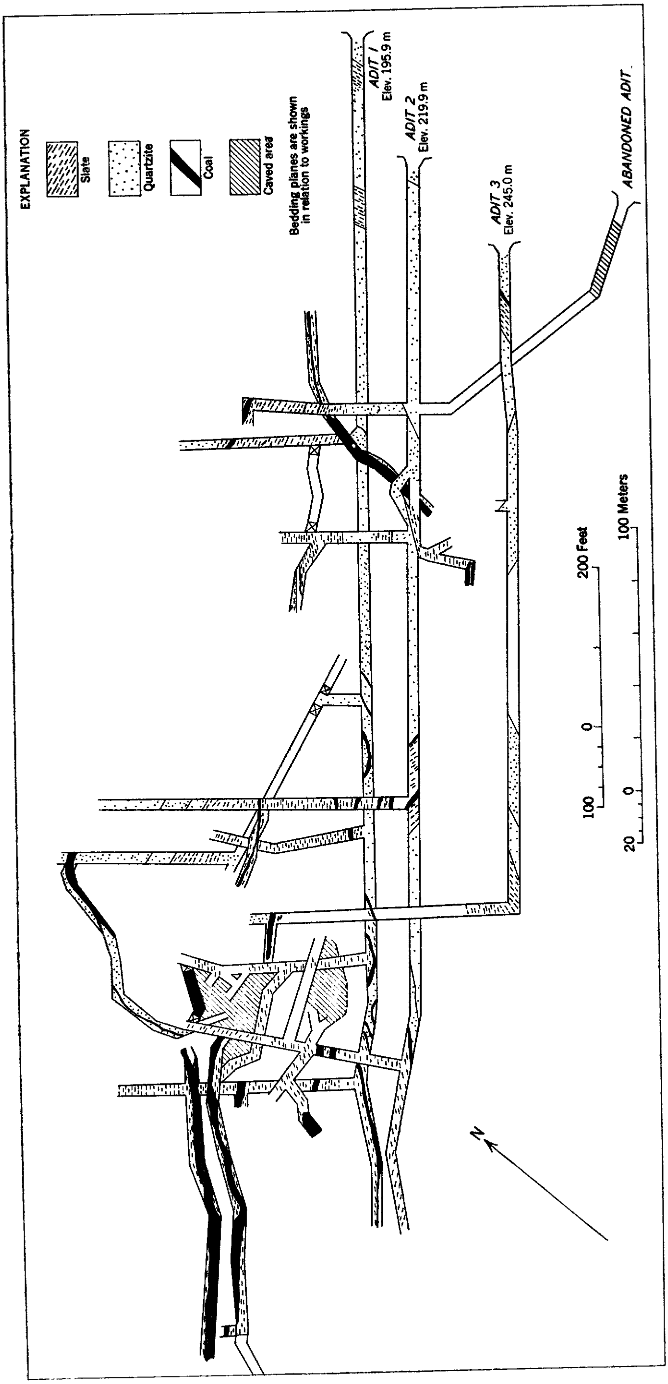

FIGURE 11.—Map of main workings, Rodong mine.

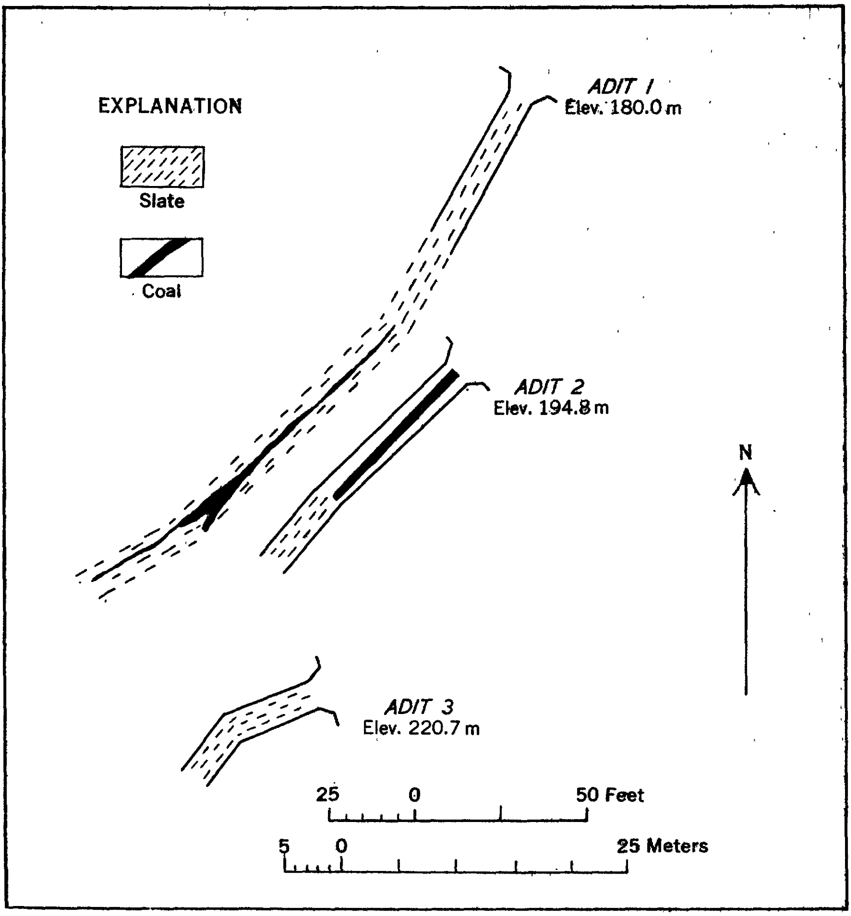

FIGURE 12.—Map of main workings, Duk Sang mine.

The Duk Sang is the newest mine in the field, and little exploratory work has been done. At the time of the writer's visit there was no road to the mine from the highway.

One bed of coal has been found in the mine. The mine manager states that in adit 1 coal was traced for 20 meters; although at no place did it exceed a few centimeters in thickness except about 40 meters from the portal where the bed widened to about 3 meters for for a distance of about 4 meters. The bed then narrowed to about 30 centimeters for a distance of 6 meters. At the time of the visit about 30 centimeters of coal was visible in the face. A few centimeters of coal was found in the level above. Hatae (1939) estimated that the coal had an average thickness of 4 meters in the area; however, an average thickness of 0.5 meter seems more nearly correct.

This mine is being opened near the Surum-san fault zone; hence, at a distance of a few hundred meters to the southwest, the strata are very strongly folded and faulted. The thinness of the coal bed and the proximity of the fault zone indicate that coal will not be found here in commercial quantities.

SAPYONG AREA

The Sapyong mining area lies on the west side of the Han-gang and extends for about 200 meters north and an equal distance south of a small tributary of the Han-gang. The mine lies on the opposite side of the Han-gang from the village of Sapyong which is the future terminus of the railroad spur. The mine consists of three adits which have disclosed coal (fig. 13).

Three beds of coal are present. The upper bed is reported to have been 9 meters thick, but at the time of the writer's visit about 2 meters of coal was visible. The middle bed is 7 to 15 meters stratigraphically below the upper bed and about the same distance above the lower bed. The middle and lower beds are thinner than the upper. All beds pinch and swell.

The coal-bearing strata are cut off at the west end of all three adits by a fault which brings the Great Limestone series into contact with the Bansong formation. An igneous intrusion has eliminated the Bansong formation in the area immediately south of the mine. If the coal-bearing strata are present to the north, they lie beneath the channel of the Han-gang. As a result of these boundaries probably only a relatively small tonnage of coal is left in this area.

Exposures of the Bansong formation on both sides of the Han-gang some 5 kilometers south of the Sapyong mine seem to be relatively free from intrusive rocks. Several thin streaks of impure coal which dip at a high angle are visible in the road cuts along the south side of the Han-gang about 2.5 kilometers west of the Tangyang mine office. If further prospecting is to be done, this area which is underlain by the Bansong formation might be worthy of consideration.

PRODUCTION

The figures for annual production of coal from the mines in the Tangyang field are tabulated in table 1. The Rodong, Sapyong, and Taedae-ri mines have been in nearly constant operation since 1945. The Kichon mine was abandoned in 1947. The Pobal was opened in 1948, and the Duk Sang was opened in 1949. At the time of the visit no coal had been shipped from the Duk Sang mine because no road had been built to the mine portal.

According to the records of the Tangyang Mining Co. the total production from all mines in the field was 70,210 metric tons. The

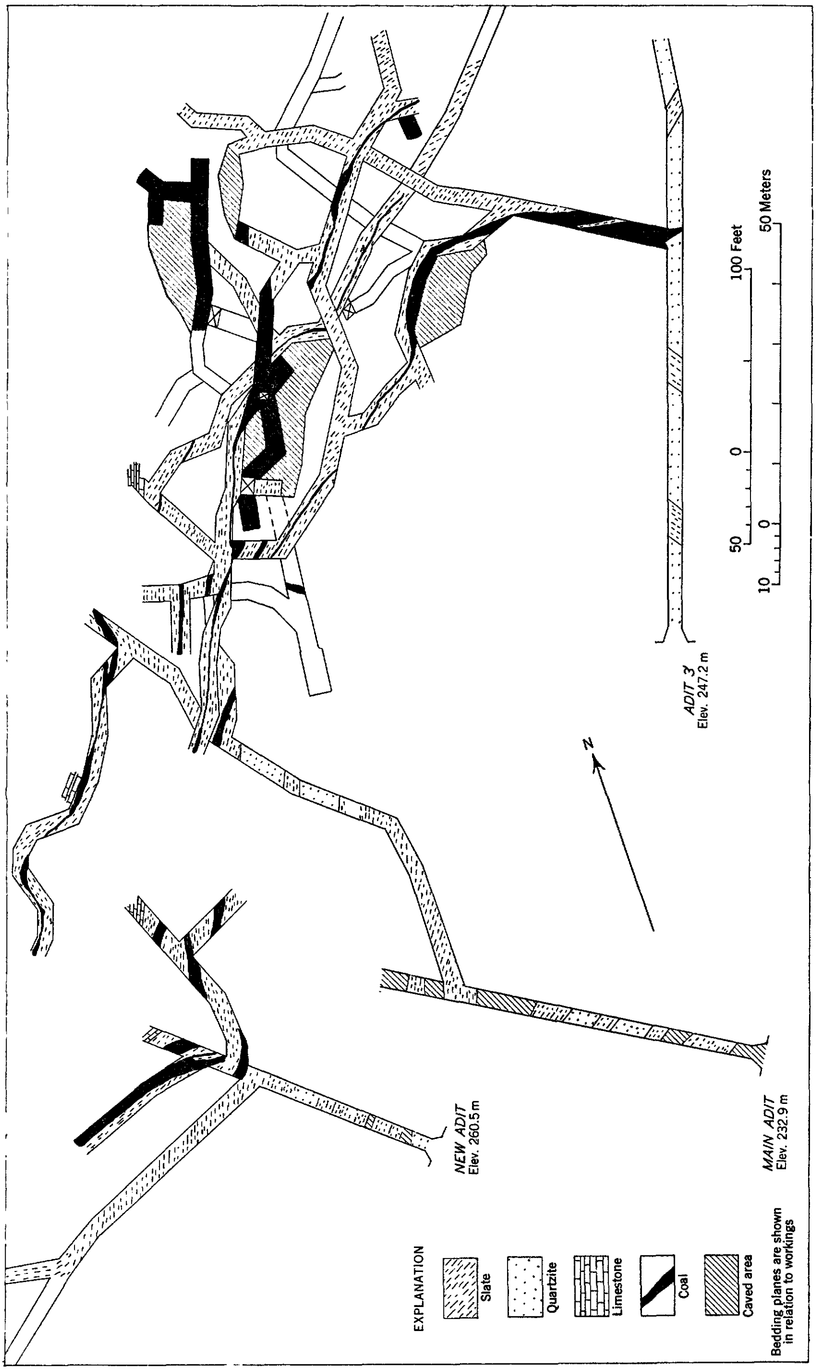

FIGURE 13.—Map of main workings, Sapyong mine.

total tonnage shipped was 44,387 metric tons. At the time of the visit stockpiles of coal at all mines except the Sapyong were negligible. In the stockpile at the Sapyong mine there was about 1,000 metric tons of coal. The discrepancy of more than 20,000 tons between the amount of coal produced and the amount shipped is difficult to explain. The discrepancy may be due in part to the fact that the amount of coal produced is estimated rather than measured, and the amount of coal shipped can be gaged more accurately. Perhaps the number of tons of coal shipped from the field is in reality close to the number of tons produced.

TABLE 1.—*Production in metric tons from the Tangyang coalfield*

[Data obtained from the Tangyang Mining Co.]

Year	*Rodong*	*Sapyong*	*Taedae-ri*	*Kichon*	*Pobal*	*Duk Sang*	*Total*
1945							
Produced	2,398	1,500	60	485	--------	--------	4,443
Shipped	--------	--------	--------	--------	--------	--------	--------
1946							
Produced	4,817	6,233	3,080	1,338	--------	--------	15,468
Shipped	4,860	19	--------	--------	--------	--------	4,879
1947							
Produced	6,548	6,874	8,546	2,146	--------	--------	24,114
Shipped	6,843	3,063	--------	2,346	--------	--------	12,252
1948							
Produced	3,978	3,117	2,853	--------	52	--------	10.000
Shipped	3,200	7,168	7,926	--------	--------	--------	18,294
1949 (to Nov. 1)							
Produced	4,924	5,769	4,329	--------	1,056	107	16,185
Shipped	4,328	1,964	2,646	--------	24	--------	8,962
Produced	22,665	23,493	18,868	3,969	1,108	107	70,210
Shipped	19,231	12,214	10,572	2,346	24	--------	44,387

RESERVES

The calculated inferred reserves of anthracite coal in the south Tangyang district are shown in table 2. About 6 million metric tons are present in three beds above the level of the drainage of the main tributaries of the Han-gang. About 20 million metric tons are present below drainage. Little coal will be obtained from the two thin lower beds, and the bulk of production will have to come from the upper bed, the average thickness of which ranges between 1 meter and a few centimeters. In the south Tangyang district this bed extends for about 15 kilometers, hence, large quantities of waste rock will have to be removed during mining operations in comparison to the amount of coal produced.

No reserves were calculated for the Duk Sang or Sapyong mines. In the former mine the bed is thin, and the mine lies close to a zone of intense deformation. The latter mine will yield several thousand tons of coal, but probably the most productive areas are mined out.

More prospecting will have to be done before accurate information is available concerning the reserves in the north Tangyang district. Some coal is undoubtedly present; however, the writer believes that it is too thin to be of commercial importance. Prospecting along the trend of the Sa-dong formation north of the area of the map (pl. 11) might reveal the presence of minable coal beds.

TABLE 2.—*Inferred reserves of coal in Tangyang field*[1]

Mining area	*Average angle of dip (degrees)*	*Length of bed (meters)*	*Area (square meters)*		*Average thickness (meters)*	*Specific gravity*	*Reserves (metric tons)*	
			Above drainage	*Below drainage*			*Above drainage*	*Below drainage*
South Pobal	30	1,350	270,000	810,000	1.0	1.8	480,000	1,460,000
North Pobal	30	1,720	344,000	1,032,000	1.0	1.8	620,000	1,860,000
South Yongchun	30	2,300	4,600,000	13,800,000	.5	1.8	4,100,000	12,400,000
South Taedae-ri	40	1,750	263,000	788,000	1.0	1.8	470,000	1,420,000
North Kichon	40	1,680	252,000	756,000	1.0	1.8	450,000	1,360,000
South Rodong	45	1,430	200,000	601,000	1.0	1.8	360,000	1,090,000
Total							6,480,000	19,590,000
Grand total								26,070,000

[1] Coal with 20 percent or less ash.

QUALITY

Tangyang coal is anthracite with a high content of ash. Hatae's analyses (1939) of six samples of coal from the five mining areas in the Tangyang field are shown on table 3. These analyses indicate that, with the exception of that in the Duk Sang area, the coal is rather uniform in composition.

Analyses of coal samples from the south Tangyang district and from two adjacent fields were made by the U. S. Bureau of Mines. The results of these analyses are shown in table 4. The single analysis of Jurassic coal from the Sapyong mine indicates that it is somewhat superior to the Permian coal from the other mines in the field. The analysis of the combined sample from the Rodong, Taedae-ri, and Pobal mines indicates that this Permian coal is relatively higher in ash. The relative superiority of Jurassic coal over Permian is borne out in table 3. The discrepancy between the Japanese analyses (table 3) and those prepared by the Bureau of Mines (table 4) may be explained by the fact that run-of-the-mine samples were analyzed by the Bureau of Mines, whereas the Japanese samples were probably handpicked.

Analyses of coal samples from the Mungyong and Eunsong fields are given in table 4. These are small fields that lie southwest of the Tangyang field along the trend of the strata (Cheong, 1956). They are separated from each other and from the Tangyang field by igneous intrusions. The coal in these two fields occurs in the Sa-dong formation.

TABLE 3.—*Proximate analyses of coal from the Tangyang field*

[Prepared by Hatae, 1939; 1, secondary lump, dust compressed naturally; 2, dust; 3, secondary lump; 4, primary lump; 5, dust; 6, dust]

	Duk Sang (1)	*Rodong* (2)	*Kichon* (3)	*Kichon* (4)	*Pobal* (5)	*Sapyong* (6)
Moisture	6.57	5.65	4.64	4.06	4.56	3.40
Volatile	3.20	5.49	3.36	2.16	2.89	2.96
Fixed carbon	62.00	78.90	73.74	84.08	79.44	82.12
Ash	28.23	9.96	18.90	9.76	13.11	11.52
Sulfur	Tr.	.54	Tr.	Tr.	[illegible]6	.51
Calories per kilogram	--------	6,583	5,980	6,840	6,[illegible]8	6,614
Specific gravity	2.01	1.83	--------	--------	1.84	1.80

TABLE 4.—*Analyses of coal from Tangyang mines and Mungyong and Eunsong mines nearby*

[U. S. Bureau of Mines, H. M. Cooper, chemist. Form of analyses: A, air dried; B, as received; C, moisture free]

Field	Tangyang			Tangyang			Mungyong			Eunsong		
Mine	Sapyong			Combined [1]			Haibang and Tongsan			Eunsong		
Laboratory no	D-48117			D-47161			D-47376			D-47791		
Form of analyses	A	B	C	A	B	C	A	B	C	A	B	C
Proximate:												
Moisture	3.5	4.8	------	3.8	4.7	------	4.1	7.0	------	3.1	6.5	------
Volatile matter	4.3	4.2	4.4	4.9	4.8	5.1	4.6	4.5	4.8	4.7	4.5	4.8
Fixed carbon	55.4	54.7	57.5	41.2	40.9	42.8	52.3	50.7	54.5	66.0	63.7	68.1
Ash	36.8	36.3	38.1	50.1	49.6	52.0	39.0	37.8	40.7	26.2	25.3	27.1
Ultimate:												
Hydrogen	1.2	1.3	.8	1.0	1.1	.6	1.1	1.4	.7	1.4	1.7	1.1
Carbon	55.0	54.2	57.0	41.1	40.7	42.7	52.9	51.3	55.2	66.4	64.0	68.5
Nitrogen	.3	.3	.3	.2	.2	.2	.3	.3	.4	.5	.4	.5
Oxygen	5.4	6.7	2.5	6.6	7.4	3.4	6.4	9.0	2.7	4.7	7.9	2.0
Sulfur	1.3	1.2	1.3	1.0	1.0	1.0	.3	.2	.3	.8	.7	.8
Heat value (Btu)	8,140	8,030	8,430	------	------	------	7,620	7,390	7,950	9,980	9,630	10,290

[1] Sample from Rodong, Taedae-ri, and Pobal mines.

LITERATURE CITED

Cheong Chang Hi, 1956, Geology of Mungyong-Eunsong and Hwasun Coalfields: U. S. Geol. Survey Bull. 1041–B, p. 7–10.

Hatae, Nobuhiro, 1939, Stratigraphical division of Heian system on fossil foraminifera: Jubilee pub. in commemoration of Prof. H. Yabe, Tohōku Imp. Univ., Sendai, Japan, v. 1, p. 551–562.

Kawasaki, Shigetaro, 1925, Some older Mesozoic plants in Korea: Geol. Survey Korea Bull., v. 4, pt. 1, p. 66.

——— 1927, The flora of the Heian system: Korea Geol. Survey Bull., v. 6, pt. 1.

Kobata, Nobuhiro, 1942, Geology of the Tanyang area, Ch'ŭngch'ŏng-pukto: Kyoto Imp Univ. Geol. and Mineralogy Class, Technol. rept., no. 1.

Kobayashi, Teiichi, 1933, A sketch of Korean geology: Am. Jour. Sci., 5th ser., v. 26, no. 156, p. 585–606.

Nakamura, Shintaro, 1918, The Jido overthrust: Geol. Soc. Japan Jour., v. 25, no. 293, p. 25.

Tamura, Titaro, 1917, Report on mineral resources of South Heian-do: Min. Res. of Korea, v. 2, no. 2, p. 5.

Yabe, Hisakatsu, 1919, Report of the geology of anthracite seams in P'yŏngan-namdo, Korea: Geol. Survey Korea Bull., v. 1, no. 1, p. 26.

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UNITED STATES DEPARTMENT OF THE INTERIOR

Fred A. Seaton, *Secretary*

GEOLOGICAL SURVEY

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[The letters in parentheses preceding the titles designate the individual chapters]