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Granitic plutons and ore deposits in the Okcheon Zone, Korea

DAI SUNG LEE
Department of Geology, Yonsei University, Seoul, Korea.

Abstract: In the southern part of the Korean peninsula, a broad zone of diagonal lineaments trends northeasterly parallel with the regional structure of that part of Asia. The belt named the "Okcheon Orogenic Zone" by Kobayashi (1953), consists mainly of thick sequences of marine and terrestrial sediments ranging from Precambrian to Cretaceous. The Okcheon Zone overlies a geosynclinal basement of Precambrian granitic metamorphic rocks and is in contact with migmatitic bodies along its southeast margin and batholithic granite plutons along its northwest margin. Within both of these marginal units, are irregular-shaped granitic stocks, acidic dikes and paleovolcanics in association with minor basic bodies.

The plutons associated with the zone can be grouped into three different subzones: SE-subzone for the migmatitic and schistose plutons of southeast margin, 101-181 m.y. old; NW-subzone for those of northwest margin, 112-163 m.y. old; and C-subzone for those of central part of the zone, 63-183 m.y. old. The intrusives in C-subzone are further subdivided into older granites (148-183 m.y. old) and younger granites (63-106 m.y. old).

The metallogenic map of South Korea suggests that, in the Okcheon Zone, it is possible to delineate an elongated polymetallogenic province in the general orientation of the zone intimately related with the migmatic and plutonic zones mentioned. Moreover, the mineralization in this province was basically controlled by patterns of local geology involving country rocks and related igneous rocks, that permit subdivision of the province into the following three parts. *Northeast province* consists dominantly of thick Paleozoic calcareous sediments, contains the most productive and highly diverse assemblage of ore deposits, such as, gold silver, tungsten-molybdenum, iron, lead-zinc, fluorite and some copper deposits of pyrometasomatic and hydrothermal origins. Most of these deposits are related to the older and younger granites and granitic porphyries of C-subzone. *Middle province* is characterized by predominant argillaceous and partly calcareous sediments of Precambrian to Paleozoic age. In this province gold-silver mineralization is clearly related to the plutons of SE-and NW-subzones, whereas, a productive fluorite district is related to the younger plutons of C-subzone. *Southwest Province* consisting of Mesozoic volcanic and arenaceous sediments, is practically barren except for traces of rare elements in placer deposits, and pyrophyllite and allunite in hydrothermal deposits.

INTRODUCTION

In the southern part of the Korean Peninsula a broad zone of diagonal lineaments, known as the Okcheon* Zone, trends northeasterly parallel with the regional structure of that part of Asia. This direction, which was called the "Sinian direction" by Pumpelly (1866), extends from the South China Block in the southwest to Sikhote Alin, U.S.S.R. in the northeast. According to the recent paper of Lin (1971), the Far East is geotectonically situated at the intersection of the Tethys and the Circum-Pacific fracture and fold belts (Fig. 1). From this viewpoint the Sinian direction belongs to the Circum-Pacific fracture and fold belt. The most remarkable part of the belt in Korea is a narrow fold and fracture zone 60-90 km wide and 460 km long.

Since the Japanese geologist K. Inouye initiated the geological study of the zone in 1907, many geologists have attempted to clarify the geology, geological history and economic geology of the zone. However, numerous problems remain.

* This is the Korean form of the Japanese pronunciation, Yokusen, and is also written as "Ogcheon" in Korean.

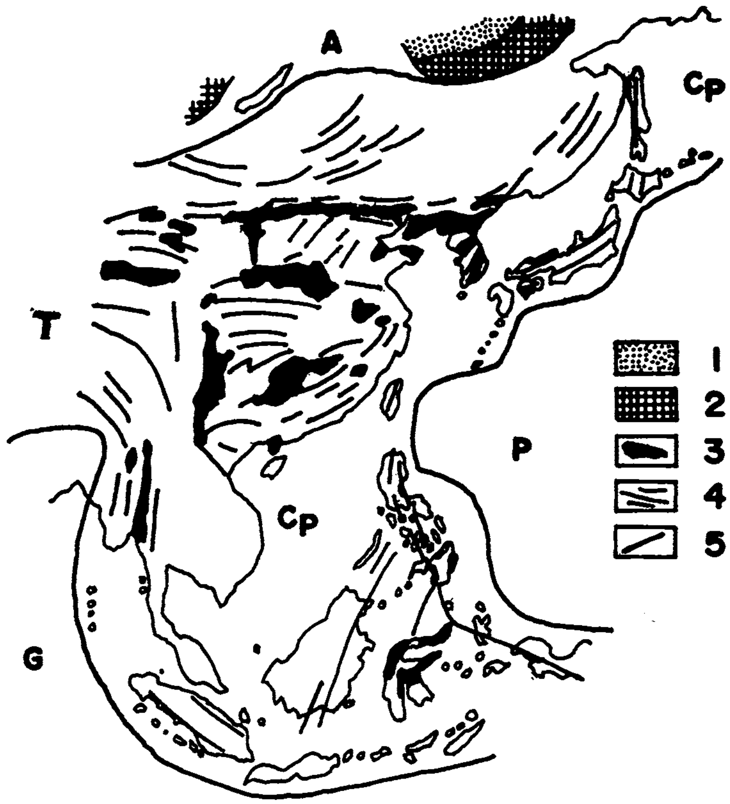

Fig. 1. Map showing the intersection of two fold and fracture belts in Eastern Asia (modified from Lin, 1971) 1: Cover of the platform, 2: Basement of the old platform, 3: Basement of Pre-Paleozoic fold belt, 4: Caledonian to Alpian fold belts, 5: Boundary, P: Pacific block, G: Gondwana block, A: Angara block, T: Tethys fracture and fold belt, Cp: Circum-Pacific fracture and fold belt.

SUBDIVISION OF THE OKCHEON ZONE

The zone named by Kobayashi (1953) as "Okcheon Orogenic Zone" refers to thick sequences of marine and terrestrial sediments/metasediments ranging from Precambrian to Cretaceous which overlie a geosynclinal basement of Precambrian metamorphic complex. The Okcheon Zone contains widely distributed plutonic bodies, which consist of migmatites along the southeast margin of the zone, batholithic granite masses along the northwest margin, and in the central part of the zone are irregular-shaped granite stocks, acidic hypabyssal intrusives and acidic to intermediate paleovolcanics in association with minor gabbroic bodies.

The plutons are grouped into three subzones (Fig. 2): the SE-subzone for the plutons of the southeast margin; the NW-subzone for those of the northwest margin; and the C-subzone for those of the central part of the zone.

The south boundary of the SE-subzone is not sharp but mostly transitional to the metamorphic complex which flanks the south side of the Okcheon zone. In this study the south boundary was placed along the southern margins of the first belt of granitized masses which parallel the general trend of the Okcheon zone. The northern boundary of the SE-subzone which separates it from the C-subzone is relatively clear-cut and is marked either by contact metamorphism or nonconformity with the sedimentary rocks in C-subzone.

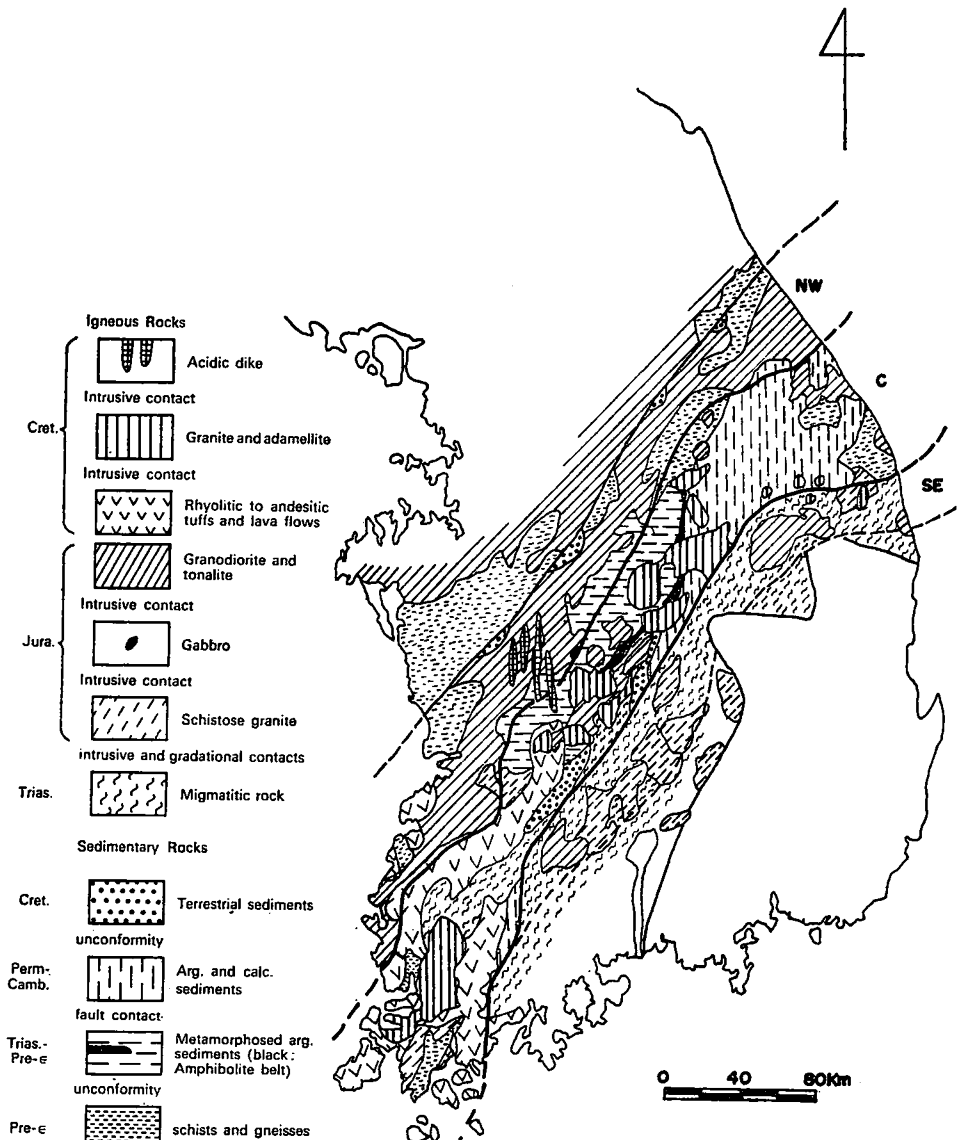

Fig. 2. Zoning of Okcheon Orogenic Zone, Korea

In contrast, the NW-subzone is bounded at the north by a trough of conglomeratic sediments which parallels the Okcheon zone, and on the south by the contact between the batholithic rocks of the subzone and the sediments of C-subzone.

The subdivisions have a significance beyond a mere geographic grouping of the plutonic bodies. They reflect on the tectonic features of the orogenic development of the zones.

LITHOLOGY AND AGES OF THE SUBZONES

SE-subzone (Southeast schistose granite and migmatite zone)

The plutons in this subzone are mostly migmatites and schistose granites which are closely related to the Precambrian metamorphic rocks and their marginal facies often grade into porphyroblastic gneiss or biotite gneiss, and also occasionally to mylonite. All samples contain microcline and are mostly adamellitic to granodioritic except for some schistose pebbles in Mesozoic conglomerate which are quartz tonalite (modal plots shown in Fig. 3).

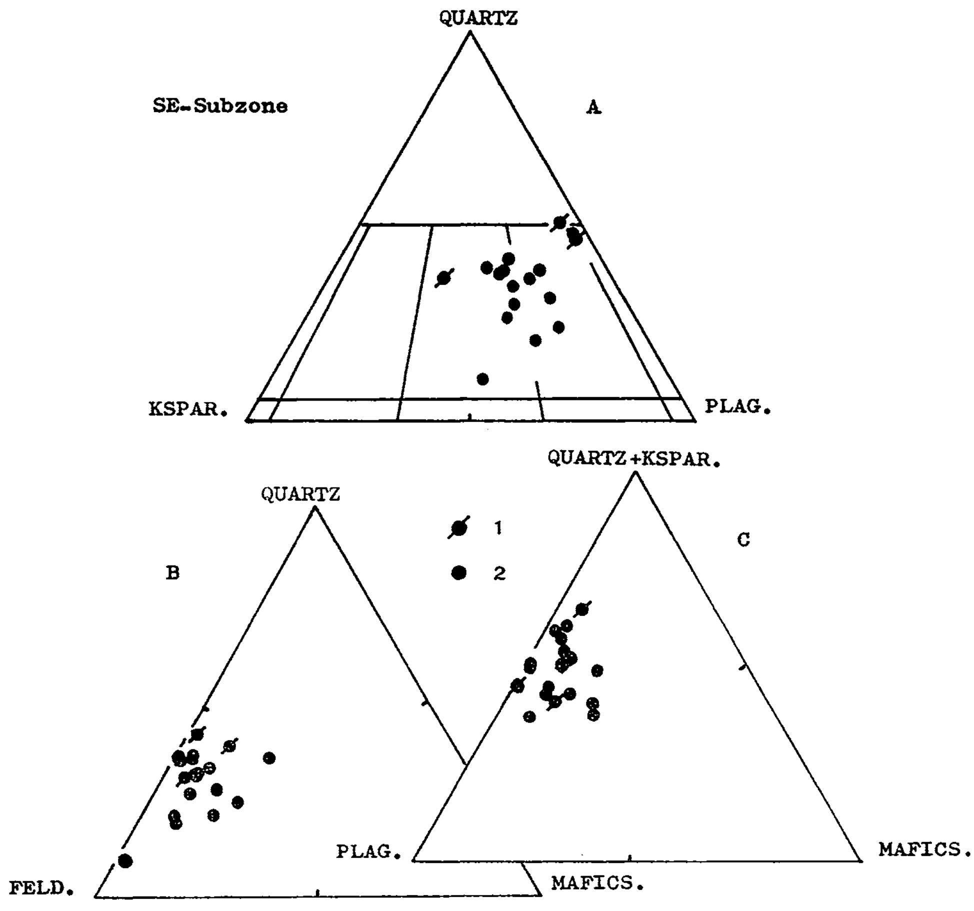

Fig. 3. Triangular diagrams of modal compositions, SE-subzone (1) schistose granite pebble in Mesozoic conglomerate. (2) schistose granite and migmatitic rock.

Major mineral components of the migmatite are plagioclase, microcline and quartz, with minor biotite, epidote and sometimes accessory sphene and tourmaline. Myrmekitic texture is fairly abundant between microcline and plagioclase, and also between other minerals. Figures 3A and 3B show that the data points, based on Table 1A, are scattered in a broad area.

Ten samples of granitic rocks from this subzone have been used for isotope age-dating (Table 2 and Fig. 4). They indicate that the age of migmatization or granitization ranges from 101 to 181 m.y.

NW-subzone (Northwest gabbro-tonalite-granodiorite complex zone)

This subzone is a complex of batholithic dimensions composed of rock types ranging from gabbro to tonalite and granodiorite to adamellite. Cross-cutting relationships indicate that the order mentioned is also an age sequence, which might be accounted for by magmatic differentiation. The complex is elongate and parallel with the general trend of the Okcheon Zone. It, however, partly cuts across the folded sediments of C-subzone. The masses of the complex are mostly massive except for the marginal parts associated with pre-existing rocks, which have been affected by relatively low-grade contact metamorphism. In the middle part of the zone the complex itself is intruded by a group of northerly trending porphyritic dikes. Brief petrographic descriptions are given below.

Gabbro: The gabbro forms a small stock intruding metasediments at the margin of the middle of this subzone. Major mineral constituents are cummingtonite and plagioclase accompanied by magnetite and apatite. Euhedral plagioclase crystals are often included in large euhedral to subhedral cummingtonite crystals.

Tonalite: The exposures of the tonalite masses are mostly along the southern margin of this subzone.

Essential mineral constituents of the rock are plagioclase, quartz, hornblende and biotite, accompanied by apatite, zircon, magnetite and interstitial calcite.

Granodiorite-adamellite complex: In spite of its huge mass, the complex is not particularly variable in rock type, the principal part of the mass is granodiorite to adamellite, whereas along the southeast margin it grades into muscovite granodiorite or two-mica granodiorite. All samples from this subzone contain microcline rather than orthoclase or perthite, and myrmekite is accessory. The mineral assemblage of this complex distinguishes it from the younger granites of the C-subzone which will be described in the following section. Some samples from the middle part of this subzone contain corroded garnet grains and others have remarkable amounts of sphene.

In Fig. 5B and 5C, the tri-component plots of modal analyses (Table 1B) of the granite rocks from this subzone show serial variations in mineral compositions. The ages of nine granitic samples from the subzone range from Middle Jurassic to Middle Cretaceous (Table 2 and Fig. 4).

C-subzone (Central granodiorite-adamellite zone)

The granitic stocks in this subzone vanishes toward the northeast where a thick Paleozoic limestone plateau occurs and toward the southwest which is an area of Cretaceous volcanic flows and sediments. The plutons in C-subzone can be classified into

TABLE 1

MAJOR MODAL COMPOSITION OF THE PLUTONS IN THE OKCHEON ZONE (FROM LEE, 1971)

A. SE-subzone

	SEj**					SEc		SEod								Peb		
Serial No.	9	10	12	13	14	16	17	18	19	20	21	22	23	24	25	27	28	29
Sample No.	K-23	48	40	45	63	42	41	43	50	52	44	51	66	65	46	47	49	67
Quartz	26.2	32.5	33.3	25.6	34.7	20.1	17.7	30.6	20.9	24.0	27.2	31.4	8.0	35.5	30.2	30.6	39.0	36.7
Orthoclase																		2.7
Microcline		17.1		22.3	24.1			12.7	23.6	13.0	17.2		33.9	14.1	19.1		2.3	
(Microcline + Microper.*)	13.7		22.8			16.0	21.4					1.9				32.1		
Microper.*															1.2			
Plagioclase	30.8	29.2	29.6	39.1	30.6	49.6	47.3	38.3	36.7	41.1	34.0	32.8	39.0	45.2	30.2	21.7	44.2	33.8
Myrmekite	5.2	3.2	8.5	2.8	3.2	0.8	X	2.7	2.0	1.6	13.1			1.2	4.6	2.0	0.1	

*: Microperthite, X: indicates trace amount
**: code of pluton mass, it is same as that in Fig. 7.

B. NW-subzone

	NWg	NWt				NWcx											
Serial No.	30l	31	32	33	34	35	36	37	38	39	40	41	42	43	44	46	47
Sample No.	55	33	30	26	35	K-12	K-25	38	37	34	35	32	31	29	28	27	22
Quartz	2.1	14.8	5.5	14.2	12.6	35.1	27.3	33.2	20.3	34.7	28.1	32.5	24.1	2.2	30.2	34.8	32.4
Orthoclase			1.1														
Microcline		1.6			1.4	19.4	14.9	12.7		27.8	33.3	25.8		15.5			
(Microcline + Microper.*)									16.1				24.8			27.0	24.3
Microper.*						1.8	1.6								24.6		
Plagioclase	27.8	59.2	50.2	44.7	38.1	36.4	42.4	42.2	48.0	28.2	31.7	31.5	40.9	38.8	35.6	29.4	36.7
Myrmekite		0.2			0.1	1.5	3.2	0.5	0.5	0.9	0.5	3.1	1.5	1.1	0.1	3.4	0.4

C. Older group, C-subzone

	Coy	Cog	Cok				Cob						Con	Cod
Serial No. Sample No.	48 K-57	49 39	50 24	51 64	52 23	Av. of 7 Cok*	53 20	54 19	55 18	56 21	Av. of 11 Cob**	Av. of 5 Cob's	57 B.N.	58 K-34
Quartz	26.4	24.6	32.9	31.6	28.9	26.8	21.0	23.5	31.4	25.8	27.7	29.1	14.7	22.3
Orthoclase								0.2		1.6				
Microcline					13.3	19.4	12.3	28.4		17.5	22.5	20.9	2.4	3.6
				19.5					18.8					
Microper.*	15.9	29.7	18.4		0.6		6.2	0.2					9.2	
Plagioclase	49.1	35.6	40.9	40.4	37.3	44.2	43.4	33.1	38.0	40.9	41.7	40.5	38.9	55.6
Myrmekite	X	0.7	0.9	1.4	X		1.1	4.7	2.0	0.3			0.5	

D. Younger group, C-subzone

	Cys						Cyw							Cym	Cyb		Cyd		Cydg	Cyh
Serial No.	60	61	62	63	64	65	66	67	68	69	70	71	Av. of 16 Cys*	73	75	76	77	78	79	17
Sample No.	1	2	3	4	7	16	15	Mu-1	K-36	Mu-2	Gr-68	11		13	5	6	9	10	8	80
Quartz	39.6	37.9	36.5	31.5	39.1	36.3	31.9	32.9	36.9	36.4	41.9	33.8	31.8	38.7	27.4	31.5	33.8	32.6	32.0	33.2
Orthoclase						0.4			1.4					5.4						
Microcline	0.1					3.1			8.2	23.6		5.1							0.5	
Microper.*	43.7	39.4	50.1	45.0	33.1	29.8	39.0	43.0	37.8	13.5	40.3	27.3	41.3	28.3	32.8	32.1	44.3	41.8	32.8	29.6
Plagioclase	15.8	20.0	11.8	20.4	25.4	26.1	25.0	20.1	13.4	21.4	15.9	29.9	24.7	25.4	28.9	27.9	18.6	23.7	25.7	33.0
Myrmekite					0.6	0.7	0.1							0.4		1.8			0.1	

TABLE 2

K-Ar AGES OF GRANITIC ROCKS IN OKCHEON ZONE

Subzone		Sample No.	Mineral used	K-Ar age (m.y.)	Range and age, Kulp (1961)
		31	Biotite	181	
		29	Biotite	178	
		33	Biotite	170	
		K-47	Biotite	167	101–181
		30	Biotite	166	Early Jurassic to
SE		26	Biotite	159	Middle-Cretaceous
		41	Biotite	155	
		42	Biotite	133	
		40	Biotite	107	
		54	Biotite	101	
		10	Biotite	163	
		K-48	Biotite	159	
		25	Biotite	158	
		44	Biotite	156	112–163
NW		12	Biotite	153	Middle Jurassic to
		9	Biotite	153	Middle Cretaceous
		45	Biotite	148	
		4	Biotite	121	
		38	K-feldspar	112	
		K-40	Muscovite	183	
		11	Biotite	166	
		34	Biotite	164	148–183
	older	8	Biotite	163	Late Triassic to
		K-69	Biotite	158	Upper Jurassic
		39	Biotite	148	
		24	Biotite	148	
		14	Biotite	109 }	
			K-feldspar	85 }	
		23	K-feldspar	106	
		R-1	Whole rock	92	
		15	Biotite	90 }	
C			K-feldspar	87 }	
		6	Biotite	89	63–106
		K-38	Biotite	88.6	Middle Cretaceous
		K-61	Biotite	88	to Early Tertiary
	younger	K-39 &			
		39	Biotite	87	
		1	Whole rock	87	
		K-37	Biotite	87	
		R-2	Whole rock	85	
		7	K-feldspar	84 }	
			Biotite	72 }	
		35	K-feldspar	83	
		Hp-19	Whole rock	67	
		Hp-20	Whole rock	63	

The sample numbers are the same as those in Fig. 4.

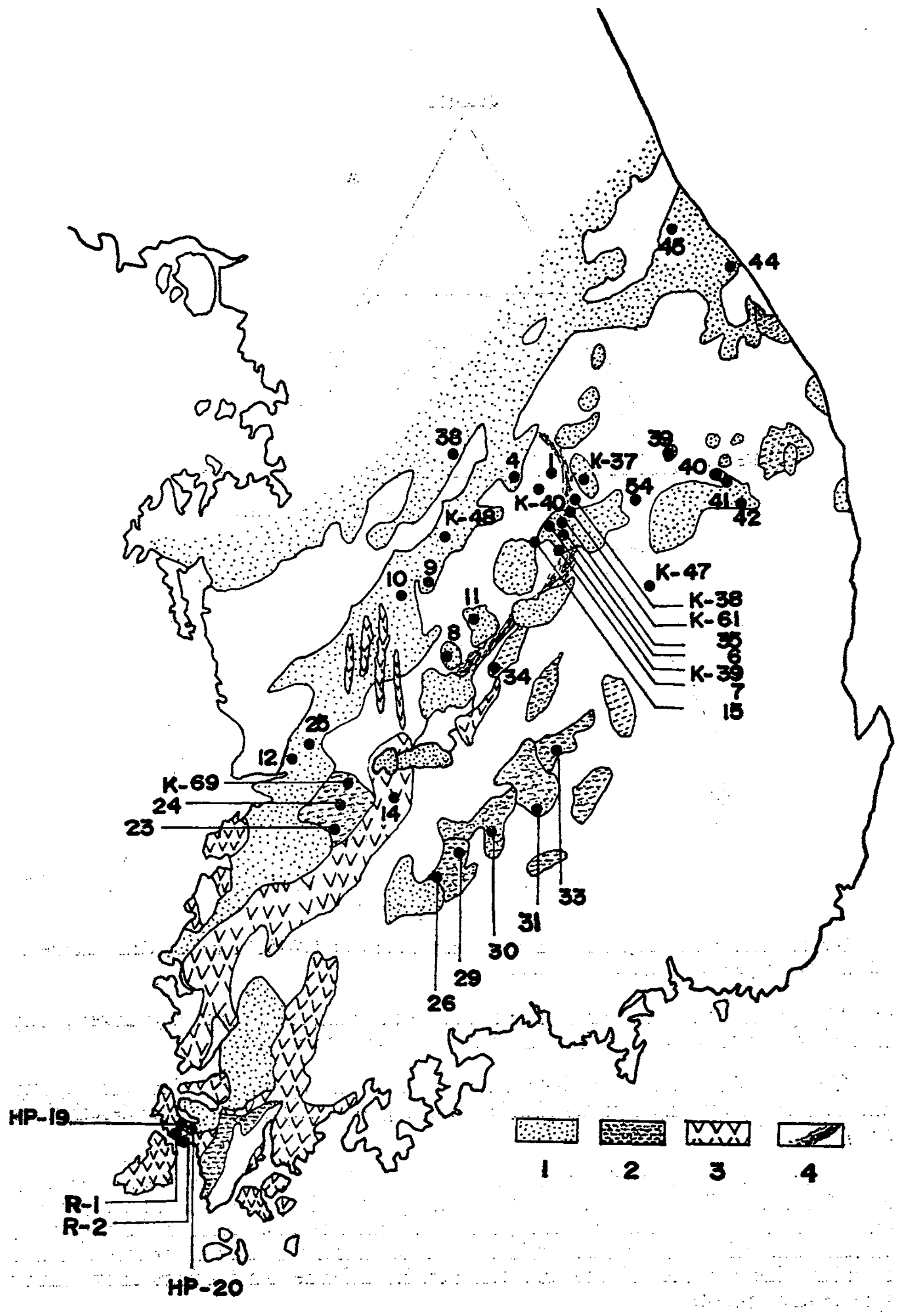

Fig. 4. Sample points for isotopic ages of plutons in Okcheon Zone listed in Table 2. (1): Massive granite, (2): schistose granite or migmatitic rock, (3): porphyries and volcanic rocks, (4): belt of ophiolitic rock.

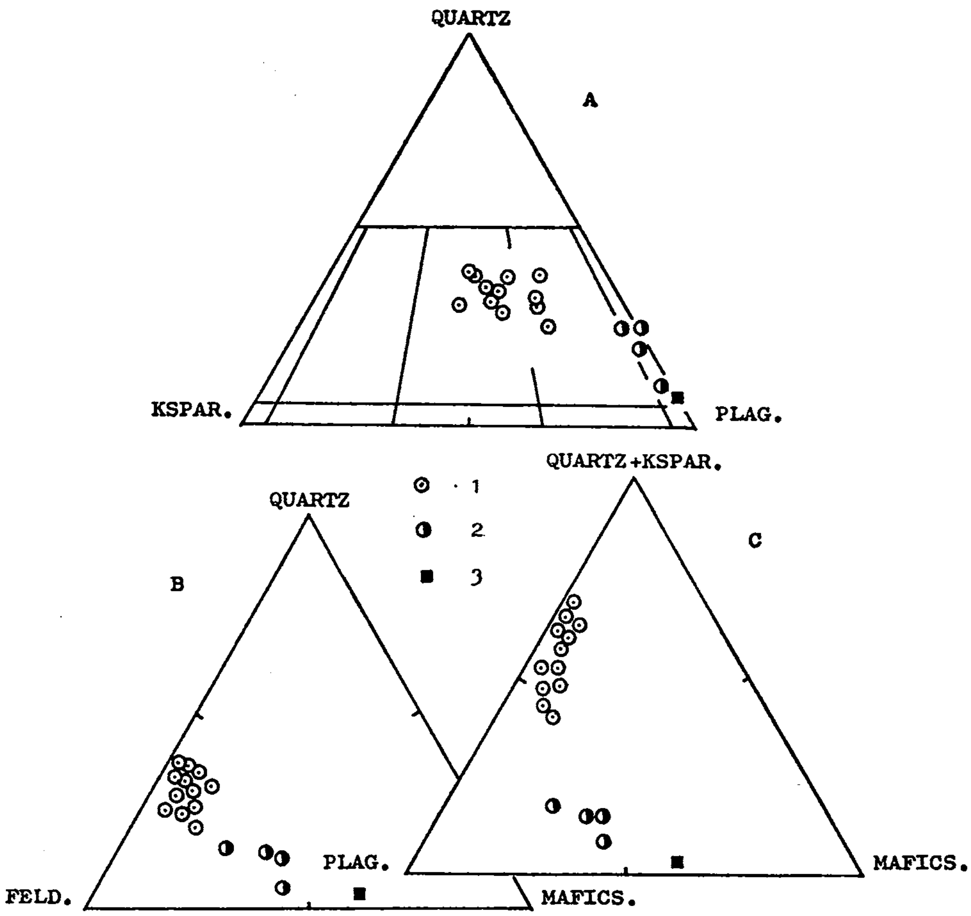

Fig. 5. Triangular diagrams of modal compositions of NW-Subzone. 1: Granodiorite & adamellite complex, 2: Tonalite, 3: Gabbro.

an older group of Jurassic granodiorite-adamellite masses and into a younger group of Cretaceous to very early Tertiary adamellite-granite masses.

The grouping is based on K-Ar determinations on 7 specimens of the older group and 15 from the younger group (Table 2 and Fig. 4). Brief petrographic descriptions are given below:

Older group: The rocks are dominantly granodiorites and some adamellites (Fig. 6 and Table 1C). Their mineral constituents are quartz, microcline and/or microperthite and plagioclase as essential minerals, biotite as characteristic accessory, and epidote, chlorite and sericite as secondary minerals. Some masses contain remarkable amounts of microcline perthite, biotite and common hornblende. And others show minor sphene and epidote.

Younger group: The rocks are generally massive, fine-to coarse-grained, pink to gray and miarolitic in places. Most are much more leucocratic than those in the

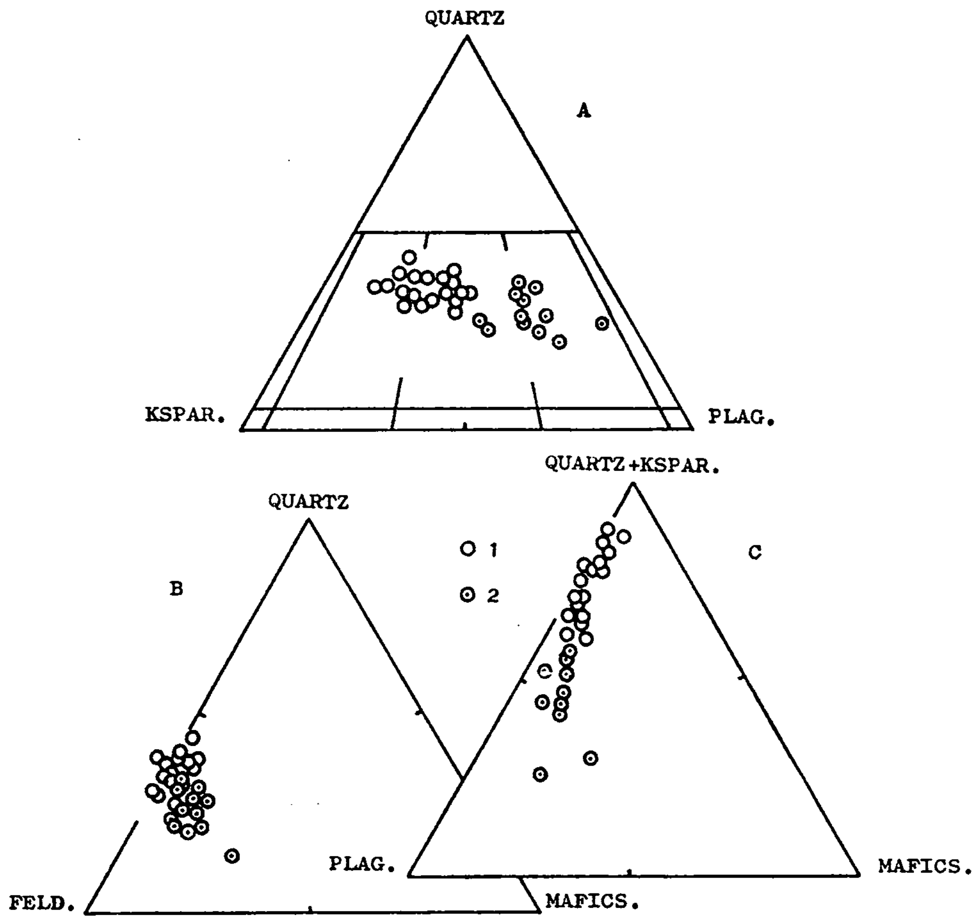

Fig. 6. Triangular diagrams of modal compositions of granitic rocks of C-subzone. 1: younger group. 2: older group.

other subzones. The potash feldspar is chiefly perthite (cryptoperthite or microperthite) and microcline is rare with few exceptions. Usually the amount of myrmekite present is less than in other rock types, and some masses contain rather abundant muscovite (Table 1D). Table 3 indicates some modal comparisons of the subzones of the middle part of the zone (Lee, 1971). In the middle part, orthoclase is scarce throughout and microcline and microperthite (or micro- and cryptoperthite) predominate. Except in the younger group of C-subzone where microcline perthite is dominant, potash-feldspar is represented by microcline (Table 3). The older group of C-subzone contains sphene and epidote as much as the SE- and NW-subzones do, while the younger group of C-subzone lacks these accessories.

In summary, the plutons in each subzone are characterized by their rock properties, tectonics and field evidence as follows. The plutons in the SE-subzone are strongly migmatitic in association with a geosynclinal basement of gneisses and schists.

TABLE 3

SOME MINERAL COMPARISON OF THE SUBZONES

Subzone	K-feldspar (major)	C.I.* range(%) (Ave.%)	Qtz+kf+pl range(%) (Ave.%)	Myrmekite (%)
SE	Microcline	0.7—22.8 (8.5)	68.6—97.4 (87.6)	0—13.1
NW	Microcline	2.0—36.7 (13.4)	59.3—94.8 (85.6)	0— 3.4
C older	Microcline and Microperthite	4.1—25.7 (11.2)	65.2—95.1 (87.7)	0— 4.7
C younger	Microperthite	0.8—5.5 (3.2)	95.1—99.2 (96.8)	0— 1.8

*colour index

The plutons in the NW-subzone seem to be magmatic because they have intruded into metasediments of the C-subzone with irregular contacts and resulted in the development of low grade contact metasomatic aureoles with andalusite-cordierite assemblage in argillaceous layers.

The plutons of older group in C-subzone have the two-fold characteristics of NW-subzone and younger group of C-subzone in terms of their ages, petrography and occurrences.

The plutons of the younger group in C-subzone are completely independent from others in their ages and lithology.

MAGMATIC EVOLUTION

The present study on the Okcheon Zone and adjacent areas reveals that at least twelve plutonic, mainly igneous, events have taken place. These events can be grouped into the following five stages in terms of magmatic evolution in the geosyncline.

(1) Pre-tectonic stage — volcanics in the early sediments (Precambrian ?), and amphibolite belt (Paleozoic ?) and some volcanic sediments in the very Early Jurassic formations.

(2) Syn-tectonic stage — mainly of plutons in the SE-subzone in the Early Jurassic.

(3) Late-tectonic stage — plutons in the NW-subzone and the C-subzone older group in the Late Jurassic.

(4) Post-tectonic stage — Several units of volcanics, C-subzone younger group and hypabyssal rocks in the Late Cretaceous.

(5) Tertiary volcanic stage — pitchstone dikes in the Tertiary (?).

The data suggest cyclical processes in the Okcheon Zone, beginning with orogenic movement called the Songlim Disturbance in the Late Triassic to Early Jurassic. The movement reached its peak in the Daebo Revolution (or Disturbance) in the late Jurassic with widespread effects in Eastern Asia and ceased in the Late Cretaceous.

Figure 7 shows the sequences of igneous activities and the relations of each pluton to corresponding crustal movements in the middle part of the zone. The magmatic activity in the zone is mostly acidic and each plutonic event was preceded by volcanic eruptions. Intermediate or basic igneous units are rare although very small amounts of basic to ultrabasic rocks are exposed in the forms of meta-andesitic flows, especially in the southwest, and a small gabbroic stock and amphibolite metamorphic belt in the middle of the zone.

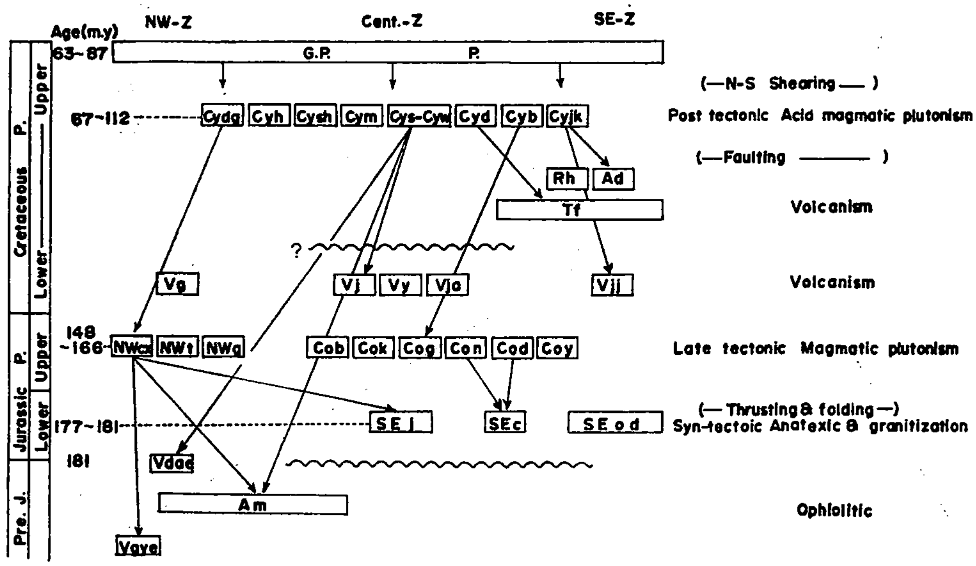

Fig. 7. Relationship between igneous events in the middle part of the Okcheon Zone. Arrows indicate the intruded older masses. The symbols in rectangles indicate specific masses, but in this text they are not named (Lee, 1971)

The amphibolite belt was studied by the author and others who concluded that it was derived from volcanic sediments, mainly meta-andesitic tuff and some basaltic flows and may have been a Pre-Jurassic ophiolitic zone. Recently the belt is being reviewed by others as marking a possible geosuture.

The variation diagrams of $Na_2O + K_2O$ and CaO based on the chemical analyses of 46 granitic samples from SE-, NW- and C-subzones indicate that they belong to the calcic rock series according to Peacock's criteria.

To explain higher content of Al_2O_3 in the chemical analyses of 61 samples from the Okcheon Zone the author used the AKF diagram which was applied in the consideration of the contamination trends of granite by Oba (1962). The diagram suggests the existence of two contamination trends of the plutons in the Okcheon Zone. One indicates an increase of the A-component and the other indicates a decrease of the F-component. These two trends make a dashed curve with an arrow in the diagram of Fig. 8. A line was drawn in the diagram representing the trend of tonalite-grano-

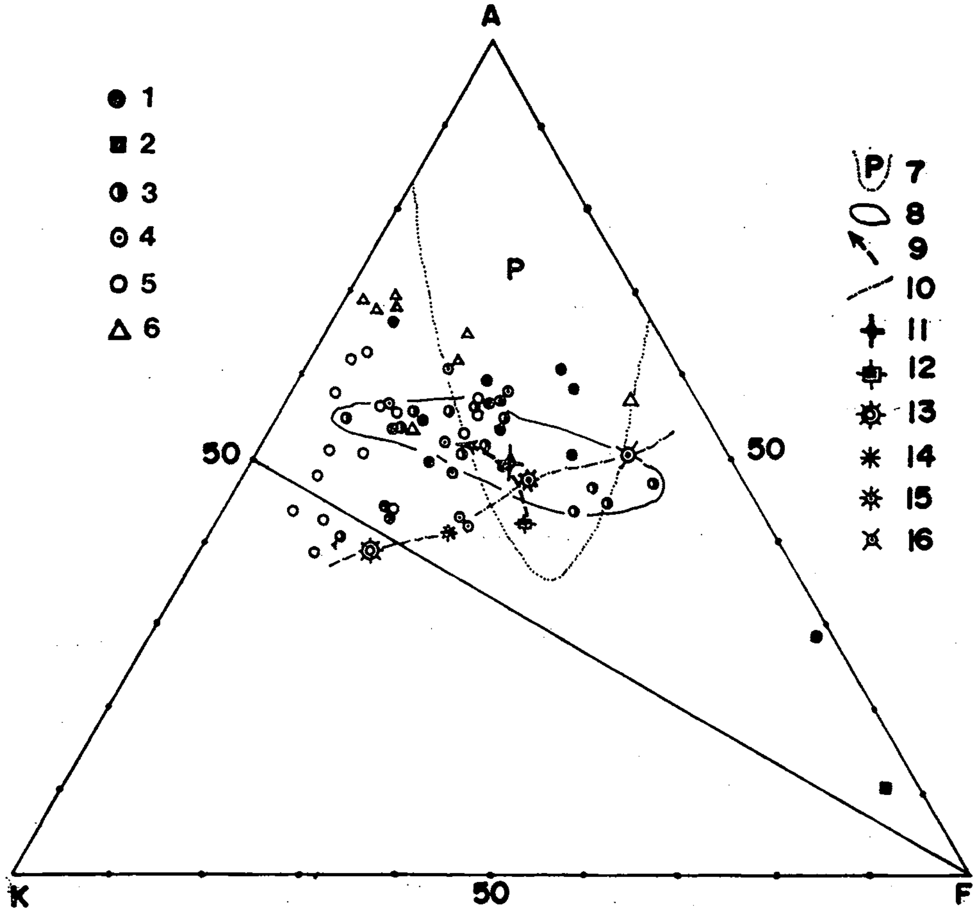

Fig. 8. Comparison granitic rocks in the middle part of Okcheon Zone with those of Japan and world averages. From Okcheon Zone, (1): schistose granite and migmatitic rocks of SE-subzone: (2): gabbro and (3): tonalite & granodiorite of NW-subzone, (4): granodiorite & adamellite of C-subzone older group, (5): adamellite & granite of C-subzone younger group and (6): acidic dikes. (7): Pelitic rock area, (8): Data point area of NW complex pluton, (9): Trend of SW Outer Zone granites in Japan — Hiroshima granites in Japan — Okcheon Zone granites in Korea, (10): Trend of tonalite-granodiorite-adamellite-calc alkali granite, (11): Av. of 21 Hiroshima granites (Yoshida, 1961), (12): Av. of 63 SW Outer Zone granites (Oba, 1961), (13): Av. of 72 calc alkali granite (Nockolds, 1964), (14): Av. of 121 adamellites (do), (15): Av. of 137 granodiorites (do.), (16): Av. of 58 tonalites (do.).

diorite-adamellite-alkali granite; "differentiation trend line" based on the data of Nockolds, (1964), Oba, (1961) and Yoshida, (1961). With regard to the A-component apex of the diagram the point of average of outer zone granites of Japan is ploted on the opposite side of the differentiation trend line. On the other hand, the point of average of Hiroshima granites is on the side of the A-component apex crossing the differentiation trend line. It means that the inner zone of Japan has a higher A-component. The average point of plutons of the Okcheon Zone goes further towards A-component and curves somewhat towards K side.

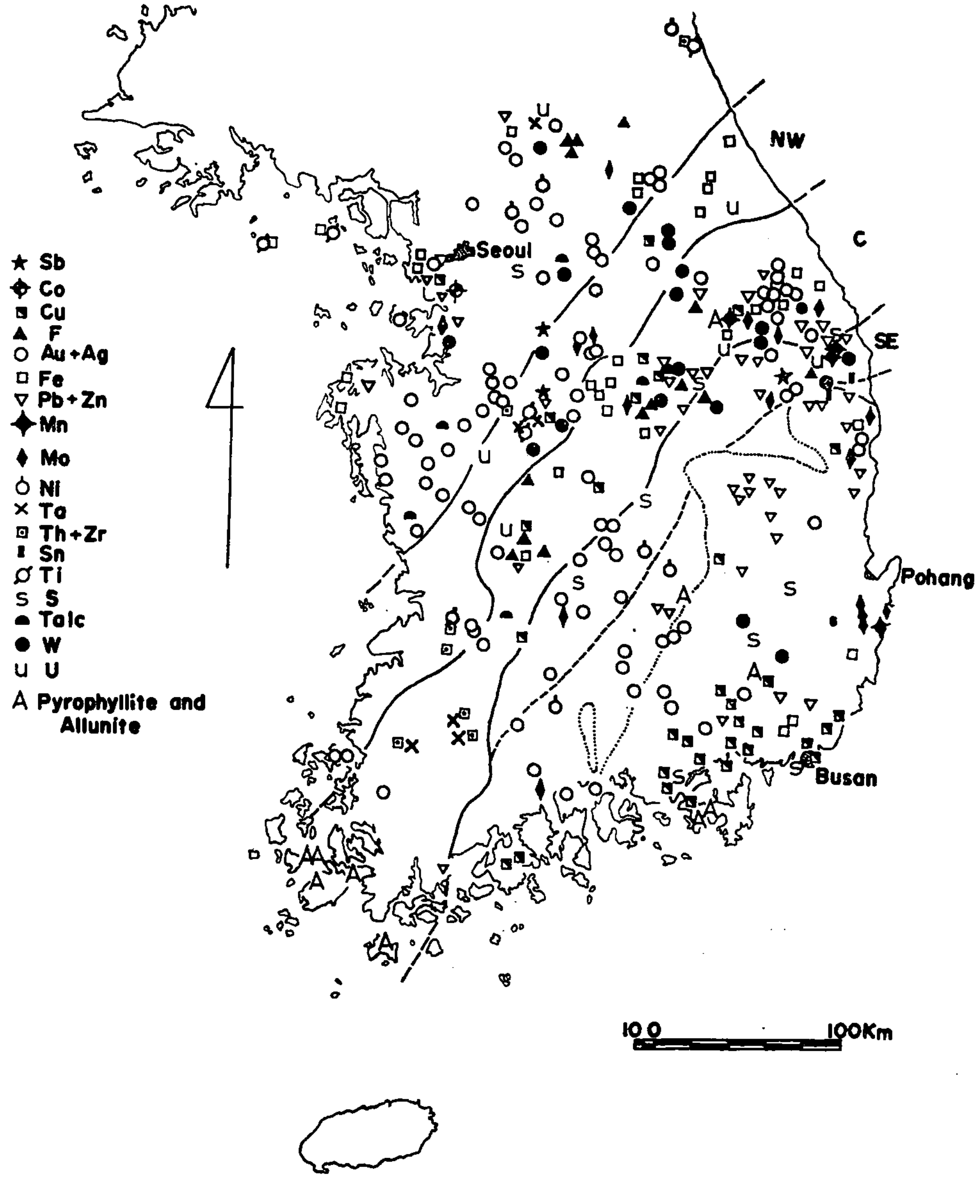

Fig. 9. Distribution of ore deposits in South Korea

The diagram suggests that the granitic plutons in Okcheon Zone were contaminated by argillaceous crust and also increased in K-content.

MINERALIZATION

The metallogenic map (Fig. 9), simplified from a more detailed original (GMIK, 1974), suggests that the Okcheon Zone contains a polymetallogenic province elongated

TABLE 4

SUBDIVISION OF MINERALIZATION* IN THE OKCHEON ZONE

Igneous subzone		NW	C		SE
Province and country rocks	type of ore deposit		older group	younger group	
NE province: Mainly limestones (Cambro-Ordovician); arenaceous and argillaceous sediments (Late Paleozoic and Jurassic). some Precambrian metasediments.	ortho.**				
	peg.	U		U	W
	pyro.	Fe,W	Pb+Zn,W	Pb,W,Fe	C,Mn
	hydro.	Au,W,Cu	Fe,Au,Pb+Zn,Talc	F,Pb+Zn,W,Mo	Au,Pb+Zn,W,Fe,Sb,F
Middle province: Mainly argillaceous, partly calcareous sediments (Precambrian to Early Paleozoic), associated with Cretaceous ruditic and argillaceous sediments	ortho.				Ni
	peg.				Feldspar
	pyro.		Fe		
	hydro.	Au+Ag,Mo	Cu,Au+Ag,Pb+Zn	F,Cu,Mo	Au,S(pyrite)
SW province: Mainly acidic to andesitic tuffs and flows, argillaceous sediments (Late Cretaceous) associated with migmatite and gneisses derived from Precambrian sediments.	ortho.				Ni
	peg.			Zr,Th,Ta, Mica	
	pyro.				
	hydro.	Au		Pyrophyllite Allunite	Au

* Excluded sedimentary and metamorphic ore deposits

** ortho; orthomagmatic deposit, peg; pegmatite and pneumatolytic deposit, pyro; pyrometasomatic deposit, hydro; hydrothermal deposit.

parallel with the zone and closely related to the migmatitic and plutonic subzones abovementioned. On the basis of local geology the province can be subdivided into: Northeast, Middle and Southwest provinces.

As seen in Table 4 and Fig. 9, the *Northeast province* consists dominantly of thick calcareous and argillaceous sediments of Cambro-Ordovician age, which contain the most productive and diverse ore deposits. The most productive lead-zinc, tungsten-molybdenum and fluorite deposits are related to the plutons of C-subzone. However, several productive large magnetite deposits occur in the NW-subzone, and a manganese and some lead-zinc ore deposits in the SE-subzone.

The country rock of *Middle province* is dominated by argillaceous, partly calcareous sediments which have undergone regional and contact metamorphism. The sequence of the sediments (called the Okcheon Group) has been the subject of intense controversy concerning its structure, stratigraphy and age. In this area mineralization is clearly selective; gold-silver and some molybdenum are related to the plutons of SE- and NW-subzones, whereas fluorite production is limited to the contact between calcareous strata and younger granite and granophyre of C-subzone and is not found along the contacts of plutons of the older group of the same subzone. Some copper deposits are distributed along the ophiolitic belt though they are not economic. In general mineralization in this province is less abundant than in the NE-province.

Southwest province comprises acidic to intermediate volcanic sediments and flows, and arenaceous and argillaceous terrestrial sediments. The province is practically barren in mineralization so far as is known except for pyrophyllite and allunite deposits formed by hydrothermal alteration of tuffaceous sediments near the young plutons of C-zone along the suothwest coast of the Korean peninsula, and some placer deposits of rare elements, such as tantalum, thorium, and zirconium.

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