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Geochemical Exploration Technics in the Pungchon Limestone Area

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ABSTRACT : Most of significant ore deposits in South Korea such as the Sangdong W-Mo, the Yeonhwa Pb-Zn and the Geodo Cu-Fe skarn ore deposits occur at the southern limb of the Hambaeg syncline in the Taebaeg Basin. The mineralization took place in the interbedded limestone of the Myobong Formation and the Pungchon limestone of the Great Limestone Group of the Cambrian age, generally striking E-W and dipping 25-30 degrees north. There are no outcrops of the skarn-type orebody at the northern limb of the syncline. In order to find a clue of a possible hidden orebody localized at the limestones in the northern limb, a lithogeochemical exploration by using carbon isotope and some elements such as Si, Ca, Fe and Al at the Sangdong Mine area has been attempted as for a modelling study. For this study, 45 samples from the Pungchon limestone which do not show any megascopic indication of mineralization have been taken in both the mineralized zone and the unmineralized zone at the Sangdong Mine area. Analytical data show that there are big differences in the contents of CaO and Al_2O_3 between the Pungchon limestone of the mineralized zone and that of the unmineralized zone. Carbon isotope data exhibit that $\delta^{13}C$ values of the Pungchon limestone in the mineralized zone are highter than those in the unmineralized zone. The difference in the analytical values of CaO, Al_2O_3 and the carbon isotope between the mineralized and the unmineralized zones is as follows ;

	Unmineralized zone	Mineralized zone
CaO	51.3%	43.5%
Al_2O_3	0.6%	2.4%
$\delta^{13}C$	- 0.39 permil	- 0.56 permil
Fe_2O_3	0.9%	1.4%
SiO_2	3.0%	2.4%

The decrease in the Si content of the Pungchon limestone in the mineralized zone is contrary to the result of the previous study (Moon, 1987). On the basis of identification of the increase in the Al content of the limestone in the mineralized zone, it could be deduced that the decrease in the Si content of the Pungchon limestone might be due to the result of increase in the alteration products mainly occurred along fracture-system such as joint cracks or minor faults and that the phenomena shown by the Si and Al content in the mineralized zone might be derived from the thermal effect of granite extended mineralizing activity to the overlied limestone on the surface. Higher mean values of Fe and Al as well as lower mean values of carbon content and the $\delta^{13}C$ than mean values of those in the Pungchon limestone at the northern limb of the Hambaeg Syncline may be applicable in exploration for blind orebodies.

INTRODUCTION

It is understood that skarn type ore deposit is one of the most promising base metal producers in South Korea. An earlier study of the genesis of the Sangdong W skarn ore deposit (Moon, 1983) contributed to discovery of a new skarn orebody as well as a granitoid source rock for the W mineralization at the Sangdong Mine. Review of skarn deposits occuring in the southern limb of the Hambaeg syncline in the Taebaeg Basin (Moon, 1989) leads to a conclusion that there is a greater emphasis placed on deep drilling in order to discover blind orebodies in the northern limb of the syncline in the basin. Recent deep drilling explorations conducted by Korea Mining Promotion Cooperation (KMPC) have proved again an earlier result of lithogeochemical approach to exploration in the same horizoned limestone layer as the Sangdong Main Orebody by exposing highly enirched W skarn ore. The location of the blind W skarn ore discovered by 1.3km deep drilling corresponds to the anomalous area detected by a previous study (Moon, 1987), which may be much

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deeper part of mineralization of the interbedded limestone in the Myobong Slate Formation.

The exploration result of KMPC has disclosed a precious information of mineralization in the interbedded limestone near the axis of the syncline in the southern limb. With confirmation of the anomalous zone at the southern limb, the author's desire and emphasis for exploration in the northern limb of the syncline are encouraged and extended to develop a new technique (methodology) of geochemical exploration.

Purpose of this study is to attract interest of personnels who are involved in a policy of mineral resources by presenting new data obtained from lithogeochemical approach or stable isotopic analysis of limestone.

It is convinced that the application of results of this study could contribute to find hidden skarn type orebodies in limestone areas such as in the Taebaeg Basin of South Korea.

GEOLOGICAL SETTING

The geology of the Taebaeg Basin is mainly composed of Cambro-Ordovician sediments and coal-bearing Carboniferous sediments. The former, which is significant as the host for mineralization, consists of Choseon Su-

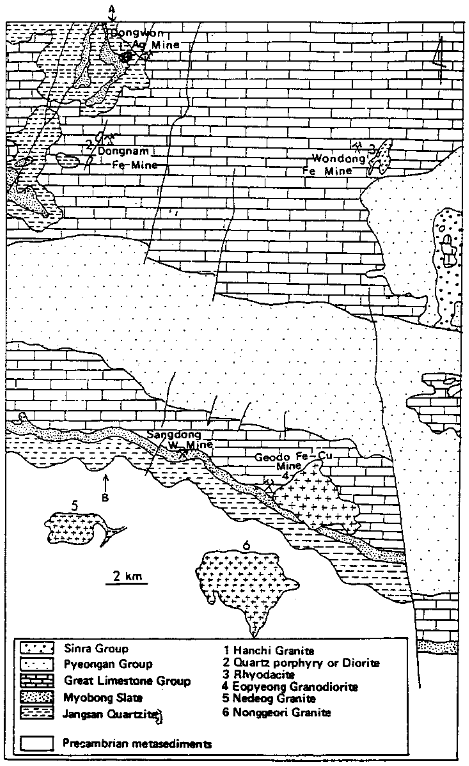


Fig. 1. Geological map of the Taebaeg Basin near the Sangdong Mine area.

Triassic Carboniferous		Pyeongan Group.	Hongjeom, Sadong, Gobang and Nogam Formations Sandstone, shale, limestone, conglomerate & coal bed:
******************** Unconformity ********************			
Ordovician			Maggol Limestone (250-300m thick) Grey and dark grey limestone and dolomitic limestone
			Dumugol Formation (200-300m thick) Vermicular limestone and greenish grey sandy shale and marl.
	Joseon Supergroup	Great Limestone Group	Dongjeom Quartzite (20-30m thick) Dark grey and pale brown quartzite.
Cambrian			Hwajeol Formation (100-150m thick) Vermicular limestone, sandy shale and slate.
			Daegi Formation (Pungchon Limestone, 350-400m thick) Milky white limestone.
		Yangdeeog Group	Myobong Slate (80-150m thick) Shale, phyllite, slate and several interbedded limestones.
			Jangsan Quartzite (150-200m thick) White to dark grey quartzite.
******************** Unconformity ********************			
Precambrian		Yulri Group	Meta-sediments Spotted mica schist, Argillaceous slate or phyllite.

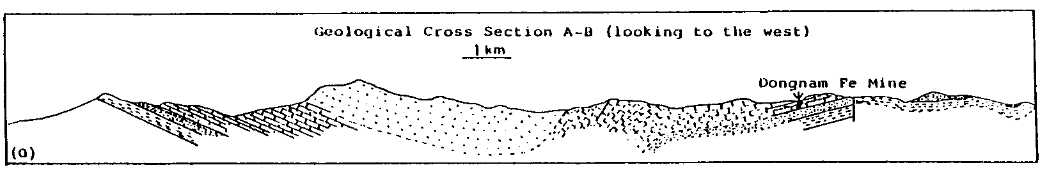
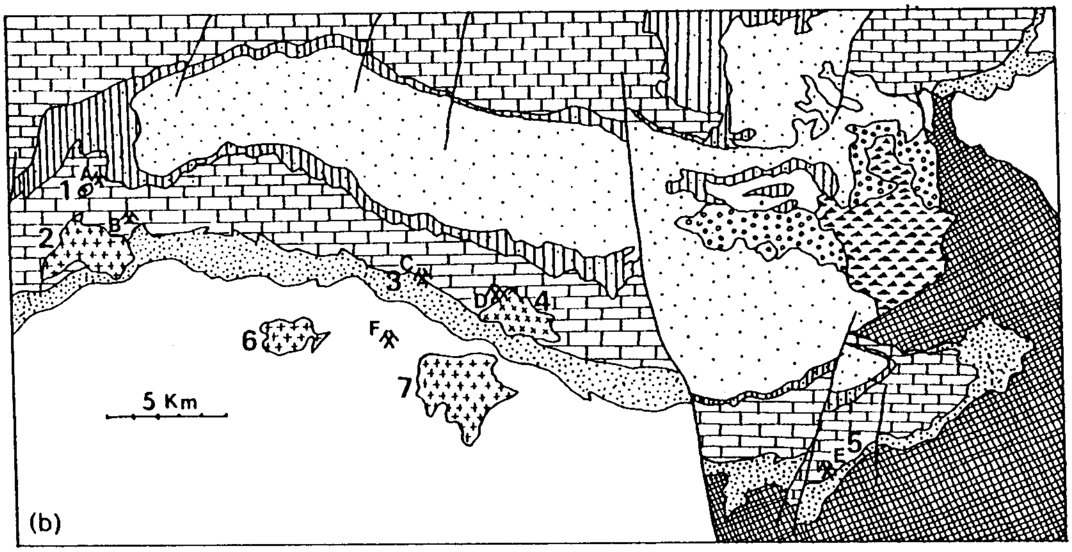


Fig. 2a. Geological Column and Section of the Taebaeg Basin.

pergroup including the Jangsan Quartzite, Myobong Slate and the Great Limestone Group in order from the bottom of the basin overlying Precambrian metasediments or plutons (Fig. 1).

The stratigraphy of the Hambaeg basin is summarized in Fig. 2a and 2b. The Choseon Supergroup strikes generally N70° to 80°E parallel to the axis of the Hambaeg syncline and dips



INDEX: Shinra Group. Pyeongan Group. Hongjeom Formation. Great Limestone Group. Yangdeog Group. Precambrian metasediments. Cretaceous basic plutons. Precambrian granite-gneiss.
1.Shinyemi stock. 2.Imog Granite. 3.Sangdong Granite(drilling core). 4.Eopyeong Granodiorite. 5.Quartz-porphyries(rarely exposed). 6.Nedeog Granite. 7.Nonggeori Granite. A-Shinyemi(Pb,Zn)deposit. B-Imog(Pb,Zn) deposit. C-Sangdong(W,Mo)deposit. D-Geodo(Cu,Fe)deposit. E-Yeonhwa (Pb,Zn)deposit. F-Sunkyeong(Sn)deposit.

Fig. 2b. Location of plutons and ore deposits in the southern limb area of the Hambaeg syncline.

Table 1. Geochronology of plutons related with mineralization in the southern limb area of the Hambaeg syncline.

Name of Plutons	Age(MA)	Name of Deposits	Age(MA)	Reference
1 Shinyemi Stock	60	Shinyemi Mine (Pb-Zn skarn)	75	Kim and Kim(1978)
2 Imog Granite	93	Imog Mine (Pb-Zn skarn)		Yun(1985)
3 Sangdong Granite (unexposed)	85	Sangdong Mine		Ferrar et al. (1978)
4 Eopyeong Granodiorite	107	Geodo Mine (Cu-Fe skarn)		Ferrar et al. (1978)
5 Quartz Porphyries (rarely exposed)		Yeonhwa Mine	73	Sato et al. (1981)
6 Nedeog Granite	1720	Sunkyeong Mine (Sn pegmatite)	1790	Yun (1985)
7 Nonggeori Granite	1762			

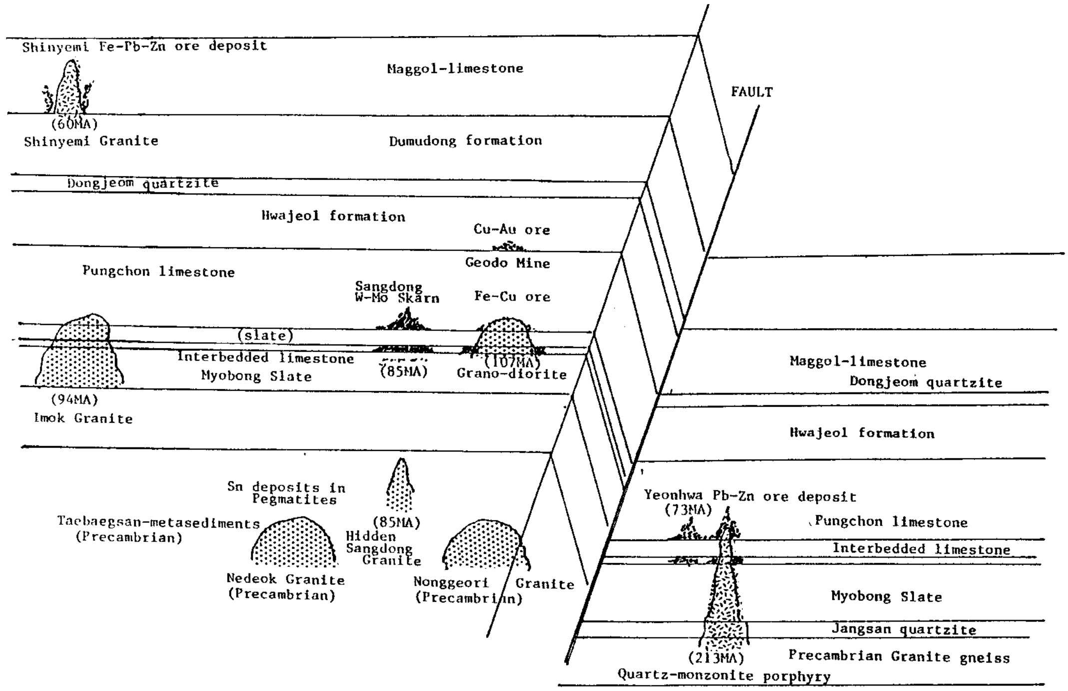


Fig. 3. Diagrammatic projected vertical section of localized ore deposits related with plutons in the interbedded limestone of the Myobong Slate and in the Great Limestone Group.

25° to 35°NE at the southern limb and 10° to 15°SW at the northern limb of the syncline.

All the skarn ore deposits in the Taebaeg Basin are localized in the interbedded limestone layers of the Myobong Slate and in the lower parts of the Great Limestone Group. The ore deposits of the southern limb tend to show the classic metallogenic zonation around a common source. From the Sangdong to the Yeonhwa Mine, significant ore elements forming ore bodies are W-Mo, Fe-Cu, and Pb-Zn from the west to the east along the limestone horizon. On the western side of the basin, a Pb-Zn deposit occurs in a higher horizon corresponding to the upper layer of the Great Limestone Group. Outcrops in the northern limb area are mainly composed of upper layers of the Great Limestone Group. Two Fe deposits associated with W mineralization occur in the upper layers of the Great Limestone Group. They have not been fully explored, and further development has ceased because present metal prices are very low. Several plutons crop out in the southern limb area. They have all been age dated and a genetic relationship with ore deposits has been found, as presented in Table 1 and Fig. 3.

A hidden source rock responsible for the Sangdong tungsten deposit has been inferred by fluid inclusion studies (Moon, 1983). Discovery of this hidden granite related to W mineralization suggests that emplacement of granite may be important in the formation of blind orebodies in the northern limb area.

Modelling Site for Geochemical Exploration in Limestone Area.

Recent deep drillings by KMPC have disclosed a remarkable tungsten skarn orebody at about 1km depth from the surface. It is very interesting that the drilling site is on a line crossing the Great Limestone Group, which corresponds to the anomalous site detected by Si, Fe and Ca lithogeochemistry of the interbedded limestone (Fig. 4).

The previous study of host-rock lithogeochemistry applicable to exploration in the Hambaeg syncline (Moon, 1987) dealt with lithogeochemistry of the interbedded limestone which corresponds to the skarn orebodies of the Sangdong W and the Yeonhwa Pb-Zn ore deposits. This study deals with mainly the Pungchon limestone which contains orebodies at bottom of the layer in the Sangdong and the Yeonhwa Mines. It is found that there are difficulties to

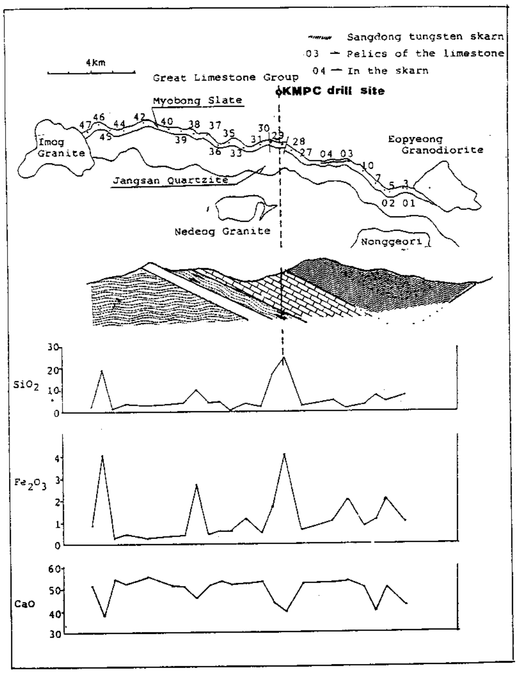


Fig. 4. Location of sampling from the interbedded limestone in the Myobong Slate and its lithochemical anomalies(Si, Fe, Ca oxides).

take samples from the interbedded limestone in the northern limb of the syncline, that is a target area for geochemical exploration, because of poor our crops. Therefore, the Pungchon limestone was chosen as a modelling site for geochemical exploration in limestone areas.

Several lines crossing the Pungchon limestone bed are selected in the mineralized zone and in the unmineralized zone (Fig. 5). The mineralized zone refers to outcrops of the Pungchon limestone above the Sangdong tungsten skarn with lateral extension of 1.5km, while the unmineralized zone refers to the Pungchon limestone in which no mineralization is confirmed near the mine.

LITHOGEOCHEMICAL APPROACH

Several samples have been taken on each of eight lines crossing the Pungchon limestone in the mineralized and unmineralized zones (Fig. 5).

Based on the previous result (Moon, 1987), Si, Fe and Ca were chosen as major element-path finder. Since it is noticed that high content of Mg in limestones results in decrease of Ca content, Mg was included to analyses. Even in the previous study, Al was not considered as an indicating element. However, it is found that

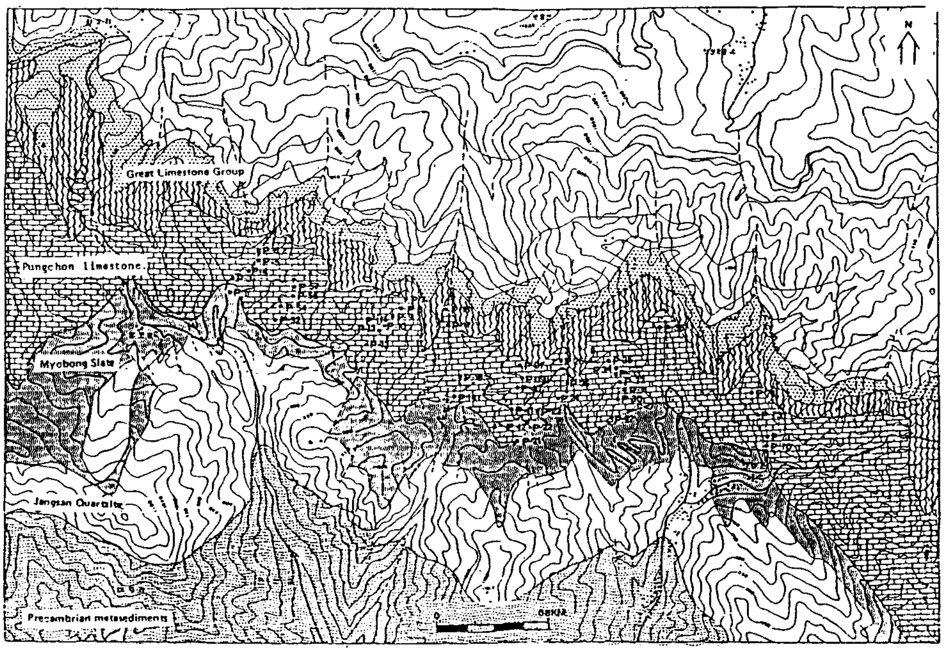


Fig. 5. Map of sampling location at the Sangdong Mine area.

Table 2. Chemical compositions of the interbedded limestone in the Myobong Formation.

Oxides(wt.%).

Sample	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	K_2O	Na_2O	P_2O_5	LOI	Total
1s-3	5.71	0.06	1.49	0.98	0.17	11.50	41.59	0.00	n.d	n.d	37.32	98.82
1s-5	3.90	0.03	0.62	2.04	0.14	1.98	49.79	0.24	n.d	0.06	40.83	99.65
1s-7	6.70	0.06	1.60	1.09	0.09	0.84	39.49	0.68	n.d	0.03	39.49	99.33
1s-10	2.45	0.02	0.54	0.76	0.06	3.24	49.73	0.22	n.d	0.03	42.56	99.59
xf-01	2.67	n.d	0.89	0.83	0.20	17.36	32.81	0.03	n.d	n.d	43.55	98.34
xf-02	3.81	n.d	2.60	0.71	0.34	0.84	49.34	0.25	n.d	0.06	40.96	98.94
xf-03	1.43	n.d	1.85	0.38	0.20	0.09	52.58	0.10	n.d	0.05	42.43	99.72
xf-04	4.38	n.d	1.14	1.01	0.28	0.96	52.25	0.05	n.d	0.06	39.45	99.59
1s-27	1.78	n.d	0.26	0.60	0.22	2.09	52.03	0.04	n.d	0.07	41.92	99.01
1s-29	24.35	0.30	4.71	4.55	1.03	1.39	39.59	0.11	n.d	0.49	23.84	100.38
1s-30	15.94	0.17	1.35	1.71	0.68	1.04	43.15	0.58	n.d	0.07	33.99	98.08
1s-31	1.71	n.d	0.43	0.49	0.26	0.85	52.98	0.09	0.01	0.03	42.19	99.05
1s-33	3.67	0.04	0.73	1.15	0.35	0.96	52.77	0.25	n.d	0.03	41.14	101.08
1s-35	0.92	0.02	0.61	0.59	0.07	1.12	52.14	0.19	n.d	0.01	42.86	98.53
1s-36	4.35	0.05	1.27	0.60	0.05	1.05	53.51	0.51	n.d	0.02	40.42	101.82
1s-37	3.98	0.04	1.00	0.43	0.15	1.35	50.47	0.38	n.d	0.12	40.69	98.60
1s-38	10.27	0.35	1.78	2.68	0.69	1.77	45.26	0.19	n.d	0.13	35.85	98.98
1s-39	4.02	0.04	0.96	0.37	0.10	1.92	50.58	0.37	n.d	0.02	41.01	99.41
1s-40	3.61	0.04	0.88	0.33	0.11	2.11	50.94	0.38	n.d	0.02	41.18	99.59
1s-42	2.44	0.03	0.95	0.29	0.09	0.93	55.04	0.48	n.d	0.03	41.39	101.68
1s-44	3.16	0.02	0.86	0.93	0.20	0.57	51.93	0.34	n.d	0.14	40.70	98.85
1s-45	1.45	0.02	0.47	0.26	0.11	0.89	54.37	0.30	n.d	0.07	42.00	99.93
1s-46	18.92	0.22	2.91	4.02	1.48	1.56	37.95	0.64	1.07	0.18	30.24	99.20
1s-47	2.06	0.02	0.44	0.83	0.08	4.66	51.19	0.07	n.d	0.03	41.17	100.54

aluminium content showed an unusal high value at the same location as Fe and Si showed anomalous values (Table 2), therefore, Al was added to analysing elements.

Difference in Mean Contents of CaO, Fe_2O_3, SiO_2 and Al_2O_3 and Interpretation.

Anomalous results of selected major elements such as Ca, Fe and Si were defined as leakage anomaly in the interbedded limestone in the earlier study(Moon, 1987). These elements seem to show anomalous values from the Pungchon limestone in the mineralized zone. Contents of Mg show that dolomitic limestone layers are intercalated in pure limestones in the Pungchon limestone. In dolomitic composition, Ca content is in inverse proportion to Mg content, therefore, variation of Ca content in the dolomitic limestone should be disregarded to evaluate average content of Ca in the Pungchon limestone for the purpose of application in geochemical exploration.

Results of geochemical analyses for the Pungchon limestone are given in Table 3.

It is obvious that Ca content in the limestone is substantially decreased in the mineralized zone. Average content of CaO in the Pungchone limestone in the unmineralized zone is 51.3%, while 43.5% in the mineralized zone.

Fe content seems to increase in the mineralized zone, it seems to be insignificant, because it varies from 0.9 to 1.4% Fe_2O_3. Contrary to the result of the earlier study (Moon, 1987) in which the anomalous value of SiO_2 was very high, Si content does not show a big difference between the mineralized and the unmineralized zones. Average value of SiO_2 in the unmineralized zone is 3.0%, while 2.4% in the mineralized zone.

In the previous study, it is found that variation of Al content in the interbedded limestone is more or less the same as Fe content (Table 2). As same as expected, the Pungchon limestone exhibits a significant difference in mean value of Al_2O_3 in between mineralized and unmineralized zones. Whereas the average value of Al_2O_3 in the unmineralized zone is 0.6%, the mineralized zone has 2.4% Al_2O_3.

The lithogeochemical changes of the Punchon limestone seem to be little different in the variation of the indicating elements from those of the interbedded limestone as shown in the earlier

Table 3. Contents of CaO, Fe_2O_3, SiO_2, and Al_2O_3 in the Pungchon limestone at the Sangdong Mine area.

Sample No.	CaO(%)	MgO(%)	Fe_2O_3(%)	SiO_2(%)	Al_2O_3(%)	Reference
P-1	52.0	1.56	1.24	3.24	0.47	
P-3	52.4	1.31	1.12	2.67	0.63	Cross Line 1
P-4	33.0	15.37	0.75	1.17	0.63	Unmineralized Zone
P-5	35.6	12.36	0.97	0.82	0.14	
P-6	54.2	1.31	0.30	0.55	0.24	
P-52	49.9	2.21	1.52	3.95	0.83	
P-54	50.6	2.31	1.43	4.64	0.53	Cross Line 2
P-56	53.0	1.41	0.66	3.07	0.11	Unmineralized Zone
P-57	42.9	2.01	1.46	8.13	1.70	
P-13	44.9	2.87	1.38	5.40	1.21	
P-12	48.5	1.86	1.21	6.03	1.31	
P-11	51.6	1.56	0.55	3.13	0.87	Cross Line 3
P-10	52.6	1.91	0.47	3.19	0.39	Unmineralized Zone
P-9	52.7	2.32	0.51	2.28	0.48	
P-8	31.2	18.69	0.68	0.63	0.25	
P-7	52.6	1.57	0.61	1.42	0.49	
P-14	52.8	1.98	0.87	2.35	0.55	
P-15	44.6	3.62	1.26	3.92	0.88	Cross Line 4
P-17	35.8	14.61	0.94	5.07	0.16	Marginal Zone
P-18	53.3	2.06	0.39	0.37	0.22	of the Sangdong
P-51	51.3	1.61	0.06	0.90	0.45	orebody
P-50	30.3	1.81	0.31	1.13	0.60	
P-42	48.1	1.91	0.69	4.08	2.15	
P-41	32.2	15.92	2.69	0.43	1.06	Cross Line 5
P-40	21.9	6.65	1.58	0.08	3.36	Mineralized Zone
P-39	27.8	7.86	2.89	0.22	3.44	
P-37	41.8	1.01	1.17	0.22	3.02	
P-21	47.1	3.65	1.15	8.59	0.78	
P-22	52.4	1.56	0.43	3.89	0.35	Cross Line 6
P-23	50.7	3.08	0.87	2.78	0.32	Mineralized Zone
P-24	33.9	16.09	1.48	3.77	0.73	
P-25	48.1	4.22	1.28	2.84	0.13	
P-26	51.4	1.56	6.41	3.73	0.76	
P-27	49.4	0.71	1.52	8.79	1.85	
P-30	49.1	0.40	0.86	4.52	1.10	Cross Line 7
P-31	28.9	1.61	1.26	1.31	3.89	Mineralized Zone
P-32	39.3	0.81	0.89	0.47	6.08	
P-33	31.4	3.63	1.89	0.39	5.44	
P-34	24.4	10.08	1.49	0.38	4.04	
P-35	50.2	1.81	1.00	0.07	2.76	
P-36	42.6	1.01	0.63	0.05	3.51	
P-70	52.3	1.67	1.95	3.26	0.35	
P-71	54.3	1.15	0.60	2.37	0.33	Cross Line 8
P-73	53.1	2.06	0.39	2.07	0.22	Unmineralized Zone
P-74	53.7	0.91	0.63	2.78	0.11	

study (Moon, 1987). It was interpreted that the anomalously high value in the interbedded limestone with thickness of 6 to 7 meters might be due to leakage of silicate fluid from mineralizing feeder structures. Contrary to expectation according to the result of the previous study, Si content appears to be lower in the mineralized zone than the unmineralized zone.

The Pungchon limestone overlied over the Sangdong W skarn orebody is relatively too thick comparing to the interbedded limestone for ascending silica fluid to pass through the whole layer with thickness of 350-400 meters.

Whereas the silicate fluid reacts easily with limestones in fractured system, which is represented by silicification or cherty rock in the mine, some acidic solution derived from or related with mineralization could pass through fine fractures of the limestone. Due to this assumption as mentioned above, the decreased Ca content in the mineralized zone is reasonably explained by removal of Ca^{2+} from the limestone in progress of alteration.

It is remarkable that Al_2O_3 exhibits much higher values in the mineralized zone than the unmineralized zone. It can be interpreted in two ways ; as Al is understood as a immobile elements, the decrease of Ca content in the mineralized zone due to the alteration results in enrichment of Al_2O_3 in the outcrop of the limestones. It might be assumed that some amount of Al could infiltrate through fracture systems in the limestones during the process of strong mineralization. However, the former assumption is more preferable, since it could be deduced that the decrease in the Si content of the Pungchon limestone in the mineralized zone might be due to the result of increase in the alteration products mainly occurred along fracture systems such as joint cracks or minor faults. This phenomena shown by the Si and Al contents in the mineralized zone might be derived from the thermal effect of a granitoid extended mineralizing activity to the overlied limestone on the surface.

With standard mean values of CaO and Al_2O_3, it is concluded that CaO and Al_2O_3 are the most effective indicating elements for exploration in limestone areas such as the Taebaeg Basin in South Korea.

ISOTOPIC APPROACH

Isotopic Composition of the Pungchon Limestone

Oxygen and carbon isotopic compositions of the Pungchon limestone have been reported by Kim (1980), Moon (1983) and Park and Woo (1986). Particulary, Park and Woo (1986) have studied on the isotopic compositions of the Pungchon limestone to understand the origin of sedimentation, while Moon(1983) dealt with variation of the isotopic composition of limestones or hydrothermal calcite, related with mineralization.

Park and Woo (1986) assumed that the Pungchon limestone formed under the temperature of 42.8℃ to 67.4℃, at 1.4 to 2.2km deep from the sea level and the geothermal effect during a burial diagenesis.

It is understood that carbon isotopic composition of limestones could be changed by recrystallization relating to mineralization after diagenetic formation. Fractionation of the isotope of an element can occur in nature as a result of chemical, physical or biological processes(Rao, 1989).

$\delta^{18}O$ values of the Pungchon limestone show relatively a wide range from −9.3 to −18.2 permils while $\delta^{13}C$ values were ranged from −2.5 to +1.6 permils as shown in Fig. 6 (Park and Woo, 1987). The latter shows narrow range as shown in worldwide limestone. For convenience, variation of $\delta^{18}O$ values seems to be difficult for using data as indicators in geochemical exploration, because of too wide and various range, therefore, only variation of carbon isotopic composition is dealt in this study.

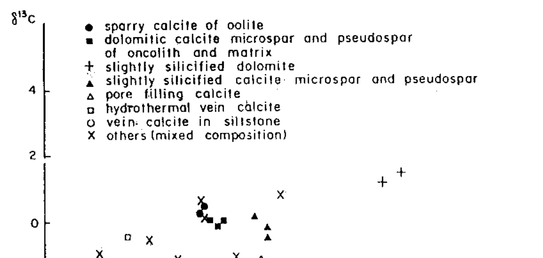


Fig. 6. Carbon and oxygen istope composition of the Pungchon limestone (Park and Woo, 1986).

Application of Carbon Isotope in Exploration

According to fluid inclusion study (Moon, 1983), it is confirmed that CO_2 gas derived from or related with mineralizing fluid would be often involved in mineralization. The ratio of $^{13}C/^{12}C$

in the limestone may be possibly changed by introduction of ^{12}C into a calcite. An earlier study demonstrates that calcites formed during hydrothermal mineralization show much lower values than the Pungchon limestone, ranging from -4 to -9 permils in $\delta^{13}C$.

Even in the interbedded limestone of the Myobong Slate, $\delta^{13}C$ values gradually change such as −1.89 permil at near the skarn orebody, −1.87, −1.90, −1.41, −1.09, −1.36, −1.03, −0.75, +1.25 and +0.86 permils at far distance from the skarn orebody as shown in Fig. 7.

A trend of changing values of carbon isotope in the limestone is effected by distance from the skarn orebody, due to increase of ^{12}C by hydrothermal activity in the limestone. It may be also due to increase of ^{12}C in the meltwater (Rao, 1988) during recrystallization under assumption of strong minearlization depending upon the distance from the heat source.

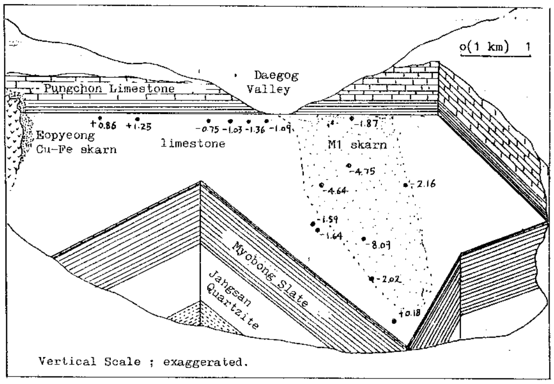
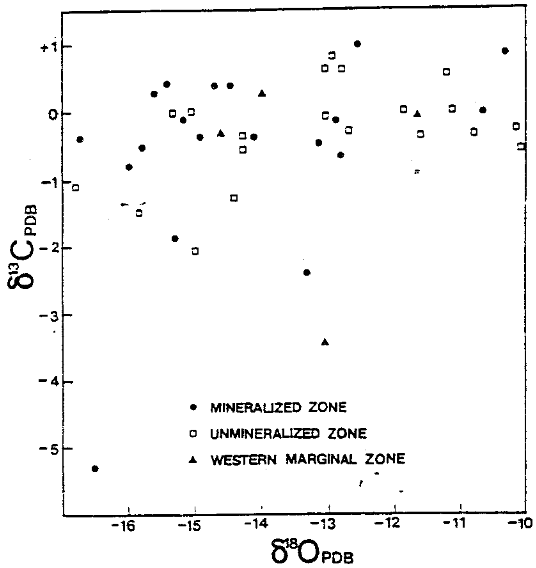


Fig. 7. A schematic diagram showing variation of $\delta^{13}C$ values for non-mineralized limestone and mineralized zone at the Sangdong Area (Moon. 1983).

Difference In Carbon Isotope Values In The Mineralized And Unmineralized Zone

All the samples analysed for CaO, SiO_2, Fe_2O_3 and Al_2O_3 were analysed for carbon and oxygen isotopes. Results of the isotopic analyses are given in Table 4. As mentioned before, for convenience, only carbon isotopic compostition is considered for application in this study. It is clearly noticed that $\delta^{13}C$ values of calcite or limestone tend to decrease the arithmetic value or increase the absolute number with negative sign depending upon hydrothermal activity.

Comparative results of mean values of $\delta^{13}C$ in between the mineralized and the unmineralized zones may suggest that the result could be



g. 8. $\delta^{13}C$ and $\delta^{18}O$ variation in the Pungchon nestone.

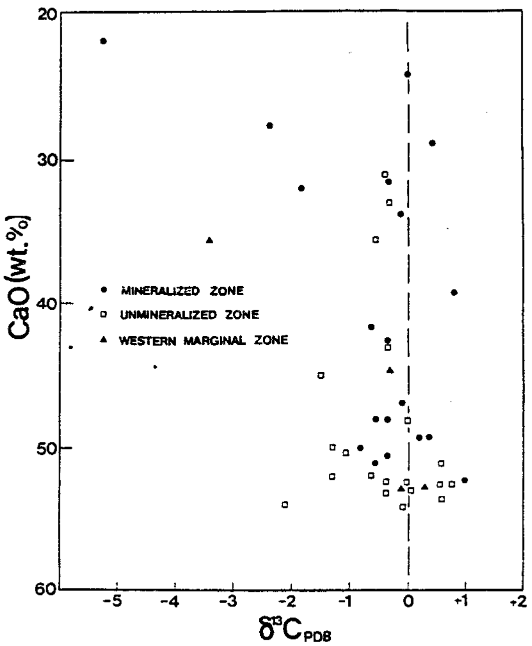


Fig. 9. Variation of $\delta^{13}C_{PDB}$ against CaO(%) in the Pungchon limestone at the Sangdong Mine area.

Table 4. Carbon and oxygen stable isotope compositions of the Pungchon limestone at the Sangdong Mine area.

Sample No.	$\delta^{18}C$(‰) PDB	$\delta^{18}O$(‰) PDB	$\delta^{18}O$(‰) SMOW	Reference
P-1	-1.33	-16.56	13.79	
P-3	-0.03	-11.25	19.26	Cross Line 1
P-4	-0.31	-10.25	20.39	Unmineralized Zone
P-5	-0.54	-10.06	20.49	
P-6	-0.09	-13.05	17.40	
P-52	-1.30	-14.43	15.98	
P-54	-1.08	-16.79	13.55	Cross Line 2
P-56	-0.36	-11.60	13.55	Unmineralized Zone
P-57	-0.35	-12.71	17.70	
P-13	-1.52	-15.83	14.55	
P-12	-0.02	-14.82	15.53	
P-11	0.57	-12.79	17.67	Cross Line 3
P-10	0.79	-12.93	17.53	Unmineralized Zone
P-9	0.52	-11.21	19.30	
P-8	-0.37	-10.78	19.75	
P-7	-0.36	-14.25	16.17	
P-14	0.25	-13.51	16.93	
P-15	-0.31	-14.68	15.73	Cross Line 4
P-17	-3.47	-13.07	17.38	West marginal Zone
P-18	-0.11	-11.15	19.94	of the Sangdong orebody
P-51	0.69	-11.48	19.03	
P-50	0.45	-13.81	16.62	
P-42	-0.36	-16.71	13.63	
P-41	-1.84	-15.30	15.09	Cross Line 5
P-40	-5.25	-16.47	13.88	Mineralized Zone
P-39	-2.37	-13.33	17.12	
P-37	-0.63	-12.82	17.64	
P-21	-0.08	-14.93	15.47	
P-22	0.98	-12.56	17.92	Cross Line 6
P-23	-0.34	-14.14	15.25	Mineralized Zone
P-24	-0.15	-12.89	17.57	
P-25	-0.52	-13.14	17.32	
P-26	-0.47	-15.79	14.58	
P-27	0.24	-15.34	15.04	
P-30	0.38	-14.55	15.86	Cross Line 7
P-31	0.42	-15.41	14.98	East marginal Zone
P-32	0.81	-10.32	2.22	of the Sangdong orebody
P-33	-0.36	-14.71	15.70	
P-34	-0.001	-10.69	19.84	
P-35	-0.80	-15.97	14.40	
P-36	-0.36	-14.93	15.48	
P-70	-0.60	-13.77	16.67	
P-71	-2.09	-14.99	15.41	Cross Line 8
P-73	-0.01	-11.87	18.62	Unmineralized Zone
P-74	0.62	-13.07	17.38	

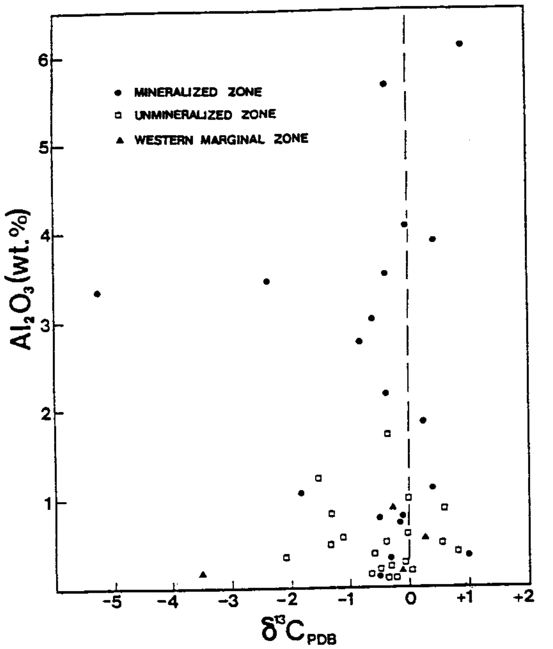


Fig. 10. Variation of $\delta^{13}C_{PDB}$ against Al_2O_3 in the Pungchon limestone at the Sangdong Mine area.

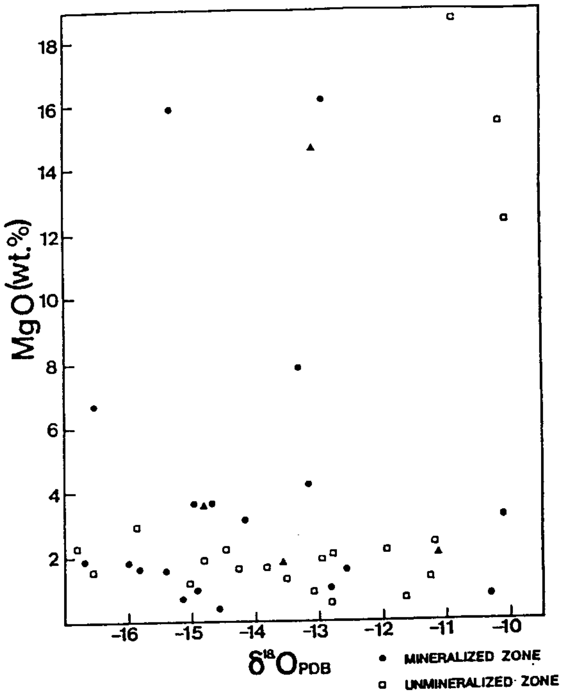


Fig. 11. Variation of $\delta^{13}C_{PDB}$ against MgO in the Pungchon limestone at the Sangdong Mine area.

applicable to exploration, since the mean value of $\delta^{13}C$ of the Pungchon limestone in the mineralized zone, -0.39 permil, is substantially different from that in the unmineralized zone, -0.56 permil.

It is found that mean values of the carbon isotopes are useful only for comparison. However, it is necessary for using the data in geochemical exploration that the range of variation in $\delta^{13}C$ value defining pure limestones must be fixed as standard values. According to data of Kim (1980) and Park and Woo (1986), it is reasonable that $\delta^{13}C$ values of the Pungchon limestone in the unmineralized zone range from $+1$ to -2 permils. Under the above assumption, it may be possibly defined that lower vlaues of $\delta^{13}C$ than -2 permil should belong to the anomalous values.

As shown in Table 4 and Figs. 8, 9 and 10 the anomalous values of carbon isotopic composition such as -3.46, -5.25 and -2.37 permils are confined to the mineralized zone.

In terms of statistic viewpoint, anomalous values detected in the mineralized zone are too small numbers to accept them as reliable data. However, it is convinced that even limited numbers of the anomalous values are worthwhile to

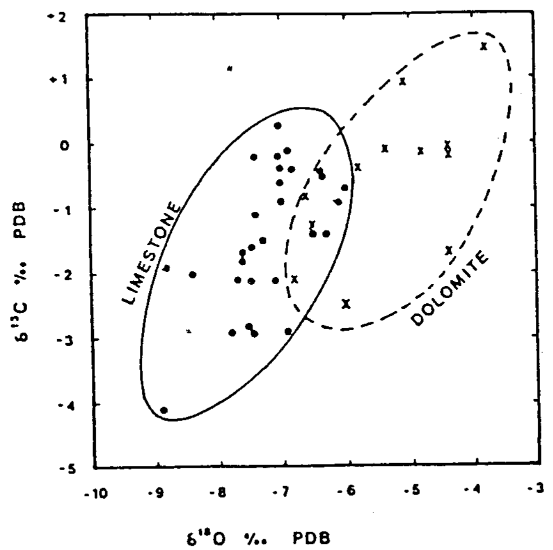


Fig. 12. $\delta^{18}O$ and $\delta^{13}C$ variation in the Gordon Limestone in 40 samples from Mole Creek(Rao, 1989).

be considered as explained as a scanning effect of human body in order to find a organic defect which is, speaking figuratively, equivalent to the anomalous spot representing hidden orebody in the underground of the earth. As shown in the Gordon Limestone(Rao, 1989, Fig. 12), even one anomalous carbon isotope value of limestone should be studied with viewpoint of the applicable data to exploration.

Figs. 11 and 12 show a clear difference in oxygen isotope composition between pure limestone and dolomitic limestone.

However, it is noticed that oxygen isotope compositions are not useful data to apply for exploration in limestone area.

Relative Variation In $\delta^{13}C$ Against Other Elements.

Park and Woo (1986) described that $\delta^{13}C$ values seemed to vary with depth. However, it is hardly found there are any regularity of variation in $\delta^{18}O$ as well as $\delta^{13}C$ values of the Pungchon limestone as shown in Fig. 8. CaO content vs. $\delta^{13}C$ are shown in Fig. 9. Most of analytical results of the mineralized zone are plotted in the same field as those of the unmineralized zone except 4 points. The anomalous points are exceptional values of CaO as well as $\delta^{13}C$. Particularly, the lowest value of CaO content is in accord with the lowest value of $\delta^{13}C$. As shown in Fig. 10, half of analytic values of Al_2O_3 from the mineralized zone are separately plotted in different field from those of the unmineralized zone. It is not clear to explain the reason why the highest value of Al_2O_3 is out of accord with the anomalous value of $\delta^{13}C$. It may be due to addition of aluminium in the meltwater of the limestone along fracture systems in the mineralized zone. In some way, weathering may has an important role to change the chemical compositions of the limestone. In order to understand the mutual relation between the variation of CaO and Al_2O_3 against $\delta^{13}C$ values in the limestone, further detailed study is essentially required.

CONCLUSION

Three indispensable conditions to form skarn ore deposits are limestone, structure and granitoid. The Taebaeg Basin has the most potential area to contain the skarn deposits such as the Sangdong and the Yeonhwa skarn ore deposits in this respect.

It is obvious that lithogeochemistry such as CaO, Fe_2O_3, SiO_2 and Al_2O_3 is effectively applicable to exploration in the limestone area. For the purpose of using the lithogeochemistry in the mineral exploration, relative chemical values of the limestone in the unmineralized zone are essentially required as a background of limestone in the exploring target area.

Certain increase of Al_2O_3 and decrease of CaO in the limestone contents may indicate relative strength of the thermal effect from the underlying granitoid. The thermal effected limestone on the surface may be different from the uneffected limestone by showing different chemical behaviours of weathering.

Even though there are some problems in terms of statistic viewpoint, the variation of $\delta^{13}C$ values could be indicators for exploration in the limestone area as Ca and Al contents.

Since we have raw data of lithogeochemistry of the Pungchon limestonee in the southern limb of the Hambaeg Basin, it is concluded that higher mean values of Al and Fe as well as lower mean values of the $\delta^{13}C$ at the limestone in the northern limb of the syncline may be applicable to exploration for finding a hidden skarn orebody in the targeting limestone area.

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문 건 주

요약 : 우리나라에서 중요한 금속광상인 상동 중석, 연화 연-아연, 거도의 동-철 광상은 모두 태백분지내 함백향사 남익부에 위치하고 있다. 이들 광화작용은 대체로 동서 주향에 25-30도 북향한 경사로 놓여진 캠브리아기의 묘봉층내 석회암 협층과 풍촌 석회암에서 일어났다. 함백향사의 북익부에는 동일한 지질내에 동일형의 광상이 노출되어 있지 않아, 이 지역에서의 잠두광체를 찾기위한 수단으로 알려진 상동광산 지역에서 암석지화학적, 특별히 Si, Ca, Fe및 탄소 안정동위원소를 이용한 탐사연구를 시도하였다. 광화대와 비광화대의 석회암 사이의 CaO와 AL_2O_3 함량은 큰 차이를 보이고, 탄소동위 원소 분석결과 역시 $\delta^{13}C$ 값이 광화대에서 더 낮은 값을 보이는 바 그 내용은 아래와 같다.

	비광화대	광화대
CaO	51.3%	43.5%
Al_2O_3	0.6%	2.4%
$\delta^{13}C$	-0.39 permil	-0.56 permil
Fe_2O_3	0.9%	1.4%
SiO_2	3.0%	2.4%

광화대내의 풍촌석회암의 Si 함량이 감소한 것은 앞선 연구(Moon. 1987) 결과와 상치되는 바, 광화대내의 석회암중 Al 함량이 증가한 사실을 확인한 사실을 근거로 생각해 볼때, Si의 감소는 열극, 균열, 또는 소규모의 단층을 따라 주로 발달된 변질물의 증가에 따른 결과로 유추되기도 한다. 따라서 광화대내의 Si와 Al 함량이 보여주는 현상은 화강암류로부터 전달된 열의 영향으로부터 기인된 것으로 상위 지표부의 석회암에 이로부터 광화활동이 이어진 것으로 여겨진다. 만약 함백향사의 북익부에서 풍촌석회암의 Fe, Al의 함량이 평균 함량치 보다 높을 뿐만 아니라, Ca와 Si는 낮고 Ca 함량과 $\delta^{13}C$의 값이 평균치보다 낮은 값을 보이는 경우는 잠두광체 탐사에 이용될 가치가 있다고 본다.