CHARACTERISTICS OF SURFICIAL BRIGHTNESS TEMPERATURE AND REFLECTIVE SPECTRUM IN SPORADIC PERMAFROST REGION

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ABSTRACT

Based on observation on the ground surface infrared temperature and seasonal pattern of ground surface reflection spectrum from various kind of permafrost surface for four seasons in permafrost region at Reshui, Qinghai Province, it was suggested that the time before dawn in spring is the best period for infrared remote sensing, 380-1200 nm multispectrums are hard to distinguish various kind of permafrost, but they can be used to indicate existance of thick-layed ground ice.

INTRODUCTION

About 22.3% of the total territory in China is underlain by permafrost, and in the vicinity of the southern boundary and lower limit of permafrost, permafrost exists in sporadic state. The engineering conditions in seasonally frozen ground and permafrost vary greatly, so it is very important to distinguish permafrost from seasonally frozen ground by using the remote sensing data. We analysed, in this paper, the variation regularities of surficial brightness temperature and reflective spectrum in Reshui sporadic permafrost region of Qinghai Province with the field measurements and presented the optimum time for infrared remote sensing and the distinguishability of various frozen ground.

1. MEASUREMENT OF SURFICIAL BRIGHTNESS TEMPERATURE

1.1 Measuring Instrument and Observation Fields

Instrument used in the measurement was KR-2007 radiometer made in Japan. Its main functions are as following:

visible field: τ/28.6 cm, where τ is the distance from the instrument to the measured object;
temperature range: -10 — +150°C;
response wavelength: 380 — 1200 nm;
accuracy: ±1.5°C for 0 — +150°C and ±3.0°C for 0 — -10°C;
display: digital display;
response time: 0.7 sec.;
transmittance range: 0.5 — 1.0, continuously adjustable.

The adjustor of transmittance was set at 1.0 in the measurement. Since the radioactive brightness temperature digitally displayed was uncalibrated by the transmittance, the temperature discussed in this paper meant surficial brightness temperature. The measurement of surficial brightness temperature aimed at understanding seasonal variation of surficial brightness temperature both in seasonally frozen ground and in permafrost areas. Therefore, the seasonally frozen ground and nearby permafrost areas were chosen for the field experiment in order to compare during every season. We mainly dealt with the results gained in No.1 observation field (see Table 1)

Table 1. Conditions No.1 Observation Field

Type of frozen ground	Seasonally frozen ground				Permafrost			
Seasonally frozen ground	Lying on river flood plain, loose silty sand and sparse vegetation on the surface				Lying on high river flood plain lowland the surface was covered by thick vegetation and overlain by turf. Ice content near permafrost table ranged from 50-80%			
Water content (%)	Spring 26	Summer 30	Fall 50	Winter No data	Spring 133	Summer 135	Fall 116	Winter No data
Mean annual ground temp. (°C)	0.0 — 2.0				-0.1 — -0.5			

1.2 Seasonal Variation of Surficial Brightness Temperature

The sun is the thermal radiation source of the earth's surface, and the duration and identity of the solar radiation varied periodically from day to night and season to season.

a. Summer During the period of temperature rise in the day, the temperature rise of seasonally frozen ground was quicker than that of permafrost. During the period of temperature lowering, the result was opposite, i.e. the brightness temperature of permafrost was higher than that of seasonally frozen ground. The surficial brightness temperature of seasonally frozen ground was higher than that of permafrost at noon, but adverse result could be obtained at night. Table 1 shows that in permafrost area, the surface was underlain, by turf water content was large and vegetation was thick, and that in the seasonally frozen ground, the surface was underlain by coarse-grained soil, vegetation was sparse and moisture content was lower. Thus, permafrost, with larger heat capacity in summer, had low temperature during the day and high temperature at night (Sabins, 1980). Permafrost was characterized by slow (temperature lowering and rise, low) maximum value at noon, and high minimum value at midnight. The reasons for these were the evapotranspiration cooling in the day and the insulation of vegetation at night. (see Fig.1-1)

b. Winter The brightness temperature of permafrost lowered and rose rapidly and was higher than that of seasonally frozen ground in the day. The curves of brightness temperature of permafrost and seasonally frozen ground at night intersected each other many times in Fig.1-2, and no regularities could be observed. The reason for the phenomenon was that the actual brightness temperature could reach -20 — -30°C which was beyond the instrument measurement range. The fact that the temperature of permafrost was lower than that in seasonally frozen ground at night had been proved by the mercury thermometer (Fig.1-3).

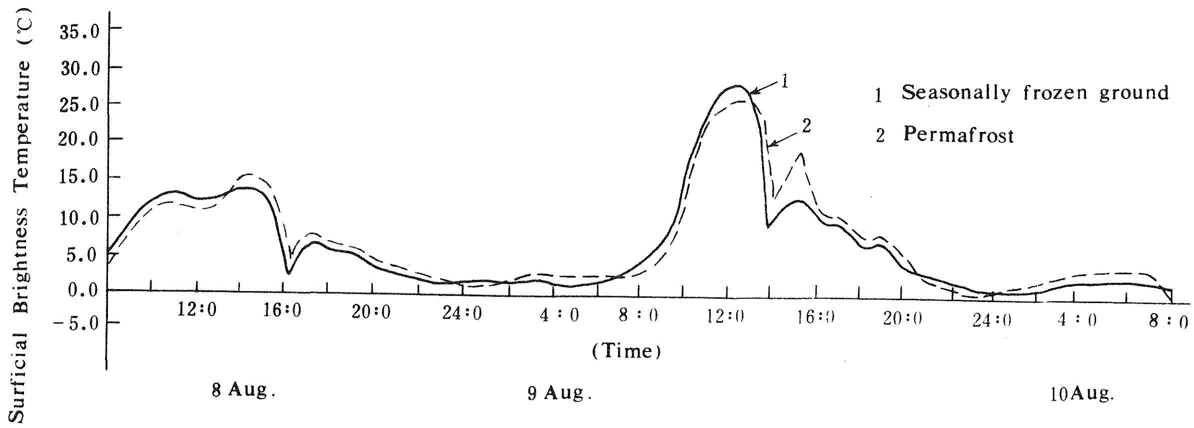

Fig. 1-1. Surficial Brightness Temperature Curves in Summer

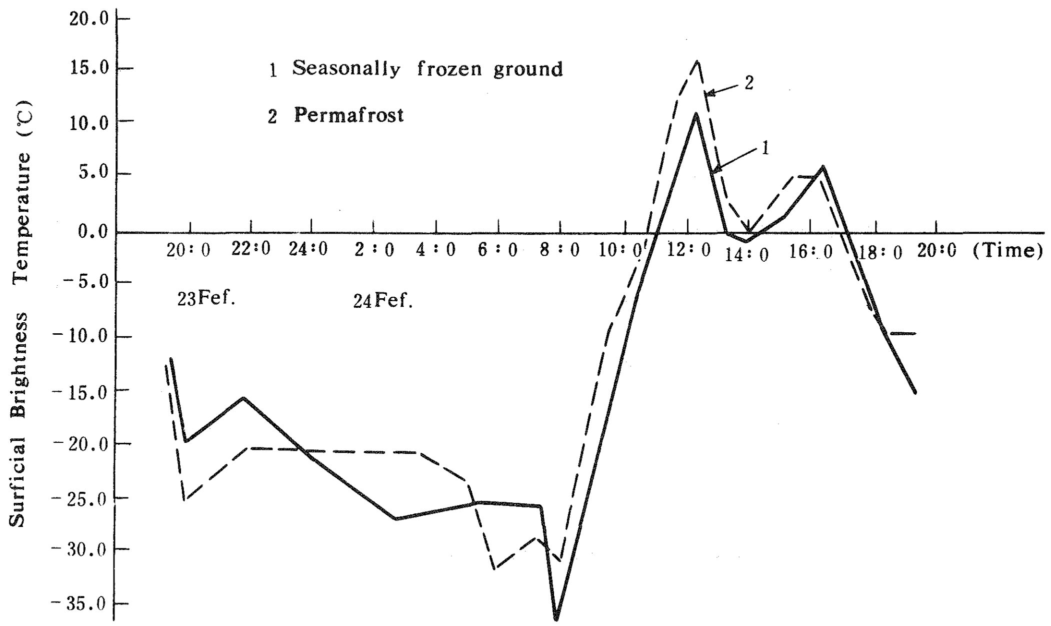

Fig. 1-2. Surficial Brightness Temperature Curves in Winter winter

c. Fall The ground surface thawed in the day and froze at night. Vegetation dried up, but there was some green color at root. The cooling of evapotranspiration became weaker. At this time, the diurnal variation of temperature of the ground surface belonged to transition type. The temperature of the ground surface was similar to that in summer, but similar to that in winter at night (Fig.1-4).

d. Spring The ground began to thaw and vegetation sprouted. The variation of surficial brightness temperature was similar to that in summer. Permaforst had features of slow temperature rise and lowering, and of high minimum value. Sprout could only be found in root which was overlain by dried up yellow grass. Under the solar radiation, the temperature of vegetation

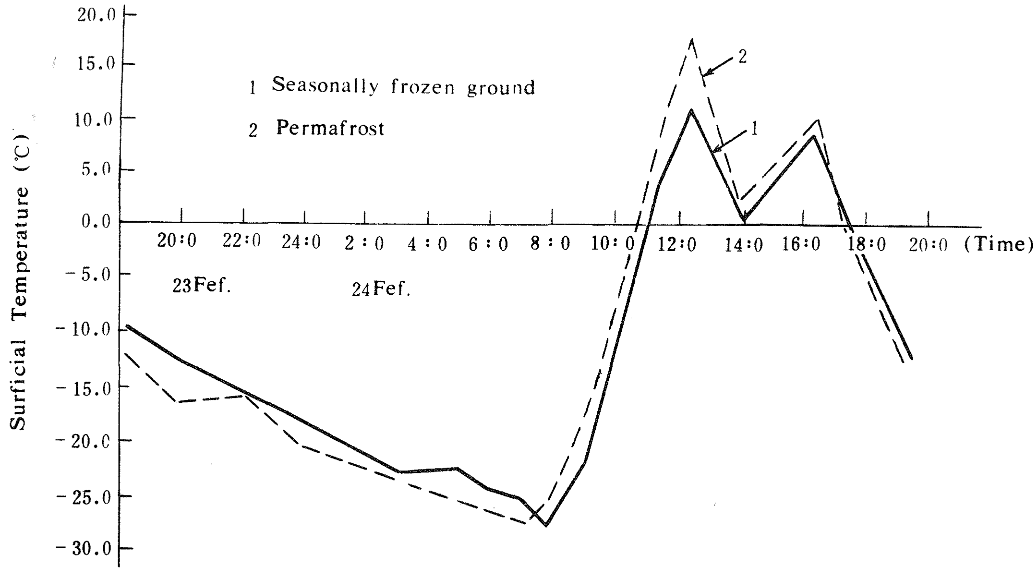

Fig. 1 3. Surficial Temperature in Winter

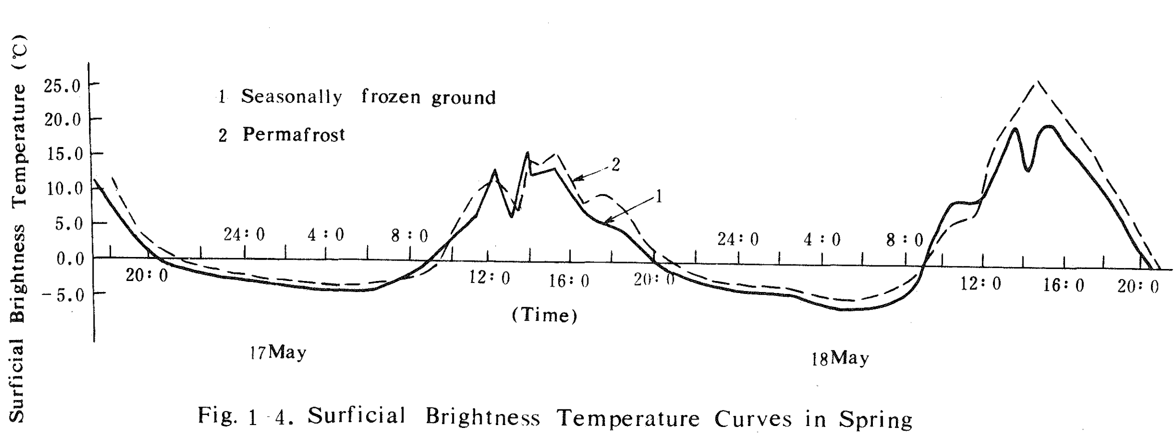

Fig. 1 4. Surficial Brightness Temperature Curves in Spring

rose straight. The maximum value of surficial brightness temperature of permafrost was higher than that in seasonally frozen ground (Fig.1-5).

The diurnal variation of surficial brightness temperature in sporadic permafrost region was controlled not only by soil and moisture conditions but also by freezing and thawing of ground, withering and sprouting of vegetation and thermal regime. The law for the diurnal change of surficial brightness temperature was the basis to analyse infrared images in frozen ground regions. Grasping these laws had important significances for the interpretation of infrared images in different seasons in both permafrost and seasonally frozen ground regions.

1.3 Optimum Period for Infrared Remote Sensing in Sporadic Permafrost Regions

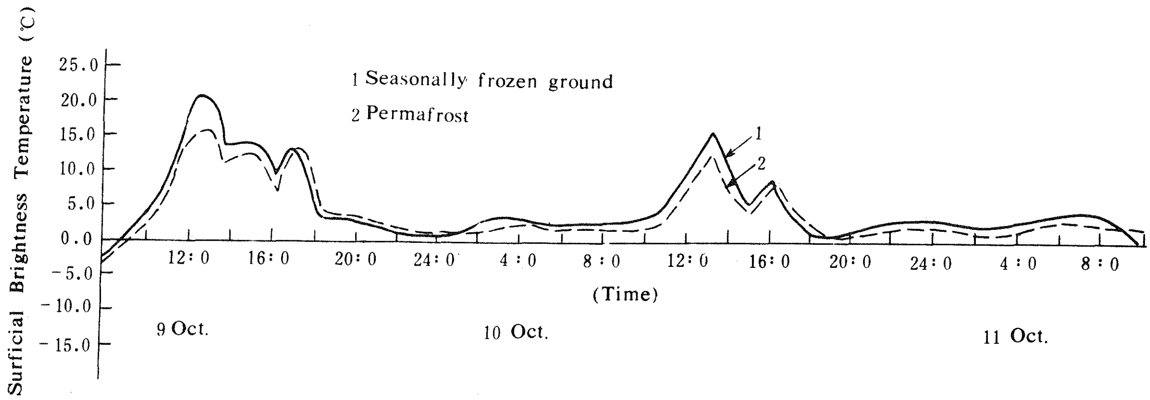

Fig. 1-5. Surficial Brightness Temperature in Fall

The optimum period here meant the time within which the thermal infrared images with the highest resolution in a certain region could be obtained. The more the temperature difference between objects was, the higher the image resolution, so we took minimum temperature difference as the basis for selecting the optimum time. Each two data of surficial brightness temperature were combined and compared so that the maximum and minimum brightness temperature differences of ground surface could be found. According to the diurnal variation of surficial brightness temperature rise and lowering, the course curves were divided into four stages. Then, the mean values of maximum and minimum temperature differences were calculated for each stage, the Table 2 showed that maximum mean minimum temperature difference occured in winter and was smaller in spring, smallest in summer and fall. Below the ground surface was thawed soils in summer and fall, and at this time the water content and the heat capacity of soil increased, but the heat-absorbing and-dissipating conducted slowly. These facturs gave rise to the small difference of brightness temperature. On the other hand, the soil below the surface was frozen in winter and just began to thaw in spring. The adjustable function of moisture was not as clear as that in summer and winter. Surficial brightness temperatures in winter and spring were sensitive to the climatic change. Subsequently, the differences of surficial brightness temperature between various kinds of frozen ground were considerable. If considering the conditions of temperature difference only, winter would be the optimum period for infrared remote sensing. Unfortunately, the severe climate in permafrost regions creates more difficulties for field work and influences the stability of instrument, so the data measured might be unbelievable. Based on the above analysis, spring was selected as the optimum period for infrared remote sensing. The surficial brightness temperature course curves in Fig.1-5 indicated that the temperature difference in the day was considerable, but the interferentical factors and thermal intersection points were also numerous, and no special regularities could be observed. The stability and regularity were better at night, and the maximum night thermal contrast occured before dawn at which there was little influence of sun and shadow. Therefore, it was the optimum time to record temperature differences caused by the different thermal characteristics of earth objects (Liang, 1981). The period before down in spring was selected at last as the optimum time for infrared remote sensing in frozen ground areas.

Table 2. Mean Maximum and Minimum Temperature Differences in Various Time Intervals (°C)

Seasons	Spring		Summer		Fall		Winter	
Intervals	Max.	Mini.	Max.	Mini.	Max.	Mini.	Max.	Mini.
Temp. rise (6 — 11 a.m.)	7.6	1.6	3.8	0.1	5.5	0.2	26.5	2.0
High temp. (12 a.m. — 15 p.m.)	10.1	0.8	7.0	0.3	4.7	0.3	7.0	1.3
Temp. lowering (16 — 19 p.m.)	5.2	0.5	4.8	0.4	2.9	0.2	8.3	0.8
Stable temp. (20 p.m. — 5 a.m.)	3.4	0.5	3.1	0.2	5.9	0.2	23.1	2.1

2. MEASUREMENT AND ANALYSIS OF REFLECTIVE SPECTRA FOR VARIOUS FROZEN

2.1 Measuring Instrument and Observation Field

The instrument used was SRM-1200 spectral radiometer with grating spectrometer, made in Japan. Its wavelength range was 380-1200 nm, resolution was 10 nm and the visible field angle was 1°x6°. The measurement proceeded automatically by sweep, and the output was given out digitally in printed form. The reference white and grey plates was made of Ba SO . Local time 10 a.m. to 2 p.m. was selected for the measurement.

Field features for reflective spectra showed as Table 3.

2.2 Seasonal Variation of the Surficial Reflective Spectra of Various Frozen Ground

The reflective spectra characteristics of various frozen ground possessed apparent seasonal variation regularities in different seasons. This result showed actually the seasonal changes of vegetation and its development stages. Vegetation in summer was vigorous, and the reflective spectrum was typically vegetation type (Fig.2-1). Vegetative in winter was dried up, and its reflective spectrum was apparent soil type (Fig.2-2).

But vegetation just began to sprout in spring and was not dried up completely in fall, therefore, the reflective spectrums in both spring and winter were transitional type (Figs.2-3 and 2-4).

2.3 Distinguishability of Spectrum Reflection of Various Frozen Ground

In order to seek the distinguishability of multispectrum data to each kind of frozen ground, the surficial reflectances of various frozen ground in different seasons were taken as variables, and group analysis method was used to combine and classify the data. The classification indicated that

Table 3. Field Features for Reflective Spectra

No	I		II		III		IV	
Type of frozen ground	Seasonally frozen ground		Ice-less permafrost		Ice-rice permafrost		Ice-saturated permafrost	
Surficial features	River flood plain, sparse vegetation and loose silty sand on the surface		High river flood lowland, about 50% coverage degree of vegetation, turf on the surface		High river flood lowland, hummocks and turf on the surface, about 80% of the surface covered by vegetation		High river flood swamp, hummock and turf on the surface, about 80% of the surface covered by vegetation	
Water content (%)	Spring 34	Summer 30	Spring 34	Summer 63	Spring 95	Summer 95	Spring 141	Summer 145
	Fall 39	Winter no data	Fall 67	Winter no data	Fall 116	Winter no data	Fall 147	Winter no data
Engineering geologic conditions	better		good		not good		bad	
Reflectance (%)	big ——————————————————— small							

the spectrum reflection of frozen ground had little difference. It was hard to identify various frozen ground within the wavelength range 380-1200 nm. But based on the regularities according to which the reflectance decreases with increasing moisture content, it had indicative significance to distinguish the earth sections with thick-layed ground ice.

Since the development of ground ice is well related to moisture regime while water has the characteristics of absorbing wave spectrum within the near infrared wavelength, the greater the water content of soil is, the lower the reflectance of the soil is. This is the mechanisms for the interpretation of thick-layed ground ice.

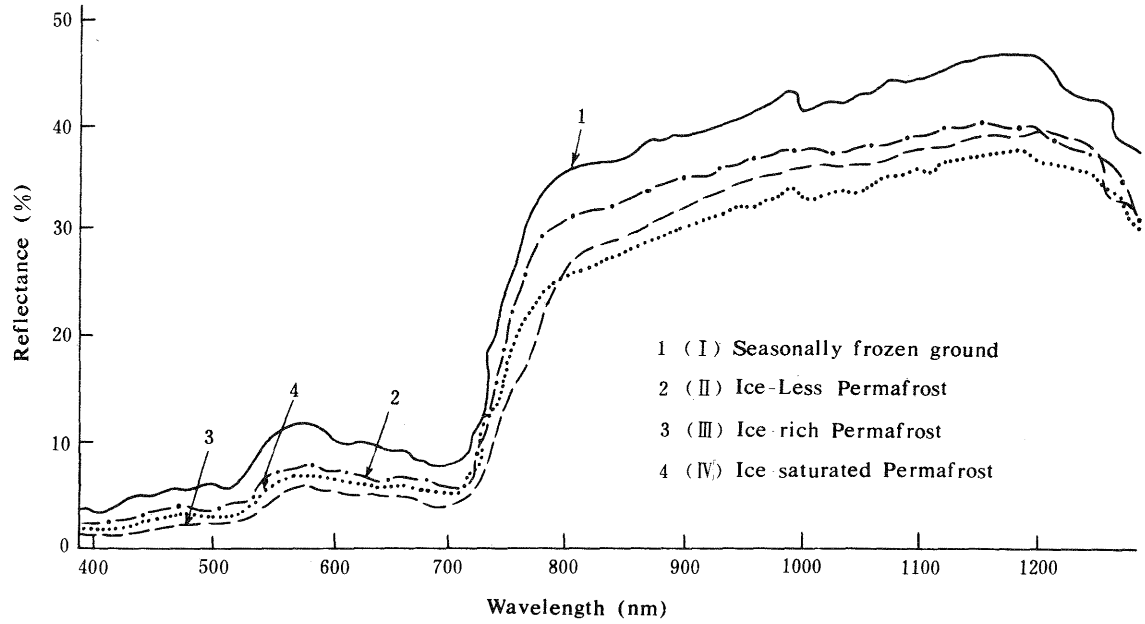

Fig. 2-1. Spectrum Reflection Curves of Various Frozen Ground in Summer

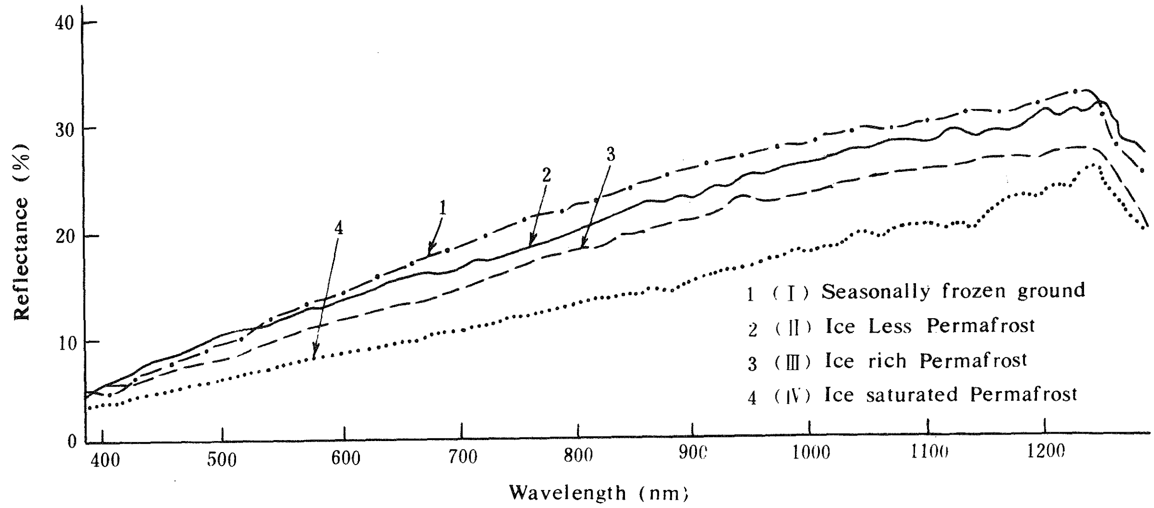

Fig. 2-2. Spectrum Reflection Curves of Uarious Frozen Ground in Winter

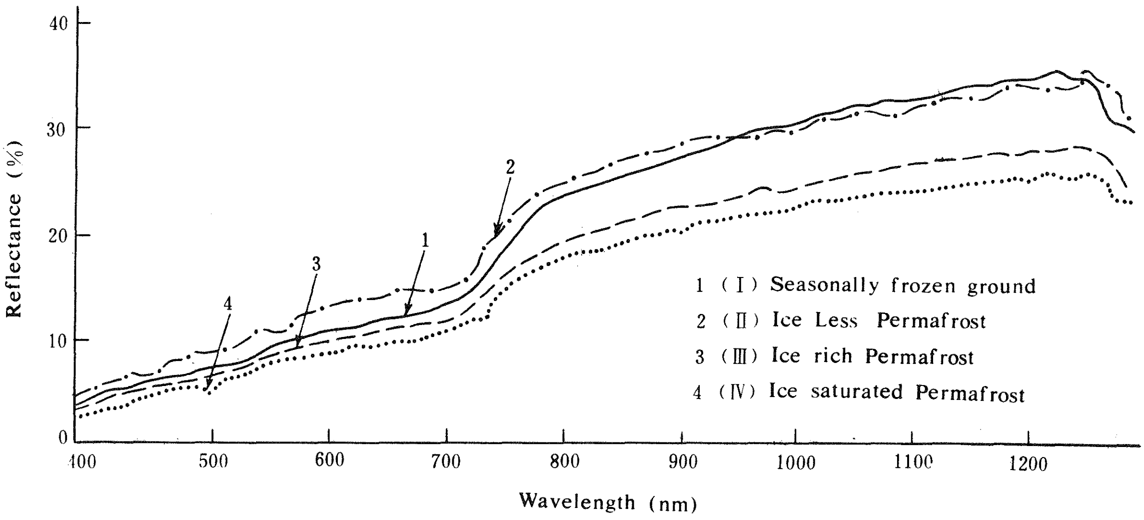

Fig. 2-3. Spectrum Refletion Curves of Various Frozen Ground in Spring

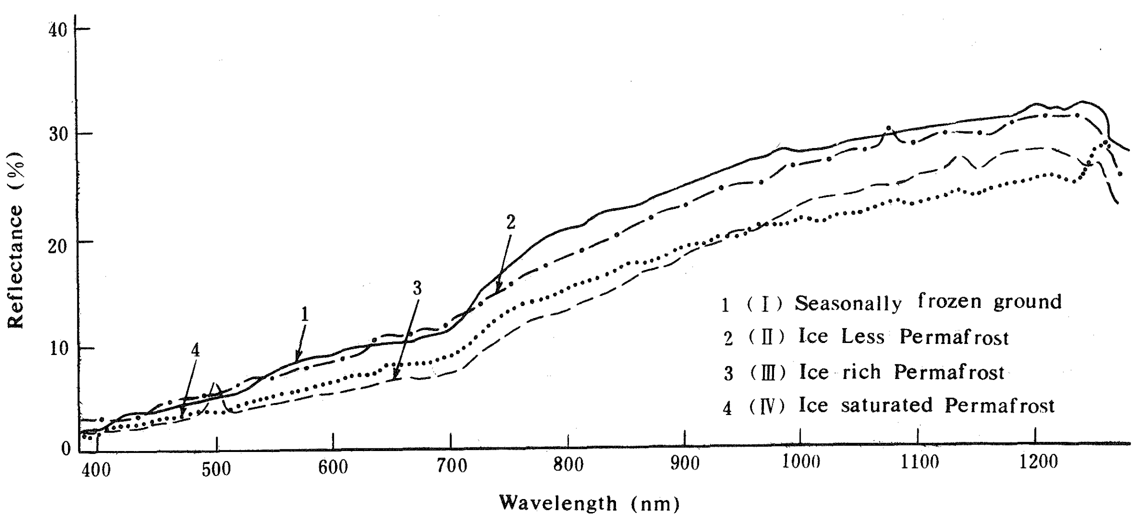

Fig. 2-4. Spectrum Reflection Curves of Various Frozen Ground in Fall

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