



High Power Pseudo-Random Low Frequency Ground Penetrating Radar and Its Application in Permafrost Area Gas Hydrate Exploration

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Abstract: Gas hydrate is a crystalline substance formed by gas and water under certain temperature, pressure and storage conditions. In 2008, China Geological Survey drilled and detected gas hydrate samples in Muli Basin, Qinghai Province. This is the first time that gas hydrate was found in permafrost area of China. The results of drilling and logging show that gas hydrates in Muli area occur in mudstone and siltstone fissures under permafrost overburden or in sandstone pore, and have the characteristics of shallow burial depth, low saturation, discontinuous horizontal and vertical distribution. Ground Penetrating Radar (GPR) is a geophysical exploration method which uses high frequency electromagnetic waves to detect the distribution of underground media. GPR has the advantages of high target detection resolution, visual, real, reliable and easy to identify. The physical properties of ground penetrating radar are premised on dielectric constant and resistivity. Frozen soil is a frozen multiphase component formed under the combined action of soil, water and temperature. Its electrical characteristics (resistivity, dielectric constant) are quite different from those of the unfrozen state. Because of the great difference between the resistivity and dielectric constant of water and ice, when the temperature drops to 0°C, the dielectric constant of soil decreases sharply, while the resistivity of soil increases sharply, and increases sharply with the decrease of temperature. Logging data statistics in Muli area show that the resistivity of frozen soil in this area is about three times higher than that of non-frozen soil. In summary, the application of ground penetrating radar technology in direct detection of hydrate reservoirs in Muli area has good physical and geological conditions. The first GPR test of natural gas hydrate has been carried out in Qilian Mountains since 2010. We have used two kinds of low frequency ground penetrating radar system, Groundvue 6 from UK and CAS-U25 from China. Both of these instruments are based on the traditional impulse system. Due to the limitation of pulse amplitude, there are some problems such as shallow detection depth and poor anti-interference ability, which make it difficult to reach the depth of gas hydrate reservoir in Muli area. In order to further improve the detection depth and the quality of GPR signal, we adopt the pseudo-random coded signal and acquire the radar signal with stronger signal-to-noise ratio to

Table 1 Main parameters of High Power Pseudo-Random Low Frequency Ground Penetrating Radar

Parameter	Value
Encoding method	8192 sets of Golay coding
Code width	80 ns
Phase encoding length of each group	8
Emission peak power	1kW
Receiver sensitivity (including pulse compression)	-130dBm
Mixed sampling interval	5ns
Gain range of time-varying gain circuit	-10~53dB
Linear mean times	1/2/4/8/16
Emission center frequency	12.5MHz
Pulse repetition frequency	200KHz
Antenna form	12.5 meter long resistance loaded dipole antenna
Maximum detection window	4200ns

Table 2 Comparison table of main indicators of different GPR system

	CAS-U25 (IECAS)	Groundvue 6 (UTSI)	pseudo-random coding radar
Emission peak power	500W	1kW	1kW
Central frequency	12.5MHz	15MHz	12.5MHz
System dynamic range	168dB	174dB	215dB
Receiver sensitivity	-90dBm	-92dBm	-130dBm
Sampling points	256-4096	256	256-4096

achieve deeper detection depth. Pseudo-random coded signal is a kind of signal with large time-bandwidth product. By transmitting a signal with long duration and then compressing the pulse, a pulse response function similar to that of a narrow pulse can be obtained. The excellent characteristics of pseudo-random coded signal can make up for the shortcomings of traditional pulse radar, which can increase signal strength and maintain signal resolution. Based on the existing pseudo-random coded radar, we focused on improving the high-power transmitter, and integrated a set of high-power pseudo-random coded radar using Golay complementary code. Its main parameters are shown in Table 1. The main parameters of three kinds of low frequency ground penetrating radar instruments used are compared as shown in Table 2. It can be seen that the peak power of pseudo-random coded GPR is twice as high as the traditional GPR, which greatly enhances the intensity of

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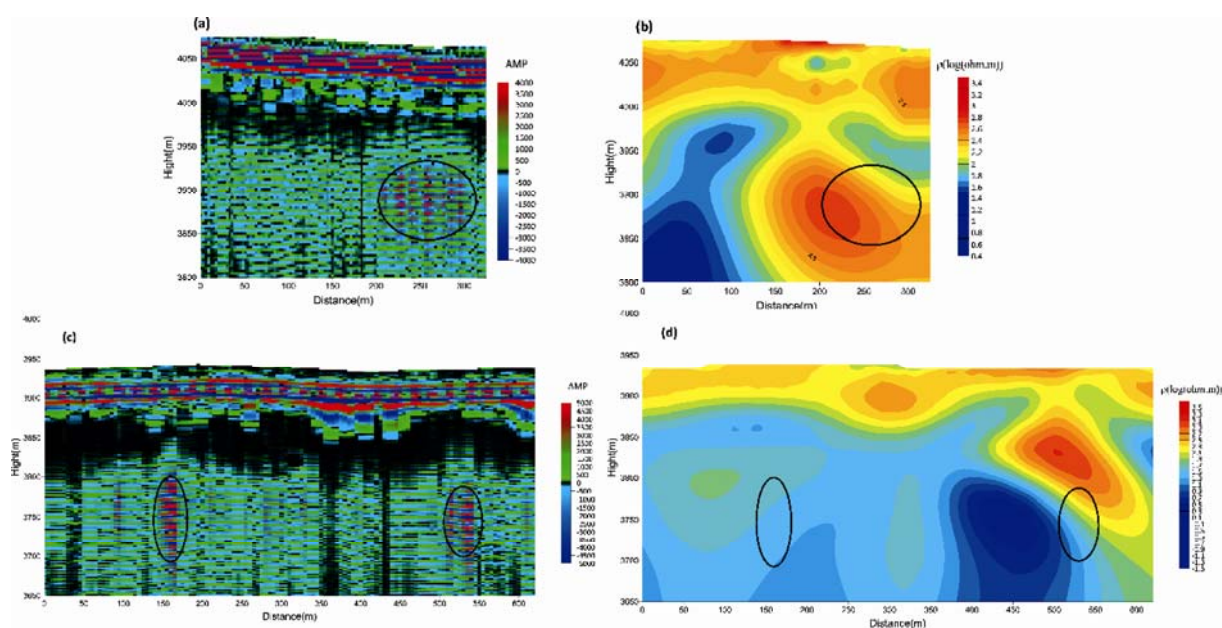


Fig.1.GPR profile and AMT profile in Muli area.

The strong reflection signal in black ellipse indicates suspected gas hydrate reservoir

(a) GPR profile of line DK92;(b) AMT profile of line DK92;(c) GPR profile of line AJ10;(d) AMT profile of line AJ10

transmitting signal, and the sensitivity of receiver and dynamic range of system are also greatly improved compared with the other two instruments. This shows that the ability of receiving weak signal is also enhanced while the transmitting signal of pseudo-random coded ground penetrating radar is enhanced. Through the method experiment and theoretical research, the low-frequency ground penetrating radar system based on pseudo-random coding technology is applied for the first time to achieve the detection depth of more than 200 meters in the permafrost area of mid-latitude. Obvious radar reflection signals are found in hydrate reservoirs. The "high frequency and strong amplitude" characteristics of the reflected signals can be used as the electromagnetic identification marks of gas hydrate reservoirs. The application of ground penetrating radar technology to gas hydrate reservoir exploration in permafrost region of Qinghai-Tibet Plateau is an extension of the application field of ground penetrating radar, and also an effective exploration method and technological innovation in the field of gas hydrate exploration. Previous studies show that both AMT and GPR methods have direct response to natural gas hydrate reservoirs in the permafrost areas under appropriate conditions. For AMT method, hydrate is high resistivity anomaly, distributed near faults and nearly horizontal distribution. The accuracy and reliability of gas hydrate reservoir detection can be improved by joint interpretation of the two methods. Fig. 1 is two typical AMT and GPR profiles in Muli area. Comparing the apparent resistivity of AMT with GPR high frequency strong reflection signal, it is found that there are great corresponding relations.

Key words: Pseudo-Random signal, low frequency GPR, gas hydrate, permafrost

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