Ground Penetrating Radar
(GPR)

- GPR is a reflection technique that requires very low power. It is a time-domain impulse radar, and transmits broad bandwidth pulses into geologic materials. A time-domain radar act as a sounding device similar to depth finders in boats. A short pulse in the frequency range of 10 - 1000 Mhz is used. The propagation of the pulse is controlled by the relative dielectric permittivity (dielectric constant, ξ_r) which is dimensionless, relative magnetic permeability (μ_r), and the conductivity (σ) of the subsurface. Dielectric conduction takes place in poor conductors and insulators, which have no free carriers, by slight displacement of electrons with respect to their nuclei. (Dielectric constant**:** A measure of the capacity of a material to store charge when an electric field is applied.)

- Radar-wave behavior in geologic media can be described in terms of conventional optics. Snell's Law is modified to $\xi_a \sin 2\phi_a = \xi_b \sin 2\phi_b$, where ξ_a and ξ_b are the dielectric constants of the two different media.

- The velocity of a radar-wave can easily be estimated for a particular material by taking the square root of its dielectric constant ($V = .3/\sqrt{\xi_r}$ m/ns); the .3 is because radar-waves are referenced to the speed of light in air or in vacuum (.3 m/ns). Dielectric constants for most dry geologic materials range from 4 (quartz sand) to 7 (shales and carbonates).

- Water, however, has a dielectric constant of 81 at 20°C and radically alters the velocity of the radar-wave traveling through materials and can cause serious errors in estimating depth. Saturated quartz sands will have a dielectric constant of up to 30; granite will rise from 5 to 7 as it becomes wet; dry soils will rise from 8 to about 20 as they become wet.

- Soil conductivity also influences radar-wave interaction with geologic media. Radar works best passing through low conductivity materials such as dry granites and limestones. Clays with high conductivities are hard on radar waves, and the longest wavelength antennas can only get down 0.5 meters or so in wet clays.

- Water clearly influences conductivity because of its ability to dissolve salts. GPR can be used to profile fresh-water lakes if the water depth is no more than 10 meters.

- Attenuation or loss of radar energy is a complex function of the dielectric and electrical properties of the media through which the radar signal is traveling. Attenuation factor is controlled by the conductivity (σ), the relative magnetic permeability (μ_r), and the relative dielectric permittivity (ξ_r) of the medium as well as the frequency of the signal itself.

- Where dielectric contrasts in the subsoil materials are sharp, the radar echoes will record an interface between the two just as seismic reflection does when there is an acoustic impedance contrast across an interface. Wiggle plots showing data from

either technique are indistinguishable as are velocity analysis techniques. T^2 - X^2 plots are commonly used to get velocity instead of published values since these values can be error if water is present.

- Radar surveys are done by towing a transducer or antenna of an appropriate wavelength by hand, or behind a vehicle over the area of interest. GPR transducers work as transmitters and receivers; commercial antennas work with center frequencies of about 50 to 1000 Mhz. Penetration depths varies inversely with frequency; commercial 50 Mhz antennas have achieved depths of more than 1000 nanoseconds, or about 60 meters in granite or carbonate bedrock.

- The transmitter typically emits a broad bandwidth pulse every 50,000th of a second, then switches to or becomes the receiver, which "records" for about 20 microseconds before another pulse is sent. Because the waves are traversing the ground at sub-light velocities ample time is available for transmitted pulse to be reflected back and processed before another pulse is emitted. As the transmitted pulse moves from air into another medium the pulse slows, depending on the dielectric constant of the material, and the wavelength decreases.

- Radar waves can generally resolve objects on the order of one-half wavelength and the wavelength of the radar-wave decreases as it encounters higher dielectric material with depth so the resolution increases.

- GPR technology can be used to determine depth to bedrock and or water table, locate buried ordnance at gunnery ranges, caskets, map sinkholes, and to find fossil vertebrates, or buried bodies in homicide cases.