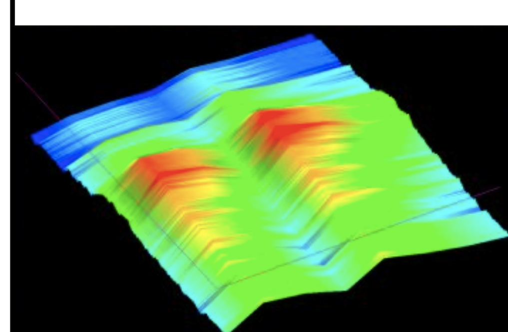
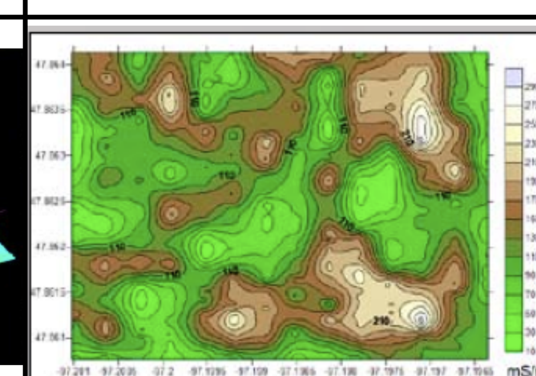
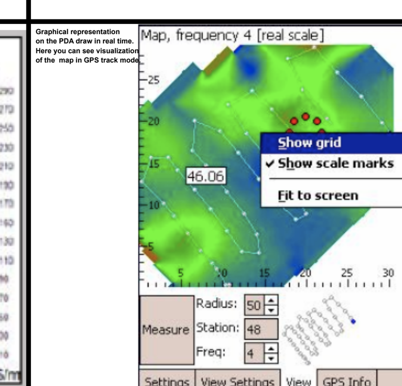
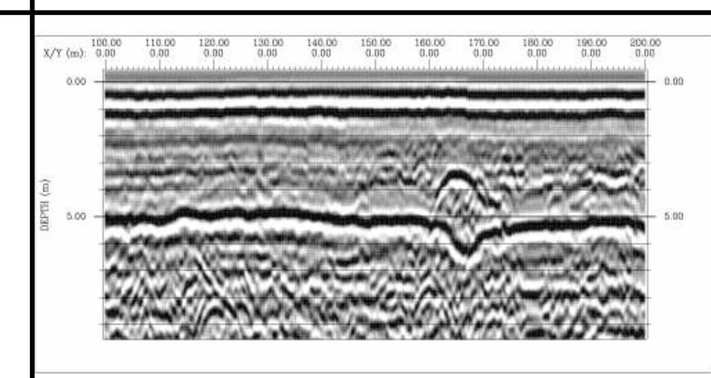
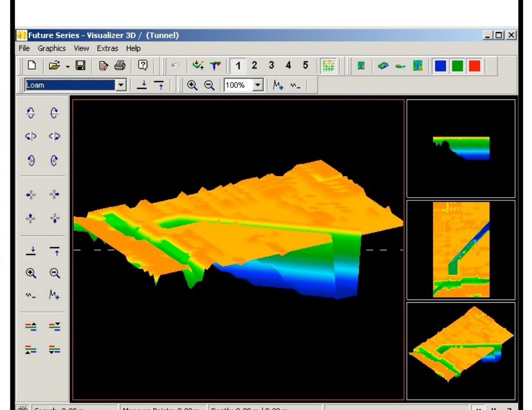
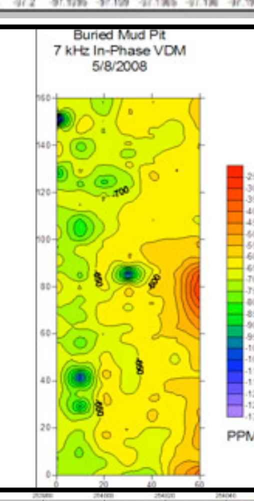
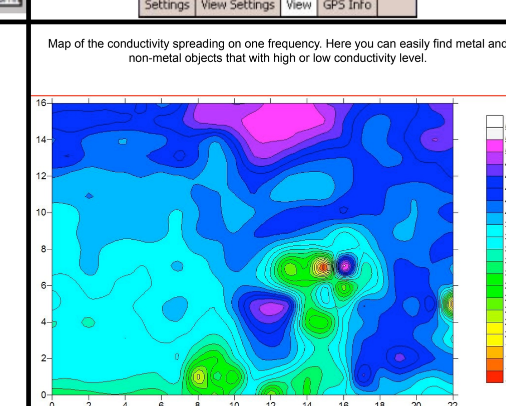
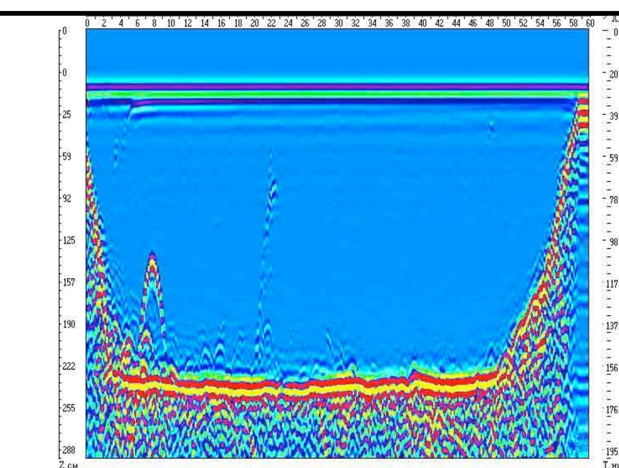
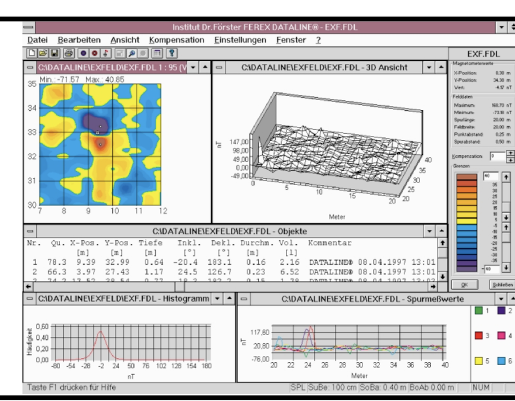
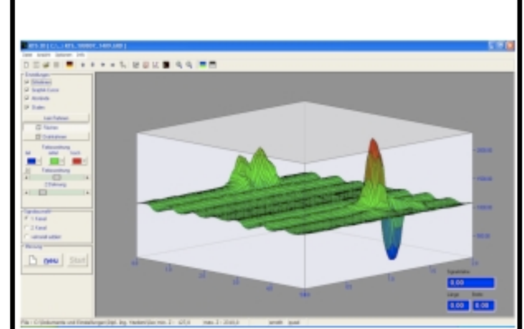
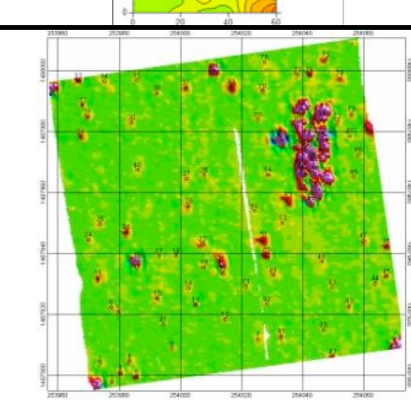
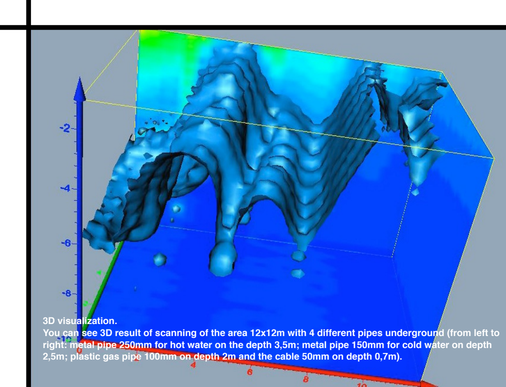
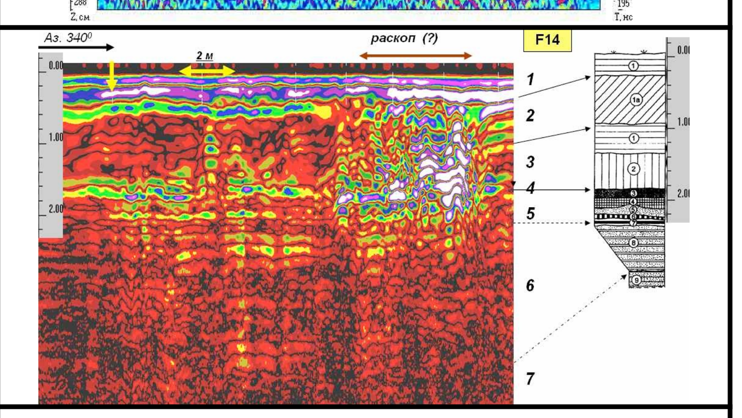
Equipment for non-contact underground researching.

	Deep metal detector	Magnetometer	Passive anomaly detector (Imager)	Profilers (frequency domain electromagnetic induction system)	NEMFIS; AEMP-14 (frequency domain electromagnetic induction system)	GPR
Principle of work	VLF Technology Very low frequency (VLF), also known as induction balance, is probably the most popular detector technology in use today. In a VLF metal detector, there are two distinct coils: Transmitter coil - This is the outer coil loop. Within it is a coil of wire. Electricity is sent along this wire, first in one direction and then in the other, thousands of times each second. The number of times that the current's direction switches each second establishes the frequency of the unit. Receiver coil - This inner coil loop contains another coil of wire. This wire acts as an antenna to pick up and amplify frequencies coming from target objects in the ground. The current moving through the transmitter coil creates an electromagnetic field, which is like what happens in an electric motor. The polarity of the magnetic field is perpendicular to the coil of wire. Each time the current changes direction, the polarity of the magnetic field changes. This means that if the coil of wire is parallel to the ground, the magnetic field is constantly pushing down into the ground and then pulling back out of it. As the magnetic field pulses back and forth into the ground, it interacts with any conductive objects it encounters, causing them to generate weak magnetic fields of their own. The polarity of the object's magnetic field is directly opposite the transmitter coil's magnetic field. If the transmitter coil's field is pulsing downward, the object's field is pulsing upward. PI Technology A less common form of metal detector is based on pulse induction (PI). Unlike VLF, PI systems may use a single coil as both transmitter and receiver, or they may have two or even three coils working together. This technology sends powerful, short bursts (pulses) of current through a coil of wire. Each pulse generates a brief magnetic field. When the pulse ends, the magnetic field reverses polarity and collapses very suddenly, resulting in a sharp electrical spike. This spike lasts a few microseconds (millionths of a second) and causes another current to run through the coil. This current is called the reflected pulse and is extremely short, lasting only about 30 microseconds. Another pulse is then sent and the process repeats. A typical PI-based metal detector sends about 100 pulses per second, but the number can vary greatly based on the manufacturer and model, ranging from a couple of dozen pulses per second to over a thousand. If the metal detector is over a metal object, the pulse creates an opposite magnetic field in the object. When the pulse's magnetic field collapses, causing the reflected pulse, the magnetic field of the object makes it take longer for the reflected pulse to completely disappear. This process works something like echoes: If you yell in a room with only a few hard surfaces, you probably hear only a very brief echo, or you may not hear one at all; but if you yell in a room with a lot of hard surfaces, the echo lasts longer. In a PI metal detector, the magnetic fields from target objects add their "echo" to the reflected pulse, making it last a fraction longer than it would without them.	A magnetometer is a scientific instrument used to measure the strength and/or direction of the magnetic field in the vicinity of the instrument. Magnetometers can be divided into two basic types: Scalar magnetometers measure the total strength of the magnetic field to which they are subjected, and Vector magnetometers have the capability to measure the component of the magnetic field in a particular direction. The use of three orthogonal vector magnetometers allows the magnetic field strength, inclination and declination to be uniquely defined. Examples of vector magnetometers are fluxgates, superconducting quantum interference devices (SQUIDs), and the atomic SERF magnetometer.	Anomaly detector - is passive device, an indicator of geophysical anomalies based on detecting changes of EM field of the Earth. Some detectors have highly sensitive gauge of electromagnetic radiation of biological objects including human bodies.	Based on the design principles of inductive electromagnetics, Ground Conductivity Meters provide a non-invasive method for measurement of subsurface conductivity and magnetic susceptibility. Without any requirement for soil-to-instrument contact, surveys can be performed quickly – facilitating dense data collection and, consequently, excellent spatial resolution – and over most geologic environments, including conditions of highly resistive surface materials such as sand and gravel.	NEMFIS and AEMP-14 designed to study of geoelectric situation on the depth up to 7 m. The device can operate on 14 frequencies. It means that the data acquired can describe the geoelectric situation at 14 levels of depth. In horizontal plane the responding media is the ellipse with one constant axis length (2.5 m) and second axis length depending on the frequency 0.5 – 7 m. Having such a good resolution we can state that the unit is intended for 3D specification of geoelectrical parameters of the volume at a depth up to 7 meters with heterogeneous inclusions dimensions 0.5 x 0.5 x 2.5 m or more.	Ground-penetrating radar (GPR) is a geophysical method that uses radar pulses to image the subsurface. This non-destructive method uses electromagnetic radiation in the microwave band (UHF/VHF frequencies) of the radio spectrum, and detects the reflected signals from subsurface structures. GPR can be used in a variety of media, including rock, soil, ice, fresh water, pavements and structures. It can detect objects, changes in material, and voids and cracks. GPR uses transmitting and receiving antennas or only one containing both functions. The transmitting antenna radiates short pulses of the high-frequency (usually polarized) radio waves into the ground. When the wave hits a buried object or a boundary with different dielectric constants, the receiving antenna records variations in the reflected return signal. The principles involved are similar to reflection seismology, except that electromagnetic energy is used instead of acoustic energy, and reflections appear at boundaries with different dielectric constants instead of acoustic impedances. The depth range of GPR is limited by the electrical conductivity of the ground, the transmitted center frequency and the radiated power. As conductivity increases, the penetration depth also decreases. This is because the electromagnetic energy is more quickly dissipated into heat, causing a loss in signal strength at depth. Higher frequencies do not penetrate as far as lower frequencies, but give better resolution. Optimal depth penetration is achieved in ice where the depth of penetration can achieve several hundred meters. Good penetration is also achieved in dry sandy soils or massive dry materials such as granite, limestone, and concrete where the depth of penetration could be up to 15 m. In moist and/or clay-laden soils and soils with high electrical conductivity, penetration is sometimes only a few centimetres.
Type of equipment	Control	Measurement and control	Control	Measurement and control	Measurement and control	Measurement and control
Frequency diapason	1-28 frequencies - 2,5-100 kHz.	—	Equipment is set to receive normal earth electromagnetic field emissivity on frequency from 10 Hz to 10 kHz.	1, 3, 10 frequencies from 330 Hz to 96 kHz.	14 frequencies - 2,5-250 kHz (harmonical signal).	1-4 frequencies from 100 kHz to 3,5 GHz (quasi-harmonical signal).
Qty and type of sensors (antennas, coils, etc.)	1 pc - transmitting coil 1 pc - receiving coil	Rotating coil magnetometer Hall effect magnetometer Proton precession magnetometer Fluxgate magnetometer Cesium vapor magnetometer SQUID magnetometer SERF atomic magnetometers	From 1 to 8 - sensors It can be gradiometers, magnetometers and etc.	1 pc - transmitting coil 1 pc - receiving coil Some of devices has third coil for buckets of the primary field	1 pc - transmitter 2 pcs - magnet dipoles 1 pc - coil for primary field measuring	1 pc - transmitting antenna 1 pc - receiving antenna
Maximum penetrating depth	Depends of type and dimensions of the coil from 2,5 m to 5 m.	From 2m - maximum depth depends of dimensions of the objects.	2-4 m	7-10 m.	7-10 m	Depends of the antennas frequency and type- from 0,5 m to 100 m.
Minimal dimension of detectible object	If metal detector work on high frequency (to 100kHz) it can detect very little objects with dimensions several millimeters.	Depends on magnetometer sensitivity. Detectable object can has dimensions - several millimeters.	It is impossible to detect small objects (coin) with such detectors (maybe if the penetrating depth several centimeters). Anomaly detectors use to define geopathogenic zones, big geological fracture, big ferrous objects, big cavity and etc. It is not effective to use anomaly detector for archeological work - but it is fast method to find any big anomaly on the ground. Maximum depth depends of size of anomaly and type of sensors.	Objects with dimensions start from 15x15 cm	Objects with dimensions start from 15x15 cm	W**ith high frequency antennas** It is possible to detect objects with dimensions - several centimeters, but the penetrating depth for small objects about 0,3-1 m. Also it is important that operator must have good experience in analyzing of GPR data.
Detectable objects	Metal objects (Non-ferrous and ferrous)	Just ferromagnetics (objects that conclude ferrous)	Ferromagnetic, difference of near surface magnetic field.	Any objects that has contrast difference of conductivity value from the ground. (conductors, dielectrics)	Any objects that has contrast difference of conductivity value from the ground. (conductors, dielectrics)	Contrast anomalies from any objects.
Data interpretation	Target ID visualization, characteristic of signal in VDI value, visualization, and etc.	Arrow visualization, diagram of the values, graphical representation of the magnetizing force dynamic (with optional data collector and specific software).	Boundary identity of the anomalies from the ground. Arrow visualization or graphical representation of the magnetizing force dynamic (with optional data collector and specific software).	Visualization of apparent conductivity (and other transformations of signal) spreading on several frequencies. - maps for each freq. - 1D/2D inversion for some case.	Visualization of conductivity spreading on several frequencies - maps for each freq.; - 3D visualization of signal spreading; - 1D/2D inversion for some case.	Visualization of the boundary of the contrast underground anomalies on two dimension «depth cut» plane. Operator must has special experience for GPR data interpretation. If GPR has optional equipment for position tracking - it is possible to get 3D visualization of the underground anomalies.
Visualization						
						
						
Good sides of devices	Possibility to recognize type of the metal. High speed of detecting. Simple interpretation.	Possibility to use magnetometer for discrimination of ferrous objects on the depth more then 1m. High sensitivity for big ferrous objects.	Easy localization of the geo-anomalies.	Operative mapping of the conductivity spreading on different frequency. Some devices (GSSI EMP-400) has real-time visualization (only maps) and GPS tracking. Simple interpretation.	Possibility to scan big areas in automatic mode with GPS tracking and real-time visualization of maps and profiles. Good noise immunity (sensitivity 50nV). Simple 3D visualization. Best additional equipment with the GPR. Simple interpretation.	Fast receiving of «depth cuts». Good accuracy of depth measuring. Good depth penetrating with special antennas.
Bad sides of devices	Sensitivity only to metal objects. Low depth penetrating. Impossible for depth measuring (more then 30cm). Low depth of right discrimination (below 1m).	Sensitivity only to ferromagnetic.	Sensitivity only to big anomalies. Very often false signals because of sensors type. Impossible for depth measuring.	Impossible for work on high conductivity structure.	Impossible for work on high conductivity structure.	Difficult data interpretation. Measuring environment must be homogeneous. Some of GPRs needs for optional equipment for good noise immunity.
Brands on the market	Famous brands of deep metal detectors: «Whites» - UK, «Minelab» - Australia, «Garrett» - USA, «Fisher» - German, «Lorenz» - UK, «DETECH» - USA, and others.	Famous brands: «Foerster Group» - Germany, «GEM System» - Canada, «Scintrex» - Canada, «Geometrics» - USA, and others	Manufactures of anomaly detectors (imagers): «Accurate locators» - USA, «OKM» - Germany, «KTS-electronic» - Germany, and others.	EM-31 - «Geonics» - Canada, EMP-400 - «GSSI» - USA, GEM-300 - «GSSI» - USA, GEM-2 - «Geophex» - USA, and others.	Scanner NEMFIS and profiler AEMP-14 developed by Russian Science Academy in A.A. Trofimuk Institute of Petroleum Geology and Geophysics.	Famous brands: «GSSI» - USA, «Mala-Geoscience» - Sweden, «Geotech» - Russia, «Radar Systems» - Latvia, and others.
Cost of the equipment	From 700 € to 8000 €	From 1000 € to 30000 €	From 2500 € to 43000 €	From 12000 € to 20000 €	From 9200 € to 13000 €	From 10000 € to 150000 €