

SCG010-01

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## Near-Surface 3D Imaging of Buried Metallic Objects Using Real-Time Data Fusion of GPR and IGPS

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### ABSTRACT

The 3-Dimensional GPR image allowed the generation of time/depth slices images that effectively illustrate the geometry of the near surface structures. Moreover, crossline image resolution in the order of centimeters is needed for detecting small targets. Therefore, a new 3D GPR system has been developed to measure the position with millimeter accuracy. In this system, positions data is obtained by iGPS, which provides millimeter accuracy x, y, and z coordinates simultaneously from a small detectors attached to moving GPR antennas. For a heterogeneous subsurface, minimum grid spacing of GPR measurements is required and has to be an eighth of a wavelength or less in all directions for correct grid-point assignment. This clear image could not be achieved with the conventional GPR which includes a few centimeter position errors.

A 500 MHz commercial GPR system and rotary laser positioning system (RLPS) have been used at two pre-designed test sites belong to Osaka Gas Company. These two sites have quiet complicated buried pipes at different depths and with different diameters. The data was acquired along survey having 5cm inline and 2.5cm crossline spacing. Both iGPS and GPR data is stored independently and later regularized, fused and re-arranged on rectangular grid. A 3D-fk migration of the three dimensional fused data on the basis of a constant velocity (7.5 cm/ns) is performed. The 3D migrated depth slice data has been used for picking the buried objectives only by extracting the positive and negative high amplitudes in each individual slice. Such high amplitudes picks have been displayed in a 3D cube for better visualization.

Keywords: IGPS, GPR, Data fusion, 3D-fk migration, 3D imaging, Buried objectives

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## Characterizing subsurface fractures based on forward molding of EM scattering from synthesized fractal fractures

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We developed a new full polarimetry subsurface borehole radar measuring system which can be applied for several applications one of them is subsurface fractures characterization. But, In order to understand the scattering behavior of electromagnetic waves from subsurface fractures, we utilize FDTD numerical simulation for synthesized fracture models. In this approach we use single fracture model as it represents the nucleus for whole fracture set and from it we realize the interaction of electromagnetic wave fractures. These synthetic fractures have isotropic surfaces and were created by a spectral method based on fractional Brownian motion. Thus the fractal surface is created by the inverse Fourier transform of the spectrum components with random phase that are given according to the scaling law of the surface height. On the other hand, the upper fracture surface is created by introducing spectrum components for the lower surface with the same amplitude as that of the upper surface but with a different relative phase from the lower surface. For simplification, we maintained a constant fracture aperture which can be considered as normal fracture case with full water saturated type for examination the fracture roughness parameter. In FDTD model, we use plane wave as electromagnetic source and frequency ranges between 1 MHz up to 200 MHz. Firstly, We observe the electromagnetic scattering for one fractal rough fracture aperture and examine the electromagnetic scattering properties from various fracture rough surfaces with 3 cm fracture aperture width and we concluded that the cross polarization (HV and VH) is a significant component for characterizing subsurface fractures where its mean power scattering matrix values are increasing with roughness of fracture models parameter for normal incidence plane wave case. Entropy and Alpha distribution are well known parameters for characterizing the scattering mechanism in SAR remote sensing; we proposed the same configuration in our forward modeling for EM scattering from fracture model by 2D observation plane which can be represented as SAR image. 2D observation plane is located regularly in X and Y directions close to the fracture model with a fixed separation in both directions to recover the scattering from certain illuminated zone from fracture surface. Analyzing the Entropy and Alpha distribution parameters at each single frequency from synthesized fractal fracture we notice variability of the results due to fracture roughness parameter as Entropy-Alpha distribution values increasing especially at 60 MHz and 80 MHz with RMS fracture roughness. Furthermore, we characterize the fracture aperture content when it has water, air and hydrocarbon filled materials and we figure out that Entropy parameters is the high for water filled fracture aperture as the scattering complexity is the largest in this case.

**Keywords:** subsurface fracture characterization, FDTD modeling, full polarimetry borehole radar, power scattering matrix, Entropy and Alpha distribution

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## PSO vs. GA vs. VFSA: A comparison of performance, accuracy and resolution with respect to inversion of SP data.

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### Introduction

The process of geophysical inversion is pivotal to data interpretation. It aims to find the closest fitting relationship between the observed and computed data obtained henceforth. The target of finding the best model among viable alternates that produces the least deviation from the observed data is known as optimization. This paper aims to compare three global optimization methods namely Genetic Algorithm (GA), Very Fast Simulated Annealing (VFSA) and Particle Swarm Optimization (PSO) in reference to inverting Self Potential (SP) data.

### Algorithms

Genetic Algorithm (GA) is a global optimization algorithm that mimics the process of biological evolution to find the best solution. It operates by meta-heuristic way which generates solution to optimization problems using techniques inspired by natural evolution such as inheritance, mutation, selection and crossover. Solutions are represented generally in strings of real numbers. Unlike GA, Particle Swarm Optimization (PSO) is a population based stochastic optimization technique which works on principle inspired by social behavior of bird flocking. Convergence to obtain optimum solution is carried out by calculating fitness value at each iteration and correcting those using local and global best in the neighborhood. On the other hand, Very Fast Simulated Annealing (VFSA), a variant of Simulated Annealing simulates the physical process of annealing which cools a heated object very slowly to minimize the randomness in the system and hence the energy. Here the error function is the analogous equivalent of energy that is optimized to reach a global minima.

### Forward Equation

$$K[(x-x_0)\cos(a)+(z)\sin(a)]/[(x-x_0)^2+z^2]^q$$

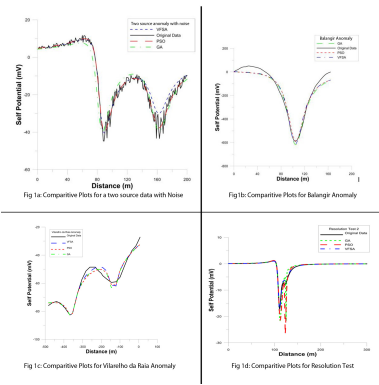
### Data and Models

Self-Potential (SP) anomalies in general are used for mineral and ground water exploration. The SP anomaly due simple geometric bodies is given by a simple equation which forms the forward problem in this inversion scheme and gives the position( $x_0$ ), depth( $z$ ), dipole moment( $K$ ), shape( $q$ ) and angle of polarization( $a$ ) of the source body. The algorithms were tested on the basis of their performance, accuracy and flexibility. Mean Square Error was taken as the objective function in all the cases. Both synthetic and field data were used to evaluate the algorithms. Among synthetic data there were both noise free and noise corrupted data sets generated by bodies of spherical and cylindrical shapes. To increase the complexity, a combination of two sources in the same profile was also implemented with after adding 20% random noise. Additionally, a resolution test was performed which outlined the ability of an algorithm to resolve two closely placed bodies exhibiting SP anomalies. The distance between the two sources was initially kept at 10m with 10m increments in the subsequent data sets. Finally, two field datasets from Balangir, India and Vilarelho da Raia region, Portugal were inverted and the results were compared. While the former field dataset was a single source anomaly, the latter was a two source anomaly. The comparative plots of the field anomalies are shown in Fig. 1b and Fig. 1c while those of a two source anomaly and one of the resolution tests are shown in Fig. 1a and Fig. 1d respectively.

### Conclusions

All the three algorithm were coded in FORTRAN77. The results obtained by three algorithms were comparable. However, the resolution capability of VFSA was the best followed by PSO and VFSA. PSO obtained the optimum results quicker than

the other two. The variable probabilistic parameters were the least and very well established in the case of PSO. As a result fine gained control over the algorithm was quite easy. However, with GA and VFSA there were more probabilistic parameters which made fine tuning quite an effort.



**Keywords:** Self Potential, Inversion, Optimization, Particle Swarm Optimization, Very Fast Simulated Annealing, Genetic Algorithm

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## Quantitative estimation for solute movement in vadose zone beased on crosshole radar data and petrophysical relationship

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One of the best ways to solve problems with nitrate contamination of groundwater in agricultural areas is to improve fertilization and farming methods to reduce the leaching rate and impacts of nitrate to the groundwater. Recently, we can find some successful examples of the effort of farmers that maintain low input farming to overcome this problem. On the contrary, we can find cases in which the improvement of farming and the reduction of the amount of fertilizer applied have little effect for improving the quality of groundwater.

In order to maintain sustainable efforts in agriculture for environmental conservation, contamination and purification processes must be clarified. However, it is difficult to explain all the processes because they are subsurface phenomena and cannot be observed directly. This uncertainty and opacity are major obstacles to the improvement of water quality in watersheds contaminated by non-point sources. A technique to clarify the contamination process and to assess the effects of nitrate leaching rate, rain infiltration ratio and other principal factors affecting groundwater quality should be established.

Clarification and quantitative estimation of hydrological phenomena in the deep vadose zone are essential and necessary in environmental science and engineering. However, it is difficult to explain these phenomena because of a lack of proper measurement methods. We propose a method to monitor soil water and solute dynamics quantitatively in the vadose zone. This approach is based on time-lapse cross-borehole ground-penetrating radar (GPR) measurements in the vadose zone and petrophysical relationship between electromagnetic property of soil and soil solution.

The objective of this research is to develop a method to clarify the dynamics of soil water and solute quantitatively in the vadose zone, which is a zone of unsaturated soil from soil surface to groundwater. The proposed method was tested in Makinohara Plateau in Shizuoka Prefecture to evaluate the applicability.

**Keywords:** Ground Penetrating Radar (GPR), Cross-hole geophysics, Time-lapse, Vadose zone hydro-geophysics, Soil environment, Solute movement

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## 2010 ARCHAEOGEOPHYSICAL STUDIES CONDUCTED AT HARSENA PALACE OF FORTRESS OF THE MAIDENS

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The province of Amasya is located inland of the Central Black Sea Region. The province is between 34.57- 36.31 east longitude and 41.04 - 40.16 north latitude. The sea level of the province is 1,150 m and its provincial center is 411.69 m above sea level. Amasya (Amaseia) is an important city in the history of Anatolia. The city was given the name Hakmis/Hakpis according to Hittite sources. The Amasya Fortress was founded on Mount Harsena as the most convenient place to defend the city. From the Early Bronze Age (3200 BC) to the end of the Ottoman period, it was used for defense purposes. The first settlement at Amasya commenced around 5500 BC and continued without interruption under the Hittites, Phrygians, Kimmers, Scythians, Lydians, Persians, Hellenes, (Pontuians), Romans, Byzantines, Danismends, Seljuks, Ilkhanids and Ottoman periods. The fortress standing at the northern end of Amasya consists of three sections known as the Inner Town (Hatuniye Neighborhood), the Palace of Maidens and the Upper Fortress (Har?ena).

During the Hellenistic Age, the Tombs of the Pontic Kings in Amasya, as the capital of the Pontic kings between 333 BC and 26 AD, were carved from calcareous rocks in the southern foothills of Mount Harsena. The Fortress has four gates named: Belkis, Saray, Maydonos and Meydan, a water well named Cilanbolu, as well as a cistern and prisons. Seventy meters below the fortress is an underground stairway dating back to 3 BC that stretches to the Kizilirmak River and the Tombs of the Kings as well as the remains of a bastion and a mosque.

On the southern skirts of the fortress, the remains of the Palace of the Maidens used by the Ottomans as well as a 20-25 meter straight wall rising from the mountain skirts that is carved from calcareous rocks and that includes 18 large and small stone cemeteries dating from 3 BC can be found.

The Palace of the Maidens is below the caves which are located above the inner fortress. When the niece of governor Isfendiyar Bey, Dograk Hatun arrived at Amasya and not being able to enter the Seljuk Palace, the Palace of the Maidens was built. The Palace of the Maidens housed Ottoman princes, ladies and governors for over 150 years and was used continuously until 1852. Today it stands in ruins.

In terms of topographic location, Amasya exists today without having changed for centuries. Founded on the skirts of the valley where the Kizilirmak (Iris) River flows through, for reasons of settlement, security and defense, it was built among the rising foothills north of the Kizilirmak River among a hill surrounded by a fortress and expanded from the slopes to the floor of valley as security was made available.

The Fortress of Amasya consists of three main sections of Lower City that declines from the top to the lower end; the fortress terrace (basilica) known as the Palace of the Maidens and the Upper Fortress known as the Harsena Fortress. The section known as the Palace of the Maidens of Amasya Fortress is on a terrace that is against the mountain behind it.

Using geophysical techniques in archaeological site is rather important in terms of both saving time and reducing the cost. For these reasons, in order to research foundation structure of Amasya Fortress and to determine the locations in which excavations will be executed in the 2011 excavation season, GPR and magnetometer methods were used in Amasya. After taken magnetic and GPR measurements, it was clear that the magnetic maps and GPR radargrams indicated regular anomalies in the foundation of structure. In the light of these data, it was decided that trenches will be executed at these locations during the 2011 excavation season.

Keywords: Amasya- Harsena Castle, Archaeogeophysics, Magnetic Survey, GPR

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## ARCHAEOGEOPHYSICAL STUDIES CONDUCTED ON SINOP MITRIDATES PALACE (BALATLAR CHURCH)

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Sinop, Turkey was founded at the tip of Cape Boztepe on Sinop Peninsula on the most northern edge of the Black Sea coast. The Balat Church complex in Sinop houses a stratigraphic structure stretching from Roman times to the Ottoman period. These structures include an area that has been systematically used for long periods from the Romans to the Ottoman State on the Black Sea coast of Anatolia.

From the early period to the present day since Sinop was built on the same location, it is not easy to discern the urban fabric of different periods. Within the city, the most important archeological finding involving the late Roman and early Byzantium periods, and known in scientific journals and colloquially, is the Balatlar Church or the Mitridates Palace. This site is a cross planned large structure and although there are no remains of the roof of the structure, the 5 to 6 m height walls have remained intact to this day and consist of what may be defined as triangular planned chambers that are inter-connected to each other. Despite the fact that only the outer walls remain standing, remnants or traces of carriers or the grounds of the inner sections of the area surrounded by the walls are not present. The remains of a cistern of four sections attached to each other that is triangularly planned and that is covered with barrel vaults are assumed to be related to this structure.

The building complex known as Balatlar Church is surrounded by chambers with high walls that are connected to each other. This large complex considered as an important structure when first built was used for different purposes in later periods. Various views on the function of the structure are as follows: It is thought that the name Balat comes from the Latin Palatium and that it was a palace dating back to the late Roman-early Byzantium period. Historical sources indicate the existence of large silos that stored grains arriving from the northern Black Sea to Sinop during the Byzantium Empire. Since a large part of the remnants of the structure are in the shape of large chambers, it is assumed by researchers that these chambers were used to store grains. Another hypothesis is that the structure might be a section of well-known gymnasium of Sinop bath (Thermae) complex dating back to the Roman period. The fact that large cisterns are located nearby and that layout of the plan recalls the monumental baths of Roma increases the likelihood that this hypothesis is correct. It is also assumed that the structure was used as a monastery at a later time.

Given historical past of Sinop, the Pontos inscriptions on the walls and being known as a palace, the debate on what the function of the Balat Church complex is still continues. The Palace has been considered as a grain silo, as a gymnasium bath (bearing in mind its scale) or as a monastery. However, the common view of researchers is that it is not possible to know the period the structure was built, its phases and its functions until excavation work is conducted on the site.

In planning the excavation work on the Balat Church complex, geophysical work was conducted in identifying the existence of the architectural remains of the well-known gymnasium bath complex of Sinop dating back to Roman times: the Pistina (pool), Apoditerium (the changing room section), Caldarium (the hottest section of the baths), Hypocaust (the heating installations section) and the Tepidarium (the tepid section of the baths). Using a proton magnetometer, a measurement of the vertical gradient was taken of the site. With the magnetic maps obtained, the magnetic anomalies attributed to the architectural remains of the underground heating installation made up of brick or stone columns where hot air could freely circulate from the hearth or furnace of the Roman bath were identified.

Keywords: Sinop-Mitridates Palace, Archaeogeophysics, Magnetometer, Balatlar Church, Gymnasium, Roma Bath

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## Reconnaissance Geophysical Survey of groundwater aquifer at Ayun Musa Hot Springs, Egypt

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Since the beginning of the history, Sinai Peninsula is one of the main geographic units of Egypt. It lies at the crossroads of the continents of Africa and Asia, and actually represents the Asiatic part of Egypt. It had always been evident that Sinai region has a great economic development. Now, Sinai is moving rapidly towards huge investments in development. Groundwater is one of the main resources for such development projects. One of the targeted areas for development is Ayun Musa area.

Ayun Musa area lies on the Eastern side of the Gulf of Suez. Generally, the area is flat, but includes a few minor topographic highs occurring at different localities in the central and eastern parts of the studied area. The geological succession at Ayun Musa area starts by the Miocene rocks represented by Marl, sandstone, and limestone at other parts with thickness up to 150 m. This is, uncomfortably, followed by lower Cretaceous Nubian sandstone. The Nubian series in the area is differentiated mainly into marine formations of upper Jurassic and Lower Cretaceous age with dominant thickness succession of clays and Limestone containing intercalated water-bearing sandstone with thickness up to 150 meters. This unit is followed by upper Jurassic rocks of Marl, sandy limestone interbeds with total thickness of 110meters.

Structurally, the Gulf of Suez depression is one of the most intensively faulted area in Egypt. Many tectonic movements have taken place in the area since early times of Precambrian. During the early cretaceous to late Miocene period, there was vertical uplifting of the earth's crust, together with the effect of the complicated tectonics that arose from anticlockwise rotation of Arabian relative to African plates during that period. Locally at Ayun Musa area, there is a major uplifting system extending ENE-WSW direction.

The geophysical investigation described in this work was carried out by DC resistivity survey utilizing Schlumberger array of electrode separation. Nineteen Vertical electrical sounding stations (VES) were measured in the area. The electrode separation started with  $AB/2 = 2$  up to 1000 meters in successive steps. The distance between stations varies between 300 and 500 meter as to be more or less in grid pattern. However, some considerations had been taken into the account such as the land surface slope might not be more than 30 degree along the spread. Such points imply the basis and the applicability of the Schlumberger array. Altogether hindered us to make all the stations with the same spread direction.

Keywords: DC resistivity, groundwater, Sinai, Egypt

# Japan Geoscience Union Meeting 2011

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## Tracing a buried pipeline using multi frequency Electromagnetic

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In this paper I describe the application of multi frequency broadband electromagnetic techniques to locate buried pipelines. At desert or arid areas, regular geophysical surveys usually are difficult to carry out. EM techniques could be the best among geophysical techniques to be used for this target. The EM survey was performed using a Geophysical Survey Systems, Inc. GEM-300 multi-frequency electromagnetic profiler. It is a handheld electromagnetic induction-type instrument that measures in-phase and quadrature terrain conductivity without electrodes or direct soil contact. 6 different frequencies have been used simultaneously. The slice maps for conductivity distribution at each frequency could help to trace the extension of the pipeline.

Two pipelines were traced successfully with 20 meters spacing of each others.

Keywords: EM, conductivity, pipelines

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## Inversion of self potential anomaly using particle swarm optimization method- A MATLAB environment

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The paper deals with a novel method based on Particle Swarm Optimization (PSO) of the inversion of geoelectrical single and multiple self potential (SP) data anomaly of idealized body. The PSO algorithm is inspired from the observations of the social behavior of animals, such as bird flocking or fish schooling. PSO is also a population based optimization algorithm like other evolutionary algorithms. In this method, members of the population are called as the swarm and each individual within the swarm is called as the particle. During the solution process, each particle in the swarm explores the search space through their current positions and physical property of earth. The PSO based algorithm is developed in MATLAB environment that made users friendly and runs the algorithm to produce the results more efficiently with optimal error. This also gives advantages over other conventional environment. In order to check the stability and accuracy of the algorithm, the developed algorithm is implemented and tested on synthetic SP data and finally applied to three field data from Bakreshwar thermal region and Surda region of India and Vilarehlo da Raia region of Portugal. The performances by PSO are compared with previous results and these results are well correlated with standard squared error. In general it is observed that the PSO method is faster and its performance is better compared to previous squared error without any initial assumptions of SP anomaly

Keywords: SP data, Inversion, PSO, MATLAB

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## Characteristics of Offshore Microseism Excitations Revealed by Noise Correlations

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Taking advantage of a unique opportunity provided by a dense array of coastal short-period seismic stations and the diverse bathymetry around Taiwan, we examine how the long-range coherent ambient noises are influenced by surrounding ocean settings using the cross-correlation functions (CCFs) between pairs of stations. The effective energy of the CCFs derived from three components of short-period seismometer data falls within the frequency range of the short period secondary microseism (SPSM). The spatial variations mapped from the amplitude asymmetry of CCFs and source migration images evidently demonstrate that the SPSM strengths are closely linked to the drastic changes in offshore ocean characteristics and result in much stronger SPSM in the shallow and narrow Taiwan Strait than in deep open seas of eastern Taiwan. The temporal variations of the CCF strengths exhibit very good correlations with the wind speeds and wave heights, explicitly indicating the observed SPSM is dominated by local sources generated from wind-driven ocean waves around offshore Taiwan. We also look into the long-period microseism excitations from the continuous data recorded by broad-band stations in Taiwan, Japan and Korea. We present the preliminary results on how the microseism excitations of different frequency bands are influenced by the nearby offshore settings.

Keywords: short period secondary microseism, noise correlation, microseism excitations

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## Estimation of bedrock depth in Beijing, China, using microtremor array analysis

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In order to draw the bedrock geological map in plain area of Beijing, we conducted array measurements of microtremors at eight sites in city Beijing and its adjacent area to estimate deep S-wave structures and obtained their pre-Cenozoic bedrock depth.

We use three aperture arrays with different radii between 40 to 300m at each observation site to collect the microtremor data and estimate the phase velocities of the fundamental mode of the Rayleigh waves from the vertical components at each site by using the SPAC (Spatial Auto-Correlation) method (Aki, 1957). The estimated frequency ranges for the phase velocities were about 0.3~3.9Hz. The 1-D structure models down to a depth of about 3 km were estimated by fitting of the observed and the theoretical phase velocities through a nonlinear inversion using a genetic algorithm (GA) (Cho et al., 1999).

The results reveal that the deepest bedrock located in Beijing rift, the depth is 1510 m, and the shallowest depth is only 170 m, located in Laiguangying uplift. The difference of the pre-Cenozoic bedrock depth between eight sites in plain area of Beijing is about 1300 m. The depth of the bedrock surface has changed dramatically, related to different tectonic units. Since the deep S-wave velocity structure of Beijing City and its adjacent area had been basically unknown, we delineate it for the first time in this article using array measurement of microtremors.

**Keywords:** bedrock depth, array measurements of microtremors, spatial auto-correlation method, estimate deep S-wave structures, plain area of Beijing, China

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## The surging of the liquefied lateral flow in the Aratosawa reservoir at the initiation of huge landslide masses trigger

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The Iwate-Miyagi Nairiku Earthquake in 2008 had triggered the huge landslides in the upper reach of Aratosawa reservoir. The initiation of these landslides are closely related to the strong ground motion, the geological setting, the spatial distribution of the old landslide masses, the liquefaction of the ground, and the rise-up of the groundwater after the dam construction. These particular conditions results in a chain of instabilities of mass in the watershed. The initiations of the rapid removal of the valley sediment were the liquefaction and lateral flows of the valleys which resulted in the prompt removals or disappearances of valley sediments. And the instabilities of the foot part of the slope had triggered the huge landslides in the upper reach. The Aratosawa reservoir was constructed and filled up in the year of 1998, this earthquake was the first terrible shaking of foot of the slopes with the 20 meters of groundwater rise-up. These processes were analyzed by the use of the archived observation results of water level of Aratosawa reservoir which had been missing because of power cut just after the main shock. The prompt first rise-up of the water level suggests the propagation of the hydraulic bore generated by the rush-in of the liquefied lateral flow in the reservoir, and the second slow rise-up of the water level corresponds to the creeping intrusion of the huge landslide masses into the reservoir. The density and the velocity of the first liquefied lateral flow were large enough to crash the bridge in upper reach of the Shitsumikukisawa valley.

Keywords: Iwate-Miyagi Nairiku Earthquake, Aratosawa Reservoir, hydraulic bore, liquefaction, landslide

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## Earthquakes induced landslides reflected by DC resistivity and high frequency electromagnetic data

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The main objective of this paper is to present the DC resistivity and high frequency electromagnetic (HFEM) monitoring system that may provide in near real-time the landslide hazard level related to the intermediate depth earthquakes occurred in the seismic active Vrancea zone (Romania). Thus, the specific methodology and software packages have been applied for obtaining all the important HFEM parameters and to point out their anomalous behavior versus the specific pattern pre-established in non geodynamic conditions. Consequently, by analyzing the data carried out at the Provita de Sus landslide (test-site), placed in Subcarpathians area, at about 100 km far away of epicenter zone, it was possible to assign the increase of the landslide motion related to the local active fault which has been reactivated by the earthquakes of magnitude higher than 4, triggered in the Vrancea zone in a span of two years (2009 and 2010). There were three more important aspects that became the major selection criteria of this landslide as test site: (i) it is an earthquake triggered landslide followed by post seismic slow slipping ground motion that can be monitored; (ii) it is situated nearby Provita de Sus locality and can endanger life and property, owing to a high probability of flood, which might be produced by damming Provita river due to rock falls into the watercourse; (iii) the existence of logistic base (Geodynamic Observatory Provita de Sus) able to supply optimal monitoring conditions and wireless connection with the Center of Bucharest. In the end, this paper illustrates the stage of the monitoring system implementation and the results highlight the utility of merging the electric (DC resistivity) and electromagnetic precursory parameters (normalised function  $B_{zn}$ , anisotropy, skewness and strike) with different 2D tomographic images associated with post seismic landslide processes. Subsequently, in the Provita de Sus test site, it was possible to provide information regarding the both specific ground motion produced by the interference between seismic triggered factors with local geotectonic conditions and landslide hazard level.

Keywords: EM data, earthquakes, landslides

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## The 3D analyses of the huge landslide mass movements triggered by the Iwate-Miyagi Nairiku Earthquake in the upper reach

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The Iwate-Miyagi Nairiku Earthquake in 2008 had triggered the huge landslides in the upper reach of Aratosawa reservoir. The huge mass movements had occurred on the adjacent slopes of the upper reach of the reservoir. The initiation of the huge mass was directly the strong ground motion of the main shock. The following liquefaction had occurred in the valley bottom of the slopes, and valley bottom sediments run out from valley. Several parts or masses had triggered to move to down slope after the rush-in of the lateral flow from the valleys. The cross sectional explanations of the landslide mass movements were reported by The Japan Landslide Society(2009). The behaviors of huge landslide masses were too complicate to discuss in two dimensions with single cross section. Then 3D analyses were tried to clarify the movements of the huge landslide masses using DEMs.

Keywords: Iwate-Miyagi Nairiku Earthquake, Aratosawa Reservoir, landslide, 3D analyses

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## Earthquake-triggered tilts, up and down motions of a huge mass in the Aratozawa Landslide Area

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The 2008 Iwate-Miyagi Nairiku Earthquake induced a huge landslide at the upper reaches of Aratozawa reservoir. The movement of a huge mass that is 600m\*500m in size reached to about 340m in distance. We performed aftershock observations in the Aratozawa area using broad-band strong-motion seismometers. We detected transient long-period horizontal and vertical ground motions in aftershock seismograms. The long-period horizontal and vertical ground motions are due to tilts and up/ down motions of the ground triggered by aftershocks, respectively. Site amplification characteristics for the mass show a significant peak at around 1 Hz, suggesting a resonant vibration of the mass due to the incidence of seismic waves. The results obtained in this study indicate instability of the huge mass that has experienced a large landslide.

Keywords: landslide, Aratosawa Reservoir, Iwate-Miyagi Nairiku Earthquake, seismic response, ground tilting, ground rising and descending