Seismoelectric Method

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Abstract

The seismoelectric method is little known in Brazil but has very interesting applications, especially for the environmental area, as the review below demonstrates.

Introdutcion

According Dupois, 2008, the seismoelectric method identifies the changes in porosity, permeability and pore fluid with contrasts, may assist in the management of groundwater, generating information on infiltration, consolidation and stability of the soil, therefore, the electrokinetic properties of soil obtained from the seismoelectric experiments can help engineers and scientists in developing eletro-osmosis remediation campaigns to determine the contaminants from soil or drainage and thus to stabilize the land.

Method

The first method was proposed to be seismoelectric modulation of constant tension in the Earth by seismic stress, which is also known as J-effect on Russian literature (Ivanov, 1949).

Staham and Blau, 1936, a patent document, describe an invention that uses a larger volume of soil samples from a seismograph, and should alleviate some problems caused by surface wear. They also stress that the modulation of the resistivity that occurs at depth, should be perceived on the surface before the waves reach the sensor surface, thus allowing a separation of surface waves and reflection.

Thompson (1936) is the first to report these seismoelectric measurements in the scientific literature. The battery connected to the primary winding of a transformer is used to inject a constant current to the ground through two grounding electrodes. The transformer is used to separate the modulation signal of the current applied to the electrodes. Since the modulated signal is time dependent, it is felt by the secondary winding of the transformer, while the battery current does not induce a response (once the transformer core saturation is not taken).

Thompson (1936) quickly discovered that the sources of noise limit the ability to make seismoelectric measurements. The two sources of noise that he identifies are: (1) contact impedance, which resolved partially wetting the soil with a salt solution, and (2) possible telluric currents, which protects with a three electrode array. He also notes that the modulated signal is largely generated at the site where the electric gradient is higher (ie the electrodes) and therefore not part of the seismic activity uniformly. Later, Thompson (1939) uses an inductive charging circuit test to demonstrate that the signal is generated by modulating the resistivity and not just the surface of the electrode effects.

It is interesting to note that the telluric currents are often discussed as a potential source for producing signals sismoelétricos due to modulation of the resistivity. In practice, the experiments reported in the literature often use a current source applied to the land through earth electrodes.

The ability to modulate strong telluric currents still exists but has not been reported in the literature, except by Dupuis et al. (2007), which may explain the strong signal non-inverting simultaneously observed at times early in the shot. Also interesting is that in the experiments reported seismoelectric signs related to modulation of seismic stress of ground currents associated with the power grid, which are a strong source of noise in making electrical measurements. It is possible that these currents can be modulated and produce seismoelectric signals. The polarity of the signal simultaneously observed for the individual shot records would be similar to what is expected to telluric currents (ie, non-inverting both sides of the shooting), but depends on the phase of electric current at the instant when they are modulated by seismic stress. As the seismic sources are usually not synchronized to the grid, the instant in time when the seismic stresses are applied to modular different part of alternating current that flows to the ground.

The last systematic investigation of resistivity modulation was reported by Long and Rivers (1975), who used a Wenner array to try to generate signals from deeper layers.They noted that the measured signals resembled more the compressional waves and Rayleigh.

Examples

The seismoelectric mechanism of interest in this work was first reported by Ivanov (1939). He named the effect as observed seismoelectric E-effect in order to differentiate it from the earlier reported seismoelectric effect and what he called the J-effect. The E-effect is different from the J-effect in that it is not necessary to inject current in the ground to observe the signal. To confirm that the signal observed by him was not the modulation of the telluric currents, he detonated explosives in front and beside the electrodes and noted that the polarity of the signal changed with the location shooting. This characteristic does not fit the model of resistivity modulation, since the compression of the land by a tidal wave that comes under the electrodes to change the resistivity in the same way, regardless of the direction from which the wave traveled.

Martner and Sparks (1959) were the first to notice seismoelectric interfacial signals to b electrokinetic in origin. In their first experiment, the shots were fired at different depths seismoelectric variables and signals were measured by electrical receptors on the surface. They observed a "electroseismic pulse " that was generated in the basement and reached the surface before the first seismic signal. In a second experiment, the explosives were detonated in the shot depth, while sismoelétricos signals were measured by a single electrode placed in a hole and referenced to the surface.

During the 1960s, seismoelectric methods were tested to determine whether they were effective for detecting nuclear explosions.
According Dupois (2008), the experiments of Zablocki and Keller (1961) and Broding et al. (1963) concluded that the seismographs and geophones are more sensitive and easier to use wider, the standard plain surface conditions.

During the years 1970 and 1980, Russian scientists have continued with efforts to develop the seismoelectric method as a tool for mineral exploration. The experiences and advances made by the Russians to use piezoelectric and electrokinetic phenomena during this time, are described by Neishtadt et al. (2006). In the west, seismoelectric method seemed to fall into disuse until the 1990s.

Dupois (2008) explains that the interest in seismoelectric effects in Western literature was given by Thompson and Gist (1993), who presented the results of large-scale seismoelectric experiments, where seismoelectric interfacial signals images were used for interfaces between sands of high permeability and water-saturated shale low permeability to depths of 300 m. They give the first description of the interfacial characteristics of the signal that must arrive simultaneously at spaced receivers, and exhibit the symmetry and amplitude of variation of a dipole source located at the interface.
He also puts the first laboratory experiments that relate seismoelectric effects of electrokinetic origin are summarized in Parkhomenko (1971), although the literature has several typos that make it difficult to obtain original copies of the cited work.

According to Parkhomenko (1971), Mauchly (1918) was the first to observe the effect sismoelétricos laboratory while he was trying to understand the effects of pressure and temperature on the earth current measurements. Sandy soil was packed in a glass tube (amalgamated zinc) electrodes were placed at the top and bottom of the tube. Mauchly saw a different potential between the electrodes and a polarity reversal when the vial was turned upside down. He commented that this effect was observed when the matter was neither completely dry nor completely saturated. Experiments by Antsyferov (1958, 1962), using an active source of ultrasound found that the signal amplitude was dependent on sismoelétricos water saturation of a sample of slate.

Chen and Mu (2005) developed an experiment in an enclosure made of acrylic. An ultrasound transducer was used as a piezoelectric source and platinum electrodes were used in combination with a data acquisition system for measuring signals sismoelétricos. Filled with quartz sand and sodium chloride solutions of varying concentrations were used in the experiments. The authors found that the amplitude of the co-seismic had a strong dependence on electrolyte concentration. At concentration of 0.3%, the maximum amplitude was observed, whereas for electrolyte concentrations below and above this point, the amplitudes were lower.

In a second set of experiments, a layer of oil was introduced into the system. The interfacial signals were measured, but the data showed a strong bias DC-component that obscured much of the character of the signal.

The dependence of seismoelectric signal amplitude electrolyte concentration and hence conductivity, was revised in experiments by Block and Harris (2006). Their experimental setup consisted of a cylindrical tube made of PVC that medium grain sand or glass beads were saturated with solutions of NaCl concentration variável. Nine electrodes Ag / AgCl were distributed vertically in the column and used to measure the seismoelectric signals. The source was a 100 kHz transducer driven with bursts of 50 kHz sine wave. This source was placed at the top of the column and was separated from the porous material by ≈ 1 m of saline. Block and Harris noted signs in interfacial fluid interface ua / sediment and a decrease monotonical measure of the extent of co-seismic signal with the electrolyte concentration increased. This result is different from that of microspheres obtained by Chen and Mu (2005) using quartz sand.

The numerical model presented by Block and Harris (2006), which provides the amplitude of the co-seismic, offered an explanation for the behavior observed by Chen and Mu (2005), and for their own data. The increase in the amplitude of the co-seismic with increasing electrolyte concentration occurs because the sands are not negligible surface conductivity. The peak amplitude occurs when the contributions from the driving surface and pores, are approximately equal.

Results

Ivanov (1939), demonstrated that there was observed the electrical signal related to the vibration of the electrode, varying its mass and observing that the signal was independent of the mechanical vibration of the electrodes. As an additional confirmation, he noted that the E-effect is often preceded by seismic waves, and therefore exist before any vibration of the electrodes. At the end of the article, Ivanov warns the reader that these effects were only observed in the district of the former USSR, Bashkir, and they were only observed above the background noise when large loads of explosives were used, which limits its usefulness.

The following year he published a second article Ivanov (Ivanov, 1940) where he also presented results of field and explained some of the potential origin of the E-effect seismoelectric effect who also drew the second type. In their experiments, only one channel was recorded which made it very difficult to determine the source of the electrical signal from the ball fields, which are often similar to the characteristics of the E-effect. Attempts were made to subtract a signal reference electrode remotely using the three methods proposed by Thompson (1936), the attempts failed due to impedance mismatch local contact. In discussing the results, Ivanov rejected the piezoelectric effect to explain the measured signals and suggests that the signal can be of electrokinetic origin.

Already Martner Sparks (1959) based on his observations concluded that the signal was generated seismoelectric interfacial layer at the base of weathering. This led them to propose that the difference in arrival time between a critically refracted P wave signal sismoelétricos and can be used to determine the thickness of the weathered zone.

Thompson and Gist (1993), concluded his article by proposing and that more efforts be made to develop methods and sismoelétricos eletrossismicos for surface exploration and environmental applications.

According Dupois (2008), this successful field by Thompson and Gist (1993) is soon followed near the surface of experiments that record signals of interfacial shallow interfaces (Butler et al., 1994, 1996, Wolfe et al., 1996, Mikhailov et al., 1997a). The interfacial signal appears at the beginning of seismoelectric recorded.These initial signs, however, in some cases become difficult to distinguish the origin of related disorders.

Dupois explain that the other experiments Parkhomenko and San-Chien (1964) and Gaskarov and Parkhomenko (1971) corroborate the dependence of the amplitude of the seismoelectric signals with water content, and showed no seismoelectric signs generated when the samples are completely dry. The field sismoelétricos rapidly increases the initial introduction of moisture in the sample, but the humidity also increases is modest. The abrupt increase observed in the seismoelectric effect on water saturation is low, intuitively satisfactory, because the electrical double layer can only be formed if the pore fluid counterions are present.

Latest in Russian literature (Fedotov et al., 2004) explains this dependence on moisture in the soil for the presence of an organo-gel layer made of colloidal particles coating the solid grains. In soils that are formed by weathering to contain organic compounds, gelation is reported to be especially pronounced. Fedotov et al. (2004) explain that the organo-gel forms a network that can effect a soil properties such as mechanical properties, salt and different fusion rates electrokinetic / seismoelectric response.

This network organo mineral gel can be destroyed by drying the soil samples and can be completely restored by addition of distilled water until the water content reaches its natural level. After enough moisture is present to form the electrical double layer, increases in water content can actually lead to a decrease in amplitude as observed by sismoelétricos Gaskarov and Parkhomenko (1971) on one of their samples of lime when the water saturation increased more than 60%.

After the derivation of the governing equations for seismolectric effects in porous media saturated by Pride (1994) and Pride and Haartsen (1996), several scientists conducted laboratory experiments to verify the model. Zhu et al. (1999), found that measurements made at ultrasonic frequencies in the water well saturated models constructed from natural rocks (granite and slate), and artificial materials (lucite and glued sand). The receivers and the source models were placed in wells and experiences of both seismoelectric and electrosseismic experiments were made.

Zhu et al. (1999) concluded that the magnitude and frequency of seismoelectric signal is not only related to the tidal wave, but also the material properties, permeability and conductivity. They also found that the electric sources placed in any pit or hole in the wall, inducing Stonely waves could be received by monopolar acoustic transducers and the interface between lucite and sand glued producing a seismoelectric interfacial signal.

After their experiments and Mu Chen (2005) concluded that the methods are sensitive to seismoelectric interfaces oil / salt water and therefore should be of interest to the petroleum industry.

Block and Harris (2006) concluded that their numerical simulations based on equations that determined by Pride (1994), show good agreement for a wide range of pore fluid conductivity, but it is important to have a robust model of electrical conductivity when the porous medium is saturated with weak electrolytes.

Conclusions

For Dupois (2008), the amplitudes of weak seismoelectric signals has been a greatsource of difficulty intaking significant steps in the field.

Natural electromagnetic noises and cultural (human generated) are often two or three orders of magnitude larger than seismoelectric signals sought and the traditional seismic recording systems or electromagnetic / electric arenot optimized for your measurement.

The use of multi-channel acquisition systems helps

improve the ability to characterizethe signal and identify the two different types of seismoelectric signals (eg Martner andSparks, 1959, Thompson and Gist, 1993, Butler et al., 1996) .
The seismographs are by farthe most common type of acquisition data system used to acquire seismoelectric signals this time.

The digital seismographs with wide dynamic range (24 bits) makes possible the development of post-acquisition data processing to combat the noise from high voltage lines, which is the strongest source of noise observed in experiments in many fields of North America .

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