SOLUTION MINING RESEARCH INSTITUTE
www.solutionmining.org

105 Apple Valley Circle
Clarks Summit, PA 18411, USA

Telephone: +1 570-585-8092

Technical
Conference
Paper

Introducing SEISMOSAL®
a New Revolutionary Method of Prospecting for Salt

ATS Electro-Seismic Mapping of Salt Deposits of Swiss Salines at Riburg, Switzerland

Vladimir M. Sedivy

Salt Partners Ltd., Erlenbach-Zurich, Switzerland

John McKendry, Michael du Preez

ATS Group, Gisborne, New Zealand

SMRI Fall 2018 Conference
24-25 September 2018
Belfast, Northern Ireland, UK

Solution Mining Research Institute Fall 2018 Conference
Belfast, Northern Ireland, UK, 24-25 September 2018

Introducing SEISMOSAL® - Revolutionary Method of Prospecting for Salt
ATS Electro-Seismic Mapping of Salt Deposits of Swiss Salines at Riburg, Switzerland

Vladimir M. Sedivy
Salt Partners Ltd., Erlenbach-Zurich, Switzerland

John McKendry, Michael du Preez
ATS Group, Gisborne, New Zealand

Abstract

In March 2016, ATS Group approached Salt Partners with a proposal to test the ATS electro-seismic technology over some known salt deposits. The ATS electro-seismic technology facilitates mapping of geological structures, determination of their hydro-geological properties and 3D modelling of the results.

Salt Partners are active in the field of salt production and processing. It includes consultancy concerning feasibility of exploitation of salt and brine deposits. This requires drilling and core sampling, but the number of boreholes can be reduced if the extent of the deposit is determined, for example, by seismic exploration. The ATS electro-seismic method appears to be faster, more precise and cheaper, ant therefore Salt Partners adopt it for their work.

In April 2016, Salt Partners approached Swiss Salines with the request to permit electro-seismic mapping of the salt deposit located to the north of the Riburg saltworks. The ATS electro-seismic mapping was performed on 22.6.16 by Yannick Schauwecker and Vladimir M. Sedivy of Salt Partners. Erica Sedivy was shooting pictures. The required equipment consisted of a GPS camera, 250 mm diameter metal plate, 2 metal electrodes, stereo recorder with wires and a sledge hammer. 20 mapping points in 3 lines along field roads were selected for the test. Along the roads, the mapping points were approx. 70 m apart. The lines were approx. 100 m apart. The GPS and stereo recordings were sent to ATS Group for evaluation. Their report, including a 3D model of the surveyed site, was issued on 30.6.16. Information available from Swiss Salines concerning the known salt deposit profiles and qualities was then incorporated into the model. Substantial amount of work was then carried out concerning the seismic velocities and their correlation with salt physical and chemical properties. Anomalies observed at some mapping points were explained by the influence of underground pipelines and cables, pumping station and overhead power lines crossing the mapped field. The final report was issued on 12.10.17.

The ATS electro-seismic mapping method, presented in this paper, determines the location of the top and bottom of the salt layer and its profile with an accuracy of about one meter to the depth of approx. 300 meters. The 3D model also indicates the presence of intermediate layers of poor quality salt. Accurate interpretation of the results is possible when correlated with just one core sample obtained from the investigated geological formation. In addition, detailed information concerning the formations overlying the salt deposit, such as porosity and water content, is made available for planning the productive boreholes. The ATS electro-seismic mapping method can be employed to depths exceeding 5'000 meters. However, the accuracy of such application remains yet to be tested.

The ATS electro-seismic mapping method is a revolutionary advancement in prospecting for salt. It is fast, accurate and substantially more economic than conventional drilling and

seismic explorations. Salt Partners are pleased to announce the availability of ATS electro-seismic mapping method for commercial applications.

Key words: SEISMOSAL®, electro-seismic mapping, electro-telluric mapping, rock salt, sal prospecting, solution mining

1. Introduction

1.1. Standard Rock Salt Prospecting Methods

Several methods of geological prospecting in general and prospecting for rock salt deposits in particular exist and have been well established, among them geophysical methods such as gravimetric, seismic, electrical, electromagnetic, magnetic, radiometric, etc, further geochemical methods and finally various forms of borehole drilling. Whereas gravimetric methods can indicate large, diapiric formation of salt based on the difference of the density of salt around 2.15 – 2.2 t/m3, and the surrounding rock having density of say around 2.5 – 3 t/m3, seismic methods are more precise and can determine the shape of the salt deposit with higher accuracy. Geochemical methods rely on physical samples being available for analysis but the simple existence of salinity in salt springs, for example, is an evidence of salt in some form being deposited underground. Finally, drilling is the only conclusive proof of salt occurring at a certain depth below ground and the drilling logs, the core samples and their analyses provide the full information required for determination of suitability for exploitation and the most suitable mining method.

The electro-seismic mapping method presented in this paper provides new, rapid, accurate and substantially more economic method than conventional explorations. Although it cannot replace drilling as a source of analysable samples, it can determine the shape of the underground salt deposit and reduce the number of boreholes to a minimum.

1.2. ATS Geological Prospecting Suite (Geosuite)

In March 2016, Salt Partners were contacted by ATS Group New Zealand. ATS asked Salt Partners whether we would be interested to try their electro-seismic method for exploration of salt deposits. ATS Group have been developing Geosuite, a software-based geophysical tools for investigation of underground geological formations, with the prime purpose of discovering aquifers suitable for groundwater exploration. However, in the course of their work, they found that the same method can be used for exploration of oil and even gold.

Salt Partners made previous experience with core sampling of salt deposit at Cape Cross in Namibia. In 2013, we were planning a large solar rock salt recrystallisation facility there. We needed to know where precisely the rock salt deposit is located below the sandy overburden. This exploration was done by a local company by drilling. It was slow. It took at least two days to get samples of salt and mud from relatively soft ground down to depth of about 15 meters. We needed the salt layer profiles over a total area of tenths of square kilometres. The drilling took several months.

If we would have had a method where by simple hit on the ground would have told us how deep the salt is, we would have saved us months and thousands of dollars.

So, we said yes, we are interested.

2. Scientific Background

2.1. Background Work on Principles of Electro-Seismics [22]

The first work done that contributed to the development of the electro-seismic effect was done in 1944 by Frenkel. He described the relative flow of fluid to the matrix brought about by the passage of a compression seismic wave through the medium. He investigated the induced electric fields generated by this relative motion of fluid, matrix interaction with Helmholtz-Smoluchowski equations. However, his investigations did not fully explain this relationship. In 1964, Biot made further progress by developing theories that predicted movement of a seismic wave through a saturated porous media. Various advances toward the development of a general equation describing the link between the relative fluid matrix interaction, and the electro-magnetic fields induced by this motion, were formulated between 1962 and 1994. These developments include irreversible thermodynamic coupling effects in porous media and averaging of fluid volume to determine the governing equations of the electro seismic effect. Then in 1995, Haartsen and Pride explained the electromagnetic field induced by the fluid motion relative to a porous matrix as being generated by dynamic current imbalances. These current imbalances are generated by plane sheer waves moving across and interface between rocks with different electro seismic properties. These net current imbalances induce an electromagnetic field which can be read at the surface as an interface response. However, if the plain sheer waves pass through a homogeneous saturated medium, with no interfaces of different electro kinetic properties, then the net currents induced will be balanced and cancel each other out. This essentially means there is no current flow induced by the relative motion of the fluid and matrix. This means no electromagnetic fields are induced that can be read at the surface. In 1997 Haartsen and Pride made use of their findings on electromagnetic interface response to investigate electro kinetic waves from single point sources in layered rock formations. They discovered saturated media interfaces produced a response equivalent to that of a dipole induced field on the interface directly under the seismic point source. In 1980, Chandler used a theoretical model and saturated core samples in laboratory experiments to relate the rise time of electro seismic signals to permeability. However, Haartsen in 1998 proved that the electro seismic response is a function of the salinity, porosity and permeability of a porous elastic media.

2.2. The Electric Double Layer

Grains of rock display net electric charges on their surfaces due to unsatisfied chemical bonds. In an aquifer, water makes contact with these charged surfaces and an electric potential is produced, since water is also electrolytic in nature. This potential difference then draws the free ions in the water toward the surface of the grain of rock where an electric double layer is formed. An electric double layer consists of a layer of ions drawn into the solid surface by electrostatic Van der Waal forces. This inner layer is called the Stern layer, while the outer layer consists of free ions in the water drawn in by the potential difference across the rock grain surface. This outer layer is called the Gouy layer. The Stern layer is only one ion thick and as shown in Figure 1, the electric potential drops sharply across this layer. Boltzmann distributions can be used to describe the concentrations of ions in the Gouy layer, provided that the electrolytic content in the water is lower than 0.1 moles per liter. The electric potential in this layer of diffused ions is described by the following equation:

$$\varphi(x) = \varphi_0 e^{-\kappa x} \tag{1}$$

Where:

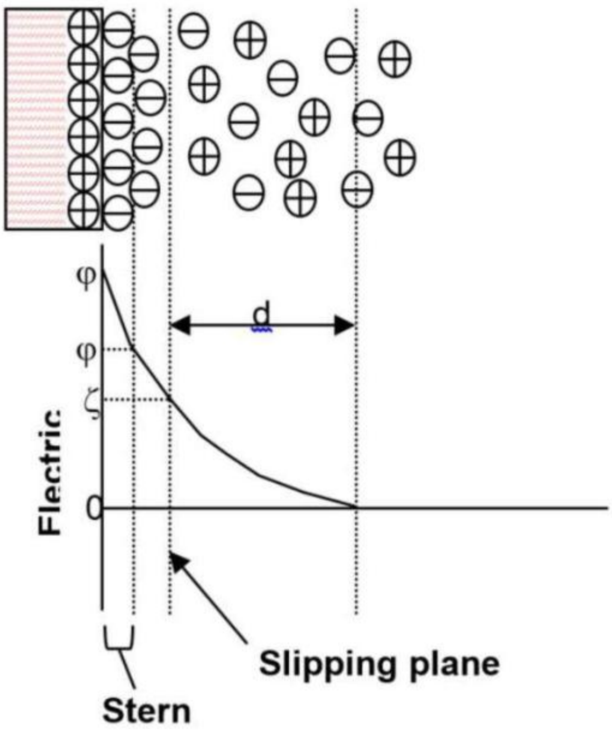
k = inverse Debye radius

χ = distance from the charged surface

The slipping plane is the area where relative movement between the solid and water allow for motion between the outer diffused layer of ions and the inner strongly bound ions. This slipping plane has an electric potential across it that is called the zeta (z) potential. This electric potential is produced by the shearing between the inner and outer ions of the Stern and Gouy Layers. The Zeta potential plays an important role in the electro kinetic effect and is part of the equation used to determine the electromagnetic coupling tensor, which in turn determines the magnitude of the electromagnetic field induced.

2.3. The Electro-Seismic Effect

Figure 1: The electric double-layer



The electro seismic effect can be observed when a fast traveling p wave intersects a water saturated interface of differing inelastic or electrical properties. The electro seismic effect is in effect a form of converted energy which is released as dissipated energy. This conversion of energy takes place when a fast-moving P waves produce slower P waves as it passes through the interface. These slow P waves produce much more movement between the rock and water. This in turn leads to a high loss of energy in the form of heat due to friction and electro seismic effects, such as electromagnetic radiation due to ionic movement. Electro seismic signals are produced by the out of phase motion between all the ions in the water and those attached to the rock. The relationship between applied pressure P and electric potential response f for a porous rock is generally given by the following equation (Millar and Clarke 1997):

$$\phi = -CP = -\left(\frac{\varepsilon\varepsilon_0\zeta}{\eta\sigma}\right)P \qquad (2)$$

Where,

ϕ = electrical potential response or streaming potential

C = electro-kinetic coefficient

P = applied pressure

$\varepsilon\varepsilon_0$ = permittivity of the pore space

ζ = zeta potential

η = fluid viscosity

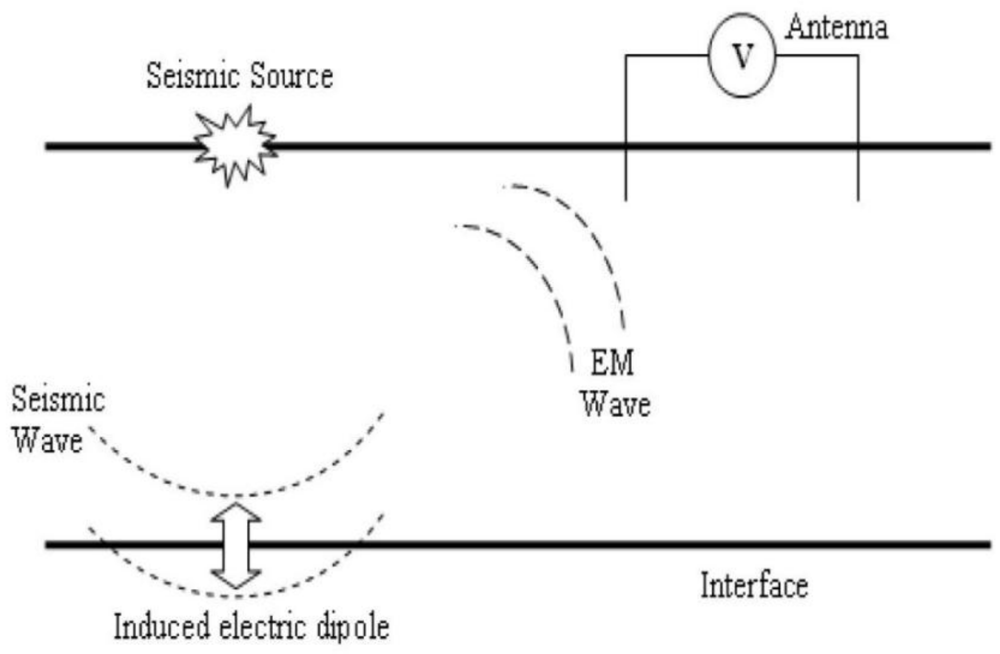
σ = electrical conductivity

This equation relates the electrical potential response f developed in a porous rock to the stimulus of an incident pressure change P, allowing the rock to be characterized by C on a macroscopic scale when modelling such electro-kinetic responses. To see how the electro-seismic function is derived please refer to Fourie's dissertation on electro-seismic field theory 2003 [6].

2.4. Seismic Wave Behavior

A seismic wave propagating in a medium can induce an electrical field or cause radiation of an electromagnetic wave. There are two electro-seismic effects that are considered in this report. The first effect is caused when a seismic wave crosses an interface between two media. When the spherical P-wave crosses the interface, it creates a dipole charge separation due to the imbalance of the streaming as shown in Figure 2. The second effect is caused when a seismic head wave travels along an interface between two media. It creates a charge separation across the interface, which induces an electrical field. This electric field moves along the interface with the head wave and can be detected by antennas when the head wave passes underneath as shown in Figure 3. Currents induced by the seismic wave on opposite sides of the interface. The electrical dipole radiates an EM wave which can be detected by remote antennas.

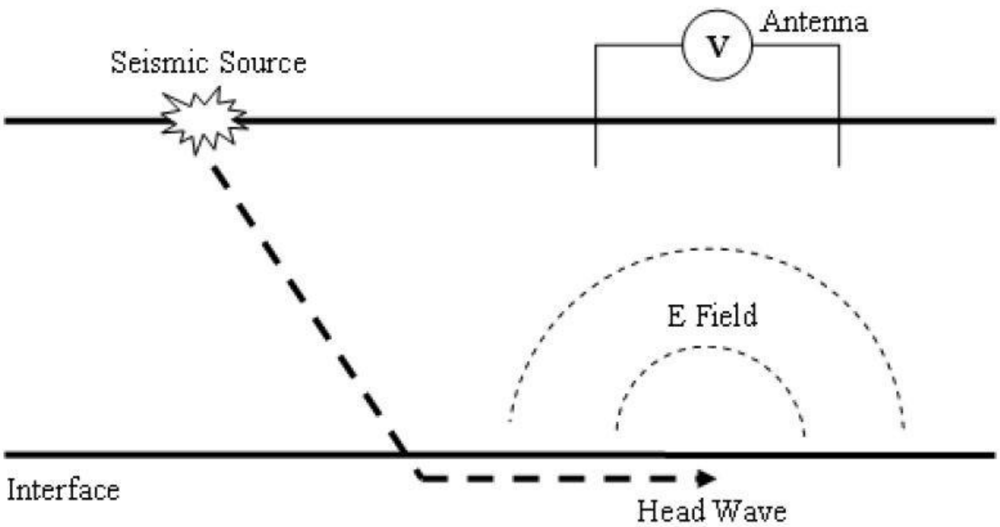
Figure 2: Seismic wave crossing an interface generating an electromagnetic wave



2.5. Electro-Telluric Geophysics

When energy from the sun make contact with the earth it causes variations in the geo-magnetic field that surrounds the earth. These variations induce electrical currents to flow within the earth surface. These currents are called telluric currents. When the frequencies of these telluric currents are low, they can penetrate thousands of meters into the earths subsurface. The higher the frequency of telluric current, the shallower the penetration into the earth will be. By measuring the amplitudes, phase and frequencies of these telluric currents, the apparent resistivity of the geological formations that they are flowing within can be determined. This is done by recording the electromagnetic waves caused by the electric field generated by the telluric currents.

Figure 3: Head wave traveling along an interface generating an electric field



3. How was the ATS Electro-Seismic Mapping at Riburg in Switzerland Performed

3.1. Organisation

After agreeing to the ATS Group offer for cooperation, our first thought was: Where are we going to try it? We thought – perhaps the Swiss Salines. Their solution mining history goes back to 1821 when Carl Christian Friedrich Glenck (1779-1845) launched his systematic search for salt in Switzerland. After many trials and disappointments, he discovered in 1836 rock salt deposit alt in north-western Switzerland at a drilling depth of 107 meters and commercial solution mining, brine evaporation and salt crystallization were established in the following years. In 1970-ies, the author of this paper worked for Escher Wyss, then famous company in Zurich, who designed and supplied the salt evaporation plants, based on mechanical vapor recompression, for Swiss Salines. Thanks to this good old relationship, Salt Partners received the permission and support of Swiss Salines to perform the electro-seismic mapping of the salt deposits located at Neumatt to the north of the Riburg saltworks.

3.2. Tools required for electro-seismic mapping

Figure 4: Electro-seismic mapping tools:

For our electro-seismics mapping work, we used the following equipment:

- Instead of smartphone, we used a voice recorder;
- Sledgehammer, 5 – 10 kg, The heavier, the grater depth can be explored. Mechanical or hydraulic hammer / stone breaker must be used for mapping depths grater than about 1’000 metres;
- 2 Stainless steel pins, about 25 mm diameter and about 75 cm long;
- Steel plate, about 25 mm diameter and about 25 mm thick, with handles, Larger and thicker plates are required for reaching grater depths with mechanical or hydraulic hammers;
- Set of cables with clamps and audio connection to the recorder;
- Recorder;
- Camera with integrated GPS;
- Block of paper and thick black marker for mapping point identification. The identification label position must be recorded by voice in the recorder and by taking a pocture with the camera;
- Strong man;
- Personal protection equipment.

4. Site Selection: Swiss Saltworks, Riburg, North of Switzerland

Figure 5: Neumatt Fields, North of Swiss Saltworks at Riburg

The selected Neumatt site was about 660 m long and 200 m wide. At this site, we selected about 30 mapping points along the access roads and in the middle of the fields where operative solution mining cavities are located. On the mapping day on 22.6.16, the temperature reached 35°C. Therefore, we refrained from using personal protection equipment – except for a strong sun lotion. However, the works was performed without any accident. The next day, the recordings and GPS data of 29 striking points were transmitted to ATS Group for evaluation

5. Salt deposit data provided by Swiss Saltworks

Swiss Saltworks kindly provided extensive data concerning the rock salt deposit and the various underground infrastructures, which could have disturbed the electro-seismic responses, among other the following:

- Top of salt layer contour map;
- Bottom of salt layer contour map;
- Drilling logs at points R26 and R36 needed for method calibration;
- Salt layer profile interpolated from 8 exploratory drillings by Hauber;
- Locations of electrical cables;
- Locations of brine piping;
- Locations of water piping;
- Locations of existing brine caverns.

As can be seen further below, the presence of an operating water pump station near the mapping point No. 24, even to the extent of counting 58 strokes, out of them 48 false, 36 of them being rejected and 22 of them being used for correlation, compared with 10 strokes actually being made. The data quality assessment methodology of the system has thus been verified.

6. Content of ATS Electro-Seismic Evaluation Report

Four days after the carrying out the electro-seismic mapping in Riburg, Salt Partners received the evaluation of the collected data by ATS Group in form of a report. The report consists of the following:

- 99 pages;
- Introduction with theoretical part;
- Project overview
- 3 GPS location determinations for each strike point, i.e. latitude, longitude and elevation above main sea level;
- 17 data quality assessment and control evaluations with detailed description of methodology for each of the 29 strike points, table of data and 17 graphical visualisations of the evaluation results;
- Description of the 3D data model methodology, such as interpolation, gridding, blanking, transparency, modifications and auto-constrains;
- Description of the Adobe Acrobat 3D model using Golden Software Voxler 3 package. The model contains the above mentioned 17 data quality assessments, 3 data sets related to GPS positioning, 12 electro-seismic data interpretation sets and 10 electro-telluric data interpretation sets;
- Detailed description of each electro-seismic investigation / interpretation, such as hydraulic conductivity tomography, electro-seismic coupling coefficient tomography, fracture analysis, etc. These data are mainly relevant to investigation of aquifers. Whereas presence of aquifers above rock salt deposits is important for design of the borehole drilling methodology, it is less important for the determination of the rock salt deposit itself;
- Detailed description of each electro-telluric investigation / interpretation, such as electro-telluric tomography, electro-telluric gradient tomography, electro-telluric interface tomography (ETIT), etc. This set of data, specially the electro-telluric interface tomography, which detects the position of changes in geological electrical conductivity variability, has, after calibration of seismic velocities on the bases of available drilling data, determined the Riburg cap rock / salt interface with an accuracy of +/- 1 meter in the depth of 155 meters above sea level, i.e. approx.. 140 - 145 m below ground;
- Detail description of coordinate system, interpretation, parameters, assumptions and limitations. The report explains in detail why accuracy higher than +/- 1 meter is difficult;
- 24 electro-seismic and electro-telluric data renderings;
- 3-dimensional model of the data renderings in 29 Views. The View No. 17 illustrates the determination of the cap rock and rock salt interface with the greatest accuracy. This is further discussed in further below;
- Salt layer profile by company Hauber, as made available by Swiss Saltworks, was incorporated in the 3D model. The Hauber salt layer profile was created by interpretation of 8 borehole logs;

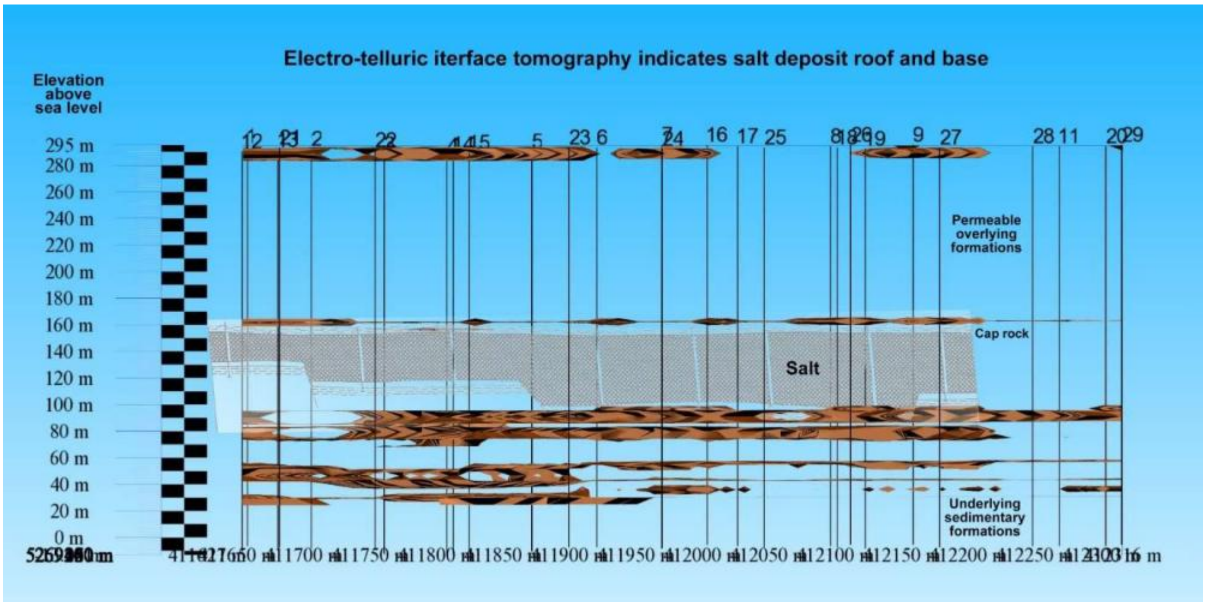
- Detailed description and interpretation of 24 data sets as visualised in the 3D model;
- 22 References.

7. Calibration of the 3D Model

Close examination of the original 3D model submitted on 26.6.16, when compared with the site data provided by Swiss Saltworks subsequently, showed clearly the presence of aquifer above the salt deposit, however, the position if the cap rock didn't correspond sufficiently accurately with the position determined by the previous drilling. ATS Group explained the discrepancy by the seismic velocity that was used in the model to calculate the speed of the seismic pressure wave and the time required for the electromagnetic wave to reach the dipole antenna. The aquifer is fully saturated with water supplied from the river Rhine, flowing only about 600 – 1'460 meters away from the site. Also, the seismics velocity of the pressure wave in the salt layer itself was originally incorrectly assumed and had to be corrected.

Similarly, whereas the position of the boreholes for which the drilling logs were available was correct, the precise position of the rock salt profile, as determined by Hauber, was incorrectly positioned in the 3D model. Some time was required to recognise and rectify these discrepancies. However, the View No. 17, shown further below, is now believed to be accurate. On that bases, the determination of the cap rock / rock salt interface with an accuracy of +/- 1 meter in the depth of 155 meters above sea level is believed to be correct.

Figure 6: View No. 17, Electro-Telluric Interface Tomography



Having verified the capability of the ATS electro-seismic mapping method, Salt Partners proceeded with the registration of the method for rock salt prospecting under the Registered Trademark SEISMOSAL®.

8. Why is Accuracy of +/- 1 Meter Possible

As mentioned in the description of the report above, the electro-telluric interface tomography detects the position of changes in geological electrical conductivity variability and is shown on the View No. 17, shown further below. To interpret this, let's consider the mechanism of cap rock formation.

All salt on Earth originates from sea water. Sea water contains, among other salts, also calcium sulphate. When sea water evaporates, the calcium sulphate precipitates, depending on temperature, as gypsum ($CaSO_4.2H_2O$) or as hemihydrate ($CaSO_4.1/2H_2O$). By the time the sea water reached saturation with respect to sodium chloride (NaCl), most of the calcium sulphate has precipitated, but not all. The calcium sulphate remaining in the brine saturated with respect to sodium chloride precipitates together with the crystallising sodium chloride. Thus, all salts contain calcium sulphate. Depending of the degree of oversaturation of the saturated brine with calcium sulphate, the $CaSO_4$ content in the salt can vary between a minimum of about 0.5% and up to about 3%.

Through geological processes, such as growth of the crystallising salt layers, sinking of the salt deposits, accumulation of overburden, temperature and pressure increase in deep geological formations, etc., the salt gets compacted and re-crystallised. The components of sea water, which are more soluble than sodium chloride, get to large extent expelled form the salt bulk. Calcium sulphate, however, together with insoluble substances, remains locked in the salt. Through the high temperatures and pressures, the gypsum and the hemihydrate loose crystalline water and form anhydrite ($CaSO_4$).

Through some further geological processes, such as local pressure variation, creep and formation of diapirs, the salt may rise upwards towards the surface. Similar process takes place when erosion reduces the thickness of the overburden. When the salt progresses near the surface, it may get in contact with ground water and it dissolves. The anhydrite and the insolubles, however, remain undissolved. This undissolved layer forms the cap rock, which protects the salt against further dissolution. In some cases, the salt doesn't dissolve, it protrudes the ground surface and form, what is known, for example in Cardona, Spain, as the so called "Montagna de la Sal". In other places, for example in Iran, these salt mountains can reach huge dimensions.

The dissolution of salt below the cap rock in the overlying ground water is not finished. The cap rock, however thick and hard, is not impervious. It is porous and the pores contain humidity. This humidity proceeds to the salt, dissolves it and the ions of sodium and chloride migrate through the cap rock towards the ground water by diffusion. In this process, a concentration gradient is formed, resulting in change of conductivity between the humidity near the salt and the humidity near the ground water. And it is exactly this change in geological electrical conductivity variability that the electro-telluric interface tomography can detect. Depending on the thickness of the cap rock, the electro-telluric interface tomography can detect geological formations of different thicknesses. However, it is the lower strata of the cap rock that indicates the top of the salt deposit. Below this layer there is no water in the rock salt and therefore there is no electro-seismic or electro-telluric response.

Thus SEISMOSAL®, being a methodology for salt prospecting, can determine multiplicity of geologic formations above and below the rock salt deposit but not the rock salt itself. The rock salt appears a void. Three are not many, if any, geological formations completely water free. However, as this cannot be excluded, at least one borehole is required to verify that what appears as a void, is actually rock salt.

9. SEISMOSAL® Potential Applications

So far, we were asked the following questions concerning potential SEISMOSAL® capabilities and applications:

- Can SEISMOSAL® determine the edge of a diapiric formation?
- Can SEISMOSAL® determine a solution mined cavern and its shape?

We are convinced that SEISMOSAL® can determine the edge of a diapiric formation. The electro-seismic pressure wave travels downwards in a near-spherical form but only the electromagnetic responses generated directly below the seismic source are recorded using the dipolar antenna. Therefore, assuming striking point matrix sufficiently fine, the striking point away from the edge of the diapir will show no void and the point above and inside the edge of the diapir will show a void. Depending on the shape of the diapir, the void may proceed up to the end of seismic response, in which case the diapir is still increasing its diameter, or the void comes to an end and other, ground water bearing formations may appear below the void, in which case the diapir has a form of a mushroom.

Whether or not SEISMOSAL® can determine a solution mined cavity and its shape is unknown for the time being. Striking points in Riburg next to the known cavity gave false signals because the cavity was in operation, with water being pumped in and brine flowing out and with electrical wiring carrying current. However, the following theoretical considerations can be made:

- Caverns consist of interface between rock salt and brine. This interface may generate some electro-seismic or electro-telluric response;
- The surface of rock salt being dissolved in undersaturated brine contains particles of anhydrite and insolubles, which may generate some electro-seismic or electro-telluric response;
- Particles of anhydrite and insolubles, released from the rock salt by dissolution, fall to the bottom of the cavern forming a sludge deposit. This deposit is a relatively low density, porous geological formation, saturated with conductive fluid – brine – and therefore is should respond the seismic wave.

There are theoretical considerations. As always – the taste of the cake is in eating.

ATS and Salt Partners are actively seeking opportunities for further testing and development of this promising new salt prospecting method.

10. Acknowledgement

The authors, ATS Group and Salt Partners are grateful to the following companies and persons for permitting, supporting and carrying out the work associated with the first test of the SEISMOSAL® technology in Riburg:

- Dr. Urs Ch. Hofmeier, Managing Director, Swiss Saltworks, for giving the permission to perform the work;
- Mr. Carlo Habich, Manager Business Unit Industrial Salts, Swiss Saltworks and member of the Board of Directors of the family company who owns the Neumatt farm and fields;
- Mr. Gabor Fuchs, Manager Geology, Swiss Saltworks, for providing known geological information concerning the Neumatt salt deposit;

- Dr. Claudio Philipp Sedivy, Managing Director, Wildbiene + Partner, for lending to us the strong arms of Yannick Schauwecker;
- Mr. Yannick Schauwecker, Wildbiene + Partner, for his hard work with sledgehammer;
- Mrs. Erica Sedivy, Administrator, Salt Partners Ltd., for video recording of the Riburg site electroseismics mapping;
- Mrs. Isabella Sedivy, Director, Salt Partners Ltd., for producing the video interview Introducing SEISMOSAL® - a Revolution in Salt Prospecting, broadcasting on YouTube under the following link: https://www.youtube.com/edit?o=U&video_id=fXCj3ngAuks.

11. References

1. Biot, M. A. (1956) Theory of propagation of elastic waves in a fluid-saturated porous solid. I. Low frequency range. *Journal of the Acoustical Society of America.*

2. Biot, M. A. (1956) Theory of propagation of elastic waves in a fluid-saturated porous solid. II. Higher frequency range. *Journal of the Acoustical Society of America.*

3. Biot, M. A. (1962) Generalized theory of acoustic propagation in porous dissipative media. *Journal of the Acoustical Society of America.*

4. Botha, J. F., Verwey, J. P., Van der Voort, I., Vivier, J. J. P., Colliston, W. P. and Loock, J. C. (1998) *Karoo Aquifers. Their Geology, Geometry and Physical Behavior*. Water Research Commission.

5. Butler, K. E., Russell, R. D. and Kepic, A. W. (1996) Measurement of the seismo-electric response from a shallow boundary. *Geophysics.* http://sep.stanford.edu/data/media/public/sep/berryman/Electroseis/Geoph01769.pdf

6. Fourie, F. D. (2000) *An Introduction to Geophysics for Geohydrologists*. Unpublished lecture notes. Institute for Groundwater Studies, University of the Orange Free State.

7. Garambois, S. and Dietrich, M. (2001) Seismo-electric wave conversion in porous media: Field measurements and transfer function analysis. *Geophysics.* http://sep.stanford.edu/data/media/public/sep/berryman/Electroseis/Geoph01417.pdf

8. Haartsen, M. W. and Pride, S. R. (1997) Electro-seismic waves from point sources in layered media. *Journal of Geophysical Research.* http://onlinelibrary.wiley.com/doi/10.1029/97JB02936/abstract

9. Haartsen, M. W., Dong, W. and Toksöz, M. N. (1998) Dynamic streaming currents from seismic point sources in homogeneous poroelastic media. *Geophysical Journal International.*

10. Ishido, T. (1981) Experimental and theoretical basis of electrokinetic phenomena in rock-water systems and its application to Geophysics. *Journal of Geophysical Research.*

11. Kepic, A. W., Maxwell, M. and Russell, R. D. (1995) Field trials of a seismoelectric method for detecting massive sulphides. *Geophysics.*

12. Martner, S. T. and Sparks, N. R. (1959) The electroseismic effect. *Geophysics.*

13. Maxwell, M., Russell, R. D., Kepic, A. W. and Butler, K. E. (1992) Electromagnetic responses from seismically excited targets B: Non-piezoelectric phenomena. *Exploration geophysics.*

14. Mikhailov, O. V., Haartsen, M. W. and Toksöz, M. N. (1997) Electroseismic investigation of the shallow subsurface: Field measurements and numerical modelling. *Geophysics.*

15. Millar, J. W. A. and Clarke, R. H. (1997) *Electrokinetic techniques for hydrogeological site investigations*. *Groundflow*

16. Pride, S. R. (1994) Governing equations for the coupled electromagnetics and acoustics of porous media.

17. Pride, S. R. and Haartsen, M. W. (1996) Electroseismic wave properties. *Journal of the* Acoustical Society of America.

18. Pride, S. R. and Morgan, F. D. (1991) Electrokinetic dissipation induced by seismic waves. Geophysics.

19. Ranada Shaw, A., Denneman, A. I. M. and Wapenaar, C. P. A. (2000) Porosity and permeability effects on seismo-electric reflection. In: Proceedings of the EAGE conference.

20. Russell, R. D., Butler, K. E., Kepic, A. W. and Maxwell, M. (1997) Seismoelectric exploration. The Leading Edge.

21. Rosenberg, M., Wallin, E., Bannister, S., Bourguigon, S., Jolly, G., Mroczek, E., Milicich, S., Graham, D., Bromley, C., Reeves, R., Bixley, P., Clothworthy, A., Carey, B., Climo, M. (2010) Tauhara Stage || Geothermal Project: Geoscience Report, GNS Science Consultancy Report 2010/138.

22. Du Preez, M. (2005) Accuracy of Electro-Seismic Techniques Applied to Groundwater Investigations in Karoo Formations. Master Thesis: University of the Free State

23. ATS Website, https://www.atsgeosuite.net

24. Vladimir M. Sedivy (2018) Introducing SEISMOSAL® a Revolutionary Method of Prospecting for Salt, Presentation at the Annual EuSalt 2018 General Assembly and Meeting, 7-9.3.2018, Hotel Pullman, Basel, Switzerland

25. Swiss Salines Website: https://www.salz.ch/en/about-us/history/