Journal of Applied Geophysics 226 (2024) 105398

Contents lists available at ScienceDirect

Journal of Applied Geophysics

journal homepage: www.elsevier.com/locate/jappgeo

Contribution of VLF electromagnetic survey to the investigation of Hessdalen lights (Norway)

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ARTICLE INFO

Keywords:
Hessdalen lights
VLF measurements
Geophysics
Geomorphology

ABSTRACT

Hessdalen valley in Norway is known for luminous phenomena suddenly and evenly appearing temporarily. Since several decades, these phenomena are observed by many witnesses, and they are sometimes traced by geophysical devices. The first appearance in modern times was reported in 1981 but systematic observations started during winter of 1984 when the Hessdalen project was launched. Later, Østfold University College led the project and yearly organized one to two field campaigns, with the objective to systematically record and investigate the phenomenon. Till that epoch, detailed tectonics, fault systems and superficial conductive structures remained unknown. Therefore, during the last years, VLF surveys have been performed in Hessdalen valley as part of six geophysical field campaigns which sometimes also included Total Magnetic Field and Self Potential spatial ground measurements. VLF measurements have been carried out on a 20 m average spacing along many traces totaling to100 km length. The entire covered area was about 100 km^2.In this paper, we focus on the results of the VLF measurements. Several conductive zones have been found. They are mainly related to mineral deposits (mainly sulfides). The trace at the ground surface of these conductive zones could suggest that they draw an ellipse of 6 by12 km, related to the shape of the gabbro intrusion present in the area and oriented in the SW-NE direction. The results combined with other geophysical data contribute to better understand how the near surface structures (depth less than a few hundred meters) could supply the generation of the so-called Hessdalen lights ('HL') and explain why these lights appear inside this valley. The particular geological structure detected in Hessdalen valley may encourage similar campaigns in other areas where similar phenomena are observed.

1. Introduction

Luminous phenomena have been reported in some localized areas over the world during the last decades. Unfortunately, scientific examination of such lights is scarce. It is therefore difficult to discern genuine luminous phenomena from lights caused by human activities. Areas where luminous phenomena have repeatedly been reported include Hessdalen, Norway (Hauge, 2010), Marfa, Texas, USA (Stephan et al., 2011; Darack, 2008), Silver Cliff, Colorado, USA (), Paasselkä, Finland, and Queensland, Australia (Pettigrew, 2003; Moravec, 2003). These transient appearances of atmospheric lights easily spark the imagination of people.

Although luminous phenomena ('LP') in Hessdalen valley were first reported in 1811, scientific investigations only began in 1984 (Hauge, 2010). To find out the real genesis of these lights, a *Hessdalen project* was gradually enlarged by camera monitoring, and yearly field campaigns during which geophysical devices were implemented (Teodorani, 2004; Hauge, 2010). However, a hypothesis considering a possible interaction between geology, tectonics and the environmental conditions, has not yet been considered.

A key consideration must be underlined right now. Hessdalen valley is located in a very remote and almost uninhabited region (~62°44′N-62°54′N/~10°54′E-11°54′E). During winter, the temperature can be below −30 °C and wind can blow up to190 km/h. These harsh conditions associated with dozens of lakes and muskeg areas make geophysical observations difficult to implement and maintain in the long term

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https://doi.org/10.1016/j.jappgeo.2024.105398
Received 21 March 2022; Received in revised form 28 January 2024; Accepted 10 May 2024
Available online 11 May 2024

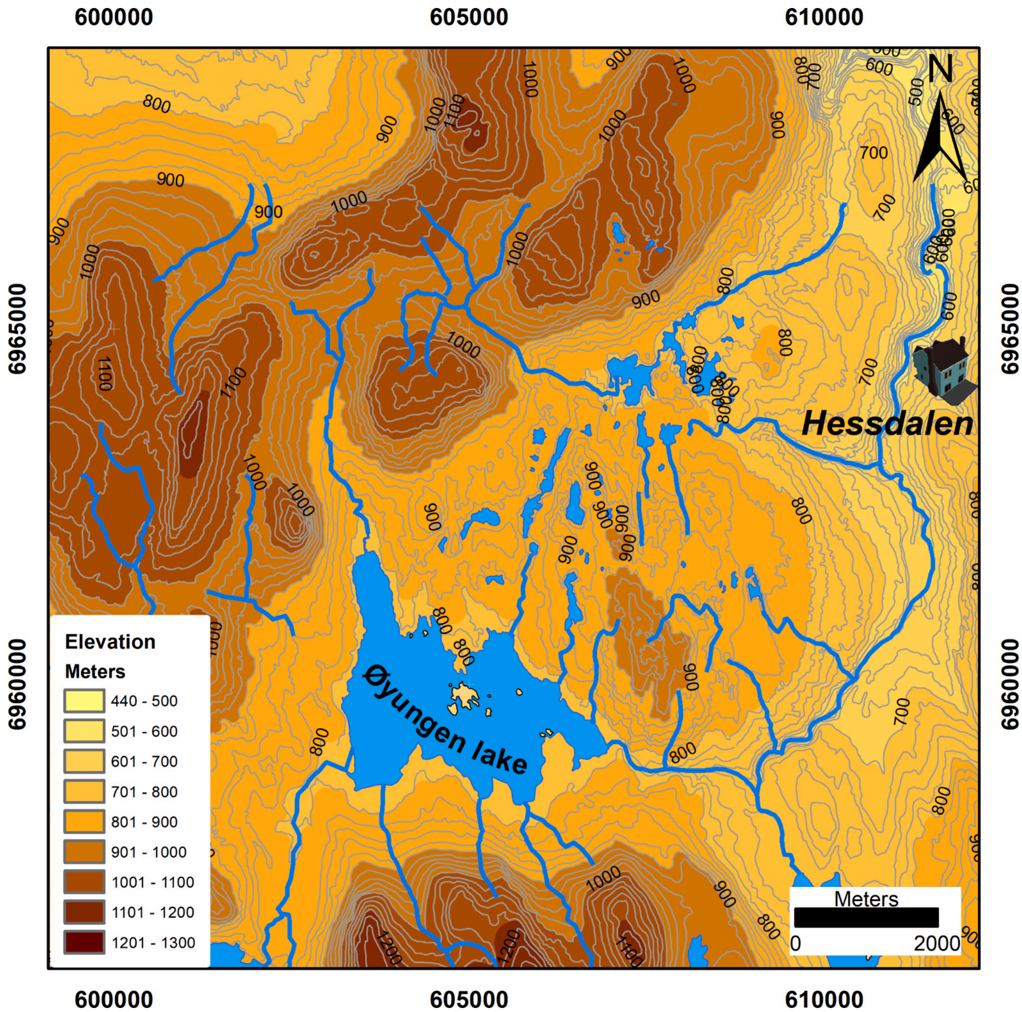

Fig. 1. Elevation map of the regional area. Horizontal coordinates are in UTM.

(Fig. 1). Our initial assumption was that, under specific conditions (hydrological, meteorological, geological structure, electromagnetic activity), interactions between Earth 's subsurface and atmosphere could result in the generation of various geophysical phenomena including atmospheric lights.

The first scientific survey on Hessdalen phenomena was conducted by Teodorani (2004). Characteristics of the lights, based on numerous visual sightings, are now relatively well known, according to their size, color, shape and duration. During field campaigns operated during the last 10 years, about 600,000 pictures were taken by Østfold University College to look for the phenomena. An examination of these pictures, carefully excluding any lights that might be caused by human activities, shooting stars, etc., show that most of the Hessdalen lights are white in appearance. Other colors, in particular red ones, have occasionally been reported, but there is currently not enough evidence to conclude whether these are rare variations of the Hessdalen lights, or a result of falsely identifying other light sources as the Hessdalen phenomena. The duration of the lights can be from seconds up to 1 h. The most common observations last for a very few minutes. The lights are spherical or oval shaped, and occasionally they appear in clusters. They can stand still or move rapidly across the sky. They can appear both above and near the horizon. Nearly 90,000 pictures were taken up towards the sky with fish-eye lenses. But no capture of the phenomenon with this setup was obtained, suggesting that the lights appear relatively close to the ground.

Irregular and time-spaced field campaigns could only be performed. The Hessdalen lights have been observed by RADAR echoes (Hauge, 2010). Attempts to correlate the lights with signals in other physical parameters (magnetic field disturbances, Electromagnetic disturbances and their related VLF emissions, weather data, radioactivity) are in progress, but more simultaneous physical data accompanying HL are still needed for assuming a final interpretation.

Tentative modeling has suggested a triggering mechanism - not well defined till now - that sometimes produce electric currents propagating from the Earth into the atmosphere (Monari et al., 2013). Piezoelectric and related electromagnetic fields were suggested as driving mechanisms, but the origin of the phenomena isstill unclear (Zou, 1995; Paiva and Taft, 2012).

Relationships between lights and seismic activity were examined by Theriault et al. (2014). The authors suggest that lights appearance could be related to tectonic stresses. This assumption is based on the mechanism of stress-activated electric currents in rocks releasing mobile charge carriers (Freund, 2010). These carriers could flow along stress gradients accumulated close to the surface leading to the generation of lights by ionization of air molecules. However, seismicity in Norway and especially in Hessdalen valley is so weak that this hypothesis cannot be retained. For instance, no earthquake of magnitude above 2.5 has occurred since 2000 (https://earthquake.usgs.gov/).

All these suggested mechanisms require the presence of electrically conductive structures in the sub-surface able to drive a current flow up to the ground surface.

Later, Monari et al. (2013) suggested the existence of a natural battery between the western and eastern sides of the valley. The western local mines containing iron and zinc could suffer oxidization and the related ionic charges could be transported to the eastern side of the

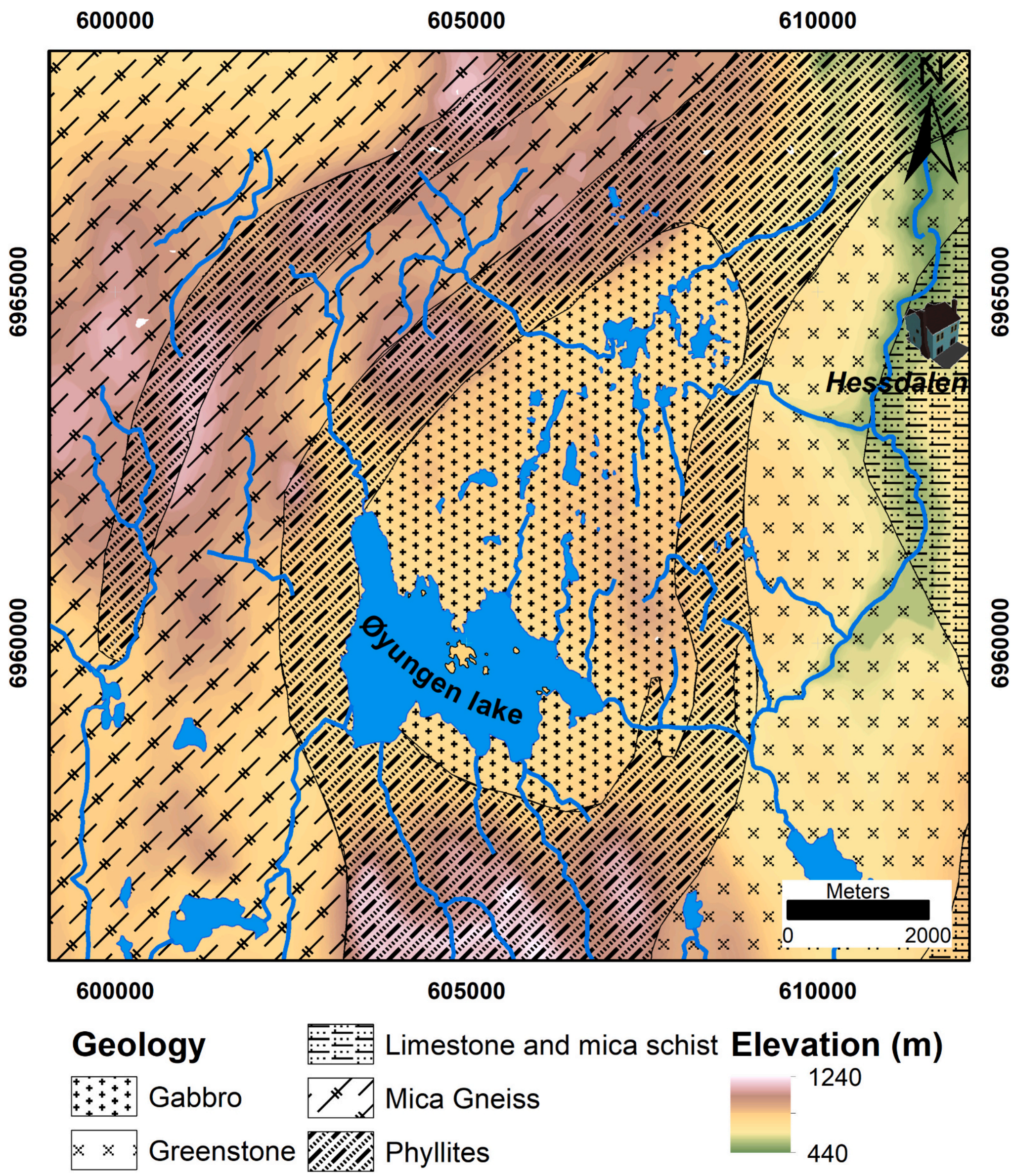

Fig. 2. Geological map of the regionalarea.

valley where oxidized minerals of copper mines could be the seat of a chemical reduction. These transfers of ionic charges would be carried by ground waters circulations between both sides of the valley. It was supposed that the interaction between mining structures could lead to the activation of a series of many mini-galvanic cells generating strong electrical fields. Such anomalies of the electrical field were measured by means of EFM (Electric Field Meter) in Hessdalen during field campaigns (Hauge and Kjøniksen, personal communication).

On the other hand, the appearance of strong transient electric voltages above the ground surface suggests short-live accumulation of electric charges in the ground or in the low atmosphere (Monari et al., 2013).

The contribution of the present work is therefore to primary detect and map geological features and conductive structures over a large area of the valley (100 km^2) which could act as conductive and electrical sources.

Among geophysical methods able to quickly map electrically conductive structures over large areas in spite of harsh conditions, the Very Low Frequency (VLF) method is quite efficient. This light equipment provides fast measurements (<1 min at each spot). The depth penetration of the method can reach a hundred meters or more, depending on the VLF frequency used and the ground conductivity. Measurements have been performed along profiles totaling a length of 100 km with a mean 20 m sampling rate. The location of each survey point was done with a portable GPS and was controlled on a 1/10,000 topographic map (Fig. 3).

2. Geological setting of the area

The dominating geological units in Hessdalen valley are Gabbro and Amphibolite formations surrounded by phyllites (Fig. 2). Mica schists at the eastern part of the valley are brownish grey with small segregations of quartz. Disseminated sulfides result to rusty appearance of weathered surfaces (Boe, 1974) while graphite is observed in some places.

A main and huge gabbro body underlies Øyungen lake and extends to the north. The surface outcrop reaches 45 km^2. This intrusion is inhomogeneous and contains a large concentration of quartz-diorite sills and dykes (Flatebo, 1968). This author points out the occurrence of deep-seated magnetic bodies in the area located 10 km east and 12 km north-east to Øyungen lake. The existence of these bodies is related

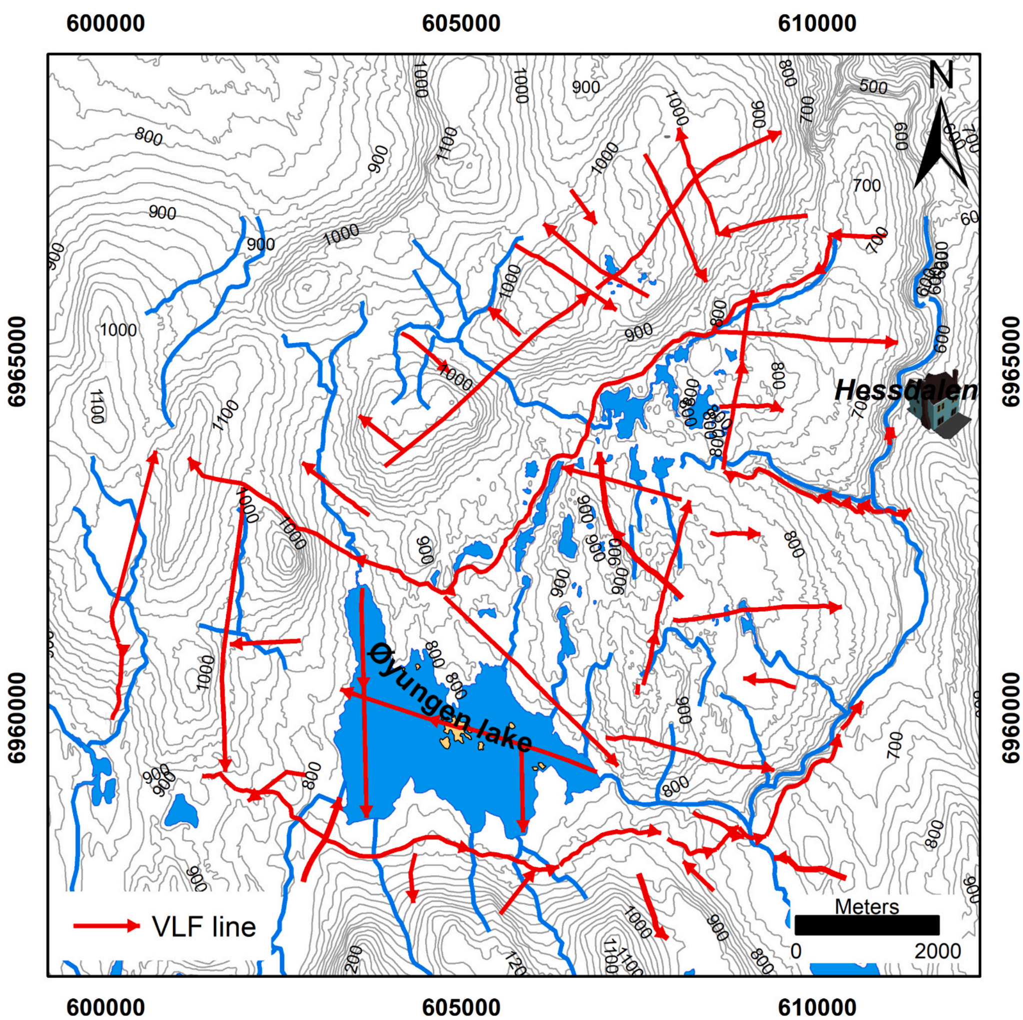

Fig. 3. Layout of VLF profileslines(altitude isolines are given every 10 m).

tosub-surface gabbroic intrusions carrying magnetite.

Exposed gabbro located in a wider region is known to have different magnetic properties. However, the Øyungen gabbro presents no large magnetic anomalies. Probably, the andalusite growth occurred in the contact aureoles around the intrusion, giving clues to the intensive andalusite porphyroblasts.

The main geological event in the area probably related to the generation of mineral deposits, is the gabbro intrusion which has driven the metamorphism and has created a contact aureole. This is a zone of contact metamorphism that surrounds an intrusion, and it is interesting in the present case because new minerals are formed, or existing minerals recrystallize into larger grains in this zone. It is noted that the grade of low-pressure metamorphism increases towards the center of the intrusion. The vertical distance down to the presumed deep-seated gabbro could be 2–3 km (Boe, 1974). In the same article, it is noted that a magnetic anomaly north to Øyungen lake is most likely a sub-surface gabbroic intrusion carrying magnetite.

The presence of mineral deposits of zinc (Zn) and iron (Fe), are abundant to the west of the river crossing Hessdalen town while copper (Cu) accompanied with iron (Fe) deposits are mainly present on the eastern mountain side (Monari et al., 2013).

3. Geophysical investigations

The appearance of lights in the nearby ground surface atmosphere implies a local genesis of the lights. Therefore, geophysical prospecting was of primary importance for evaluating the possible contribution of tectonics or/and geological setting in the genesis of the lights. Another condition prevailing to all proposed models would be the existence of strong transient electrical currents *escaping* from the Earth into the atmosphere. Thus, highly electrical conductors in the ground would exist in the valley allowing transient atmospheric electrical currents (Zou, 1995; Teodorani, 2004; Theriault et al., 2014). This type of conductors could be related either to mineral deposits or to tectonic features such as regional tectonic faults. Accordingly, any geophysical method aiming to the detection of such buried conductors in the sub-surface must satisfy several specifications:

- Be designed for detecting geological bodies of different electrical properties at depth (i.e., electrical resistivity),
- Be easily portable and applied: Only foot surveys can be performed on such so wide wild area (about 100 km^2),
- Deliver high resolution data. Aerial geophysical regional maps (Total magnetic field and gravity anomalies) were previously performed, but the corresponding 1/25,000 scale didn't allow detection of local anomalies as well as their geometry.

Considering these requirements, VLF was the chosen geophysical method.VLF is an electromagnetic method which uses the horizontal magnetic component of a given primary field coming from a remote transmitter. Principles of the VLF method can be found in several articles (Paal, 1965; Baker and Myers, 1979; Saydam, 1981; Ebrahimi et al.,

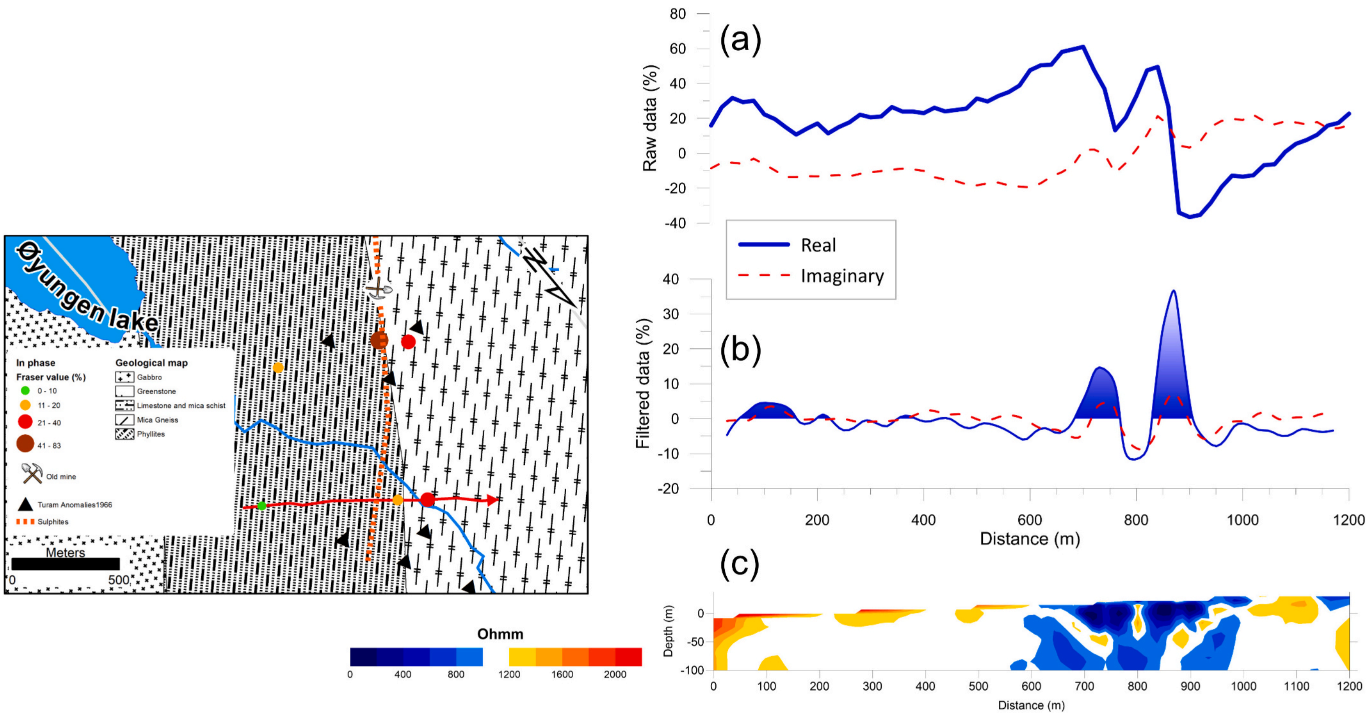

Fig. 4. (a) Raw data, (b) Fraser filtered data, (c) resistivity model.

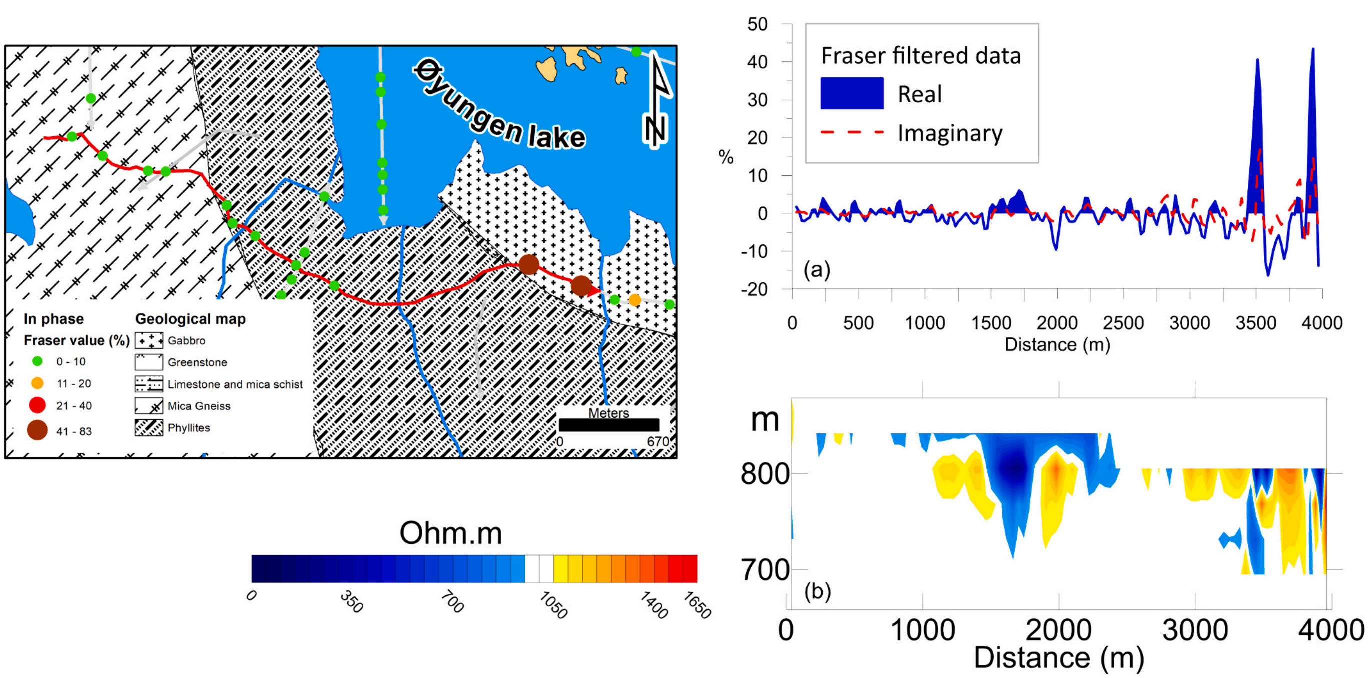

Fig. 5. (a) Fraser filtered data, (b) resistivity model (scale exaggeration in the elevation axis due to the large distance of the profile).

2019). Revealed conductive bodies are essentially related to mineral deposits or to aquiferous fractured systems.

3.1. VLF measurements

Six field campaigns, performed between 2014 and 2019, gave rise to 67 profiles totaling >100 km of measurements (Fig. 3). The sampling interval between consecutive measurements was 20 m, providing a total of about 5000 measurements. For each profile, the proper VLF transmitter was chosen for its strength and the direction of the profile. In each case, the perpendicularity of two directions (station and profile) was kept so that the horizontal magnetic component of the primary EM field coming from the transmitting station was aligned with the direction of the profile. The electromagnetic stations transmitting at 19.6, 20.9, 22.1, 23.4 and 23.9 kHz have been used.

3.2. Data processing

The concept of the VLF method is that above a homogeneous ground, the magnetic component of the primary field is horizontal. In the

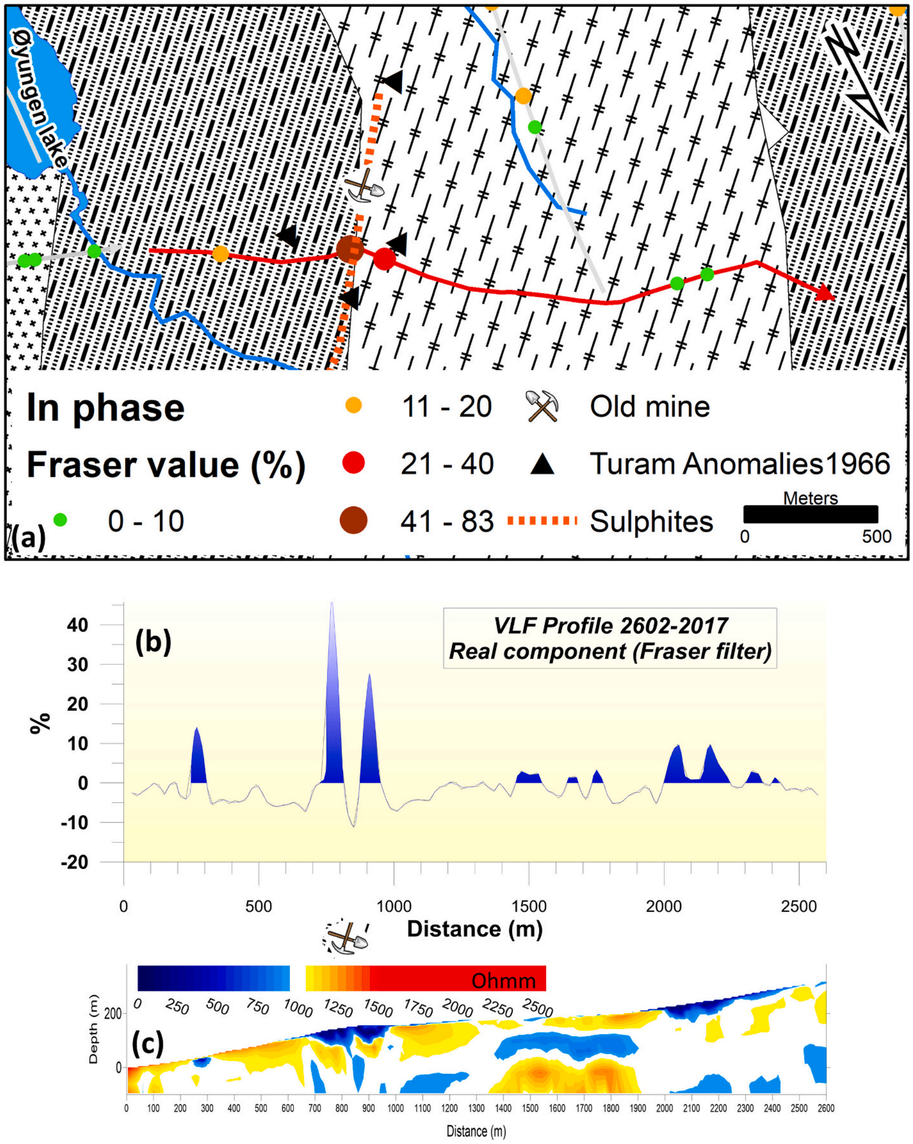

Fig. 6. (a) VLF profile location on the geological map; geology is described in Fig. 1, (b) Fraser filtered data, (c) resistivity model.

presence of a sub-surface conductor, a secondary magnetic field is produced and contributes to a resultant magnetic field which is elliptically polarized. The measured parameters by VLF instruments are transformed into the ratio of the vertical field H_z to the horizontal primary field H_o (the 'y' direction).

At each measuring point along a profile, the real (in phase) and imaginary (quadrature) components of the magnetic field along the profile were recorded. The in-phase (Re) and quadrature (Im) components are given in percentage, as ratios of Hz/Ho, related to the tilt angle 'θ' and the ellipticity 'e' (Karous and Hjelt, 1983).

$$Re(H_z/H_o) = 100^{*}tan(\theta) \qquad Im(H_z/H_o) = 100^{*}e$$

In the first step, the real component is plotted versus the distance traveled along the profile. A bipolar anomaly is formed when the measurements cross a conductive body and that gives in real time information about an existing conductor at depth. In addition, the real time detection of conductors allows for adjustment of the distance between consecutive measurements and to get a higher spatial resolution of the conductor, up to 5 m. Further computing processing allows the exact positioning of the conductor, the calculation of the depth and an estimation of the electrical resistivity.

Data processing was initially performed by applying the Fraser filter that transposes the bipolar anomaly into a positive anomaly the maximum of which is right above the conductive body (Fraser, 1969). Averaging weighted values between successive measurements largely reduces the noise level, with a factor of ten in average. The Fraser filter may be expressed as follows:

$$F_{2,3} = \frac{(M_3 + M_4) - (M_1 + M_2)}{4}$$

Where M_1, M_2, M_3 and $M_4$are successive measurements of the real or imaginary part of the resultant magnetic component.

Then, data are inverted using *INV2DVLF* code, to get 2D resistivity models (Santos et al., 2006). During some of the VLF campaigns, horizontal electric fields were simultaneously recorded as well as at remote stations in the valley. From these records, the computed average apparent resistivity between about 20 Hz and a few seconds was about 1000 Ωm. Magnetotelluric analysis is in process and will concern further study. Regarding VLF modeling, a resistivity model along each line was computed by referencing it to a homogenous half-space resistivity. In accordance with the preliminary magnetotelluric analysis, the 1000 Ωm value was chosen as starting value for all VLF surveys. This average value is also typical for bedrocks, especially for gabbros (Hyndman and

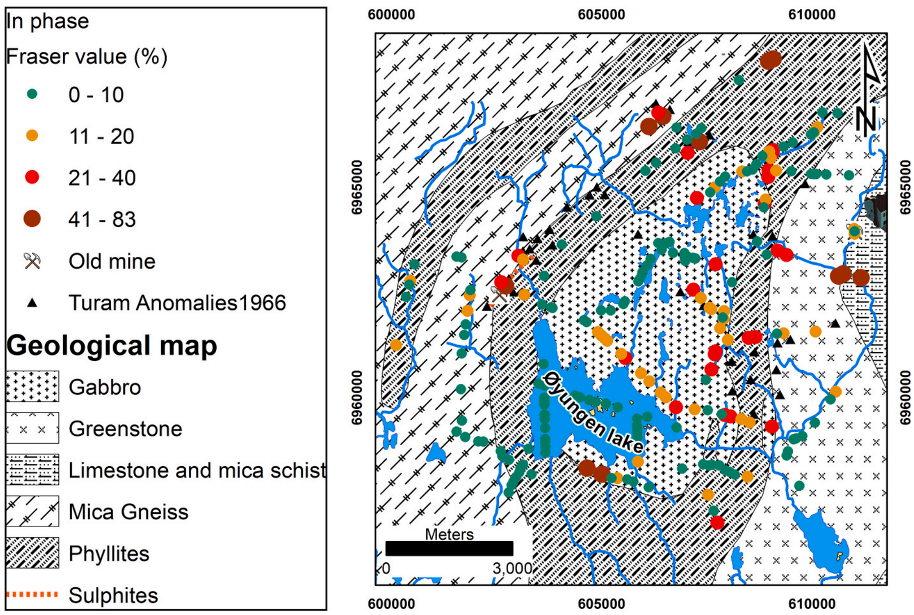

Fig. 7. Conductive zones detected by VLF method.

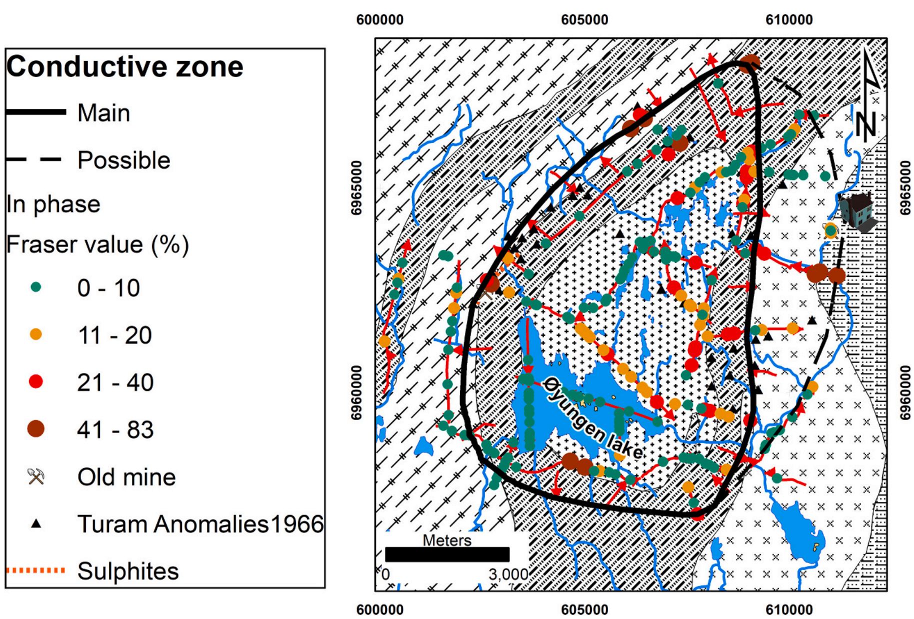

Fig. 8. Global **c**onductive zone delineated by the VLF results.

Drury, 1977). The color scale was designed for drawing conductive zones of resistivity <1000 Ωm in blue. Resistivity values attributed to different geological formations are calculated relatively to the initial resistivity given to the half space; therefore, the most important information arising from the inverted model is the contrast between the conductive bodies and the initial resistivity.

3.3. Data analysis

In the following, data analysis along two profiles located to the north and south of Øyungen lake are described. The first survey is 1100 m long while the second reaches 4000 m.

3.3.1. Northern Øyungen profile

Fig. 4a and b are related to raw and filtered data of a profile located to the north of Øyungen lake (red line in left and side cartoon of Fig. 4). Blue areas indicate the conductive zones. The final resistivity model related to the profile is presented in Fig. 4c.

Let us describe the successive results expressed by Fig. 4a, b and c. First, the large variations of the real component forming bipolar anomalies indicate the presence of conductors (Fig. 4a). Filtered data transform the bipolar anomalies into positive peaks showing the exact location of the sub-surface conductor as well as its approximate inclination (Fig. 4b). Positive peaks are shaded to make clearer the location of conductors. The shape of the peak denotes the inclination of the conductor. Symmetrical curve shows a vertical conductor, while, in case of an asymmetric curve, the moderate slope shows the direction of the inclination of the conductive body. Along the profile under study, two conductors are detected at 700 m and 850 m from the beginning of the survey. At the end, the IND2dVLF modeling depicts, in a cross section plot up to 200 m depth, the contours of the sub-surface conductors (Fig. 4c). The regularization method used in Frazer 's Smith model is the

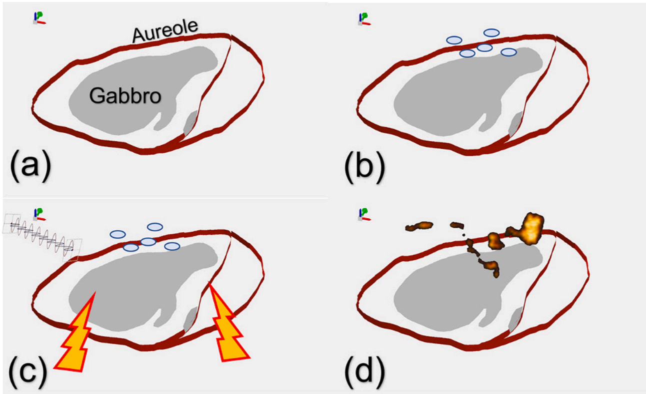

Fig. 9. Possible mechanism of Hessdalen lights generation within the area surrounded by the aureole. (a) location of the aureole respectively to the gabbro intrusion, (b) Possible large concentration and emission of bubbles of gas through faults and fractures (i.e., radon), (c) high electrical discharges during high EM activity, amplified by the conductive aureole, (d) luminous phenomena due to the ionization of the gases.

smoothness-constrained least-squares method (Santos, 2006). Cell size increases with depth, from several meters to a hundred meters. Conductive bodies (resistivity <1000 Ωm) are drawn in blue.

3.3.2. *Southern Øyungen profile*

This 4000 m long profile (red line in left and side cartoon of Fig. 5) is oriented West-East and lies to the southern edge of Hessdalen valley. Filtered data are presented in Fig. 5a and the 2D modeling in Fig. 5b with the same colors scale as in Fig. 4.

The real part of the filtered data shows that the VLF survey met many small positive anomalies to the west and south of Øyungen lake (distance ≤3300 m). On the opposite, sharp and narrow positive anomalies stand to the south-east of the lake (Fig. 5a). Fig. 5b clearly illustrates that the small positive anomalies form one conductive body which extends over 1500 m with a maximum rooting depth of 120 m. To the east, the conductive bodies have a small width (≤ 150 m) but they take root at >100 m depth. It is pointed out that the diversity in the form of the filtered curves is due to different mineralogical and geological subsurface bodies.

The data processing described above was applied to all profiles. Data inversion gave rise to the detection of conductive bodies all over the 100 km^2 covering Hessdalen valley.

4. Interpretation of VLF observations

As mentioned earlier, processing of VLF data allows the identification of electrical conductive bodies. The examination of possible relationships between conductive zones first requires the analysis of the major specific features. The first issue is the distribution of these bodies. Are they spread all over the entire area or grouped in a way that they possibly generate electrical conducting paths in the ground? Secondly, the nature of these bodies is also of major importance. Are high conductivity zones caused by minerals deposits, groundwater, or by the combination of both? Finally, the knowledge of the geometry and the spatial distribution contribute to determine the different physical processes possibly related to ground water flows and electrical charges transfers. Large extensive conductive bodies may favour physico-chemical processes (i.e. oxido-reduction processes) while narrow and deep rooting conductors could be associated with faults systems preventing lateral hydraulic and electric transfers. To analyse these issues, the location of each conductive zone has been picked up and drawn on similar maps.

In Fig. 6, VLF results along a profile located to the north-west of Øyungen lake and observations obtained by previous studies are integrated. Positive anomalies revealed by the real component of the Fraser filter along the VLF profile are reported on the map (Fig. 6a). It is noteworthy that the two main nearby strong VLF anomalies of 47 and 28%, respectively located at 800 and 900 m along the profile, are in the vicinity of an old mining area. Corresponding electrical resistivities are <100 Ωm, i.e., 10 times less than the average resistivity value of the half-space (1000 Ωm). The two bodies are therefore extremely conductive, and they sink at >100 m depth.

In addition, conductive bodies, detected by Turam geophysical electromagnetic method, applied back in1960 by the Norwegian Geophysical Survey (NGU), are positioned in the same area, following a lineation of SW-NE orientation (Bugge and Rui, 1966). Finally, a zone of sulfites is recognized along a lineament of 1500 m length. This one goes through an old mine and the exact spots of the two largest VLF anomalies. All these results lead to the assumption that the VLF anomalies are generated by mineral deposits located at the boundary of the phyllite and mica gneiss geological structures. In Fig. 7, conductive bodies found by VLF profiles over 100 km^2 of surveys are reported on the geological background. Conductive bodies found by previous studies are also reported. Rectangles showing the locations of Figs. 4, 5 and 6 are presented, too. It clearly appears that the Turam anomalies fit well with the VLF anomalies at all locations where both methods were applied.

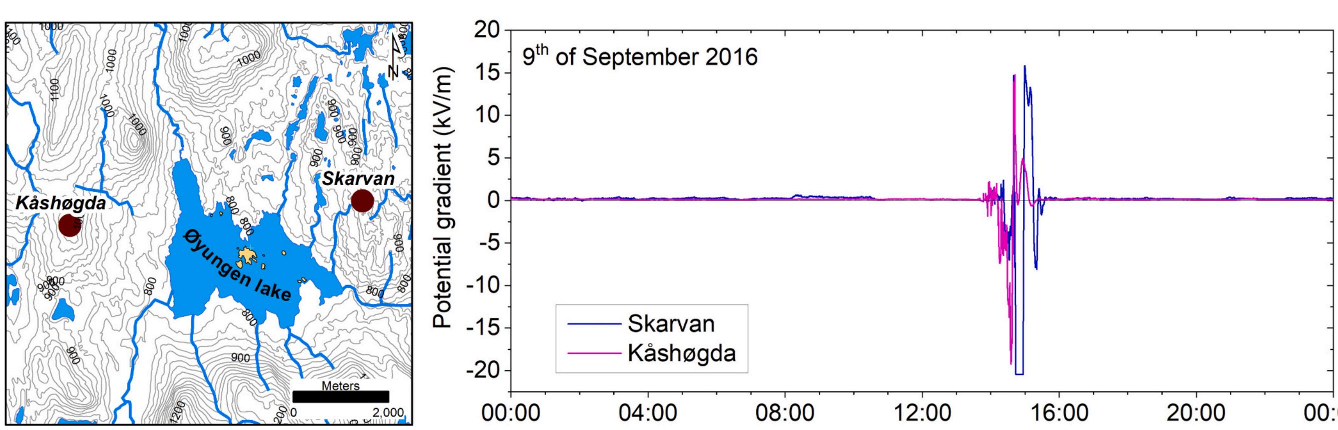

Fig. 10. On the left, is the location of the measuring stations. On the right, potential gradient (PG) of the atmospheric electric field measured with Boltek electric field mills from two mountain tops in Hessdalen valley.

5. Possible relationships between VLF anomalies and Hessdalen lights

5.1. Conductive bodies and metamorphism

It has been previously mentioned that one assumption, related to the genesis of transient lights in Hessdalen valley, is that electric currents could exist and propagate from the ground into the atmosphere. This mechanism and the environmental conditions are considered hereafter.

Following this primary concept, the VLF surveys may bring into light information on conductive structures over a large part of the valley and on possible sub-surface pathways for electric currents. Several conductive bodies rooting at 100 m depth, and more, are the seat of large concentrations of minerals deposits. Referring to the presence of mines, the minerals deposits could be composed of Fe, Zn and Cu and related oxidized components.

It is noticeable that several anomalies are present at the western side of the map, but they are not considered as part of the ring because the direction of the VLF profiles was North-South meaning that the conductive zones are mostly oriented to East-West, not therefore in accordance with the main ones.

If we consider the location of the most conductive bodies (Frazer filtered value >20%), one could trace at the ground surface a ring connecting these structures (thick black line in Fig. 8). This approximate ring follows the outer limit of the gabbro body. In such a case, it would be related with an aureole. Let's remind that an aureole is described as a ring surrounding an igneous intrusion (Mason and Liu, 2018). Contact metamorphism takes place around deep magma bodies that cool very slowly and turn into plutonic rocks as gabbro. During this process, chemical reactions can lead to the creation of large grained recrystallized minerals (Dunn and Valley 1992; Gillis and Coogan, 2019). Consequently, the conductive zones detected by the VLF anomalies could be associated with the aureole due to the gabbro formation and its metamorphism.

To go further, the most conductive anomalies are mainly set along the aureole and undoubtedly correspond to old mines (Fe, Zn, and Cu), large number of sulfides deposits, conductive bodies rooting at a hundred of meters and more and to ionic ground waters flows. In these areas, the electrical conductivity becomes much higher (i.e. 10 Ωm or less for sulfides) than in the surrounding bedrocks (up to 1000 Ωm). These rooting zones can become traps that concentrate electric charges and give rise to a strong electrical field around.

5.2. Provisional hypothesis on the genesis of Hessdalen lights

Although much more geophysical investigations must be carried out in Hessdalen valley, we may initiate the hypothesis that the peculiar environmental conditions (presence of large minerals deposits and ground waters) as well as the geological/structural metamorphisms are necessary components in the formation of transient local atmospheric lights. This assumption could serve as guideline for further research (Fig. 9).

In Fig. 9a, a very basic geological model is drawn including the gabbro formation and the aureole according to VLF and Turam (Bugge and Rui, 1966) results, the locations of old mines and sulphides deposits. In Fig. 9b, bubbles of ionized gas are added following Monari et al. (2013) assumption on transient appearance of gas above the ground of the valley. Ioannides et al. (2003) suggested Radon gas release from fault lines.

In Fig. 9c, some electrical conducting areas are shown, from which strong electrical fields may rise and interact with the atmosphere. In the presence of gas such as radon, ionization could participate to the generation of the lights (Fig. 9d).

As shown in Fig. 10, large variations of the potential gradient ('PG') of the atmospheric static electric field are sometimes observed in Hessdalen valley. While PG variations in the atmosphere may induce currents within the aureole "loop", currents flowing within the "loop" may also induce PG variations. Accordingly, localized enhancement of PG variations may be emphasized by weather conditions (e.g., passing cumuliform clouds) could induce transient currents within the aureole, which may generate local secondary electromagnetic fields at other spots along the aureole. These fields could become strong enough to initiate photoelectric phenomena. This concept could be supported by the geological setting and the mineralized zones in the Hessdalen valley. Further statistical examination of long-term geophysical records will be necessary for assuming a further accurate interpretation.

It would also be interesting to conduct similar geophysical surveys in other locations where light phenomena have been reported. Paasselkä in Finland has formations of impact melt rocks, including crystalline structure (Schmieder et al., 2008). Silver Cliff, Colorado, USA is located in a mining district as Hessdalen valley (Bunch and White, 1988). Other spots in the World where similar lights are repeatedly observed also exhibit interesting geological/geophysical formations.

6. Conclusion

VLF measurements, as a part of an international cooperation program on Hessdalen lights between Norway, Greece, France, and Italy, were focused on the detection and the mapping of conductive zones, related to tectonic features and mineral deposits.

Many conductive bodies, the spatial extension of which goes from some tens of meters to 500–600 m, are embedded from the ground surface to100 m depth or more. These bodies are mainly mineral deposits as it was suspected by previous studies (Boe1974). These conductive bodies trace a ring at the ground surface which could be related to an aureole formed by a gabbro intrusion and its metamorphism. As a result, this conductive ring *deeply* rooted could increase electrical charges circulation and concentration in the ground. It would be easily favored by the large number of lakes, ponds, streams, and permanent wet soils (Fig. 1).

For the first time, extensive and detailed geophysical prospecting was performed in Hessdalen valley. It brings into light that geology, metamorphism, mineral deposits, and meteorological environment gang up on electrical currents rising in the sub-surface. Finally, results point out a possible origin of possible electrical sources in the valley and suggest a provisional mechanism for the formation of the transient Hessdalen lights into the atmosphere. Outcomes should initiate much more multi-disciplinary detail studies.

CRediT authorship contribution statement

G.N. Vargemezis: Writing – review & editing, Writing – original draft, Methodology, Investigation, Data curation, Conceptualization. **J. Zlotnicki:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Investigation, Data curation, Conceptualization. **B.G. Hauge:** Writing – review & editing, Investigation. **A.-L. Kjøniksen:** Writing – review & editing, Supervision, Investigation, Funding acquisition. **E.P. Strand:** Writing – review & editing, Investigation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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