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ELECTROMAGNETIC SIGNALS IN ELF BAND RELATED TO THE SEISMIC SEQUENCE OF VERZEGNIS (UDINE – ITALY) IN JUNE – JULY, 2019 - MAGNITUDE MAX. EQUAL TO 3.9 Mw

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ABSTRACT

Numerous are the testimonies of electromagnetic signals precursors of seismic events detected with the most different modalities, starting from the radio signals received from radio amateurs to arrive at the monitoring of particular frequencies of the electromagnetic spectrum not only by institutional bodies but also by amateurs.
This article concerns anomalous electromagnetic signals detected in the ELF band from a dedicated monitoring station, located in Trasaghis in the province of Udine, correlated to a series of seismic events (max 3.9 Richter) occurring in the Tolmezzo - Verzegnis - Venzone area province of Udine (Italy) between June, 16 and July, 07, 2019.
The station detected the first anomalous signals eighteen days and then again three days before the main event. The signals then continued even further, probably indicating the continuing state of tension, as evidenced by the subsequent seismic events.
The detected signals are located in the band between 1 and 10 Hz, and were detected by a very high inductance antenna connected to a standard seismic station. The similarity with other signals detected by the twin station of Pasian di Prato (UD) during the events of 2016-2017 in central Italy is significant.
It is therefore suggested to use a mobile station in order to detect the state of seismic stress in an area already affected by an important seismic event for prevention and civil protection purposes.

KEYWORDS

Seismic precursors, electromagnetism, ionosphere.

DISCUSSION

The study of the precursor phenomena of seismic events has historical roots and despite the difficulty of obtaining sufficiently precise results able to predict the area, intensity and timing of activation of relevant events, the studies continue with encouraging results that perhaps, in the future, will be able to provide some responses that can be used for prevention and civil protection purposes.
Electromagnetic signals recorded in correspondence, in advance and subsequently to earthquakes of considerable magnitude, have also been detected by amateurs radio.
One phenomenon in particular has been the subject of study by prof. Enzo Mognaschi of the University of Parma. He analyzed the phenomenon starting from the information obtained from the amateur radio Mr. Marco Eleuteri di Todi (PG) who observed unusual changes in the background electromagnetic noise observed before the May 12th 1997 Magnitude Magnitude of 4.7 Richter, with epicenter in Massa Martana (PG) – Italy, which was followed by a more devastating 6.0 with epicenter in Annifo (PG) on 26 September of the same year.
In the 90s of the last century, studies to detect precursory signs were numerous in that, during this period, scientists were convinced to prevent large earthquakes by studying these signals. Despite numerous attempts, however, it has been shown that not all seismic events are accompanied by precursor signs or that these, however, are not always detectable, since they depend on different physical conditions that can change from site to site. This has challenged the possibility of using these phenomena systematically for earthquake prediction. In recent years, however, some researchers have begun to study the phenomenon with new techniques, in the hope of being able to find more data that may prove useful for the prediction of important seismic events.
The precursor signals, in general, are induced by the phenomenon of dilatancy which normally precedes a seismic event. The signals are different and are listed by Cicerone et al. (2009).
Some of these phenomena have been studied more frequently, such as the concentration variations of the argon gas and especially of the radon gas (Biagi et al. 2004) (Riggio and Santulin 2015).
Recent studies have also analyzed the possibility that magnetic storms of solar origin may be able to produce a seismic trigger on areas already subjected to stress (Casey and Choi 2017).
The ability of rocks to emit energy in the form of electromagnetic waves has been verified in the laboratory by several researchers (Frid et al. 2000) (Nardi 2009). Its electrical properties have also been analyzed, finding that these very according to temperature, electrical voltage, frequency and chemical properties (Engler 2011) (Olhoeft 1981).

The possibility of exploiting electromagnetic signals to predicting seismic events has been the object of study by many other researchers through ground instruments (Minadakis et al.2011) (Lacidogna et al. 2011) Manno 2003) (Mavrodiev and Thanassoulas 2001). In particular, Gershenzon and Bambakidis (2001) proposed a model for the characterization of electromagnetic seismic signals.
Soil electric fields (Thanassoulas 2007) have also been studied in order to predict the formation of relevant seismic events. Thanassoulas et al. (2008) have shown that such signals can also occur in correspondence with the increase in lithospheric stress due to lunar tides. It has also been verified that charged particles, branched from internal areas of the lithosphere, can reach the surface and rise up to the ionosphere (Aleksandrin et al. 2003).
Many researchers have studied the correlation between electromagnetic signals and relevant seismic events (Parrot 1990) (Fidani 2012) (Cataldi et al. 2017) (Molchanov et al. 2003) (Ida et al. 2008) (Eftaxias et. Al 2000). Petraki et al. (2015) list a long series of seismic events related to electromagnetic signals recorded before them.
The path of electromagnetic waves within the lithosphere has also been studied (Petraki et al. 2015). Furthermore, it is not excluded that inside the lithosphere wave guides may be created as indicated by Sujay Pal (2015). Barr et al. (2000) analyzed the propagation of VLF and ELF waves.
Some researchers have verified the possibility of finding the direction of origin of electromagnetic signals in order to identify the epicenter of a relevant earthquake even with stations located in areas disturbed by background noise (Tutsui 2005) (Straser et al. 2018) (Ohta et al. 2011).
Winda Astuti (2014 - 2013), using the method developed by Thanassoulas, deals with the possibility of deriving the epicenter position by analyzing the electrical signals of the ground captured by means of earth dipoles.
Other researchers, on the other hand, have studied anomalous signals received from satellites in orbit recorded before the occurrence of relevant seismic events (Zhang et al. 2012).
It was possible to verify that the satellites can capture changes in the state of the ionosphere in correspondence with areas subjected to seismic stress (Parrot 1990) (Henderson at al. 1993) (Kelley 2017) (Bhattacharya and Gwal 2007) (He and Heki 2018) (Pulinets 2004).
Recently He and Heki (2017) have analyzed changes in the ionosphere status detected by GPS satellites, managing to correlate these anomalies to specific areas subjected to seismic stress in which, subsequently, strong earthquakes occurred.
Still through satellite surveys, variations in proton flux were detected before seismic events (Cataldi et al. 2017).
The study of electromagnetic seismic precursors by amateurs with different methodologies derived from their own experiences, in Italy has been active for several years.
Among others: Renato Romero (www.vlf.it) Adriano Nardi (INGV), Cristiano Fidani (CIEN) (Fidani 2017) Violi Roberto (Giano Network https://retegiano.jimdo.com) and myself (FESN www.fesn .org - ARI www.ari.it).

Seismic Sequence

The seismic sequence object of the present work has occurred in the area between the Municipalities of Tolmezzo, Verzegnis, Venzone, Resiutta and Osoppo in the province of Udine, in a period of time between June 16 and July 7, 2019.
The maximum magnitude achieved was 3.9 Richter.
It should be noted that the most significant events occurred in the Municipality of Verzegnis.
In total, the Seismological Center of Udine (www.rts.crs.inogs.it) detected 51 events having magnitudes between 0.1 and 3.9 Richter within a radius of about 20 kilometers from the Trasaghis station. The most relevant were about 14 kilometers away.
The seismic sequence seems to indicate a state of widespread stress in the faults of the considered area, probably a consequence of the first seismic shock occurred in the Municipality of Verzegnis on 14.06.2019, at 13.57 UTC, M. 3.9 Richter.

Sequenza sismica compresa tra il 14 giugno e il 16 luglio 2019 nella zona di Verzegnis - Tolmezzo - Venzone

Fonte: OGS - Centro ismologico Udinese - www.http://rts.crs.inogs.it

N.	Event id	Date	Lat	Lon	Mag	Location
1	122871	14/06/2019 10:55	46,3575	13,0253	0.6	2 km SO di Cavazzo Carnico (Udine)
2	122875	14/06/2019 13:57	46,3910	12,9860	3.9	1 km NO di Verzegnis (Udine)
3	122883	14/06/2019 14:01	46,3928	12,9865	1.1	1 km NO di Verzegnis (Udine)
4	122884	14/06/2019 14:06	46,3910	12,9955	1.5	0 km NE di Verzegnis (Udine)
5	122886	14/06/2019 14:08	46,3880	13,0083	0.3	1 km E di Verzegnis (Udine)
6	123173	14/06/2019 14:16	46,3955	12,9920	0.3	1 km N di Verzegnis (Udine)
7	123175	14/06/2019 14:26	46,3970	12,9803	0.4	1 km NO di Verzegnis (Udine)
8	122888	14/06/2019 14:33	46,3945	12,9927	0.5	1 km N di Verzegnis (Udine)
9	122889	14/06/2019 15:40	46,3923	12,9970	0.4	1 km NE di Verzegnis (Udine)
10	122890	14/06/2019 16:13	46,3932	12,9917	2.0	1 km N di Verzegnis (Udine)
11	122895	14/06/2019 19:09	46,3937	12,9973	1.0	1 km NE di Verzegnis (Udine)
12	122898	14/06/2019 19:14	46,3932	12,9900	0.8	1 km NNO di Verzegnis (Udine)
13	123177	14/06/2019 19:32	46,3152	13,2602	0.5	6 km N di Lusevera (Udine)
14	122906	14/06/2019 22:07	46,3942	13,0003	1.7	1 km NE di Verzegnis (Udine)
15	123179	15/06/2019 01:48	46,3420	13,1302	0.4	1 km NO di Venzone (Udine)
16	123180	15/06/2019 02:10	46,3357	13,1215	0.3	1 km O di Venzone (Udine)
17	122914	15/06/2019 03:15	46,3883	13,0028	0.5	1 km E di Verzegnis (Udine)
18	122915	15/06/2019 03:44	46,3442	13,1320	0.5	1 km NNO di Venzone (Udine)
19	122916	15/06/2019 03:58	46,4545	12,9360	0.1	3 km N di Lauco (Udine)
20	122917	15/06/2019 04:12	46,4013	12,9923	3.4	1 km N di Verzegnis (Udine)
21	123181	15/06/2019 05:06	46,3480	13,1443	0.4	2 km NNE di Venzone (Udine)
22	123183	15/06/2019 07:18	46,3733	13,0242	0.4	1 km ONO di Cavazzo Carnico (Udine)
23	123184	15/06/2019 07:35	46,3888	12,9882	0.3	0 km ONO di Verzegnis (Udine)
24	123185	15/06/2019 07:43	46,3803	12,9918	0.1	1 km S di Verzegnis (Udine)
25	123186	15/06/2019 07:50	46,3892	12,9902	0.1	0 km NO di Verzegnis (Udine)
26	123187	15/06/2019 07:54	46,3467	13,1317	0.3	2 km NNO di Venzone (Udine)
27	122927	15/06/2019 14:08	46,3903	13,0015	1.7	1 km ENE di Verzegnis (Udine)
28	122939	15/06/2019 19:14	46,3395	13,1270	0.5	1 km NO di Venzone (Udine)
29	123188	15/06/2019 19:31	46,3420	13,1372	0.1	1 km N di Venzone (Udine)
30	122945	15/06/2019 20:33	46,3960	13,0062	1.3	1 km OSO di Tolmezzo (Udine)
31	122950	15/06/2019 20:41	46,3918	12,9977	0.3	1 km NE di Verzegnis (Udine)
32	122955	15/06/2019 21:52	46,3890	12,9833	0.2	1 km O di Verzegnis (Udine)
33	122968	16/06/2019 00:02	46,3370	13,1225	1.2	1 km ONO di Venzone (Udine)
34	122972	16/06/2019 03:58	46,3890	12,9880	0.7	0 km ONO di Verzegnis (Udine)
35	123202	16/06/2019 04:15	46,3360	13,1297	0.3	1 km ONO di Venzone (Udine)
36	122979	16/06/2019 13:40	46,3930	12,9897	3.0	1 km NNO di Verzegnis (Udine)
37	123233	16/06/2019 20:38	46,3630	13,1547	0.3	3 km NNE di Venzone (Udine)
38	122997	16/06/2019 21:39	46,3395	13,1260	0.7	1 km ONO di Venzone (Udine)
39	123234	16/06/2019 21:46	46,3480	13,1323	0.4	2 km NNO di Venzone (Udine)
40	122999	16/06/2019 22:54	46,3375	13,1273	0.5	1 km ONO di Venzone (Udine)
41	123125	22/06/2019 18:03	46,3335	13,2152	1.3	6 km E di Venzone (Udine)
42	123168	25/06/2019 01:49	46,3900	12,9913	0.3	0 km N di Verzegnis (Udine)
43	123252	26/06/2019 00:46	46,3422	13,1598	0.1	2 km ENE di Venzone (Udine)
44	123196	26/06/2019 04:18	46,4312	13,1642	0.4	4 km NO di Moggio Udinese (Udine)
45	123292	29/06/2019 00:16	46,3927	12,9982	0.3	1 km NE di Verzegnis (Udine)
46	123337	29/06/2019 14:30	46,3885	12,9988	0.3	1 km E di Verzegnis (Udine)
47	123473	05/07/2019 17:56	46,2382	13,1065	0.5	3 km SE di Osoppo (Udine)
48	123506	07/07/2019 12:06	46,3897	12,9777	0.7	1 km O di Verzegnis (Udine)
49	123510	07/07/2019 21:09	46,3988	12,9963	3.0	1 km NNE di Verzegnis (Udine)
50	123569	10/07/2019 03:19	46,3938	13,0207	0.4	0 km SSE di Tolmezzo (Udine)
51	123693	16/07/2019 02:05	46,3475	13,2322	1.0	5 km S di Resiutta (Udine)

Fig. 1 – List of seismic events detected by the Seismological Center of Udine (INGV) between in 2019/06/14 and 2019/07/16 in the area between Tolmezzo, Venzone, Verzegnis and the immediate vicinity. The most relevant events are highlighted in green and yellow.

MAIN EVENT

The main event took place on June 14, 2019, at 13:57 UTC. The moment magnitude calculated by the Centro Ricerche Sismologiche di Udine, headed by the Istituto Nazionale Gefisica e Vulcanologia, was 3.9 Mw.
The main shock was preceded by a small event of 0.6 Richter occurred a few kilometers away in the area of Cavazzo Carnico.
After the shock of 3.9 Mw and until July 16, 2019, another 49 shocks with a magnitude of between 0.1 and 3.4 Mw have followed.

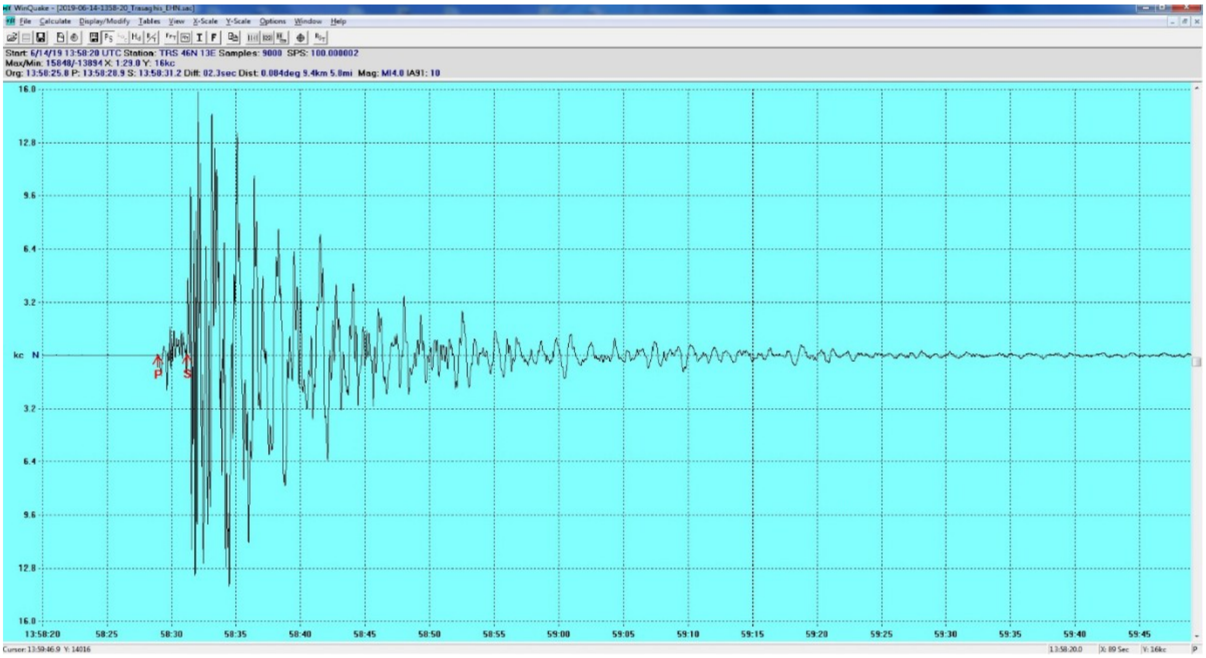

Fig. 2 – Seismogram of the main event with a magnitude of 3.9 Mw, which occurred in the Municipality of Verzegnis (UD) on June 14, 2019, at 13:57 UTC. The seismogram was produced by the Trasaghis amateur station using a FMES (Fluid Mass Electrolitic Sensor) built by the author.

Fig. 3 - Map of the considered area with the epicentres of the seismic events detected highlighted. The main events are in green

Fig. 4 - Map of capable faults in the considered area (red lines). (ISPRA - ITHACA - ITaly HAzards from CApable faults)

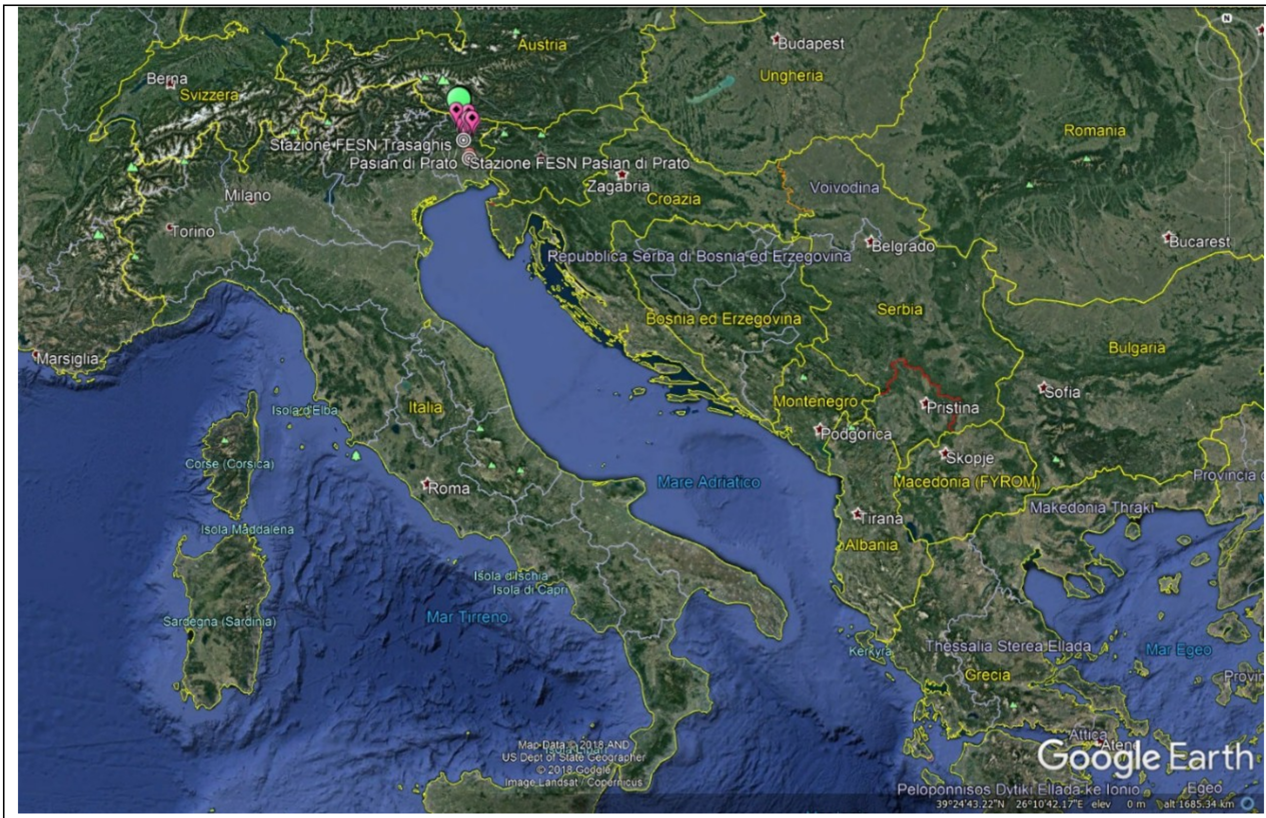

Fig. 5 - Localization of FESN stations of Pasian di Prato and Trasaghis

CHARACTERISTICS OF THE MONITORING STATION

The construction of the monitoring station is the result of sharing experiences and skills among different researchers.

The first component of the station is the very high inductance antenna. This device consists of about 100,000 turns of insulated copper wire of 0.20 mm diameter, wound on coils of about 17,000 turns each, formed by a 50 mm diameter fiberglass reel.

Fig. 6 Realisation of the antenna with very high inductance Note the 6 coils with 17,000 turns of insulated copper wire and the protruding core formed by soft iron bars.

These coils are inserted into a plexiglass tube which is in turn filled with soft iron bars.
The coils are finally wrapped in a loop of aluminum foil which acts as a screen for parasitic electric fields.
An external tube made of HDPE (High Density Polyethylene) protects the entire construction.
The antenna is positioned vertically.

The amplification and filter circuit used is suitable for the connection of seismic sensors (eg geophones) and was designed by Mauro Mariotti, owner of the SARA company in Perugia, supplier of seismic prospecting equipment.

The device used was built by the author of this article based on the original plans.
The signal received from the antenna, amplified and filtered, is sent to an 18-bit resolution digital/analogue conversion card, whose design is always by the firm of Sara in Perugia and whose construction also was homemade.

The output data from the A/D card are processed by the software for S.O. Windows named Seismowin, produced and made available free of charge by the SARA company (http://www.sara.pg.it).

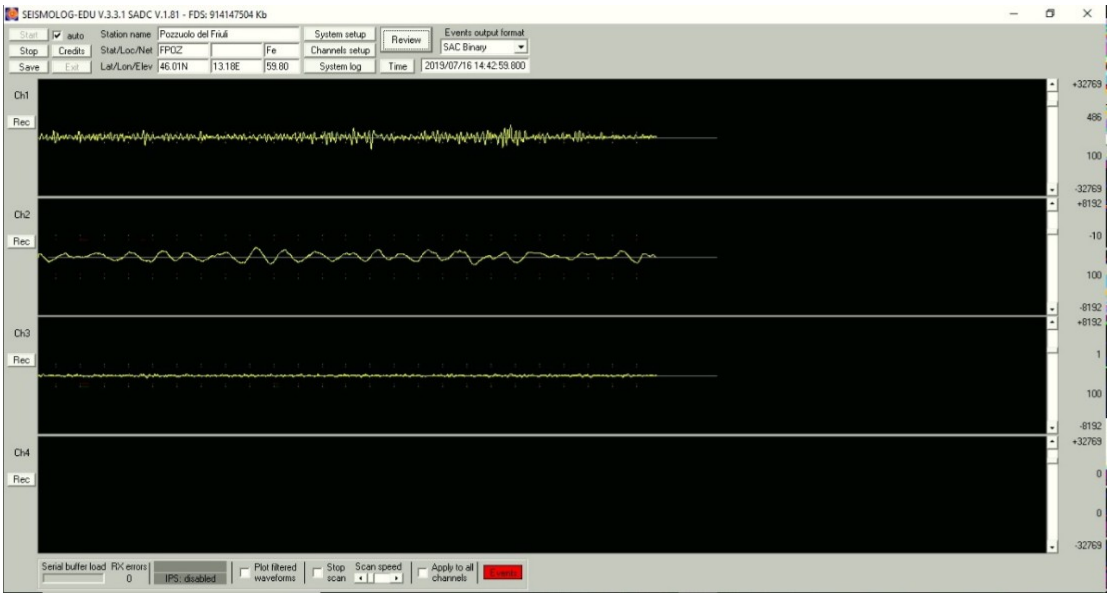

Fig. 7 - Screenshot of the Seimolog-Edu software (Seismowin element) used, together with a data acquisition device, for recording seismic events using a personal computer with a Windows operating system. Note the three real-time traces of the connected sensors. In the case of operation with the aforementioned antenna, one of the channels is reserved for the latter.

The Seismowin software processes the signal producing, in addition to the video reconstruction of the signal in real time, also the "DRUM" screen, that is the daily recording in the time domain and the "DRUM FFT", a daily spectrogram obtained by Fourier transformed.
In order to allow other researchers to duplicate the experience reported here it is specified that the instrumentation described above, apart from the antenna, can be replaced with a standard seismic monitoring station, preferably 24-bit, provided that it is compatible with the Seismowin software.

CHARACTERISTICS OF MONITORING

The station monitored and saved the daily screens of the electromagnetic signal detected by the antenna, between 0 and 25 Hz, for the entire period considered.
During this period it was found that the station detects a relatively low background noise, considered its position in a foothill area sufficiently distant from sources of significant anthropogenic noise such as power lines or other sources of disturbance. In any case the network frequency at 50 Hz is sufficiently above the band considered, so as not to generate interfering signals.
In the standard screen, recorded with relatively minor differences compared to the one presented below, the characteristics of the background noise can be seen, indicated in the image by the green color, covering most of the screen where the reference hours are indicated on the abscissa , starting from 0:00 UTC until 24:00 UTC and on ordinate the monitored frequencies are indicated, starting from 0 up to 25 Hz. The sampling frequency is equal to 100 Hz.

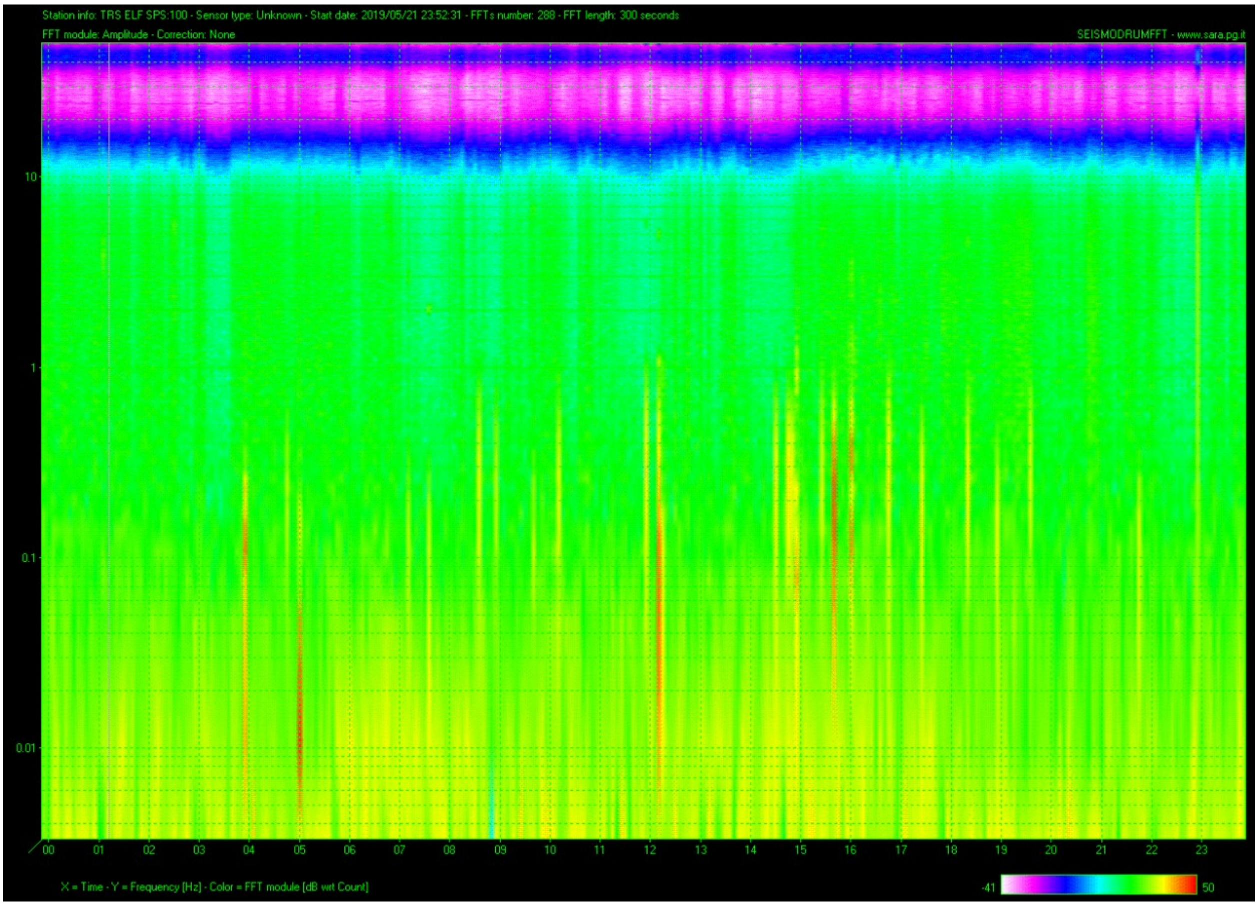

Fig. 8 - Spectrogram related to a day of recording of electromagnetic activity. On the x-axis the time expressed in hours, on the ordinate the reference frequency (0-25 Hz). At the bottom right the color references in the range between -41 and +50 dB / count. Note the yellow and red bars relating to disturbances of anthropogenic and natural origin (motors, lightning and other) and the part between about 1 and 10 Hz without interference.

The number of vertical bars that make up the screen is equal to 288, processed on the basis of the detected signal portion comprising 300 seconds.
It can be noted that in the band between about 0.5 Hz and about 10 Hz, the detected signal is quite homogeneous and free from interference and it is therefore possible to detect any anomalies in this band.
The monitoring carried out was characterized by almost zero anomalies from the first start, generating screens comparable to those detected by the twin station located in Pasian di Prato (UD) which is located at a distance of about 27 km, in line of air, compared to the Trasaghis station.

ANOMALOUS SIGNALS

The first anomalous signals were recorded by the Trasaghis station starting from 26 May 2019, consisting of an increase in background noise that lasted throughout the day.
On May 29th, shortly after 07.00 UTC, another anomalous signal was recorded consisting of a focused signal at a frequency slightly higher than 1Hz which lasted until about 5.00pm on June 1st.
The increase in background noise also occurred on June 2, 12, 13, 14, 15, 16 and 17; June 15 with particular intensity.

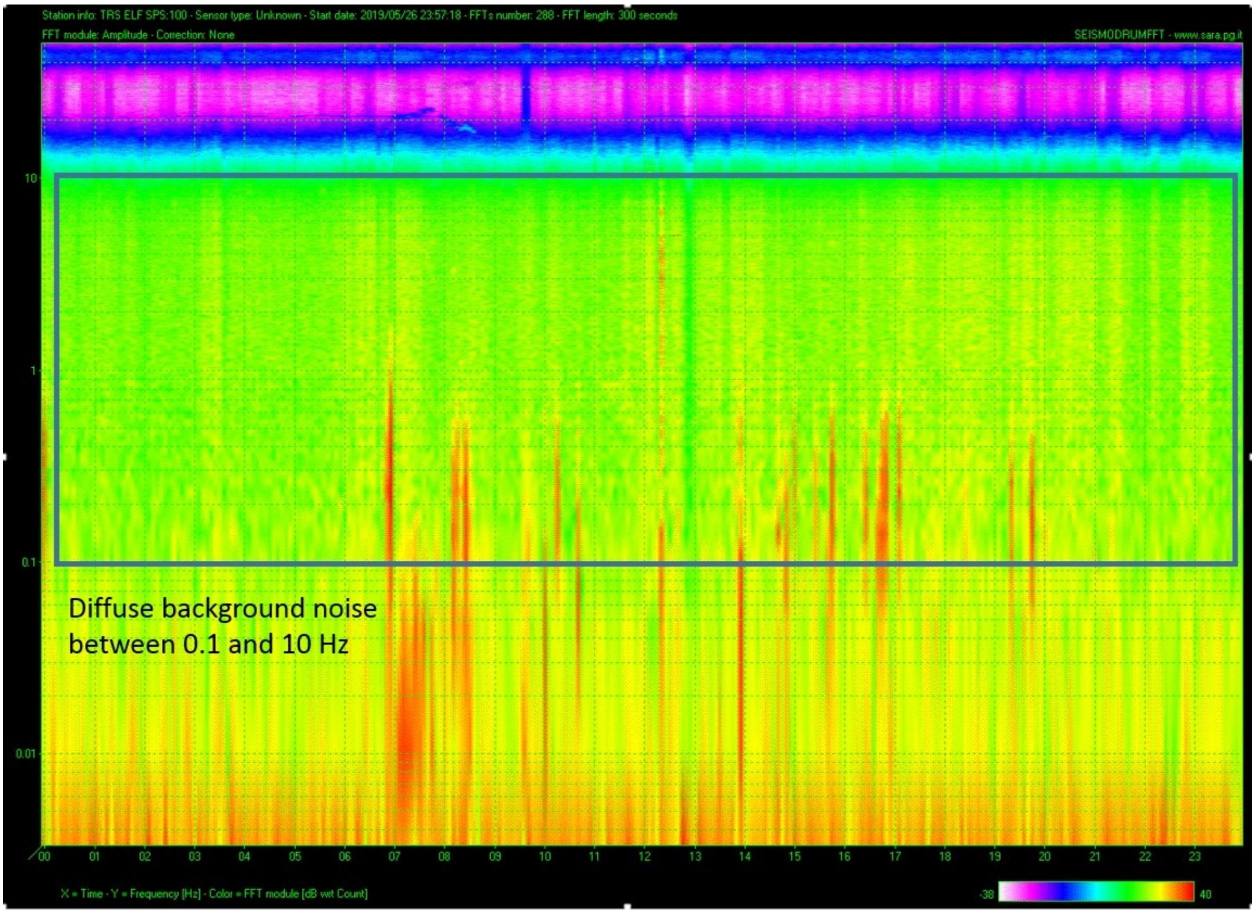

Fig. 9 - Spectrogram of June 26, 2019. Note the increase of the background noise in yellow on the green background included in the rectangle in the signal band between 0.1 and 10 Hz.

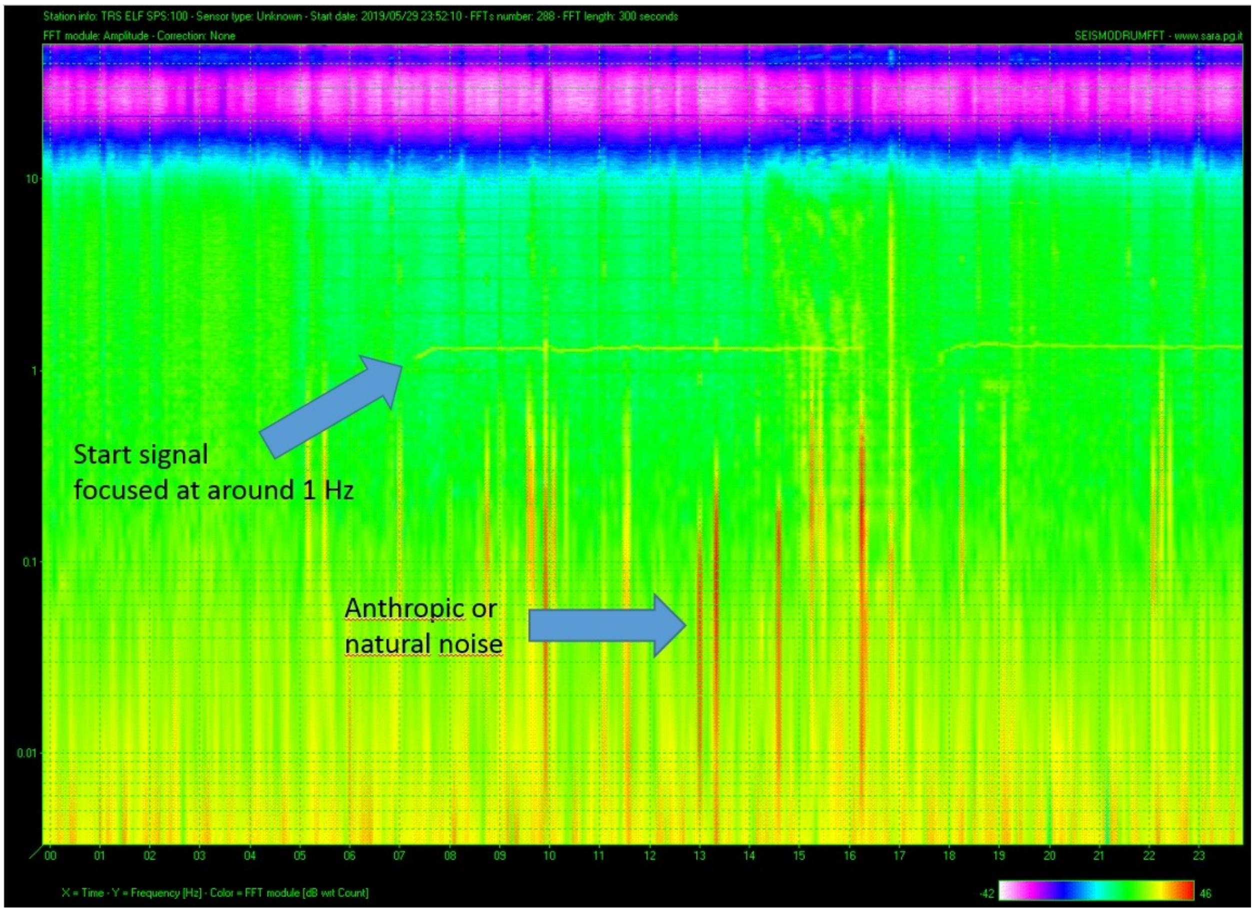

Fig. 10 - Program of May 29, 2019. Note the beginning of the focused signal at about 1 Hz and the anthropogenic or natural noise in the band between 0 and 1 Hz approximately.

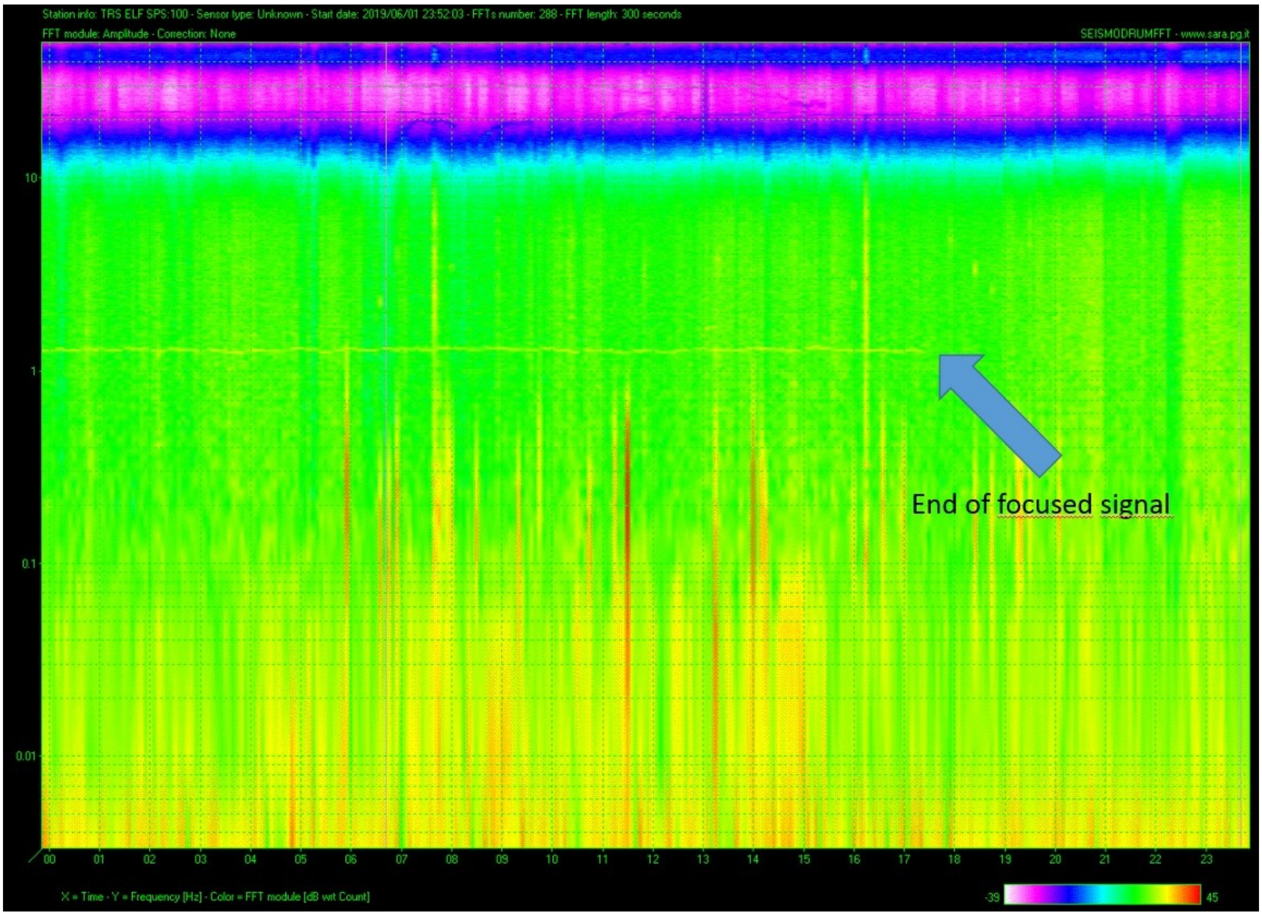

Fig. 11 - Spectrogram of June, 01, 2019. Note the end of the focused signal at about 1 Hz after about 58 hours.

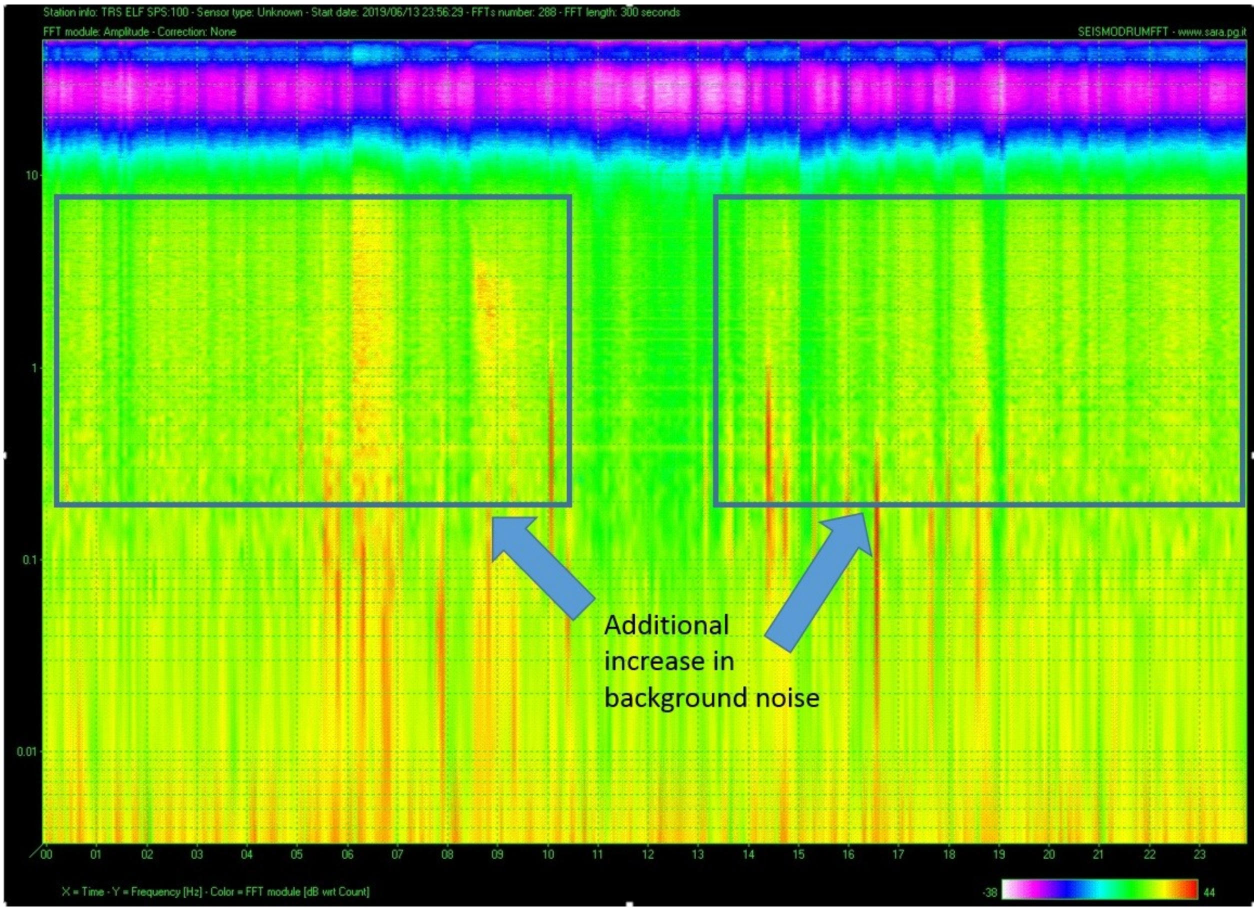

Fig. 12-Spectrogram of June 13, 2019.Note the increase in background noise.

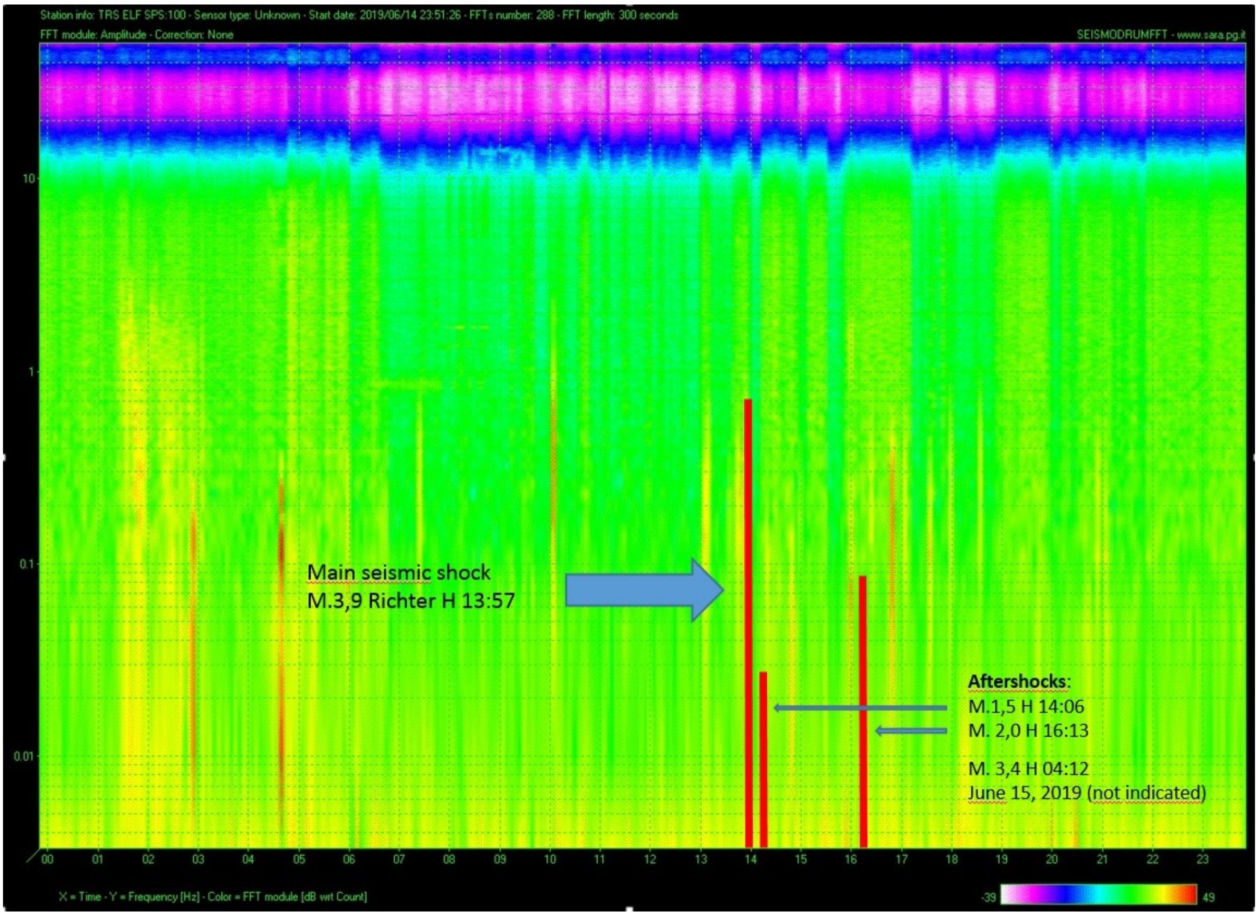

Fig. 13– Spectrogram of June 14,2019with the most significant events highlighted.

It should be noted that similar signals comprising both the increase in diffuse noise and the signal focused around 1 Hz were recorded in the twin station of Pasian di Prato in conjunction with the seismic events of central Italy in 2016 and 2017. This survey was the subject of a previous article (27).

CONCLUSIONS

The actual capacity of rocks subject to seismic stress to emit signals by means of a piezomagnetic effect in the band considered by the present article has already been analyzed by other researchers. It is therefore reasonable to think of correlating the anomalous signals received with the stress state of the faults existing in the vicinity of the Trasaghis station, which were probably activated due to the stresses induced by the first important event in Verzegnis.

It is important to note that the first anomalous electromagnetic signals were detected 18 days before the main event and that these signals continued well beyond this event, probably highlighting the stress state of the faults involved in the area.

Therefore, following this experience, it is possible to experiment with the use of a standard mobile seismic station, equipped with an antenna similar to that present in the reference station, to monitor the stress state of faults activated by high events magnitude, positioning the station near the epicenter in order to try to assess potential further aftershocks for the purpose of study, prevention and civil protection. However, it should also be considered that the responses of the various sites can be very different and therefore any data collected in these conditions will have to be evaluated with the utmost care and prudence.

The absence of similar signals, during the period considered, in the Pasian di Prato station, is probably due to the greater distance with respect to the source area (about 45 km) and to the limited hypocentral electromagnetic energy released.

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