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Saving Legacy Seismological Data for South-Western Romania

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ABSTRACT

Preserving historical analogue seismograms and observational documents is vital for maintaining an accurate, long-term record of regional seismic activity and safeguarding irreplaceable information on seismic past events.

Historically shaped by shifting political eras, resource constraints, and changing technological paradigms, Romanian seismology relies heavily on systematic conservation to bridge early observations with modern digital monitoring systems.

This study presents the ongoing efforts to inventory and preserve the legacy seismological records stored at the Timisoara Seismological Observatory, covering six key historical stations in southwestern Romania: Timisoara (TIM), Susara (SSR), Gura Zlata (GZR), Buzias (BZS), Banloc (BANR), and Siria (SIRR). Out of an estimated 150,000 analogue records (smoked paper, photographic paper, and ink on paper), over 58,000 ink-on-paper seismograms spanning 1977–2017 have been chronologically sorted and catalogued into the *Heritage Legacy Inventory of Seismograms in Romania* (HELIOS-R). Furthermore, high-resolution scans (1200 dpi) and standardized metadata were generated for 45 seismograms corresponding to 17 nuclear explosion tests (1979–1992) to contribute missing southwestern Romanian data to the *Nuclear Explosion Legacy Data* (NELD) repository. These systematic preservation initiatives ensure uninterrupted data continuity, enrich national and international databases, and provide crucial data for re-evaluating historical events, refining seismic hazard assessments, and conducting global nuclear monitoring research.

Key words: legacy seismograms, seismic inventory, HELIOS-R, southwestern Romania, historical seismology

ARTICLE HIGHLIGHTS

- This paper is a monographic review on the evolution of 6 seismic stations in the south west region of Romania
- This paper presents a timeline of the analogue equipment that operated at each seismic station.
- The efforts of preserving a consistent number of seismograms, the inventorying process and relevant information on how to access this data are highlighted.

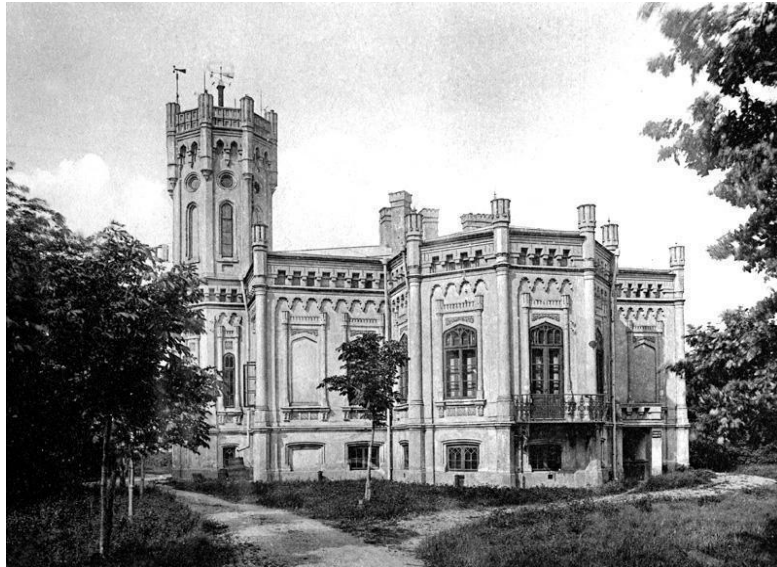
1. INTRODUCTION

Preserving historical analogue documents and seismograms is vital for maintaining an accurate, long-term record of the regional seismic activity, as these documents contain irreplaceable snapshots of past events. Within the context of Romanian seismology, this discipline evolution has been historically arduous, shaped by shifting political eras, resource constraints and changing technological paradigms. Safeguarding legacy records is both a scientific necessity and a cultural imperative (Oancea et al., 2026). Systematic conservation and digitization bridge the gap between historical observations and modern digital monitoring systems, ensuring uninterrupted data continuity. Ultimately, preserving this observational heritage enriches both national and international seismological databases, providing crucial data for contemporary seismic hazard assessments, climate-tectonic research and global earthquake studies.

1.2 BRIEF HISTORIC BACKGROUND

Seismic monitoring in Romania has passed through several significant stages, from the first macroseismic observations to the installation and expansion of complex instrumental networks. The seismic monitoring started at the end of the XIXth century - early years of the XXth century in Bucharest, Timisoara and Cluj.

The first efforts towards the installation of adequate measuring and recording instruments and macroseismic data collection in Romania were led by Stefan Hepites. In 1889 Hepites established the first seismic station in Romania, at Cutitul de Argint (Figure 1a), in Bucharest, in the building of the Meteorological Institute. After a short period of time, a building dedicated to the seismological service was constructed next to the main building (Figure 1b). The first installed seismic instrument was a Brassart seismoscope that operated until 1914 (Radu, 1997). Initially the seismological service was integrated within the Astronomic Observatory of the Romanian Academy in Bucharest (Cutitul de Argint). In the early 1960's the seismological service was transferred to the Geophysics Research Center and underwent administrative changes until 1994 when the National Institute for Earth Physics (NIEP) was founded with the headquarters in Magurele, Ilfov county (Marmureanu et al., 2020).



(a)



(b)

Figure 1. (a) Cutitul de Argint – the first seismic station in Romania, in the building of the Meteorological institute in Bucharest

Source (a): Antoniu Alexandru, Meteorological Institute of Bucharest around 1904

(b) The building of the seismological service in Bucharest, in 1925 (right corner)

Source (b): Photographic archive of the Astronomical Institute of Romanian Academy

In Timisoara, the meteorological and seismological service was established in 1897 under the supervision of Edé Berecz. The first instrument that operated there is still unknown to us, but early publications (Tőkés, 1904) showed that a Cacciatoare seismoscope and a Rossi-Forell seismograph were installed in 1899. Later, in 1904, a seismic pavilion was inaugurated (Figure 3), hosting a modified Vicentini seismograph.



Figure 3. Edé Berecz in front of the seismic pavilion at the Timisoara meteorological and seismological station

Source: L. Tőkés, 1904

In Cluj, the seismic service was established in 1911 by Jenő Cholnoky. The station was equipped with two seismographs built by Carl Mainka especially for this location (Cholnoky, 1911). Photographs of the original Mainka seismometers were found in the Photographic Collection *Jenő Cholnoky* in the archives of the Babes-Bolyai University in Cluj (Figure 4).

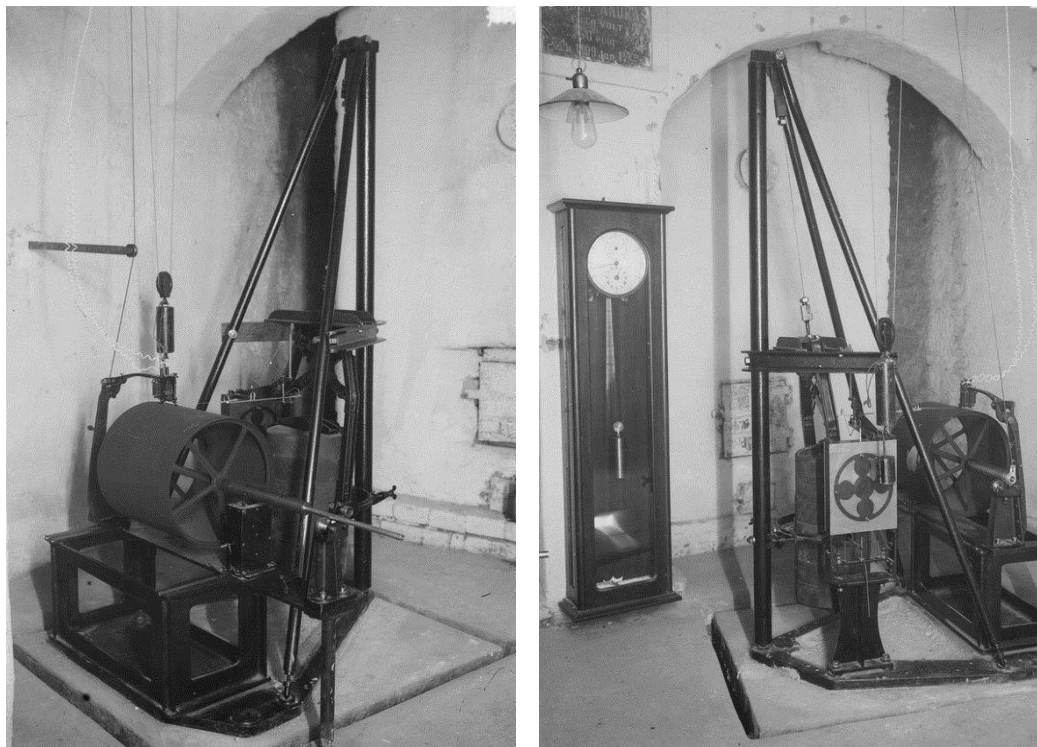


Figure 4. The original horizontal Mainka seismograph, installed in Cluj in 1911 by Jenő Cholnoky. NS component (left) and EW component (right).

Source: <http://cholnokyphotos.gisit.ro/> accessed on 16.07.2026

After the First World War the seismic station was abandoned and the Mainka instruments were deteriorated. In 1934 the seismographs were transferred, with the help of Ioan Curea, to the Bucharest Observatory to be restored by Gheorghe Demetrescu and his assistant Mircea Marcopol. Between January 1935 to July 1936 the Mainka seismographs were tested for their function capabilities at the Bucharest Observatory (Curea, 1940). The results were published in the yearly seismic bulletin (Demetrescu, 1935, 1936).

The original Mainka instruments were so deteriorated that repairing them back to the original state was impossible. Only the metal frame and pendulum weights were actually retrieved as the mechanical parts were damaged beyond restoration possibilities. A detail, given by Ioan Curea (Curea, 1940), was that the time mark system at the original Mainka instruments was fragile and unstable when recording an event. Given this situation, during the restoration process, many important features of the seismographs were improved, including the time mark system. In these conditions, with the important improvements brought to these instruments they were no longer the original Mainka seismographs. We will refer to it as Mainka Modified.

In July 1939 the Mainka Modified (MM) instruments were brought back to Cluj. By October 1939 Curea managed to obtain the agreement to install the Mainka Modified seismographs in the basement of the Royal Academic College (actual Academic College) (Figure 5).

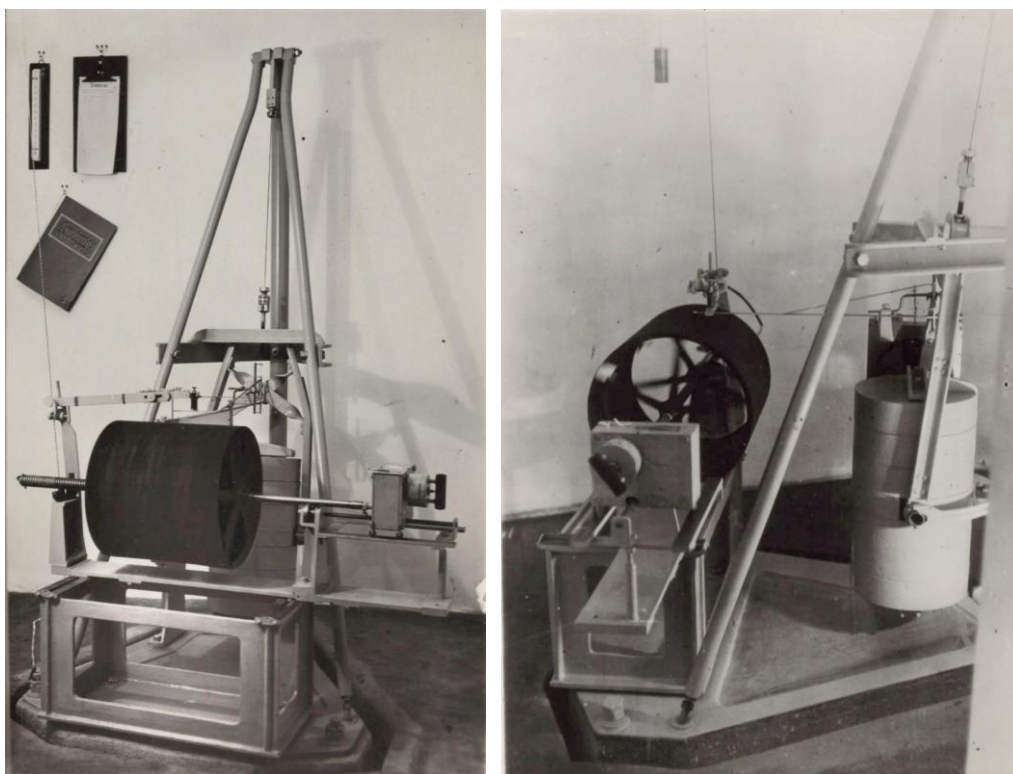


Figure 5. Mainka Modified seismograph (EW component), installed in Cluj in 1939 by Curea at the Royal Academic College

Source: Photographic archive of the Timisoara Seismological Observatory

The seismic station started its official service on 24 January 1940. It operated only for a short period of time, until July 1940, due to World War II harsh conditions (Curea, 1940). During this time, the seismic station recorded a number of 33 earthquakes (out of which 8 were from Romania) (Curea, 1940).

Due to the tensioned political situation, Curea had to leave Cluj and moved to Timisoara, leaving the seismic station and instruments in functional conditions (Curea, 1944a). Later, in 1963, Curea relocated the Mainka Modified seismographs from Cluj to Timisoara (Radu, 1997).

Coming as a great challenge at first, losing all those great efforts in a matter of days due to circumstances that could not be controlled, it seems that this was in fact the starting point of the reestablishment of the seismic service in Timisoara.

The Mainka Modified instruments represented the benchmark model for constructing a new set of seismographs in Timisoara by Curea with the guidance received from Demetrescu.

The development and evolution of these research centers was not isolated, even though it started as local initiatives. While at the beginning of the 1940s, there were less than 10 seismic stations in Romania, the need for a unified and high-performance network became evident, due to the high level of seismicity. A major turning point was the large earthquake of March 4th 1977 (Mw 7.4), which demonstrated the need for a much denser network of seismic stations. Between 1968 and 1995, the number of seismic stations increased significantly reaching 51 monitoring points in 1995 (Popa et al., 2015). By this time a data transmission system to the headquarters via radio link was installed in Magurele (for the stations AAR, BRD, CEA, CFR, CGN, CLI, CLO, COZ, CVO, HNM, ISR, MLR, MSR, MTU, PPE, SNX, SRE, TLB, VLR, VRI) and in Timisoara for the south western Romania seismic stations (BZS, BANR, SIRR) (Marmureanu et al., 2020) as seen in Figure 6.

Later, in the early 2000s, digital technology was introduced gradually to every seismic station in Romania. As the network expanded, new stations were installed and the analogue stations were replaced with digital technology.

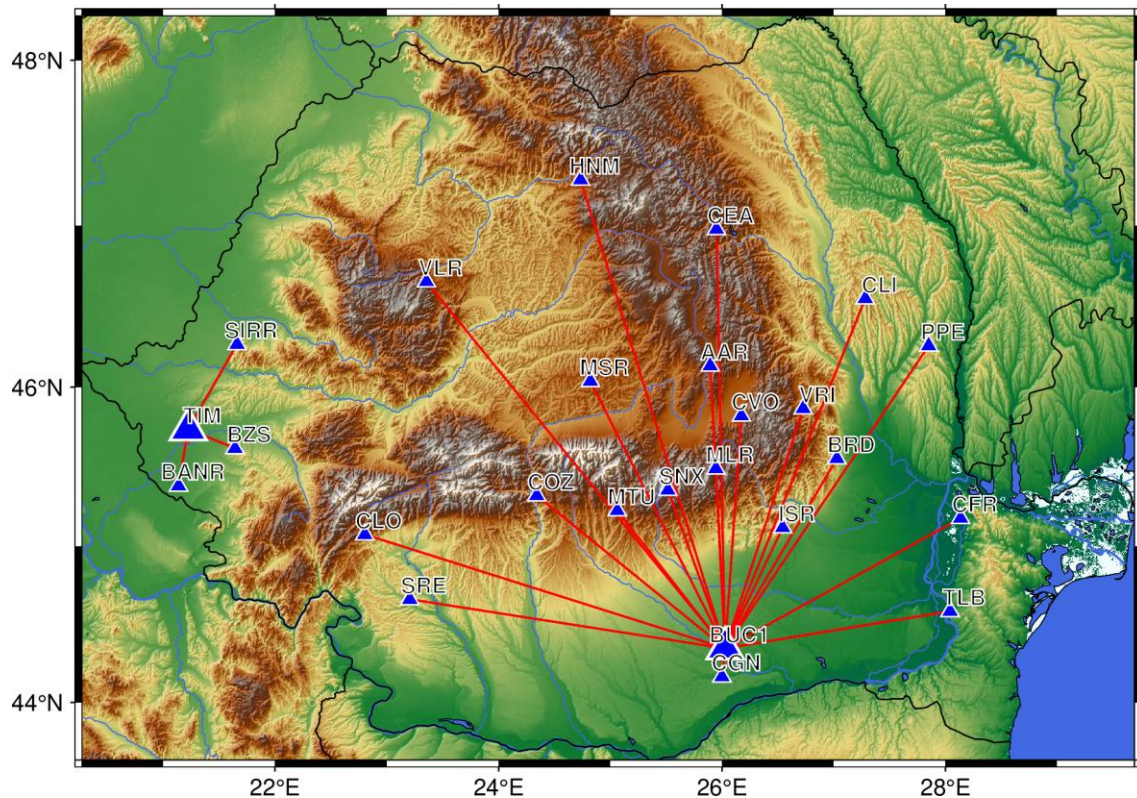


Figure 6. The network of seismic stations that transmitted data via radio link to Magurele headquarter (BUC1) and Timisoara Observatory (TIM)

2. SEISMIC STATIONS FROM THE SOUTH-WESTERN PART OF ROMANIA

2.1 Timisoara Seismic Station (TIM)

In Timisoara, the Hungarian Society of Geography founded in 1897 the establishment of a permanent meteorological and seismological observation station under the guidance of Edé Bercz. The station was equipped in 1899 with a Cacciatore seismoscope with mercury flow and a Rossi-Forell electric seismoscope with sound alert, followed in 1904 by a Konkoly-Vicentini seismograph (Figure 7) with recording on smoked paper (Table 1). The station functioned continuously until the death of Edé Bercz in 1910.

The seismologic and meteorologic service was taken over by his daughter, Otilia Bercz. From 1910 until 1919 the seismic station operated with intermittence, because the mechanical maintenance was difficult to sustain during the difficult time of war (Vanciu Rau, 2022).

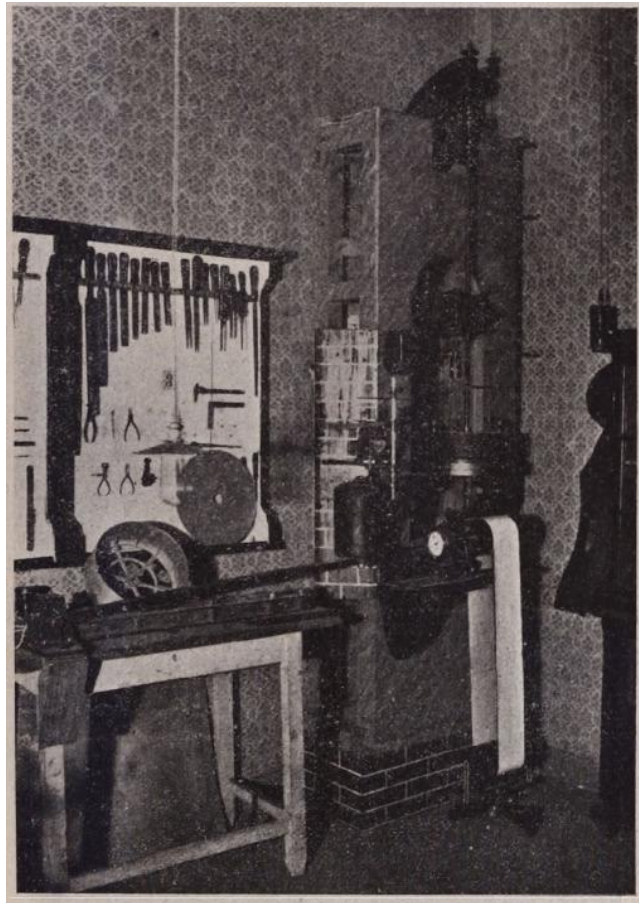


Figure 7. The Konkoly-Vicentini seismograph installed in Timisoara seismic station in 1904
Source: Source: L. Tőkés L, 1904

After the end of the First World War, in 1919 the seismic service ceased in Timisoara and the Konkoly-Vicentini seismograph was abandoned.

There was no seismic monitoring in Timisoara between 1919 and 1943. At that time, Curea identified the abandoned seismic station in Timisoara and concluded that the instruments were completely damaged with no viable chance of restoration.

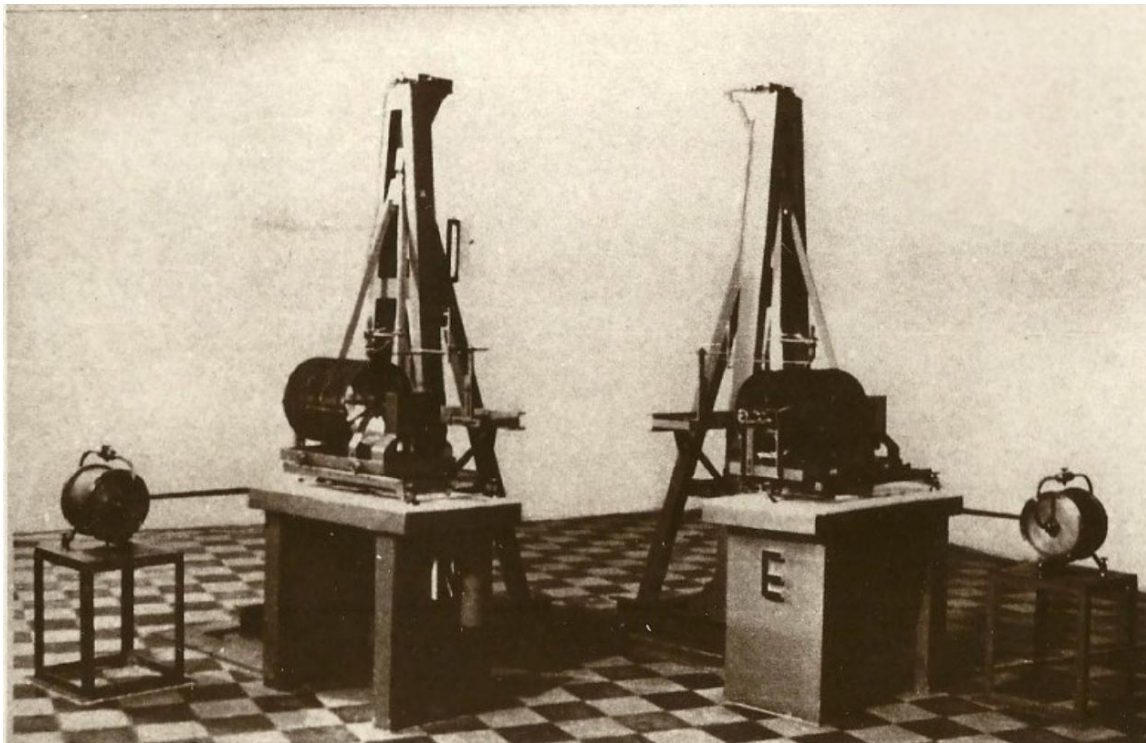
Following the large Vrancea earthquake on 10th November 1940 (Mw 7.7), Curea managed to secure funding from the city Town Hall of Timisoara to reestablish the seismic service in Timisoara (Curea, 1944 b).

In 1943 the new seismograph was officially put into function (Table 1) and the seismic service was restored in Timisoara (Curea, 1944 a). The new seismograph was built following the Mainka Modified pattern, but with slight adjustments and adaptations to best accommodate the instrument locally. Having in view the substantial contribution of Curea and Demetrescu, we will refer to this seismograph as Mainka-Demetrescu-Curea (MDC). The MDC seismograph was constructed entirely in Timisoara.

The MDC seismograph operated in Timisoara for a brief period, from September 1943 to April 1944 when the seismic station ceased activity due to World War II.

Timisoara seismic station resumed activity starting with 6th June 1950, this time hosted and administered by the Polytechnic Institute of Timisoara (Oros, 2004). Having better conditions of operation, the MDC seismograph (Figure 8 a) was installed and put into function with two

horizontal components (NS and EW) fixed on concrete pillars in the basement of the former Roman-Catholic Highschool (Figure 8 b).



(a)



(b)

Figure 8. (a) Mainka-Demetrescu-Curea seismograph in the basement of the Polytechnic Institute around 1964

(b) Romano-Catholic high school building attributed to the Polytechnic Institute where the seismic service was resumed in 1950

Source: Photographic archive of the Timisoara Seismological Observatory

In 1966, a building constructed specifically for hosting the Mainka seismograph was inaugurated in Timisoara, under the direct instructions of Curea (Figure 9).



Figure 9. The new building of the seismic station in Timisoara, inaugurated in 1966
Source: Photographic archive of the Timisoara Seismological Observatory

The MDC seismograph (Figure 10) was successfully relocated and installed in the new building dedicated to the seismic service where it still exists today in the original position.

The MM seismograph from Cluj was transferred to Timisoara in 1963 and installed in the newly inaugurated building in 1967, next to the MDC instruments (Figure 11). The MM seismograph was put into operation in 1970, according to the annual seismic bulletins (Curea, 1970).

The station was equipped with a supplementary short-period electrodynamic equipment, Kirnos – SKD (Radu, 1997) (Figure 12) that was installed in 1970 as mentioned in the station books (Table 1).

The early seventies represented an increase in monitoring equipment installation and a development and expansion of the seismic network in the western part of Romania.

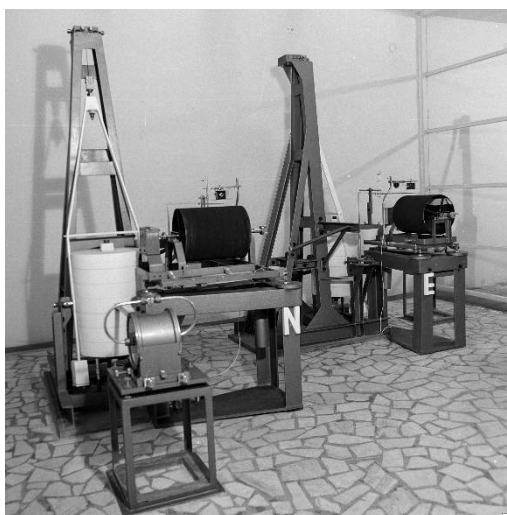


Figure 10. Mainka-Demetrescu-Curea mechanical seismographs installed at the Timisoara Observatory in 1966 (*left*); the same instrument in a preservation state in 2025 (*right*)
Source: Photographic archive of the Timisoara Seismological Observatory



Figure 11. The Mainka Modified seismographs from Cluj relocated to the new building in Timisoara (*left*) and the same instruments in preserving state (*right*)
Source: Photographic archive of the Timisoara Seismological Observatory



Figure 12. The electrodynamic seismographs SKD (Z, NS, EW components) installed at Timisoara station in 1970: The sensors (*left*) and the photographic recording system (*right*).
Source: Photographic archive of the Timisoara Seismological Observatory

In April 1977 Timisoara seismic station was equipped with a supplementary short-period electromagnetic DD1 seismometer (Peking Factory). Later, in 1995 the equipment was completed with a S13 seismometer (Teledyne Geotech).

In the western part of Romania, the Timisoara seismic station was raised to the level of a regional Observatory and the analogue data recorded at 6 seismic stations (TIM, BZS, SSR, GZR, BANR, SIRR) were collected and processed at the Timisoara Observatory (Figure 13).

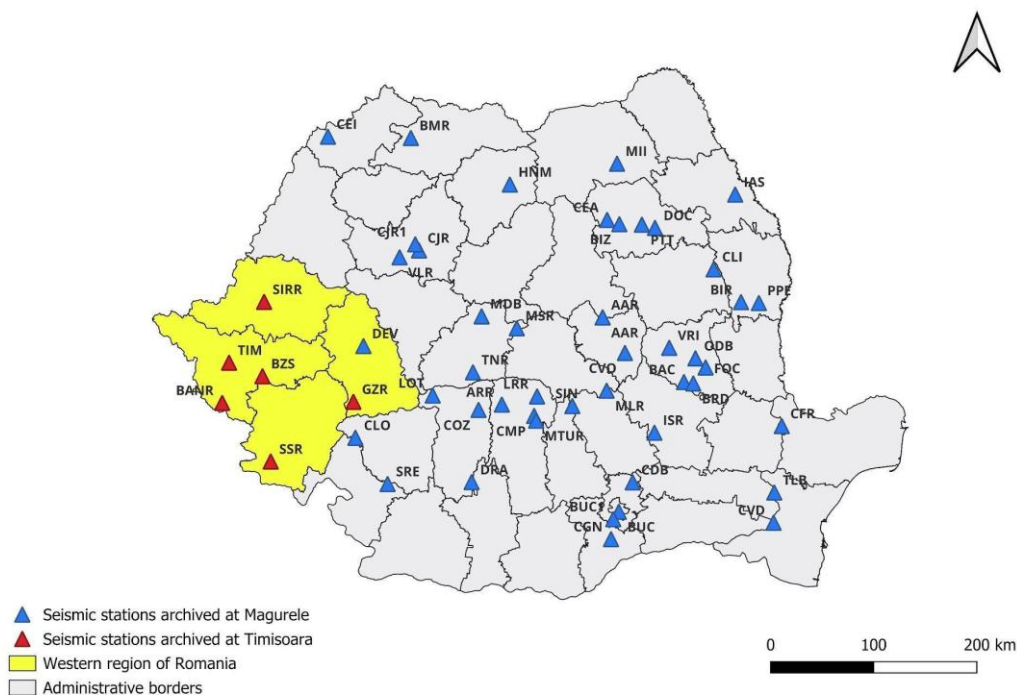


Figure 13. The recordings provided by the seismic stations in the western part of Romania were archived and stored at the Timisoara Observatory

The analogue instruments that operated at the Timisoara seismic station are presented in Table1.

Table 1. Analog instruments installed at Timisoara seismic station (TIM) listed in chronological order

TIM					
Start date	End date	Instrument	Recording type	Instrument type	Component
1902	1919	Cacciatore	-	Seismoscope with mercury flow	-
		Rossi-Forell	Smoked paper	Mechanic seismoscope with sonor alert	-
1904	1919	Konkoli-Vicentini	Smoked paper	Mechanic seismograph	N, E, Z
23.09.1943	30.04.1944	MDC	Smoked paper	Mechanic seismograph	N, E
06.06.1950	31.12.1965	MDC	Smoked paper	Mechanic seismograph	N, E
01.08.1966	N/A	MDC	Smoked paper	Mechanic seismograph	N, E
01.01.1970	N/A	MM	Smoked paper	Mechanic seismograph	N, E
01.01.1970	N/A	SKD	Photographic paper	Photo galvanometric seismograph	N, E, Z
04.04.1977	16.12.2008	DD1	Ink on paper	Electromagnetic	N, E, Z
28.09.1995	13.01.2009	S13	Ink on paper	Electromagnetic	N, E, Z

2.2 Susara Seismic Station (SSR)

In 1969, Curea established the second seismic station in south-western Romania, Susara (SSR) station. Built initially as a university multidisciplinary research centre for geographic, botanic and ethnological studies within the West University of Timisoara, the research facility at Susara included also a permanent seismic service (Vanciu Rau, 2022). The seismic station was settled on a remote location with very low noise and provided seismic recordings of high quality. The first seismic equipment at SSR was an electrodynamic seismometer Vegik with recording on photographic paper (Figure 14) installed in 1969, followed by a Kirnos-SKD seismometer in 1970 (Figure 15, top). After the large 1977 Vrancea earthquake (M_w 7.4), the station was also equipped with a DD1 short-period seismometer. An example of a seismogram recorded at SSR station, with the DD1 seismometer, is presented in Figure 16 for the moderate magnitude earthquake (M_w 5.0) from 30 March 1979 in the northern part of Romania, at an epicentral distance of 363 km.



Figure 14. Vegik seismometer installed at Susara station in the early 1970s
Source: Photographic archive of the Timisoara Seismological Observatory

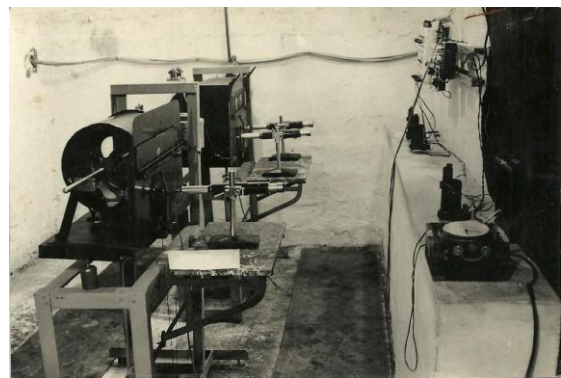
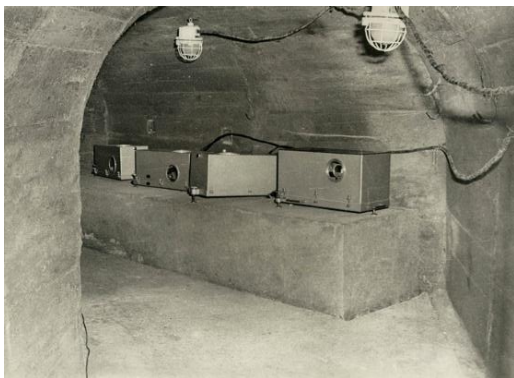
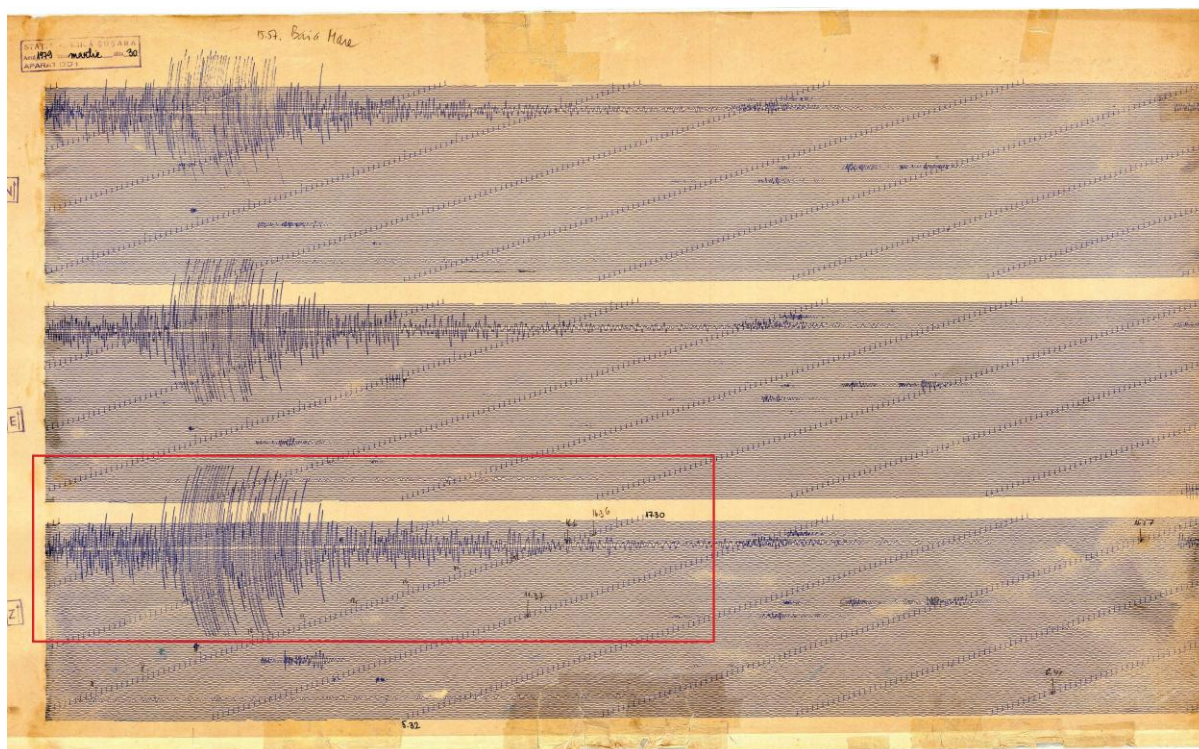
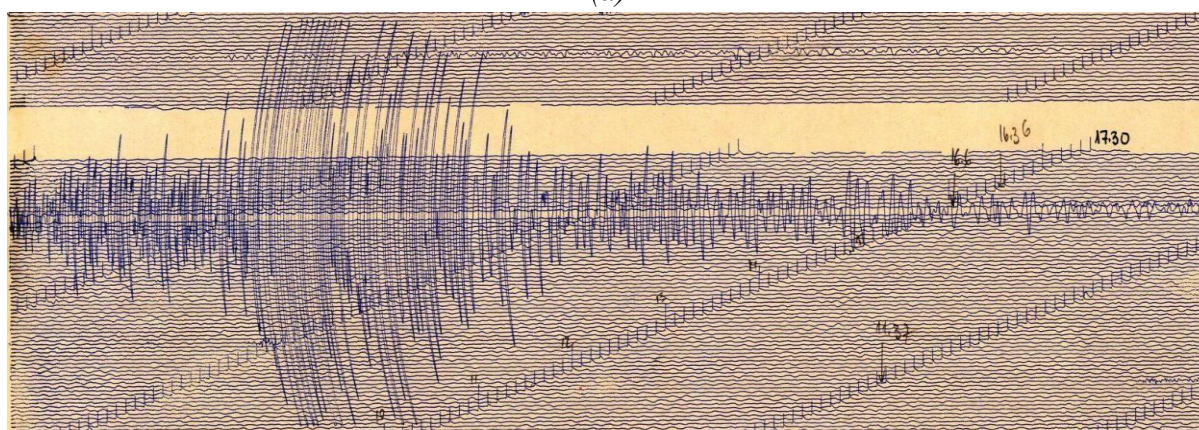


Figure 15. Susara seismic station. *Top:* SKD seismic sensors installed on pillars in a mountain gallery (*left*), the optical recording system (*right*). *Bottom:* the building of the seismic station and research center (*left*), the control and study room (*right*),
Source: Photographic archive of the Timisoara Seismological Observatory



(a)



(b)

Figure 16. (a) Earthquake (Mw 5.0) recorded on 30 March 1979 at SSR seismic station with the DD1 seismometer

(b) Detail of the earthquake recorded on the vertical component (Z)

Source: Seismogram Archive at the Timisoara Seismological Observatory

Table 2. Analog instruments installed at Susara seismic station (SSR) in chronological order

SSR					
Start date	End date	Instrument	Recording type	Instrument type	Component
Aug.1969	1971	VEGIK	Photographic paper	Photo galvanometric	E, Z
Jan.1971	N/A	Kirnos-SKM III	Photographic paper	Photo galvanometric	N, E, Z
14.11.1978	01.06.1999	DD1	Ink on paper	Electromagnetic	N, E, Z

In 1999 Susara station was suspended from operation due to administrative issues regarding the property. While a state of the art seismic station for the early 1970, and still with very good recordings until its last days, Susara seismic station represented an etalon of quality recordings at international level.

2.3 Gura Zlata Seismic Station (GZR)

Established on 1st April 1977 (Figure 17) in the Retezat Mountains, Gura Zlata (GZR) seismic station was built to expand the seismic coverage in southwest Romania, alongside the existing TIM and SSR stations. Its isolated, low-noise mountain location allowed it to deliver exceptionally clear, high-quality recordings, making it a regional reference station.

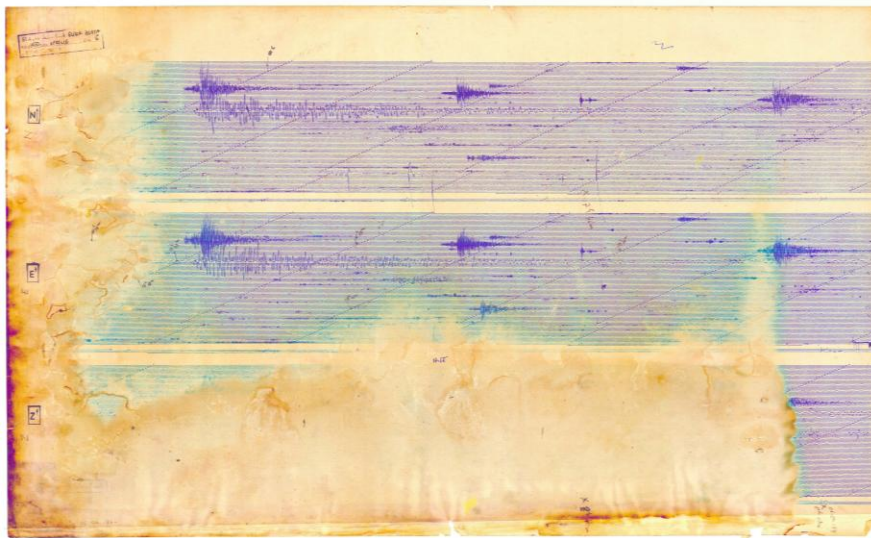


Figure 17. The first seismogram (06 April 1977) recorded at the GZR seismic station with the DD1 seismometer

Source: Seismogram Archive at the Timisoara Seismological Observatory

GZR was initially equipped with a short-period analogue DD1 electromagnetic seismometer (Table 3) with recording ink on paper. Because of its high sensitivity, the analogue station successfully recorded major global teleseisms and historical underground nuclear tests from the Soviet Union/Kazakhstan.

Usually, the operation of this kind of analogue stations at optimal parameters required the presence of a technician to verify the correctness of the time, supply ink to the recording system, replace seismograms, and note the start/end date and time of the seismogram.



(a)



(b)

Figure 18. (a) The old building of the Gura Zlata seismic station
(b) Newly inaugurated building of the Gura Zlata seismic station
Source: Photographic Archive at the Timisoara Seismological Observatory

Gura Zlata seismic station passed entirely to modern digital technology between 2006 and 2007. This digital evolution removed the need for permanent on-site staff, and following the demolition of the old degraded facility (Figure 18 a), a brand-new state-of-the-art seismic observatory building was officially inaugurated in 2025 (Figure 18 b).

Table 3. Analogue instrument installed at Gura Zlata seismic station (GZR)

GZR					
Start date	End date	Instrument	Recording type	Instrument type	Component
01.04.1977	2006	DD1	Ink on paper	Electromagnetic short period	N, E, Z

2.4 Buzias Seismic Station (BZS)

The Buzias (BZS) seismic station was established in late 1977 and put into operation on November 16, 1978.

The site was selected to ensure uniform territorial coverage in southwestern Romania and to monitor the active Buzias-Recas seismic fault, and for its isolation from urban seismic noise. The station was equipped with a DD1 short-period electromagnetic seismometer (Figure 19).

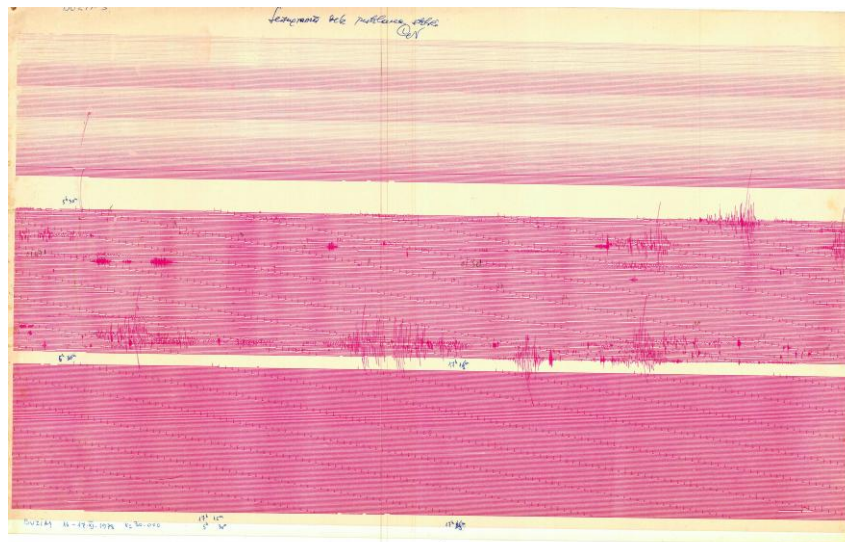


Figure 19. The first seismogram (16 November 1978) recorded with the DD1 analog seismometer at Buzias (BZS) seismic station

Source: Seismogram Archive at the Timisoara Seismological Observatory

In 1980, a permanent facility featuring a sensor room designed after Curea's Timisoara station plans was completed, and the DD1 seismometer was installed (Figure 20).



Figure 20. The permanent building of the Buzias seismic station in the early 1980s
Source: Photo archive of the Timisoara Seismological Observatory

In 1980, a S5S triaxial electromagnetic seismometer with a 5-second intermediate oscillation period was also installed (Figure 21). The S5S seismometer response band frequency (Shishkevish, 1975) fits perfectly with the intermediate-depth Vrancea earthquakes frequency range. Up to now, we have not identified in the archive any seismogram belonging to this instrument. For this reason, its exact operational parameters, and recorded data remain under archival review.



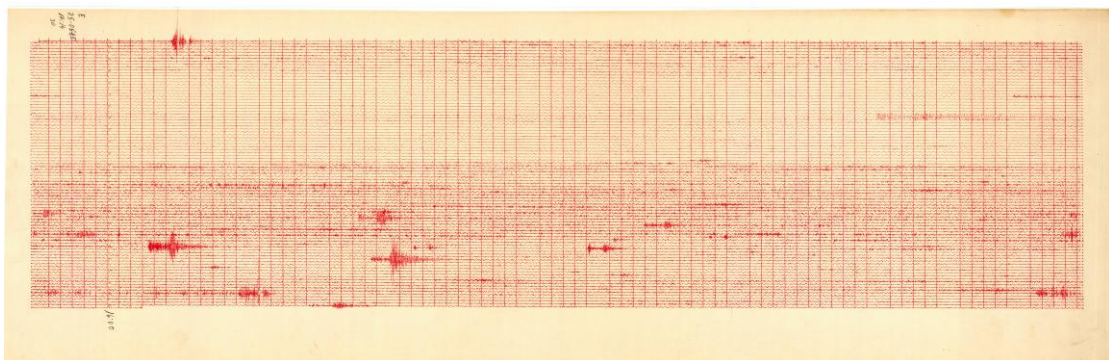
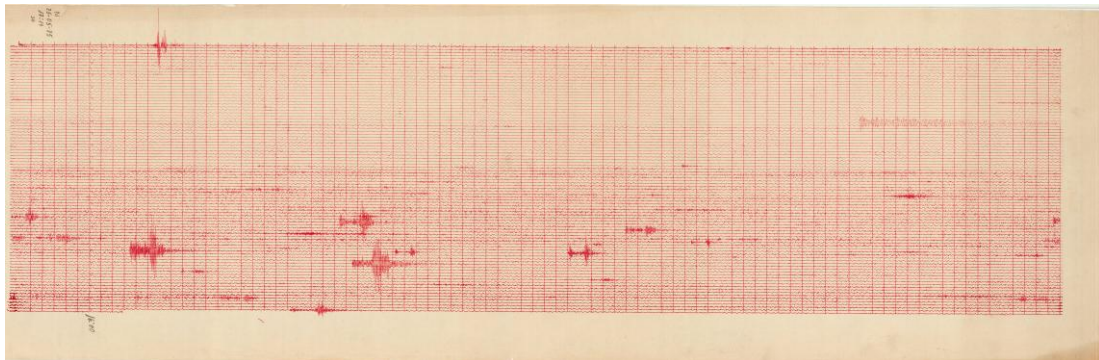
Figure 21. The 3 component DD1 seismometer (cased in plexiglass box) and of the S5S seismometer (cased in metal box)
Source: Photo archive of the Timisoara Seismological Observatory

In 1983, a Teledyne Geotech S13 short-period seismometer was installed (Figure 22), transmitting data via radiolink to the Timisoara Seismological Observatory (Figure 23).



Figure 22. Teledyne Geotech S13 seismometer (recording system) installed at Buzias seismic station in 1983

Source: Photo archive of the Timisoara Seismological Observatory



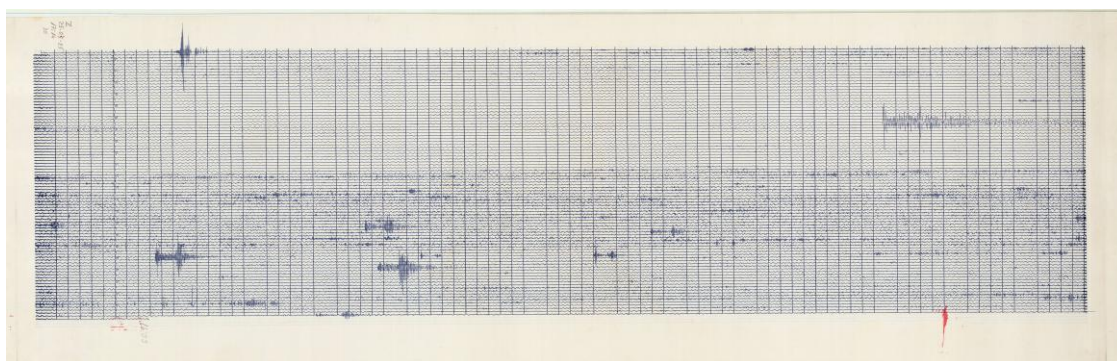


Figure 23. Seismograms from the BZS station (25 May 1985) recorded on the S13 Teledyne Geotech seismometer. From top to bottom, N, E, Z components
Source: Seismogram Archive at the Timisoara Seismological Observatory

By 1995, the physical recording systems were moved entirely to Timisoara, leaving only the sensors at Buzias.

Today, the Timisoara archive preserves over 12,000 legacy analogue seismograms from BZS station. The modernization process began in 1994, transitioning BZS station from analogue to digital (Table 4).

Table 4. Analog instruments installed at Buzias seismic station (BZS) in chronological order

BZS					
Start date	End date	Instrument	Recording type	Instrument type	Component
16.11.1978	1980	DD1	Ink on paper	Electromagnetic, short period	N,E,Z
1980	2004	DD1	Ink on paper	Electromagnetic, short period	N,E,Z
1980	N/A	S5S	Photographic paper	Electromagnetic, short period	N,E,Z
1983	2004	S13	Ink on paper	Electromagnetic, short period	N,E,Z

2.5 Banloc (BANR) and Siria (SIRR) Seismic Stations

Both Banloc (BANR) and Siria (SIRR) seismic stations were established and put into operation between September and October 1995. To facilitate easier maintenance and ensure operations in quiet areas protected from urban seismic noise, both stations were strategically placed within the perimeters of remote local meteorological stations.

Initially, both locations were equipped with analogue Teledyne Geotech S13 electromagnetic short-period seismometers. For these initial setups, only the vertical (Z) component was operational, and the data was transmitted via radio link (Figure 24) directly to the Timisoara Seismological Observatory, where it was recorded on paper seismograms with ink.



Figure 24. The radio tower was installed in 1995 at the Timisoara Seismological Observatory for radiolink data transmissions from the BZS, BANR, and SIRR seismic stations.

Source: Photo archive of the Timisoara Seismological Observatory

Since August 2008, BANR and SIRR stations transitioned to digital monitoring, enabling real-time data transmission directly to the National Institute for Earth Physics (NIEP) data center in Magurele. Recordings on paper were no longer needed and were suspended. An example of seismograms from BANR (Figure 25) and SIRR (Figure 26) can be seen below.

The evolution of seismic equipment replacements is presented in Table 5 for BANR and in Table 6 for SIRR.

Table 5. Analog instrument installed at Banloc seismic station (BANR)

BANR					
Start date	End date	Instrument	Recording type	Instrument type	Component
28.09.1995	2008	Teledyne Geotech – S13	Ink on paper	Electromagnetic, short period	Z

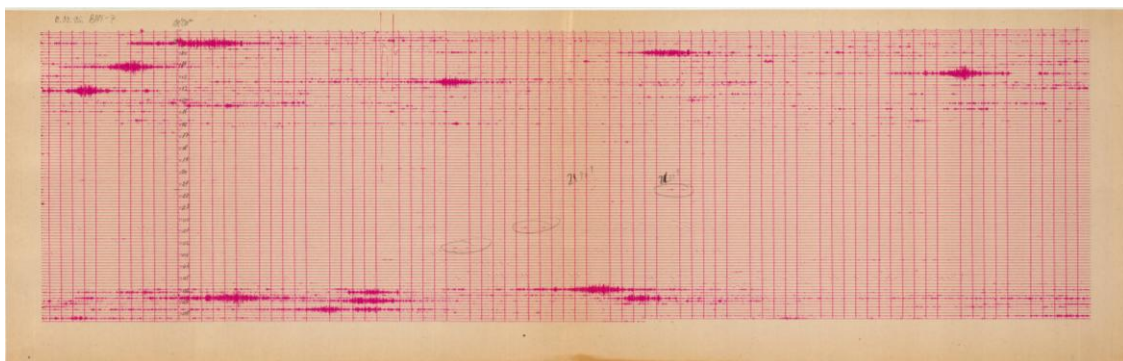


Figure 25. Seismogram recorded for BANR seismic station on 12.02.1996
Source: Seismogram Archive at the Timisoara Seismological Observatory

Table 6. Analog instrument installed at Siria seismic station (SIRR)

SIRR					
Start date	End date	Instrument	Recording type	Instrument type	Component
19.10.1995	09.08.2008	Teledyne Geotech – S13	Ink on paper	Electromagnetic, short period	Z

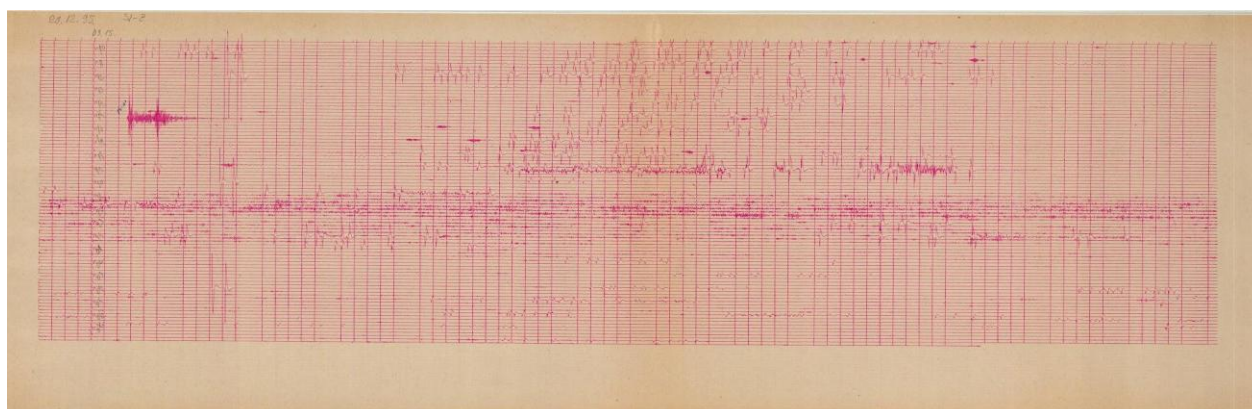


Figure 26. Seismogram recorded for SIRR seismic station on 20.12.1995
Source: Seismogram Archive at the Timisoara Seismological Observatory

Based on the inventory carried out at the Timisoara Observatory up to date, the archive contains an estimated number of over 150,000 seismograms on smoked paper, photographic paper, ink on paper, over 300 station books and a library of international seismic bulletins and publications of over 2,000 titles. These seismograms were collected and stored from the stations in western Romania (TIM, SSR, GZR, BZS, BANR, SIRR).

Currently, Romania Seismic Network is one of the most modern in Europe with over 200 seismic stations (broadband and short period) and GNSS (Global Navigation Satellite System), with very good detection capability and a good territorial distribution.

In the process of expanding the seismic monitoring in Romania, the Romania Seismic Network was established and is managed by the National Institute for Earth Physics (NIEP).

3. SEISMOGRAM INVENTORY AND STORAGE OF ANALOGUE SEISMOGRAMS AT TIMISOARA OBSERVATORY

Since seismological monitoring started at the end of the 19th century, almost simultaneously, both in Bucharest (Cutitul de Argint) and in the western part of Romania (Timisoara), the foundations of two important research centers were set up.

Today almost 80% of the seismograms recorded on paper at the stations in the eastern and southern part of the country are stored in the archive of the NIEP headquarters in Magurele, the remaining 20% from the stations in the western part are stored at the Timisoara Seismological Observatory (Figure 27).

In total, the seismogram archive covers a period of over 70 years of seismogram recordings on paper, from the early 1940s to 2017 (smoked paper, photographic paper, ink on paper).

It is worth mentioning that in the archive of Magurele there are still a few seismograms, from the Omori-Bosch seismograph from the early 1900s, from the first station established at Cutitul de Argint.

In 2022, a process of inventorying seismograms stored from the 6 seismic stations in western Romania began at the Timisoara Observatory: Timisoara (TIM), Susara (SSR), Gura Zlata (GZR), Buzias (BZS), Banloc (BANR) and Siria (SIRR).

Until the end of 2025 from an estimated 150,000 seismograms, over 58,000 seismograms (ink on paper) were sorted chronologically, for the time interval 1977-2017, for each seismic station and indexed in the dedicated inventory named *Heritage Legacy Inventory of Seismograms in Romania* (HELIOS-R) (Rau et al., 2026).



Figure 27. The analogue seismogram archive of the National Institute for Earth Physics is stored and preserved in two locations: Magurele (left down) and Timisoara (left up)

The inventory process was a challenge because the seismogram archive was transferred at least in three different locations after 1990 and it was stored inappropriately so the seismograms got mixed (Figure 28) and some of them damaged (Figure 29), mostly were affected by water infiltrations and mould. When the inventory process started, the working team had to select each document in part (seismogram, station book, photographs, internal documents, etc) and index them in a specific table.



Figure 28. Seismogram archive at the Timisoara Observatory before sorting
Source: Photo archive of the Timisoara Seismological Observatory



Figure 29. Example of damaged seismograms
Source: Photo archive of the Timisoara Seismological Observatory

During the sorting process we have identified valuable metadata sources provided by old film rolls, photographs, station notebooks, lanternslides, instrument manuals and internal documents (Figure 30).



Figure. 30 Station notebooks, top: instrument manuals (*left*), film rolls and lanternslides (*right*); bottom: pictures after seismograms (*left*) and a detail on a lanternslide (*right*)
Source: Photographic archive of the Timisoara Seismological Observatory

Images of the time consuming inventory process can be seen in Figure 31. By the end of 2025 a first stage of the inventory was achieved: sorting and indexing the analogue seismograms from S13 and DD1 seismometers. At the beginning of 2026 new and proper storing boxes for seismograms were acquired and the seismograms are now transferred in the new storage. After this stage is complete, we will continue with indexing the next batch of seismograms on photographic paper and smoked paper.

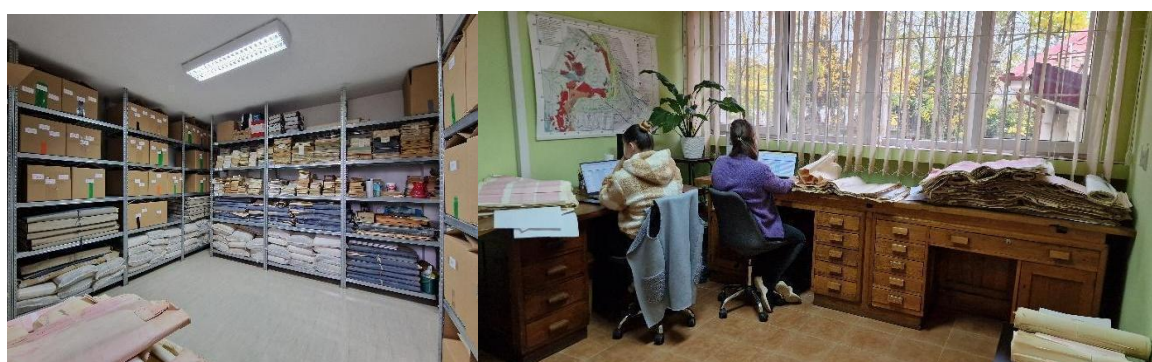


Figure 31. Intermediate stages of the seismogram inventory (*left*); seismogram indexing (*right*)
Source: Photo archive of the Timisoara Seismological Observatory

The analogue seismograms inventory contains identification details such as: station name, date of the seismogram, start and end time of the recording, instrument type, recording type and the preservation state of the seismogram, time corrections, observations and additional notes on the seismograms. For each seismogram (by components) the current state of preservation is mentioned: from Very Good (VG) to Good (G), Deteriorated (D) and Very Deteriorated (VD) as seen in Figure 32.

HELIOS-R inventory provides useful information about regional seismic activity recorded at stations in the western part of the country between 1977 and 2017 and constitutes an important source of information for data exchanges with national and international data centres and institutes interested in data from the archive period as well as various studies and research.

HELIOS - R Heritage Legacy Inventory of Seismograms - Romania									
Nr.	Station code	Date	Start time (UTC)	End Time (UTC)	Instrument type	Recording type	Seismogram component		
							Z	N	E
1	1977								
2	TIM	04.04.1977	06:57:00		DD1	ink on paper	G	G	G
3	1978								
4	TIM	30.05.1978			DD1	ink on paper	G	G	G
5	TIM	31.05.1978			DD1	ink on paper	G	G	G
6	TIM	03.06.1978	07:25:00		DD1	ink on paper	G	G	G
7	TIM	04.06.1978			DD1	ink on paper	G	G	G
8	TIM		05:32:00	19:37:00	DD1	ink on paper	G	G	G
	TIM	20.06.1978	17:45:00	05:47:00	DD1	ink on paper	G	G	G
9	TIM	21.06.1978	05:50:00	17:55:00	DD1	ink on paper	D	D	D
10	TIM	21.06.1978	18:00	05:32	DD1	ink on paper	D	D	D
11	1979								
12	TIM	10.11.1979			DD1	ink on paper	G	G	G
13	1980								
14	TIM	18.01.1980	06:10:00	17:50:00	DD1	ink on paper	D	D	D
15	TIM	18.01.1980	17:55:00	05:30:00	DD1	ink on paper	G	G	G
16	TIM	19.01.1980	05:36:00	05:25:00	DD1	ink on paper	G	G	G
17	TIM	19.01.1980	05:30:00	05:00:00	DD1	ink on paper	G	G	G
18	TIM	20.01.1980	05:00:00		DD1	ink on paper	G	G	G
19	TIM	21.01.1980	19:21:00	05:25:00	DD1	ink on paper	G	G	G
20	TIM	23.01.1980	07:15:00	17:05:00	DD1	ink on paper	G	G	G

Figure 32. Example of the seismogram inventory work at the Timisoara Observatory
Source: HELIOS-R, 2026

Indexing seismograms is a meticulous process that requires attention in handling the fragile seismograms and the correct identification of each one as some do not have the station stamp marked on them. In this first stage of inventory only seismograms from two types of instruments: S13 - Teledyne Geotech and DD1 were sorted, indexed and relocated in appropriate storage cardboard boxes (Figure 33). HELIOS-R inventory is structured on individual sheets for each station and instrument with specific details regarding each seismogram (Figure 34).



Figure 33. The seismogram archive at the Timisoara Observatory as an ongoing activity of saving and preserving analogue seismograms

Source: Photo archive of the Timisoara Seismological Observatory

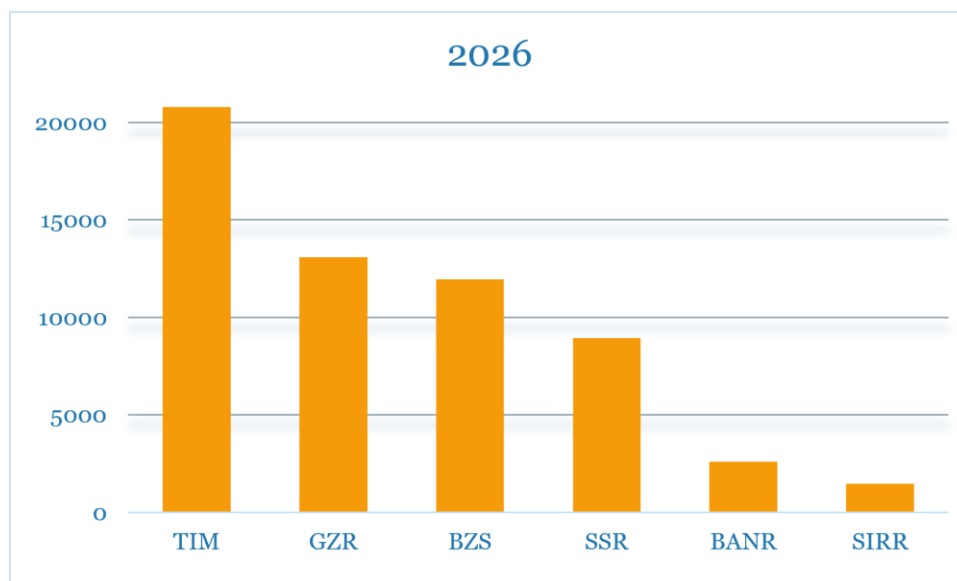


Figure 34. Evolution of the seismogram inventory process on each individual station

4. CONTRIBUTION OF THE TIMISOARA OBSERVATORY TO THE NUCLEAR EXPLOSION LEGACY DATA (NELD) REPOSITORY

Recently, NIEP participated in the Legacy Data Rescue for Nuclear Explosion Monitoring Data Project together with four other institutes from Austria, Bulgaria, Republic of Moldova, and USA. Romania contributed with 421 scanned seismograms recorded at 39 national stations. At that time, only seismograms from the NIEP headquarters in Magurele were used.

During the inventory process of the seismograms in the Timisoara Seismic Observatory archive, good quality recordings of nuclear tests were identified. A number of 17 nuclear tests conducted during 1979-1992, with mb magnitudes from 5.2 to 6.4 recorded in the western part of Romania at distances of 18-48 degrees were identified and their recordings scanned and prepared to be added to the NELD repository.

A total of 45 seismograms recorded at TIM, SSR, GZR, BZS, BANR, SIRR stations were scanned at high resolution (1200 dpi), using the requirements used for building NELD repository.

Metadata files were created for each scanned seismogram. They include essential information regarding event identification data (date, time, coordinates), station information and location, instrument type and recording system as well as sensor parameters, side notes and time corrections. The methodology for compiling metadata files within the NELD project consisted of utilizing a standardized template developed by the Leidos (USA) team, structured into two worksheets (*record metadata* and *channel metadata*) and comprising a set of 72 parameters (58 of which are mandatory) designed to provide the necessary support for the subsequent vectorization process (Oancea et al., 2026). The information was extracted by inspecting historical archives, seismic bulletins, national catalogues, station logbooks, etc.

Information on the nuclear explosions was obtained from the Waveforms From Nuclear Explosions (WFNE) repository (Oancea et al., 2024). As the seismogram inventory is still an ongoing activity, the perspective of adding more recordings to the NELD database with the quality events recorded at the seismic stations in the western region of Romania is an accomplishable goal.

To guarantee a perfect correlation between scans, notes, and metadata files, a rigorous file-naming convention was implemented (based on the nuclear explosion ID, station code, channel code, and instrument type), and the SEED nomenclature was adopted for the scanned analogue channels. In parallel, information regarding coordinates and historical station channels was structured according to the CTBTO International Data Center database standards (*site* and *sitechan* tables) to ensure compatibility with current digital data streams. Finally, all completed datasets and metadata underwent a rigorous quality control and revision process at the delivery level before being processed through automated parsing scripts and integrated into the relational tables of the unified NELD database (Oancea et al., 2026).

During the sorting process of the seismograms with nuclear tests we have identified seismograms with clear signals, especially for the remote stations such as SSR and GZR. Some of them are recordings of multiple explosions (Figure 35).

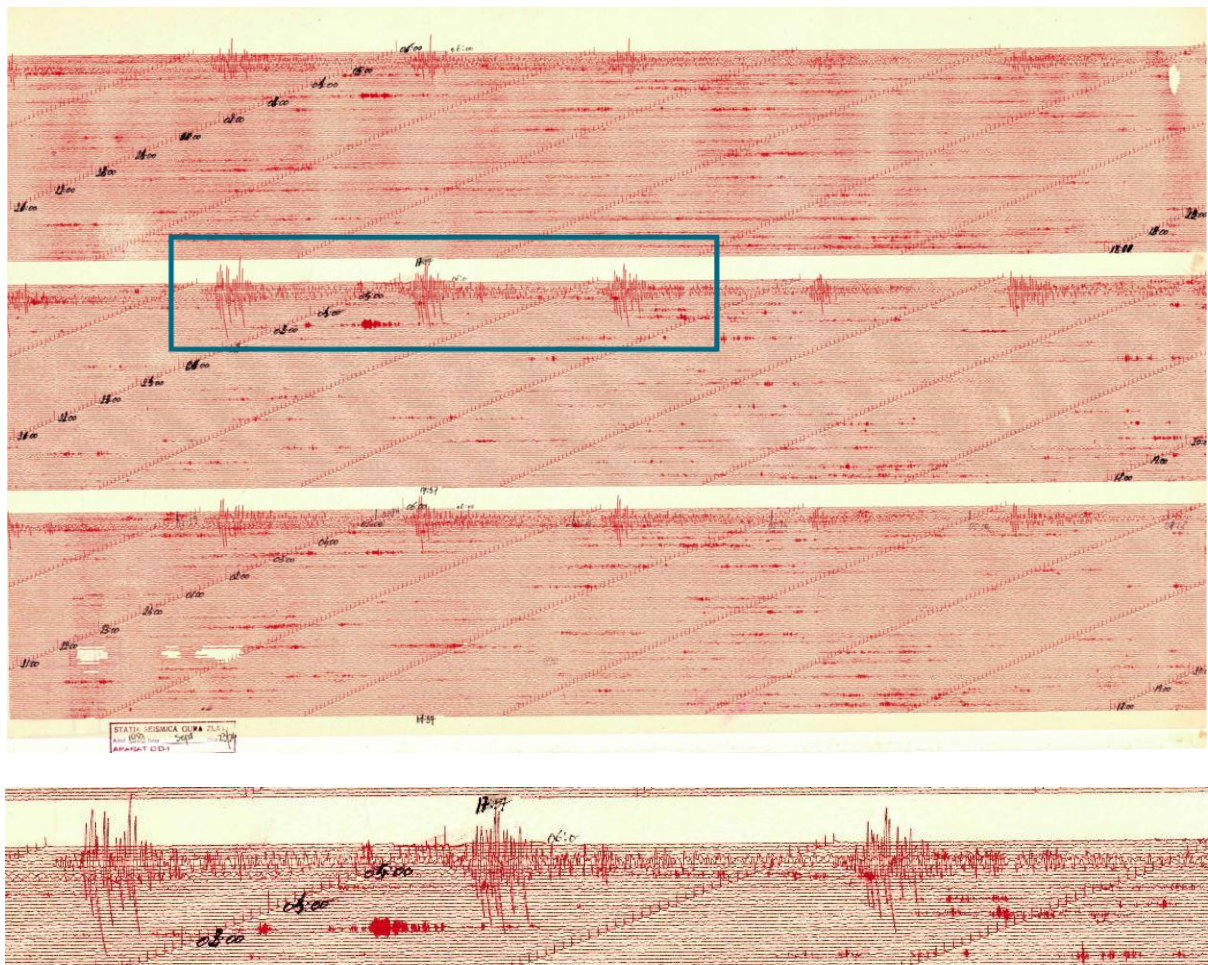


Figure 35. Example of seismogram and detail with a recording of three nuclear explosions detonated in Astrahan, Russia, test site on 24 September 1983 and recorded at GZR station

This work was more an exercise to sample the work flow and methodology and was delivered as requested. We can consider a future complete inventory of the recorded nuclear tests within the analogue seismogram inventory as soon as HELIOS-R will be completed also for the smoked paper and photographic paper seismograms.

CONCLUSIONS

Systematic inventorying and archiving of historical analogue seismograms at the Timisoara Seismological Observatory successfully rescued over 60 years of regional observational data across southwestern Romania, bridging early mechanical measurements with modern digital monitoring networks.

By late 2026, over 58,000 ink-on-paper seismograms recorded between 1977 and 2017 at six stations (TIM, SSR, GZR, BZS, BANR, SIRR) were sorted, indexed, and relocated into protective storage under the *Heritage Legacy Inventory of Seismograms in Romania* (HELIOS-R) inventory. The inventory is open access and seismograms can be requested for detailed studies on regional and teleseismic events.

The study also demonstrated a successful workflow by retrieving, scanning and generating standardized metadata for 45 high-quality seismograms corresponding to 17 historical nuclear tests recorded at these six stations, adding them to the NELD repository.

Following the completion of the ink-on-paper batch, future efforts will extend the HELIOS-R inventory to the remaining legacy seismograms, including fragile smoked-paper and photographic-paper seismograms.

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STATEMENTS AND DECLARATIONS

The authors have no conflicts of interest to declare that are relevant to the content of this article.

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