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SEISMIC PATRIMONY PRESERVATION TUTORIAL

I. What can we do with analog seismograms and related seismic documentation?

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PROLOGUE

Origin and purpose

The Fabra Observatory (*Observatori Fabra*) has been operating in Barcelona since 1904. It was created and maintained by the *Royal Academy of Science and Arts of Barcelona* (*Reial Acadèmia de Ciències i Arts de Barcelona* – RACAB), an association of researchers in earth science and its applications established in 1764. It has always been devoted to astronomical, meteorological and seismological observations and studies. Seismic observations in *Observatori Fabra* started in 1906 and have been maintained active since then. They included instrumental registers and macroseismic data collected from a number of sources, mainly from eastern Spain. The historical archive includes thousands of seismograms and complementary documentation such as manuscript and printed bulletins, registers and station notebooks, scientific and divulgative articles in journals and newspapers, letters and scientific correspondence, printed publications from many other institutions, etc. Almost all instruments from that epoch are conserved in our small museum or are still being used for different purposes.

Observatori Fabra is still an active institution with the main goal of working on interesting contributions to the scientific community. During the last decades we have increasingly devoted more of our limited resources to preserve, use and share as much of our seismic heritage as possible. We collaborated with TROMOS and EUROSEISMOS and performed through many modest other projects partial inventories, restorations, studies and scannings. Besides, the observatory has outreach as another goal: has a museum of used instruments, holds courses, conferences, scholar visits, and many other occasional activities. We are proud of maintaining our long tradition of being willing to share and collaborate in both scientific and outreach purposes with other investigators, institutions, individuals and groups in many and extremely diverse ways. An extensive summary of our seismic historical patrimony, along with a detailed inventory up to that date, were already presented in several international congresses and forums in order to contact and keep in touch with other institutions interested in these same fields.

The year 2014 was the 250th anniversary of RACAB and the 100th anniversary of Mainka seismographs series (operating in smoked paper 1914-1998). Besides, the RACAB main building in Barcelona center and the *Observatori Fabra* building had been recently officially declared buildings of cultural-historic national interest by the Spanish government. Moreover, *Observatori Fabra* was also awarded with the *Historical Site* distinction by the *European Physical Society*. These anniversaries and distinctions encouraged and facilitated to initiate, continue and develop many projects to recover, conserve and promote the historical patrimony of the observatory. Thanks to the inestimable advice, help and support from other particulars and institutions, such as *Institut Cartogràfic i Geològic de Catalunya* (ICGC) and *Istituto Nazionale di Geofisica e Vulcanologia* (INGV), we have been able to perform record inventories, restorations, studies and scannings.

From its very beginnings, *Observatori Fabra* has maintained a close and permanent relationship of mutual collaboration with the local public agency in charge of seismology in Barcelona area, which has been sequentially *Servei Geològic de Catalunya* (SGC), *Institut Cartogràfic de Catalunya* (ICC), *Institut Geològic de Catalunya* (IGC) and *Institut Cartogràfic i Geològic de Catalunya* (ICGC). Thanks to the help and support from ICGC and its previous institutional versions, we have been increasing the detailed inventory of seismograms and have scanned most of the macroseismic documentation, bulletins, and other related studies. The amount of classified and scanned documents is increasing and we are working to open freely most of these records and results from finished and ongoing projects to the scientific community and general public.

Besides, we collaborated intensively with Graziano Ferrari and SISMOS group initiatives in INGV. In addition to TROMOS and EUROSEISMOS initiatives, thanks to their help and support

many pieces from old instruments could be restored, many of our seismograms and of the accumulated complementary documentation for the study of the seismic records (station books, notebooks with corrections, etc) were scanned. In fact, the origin of our participation in the elaboration of this tutorial were these works and the preparations for the exhibition "*Dal cielo alla terra: meteorologia e sismologia a Firenze dall'Ottocento a oggi*" ("From the Sky to the Earth: meteorology and seismology in Florence from the 19th Century to Nowadays") in the prestigious *Galleria of Palazzo Medici Riccardi* ,where *Observatori Fabra*'s *Microsismografo Agamennone* instrument was shown to the public. During one of the travels to pursue those works, Graziano Ferrari kindly arranged several visits through some selected old observatories in Italy with Maria Teresa Merino (person in charge of seismology section in Fabra Observatory) and Tana Andrades (specialist in conservation and restoration in the respective services for the old archives in the *University of Barcelona -CRAI*). Grazziano Ferrari, as *Head of Functional Unit SISMOS* in INGV and *Coordinator of the Working Group "Methods and Data for the Study of Warthquales Recorded on Pre-WWSSN Seismograms"*, had already several decades of visits and experiences throughout many kinds of institutions, old observatories and archives. He wisely suggested the increasing need for some reference and basic knowledge compilation easily and freely available to all kinds of archives responsibles and curators in order to avoid loosing more seismic heritage and that the recent and ongoing *Observatori Fabra* experiences could be regarded as useful examples for both errors and suggestions, with the following main goals in mind: 1) set an example of doable activities and projects that a small independent observatory can undergo related to seismic heritage, even with severe limitations of resources and personnel; and 2) share with others our experiences, strategies and a few suggestions of what and why to do or NOT to do for each case.

The idea of elaborating some kind of written guide elaborated in a cooperative way was circulating and regarded as highly positive and useful during several years, but the personal and professional duties and understandably limitations of all people contacted to make it possible (including the retirement of Graziano Ferrari) did not allowed to materialize it. After several years, Josep Batlló from ICGC decided to leadership the initiative towards the elaboration of the tutorial presented here as a common project supported by RACAB - ICGC offered freely to the international community.

The scope, purpose and elaboration of this tutorial has been progressively presented and discussed to a potentially interested audience through several public contributions in international forums and congresses in order to result in an enriched useful reference with as many contributions, doubts, and observations from our colleagues as possible. We decided to create a tutorial centered in paper-based legacy seismograms and its complementary documentation devoted to ease the smallest institutions to recognize their seismic patrimony and to face some minor actions or projects to improve its preservation and use, as a brief and useful compendium of best practices and problems to avoid about identification, inventory, conservation/preservation, restoration, use and exposition of seismic patrimony. We think it can also be useful to bigger institutions as a guide to sharing initiatives towards using their limited available resources with accorded goals, standards and practices in order to maximize potential results.

The first public beta version of the complete tutorial was presented and placed available online during ESC2024 and this first final version includes suggestions, corrections and improvements received since then.

I sincerely hope this initiative helps to observatories and institutes with seismic heritage with as much external influence and corrections as possible.

Jorge Núñez de Murga

Director of Observatori Fabra

INTRODUCTION

Goals, resources and constraints

Instrumental seismic recording began in the second half of the 19th Century and has since evolved into the sophisticated digital networks we use today. However, for over a century—until the late 20th century—seismic ground motion was recorded using analog instruments.

Analog seismograms and related documentation contain a wealth of original and scientifically valuable data. Preserving and utilizing these records requires dedicated effort. Recognizing this need, several initiatives were launched within IASPEI (*International Association of Seismology and Physics of the Earth's Interior*) and, at the European level, within the ESC (*European Seismological Commission*). In 1992, a Working Group on the "*History of Seismometry*" was established and has remained active to this day (see references [1], [2]). Seminal Italian projects such as TROMOS and SISMOS served as catalysts for further European developments (see reference [3]).

Many of these initiatives rely on voluntary contributions, which poses a significant challenge to their long-term sustainability. Nonetheless, there is growing recognition of the scientific importance of legacy seismograms and the urgent need to preserve and make use of them. This awareness has led to dedicated sessions at General Assemblies, where experiences and strategies are shared. These efforts aim to optimize limited resources through standardized, practical objectives that maximize the potential impact (see the final section of this manual: *Resources and References*).

Despite these advancements, many original records remain at risk—often stored in inadequate conditions within small (and sometimes larger) institutions that lack the resources or recognition necessary for proper preservation. In many cases, both human and material resources are scarce, making it extremely difficult to improve the current situation.

Legacy seismograms are not only scientific records—deliberately obtained data documenting seismic activity—but also unique historical artifacts (such as medieval manuscripts). As such, they require careful preservation to ensure their availability for future generations.

In many institutions, the custodians of these collections—referred to as curators in archival terminology—are scientists with backgrounds in physics, mathematics, or Earth sciences. While they are well-versed in the scientific content of the seismograms, they often lack knowledge about the physical characteristics of the materials and the specific preservation measures required. Conversely, when seismograms are housed in libraries or general archives, access can be limited because curators may not recognize them as scientific data, focusing instead solely on preservation.

Although these challenges have begun to be addressed in recent years, much work remains to be done to bridge the gap between scientific and archival perspectives.

From the Working Group (WG), we firmly believe that guidance and collaboration on the preservation of legacy seismograms are essential. This freely distributed short handbook offers basic recommendations to help curators to respond appropriately to preservation needs.

We have aimed to make this guide as clear and accessible as possible, targeting readers with no prior expertise in the subject. It presents a concise overview of common issues, key considerations, practical suggestions, and foundational concepts. To maintain simplicity, examples from other initiatives are included in tables and figures, while more detailed and comprehensive references are provided in the final section.

This brief manual will provide a basic knowledge on the topic so that the interested reader can access other much more extensive literature that deals with the different topics in depth without getting lost.

This manual is intended to equip readers with the basic knowledge needed to explore more in-depth literature without becoming overwhelmed. As a starting point, we focus primarily on analog

seismograms recorded on paper—whether smoked, photographic, or ink-based—and their accompanying documentation, as these are the most common and accessible among historical records.

Legacy seismograms are not isolated artifacts—they are products of their time, shaped by the scientific, social, and technological contexts in which they were created. For this reason, it is equally important to preserve and document the broader environment surrounding their production, even though these aspects are not covered in detail in this manual to maintain its simplicity and focus. Key elements worth considering include:

- **Original Instrumentation and Related Materials:** This includes the seismic instruments used at the recording stations, along with any associated documentation and tools used for preparation, maintenance, and post-processing. Items such as calibration records, operation manuals, materials and tools for smoked or photographic paper processing, and information on the origin and composition of materials are all valuable for understanding and preserving the records.
- **Physical and Operational Contexts:** The locations where instruments were installed and operated, as well as the spaces used for maintenance, preparation, storage, and analysis of the seismograms and their accessory documentation, are crucial to document. Historical context and graphic information, including photographs, drawings, or architectural plans, can help resolve recurring questions about the conditions under which the data were recorded.
- **People and Practices:** Knowledge about the individuals involved in the operation of seismic stations, data processing, and archiving is essential. Much of the procedural knowledge was transmitted orally, and understanding the roles and routines of these individuals can be key to interpreting the records. Interviews, oral histories, and personal accounts should be recorded and preserved as integral parts of the documentation.

Looking ahead, we plan to expand this handbook with the support and collaboration of the seismological, archival, and conservation communities. Our vision is to develop a collaborative, dynamic, and evolving resource—similar in spirit to the New Manual of Seismological Observatory Practice (NMSOP, see reference [4])—where topics are continuously updated and expanded. This guide could serve as a complementary resource to the NMSOP, focusing specifically on the preservation and contextualization of legacy seismograms.

Figure 0. Some seismograms from the first seismic station in Observatori Fabra (Barcelona, 1906-1913). Before (left) and after (right) considering and applying techniques and recommendations included in this manual. Source: Observatori Fabra

CHAPTER 1

IDENTIFICATION OF SEISMIC PATRIMONY

How to get started: What do we have and what condition is it in?

Introduction

If we are responsible of a legacy seismograms collection or we discover one, it is essential to know which materials/elements includes it and in which conditions they are before considering what can be done about them. Basic answers to some questions (what?, how?, where?) must be answered as best as possible before considering what can be done (why?, when?, for what?, with what?).

In the following sections, we shortly review which things are considered seismic heritage and what basic questions need to be asked about each of them.

IMPORTANT

- In this chapter we point to several issues to take into account in this preliminary phase. It is interesting to note something for each highlighted aspect below, and even for those for which we do not get answers, to be able to distinguish whether this lack is due to doubts, due to some difficulties in being able to find out at this initial stage, or because there is total ignorance in respect.

- This identification phase is purely informative. During this initial exploration, it is necessary to minimize the risk of introducing disorder, damage or irreversible changes to the preserved materials that could affect their conservation or possible inventories or subsequent studies. That's why we recommend reading chapters 2 and 3 before starting it.

- It is important to check if, among the materials under inspection, there are seismograms without useful record, cut or broken pieces, photographs or copies of originals and any other materials we find together with or related to the seismograms. And try to keep them too because they can be used to clarify doubts and/or carry out tests and studies described in later sections.

Seismograms

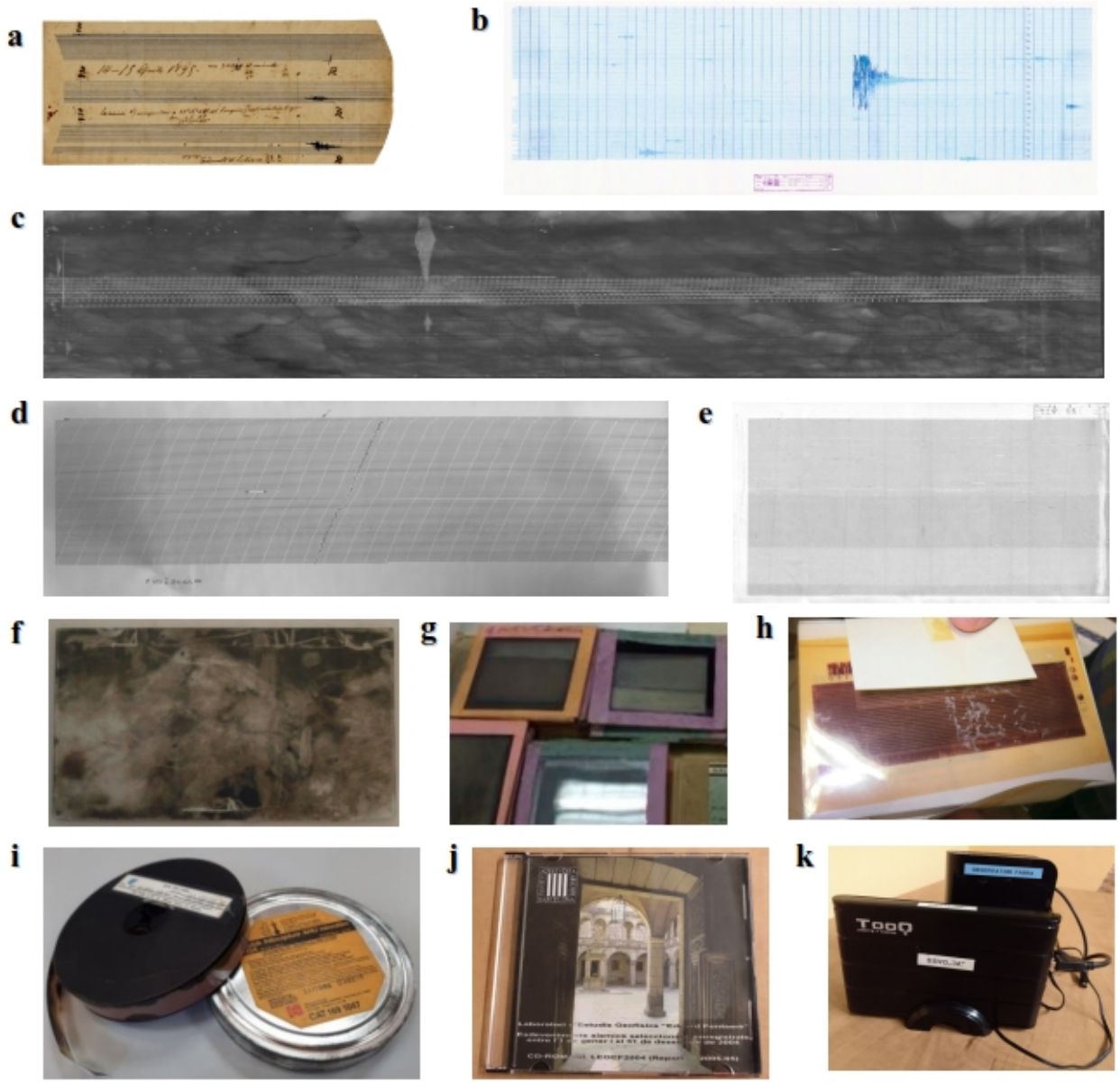

Figure 1. Some examples of the diversity of supports and materials with analog seismograms recordings: (a) old paper with inscription in ink by a needle from beginnings of XX century of mechanical sensor; (b) paper with ink by a needle from last years of XX century of electromagnetic analog sensor; (c) smoked paper marked by a glass needle and fixed afterwards with rubber solution of mechanical sensor; (d) photographic paper with light inscription and revealed afterwards of analog electromagnetic sensor measurements; (e) thermal paper with inscription by thermal needle of analog electromagnetic sensor measurements; (f) smoked glass inscription by metallic needle and fixed afterwards of mechanical sensor; (g) glass photography revealed afterwards of mechanical sensor; (h) celluloid photography fixed in negatives of analog electromagnetic sensor ; (i) microfilm negatives of analog electromagnetic sensor ; (j) digitized in CDs as "permanent" support of analog electromagnetic sensor; (k) magnetic hard drive with digitized measurements from analog electromagnetic sensor. Sources: INGV (a, f, g); Observatori Fabra (b, c, d, j, k); ICGC (e); Observatorio de Toledo (h, i).

Seismograms are the original **instrumental records**. As irreplaceable original data that they are (in general they are unique pieces, of which there is no copy), their correct long-term conservation is a priority.

They can be very **different in their physical constitution**.

Particular attention should be paid to identify as many of the following details as possible:

- ✓ **The type of media on which the registration was made.** The most common is to find one of the following:
  - paper with inscription in ink (Figures 1a and 1b),
  - smoked paper (Figure 1c),
  - photographic paper (Figure 1d),
  - thermal paper (Figure 1e),
  - smoked glass (Figure 1f),
  - glass or celluloid photography (Figures 1g and 1i),
  - microfilm (Figure 1i),
  - digital support (tapes, diskettes, cassettes) (Figures 1j and 1k)

- ✓ **The system with which the registration has been made on the physical support:**
  - inscription by typographic ink (Figures 1a and 1b),
  - alteration of the substrate by friction and subsequent fixation (Figures 1c and 1f),
  - revealed or veiled (either positively or negatively) (Figures 1d, 1g and 1h),
  - alteration of the substrate by a thermal needle (Figure 1e),
  - analogue electromagnetic register (Figures 1d, 1i and 1j),
  - digitized (whether from original analog or digital data) (Figures 1j and 1k)

- ✓ **Annotations and other additional marks**
  - ➔ Places where its presence is detected with respect to the registration:
    - above, next to, or behind the instrumental record (Figures 1a to 1e),
    - on stickers or other glued substrates (Figure 2a),
    - on additional papers, wrappers, filing cabinets or other preserved substrates attached to the seismogram (Figures 1i, 1j, 2b and 2c),
    - on the creation and/or storage structure (whether analog or digital) (Figures 1k, 2e and 2f),
    - on the same digital file via metadata, headers, order, or properties determined by the chosen format (Figures 1j and 1k),
    - on another digital file or attached analog information (Figure 1k).
  - ➔ Materials with which they have been made:
    - pad/prints in ink (Figures 1b, 2e and 2g),
    - manuscripts (Figures 1a and 2a),
    - graphite (pencil) (Figure 2b),
    - colored pencils (Figure 2g),
    - ink (Figure 2f),
    - marks or mechanical friction (Figure 2d),
    - digitization or computerized automation (Figures 1j and 1k).
  - ➔ Type of content and meaning (texts, drawings, etc.).

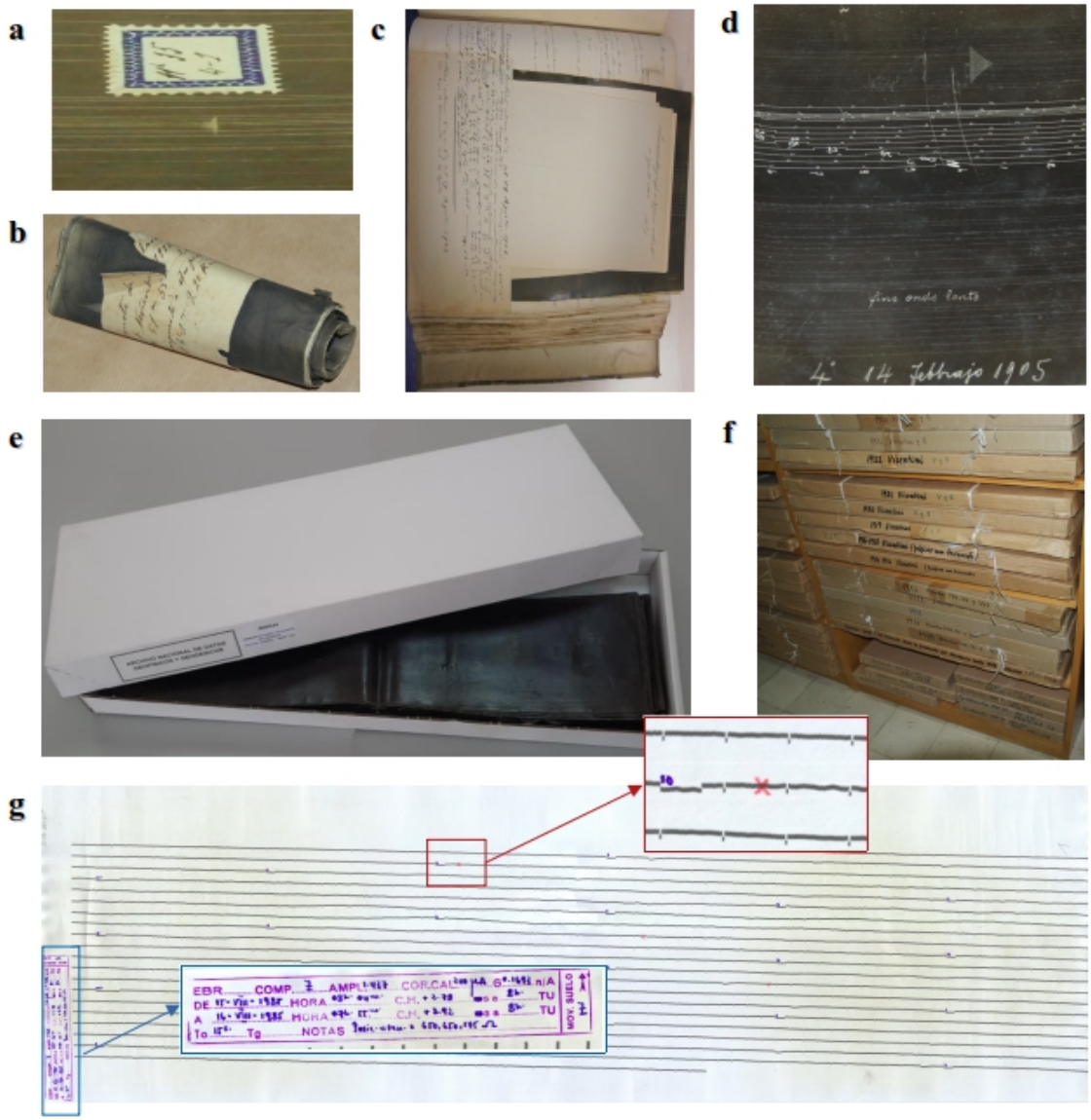

Figure 2. Some examples of the diversity of annotations and other additional marks on analog seismograms recordings: (a) paper with inscription in ink glued to a smoked paper seismogram; (b) smoked paper rolled with a paper with some information surrounding it; (c) pieces of smoked paper stored into the observations book all together with the rest of the information gathered about the registered earthquake; (d) smoked paper with inscriptions made by mechanical friction and afterwards fixed with the rest of the register; (e) smoked papers kept in a phN box with inscriptions about the contents marked with a pad and also on a printed sticker; (f) smoked paper kept in cardboard boxes with manuscript inscriptions written using a marker pen; (g) photographic paper with ink marks (by pad and manuscript) and pen and pencil. Sources: INGV (a, c, d); Observatori Fabra (b);Observatorio de Toledo (e); Observatori de l'Ebre (f, g).

- ➔ Whether or not there is a risk of losing the connection between the mark and the record and/or content to which it refers in order to alter the order or form of the original file or archive.

✓ **Organization, conditions and materials in which it has been filed and preserved.**

- File individually or by groups of seismograms (Figure 3b vs Figures 3a and 3b).
- Wrap directly in contact (Figures 3a and 3b).
- Possible additional wraps not directly in contact (Figures 3b and 3c).
- Adhesives or other substrates stuck to the wraps, with special interest in estimating the risk of detachment (Figures 3a and 3c).
- File organization procedures, if any.
- Ancillary documentation filed with the seismograms, in the same space, that now can be found in another known place or that is missing (Figure 2c).
- Location: space and access conditions.
- Entities and persons directly responsible for storage, archiving, maintenance, conservation, studies/works and consultations.
- Is this the original archive and organization? If not, can we know how it was previously? (Figure 0).
- Do partial or full copies exist in different formats to the originals?

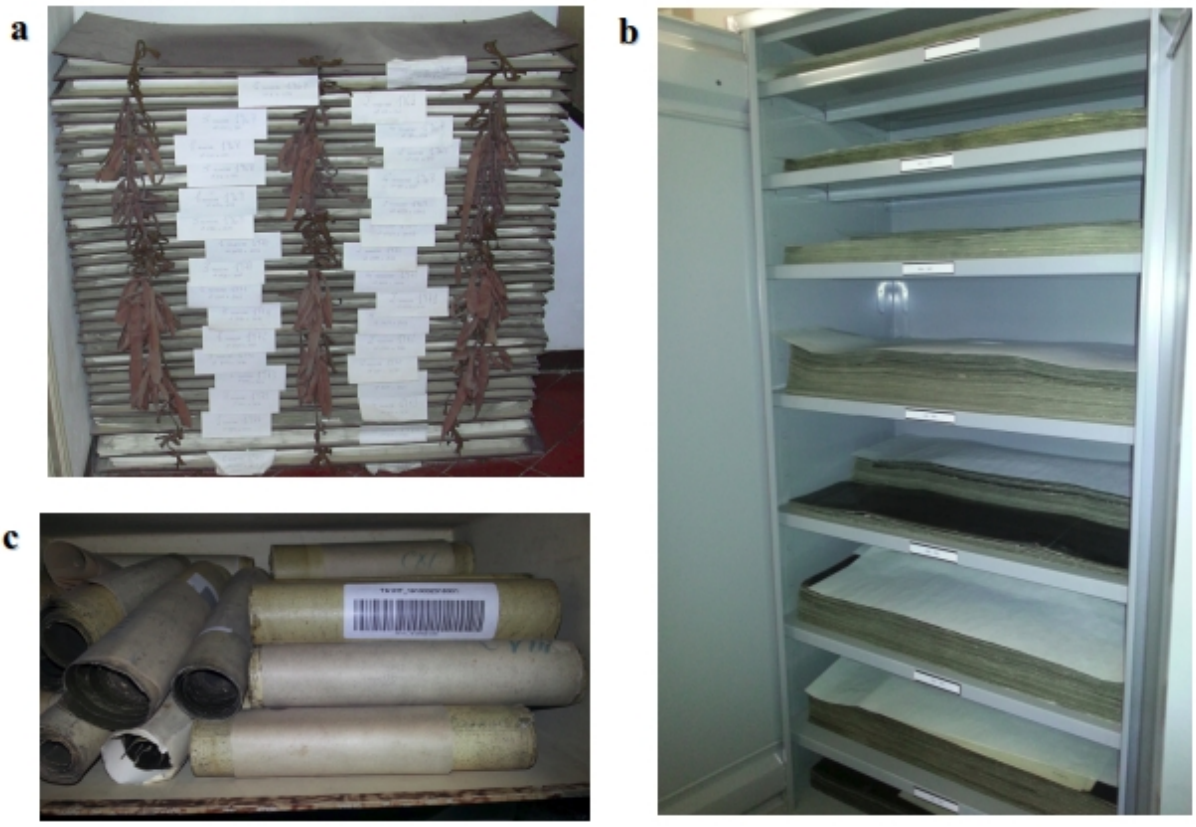

Figure 3. Some more examples of the diversity of ways and materials in which analog seismograms have been filed and preserved: (a) photographic paper seismograms in piled up cardboard folders attached with strings and lose papers with information about its contents; (b) smoked paper seismograms accumulated flattened in a proper ventilated fireproof wardrobe with a neutral paper between contiguous seismograms to avoid future conservation problems; (c) smoked paper seismograms rolled up on themselves, some wrapped in paper with additional information, stored into a cardboard box and with modern additional information in a code bar sticker. Sources: Observatori Fabra (a); INGV (b, c).

Additional and accessory documentation

We understand by **accessory documentation** all those documents related to the original recorded data, the instruments with which they were acquired, and any contemporary or subsequent elaboration related to these data or instruments.

They are **often essential** for a correct analysis of the seismograms. And, even when they seem redundant, they can be very valuable for future studies or processing other than the initial ones, or even for retracing, finding and correcting some original error or oversight.

In this identification phase **nothing is considered redundant**. Whether original, copies or processed, all existing accessory documentation must be identified and documented. It is not surprising that in some cases apparently redundant copies or materials turn out to be essential later due to certain "errors" or accidents.

Most common complementary documentation that we can find are:

- Station books: data acquisition station control documentation or logs (Figure 4a).
- Data books: documentation or receipt log or study of own and/or third-party data of detected phenomena (Figure 4b).
- Technical books: documentation of incidents, repairs or maintenance (Figure 4c).
- Calibrations: original data or results of calibrations performed (Figure 4d).
- Photographs or graphic documentation of instruments, places, materials, people, etc. (Figures 4e to 4h).
- Manufacturer's catalogs or other documents with additional information or highly technical details of instruments, materials and/or facilities (Figure 4h).
- Publications of more or less elaborated data (Figures 4i and 4j).
- Internal or external correspondence (Figures 4k and 4l).
- Manuals of technical procedures, archives or data analysis (Figures 4m, 4n and 4o).
- Backups or useful information about digital security materials and protocols, in case digitized copies exist.

In all these cases, the following aspects must be documented as thoroughly as possible during the identification phase:

- what it is: type of complementary documentation, whether it is one of those mentioned above or some other additional type;
- who made these registrations, for what purpose and in what context;
- primary source (written during the registration or right at the start and end of it), secondary (data noted or copied shortly after by the person responsible for the records or instruments) or others (compilations, subsequent processing, protocols, annexed information or not directly dependent on data acquisition);
- what period of time it covers: beginning, end, periodicity of the records, and if they are continued in a homogeneous way or there are more or less obvious interruptions;
- if it consists of one or several volumes directly related as part of the same documentary unit;
- which instrument/s or other data refer to: sensor/s, recorder/s, archive material, processed, etc.

And also, the same aspects detailed in the previous section, in an analogous way:

- Type of media on which the registration was made.
- Systems with which the registration has been made on the support.
- Annotations and other additional marks.
- Form and materials in which it has been filed and preserved.

Figure 4. Some examples of the diversity of complementary documentation that we can find among Observatori Fabra analogical patrimony: (a) station book, with logs of recordings and other instrumental incidences; (b) data book, with detailed information for each detected or reported earthquake; (c) notebook with comments about major repairs of the instruments; (d) book with calibration measurements performed and results obtained, with used formulae in the back cover; (e) photograph taken during Mainka pendulums installation in 1913; (f) photograph taken some years later, when they were fully operational; (g) photograph taken decades later, when there were also some other photographic and electronic instruments; (h) technical diagrams of Mainka pendulums; (i) bulletin from 1914 elaborated to be published and sent to other institutions; (j) manuscript for bulletin from 1939 never published due to difficult times during Spanish civil war and second world war; (k) folders with archive of international correspondence classified by origin; (l) postcard of acknowledgment of having received the original seismograms petitioned; (m) codes and protocols to understand the international telegrams with seismic data; (n) telegram received from Toledo Observatory; (o) "register" of phases from an earthquake analog register marked on a graph paper (upper image, from the front side) and a summary of its known parameters in the rear (lower image, from the rear side). Sources: ICGC(h) and Observatori Fabra.

Conservation state / Most common problems

In this initial exploration, it is very important to record the general state of conservation of the heritage in as much detail as possible, and in particular to highlight if we detect any of the following problems on an occasional, frequent or global basis:

- Fungus or other non-animal infestations (Figures 5a to 5c).
- Adhesion (Figure 5c).
- Insects, rodents or remains that indicate animal infestation (Figure 5d).
- Dirt or stains, and if we know the possible origin (Figure 5e).
- Mutilations, losses or scratches (Figures 5a and 5c).
- Oxidation or damage to the materials: by ink, by light, by the type of paper or material, by contact, etc. (Figure 5f).
- Deformations (Figure 5g).
- Lack of software and/or hardware to be able to fully or partially access the information contained.

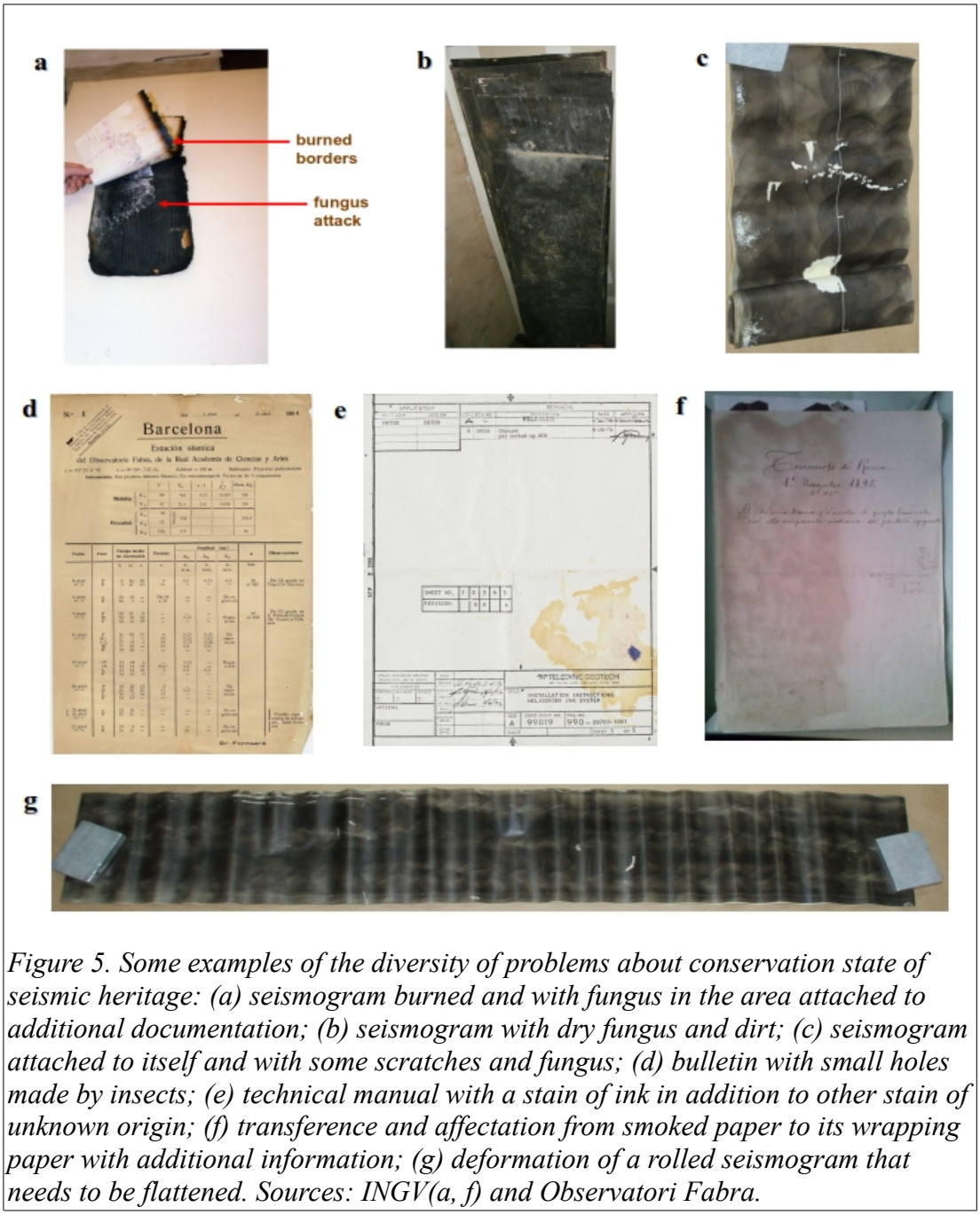

Figure 5. Some examples of the diversity of problems about conservation state of seismic heritage: (a) seismogram burned and with fungus in the area attached to additional documentation; (b) seismogram with dry fungus and dirt; (c) seismogram attached to itself and with some scratches and fungus; (d) bulletin with small holes made by insects; (e) technical manual with a stain of ink in addition to other stain of unknown origin; (f) transference and affectation from smoked paper to its wrapping paper with additional information; (g) deformation of a rolled seismogram that needs to be flattened. Sources: INGV(a, f) and Observatori Fabra.

CHAPTER 2

INVENTORIES AND CATALOGS

What lists of items and related data do we need and how to get them.

Introduction

In order to face a specific project (just to know how a seismograms archive is organized, to improve its organization, to improve its preservation in the future, to build it from scratch, etc.), we need to know what it involves, how much and how are its contents. A list or set of lists with this information mainly based on counting units will be called inventories here, while those that prioritize information based on their type or contents will be called catalogs. Their structure and exact content will depend in each case on the objectives and available resources of the project.

In the following sections, we shortly review some basic ideas and recommendations to maximize the potential results of these efforts for those specific cases involving analog seismograms and their accessory documentation.

IMPORTANT

- This phase is no longer a purely informative one, as in the previous chapter. Now we seek to extract as much information relevant to the defined goals as possible from the available seismic patrimony, and that may involve acting on it, making some manipulation or changes (on the seismograms, on the boxes they are contained, etc.) that could be irreversible. Therefore, it takes a significant work of previous detailed planning of the objectives and of each task to be done and its possible effects before starting to work on any of them.

Preliminary planning of the tasks

The preparation/elaboration of an inventory or catalog requires **detailed planning**. It is no longer the carrying out of an exploration and listings for informational purposes as in the previous phase of identification described in chapter 1. Now it is a project in itself that will require much more extensive and detailed, methodical and careful work that, depending on the volume and particularities of the seismic patrimony, may need significant resources. So, it is important to perform a good planning to maximize the obtained results. The preliminary planning of the tasks is the first part of this work, and if it is done in a sufficiently complete and detailed way, it will make the later stages much easier and will avoid failing into inconsistencies and other problems that could create repetition of tasks and undesirable corrections.

We recommend carrying out this planning explicitly documented with as much care and attention as possible, and taking into account the following important aspects to consider:

- Depending on the final objectives, different data are needed, but in order to avoid accidents or future conservation problems, it is better to minimize the number of interventions upon the patrimony materials (seismograms, documents, etc.). Therefore, it is recommended to extract as much additional data as possible when there is a doubt of whether that could be needed in the future or not.

- It is crucial to collect information as complete as possible about how the physical situation of the patrimony is BEFORE changing anything. We recommend to plan/take enough time to carry out and extensively document the preliminary identification phase (chapter 1) and to collect and make photographs, diagrams, descriptions, explanations, etc. of the original organization of the seismic patrimony and any other elements or surroundings (boxes, labels on shelves, etc.), as well as from the space around them or related in some way.

- Depending on its state of preservation and available resources, this phase must be carried out before, after or in parallel with the preservation and/or restoration actions that could be considered necessary. Besides, the subsequent use and preservation that is intended for this patrimony has to be taken into account. That's why we recommend reading this entire manual before starting the detailed approach and the inventory or cataloging tasks.

- Basic resources (budget, time and staff) are usually scarce and very unstable. You might have insufficiently anticipated them or be left without an important part for many more or less unexpected reasons. Or, instead, a formidable opportunity might appear but with very little preparation time and possibilities to take advantage of it. The management of foreseeable contingencies is a very important point to take into account when planning and coordinating the work to be done. That's why it is very important that the proposed work is: (i) as scalable as possible; (ii) useful for parts even when incomplete; (iii) well documented; and (iv) easy to resume if unexpectedly interrupted.

- The preparation of the detailed planning of the tasks should go from global to particular. Initially consider a minimal useful classification very similar to the original. Then consider one by one the particular interests of the objectives that justify a different reorganization of the data and the positive and negative effects they can have on the overall work (plainly, consider "pros" and "cons"). And finally, consider how special cases could be dealt with, such as: a) if out-of-place seismograms will only be documented or if they will be rearranged; b) if you want

to highlight any special data such as whether or not a seismogram contains any earthquakes from a certain catalog; c) whether or not seismograms with significant degradation will be set aside during the inventory tasks to be restored or to will be preserved differently from the rest; and so on. It is important that the selected approaches to the tasks are as detailed and contemplates as many cases as possible before the works start.

- Even if it seems redundant, it is usually easier, progressive and scalable to inventory first the more external units completely (such as boxes, shelves, folders, etc.) and to leave for a second stage, once that has been finished, the inventory or catalog of their internal contents (seismograms, books, letters, etc.).

- Setting up a database with several interrelated tables makes this planning stage more complex, but in case of need it is much more versatile and easier to be readjusted than the typical lists, especially for catalogs. In any case, for each list, additional unique codes should be proposed, different than the correlation codes between the tables of the same database.

- Have in mind that those results that are made public or displayed are always a by-product or a reduction of the accumulated data set. When creating each table or list, it must be as comprehensive, complete and complex as possible, even if there are fields not filled in many cases. It is important to clearly distinguish in those cases between: (i) non-existent; (ii) unknown; (iii) negative; o (iv) other specific "error/s code/s".

- Exploring how other institutions with more or less similar seismic patrimony have faced these tasks can provide valuable insights, warnings and examples. We strongly recommend exploring the references included in the last section of this manual *Resources and References* and other works, even those still in progress.

Code (integer)	Value	Meaning
	void	Field not filled yet for that register (p. ex. while this table is still in process to be filled in).
0	0	0 seismograms, filled after being reasonable sure that there is no seismogram with records for that earthquake from Station ID.
any number within: {1, 2, 3, ..., 127}	1, 2, 3,..., 127	The number of seismograms with records for that earthquake from Station ID (the type of each seismogram and its properties will be registered in other fields of the table "Identified Earthquakes from Station ID" and in other related tables with information about properties of those different seismograms.
-128	NO	There is logic to find any possible seismogram record for that earthquake from Station ID, for example because the station ID instruments were installed after that earthquake date.
-1	Err1	There could be some, but the exact number of seismograms is unknown because a particular problem, such as for example that there could be some possible seismograms but some of them cannot be looked up yet because of being sent away for restoration.
-2	Err2	There could be some, but the exact number of seismograms is unknown because another particular problem, such as for example that there is complementary documentation about being identified in some possible seismograms which cannot be looked up yet because they are still to be found.
any number within: {-3, -4,..., --127 }	Err#, being: #=-3,...,-127	Other particular cases there there could be some but the exact number is unknown because another foreseeable particular problem that we are interested to be marked differently just in case in the future we could be interested in searching for those particular cases.

Table I. Example of possible admissible values for the integer object "Number of analog seismograms with records from the earthquake" from the Table "Identified Earthquakes from Station ID" linked to the register related to a certain identifying code from the Table "Earthquakes" from a catalog that uses relational databases. This theoretical example shows how database architecture planning, even apparently complex, helps to discriminate specific situations and gather additional information potentially useful for many possible future uses.

Figure 6. Some examples of different seismic archives to illustrate how the preliminary planning of the tasks for a specific inventory or catalog could be highly depend on, not only its objectives, but also the accessibility, preservation conditions and previous knowledge of the seismic patrimony: Massive storage facilities in California shown in A1, filled up with seismic patrimony, provoke difficult accessibility and high risk of degradation. Partially burned seismograms from Lisbon (shown in B1 and closer in B2) are so damaged that require important restoration and advances techniques of safe manipulation. On the other hand, Observatori de l'Ebre archive shown in C1, C2 and C3 has managed to be maintained rather well preserved and easily accessible (even with digitized copies available online), with the scarce human and material resources typical of small institutions. And finally, Observatorio de Toledo, as the central institution of the national seismic network in Spain, has been able to create a more professional and modern archive (shown in D1, D2 and D3) to conserve their seismic patrimony to avoid further deterioration and loss, and to carry projects of detailed cataloguing and digitization of its more than one million of seismograms in different formats and supports in addition to their seismic complementary documentation. Sources: L.Hawng (A1); J.Batlló (B1, B2), Observatori de l'Ebre (C1, C2, C3) and Observatorio de Toledo (D1, D2, D3).

Basic templates

Each inventory or catalog project must have its own template of data to be obtained that will depend on the specific set of patrimony to which it refers and the objectives of the specific project. If the project has been planned by scalable phases, each of those phases could have its own particular template.

For example, let's consider the theoretical case, with strong limitations in resources and time available, of a catalog of a small network of stations with seismic patrimony, whose only objectives are location of their seismic patrimony and evaluation of how much could cost a possible future project for moving all that seismic patrimony to a centralized storage with better preservation conditions. The preliminary planning of the tasks has divided them in subsequent phases:

- ✓ In phase A, each station in the network is documented and contacted to encourage them to perform their own identification of their seismic patrimony (as explained in chapter 1).
- ✓ In phase B, some additional questionnaires are prepared using those preliminary identifications to achieve one or more common catalogs of the different types of patrimony present in those stations, with as many information as possible about and their diverse processes involved: recording, identification, publication and their particular state of preservation.
- ✓ In phase C, additional more specific measurements and quantitative evaluations are planned for each type of patrimony to design their preservation conditions needed and the volume, weight, risks, costs, etc. involved in a possible movement to a centralized storage.

In this theoretical case, each phase will need their own templates, and most probably the template fields for one phase will depend on the results of previous phases. They also would depend on whether the produced catalogs will be published or not, on whether there is foreseeable continuation to these efforts or not, etc. These phases could lead to different results, ranging from several lists or simple inventories more or less related, up to a coordinated and scalable catalog that could be increased and used in the future with further purposes.

In any case, it is important to consider that this effort to obtain these data, in order to be most useful also to others, should be in accordance with the "**FAIR metadata**"principles, which refers to obtaining *Findable, Accessible, Interoperable, Reproducible data* (see references [5] and [6]) .

Similar projects previously initiated by other institutions and some initiatives to standardize this type of data for seismic patrimony can be found in the last section of this manual *Resources and References*.

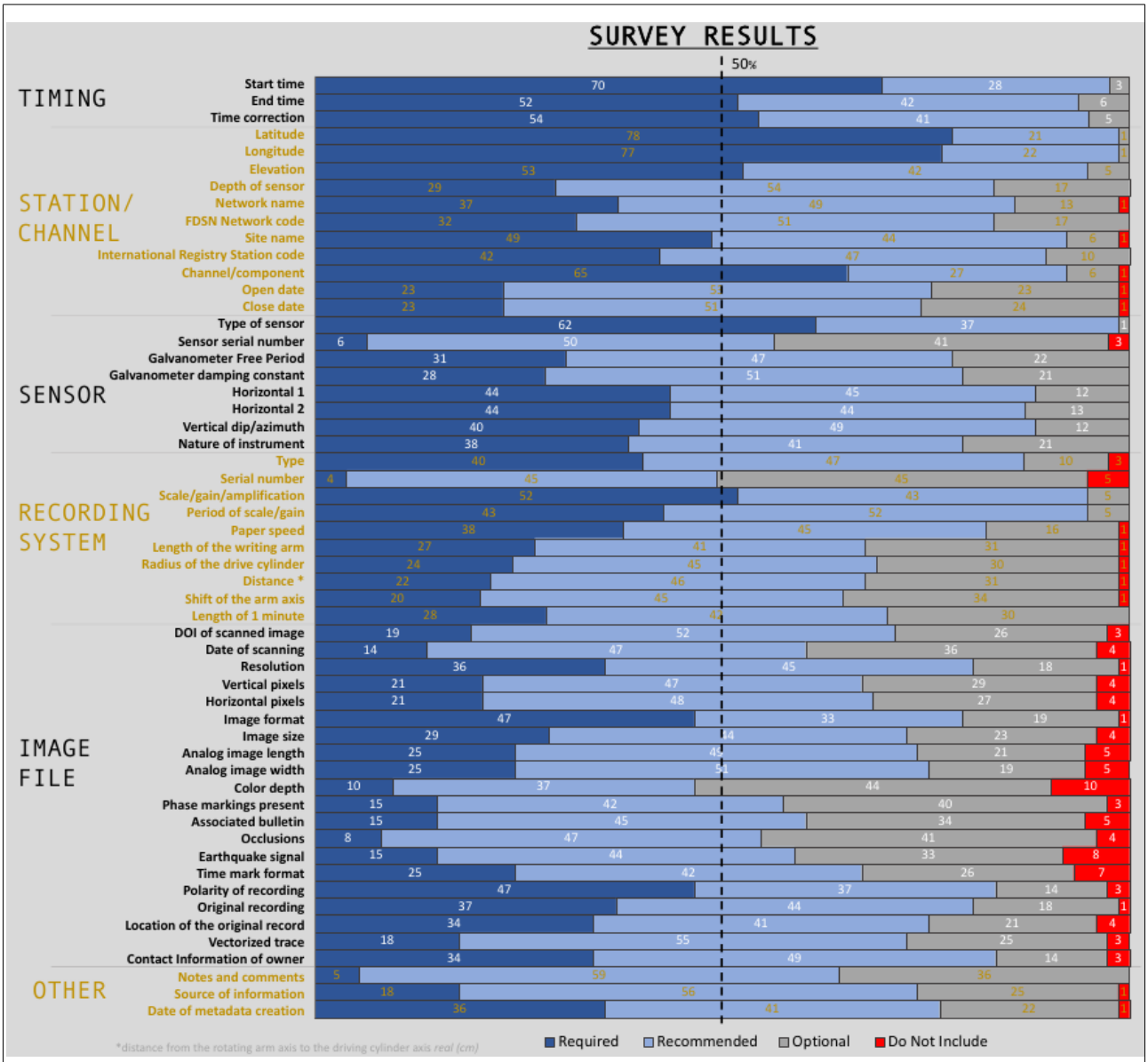

Figure 7. List of the 55 metadata elements suggested for scanned images of analog seismograms in order to create a standard that will allow centers to coordinate in their publication and to ease the use of them under FAIR premises. A survey was sent to a number of centers all over the world asking to indicate for each of those elements if they thought they should be required, recommended, optional or directly do not include it. The graphic shows the survey results presented in reference [7]. Source: L.Hawng and T.Ahern.

CHAPTER 3

CONSERVATION AND PRESERVATION

How to and not to do to best preservation with available resources.

Introduction

Preventive conservation is a discipline that is based on preventing deterioration through the relationship of heritage with its environment. The first essential step is to evaluate the space and the initial state of materials (seismograms, station books, etc.). Then consider and plan in detail the urgent minimum changes to solve the most serious problems detected. The rest of the changes or improvements that do not relate to problems that involve a risk to heritage will be considered, studied and subsequently valued more calmly and with much more planning according to the possibilities of each institution in a way that also fulfills the purpose and goals of its use and final visibility.

IMPORTANT

- Do not assume that all changes are for better. Studying how to maintain and/ or preserve optimally does not necessarily imply making significant changes or expenses. Sometimes it only involves basically assessing, recognizing and properly documenting protocols that have long existed with very small or practically non-existent changes.
- Possibilities and purposes for each archive and institution are very different. Not only in terms of its economic resources and planned activities, but also in similar previous experiences and interrelationships with other projects.
- Many difficult or impossible to recover losses and degradation could have been avoided with proper exploration, evaluation and planning, without great resources or costly interventions.

Evaluation of space, furniture, materials and related risks

The evaluation of the space and the present state (conditions) in which the heritage is located should include at least the following aspects:

- ✓ **Ordinary Space Features:**
  - Existing basic services and facilities (electricity, water, gas, etc.) and active and passive mechanisms to avoid associated risks (floods, fires, excessive humidity, etc.).
  - Ordinary ventilation and cleaning services and protocols.
  - Active and passive control of infestations (insects, rodents and birds especially).
  - Security in case of robbery or vandalism.
  - Assessment of the most significant natural and artificial risks.
  - Sketches with accesses, ventilation and work and/or passage areas.

- ✓ **Ordinary storage furniture features:**
  - Open or closed (indicating the type of closure and ventilation).
  - In contact or isolated / damped with respect to the ground.
  - Materials (wood, metal, plastics, etc.).
  - Total capacity, useful available volume and occupied/available useful volume.
  - External and internal dimensions.
  - Weight per available support unit and weight currently supported.
  - State of conservation of furniture and possible pathologies.
  - Sketches with location in space, access/openings and internal distribution of heritage.

- ✓ **Ordinary characteristics of the storage, protection and marking elements directly in contact with the heritage:**
  - Type: box, folder, wrap, separations, covers, strings, etc.
  - Materials (wood, metal, plastics, etc.) recording their thickness and if they have special characteristics (fireproof/fire-resistant, ph neutral -phN-, opaque/translucent/transparent, treated against infestations, etc.).
  - Total volume, useful available volume and occupied/available useful volume.
  - External and internal dimensions.
  - Maximum interior and exterior weight that supports per unit (theoretical and real currently)
  - State of conservation and possible pathologies (degraded, infested, dirty, etc.).
  - Could it not be suitable for the material you are in contact with? (phN, translucent/opaque, etc.).
  - Is it being used properly? (content that stands out for excess or excessive incorrect dimensions, incorrectly closed, excessive weight on top, incorrect position, etc.).

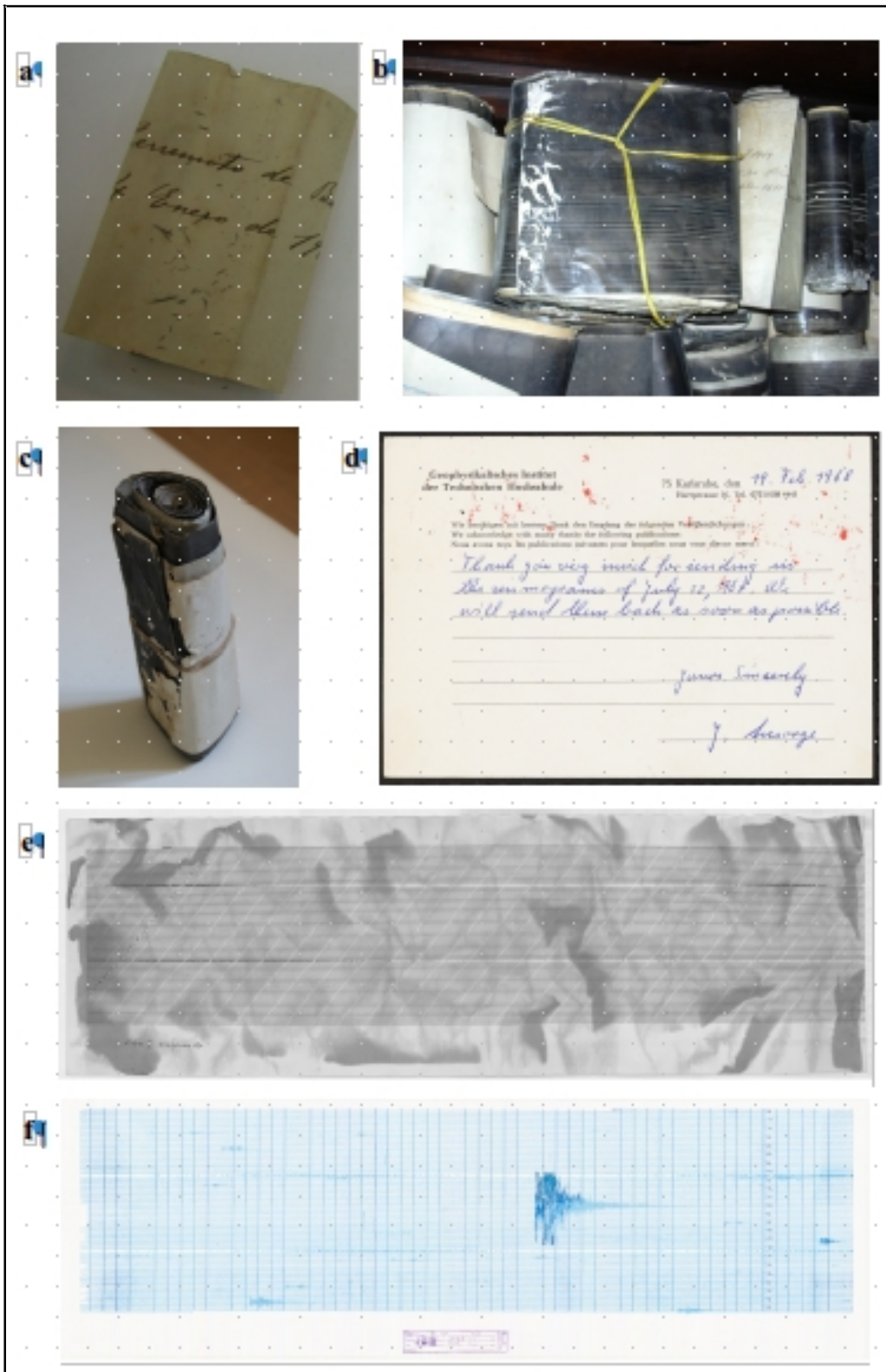

Figure 8. Some more examples of the diversity of problems about conservation risks: 8a) surface dirt; 8b) mechanical degradation due to improper storage; 8c) inadequate acidifying paper in direct contact; 8d) ink spots; 8e) degradation of chemical components; 8f) ink atenuation because of excesive exposition to sunlight. Source: Observatori Fabra.

- ✓ **Variable Space Features:**
  - The main variables to be measured are:
    - ➔ Climatic conditions: Temperature and humidity are the main variables.
    - ➔ Natural or artificial lighting, direct or indirect, indicating approximate frequency range in each case is also fundamental.
  - For each case, it is necessary to measure or at least estimate the maximum, minimum and cycles of typical oscillations (diary, monthly, seasonal and annual).
  - Estimated measurements and values must be for contact surfaces and air (inner and outside furniture and other enclosed spaces).
  - It is also necessary for the annexed rooms/spaces with direct connection and exterior spaces to foresee the possible impact of a failure of the mechanisms of artificial control of the elements, activity-related effects on poorly isolated annexes, etc.

- ✓ **Specific pathologies and problems detected in documents. In each case, at least the % of the documents affected and the maximum degree of impact observed must be evaluated, possibly with an objective scale of severity:**
  - Cleanable surface dirt: dust, pollen, small accumulated elements, etc.
  - Spots (from use, contact, oxidation, etc.).
  - Oxidation and acidification: by the composition of the paper, by contact with another annex material (ink, acidified paper, etc.), by excessive exposure to light, by extreme climatic conditions, …
  - Mutilations, tears, losses, scratches, deformations or other mechanical damage.
  - Adhesions, indicating if it is due to degradation of the material or different origin.
  - Fungus, indicating all the possible additional information such as: color, relief, geometry, etc.
  - Animals or remains of their presence (insects, rodents, reptiles, etc.) indicating whether they seem recent or past, in addition to any other additional information.
  - Other degradations, indicating as much additional information as possible (flooding, exposure to smoke, burns, etc.)

- ✓ **Access and planned activities on heritage and its environment, indicating the minimum and maximum frequency for each type of manipulation. Especially those that may suppose:**
  - Risk due to manipulation.
  - Risk due to changes in usual environmental conditions.
  - Risk of disorder or accidental loss.
  - Risk due to theft or vandalism.
  - Risk of incursions, infestations, sources of dust, pollution or foreseeable occasional effects.

Actions and protocols to be planned and prepared

Before introducing any change, it is necessary to explore, consider, plan and explicitly document the current state and the reasonably expected objectives for each of most common conservation and preservation actions:

1. Environmental control.
2. Infestation Control.
3. Ordinary cleaning of spaces, furniture and storage.
4. Cleaning of seismic heritage, if necessary.
5. Access control and security.
6. Control of the planned activities/visits/uses.
7. Direct manipulation of seismic heritage.
8. Transport and/or temporary exposure.
9. Regular monitoring of deterioration.
10. Specific actions and urgent decisions in the event of incidents.

It is strongly advised to document at least ***when***, ***who*** and ***how*** for each of those topics. Also to revise them with a previously decided periodicity.

The resulting documentation of the initial state, the desired objectives and any revision of them should be kept along with the additional reports or documentation of any related incident that might arise. Not only to keep track of the progresses but also as useful data for example to detect recurrent problems or for be able to perform any possible future estimation of best resources distribution.

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Figure 9. Is prefereable to clean only the protective containers instead of the heritage itself. Only when it is really needed and simple/easy, mechanical cleaning could be applied to the heritage avoiding at all costs to damage or scratch surfaces or pieces using the softer option available. Using dry air (to avoid moisture when applied) gently applied from a reasonable distance (to avoid too much pressure or sudden change of temperature) could be used only if the material is not too fragile. Be aware that using any further instruments, liquids or other chemicals is not considered cleaning for preservation/conservation, but restoration instead (see next chapter). Source: Observatori Fabra.

General suggestions

There are three main rules to be always followed and have in mind during all the phases related with conservation and preservation of seismic heritage:

I. An archive that has been reasonably well preserved for a long time without great environmental or activity oscillations can be preserved without significant changes if it continues in the same micro-climate/conditions, even if it does not meet all the ideal parameters. In any case, it is advisable to explicitly document the prior evaluation of the space, furniture, materials and associated risks, as well as the actions and related protocols already mentioned.

II. Good protection must avoid dirt, stains, mutilations, oxidations, deformations, etc. as much as possible. These affectations, if previous, do not require urgent action, but must be planned which changes in conservation and manipulation must be introduced to avoid increasing them and gradually correcting them or during possible manipulations or future actions.

III. It is important to make the availability and use of seismic heritage compatible with proper preservation. Even with the advice within this section it is important to achieve a balance between acceptable preservation and access that allows its usefulness and availability in order to be known and therefore recognized, since this will also, in the long run, have an impact on the interest of its preservation.

Figure 10. With materials such as Remay@, Melinex@ and phN cardboards or papers and a bit of handicraft the heritage can be more easily exhibited with a reasonable protection from light, humidity and other risks at low cost. Source: Observatori Fabra.

Figure 11. Three examples of seismic heritage conservation approach. a) Observatori Fabra has introduced important changes and interventions in the last decades with limited resources in order to solve previous preservation problems detected and ease its use and exhibition; b) Observatori de l'Ebre archive is reasonably well preserved and available to use, so no urgent intervention is planned yet and nowadays their efforts focus in scanning; c) Observatorio de Toledo, as the main as the central institution of the national seismic network in Spain, has been able to create a more professional and modern archive. Sources: Observatori Fabra; Observatori de l'Ebre; Observatorio de Toledo.

More specific suggestions to consider

- Wrapping materials are often the main cause of the degradation of the contained seismic heritage. It is essential to ensure using opaque neutral phN papers and cardboards that allow ventilation. In those cases where it is not possible to have the necessary resources to change the inadequate materials, you can choose to wrap them or interpose sheets of neutral material (paper, cardboard or other suitable materials) to avoid direct contact until it can be replaced.

- It is worth noting the need to always avoid seismic heritage being in direct contact with:
  - ✘ rubbers or similar materials quickly degradable and leaving waste,
  - ✘ adhesives or plastic glue,
  - ✘ oxidable metals (such as staples or clips),
  - ✘ papers or cardboards with colours and/or acidifying inks that could cause transfers.

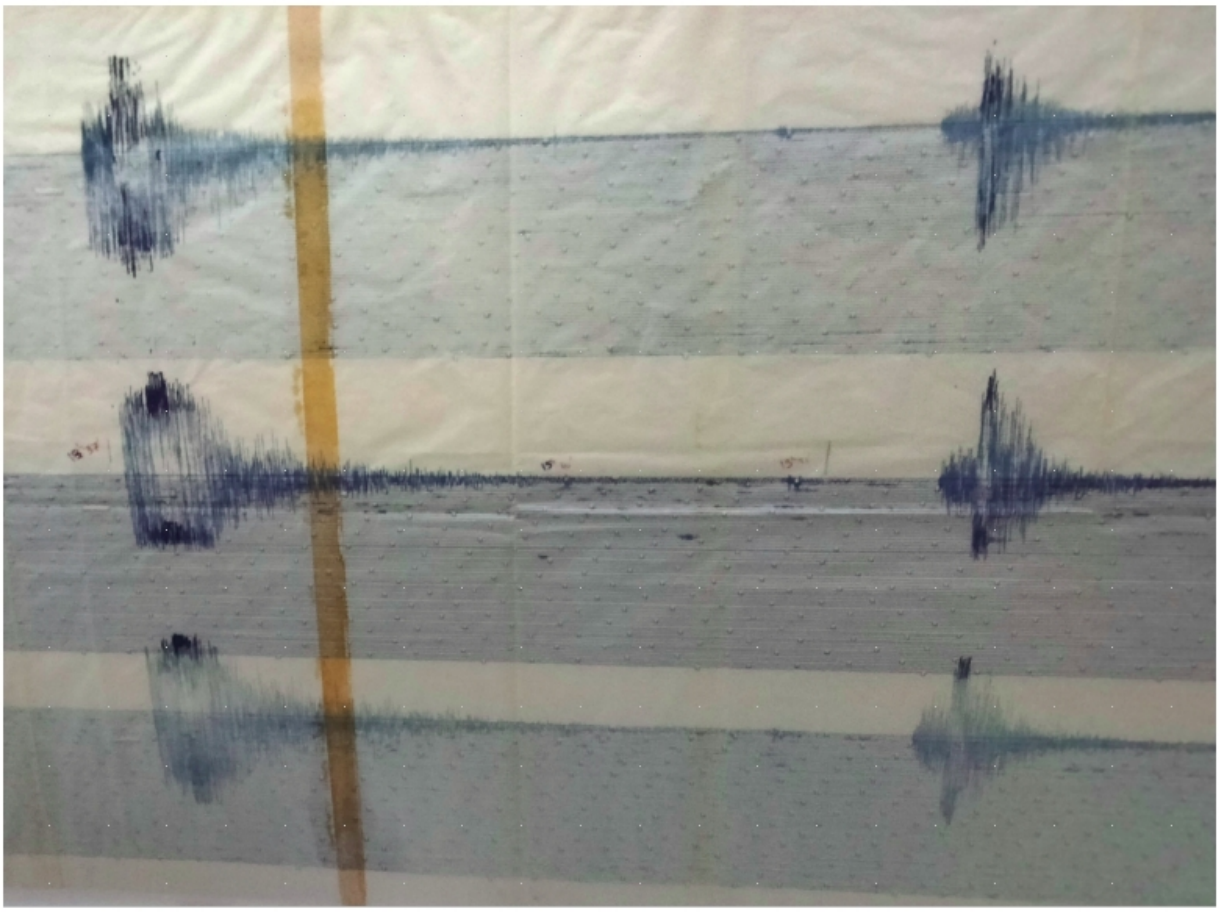

Figure 12. Wrong materials in direct contact can cause serious preservation problems in the long-term . Source: Observatori Fabra.

- Closed storage is preferable to avoid environmental pollution and many of the most frequent risks, but it must be ensured that it is with the appropriate materials that can guarantee proper ventilation and environmental and access conditions.

Figure 13. Folders with strings were very usual containers in the past. Unfortunately, they do not protect enough from insects, environmental pollution nor dust. Moreover, strings often cause accidental strips. Cardboard phNboxes or adequate drawers are better options in all those aspects. Source: Observatori Fabra.

- It is recommended a closed space with controlled uses and access. Far from places or facilities of ordinary services that involve unnecessary risks by accident (such as water, electricity, gas, drainage, attics, basements, etc.).

- For the design of the spaces, in addition to storage plans, it is necessary to take into account where and how the planned manipulation of the materials will occur. And if the storage space is expected to be shown in some way.

Figure 14. Adequate gloves, masks and tools to manipulate heritage should be kept available or even easily visible in place to minimize manipulation deterioration and prevent allergies or other health risks. To select adequate sizes for each case is very important for a comfortable and proper use. Cotton gloves are the most soft, comfortable and reusable option. Latex, silicon or nitril ones can be also used as cheaper and versatile options, but only if they leave not traces (beware of added dusts/materials or deteriorated gloves). Source: Observatori Fabra.

- Fireproof metal shelves, drawers and accessories painted with safe paint are preferable to wood ones because they have far fewer risks and are easier to clean and maintain.

Figure 15 Protective surfaces should be used in every exposed material .Besides control and security against thieves, it helps to avoid accidents and unproper handling and makes easier the control of unexpected activities or use. Locks are strongly advisable, even if not always closed or with common/easy keys. Source: Observatori Fabra.

- Avoid stacking large amounts of volume or weight in order to minimize the risks of deformations or mechanical degradation of both materials and storage furniture.

- In general, the less light the better (both in intensity and in exposure time). Being direct natural light the worse. That especially affects, in order of importance, to:

    1) Photographic substrates.
    2) Thermic paper.
    3) Inks.
    4) Paper (including smoked paper).
    5) Other materials.

- It is important to ensure regular and soft ventilation that produces air renewal. And to avoid occasional condensations and nearby works or sources of contamination that may dirty and/or affect the material (works, repairs, fumigation, painting, etc.).

- The ideal temperature of a mixed archive is between 18ºC and 20ºC.

- Ideal humidity depends more heavily on the type of material. There are many nuances to consider in the specialized bibliography, but in *Table II* we show approximate ranges that are sufficiently valid for most cases within which no significant degradation by humidity should occur.

- The further away from recommended ranges for temperature and humidity and the more oscillations occur (especially fast ones), the more degradation will be caused on seismic patrimony.

Substrate material	Minimum humidity	Maximum humidity
Smoked paper	50	55
Paper with ink	50	55
Thermal paper	45	50
Photographic	45	50

Table II. Optimal conservation recommendations of maximum and minimum humidity for several types of seismograms.

Figure 16. When economical resources are scarce nowadays there are cheaper options that could help to control at least maximum and minimum temperature and humidity, which are the most critical to monitor. Source: Observatori Fabra.

- Infestations and fungi must be resolved as urgently as possible. It is very important to immediately isolate the affected elements from the rest to prevent their spread as far as possible.

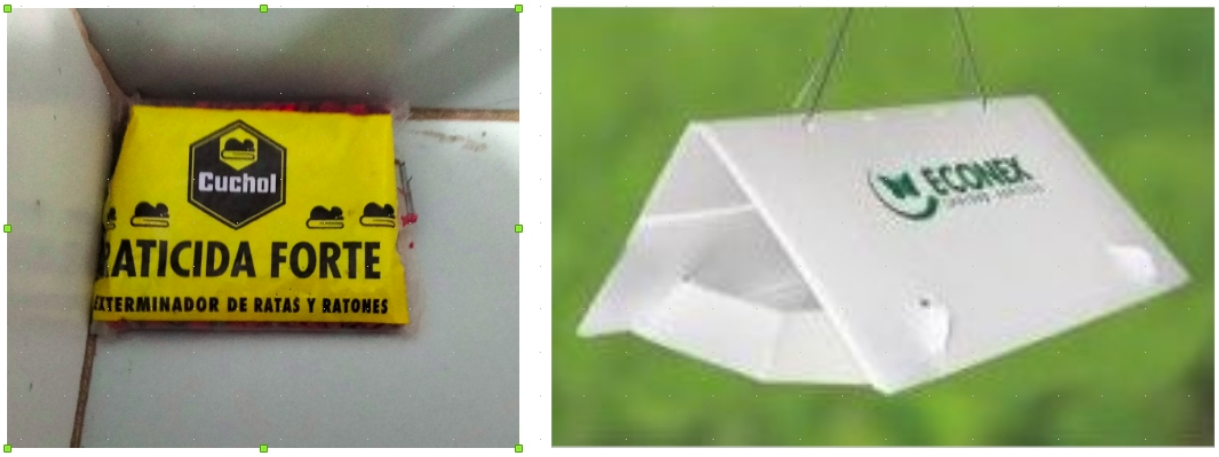

Figure 17. Insect or rodent traps can be easily handcrafted, but there are also many cheap options available in the market to control pests as soon as possible. Every trap must be revised periodically to be useful. It is important to use traps that do not atract at all inside the heritage containers and to place the other with chemicals only outside to avoid attract new colonies. Sources: Observatori Fabra and https://www.e-econex.net

Figure 18. Cleaning with a known periodicity also helps to detect possible infestations or other problems and determine since when could exist or not. Source: Observatori Fabra.

CHAPTER 4

RESTORATION

Realize when, what, and how it should/could or not be done.

Introduction

A restoration action must be evaluated only after an adequate assessment and assuming the risks involved. In case of doubt, it is always preferable to improve conservation and postpone restoration for when we are sure of its suitability. However, in this chapter we describe some small interventions that may be useful if necessary, mainly to help with the interaction with restoration staff and to ease to decide among the possible options in consideration.

IMPORTANT

- Restoration must be directed to the recovery of the potential unity of objects, whenever possible, without committing a historical or artistic falsification and without making the marks of the passage of time on the object disappear.
- Only after an adequate exploration, documentation and study could be worth assessing whether it is worth the risk of doing it and what steps it will consist of. The assessment is not only about the element to be restored but also the activities and their previous, subsequent and predictable environment. In case of doubt, it is better not to perform the restoration, except in cases of imperative and obvious need and urgency according to all the specialists consulted unanimous criteria.
- It is always preferable to have the restoration done by qualified professionals with experience on elements that are very similar to those to be treated. But if this is not possible due to urgency, there are some small techniques and tips that we describe below, with the warning that if they are executed it must always be very carefully and having previously confirmed that the execution of the technique is mastered after numerous controlled tests before risking doing so on real seismic heritage (seismograms and additional materials).

Preliminary planning before restoration

All the details must always be studied and documented with special care before considering any restoration. In addition to the exploration and study described in chapter 1, it is necessary to document in detail:

- ➔ Arguments that justify the need and urgency of restoration (must be factors that cannot be achieved or improved by changes in conservation).
- ➔ Any relevant knowledge about the type and cause of deterioration of the element to be treated.
- ➔ The type and degree of risks and the reversibility of the treatment proposed, as well as whether it can impact the contiguous elements.
- ➔ Compatibility between the different elements present.
- ➔ All the details of the element to be treated, including photographs and general and particular comments of its previous aspect, marks, annexed elements, problems or pathologies to be solved and others that are not sought to be solved, etc.
- ➔ The place, facilities and team responsible for the previous study and the later execution of the proposed restoration (they may be different and more than one group for each case).

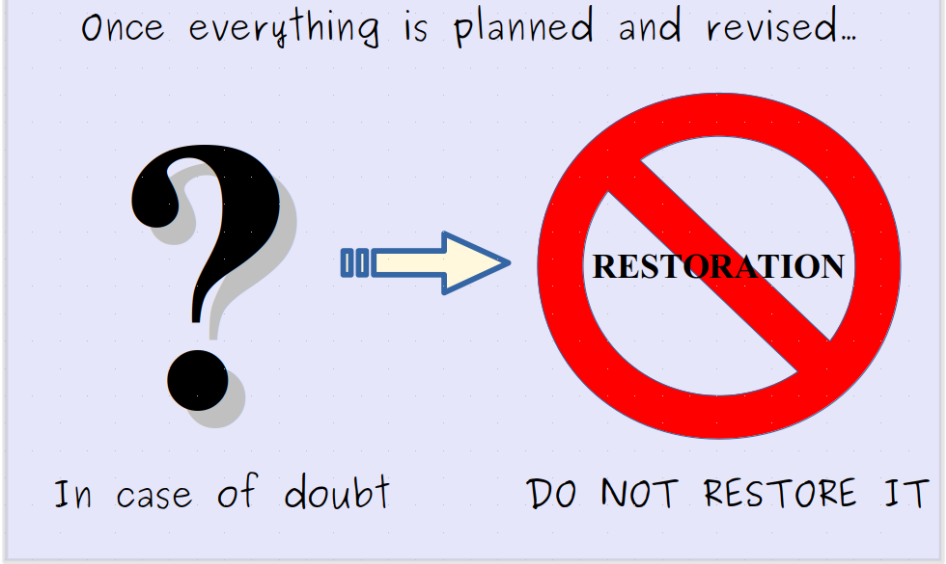

Figure 19. Even though restoration is strongly discouraged to be performed by non-professionals, this manual includes this chapter to give the reader a bit of information and terminology to be able to explore and consider possible restoration projects.

Control documentation

This includes the documentation that must be elaborated by the person in charge of the execution of the restoration ***BEFORE*** starting any action. The previous identification must contain a detailed description and the state of conservation of the seismic heritage at the time of the beginning of the study, as well as enough photographic documentation to show it graphically.

It should include at least the following fields:

- ✔ Curator in charge: contact data necessary for any past, present or future consultation.
- ✔ Restorer in charge: contact data necessary for any past, present or future consultation.
- ✔ Registration code: unequivocal identification code or number for the element.
- ✔ Identification: description of the type of element (photo strip, manuscript document, etc.).
- ✔ Date of entry: the date on which the decided restoration, if any, could begin.
- ✔ Origin: location and surroundings of its origin (season, instrument, time, etc.).
- ✔ Dimensions: geometry and descriptive sizes (for example: rectangular with height 10cm, width 15cm and depth 0.1cm).
- ✔ Support type: satin paper, chemical paper, cardboard, etc.
- ✔ Registration technique: ink, photographic, smoked, etc.
- ✔ Annotations and marks: type and description one by one, indicating if they were made by pencil, pen, scratches, etc.
- ✔ Observations: any additional element or comment that is considered interesting.

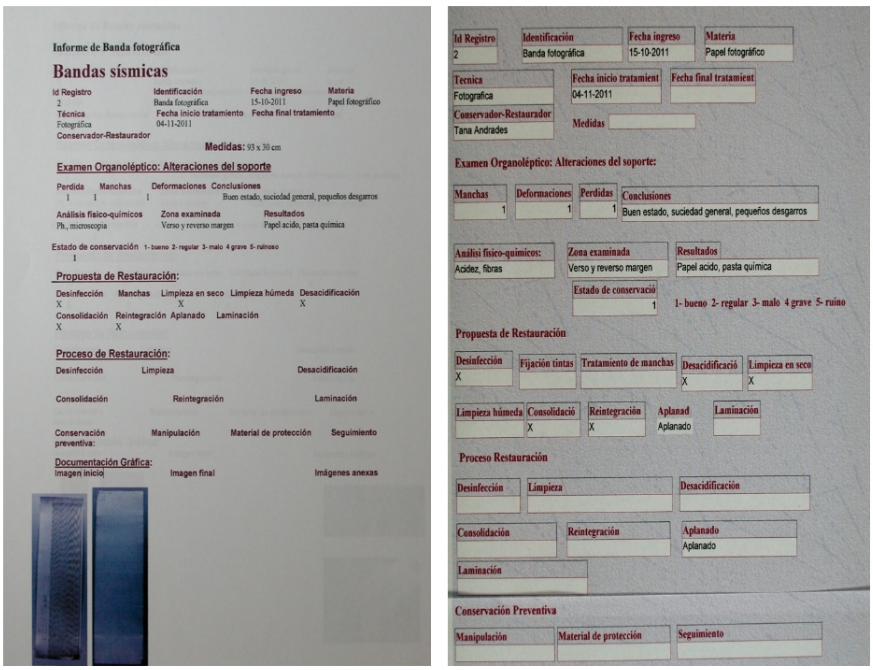

Figure 20. Example of control documentation previous to a restoration of a seismogram from Observatori Fabra to consider whether to be performed or not at CRAI premises (see reference[8]). Source: T.Andrades.

Detailed evaluation of composition and status of conservation

Before acting, the previously diagnosed conservation status must be confirmed and quantified based on visual analysis and some chemical tests.

As visual analysis it is important to estimate whether the origin of the pathologies seems to come from the following origins:

- Physical deterioration: scratches, loss of support, tears, deterioration due to storage problems, etc.
- Chemical deterioration: acidity, oxidation, contact affectation of other elements, etc.
- Biological deterioration: fungi, insect infestation, attack or remains of other animals, etc.

With regard to possible chemical tests, it is important to point out that determining which one must be carried out depends on the treatment to be weighed, avoiding as much as possible the extraction of samples. If it were essential to do so, they should in any case be of the smallest possible size and from a hidden and discreet area without useful registration. You must be fully aware that a negative result of the test is only indicative because it does not ensure that it will be also negative for the whole the element.

The most common chemical tests are:

- **Ink Solubility.** Before carrying out any treatment with water or any other solvent, it must be verified that it can be applied without risks.
- **Solubility of the adhered elements that must be separated.** Necessary to determine the suitable solvent or heat application to separate adhesives, self-adhesive ribbons, fat spots and other similar elements that could cause deformations and pathologies otherwise. These tests must be used locally.
- **pH measurement.** The element will be considered as excessively acidic when it has pH values below 6 and alkaline above 8.5. Ideally, the pH should be between 7 and 8. There are two basic systems for measuring the degree of acidity or alkalinity: colorimetrical methods and electromechanical methods. In any case, manufacturer's instructions should be followed.
- **Analysis of fibers.** It is important to determine the presence of lignin and/or paper fibers in order to know the composition of the substrate. The most common tests performed for its detection (see reference [9]) are the following:
  - ➔ Lignin. A drop of the fluoroglucinol reagent becomes purple red for compositions of 5% or more, with the intensity of the colour being an indication of %.
  - ➔ Paper fibers. The main chemical fibers and plasters can be identified depending on the resulting colours with Herzberg reagents in general and Lofton-Merrit for lignified fibers. Herzberg's dye is very useful for determining mechanical, chemical and derived from natural cellulose fibers cloth plasters. Lofton-Merrit only dye the lignified plasters by changing the intensity with the % lignin present.

Ink Solubility	Adhered elements, spots	pH measurement
- Apply one drop on the ink or annexed element and immediately dry it with absorbent paper (secant paper or filter paper) which if it gets stained will show that is soluble. - Use a cotton swab or cotton bud with only a little of this solvent and observing if it gets stained by rolling it on the material without rubbing.	- Apply a minimum drop of solvent and monitor its behaviour and effect on both the element to be removed and the support of the element of interest by stretching slightly with tweezers, slowly separating with scalpel or using a spatula to estimate whether it is or not sufficiently softened. - Apply local heat to test suitable separation the adhesion.	- Colorimeter: based on chemical indicators that change colour according to pH, usually found either in strips that are impregnated with the sample or in the form of markers (those that can produce permanent dyes spots should be avoided). - Potentiometer: instrument with two electrodes to measure the electrical conductivity of a sample solution.

Table III. Basic indications and tips for most common tests applications.

Herzberg's dye results	
Fiber type	**Colour**
Lignified	Yellow
Chemical slightly delignified	Yellowish brown
Semi-chemical	Green to yellowish grey
Cloth (e.g. cotton, linen, hemp)	Wine red
Low lignified (e.g. wood, cereal straw)	Blueish grey to violetish blue
Artificial (rayon, viscose,etc.)	Colorless or light yellow

Table IV. Most common results for Herzberg's dye test applications.

Lofton-Merrit's dye results	
Fiber type	**Colour**
Mechanical and thermomechanical	Bright blue
Semi-chemical	Dark violet
Chemical raw to sulphate	Blue-green to light blue
Raw to sulphite	Purple violet
Chemically whitened and cloths	Colorles

Table V. Most common results for Lofton-Merrit's dye test applications.

Figure 21 . Cloth fiber (Herzberg's colorant). Source: T.Andrades.

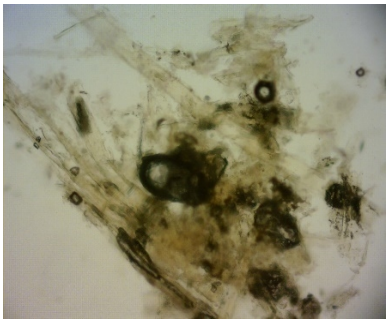

Figure 22. Lignified fiber (Herzberg's colorant). Source: T.Andrades.

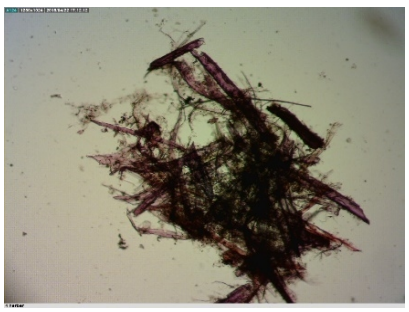

Figure 23. Semi-chemical fiber (Lofton-Merrit's colorant). Source: T.Andrades.

Simplified restoration procedures

Restoration processes are essentially manual, although some can be mechanized with specific tools to facilitate application to a large volume of cases. It is very important that, as far as possible, the intervention is carried out by qualified staff. Only when it is not possible and there is a need and urgency justifying it, should other authorized persons be tried for having done enough successful tests in a demonstrable way.

- ✓ Cleaning of the deposited surface dirt. It is necessary before any other restoration process and when dirt can cause the physical or chemical instability of the material or the difficulty of fulfilling its designated function. It should always be taken into account and avoid affecting the non-original elements that have been intentionally added such as handwritten annotations, tampons marks, etc. The most common mechanisms are:
  - ➔ Mechanical surface cleaning, with thin hairbrushes more or less thick combined with aspiration tables or domestic vacuum cleaners in the softest possible mode (those with adjustable power with different nozzles would be the most convenient).
  - ➔ Cleaning with instruments to eliminate adhesion (from insect detritus, glue, mud, etc.). Scalpel tips, spatulas or even eraser tips for ink or even harder rubbers are usually used. These processes involve much more danger of affecting support with losses or erosion, so you have to be sure of using the right instruments in each case and that you master the technique to be applied.
  - ➔ Wet cleaning, if the support allows it, gently passing without rubbing the cotton swab or cotton bud slightly wet in water or other solvents. Before applying these techniques, the possible excess humidity should be eliminated with a dry paper so that no dirt penetrates into the substrate.

- ✓ Elimination of adhered elements and spots.
  - ➔ Old rubber-based adhesive tapes can be mechanically removed with hot spatulas or heat application, always without direct contact to prevent the adhesive from penetrating into the support. For each case make sure of using the appropriate instrument or environment control to separate the adhesion minimizing other risks.
  - ➔ The slightly aging adhesive tapes can be removed with the application of solvents by impregnation such as xylene, toluene, etc. The oldest ones usually come out with solvents with acetone, tetrahydrofurane, etc. In case of resistance, several solvent mixtures can be tested (see reference [10]).
  - ➔ When applying the chosen solvent or local heat, it is necessary to proceed slowly enough to carefully monitor, with the appropriate mechanical elements, the behaviour and effect on both the element to be removed and the support of the element of interest. This is necessary to estimate whether it is or not sufficiently softened to further act onto it (or not) to continue the separation process. The previous tests should help to determine adequate quantities to apply and speed of process.

➔ Possible remnant spots should be tested and treated after the complete adhered element is retired. In some cases the separation process generates or changes the possible spot to restore.

✓ Dive wash. Aqueous washing that favors the elimination by dissolution and extraction of degradation products that cause the acidification and yellowing of the support. Oxidation and spots of microorganisms do not disappear, but some soluble or adhesive spots and additions of old repairs do. Before considering it, handwritten annotations, inks, and other elements must be taken into account. There may also be a loss of the brilliance of the support in the case of satin papers. In order to carry out the process, the following materials are needed:

➔ Laminae that allow the circulation of water, of greater dimensions than the original, which allows easier and safer handling of the original during the different phases of washing. Different materials of non-woven synthetic fibers are currently used that are not adherent, do not deform, resist heat and many solvents. The most common are marketed under the following denominations: Remay@ (polyester), Hollytex@ (smooth polyester), Celex@ (nylon) and Kiara@ (polyester and polypropylene). In the last section of this manual *Resources and References* we include some examples of companies selling these materials.

➔ Flat washing container. As far as possible, with a drain pipe to avoid additional manipulations. Trays can also be used with due precautions and transfers.

✓ Washed by flotation. More recommended than the previous one when the support shows fragility and it is not recommended too much manipulation on it. It is very similar, but now the water level is very low and the element is put to be washed above the fabric so that by capillarity the degrading elements are dissolved without manipulating them.

✓ Washing with secant papers, aqueous gels or on felt. Very similar to washing by flotation, but now the originals are placed on these materials long enough moistened for the degrading elements to be diluted by capillarity. It is a slower process but more suitable for very delicate materials that do not allow excessive higher humidity.

✓ Drying. The most recommended drying procedure is in the air, on a flat and ventilated surface without currents, which allows a uniform and progressive drying. Pressed drying is not recommended because dimensions can be modified, leaving marks of the fibers of the supports, loss of shine and a non-uniform drying that produces deformations and tensions.

✓ Stabilization. It is the deceleration of chemical reactions that cause deterioration due to environmental conditions. Humidity and temperature control is usually the most frequent and effective, preferring storage in slightly cooler environments than previously recommended. There are also other treatments to chemically stabilize certain specific reactions, such as paper aqueous washing to dissolve soluble acid components and acidic products formed by the absorption of contaminants.

✓ Deacidification. It is the neutralization of acidic particles by introducing alkaline compounds into the fibers, which act as a reserve for the neutralization of the acids that can be generated over time due to the aging of the paper. They can be:

➔ Aqueous treatments. The most common is the dissolution of calcium hydroxide that creates an alkaline reserve when dried by the action of hydroxide with CO2 from the air.

➔ Non-aqueous treatments. Recommended for water-sensitive or non-stable materials due to their high degree of deterioration. They are applied by nebulization or with brushes. The components on the market are usually toxic, so they must be manipulated with the appropriate means indicated by the manufacturer and preferably only by professionals.

✓ Consolidation. It consists of providing the support with mechanical resistance that facilitates its manipulation with the reinforcement and cohesion of the fibers. Usually with an adhesive that makes it more resistant and allows writing with ink without penetrating inside the fibers of the original substrate. Some of these adhesives due to their composition have long been detrimental to conservation as they may contain elements that harm and destabilize (such as starches) or that make them susceptible to biological attacks and oxidation. It should be noted that during washing processes these additional layers may disappear due to the dissolution of their components. The most common adhesives are:

- Midons. They offer great stability and most of the old papers were treated like this.
- Gelatines. Composed of the cooking of remains of parchments or remains of animal skins. They give good results due to their penetrability while in some cases they provide alkalinity (parchment gelatin).
- Modified cellulose. It is very stable, both dissolved in water and alcohol.

For its application we will always use a Remay tipus or similar support. It can be done in the following ways:

➔ Using brushes, applying on both sides. It must be applied from the center to the ends in order to avoid dilatations or the substrate blew when drying.

➔ By immersion, introducing it with the support to act for a certain time (usually 20 to 30 minutes) and then letting it dry in the air.

➔ By nebulization. Especially advisable when the substrate state does not allow any of the other options above.

✓ Repair of breaks or tears. Repairs with specialized self-adhesive materials are quick and eventual solutions that in many cases allow the conservation of pieces or fragments and prevent damage from increasing, but in the long run they can be harmful because adhesives become unstable.

➔ In tab strips a neutral adhesive (methylcellulose or starch) is applied to the fibers on both sides of the break joining and fitting them well. It is protected

with a synthetic fabric such as Remay@ on both sides and dried by local pressure between drying materials or with a hot spatula. In the case that the fibers are scarce, the cutting is reinforced with a Japanese lame paper piece.

➔ In clean cut tears, reinforcement is always required for repair, applying the adhesive and a piece of defibrated Japanese lame paper. For further consolidation, it is possible to assess the suitability of making the repair on both sides of the original.

✓ Reintegration of loss of support. It is the application of additional new support to the sites where the loss occurred. The criteria for this intervention will be the same as for all restorations: minimum intervention, neutral elements, differentiation with the original and as much reversibility as possible of all the materials and adhesives used. It may be:

➔ Manual reintegration. It consists of the adhesion of a new substrate in the same way and size of the lost area, seeking the least possible invasion of the original so that the fibers that allow adhesion do not cover the original more than essential and by the area where it least affects its possible use or interest. The adhesion is done in a similar way to the repairs described above, but now the adhesive is applied only to the material to be added to the contact areas, carefully combing them so that they have a greater area and grip contact.

➔ Mechanical reintegration. The base is the defibration of Japanese paper fibers in water with adhesive. The manual technique, recommended for small losses or holes, is carried out in a suction table where the original is placed with a Remay@ base and drops are deposited in all the fibers in water with the adhesive until obtaining the desired thickness that will form a new paper. It ends by applying an adhesive to the reintegrated set. For larger areas, paper reintegrating machines such as those invented by Esther Alkalay in the early 1960s (see reference [11]) are more effective. With a similar operation to the paper manufacturing process, the paper fibers in suspension in water are passed through the original so that for simple gravity they are deposited in the areas with losses forming new paper. These machines have evolved and improved until now they do the process very quickly and effectively even when the areas to be reintegrated are very large. To finish the mechanical reintegration, an adhesive is applied to the reintegrated area to achieve greater consistency and drying is done in the air or by press.

➔ Lamination. It is the adhesion of a reinforcement paper, usually a Japanese lame paper, with an adhesive similar to the previous ones. It is used only in very extreme cases when the support is very weak, so its manipulation is not possible to be performed by any of the above options, such as in cases of great fragility due to acidity, extreme weakness for microorganisms, etc. It is a very invasive modification of the original support and should preferably be done on the face with less writing or information since the Japanese lame paper modifies the visibility of the information.

Figure 24. Examples of restoration procedures. Each element always requires individual attention. Source: T.Andrades.

CHAPTER 5

USE AND RAISE AWARENESS

How to best use it to avoid damage and risk of loss.

Introduction

What is not seen and used is easily devalued. It is essential to maximize the correct use of the heritage for its own long-term conservation. In many cases, the recognition and value that it gets depends more than desirably on its visibility and use. Without those, it is usually significantly more difficult to obtain resources for its proper conservation. The objectives of correct use, manipulation and exposure are to determine the true state of conservation, identify potential risks and guarantee their maintenance or improvement in a compatible way.

IMPORTANT

- A correct manipulation or exposure can favour in the long run the conservation of the heritage by increasing their use and visibility and, consequently, their perceived value and the possibility of maintainance or improvement of its present conservation.
- Inadequate temperature, humidity or light radiation can be much more difficult to control than well-planned manipulations and exposures if a policy of restriction of use is developed depending on the type of user and target and the associated risks.

Complete and updated documentation

It is important to have the heritage materials well documented, besides to carry out an explicit and well-documented follow-up of the activities in which it is used or exposed. Not only to be able to access opportunities to obtaining future resources, but also to be able to assess whether their conservation and manipulation is the right one or whether it is necessary to make some specific intervention or update some protocol in this regard.

Some of the most dangerous moments are when sudden changes occur in staff, department or institution in charge of the heritage. Good prior documentation of heritage and associated processes such as those described in the previous chapters facilitates training and transfer in general, thus greatly reducing the possible risks.

It is interesting to keep multiple digital copies and printed copies of documentation, in all the spaces and computers of the working group responsible for heritage and related works. It is also advisable to keep a copy of the digital ones on the servers of the department or institution of reference. And of the prints as part annexed to the same archive where the analogue heritage is stored.

It is important to review and update or expand the documentation periodically and when any significant change occurs.

It is also interesting to keep the documentation prepared for the projects that were postponed or dismissed for any reasons, from inventories or catalogues, conservation plans or restoration assessments.

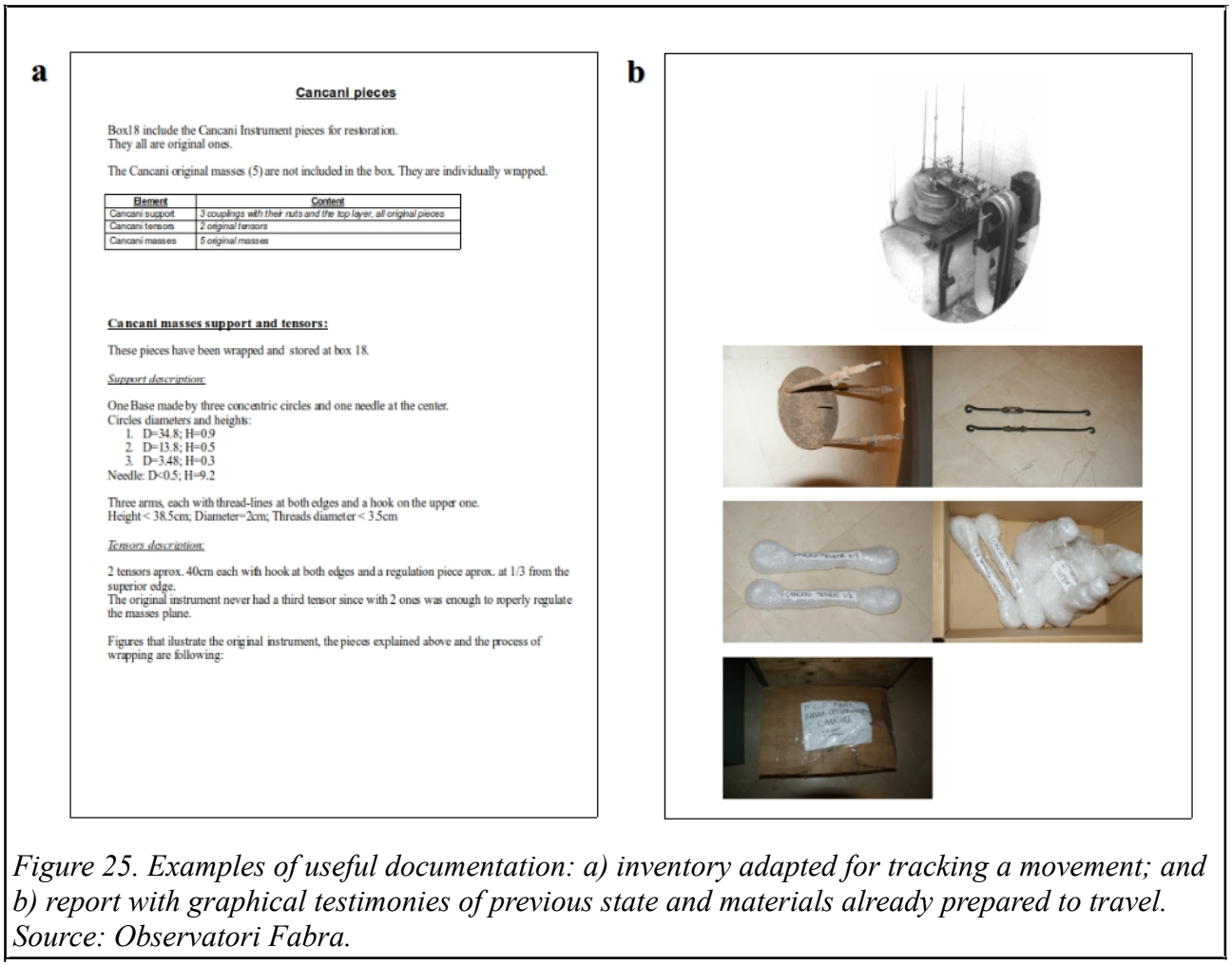

Figure 25. Examples of useful documentation: a) inventory adapted for tracking a movement; and b) report with graphical testimonies of previous state and materials already prepared to travel. Source: Observatori Fabra.

Visibility

We must give visibility to both the heritage itself and to each of the related works or those to which it contributes significantly to.

Visibility must be achieved at different levels at the same time:

- Among the staff within the institution itself to improve the competence for resources and possible substitutions or reallocations of responsibilities in their respect.
- Among directly related institutions to facilitate possible synergies or future joint actions.
- Among the professional community directly related to similar heritage or to the possible uses that may be given.
- Among general public, considering adaptations that take into account their various interests and knowledge prior to this respect.

Single documents or one side flat pieces can be more suitably exposed using transparent Remay@ as coverage with a melinex base that allows ventilation avoiding fungi and dirt.

It is advisable to periodically change the pieces chosen for the exhibition and update their state of conservation and the incidents detected in each change.

Contributions to conferences, publications or partial translations of reports help to keep a minimum of information in a language intended to be disseminated outside the usually related working group.

Digital images and other digitizations of heritage facilitate their visibility and dissemination for multiple uses and actions while minimizing the most direct manipulations to the essential ones.

In order to achieve a better follow-up of the works where they are used, a differentiated policy of sharing digital products can be valued according to their dpi density, detail, resolution, etc.

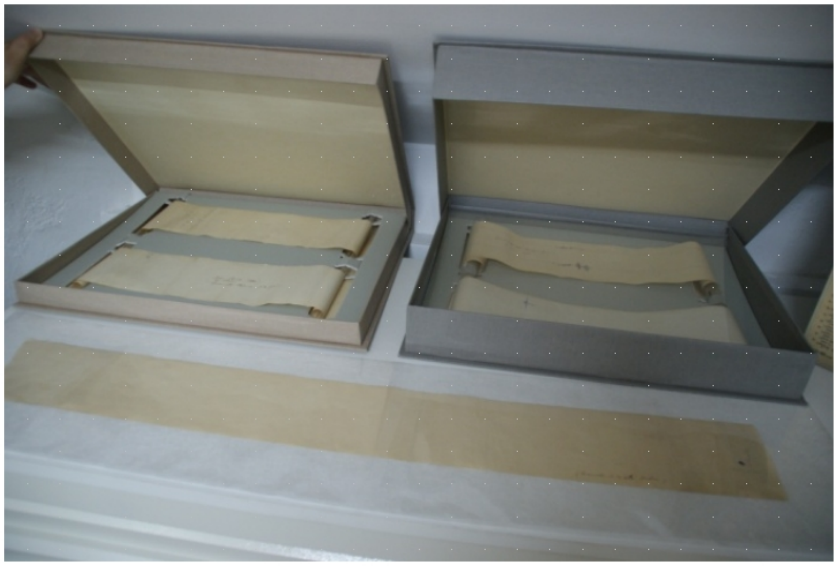

Figure 26. Special cases of seismograms deserve special phN containers to provide adequate conservation with easy visualization. Source: Observatori Fabra.

Preferred Uses

There are many possible uses for analogue seismic heritage. The last section of this manual point out to resources that include a lot of examples from very diverse nature and purpose. Some within the most common ones could be:

- ✓ Divulgation by direct exposition (both occasional or extended exhibition of originals).
- ✓ Elaboration of reproductions (low resolution scanning, partial reproductions, etc.).
- ✓ High resolution scanning to obtain digital copies.
- ✓ Digitalization of seismograms or OCR of additional documentation for analysis purposes.
- ✓ Compilation of data for external catalogues (regional network, ISC, etc.).
- ✓ Historical studies of specific phenomena (historic earthquakes, artificial explosions, etc.)
- ✓ Studies of microseismicity.
- ✓ Studies of anthropogenic seismicity.
- ✓ Studies about seismic stations and/or instrumentation.
- ✓ Detailed additional revisions of limited pieces for specific purposes.

Any global or detailed revision, exposition or any other kind of use of analogue seismic heritage involves certain level of manipulation that requires previous risk assessment and adequate preparations.

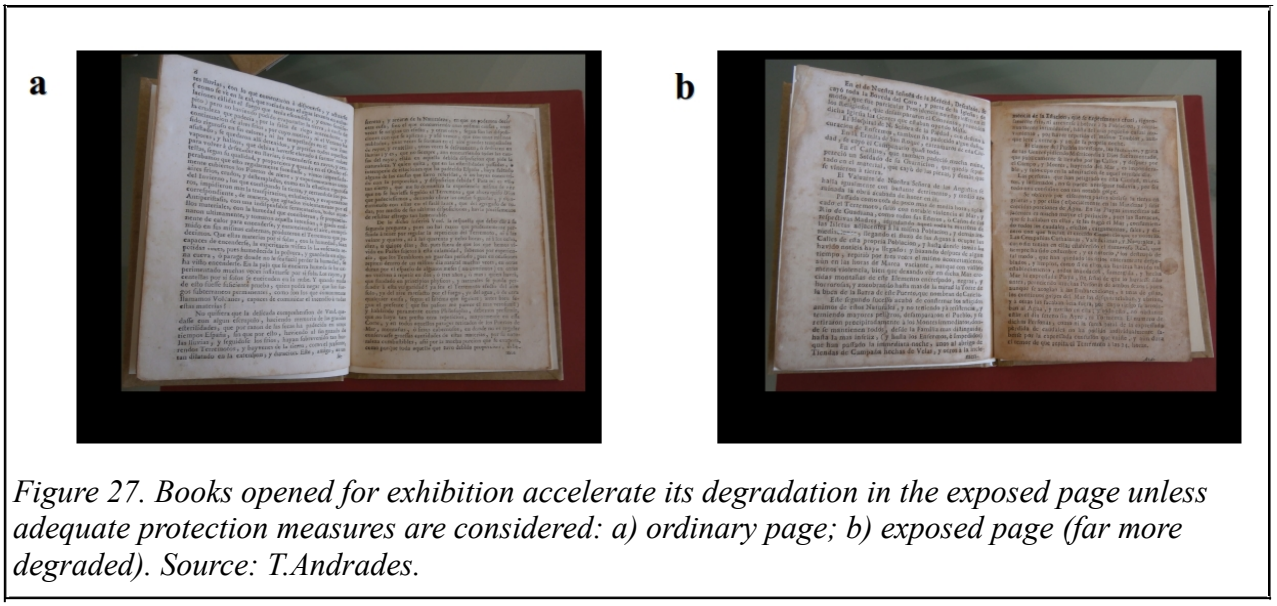

Figure 27. Books opened for exhibition accelerate its degradation in the exposed page unless adequate protection measures are considered: a) ordinary page; b) exposed page (far more degraded). Source: T.Andrades.

Always keep in mind the following aspects:

- Heritage originals are fragile and must be handled with care. When use occurs plan ahead stronger preservation measures keeping in mind that they are irreplaceable. Make sure to prepare and apply clear policies about who, how, when and for what is or is not allowed to access them.

- Keep always in mind that wilful destruction is a quick and possible risk. Most institutions undergo great pressures to justify the costs devoted to maintain patrimony within its limited resources. Therefore, try to avoid any use often is not an advisable or even viable recommendation. The most long-term solution to avoid wilful destruction is a correct preservation with well prepared and documented plans and policies for its use and visibility.

- Never destroy or endanger original data nor documentation since they are irreplaceable. Keeping original records is a basic and strong rule that should never be seen as hoarding. Even when already "fully" processed, scanned or copied somehow, original records should be preserved and given use and visibility to avoid the risk of loses.

  - ➔ Analog records provide invaluable information to be explored and exploited with present and future knowledge. But they need to be preserved and easy to convert to other formats once and again, who knows how many times because one's generation noise can be other's generation signal.

  - ➔ Every intervention or processed data has a non-negligible % of errors or loses, or will have in the future. Even the most verified process might have, or most probably will have, some.

  - ➔ Formats evolve very quickly and soon might be difficult to ensure their recovery because of changes of technologies (p.ex.: floppy disks, zip or magnetic bands), standards (e.g.: original registered formats vs. mseed, etc.) or expected durability (e. g.: microfilms, CDs, DVDs). In addition to be safer, often it is also even more easy and even cheaper in the long term to preserve original analogue records than their digitized and/or processed copies.

- Patrimony disorder or separation is a great danger in almost every interventions. It should be avoided as far as possible unless there are very justified reasons for a partial change during short time, well documented and with a previous detailed planned verification when the intervention finishes.

- Minimize transportation. Those are crucial moments when damages (both accidental and due to improper handling) occur. Disorder and damages are very difficult to avoid, leading easily to even partial losses. Local interventions, whenever possible, should be preferred to help to minimize them.

- Scanning is a very costly and dangerous process. Unfortunately, not all scan projects will allow digitizing correctly enough the data in the future from those scanned images. It is important to explore not only costs vs. present objectives, but also possible limitations for each possible different approach for the scanning options, current standards and other previous initiatives with their own results and limitations.

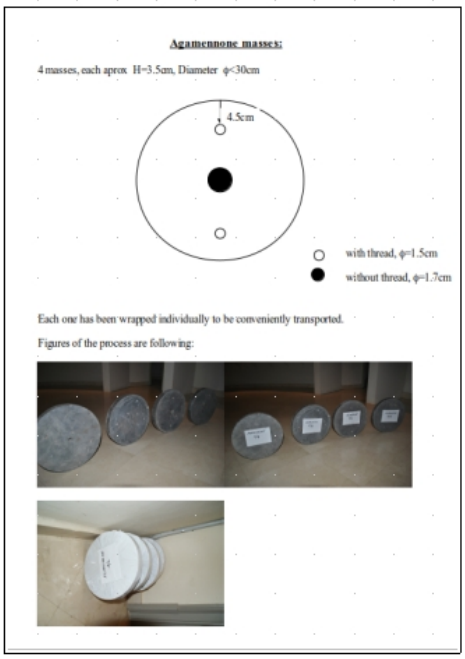

Figure 28. Extra layers of protection must be used for transport and exhibition. Be aware of risks of unexpected humidity, temperature and position changes and prepare accordingly. Prepare an extended inventory of each piece of heritage with photographs from their original situation, prepared to be sent, exhibited, and once back to its permanent storage. Documentation of any change (or that fully revision has been made but no change has been detected) should be kept along with the rest of the documentation of the heritage Source: Observatori Fabra.

- Standards greatly facilitate the interoperatibility and crossed uses of data produced. Any intervention should try to involve and produce as much FAIR metadata as possible to ease and therefore increase its present and future use.

- Try to expand areas of interest of your patrimony.

  - ✓ Scientific use and visibility of seismic analogue patrimony do not necessarily reduce to earthquakes and their related hazards. Seismic analog records and documentation can be very useful to many other geophysical studies of earth crust, deep internal structure, terrain local structure and fault mapping, volcanic studies, landslides, etc. Moreover, they are also very important for other more diverse fields such as vigilance of explosions and other artificial structures, study of glaciers and other meteorological and oceanic phenomena, etc.

  - ✓ Historical importance in broader terms should not be avoided nor infra-valuated. War bombings and many other historical local effects recorded forever in seismic analog records deserve also attention and recognition. Besides, analogue records could apport significant information about the historical importance of the different technologies to obtain those records, the people in charge of them, their processes and their results, etc.

- Keep in mind and respect your institution and other institutions policies for credit recognition.

  - Try to keep in touch and explore other's initiatives, both successful and problematic. Sometimes we learn more from unexpected problems than from expected results. Do not hesitate to recognize and mention those learned lessons.

  - Cite always appropriately data origins and try to recognize other's efforts to maintain it and make it accessible.

  - Push for a FAIR use of your patrimony but accept and navigate within your institutions present policies. Drastic changes sometimes lead to unexpected risks or critical decisions. Long term changes often need time to occur peacefully.

  - Try to join external collaborations and standard practices as far as possible. Joint efforts and dissemination of knowledge can be one of the most helpful resources.

Figure 29. Melinex and Remay are used in Observatory Fabra to be able to see the seismogram on top when drawer opens so visits can see selected originals keeping reasonable protection. Source: Observatori Fabra.

RESOURCES AND REFERENCES

Where to search for more? Who might ask to?

This is just a brief and limited manual made as a simple guide to start with only basic knowledge on the topic so that the interested reader can access other much more extensive literature that deals with the different topics in greater depth without getting lost. References and resources in this section include more detailed, extensive, and comprehensive information. Additional online resources contain diverse url with listings and compendiums more extense and updated that this short manual.

Legacy seismograms and stations:

There are three main websites where to find information on legacy seismograms and stations in Europe:

- SISMOSLAB (INGV):
  https://sismoslab.ingv.it/

- ESC Working Group 02-13 "Preservation, valorisation and analysis of seismological legacy data":
  https://www.legacy-seismograms.eu/

- Legacy Seismic Data Project (LSD):
  https://legacy-seismic-data.github.io/

Complementary information can be found in the bulletins stored in the *International Seismological Centre (ISC)* section *Printed Station Bulletins*:
https://isc.ac.uk/printedStnBulletins/

Also at the *Seismo Archives* at:
https://ds.iris.edu/seismo-archives/

Also at the *Euroseismos* website at:
https://storing.ingv.it/es_web/index.htm

And at the *SISMOS SeismogramRequest 2.0* website at:
http://seismogramrequest.rm.ingv.it/

Preservation and conservation:

A website with a large amount of information on preservation and conservation is the ***Northeast Document Conservation Center***
https://www.nedcc.org/

Specifically for paper conservation:
https://www.nedcc.org/paper-conservation-at-nedcc/resources

With helpful pages such as:
https://www.nedcc.org/free-resources/preservation-leaflets/overview
https://www.nedcc.org/free-resources/overview

Another website plenty of information is the ***Weissman Preservation Center*** from Harvard University:
https://preservation.library.harvard.edu/weissman-preservation-center

And, specifically:
https://preservation.library.harvard.edu/guidelines

In case of further curiosity on more advanced topics, there are online resources by and for conservators and related fields operated by the Foudation for Advacement in Conservation available through **CoOL Conservatoion OnLine website**:
https://cool.culturalheritage.org

The authors of this manual have obtained most materials and services for the projects performed in Observatori Fabra (Barcelona) from the following companies:
https://www.arteymemoria.com/eng/home.html
https://www.tecnihispania.com

But additional providers lists can be found online such as in:
https://cool.culturalheritage.org/bytopic/suppliers/

The ***Society of American Archivist*** (**https://www2.archivists.org/aboutsaa**) publishes a journal with interesting contents:
https://www2.archivists.org/american-archivist

Other Journals on the tòpic are:

- Journal of the American Institute for Conservation
https://www.tandfonline.com/journals/yjac20
- Heritage
https://www.mdpi.com/journal/heritage
- Heritage Science
https://heritagesciencejournal.springeropen.com/

FAIR Principles:

Important references on **FAIR Principles** are:

- L. J. Hwang, T. Ahern, C. J. Ebinger, W. L. Ellsworth, G. G. Euler, E. A. Okal, P. G. Okubo, W. R. Walter (2020). *Rescuing Legacy Seismic Data FAIR'ly*. Seismol. Res. Lett., 91 (3): 1339–1340. **https://doi.org/10.1785/0220200027**.

- Wilkinson, M., Dumontier, M., Aalbersberg, I.J., Appleton, G., Axton, M., Baak, A. et al. (2016). *The FAIR guiding principles for scientific data management and stewardship.* Scientific Data, 3, 160018. **https://doi.org/10.1038/sdata.2016.18**.

- P. G. Richards, M. Hellweg (2020). *Challenges and Opportunities in Turning Large U.S. Archives of Analog Seismograms into a Modern Usable Resource.* Seismological Research Letters; 91 (3), 1531–1541. https://doi.org/10.1785/0220200053.

Other projects for preservation of seismograms:

Information about Institutions developing projects for preservation of seismograms in different countries can be found on several articles following:

Italy

Michelini, A., B. De Simoni, A. Amato, and E. Boschi (2005). *Collecting, digitizing, and distributing historical seismological data*, Eos Trans. AGU, 86(28), 261–266, **https://doi.org/10.1029/2005EO280002**.

Ferrari, G. (a cura di) (2014). *Dal cielo alla terra. Meteorologia e sismologia in Italia dall'Ottocento a oggi*, Bononia University Press, Bologna, 298–301, **https://doi.org/10.1029/2005EO280002**.

https://storing.ingv.it/tromos/home.htm

https://storing.ingv.it/es_web/index.htm

https://sismoslab.ingv.it/index.php

Japan

Satake K., H. Tsuruoka, S. Murotani, K. Tsumura (2020). *Analog Seismogram Archives at the Earthquake Research Institute*, the University of Tokyo. Seismol. Res. Lett., 91 (3): 1384–1393. **https://doi.org/10.1785/0220190281**.

http://wwweic.eri.u-tokyo.ac.jp/susu/index_en.html

Furumura M., K. Iwasa, Y. Suzuki, T. Demachi, T. Ishibe, R. S. Matsu'ura (2020). *Data Retrieval System of JMA Analog Seismograms in the Headquarters for Earthquake Research Promotion of the Japanese Government*. Seismol. Res. Lett., 91 (3): 1403–1412. **https://doi.org/10.1785/0220190303**.

http://www.susu.adep.or.jp/

Matsu'ura R. S., Norihito Umino, Yoshiaki Tamura, Yoshihisa Iio, Minoru Kasahara, Takahiro Ohkura (2020). *The Achievement of Archiving Analog Seismograms in Japanese Institutes for 15 Yr*. Seismol. Res. Lett., 91 (3): 1452–1458. **https://doi.org/10.1785/0220190301**.

Spain

https://www.ign.es/web/ign/portal/archivo-datos-geofisicos

China

Wang J. (2020). *Conservation and Utilization of Historical Seismograms from Early Stage (A.D. 1904–1948), Mainland China*. Seismol. Res. Lett., 91 (3): 1394–1402. **https://doi.org/10.1785/0220190268**.

Denmark

Dahl Jensen T., L. Lund Jacobsen, A□S. Graulund Sølund, T. B. Larsen, P. H. Voss (2022). *100 Years of Paper Seismograms from Denmark and Greenland*, 1907–2008. Seismol. Res. Lett., 93 (2A): 1026–1034. **https://doi.org/10.1785/0220210311**.

Mexico

Pérez Campos X., S. Armendáriz□Sánchez, V. H. Espíndola, M. Castro□Escamilla, J. Perez, L. M. Casiano, I. Rodriguez Rasilla, C. Cárdenas Monroy, A. Cárdenas (2020). *Preservation and Reuse of Historical Seismic Data in Mexico*: SISMOMex and the Online "National Seismogram Library". Seismol. Res. Lett., 91 (3): 1482–1487. **https://doi.org/10.1785/0220190340**.

http://www.sismoteca.unam.mx/3

United Kingdom

Henni P.H.O., J.H Lovell & K.I.G. Lawrie (2000). *UK Historical Seismograms and Bulletins Held in the NSA*, BGS, Edinburgh, 178pp.
https://www.earthquakes.bgs.ac.uk/hazard/pdf/wl9921.pdf

https://www.earthquakes.bgs.ac.uk/archive/Archive_reports.htm

France

Rivera L., S. Lambotte, J. Fréchet (2021). *The historical seismogram collection in Strasbourg*. Comptes Rendus. Géoscience, 353 (S1), 281-299.
https://doi.org/10.5802/crgeos.90.
https://comptes-rendus.academie-sciences.fr/geoscience/articles/10.5802/crgeos.90/.

Switzerland

Grolimund, R., & D. Fäh (2021), *Instrumental Earthquake Observation and Documentation by the Swiss Seismological Service in the Early Instrumental Period. 1912–1963. Historical Context of Data Production and Documentation of the Collection of Historical Instrumental Earthquake Data*, Report SED/HIST/R/003/20210131, ETH Zurich, **https://doi.org/10.3929/ethz-b-000465552**.

USA

Ishii M., H. Ishii, B. Bernier, E. Bulat (2014). *Efforts to Recover and Digitize Analog Seismograms from Harvard Adam Dziewoński Observatory*, Seismol. Res. Lett., 86 (1): 255–261. **https://doi.org/10.1785/0220140165**.

http://www.seismology.harvard.edu/hrv.html

Other collections of digital images:

Information on collections of digital images in different countries can be found on several articles following:

Italy

Michelini, A., B. De Simoni, A. Amato, and E. Boschi (2005). Collecting, digitizing, and distributing historical seismological data, Eos Trans. AGU, 86(28), 261–266, **https://doi.org/10.1029/2005EO280002**.

https://sismoslab.ingv.it/index.php/tools/la-navigazione-nelle-fonti-digitali

http://seismogramrequest.rm.ingv.it/

https://teseo.rm.ingv.it/

Spain

Batlló J., Villaseñor, A.; Jara, J.A.; Merino, M.T.; Solé, G.; Unamuno, J. (2023). Preservación digital de sismogramas analógicos y otros documentos en el Institut Cartogràfic i Geològic de Catalunya (ICGC), X Asamblea Hispano-Portuguesa de Geodesia y Geofísica - Artículos, 378-386. **https://doi.org/10.7419/162.07.2023**, ISBN: 978-84-416-7540-7.

https://www.icgc.cat/en/Mapes-i-geoinformacio/Dades-i-productes/GeoData/Databases-and-catalogues/Analog-seismograms

Japan

Furumura M., K. Iwasa, Y. Suzuki, T. Demachi, T. Ishibe, R. S. Matsu'ura (2020). Data Retrieval System of JMA Analog Seismograms in the Headquarters for Earthquake Research Promotion of the Japanese Government. Seismol. Res. Lett., 91(3): 1403–1412. **https://doi.org/10.1785/0220190303**.

Romania

Paulescu, D., Rogozea, M., Popa, M. et al. Digitized Database of Old Seismograms Recorder in Romania. Acta Geophys. 64, 963–977 (2016). **https://doi.org/10.1515/acgeo-2016-0039**.

Iceland

Einarsson, P., & Jakobsson, S. (2020). The analog seismogram archives of Iceland: Scanning and preservation for future research. Jokull, 2020(70), 57-72. **https://doi.org/10.33799/jokull2020.70.057**.

Iran

Aghajani, M., Ahmadi, H., Mirzaei, N., Batlló, J. (2023). Digitizing analog seismograms of Iranian seismic stations - preserving records for strong earthquakes in Iran 1960–1990. J. Seismol., 27, 693–706. **https://doi.org/10.1007/s10950-023-10158-4**.

References

[1] *European Seismological Comission. Current Working Groups*. Online at [last visit: september 2024]: http://www.esc-web.org/working-groups.html [last visit: september 2024].

[2] *Legacy Seismograms.* Online at [last visit: september 2024]: https://www.legacy-seismograms.eu/

[3] *SISMOSLAB. Laboratorio avanzato di sismometria storica..* Online at [last visit: september 2024]: **https://sismoslab.ingv.it/**

[4] New Manual of Seismological Observatory Practice (NMSOP-2). IASPEI, GFZ German Research Centre for Geosciences, Potsdam. DOI: 10.2312/GFZ.NMSOP-2. Online at [last visit: september 2024]: https://bib.telegrafenberg.de/publizieren/bibliotheksverlag/nmsop

[5] HWANG L. J., AHERN T., EBINGER C. J., ELLSWORTH W. L., EULER G. G., OKAL E. A., OKUBO P. G., WALTER W. R., (2020). Rescuing Legacy Seismic Data FAIR'ly. *Seismological Research Letters* (2020) 91 (3): 1339–1340. Online at [last visit: september 2024]: **https://doi.org/10.1785/0220200027**

[6] WILKINSON M., DUMONTIER M., AALBERSBERG I.J., APPLETON G., AXTON M., BAAK A. et al. (2016). The FAIR guiding principles for scientific data management and stewardship. *Scientific Data*, 3, 160018 (2016). Online at [last visit: september 2024]: https://doi.org/10.1038/sdata.2016.18.

[7] AHERN T., HWANG L. J. (2021). Advancing the reuse of Legacy Seismic Data FAIRly.[poster] *Poster 053, Session 09, 37th General Assembly of the European Seismological Commission ESC2021* (2021). Program Online at [last visit: september 2024]: https://www.erasmus.gr/microsites/1193/final-detailed-programme

[8] *CRAI Taller de restauració, Universitat de Barcelona (UB).* Online at [last visit: september 2024]: https://crai.ub.edu/coneix-el-crai/direccio-unitats/gestio-colleccio/taller-restauracio

[9] GARCÍA-HORTAL J. A., (1993). *Constituyentes fibrosos de pastas y papeles : morfología, análisis microscópico.* Terrassa: Departamento Ingeniería Téxtil i Papelera Especialidad Papelera y Gráfica. ISBN 8460086585.

[10] SMITH M.A., JONES N. M. M., PAGE S. L., DIRDA M. P. (1984). Pressure-Sensitive Tape and Techniques for its Removal From Paper. *Journal of the American Institute for Conservation (JAIC).* Volume 23, Issue 2, Article 3 (pp. 101 to 113) (1984). Online at [last visit: september 2024]: https://doi.org/10.1179/019713684806028241 (Available online previous (1983) free version at: https://cool.culturalheritage.org/coolaic/sg/bpg/annual/v02/bp02-13.html)

[11] NELSON, C. W. Technical Notes. *The American Archivist*, vol. 36, no. 4, 1973, pp. 573–81. *JSTOR* (1973). Online at [last visit: september 2024]: http://www.jstor.org/stable/40291658