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Revitalizing vintage seismic reflection profiles by converting into SEG-Y format: case studies from publicly available data on the Italian territory

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Abstract

In recent decades, geological modeling has significantly evolved, relying on the growing potential of hardware and software to manage and integrate vast datasets of 2D-3D geophysical underground data. Therefore, digitization and integration with other forms of data can often improve understanding of geological systems, even when using so-called vintage or historical data.

Seismic reflection data have been extensively acquired mainly for hydrocarbon exploration since the 60s generating large volumes of data. Typically, these data have been for private commercial use and are relatively unavailable for research.

However, with time, large volumes of vintage seismic reflection data in many countries worldwide are now becoming publicly available through time-based de-classification schemes.

Such data have a great potential for modern-day geo-research, unleashing opportunities to improve geological understanding through re-interpretation with modern methods.

However, a downside of these vintage data is that they are often only available in analog (paper, raster) format. The vectorization of these data then constitutes an essential step for unlocking their research potential.

In 2018 INGV established the SISMOLAB-3D infrastructure, which is mainly devoted to analyzing digital subsurface data, such as seismic reflection profiles and well-logs, to build 2D-3D geological models, principally for seismotectonics, seismic hazard assessment, and geo-resources applications.

In this contribution, we discuss the robustness of the WIGGLE2SEGY code, firstly published by Sopher in 2018, focusing on examples from different tectonic and geodynamic contexts within Italian territory. We applied the SEG-Y conversion method to onshore and offshore raster seismic profiles related to ceased exploration permits, comparing the results with other published archives of SEG-Y data obtained from the conversion of vintage data.

Such an approach results in digital SEG-Y files with unprecedented quality and detail. The systematic application of this method will allow the construction of a comprehensive dataset of digital SEG-Y seismic profiles across Italy, thereby expanding and sharing the INGV SISMOLAB-3D portfolio with the scientific community to foster innovative and advanced scientific analysis.

Keywords: Vectorization of vintage seismic profiles into SEG-Y; WIGGLE2SEGY MATLAB-based code; Seismic profiles digital database; Italian territory; 2D/3D geological models

1. Introduction

In recent years, the geoscience community has witnessed a moment of great scientific ferment to respond to the compelling challenges posed by the need to mitigate climate change through the energy transition toward using more sustainable energy resources.

Subsurface crustal exploration has been traditionally related to intense research of high potential energy sources such as hydrocarbons, to which the development of scientific disciplines such as geology and exploration of the subsurface through geophysical techniques has been intimately connected.

In this context, geological models have always played a fundamental role in identifying and characterizing exploitable resources in the subsurface. Traditionally, most data for exploring the subsurface, such as seismic reflection profiles and well data, have been acquired mainly by private entities such as oil and gas companies. Nevertheless, few joint venture experiences between oil companies and research institutions can be listed.

For example, the Italian project CROsta Profonda (CROP) was carried out in the ‘90s in the framework of the collaboration between CNR (National Research Council), CNR-ENEL (Ente Nazionale per l’Energia Elettrica), and ENI oil company to investigate the deep crust of Italy [http://www.crop.cnr.it/, Scrocca et al., 2003], with data acquired and processed mainly by OGS (Istituto Nazionale di Oceanografia e Geofisica Sperimentale).

During the last century, a vast amount of subsurface data in the Italian territory and surrounding seas were acquired by various oil and gas companies, consisting of more than 250,000 km of 2D seismic lines, 35,000 km^2 of 3D seismic surveys, and more than 7,000 wells [Bertello et al., 2010, Figure 1A].

Hydrocarbon exploration mainly focuses on the shallow part of the upper crust (generally up to the first 5-10 km), providing key data not only for industry but also for multidisciplinary research studies of seismically active and volcanic structures and, more in general, on the tectonic evolution of the Italian region [among others: Bruno et al., 1998; Conti et al., 2022; Milia et al., 2003].

A new branch of activities devoted to the sustainable use of the underground in the energy transition perspective also envisages many applications of geological models for CO_2 capture and storage (CCS), methane storage, and geothermal exploitation. These aspects have already been approached in the Italian territory using information from the public [e.g., Buttinelli et al., 2011, Procesi et al., 2013, Civile et al., 2013, Proietti et al., 2021], or confidential subsurface datasets [ISPRA, 2015].

Unfortunately, the geoscientific research community can hardly access the high-quality (often digital) subsurface data acquired by for-profit organizations. On the other hand, the public databases containing large amounts of vintage seismic reflection data provide a valid alternative to this lack of data by applying procedures that produce ready-to-use high-quality datasets that can be incorporated into advanced geo resources and geo-hazard analyses.

2. Publicly available Italian underground datasets

There are two primary public databases [ViDEPI, https://www.videpi.com/videpi/videpi.asp, and SNAP, https://snap.ogs.trieste.it/, Diviacco et al. 2015, 2019] of subsurface data within Italian territory, to which the scientific community generally refers. They consist of a widely distributed volume of underground data and a suitable density applicable for multiscale geological analyses (Figure 1).

The ViDEPI database (https://www.videpi.com/videpi/videpi.asp) consists entirely of data in raster format, i.e., scans of a certain percentage of the seismic profiles acquired by oil companies as part of the research permits granted in Italian territory, which have expired by at least ten years. The dataset includes structural maps, seismic acquisition plans, and composite log data of a percentage of wells drilled in Italian territory. It has more than 4,000 technical reports of mining permits and concessions, almost 2,300 wells logs, 578 seismic lines from seismic reconnaissance campaigns in offshore areas, 70 seismic lines from the CROP project; as well as nearly 2400 seismic lines acquired in expired mining permits and concessions (Figure 1B).

The SNAP database (Seismic data Network Access Point, snap.ogs.trieste.it/cache/index.jsp) is a web-based platform managed by OGS. It contains geophysical data in both raster image and digital SEG-Y format that can be interactively previewed and accessed (Figure 1C). SNAP provides the raster version of the same data contained in ViDEPI and the digital version of the “Reconnaissance seismic campaigns in the offshore areas”, which is a large dataset of seismic profiles in the offshore area around the Italian territory. These data are publicly accessible only for the raster part, while the SEG-Y part is accessible only upon request and authorization through a specific form.

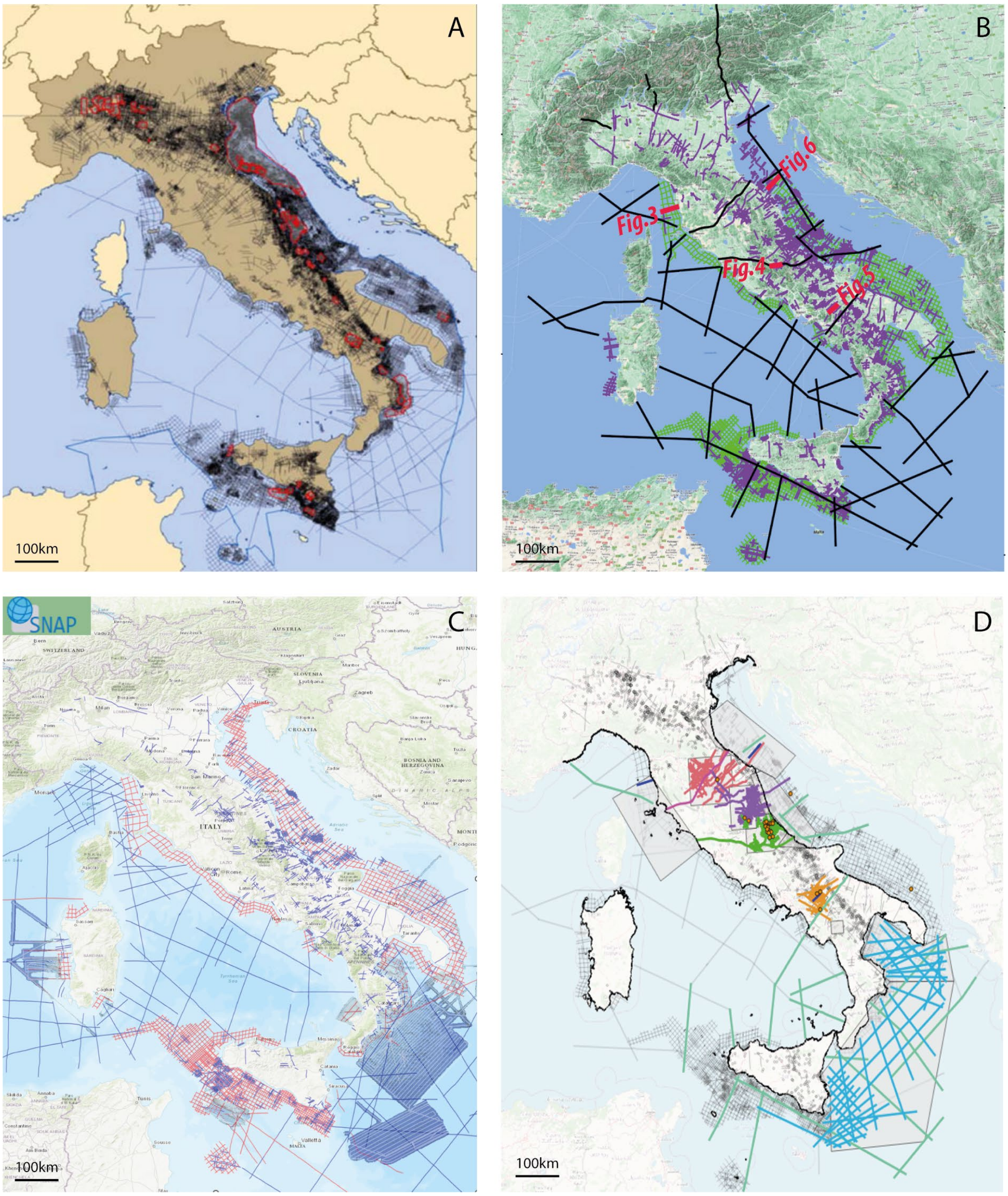

Figure 1. A) 2D (black lines) and 3D (red areas) seismic surveys acquired on the Italian territory (after Bertello et al., 2010); B) Traces of publicly available raster seismic profiles on the Italian territory from the ViDEPI dataset (*Visibilità dei dati afferenti all'attività di esplorazione petrolifera in Italia* https://www.videpi.com/videpi/geografica.asp): Reconnaissance seismic campaigns of the offshore areas (green lines); CROP Atlas Project (seismic reflection profiles of the Italian crust, black lines); Seismic lines acquired in expired mining permits and concessions (purple lines). Red bold lines represent selected seismic profiles analyzed in this contribution. C) Seismic data Network Access Point (SNAP) database (https://snap.ogs.trieste.it/cache/index.jsp) seismic 100 profiles: Reconnaissance seismic (red lines); Other seismic profiles (blue lines); D) INGV SISMOLAB-101 3D dataset: colored lines and dots for already in-house SEG-Y seismic profiles and digital wells 102 data, grey lines and dots for raster data. Grey polygons represent current areas of SISMOLAB-3D 103 scientific activity.

The SEG-Y seismic profiles within SNAP were vectorized following Miles et al. [2007] approach by implementing the code-named SeisTrans in the frame of the EC MAST projects Seiscan and SeiscanX.

The CROP project dataset includes almost 10000 km of seismic profiles, 1250 km onshore, and 8700 km offshore. This dataset comprises a crustal-scale exploration of the Italian lithosphere. The data were acquired by OGS (with ENEL and CNR financial support) with rapid processing up to stack versions, likely in collaboration with Eni. The interpretation has been made extensively for the entire dataset by Scrocca et al. [2003] and Finetti, [2005]. The raster images of the CROP seismic profiles are available within the ViDEPI project. The SEG-Y data are only available upon request and the payment of a fee to CNR-ISMAR.

Generally, all these subsurface data are of enormous importance for the geo-research community; nonetheless, their use may present some challenges. First, the publicly available data from these datasets is a substantially reduced percentage compared to the total amount known to exist (Figures 1A, B, and C). This inhomogeneity could hamper a realistic reconstruction of underground geological models, especially where precision and resolution are needed to infer the geometry of geological structures robustly (e.g., seismotectonics and seismic/volcanic hazard assessments, seismicity induced by hydrocarbon and geothermal exploitation).

Secondly, the raster data are generally the result of scans of old printed seismic profiles that are often warped or distorted due to the poor quality of the scanning/rasterization procedure. Remains of paper folds can be observed, which obscure data and add noise. In the worst cases, interpretation is annotated on the scanned sections obstructing the data.

In some cases, these are seismic profiles whose geometry is not perfectly known as the positioning file has undergone shifting modifications (e.g., it is impossible to recover the exact geographical position of the original CDPs). At the same time, data acquisition and processing information are often unavailable.

Considering some of the critical issues just described, it is of fundamental importance that the scientific community may have open access tools for building high-quality and digital subsurface datasets, which can be utilized in research, especially in areas with significant knowledge gaps, such as geo-hazard analyses. An example of such a study would be to carry out thorough investigations for recognizing and mapping faults in the subsurface, which could then be associated with earthquakes' hypocentral locations [e.g., Buttinelli et al., 2021, Govoni et al., 2014, Barchi et al., 2021 for recent seismic sequences in the Italian territory] and active faults [e.g., Mirabella et al., 2004; Maesano et al., 2020; Panara et al., 2021]. Hence, it is necessary to handle good quality data to make robust inferences for seismotectonics.

In this framework, INGV established in 2018 the SISMOLAB-3D infrastructure, which is mainly devoted to the analysis of digital subsurface data, such as seismic reflection profiles and well-logs, to build 2D-3D geological models, principally for seismotectonics, seismic hazard assessment, and geo-resources applications, with primary areas of activity in Italy (Figure 1D).

To obtain digital data from public raster underground datasets for the necessities of the geo-research community, the SISMOLAB-3D adopted a program called WIGGLE2SEGY for the vectorization of raster seismic reflection profiles into standard SEG-Y format. WIGGLE2SEGY is a MATLAB-based tool developed by Sopher [2018].

In this contribution, we present some case studies on publicly available seismic profiles on the Italian territory to describe the robustness of the approach and its potential when applied to the large vintage datasets available in the Italian region.

We tested the WIGGLE2SEGY approach by comparing the conversion results from raster to SEG-Y of two offshore seismic reflection profiles in ViDEPI and SNAP. After this comparison, we tested the same approach to onshore seismic reflection profiles with the different quality provided by various companies in the ViDEPI database.

The vectorization of SEG-Y files via WIGGLE2SEGY performed by SISMOLAB-3D (INGV) would also gather and re-elaborate public subsurface data to preserve their overall data quality content. The final goal will be to gradually build and populate a comprehensive dataset of digital SEG-Y seismic profiles, which would constitute the INGV portfolio to share with the scientific community for future advanced scientific studies.

3. Methodology

There are numerous non-commercial and publicly available methodologies for converting raster files into SEG-Y format working under various operating systems [e.g., Seistrans – Miles et al. 2007; image2segy – https://gma.icm.csic.es/ca/image2segy, Farran, 2008; Tif2segy – http://seismic.ocean.dal.ca/pwp_wiki/static/Tif2segy.html;

SeismiGraphix – http://www.seismigraphix.com/] as well as numerous commercial software (e.g., ImageToSEGY – https://chesapeaketech.com/products/imagetosegy/; LEASSV – http://www.lynxinfo.co.uk/software-leassv.html). A comprehensive comparison of freely available geophysics software can be found at https://en.wikipedia.org/wiki/Comparison_of_free_geophysics_software link.

The choice of INGV SISMOLAB-3D to join the Sopher, [2018] WIGGLE2SEGY methodology is because the Matlab-based code is publicly available to the scientific community so that anyone can reproduce the results of every vectorization attempt of a public raster dataset. This code is highly versatile as it works directly on the image characteristics and attempts to recognize and eliminate the signal associated with timelines and baselines (Figure 2). The routine also removes noise associated with data aging in paper format (folds, gray zones) and scan problems (white/black dots and areas of high/low contrast). Moreover, it applies a frequency filter to eliminate artifacts with frequencies outside the bandwidth of the data present in the raster version.

The methodology has several steps:

– *Preparation of data for vectorization*

The first step for the vectorization of vintage seismic profiles is the definition of their geometry in space. Most information on the positioning of the seismic profiles is usually available on raster base maps provided within the public database (e.g., ViDEPI). The base maps are georeferenced using GIS software (e.g., QGIS, https://www.qgis.org/it/site/), and the Common Depth Points (CDP) position are digitized in ASCII files containing the CDP number and their coordinates.

– *Vectorization and frequency filtering*

The approach adopted in WIGGLE2SEGY includes various input parameters and vectorization modes. The reader should refer to Sopher [2018] for details about the conceptual procedure adopted in WIGGLE2SEGY.

A preliminary enhancement of the original raster data is often necessary. This step is achieved by using ordinary image manipulation software (e.g., GIMP, https://www.gimp.org/) by converting the eventual color or grayscale images into black and white TIFF images using a threshold filter which allows modulating of the contrast of the image. Rotation and shape corrections of the original image can be performed at this stage to obtain less deformed images.

The input parameters of WIGGLE2SEGY require the number of pixels that define the baselines and timelines width, which can be measured on the original raster image.

We used pixel sum methods for the vectorization, simply counting the number of black pixels in a window around each trace. This method is best suited for cases when the complete wiggle trace is not present on the image due to the plotting style. In these cases, some negative amplitude information is missing from the image and cannot be recovered.

The processing parameters (displayed on the original raster section) allow determining the band-pass filter to use in the conversion. Seismic raster data often contain information on the time-variant filter adopted during processing procedures. Setting the band-pass filter based on the original processing can help to remove artifacts in the conversion process, e.g., spurious seismic events associated with timelines on the scanned image (Figures 3 and 6).

A quality control plot is produced for each vectorized SEG-Y and allows for an on-the-fly visual inspection of the quality of the conversion. Also, a Frequency-Amplitude plot is built to allow for a quantitative check of the recovered signal. The eventual presence of anomalous spikes in the Frequency-Amplitude plot may suggest that not all the timelines were correctly erased, which can appear as abnormal high-amplitude signals at specific frequencies.

The procedure produces SEG-Y in IEEE floating format, which can be directly inserted into commonly used educational and commercial software for seismic interpretation (e.g., dGB Earth Science OpendTect, https://www.dgbes.com/; Petroleum Experts MOVE, https://www.petex.com/products/move-suite/; IHS Markit Kingdom suite, https://ihsmarkit.com/products/kingdom-seismic-geological-interpretation-software.html; Schlumberger Petrel, https://www.software.slb.com/products/petrel; Halliburton-Landmark DecisionSpace365, https://www.landmark.solutions/ds365; EMERSON GOCAD, https://www.pdgm.com/products/GOCAD) or opened with free SEG-Y viewers (e.g., Kogeo seismic toolkit, http://www.kogeo.de/; SeiSee, https://seisee.software.informer.com/).

The SEG-Y files can also be processed further with other Matlab-based codes such as SegyMAT (http://segymat.sourceforge.net/), for instance, to merge contiguous seismic profiles vectorized separately or to erase parts of contiguous profiles in an overlapping area.

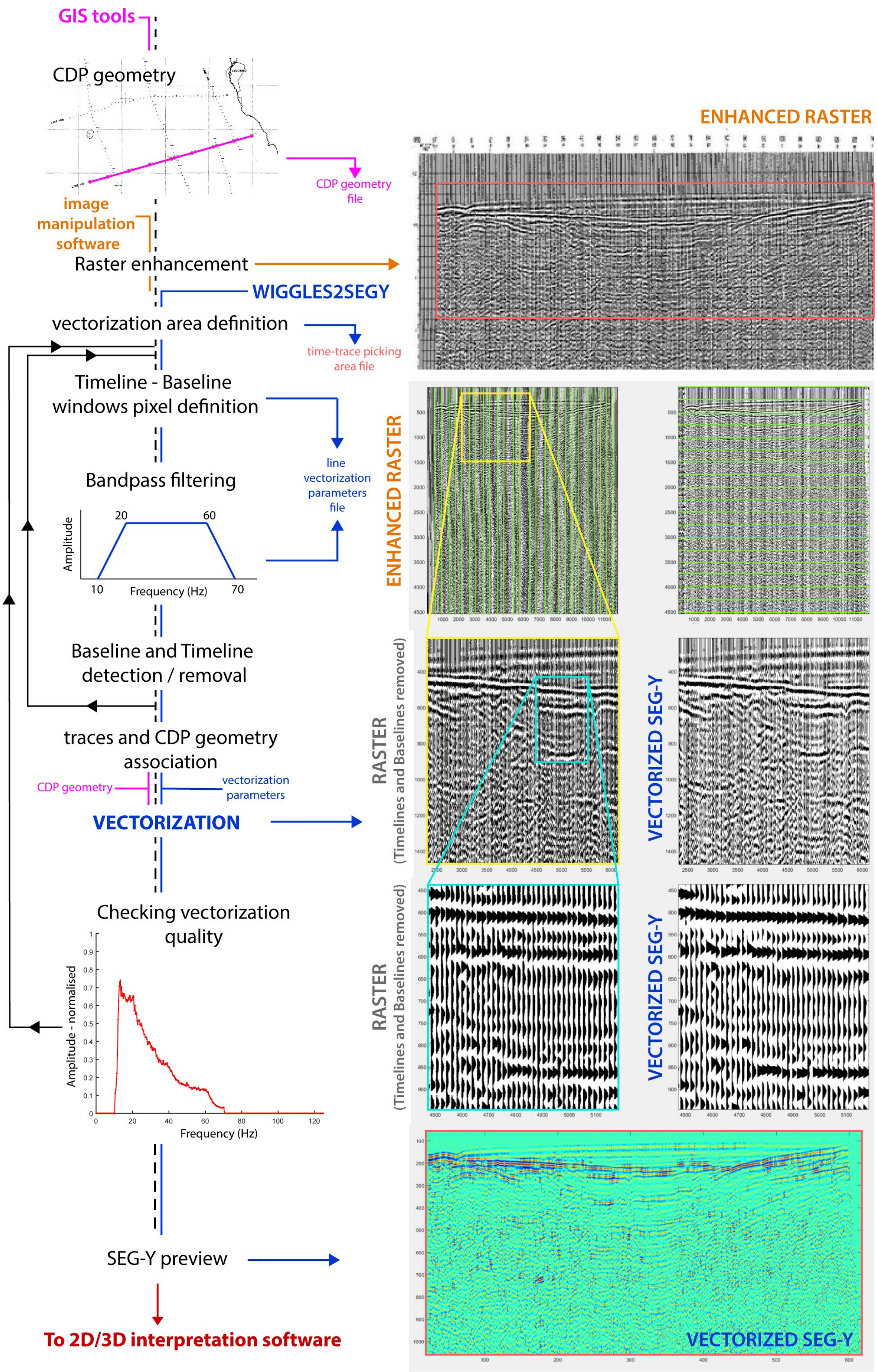

Figure 2. WIGGLE2SEGY workflow from raster preparation to SEGY vectorization and output. The iterative procedure is performed for a survey first few sections. After finding the optimum parameters, no iteration is typically applied for the remaining lines in the survey.

We have noticed from the application of this vectorization procedure that the produced SEG-Y files have unprecedented detail and generally have better quality than that obtained from other published methods utilized within currently available academic software [e.g. Diviacco et al., 2015, Conti et al., 2022]. Considering the quality of these data, we anticipate that more robust and reliable interpretations and geologic inferences can thus be made from these data.

In the following paragraphs, we describe 4 case studies regarding the vectorization of available vintage raster seismic profiles in different geographic and geological contexts across Italy: two cases in the Tyrrhenian and Adriatic offshore and two in the central and southern Apennines.

4. Case studies

This section discusses the vectorization results from four publicly available vintage raster seismic profiles within Italian territory (Figure 1B). We decided to take the rasters from the ViDEPI database because it is the most easily accessible among the ones discussed. We selected these cases since they provide representative examples of the data quality scenarios encountered in Italy. They generally lead to different vectorization and final quality approaches using the WIGGLE2SEGY tool.

We present, in order: a migrated seismic profile in the Northern Tyrrhenian Sea offshore; a reprocessed migrated seismic profile acquired across an intermontane basin in the central Apennines, which originally shows an overprinted interpretation; a seismic stack profile acquired at the end of the 70s in the Southern Apennines of Italy; a high-quality migrated seismic profile in the Northern Adriatic Sea.

4.1 Migrated seismic profile in the Northern Tyrrhenian Sea offshore

The first case study discussed is a seismic profile extracted by the ViDEPI database in the Northern Tyrrhenian Sea, close to the coast around Livorno city, the E-110 line (Figures 1B and 3, https://www.videpi.com/videpi/sismica/dettaglio.asp?codice=E-110). This profile was acquired in the late 60s and processed to obtain a version with detailed parameters reported in Figure 3.

Applying WIGGLE2SEGY to the original raster worked very well in removing the timelines, producing a SEG-Y with very high quality regarding the reconstructed seismic traces. Various features appear more evident than in the original scanned raster file, which can be displayed as a variable density plot (Figure 3). A sensible preservation of original data content can be readily appreciated by looking at the removal of shadows associated with paper folding and the conservation of wiggles. In this way, an interpreter can better perceive the continuity between signals that cannot be performed with the same accuracy on the original grayscale image. Internal unconformities can be observed within each basin in an exact way and with unprecedented detail, allowing us to track their depositional evolution in the regional geodynamic context of the Northern Tyrrhenian Sea opening and evolution (e.g., Buttinelli et al., 2014; Cavirani, 2021).

4.2 Seismic profile acquired across an intermontane basin in the central Apennines

The second case study is represented by an over-migrated seismic profile coming from a network of seismic profiles in the Fucino basin in the Central Apennines (Figure 4). Historical earthquakes have affected this area (e.g., the Marsica earthquake of estimated magnitude 7.0 on 13 January 1915, http://marsica1915.rm.ingv.it/it/79/il-terremoto-del-1915), leaving clear signs of coseismic surface faulting and other environmental effects.

We chose this case study because, frequently, the versions of the seismic profile recovered from public databases have the geologic interpretation annotated on the scanned paper. This circumstance makes it difficult to use the data in subsequent analyses in 3D interpretation environments (e.g., Petex Move, Petrel). Even if these/the software can load raster images to be associated with the trace of seismic profiles and SEG-Y digital data, non-negligible hand-made interpretations can affect any re-interpretation or hamper the possibility of making new interpretations that can be modified or integrated.

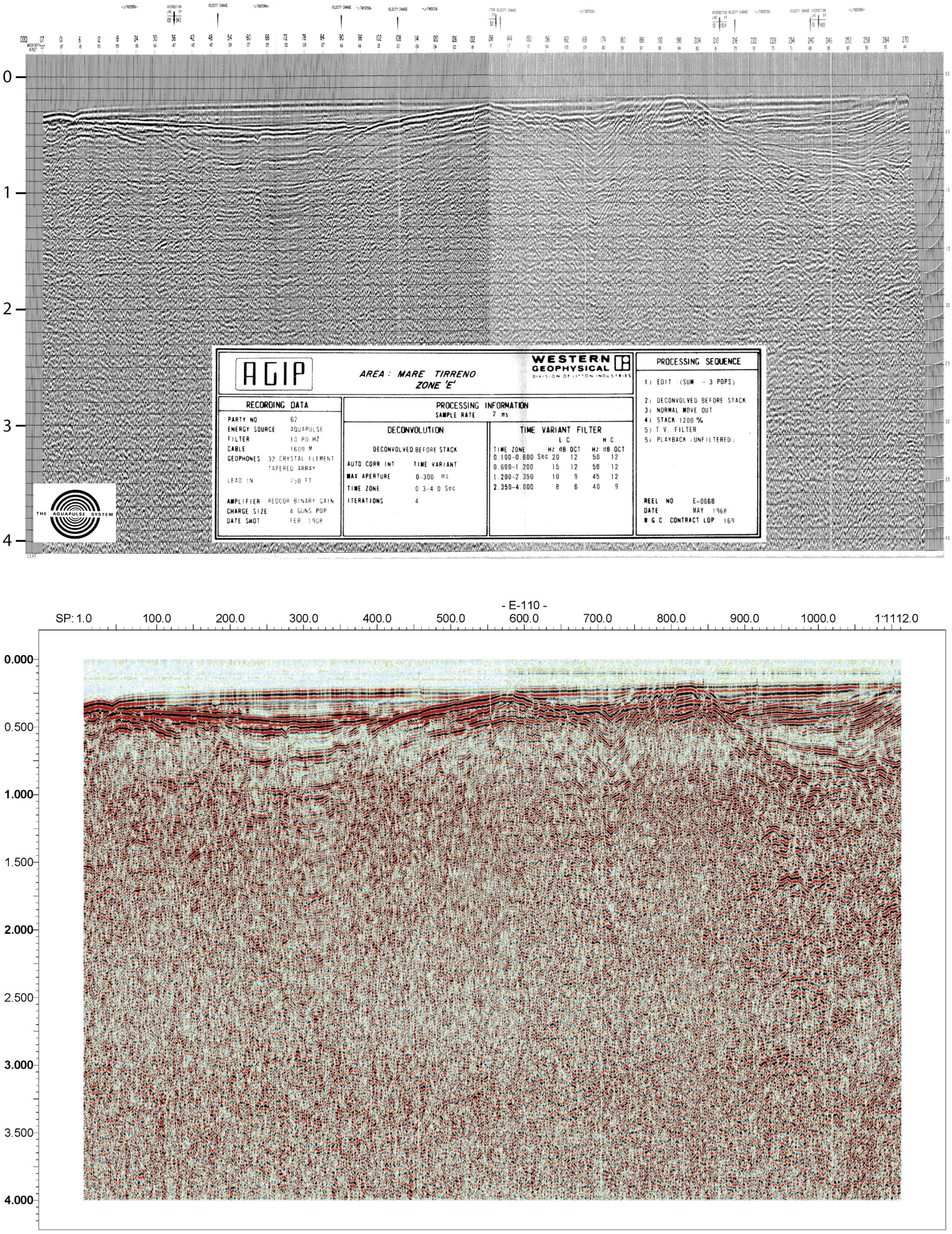

Figure 3. E-110 publicly available migrated seismic profile in raster format (upper panel, enhanced version after the ViDEPI database https://www.videpi.com/videpi/sismica/dettaglio.asp?codice=E-110) and vectorized SEG-Y format via WIGGLE2SEGY Matlab-based tool (lower panel). Vertical scale in TWT (sec) for both versions and CDP definition for horizontal reference. See Fig. 1B for the trace location.

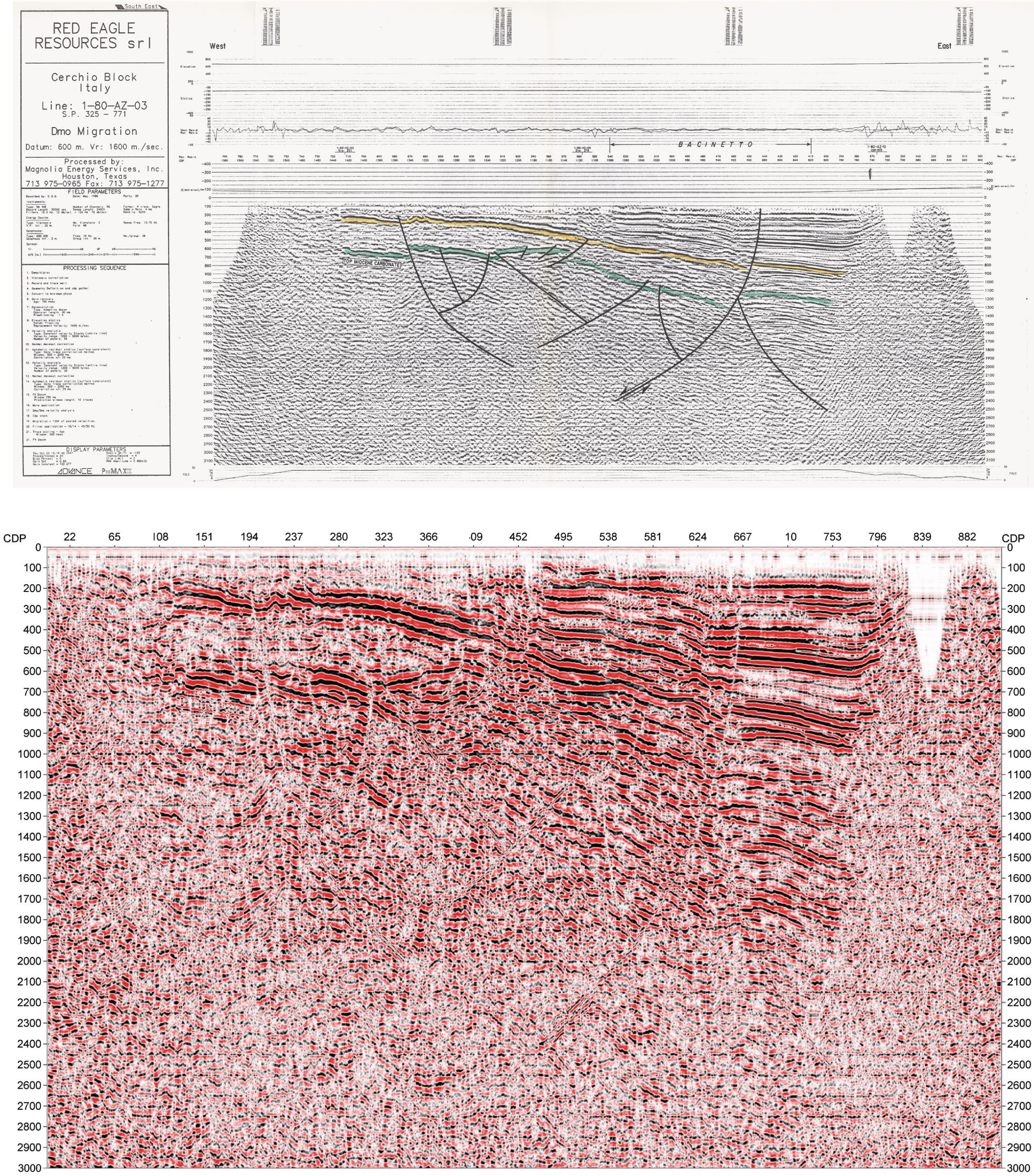

Figure 4. 1-80-AZ3 publicly available migrated seismic profile in raster format (upper panel https://www.videpi.com/deposito/videpi/allegati/1099.pdf) and vectorized SEG-Y format via WIGGLE2SEGY Matlab-based tool (lower panel). Vertical scale in TWT (sec) for both versions and CDP definition for horizontal reference. See Fig. 1B for the trace location.

In this case, the WIGGLE2SEGY approach performs well to remove the effect of the hand-made interpretation on the scanned image, both for pen traces and color highlights (Figure 4). Considering that the pen or pencil trace represents a relatively high-frequency signal, properly tuning the frequency filtering parameters of the code makes it possible to remove it, extracting only the original signal. The only flaw accepted, considering the quality of the starting data, is that part of the frequency content may be lost depending on the thickness of the pencil used for the interpretation. If the band-pass filter is not enough to remove previous interpretations, some preliminary operation in graphic software (to erase the interpretation from the image) may be necessary before starting the procedure. In these cases, some shadows and remnants of interpretations often still remain where the pen trace has obscured the seismic data.

However, in this case, it is possible to comment on how the WIGGLE2SEGY approach worked well, producing a SEG-Y ready to be reinterpreted from scratch. The geometries inside the basin can be seen much better than in the raster data. In particular, some unconformities which change into paraconformity in the depocenter of the basin can be very well recognized. The boundary faults of the basin that controlled the deposition within it during their activity are also more evident (Fig. 4).

It is reasonable to foresee that applying this conversion approach to the network of raster profiles available for the Fucino basin will produce digital data of such high quality. In this way, it is possible to reconstruct the 3D geometries of the main horizons and faults and provide further constraints to the previous interpretations [e.g., Cavinato et al., 2002; Patruno and Scisciani, 2021]. This enhancement might finally lead to a much more solid assessment of the recent activity of these faults and their cumulative medium and long-term slip rates. The results based on the re-interpretation of such a rejuvenated high-quality dataset are ongoing while being of great interest in tectonically active areas such as the Central Apennines, where the correct evaluation of the recent activity of the faults has an impact on the seismic hazard assessment.

4.3 Seismic profile in the Southern Apennines

The third case study represents a seismic stack profile acquired in the Southern Apennines at the end of the ‘70s of the last century.

This seismic profile was chosen to test the ability of WIGGLE2SEGY to digitize data with relatively low quality, similar to other profiles available in areas of high structural complexity, such as the southern Apennines thrust-and-fold belt in Italy. In these areas, the inferences on the shallow crustal setting have always been very variable [e.g., Patacca & Scandone, 2007, Scrocca et al., 2007] for the scarce constraints at depth due to the overall low quality of the commercial seismic profiles.

This problem is quite common where limestone-dolomitic lithologies outcrop and in the presence of rough topography, which are situations widely observed in large areas of the central and southern Apennines.

Despite this, the vectorization approach used here is of interest compared to others in use because of its capability of removing timelines and baselines and the possibility of a refined tuning of the filtering parameters. After vectorization, various features, such as reflections and faults, appear more evident using a variable density display.

The results obtained from the vectorization of this seismic profile (Figure 5) allow us to make the following considerations: i) the timelines and baselines are removed very well: this means that the code successfully “recognized” what is not data even with a low-quality input dataset, predominantly, in conditions with poor vertical and horizontal coherence. Moreover, in areas with no outcropping carbonate lithologies but flysch and terrigenous sequences, some geometries of the underground can be more easily recognized.

Although the general quality of the result is fair, we think that also, in this case, the approach used has increased the intrinsic value of the original data and that if properly integrated with the surface and other underground data (e.g., a network of seismic profiles) or other geophysical independent techniques, these digital data too can be exploited to build geological models.

4.4 Migrated high-quality seismic profiles in the Northern Adriatic Sea

As the last case study, we chose a migrated seismic profile with a high quality already in its publicly available raster version. This profile is located on the compressive front of the Northern Apennines, in the offshore area along the Marche region coastline (see Figure 1B for the location).

Despite the high quality of the raster data, this case allows us to appreciate how much the conversion with WIGGLES2SEGY can push analyses to a higher level even with public data (e.g., ViDEPI, SNAP).

The vectorization produces an almost total removal of the signal associated with timelines and baselines. Astonishingly, comparing the raster with the vectorized SEG-Y, we observe that the SEG-Y closely resembles the original data with an unprecedented internal resolution (Figure 6).

This excellent quality unleashes a further improvement in the detection capacity of the internal depositional architecture between key seismic reflectors with respect to already published literature for the same sectors

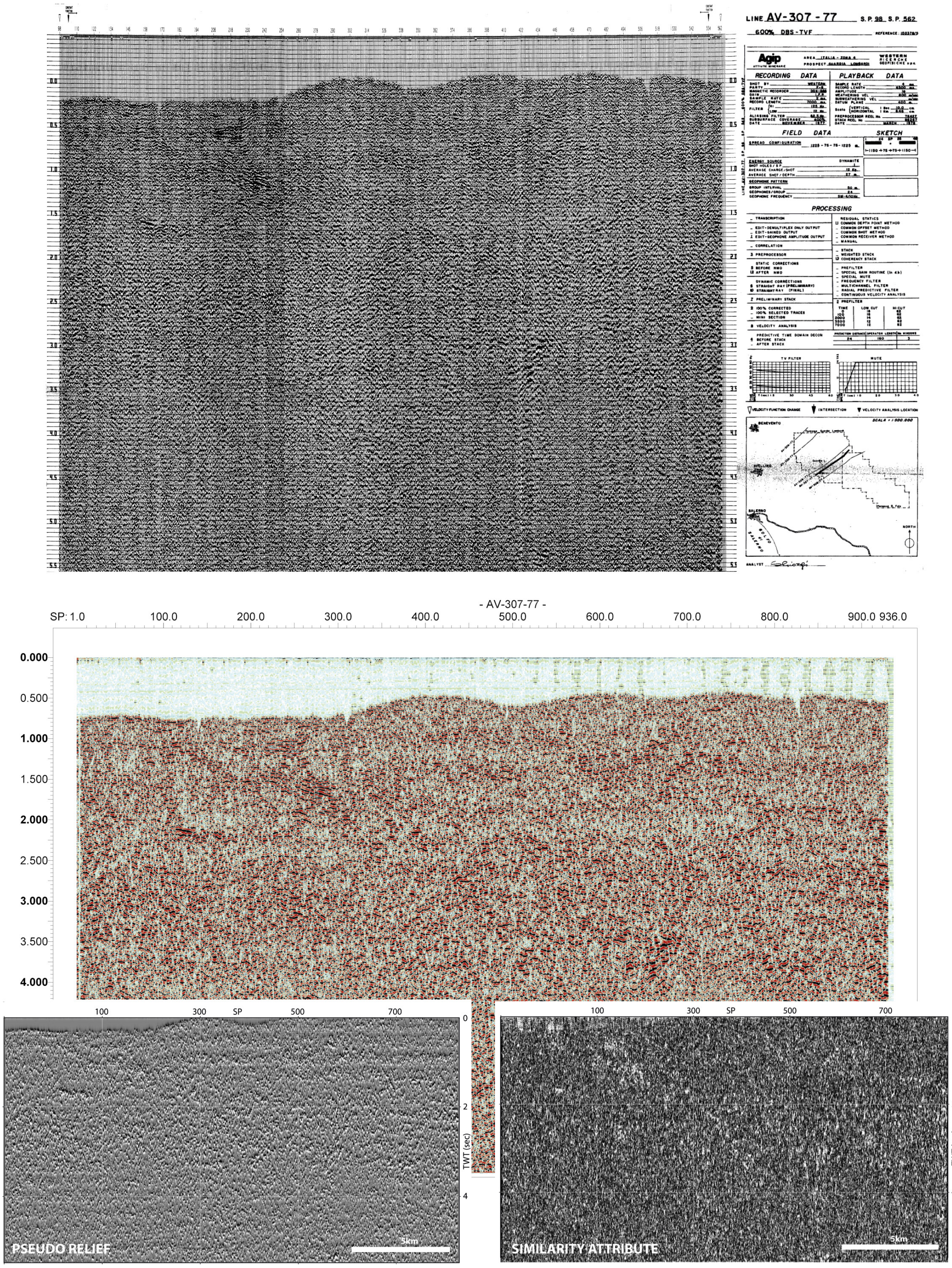

Figure 5. AV-307-77 publicly available seismic profile in raster format (upper panel https://www.videpi.com/deposito/videpi/allegati/2904.pdf) and vectorized SEG-Y format via WIGGLE2SEGY Matlab-based tool (lower panel). Examples of post-processing working on the seismic attributes (Pseudo Relief and Similarity) are also shown. Vertical scale in TWT (sec) for both versions and CDP definition for horizontal reference. See Fig. 1B for the trace location.

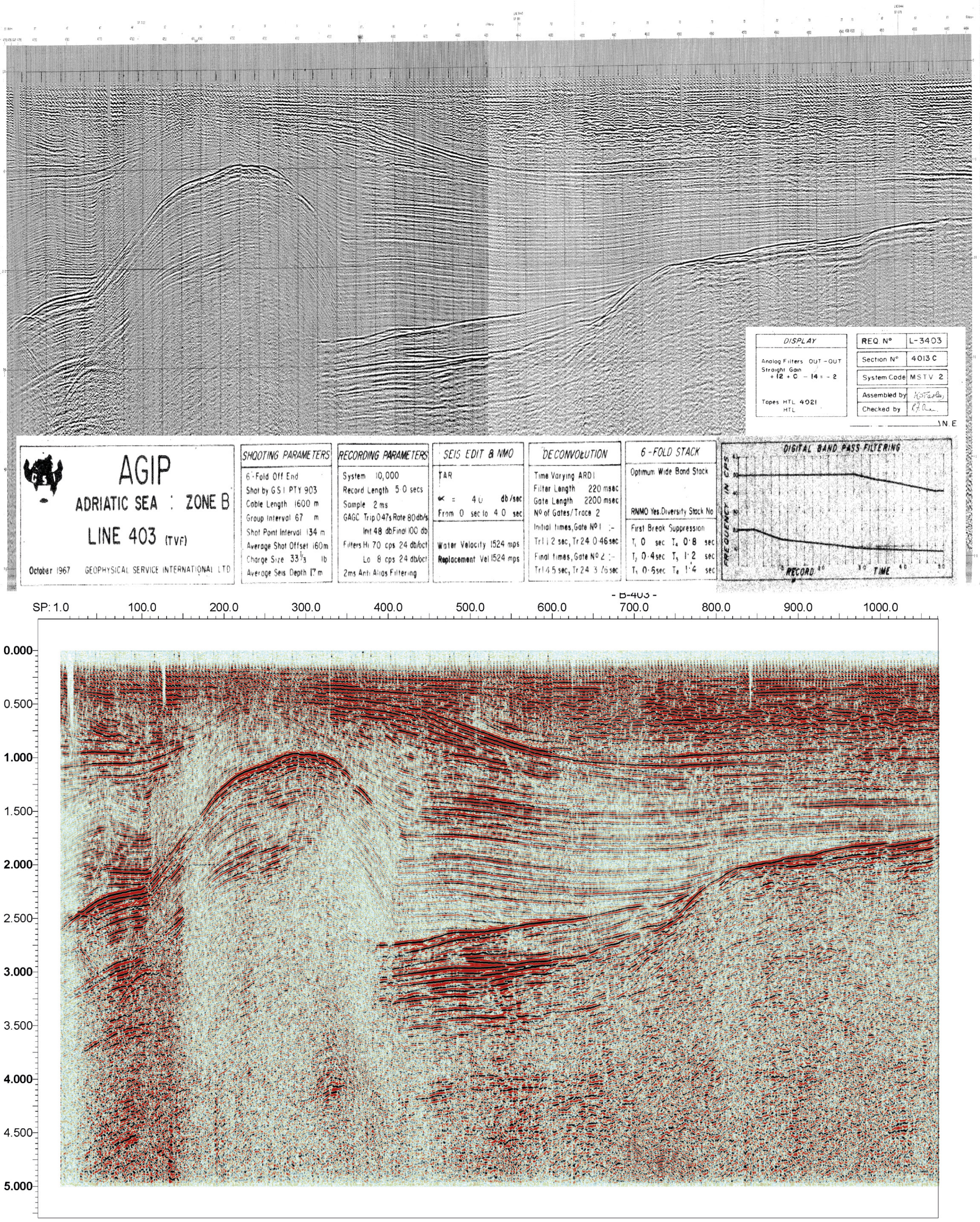

Figure 6. B-403 publicly available seismic profile in raster format (upper panel https://www.videpi.com/videpi/sismica/dettaglio.asp?codice=B-403) and vectorized SEG-Y format via WIGGLE2SEGY Matlab-based tool (lower panel). Vertical scale in TWT (sec) for both versions and CDP definition for horizontal reference. See Fig. 1B for the trace location.

[e.g., Pezzo et al., 2020; Bigi et al., 2013; Mancinelli and Scisciani 2020; Maesano et al., 2013] and directly comparable with SEG-Y data provided by oil & gas companies [Panara et al., 2021]. This improvement also broadens the field of analysis for the definition of the activity of geological structures, such as the evaluation of slip rates and depositional rates, which are parameters that have a substantial impact in the assessment of the hazard associated, for example, with seismogenic structures [e.g., DISS Working Group, 2021]. In these areas, during the Pleistocene, the sedimentation rates were faster than the tectonic rates by one order of magnitude, leading to the complete burial of the frontal thrust of the Apennines [Maesano and D'Ambrogi, 2017]. Nonetheless, the geometry of the main intra-Pleistocene horizons both in the Adriatic and in the Po Plain [Amadori et al., 2019] has recorded the eventual activity of the underlying faults [Panara et al., 2021], and also the relocation of the seismicity in the area suggest that the frontal thrusts are still active and seismogenic [Battimelli et al., 2019]. The use of subsurface information thus may be crucial to refining the knowledge of the recent compressive deformation at the Apennines front.

5. Conclusions

In this contribution, we presented and discussed the application of the WIGGLE2SEGY vectorization code [Sopher, 2018] to four case studies within different geodynamic contexts of the Italian territory. The code allows transforming seismic profiles from raster format into digital SEG-Y. We selected those cases since they represent the various seismic subsurface data quality that can be recovered in the public databases from Italy. Such different scenarios translate into distinct styles of approach to vectorization and final quality of digital data using the WIGGLE2SEGY tool.

According to the results presented here, we can comment on the unprecedented high quality and detail of the SEG-Y files produced compared to other available conversion strategies and starting from the same raster initial dataset.

WIGGLE2SEGY proved to represent an easy-to-use and valid alternative to other codes commonly used in academia and research (e.g., those used for vectorizing the seismic profiles available in the SNAP database).

For all the case studies, WIGGLE2SEGY allows for recovering most of the signal along the seismic traces and works very well in removing timeline, baseline, and hand-made paper interpretations. This latter, in particular, means that old data with a very poor starting quality, considered unusable for further quantitative studies because existing only in interpreted raster format (e.g., material belonging to the ViDEPI dataset), can be recovered and made usable for research purposes.

Furthermore, post-processing procedures can be performed on the digitalized data by working on the seismic attributes with the appropriate software (e.g., OpendTect, Figure 5).

The INGV SISMOLAB-3D adopted this approach because it constitutes a resource for gathering and re-elaborating public analogic subsurface data to preserve their original data quality content, integrate them with already available digital SEG-Y data, and exploit them for seismotectonic studies of the Italian territory. Integrating such datasets would lead to the construction of 3D geological models based on the elaboration of digital and high-quality subsurface data.

Furthermore, inferences based on these geological models often impact the assessment of the hazard associated with strong earthquakes that characterize a large part of the Italian territory, as well as the anthropogenic hazards linked to geo resources exploitation as the induced seismicity. The final goal of the SISMOLAB-3D will be to gradually build and populate a comprehensive dataset of digital SEG-Y seismic profiles, which would constitute the INGV portfolio to be shared with the scientific community for future advanced scientific analysis.

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Data and sharing resources: All the datasets and codes used in this contribution are publicly available and correctly referenced within the text.

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