Bollettino di Geofisica Teorica ed Applicata Vol. 55, n. 4, pp. 755-788; December 2014
DOI 10.4430/bgta0118

Early instrumental seismicity recorded in the eastern Alps

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(Received: April 9, 2013; accepted: January 16, 2014)

ABSTRACT Three hundred and seventy-five earthquakes recorded by the Trieste station in the eastern Alps in the early instrumental period, i.e., before the occurrence of the destructive event of May 6, 1976, have been located after painstaking gathering of seismograms and bulletins. Analysis of the statistical parameters of the locations, together with comparisons with other instrumental and macroseismic locations, have allowed us to assess the quality of the results obtained, taking into account the often limited nature of the data. Using a process of digitization and the study of seismograms, focal parameters, particularly the magnitude M_W, have been recovered for three earthquakes of the 1950s and 1960s.

Key words: early instrumental earthquakes, old seismograms, bulletin, digitization, magnitude, NE Italy, Trieste.

1. Introduction

As part of the Interreg IV European Project "HAREIA - Historical and Recent Earthquakes in Italy and Austria", the Istituto Nazionale di Oceanografia e di Geofisica Sperimentale (OGS) has carried out a reappraisal of the instrumental seismicity in the eastern Alps through reassessment of hypocentral parameters of the events recorded by the OGS stations (Trieste, and those of the regional seismometric network of Friuli-Venezia Giulia, which has been operating since 1977). One of the aims of the HAREIA project was to produce a new and uniform earthquake catalogue covering both the historical and the instrumental periods for future reassessment of the seismic hazard in the eastern Alps. The final goal of the review of early instrumental data was, therefore, to establish a freely accessible platform of earthquake locations and ancillary data (station coordinates, location parameters, seismic station readings, etc.) for the seismicity of the eastern Alps themselves. The obtained locations were, then, compared with the macroseismic locations and thus the final HAREIA catalogue was obtained (Rebez, 2012).

Concentrating on north-eastern Italy, the Friuli-Venezia Giulia region has a long history of instrumental seismological data collection because the station at Trieste had been part of the Austrian seismometric network since 1898. That is from shortly after the 1895 Ljubljana earthquake, when a seismograph was placed on the top floor of a building located in the centre of Trieste (Böhm, 1998). The Trieste station was in operation until 1918 when it was moved 1.5 km westwards (international code TRS) to another city building and was managed from 1931 by the Istituto di Geofisica di Trieste, from 1941 by the Istituto Talassografico di Trieste, from 1949 by the Osservatorio Geofisico, and since 1958 by the Osservatorio Geofisico Sperimentale, now OGS,

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and the archives from 1931 onwards are still being maintained. In 1963, the seismological station was moved from the centre of Trieste to a low-noise site on the Karst plateau (Borgo Grotta Gigante with the new station code TRI) and equipped with the instruments of the World Wide Standardized Seismographic Network, coordinated by the U.S. Geological Survey. Past earthquake activity in and around the Friuli-Venezia Giulia region has thus been documented in an uninterrupted series of seismological bulletins from the Trieste stations (TRS, TRI) since 1931. The bulletins relating to the Austrian period (1898 to 1918, available at INGV and ENEA) have also been consulted for events of relevance to this work.

In the early years of the 20th century there were numerous research institute and university observatories, with seismographic instruments in the general eastern Alps region: in Padua, Treviso, Venice, Graz, Innsbruck, Ljubljana (LJU), Rijeka (formerly Fiume) and Pula (formerly Pola). In the 1960s and 1970s, the Italian electric agency (ENEL) installed seismographs in the proximity of its dams in the eastern Alps (at Ambiesta, La Maina, Mis, Pieve di Cadore, Somplago, Tolmezzo, and Vajont). Further away, some other stations such those at Bologna, Salò, Klagenfurt, Cerknica, and Zagreb carried out effective recordings of the earthquakes in the eastern Alps.

Retrieving original data for earthquakes occurring in the early decades of the 20th century is quite difficult because several institutions managing the seismological stations no longer have all the old seismograms and sometimes the seismological bulletins are also lacking. It was, therefore, necessary to have recourse to phase readings reported in bulletins of international agencies [mainly the International Seismological Centre (ISC), former International Seismological Summary (ISS)] to fill in the missing data.

This paper summarizes an analysis of the seismological data relating to all seismic events in the eastern Alps (i.e., between 45.0° and 47.5° N and 10.0° to 15.0° E) recorded by the seismic station of Trieste, while referring the early instrumental period, i.e., before May 6, 1976, when a seismic sequence started as documented in several specific studies (e.g., Finetti *et al.*, 1979; Poli *et al.*, 2002; Carulli and Slejko, 2005).

2. Data gathering

All the stations operating in Europe and recording events from October 30, 1901 to May 5, 1976, at least for some periods, are reported in Fig. 1a: the total is 222 but 12 lie outside the geographical limits of the figure. The histogram in Fig. 1b shows the number of stations operating per decade both in Europe and within the current borders of Italy, the eastern borders of Italy having been subjected to repeated changes in the 20th century, as it is well known. As already mentioned, the Trieste seismic station was the only one operating before 1977 in north-eastern Italy, being managed by a public research institution and whose data were distributed worldwide. Seismogram and bulletin collections were carried out for the main events in the study area as recorded by the Trieste station, while drawing also on the data reported in the ISS and ISC bulletins.

The complete list of events is reported in the Appendix. The phases of some Italian stations have been subject to reinterpretation (i.e., BOL, CHV, FIR, PAD, PAV, RCI, RDP, ROM, and SAL) as well as those of the previously mentioned ENEL stations. In addition the seismograms of some stations in Austria (IBK, KFA, KMR, MOA, OGA, SCE, and VIE) and in Germany (BHG,

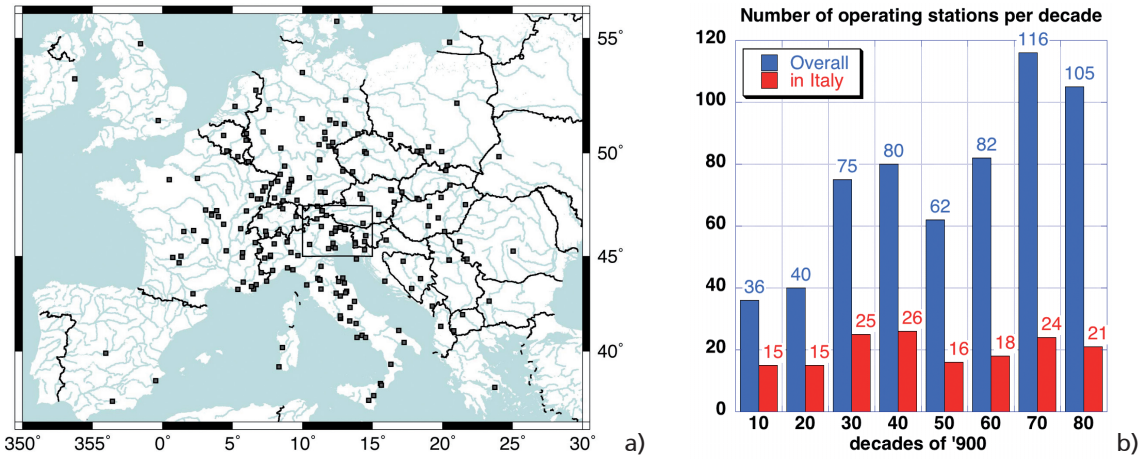

Fig. 1 - Seismological stations in the period October 30, 1901 - May 5, 1976: a) map of the operating stations in Europe, the total amount is 222 (12 are outside the geographical limits of the map), some stations operated only for a limited interval; b) total number of stations operating per decade both in Europe (blue bars), and within current Italian borders (red bars).

FUR, GAP, HOF, HOH, MNH, MSS, RAV, and STU) were completely re-read [station codes and coordinates are taken from the International Registry of Seismograph Stations (ISC, 2011)]. All other phase readings come directly from the ISS and ISC bulletins.

Fig. 2 shows the normalized distribution of the actual number of phases used for the earthquake localizations (blue bars), grouped by stations that fall within ranges of 100 km from a central point of the Friuli-Venezia Giulia region established as 46°N and 13°E. The thick red horizontal stripe indicates the corresponding normalized number of stations using the same criteria. 57% of the stations

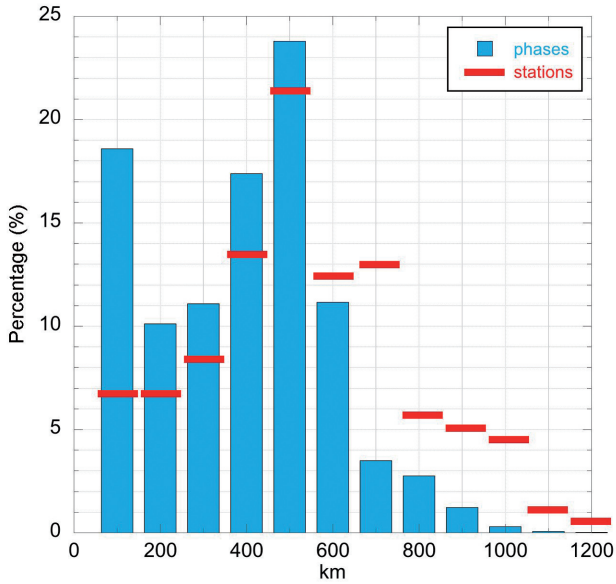

Fig. 2 - Percentage of actual number of phases (blue bars) and of stations (thick red horizontal stripes) used for localization, grouped by distance from a central point in Friuli (fixed at 46° N and 13° E).

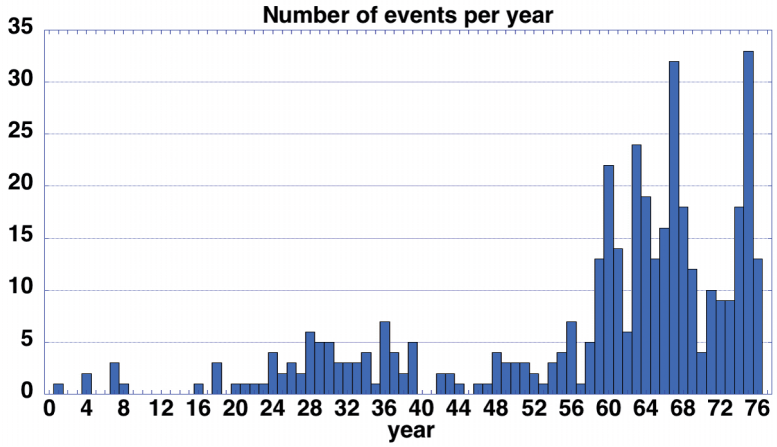

Fig. 3 - Time distribution (number of events per year) of the 375 analyzed earthquakes for the period October 30, 1901 - May 5, 1976.

within 500 km contribute with 84% of the effective phases used. In contrast, despite having used stations with distances greater than 500 km (43% of the total number of stations), the contribution in terms of phases used is reduced to 16% (or just 8% for distances greater than 600 km).

Most of the studied events occurred in the second half of the 20th century (Fig. 3). It is quite reasonable that at the beginning of the century the number of documented events is very small. There are, in fact, only 12 events recorded before 1920: among these, 7 before 1910 (the large circles in Fig. 4). An increasing number of earthquakes started to be recorded from the 1920s, after the First World War, but another equally reasonable lack of seismicity data is recognizable during the Second World War. The number of analyzed seismic events progressively increases after 1950 and 272 of the events of the entire data set (68%) were reported after 1960 (Fig. 3).

3. The processing of the data

3.1. Code and input parameters

The original HYPO71 code (Lee and Lahr, 1975) was used for location. HYPO71 is a computer program for determining hypocentre, magnitude, and first motion pattern of local earthquakes and was first released in 1971. It is perhaps the first earthquake location program to have achieved worldwide application. Before it, the use of EPIC (Bolt and Turcotte, 1964) was relatively restricted. Despite its simple modelling of the Earth's structure as plane-parallel layers in a region of geological and structural complexity such as that of the the eastern Alps, it still represents the best trade-off between accuracy and the large dimensions of the area under investigation. 3D processing has been passed over at this stage in order to have continuity with the standard processing operated by OGS with seismometric data from the regional networks. The standard structural model (Riggio and Russi, 1984) applied for the analysis of events recorded by the OGS regional network was considered suitable for the study area concerned (45.0° - 47.5° N and 10.0° - 15.0° E: box in Fig. 4). This consists of a layer from the surface down to a depth of 22 km with V_P = 5.85 km/s, a layer from 22 to 39.5 km depth with V_P = 6.8 km/s, and a half-space below 39.5

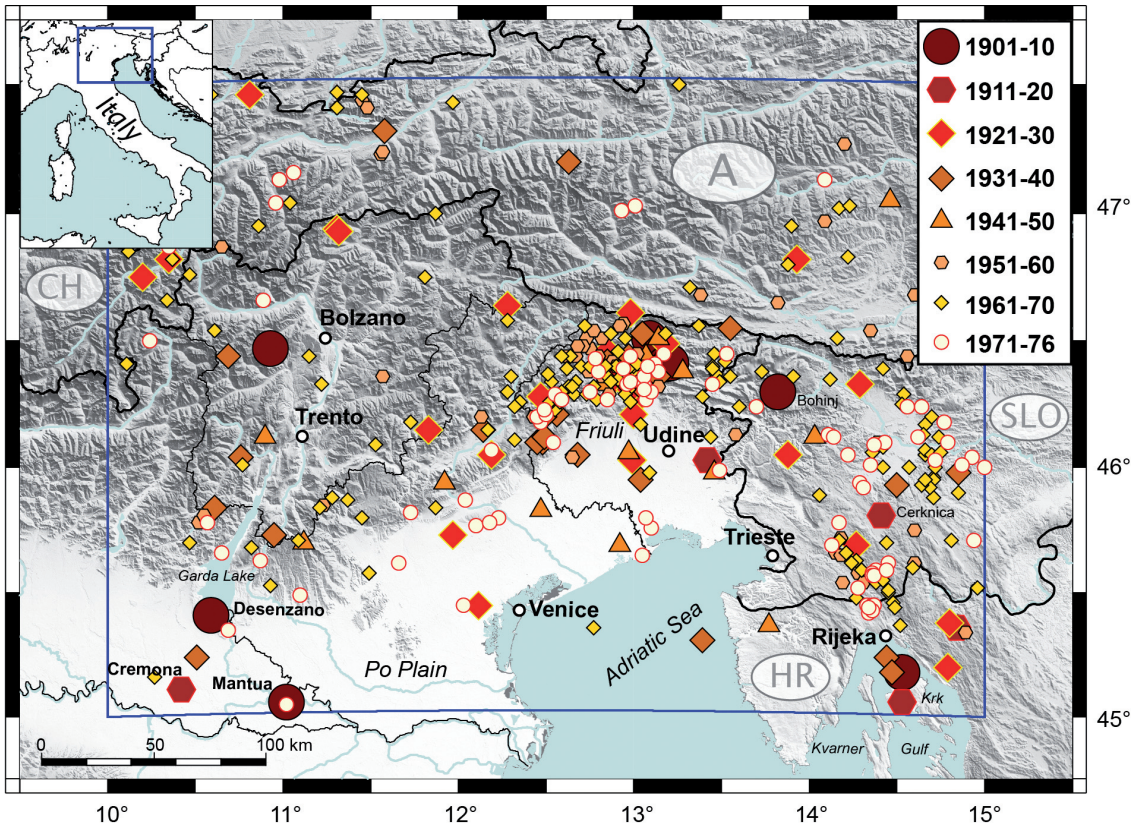

Fig. 4 - Map of the 375 relocated events inside the study area (45.0° - 47.5° N and 10.0° - 15.0° E) occurring in the period October 30, 1901 - May 5, 1976 grouped by decade. 7 events occurred between October 30, 1901 and 1910 (large brown circles); 5 between 1911 and 1920 (large brown hexagons); 30 between 1921 and 1930 (large red diamonds); 32 between 1931 and 1940 (large dark orange diamonds); 17 between 1941 and 1950 (dark orange triangles); 61 between 1951 and 1960 (small orange hexagons); 158 between 1961 and 1970 (small yellow diamonds); 92 between 1971 and May 5, 1976 (light yellow small circles).

km depth, with V_P = 8.0 km/s. A P to S-wave velocity ratio of 1.78 was used.

As a general procedure, if the time signal was poor or in the presence of apparent inconsistencies, the difference between arrival times of the P and S waves has been taken into account. Not all the station clocks were synchronized with the radio signal and so some readings in the bulletins' reports give constant deviations, whether ahead or as delay, with respect to the actual time. This was not, however, seen as sufficient reason for rejecting all the data. When the S-wave onset was in question, less weight was given to that phase. Where the seismograms were not available, the accuracy of the timing reported in the bulletins was difficult to assess. According to a preliminary location, stations showing residual time exceeding +/- 2 s for P-waves and +/- 4 s for S-waves were excluded from the final analysis. Only data recorded by stations within an epicentral distance of 1000 km were considered. Where there were no stations close to the epicentre that could have fixed the focal depth, tests fixing the hypocentral depth at different distances (4, 7 and 12 km) were performed for events with an unrealistic result for hypocentral depth of less than 1 km or greater than 45 km, seeking the best result in terms of root-mean-square (Rms) error in time. An asterisk in the Appendix indicates these events (there being 38 in total).

Some of the parameters of the program have been changed in order to adapt location procedure to the characteristics of the seismicity in the study area. The values changed with respect to default figures are shown in Table 1 together with their description. TEST (01) (the cut-off value for the Jeffreys' weighting) is designed for data sets containing large timing uncertainties. In the first run of the code the default value of 0.1 was used. The epicentral localizations with large errors were checked separately. In most cases, fixing the focal depth greatly decreased uncertainties. Then TEST (01)=100 was used. Comparisons between the two data sets obtained using the two above-mentioned values for TEST (01), respectively 0.1 and 100, showed that 69% of the locations differ by less than 2 km. 4% of reported distances were more than 10 km (15 of 374). These include the case of February 11, 1944, which, as we will see later, is one of the worst cases in our database in terms both of associated errors and distances with respect to the macroseismic epicentre, the case of January 1, 1960, for which, however, the nearest station was situated at 0.2 km, and the case of August 18, 1967 for which the nearest station was at 260 km.

Table 1 - Input values used for the HYPO71 (Lee and Lahr, 1975) code.

Test	Input	Default Value	Definition
TEST (01)	100.0	0.1	The cut-off value for rms below which Jeffreys' weighting of residuals is not used. It should be set to approximately the overall timing accuracy of P-arrival in seconds.
TEST (02)	120.0	10.0	For each iteration, if the epicentral adjustment is greater than TEST (02), this step is recalculated without focal depth adjustment. TEST (02) should be set to a value approximately equal to the station spacing in km.
TEST (10)	50.0	100.0	If the latitude or longitude adjustment (DX or DY) is greater than TEST (10) then DX is reset to DX/(J+1), and DY is reset to DY/(J+1), where J=D/TEST (10), D being the larger of DX or DY.
TEST (11)	20.0	8.0	Maximum number of iterations in the hypocentral adjustment.

3.2. Error analysis

Earthquake location is a non-linear problem, as discussed in Lee and Stewart (1981), and there is no fool proof method to solve this because input data may be insufficient to remove the problem. Precise checking of the input data is, however, essential before any earthquake location program can be run. The statistical errors in relation to the location depend on the accuracy of the velocity model used to compute earthquake location, the weightings assigned to arrival times and the procedure used to locate the earthquake. Even if there are accurate station coordinates (better than ±0.1 km if possible), a reasonable crustal structure model (e.g., from controlled explosions), and reliable P and S arrivals, no computer programs will give correct answers if the input data contain errors. It must also be borne in mind that small residuals and standard errors are insufficient to assure an accurate hypocentre result.

Quantitative analysis using statistical tools was carried out on all the error data set produced by the algorithm HYPO71 (Lee and Lahr, 1975). The results provide information on the reliability of the earthquake location. These are considered separately below.

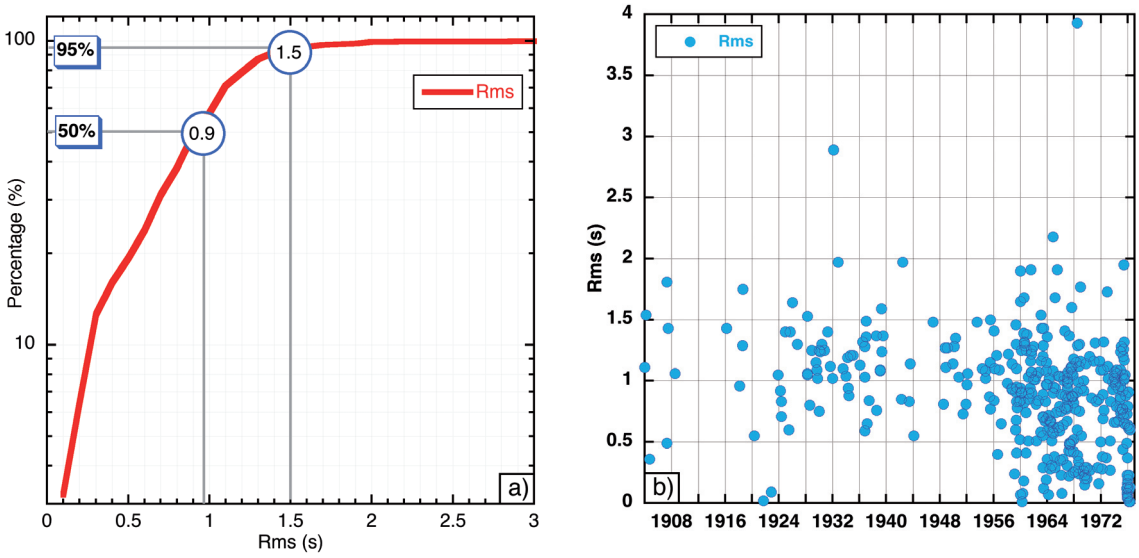

Fig. 5 - Root-mean-square (rms) travel time residual, in seconds, for the 375 relocated events in the period October 30, 1901 - May 5, 1976: a) statistical distribution; b) individual error vs. time.

The Rms travel time residual, in seconds, provides a measure of the fit of the observed arrival times with predicted arrival times according to the computed location. Small numbers reflect a better data fit though it also depends on the number of arrival times used. For this reason, a complete analysis of location errors is given here as opposed to a simple check on rms values. The median value of Rms for the whole data set of 375 locations is 0.9 s (minimum 0.01 s and maximum 3.9 s); 57% of the entire data set has a value less than, or equal to, 1 s and 99% less than, or equal to, 1.5 s (Fig. 5a). Only three records have a time residual greater than 2 s (Fig. 5): i.e., June 22, 1968 (Rms = 3.9 s), February 19, 1932 (Rms = 2.9 s) and May 5, 1950 (Rms = 2.15 s). Even if it is not immediately visible from the picture emerging, the general trend for rms values decreases from the beginning of the 20th century to the 1970s (Fig. 5b).

The horizontal and vertical uncertainties in an event location are based respectively on the values of Erh and Erz. The median standard error on epicentre location (Erh) is 3.7 km. 95% of the data have a value less than, or equal to, 11 km (Fig. 6a). Two events have very poor horizontal location with an error greater than 20 km and are, as said, the May 5, 1950 quake with an Erh of 20.4 km and February 11, 1944 with an Erh of 32.8 km. In this case the number of phases used is only 5. In total 21 events have an erh larger than 10 km. Apart from the three bad cases, which are not reported in Fig. 6b, it is quite clear there has been in recent years a trend towards a diminishing Erh.

A good depth estimate can be obtained only if there is a recording station close to the epicentre (i.e., a distance less than double the hypocentral depth): this was very rarely the case in the early instrumental period. The median standard error of the focal depth (Erz) is 4.8 km, 87% with a figure of less than, or equal to, 10 km (Fig. 7a). Five events have an Erz greater than 30 km. Two of the 5 also have a high erh, as discussed previously. The other three are those of April 14, 1974 (Erz = 38.89 km), December 11, 1975 (Erz = 34.6 km) and September 4, 1971 (Erz = 32.5 km). Apart from the first, for which no close stations were available, for all the others only a small number of phases is available (5 and 8 respectively).

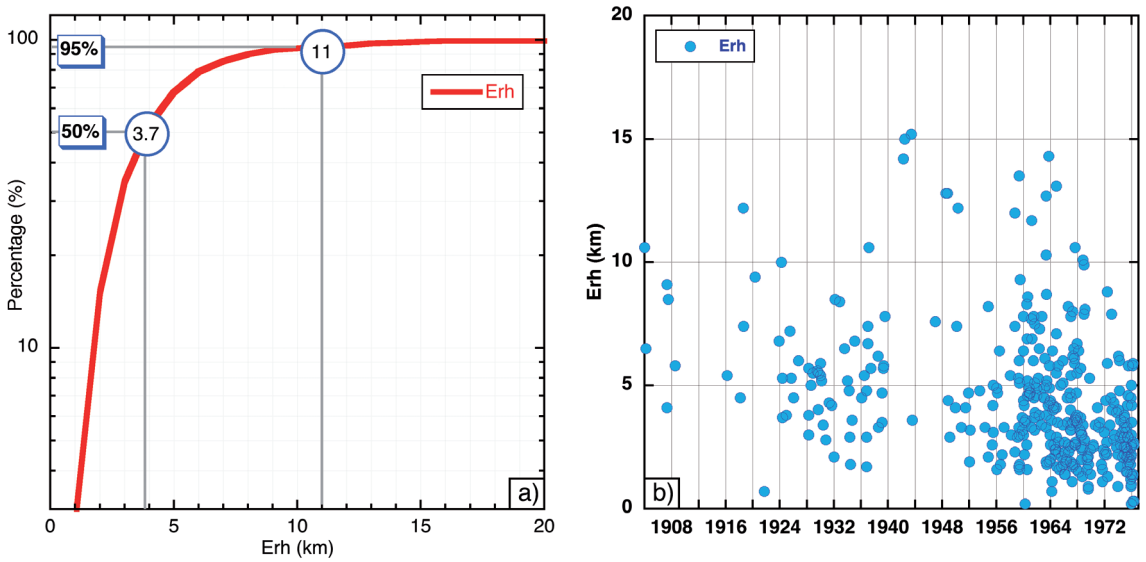

Fig. 6 - Standard error on the epicentre location (Erh), in km, for the 375 relocated events in the period October 30, 1901 - May 5, 1976: a) statistical distribution; b) individual error vs. time.

As regards events relatively far in the past, the number of station readings used in the locating procedure (No) provides a fair indication of location quality (Fig. 8a). It should be pointed out that P and S arrivals from the same station are counted as 2 readings. Increased numbers of arrival-time observations generally result in improved earthquake locations: 12 events have No>50 with an associated good location quality. The median number of phases is 13 (minimum 4, maximum 90), and 28% of the data set has a phase number of less than, or equal to, 10 readings.

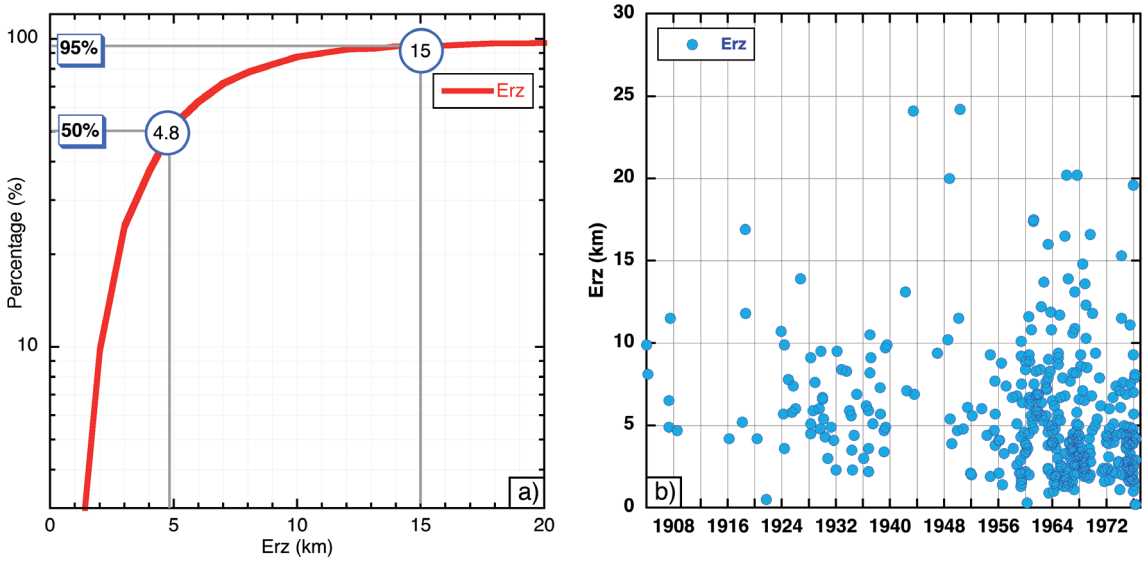

Fig. 7 - Standard error of the focal depth (Erz), in km, for the 375 relocated events in the period October 30, 1901 - May 5, 1976: a) statistical distribution; b) individual error vs. time.

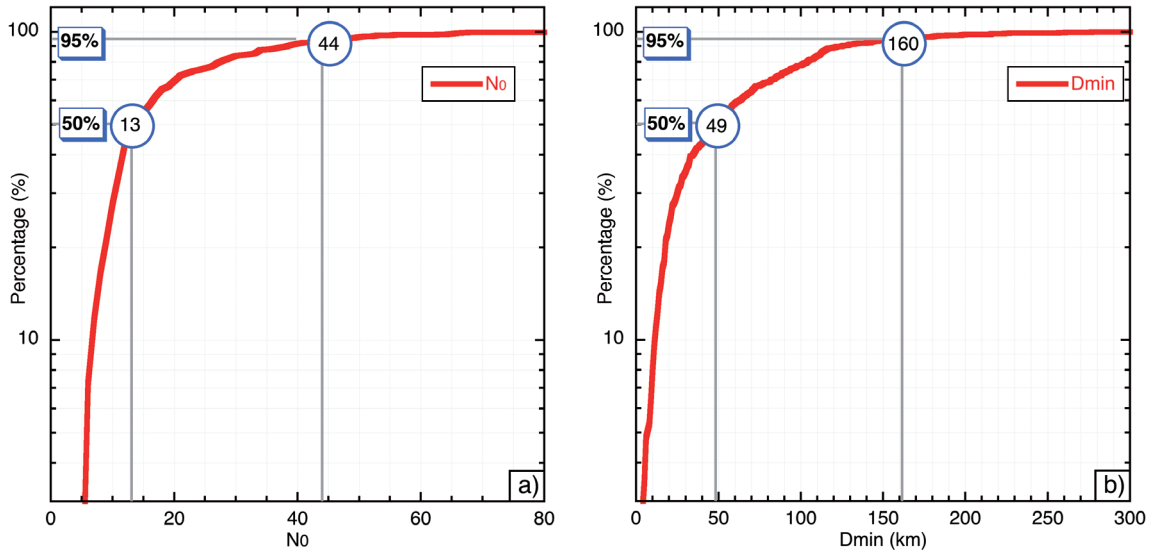

Fig. 8 - Statistical distribution for the 375 relocated events in the period October 30, 1901 - May 5, 1976: a) number of station readings used in locating earthquakes (No); b) horizontal distance from the epicentre to the nearest station (Dmin) in km.

The range of the horizontal distances from the epicentre to the nearest station in km (Dmin) is from 0.2 to 277 km (this last in the case of the October 5, 1963 event). In general, the smaller this number the more reliable the calculated depth of the earthquake. The median distance is 49 km and 51% of the whole database has an epicentre distance within 50 km (Fig. 8b).

The largest azimuthal gap between azimuthally adjacent stations in degrees (Gap) is within 180° for 83% of the readings, the range being from 35° to 332° (Fig. 9a). In general, the smaller this number, the more reliable the calculated horizontal position of the earthquake. Earthquake locations with an azimuthal gap larger than 180° typically have large Erh and Erz values (although exceptions are also numerous in our own database). According to Fig. 9b Gap has not diminished in more recent years.

4. Results

Three hundred and seventy-five events recorded by the Trieste station fall within the selected study area (box in Fig. 4). The earliest event in our data set dates from October 30, 1901 which we located near Desenzano del Garda on the southern shore of Lake Garda. In this area we have located two other events: one of April 25, 1907 (San Benedetto Po, near Mantua) and one of July 19, 1918 (Piadena, near Cremona). In the first two decades of the last century three events occurred in the Friuli region: that of July 2, 1907 (Zuglio, in Carnia, i.e., northern part of Friuli), that of July 10, 1908 (Moggio Udinese, in Carnia) and that of May 5, 1920 (Premariacco, near Udine). Two events occurred in the Kvarner Gulf (Croatia), on September 16, 1904 and March 12, 1916. Two events occurred in Slovenia, on March 10, 1904 (Bohinj Lake) and on August 13, 1918 (Cerknica). Completing the list is the event of April 20, 1907 which occurred in Rumo, west of Bolzano, and the event of February 19, 1918 which happened at Delnice, east of Rijeka

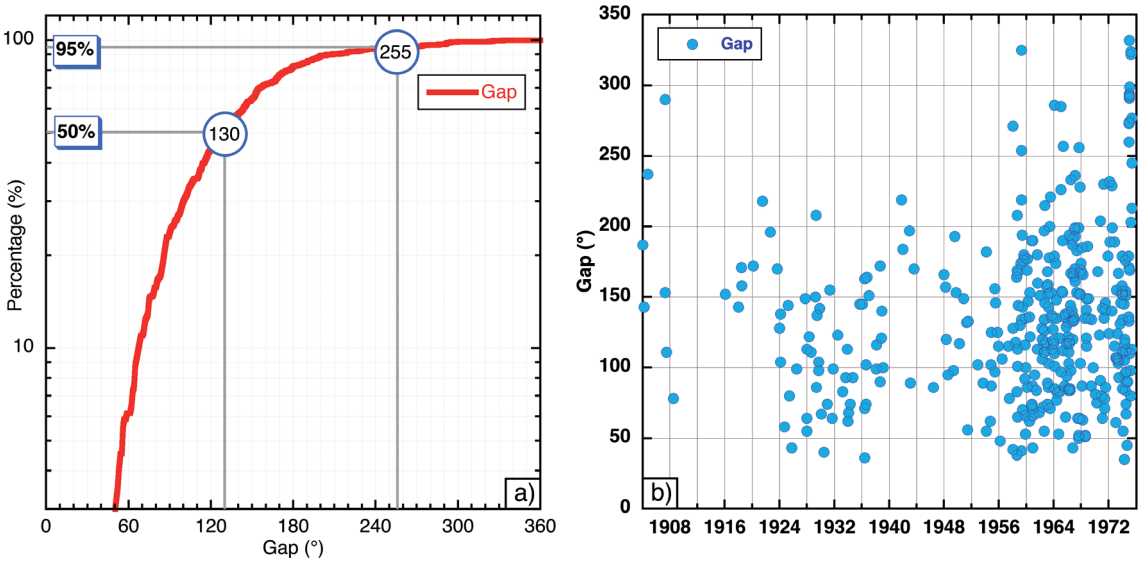

Fig. 9 - Largest azimuthal gap between azimuthally adjacent stations, in degrees, for the 375 relocated events in the period October 30, 1901 - May 5, 1976: a) statistical distribution; b) individual value vs. time.

(Croatia). Looking at Fig. 4 in detail, there are three main clusters of seismicity. Starting from the east, a quite evident group of seismic events characterizes central Slovenia, near Ljubljana and its surroundings. To the south, the past seismic activity is concentrated in the Ilirska Bistrica - Sneznik Mt. area (north of Rijeka), with events along a line that we could draw to the south up to the Krk Island (Croatia), and to the north close to Postojna (Slovenia) and still further north, near the Italian border, in the Bohinj area (Slovenia). The only clear cluster of events in Italy is located mainly along the pre-Alpine arc across the Friuli-Venezia Giulia and Veneto regions. Sparse seismicity characterizes other areas both in Italy and Austria.

4.1. Comparison with macroseismic locations

When considering earthquakes of the early 20th century, account has to be taken that the findings in official catalogues are essentially based on macroseismic intensity observations. One of the most important benchmarks in this field is the Catalogo Parametrico dei Terremoti Italiani [CPTI: Gruppo di Lavoro CPTI (1999, 2004), Rovida *et al.* (2011)]. We, however, also considered other catalogues and their bibliographic references, as reported in the Appendix, along with related epicentral macroseismic intensity (MCS scale). Even if instrumental and macroseismic epicentres are not the same in terms of quantity, generally speaking the closer the experimental hypocentral location is to the macroseismic one, the better the result. The usefulness of instrumental locations, in particular for older earthquakes, is to support and complement the macroseismic data (Solarino, 2005) and, if the macroseismic data are poor, to be used in their stead. This, however, provided that the instrumental data have been carefully checked and are deemed reliable on assessing the associated errors. One thing that should not be underestimated is that they may provide information on the depth of the events which cannot be easily derived from the macroseismic data.

We recovered the macroseismic epicentral determination for 196 earthquakes in our data set: 36% of the records have a difference between the two locations of less than 20 km. The map in

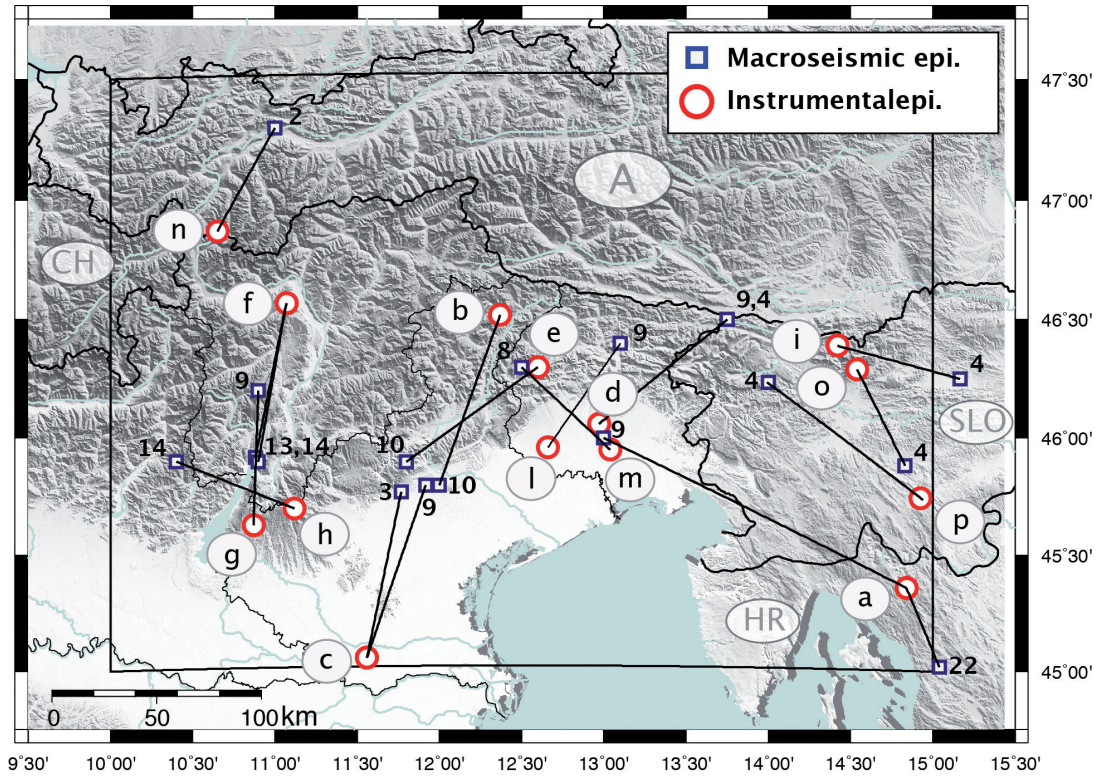

Fig. 10 - Distances between macroseismic (blue square) and instrumental (red circle) epicentres for the following earthquakes: a = 1918/02/19; b = 1927/12/31; c = 1921/09/12; d = 1944/02/11; e = 1929/08/19; f = 1942/06/20; g = 1975/06/01; h = 1948/07/17; i = 1961/04/05; l = 1950/02/20; m = 1935/01/17; n = 1951/06/07; o = 1964/06/04; p = 1964/11/07. The bibliographic reference of the macroseismic epicentre is the same as reported in the Appendix.

Fig. 10 shows 14 cases (7.5%) where the distance between the two epicentres is greater than 50 km. If there were two bibliographic sources for the macroseismic location, the average value was taken and reported in the Appendix. In the case of those few cases (a total of 8) where there were large discrepancies (distances greater than 10 km between the two macroseismic locations taken from literature) the lesser of the two has been reported (indicated with an asterisk alongside the reference number) with respect to the instrumental epicentre. Noteworthy is the case of the event of February 19, 1918 with I_0 of VI (a in Fig. 10 with reference number according to the Appendix) localized according to Postpischl (1985) at the centre of the Friuli-Venezia Giulia region, and in NW Croatia according to Herak *et al.* (1996) being respectively 160 km and 41 km from the instrumental location obtained in the present work. A distance greater than 20 km between the two macroseismic locations is listed for the following events: July 19, 1918 (31 km), April 14, 1931 (28 km), and July 7, 1938 (23 km). With the exception of the second, whose macroseismic epicentre was determined with 160 points of macroseismic intensities (CPTI), the other two both have a low macroseismic intensity value (equal to IV and V MCS respectively) obtained from the limited number of intensity points available (8 and 7 respectively).

The case with the greatest absolute difference between instrumental and macroseismic epicentre is that of the earthquake of December 31, 1927 (b in Fig. 10) with a difference between the two locations of 85 km. After a detailed analysis, whilst considering the macroseismic epicentre as a

reference point in locating the instrumental one, a better convergence between the two locations has not been achieved. The instrumental location obtained is, then, the best possible, even though unsatisfactory, with the 8 available phase readings (CHU, INN, RAV, STR, VEN, ZAG, and ZUR) with the nearest station (INN) at a distance of 111 km.

For the earthquake of September 12, 1921 (c in Fig. 10) the distance between the instrumental and macroseismic locations is 84 km. The number of phases used for the instrumental localization was very limited at just 5, and the focal depth was fixed at 7 km. This was a small event and the associated epicentral intensity is IV, with only 3 macroseismic points available. The events of April 4, 1961 (i in Fig. 10) and June 4, 1964 (o in Fig. 10) also had an intensity of IV and the distance between the two locations is 60 km and 51 km, respectively.

As regards the earthquakes of February 11, 1944, of August 19, 1929, and of June 20, 1942 with respective distances of 78 km, 76 km and 75 km from the macroseismic epicentre (d, e, and f in Fig. 10), the instrumental localization was obtained using very few phase readings (5 and 6 for the first two). The uncertainties in the results can be clearly seen on looking at the horizontal and vertical errors; both are greater than 15 km, as already reported in paragraph 3.2. The epicentre determination of the events of July 17, 1948 (h in Fig. 10) and of February 20, 1950 (l in Fig. 10) (distance of 60 km for both) also has horizontal and vertical errors greater than 10 km (with 7 and 10 phase readings used for the location). The macroseismic epicentre of the June 1, 1975 event (g in Fig. 10) is 64 km away from the instrumental one, which is however close to that reported in the ISC bulletin (8 km away).

We can say in overall terms that, as it could be expected, there is an excellent convergence of instrumental localizations with macroseismic localizations when the data from both parts are plentiful. When the number of phases or the number of stations used is very limited, or where azimuthal coverage is not optimal, the resulting instrumental localizations are penalized. On the other hand, a macroseismic localization of an event below the threshold of damage and/or where there are few points of macroseismic observation available cannot be considered optimal.

4.2. Comparison with instrumental locations

Further analysis has been carried out to consider the available ISC instrumental locations for the earthquakes investigated in the present study. We have identified 105 common events for which a comparative analysis on certain parameters, such as Rms, Gap, and Dmin, is possible.

Considering the kilometric distance between the two epicentres, Fig 11a shows that there are some considerable differences between the events of the 1960s (even up to 90 km for the events of November 7, 1964, September 1, 1966 and December 13, 1968). Coming to more recent times, the difference is limited to a range of 20 km, with a trend (the red line in Fig. 11a, which is a simple linear fit) towards net decline.

In term of azimuthal coverage, the quality of the locations in the two databases seems to be equivalent (Fig. 11b) while, as regards the distance of the nearest station used for the location (Fig. 11c), it appears clear that in the first 30 to 50 km band there is a strong imbalance to the detriment of the ISC database. The Rms figure is that which is certainly most meaningful for describing the quality of our locations (Fig. 11d). As previously reported, 99% of our locations have an Rms equal to, or less than, 1.5 s, with only 3 cases with an Rms above 2 s, including the June 22, 1968 event (red square in Fig. 11d). The ISC locations, on the other hand, show much larger values.

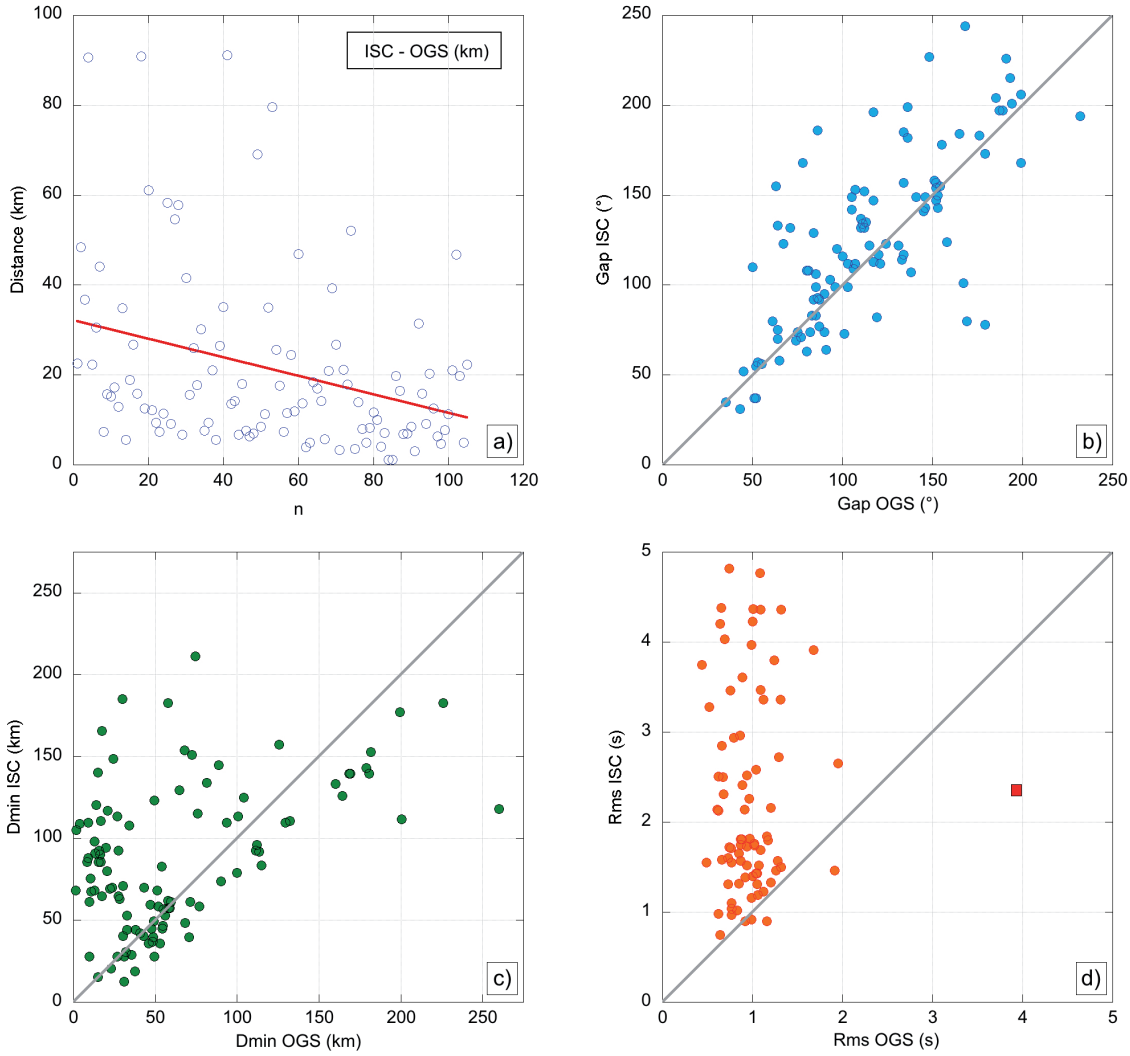

Fig. 11 - Comparison between 105 instrumental locations in common with the ISC database: a) distance between the two locations in km (the red line is a simple linear fit); b) azimuthal coverage in degrees (Gap); c) nearest station in km (Dmin); d) Rms in seconds.

5. Signal processing of the Wiechert recordings

More detailed investigation has been carried out in the case of a few events with the aim of extracting as much information as possible and also to attempt to recover waveforms, with inquiries being made at the SEISMOS databank (Michelini *et al.,* 2005). We selected events in order to share the regions included in the HAREIA project, Friuli-Venezia Giulia, Veneto, Trentino-Alto Adige (all in Italy), and Tyrol (Austria). The initial list of earthquakes was: that of March 26, 1924 (17:08, M_W = 5.07, I_0 = VI-VII) Vipiteno; February 19, 1932 (12:57, M_W = 5.02, I_0 = VII-VIII) Monte Baldo; July 24, 1943 (01:44, M_W = 5.2, I_0 = VII) Valdobbiadene, February 20, 1950 (01:55, M_W = 4.43, I_0 = V-VI) Amaro; July 23, 1955 (03:54, M_W = 4.56, I_0 = VI) Maniago; January 31, 1956 (02:25, M_W = 5.13, I_0 = VII) Ilirska Bistrica; April 26, 1959 (14:45, M_W = 5.23,

I_0 = VII-VIII) Carnia; March 18, 1964 (16:43, M_W = 4.77, I_0 = VI) Ilirska Bistrica. All magnitudes are from CPTI and intensities from the Appendix.

As regards the Vipiteno event we retrieved only the waveforms of the station of Messina and of Porto di Capri but they were not utilizable (the trace was not clear). We obtained no information from the waveform databank about the Monte Baldo earthquake. Also in the cases of the Valdobbiadene and Amaro events we obtained the waveform of the Wiechert instruments of Bologna and Padova stations, but the quality was poor. The same applied to those of the Oropa observatory recordings in the case of the Maniago earthquake. The traces were, however, good for the January 31, 1956 event (Fig. 12 top) recorded by the Göttingen (GTT; see Fig. 13) and Strasbourg (STR) stations. Unfortunately the Wiechert recordings of the Trieste station were saturated. For the April 26, 1959 Carnia earthquake (Fig. 12 bottom) good signals were

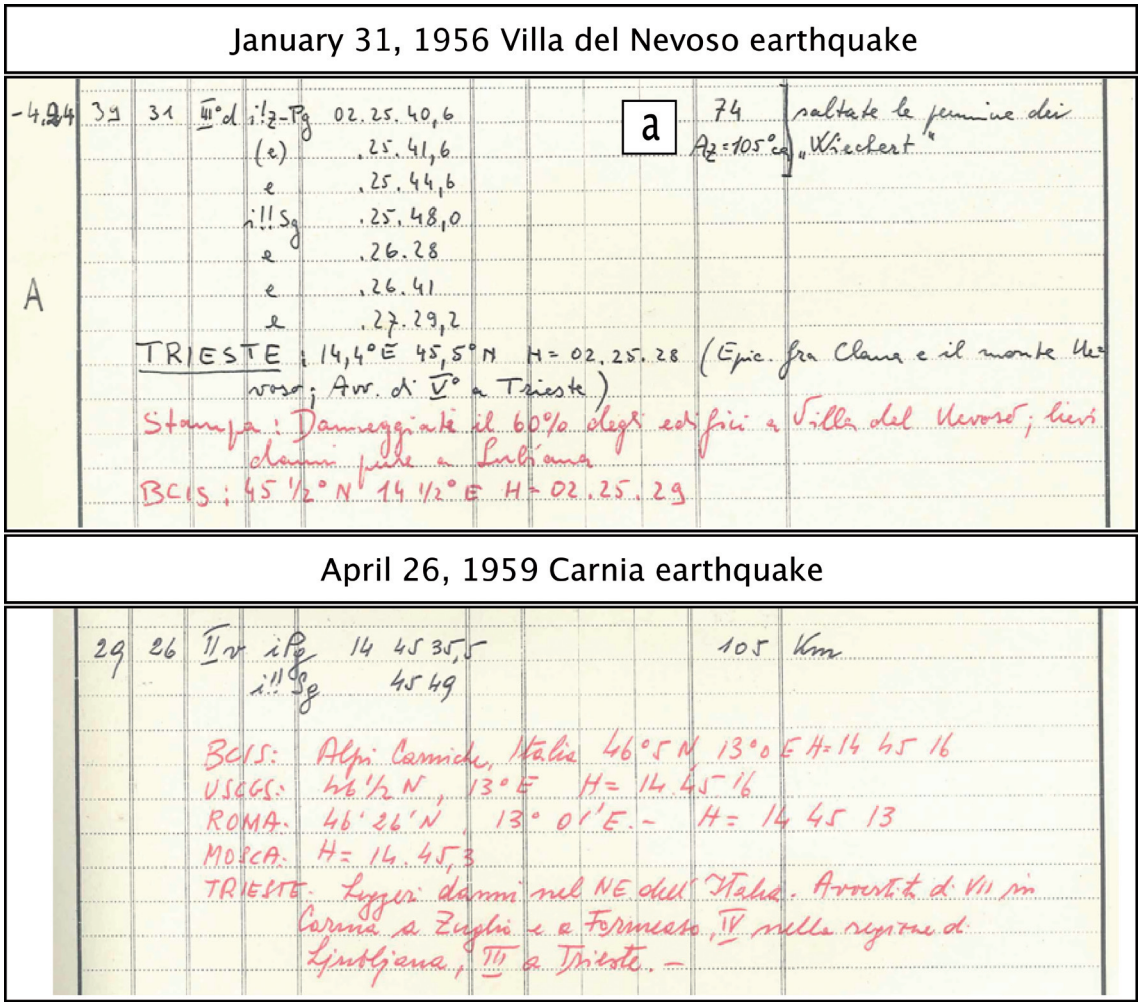

Fig. 12 - Scan of the Trieste station bulletins: January 31, 1956 Ilirska Bistrica (Villa del Nevoso in Italian) earthquake (top panel). Attached to the event page there were clippings from the local newspaper that refer to the note at the top right (a) about the nibs skipping: "…the shock was violent that the equipment could not resist, the diagram of the seismograph, in fact, after four short-term fluctuations marks an abrupt halt". April 26, 1959 Carnia earthquake (bottom panel).

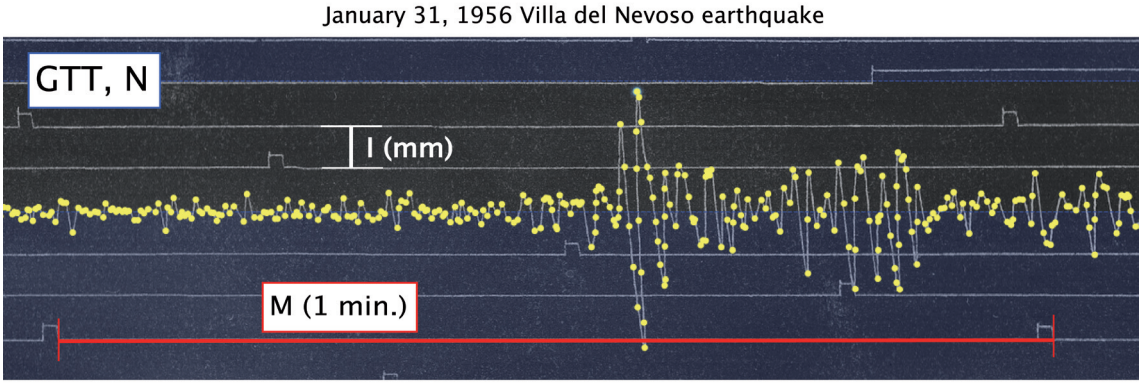

Fig. 13 - Illustration of the digitization procedure for the N-S component of the seismogram of the January 31, 1956 Ilirska Bistrica (Villa del Nevoso in Italian) earthquake, recorded at the GTT station. In the background, the scanned image of a portion of the original smoked paper record; in blue the reference system selected according to the minute marks (M) and the distance between two traces (I). In yellow the sampling points (not equally spaced).

recorded by the Pavia and Bologna stations (Fig. 14), while the traces of the Vienna station had an interruption, one component of the Trieste station was not clear (the second not visible). We obtained information on the March 18, 1964 Karst earthquake directly from the LJU station and we achieved a photographic image of the Wiechert recordings (Fig. 15).

5.1. Data available

The previous description shows that there is only sufficient data for only 3 earthquakes to justify deeper analysis.

The information related to the January 31, 1956 (02:25 UTC) event is very poor in the literature. The Italian macroseismic database DBMI04 (Stucchi *et al.*, 2007; http://emidius.mi.ingv.it/DBMI04/) reports the macroseismic intensities, according to the MCS scale only for the following 7 localities: Muggia and Ruda with *I*=V, Trieste with *I*=IV-V, Duino-Aurisina, Grado, Monrupino

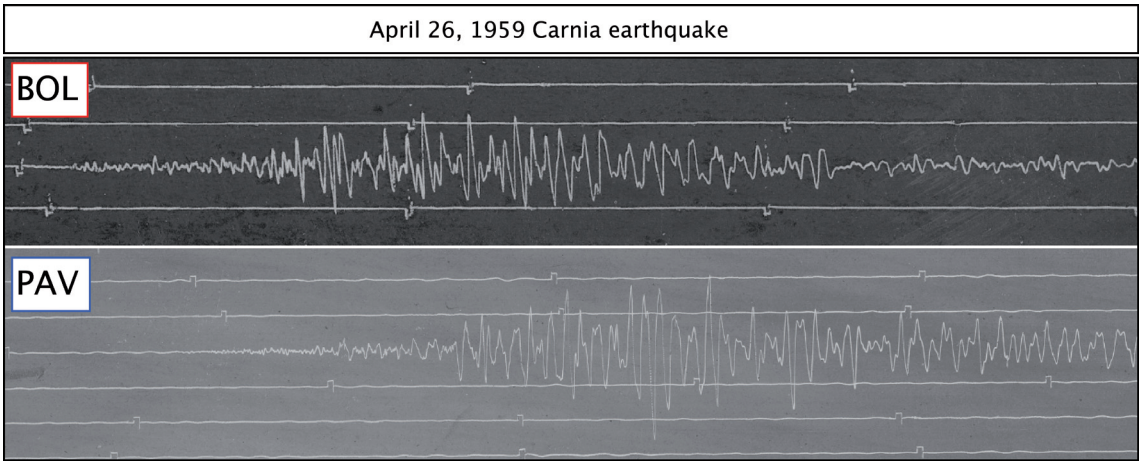

Fig. 14 - April 26, 1959 Carnia earthquake: portion of the scan image of the Wiechert seismogram recorded by the BOL and PAV stations.

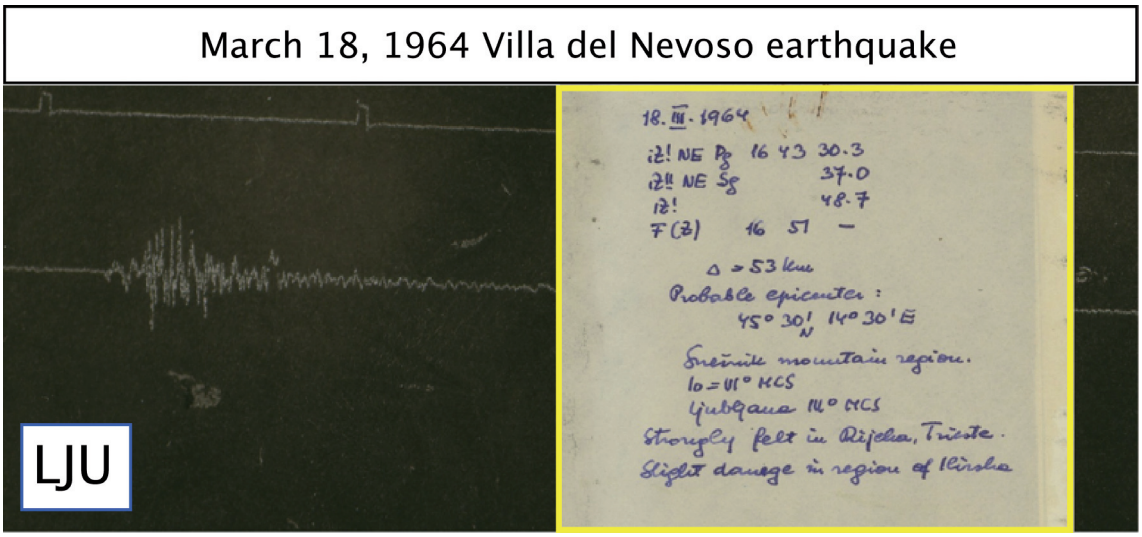

Fig. 15 - Scan of one of the two components of the photographic Wiechert seismogram of the March 18, 1964 Ilirska Bistrica (Villa del Nevoso in Italian) event recorded at the LJU station (courtesy of Ina Cecić). On the right there is a handwritten note with some earthquake parameters.

(Zolla), and San Dorligo della Valle with *I*=IV. The macroseismic location (CPTI) is 45°33'00" N and 14°16'59" E and, due to the few intensity data points it is equal to the instrumental location. The Trieste station ledger (Fig. 12 top) reports that 60% of the buildings in Ilirska Bistrica (Villa del Nevoso in Italian) were damaged and some damage was also suffered in Ljubljana. A local newspaper reported: "In Ilirska Bistrica … many houses have suffered damage, the major damage is found in the neighbouring villages, where around 95% of houses are damaged" and "the violent shock caused the breaking of water pipes in Ljubljana" (press clippings attached to the TRS station bulletin event page). The localization computed at the TRS station is 45°30' N and 14°24' E; it is reported in its ledger together with that by the Bureau Central International de Sismologie (BCIS): 45°30' N and 14°30' E (Fig. 12). As regards the magnitude, three figures are available: i) the moment magnitude derived from the macroseismic data (CPTI) M_{WM}=5.14 (±0.34); ii) the moment magnitude derived from the value of M_S (CPTI) M_{WIns}=5.12 (±0.37); and iii) the measured value of M_S=4.73 (±0.53) provided by Margottini *et al.* (1993a) based on 4 recordings. In the Slovenian earthquake catalogue (Ribarič, 1982) the event is located at 45°30' N and 14°16'59" E, the reported epicentral intensity is VII MKS and the macroseismic magnitude is 4.48. According to the relocation of the present study the epicentre is 45°34'48'' N 14°16'48'' E, with a distance of 3.3 km with respect to the macroseismic location. The focal depth is 17.6 km. The distance from the epicentre to the nearest station (TRS, whose coordinates are 45°42.5' N 13°45.8' E) is 40.7 km (the azimuthal gap being 97°). Rms is 0.84 s, while Erh and Erz are 1.6 and 2.1 km, respectively.

As regards the April 26, 1959 (15:45 UTC) Carnia event the macroseismic location (CPTI) is 46°29'02" N and 13°01'17" E. The TRS station ledger (Fig. 12 bottom) reports several locations: 46°26' N and 13°01' E by the Istituto Nazionale di Geofisica (ROMA in Fig. 12 bottom), 46°30' N and 13°00' E by both BCIS and U.S. Coast and Geodetic Survey (USCGS). In the Italian macroseismic database DBMI11 [Locati *et al.* (2011); http://emidius.mi.ingv.it/DBMI11/], 122 macroseismic intensities are reported, the maximum values are: Zuglio with *I*=VIII, Formeaso, Paluzza, Sezza with *I*=VII-VIII. The M_W (both M_{WM} and M_{WIns}) is 5.23 (±0.13) (Gruppo di Lavoro

CPTI) and the measured value of M_S based on 12 recordings is 4.89 (±0.26), provided by Margottini *et al*. (1993a). The epicentre according to the present study is 46°24'36'' N and 12°59'24'' E, 8.1 km distant from the macroseismic location. The focal depth is 6.6 km, the nearest station (45°42.5' N 13°45.8' E, ENEL station of Tolmezzo) is only 2.2 km distant (the gap being 38°). Rms is 0.91 s, while Erh and Erz are 1.7 and 1.3 km, respectively.

A hand written note received from the staff of the LJU station (Fig. 15) testifies that the March 18, 1964 event was "strongly felt in Rijeka and Trieste" while "slight damage in the region of Ilirska" was observed. In DBMI11 (Locati *et al*., 2011) the macroseismic intensities for only two localities are reported: Ljubljana with *I*=III and Trieste with *I*=VI-VII. The epicentre location reported in CPTI is 45°32'24" N and 14°21'00" E, the same reported in the ISC bulletin as received from the LJU station. Other locations reported in the ISC bulletin are: 45°25'12" N and 14°19'48" E by the Seismological Survey of Serbia (BEO), 45°30' N and 14°30' E by BCIS and 45°42' N and 14°06' E by USCGS. M_{WIns} reported in CPTI is 4.77 (±0.22) and, according to Margottini *et al*. (1993a), M_S is 4.47 (±0.45) and m_b 4.4 (±0.21). The value 4.6 for m_b by USCGS is also reported in the ISC bulletin while an M_L of 4.9 is reported for the LJU station (based on 6 data) in Ribarič (1982). The relocation according to this study put the epicentre at 45°35'24" N 14°18'00" E, that is close to the CPTI location (6 km apart from each other). The focal depth is 13.1 km, Rms is 0.72 s, while Erh and Erz are 1.1 and 1.5 km, respectively, the azimuthal gap being 71°.

5.2. Station parameters

Almost all European seismographic stations were equipped with Wiechert seismographs during the first half of the 20th century [also the TRS station in the city centre had a vertical and a horizontal ones since 1931]. The horizontal seismograph consisted of an inverted pendulum with a heavy mass (1000 kg in the case of the TRS instrument), with two degrees of play, enabling the simultaneous recording of two horizontal components (usually oriented N–S and E–W). The amplification adjustment is mechanical, uses connecting rod and lever and is separated for each component. Its value was generally variable from 150 to 250 for the 1000 kg instrument (Table 2). The partially adjustable natural period varies between 9 and 15 s. The seismic signal was recorded on smoked paper. Generally the paper was placed on a cylinder of 6 cm in diameter, moving at a velocity adjustable from 10 to 30 mm/min.

Before processing the seismograms we tried to obtain all the basic characteristics of the instruments at the time of the earthquake analysed, particularly the degree of amplification. Most of these parameters were available and were found in the literature, though unfortunately not for the operational period of the station when the earthquakes occurred. In the case of GTT and STR stations, we found different but very similar series of parameters (Table 2). We specifically tested the impact of using one or the other and found out that an arbitrary choice does not influence the results appreciably. In this regard, since our aim was M_W estimation, we calculated the displacement spectrum on the E-W component of the GTT station considering the instrument magnification factor from 100 to 200 at regular intervals of 10. While keeping the other parameters fixed, the resulting M_W values had a maximum variation of 0.2 in the range considered. We adopted an average magnification value of 150 times (and 230 for the STR station).

The stations of Bologna (BOL) and Pavia (PAV), both active from 1901 to 1976, were part of the network of observatories managed by the Istituto Nazionale di Geofisica (ING), all of which

Table 2 - Station parameters: D = epicentral distance; G = Wiechert amplification factor; $T_0(s)$ = free period; ε = damping; M = minute length on the original paper; I = distance between two traces on the original paper; $W(s)$ = time window of the signal trace digitized.

Station	Earthquake	D (km)	G	$T_0(s)$	ε	Comp.	M(mm)	I(mm)	W(s)
GTT	Jan. 31, 1956	753	179[a], 157[b], 164[c] 164[a], 147[b], 159[c]	14.5[a],11.7[b],10.1[c] 14.0[a],11.7[b],10.2[c]	0.40[b] 0.35[b]	E-W N-S	59.6 59.6	2.9 2.7	300 240
STR	Jan. 31, 1956	595	202.5[a], 248[a], 230[b]	10.1[a] 10.15[a],10.0[b]	- 0.35[b]	E-W N-S	15.0 15.0	4.2 4.0	600 420
PAV	Apr. 26, 1959	331	150[d] 150[d]	~3 ~3	- -	I II	30.6 30.6	3.0 2.8	420 600
BOL	Apr. 26, 1959	258	150[d] 150[d]	~3 ~3	- -	I II	27.9 27.9	3.1 2.9	360 300
LJU	Mar. 18, 1964	53	60[e] 60[e]	- -	- -	I II	16.2 16.2	6.0 6.0	120 120

[a] = Schlupp and Cisternas (2007); [b] = Baroux *et al.* (2003); [c] = Ritter (2002); [d] = Caloi (1955); [e] = Zivcić personal communication.

were equipped with the same instruments, including two 200 kg horizontal Wiechert seismographs and one 1300 kg vertical Wiechert seismograph (Giovani, 2007). The instrumental constants were almost everywhere identical with a magnification factor of 150 (Caloi, 1955). We used this value as it was not possible to obtain the precise individual instrument magnification value.

The LJU station was also equipped with a Wiechert seismometer. Its magnification values in 1964 were 61 for the N-S component and 57 for the E-W one along with a length of the minute of 16.2 mm, the line spacing of 6 mm, and the peak-to-peak amplitude of 3.2 mm, while the maximum amplitude (peak to zero) was 2 mm (Zivcić, personal communication). A magnification value of 60 times was adopted for the LJU station because the two components were not identified.

5.3. Signal digitization and M_W estimation

Historical seismograms contain a huge amount of useful information for the study of past earthquakes. However, recovering seismic information contained in old analogue records is not an easy task, especially in view of the generally poor quality of the original records with their illegible or missing parts. In some cases, the quality of the image (the original seismogram was recorded on smoked paper) is very good and we carried on digitizing the seismic records. We used the software for seismogram digitization and vectorization named Teseo2 (Pintore *et al.*, 2005) developed under the project SISMOS (Michelini *et al.*, 2005). This applies the due corrections according to the type of recording. Images produced by SISMOS have usually a resolution of 1016 dpi with 256 grey levels, while plain TIFF is the standard format used to store these images.

Choosing the reference system and taking into account the length of the minute as well as the line spacing on the original paper (Table 2), the digitization procedure consists extracting the sample sequence directly from the image and then converting the horizontal and vertical coordinates (x, y) into time and amplitude scales (Fig. 13).

A FORTRAN77 program was developed for the interpolation of the signal. We chose to resample all the digitized traces with a common sampling step of 0.1 s. For each seismogram we

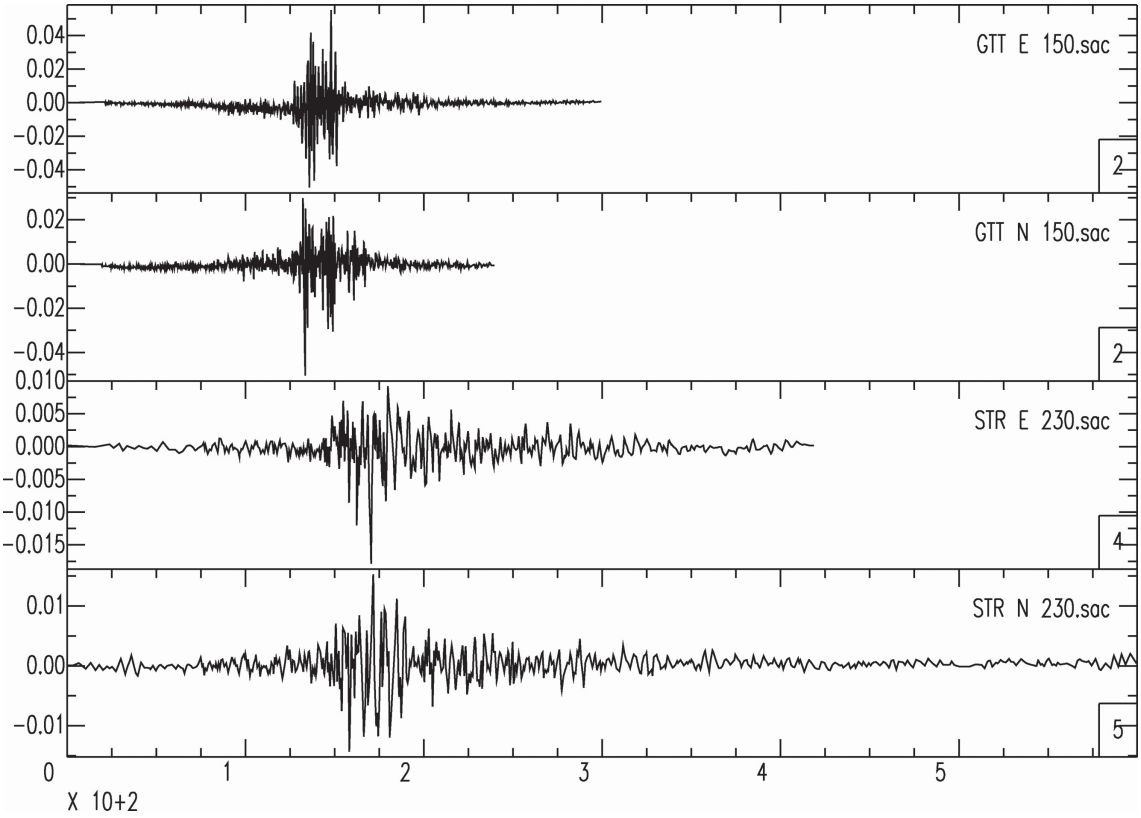

Fig. 16 - January 31, 1956 Ilirska Bistrica (Villa del Nevoso in Italian) earthquake: seismograms digitized, interpolated and scaled according to the instrumental magnification. From top to bottom, respectively: E-W and N-S components of the Wiechert recordings of the GTT station (magnification = 150) and E-W and N-S component of the Wiechert recordings of the STR station (magnification = 230).

chose a time window long enough to contain the first arrival and the tail until oscillation was no longer apparent (Table 2). The zero-mean baseline correction was applied to the final seismogram together with a band pass filter in the range 0.1 – 25 Hz (Fig. 16). When the N-S component could not be distinguished from the E-W component we called them respectively the first (the top one in the original record) and the second horizontal component.

Digitized analogue records may be used for further waveform analysis to estimate, for instance, such characteristics of the seismic source as the seismic moment (M_0) and, consequently, M_W. The estimation of these parameters should, if possible, be performed using several records of the same earthquake. However, in the case of historical earthquakes, where it is not easy to collect several digitized records, it has at times been necessary to proceed to the parameter estimate using just one seismogram.

The displacement spectra of all the digitized traces (Fig. 17) were computed for both horizontal components. As some parameters of several stations (Table 2) needed for computing the instrumental response, the spectra have been corrected for the gain amplification only. These spectra were, then, used to estimate the seismic source parameters [according to the Brune (1970)

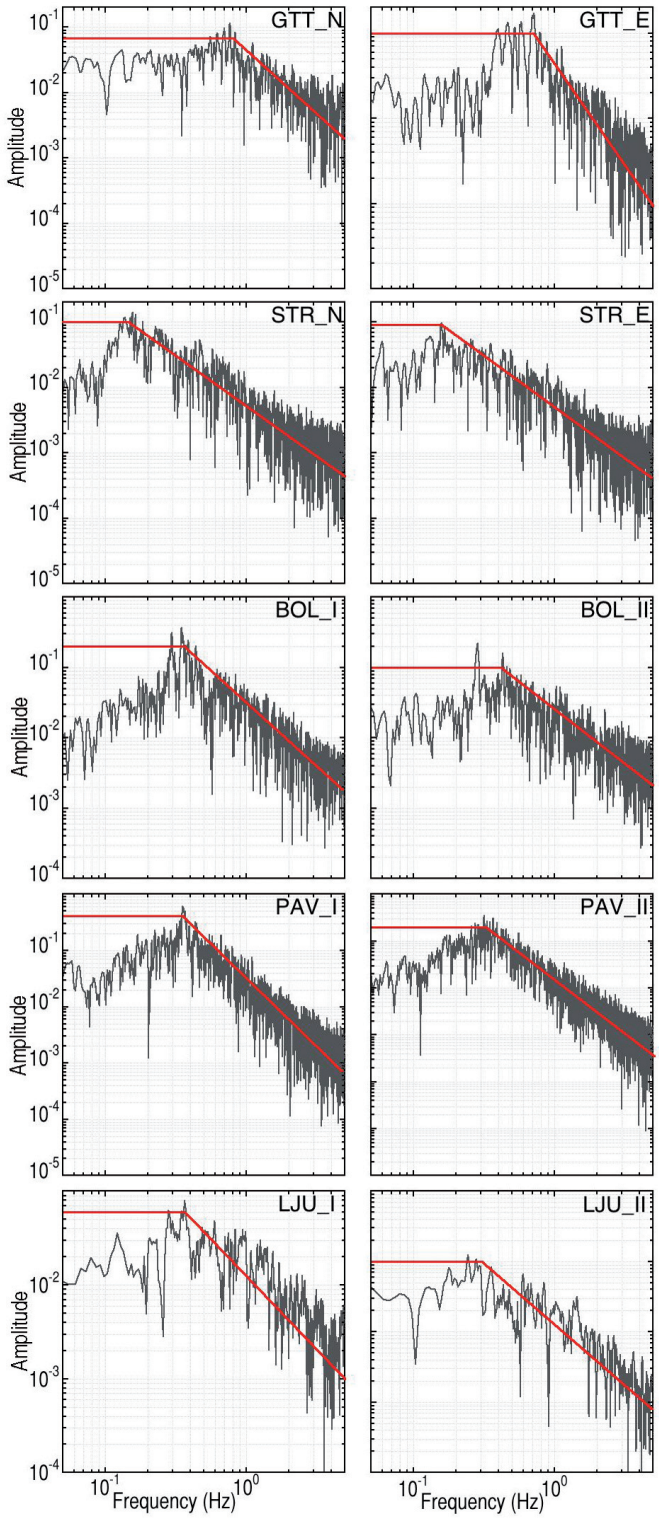

Fig. 17 - Displacement spectra for the ten digitized traces, from left top to right bottom: N-S and E-W components of GTT and STR stations of the January 31, 1956 Ilirska Bistrica (Villa del Nevoso in Italian) earthquake; I and II component of BOL and PAV stations of the April 26, 1959 Carnia earthquake; I and II component of LJU station of the March 18, 1964 Ilirska Bistrica earthquake. The spectra have been corrected for the gain amplification only.

model]. Using the spectral amplitude for 0 Hz (Ω_0), under the assumption of a homogeneous Earth model and constant S-wave velocity β, M_0 can be determined from the relationship:

$$M_0 = 4\pi r \varrho \beta^3 \Omega_0 \quad (1)$$

where r is the epicentre distance and ϱ is the Earth density. We have assumed ϱ=2700 kg/m^3 and β=3300 m/s.

M_W can be, then, estimated using the following empirical relation (Hanks and Kanamori, 1979)**:**

$$M_W = \frac{2}{3} \log M_0 - 10.7. \quad (2)$$

Table 3 summarises the source parameters obtained from the seismograms, and the associated M_W for the earthquake.

Table 3 - Source parameters: Ω_0 = spectral amplitude for 0 Hz; f_c = corner frequency; M_0 = seismic moment; M_W = moment magnitude. Comp. stands for the horizontal component of the seismogram: N = north, E = east, I and II = undefined.

Year	Comp.	Ω_0 (mm s)	f_c (Hz)	M_0 (Nm)	M_W
1956	GTT E	0.10	0.70	8.96 x 10^{16}	5.27
1956	GTT N	0.07	0.80	6.27 x 10^{16}	5.16
1956	STR E	0.09	0.15	6.35 x 10^{16}	5.18
1956	STR N	0.10	0.15	7.25 x 10^{16}	5.21
1959	PAV I	0.40	0.35	1.21 x 10^{17}	5.44
1959	PAV II	0.30	0.30	8.07 x 10^{16}	5.36
1959	BOL I	0.20	0.35	6.29 x 10^{16}	5.17
1959	BOL II	0.10	0.40	6.29 x 10^{16}	4.97
1964	LJU I	0.06	0.30	3.87 × 10^{15}	4.36
1964	LJU II	0.10	0.30	6.46 × 10^{15}	4.51

5.4. Discussion

As already stated above, the only instrumentally measured magnitude for the analyzed earthquakes was the M_S provided by Margottini *et al*. (1993a, 1993b).

The value reported for the January 31, 1956 earthquake is M_S=4.73 (±0.53) based on 4 recordings. Our estimated M_W is 5.20, as average value of the four values obtained from the analysis of the displacement spectra of the GTT and STR stations (Table 3); this represents a slight overestimation of M_W=5.13 reported in CPTI. Using an orthogonal regression between M_S and M_L (Ambraseys, 1990), we obtain the value 4.85 for M_L. As M_L should be in agreement (even

equivalent) with M_W in the magnitude range 4.0 to 6.0 (Kanamori, 1983), our estimate is, once again 0.35 higher.

The M_S of the April 26, 1959 earthquake is 4.89 (±0.26), based on 12 recordings (Margottini *et al.*, 1993a). In the same paper, for the sake of completeness, m_B=5.6, based on 1 recording is also reported. The average value calculated in this study is M_W=5.24 (Table 3): it is perfectly consistent with the 5.23 reported in CPTI, while, by applying the scaling law between M_S and M_L (Ambraseys, 1990), the lower value 4.97 for M_L (equivalent to M_W) is obtained. By applying a double transformation [m_B to m_b and then m_b to M_L; Ambraseys (1990)], from m_B=5.6 we obtain a value of M_L of 5.12, slightly lower than the M_W value calculated in this study.

For the March 18, 1964 earthquake, Margottini *et al.* (1993a) report the values M_S=4.47 (±0.45) and m_b=4.40 (±0.21), based on 3 and 4 recordings, respectively, and the value M_L=4.65 is obtained by applying the Ambraseys (1990) formula. We recomputed the duration of the recordings of the two horizontal Benioff short-period components of the TRI station (both about 452 s). Applying the formula by Rebez *et al.* (1984) we obtained a value of M_D of 4.53. With the Gasperini (2002) regression formula between M_D and M_L, calibrated for the whole of the Italian territory, we obtained M_L=4.53 and 4.63, taking into account whether or not the correction station, respectively. Our M_W of 4.44 (Table 3) seems to be an underestimation with respect the value M_W=4.77 reported in CPTI.

6. Conclusions

A review was carried out of the data recorded by the Trieste station before the occurrence of the strong May 6, 1976 Friuli earthquake. A catalogue of 375 records is our complete and definitive database for the early instrumental seismicity in north-eastern Italy from October 30, 1901 to May 5, 1976 (the day before the strong Friuli earthquake). This result has been obtained after long and careful re-reading of old seismograms found in archives of the research and religious institutions. Data comes from 1) a second reading of the seismic phases, 2) bulletins of seismological stations, and 3) ISC bulletins. The catalogue cannot in any case be considered a complete data set for the seismicity of the eastern Alps because events not recorded by the Trieste station have not been considered in the processing that has been carried out. A complete data set should also take into account local events recorded only by Austrian and/or Slovenian stations.

The digitization of analogue historical seismograms allowed us to recover seismic information contained in old records. This is particularly important in zones with a low to moderate seismicity associated with seismogenic sources with medium to long recurrence intervals. In addition to this, digitized records can be included in a database of old seismograms so that they can be used by several researchers. They will improve the studies about the spectral characteristics and the source parameters of less active sources, permitting comparison with recent results (where they exist).

The estimation of the seismic moment for old earthquakes still presents large uncertainties, in particular for those in the first quarter of the 20th century, due to the reduced number (and often the poor quality) of available seismograms.

These kinds of studies should however be persisted with because they provide a useful contribution to the improvement of seismic hazard assessment in many regions of the world. To prove this, the estimated M_W that obtained for the three earthquakes analyzed, dating the second

half of the 20th century, are fully comparable with the data available. This even though there is still discussion on M_0 evaluation as well as between the different magnitude scales even for recent instrumental earthquakes.

Acknowledgements. Many thanks are due to Ina Cecić and Mladen Zivcić, Agencija RS za Okolje Ljubljana, who provided us with the information on the March 18, 1964 earthquake recorded in Ljubljana and on the Wiechert seismograph, as well also to Graziano Ferrari, I.N.G.V. Rome, who provided us with the SISMOS seismograms. The paper benefited by a painstaking review accomplished by Mladen Zivcić and an anonymous referee and by the careful control of the English text done by Giorgia Rivoira, OGS.

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Appendix
Earthquake catalogue

Legend: Y = year; M = month; D = day; H = hour; Mi = minute; S = second; Lat = latitude (°N); Lon = longitude (°E); *h* = hypocentral depth (km; * = fixed); $M^{(S, b, L)}$ = magnitude (Ms, mb, M_L); RM = bibliografic reference for magnitude: [a] = Margottini *et al*. (1991); [b] = Margottini *et al*. (1993a); [c] = Karnik (1969, 1972); [d] = ISC catalogue (1916 - 1976); [e] = CPTI (2004, 2011); [f] = bulletin of the Trieste station (TRI) (1972 - 1976); I_0 = macroseismic epicentral intensity (MCS x 10); RI = bibliografic reference of macroseismic data: [1] = Guidoboni *et al*. (2007), [2] = Van Gils and Leydecker (1991), [3] = Archivio Macrosismico GNDT (1995), [4] = Ribaric (1982) intensity in MSK, [5] = Barbano *et al*. (1990), [6] = Toperezer and Trapp (1950) - Trapp (1960), [7] = Stucchi and Albini (1988), [8] = Reale Ufficio Centrale Meteorologia e Geofisica (1926), [9] = Postpischl (1985), [10] = Cavasino (1935), [11] = Slejko *et al*. (1987), [12] = Feliziani and Marcelli (1965), [13] = Albini *et al*. (1994), [14] = Carrozzo *et al*. (1973), [15] = Iaccarino and Molin (1978), [16] = De Panfilis (1959), [17] = Istituto Nazionale di Geofisica: Bollettino Sismico Definitivo, [18] = Malaroda and Raimondi (1957), [19] = Cvijanovic (1986), [20] = Swiss Seismological Service (2002), [21] = ENEL (1985), [22] = Herak *et al*. (1996); Dist = instrumental-macroseismic epicentral distance (km) (* preferred), No = number of phases; Gap = largest angle between adjacent stations (°); Dmin = closest station (km); Rms = time error (s); Erh = horizontal error (km); Erz = vertical error (km).

Y	M	D	H	Mi	S	Lat	Lon	*h*	M	RM	I_0	RI	Dist.	No	Gap	Dmin	Rms	Erh	Erz
1901	10	30	14	51	20.67	45.41	10.59	02	5.6[s]	e	80	1,14	22	7	187	101	1.11	10.6	9.9
1904	3	10	4	23	4.24	46.3	13.82	*12	5.2[s]	c	60	9	22	11	143	62	1.54	6.5	8.1
1904	9	16	5	36	8.53	45.18	14.53	03	4.8[s]	e	70	19,22	14	4	237	65	0.36		
1907	4	20	13	24	38.27	46.47	10.93	*04	4.0[s]	c	60	2,14	38	7	290	140	0.49	9.1	6.5
1907	4	25	4	52	18.72	45.06	11.02	01	4.5[s]	b	60	1,14	28	15	153	73	1.81	4.1	4.9

Y	M	D	H	Mi	S	Lat	Lon	*h*	M	RM	I_0	RI	Dist.	No	Gap	Dmin	Rms	Erh	Erz
1907	7	2	2	31	49.76	46.5	13.09	12	4.4^{S}	b	60	9	8	10	111	108	1.43	8.5	11.5
1908	7	10	2	13	41.3	46.41	13.18	02	5.0^{S}	b	75	1	6	16	78	96	1.06	5.8	4.7
1916	3	12	3	24	2.44	45.06	14.53	*07	5.8^{S}	c	80	19,22	26	12	152	59	1.43	5.4	4.2
1918	2	19	11	3	11.68	45.36	14.84	02	4.3^{S}	e	60	9,22*	41	8	143	91	0.96	4.5	5.2
1918	7	19	19	0	45.6	45.11	10.42	02	4.4^{S}	e	40	3*,8	24	5	171	215	1.29	12.2	16.9
1918	8	13	20	0	42.92	45.81	14.41	*04			60	4	37	6	158	55	1.75	7.4	11.8
1920	5	5	14	42	4.35	46.03	13.42	02	5.3^{S}	b	65	5,14	43	8	172	108	0.55	9.4	4.2
1921	9	12	0	24	56.94	45.06	11.56	*07	5.0^{S}	b	40	3,10	84	5	152	45	0.29	2.9	3.7
1922	11	8	10	28	41.74	47.27	11.17	*07	4.2^{S}	e				4	161	17	1.05		
1923	11	28	6	6	49.42	46.82	13.93	01	4.6^{S}	e	60	6	33	8	170	198	1.05	6.8	10.7
1924	3	26	17	8	4.85	46.93	11.32	02	4.9^{S}	b	65	9	7	7	128	38	0.92	10	5.7
1924	5	12	8	46	2.94	46.46	12.85	27	4.8^{S}	b	60	14,15	11	10	104	142	0.83	5.3	9.9
1924	5	21	15	31	52.03	46.82	10.35	02	4.1^{S}	c	55	7	26	9	138	63	0.71	3.7	3.6
1924	12	12	3	28	44.29	46.4	13.02	18	5.4^{S}	b	70	5,14	7	26	58	121	1.4	3.8	7.8
1925	7	4	17	47	51.58	46.15	11.83	03	4.3^{S}	c	55	8,9	29	7	144	89	0.6	7.2	5.8
1925	9	5	7	42	58.22	45.38	14.8	*04	5.1^{S}	b	50	4	12	16	80	106	1.4	5.3	7.4
1926	1	1	18	4	13.84	45.69	14.27	05	5.6^{S}	b	75	1,4	10	33	43	44	1.64	4.5	6
1926	9	28	21	30	47.91	46.35	12.89	15	4.7^{S}	c	60	9	18	9	99	112	1.3	6	13.9
1927	12	31	4	59	33.99	46.52	12.37	11			50	10	85	8	147	111	1.15	7.5	9.1
1928	3	26	14	40	32.58	46.49	13.18	02	5.4^{S}	c				20	64	115	1.06	3.8	4.5
1928	3	27	8	32	28.19	46.27	13.02	18	5.8^{S}	c	85	5,11	14	49	55	93	1.53	3	5.1
1928	3	29	14	52	29.69	46.61	12.98	04	4.2^{S}	c	60	8	23	12	113	121	1.05	5.7	9.1
1928	8	2	8	42	19.35	46.03	12.99	09	3.7^{S}	a	55	8,9	41	7	122	84	0.8	5	5.9
1928	11	16	3	17	7.67	46.21	13	05	4.2^{S}	c	60	9,14	18	17	111	88	1.25	5.5	7.6
1929	7	15	23	37	2.38	45.2	14.79	01			40	22	19	11	150	96	1.15	5.6	6
1929	8	19	2	53	35.67	46.3	12.6	08			50	10	76	6	246	99	0.76	15.1	15.3
1929	9	2	5	51	57.84	46.33	14.29	06	4.4^{S}	c	60	4	8	17	86	37	1.09	4	4.8
1929	10	12	6	7	59.11	46.75	10.2	38	4.3^{S}	c	50	20	9	13	137	52	1.02	5.5	9.5
1929	12	25	5	38	9.63	46.28	12.47	02			50	8	39	11	98	72	0.75	5.4	6.7
1930	1	10	21	53	9.78	46.31	12.98	03	4.0^{S}	a	60	9,14	8	12	104	94	1.25	5.9	6.6
1930	2	25	13	35	49.58	46.05	13.88	09	4.3^{S}	c	60	4	37	19	142	50	1.24	5.2	5.4
1930	5	14	0	1	12.89	46.64	12.28	12	4.7^{S}	c	55	3*,14	6	28	67	97	1.3	3.4	4.3
1930	10	7	23	26	51.02	47.46	10.81	02	5.3^{S}		70	6	11	30	40	49	1.25	2.8	3
1931	4	14	22	12	52.04	46.04	10.76	07	4.4^{S}	c	60	13*,14	11	27	74	118	1.4	4.3	4.9
1931	8	29	15	56	51.46	45.31	13.39	04	4.6^{S}	c				20	155	47	1.12	4.2	4.1
1931	12	25	11	41	10.91	46.3	13.07	13	5.2^{S}	b	70	14	3	45	64	91	1.02	2.1	2.3
1932	2	19	12	57	2.27	45.73	10.95	09	4.5^{S}	c	75	1,12	19	22	99	81	2.89	8.5	9.5
1932	10	21	18	43	16.11	47.2	12.63	01			55	6	26	12	123	174	1.97	8.4	8.4
1933	7	24	9	40	55.29	46.6	14.7	09	4.0^{S}	a	55	5,6	14	11	83	78	1.1	6.5	8.3
1933	12	27	4	43	52.97	46.15	12.14	08	4.2^{S}	a				16	93	54	1.04	5.2	5.9
1934	3	23	1	45	46.21	45.84	10.61	01	4.0^{S}	c	65	9,14	40	15	113	110	1.19	4.8	5.6

Y	M	D	H	Mi	S	Lat	Lon	*h*	M	RM	I_0	RI	Dist.	No	Gap	Dmin	Rms	Erh	Erz
1934	5	4	13	56	3.39	46.36	13.14	09	4.3^{S}	c	60	14,15*	7	27	62	94	0.94	2.9	3.5
1934	6	8	3	17	2.8	46.21	12.56	06	4.7^{S}	a	60	3,10	11	44	68	67	0.88	1.8	2.3
1934	9	4	1	26	1.65	47.32	11.58	03	4.7^{S}	e	65	2,6	19	28	74	157	1.21	3.6	4.4
1935	1	17	5	45	33.52	45.95	13.04	14			50	8	57	13	93	66	1.21	6.8	6.9
1936	2	4	8	15	57.37	45.93	14.5	16	4.2^{S}	c	55	4	36	16	145	13	1.13	4.5	3
1936	6	22	3	43	54.78	45.24	10.51	06	4.3^{S}	c	65	1,14	35	14	145	108	1.32	5.4	6.2
1936	10	18	3	10	5.19	46.1	12.48	13	5.6^{S}	c	90	5,11	4	66	36	53	1.03	1.7	2.2
1936	10	18	21	50	9.69	46.2	12.49	14	3.9^{S}	a	60	14	22	11	163	64	0.59	4.8	5.9
1936	10	19	7	5	56.44	46.1	12.45	18	4.6^{S}	b	70	9,14	10	38	71	53	1.28	2.9	3.6
1937	1	5	20	58	2.86	46.53	13.05	18	4.1^{S}	c	60	9	5	14	102	113	1.49	7.4	10.5
1937	1	9	19	13	35.55	46.55	13.55	09						14	74	103	1.36	6.7	8.2
1937	2	18	8	28	9.49	46.42	12.85	02						7	164	112	0.65	10.6	9.1
1937	6	7	22	2	59.03	46.44	10.69	13	4.1^{S}	c	60	7,14	12	15	151	169	0.84	5.7	5.1
1938	7	7	7	48	3.91	46.05	12.68	09	4.4^{S}	c	50	12,15*	3	16	99	58	1.37	6.2	7.3
1938	7	14	19	57	47.71	46.34	12.95	04	4.5^{S}	c	60	9,14	6	16	116	100	0.76	3.3	5.7
1939	2	5	22	0	0.46	45.24	14.44	18	4.4^{S}	c	65	22	13	19	172	69	1.08	4.7	4.7
1939	2	6	7	23	1.45	45.18	14.47	16	4.9^{S}	c	65	19,22	11	23	90	75	1.09	3.5	3.4
1939	4	25	18	25	2.34	46.44	12.97	13	4.4^{S}	a	60	14	17	16	121	108	1.59	5.7	9.7
1939	5	6	4	10	2.6	45.98	14.85	22	4.4^{S}	c	65	4	10	17	140	26	1.24	5.8	4.9
1939	7	10	16	28	1.82	46.12	12.49	14	4.4^{S}	c	50	9*,12	30	13	100	93	1.37	7.8	9.9
1942	4	12	0	2	2	46.12	14.03	22	4.2^{S}	c	60	4	21	9	219	57	0.85	14.2	13.1
1942	6	20	14	41	43.86	46.57	11.07	*04	3.6^{S}	c	60	13,14	75	10	162	121	1.31	14.8	8.5
1943	6	12	4	20	58.72	46.44	13.07	27	4.0^{S}	a	60	9	7	12	197	104	0.83	15.2	24.1
1943	7	24	1	44	3.22	45.94	11.92	22	4.8^{S}	b	70	14,15	6	27	89	148	1.14	3.6	6.9
1944	2	11	6	32	5.13	46.06	12.97	*04	3.6^{S}	a	60	4,9	78	5	170	78	0.55	32.8	45.2
1946	12	25	7	22	37.05	45.83	12.47	09	3.4^{S}	e	55	9	30	15	86	103	1.48	7.6	9.4
1948	7	17	19	33	55.09	45.7	11.12	04	4.7^{S}	e	50	14	60	7	166	50	0.81	12.8	10.2
1948	10	12	11	51	37.9	46.38	13.28	08	3.6^{S}	a	60	9	20	11	157	90	1.27	12.8	20
1948	11	19	11	6	49.98	46.33	12.82	*04						16	120	106	1.11	4.4	5.4
1949	2	3	22	29	0.27	46.51	13.14	09	4.7^{S}	c	45	6	3	34	95	108	1.27	2.9	3.9
1949	12	7	1	43	58.71	45.98	13.46	02	3.8^{S}	b	60	4,9	38	17	98	44	1.14	4.1	4.7
1950	2	20	1	55	46.32	45.96	12.66	*07	3.6^{S}	e	55	9	59	10	173	93	0.93	11	13.5
1950	5	5	20	53	43.07	46.47	13.08	*07						6	136	107	2.15	20.4	31.6
1950	10	24	11	47	54.4	47.05	14.46	17			60	6	19	22	117	166	1.03	3.3	4.8
1951	6	7	4	6	32.78	46.87	10.65	20			60	2	55	15	149	85	0.73	4.1	6.1
1951	11	19	19	47	55.46	46.45	13.02	19			40	12	9	12	132	6	0.81	4.7	2.1
1952	1	18	1	36	14.76	46.2	12.43	10	4.3^{S}	b	50	15	25	33	56	24	0.97	1.9	2
1952	2	23	21	56	25.31	45.66	14.15	11	4.1^{S}	b	60	4,9	18	24	133	30	1.06	3.2	5.6
1953	7	25	1	34	55.74	46.44	12.98	01	4.1^{S}	b	40	3,16	11	19	102	108	1.48	4.8	6
1954	4	25	22	17	23.17	46.42	12.88	*07	4.2^{S}	c	60	14	6	25	89	111	1.1	3.3	4.4
1954	10	11	16	45	23.56	46.32	13.14	15	4.4^{S}	b	60	14	4	36	55	12	1.02	2.1	1.9

Y	M	D	H	Mi	S	Lat	Lon	*h*	M	RM	I_0	RI	Dist.	No	Gap	Dmin	Rms	Erh	Erz
1954	10	24	12	9	35.27	47.23	11.56	09			50	6	22	11	182	160	1.08	8.2	9.3
1955	5	22	4	57	31.91	47.44	11.45	02	4.8^S	e	65	3,11	18	30	62	144	0.87	2.6	4.7
1955	6	15	8	43	6.41	47.41	11.48	11			45	6	13	16	102	147	1.15	4.2	7.7
1955	7	23	3	54	33.17	46.04	12.65	*07	4.1^S	b	60	14	18	32	87	98	1.5	3.1	3.8
1955	7	23	19	28	54.49	46.32	12.96	09			50	16	24	10	125	98	0.77	5	5.7
1956	1	31	2	25	33.8	45.58	14.28	18	4.7^S	b	70	4	4	45	97	41	0.84	1.6	2.1
1956	2	3	13	42	21.16	45.54	14.19	21	4.7^S	b	60	4,9	7	19	156	35	1.41	4.9	4.1
1956	3	8	11	3	31.71	45.65	14.18	14	4.6^S	a	60	4,9	13	11	146	32	1.1	4.7	4.1
1956	6	10	13	48	40.51	47.27	14.2	09			60	6	42	11	125	184	1.21	6.4	8.8
1956	8	15	10	15	50.6	46.13	13.58	17			40	4	15	10	115	53	0.4	1.8	1.4
1956	11	5	19	45	29.3	46.57	12.94	19	4.8^S	b	60	3,11	6	44	48	20	1.09	2.2	3.3
1957	2	10	0	13	21.02	46.68	13.38	14	3.9^S	b	50	16	38	11	106	42	0.65	3.3	7.4
1958	1	15	15	11	15.83	46.65	13.82	12			55	2	19	10	115	68	0.98	5.4	6.7
1958	3	19	16	4	0.36	46.68	14.6	12			65	4	23	40	78	126	1.22	3	3.6
1958	9	30	9	45	26.41	47.36	10.54	09			65	2,11	18	40	42	84	1.14	2.3	2.6
1958	10	1	5	2	49.25	47.22	10.52	01			40	6	6	11	271	86	0.93	7.4	5.1
1958	10	4	23	59	32.83	47.08	10.53	06						9	128	80	0.94	12	6.8
1959	2	7	7	49	17.15	46.4	13.04	02						6	118	2	0.24	2.9	2.1
1959	4	21	21	53	30.95	46.36	11.57	04			40	14	9	13	164	59	0.6	5.3	2.9
1959	4	26	14	45	17.08	46.41	12.99	07	4.9^S	b	75	5,11	8	62	38	2	0.91	1.7	1.3
1959	5	2	6	36	22.35	46.54	14.35	02			55	4	21	26	83	104	1.46	3.3	4.3
1959	5	7	22	44	21.9	45.72	14.18	*04			45	4	14	7	169	33	0.68	6	9.2
1959	5	7	22	54	19.83	45.54	14.31	02						9	208	43	1.3	13.5	10.1
1959	6	13	21	56	42.6	46.44	12.8	12	5.0^S	b	70	9*,14	11	52	65	18	1.1	1.8	1.5
1959	6	13	23	1	1.5	46.38	12.74	01						7	113	21	0.83	1.6	2.1
1959	6	13	23	32	32.12	46.47	12.75	13						8	167	22	0.41	3	1.7
1959	6	14	1	0	13.28	46.51	12.73	02			60	14	3	12	101	26	0.95	5.1	7.5
1959	7	15	23	26	11.28	46.4	12.9	24						11	144	9	0.78	9.3	6.4
1959	10	16	1	9	28.99	46.29	12.86	01						13	130	17	0.83	3.7	4.6
1959	11	25	10	16	21.73	45.75	14.6	15						10	174	33	0.52	3.2	3.3
1960	1	6	15	17	35.23	46.48	12.71	06	4.3^S	b	70	14,15	6	40	41	26	1.65	4.4	3.9
1960	1	6	15	20	54.44	46.44	12.67	05			55	12	5	4	325	27	0.07		
1960	1	6	18	28	53.42	46.4	13.02	04			35	12	24	5	254	0	1.9	3	2.2
1960	1	7	8	37	5.18	46.51	12.82	03						6	219	20	0.84	7.8	8.4
1960	1	7	14	46	35.47	46.54	12.77	02						15	134	25	0.94	6.4	8.9
1960	2	17	15	32	48.47	45.62	14.6	11			60	4	22	14	194	47	0.9	4.2	3.4
1960	2	19	2	30	17.84	45.78	10.52	12			60	13,14	9	50	70	124	1.25	2.2	3.8
1960	2	24	3	13	43.43	45.81	10.55	01						18	143	128	0.91	3.5	3.8
1960	4	3	20	13	56.24	46.48	12.68	12						5	176	27	0.01	0.2	0.3
1960	5	4	10	46	44.97	46.44	12.62	05						5	180	30	0.08	3.6	3.6
1960	6	25	17	15	25.13	46.97	14.09	02			45	6	33	6	178	104	0.18	2.6	4.5

Y	M	D	H	Mi	S	Lat	Lon	*h*	M	RM	I_0	RI	Dist.	No	Gap	Dmin	Rms	Erh	Erz
1960	7	8	8	22	56.57	46.44	14.56	12			45	6	5	9	92	44	1.39	8.3	11.6
1960	7	10	8	1	16.33	46.1	14.39	*04			40	4	18	6	116	12	1.68	6.9	9.3
1960	7	14	4	17	44.49	46.36	12.96	02	4.1^{S}	b	50	3,12	7	42	66	101	0.82	1.6	2
1960	8	8	5	45	35.79	45.85	11.23	12			50	17	37	19	53	71	1.32	5.2	6.7
1960	8	11	3	19	15.41	47.24	11.57	01			45	6	9	14	135	145	1.31	4.6	6.3
1960	8	28	23	59	14.54	46.2	12.13	09						10	100	91	1.29	8.6	8.9
1960	10	26	12	31	10.89	46.56	12.92	09			40	12	19	9	86	19	0.74	4.9	6.5
1960	11	4	13	47	9.74	46.4	12.97	01						6	169	3	0.41	4.6	5.6
1960	11	26	2	42	53.76	46.36	12.82	04						6	177	16	1.25	4.7	10.8
1960	12	18	1	53	21.59	45.34	14.89	13			50	22	32	20	147	83	1.38	4.7	5.2
1961	3	3	2	30	23.42	46.37	13.47	23			40	12	39	6	136	84	0.51	7.7	17.4
1961	3	15	1	49	37.68	46.95	10.86	09			55	6,9	17	25	62	102	1.03	3.3	4.8
1961	3	26	1	17	50.78	46.01	10.77	10						7	153	109	0.9	11.7	17.5
1961	4	5	7	15	50.92	46.39	14.42	08			40	4	60	8	122	39	0.85	6.9	7.5
1961	6	16	17	6	40.09	46.44	11.15	02						11	73	129	0.94	6	5.9
1961	7	2	21	58	38.12	45.54	14.38	08						11	190	49	1.16	7.8	6.6
1961	7	26	12	0	36.39	47.5	13.26	*04			55	6	11	17	74	188	1.91	4.5	8.3
1961	8	9	13	4	30.58	46.76	10.47	04			55	3,18	9	21	71	72	1.07	3.7	5.6
1961	8	25	12	21	56.52	47.46	10.59	23						33	43	82	1.07	3.2	6.9
1961	8	25	22	28	33.78	47.26	10.15	03			40	6	34	11	190	71	1.25	7.5	6.8
1961	8	27	13	33	36.68	47.27	10.38	01						19	87	81	1.22	5.1	6.9
1961	9	10	4	14	34.5	47.35	10.56	09			40	6	7	16	66	86	0.9	3.9	5.9
1961	12	20	18	10	28.22	46.18	11.73	02						17	95	87	1.28	4.6	5.8
1961	12	22	13	4	41.71	46.4	12.79	09			50	12	16	13	95	114	1.01	4.9	6.9
1962	3	17	21	39	37.7	46.34	12.67	06						13	84	115	1.01	5.3	8.4
1962	4	29	16	58	25.69	46.36	12.3	*04						7	180	112	0.81	6.5	12.2
1962	5	2	17	50	50.48	46.34	12.53	*04						8	113	116	1.04	3.8	5.6
1962	5	24	23	7	1.57	46.33	11.22	13						7	160	115	0.51	7.3	6.4
1962	8	13	20	2	27.4	46.51	12.95	01			50	12	22	18	68	115	0.84	3.4	5.3
1962	9	27	21	32	42.2	47.43	11.97	12			50	6	13	9	151	223	1.07	7.8	13.7
1963	1	14	20	21	54.47	46.42	13.52	02			55	9,14	11	10	128	88	0.58	4.5	7.6
1963	2	5	12	21	5.07	47.46	11.45	05			50	6	18	21	106	143	1.54	4.9	7.3
1963	2	5	12	26	5.69	47.41	11.31	01			45	6	14	16	120	135	1.16	4.5	5.6
1963	3	4	22	30	8.49	45.68	10.82	01			30	14	22	12	72	88	1.43	6.1	7.2
1963	5	13	8	52	15.01	46.29	12.66	13						10	111	112	0.71	3.3	7.9
1963	5	19	10	0	3.73	46.17	14.66	04			70	4	14	65	55	18	1.2	1.9	2.3
1963	5	19	11	19	2.37	46.12	14.74	06			50	4	6	11	126	18	0.55	3.8	4.6
1963	5	19	13	3	35.16	46.2	14.7	12			45	4	13	7	116	22	0.89	12.7	16
1963	5	19	16	18	20.96	46.13	14.65	17			40	4	12	5	197	13	0.29	10.3	2.4
1963	5	19	21	12	5.57	46.05	14.66	05			45	4	12	8	134	11	0.7	5	3.8
1963	5	31	3	36	9.53	46.08	14.42	04			45	4	32	9	111	9	1.29	8.7	9

Y	M	D	H	Mi	S	Lat	Lon	*h*	M	RM	I_0	RI	Dist.	No	Gap	Dmin	Rms	Erh	Erz
1963	6	12	19	24	37.14	45.96	14.71	04			45	4	15	15	146	17	1.43	5.2	5
1963	6	19	1	20	15.32	46	14.72	11			30	4	6	6	215	16	0.12	1.8	0.9
1963	9	2	9	18	42.42	46.26	12.35	05						10	118	103	0.67	4.2	8.3
1963	10	5	11	57	43.84	45.16	10.27	04						6	157	277	0.83	14.3	11.9
1963	10	30	4	6	19.37	46.44	12.64	02						11	74	119	0.97	5.8	10.8
1963	10	31	11	54	28.99	46.24	13.6	03			40	4	8	7	168	61	0.19	1.9	2
1963	11	15	5	15	45.66	46.07	14.66	18			60	4	9	15	89	11	1.08	4.9	3.8
1963	11	20	2	16	49.51	45.88	14.71	01			45	4	26	12	159	23	1.15	4.3	5
1963	12	7	10	18	43.41	45.95	14.71	01			50	4	18	9	152	18	0.69	3	4
1963	12	29	15	31	29.07	46.41	10.11	04						20	86	65	1.36	4.4	6.5
1964	1	1	11	4	24.91	46.53	13.18	04						14	103	19	0.97	2.6	3.9
1964	1	8	16	29	31.71	46	14.57	01			30	4	10	7	143	6	0.36	2	4.7
1964	1	26	8	17	32.73	45.7	14.44	06						9	178	39	0.6	3.6	4
1964	3	7	4	28	46.08	46.28	13.39	09						6	200	69	0.07	0.7	1
1964	3	18	16	43	20.79	45.59	14.3	13	4.5^S	b	60	4	19	64	71	42	0.72	1.1	1.5
1964	4	11	2	48	7.4	45.92	14.69	*04			30	4	19	9	221	19	1.02	6.4	6.2
1964	5	18	10	38	46.03	46.58	12.28	*04						9	153	60	0.67	4	4.8
1964	6	4	19	8	1.91	46.29	14.54	22			40	4	51	8	137	27	0.28	4.2	1.9
1964	7	6	7	47	23.65	46.05	14.7	17			40	4	4	10	135	14	0.66	4.1	3.6
1964	7	21	22	0	56.1	46.37	13.02	07	3.2^S	a				17	113	2	0.67	2.6	1.9
1964	8	31	14	33	51.94	46.12	13.44	06	3.2^S	a				13	127	38	0.51	2.2	5.3
1964	9	5	10	20	15.62	46.53	12.87	13						11	119	19	0.31	2.4	1.4
1964	10	13	3	38	1.47	46.36	12.85	02	3.2^S	a				12	117	17	0.58	2.4	3
1964	11	7	15	28	0.88	46.51	14.16	32						11	110	60	0.62	5.5	9.1
1964	11	7	15	42	40.2	45.71	14.81	34			45	4	90	14	179	43	1.08	7.1	5.7
1964	11	11	9	29	15.53	46.53	13.98	*07						5	176	69	0.86	8.7	12.6
1964	11	11	16	1	10.51	46.36	13.91	22						10	85	60	0.9	4.1	8.7
1964	11	26	16	32	59.95	46.34	13.49	10			45	4	11	21	101	33	0.57	1.7	2.2
1964	12	7	6	35	54.74	46.23	12.55	04	3.8^S	a				20	85	18	0.95	2.9	4.2
1965	2	2	14	29	28.28	46.4	12.7	08						7	174	24	0.38	3.5	11.7
1965	2	28	0	28	22.7	46.25	14.53	04			45	4	44	10	148	23	1.68	5.8	6.7
1965	3	1	5	33	7.76	46.32	12.63	12						8	135	22	0.29	2.3	5.3
1965	3	27	22	36	21.36	46.4	12.9	07	4.0^S	a				29	77	9	0.94	2.7	2.6
1965	4	19	2	27	4.4	46.28	12.59	04	4.0^S	a				26	82	20	0.74	1.6	2.5
1965	7	8	23	20	2.78	47.47	11.31	04	4.3^S	e	50	11	20	33	53	132	1.91	5	7.9
1965	8	19	19	14	26.24	46.31	12.97	08	5.0^S	b	50	9	21	49	83	8	1.04	2.1	1.6
1965	8	19	19	41	56.7	46.29	12.95	08	4.0^S	a				26	121	11	0.62	1.7	1.3
1965	10	31	4	6	16.28	45.46	14.48	04						8	226	63	0.59	5.1	6.8
1965	11	12	13	7	3.89	46.56	13.37	*12						5	285	33	1.04	6	16.5
1965	11	13	11	37	22.64	46.36	13.55	18	3.8^S	a	40	4	6	17	97	42	0.79	3.4	3.3
1965	12	15	20	4	31.93	45.93	14.64	06			40	4	5	9	154	16	0.35	1.8	1.9

Y	M	D	H	Mi	S	Lat	Lon	*h*	M	RM	I_0	RI	Dist.	No	Gap	Dmin	Rms	Erh	Erz
1966	1	23	1	31	28.24	46.11	12.32	08	4.0[s]	b	45	9	28	29	112	18	0.89	2.7	2.4
1966	2	2	2	25	22.09	46.32	12.77	06	4.0[s]	a				26	153	21	0.75	2.3	1.7
1966	2	2	2	31	11.98	46.29	12.73	02						8	190	26	0.23	1.4	20.2
1966	3	11	12	33	54.82	46.3	12.28	19						5	257	5	0.08	1.4	1.3
1966	5	4	12	1	4.21	46.32	12.65	05						10	136	23	0.36	1.9	13.9
1966	5	26	8	11	3.75	46.4	13	04	3.9[s]	a				21	87	1	0.64	2	1.5
1966	6	19	4	12	12.23	46	14.42	07	4.0[b]	d	45	4	20	14	138	10	1	4.5	4
1966	7	10	13	30	13.09	46.4	13.45	01	4.0[s]	a				27	65	30	1.04	3.5	3.9
1966	8	19	4	6	30.85	45.71	11.09	09						17	129	71	1.41	8.2	7.7
1966	9	1	23	17	21.12	45.8	11.45	09						22	117	55	0.78	2.6	3
1966	9	15	0	10	38.33	46.45	13.46	02	3.7[s]	a				20	94	33	0.88	2.3	3.5
1966	11	11	12	49	10.99	45.58	11.49	22						20	122	36	0.77	4.7	3.6
1966	12	20	9	48	59.76	46.24	12.32	11						9	132	3	0.31	1.9	1.6
1966	12	24	7	13	58.06	46.38	13.73	13	3.7[s]	a	40	4	22	15	84	51	0.67	3.2	4.2
1966	12	24	21	5	59.04	46.06	14.75	18			50	4	6	10	139	17	0.85	4	2.7
1967	1	5	20	7	26.15	46.8	13.88	07						9	103	97	1.02	7.8	10.6
1967	1	5	20	9	36.53	46.95	13.9	02						8	111	112	0.79	5.4	8.2
1967	1	6	4	43	52.62	45.84	11.87	09						16	85	49	0.94	3.2	3.7
1967	1	14	19	7	50.98	46.35	12.91	02	3.8[s]	a				19	119	10	1.07	3.4	4.1
1967	1	15	14	33	45.24	45.98	13.09	09	3.9[s]	a				18	117	41	0.99	2.5	3.4
1967	1	29	20	45	7.41	45.48	14.27	02			40	4	3	13	194	47	0.98	4.5	4.5
1967	3	22	19	14	49.71	46.26	12.53	05	3.9[s]	a				39	85	16	0.87	1.8	2
1967	3	22	19	18	32.44	46.29	12.58	*04						19	84	20	0.43	1.1	1.1
1967	4	2	14	48	42.88	46.4	12.84	08						12	144	10	0.22	1.7	2.6
1967	4	9	7	6	32.41	46.09	11.53	02						10	98	82	1.37	8	13.1
1967	4	17	15	24	30.04	46.56	12.72	09						11	233	12	0.49	3.5	2.6
1967	4	27	21	36	5.8	46.71	13.32	29						11	167	42	0.48	6.2	10.9
1967	6	8	21	27	18.97	46.06	14.36	10			45	4	10	11	133	13	0.48	6.5	4.6
1967	7	4	2	38	41.44	46.27	12.79	02						14	140	21	0.42	1.8	3.1
1967	7	20	16	20	0.04	45.6	14.59	09	3.9[b]	b	50	4	26	13	187	49	1.11	5.9	5.1
1967	7	25	11	22	45.22	45.55	14.42	21			45	4	12	15	191	54	1.1	6.1	8.2
1967	8	7	4	30	24.03	46.34	13.02	04						9	120	4	0.5	3.6	5.8
1967	8	14	10	16	16.29	46.82	10.37	02	4.9[s]	b				38	43	164	1.07	2.6	4.2
1967	8	18	12	2	51.46	46.53	10.61	*07						9	134	260	1.67	10.6	20.2
1967	9	5	11	37	4.55	45.89	14.06	08	4.0[b]	d	50	4	45	37	136	30	1.12	2.7	2.6
1967	9	5	15	18	15.01	45.63	14.27	11			40	4	13	17	167	40	0.88	3.7	3.1
1967	9	5	15	21	0.14	45.66	14.21	19			45	4	18	29	165	35	0.87	2.6	2.1
1967	11	3	13	20	32.23	45.44	14.49	09			50	4	22	12	198	64	0.87	4.7	4
1967	11	8	17	42	14.07	45.53	10.93	19						23	134	75	1.05	3.6	4.4
1967	11	29	23	41	50.52	46.39	12.62	07						12	170	18	0.25	1.6	5
1967	12	9	5	45	2.04	45.5	14.45	16						11	199	59	0.52	3.8	3.4

Y	M	D	H	Mi	S	Lat	Lon	*h*	M	RM	I_0	RI	Dist.	No	Gap	Dmin	Rms	Erh	Erz
1967	12	9	8	55	1.04	45.37	14.52	01						8	236	70	0.42	3.5	3.2
1967	12	9	9	18	33.16	45.51	14.45	02						13	193	58	1.18	5.5	6.6
1967	12	13	10	42	26.53	45.9	14.85	18			45	4	3	8	161	30	0.82	6.7	4.4
1968	3	4	9	1	5.41	46.44	12.59	02						11	183	11	0.26	1.5	9.3
1968	3	6	8	25	44.87	46.83	14.22	01						8	153	90	0.77	6.4	8.6
1968	4	25	7	40	53.35	47	11.87	16						26	64	76	1.15	3.2	3.6
1968	6	15	15	47	23.53	46.39	13.45	08						12	199	30	0.6	3.7	14.8
1968	6	22	12	21	36.43	45.88	11.28	09	4.3^{s}	b	60	11	10	67	50	68	3.93	5.7	7.1
1968	6	22	12	37	49.34	45.84	11.21	19	4.0^{b}	d	50	11	11	29	52	72	0.91	2.5	2.8
1968	7	5	7	15	26.16	46.39	13.06	*04						7	256	4	0.39	3	2.7
1968	7	5	8	39	58.36	45.95	14.66	01			50	4	15	19	152	15	1.29	3.1	3.1
1968	8	16	21	33	45.4	46.35	14.12	08	4.1^{b}	b	60	4	28	46	64	46	0.99	2	2.4
1968	8	31	11	16	36.47	46.46	12.91	10						11	228	11	0.29	3	1.9
1968	9	3	14	10	32.73	46.4	12.98	04						12	167	2	0.34	2.4	2.2
1968	9	17	12	16	37.8	45.36	12.77	18	4.1^{b}	d				33	103	71	1.12	2.5	3.1
1968	9	20	20	29	22.04	46.26	12.52	06						9	152	14	0.24	1.3	6.5
1968	10	14	16	33	51.68	47.04	11.04	04						7	174	257	1.3	10.1	13.6
1968	10	29	2	57	28.87	46.75	11.81	*04						11	169	57	0.75	3.4	2.4
1968	12	9	5	12	56.36	45.71	14.17	05			45	4	16	11	185	32	1.77	9.9	12.3
1968	12	13	0	47	22.16	46.05	10.97	*07						10	86	101	1.04	14.5	12.3
1969	1	14	0	59	17.01	46.41	13.02	12						31	63	2	0.94	2.8	2
1969	1	28	4	38	8.38	46.15	12.17	09			50	17	6	9	166	7	0.55	8.1	8.5
1969	5	24	18	54	34.19	46.3	12.59	12						11	135	20	0.26	1.6	1.8
1969	6	1	23	20	29.3	47.02	14.17	19	4.4^{b}	d	60	11	3	39	51	112	1	2	4.2
1969	6	2	3	57	29.73	47.03	14.23	31	4.1^{b}	d				36	52	112	0.92	2.1	3.6
1969	7	28	12	14	54.94	46.37	12.51	14						9	121	11	0.29	2.1	2
1969	7	28	18	30	15.72	46.28	12.56	07						9	141	18	0.15	0.8	3.3
1969	7	28	23	31	50.11	46.26	12.58	02						9	149	19	0.2	0.9	16.6
1969	8	17	13	25	1.5	46.4	12.75	07						11	115	5	0.23	1.8	2.8
1969	10	9	7	38	36.14	45.62	14.24	05			45	4	24	13	186	38	1.14	5.3	6.8
1969	11	7	22	4	25.88	46.26	12.98	10						12	135	11	0.29	2.4	4.7
1969	12	9	5	47	24.48	46.17	13.04	*04						11	149	20	0.2	1.4	11.8
1970	4	19	18	16	32.97	45.7	10.47	13	3.7^{s}	b	60	9	6	38	87	115	1.2	2.6	5
1970	5	10	7	10	35.74	46.34	12.87	04						10	134	15	0.27	2.5	9.4
1970	8	6	13	54	48.42	46.66	10.34	02	3.6^{b}	d				17	100	182	0.86	3.4	5.4
1970	12	14	7	20	30.87	46.85	10.12	04						21	81	169	1.16	4.1	7.9
1971	2	26	2	10	29.82	46.5	10.24	04						27	75	169	1.31	3.3	6.2
1971	4	9	6	9	28.69	45.78	14.17	13			40	4	2	16	168	33	0.83	3.5	2.2
1971	7	11	9	26	17.18	46.33	12.96	07						14	123	6	0.29	1.8	2.4
1971	9	4	14	55	6.32	46.1	12.54	02						8	204	25	0.16	1.1	32.5
1971	9	7	4	2	23.71	46.18	12.47	08	3.8^{s}	a				65	91	28	0.85	1.6	1.6

Y	M	D	H	Mi	S	Lat	Lon	*h*	M	RM	I_0	RI	Dist.	No	Gap	Dmin	Rms	Erh	Erz
1971	11	3	21	30	44.45	46.34	12.98	02	3.8^{S}	a				42	80	4	1.16	2.4	2.3
1971	12	18	20	12	22.64	46.2	12.45	01						12	142	12	0.5	2.2	4.4
1971	12	23	19	19	25.19	46.45	13.17	02	3.7^{S}	a				32	64	14	1.09	3.1	4
1972	3	8	23	26	9.69	46.44	12.98	13						8	230	7	0.28	4.4	2.4
1972	3	22	16	54	50.86	46.29	12.55	04						9	135	17	0.38	2.3	4.3
1972	4	22	10	18	9.71	47.03	13.01	*04	3.8^{S}	a				35	71	68	0.89	2.2	3.1
1972	4	22	10	38	51.29	47.01	12.93	03	3.6^{S}	a				19	78	65	0.69	2.7	3.9
1972	5	28	6	9	28.79	46.04	14.93	17			45	4	51	11	141	31	1.09	5.9	4.8
1972	5	28	21	13	1.32	46.01	14.87	17			30	4	54	9	146	27	1.32	8.8	6
1972	6	17	9	0	45.85	46.27	12.59	*04	3.7^{S}	a				42	86	21	0.76	1.3	1.7
1972	10	7	11	14	40.16	46.39	12.94	14						12	179	3	0.37	3.4	2.2
1972	12	10	18	37	55.03	45.97	13.94	*07	2.5^{L}	f	40	4	36	6	235	32	0.39	8.3	2.9
1973	1	18	9	6	43.9	45.45	14.33	20						11	232	53	1.12	7.9	5.1
1973	1	28	12	28	36	45.71	14.94	*04			35	4	24	10	189	49	1.02	4	4
1973	5	15	5	11	13.54	46.41	13.12	08						12	229	8	0.27	2.8	2.1
1973	5	15	10	23	45.4	46.27	13.07	08						11	140	8	0.51	4.3	7.4
1973	6	6	20	37	43.68	45.45	12.03	16	3.4^{S}	a				39	199	94	0.83	3	4.4
1973	10	5	10	26	55.16	45.59	14.38	15	3.2^{L}	f	45	4	12	20	189	50	0.93	3.9	2.7
1973	10	5	11	30	52.14	45.58	14.36	12	3.3^{L}	f	50	4	10	36	115	49	0.99	2.5	2.8
1973	12	12	0	2	41.41	47.13	14.09	38	4.1^{b}	d	50	11	9	44	61	126	1.04	2.2	7.1
1973	12	21	8	17	52.43	46.13	14.11	11	4.0^{S}	e	60	4	7	60	107	54	0.66	0.9	1.1
1974	1	16	6	14	14.69	46.12	14.14	12			40	4	25	15	107	31	1.07	6.2	6.1
1974	2	1	19	54	31.53	47.13	10.98	01						18	155	34	1.02	4	4.5
1974	3	13	9	59	38.81	45.35	10.69	37						15	124	181	0.97	4.8	15.3
1974	3	13	23	19	36.12	45.05	11.02	26						10	106	130	0.99	6	11.5
1974	4	14	7	14	48.6	45.62	11.66	44						25	103	89	0.79	2.9	38.8
1974	5	4	0	19	39.86	45.77	12.1	04						25	167	58	1.09	3.6	4.5
1974	5	6	7	50	19.79	46.33	13.45	07	3.8^{S}	a	45	9	5	43	105	30	0.66	1.7	2
1974	5	19	13	20	11.23	45.49	11.1	39						32	93	179	1.06	2.6	7.6
1974	8	2	10	58	40.71	46.87	10.35	02						23	131	160	0.94	3.1	5
1974	9	9	12	50	12.95	46.21	12.5	02	3.8^{S}	a				24	146	15	0.68	2.1	2.6
1974	11	20	8	41	49.17	45.8	12.23	04						28	179	81	0.85	3.5	2.8
1974	11	20	15	10	52.77	45.78	12.18	*04						35	158	73	0.87	2.5	2.8
1974	11	20	19	33	7.63	45.82	11.73	38						33	154	104	0.87	2.9	6.9
1974	11	22	17	3	21.55	46.07	12.19	25						28	152	24	0.77	2.5	3.7
1974	11	27	12	56	0.43	46.66	10.89	04						28	152	77	1.09	3.8	4.4
1974	12	9	13	1	33.29	46.38	13.14	12	3.7^{S}	a				27	111	13	0.96	3.7	3.6
1974	12	13	9	4	9.27	46.3	12.75	02						18	134	17	0.74	2.2	3.6
1974	12	13	22	49	54.58	45.87	12.04	08	3.8^{S}	a				33	85	50	1.24	3.3	4
1975	1	11	15	54	26.43	45.66	10.65	16	3.8^{S}	a	55	21	6	52	55	100	1.28	2.5	4.9
1975	3	7	1	34	44.58	46.38	12.8	03						26	145	9	0.77	3.1	2.8

Y	M	D	H	Mi	S	Lat	Lon	*h*	M	RM	I_0	RI	Dist.	No	Gap	Dmin	Rms	Erh	Erz
1975	3	19	13	28	50.3	46.43	12.78	08	3.9^{S}	a				33	105	16	0.77	2.5	2.4
1975	3	24	2	33	17.94	46.3	13.1	07	3.9^{S}	b	60	9	25	90	35	13	1.05	1.5	1.7
1975	4	19	21	21	34.14	46.33	13.06	06	3.6^{S}	a				26	120	28	0.92	3.3	3.9
1975	4	20	3	36	47	46.36	13.06	02	3.3^{S}	a				17	117	27	0.44	2.1	2.9
1975	4	23	16	19	20.16	46.31	13.06	13	4.0^{S}	a				52	96	10	1.2	2.4	2.2
1975	5	16	19	41	22.15	45.57	14.36	20	2.7^{S}	e	55	9	6	50	84	49	0.73	1.5	1.6
1975	5	18	1	21	40.25	45.62	14.45	05			40	4	4	24	176	48	1.26	4.2	4.5
1975	6	1	13	25	50.33	45.63	10.87	*12			55	9	64	20	154	226	1.95	2.9	3.8
1975	6	8	2	28	55.14	46.27	12.85	06						22	112	15	0.7	1.8	1.9
1975	6	16	23	41	38.53	45.78	10.57	03						43	74	199	1.32	2.9	4.9
1975	6	17	7	6	17.38	47.16	11.06	04	3.6^{b}	d				38	90	113	1.02	2.3	3.3
1975	6	18	9	19	41.11	47.04	10.96	34	4.0^{S}	a				17	151	201	1.01	4.6	11.1
1975	6	18	15	38	24.52	46.24	13.7	12			50	4	10	48	67	58	1.17	2.1	2.3
1975	7	15	7	39	40.44	46.24	14.64	13			45	4	20	10	97	24	0.65	5.8	7.5
1975	8	16	0	31	57.21	46.24	14.56	18			50	4	38	55	45	22	1.05	1.9	1.8
1975	9	16	12	21	22.97	46.45	13.53	08	3.8^{S}	a				37	90	43	0.88	2	2.9
1975	11	4	8	39	57.34	45.94	14.29	11			35	4	11	6	179	21	0.12	1.2	4
1975	11	16	4	57	50.54	46.23	12.49	09						19	136	13	0.49	1.8	1.7
1975	11	23	10	28	0.95	45.65	13.05	01	3.6^{S}	a				29	133	56	0.73	2.1	2.1
1975	11	28	19	5	23.45	46.1	14.43	12			30	4	7	5	260	10	0.23	4.5	4.8
1975	12	4	12	27	48.77	45.92	14.31	10						5	171	22	0.08	0.9	3.9
1975	12	5	11	11	45.47	45.52	14.28	12						6	273	27	0.08	1.4	2.6
1975	12	8	21	0	2.11	45.42	14.34	04						6	294	36	0.13	2.5	19.6
1975	12	9	1	1	12.08	45.45	14.36	12						5	291	33	0.05	2.2	7
1975	12	9	2	15	42.02	45.45	14.37	12						5	291	33	0.06	3	9.3
1975	12	10	15	40	50.13	45.57	14.37	33						5	274	19	0.13	2.6	2.5
1975	12	11	7	15	15.61	45.43	14.36	*04						5	293	35	0.37	5	34.6
1975	12	15	15	6	28.17	45.44	14.34	*04						5	292	34	0.16	0.2	1
1975	12	19	14	43	15.56	46.18	14.77	09			30	4	36	5	332	24	0.04	1	1.7
1975	12	24	15	23	20.68	46.03	14.72	04							4	299	15	0.19	
1975	12	25	14	25	38.61	46.4	13.08	01						13	110	27	0.64	4.2	5.7
1976	1	3	17	40	17.92	45.76	13.1	05	2.9^{L}	f				20	169	52	0.79	3.5	4.4
1976	2	16	1	7	56.92	46.05	14.22	09	2.9^{L}	f	40	4	3	10	98	24	0.91	5.8	7.9
1976	2	27	9	58	47.55	45.8	13.07	07	3.4^{L}	f				38	80	55	0.61	1.3	1.4
1976	3	16	21	12	7.65	46.01	14.35	07			40	4	3	6	203	14	0.11	1.4	4.3
1976	3	22	12	3	56.74	46.12	14.62	15						5	324	11	0.01	0.3	0.2
1976	3	22	12	59	44.04	46.1	14.79	13						5	322	21	0.23	5.9	8.1
1976	4	13	22	56	4.68	45.99	13.49	13	2.9^{L}	f	45	4	7	16	113	38	0.62	2.7	2.9
1976	4	27	17	49	4.37	45.59	14.44	22						5	277	17	0.01	0.3	0.2
1976	4	30	17	10	3.69	46.09	14.37	10						5	245	13	0.13	2.6	4.2
1976	5	3	8	51	24.53	46	15	28						4	213	53	0.6		