NON-REVIEWED CONTRIBUTION

THE MESSINA-REGGIO EARTHQUAKE OF DECEMBER 28, 1908

J.M. CARCIONE AND J.T. KOZÁK

1 Istituto Nazionale di Oceanografia e di Geofisica Sperimentale (OGS), Trieste, Italy (jcarcione@ogs.trieste.it)

2 Institute of Geophysics, Acad. Sci. Czech Republic, Boční II/1401, 141 31 Praha 4, Czech Republic

1. INTRODUCTION

Hundred years ago, on December 28, at 5 h 20 m 23 s, an earthquake of magnitude 7, followed by a tsunami, destroyed in 20 s the cities of Messina and Reggio Calabria, causing nearly 100 thousand deaths. This short article attempts to capture the nature of the catastrophe through the testimony of the survivors and witnesses, with an appropriate description of how the events occurred putting the emphasis on the scientific aspects, in a way understandable to any reader not familiar with the subject of geophysics. Results regarding latest research about this event are also briefly discussed.

The 1908 earthquake has been the strongest event, which occurred in Southern Italy since 1783. *Baratta (1910)* reported 60000 casualties while *Mercalli (1909)* estimated 120000. The earthquake was recorded at 110 stations worldwide and was followed by a tsunami with a maximum sea-wave height of 12 m at Sant'Alessio on the Calabrian coast, and penetrating there 200 m into the land.

We base our report on a few relevant articles published mainly in Nature during the two years after the event. Direct witnesses' accounts and physical explanations of the event were given, which are very similar to present interpretations; for instance, the fact that the origin of the earthquake was a fault plane of certain dimensions below the Strait of Messina. Two famous witnesses were the Russian writer Maxim Gorkij and the German geophysicist Wilhelm Meyer, who were at Capri at the moment of the earthquake and arrived in Messina on January 1, 1909. Their accounts provide a realistic and dramatic description of the events and a surprisingly accurate geophysical interpretation of the earthquake mechanisms.

The present interest in the 1908 earthquake is due to the proposals to build a bridge in the region, the largest in the world, joining Sicily and the continent. Because of the huge dimensions of the bridge, the resonance periods of the piers and the suspensions are planned to be between 8 and 20 s, so these structures can be highly excited by big earthquakes. The design of such a structure requires a detailed knowledge of the ground motion in case of tremors. The 3D simulation of the event has been used to obtain the acceleration field at the two sides of the Messina strait, where the two towers of the bridge will be built (*Carcione and Gei, 2006*).

Fig. 1. Czech wood-engraving illustration of the effects of the 1908 Messina earthquake (*Kozák Collection, University of Berkeley; http://nisee.berkeley.edu/Kozak*).

2. CONTEMPORARY REPORTS

The Czech wood-engraving (xylography) illustration (see Fig. 1) of the effects of the 1908 Messina earthquake comes from a non-identified printed source published in 1909. The title states *"Terrible earthquake in southern Italy"* while the sub-title given under the image states: *"The horror-full night of December 28 in the Messina town. Stormy sea waters flooded the town ruined by the earthquake and definitively destroyed all what yet remained."*

There were numerous reports which appeared immediately after the earthquake. The journal Nature published several articles. We provide the following most interesting extracts in italics: … *the first intimation of the disturbance was a prolonged, thunderous noise followed by a vivid flash of lightning, and at the same time by a series of violent shocks which seemed interminable. Heavy torrential rain then fell … On Tuesday, the officer of a torpedo-boat who left Messina for Reggio sent after a few hours the following message: "I cannot see Reggio; if it exists, it is no longer where it was."* (*Nature, Vol. 79, No. 2045, December 31, 1908, p. 255*).

On January 7, 1909, Nature published records obtained by the Milne seismograph at Kew (UK), 2000 km away. The signal arrived on December 28 at 4 h 23.6 m (GMT) and the maximum amplitude at 4 h 31.1 m. For the first time, the declination magnetograph recorded several distinct burrs (*C. Chree, Nature, Vol. 79, No. 2045, January 7, 1909, p. 280*). Another article described the events: *The earthquake was … as great as either of the celebrated earthquakes in 1783, which caused 40000 deaths in the same districts. … the nature* [of the sea wave] *of which is indicated by the narrative of the captain of the Hopewell; according to him, the boat, which was passing through the Straits at the time of the earthquake, seemed to leap into the air, as if a mine had exploded underneath her, and immediately afterwards a mountain of water was heaped up to starboard and rushed furiously towards Messina, while soundings showed that the bed of the sea had risen ten feet … it is of a nature of a gradually increasing strain, leading, in the end, to sudden rupture and the setting free of forces of which we still know little* (*R. D. O., Nature, Vol. 79, No. 2045, January 7, 1909, p. 287–288).*

About the Sea wave: *A man who was just embarking on a ferry-boat to go from Messina to Reggio when the shock occurred describes how the level of the water seemed suddenly to descend until the ferry touched the bottom, and then rose to a great height again - he says eight yards - hurling the ferry-boat on the landing pier, which smashed it to pieces.* About the affected area: *At Reggio the destruction seems to be even more complete than at Messina, for the whole of the city has been razed to the ground … The prefect of Reggio states that the centre of the town has settled down to the sea-level … Taormina has escaped unscathed.* The seismographic records: *The seismographic instruments at Laibach Observatory registered the earthquake at 5.22 and 6 a.m. Of twelve instruments, only one was able completely to register the successive shocks undistorted, as the oscillations were more violent than the instruments could measure … A slight further shock was felt at Palermo on December 30 … Two earthquake shocks were felt at Algiers at about 6.30 p.m. on January 1 … On January 3, however, at 5.22 a.m., a violent shock of earthquake lasting three seconds was felt at the island of Stromboli. It was accompanied by an eruption of the volcano and prolonged subterranean* *rumblings … At 11.44 p.m. on January 4, a shock of earthquake was felt at Tenerife, lasting twelve seconds … Prof. Rizzo (from the Messina Observatory) noticed that several boats anchored some distance from shore were left high and dry. On the other hand, the ground has sunk in some places in the city, notably near the Municipal Palace and Via Seminario, where in one place it has fallen eleven yards* (*Nature, Vol. 79, No. 2045, January 7, 1909, p. 288–289*).

E. Oddone from the Observatory of Messina indicated that the subterranean chamber has escaped harm, and the Vicentini seismograph recorded the event … *the earthquake began with a very slight shock, which was repeated. It increased in violence for ten seconds, and then grew less severe for another ten seconds. After these movements ten minutes passed without disturbances. A second shock of much greater intensity, and accompanied by loud subterranean rumbling, followed, and was the cause of the catastrophe* (*Nature, Vol. 79, No. 2046, January 14, 1909, p. 316*).

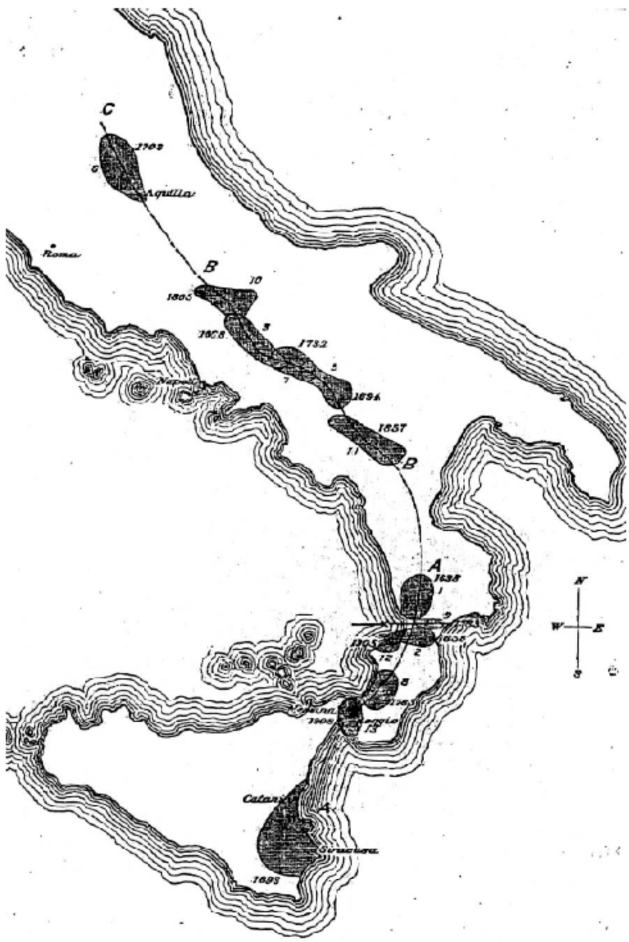

Fig. 2. Omori's map, showing the epicenters of thirteen great earthquakes in Southern Italy.

A. Ricco, director of the Catania Observatory, stated that the sea wave reached a height of 11 feet (3.35 m) at Villa San Giovanni and 7 feet feet at Catania (*Nature, Vol. 79, No. 2047, January 21, 1909, p. 347*).

Ch. Davison published a paper in "The Nineteenth Century", showing isoseismal lines of the earthquake and seismic zones of Southern Calabria, as delineated by M. Baratta. The hypothesis is a polycenter disturbance, where the epicenters are located at the Strait of Messina, and near Palmi and Monteleone (*Nature, Vol. 79, No. 2047, February 25, 1909, p. 496*).

Nature published an isoseismal map using the Mercalli scale in June 10, 1909, p. 445.

Dr. Baratta attributes the disastrous results of the recent earthquake chiefly to three causes - the damage resulting from preceding earthquakes, and especially those of 1894, 1905, and 1907; the nature of the rocks on which the houses were built; and the wretched materials used and a system of construction in complete contradiction to the elementary rules that should govern all building in seismic countries. Baratta gave the stratigraphy: yellow sands, sands and conglomerates in irregular beds, recent alluvia, Miocene sands and conglomerates, limestones and crystalline rocks (*Nature, Vol. 82, No. 2094, December 16, 1909, p. 203–204*).

After Baratta's article in Nature, two other memories appeared due to F. Omori (*Omori, 1909*) and G. Platania. The article in Nature reproduced one of Omori's maps, showing the epicenters of thirteen great earthquakes in Southern Italy (Fig. 2). F. Omori stated that the area of violent motion was elliptical in form, and about 30 km. long from north to south and about 20 km wide. Judging from the form and position of this area, the origin seems to be situated beneath the Straits of Messina.

G. Platania reported a sea wave of 11.7 m at Sant'Alessio but only 0.8 m at Torre del Faro. *The wave-velocity obtained from the formula $V = sqrt(g\ h)$ is always much greater than the observed velocity by from 25 to 57 per cent. Taking variations of depth, however, into account, the discrepancies tend to disappear* (*Nature, Vol. 82, No. 2101, February 3, 1910, p. 410–411*, g is the acceleration of gravity and h is the ocean depth).

Mercalli (1909) stated that there were six tremors during the previous month at Messina, and that two aftershocks of the 1783 event originated in the same centre as the Messina earthquake (*Nature, Vol. 83, No. 2106, March 10, 1910, p. 44*).

The Italian Government issued two reports in 1910, with articles by several experts. Amongst others, A. Ricco gave a global description, E. Camerana considered the distribution of the damage, M. Baratta investigated the relation to previous events, and G. di-Stefano described the geological setting of the area. *A Royal Commission, under the presidency of Prof. Blaserna, was appointed to investigate the sites best adapted for the re-building of the ruined towns ... As regards Messina, while recognising the unsatisfactory nature of the subsoil, it is realised that, for commercial and other reasons, the city must be re-built on its former site. In one of the appendices of the report, A. Loperfido describes the results of new series of levellings, former series having been made along the same lines in 1907–8. ... They show a lowering of 65 cm at the mareograph of Messina, a maximum of 71 cm, being attained about 3 kilometers farther north* (*Nature, Vol. 83, No. 2116, May 19, 1910, p. 353*).

Loperfido (1909), of the Istituto Geografico Militare, luckily recorded the vertical displacement of the Sicilian and Calabrian coasts, before and after the event. These

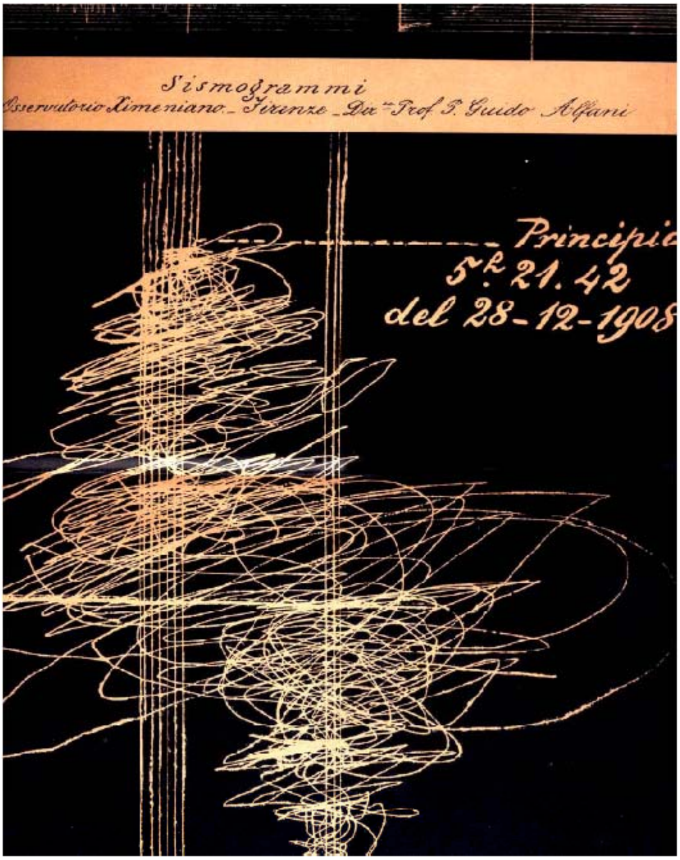

Fig. 3. Vertical component of the seismogram recorded at Firenze, at the Osservatorio Ximeniano.

geodetic data were used by *Mulargia and Boschi (1983)* to determine the focal mechanism of the earthquake (see next section).

Fig. 3 shows the vertical component of the seismogram recorded at Firenze, at the Osservatorio Ximeniano, where Father Guido Alfani was the director. He annotated: *This morning at 5.21 an impressive and extraordinary registration began at the instruments of the Observatory: The amplitudes are so large that they do not fit in the cylinders, which measure 40 cm.*

The Russian and English fleets were at the Strait and went immediately to Messina to provide the first aids and rescue the survivors. The Italian torpedo-boats "Sapfo" and "Piemonte", who were at the port at the moment of the earthquake, rescued more than 400 people.

3. TWO FAMOUS WITNESSES

The Russian writer M. Gorkij (or Gorki) and the German geophysicist M.W. Meyer were living at Capri and arrived in Messina four days after the disaster (*Meyer and Gorkij, 1909*; *Gorkij and Meyer, 2005*). As a writer, Gorkij captured the overwhelming dramatism of the event: *a huge wave raises in the sky and, covered by a white foam, it bends, crushes and falls towards the shore, wrapping, with its tremendous weight, corpses, buildings and ruins, crushing, drowning and, without breaking against the shore, it spreads and drags with it all that it touches: ships, doors, furniture, women, children, priests, workers, soldiers, students and, finally retreating, it sucks everything towards the sea, launching it over the rocks, killing who is still alive.*

M.W. Meyer, using a more technical language, provided a tectonic-volcanological description of the nature of the earthquake. For instance, he wrote: *The earthquake of South Italy had its epicenter, its crucial point, in the middle of the Strait of Messina, near the coast of Calabria, towards Reggio. The scheme reproduced in the preceding picture* (see Fig. 4)*, designed long time ago by the famous austrian geologist Sueß, and extracted from the work of Sieberg'schen, presents the SW part of the Tyrrhenian Sea limited by Calabria and Sicily. The dashed arc is the most known seismic zone, passing directly through Reggio and Messina. The dashed lines indicate the direction of the telluric events,*

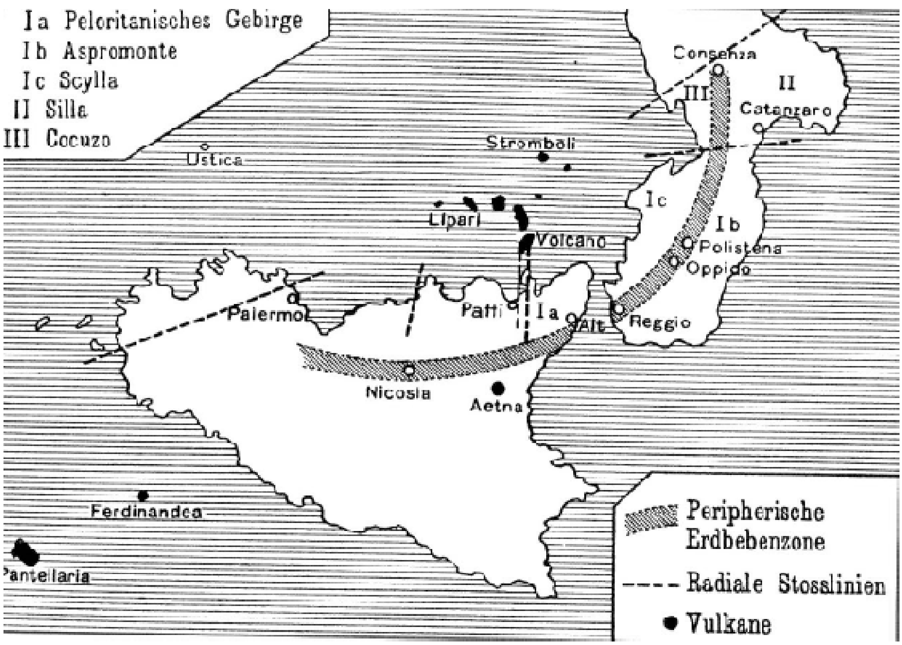

Fig. 4. Part of the Tyrrhenian Sea limited by Calabria and Sicily. The dashed arc is the most known seismic zone, passing directly through Reggio and Messina. The dashed lines indicate the direction of the telluric events.

Fig. 5. Photo of the port of Messina taken by W. Meyer.

as previously have occurred. One can see that these lines point to all the Eolic volcanic island and particularly to Stromboli, which is active from ancient times. Meyer continues with the interpretation, and states that the volcanos are not the cause of the earthquakes but a consequence of the tectonic motion of the underground: *The volcanos have something to do with the fault zone. But today we know that they are not the cause of the formation of the fractures, but their consequence. There, where such cracks are very deep, because of the motion of the big plates in the Earth crust* [plate tectonics!]*, there is a flux of magma forming the volcanos ... Of the 69 telluric events recorded till the end of the last century, 86% occurred near the mountains of the Tertiary period, hence during the last geological age previous to ours; 6%, instead, near the mountains of the primary period and only 0.4% near the most remote mountains ... On the coast, where the sea is very deep near the young mountains, nature is always active* [passive margins].

Meyer brought a camera with him and took several pictures. The photo in Fig. 5 shows the port of Messina, where the wave-like shape of the floor is probably due to the passage of the surface wave.

4. HISTORICAL FACTS

The occurrence of strong earthquakes in the region can be found in the Italian earthquake catalogues and atlases of isoseismal maps (*Postpischl, 1985*; *Carrozzo et al., 1973*). A closer look at them reveals that we may classify the earthquakes into four main groups. The first group of east Sicilian strong earthquakes (1114, 1169, 1542 and 1693) covers the region named Val di Noto, where the Collision Zone, separating Euro-Asian and African tectonic plates leaves Sicily and enters the Ionian Sea. The second group of earthquakes (1669, 1818, 1898, 1911 and 1914) is more or less linked with the volcanic processes of the largest active European volcano, Etna, since the epicenters of these earthquakes are entirely located on the SE, S and SW slopes of this monumental volcano.

The third group consists of a single anomalous event, the 1823 earthquake, whose epicenter was located on the north coast of Sicily (near Naso town). However, strong tsunami waves recorded during this event indicate that the epicenter could be located offshore in the Tyrrhenian Sea. The fourth group of strong earthquakes is related to the Messina Strait, where two of the largest European earthquakes occurred: the 1783, February 5 and the 1908, December 28 events. The first spans from 1780 to 1793, i.e., ten years after the main shock occurred. There were two main shocks on February 5 having the same epicenter intensity; the first occurred at 12 h 45 m, and the second at 18 h. Two further shocks followed on February 7 (*Postpischl, 1985*). The epicenter area of all the earthquakes covered - in general - the narrow SW Calabrian promontory from Taverna town in the north up to Melito town in the southern tip of the Italian Peninsula, including the NE corner of Sicily, north of Messina. The center of main damage, however, during the occurrence of the strongest shocks (between February 5 and March 7, 1783) progressively migrated to the NE along the Ligurian Sea coastal zone, from Scilla at the Messina Strait to Girifalco in the NE (*Placanica, 1985*). The area of macroseismic

Fig. 6. Hand-colored copper engraving illustrating the 1783 event showing the sea-entrance into the Sicily Strait seen from the north (*Kozák Collection, University of Berkeley; http://nisee.berkeley.edu/Kozak*).

perceptibility extended up to Basilicata and Campania and over the whole Calabria, Puglia and Sicily. The number of casualties was assessed at 30 to 35 thousand. Large tsunami-waves occurrence indicates tectonic vertical seismic displacements in the parts of the Liguria sea floor off the north-west Calabrian coast.

The 1783 event was investigated by several authors, e.g., *Vivenzio (1783)*, *Baratta (1901)*, *Barbano et al. (1980)*, *ENEL-DCO (1986)*, *Placanica (1985)* and *Margottini and Kozák (1992)*. In the last two books a rich imageinventory material related to the 1783 Calabria earthquake is given.

The illustration of the 1783 event (see Fig. 6) shows the sea-entrance into the Sicily Strait seen from the north. At the left, there is the light tower of Scilla damaged by the earthquake, and behind the tower the city of Reggio Calabria can be seen. In the central part of the image the waters of the Strait are disturbed by large waves and by a whirlpool causing troubles to ships and boats. At the right side, the city of Messina is portrayed as partly damaged (city walls and towers); the damaged Charibde light tower can be seen in the foreground. At the right margin, the Etna volcano is depicted. The composition is stylized, where the details related to the earthquake effects are artificially and vividly displayed. Technically, the image represents a hand colored copper engraving, a Vue d'Optique (print for optical projecting) created in 1780 in Augsburg, Germany (*Kozak collection,* see *http://nisee.berkeley.edu/kozak*).

5. THE GEOLOGICAL SETTING

According to the plate-tectonics theory, the mainland of the "Old World", i.e. Europe and the adjacent parts of Africa and Asia, is divided into the Euro-Asian and African plates. The frontier zone between the two blocks starts at the Azores in the Atlantic Ocean. It goes eastward through the Gibraltar Strait, along the north African coast to north Tunisia and from there to Sicily, penetrating the Ionian Sea. Here, this frontier zone - usually called collision zone - takes the shape of the large "Arco Calabro" which turns to the north and NW and goes along the west coast of the Italian peninsula towards the Alps. Here, it turns again and runs back to SE through the Adriatic Sea towards west Greece, Cyprus and eastward on (*Parrotto and Praturlon, 1981*).

Due to differential movements of Africa and Europe, the Mediterranean part of the Collision Zone is characterized by a high seismicity along its entire path, especially in its central part - between north Tunisia and northern Italy. In this particular segment, the Collision Zone has a complex geometry being additionally complemented by numerous side faults and tectonic anomalies, particularly at the Messina Strait. This complexity, together with strong tectonic stresses, is the cause of the repeated occurrence of strong earthquakes accompanied by an intensive volcanic activity (Vesuvius, Stromboli and Etna).

6. RECENT INTERPRETATIONS OF THE SOURCE MECHANISM

The accepted geological interpretation of the Messina Strait is that it is a narrow basin along a NNE-SSW direction cutting the Calabrian Arc, which separates the African plate from the Tyrrhenian basin. Uplift in the Pliocene generated normal faults leading to a N-S oriented graben structure. The first interpretation of the seismic events recorded at several stations was performed by *Rizzo (1910)*. *Mulargia and Boschi (1983)* proposed a fault mechanism based on the geodetic data acquired by *Loperfido (1909)*. A summary of the proposed mechanisms is given by *Pino et al. (2000)*. All the researchers conclude that the source is an extensional normal fault whose plane is nearly parallel to the strait. In particular, *Pino et al. (2000)* propose a 43×20 km fault plane with an average slip of 1.5 m and a seismic moment of 5.4×10^{19} N m ($M = 7.1$). The dip of the fault is nearly 30°.

According to interpretations based on seismic profiling (*I. Finetti, personal communication*) and the nature of the differential motion between the African and Tyrrhenian plates may exclude the normal-fault model. Research is still on-going to unravel the nature of the fault mechanism.

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