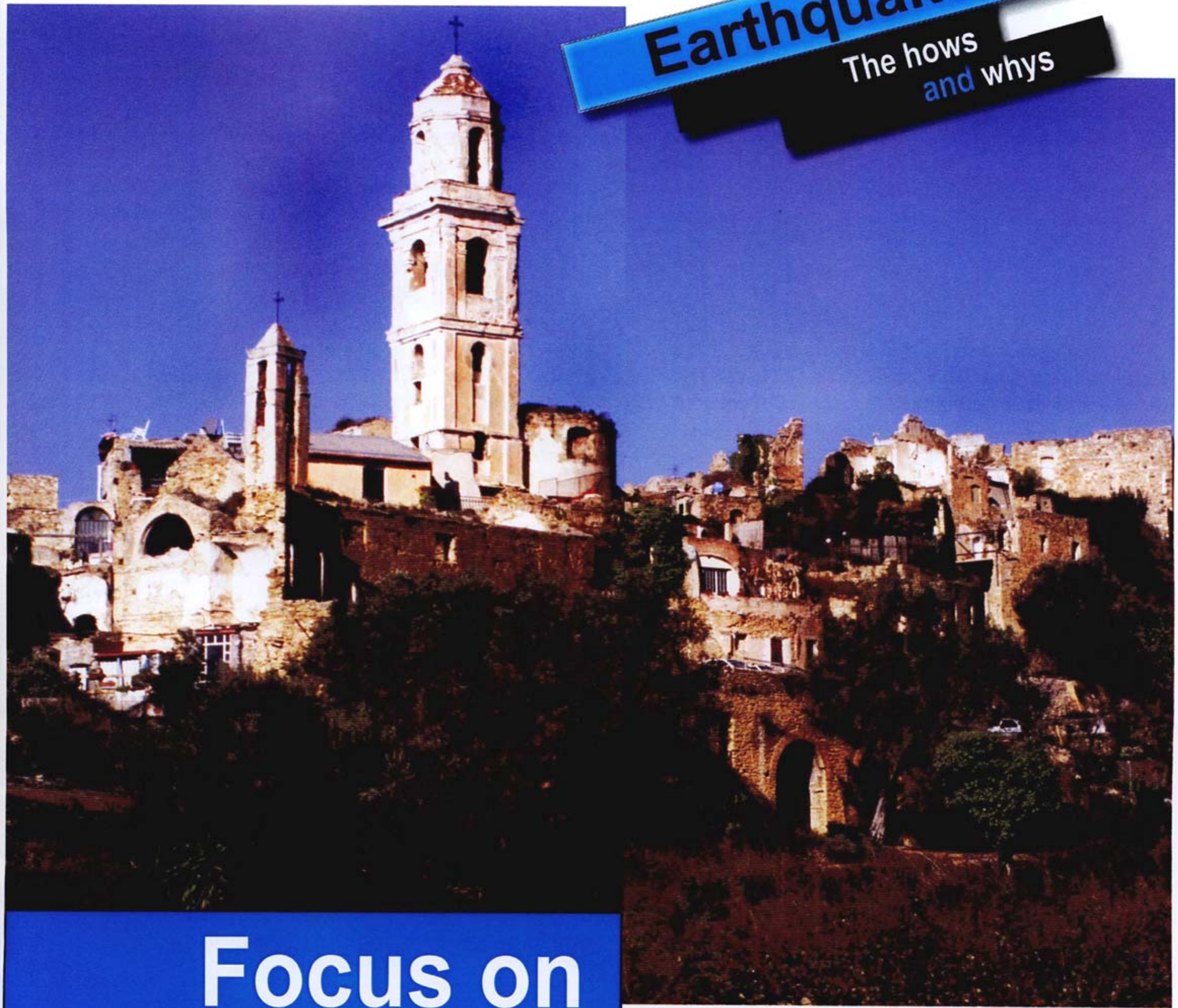
Earthquakes
The hows and whys



Focus on

The February 23, 1887 Ligurian earthquake

Huitième Année. — N° 55 CINQ CENTIMES Jeudi 24 Février 1887

LE PETIT NIÇOIS

JOURNAL RÉPUBLICAIN QUOTIDIEN

IN NICE

Our people so happy, so light–hearted until two days ago, have had a terrible awakening this morning. At 5.51 AM, a terrible earthquake shook our city, in this Wednesday, February 23, 1887.

It was like a rip in the time-space. Everything creaked, walls, furniture, the bells were ringing, the dogs barking, dismayed and trembling people jumped off from their beds and hurried to leave their homes. All of a sudden, the streets were offering their most depressing face. Shocked barely dressed women were running here and there, babies out of their cradles, on the road.

At 6.05 AM the ground trembled again. Nobody was safe anywhere and people escaped to the countryside, looking for an open field. Fortunately, the aftershock did not turn out as striking as expected, it was smaller than the main one, but you can never stay safe and you fear stronger shocks.

There is nothing more frightening than this danger for it is broad and unpredictable, a danger you cannot prevent for it happens with no warning.

Nice looks like a gypsy camp. On the Massena square, the crowd is large; people bring chairs and find their place there. On the Promenade des Anglais, in the public garden, all along the beach it is the same. Nice is moving. The panic has not ended and the shock increases. People do not go back to their homes and wait. With no news, information is telegraphed in all directions. More than four hundred people are waiting in line at the telegraph office. The news coming from Menton spread very quickly. They report of a greater disaster, houses collapsed, and many victims.

All authorities are in action, the prefect walks on the streets and recommends calm and sangfroid. Block after block, damages are more or less serious, but many buildings are ruined.

People are asked to remain calm. Many leave the city, some are in the countryside, and others are at the train station, forgetting that the danger is widespread, that the quake is not limited to the area of Nice, but it extends from Genoa to Marseille.

Genova Giovedì 24 Febbraio 1887 Anno XV - N. 55

IL CITTADINO

GIORNALE DEL POPOLO

ONEGLIA (PROVINCE OF IMPERIA)

Many houses collapsed, including the telegraph office and the Royal College. Everywhere one can see smashed roofs, shaky hips, holes in the windows, open windows and shutters flapping in the wind, curtains flutter out of abandoned houses and sometimes some piece of wall comes off and crashes down crumbling into rubble dust.

Fifteen days after the disaster, the technical committee of the civil engineering office declared 90% of houses unfit to live in.

Number of victims: 20 dead - 22 wounded.

Excerpt from the memoirs of Giuseppe Mercalli: I terremoti della Liguria e del Piemonte, Napoli 1897.

Note: Oneglia and Porto Maurizio have been under the administration of Imperia since 1923.

Patterns of activities

- Determine the intensity of the earthquake in the cities of Nice, Imperia, Genoa and Menton on the basis of historical documents.
- Imagine how the tremor was felt in Zurich, Grenoble and Turin. On the above "map of the area", record the intensity registered at different points. Identify the area where the quake was felt the strongest.
- How can you explain the exceptional circumstances occurred in the towns of La Bollène-Vésubie and Albissola?
- Using data from the seismograms, pick the arrival times of seismic waves at each station. Do your results confirm the supposed epicentre?
- Underline all the elements, in the scientific paper, that argue for an epicentre located in the sea. Identify the difficulties encountered by today's researchers in determining the geological structures involved in the 1887 earthquake.

Education and training are two ingredients that allow citizens to learn scientific information otherwise confined within laboratories, in particular in the field of environmental risk. It is in this perspective that the O3E (French acronym for European Observatory for Education and Environment) project was born. The O3E project is the follow up of a 10 year long testing phase (1997-2007) during which several national projects ("Sismos à l'École", "EDURISK" and "climAtscope") were born.

The overall objective of the O3E program is to network educational institutions, which are equipped with educational instruments and sensors to measure environmental parameters, across regions of the Latin Alps. Data on ground motion (seismometers), temperatures and rainfall (weather stations), on water resources (hydrogeology) recorded in schools are collected on dedicated servers, which are then made available to the educational community through the Internet. The so-structured O3E network becomes the starting point for many geosciences teaching and educational activities to natural hazards in order to:

- promote experimental sciences and new technologies
- network the actors involved in education and training
- develope the sense of autonomy and responsibility in young people
- strenghten and develope relations with regional partners in the field of education and academia
- foster rational awareness of the problems related to the geological heritage and to the prevention of natural hazards, that is what can make the difference, in terms of safety, when an event occurs.

Taking into account the guidelines of the program (which gives a large space to communication technologies), its educational dimension (awareness of environmental risks), its scientific content (geosciences), and its importance on a regional and even international scale (networking of schools), initiatives are started up by schools in close cooperation with the university and research community. As it is the case of this pamphlet dealing with an earthquake, which is emblematic for the regions involved in the O3E project: the Imperia –Menton earthquake occurred on February 23, 1887. The data collected here (archives, seismograms, recent oceanographic studies ...) will enable students and their teachers to deal with a case study.

The press is unanimous; the earthquake hit a vast territory from Genoa to Marseille, from the Mediterranean coast to Switzerland. Several examples help describe how people experienced this catastrophe.

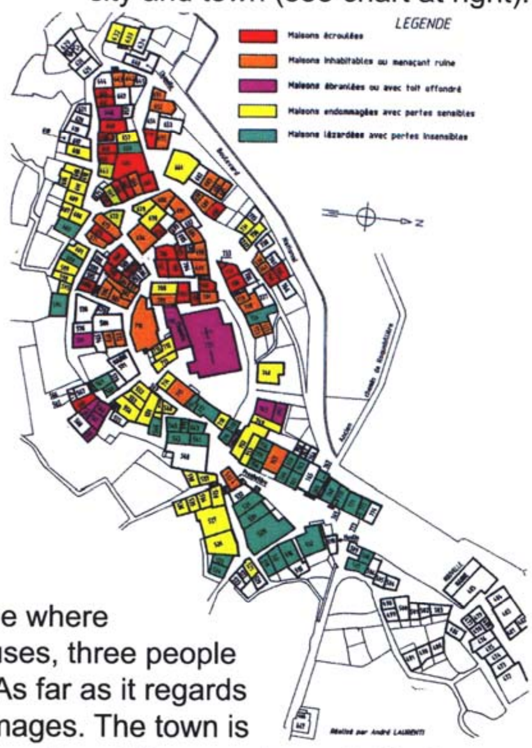
Villa Molinari dans le Borrigo
(Collection Didier Moullin)

In **Menton**, for example, the damages were terrible, appalling. Every building had been struck by a shock. Panic was widespread. According to press records, the area between the station and the Hôtel des Postes, up to the sea, was the most affected one. Many houses became unfit to live in and to public safety. The same as other buildings, which were located in the upper part of the old town, generally poorly built. The charming avenue de la Gare seemed to have undergone a bombing, up to the side of the railroad, no house was intact.

Genoa seems to have suffered less. The earthquake surprised the people during a masquerade. A terible panic was immediately sparked...The chandeliers swung, many candelabra blew out. The streets were suddenly invaded by a flood of people who hurriedly jumped off from their beds. Several houses collapsed and many families found themselves homeless. The retreat of the sea was observed in different parts along the coast, particularly in Genoa. So, the city was violently shaken by an earthquake which caused some damage in a limited number of houses. A systematic investigation was conducted to assess the intensity of the earthquake in every city and town (see chart at right).

Unusual circumstances ...

La Bollène-Vèsubie, 50 kms north of Nice. That particular day, in that town whose population is 741, the first shock was extremely intense. About forty houses collapsed, others became unfit to live in, being more or less ruined. Two people died in the disaster and some were wounded. In the municipal archives there are records saying the quake heavily hit only one part of the town, leaving the other part safe (out of 285 buildings, more than 12% collapsed and more than 26% cracked or was severely damaged: see side scheme).

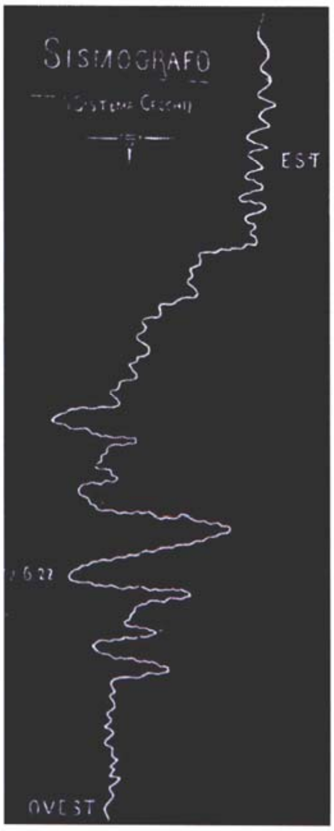


Albissola Marina, 5 kms east of Savona.
Albissola Marina is the easternmost point along the coastline where the earthquake was a disaster. There collapsed several houses, three people died along the main seafront street and 10 were wounded. As far as it regards public buildings, the kindergarten suffered considerable damages. The town is partly based on a subtle layer created by recent floods and partly on Pliocene clay soil. On the contrary, the town of Albissola Superiore, which lies on alluvial soil too, suffered only slight damages and this happened maybe because the quake's intensity was weaker there than on the coast. As far as it concerns this town, we also have some information recorded by a damages inventory published in 1897 in the memoirs of Giuseppe Mercalli: 55 houses were unfit to live in, 118 became fit to live in after being repaired, 6 were damaged or to be demolished. Number of victims: 3 dead - 10 wounded.

INTENSITY

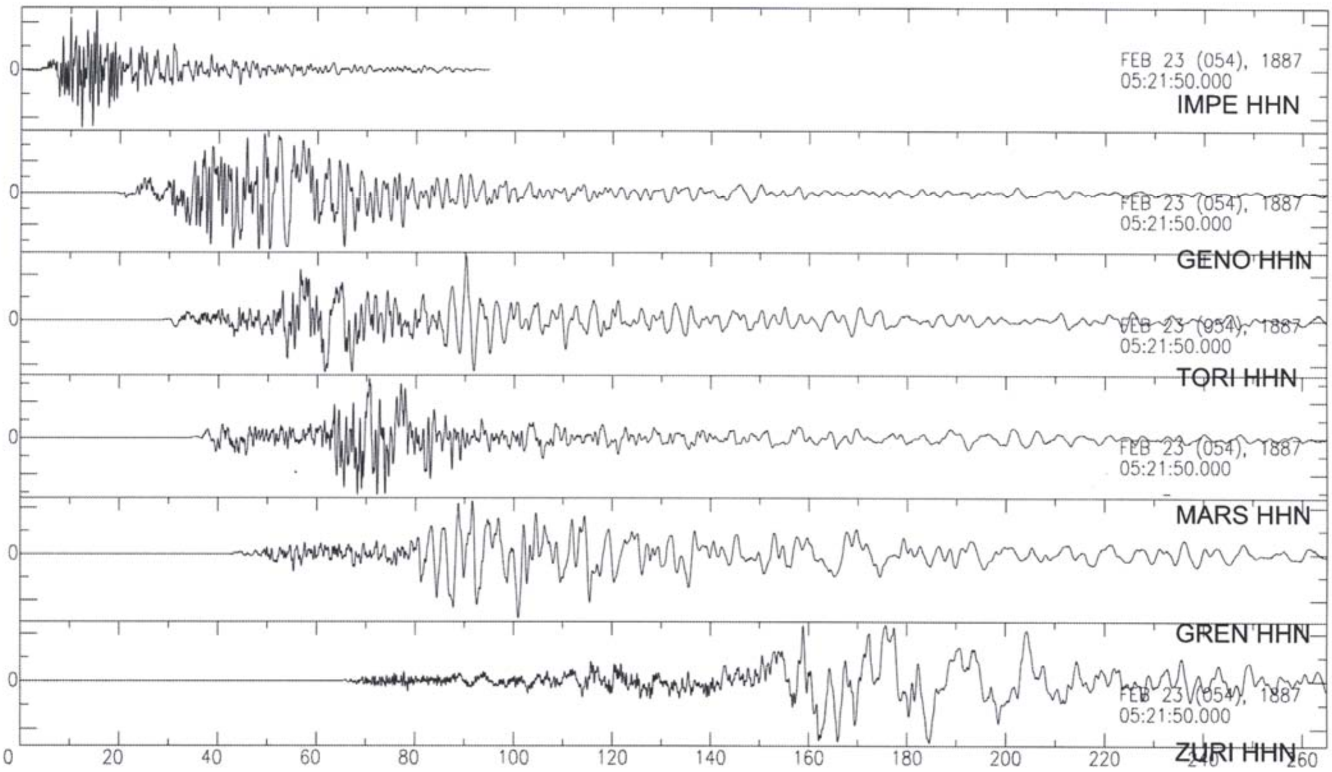
Let's spy the Earth's seismic secrets!

Town	Estimated intensity
Grasse	VI
Marseille	V
Grenoble	IV
Nice	
Imperia	
Savona	VII
Genoa	
Cuneo	VI
Turin	V
Lausanne	III
Menton	



At that time, research observers did not have many seismometers to record the seismic activity of the Earth. However, some records have been found, as it is the case of the one recorded by the Observatory of Moncalieri, near Turin.

Today, it is possible to simulate the seismograms that would be recorded in different cities if a similar earthquake occurred again. The expected seismograms for different cities are presented below. In order to get them, we have relied on the real records of the April 6th, 2009 L'Aquila earthquake, whose magnitude was 6.2.



One of the main purposes of current research projects is to determine potential seismic sources in the Latin Alps.

However, we have access to partial information only. In fact, in this region, destructive earthquakes have been rare events and so they have not left many traces in collective memory. Therefore, it is mainly the analysis of the land that provides us with data which are necessary to identify active faults and deformation mechanisms.

During the last hundred million years, the evolution of Europe has been dominated by the convergence between the African and Eurasian plates and this led first to the subduction of the Tethys Ocean and then to the collision of continents. Thus, in its present structure, the area gives evidence of this geological history. Several faults rifted the upper crust of the area, some of them reach the sedimentary cover, at about one or two kilometres in depth, as it is the case of the superposition of the Nice and Castellane tectonic arcs. Others run many kilometres through the crystalline basement, as it is the case of the Argentera – Bersezio fault (FAB).

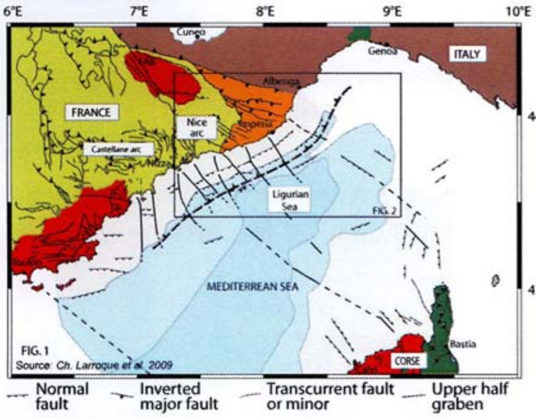


FIG. 1
Source: Ch. Larroque et al. 2009

On terra firma, the research field includes the following geological zones:

- The Argentera Massif, with its peak of 3200 mt. There has been recorded some evidence of recent deformation.
- The Nice and Castellane arcs. Geological studies have called attention to significant recent deformation.

At sea, the structure of the Ligurian region consists of:

- The north Ligurian continental margin that is very narrow and features a plateau which is reduced to few hundred meters. The active deformation of this area has been known for some time.
- The central part (about 2500 mt. below sea level), which is relatively flat and oceanic.
- The south Ligurian continental margin running north of the Corsica-Sardinia block.

The region of the Southern Alps - Ligurian Basin is one of the most seismic areas in Western Europe. For example, between January 1980 and March 2008, the seismic record unit at the French Seismological Central Bureau recorded more than 5717 earthquakes in this area.

During the last thousand years, until 1920, 68 earthquakes occurred as historically recorded in south - eastern France and north - western Italy. At least two of these earthquakes have caused significant losses in human lives and major damages. One of these two earthquakes is the Ligurian earthquake (February 23, 1887, I = X MCS), for which a magnitude of 6.5 - 6.7 is estimated. Therefore, this is an area particularly important to detect traces of these two events, and probably those of other ancient earthquakes. Many marine geophysics studies were devoted to understanding the structures of the margin and its dynamics. In order to analyze the morphology of the northern Ligurian margin, we have developed the MALISAR Project, whose main objectives are:

- Studying the morphology of the margin in order to characterize recent and active deformations,
- Determining whether potentially active structures identified on land extends on the margin,
- Featuring submarine slides and their possible connection with the deformations.

The preliminary analysis of the data provided by the MALISAR campaigns showed a number of new elements:

- The submarine slides influence the essential of the west part of the margin, but in a general way. The level of destabilization (visible on surface) of the continental slope tends to decrease towards the east;
- Some slides are on active tectonic zones, such as the area of the epicentre of the 1887 event;
- Structures in direction N70°E, oblique to the direction of the margin, form staggered landslides in the basin and some of these landslides continue on the slope;

We present briefly two peculiar points that are related to the active deformation of the margin: the landslide located at the foot of the slope, off Nice (the "Marcel" fault) and the great Imperia Promontory on the east side of the margin.

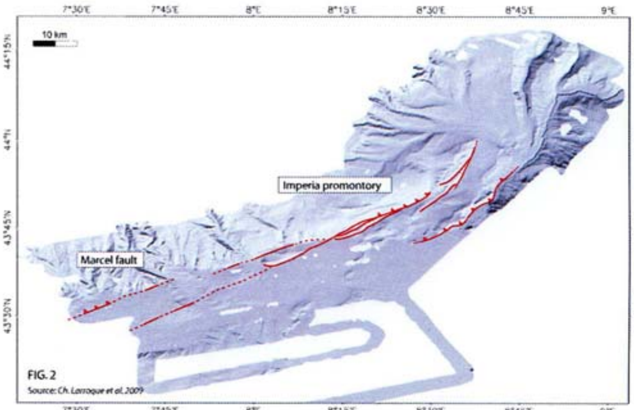


FIG. 2
Source: Ch. Larroque et al. 2009

1) The Marcel fault

The earthquakes of 1986 (ML = 3.8), 1989 (ML = 4.5) and 2001 (ML = 4.6) are located at the foot of the continental slope, about 30 kms south of Nice. This area, west of the canyon of La Roya, is crossed by a landslide that is oblique to the margin. The landslide in direction NE-SW is about 30 mt. high and is continuous over more than 10 kms

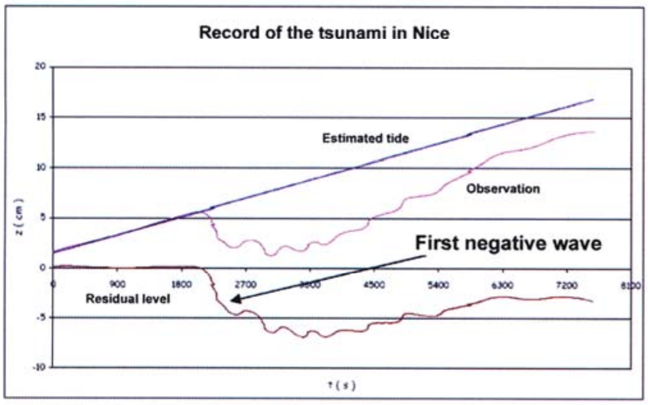
2) The Imperia Promontory

The eastern part of the northern Ligurian margin (east of 8°10E) is more elongated towards the basin and its slope is less steep than the one on the west part. It is dominated by a ridge that extends for about 40 kms between 8°10E and 8°35E. As in the west part, the top of the slope is deeply carved by canyons. However, these canyons do not follow a straight trajectory towards the basin, but they significantly divert eastward.

by the 1887 earthquake

About twenty minutes after the mainshock of the Imperia earthquake (5:21:50 GMT) several witnesses reported sea level movements on the coast and those were recorded by tide gauges in Genoa and Nice. The mapping of these movements allows one to show a tsunami of regional importance occurred, with a maximum "run up" (the maximum vertical height onshore above sea level) height of 2 mt, but it did not spread to all the western Mediterranean. Indexes are mainly located on the north coast, coherently with the epicentre near the coast of Italy and France.

In the chart below, t = 0 corresponds to the time of the earthquake, i. e. 5:21 AM in Nice or 6:21 AM in Genoa. On the mareogram data of Genoa, the amplitude of the tsunami was not more than 40 cm. The first wave recorded by the tide gauge of Genoa is a positive wave and arrives 1250 secs after the earthquake, which is 21 mins. On the mareogram of Nice, the amplitude of the tsunami is between 5 and 10 cm. The first wave recorded by the mareogram is negative and arrives 1930 secs after the earthquake, which is 32 mins.



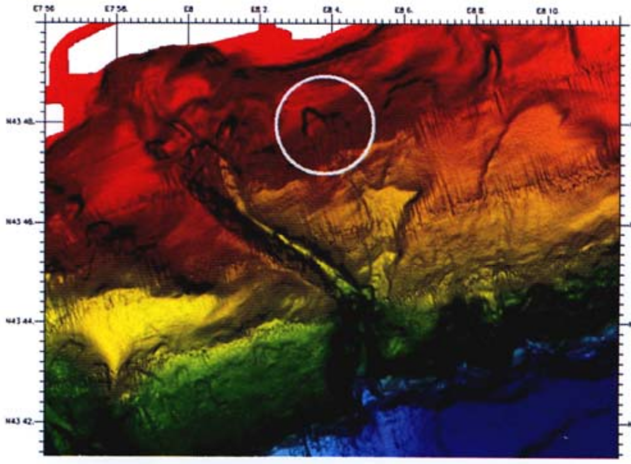
A tsunami simulation was carried out testing different scenarios in order to reproduce the beginning, the propagation and the inundation of the February 23, 1887 tsunami.

As the first scenario shows, the quake is supposed to originate from a submarine slide and one tries to test whether the volume moved by the slide is sufficient to generate the observed tsunami. The tests were carried out by sliding the volumes of each slide separately and together. In the simulations carried out, neither the observed sequence nor the time nor the amplitude of the waves could be reproduced. Therefore, a mere gravitational source can be excluded as the origin of the 1887 tsunami.

Other scenarios, based on faults movement, produce results that are coherent with observations, but this must be regarded as preliminary. The common elements that stand out are: a hypocentre located at a depth of 10 kms, a fault that measures at least 45 kms in length and is oriented parallel to the coastline and the uplift, or subsidence, of a block which is at least 10 kms wide.

All the earthquakes with a magnitude of around 6.5 do not necessarily produce fractures in surface. However, the assumed depth for the 1887 earthquake is rather superficial to find traces of fracture in the surface. The preliminary analysis of the MALISAR campaign's data has not undisputedly revealed the structures produced. However, the above-described structures, the Marcel fault and the faults that border the Imperia promontory, constitute a series of staggered faults, some of whose segments have been recently active. At the current stage, it is not possible to conclude whether one or more segments in the detected faults were activated during the 1887 event.

In the area of the epicentre, the MALISAR campaign's data, collected in August 2006, detect the presence of two detachment niches, which correspond to the sliding scars of the ground. These slides are not dated, but the morphology of the niches and the scarcity of sediment deposited on the wall seem to indicate that they are recent. Assuming they are located in the 1887 epicentre area, one can consider that they may be one of the possible consequences of the earthquake, which would have destabilized the sediments deposited in the upper continental slope. Despite everything, if this slide turned out not to be the only generator of the tsunami, this would not exclude the possibility that the slide was produced as a result of the earthquake, because the tsunami may have been generated by the earthquake and submarine slide combined.



The different results obtained at the time of this study allow us to characterize the most probable source of the earthquake, which occurred on February 23, 1887 in the Ligurian basin. It has been possible to highlight a number of potential structures. Among the major structures: a faults system located south of Imperia, at the foot of the slope; some detachment niches at the top of the slope. These submarine slides are not dated and may date back to 1887. The different modellings of seismic sources allow us to conclude that the most probable source is a normal fault, which is inclined to the south.

(Source: Ch. Larroque, 2009)

References: Larroque, C., Delouis, B., Godel, B. & Nocquet J.-M. 2009. Active deformation at the southwestern Alps–Ligurian basin junction (France–Italy boundary): Evidence for recent change from compression to extension in the Argentera massif. Tectonophysics 467, p.22–34. doi:10.1016/j.tecto.2008.12.013.

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