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The subsidence of Como coastal area, Lake Lario, Northern Italy

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The town of Como (Lombardia, Northern Italy) is seated at the southern closed edge of the western branch of Lake Como (or Lake Lario), at the foot of the Alpine Chain. It is an important cultural and industrial settlement since Roman times. Lake Como lies in a 60 km long, downstream-bifurcated river-glacial trough, intensely modelled by an ice tongue up to ca. 2 km thick during the Last Glacial Maximum. Since 1946 the lake water level is artificially controlled by a dam located at the end of the eastern branch of the lake. Nevertheless the intensely urbanized coastal area of Como, being affected by subsidence phenomena, is recurrently damaged by temporary lake inundations.

To effectively understand the origin of the subsidence, we have taken into account the role of all the different natural (Climate, Geology, Tectonics) and human ($e.g.$, artificial filling on the lake shore, water withdrawal from wells) components in the geologic and environmental evolution of the Como sedimentary basin, from Late – Pleistocene to present. Our work is based on: field survey; air photo interpretation; literature stratigraphic, archaeological, topographic, and subsurface data compilation; drilling of exploratory boreholes; monitoring of sediment compaction at the Piazza Verdi, 70 m deep, instrumented borehole; monitoring of aquifers through the Como urban piezometric network; radiocarbon dating; pollen analysis; 3D geological model reconstruction; a new precision levelling survey; SAR interferometry (PSInSAR).

The stratigraphy under the Como plain shows pro-glacial lake sediments devoid of organic matter in the lower part, shallow water lacustrine sediments rich of organic remains, alluvial deposits in the upper part. A wood sample from S. Abbondio site was

first dated at 11730±180 yr ^{14}C B.P. (Castelletti & Orombelli, 1986) and a wood sample we collected in 2003 from the same deposits has yielded ^{14}C age of 13230±120 yr B.P. An organic sample from the fluvio-lacustrine deposit (via Valleggio site) has yielded ^{14}C age of 13880±210 yr B.P. The maximum depth at which this stratigraphic layer, approximately corresponding to the original lake level, was found in boreholes under the Como plain was utilized to estimate the rate of *natural* subsidence from ca. 13,000 yr B.P. to present.

The velocity of subsidence is given by: V=(S-Δz)/T where V is the velocity, S is the sediment thickness, Δz is the sum of depth variations due to level water oscillations, T the sediments age. Supposing Δz=0, the maximum subsidence rate during the last ca. 13,000 yr is bracketed between 1 to 4 mm/yr, with the higher value distributed in the lakeshore area.

Moreover three archaeological sites of Roman age, now buried under 2.5-3 meters of sediments, have provided comparable historical long-term average subsidence rate.

Since the end of the 19^{th}century, the ground movements were measured by means of geometric levelling surveys. In May 2004 a new precision leveling survey was carried out by APAT to assess the present-day ground vertical movements. Since 1997 along the lakeshore, except for a few benchmarks that lowered with a rate higher than 10 mm/yr, the subsidence rate was 2-3 mm/yr; in the inner part of the town the velocities were smaller ($e.g.$ 1 mm/yr in the *Duomo* area).

Furthermore, TRE (*Tele Rilevamento Europa*) has measured the ground deformation by means of the Permanent Scatterer (PSInSAR) technique during the years 1992-2003. The velocities obtained in the Como plain by the two different techniques are in very good agreement, proving the reliability of the data.

At present all the shoreline area (artificially built during the 19^{th} century) is continuously sinking and the risk of lake floods progressively increases. Further investigations and monitoring already scheduled will allow a more precise constraining of the present-day trend of the subsidence in order to predict its near-future evolution and to lay down the basis for a possible prevention and mitigation planning.