

## **Multidisciplinary research for the safe fruition of an active geosite: the Salse di Nirano mud volcanoes (Northern Apennines, Italy)**

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Mud volcanoes are emissions of cold mud due to the ascent to the surface of salty and muddy waters mixed with gaseous (methane) and, in minor part, fluid hydrocarbons (petroleum veils) along faults and fractures. In the Northern Apennines mud volcanoes are closely linked to the active tectonic compression associated with thrusts of regional importance. They are mostly cone-shaped and show variable geometry and size, ranging from one to few metres, and are located in 19 sites in the northwestern part of the Apennines. Particularly noteworthy is the Nirano mud volcano field, located in the Fiorano Modenese district, which, with a surface area of approximately 75,000 m<sup>2</sup>, is one of the best developed and largest mud volcano field of the entire Italian territory and among the largest in Europe; it is thus protected as natural reserve (Salse di Nirano) since 1982. The Nirano mud volcanoes are found at the bottom of an elliptical depression, interpreted as a collapse-like structure (caldera) that may have developed in response to the deflation of a shallow mud chamber triggered by several ejections and evacuation of fluid sediments.

There are several individual or multiple cones within the field of the mud volcanoes of Nirano, with a rather discontinuous activity; apparatuses become dormant or even extinct whereas new vents can appear in other spots. In the research here presented about 50 vents have been mapped and few of them appeared in May 2016.

The mud volcanoes of the region have been known since a long time and have always aroused great interest due to their outstanding scenic value, and, in the past the mud volcano emissions have been used in many ways. Beside their cultural value, the mud volcanoes of the study area represent a tourist attractiveness as testified by the increasing number of visitors (e.g. about 70,000 visitors in 2015 in the Salse di Nirano Natural Reserve). Numerous initiatives, targeted at various potential users, have been developed in the last decades. In particular, tourist environmental maps, geotourism maps, books in hard copy and digital format, videos, virtual flights, multimedia and audio CDs have been implemented.

Although the hazard from mud volcanoes is generally low, sometimes they may lead to sudden and violent eruptions and isolated casualties have been reported. Very notable case in this regard is the event that occurred in September 2014 in the Natural Reserve of Macalube di Aragona in Sicily where a mud volcano erupted, with an ejection of mud up to about 20 m above the ground and causing the burial of two children killing them. When a given geological site acquires a tourism value, it is necessary to assess the possible natural hazard processes which might threaten the safety of visitors. In particular, fast-occurring processes might directly involve tourists in proximity of the site of interest or along access roads and footpaths. In this context, multidisciplinary research, aiming at analysing the causes and understanding triggering mechanisms of paroxysmal and dangerous phenomena in the Natural Reserve of Nirano, are in progress, funded by the Fiorano municipality. The research team is composed by experts of different disciplines (geology, geomorphology, geophysics, geochemistry, palaeontology, mineralogy, topography) from different institutions. The first results of the multidisciplinary research here presented seem to confirm that no significant and dangerous phenomena can affect visitors along the pathways of the Reserve.