SUMMARY OF ACTIVITIES CARRIED OUT OFFSHORE SCIARA DEL FUOCO IN THE FRAMEWORK OF THE GNV PROJECT #15

Immediately after the tsunami event which occurred on December 30, researchers involved in the GNV Project #15 **"The submarine portions of Italian volcanoes: their survey and assessment of the potential volcanic hazards"**, which includes Stromboli as one of the main areas of interest, organized a marine survey in the sector offshore Sciara del Fuoco, repeating a survey realized just 10 months before. The main purposes of the survey were:

A) to investigate the offshore continuation of the subaerial slide, also suggested by the marked coastal retreat of some 80 m observed at the foot of the subaerial scar;
B) to allow a better comprehension of the processes that generated the tsunami waves. Two hypothesis might be verified: 1) if (at least) part of the instability event originated in the submarine sector, as suggested by the first observations on the tsunami wave propagation pattern; 2) if and how much the subaerial landslide could have been driven by submarine instability, with related implications on the triggering phenomena;
C) to highlight the presence of submarine sectors possibly threatened by further mass wasting processes, for instance those sectors where slided materials could have deposited or where erosional morphologies have been generated.

Two surveys were carried out aboard a Coast Guard vessel in the first two weeks after the event. The first survey (9/1/03) allowed to obtain the multibeam bathymetry of the submerged prolongation of Sciara del Fuoco sector down to 300 m of depth (Fig.1a). During the second survey (15-16/1/03) the area down to –2200m was investigated with deep-water multibeam equipment. The availability of a multibeam bathymetry collected just ten months before (end of February 2002), in the framework of the GNV project #15 research activities, gave us a unique opportunity to compare the pre- and post-event morphology (Fig.2 and 3) and to calculate a first estimate of volumes of rocks involved. The main results can be summarized as follows:

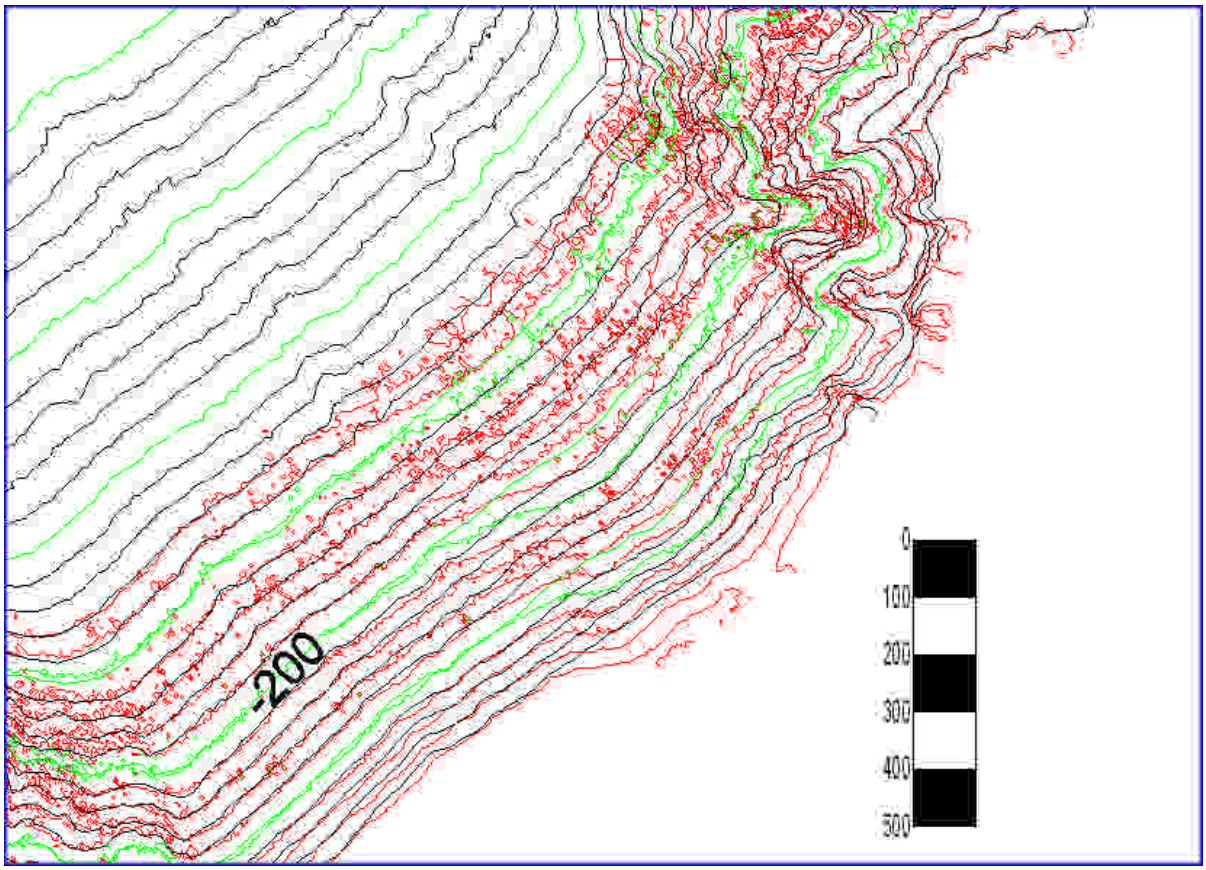

***Figure 1a**. Comparison between multibeam bathymetry of February 2002 (in black) and January 9, 2003 (in red).*

a) instability processes affects a wide area offshore the continuation of the Sciara del Fuoco. A depressed sector (**d** on figure 1b), larger than the subaerial scars, is present on the left side (looking from the sea) of the Sciara. With respect to the pre-event bathymetry, the scar is over 40 m deep in the coastal sector (maximum depth is reached at about – 150 m b.s.l.) and gradually reduces with depth (still exceeding 20 m at –300m of depth, see section G in Fig.2). The right flank appears to be in continuation with the limit of the subaerial scar (Fig.1b) while, on the left, the boundary of the submarine scar is recognizable in the first 200 m of depth, then it could be masked by deposits which accumulated as a grain flow along the offshore prolongation of the northern boundary of the Sciara. Slope breaks are present inside the scar and erosional (**e**) and depositional (**c**) features suggest possible smaller-scale instabilities.

b) Two relevant constructional features have been observed in the sector: the first (**a** in Fig. 1b) is in the nearshore and prolongates onshore. It is about 250x400 m large and up to 20 m thick and is formed by etherometric and unaltered lava blocks, as indicated by underwater shootings performed on January 15 by the Firemen Diving Vessel. It is likely to represent a lava blocks accumulation in front of the lava flow entrance to the sea. A second deposit (**b**) is present all along the northern side of the depression, showing maximum thickness of 10 m. It is composed by decimetric and centimetric loose scorias and, as suggested by the underwater observation of debris suspension, it could be originated by wave reworking of scoriaceous lava fragments or material avalanched across the shoreline from the Sciara subaerial slope, then drifted northward and dammed by the steep northern border of the submerged Sciara. These setting witnesses that the submarine morphology is evolving rapidly after the event, due to lava emission and rock fall from the subaerial slope.

c) A first estimate of the rock volume involved in the submarine landslide (more than 10 millions of cubic meters, subtracting the above mentioned depositional areas that account for 1 million of cubic meters) indicates that the submarine loss is larger than the volume mobilized from the subaerial flank and that it could have been the origin of the tsunami wave. The estimate of 10 millions m^3 is very conservative, as the scar continues downslope at least down to 400-450m.

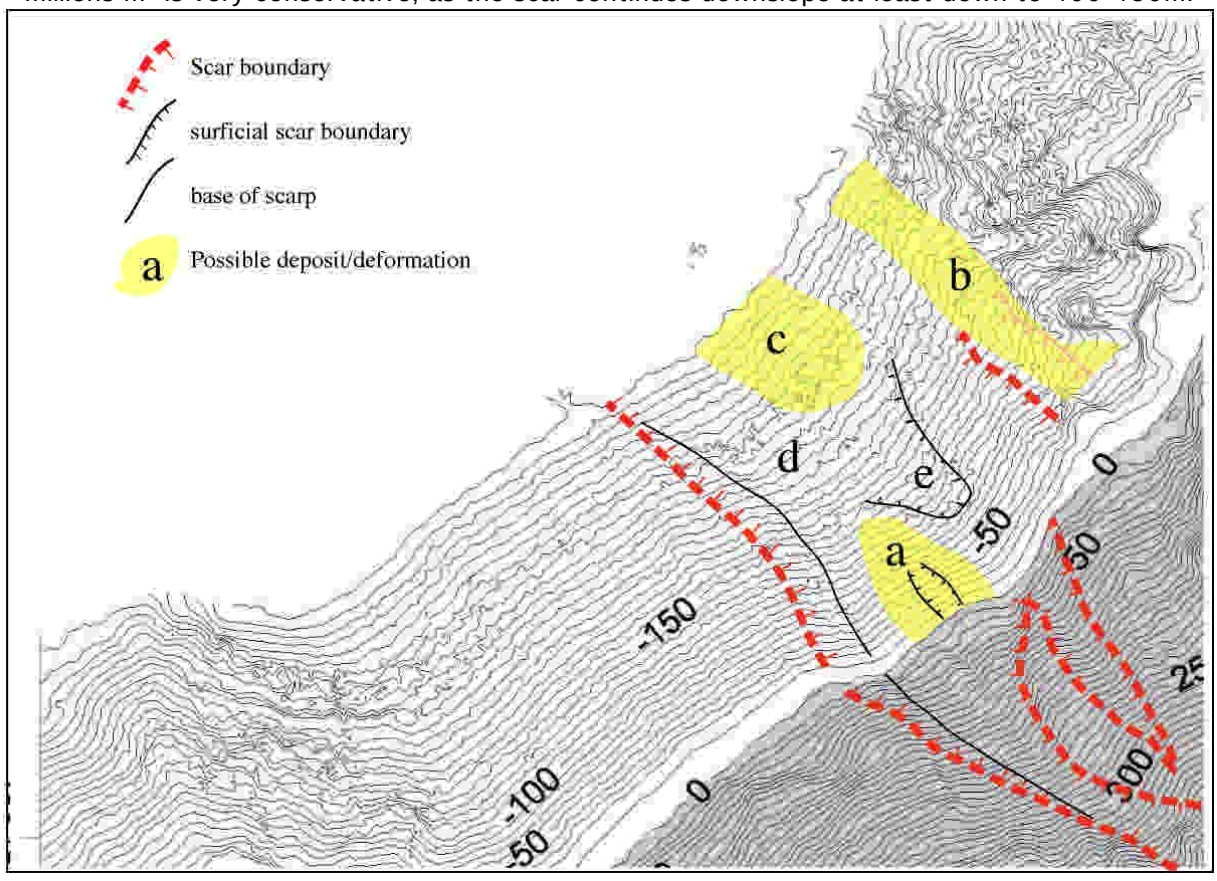

***Figure 1b**. Main morphological and depositional features down to –350 m in the offshore sector of Sciara del Fuoco. Boundaries of subaerial and submarine scars are highlighted.*

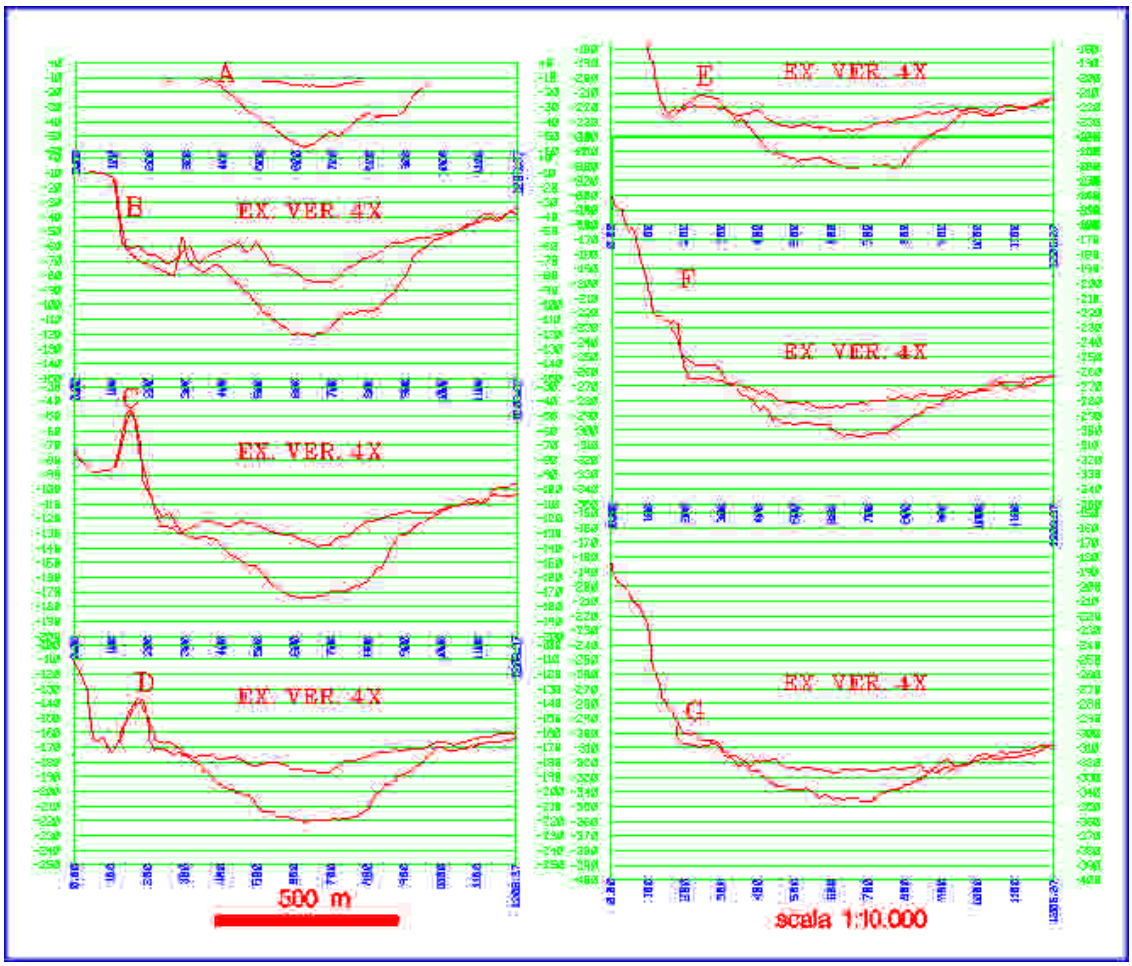

Figure 2. *Seafloor morphologies pre- and post-event in strike sections.*

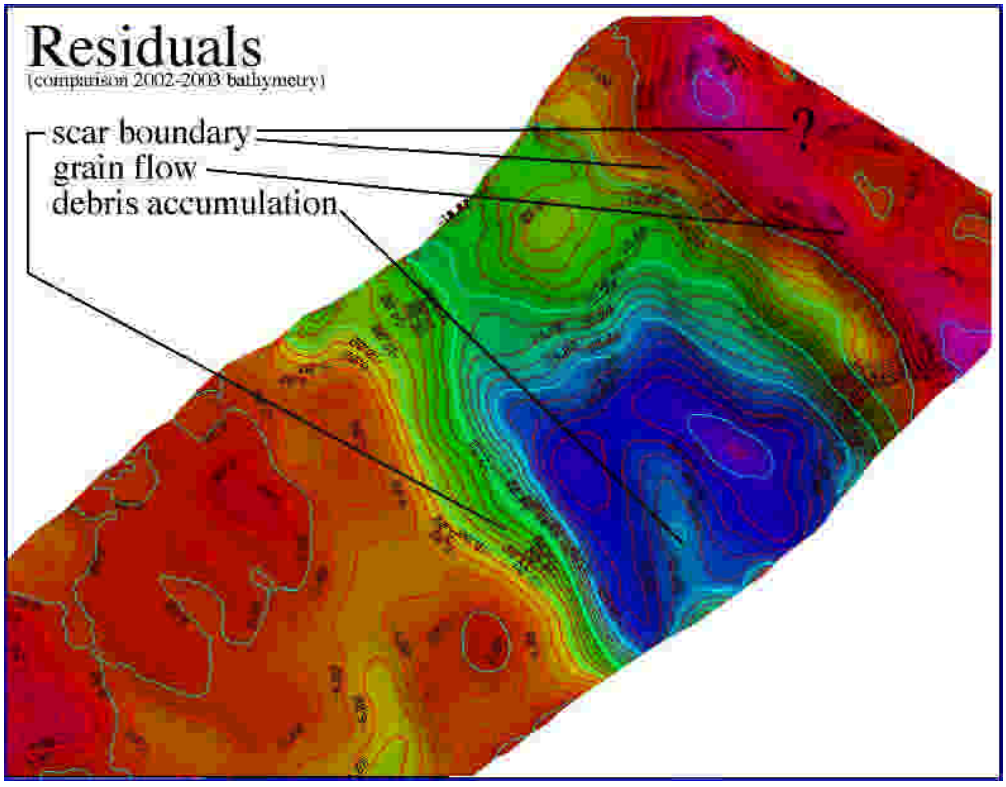

Figure 3*. Map of residuals (i.e.:difference between the 2002 and 2003 bathymetry).*

The results of the deeper survey are still in elaboration, especially as far as the comparison with the data set collected in 2002 and the volumetric estimations are concerned. Nevertheless, first considerations can be done on morphological basis (figures 4a and 4b):

a) below –400 m, where the slope gradients of the submarine flank are lower, the main depression (**d**) looses part of its morphological evidence. In continuity with the shallower one, a narrower (about 200 m wide) elongated scar is recognizable from about -470 and -550 m, down to at least -800 m (**f**). The latter accounts for a lacking (slided?) volume for this depression in the order of 1.5 millions m^3. An other, shallower slide scar is recognizable between –370 and –450 m (**g** in Fig. 4b). The elongated scar rests on a wider and shallower depression running down to, at least, -950m.
b) a possible area of deposition (and/or interested by surficial deformation) is present within the depression on the offshore prolongation of the Sciara (**h**). The presently available data do not allow verifying the nature of the observed features and a major goal of next surveys will be that of obtaining the lithologic and acoustic characterization of the seabottom also in this deep sector. A possible interpretation is that the area indicated as **h** is the partially filled prolongation of depression **d**; in this case, features **f** and **g** might be due to mass wasting processes subsequent to the main instability event. According to a different interpretation, area **d** and **h** might not be genetically due to the same erosion event and the depression **f** (and possibly **h**) should represent the deeper expression of the submarine slide scar. These hypotheses could be verified after the final processing of the acquired data set; also a possible role of pre-existing lineaments in the morphologic development of the areas subjected to instability has to be taken into account.

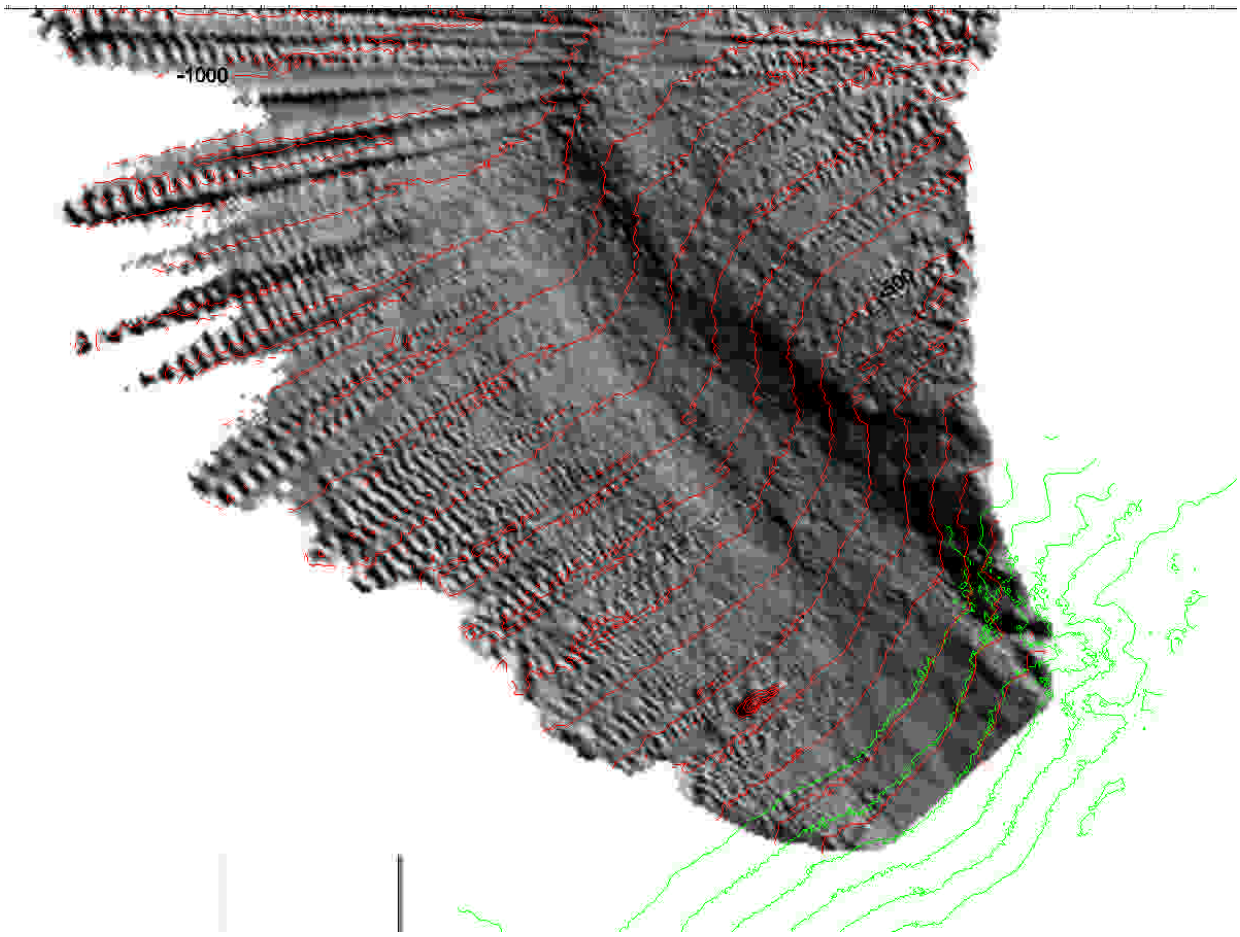

Figure 4a. Shaded relief of the submerged sector covered by the multibeam survey of January 15/16 (in green. bathymetry collected during the survey of January 9; in red: data collected during the survey of January 15,16).

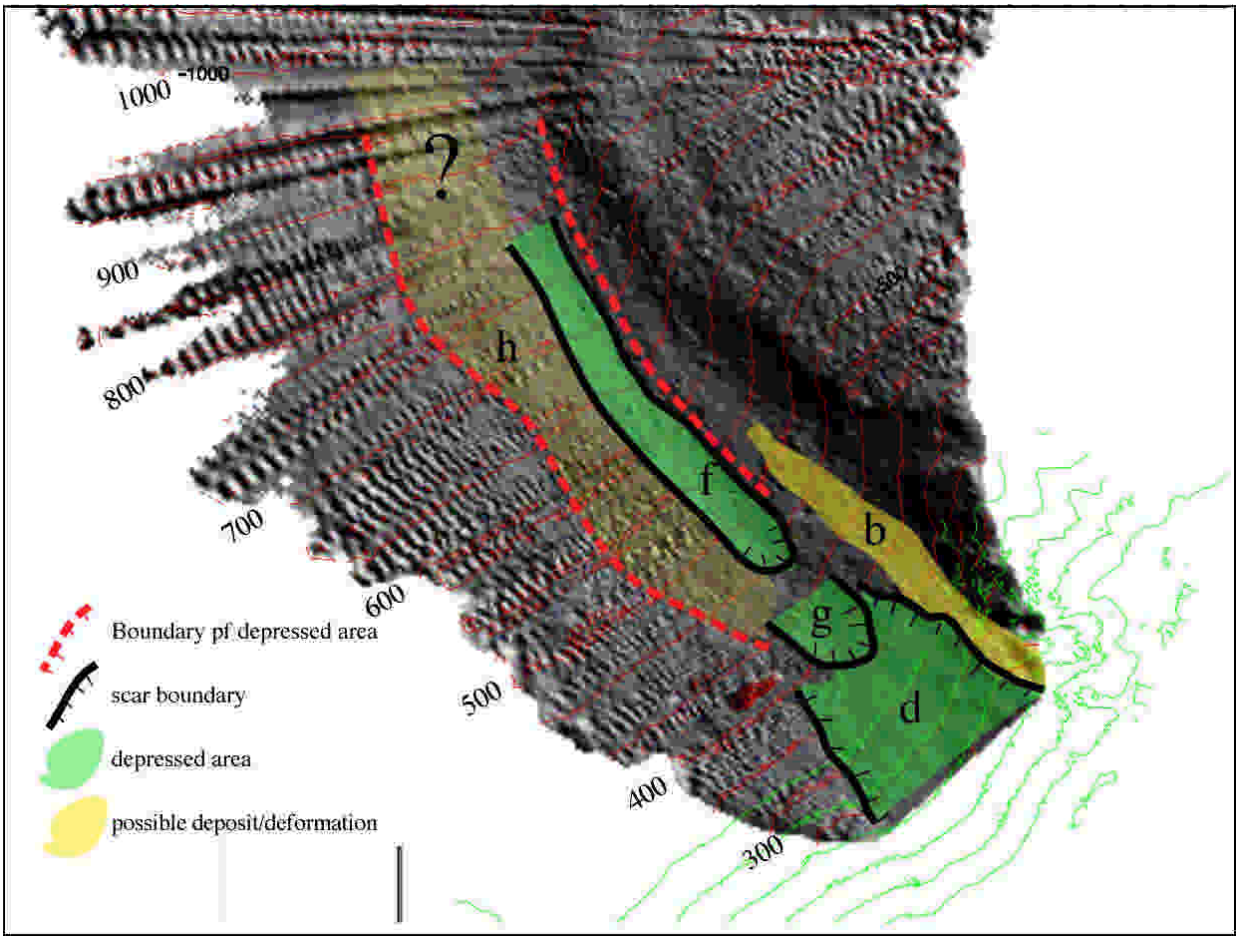

Figure 4b. Main morphologic lineaments identified in the sector

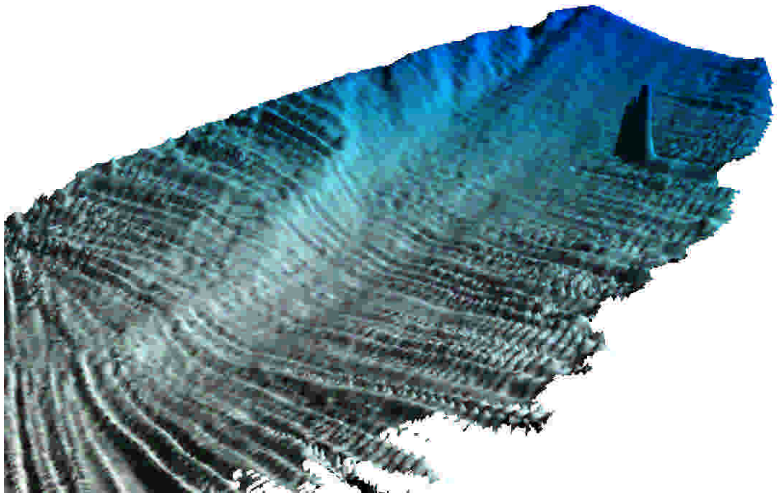

Figure 5. Three-dimensional view from unprocessed multibeam data offshore Sciara del Fuoco (view from the west side).

In conclusion, the submarine landslide which affected the Sciara del Fuoco is likely to have played a fundamental role on the subaerial instability. In terms of hazard assessment, the following considerations can be expressed:

1) In good agreement with different kind of observations, the tsunami waves could have been generated mostly by the submarine instability, affecting areas and volumes larger than the subaerial ones. This assumption shall be verified on the base of interpretations deriving from other independent researches;
2) The sector of Sciara del Fuoco, to the left of the subaerial scar (looking from the sea) might be in unstable conditions, due to the undercutting at its toe, caused by the submarine instability.
3) Evidences of further instability appear to affect both effusive and rock fall deposits at the foot of the subaerial slope as well as the submarine scar. In this last case, the occurrence of instability phenomena concurrent or successive to the main landslide events has to be verified.
4) The rest of the Sciara del Fuoco which at the moment is not affected by gravitative instability, shows a submarine setting not very different from that of the slided sector, being also a high-gradient, by-passing area for loose deposits reaching the Sciara foothill.

Finally, considering the worse possible scenario for the hazard assessment, it should be kept in mind that the main depressed area identified in the submarine portions encompasses a sector of the Sciara that is wider than the sector affected by the subaerial landslide. For this reason, it might be in relation with the widespread and, possibly, deeply seated structural weakening which is developing on the whole northern sector of the Sciara, starting near the crater area. Future instability might therefore involve sectors of the Sciara slope of wider extension with respect to what it could be hypothesized on the base only of the subaerial setting.

The aforementioned considerations result from a collective thought of participants to GNV projects n° 15 and 13 and are based on poorly processed data. These first results are given under emergency and only for Civil Protection purposes. Analysis was performed by A. Bosman, C. Romagnoli, P. Tommasi, M. Marsella, M. Bellino, L. Macelloni e E. Martorelli.

Prof. Francesco L. Chiocci
Coordinatore del Progetto GNV #15

Stromboli, 17 Gennaio 2003