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DEEP-SEATED SPREADING MODEL TESTED ON ETNA MOUNT WITH FEM

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The sliding of volcano's flank is a phenomenon that occurs for different volcanoes in the word. Spectacular examples are:

Socompa (Chile)

Bandai-san and Ontake (Japan)

Mount. St.Helens (Washington)

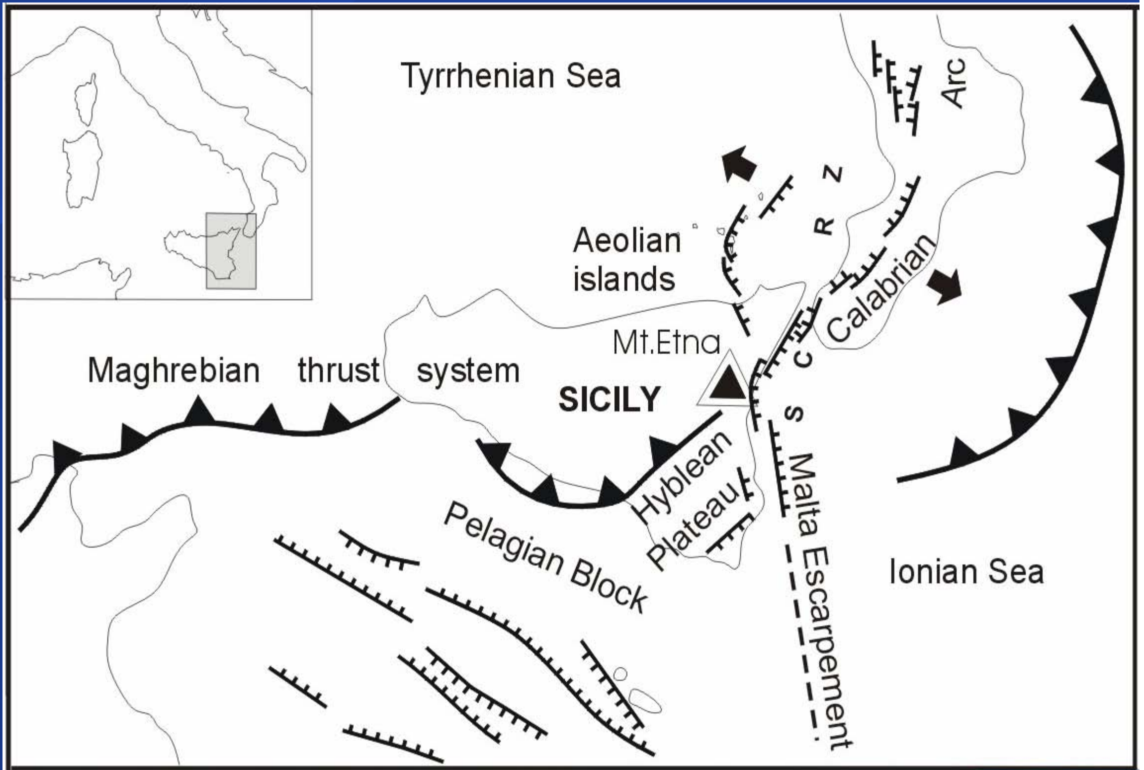
450 m of the summit was removed by slope failure

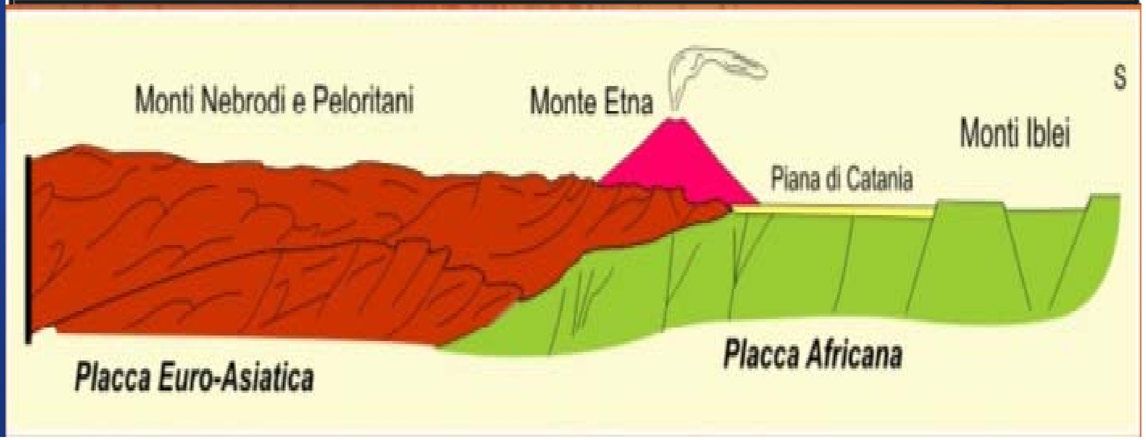
The common factor of these volcanoes is to lie on very active tectonic systems, regardless of the presence of a magmatic complex inside. Among instable volcanoes, particular attention should be paid for Etna….

The Etna volcano: structural scenario

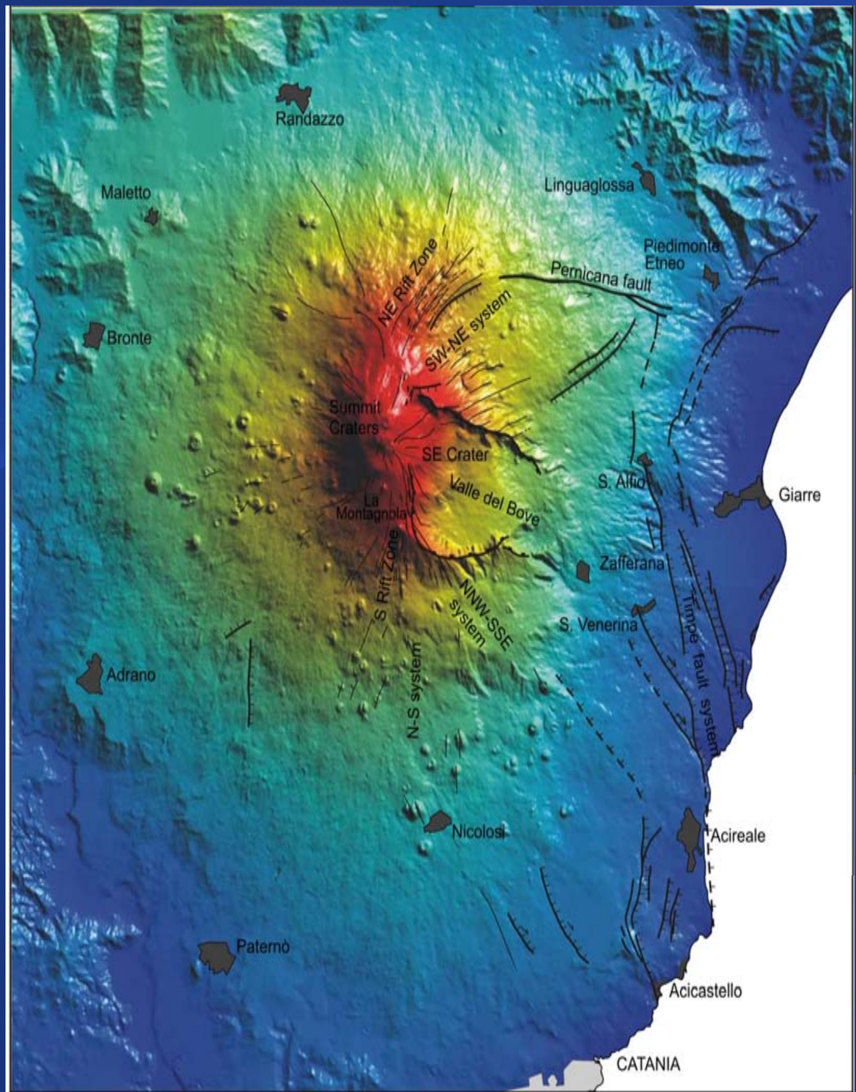
Mount Etna is located in a particular tectonic position on the west side of the Ionian coast, where the Messina-Fiumefreddo system and the Malta escarpment intersect each other, and on the collision zone between the African plate and the Euro-Asiatic one.

Its activity is moreover affected by the opening of the Siculo-Calabrian Rift in WNW-ESE direction.



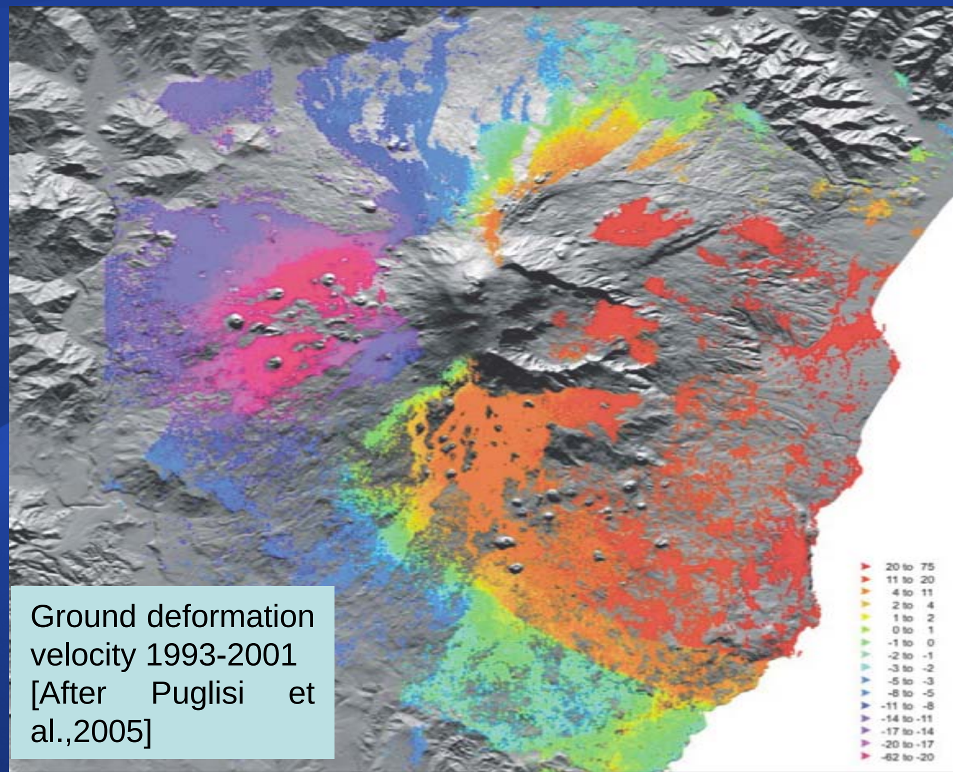


The east flank of Etna is characterized by several active faults associated with middle-low sismic activity of low ipocentral depth and by the presence of a great volcano tectonic depression known as “Valle del Bove”.



In the last 20 years several geodetic networks have been installed on Etna mount. The data acquired show that the eastern flank of Etna is unstable and is moving towards the sea.

This behaviour is also confirmed by other techniques as SAR interferometry.

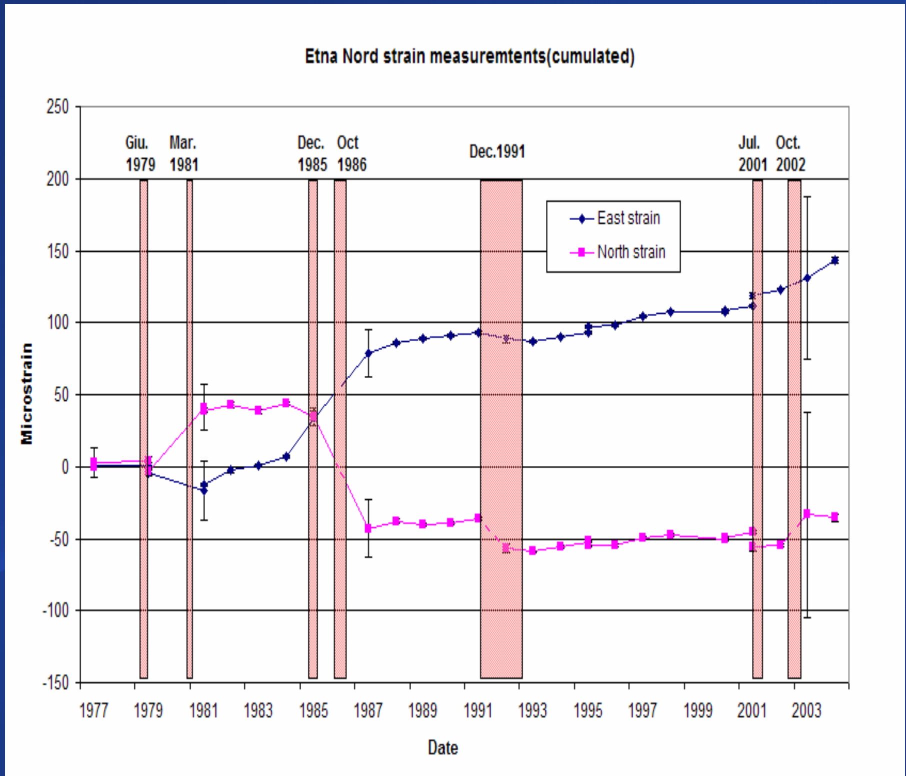


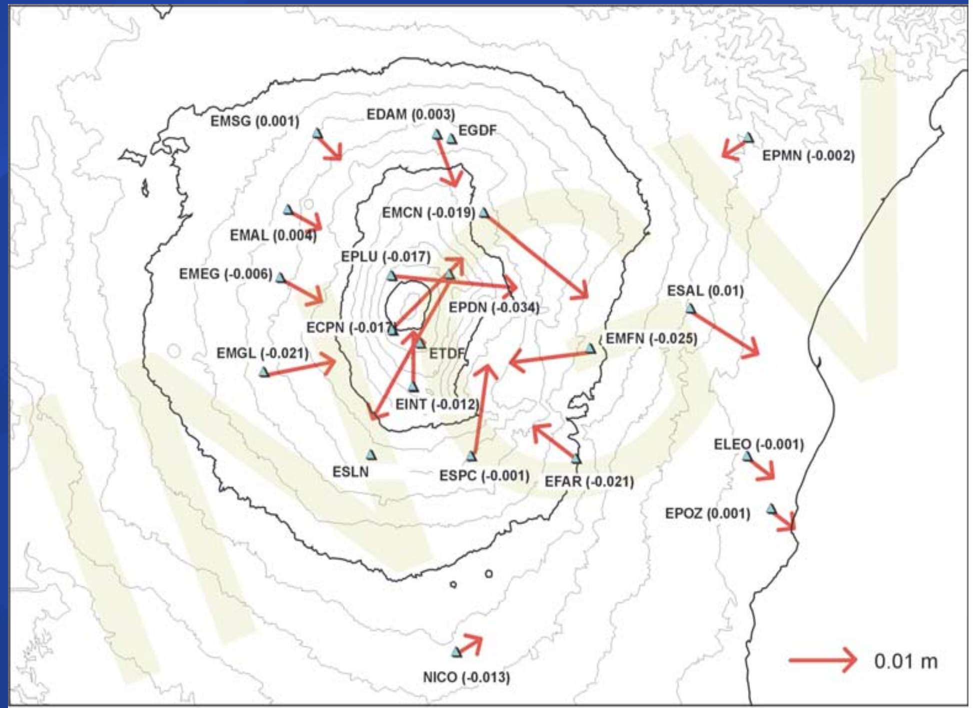
Ground deformation velocity 1993-2001 [After Puglisi et al.,2005]

Cinematics of the eastern Etna flank

EDM data

GPS permanent network data





Displacements estimation from 14 May 2008 to 10 July 2008

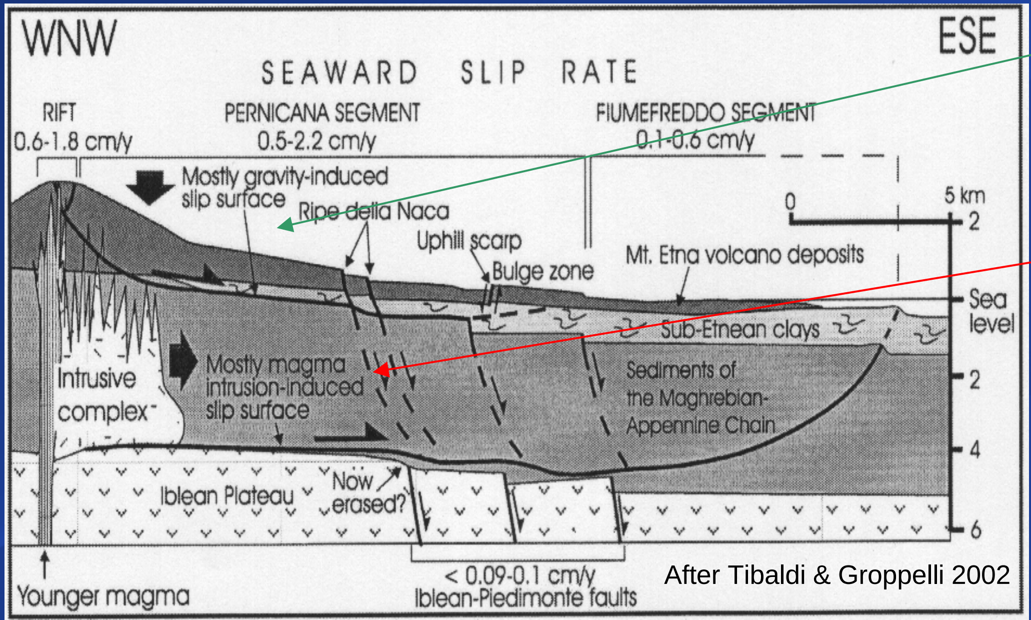
>Horizontal slip rates of some cm/year (especially along the coast);

>The displacement vectors along the coast are always directed towards east or southeast independently from inflation/deflation of the volcanic edifice;

>Displacements cannot be attributed to tectonic processes only because these would imply slip rates of some mm/year.

Possible causes

Several models have been proposed using geological and geophysical data



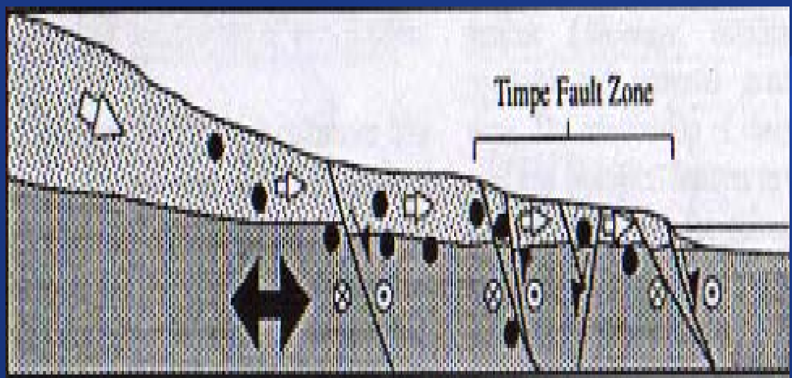
After Tibaldi & Groppelli 2002

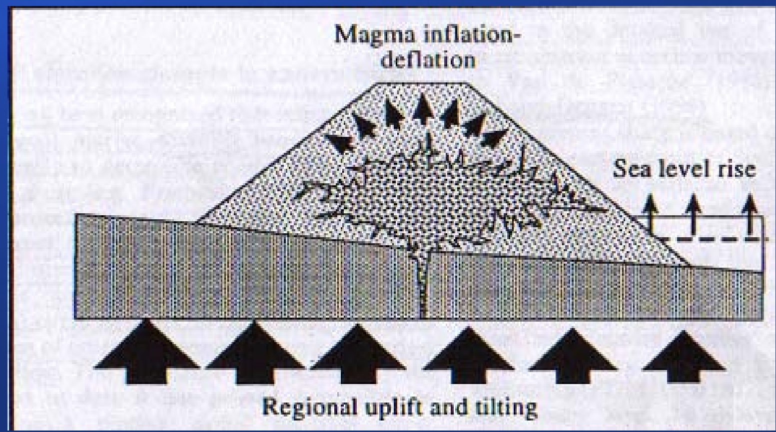
Shallow sliding model [Labaume et al., 1990; Lo Giudice & Rasà, 1992; Rasà et al., 1996; Puglisi & Bonforte, 2004] .

Deep-seated spreading model [Borgia et al., 1992; Rust and Neri, 1996; Tibaldi and Groppelli, 2002; Neri et al., 2005; Rust et al., 2005]

Other models: inflation/deflation processes, regional uplift with tilting or sea level rising with erosion of the coast. *[Labaume et al., 1990 Montalto et al, 1996; Firth et al., 1996)]*

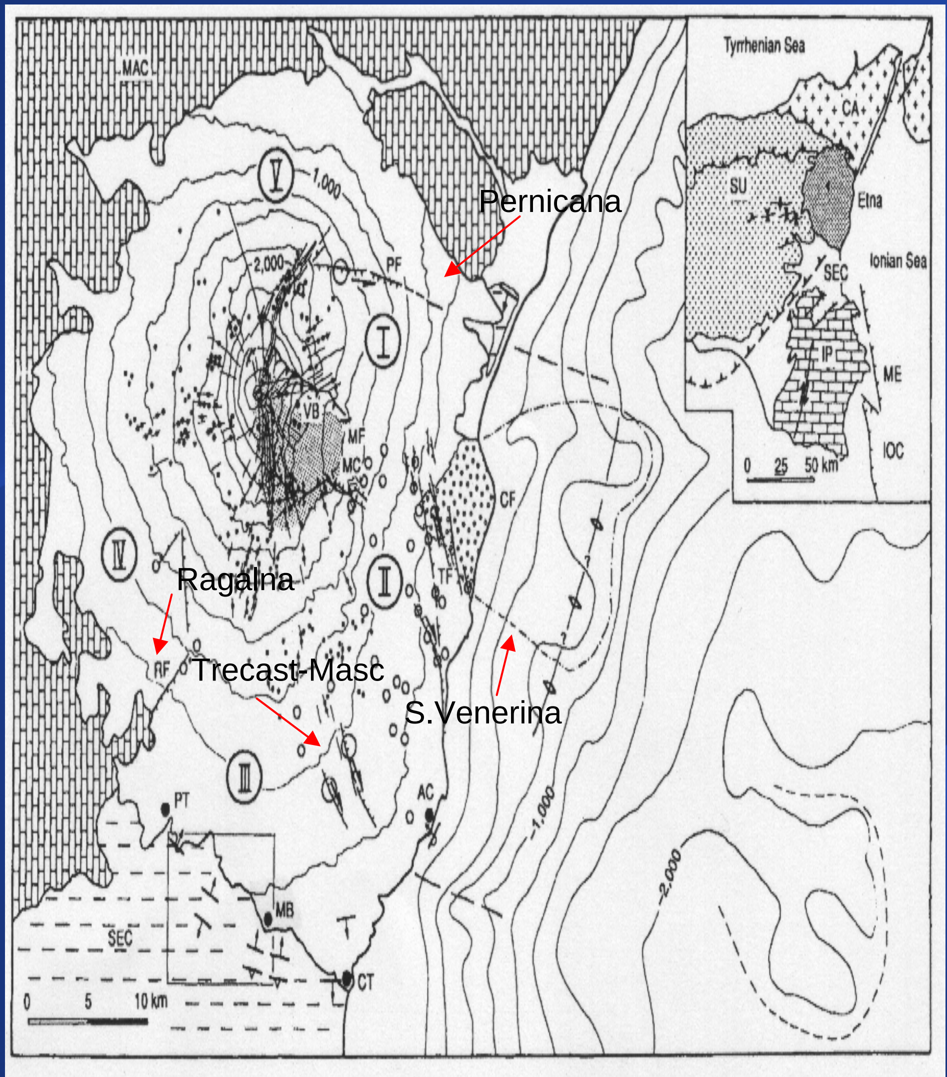
Tectonics block movements model
[Monaco et al., 1995; 1997; 2005]





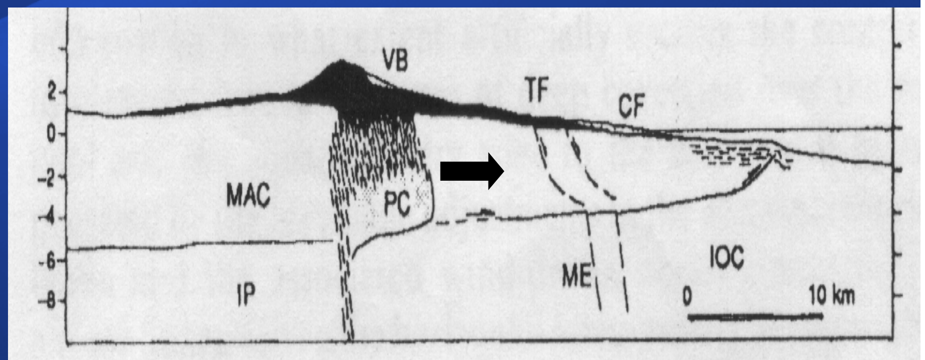
The deep-seated spreading model

The model, formulated originally by Borgia et al. 1992, is based on the study of the Hawaiian volcanoes (Poàs and Kilauea). According to the model Etna Mount is divided in five blocks on the base of the different slip rates observed.



Different phases can be summarized:

- ➢Magma uprising from the upper mantle to the crust on the west border of a PC;
- ➢Push of a dike complex (located 2-5 Km b.s.l.) over a thrust fault;
- ➢Increasing of the Coulomb stress at the faults;
- ➢Sequential movement of the blocks;
- ➢Extensional movements in the summit area and compressive one at the base of the east and south flanks are generated with formation of anticlinal folds near Misterbianco-Paternò and off-shore.



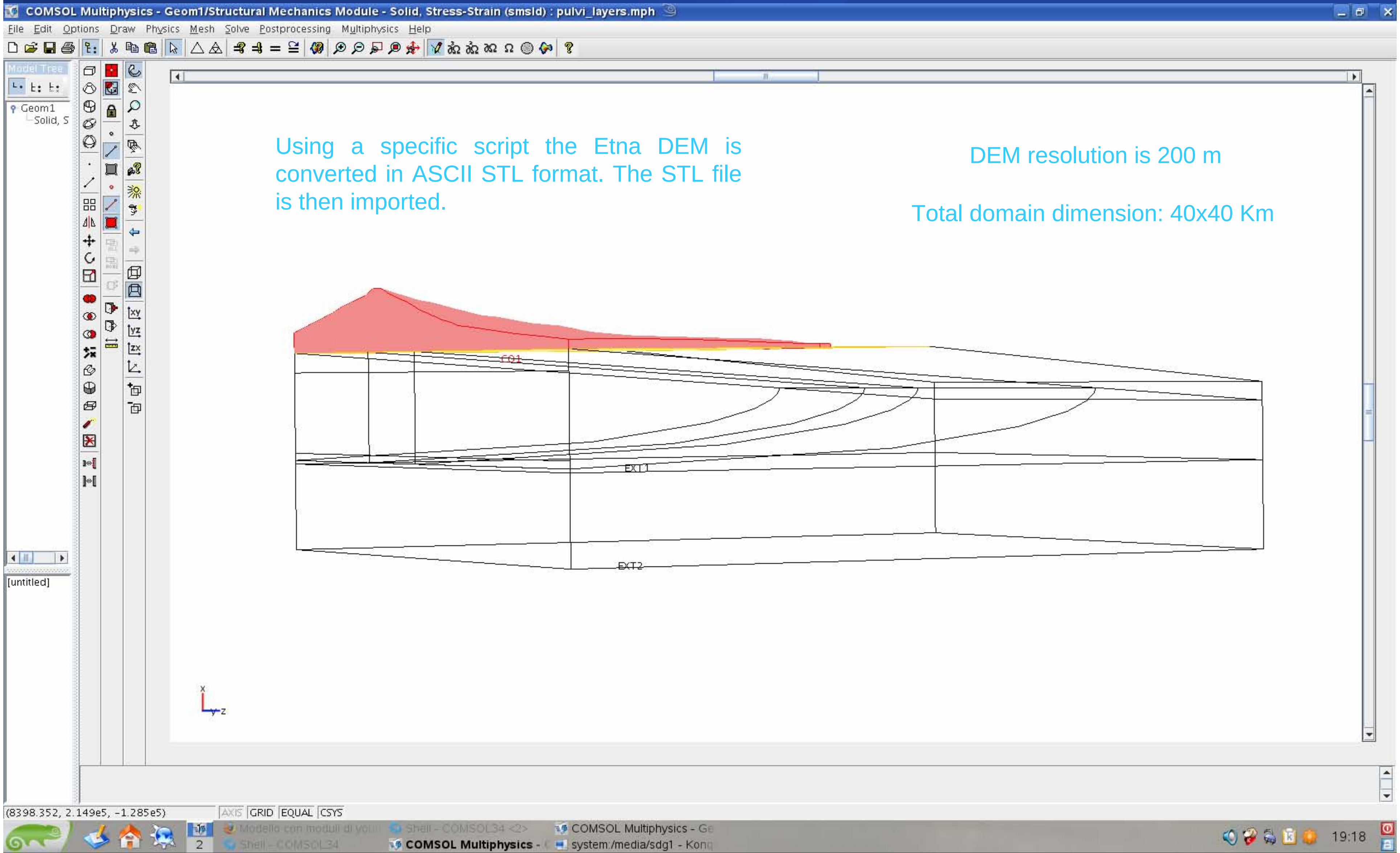
The deep seated spreading model tested with FEM

Step 1 : Creation of the geometry

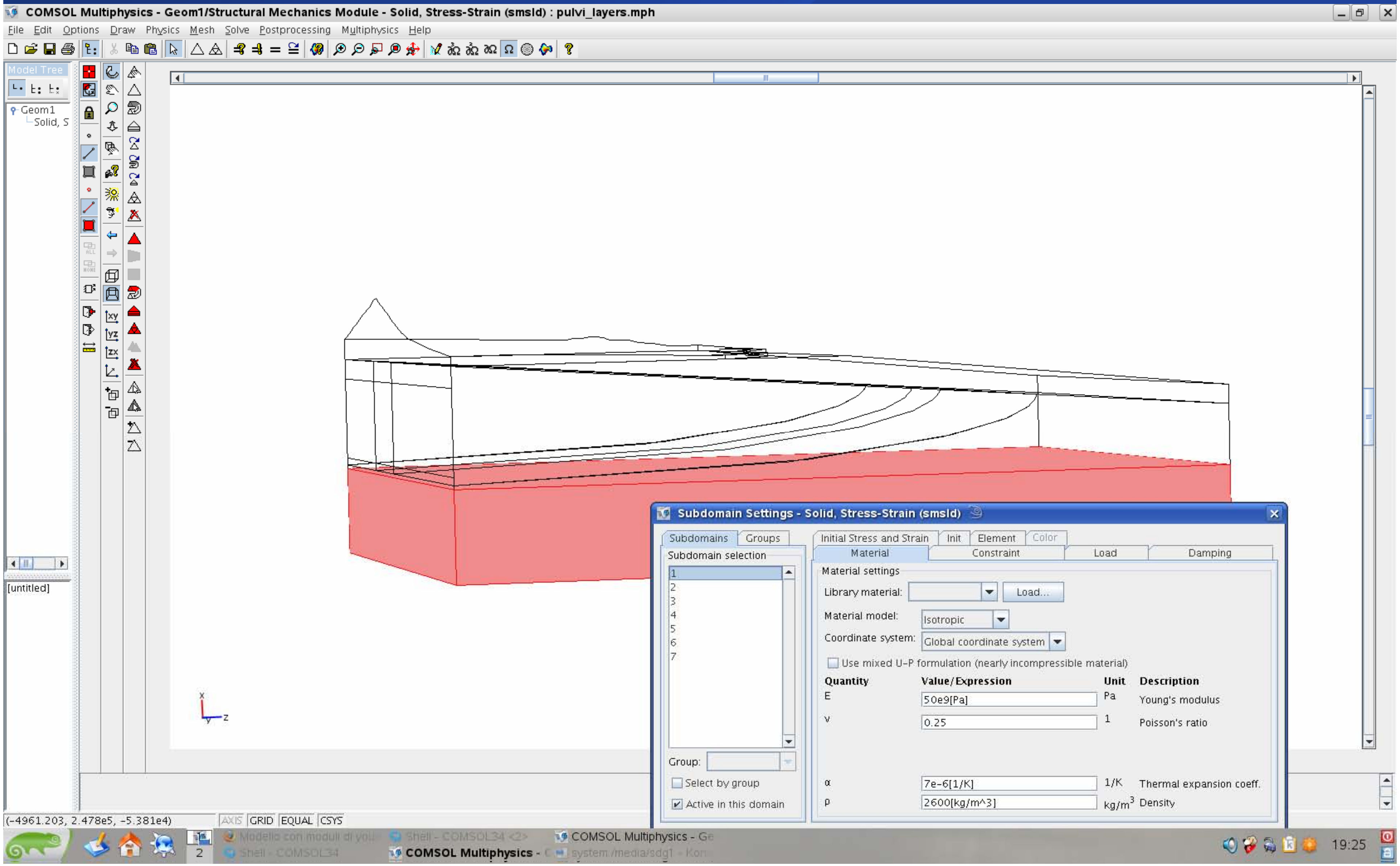
Using a specific script the Etna DEM is converted in ASCII STL format. The STL file is then imported.

DEM resolution is 200 m

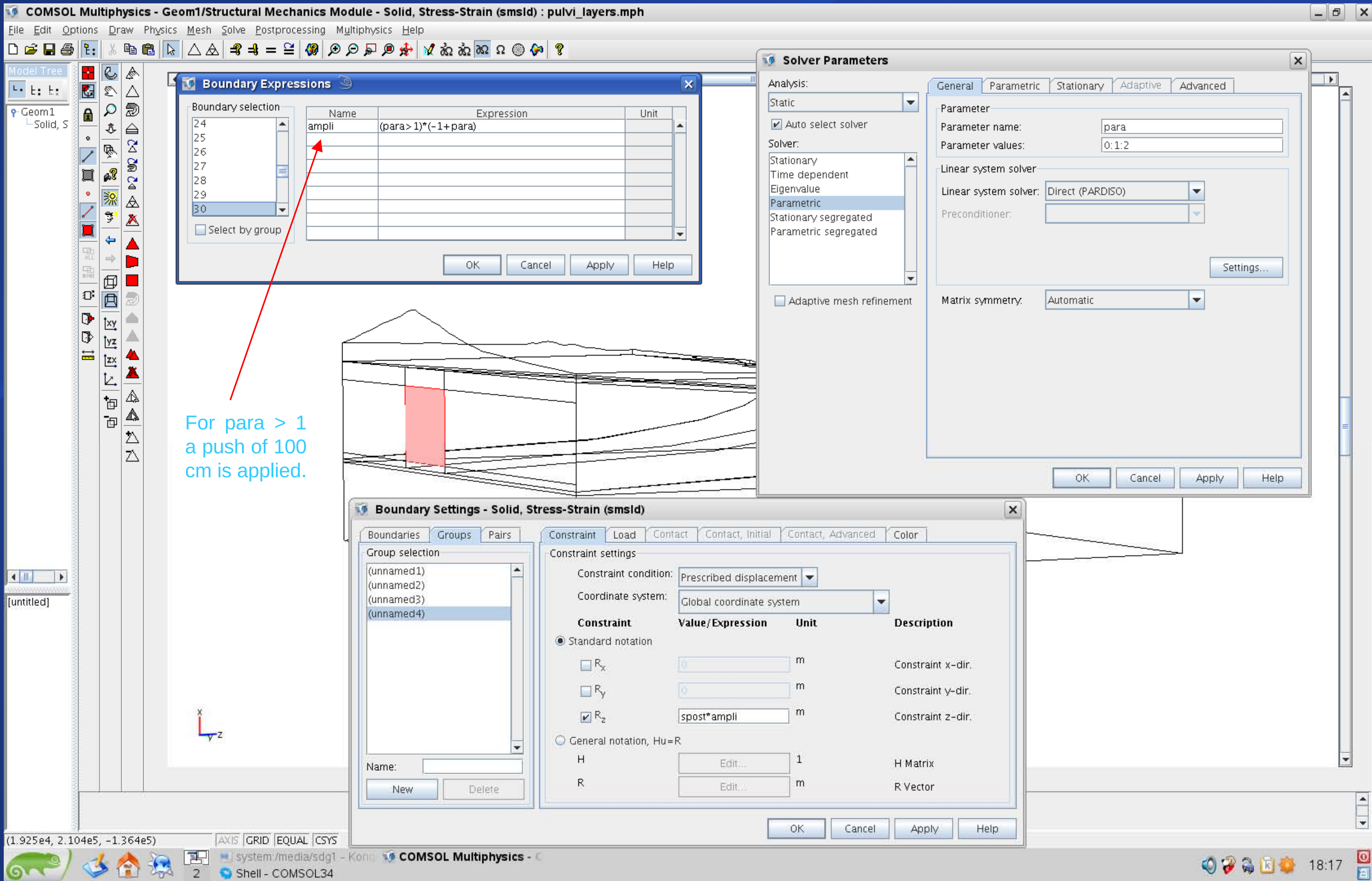
Total domain dimension: 40x40 Km



Step 2: The Subdomain Setting

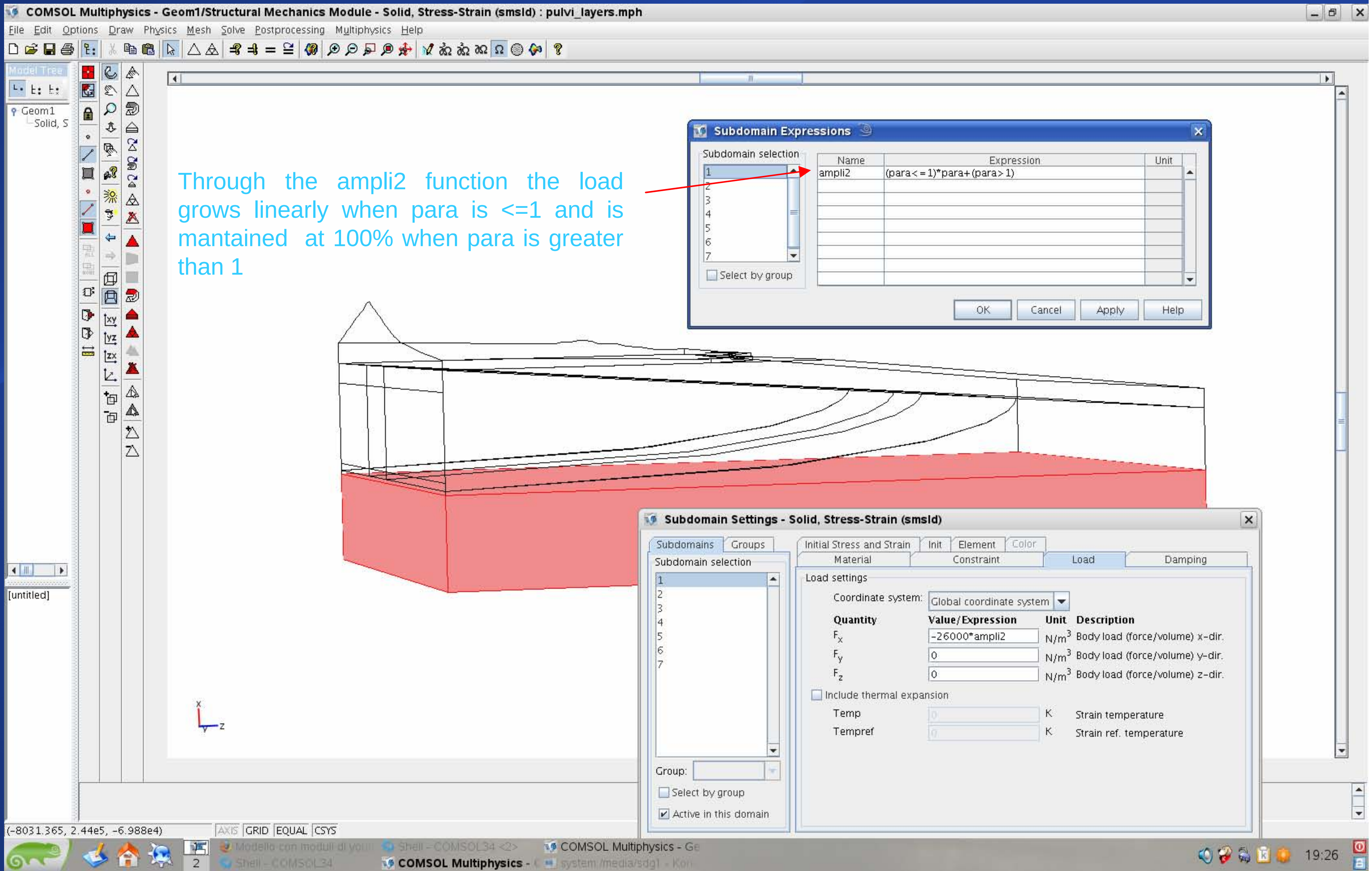


Step 3: Boundary conditions and contact setting

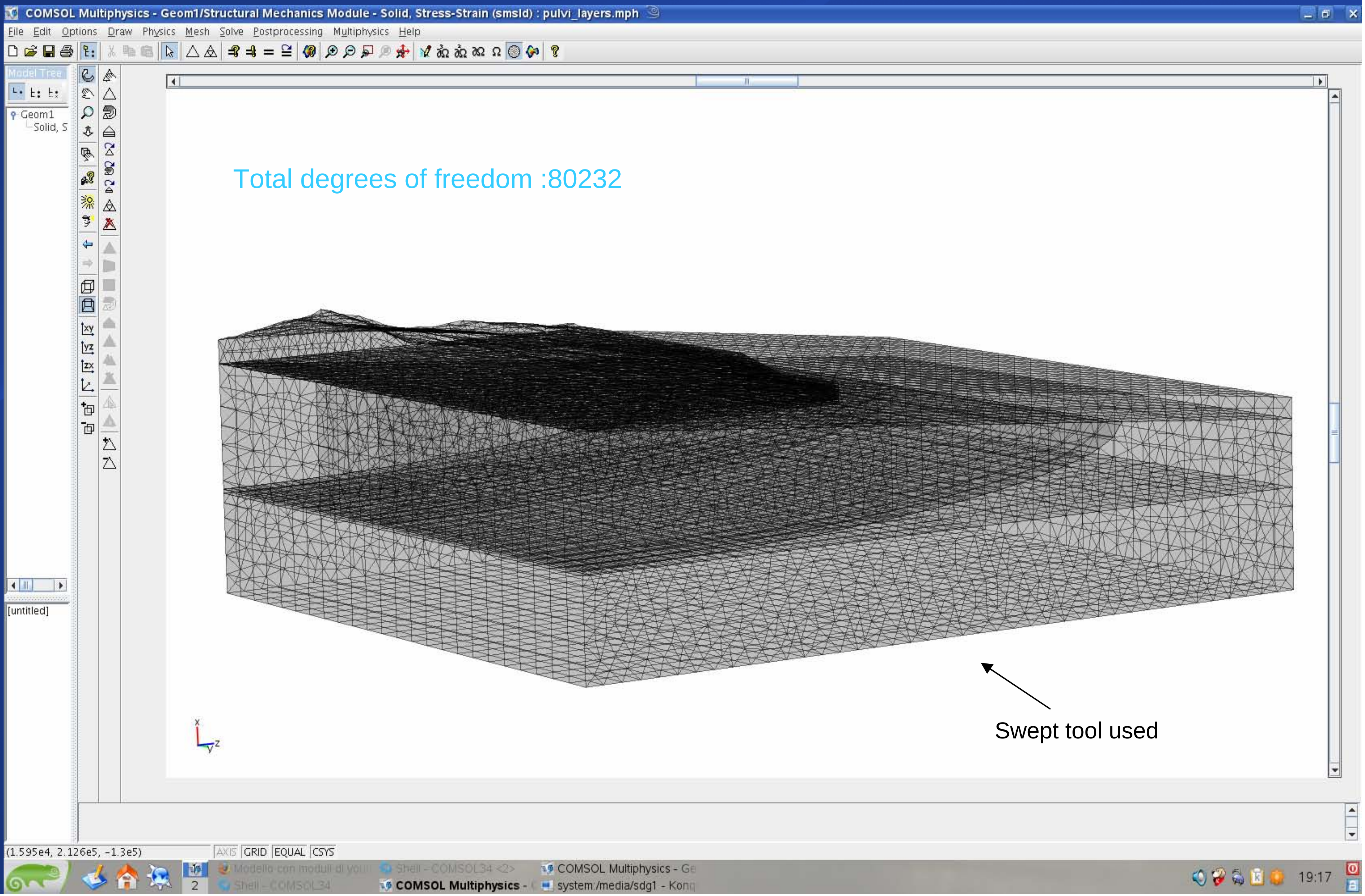


Step 4: Load parametrization

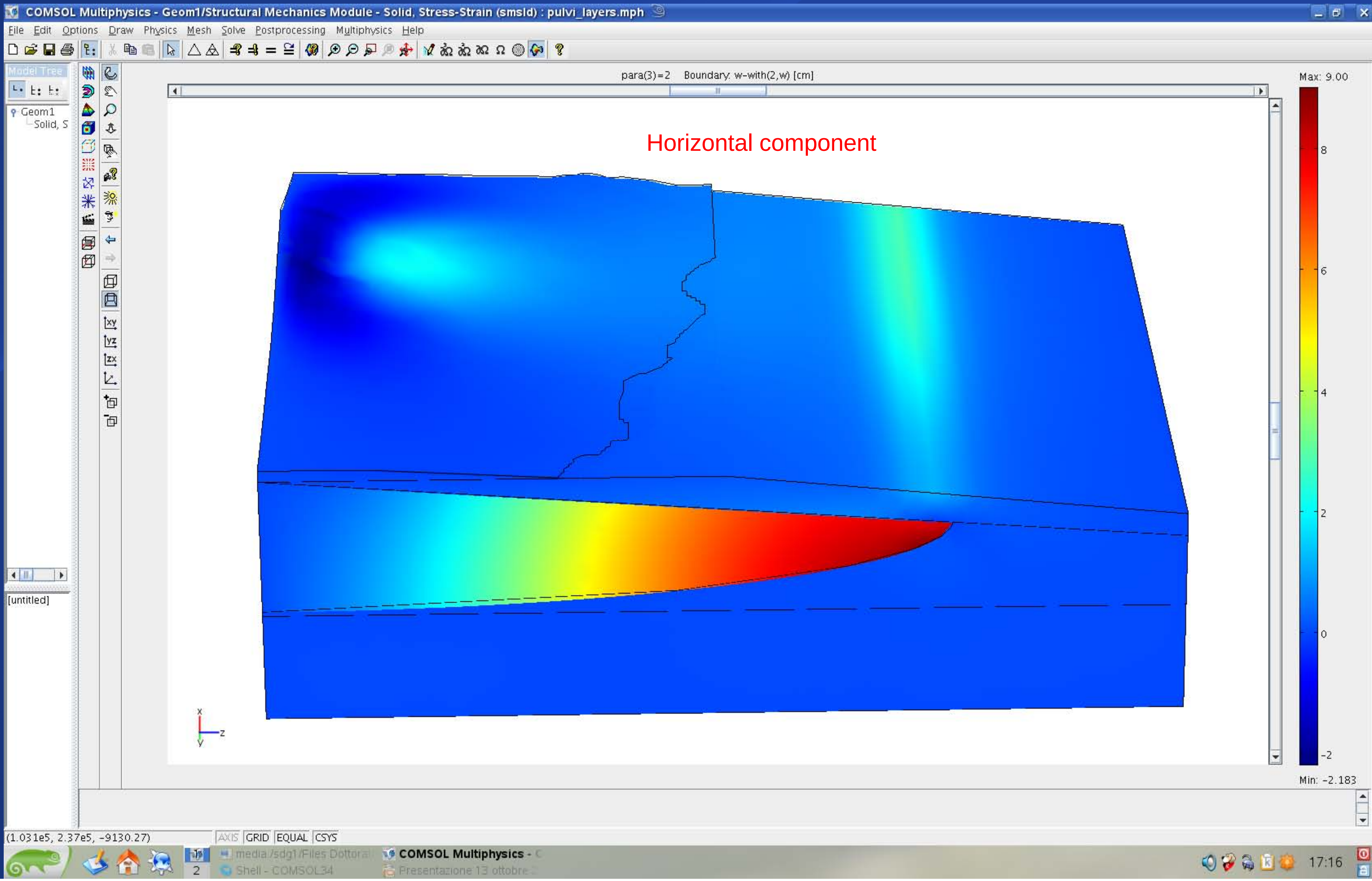
Through the ampli2 function the load grows linearly when para is <=1 and is mantained at 100% when para is greater than 1



Step 5: Mesh generation



Step 6: Results and post processing



Discussion

FEM Model results:

- The greatest displacements are observed in the “Valle del Bove” and in the final part of the ramp (anticlinal folds forming?);
- The uplift is one order greater than the horizontal components;
- Along the coast, an uplift of about 5 cm and an eastward movement of about 1 cm is observed;

Observed GPS data:

- “Valle del Bove” is not covered by GPS network. Usually, during inflation periods, variations of some cm are recorded around it. The presence of anticlinal folds off-shore is still debated in literature;
- The horizontal component is one order greater than the vertical one;
- A downlift of about 2 cm and an eastward movement of about 3 cm is observed along the coast;

Conclusion

- Important differences are observed between FEM model results and recorded derformation pattern;

- The FEM model needs to be upgraded with structural and stratigraphical elements;

- Viscoelastic and elasto-plastic regimes could be tested;

Work in progress

- Complete Etna DEM;

- Addition of the High Velocity Body (Plutonic Complex);

- Addition of the principal faults: **Pernicana, S.Venerina, Trecastagni Mascalucia, Ragalna**;

THE END

Acknowledgments. We are very grateful to Gianluigi Zanotelli and Valerio Marra (COMSOL Italy) for the productive discussions and for all the hours dedicated to the model developing.

DEFORMATION THEORY AND STRAIN PARAMETERS

By the Jacobian of the trasformation from the coordinate space (x,y) to the displacement space (u,v) we get (avoiding the rotational part) the strain tensor [Livieratos, 1980]:

$$e_{ij} = e_{ji} = \begin{bmatrix} e_{xx} & \frac{1}{2}Y_2 \\ \frac{1}{2}Y_2 & e_{yy} \end{bmatrix}$$

e_{xx}=ΔL/L (East strain) (>0 for extension)

e_{yy}=ΔL/L (North strain) (>0 for extension)

$\gamma_2 = e_{xy} + e_{yx}$ shear through each line parallel to the east axis (>0 for right lateral shear)

$\gamma_1 = e_{xx} - e_{yy}$ shear through each line parallel to NW-SE direction (>0 for right lateral shear)

$e_{xy}=e_{yx}$ shear through each line parallel to the east direction (>0 for right lateral shear)

$$\Delta = e_{xx} + e_{yy}$$

Areal dilatation: area on area unit variation (>0 for area increasing).

Considering a network with n baselines, the strain tensor parameters are calculated from the minimum squares solution of the system defined by n equations of the type:[*Livieratos* ,1980]

$$e_n = e_{xx}\sin^2(\alpha_n) + \tfrac{1}{2}Y_2\sin(2\alpha_n) + e_{yy}\cos^2(\alpha_n)$$

en is the strain of the n baseline with an azimuth (αn) respect to the north and obtained comparing the misures on two subsequent campaigns.