Study of the dynamic behavior of earthflows through the analysis of shear wave velocity in the landslide's body.

ALMA MATER STUDIORUM UNIVERSITÀ DI BOLOGNA

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INTRODUCTION

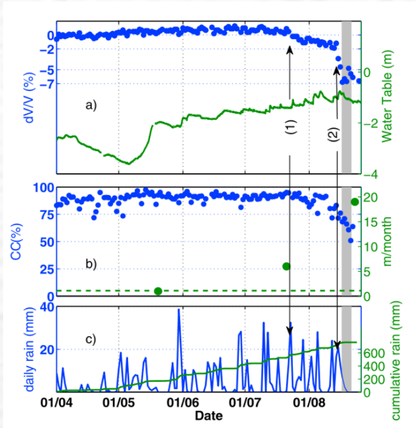


Fig.1- Green represents the water table, and blue represents the Rayleigh wave seismic velocity change of the material (Mainsant et al., 2012a)

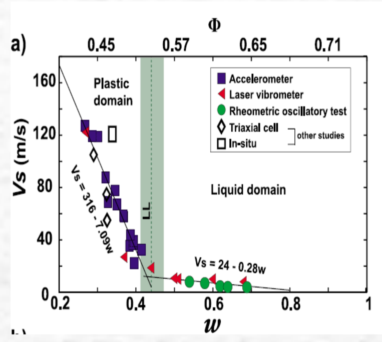


Fig.2- Vs as a function of water content w. The liquid limit LL is shown with its uncertainty by a shaded bar. Linear regression lines are drawn for the two domains (plastic and liquid) (Mainsant et al., 2012b).

MATERIALS & METHODS

I conducted periodic ReMi-MASW campaigns to assess the temporal variation of shear velocity for several landslides that were recently reactivated. I carried out acquisitions inside the landslide bodies and outside, in order to define the different value of Vs and monitoring the Vs over time. I used six geophones at 4.5 Hz, with a 2 meters distance. All the ReMi-MASW acquisitions were conducted with the Soilspy - Micromed array and all the data were elaborated with the Software Grilla (Micromed). In order to obtain the continue variation of the shear wave velocity, we installed two fixed monitoring systems on active earthflows. Precise monitoring devices were needed to this purpose since the expected variations in shear velocity were presumably small. At the beginning I performed field tests using 10Hz and 4.5Hz geophones, and I observed that the latter perform better for recording very low seismic noise. Then I built a signal amplifier by modifying a circuit designed by Rick LaHusen (USGS-CVO) for debris flow monitoring. The amplifier employs a 1000 Ohm resistor in order to amplify the signal x100 and provide a reference voltage of 1.2 V. All the equipment was thoroughly tested in the lab before field deployment. So far myself and my research group installed two monitoring systems on two active earthflows in the Northern Apennines of Italy: the first one at Silla (BO), and the second one at Montevecchio (FC). Each monitoring system consists of a solar Panel, a CR100 datalogger (Campbell Scientific), a GPRS communication system, a flash memory drive (SC115) to store data on site, a charge controller STECA SOLSUM 88F, and four 4.5Hz geophones to record the ambient seismic noise. Monitoring systems are designed to simulate a continue MASW (Multi-channel Analysis of Surface Waves) survey. These systems are integrated with other monitoring instrumentations, like rain gauges, piezometers and wire extensometers.

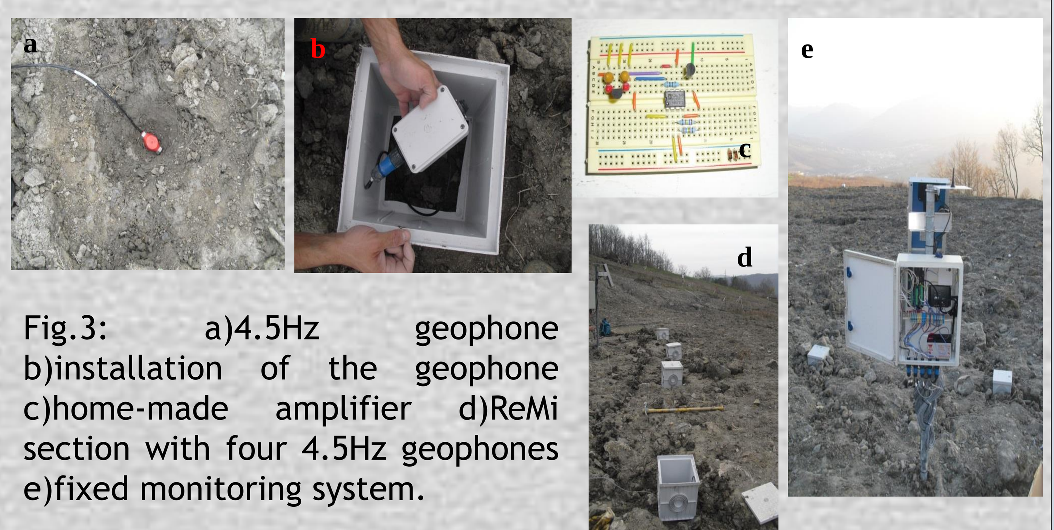


Fig.3: a)4.5Hz geophone b)installation of the geophone c)home-made amplifier d)ReMi section with four 4.5Hz geophones e)fixed monitoring system.

OBJECTIVES

The primary goal of field monitoring was to measure the variation of shear wave velocity with displacement rate in a real, active earthflow. Mainsant et al. detected a decrease of Vs ten days before the reactivation of a huge earthflow. This was explained by the fact that, during the solid-to-fluid transition, the material loose his rigidity and the void index and the water content increase, accordingly the Vs decrease. It is possible to imaging that it is very difficult to detect a similar result. So we are trying to detect an increase of Vs over time, related to the material's consolidation and the decrease of the water content. The data collected with the ReMi-MASW acquisitions will be related to all the data from the wire extensometers and the rain gauges, in order to verified a relationship between the Vs and the displacement rate.

We are also working on some lab tests on clay samples. We bought a triaxial cell modified with piezoeletric elements (bender elements), in order to study the variability of shear wave velocity at different void index. With these experiments we expect to improve our understanding about earthflows dynamics and solid-to-fluid transition.

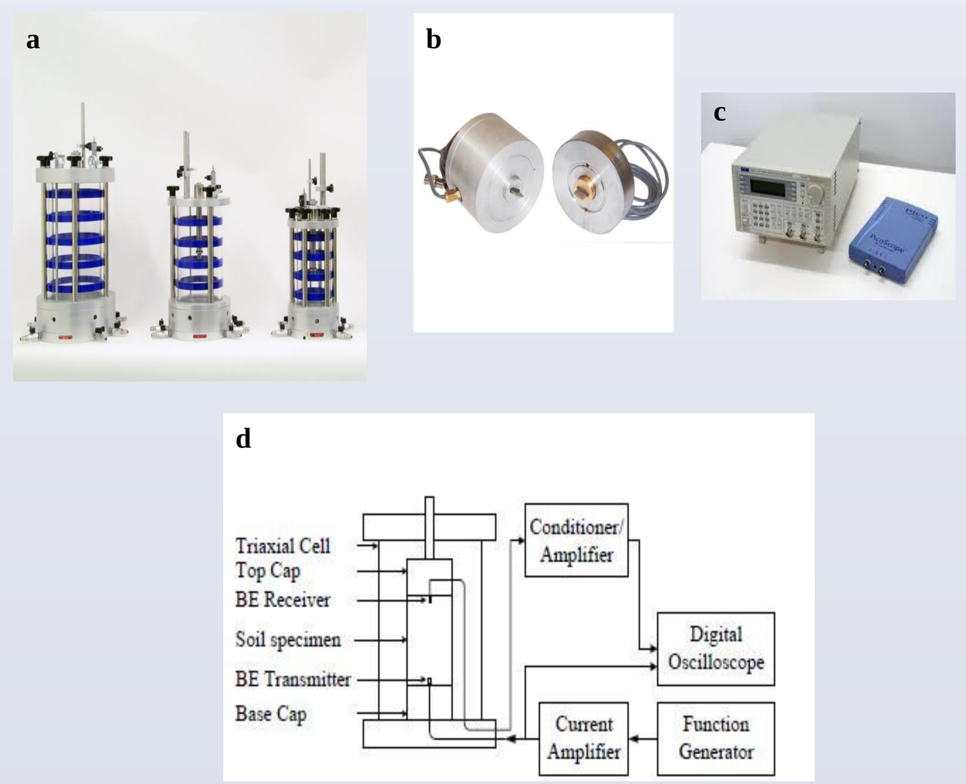


Fig4: a) modified triaxial cell, b) bender elemtens, c) signal generator and digital oscilloscopy, d) simple scheme of the lab test.

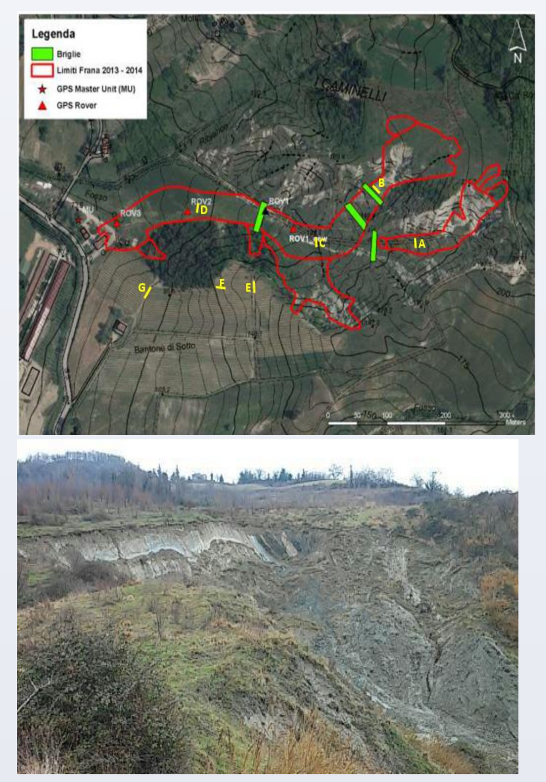
RESULTS

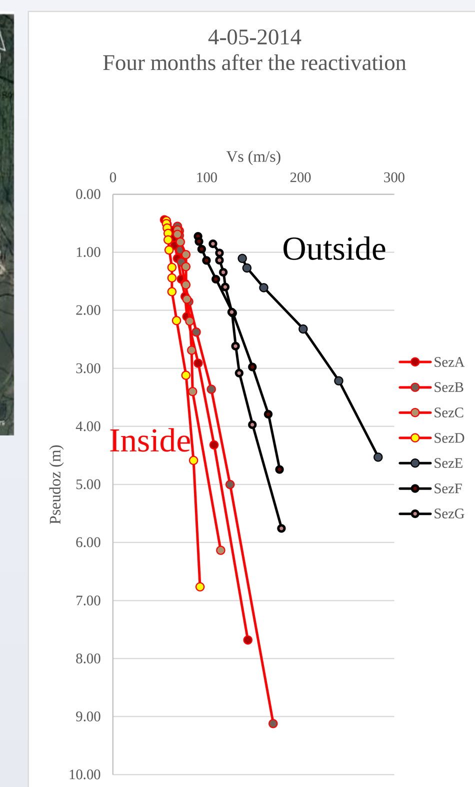
From January 2014 to February 2015 I carried out numerous ReMi- MASW surveys to characterize several active earthflows in the Emilia-Romagna Apennines. I did these measures both inside and outside the landslide's bodies, usually during the first ten days after the reactivation. At first, these measures indicate low shear waves velocity inside the landslide and high velocity outside. This is due to the different consistence of the materials and to the different water content. Then I repeated the measures over time in the same places on the same landslide, in order to detect the variability of Vs over time in correlations with the landslide's movements.

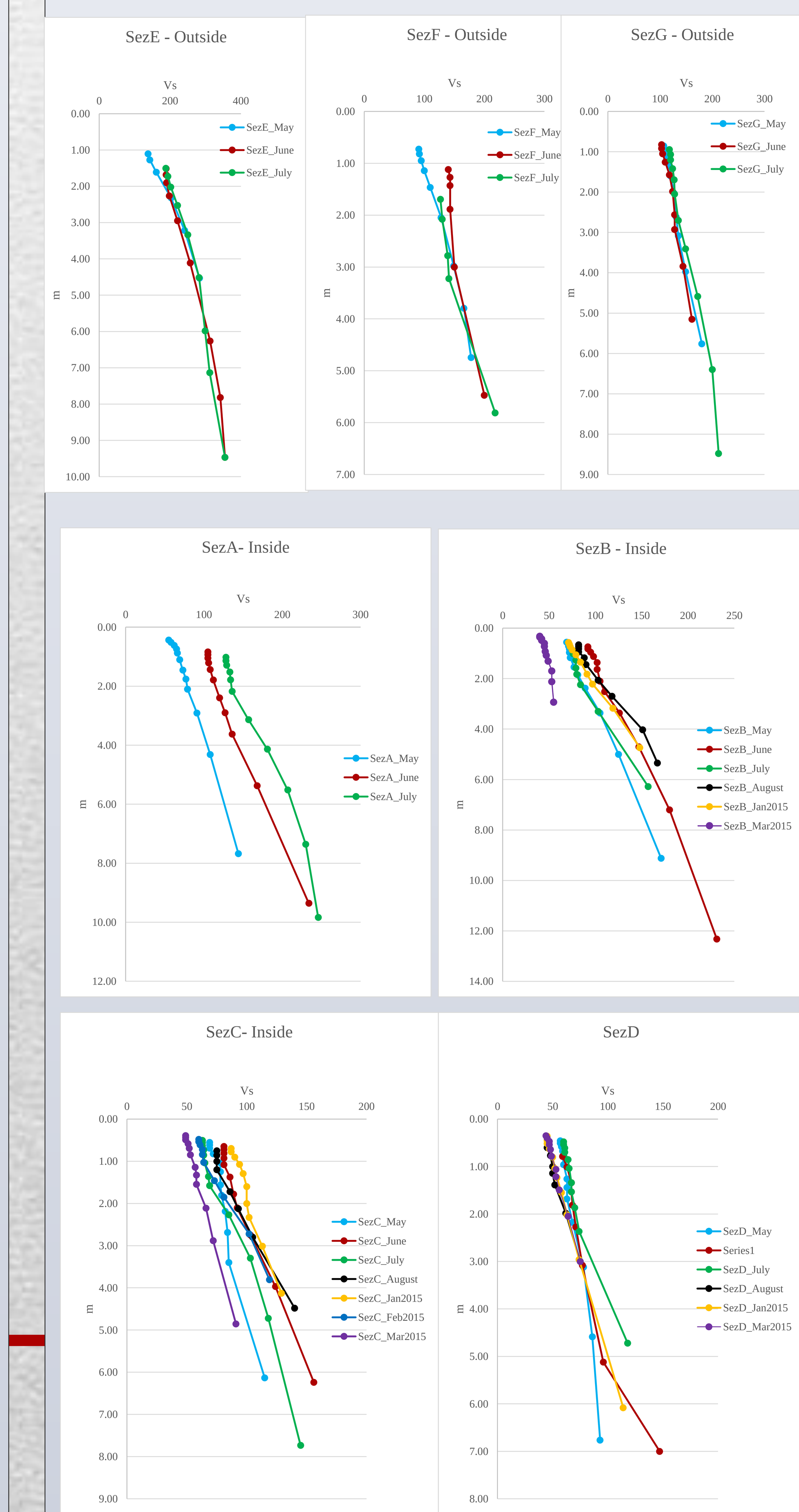
Now, I am going to show you some of my results from the Silla complex landslide and the Montevecchio earthflow.

- The Montevecchio (Forlì-Cesena, North of Italy) earthflow was reactivated the 1[th] of February 2014 (estimated volume of 240.000 m³) and increased the movement's velocity around the 7[th] of February 2014, after intense precipitations. Analyzing the data collected inside the landslide's body, I observed an increase of V_s over time, due to the decrease of landslide velocity;

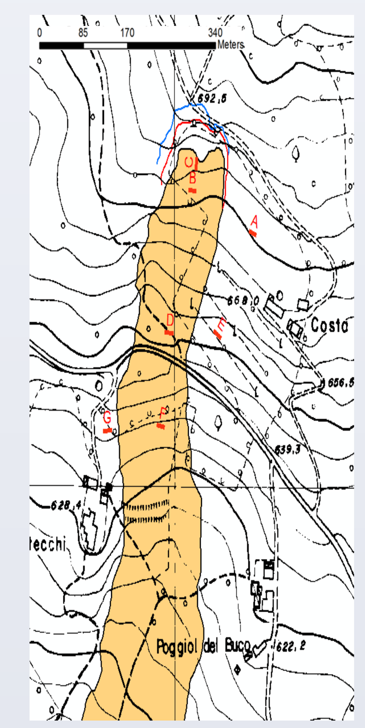
RESULTS

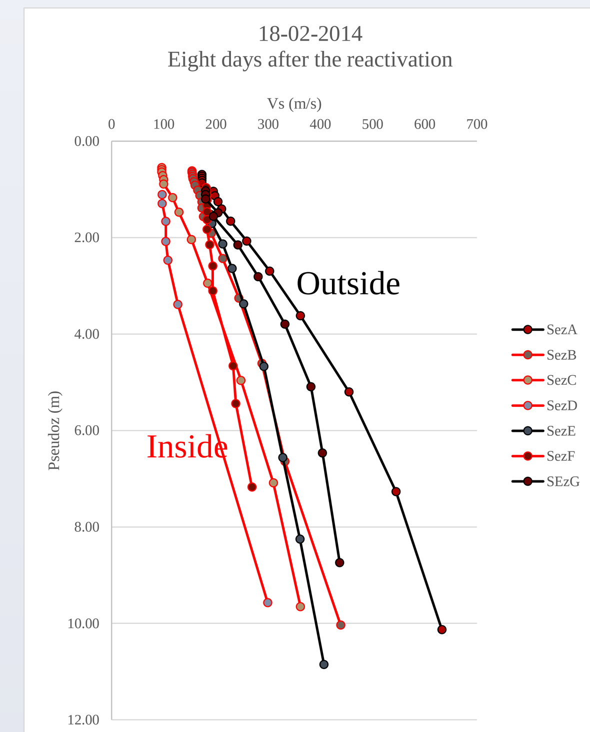


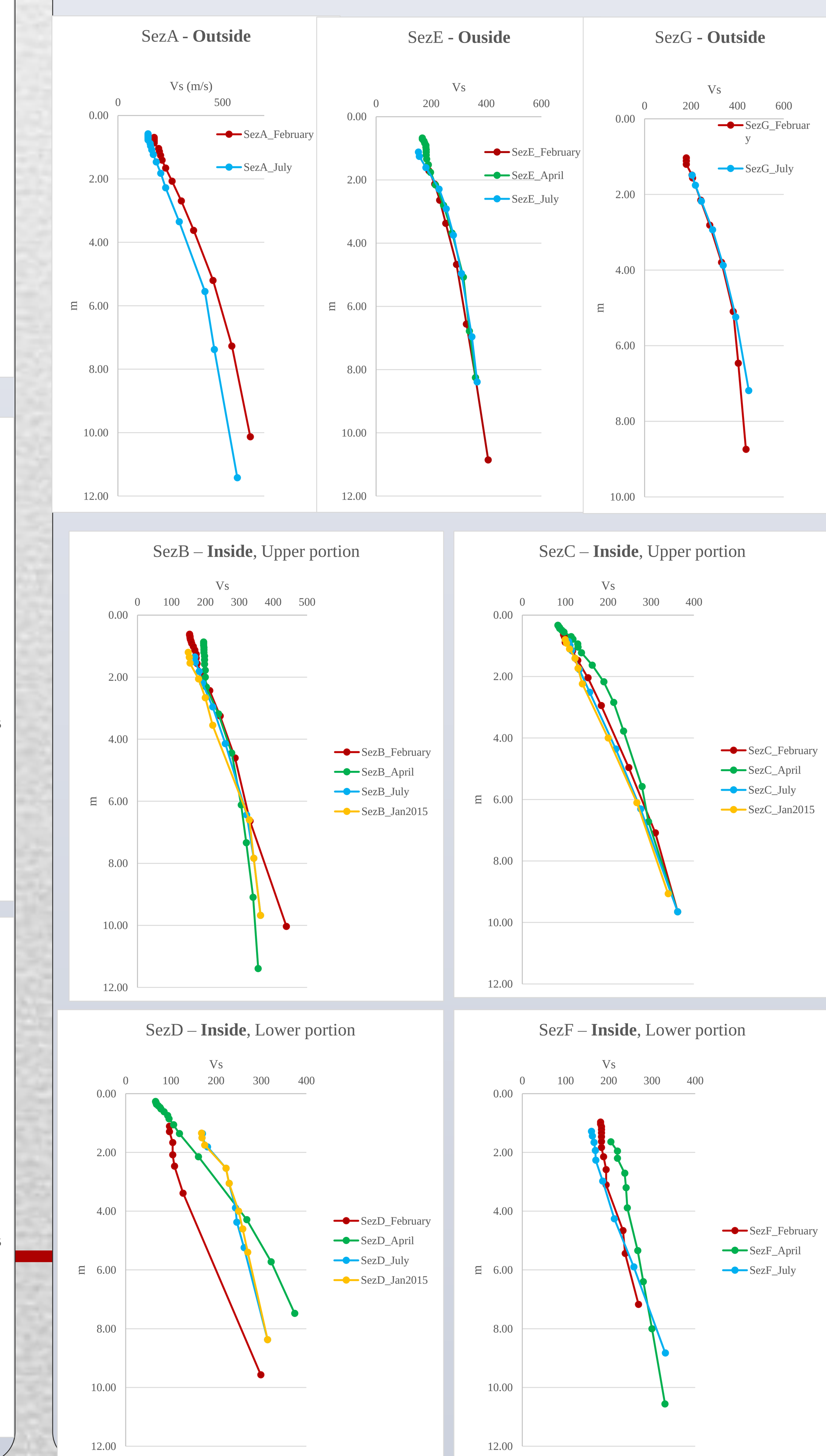




- The Silla (Bologna, North of Italy) complex landslide reactivated the 10[th] of February 2014 (estimated volume of 900.000 m³), and moved downslope with a maximum velocity in the order of several m/hour. Studying the data, it is possible to notice how the Vs increase over time only in the lower portion of the landslide. In fact the upper portion is still active, so the Vs remained unchanged over time.







CONCLUSIONS

- The measures inside the landslide's bodies are different from the measures taken outside;
- The measures taken outside the landslide's body do not show a significant V_s variability, because the material are not involved in the landslide's movements;
- The ReMi-MASW acquisitions taken inside the landslide's body show that the variation of the shear wave velocity with time is related to the movements of the landslides and to the different consistence of the materials.

Therefore by continuously measuring the ambient seismic noise in our two monitored landslides, we expect to improve our understanding about earthflows dynamics and solid-to-fluid transition. In fact the next step will be to try to find a relationship between the Vs variation, the displacement rate and the precipitation.

After all we would like to compare the results taken in field work with those taken in lab test, in order to define the value of the shear wave in the solid domain and in the liquid domain

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