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RELATIONS BETWEEN DSGSDS, MORPHOSTRATIGRAPHY OF LANDSLIDE DEPOSITS, TECTONIC AND CLIMATIC EVENTS IN CENTRAL-EASTERN SARDINIA.

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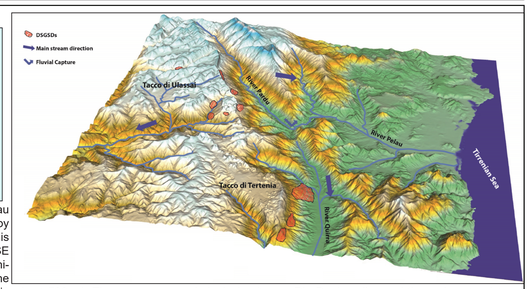
ABSTRACT:

Are presented same cases of deep-seated gravitational slope deformations (DSGSDs) and paleo-landslides in central-eastern Sardinia. This study focuses on the Quaternary landslide deposits preserved in the slope of the Rio Pardu and Rio Ulassai valleys. The area is characterized by a wide plateau with a prominent Jurassic limestone scarp overlying Palaeozoic metamorphites. The Plio-Pleistocenic uplift, linked to the Tirrenian basin opening and the consequent basalt volcanism, leads high slopes. In the middle-lower Pleistocene deepening of the valley has been accelerated by river capture process. This litho-structural setting is prone to the development of rock falls, toppling and deep-seated gravitational slope deformations. During the upper-middle Pleistocene the gravitative and fluvial dynamics are dominated by the eustatic phases. The aim of this study is to determine the morphostratigraphy and main characteristics of the Quaternary landslide deposits using geomorphic, sedimentological and morphotectonic analysis. The use of high resolution UAV (Unmanned aerial vehicle) photogrammetry and geological, structural, geomorphological surveys allowed a depth morphometric analysis and the creation of interpretative 3d models. This analysis allowed to recognize new morphostructural elements linked to compound landslide with lateral spreading and sackung characteristics which involves giant carbonate blocks and the underlying foliated metamorphites. This high-resolution data allowed the formulation of new hypotheses about evolution and kinematics of DSGSDs and landslides. The results of field surveys, geomorphological and sedimentological analysis of actual and paleo-landslide deposits show morphostratigraphic framework encompasses three order of rockfalls and three order of DSGSD. Cemented, quiescent and active landslide deposits were tentatively attributed to the Pliocene, Pleistocene and Holocene tectonic and climatic events, and compared with the traditional Quaternary stratigraphy of eastern Sardinia.

METHODOLOGY:

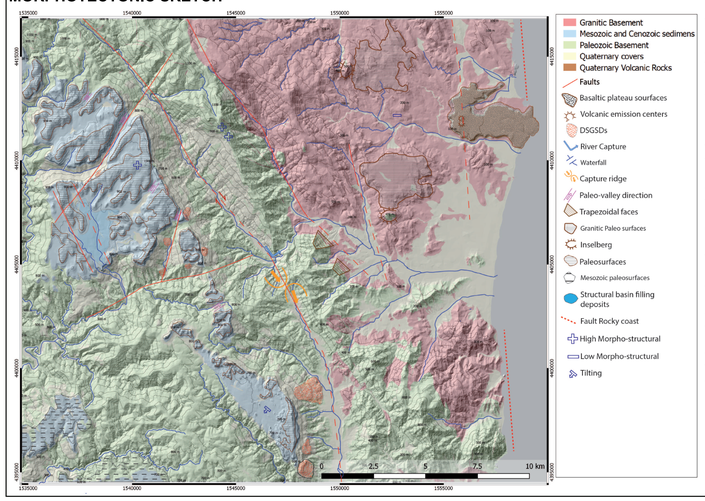
The multidisciplinary methodolological approach used aiming to define the main feature and kinematic of the DSGSDs and the rockfalls. Starting from a deep know of the geological, geomorphological processes linked to the morphotectonic and climatic evolution of the area. The first part of the study was dedicated to the geological and geomorphological and morphotectonic knowledge of the vast area, subsequently a detailed geo-structural analysis of the DSGSDs was carried out. A remote sensing activity was carried out through the interpretation of aerial photos and digital terrain models, combined with a field surveys and high resolution UAV-GNSS topographic surveys. Unmanned aerial vehicle (UAV) digital photogrammetric surveys allowed a depth morphometric analysis and the creation of DSGSDs interpretative 3d models. Greater importance has been given to the study of quaternary deposits and their stratigraphic relationships.A geological and geomorphological survey of the paleo and actual rock fall deposits in the countryside it was conducted. It was reconstructing the stratigraphic setting of the paleo landslide deposits and they relation with the geomorphological evolution of the valley and the edge plateau.

STUDY AREA



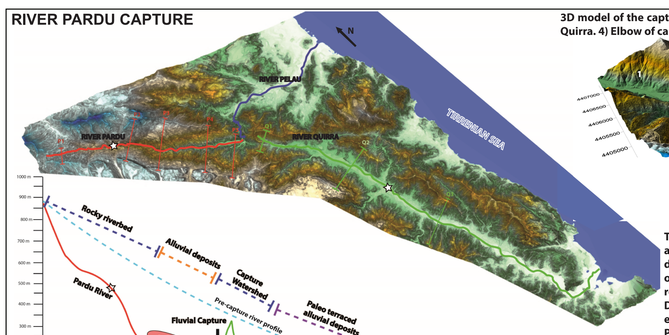
The east-central Sardinia (Italy) is characterised by a Jurassic dolomitic Plateau (Tacchi) overlying a Metamorphic Palaeozoic basement, mainly composed by metasandstone, quarzites and phyllites. Towards the coast, the basement is composed by Permo-Carboniferous granitic rocks. The main faults (NW-SE direction), are associated to the lower Miocene rotation of the Corsican-Sardinian block. These faults have been reactivated during the opening stage of the Tyrrhenian Sea. Erosion has mainly acted on the Oligo-Miocene strike-slip faults with an increase in the erosive rate during the Plio-Pleistocenic extensional tectonics, that in this sector of Sardinia it was manifested with an Uplift. In the internal area the rivers have cut deeply valleys whit high slope energy (up to about 700 m). The mean geomorphological units are Rio Pardu valley and the carbonate plateau called "Tacco di Ulassai". These slopes are often characterised by landslides and DSGSDs with Sackung and Lateral spread features. The Tacchi area is dissected by a deeply cut of Riu Pardu Valley, which extends in NNW-SSE direction following a major Tertiary fault.

MORPHOTECTONIC SKETCH



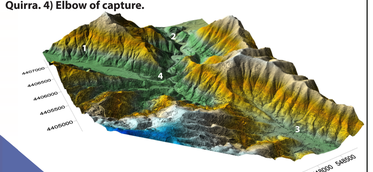
The geodynamic setting of the area is linked to the collisional context between African and European plates. The characteristics of the area are dominated by the brittle deformation processes linked to the Alpine cycle, which first appeared with a strike-slip fault in the Oligo-Miocene and in the Pliocene with an extensional component. The main director is the NW-SE on which the Pardu valley is engraved while the secondary lines are ENE-WSW and NNE-SSW. The area show morphotectonic evidences lead to the regional uplift linked to the final stage of Tirrenian basin opening.
On this study we identify tectonic geomorphology conditions of the study area which may indicate tectonic activity in the region. In Eastern Sardinia it manifests with a Uplift, recording by geomorphological indicators such as deep-seated gravitational slope deformation, fluvial captures, engraved valleys, waterfalls and heterogeneous water drainage. The river networks geometry and gravity processes show a young conformation of the landscape, tipical of an active tectonic setting.

RIVER PARDU CAPTURE



Topographic rofiles of the main valleys. Red-River Pardu; Green- River Quirra; Blue-Pelau River. The dashed lines in light blue indicate the hypothetical pre-capture profile of the Quirra and Pardu River. Above the capture area river Pardu is deeper then river Quirra becouse the increase of erosion rate subsequently the capture. Rio quirra show a old geomorfological setting with a oversized valley and with a large amount of alluvial deposits compared to the current river basin. This setting justifies the presence of active DSGSDs in the River Pardu slopes and Paleo-DSGSDs in the Quirra valley.

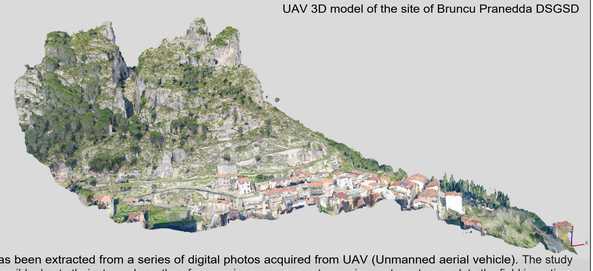
3D model of the capture area. 1) River pardu. 2) River Pelau. 3)River Quirra. 4) Elbow of capture.



The area has a deeply cut made by Riu Pardu Valley and Rio Quirra Valley, which extend in a NNW-SSE direction following a major Tertiary fault . For most of the River Pardu course the thalweg is set on rock, indicating its predominantly erosive nature. Downstream, the river is captured, turning on eastwards direction, changing his name to Riu Pelau, and then flowing into the Tyrrhenian Sea. The South of the capture the abandoned Riu Pardu Valley continues southward as Riu Quirra . This valley is characterized by a flat bottom filled of Pleistocene and Holocene terraced alluvial and slope deposits, currently in erosion. It is clear that Riu Pardu in the past was captured by Riu Pelau, causing a rapid incision upstream. Longitudinal profiles have been constructed for Riu Pardu, Riu Quirra, and Riu Pelau . Riu Pardu flows over 600 m below the dolostone contact near Ulassai where is located the main active DSGSDs.

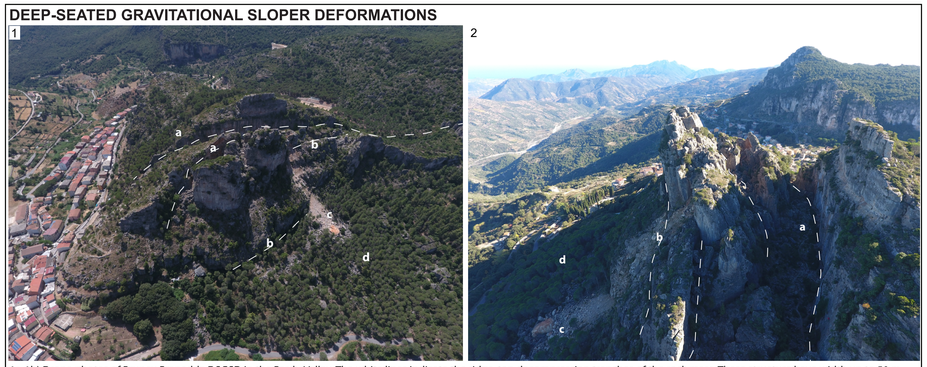
UAV surveys

UAV 3D model of the site of Bruncu Pranedda DSGSD



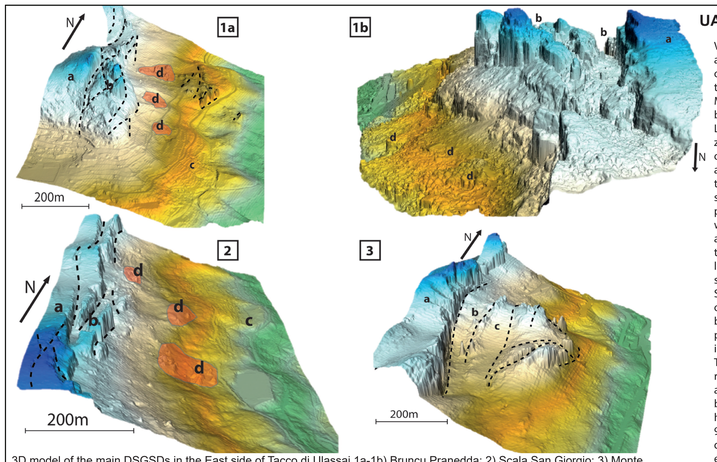
DSGSD 3D models has been extracted from a series of digital photos acquired from UAV (Unmanned aerial vehicle). The study areas are often not accessible due to their steep slope, therefore require surveys remote sensing systems to complete the field investigations. Unmanned aerial vehicle (UAV) digital photogrammetric surveys have been used as a new approaches to create a high resoluzion topography. The model has been corrected and georeferenced by Ground Control Points acquired by GNSS. GCP has been fixed on the ground and they are visible in the photograms to permit the co-registration using the software Photoscan.

DEEP-SEATED GRAVITATIONAL SLOPER DEFORMATIONS



1a-1b) Drone photos of Bruncu Pranedda DSGSD in the Pardu Valley. The white lines indicate the ridge-top decompression trenches of the rock mass. These structure have width up to 50 m, length of hundreds of meters and depth greater 50 meters. a) Open trenches filled in the lower part by rockfall deposits. b) lower open trenche. c) Rock fall deposit d) Metamorphic basement.

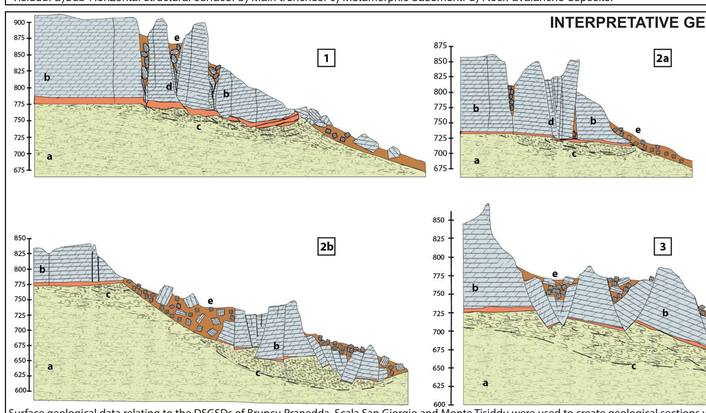
UAV 3D MODELS OF DSGSDS



3D model of the main DSGSDs in the East side of Tacco di Ulassai.1a-1b) Bruncu Pranedda; 2) Scala San Giorgio; 3) Monte Tisiddu. a)Sub-Horizontal structural surface. b) Main trenches. c) Metamorphic basement. d) Rock-avalanche deposits.

Various areas have been identified affected by DSGSDs located in the edges of carbonate plateau, the main ones on the east side of Tacco di Ulassai and Monte Tisiddu. In the top slope, in the carbonate plateau edge, the DSGSDs are a Lateral spread type and affect the Mesozoic lithologies (only the altered top side of the metamorphic basement could be affected). Lateral spreads developed in the plateau edge by exploiting pre-existing fractures. In this context there is a predominantly horizontal movement with vertical fractures in the carbonate and a zone of ductile basal deformation that affects the altered basement. In the lower part of the slope, the DSGSDs possess identified advanced stage with Sackung characteristics, with a large part of the deformation affecting the Paleozoic basement. This is evidenced because that part of the carbonatic sequence is sunk into the metamorphites.
These DSGSDs are associated with numerous rock-fall and tappling landslides affecting the carbonate walls. Dolomitic blocks with size up to 30 m on each side have been identified, moving away up to 900 m from the detachment points, these deposits are linked to mega-rockfall events with rock-avalanches feature

INTERPRETATIVE GEOLOGICAL CROSS SECTION

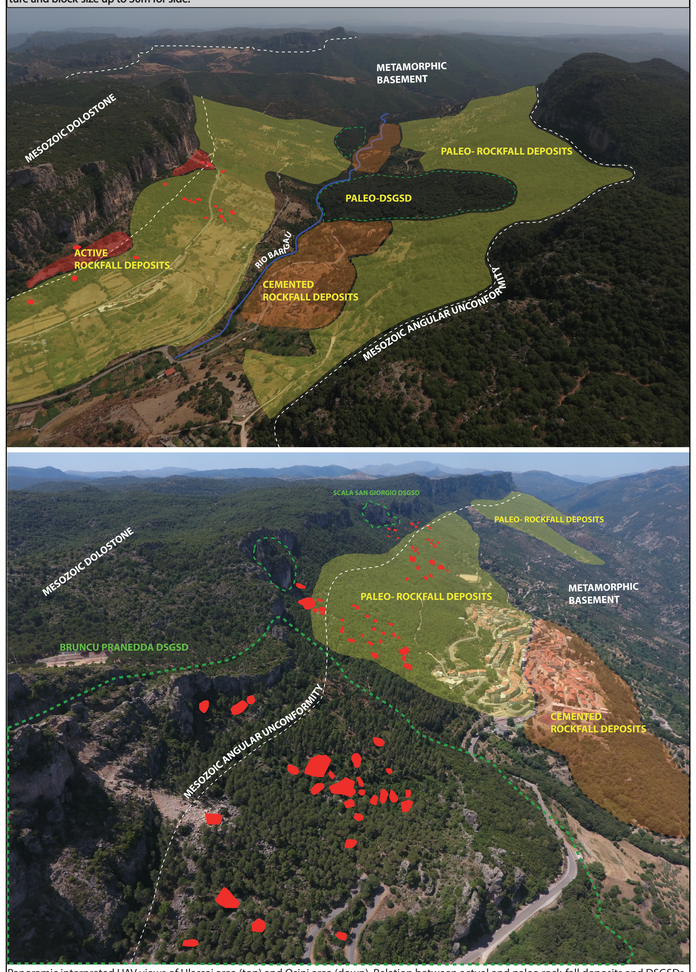


1- Scala San Giorgio; 2a-2b - Bruncu Pranedda; 3- Monte Tisiddu. a) Metamorphic basement b) Carbonatic and transitional Jurassic sucession c) Slinding surfaces area d) Main extensional trench e) Rockfall and Roch-avalanche deposits.

Surface geological data relating to the DSGSDs of Bruncu Pranedda, Scala San Giorgio and Monte Tisiddu were used to create geological sections with the aim of reconstructing a hypothetical surface of basal rupture and deep geometries.The initial stage of the movement is characterized by a Lateral Spread kinematics, with a separation of the DSGSDs from the edge of the Plateau. This happens through a horizontal movement without a vertical sinking. The stratigraphic geological setting is typical of the Lateral spreads because the formation of Dorgali (rigid formation) rests in sub-horizontal position above the deposits of the Genna Selole (orange layer) and of the altered and fractured schist basement (plastic formations). The second stage, is associated with a Sackung type deformation style that can be deduced from partial sinking of the DSGSDS inside the Paleozoic basement. In this case the breaking surface is located completely in the very fractured and schistose paleozoic basement. This is the typical lithotype on which bagging phenomena are established.

MORPHOSTRATIGRAPHIC SETTING

The most extensive quaternary outcrops are represented by landslide deposits at the foot slope of the carbonate plateau, abundant in the right slopes of the Rio Pardu and the Rio Barigau. Mass movements connected to gravity occur along the carbonate cornices with rockfall and toppling. Are indivuate three order of landslide deposits liked to the DSGSDs evolution and with sedimentological and geomorphological feature driver by climatic and tectonic Pleistocenic and Holocenic processes. The oldest is rappresented by cemented rockfall deposits located in the middle and down slope in residual outcrops affected by erosion, karst and gravitationl process. This deposit is caraterizeb by low percentage of matrix rappresented by cemented reddened sand and silt, indicated that the deposit suffered a wrong climatic stage. Paleo- rockfall deposits whith high silt-sand matrix percentage rappresented the second landslide stage and have a big distribution from the top slop up to the valley bottom. The actual rock-fall and toppling deposits are located in the down side of the plateau edge. We identified two type of landslide linked with the DSGSD evolution. The most common is linked to the decompression crack of the edge plateau and involve a large side of the urban area. The other type is linked to the collapse stage of the DSGSDs and are rappresented by megablock of dolomitic rock with rock-avalanche feature and block-size up to 30m for side.



Panoramic interpreted UAV views of Ulassai area (top) and Osini area (down). Relation between actual and paleo rock-fall deposits and DSGSDs. Red feature indicate the dolomitic megablocks that are locate at the downslope of the active DSGSDs.

LANDSLIDE LITHOSTRATIGRAPHIC UNITS

1) Mega-blocks rock avalanches depostis. 2) Rock fall near Ulassai urban area. 3) Paleo-rock fall deposits with high matrix. 4) Cemented rock-fall deposits.