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(7) Session "Tectonic Geomorphology and earthquake hazards"

Historical Landslides Reactivated by Earthquake in the NW Apennines (Northern Italy)

D. CASTALDINI[1*], G. D'AMATO-AVANZI[2], G. MANDRONE[3], M. PANIZZA[1], M. PELLEGRINI[1], A. PUCCINELLI[2], C. TELLINI[3], G. TOSATTI[1] and M. BARBIERI[1]

[1] Department of Earth Sciences, Modena and Reggio Emilia University (Italy), [2] Department of Earth Sciences, Pisa University (Italy), [3] Department of Earth Sciences, Parma University (Italy), *castaldi@unimo.it

This paper considers the results of a multidisciplinary research on historical landslides reactivated by earthquakes in the NW Apennines. The preliminary investigations has led to the collection of 12 landslides reactivated by seismic shocks. The landslides were triggered by earthquakes of 4.5 to 10 MCS degrees (3.3 to 6.5 magnitude) with epicentres as far as 20÷40 km. Earthquake-induced landslides are mainly complex or slide-type movements. The rock types involved are weak rocks, lithologically and/or structurally complex (flysch, clay shale and debris). In order to understand the complexity of the relations between all parameters affecting slope stability in static and dynamic conditions, detailed studies (at a 1:5,000÷1:10,000 scale) on geology, hydrogeology, geomorphology, soil/rock mechanics, meteorology were carried out for each landslide area and a map on seismic hazard was elaborated. In the study cases, the earthquakes are considered as a triggerring cause of reactivation of landslides controlled by rainfall.
Key Words: earthquakes, landslides, geomorphology, soil/rock mechanics, Apennines.

HISTORICAL LANDSLIDES REACTIVATED BY EARTHQUAKE IN THE NW APENNINES (NORTHERN ITALY)

1) 7 - Tectonic geomorphology and earthquake hazards
2) Doriano CASTALDINI
3) Dipartimento di Scienze della Terra
4) Università degli Studi di Modena e Reggio Emilia
5) Largo S. Eufemia 19 - 41100 Modena
6) Italy
7) castaldi@unimo.it

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Topographic Amplification and the Initiation of Landslides in Taiwan

D.N. PETLEY[1]* and W. MURPHY[2]
[1] Department of Geography, University of Durham
[2] Department of Earth Sciences, University of Leeds
D.N.Petley@durham.ac.uk

Recent seismic events in mountain areas, such as the 1999 earthquakes in Taiwan and Turkey, have triggered many landslides, significantly modifyinging the geomorphological systems. Unfortunately, our understanding of slope processes during earthquakes is still poor. This paper examines one important factor in seismically-triggered landslides, topographic amplification, in which the terrain interacts with the earthquake waves to increase peak ground accelerations. Based upon the Central Mountains of Taiwan, geological, geomorphological, geotechnical and seismological data are used to model the behaviour of 23 slopes that failed during the 1999 Chi-Chi earthquake. It is demonstrated that the locally measured peak ground accelerations alone were not sufficient to trigger the failures. However, when the stability is recalculated to incorporate accelerations predicted by a finite element model that considers shaking as a function of slope morphology, the peak ground accelerations are sufficiently high to trigger the failures. Thus, there is a quantifiable link between slope form and landslide occurrence, allowing better a better understanding of both slope stability during earthquakes and slope evolution.
Key words: landslide, earthquake, topographic amplification, Taiwan, slope

Earthquake Landslide Hazard: Case Study of Chi-Chi Earthquake, Taiwan

J. C. LIN*, C. H. JEN, T. C. JOU

Department of Geography, National Taiwan University, Taipei, Taiwan, 106

*jclin@ccms.ntu.edu.tw

An estimated 22000 landslides occurred after the Chi-Chi earthquake on 21 September 1999, which had a magnitude of 7.3 on the Richter scale. This paper attempts to classify the types of landslides associated with earthquake activity in Taiwan. Two large translational slides occurred at Tsaolin and Chiufenershan, with volumes estimated at >120,000,000 and >72,000,000 m^3 respectively resulting in 50 casualties. This is the 5^{th} landslide since 1862 at Tsaolin, which saw the landslide track and toe intercepting a 5km section of the river channel with slide tailings creating a temporary reservoir upstream. This investigation identifies earthquake related movements as the primary mechanism for instigating slope failures consisting of rock and debris falls. Secondary factors include the geological structure, slope angle and type. Geomorphological mapping has directed attention towards the potential hazards that exists from the resultant landscape. These landscapes demonstrate slope forms which will be prone to subsequent translational movements.

Key words: landslide, Chi-Chi earthquake, Taiwan

Geological and geomorphological characteristics of gigantic landslides triggerred by the 1999 Chi-Chi earthquake, Taiwan.

M. CHIGIRA[1]*, T. FURUYA[2], and W.N. WANG[3]
1Disaster Prevention Research Institute, Kyoto University
2 Graduate School of Science and Technology, Chiba University
3 Energy and Resources Laboratories, Industrial Technology Research Institute
*chigira@slope.dpri.kyoto-u.ac.jp

1999 Chi-Chi earthquake generated two huge landslides. Tsaoling landslide, 1.2 x 10^8 m^3 in volume, occurred on a dip slope of the Miocene and Pliocene shale and sandstone dipping 12-16 degrees. This landslide occurred on a slope made by previous large landslide in 1941, which removed a volume equivalent to this landslide. After this removal, weathering from the ground surface deteriorated shale thin laminae, in which slip surfaces were made. The top of the landslide in 1999 was exactly along a preexisting narrow and long depression, which was V-shaped convex upslope in a plan view. Jiu-Fun-Woo-Shan landslide, 9 x 10^7 m^3 in volume, occurred on a dip slope of the Miocene mudstone and sandstone dipping 20-36 degrees. The mudstone beds had crept slowly with slip surfaces along bedding-parallel faults and had been buckled on the lower slope, being supported by sandstone bed at the foot of the slope before the landslide of 1999. The buckling had been represented as a convex knick line on the slope before the slide. The earthquake tremor broke the sandstone support, leading to the whole slide of mudstone and sandstone.

Key words: earthquake, landslide, weathering, buckling, sedimentary rock

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Aligned Coulees in Southern Alberta, Canada: the Roles of Water, Wind and Tectonic Structure

ROBERT J. ROGERSON
Department of Geography, The University of Lethbridge, Lethbridge, Alberta T1K 3M4
rogerson@uleth.ca

Short, steep, dry tributary valleys in southern Alberta, termed coulees, are aligned approximately 070 - 080° and have been described as caused by the strong prevailing wind conditions which they essentially parallel. The coulees were probably formed in late-glacial time during the draining of extensive proglacial lakes. Measurements of coulee morphometry reveal a greater variety to their form and orientation than previously noted. Prevailing wind conditions appear to control some aspects of coulee morphometry since windward-facing slopes have more closely-spaced and longer coulees, while coulee slope morphology and processes are more directly controlled by slope aspect and illumination. Field measurements of joints in bedrock and overlying tills indicate that the coulees are probably oriented by structural controls developed from the flexing of the contemporary westward-moving North American Plate. Their impressive morphology is derived from no single dominant process but from the interplay of several processes involving water, wind and tectonic control.

Key words: oriented dry valleys, tectonic joint control, wind

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River Incision Rates in the Southern Sierra Madre Occidental, Mexico

J. LOPEZ-BLANCO[1]* and D. R. MONTGOMERY[2]
[1]Instituto de Geografia, UNAM, Circuito Ext., Cd. Universitaria, Mexico, 04510, D.F.
[2]Dept.of Geological Sciences, University of Washington, Seattle, WA 98195, USA
*jlblanco@servidor.unam.mx

The Sierra Madre Occidental (SMO) of western Mexico, the world's largest Tertiary silicic province, consists of a granitic core covered mainly by ignimbritic Oligocene rocks. Ignimbrite deposition ceased as the SMO experienced E-NE extension during the middle to late Miocene (13–5.5 Ma). Thirty K-Ar ages from published information of silicic ignimbrites were used to estimate an average age of 26±7 Ma for the upper surface of the ignimbrite sheet for use as an initial reference surface from which to estimate post-Oligocene river incision. A 90 m grid-size DTM was used to characterize contemporary topography, and an interpolated "original" topography of the ignimbritic plateau was estimated from a surface fit to the highest points in the study area. Long-term river incision rates calculated from the difference between this reference surface and longitudinal profiles of eleven rivers that flow toward the Tepic-Zacoalco rift zone (a primary topographic expression of a Plio-Quaternary N-S extension) range from about 0.03 to 0.08 mm my^{-1}, and show a gradual reduction of total incision values from west to east in N-S flowing rivers. We also report evidence of river capture due to flexural uplift along the rift zone.

Keywords: tectonic, geomorphology, ignimbritic plateau, river incision, Mexico.

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Active Gravity Tectonics: a new Model for the Quaternary Morphogenesis *of Uplifting* Mountain Chain (Abruzzi Apennines, Central Italy)

M.COLTORTI[1]* and P.PIERUCCINI[1]
[1] Department of Earth Science, University of Siena, Italy
*coltorti@unisi.it

The Abruzzi Apennines are made up of folded and eastward over-thrusted structural units, unconformably covered by Lower-Middle Pliocene coastal sediments, today lying at elevation exceeding 2000 m. The main extensional faults dip to the west and have more than 1000 m of total displacement, 100 m of which since the Late Pleistocene. They cut the uppermost structural units but do not affect the lowermost ones, since they listricate to the thrusts plains, resulting in a large-scale sackung and/or lateral spread-like movement. This geometry is connected to the Lower–Middle Pleistocene westward gravitational collapse of the mountain chain, which followed the Plio-Pleistocene uplift and represents a good model of inversion tectonics. The portion of collapsed chain is 1 to 2 km thick and the extensional faults bound some of the largest tectonic depressions of the Apennine, some of which are tectonic windows due to the lateral spread-like movement. The deposits filling the tectonic depressions constrain to the Middle Pleistocene the onset and maximum fault activity but continuous movements along the faults is documented during historical earthquakes.
Key words: gravity tectonics, inversion tectonics, tectonic depressions, Quaternary morphogenesis, Italy.

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Quantitative Analysis of Stream Network and Drainage Basins to Define theTectonic Arrangement of the Adriatic Coastal Belt of Central Italy

M. DELLA SETA, M. DEL MONTE, P. FREDI, E. LUPIA PALMIERI and F. SALVINI*
Dipartimento di Scienze della Terra, Università "La Sapienza", Roma, Italy
*salvini@uniroma3.it

Azimuthal spectra of stream orientations and morphometric parameters of drainage basins were analysed in order to define the spatial distribution and the role of regional tectonic elements, whose recent activity (or reactivation) could have influenced the morphotectonic setting of the Abruzzo-Marche coastal belt (Central Italy). The analysis of morphological and structural field evidence of tectonics, the statistical analysis of stream preferential directions and the computation of some indices connected with the asymmetry of valleys, suggested that the study area is divided into different sectors, with distinct morphotectonic setting. Several tectonic lines, also hypothesised by other Authors in the area, were supposed to be the limits between the sectors. To better locate and define these limits, azimuthal spectra of stream orientations have been realised along transects crossing the study area, following a method useful in determining the kinematics of regional tectonic elements; this method focuses on the possibility that rotation of preferential stream directions occurs as a consequence of the activity of strike-slip faults.

Key words: morphotectonics, quantitative geomorphology, drainage network, Italy

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Marine Terraces and subducting asperities : the Manta case, Ecuador

K.PEDOJA[1*], J.F DUMONT[2], D.SOREL[3], L.ORTLIEB[4]

[1] Université Paris 6, UMR 6526 Geoscience Azur. pedoja@obs-vlfr.fr

[2] Institut de Recherche pour le Développement (IRD), Geoscience azur.

[3] Université Paris Sud (Orsay).

[4] Institut de Recherche pour le Développement (IRD), Bondy.

The aseismic Carnegie Ridge is subducted in the Equatorian Trench immediately seaward of the Manta Peninsula where the highest marine terraces of Ecuador are observed. We analyse the flight of Quaternary marine terraces in this area with DEM, radar images and geomorphological field work in order to determine their spatial distribution and estimate their chronology. This approach should lead to reconstruct the uplift rates and detect irregularities in the vertical motions related to the introduction of Carnegie Ridge in the subduction zone. Two systems of five individual levels of marine terraces have been identified, up to a maximum elevation of 360m (a.s.l). In some localities, the variation in altitude of the shoreline angles is used to depict differential uplift motions within the coastal region. Combined topographic and bathymetric analyses of the continental shelf are also useful. The shallower part of the continental shelf to the SW of Manta may thus be interpreted as a wide terrace formed during glacial times, that is presently undergoing a strong uplift. These observations and interpretations lead to a better understanding of the interactions between the plate motions, the subduction of the Carnegie Ridge and the vertical deformation of the coastal region of southern Ecuador.

Key words: Marine terraces, Carnegie Ridge, Subduction, Ecuador.

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Will Santa Clara Island Disapear because of Increasing ENSO Effects?

E.SANTANA[1*], J.F.DUMONT[2], M.CRUZ[1], and M.ORDOÑEZ[3]
[1]Instituto Oceanografico de la Armada, Laboratorio de Geologia Marina, Guayaquil
[2] Institut de Recherche pour le Développement, UMR 6526 Geosciences Azur
[3] Petroproducción, CIGG, Guayaquil
*geologia@inocar.mil.ec

The Santa Clara Island is the farthest offshore island in the Gulf of Guayaquil and a protected area for some endangered bird species. Howhever, active landslides all around the island suggests that the island existency is challenged. Made of Pliocene silt and sandstone, the island formed due to the early Quaternary compressive event. Listric landslides faults originate at the border of the top platform of the island (60m o.s.l.), and the front accumulation of disorganized material reaches the coast where it is rapidly removed by waves. Direct effect of waves does not seems responsible for the landslides, the landsides being located inland. Since 1986 the top platform of the main island has lost 50% in width, and a smaller island has been reduced to emerging rocks. Morphological analysis shows an old low slope surface crossed by recent high slope. The climate of the area is usually arid, but sudden increases of rain occurred during ENSO periods, leading to the gravitational collapses. Increasing effect of the ENSO phenomenon during the last 20 years may have endangered the existence of the Santa Clara Island.

Key words: landslides, ENSO, island, coastal morphology, neotectonics