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ENGINEERING–GEOLOGICAL IMPORTANCE AND POSSIBLE ORIGIN OF THE STRESS RELIEF OF THE ROCKS OF THE CORDILLERA BLANCA, PERU

IMPORTANCE GÉOLOGIQUE ET L'ORIGINE POSSIBLE DE DÉCOMPRESSION DES ROCHES DE LA CORDILLERA BLANCA, PÉROU

MENCL V., Professor, Reserarch Engr., IGHP, Žilina, Czechoslovakia

Summary:

Stress relief causes opening of cracks as well as gravity movements of rock masses. In soils, landslides originate, often of large dimensions. Phenomena of this kind, observed in the Santa valley in Peru, are referred to. The processes, when triggered by the earthquake shocks, become of great importance for the population of the region. An attempt is made at explaining the mechanism of stress relief by analysing the origin of the important fault zone bordering the foot of the Cordillera Blanca. The assumption, as submitted, also helps in explaining the differential upheaval of the Cordillera Blanca as compared with that of the Cordillera Negra and of the coastal ranges.

Résumé:

La procédure de décompression cause l'ouverture des crevasses et aussi les mouvements de gravitation dans les masses rocheuses. Les éboulements de terre se développent fréquemment atteignant des dimensions considérables. Les phénomènes de ce genre, observés dans la vallée de Huaylas en Pérou, sont décrits. Si les phénomènes sont en plus poussés par les chocs de tremblement de terre, ils deviennent importants pour la population. Une tentative est faite d'expliquer le mécanisme de décompression en analysant l'origine d'une faille importante qui borde la Cordillera Blanca. L'analyse, comme présentée, aide aussi d'expliquer l'élèvement différenciel de la Cordillera Blanca en comparaison de cette de la Cordillera Negra et des zones de cote.

The stress-relief of rocks of the Cordillera Blanca in Peru exceeds that encountered in other mountains in that it is not limited to the flanks of the ridges but reaches deep into the massif. Figure 1 shows the state as it appears at the foot of walls of the deep U-shaped transversal glacial valleys. Most striking are the wide open cracks often forming cavities of large dimensions. Cracks of this set are of NNW-SSE direction almost parallel with the Santa valley. They indicate also dislocations along another set of surfaces, which are almost normal to the cracks and display a curvature with general dip towards the Santa valley. The competency of the high granodiorite walls is very poor due to three sets of discontinuity surfaces and small rockfalls take place several times a day. Poor stability appears especially when rockfalls are triggered by earthquake shocks. In this way the May 31, 1970 earthquake avalanche that destroyed Yungay and Ranrahirca, originated on the south-west-west flank of the northern peak of Huascarán (6670 m). It involved 8 million cu m rock debris and 3 million cu m of ice. The peak has a shape of a truncated pyramid (Fig. 2), its two flanks being in general parallel with the Santa valley. Also the opposite flank suffered by a rockfall ; important rockfalls of these two orientations also occurred on other peaks in the vicinity. The rockfalls that affected the other two flanks were of smaller dimensions. One of the rockfalls extended the fan situated between the Laguna Llanganuco and Laguna Alta (Fig. 3) and thus killed the members of the Czechoslovak mountaineering group; it contained only 1 to 2 million cu m of rock debris but 2.5 million cu m of ice.

Fig. 1 - Deep open vertical fractures and inclined continuous surfaces in the granodiorite walls of the glacial valley de Paria in the Cordillera Blanca near Huaraz, Peru. The locality is situated deep in the massif, about 6 km from the western boundary of the mountains.

Fig. 2 - The site of the destroyed village of Randrahirca et the mouth of the Shacsha valley into the Santa valley. Nevados Huascarán is in the background.

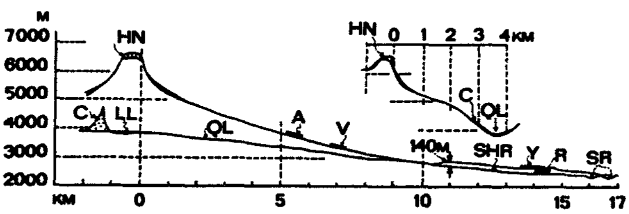

Fig. 3 - Longitudinal profiles of the paths of the Nevados Huascarán avalanches, which fell into the Santa Valley and into the Llanganuco Valley; HN - Nevados Huascarán, north peak, C - debris cone damming the stream draining the Laguna Alta (upper Llanganuco Lake) ; LL - lower Llanganuco Lake ; QL - Llanganuco Valley & A - village of Armapampa ; V - village of Vuelta ; SHR - Shacsha Valley ; Y - Yungay, R - Ranra-hirca ; SR - RIO Santa (after LLIBOUTRY et al, 1970)

Fig. 4 - Parallel oriented pattern of granodiorite, along which cleavage occurs under seismic loading, thus menacing the transformer platform of the hydro-eLectric plant at Huallanca.

Fig. 5 - The fall of disintegrated Triassic mudstone mass due to seismic shocks, Huallanca, Peru.

The stress-relief also gave rise to sheeting along the cleavage planes of the granodiorite. The earthquake shocks moved blocks on the slopes inclined at an angle of more than 36 degrees. Unfortunately, the transformer station (Fig. 4) as well as the platform of the mouths of the pressure shafts of the hydro-electric plant at Huallanca have been situated on the flanks exposed to these block movements.

On the other hand, the Triassic mudstone and fine-grained sandstone disintegrate into sandy mass susceptible to sudden falls when subjected to earthquake shocks (Fig. 5).

It is the author's opinion that the collapses of rocks cannot be attributed to the earthquake shocks only and that a considerable fracturing of rocks due to stress relief is a contributing factor. The relatively good stability of the strikingly high walls of the canyons cut into the thick mass of fluvioglacial deposits (Fig.6) of the earthquake area can be given as an indirect proof. The material of terraces also proved to be stable although they are often deposited on steep rock slopes.

While the rock masses of unstable character are widespread throughout the mountains, it is interesting to observe how much the slope failures of the deposits filling the Santa valley are limited to the lines of recent faults. An important fault borders the western toe of the Cordillera Blanca. In reality it is a few kilometers wide zone (Fig.8) in which the system of several faults developed. An assumption of the mechanism of the fault zone development is presented in Fig.7. Although it is an attempt only, it may throw some light on the as yet unexplained (WILSON et al 1967 , p.74) relative greater upheaval of the Cordillera Blanca as compared with that of the western region. It may also be helpful in explaining the deep stress relief of the rocks of the Cordillera Blanca.

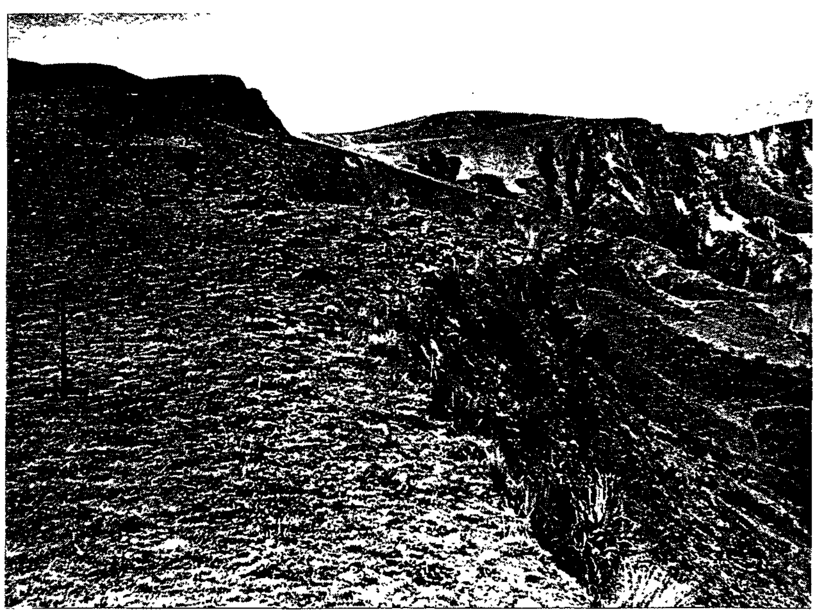

Fig. 6 - View of a small part of a large complex of canyons cut into the fluvioglacial deposits more than three hundred metres thick. The photograph shows the only place where the borders of the canyons suffered by earthquake (cracks on the left). South of Huaraz, Peru.

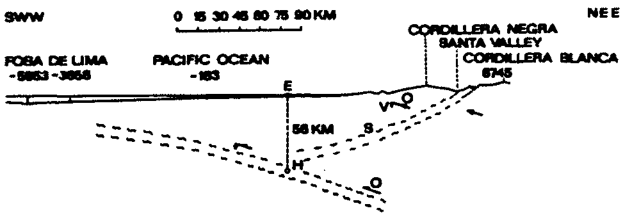

Fig. 7 - Autor s conception of the mechanism of the development of the fault zone accompanying the Santa valley in Peru. The relative overthrust O of the continental crust (on the right on the oceanic crust promotes gravity subsidence V of the latter. In reality the oceanic crust is underthrust beneath the continental crust (see e.g. DEWEY and HORSFIELD, 1970), but only the relative displacement is of importance in this case. Subsidence promotes slip movement S which gives rise to the fault zone. E, H - the epicenter and hypocenter of the May 31,1970, earthquake.

Fig. 8 - Recent eastern fault line manifested by a dark scarp wall which runs many tens of kilometres along the mountains and is accompanied by a set of fan scarps.

Fig. 9 - An example of many landslides developing in the outwash material. Photograph is taken from the front of the flattened terminal moraine. The overgrown area coincides with the western recent fault. The hill behind is of volcanic material belonging to the Cordillera Negra.

Fig. 10 - The eastern recent fault cutting the lateral moraines at the mouth of the valley de Paria near Huaraz. The width of the sunken belt bordered by the outward and bakward scarps is about 40 metres.

Fig. 11 - The "graben" of the fault zone situated op - posite to Recuay, 140 m high above the right bank of the Santa river. The plain has been irrigated which contributed to the poor stability of the slope above the river which lies to the right of the photograph.

The lack of stability of the slopes along the two recent partial faults may therefore be attributed not only to the rather steep inclination of the terrain and to the presence of water, especially in the western fault but also to the softening of the soils owing to the extension occurring normal to the fault direction (Figs.9, 10). The presence of hot springs speaks for the tensional pull across the fault zone, too.

Very impressive are the two areas where the fault zone enters the Santa valley. The upstream of Huaraz has been characterized by the old large landslide at Recuay. The "graben" of the fault zone lies 140 m above the right bank of the Santa river (Fig.11). The bank itself is formed of pyroclastic rocks. During the 1970 earthquake the slope above the right bank of the river collapsed. The head scarp of the recent slide reached 100m above the river. The slide extends across the river and the river floor was heaved upward thus forming a small hill (Fig. 12) and blocking the river.

A rather similar situation developed at Palmira, downstream of Huaraz. The toe of a large landslide situated on the fault zone is formed here by an andesite block belonging to the volcanic rocks of the Cordillera Negra. As seen from Fig. 13, the resistance of the block has been reduced by river erosion. The movement of the slope was promoted by intensive irrigation using the rear scarps of the landslide as water channels.

Fig. 12 - The toe of the landslide at Recuay. The heaved toe consisting of pyroclastic rock blocked the river.

Fig. 13 - The river leaving the volcanic rocks before entering the Cretaceous complex near Palmira. The andesite block formed the abutment of a large landslide of the glaciofluvial material filling the fault zone, which is situated behind the block. Due to gradual river erosion, the block moves slowly into the river. The roadway collapsed and was reconstructed at least two times.

References

DEWEY I.F. - HORSFIELD B. (1970) : Plate Tectonis, Orogeny and Continental Growth.- Nature, 225, 521-525.

LLIBOUTRY L. - MENCL V. - SCHNEIDER B. - VALLON M. (1970). Evaluación de los riesgos tellúricos en el Callejón de Huaylas, ue Unesco, Paris, 2208 BMS-RD. SCE.

WILSON J. - REYES L. - GARAYAR I.(1967): Geologia de los cuadrangulas de Mollebamba, - Servicio de Geología y Minería, Lima, Boletin No. 16.