The submarine "El Golfo" debris avalanche and the Canary debris flow, West Hierro Island: The last major slides in the Canary archipelago

La avalancha de El Golfo y el "debris flow" de Canarias, Oeste de la isla de Hierro: Los ultimos grandes deslizamientos submarinos del archipielago Canario

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ABSTRACT

Swath bathymetry and geophysical data of the island of Hierro show that the western flank of the island is affected, at least, by two major catastrophic slope failures. One of the two, called the El Golfo debris avalanche, led to the deposition of a sedimentary body of about 150 km$^3$ of volcanic rock debris on the upper rise. The second major instability event, named the Canary debris flow, originated at the base-of-slope of the island of Hierro, and involved a larger amount of remobilized material. New evidences suggest that the Canary debris flow is the oldest in age. As a consequence of the Canary slide event, overstepping and undermining of the lower island flanks occurred and subsequently triggered the El Golfo debris avalanche, whose deposits covered and obliterated the source area of the Canary debris flow. The triggering of El Golfo debris avalanche seems to be related also to the rift zones in the island of Hierro. From the establishment of the complex relationships between both slides, the El Golfo debris avalanche has been dated between 12,000 and 6,000 yBP.

RESUMEN

Nuevos datos de batimetría y geofísica marinas de la isla de Hierro demuestran que el flanco occidental de la isla está afectado por un deslizamiento que depositó 150 km$^3$ de derrubios volcánicos en el glacis continental superior, la avalancha de El Golfo. Un segundo evento, llamado "debris flow" de Canarias, se originó en la base del talud de la isla del Hierro y movilizó unos 400 km$^3$ de material. Nuevas evidencias sugieren que el "debris flow" de Canarias precedió a la avalancha de El Golfo. La avalancha de El Golfo pudo haberse originado a consecuencia de la socavación y sobreinclinación del talud asociados a la cicatriz del edébris flow de Canarias. Las zonas de rift en la isla del Hierro parecen haber tenido también un papel significativo en el desencadenamiento de la avalancha de El Golfo. El resultado fue el enmascaramiento del área fuente del "debris flow" de Canarias por los depósitos de la avalancha. De la determinación de las complejas relaciones entre ambos flujos, se desprende que la avalancha de El Golfo ocurrió entre 12,000 y 6,000 años BP.

Key words: submarine landslide, debris avalanche, debris flow, swath bathymetry, bottom parametric source, Hierro, Canary Islands.

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Introduction

The phenomenon of landsliding in oceanic islands often takes the form of debris avalanches. These are mainly characterized by a well defined amphitheater of scarps at their head, hummocky terrain in their lower parts, and an overall gradient less than 3° (Moore et al., 1989; Moore et al., 1994). Debris avalanches are generated by catastrophic failures and flow rapidly in single events (Moore et al., 1994). In the Canary Islands, as in other volcanic island chains, this is the typical mechanism affecting the subaerial/submarine flanks and slopes adjacent to the islands. The products of these avalanches are generally deposited in the submarine base-of-slope.

Debris flows also affect the continental rise and the base-of-slope of oceanic islands. Debris flows have, as well, amphitheaters at their heads, although with lower scarps, and a tail of deposited material longer and thinner than that of debris avalanches. Debris flows travel larger distances over slopes ranging between 0° and 2° (Masson et al., 1992b). The three-pointed star morphology of the island of Hierro reflects that the volcanic edifice has suffered three main slides as it was pointed out by Pellicer (1977) and Holcomb and Searle (1991): El Golfo, Las Playas and El Julan, the two first being particularly apparent onland (Fig.1).

The northwest facing El Golfo slide is the largest. It shows head scarps up to 1100 m high which quickly decrease in height towards the sea. These scarps, with
slopes ranging from 22° to 58°, define a large amphitheater of 14.5 km in diameter. The headwalls of this amphitheater give place to a zone of flat smoothed relief dipping towards the sea. The amphitheater is clearly marked by a system of dykes and fractures with the same orientation of the slide headwall (Pellicer, 1977) (Fig. 1). This relation between dykes and fractures, and landslides is present in other oceanic islands as the Hawaiian Ridge (Moore et al., 1989).

Las Playas slide is headed by a southeast facing amphitheater, 4.5 km in diameter. The amphitheater is bounded by scarps up to 700 m high with slopes averaging 47°.

Only the submarine part of El Julan slide has been detected by means of GLORIA long-range side-scan images (Holcomb and Searle, 1991), as no headwalls are visible on the island. Masson (1996) points out that this is an old landslide, which possibly occurred between 300,000 and 500,000 years BP, as indicated by burial of the debris avalanche deposits beneath up to 20 m of later sediment. The El Julan slide scar is probably covered by 0.5-0.08 Ma old volcanic materials belonging to the Ancient series B of Hierro and by younger, less than 0.05 Ma old, materials of the intermediate volcanic series, which altogether crop out in the area immediately onshore of the submerged part of this slide (Fuster et al., 1993).

Methods

The data on which the results presented in this paper are based, were acquired during a cruise carried out in December 1994 on board the Spanish R/V Hespérides. They include 2145 km of SIMRAD EM125 swath bathymetry tracks fully covering 8200 km² of the seafloor, 2145 km of very high resolution TOPAS Bottom Parametric Source (BPS) profiles, and 656 km of single-channel airgun seismic reflection profiles (Alonso et al., 1994).

Results

The studied data set allows to identify two large slides affecting the submarine western flank of the Hierro Island: The El Golfo debris avalanche and the Canary debris flow (Fig. 2).

El Golfo debris avalanche, as mentioned above, originated subaerially, and shows two segments with morphosedimentary significance (Fig. 2):

a) A proximal area of the avalanche characterized by subaerial scarps as high as 1100 m in the central part of the island. The bathymetry shows smooth reliefs dipping 5° north-westwards and levee-like features bounded by scarps in the submarine part of the source area. These scarps, which range between 150 and 200 m high, configure the offshore continuation of the El Golfo slide (Fig. 3).

b) A distal area covering 2600 km² characterized by hummocky terrain in the bathymetric chart (Fig. 3) and hyperbolic response in BPS records. The largest hummocks within this area are 80 m high and 1 km in diameter. Airgun seismic records show this zone to be dominated by transparent facies reaching an average thickness of 60 m and a maximum thickness of 200 m close to the mouth of the amphitheater (Fig. 4). The calculated volume for the deposit is 150 km³. The former characteristics together allows to interpret the hummocky zone as a debris avalanche according to the criteria of Moore et al., (1994).

Acoustic mapping and morphobathymetric characters of the Canary debris flow show, as well, two segments:

a) A proximal area with a NE-SW scarp at a depth of 3200 m, 5600 m long and 150 - 200 m high, situated behind the hummocks of the avalanche (Fig. 2). This area appears to have been significantly covered by the former El Golfo debris avalanche. The orientation of the main scarp in this area clearly differentiates it from the NW-SE oriented scarps of the El Golfo avalanche headwall.

b) The distal area is bathymetrically characterized by a very smooth relief only disrupted by several gentle highs with uneven morphologies (Figs. 2 and 3). These highs have elevations around 50-75 m above the surrounding ocean floor and diameters of 1 to 10 km. Airgun seismic records show these highs to be controlled by normal faults. In BPS records the Canary debris flow is mainly dominated by opaque facies evolving, with increasing distality, to transparent facies. Masson et al., (1992a) have calculated that the Canary debris flow has a volume of about 400 km³.

Discussion

It is necessary to clarify the relationship between the Canary debris flow and El Golfo debris avalanche. The calculated volume for the subaerial and submarine scarps of El Golfo is 180 km³ while the volume calculated after mapping of the avalanche deposit is on the order of 150 km³. Since the Canary debris flow has a volume of 400 km³
cumulative stresses triggering El Golfo debris avalanche. According to Carracedo (1994), they include the wedge effect of intrusive dykes, the loading stress by new volcanic materials, progressive growth vs. instability of the volcanic edifice, associated seismicity and magma swelling.

Establishing the relation between both flows allows to determine the age of the El Golfo debris avalanche, since the age of the Canary debris flow is known from Simm et al., (1991) to be 12,000 yBP. Control on the youngest limit is given by the onland scarp of El Golfo, which is covered by materials of the Tanganasoga volcano, dated to be 6,000 yBP (Fuster et al., 1993). Then, the age for the El Golfo debris avalanche ranges from 12,000 to 6,000 yBP. According to the criteria of Moore (1994), further evidence of the youngness of the El Golfo debris avalanche would be the lack of gully incision typical of the uplift stage in the evolution of oceanic islands following shield phases.

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References

Masson, D. G., Kidd, R. B., Gardner, J.

Fig. 3.- Detailed bathymetry of the El Golfo debris avalanche headwalls. A zone of hummocky terrain appears at the foot of these scarps. This zone also truncates a scarp roughly oriented NE which could correspond to one of the source areas of the former Canary debris flow. Situation in Fig. 2.

Fig. 3.- Batimetría detallada de los escarpes de cabeceo de la avalancha de El Golfo. Al pie de estos escarpes aparece una zona de terreno con "hummocks" que trunca otro escarp de orientación NE. Este escarpe podría corresponder a uno de las áreas fuente del "debris flow" de Canarias. Situación en la figura 2.

Fig. 4.- Airgun seismic profile line drawing showing El Golfo debris avalanche. Situation in Fig. 2.

Fig. 4.- Esquema interpretativo de un perfil de sísmica de reflección de cañones de aire mostrando la avalancha de El Golfo. Situación en la figura 2.