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ESC: a polygenetic seamount chain

ESC: una cadena de montes submarinos poligenética

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Resumen.- Para cuantificar estadísticamente 383 montes perteneciente a la cadena de montes submarinos de Pascua (ESC) y para definir su variabilidad morfológica, se ha ploteado su diámetro basal, área transversal, volumen, achatamiento y pendiente versus su altura comprendida entre 200 y 3300 m. Los datos fueron obtenidos con los sistemas GLORI-B y SeaBeam 2000. La distribución de la frecuencia acumulada de la altura y el volumen sugiere que hay por lo menos dos poblaciones de montes submarinos. Sin embargo, la ausencia de un modelo definido para la distribución de sus formas revela que montes submarinos de diferente origen (poligenéticos) yacen uno al lado de otro.

Introduction

The origin and physical nature of the Easter Seamount Chain (ESC), a first order feature of the Nazca plate submarine topography, remain a mystery. The chain runs roughly 3000 km from the East Pacific Rise (EPR) to the Chile-Perú Trench. From its appearance alone, it is clear that this chain is the result of long and complex interactions between the ocean lithosphere and underlying mantle. However, the nature of these interactions is unknown.

The name of this chain in the specialized literature as the Easter Fracture Zone, the Salas y Gómez Ridge, the Easter Hot Line, the Easter Volcanic Chain and the Easter Seamount Chain, reflects the various models proposed to explain its origin (Hagen *et al.* 1990). The mode of formation is under current debate, but it is certain that the volcanic constructs describe the complex interaction. The proposed models are based on either geochemical signals from dredged and exposed rocks, seismic studies, side-scan interpretation, gravity, magnetics, or satellite altimetry or a combination of some of these observations. The models include Hotspot, Leaky Fracture Zone, Hot Line and Diffuse Extension.

Other studies have described the seamount population parameters (Abers *et al.* 1988, Bemis & Smith 1993, Scheirer *et al.* 1996, Smith & Jordan 1988), but none of them has described the distribution and morphology of seamounts in a superfast spreading area like in this study. Using GLORI-B and SeaBeam 2000 new data gathered in 1995 on board the R/V Melville during GLORIA Expedition, we have analized statistically the size distribution of 383 seamounts located between 25°-29°S and 104°-113°W, for the first time, in order to get a better comprehension of this area that includes the Easter and Salas y Gómez islands (Fig. 1).

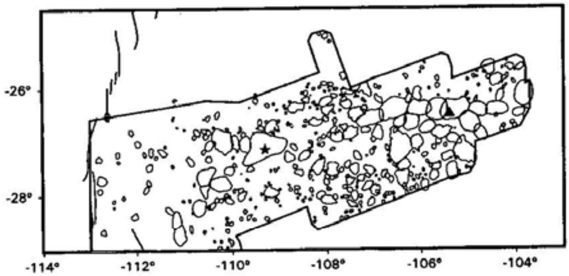

Figure 1

Location of the study area that shows the actual basal outlines of seamounts. Basal outlines of 383 seamount used in this study are digitized from bathymetry data, extracting maximun height, summit area and total volume from 0.003 by 0.003 degrees data set. For reference, it is included Easter island (star), Salas y Gómez island (triangle), the East Pacific Rise axis (thick black line) and the study area envelope (black line).

Ubicación del área de estudio que muestra el contorno basal actual de los montes submarinos. El contorno basal de 383 montes submarinos del estudio fueron digitizados de los datos batimétricos; se extrajeron la altura máxima, el área de la cumbre y el volumen total en una base de datos de 0.003 por 0.003 grados. Como referencia, se identifica la ubicación de las islas de Pascua con una estrella, Salas y Gómez con un triángulo, el eje de la Dorsal del Pacífico Oriental con una línea sólida delgada y el área de estudio con una línea sólida envolvente más gruesa.

Methods

Instrumentation

The GLORIA (Geological Long Range Inclined ASDIC) system was designed to collect acoustic side-scan image data of the seafloor in deep oceans (Goff & Kleinrock 1991, Kleinrock *et al.* 1992, Rusby 1992, Sommers *et al.* 1978, Vogt & Tucholke 1986). The system has recently upgraded to collect bathymetry data as well and is now called GLORI-B (Sommers & Hugget 1993). The GLORI-B is built in a fish vehicle, which is towed ~300 m behind the ship at a depth of ~50 m. The instrument, consisting of two parallel rows of long transducer arrays on each side, transmits a 2 second-long 6.5 kHz pulse every 20-40 seconds within a narrow beam (2.7°). The returning signal is correlated (to compress the pulse) and is recorded in digital form for subsequent processing. The intensity and travel time of the return signal are used to calculate imagery of the seafloor. The full image swath is 45 km wide. At 8 knots towing speed, the data have an along track resolution of ~125 m and a cross-track resolution of ~45 m.

The SeaBeam 2000 is a hull-mounted a multi narrow beam system designed toward production of bathymetry maps rather than seafloor acoustic images (Goff & Kleinrock 1991, Kleinrock *et al.* 1992, Rusby 1992, Sommers *et al.* 1978, Vogt & Tucholke 1986). However, seafloor acoustic intensity is recorded enabling acoustic imaging of the seafloor. The system transmits a 2.7° wide beam at 7 msec-long pulse, which gives a range resolution of about 5 m for imagery and a cross-track resolution of about 14 m for the outer beams in 5 km water depth. The outer beams extend 60° to either side of vertical. The raw image data include both acoustic intensity and beam angle, which has 12-bit resolution stored in 16-bit words and a subset of 4-bit gray scale data, 1000 pixels per ping. At a depth of 3 km the system records image swaths of ~10 km wide.

Statistical processing

To evaluate the components that are responsible for seamount shape variability, statistics have been compiled for individual seamounts. There are a total of 533 seamounts in the height range of 200 - 3300 m. This population was reduced to 383 seamounts by eliminating those with aspects ratios more than 2 (Table 1). Their morphology is variable and complex, thus the determination of flatness and flank slope is based on the seamount approximation as a truncated elliptical cone. Seamount size distribution for volume and heigh were fit by a power-law and exponential-fit cumulative frequency distributions. Thus height has been plotted against six seamount parameters: basal radius, summit radius, volume, cross-sectional area, flatness and slope, in order to evaluate wich parameters are correlated and can be used to best describe this population.

Table 1

Statistical summary of 383 seamounts.

Resumen estadístico de los 383 montes submarinos.

	Height[a,b] (m)	Basal area[c]	Slope[d] (km^2)	Flatness[d] degree	Volume[c] (km^3)	Cross-sectional area[d] (km^2)	h/r_{min}
Mean	640	174.6	7.6	0.13	160	7.3	0.25
Std. Dev	540	378.9	3.8	0.10	480	15.9	0.01
Minimun height	200	4.6	1.7	0.01	1	0.3	0.06
Maximun height	3300	3757.4	22.0	0.57	5340	31.8	0.61

[a] Only considered seamounts with heights greater than 200 m and aspect ratio < 2.

[b] Measured from the average seafloor depth surrounding each seamount to its shallowest extent.

[c] Determined by digitizing the base of each seamount by inspection and extracting the data from the gridded GLORI-B bathymetry.

[d] Based on approximation of the seamount as a regular truncated elliptical cone.

Results

Young seamounts are found close to the ridge axis as well far off-axis. It is observed from side-scan intensity and preliminary radiogenic age data, that volcanism is not contemporaneous along the entire length of the chain. Large seamount edifices (heights >2450 m and a volume of 1200 km^3) are only found on seafloor age greater than Chron 3 (~4 Ma), or a distance greater than ~300 km from the axis, assuming a half spreading rate of 75 km/m.y. (DeMets 1994). Additionally the ages of the large seamounts are much greater than the age of the seafloor up on which they lie, with ages ranging from 0.08 Ma to 2.6 Ma crust.

The slope distribution of seamounts shows that there is no a clear pattern in their source. In general, seamounts are coalesced into several broad chain, but in detail they are distributed sporadically with respect to both size and shape. The seamount population in this region is interpreted as being polygenetic. The cumulative frequency distributions of height and volume (Fig. 2) suggests that at least two populations of seamounts would be present, based on a distinct break at approximately the same point in the seamount size distributions.

Whether the power-law fit or the exponential fit is used, at least two distinct sub-populations are required. For volume and height, these distinct subsets are proposed to be related to different underlying physical processes which result in different styles of volcanism.

Literature Cited

Abers GA, B Parsons & JK Weissel. 1988. Seamount abundances and distributions in the southeast Pacific. Earth and Planetary Sciences Letters 87: 137-151.

Bemis KG & DK Smith. 1993. Production of small volcanoes in the Superswell region of the South Pacific. Earth and Planetary Sciences Letters 118: 251-262.

Goff JA & MC Kleinrock. 1991. Quantitative comparison of bathymetric survey systems. Geophysical Research Letters 18: 1253-1256.

DeMets C, R Gordon DF Argus & S Stein. 1994. Effects of recent revisions to the geomagnetic reversal time scale on estimates of current plate motions. Geophysical Research Letters 21(20): 2191-2194.

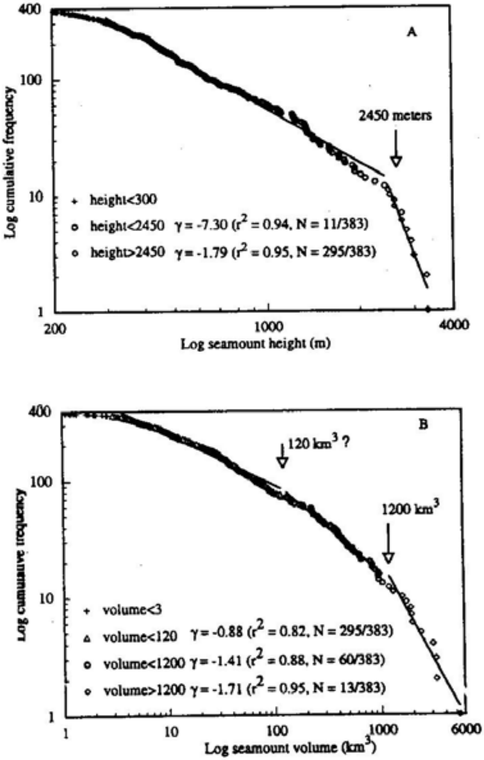

Figure 2

Multiple linear least-square fits to the power-law cumulative frequency size distribution. A different distribution is fit over different size ranges to accommodate observed slope changes. (A) Cumulative frequency distribution for height plotted on log-log axis. Note the inflection at 2450 m. (B) Volume cumulative frequency distribution displayed on a log-log axis. Note the main inflection at 1200 km^3 and the secondary one at 120 km^3.

Ajuste múltiple lineal al mínimo cuadrado de la distribución de frecuencia del tamaño acumulado. Para acomodar los cambios de pendiente observados, se ajustó una distribución para diferentes tipos de rangos. **(A)** La distribución de la fecuencia acumulada de la altura fue ploteada en un sistema de coordenadas log-log. Note la inflexión de la curva a los 2450 m. **(B)** La distribución de la frecuencia acumulada del volumen se muestra en un sistema de coordenadas log-log. Note la inflexión en 1200 km^3 y 120 km^3.

Hagen RA, NA Baker, DF Naar & RN Hey. 1990. A SeaMARC II survey of recent submarine volcanism near Easter Island. Marine Geophysical Researches 12: 297-315.

Kleinrock MC, RN Hey & JAE Theberge. 1992. Practical geological comparison of some seafloor survey instruments. Geophysical Research Letters 19: 1407-1410.

Rusby IR. 1992. Tectonic pattern and evolution of the Easter Microplate based on GLORIA and other geophysical data. Ph.D. Thesis, University of Durham, England, 272 p.

Scheirer DS, KC Macdonald, DW Forsyth & Y Shen. 1996. Abundant seamounts of the Rano Rahi seamount field near the Southern East Pacific Rise, 15°S to 19°S. Marine Geophysical Researches 18: 13-52.

Smith DK & TH Jordan. 1988. Seamount statistics in the Pacific Ocean. Journal of Geophysical Research 93(B4): 2899-2918.

Sommers ML, RM Carson, JA Revie, RH Edge, BJ Barrow & AG Andrews. 1978. GLORIA: an improved long range side-scan sonar. In: Proceedings IEEE/IERE sub-conference on Offshore instrumentation. Oceanology International '78. Technical Session J, London, BPS Publications, Ltd., London, p. 16-24.

Sommers ML & DQJ Hugget. 1993. From GLORIA to GLORI-B: New upgrades add swath bathymetry to 20-years old GLORIA reconnaissance sonar images. Sea Technology, June, p. 64-68.

Vogt PR & BE Tucholke. 1986. Imaging of ocean floor: History and state-of-the-art. The Western North Atlantic region. Boulder, Geological Society of America, Inc., 123 p.

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