ESC: a polygenetic seamount chain
ESC: una cadena de montes submarinos poligenética

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Resumen.- Para caracterizar estadísticamente 383 montes pertenecientes a la cadena de montes submarinos de Pacífico (ESC) y para definir su variabilidad morfológica, se ha analizado su diámetro basal, área transversal, volumen, submersión 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 (poligenético) 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-Peru 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 Lode, 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 geochronological data 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 Lode and Diffuse Extension.

Other studies have described the seamount population parameters (Abers et al. 1988, Bennis & Smith 1993, Schreier et al. 1996, Smith & Jordan 1988), but none of them has described the distribution and morphology of seamounts in a superfast spreading area like this study. Using GLORI-B and Seabeam 2000 new data gathered in 1995 on board the R/V Melville during GLORIA Expedition, we have analyzed 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. The basal outline of 383 seamount used in this study are digitized from bathymetry data, extracting maximum 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 bathimétricos, 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 incluye la ubicación de las islas de Pacas con un asterisco, Salas y Gómez con un triángulo, eje de la Dorsal del Pacífico Oriental con una línea sólida negra y el área de estudio con una línea sólida revolvente 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 ocean (Gulf & Kleinrock 1991, Kleinrock et al. 1992, Raubel 1992, Sommers et al. 1978, Vogt & Tucholke 1980). The system has recently upgraded to collect bathymetry data as well and is now called GLORI-B (Sommers & Huggins 1993). The GLORI-B is built in a ship 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 suppress 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 Seabream 2000 is a hull-mounted a multi-narrow beam system designed toward production of bathymetry maps rather than seafloor acoustic images (Gulf & Kleinrock 1991, Kleinrock et al. 1992, Raubel 1992, Sommers et al. 1978, Vogt & Tucholke 1980). However, seafloor acoustic intensity is recorded enabling acoustic imaging of the seafloor. The system transmits a $2.7^\circ$ 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 includes 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 333 seamounts in the height range of 200 - 3300 m. This population was reduced to 383 seamounts by eliminating those with aspect ratios less 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 height 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 which parameters are correlated and can be used to best describe this population.

Table 1

<table>
<thead>
<tr>
<th>Height (m)</th>
<th>Basal area (km²)</th>
<th>Slope (degree)</th>
<th>Flatness (°)</th>
<th>Volume (km³)</th>
<th>Cross-sectional area (km²)</th>
<th>h/V_max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>640</td>
<td>174.6</td>
<td>7.6</td>
<td>0.13</td>
<td>160</td>
<td>7.2</td>
</tr>
<tr>
<td>Std. Dev.</td>
<td>540</td>
<td>378.9</td>
<td>9.8</td>
<td>0.10</td>
<td>480</td>
<td>15.9</td>
</tr>
<tr>
<td>Minimum</td>
<td>200</td>
<td>4.6</td>
<td>2.1</td>
<td>0.01</td>
<td>1</td>
<td>0.3</td>
</tr>
<tr>
<td>Maximum</td>
<td>3300</td>
<td>3757.4</td>
<td>22.0</td>
<td>0.57</td>
<td>5340</td>
<td>31.8</td>
</tr>
</tbody>
</table>

* Only considered seamounts with heights greater than 200 m and aspect ratio < 2.
* Measured from the average seafloor depth surrounding each seamount to its shallowest extent.
* Determined by digitizing the base of each seamount by inspection and extracting the data from the gridded GLORI-B bathymetry.
* 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. (DuMets 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 0.68 Ma to 2.6 Ma crust.

The slope distribution of seamounts shows that there is no 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


Recibido en septiembre de 1998 y aceptado en marzo de 1999