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Compositional diversity in peridotites as result of a multi-process history: The Pacific-derived Santa Elena ophiolite, northwest Costa Rica

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ABSTRACT

The Santa Elena ophiolite (SEO) is an ultramafic nappe of more than 270 km^2 overlying a tectonic serpentinite–matrix mélange in northwest Costa Rica. It is mainly composed of Cpx-rich and Cpx-poor harzburgites (~2.5 km-thick), with minor lherzolite, dunite and chromitite, as well as intrusive mafic sills and subvertical dikes, which coalesce into an upper Isla Negritos gabbroic sill complex. Minerals and whole-rock features of the Cpx-rich and Cpx-poor harzburgites share features of the abyssal and supra-subduction zone (SSZ) peridotites, respectively. To explain these characteristics two-stages of melting and refertilization processes are required. By means of trace element modeling, the composition of Cpx-rich harzburgites may be reproduced by up to ~5–10% melting of a primitive mantle source, and the composition of Cpx-poor harzburgites and dunites by ~15–18% melting of an already depleted mantle. Therefore, the Cpx-rich harzburgites can be interpreted as product of first-stage melting and low-degrees of melt–rock interaction in a mid-ocean ridge environment, and the Cpx-poor harzburgites and dunites as the product of second-stage melting and refertilization in a SSZ setting. The mafic sills and the Isla Negrito gabbros are genetically related and can be explained as crystallization from the liquids that were extracted from the lower SSZ mantle levels and emplaced at shallow conditions. The Murciélagos Island basalts are not directly related to the ultramafic and mafic rocks of the SEO. Their E-MORB-like composition is similar to most of the CLIP mafic lavas and suggests a common Caribbean plume-related source. The SEO represents a fragment of Pacific-derived, SSZ oceanic lithosphere emplaced onto the southern North America margin during the late Cretaceous. Because of the predominance of rollback-induced extension during its history, only a limited amount of crustal rocks were formed and preserved in the SEO.

1. Introduction

Peridotites from tectonically emplaced ophiolites represent variably depleted solid residues of oceanic upper mantle left behind after mantle melting and crust–mantle segregation (Bodinier and Godard, 2003; Dilek and Furnes, 2011; Dilek et al., 2000). Chemical and mineral data from these rocks provide important information about the mantle process of melt generation, fluid phase enrichment, and melt–mantle interactions subsequent to melt extraction (Bodinier et al., 2008; Hellebrand et al., 2001; Kelemen et al., 1992; Parkinson and Pearce, 1998). These data also contribute to discriminate the original tectonic setting of lithosphere generation (Godard et al., 2008; Marchesi et al., 2012; Pearce et al., 2000).

The melting history of the upper mantle and its compositional heterogeneity can be deduced from the geochemical and petrological data of ophiolitic peridotites, which are mainly of abyssal and supra-subduction zone (SSZ) types. In this sense, abyssal peridotites represent the residues of fractional melt extraction to form mid-ocean rift basalts (MORBs) (Dick and Bullen, 1984; Niu, 2004). Modal analysis and major and trace element concentrations in minerals show that these relatively fertile peridotites are lherzolites and clinopyroxene (Cpx)-rich harzburgites formed by small to moderate amounts of melt extraction (5–15% partial melting) under dry conditions. In contrast, SSZ peridotites are generally Cpx-poor harzburgites and dunites characterized by strongly depleted whole-rock incompatible trace element concentrations (Parkinson and Pearce, 1998; Pearce et al., 2000) and mineral compositions indicatives of higher degrees of partial melting (15–22%) when compared to abyssal peridotites (Arai, 1994). These ultra-depleted peridotites are more likely derived from the hydrous (re)melting of relatively fertile peridotites in a SSZ environment, producing boninite-like melts (Escuder-Viruete et al., 2014; Marchesi et al., 2009; Pagé et al., 2009).

The spatial coexistence of abyssal and SSZ-type mantle peridotites has been described in several ophiolites (Choi et al., 2008; Dilek and Furnes, 2011; Saka et al., 2014; Uysal et al., 2012). Modal composition, mineral chemistry, whole-rock trace and platinum-group element data suggest that formation of SSZ peridotites requires at least two-stages of melting and refertilization processes (e.g., Marchesi et al., 2009). Further, the textures and mineral chemistry of some peridotites are inconsistent to be residual in origin and they are interpreted to be

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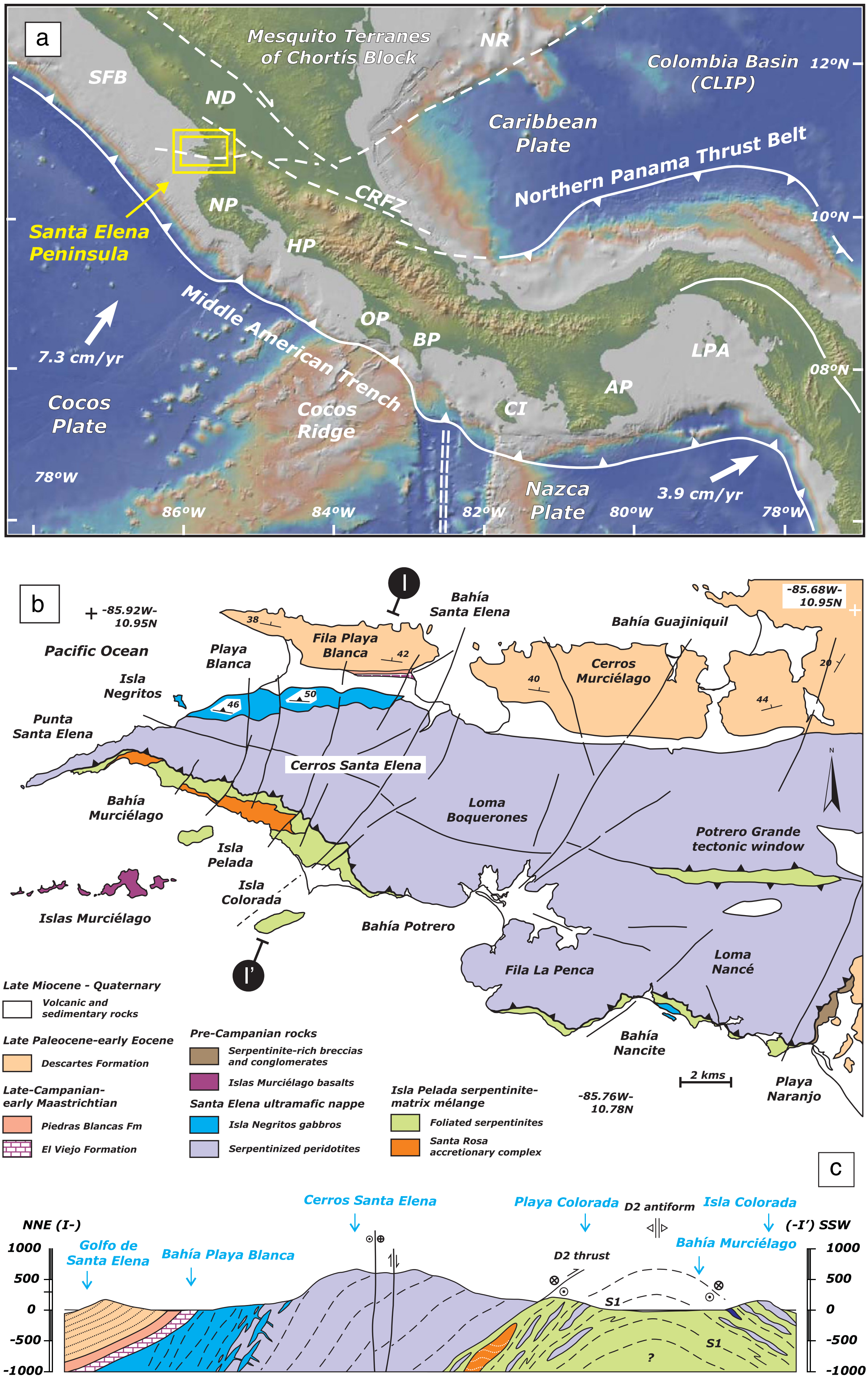
a
Mesquito Terranes
of Chortís Block
NR
Colombia Basin
(CLIP)
12ºN
SFB
ND
Caribbean
Plate
Northern Panama Thrust Belt
NP
CRFZ
10ºN
Santa Elena
Peninsula
HP
Middle American Trench
7.3 cm/yr
OP
BP
LPA
08ºN
Cocos
Plate
Cocos
Ridge
CI
AP
78ºW
Nazca
Plate
3.9 cm/yr
86ºW
84ºW
82ºW
80ºW
78ºW
b
-85.92W-
10.95N
I
Bahía
Santa Elena
-85.68W-
10.95N
Bahía Guajiniquil
Pacific Ocean
Playa
Blanca
Fila Playa
Blanca
Cerros
Murciélago
Isla
Negritos
Punta
Santa Elena
Cerros Santa Elena
Bahía
Murciélago
Loma
Boquerones
Potrero Grande
tectonic window
Isla
Pelada
Isla
Colorada
Islas Murciélago
Bahía Potrero
Fila La Penca
Loma
Nancé
Bahía
Nancite
Playa
Naranjo
I'
2 kms
-85.76W-
10.78N
Late Miocene - Quaternary
Volcanic and
sedimentary rocks
Late Paleocene-early Eocene
Descartes Formation
Late-Campanian-
early Maastrichtian
Piedras Blancas Fm
El Viejo Formation
Pre-Campanian rocks
Serpentinite-rich breccias
and conglomerates
Islas Murciélago basalts
Santa Elena ultramafic nappe
Isla Negritos gabbros
Serpentinized peridotites
Isla Pelada serpentinite-
matrix mélange
Foliated serpentinites
Santa Rosa
accretionary complex
c
Cerros Santa Elena
Playa Colorada
D2 antiform
Isla Colorada
NNE (I-)
(-I') SSW
Golfo de
Santa Elena
Bahía Playa Blanca
Bahía Murciélago
D2 thrust
S1
S1
1000
500
0
-500
-1000
1000
500
0
-500
-1000