Título: *Metamorphic and magmatic consequences of subduction of young oceanic lithosphere and exhumation in a serpentinite subduction channel. Eastern Cuba / Consecuencias metamórficas y magmáticas de la subducción de una litosfera oceánica joven y la exhumación en un canal de subducción serpentinítico. Cuba oriental*
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Fecha de lectura: *20 de septiembre de 2010*
Tribunal: *Fernando Bea Barredo (Presiente), María Teresa Gómez Pugnaire (Secretaria), Walter V. Maresch, Andrés Pérez Estaún, Joan Carles Melgarejo i Draper*
Calificación: *Sobresaliente "Cum laude"*

Metamorphic and Magmatic Consequences of Subduction of Young Oceanic Lithosphere. Eastern Cuba

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INTRODUCTION

The subduction channel concept was defined to describe complex rock assemblies developed in the interface between the subducting and the hanging wall plates in a convergent margin. The subduction channel model provides a mechanism for the exhumation of subducted high pressure rocks accreted as blocks to the overlying accretionary prism formed, mostly, by sediments. The subduction channel concept has been extended to much deeper near-sub-arc depths by means of thermo-mechanical and conceptual models. In this context the subduction channel is formed by the mantle wedge peridotite hydrated in the antigorite stability field (i.e., below ca. 650 ºC). The fluids necessary for this serpentinization process are thought to be provided by prograde metamorphism of the subducted slab (serpentinites, altered basaltic crust and sediments).

The exposed materials exhumed from the plate interface (i.e. mélange) contain information about processes taking place during long periods of time, making the mélanges the best laboratory for the study of processes occurring in the plate interface to ca. 100-150 km depth. The occurrence of a well preserved Cretaceous subduction channel in eastern Cuba makes this region an appropriated area to study the evolution of subduction channels during tens of millions of years, from onset of subduction to final exhumation. This work is focused to the magmatic and metamorphic characteristics of amphibolite blocks, associated tonalite-trondhjemite bodies and the ultramafic blocks and matrix from these mélanges, especially in the La Corea mélange *(Fig. 1)*. This mélange contains high pressure blocks in a serpentinite matrix and occurs at the base of the Mayarí-Cristal ophiolite. For them a complete methodology was used that included metamorphic petrology, geochemistry, geochronology, numerical modelling and plate tectonic interpretation.

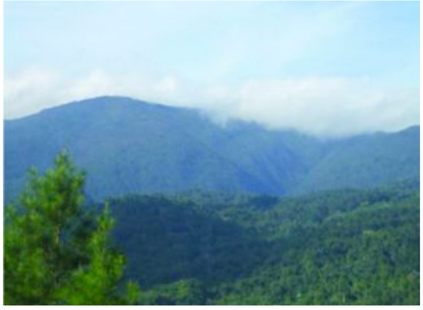

fig 1. . Panoramic view of the La Corea mélange (from South to North), with the Sierra de Cristal in the back

AMPHIBOLITE BLOCKS

Amphibolite blocks of La Corea mélange have MORB affinity and heterogeneous compositions. The main mineral assemblage consists of pargasitic amphibole + epidote + quartz + rutile + titanite ± garnet ± phengite, lacking primary (peak) plagioclase. Peak metamorphic conditions determined using the average P-T method and isochemical P-T projections calculated with software THERMOCALC indicate 690-710 ºC and 14-15 kbar, appropriate for wet melting of metabasite. Infiltration of H_2O likely occurred once the blocks were accreted to the hanging wall, triggering partial melting of the metabasites and the formation of trondhjemitic-tonalitic melts extracted out or precipitated inside the rocks as pockets. These partial melting of a subducted young oceanic lithosphere in eastern Cuba is unique in the Caribbean realm (and probably in the world). This scenario can only be compared with the Catalina schist in south western USA, having significant consequences for the plate tectonic interpretation of the region. Formation of the subduction channel (mélange) took place upon cooling during continuous subduction and fluid migration to the upper plate mantle, allowing the blocks to start exhumation and further cooling following counterclockwise P-T paths during retrogression. The La Corea and Sierra del Convento mélanges share similarities in terms of structural position, lithology, age, P-T paths, and petrological processes, suggesting that they formed synchronously in the same subduction system close to a subducting oceanic ridge.

CONVECTIVE CIRCULATION

Although most of the amphibolite blocks have similar metamorphic evolutions (i.e., counterclockwise P-T paths), some blocks have particularities, like coarse garnet porphyroblasts with well defined oscillatory concentric zoning. Calculated P-T conditions for this sample using mineral inclusion assemblages and isochemical P-T projections

palabras clave: La Corea Mélange, Canal de Subducción, Fusión Parcial, Anfibolita, Modelos Numéricos

key words: La Corea Mélange, Subduction Channel, Partial Melting, Amphibolite, Numerical Modelling

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reveal large P-T recurrences best explained by large-scale convective movement of the tectonic block in a serpentinitic subduction channel. P-T conditions attending garnet growth followed an overall counterclockwise path as a consequence of continued refrigeration of the subduction channel during ongoing underflow. These findings constitute the first report of large scale convective circulation of deeply subducted material in the subduction channel, and are consistent with the thermo-mechanical behavior of the channel predicted by numerical models.

TONALITE-TRONDHJEMITE ROCKS

Field, petrologic and whole-rock chemical data indicate that tonalitic-trondhjemitic rocks from the La Corea mélange represent melts formed during partial melting of subducted amphibolites. Primary mineral assemblage consists of plagioclase + quartz + phengite ± epidote ± paragonite ± pargasite. SHRIMP zircon ages of the trondhjemites provide crystallization ages ranging from 105 to 110 Ma, dating partial melting processes in the subduction environment. The process implied accretion of subducting amphibolites to the upper plate and ensuing infiltration of fluids evolved from downgoing slab. Partial melting of the amphibolite in the subduction environment indicates a very hot subduction environment caused by subduction of a very young oceanic lithosphere (oblique ridge) and, perhaps, onset of subduction (at ca. 120 Ma). Continued subduction during the Late Cretaceous (of older -colder- lithosphere) allowed cooling of the subduction system and serpentinization of the upper plate mantle wedge, forming a serpentinite matrix subduction channel with HP blocks. ^{40}Ar-^{39}Ar cooling ages of phengite of 83-86 Ma indicate very slow exhumation rates of ca. 1 mm/yr during the oceanic convergence stage. Data from related serpentinte-matrix mélanges of eastern Cuba and Dominican Republic suggest variations along strike in the upward flux rate from 0.7 to 4.8 mm/yr. Regional data indicate final exhumation of the mélange at 70-65 Ma as a result of arc-platform terrane collision in the region.

BA-RICH ROCKS

A special group of amphibolite blocks and associated tonalite-trondhjemite rocks in La Corea and the Sierra del Convento mélanges are characterized by abundant presence of white mica. These groups of rocks show enrichment in mobile elements, especially in Barium. Major and trace element composition of phengite-bearing Ba-rich amphibolite, trondhjemite, pegmatite and Qtz+Ms rocks from these mélanges demonstrate the circulation of Ba-rich fluids and melts in the subduction environment. The amphibolite represents subducted MORB material affected by fluid infiltration at high temperature. The trondhjemite was formed by fluid-fluxed melting of amphibolite and represents pristine slab melts that did not react with the upper plate mantle. The pegmatites are interpreted as magmatic products after differentiation of trondhjemitic melts, while Qtz-Ms rocks probably represent material crystallized from a primary sediment-derived fluid. Principal Component Analysis (PCA) indicates that phengite chemistry is primarily governed by the celadonite (tschermak) exchange vector ((Mg,Fe)Si-(VIAl IVAl)$_{-1}$) combined with the celsian (BaAl-KSi$_{-1}$) and paragonite (NaK$_{-1}$) exchange vectors. Crystallization of the studied magmatic rocks in the subduction environment made phengite to act as a sink, rather than a source, for Ba (and other LILE, Pb, Sr), preventing the transfer of these elements to the mantle wedge. This strengthens the importance of phengite stability in the subduction environment for control of the flux of material from the slab to the volcanic arc environment.

ULTRAMAFIC ROCKS

Two main groups of ultramafic material appear in the La Corea mélange associated with the high pressure blocks: antigorite- and antigorite-lizardite-serpentinites. The strong alteration (i.e., serpentinization, Cr-spinel transformation) of ultramafic protoliths indicate pervasive fluid flow, best explained if the rocks experienced hydration during infiltration of fluids evolved from the subducted slab. Antigorite serpentinites (mainly composed of antigorite, >93 %) have harzburgitic protolith and most likely formed at depth after hydration of the mantle wedge (Caribbean lithosphere) by fluids derived from the SW-dipping subducted slab (Protocaribbean lithosphere). Antigorite-lizardite serpentinites are of harzburgitic-lherzolitic composition, having clinopyroxene porphyroblasts and are best explained as abyssal (meta)peridotites (Protocaribbean lithosphere) accreted to the subduction channel developed in the Caribbean-Protocaribbean plate interface. Antigorite-serpentinites document large-scale hydration of the Caribbean plate mantle wedge and the formation of a thick subduction channel which allowed exhumation of accreted subducted material during Cretaceous times. Both types of serpentinites were exposed together in the mélange during the late Cretaceous, produced by the obduction of the overriding Mayarí-Baracoa ophiolitic belt that led to exhumation of the subduction channel (mélange).

THERMO-MECHANICAL MODELS

Thermo-mechanical modelling was used to simulate induced initiation and progress of subduction of young (10-30 Ma) oceanic lithosphere, with variation in the rate of induced convergence (2, 4 and 5 cm/yr) across a pre-existing rheologically weak fracture zone. A 2D thermo-mechanical numerical model was developed using the I2VIS code based on conservative finite differences and non-diffusive marker-in-cell techniques. It was found that the age of oceanic lithosphere strongly influences dehydration of subducted oceanic crust and underlying mantle peridotite, as well as partial melting of the slab, favoured for younger lithospheres. The rate of induced plate convergence has, in turn, strong influence for the spontaneous slab retreat. Partial melting of the subducted young crust creates thermal-chemical instabilities (cold plumes) that ascend along the slab-mantle interface until they penetrate the upper plate lithosphere and produce volcanic arcs. However, under special circumstances (e.g., 10 Myr age of lithosphere and 4 cm/yr of convergence rate) cold plumes crystallize at depth in the slab-wedge interface region shortly after onset of subduction. These plumes have no significant influence on the evolution of the upper plate mantle and arc crust. Consequently, we suggest that the partially molten blocks from the eastern Cuba serpentinite mélanges represent fragments of an aborted thermal-chemical plume frozen at depth. Exhumation of this type of plumes is expected to take place within subduction channels, as in the Cuban example, for they freeze at relatively shallow depth (ca. 50 km) in a region close to the slab-wedge interface where buoyant serpentinitic subduction channel is generated with time during ongoing subduction.