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THE CHORTÍS BLOCK—SOUTHWESTERN MÉXICO CONNECTIONS: U-Pb ZIRCON GEOCHRONOLOGY CONSTRAINTS

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ABSTRACT. The proposed connections between basement terranes of southwestern México and the Chortís Block of Central America are tested in this paper, which focuses on metamorphic units in northern Chortís that outcrop in southeastern Guatemala. Two chief units are recognized: the mid- to high-metamorphic grade Las Ovejas Complex made up of ortho-, para-gneisses, schists, amphibolites and marbles; and the tectonically juxtaposed, low-metamorphic grade San Diego Phyllite. U-Pb geochronology carried out by LA-ICPMS on zircons separated from both units reveal major differences between them. The high-grade metamorphism and deformation of Las Ovejas Complex is bracketed between ~27 and ~37 Ma, which correspond to the U-Pb zircon ages of the oldest cross-cutting dikes and youngest zircons in metasedimentary samples. Las Ovejas samples share xenocrystic and detrital zircon populations of Middle-Late Jurassic, Middle-Late Triassic and Permo-Carboniferous age. In contrast, the San Diego Phyllite contains zircons that overlap at ~830 to 870 and ~1150 to 1220 Ma, with the youngest concordant zircons yielding Cambrian age. The contrast in population ages supports the idea that Las Ovejas Complex and San Diego Phyllite are different lithotectonic units tectonically juxtaposed during or after their exhumation. When compared with available U-Pb zircon data for southern México, Las Ovejas Complex show similarities to samples of the Guerrero terrane, mainly the Arteaga Complex and Zihuatanejo subterrane, as well as to the southern and northern portions of the Cuicateco terrane. The San Diego Phyllite shows instead similarities with the Teloloapan subterrane of the Guerrero terrane, the Mexcala Formation, the low-grade units of the Cuicateco terrane and the Grenvillian ages of the Oaxacan Complex metaigneous samples, as well as some of the samples belonging to the Maya Block. We propose a tectonic model in which the Las Ovejas Complex was a portion of a fringing arc located in front of the Cuicateco terrane of southwestern México, removed during the Early Tertiary by docking of the Chortís Block represented by the San Diego Phyllite, and tentatively by similar units recognized elsewhere in the Chortís Block in Honduras and Nicaragua. Eocene-Oligocene metamorphism and deformation of the Las Ovejas Complex would be a result of its displacement off southern México, mainly characterized by sinistral stretching and tectonic Cenozoic transport.

Key words: Chortís Block, U-Pb geochronology, detrital zircons, LA-ICPMS, southern México, Guatemala

INTRODUCTION

Subduction erosion as well as fault-related lateral removal of blocks are the principal mechanisms at convergent margins that are responsible for plate margin destruction and sediment recycling (for example, von Huene and Scholl, 1991; Clift and Vannucchi, 2004). One of the typical examples of lateral transport along continental margins is represented by the Salinian block in the US Cordillera (Page, 1981; Barbeau and others, 2005), which has been affected by right-lateral Cenozoic translations. In contrast, the Middle America trench has been described as a typical example of continental margin truncation due to subduction erosion (Ranero and von Huene,

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2000; Ducea and others, 2004b). In southern México the Acapulco trench is also described as a place where the two mechanisms of continental margin truncation have been present. For instance, the first tectonic reconstruction of Middle America by Malfait and Dinkelman (1972) firstly proposed a former adjacency between the basement of southernmost North America (southern México, Guatemala and Belize) and the continental basement of the northwestern Caribbean Plate (also known as Chortís Block) prior to the Tertiary, chiefly based on two geologic features: (1) basement rocks in southern México and the Chortís Block were then believed to be of coeval age; and (2) the recognition of truncated geologic units at the Mexican Pacific coast (for example, de Cserna, 1965) suggesting that the Chortís Block represented the missing portion of southern México, displaced southeastward during the Tertiary. Analogous tectonic reconstructions have since been presented by numerous authors (for example, Pindell and others, 1988; Ross and Scotese, 1988; Meschede and Frisch, 1998; Pindell and Kennan, 2009; Ratschbacher and others, 2009), whereas in a fundamentally different model Keppie and Morán-Zenteno (2005) propose that the Chortís Block would have migrated northeastward from an Eocene position in the Pacific ocean, to its current location, following a pole of rotation located near Santiago de Chile.

Evaluation of the relative position between Chortís and southern México requires further geochronologic and stratigraphic correlations between both sides, because available data are scarce, especially for basement units and detrital ages from the Chortís Block. This paper presents new LA-ICPMS (laser ablation inductively-coupled plasma mass spectrometry) U-Pb geochronology data from six samples of Las Ovejas Complex and two samples of San Diego phyllite from southeastern Guatemala, which represent the northernmost metamorphic basement commonly associated with the Chortís Block (Donnelly and others, 1990; Ortega-Gutiérrez and others, 2007; Ratschbacher and others, 2009). Comparing these new geochronologic data with currently available basement and detrital ages of southern México allows a more robust evaluation of the proposed connections between these two major geological provinces hence substantially constraining the general tectonic evolution of the Caribbean–Gulf of México region. These new data also provide critical information on the geologic evolution of the southernmost continental margin of North America, particularly in relation to early Cenozoic magmatic arc migration (for example, Schaaf and others, 1995; Morán-Zenteno and others, 1996), continental margin uplift and subsidence events (Morán-Zenteno and others, 1996; Keppie and others, 2009), and the timing, geometry, and kinematics of evolving plates in the area (for example, Stock and Lee, 1994; Meschede and Frisch, 1998).

GEOLOGIC FRAMEWORK

An array of distinct blocks (or terranes) compose the crustal structure of southern México (fig. 1). From west to east these blocks include: (1) the Guerrero composite terrane, mostly of Mesozoic age and composed of low- and medium-grade metamorphic rocks, including submarine, arc-related protoliths, marine and continental sedimentary sequences, and continental rift tholeiites, MORB's and OIB's (Centeno-García and others, 1993; Freydier and others, 1996; Elías-Herrera and Ortega-Gutiérrez, 1998; Talavera-Mendoza and others, 2007; Martini and others, 2009); (2) the Mixteco terrane, composed of a Paleozoic polymetamorphic basement (Acatlán Complex) characterized by a series of thrust nappes, including Ordovician megacrystic granites that intruded medium-grade metasediments, an eclogite-facies metamorphic suite of Devonian-Carboniferous age, late Carboniferous rift-related continental rocks, and a mid Paleozoic–Early Triassic (?) sedimentary cover partially overprinted by a Middle Jurassic, high-temperature tectonothermal event (Ortega-Gutiérrez and others, 1999; Keppie and others, 2006 and 2008; Talavera-Mendoza and others, 2005;

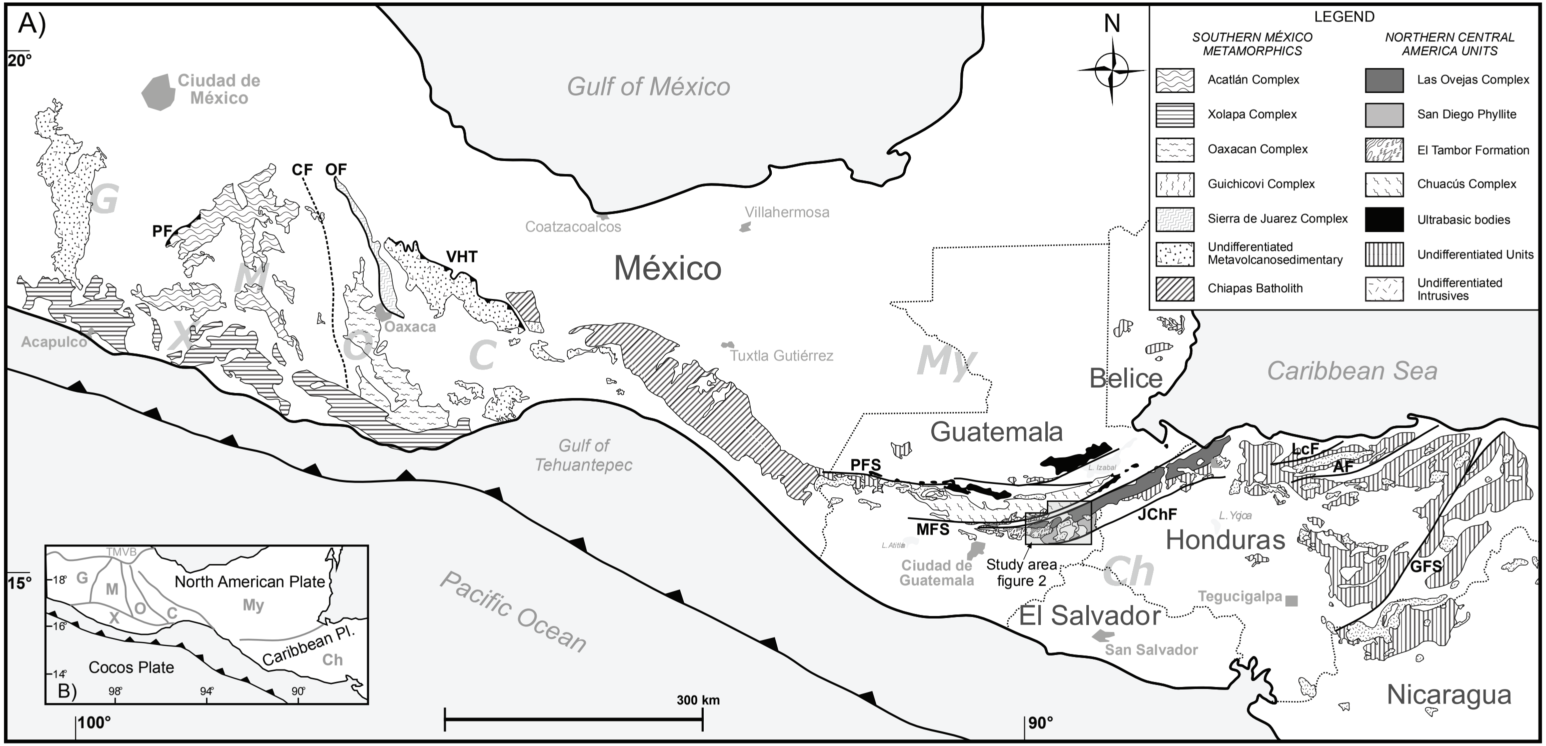

Fig. 1. (A) Generalized geological map of Southern México and Northern Central America showing the different metamorphic units and major tectonic features. Faults names: PF: Papalutla Thrust, CF: Caltepec Fault, OF: Oaxaca Fault, VHT: Vista Hermosa Thrust, PFS: Polochic Fault System, MFS: Motagua Fault System, JChF: Jocotán-Chamelecón Fault System, LcF: La Ceiba Fault, AF: Aguan Fault, GFS: Guayape Fault System. (B) Schematic terrane subdivision of Southern México and Northern Central America. Key: G: Guerrero Terrane, M: Mixteco Terrane, O: Oaxaca Terrane, C: Cuicateco Terrane, X: Xolapa Terrane, My: Maya Block, Ch: Chortís Block. Geology based on Ortega-Gutiérrez and others (1992) for southern México and French and Schenk (2004) for northern Central America.

Nance and others, 2006; Vega-Granillo and others, 2007; Ortega-Obregón and others, 2009); (3) the Oaxaca terrane, characterized by Grenvillian (1300-990 Ma), granulite-facies basement (Oaxacan Complex; Solari and others, 2003; Keppie and others, 2003) and unconformably overlain by a latest Cambrian to Carboniferous sedimentary cover (Gillis and others, 2005); (4) the Cuicateco terrane (southern sector), which contains a sequence of Mesozoic, low to medium-grade phyllites and schists intruded by Late Cretaceous MORB dolerites (Pérez-Gutiérrez and others, 2009a); (5) the Maya Block (Dengo, 1969), which extends from La Mixtequita massif (Oaxaca) to the Polochic-Motagua fault system, and includes Grenvillian granulites (Guichicovi Complex, Weber and Köhler, 1999), large areas exposing metasedimentary and intrusive Paleozoic rocks in the Chiapas Massif (Weber and others, 2008 and 2009), Altos Cuchumatanes (Solari and others, 2009 and 2010a), the Maya Mountains in Belize (Steiner and Walker, 1996; Martens and others, 2010), Western Guatemala (Ratschbacher and others, 2009) and Central Guatemala (Ortega-Obregón and others, 2008), basement units that are mantled by late Paleozoic sedimentary strata belonging to the Santa Rosa Formation (Weber and others, 2006), Jurassic red beds (Todos Santos Formation; Blair, 1988; Godínez-Urbán, ms, 2009), as well as both deformed and undeformed Cretaceous and Tertiary marine sediments (Pérez-Gutiérrez and others, 2009a; Mandujano-Velázquez and Keppie, 2009, and references therein).

The Guerrero, Mixteco and Oaxaca terranes are truncated by the high-grade Xolapa Complex along the Pacific coast of southern México. The Xolapa Complex is made up of Mesozoic migmatitic orthogneisses and siliciclastic metasediments, intruded by Eocene-Oligocene calc-alkaline plutons that exhibit diverse degrees of deformation. Of the various Jurassic to Oligocene igneous and metamorphic events recorded in the Xolapa Complex (Herrmann and others, 1994; Ducea and others, 2004a), the most conspicuous is the *ca.* 130 Ma migmatization (Pérez-Gutiérrez and others, 2009b). There is no agreement upon the tectonic significance of the Xolapa Complex; whereas some authors regard it as a suspect terrane accreted to mainland México during Mesozoic time (for example, Campa and Coney, 1983; Sedlock and others, 1993; Corona-Chávez and others, 2006), others propose an autochthonous model in which the Xolapa Complex would be the product of Tertiary thinning and re-heating of pre-existing continental crust (for example, Herrmann and others, 1994; Schaaf and others, 1995; Morán-Zenteno and others, 1996; Ducea and others, 2004a; Ratschbacher and others, 2009).

The Chortís Block, which is the focus of this study, is part of nuclear Central America and it constitutes the only portion of the Caribbean Plate where continental basement predominates. As initially defined (Dengo, 1969), the Chortís Block is bounded on the north by the active Motagua fault in Guatemala, and on the south by the Hess escarpment and its continuation in Nicaragua/Costa Rica. Rogers and others (2007a) and Ortega-Gutiérrez and others (2007) recognized an assemblage of disparate terranes and geologic provinces within the Chortís Block, but the boundaries and geologic evolution, especially of the southernmost terranes, remain poorly understood.

Although the geochronology of the northwestern region of Chortís Block has advanced in recent years, few geochronological ages on the crystalline basement of the Chortís Block are available and U/Pb detrital ages are nearly unknown. For a review on the published ages of basement units in the Chortís Block the reader is referred to Martens and others (2007) and Ratschbacher and others (2009).

MAIN BASEMENT UNITS OF THE NORTHERN CHORTÍS BLOCK

The basement of the northwestern Chortís Block is characterized by: (1) the extensive low-grade San Diego Phyllite that includes minor quartzite layers; (2) the high-grade metamorphic rocks of the Las Ovejas Complex (LOC) and Omoa Complex in NW Honduras; and (3) the various generations of deformed and undeformed granitic intrusions south of the Motagua Fault.

San Diego Phyllite

The San Diego Phyllite is composed of low greenschist-facies metasediments such as phyllitic shales, quartzites, and minor arkose (Lawrence, ms, 1975). In the field, the San Diego Phyllite is readily distinguished from other units by the prevalence of pelitic protolith and the abundance of millimeter-size pyrite casts. To the north, major faults separate the San Diego Phyllite from the LOC and the El Tambor Formation. The southern limit of the San Diego Phyllite is the Jocotán Fault, which juxtaposes the phyllites with the Cretaceous Yojoa limestones and the Tertiary volcanics of the Central America Volcanic Arc. The only non-tectonic boundary of the San Diego Phyllite is the intrusive contact against the Chiquimula pluton, with a poorly constrained whole rock Rb-Sr age of 50 ± 5 Ma (Clemons, ms, 1966; Clemons and Long, 1971).

The San Diego Phyllite is a particularly enigmatic unit of the Chortís Block; it is the least studied and perhaps too the least understood. It is unknown whether the unit is a correlative of the pre-Middle Jurassic Cacaguapa Schist, exposed southward throughout Honduras and northern Nicaragua (Martens and others, 2007). Another important unresolved issue is whether or not the San Diego Phyllite constitutes one of the protoliths of the LOC.

Las Ovejas Complex

The Las Ovejas Complex constitutes a fault-bounded, high-grade metamorphic unit exposed south and parallel to the Motagua Valley in the southeast region of Guatemala (Bosc, ms, 1971; Lawrence, ms, 1975; Schwartz, 1976). Similar rocks have been recognized in the Sierra de Omoa of northwestern Honduras (Horne and others, 1976), and these extend as far as Roatán Island off mainland Honduras (McBirney and Bass, 1969). Overall, the LOC can be subdivided into metamorphosed volcanosedimentary rocks and granitic components. The former includes interlayered quartzo-feldspathic gneisses, schists, marbles, and amphibolites containing mineral assemblages indicative of mid-amphibolite facies conditions. The metagranitic component includes metamorphosed intrusives of dioritic to granodioritic composition, granitic dikes, and deformed pegmatites. The LOC, showing pervasive ductile foliation and lineation, attained medium- to high-grade metamorphic conditions as indicated by the presence of migmatites. Both fabric elements are expressed by aligned and commonly deformed biotite and muscovite that are sub-parallel to the main trace of the Motagua fault.

Gneisses in the LOC are generally micaceous. In the eastern portion of the studied area, paragneisses contain muscovite-rich lenses. Orthogneisses are mainly composed of medium- to fine-grained biotite-bearing rocks. The gneisses are particularly abundant south of Gualán (fig. 2). Schists include biotite schists, two-mica schists, calcareous schists, staurolite-bearing schists and staurolite+garnet schists. In general, the schists are well foliated, presenting a penetrative, subhorizontal, and roughly E-W trending ductile mineral lineation made up of mica-aligned ribbons parallel to the stretching lineation defined by quartz crystals. Schists are commonly folded, usually as centimeter-scale crenulation, but also as 2 to 3 m wide folds of outcrop scale. The main outcrops of schists occur south of Huité and west of San Nicolás (fig. 2), where they show a dominant porphyroblastic fabric defined by large garnet and/or staurolite crystals. Metasedimentary rocks of the LOC also include 50 cm- to 4 m-thick layers of light gray marbles interbedded within schists, paragneises and amphibolites. The marbles range from massive to slightly foliated to finely foliated and lineated, and are mainly made up of calcite, with local development of silicates such as diopside, garnet and more rarely spinel.

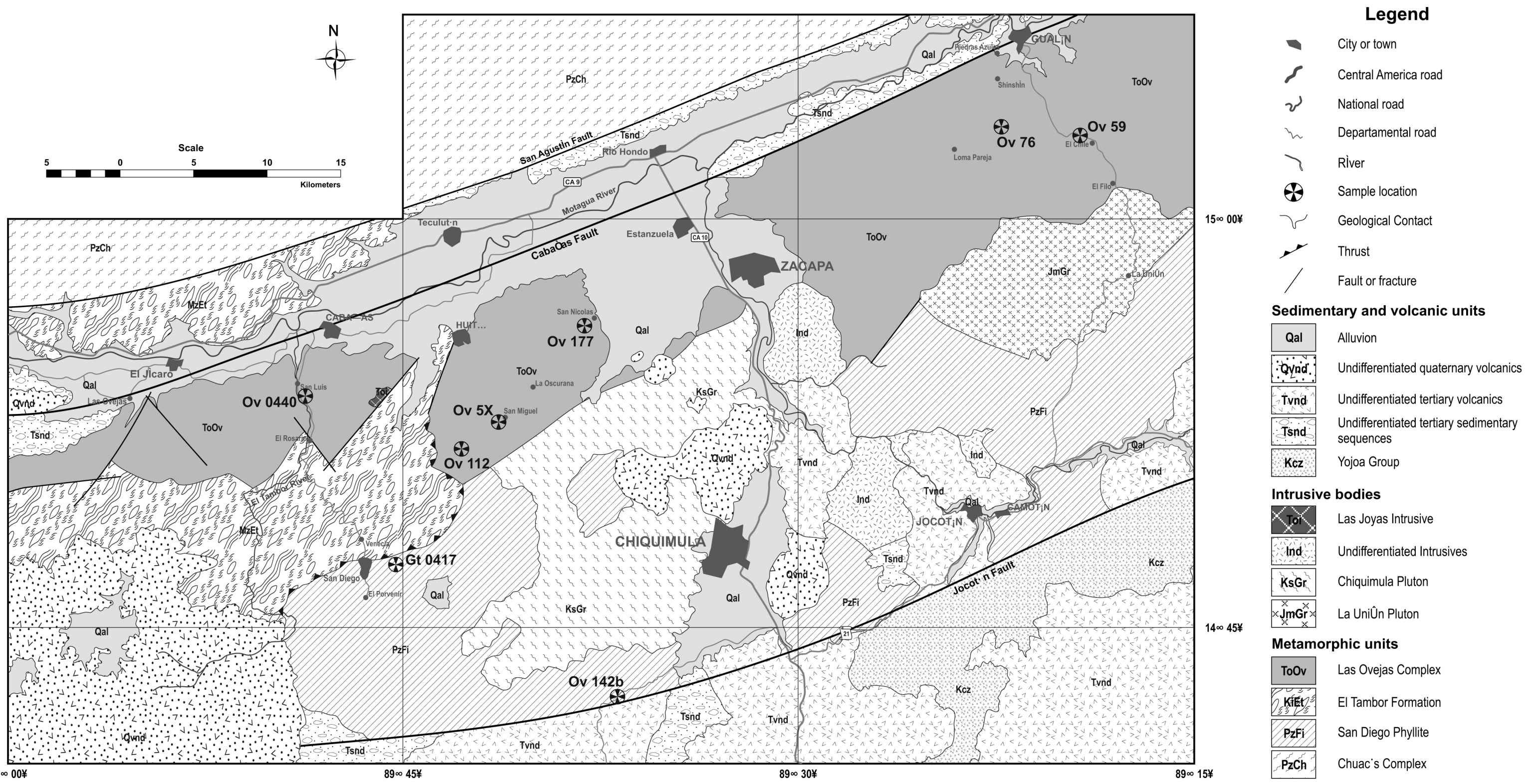

Fig. 2. Geologic map of southeastern Guatemala, Chiquimula-Zacapa region with localities mentioned in the text and dated samples locations.

Granitic Intrusions

In the LOC it is common to observe numerous granitic to granodioritic intrusions that range in size from cm-scale dikes to up-to 2 km, mappable units. The intrusives are of different ages as revealed by field crosscutting relations and distinct ductile fabrics that range from massive to deformed. These granitic rocks are important because they represent the underlying crust and because their crosscutting relationships with the country rock, as well as their degree of deformation, help to constrain the age of intrusion, deformation, and metamorphism.

Previous Geochronology

Available basement ages of the northern Chortís Block indicate igneous and metamorphic events as young as Tertiary (see reviews by Donnelly and others, 1990; Martens and others, 2007; Ratschbacher and others, 2009). Sparse K-Ar and Rb-Sr analyses have yielded late Paleozoic to Oligocene ages. Manton and Manton (1984) report Late Cretaceous U-Pb ages (*ca.* 93, 80, and 81 Ma), as well as Oligocene (*ca.* 29 Ma) in northern Honduras. Ratschbacher and others (2009) published U-Pb ages of granites and orthogneisses from the northern fringe of the Chortís Block, mostly from the LOC. Their results show that most magmatic rocks were formed in the 190 to 140 Ma range, and a second ubiquitous event formed migmatites and small intrusions at *ca.* 36 to 40 Ma. Their U-Pb crystallization and Ar-Ar cooling ages constrain the age of deformation to <39 Ma. Similar igneous events have been identified in the Xolapa Complex, Southern México, and the U-Pb dating of igneous rocks supports a correlation between this complex and the LOC (for example Herrmann and others, 1994; Solari and others, 2007; Pérez-Gutiérrez and others, 2009b; Ratschbacher and others, 2009). Xenocrystic ages reported by Ratschbacher and others (2009) further revealed zircons of Mesoproterozoic, *ca.* 400, 330, 275, and 245 Ma ages. Solari and others (2009) conducted the first detrital zircon U-Pb geochronology study of the northern Chortís Block. A quartzite from the San Diego Phyllite yielded abundant detrital zircon ages at *ca.* 980 Ma and 1130 Ma, and the youngest population yielded *ca.* 520 Ma, indicating Phanerozoic deposition (see sample Gt 0417 below).

SAMPLES

To evaluate the provenance of the rocks belonging to LOC and the neighboring San Diego Phyllite, as well as their possible terrane correlation, six metasedimentary and metaigneous samples were selected for dating by Laser Ablation–Inductively-Coupled Plasma Mass Spectrometry (LA-ICPMS) U-Pb geochronology. One additional undeformed granite (Ov 0440), whose field relationships are reported below, was also dated to constrain the metamorphic age. LA-ICPMS has been proven very useful because it is fast allowing many zircons to be dated, and is precise and accurate enough to yield meaningful results (Hoskin and Schaltegger, 2003; Ireland and Williams, 2003; Gillis and others, 2005). Sample preparation followed common techniques (for example, Solari and others, 2007), that is employing jaw crushing, grinding with a disk grinder, Wifley shaking table, Frantz magnetic separator up to 1 Amp, heavy liquids, and then careful picking under binocular microscope. Samples Ov 0440, Ov 112, Ov 177, Ov 5x, and Ov 142b were dated at Centro de Geociencias, UNAM, following the methodology reported in Solari and others (2010b) and Solari and Tanner (2011). Samples Ov 59 and Ov 76 were dated at LaserChron Laboratory, University of Arizona, Tucson (AZ), following the methodology reported by Gehrels and others (2008). The data are reported in table 1. Single analyses are contained in the annexed supplementary table A1 (http://earth.geology.yale.edu/~ajs/SupplementaryData/2012/04deLeonTableA1.xls)

Table 1

Synthesis of the U-Pb geochronological results obtained on samples belonging to the Las Ovejas Complex and San Diego Phyllite, southeast Guatemala

Sample	Lithology	Latitude N	Longitude W	Crystallization[1]	U-Pb ages Maximum deposition age[2]	Inherited ages[3]
Ov 0440	Undeformed granite dike	14° 53’ 28.9”	89° 48’ 42.0”	27.3+0.4/-0.6 Ma		1023, 1082 Ma
Ov 59	Biotite orthogneiss	15° 03' 09.7”	89° 19' 55.5"	170.2 + 1.28/-0.85 Ma		227-244, 253-286, 516, 651-738, 1033-1279, 2040 Ma
Ov 76	Biotite orthogneiss	15° 02' 12.6"	89° 23' 08.6"	170.5+0.75/-0.74 Ma		255, 455, 535, 710-850, 1060-1245, 1990-2040 Ma
Ov 112	Quartz-muscovite schist	14° 52' 13.3"	89° 42' 31.9"		< 237 Ma	179, 289, 369-400, 482, 620-939, 1161, 1715 Ma
Ov 177	Two mica-garnet staurolite schist	14° 56' 00.4"	89° 38' 16.0"		37.6+0.5-0.3 Ma	278-324, 615-633, 1106-1247, 1868 Ma
Ov 5x	Two mica-garnet staurolite schist	14° 52' 42.3"	89° 41' 21.0"		< 150 Ma	149-200, 207-249, 270-290, 302-334, 1111-1188 Ma
Ov 142b	Fine grained meta-sandstone	14° 42' 23.7"	89° 37' 16.9"		< 747 Ma	945-1300, 1471, 1779-1854, 1098 Ma
Gt 0417**	Fine grained meta-sandstone	14° 47' 13.5"	89° 45' 36.3"		< 520 Ma	520-555, 937, 963, 1038, 2295 Ma

[1] Crystallization age for igneous samples.

[2] Maximum deposition age for metasedimentary samples, as indicated by the youngest concordant cluster of overlapping zircon ages.

[3] Inherited ages in igneous samples, or detrital ages as expressed by most prominent zircon clusters in metasedimentary samples. Age errors are expressed at $\pm 2\sigma$ level.

** Sample previously reported by Solari and others, 2009.

RESULTS

Las Ovejas Complex

Ov 0440, undeformed granite dike.—This sample was taken from a dike of the Las Joyas granite, an undeformed and unmetamorphosed unit that in turn intrudes the LOC and the El Tambor Complex. These field relations imply that the age of the dike is an upper limit for the age of metamorphism. The dike is a crystalline rock with phaneritic and hipidiomorphic texture, composed of alkali feldspar, quartz, minor plagioclase, and scarce biotite. Alkali feldspar crystals are *ca.* 3 to 15 mm subhedral to anhedral grains, quartz crystals are *ca.* 2 to 10 mm anhedral to irregular grains, plagioclase occurs as subhedral *ca.* 2 to 5 mm crystals, and biotite occurs as reddish-brown flakes <1 mm in size.

Zircons separated from this sample are euhedral and prismatic to stubby. Cathodoluminescence imaging (CL) reveals the presence of inherited cores, with well-developed, oscillatory-zoned overgrowths (fig. 3A). We performed 31 analyses, 11 of which were discarded due to large discordance. Eighteen analyses yielded Oligocene ages. Of these, the algorithm by Ludwig and Mundil (2002) identified a coherent group of 12 analyses with mean $^{206}Pb/^{238}U$ age of 27.3 + 0.4/−0.6 Ma (fig. 4A). Two core analyses yielded Grenvillian, 1023 ± 25 and 1082 ± 36 Ma $^{207}Pb/^{206}Pb$ ages. Based on the high Th/U ratios and the oscillatory zoning of the dated overgrowths (for example, Hoskin and Schaltegger, 2003) we interpret the median age as the time of igneous crystallization of the dike intruding the undeformed granite.

Ov 59, fine-grained biotite orthogneiss.—The sample is a fine-grained gneiss (<2 mm in grain size) that crops out along the road from Gualán to La Unión (fig. 2). It is composed of biotite, feldspar, quartz, and minor muscovite. The fabric of the rock is defined by mm-scale compositional banding, schistosity, and mineral lineation mainly represented by biotite flakes. We envisage that such a unit could represent a metamorphosed pyroclastic deposit.

Zircons separated from this sample have heterogeneous characteristics. Their size ranges from 100 to 250 μm, their color ranges from colorless to pale yellow or dark pink-red, and their morphology varies from euhedral, mainly elongated bypyramidal, to subhedral, ovoid-shaped to round, or multifaceted. Due to the wide variety of zircons, we decided to analyze 110 crystals. One analysis was discarded because it was >30 percent discordant. The high Th/U ratios of the remainder analyses and the oscillatory-zoned CL texture suggest that most zircons of this sample are igneous in origin (fig. 3B). The most conspicuous age group is Jurassic, which yields a mean $^{206}Pb/^{238}U$ age of 170.2 + 1.3/−0.8 Ma out of 56 coherent analyses (in the terms of the Ludwig and Mundil, 2002, algorithm), interpreted as indicative of the crystallization age of the igneous protolith. Other inherited components are also present (table 1) including Triassic (227-244 Ma), Permian (253-286 Ma), Cambrian (516 Ma), Neoproterozoic (651-738 Ma), Grenvillian (1033-1279 Ma), and a few Paleoproterozoic ages (2040 Ma) (fig. 4B).

Ov 76, medium-grained biotite orthogneiss.—Sample Ov 76 was taken southwest of Gualán (fig. 2). It is a medium- to coarse-grained gneiss composed of biotite, feldspar, and quartz. This rock is penetratively foliated and lineated but the compositional banding is poorly defined due to the predominantly micaceous character of the rock and the presence of abundant ~2 to 15 mm porphyroclasts of feldspar and quartz. In general, this rock can be interpreted as a metamorphosed quartz diorite.

There is great variability in the zircons separated from sample Ov 76. Some are short, others are prismatic to elongated with well-developed crystal faces. Rounded grains are rare. The zircons range in size from 100 to 350 μm. As with other samples, the zircons exhibit a wide range of colors. Cathodoluminescence (CL) textures showed abundant grains with oscillatory zoning and few crystals with cores surrounded by

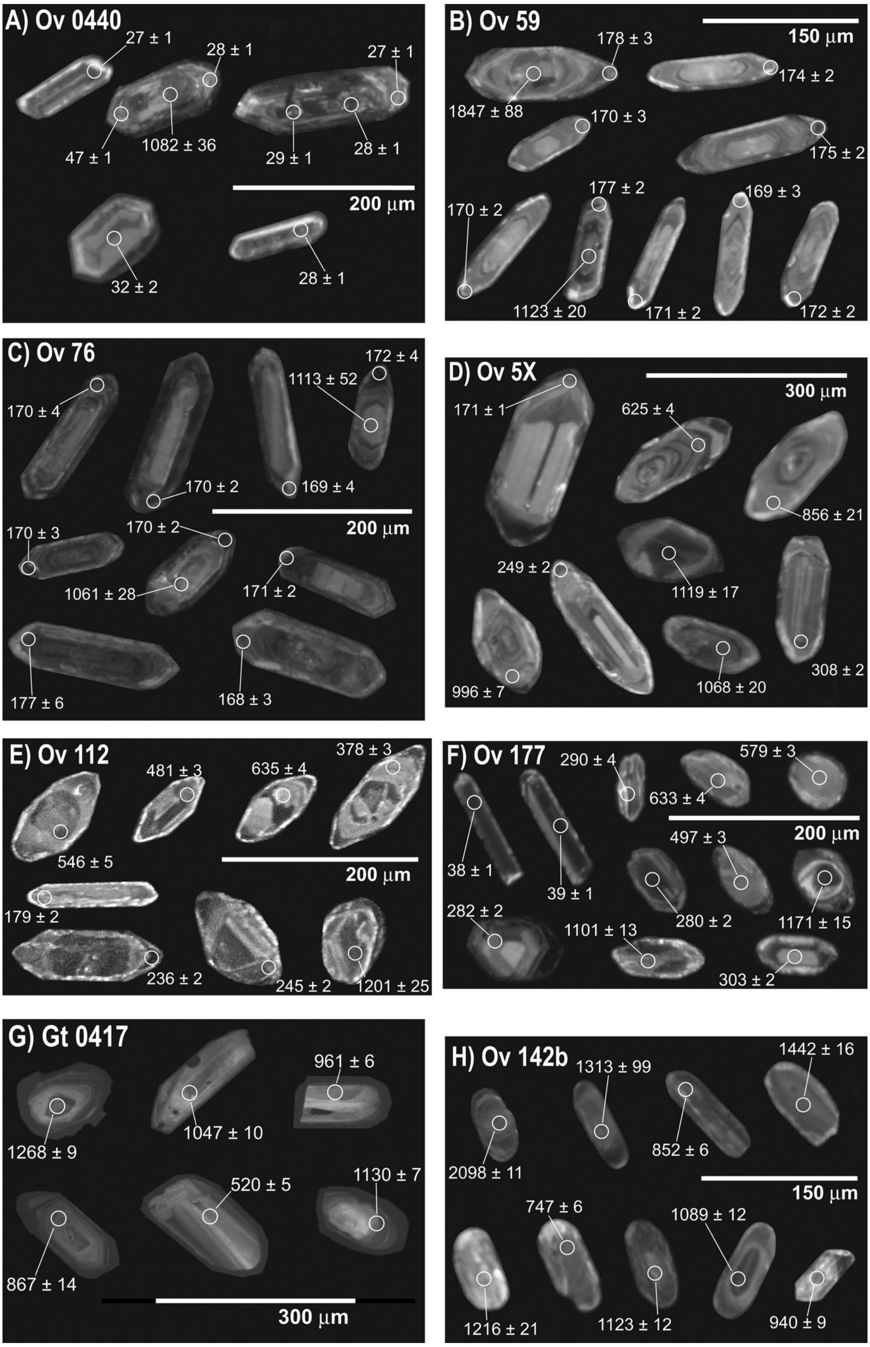

Fig. 3. Cathodoluminescence images from Las Ovejas Complex and San Diego Phyllite samples illustrative of the internal textures observed in the studied zircon populations. White bars are indicative of the zircon sizes and white circles mark approximate location of analyzed spots. Numbers refer to best age.

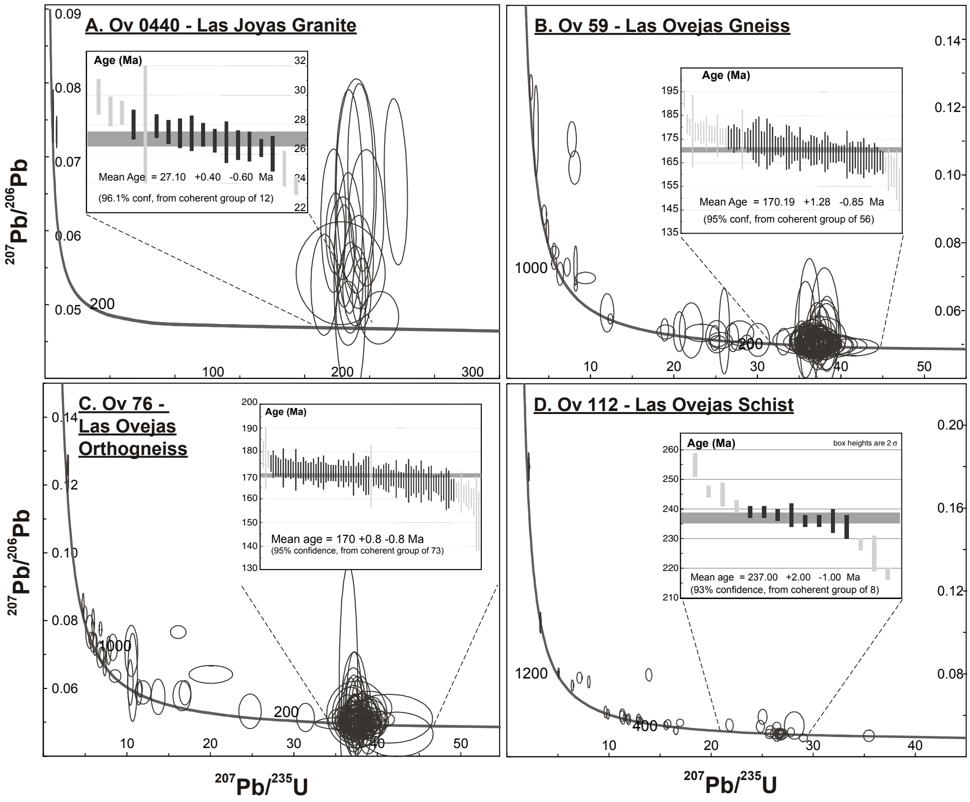

Fig. 4. U-Pb concordia diagrams for the dated samples. (A-F) are Tera-Wasserburg diagrams including all acceptable analyses. Data is corrected for common Pb using the method outlined by Andersen (2002). Insets in (A), (B), (C), and (D) are mean $^{206}Pb/^{238}U$ ages calculated using the TuffZirc algorithm of Ludwig and Mundil (2002).

oscillatory overgrowths (fig. 3C). A total of 115 spots were dated, including both cores and rims. The overgrowths and some of the cores yielded Jurassic ages defining the dominant age group of the sample. A coherent group of 73 analyses yields a mean $^{206}Pb/^{238}U$ age of 170.15 + 0.75/−0.74 Ma (fig. 4C). This age is also interpreted as indicative of the igneous crystallization of the protolith. The remainder cores correspond to inherited zircons that yielded Permian (*ca.* 255 Ma), Ordovician (*ca.* 455 Ma), Cambrian (*ca.* 535 Ma), Neoproterozoic (710-850 Ma), Grenvillian (1060-1245 Ma) and Paleoproterozoic (1990-2040 Ma) ages.

Ov 112, quartz-muscovite schist.—This sample was collected south of Huité (fig. 2). It is a fine-grained, green-gray schist composed of white mica and quartz with finely-spaced foliation and mineral lineation. The white mica defines the foliation by smooth, continuous, and subparallel schistose domains up to 1 mm thick. The sample contains minor staurolite as small subidioblastic grains (<0.25 mm) randomly distributed throughout the rock.

The sample yielded few zircons, hence only 40 analyses were performed. Most zircons are stubby, elongated, or ovoid-shaped; few are long prismatic with or without pyramidal terminations. Under CL, most zircons show cores characterized by oscillatory zoning bordered by thin rims (fig. 3D). The analyses yielded detrital ages ranging from Jurassic to Neoarchean time. The youngest zircon has a concordant age of 179

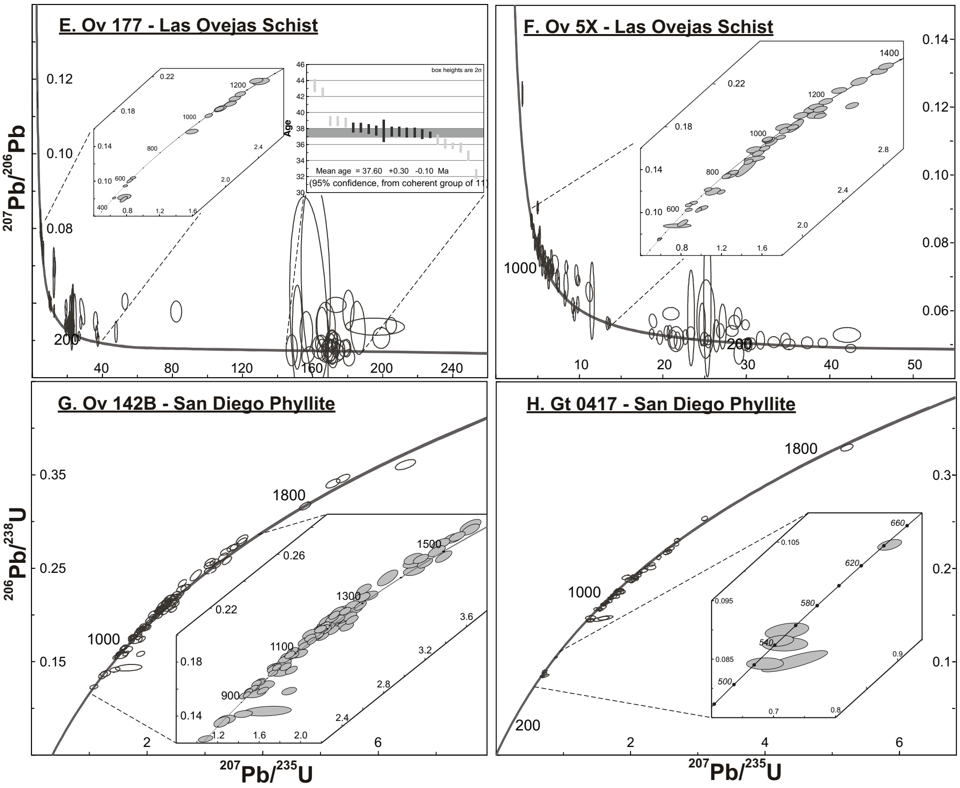

Fig. 4 (continued). Insets in (E-H) are detail Wetherill concordias. Error ellipses in concordia diagrams and box height in mean calculations are 2σ.

Ma, and the youngest population is defined by eight nearly-identical analyses that yielded a robust $^{206}Pb/^{238}U$ mean age of 237 + 2/−1 Ma (fig. 4D), indicative of a maximum age of sedimentation possibly slightly older than the crystallization ages obtained on samples OV 59 and OV 76. Other less prominent age groups are Permian (289 Ma), Devonian (369-400 Ma), Ordovician (482 Ma), and Neoproterozoic (620-939 Ma). The two oldest zircons yielded $^{207}Pb/^{206}Pb$ ages of 1708 ± 35 and 2652 ± 24 Ma.

Ov 177, two-mica garnet staurolite schist.—This sample is a medium- to coarse-grained schist sampled in San Nicolás river near San Nicolás town (fig. 2). This rock is made up of muscovite, biotite, quartz, feldspar, garnet, staurolite and minor opaques. The rock exhibits a poor foliation. Garnet crystals are idioblastic and vary in size from <1 to 10 mm. Staurolite crystals are subidioblastic grains with size from <1 to 3 mm.

Zircons from this sample show disparate shapes from short stubby grains to elongated prisms with pyramidal terminations. Fragments of larger grains are also abundant. Under CL most zircons show either sector or oscillatory zoning (fig. 3E). A few crystals show low luminescence and lack zoning. A total of 90 analyses were performed; of these, eight were rejected due to >30 percent discordance or large $^{207}Pb/^{206}Pb$ error. The remainder of the analyses yielded a cluster of Late Eocene zircons with a mean $^{206}Pb/^{238}U$ age of 37.6 + 0.5/−0.3 Ma (fig. 4E). Inherited ages are also abundant, ranging from the late Paleozoic (278-324 Ma), Neoproterozoic (615-633 Ma), Grenvillian (1106-1247 Ma), up to one zircon that yielded a Paleoproterozoic (1868 Ma) age. Few of the analyzed zircons yielded slightly younger ages between 32 and 36 Ma (fig.

4E, inset) but they are variably discordant, as possible consequence of Pb loss, and thus are not considered in the above mean age.

Ov 5x, two-mica garnet staurolite schist.—Sample Ov 5x is a fine- to medium-grained schist sampled south of Huité (fig. 2). It contains muscovite, quartz, feldspar, biotite, garnet and staurolite as principal minerals. The rock is penetratively foliated and it shows incipient lineation. The foliation is spaced and consists of micaceous domains interlayered with quartzo-feldspathic domains. The garnet crystals are idioblastic up to 1 mm. The staurolite is scarce and occurs in subidioblastic <1 mm crystals.

Most zircons from this sample are pale orange or pink, elongated or short prismatic, and many have abraded, pyramidal terminations. CL imaging shows oscillatory zoning, interpreted to reflect igneous crystallization, in both cores and overgrowths (fig. 3F). The igneous origin of the zircons is also suggested by >0.01 Th/U ratios (table 1). Eighty-five zircons from this sample were analyzed. Four analyses were rejected due to large discordance. The remainder analyses define an inherited age pattern with ages ranging from 149 Ma, the youngest concordant zircon, to 2012 ± 19 Ma, which is the ^{207}Pb/^{206}Pb age of the oldest grain (fig. 4F). Many of the analyzed zircons are concordant within analytical error defining a probability density plot including several age groups: Jurassic (149-200 Ma, with 200 Ma being the largest peak), Triassic (207-249 Ma), Permian (270-290 Ma), Carboniferous (302-334 Ma), few grains with early Paleozoic, Neoproterozoic, and Grenvillian (1111-1188 Ma) ages.

San Diego Phyllite

Ov 142b, fine-grained meta-sandstone.—This sample was collected from a 30 cm-thick layer of meta-sandstone within the San Diego phyllite. The rock shows relic sedimentary texture. The main constituents are quartz, subangular to rounded lithic fragments, and minor white mica flakes. The abundant zircons in the sample are characterized by pink, violet or honey color. Their size ranges from 80 to 380 μm and their shape is dominantly ovoidal to spheroidal, with well-abraded terminations, often a distinctive sign of sedimentary transport. Under CL, the zircons are poorly luminescent and some have partially resorbed cores with dark rims showing faint oscillatory zoning (fig. 3G). The zoning, together with the elevated Th/U ratio >0.07 (table 1) suggest an igneous, primary origin. Ninety-five analyses were performed by selecting a variety of grains with different size, color, and morphology. Fourteen analyses, although precise, were discarded because they were >5 percent reversely discordant.

The remainder of the analyses straddle the concordia between 747 Ma, age of the youngest concordant crystal, and 2098 ± 14 Ma, the ^{207}Pb/^{206}Pb age of the oldest discordant crystal (fig. 4G). The analyses in between these end members are concordant to slightly discordant, and they define a probability density curve with main peaks of Neoproterozoic (827 Ma), Grenvillian (945-1300 Ma), and minor peaks in the Early Mesoproterozoic (1471 Ma), and Paleoproterozoic (1779-1854 Ma).

Gt 0417, fine-grained meta-sandstone.—The detrital geochronology of this sample of the San Diego phyllite was previously published in Solari and others (2009; dates by LA-ICPMS at ANU, Australia). It was collected in the area covered by this study and we include it here for comparison. Similar to sample Ov 142B, sample GT 0417 is a fine meta-sandstone composed of weathered biotite, minor chlorite, quartz, sericitized plagioclase, opaque minerals, and pyrite.

Zircon CL imaging and Th/U >0.04 suggest that most of the analyzed detrital zircons were derived from igneous rocks (fig. 3H). The youngest zircon population is Cambrian (~520-555 Ma, fig. 4H), implying Phanerozoic deposition. Most zircons yielded Precambrian, 890 to 1400 Ma ages, with main peaks at 937, 963, 1038, and 2295 Ma (fig. 4H).

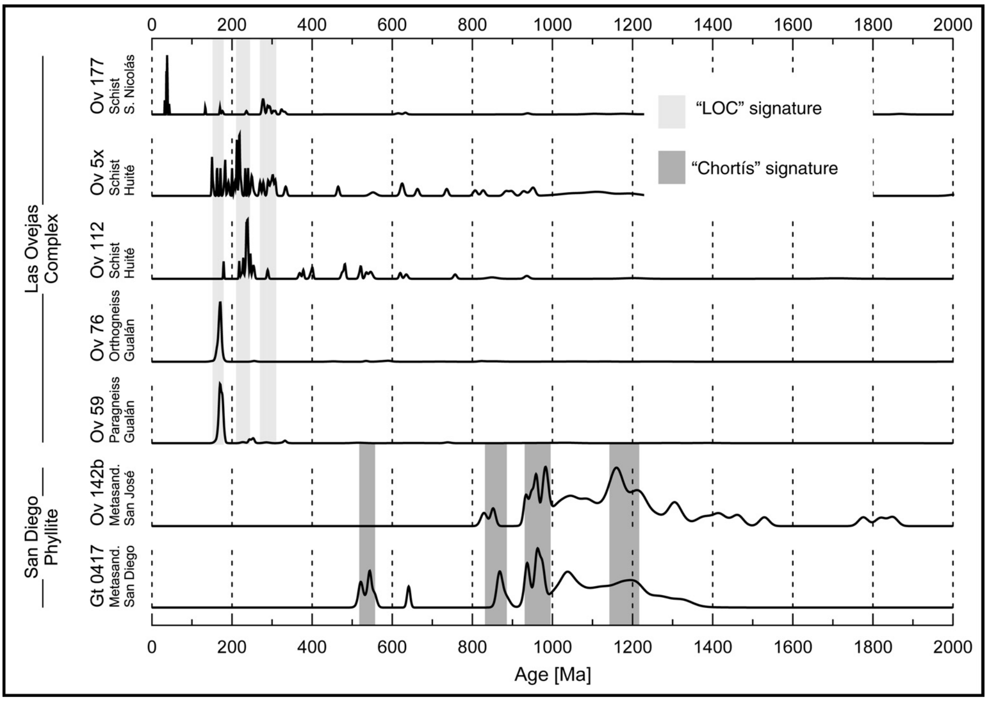

Fig. 5. Probability distribution diagrams for the selected samples of LOC. Light gray shaded areas indicate the main age distribution overlap observed in detrital zircons belonging to LOC (Middle-Upper Jurassic, Middle-Upper Triassic and Permo-Carboniferous); dark gray shaded areas indicate age overlaps observed only in samples belonging to the San Diego Phyllite (*ca.* 830-870 and *ca.* 1150-1220 Ma); medium gray shaded areas show a partial provenance overlap between samples of LOC and San Diego Phyllite.

DISCUSSION

Constraints on Ages of Units and Metamorphism in the Northern Chortís Block

Our new U/Pb zircon geochronology constrains the timing of deformation and protolith formation of the various components of the LOC; the results are consistent with the previous study of Ratschbacher and others (2009). Deformation and amphibolite-facies metamorphism occurred prior to the 27.3 + 0.60/−0.80 Ma crystallization of undeformed granites (that is, Ov 0440). The youngest detrital zircon population of schist Ov 177 (fig. 4E, inset) has a mean ^{206}Pb/^{238}U age of 37.6 + 0.5/−0.3 Ma (n = 11), indicating that LOC metasediments were deposited, buried, metamorphosed and intruded in a relatively short time span between 37 to 27 Ma. Further studies are needed to better constrain the time and P-T conditions of this metamorphic event, as well as to better constrain its relationships with southern México.

A distinctive feature of the LOC is the ubiquity of Permo-Triassic and Jurassic zircons (fig. 5). Abundant igneous zircons of Jurassic age (*ca.* 170 Ma) are found in samples Ov 59 and Ov 76. Similarly aged detrital zircons were also found in metasedimentary samples (for example, samples Ov 112 and Ov 5x). Samples dated by Ratschbacher and others (2009) also yielded this characteristic age. It is therefore safe to argue that a significant portion of the LOC includes, or belongs to, a Jurassic magmatic suite. The Jurassic component was also an important detrital source for LOC younger sedimentary rocks, implying post–mid-late Jurassic deposition of those protoliths, which were then amalgamated together during the Eocene-Oligocene metamorphism.

Permian to Late Triassic zircon populations are also characteristic of LOC metasediments (for example, samples Ov 112 and Ov 5x; fig. 5). Zircon Th/U ratio and CL texture are consistent with igneous origin; we conclude that a Permo-Triassic source within or near the LOC shed abundant zircons into the depositional area of the LOC after the Jurassic. In contrast, early Paleozoic or older zircon populations are minor, but present, in the studied LOC samples. For instance, sample Ov 112 contains a few Early Ordovician to Cambrian zircons and Ov 5x contains a few Neoproterozoic zircons. The studied LOC samples are not devoid of Precambrian igneous zircons, however samples of that age are yet to be discovered or described in this locality. Because of the abundance of Precambrian rocks in the potential correlative areas in southern México (for example, Acatlán and Oaxacan Complex, Maya block, see below), it is clear that the Precambrian zircons found in younger, Mesozoic sediments of LOC possibly belong to those localities.

The dated LOC samples bear many geochronologic similarities with each other as reflected in the coincidence of peaks in the probability density plots (fig. 5; notice overlap of Middle-Upper Jurassic, Middle-Upper Triassic and Permo-Carboniferous peaks, light-shaded areas). The overlap suggests that both metasedimentary and metaigneous samples belong to a single geologic coherent unit, giving more strength to the suggestion of Ortega-Gutiérrez and others (2007) that LOC was a tectonic block, possibly allochthonous to the Chortís Block. This conclusion is not trivial, as the samples were obtained near the Motagua Fault zone where a variety of individual geologic blocks with disparate geologic histories has been recognized (see for instance Ortega-Gutiérrez and others, 2007; Ratschbacher and others, 2009).

There is also great resemblance between the age probability density plots of the two San Diego Phyllite samples (Ov 142b and Gt 0417; fig. 5). The similarities are characterized by Cambrian and older populations, mostly in the 800 to 1400 Ma range. However, there is little overlap in age groups between the LOC and the San Diego phyllite samples, and no coincidence between major populations. For instance, none of the Mesozoic-Tertiary zircon populations characteristic of the LOC are present in the San Diego Phyllite, whereas the LOC contains few of the Grenvillian zircons ubiquitous in the San Diego.

Thus we conclude that LOC and San Diego Phyllite sedimentary protoliths were deposited at very different times, the San Diego sediments being much older, and possibly in different places, as suggested by the different detrital zircon patterns (fig. 5). This is one among many geologic features that suggests that indeed the LOC and San Diego Phyllite are distinct lithotectonic units that were tectonically juxtaposed, perhaps during or after Eocene-Oligocene metamorphism of the Las Ovejas Complex.

Detrital Zircons Correlations with Southern México

The data presented here allow evaluation of correlations between the Chortís Block and those terranes of southern México for which detrital zircon geochronology is available. Recently, several papers have suggested correlation between blocks based on geological data and piercing points. Cerca and others (2007) proposed a model for the Late Cretaceous in which they matched the shortening of the Guerrero-Morelos platform in southern México (GMP in fig. 6A) (Albian-Cenomanian) with that of the Agua Blanca basin in central Honduras, and subsequent transpression and displacement of the Chortís Block toward SE by the Paleogene. Rogers and others (2007b) proposed a correlation between the Chortís Block and southern México based on common geological features such as the presence of Precambrian basement, similar Mesozoic cover, mid-Cretaceous arc geochemistry, and the same alignment of Late Cretaceous structural trends reported by Cerca and others (2007) as well as alignment of a conspicuous magnetic boundary separating Mesozoic from pre-Mesozoic crustal domains in both blocks. Both models imply a Late Cretaceous fit of the Chortís Block, directly west of southern México, with the westernmost tip between Acapulco and Zihuatanejo (figs. 1 and 6A). Thus, in the Cerca-Rogers model the LOC, presently located in southeastern Guatemala, would lie right in front of Zihuatanejo (Guerrero terrane, fig. 6A) during the Late Cretaceous.

For comparison, we present in figure 6 a compilation of U-Pb zircon detrital ages comprising samples from: (1) the Maya Block in Chiapas (Weber and others, 2008, and references therein; Weber and others, 2009), labeled as My in figure 6B; (2) the Grenvillian Oaxacan Complex (for example Ducea and others, 2004a) and its Paleozoic to Mesozoic sedimentary cover (Gillis and others, 2005), labeled as O in figure 6A; (3) the Paleozoic Acatlán Complex (for example Ortega-Obregón and others, 2009), labeled as M in figure 6A; (4) Mesozoic samples belonging to the Cuicateco terrane (C in fig. 6A) (Pérez-Gutiérrez and others, 2009a; Mendoza-Rosales and others, 2010); (5) the Xolapa Complex (Ducea and others, 2004a; Pérez-Gutiérrez and others, 2009b) (X in fig. 6A); and (6) the Guerrero terrane (Talavera-Mendoza and others, 2007; Martini and others, 2009; Venegas-Rodríguez and others, 2009) (G in fig. 6A).

Detrital zircons from the Maya Block (Jocote, Sepultura, and CMC units; Weber and others, 2008 and 2009) are characterized by Devonian (412-429 Ma), Pan-African (544-844 Ma), Grenvillian (*ca.* 980-1200 Ma), and 1400 to 1600 Ma ages (fig. 6B). Similar populations were obtained by Martens and others (2010) in samples from the Maya Mountains of Belize (probability density plot #22 of fig. 6B). Detrital zircons in the southern Oaxacan Complex were measured along a transect by Ducea and others (2004a), with three samples showing concordant to nearly concordant zircons spanning between ~1.0 to ~1.3 Ga. The Oaxacan Complex sedimentary cover was studied NW of Oaxaca city, in the Santiago Ixtaltepec and Tiñu sectors by Gillis and others (2005). The zircon samples they dated (fig. 6B) show ages of 1007, 1222 Ma (Tiñu Fm.), 472 and 998 Ma (Santiago Fm.), and 360, 977, 1041 and 1188 Ma (Ixtaltepec Fm.), indicating, in part, locally derived material from the underlying 1.0 to 1.3 Ga Oaxacan Complex (Keppie and others, 2003; Solari and others, 2003) and unknown Devonian-Ordovician sources, possibly in the near Acatlán Complex (for example Talavera-Mendoza and others, 2005; Miller and others, 2007; Ortega-Obregón and others, 2009). Several U-Pb zircon dates have been reported from the southwestern Acatlán Complex, in the neighboring localities of Olinalá to Ixcamilpa (figs. 6A and 6B) have primary populations with early Permian to latest Carboniferous, Ordovician, Pan-African–Neoproterozoic, Grenvillian (988-1200 Ma), and few Meso- to Paleoproterozoic zircons (Ortega-Obregón and others, 2009). East of the Oaxacan Complex, the southern Cuicateco terrane metasedimentary sequences (C in figs. 1 and 6A) are indicative of a latest Cretaceous or post–Late Cretaceous deposition (youngest detrital zircon population at 78 Ma, #14 in fig. 6B), and most important zircon peaks at 113, 262, 542, 630 and 1198 Ma (Pérez-Gutiérrez and others, 2009a). The same authors report in the southern Maya block detrital zircons belonging to the Jurassic Todos Santos Formation, with primary populations yielding Triassic, Permian, Pan-African, and Grenvillian ages (probability density plot #12 in fig. 6B). In the northern Cuicateco terrane, recent data of Mendoza-Rosales and others (2010) show similar patterns, with the most prominent peak at 126 Ma, followed by Permian, Ordovician, and similar Grenvillian distribution with peaks at 1022 and 1187 Ma (#13 in fig. 6). Detrital zircon ages from the Xolapa Complex are scarce. The only available data indicate a widespread Jurassic magmatic event, as well as important magmatism occurring at 129 to 134 Ma and bracketing deformation and migmatization (Ducea and others, 2004a; Solari and others, 2007; Pérez-Gutiérrez and others, 2009b). Northeast of Acapulco the Papalutla Fault probably marks the limit between the Acatlán and the Guerrero composite terrane. In the southwestern Guerrero terrane, where several detrital zircon data were recently published, different arcs were recog-

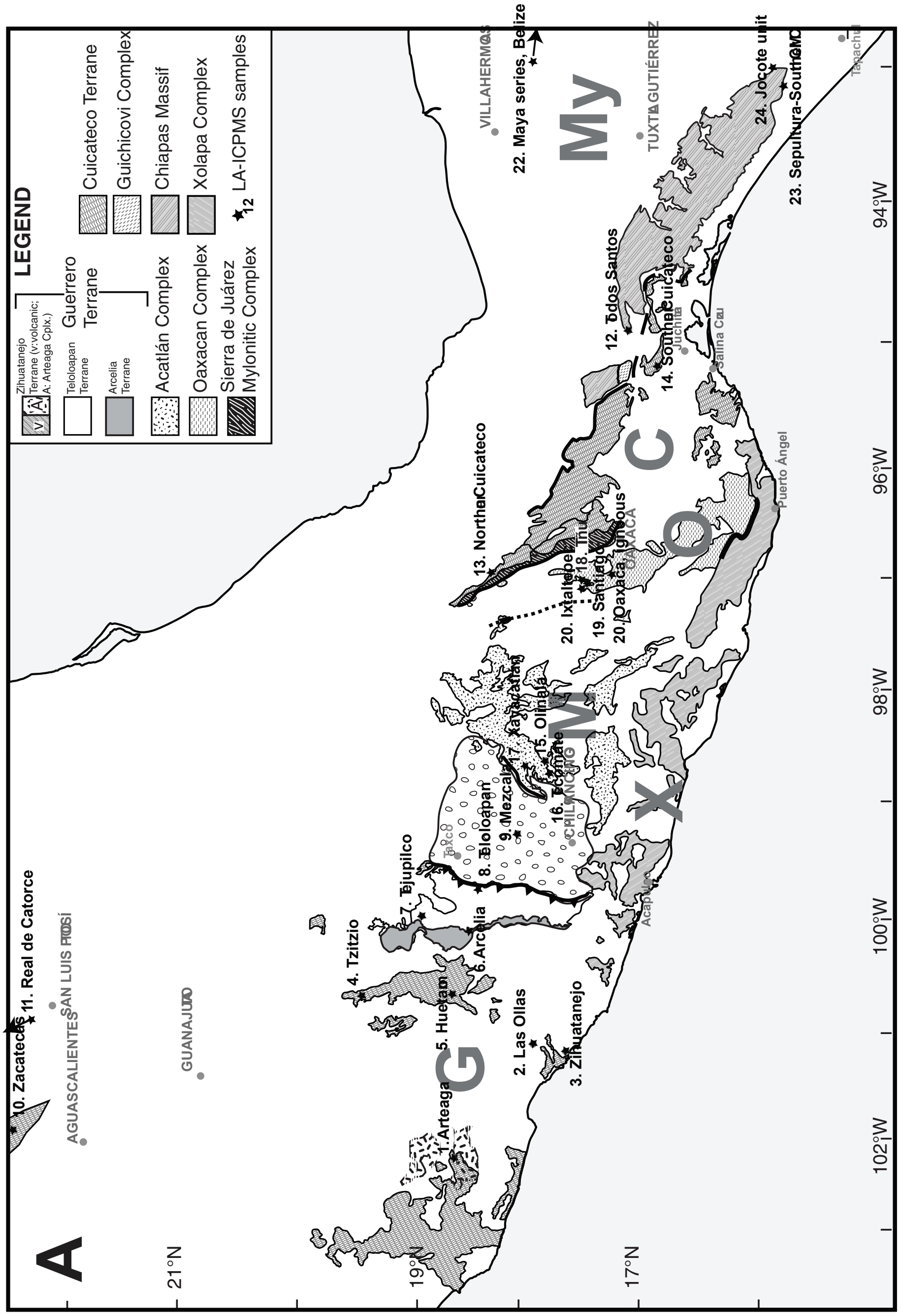
A
LEGEND
Zihuatanejo Terrane (v: volcanic; A: Arteaga Cplx.)
Teloloapan Terrane
Arcelia Terrane
Guerrero Terrane
Acatlán Complex
Oaxacan Complex
Sierra de Juárez Mylonitic Complex
Cuicateco Terrane
Guichicovi Complex
Chiapas Massif
Xolapa Complex
LA-ICPMS samples
12
1. Arteaga
2. Las Ollas
3. Zihuatanejo
4. Tzitzio
5. Huetam
6. Arcelia
7. Tejupilco
8. Teloloapan
9. Mezcala
10. Zacatecas
11. Real de Catorce
12. Todos Santos
13. Northern Cuicateco
14. Southern Cuicateco
15. Olinalá
16. Tecomate
17. Xayacatlán
18. Tnu
19. Santiago
20. Ixtaltepec
20. Oaxaca, Igneous
22. Maya series, Belize
23. Sepultura-Southern CMC
24. Jocote unit
G
M
X
O
C
My
AGUASCALIENTES
SAN LUIS POTOSÍ
GUANAJUATO
Taxco
CHILPANCINGO
OAXACA
Acapulco
Puerto Ángel
Juchitán
Salina Cruz
VILLAHERMOSA
TUXTLA GUTIÉRREZ
Tapachula
21°N
19°N
17°N
102°W
100°W
98°W
96°W
94°W

Fig. 6.

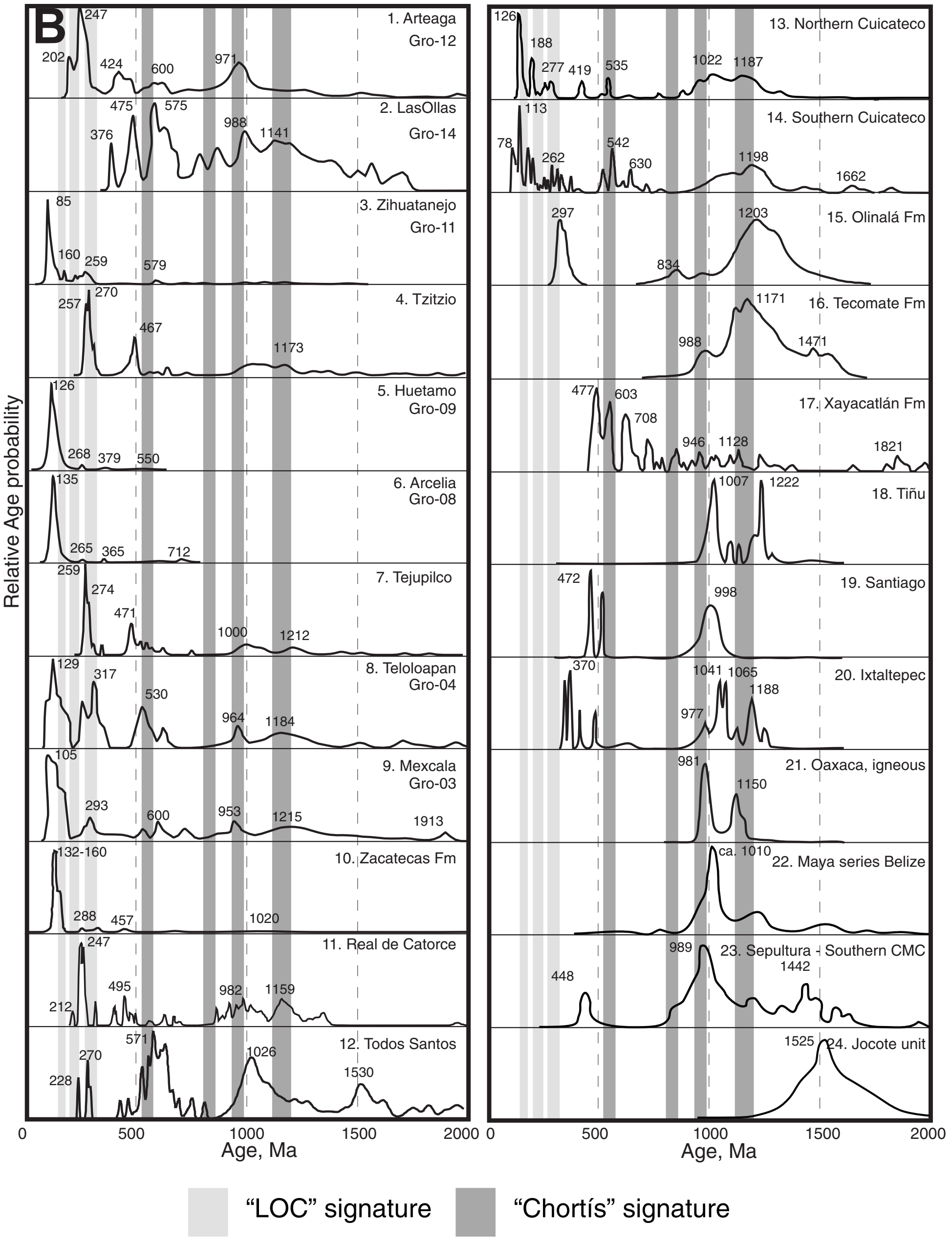

Fig. 6. (continued) (A) Sample location of detrital zircon data of western, southern and southeastern México samples. Sources: Arteaga, Las Ollas, Zihuatanejo, Huetamo, Arcelia, Teloloapan, and Mexcala detrital distribution diagrams are from Talavera-Mendoza and others (2007); Tzitzio and Tejupilco are from Martini and others (2009); Zacatecas Fm. is from Escalona-Alcazar and others (2009); Real de Catorce is from Venegas-Rodríguez and others (2009); Todos Santos Fm. and Southern Cuicateco are from Pérez-Gutiérrez and others (2009a); Northern Cuicateco is from Mendoza-Rosales and others (2010); Olinalá Fm., Tecomate Fm., and Xayacatlán Fm. are from Talavera-Mendoza and others (2005) and Ortega-Obregón and others (2009); Tiñu, Santiago and Ixtaltepec Fms. are from Gillis and others (2005); the Oaxaca igneous distribution is from Keppie and others (2003); the Maya series of Belize is from Martens and others(2010); the Sepultura–southern CMC and Jocote units are from Weber and others (2008). Light gray, bold letters indicate the terrane subdivision as in figure 1B. Name and starred numbers indicate the samples correspondence as in B. (B) Comparison of zircon data of figure 6A, with main age distribution overlaps found in the LOC and San Diego Phyllite. Shaded areas as in figure 5.

nized (Elías-Herrera and others, 2000; Talavera-Mendoza and others, 2007; Centeno-García and others, 2008). From west to east, samples reveal the existence of detrital ages ranging from the Triassic, Paleozoic, Pan-African and Grenvillian (Arteaga Complex, Talavera-Mendoza and others, 2007), to Paleozoic, Pan-African and Grenvillian (Las Ollas Complex, Talavera-Mendoza and others, 2007), to Late Cretaceous and late Permian (Zihuatanejo, Talavera-Mendoza and others, 2007) (figs. 6A and 6B). In the areas of Huetamo and Arcelia, detrital ages are mainly Early Cretaceous (126-135 Ma, Talavera-Mendoza and others, 2007), whereas they range from Permian (257-270 Ma), to Ordovician (467 Ma) and Grenvillian (1000-1173 Ma) in the Tzitzio area (Martini and others, 2009). The same, almost identical pattern is recognized in Tejupilco, with age distributions of 259 to 274 Ma, 471 Ma, and 1000 to 1212 Ma (#7 in fig. 6B). These similarities led Martini and others (2009) to propose that the Teloloapan-Tejupilco and Tzitzio-Zihuatanejo areas are in fact the same terrane. In the Teloloapan area, another sample was previously studied by Talavera-Mendoza and others (2007), who reported the main zircon distributions at 129, 317, 530, 964, and 1184 Ma, similarly to which they reported for Arcelia and Huetamo localities, as well as for the overlapping Mexcala Formation (105, 293, 600, 963, and 1215 Ma) (fig. 6). Farther north, the Zacatecas Fm. has a poor zircon distribution of Early Cretaceous to Jurassic ages (132-160 Ma), followed by 288, 457, and 1020 Ma (Escalona-Alcázar and others, 2009) (fig. 6), resembling data reported for the Tejupilco and Tzitzio units. Venegas-Rodríguez and others (2009) reported similar results in the Sierra de Catorce, with the presence of Triassic (212-247 Ma), Late Cambrian (495), and Grenvillian (982-1159 Ma) detrital zircons (fig. 6B).

We compare the above data from adjacent terranes in southwestern and central México with the main detrital age distribution patterns observed in the LOC and adjacent San Diego Phyllite, which are represented as vertical, shaded bands (fig. 6B). Some probability plots such as the Teloloapan, Mexcala and Cuicateco terrane samples fit the Early Cambrian, Panafrican and Grenville density distribution of the San Diego Phyllite samples. Other southern México samples have similar distributions only for Grenville time: for instance, the northern Cuicateco, the Oaxaca igneous samples, and the Sepultura Formation and southern CMC (Weber and others, 2008). The probability distribution of ages for the LOC samples bear some similarities with samples belonging to the Guerrero terrane, mainly from the Arteaga Complex and Zihuatanejo (Talavera-Mendoza and others, 2007), because the other localities are poor in Jurassic zircons and practically devoid of Triassic ones. LOC zircons bear the most similar detrital distributions to those samples belonging to the southern and northern sectors of the Cuicateco terrane, which present a wide array of Jurassic, scarce Triassic, and Permo-Carboniferous detrital zircons.

TECTONIC MODEL

Current paleogeographic models (for example Cerca and others, 2007; Rogers and others, 2007a; Silva-Romo, 2008; Pindell and Kennan, 2009, and references therein) link the Chortís Block to southwestern México. For instance, the Cerca and others (2007) and Rogers and others (2007a) models restore the northern Chortís Block such that the LOC and the Zihuatanejo-Arteaga complexes of the Guerrero terrane are adjacent in the Late Jurassic–Early Cretaceous implying subsequent left lateral offsets of at least 1,200 km consistent with the estimated 1,100 km displacement on transform sea floor faults along the Cayman Trough (Wadge and Burke, 1983; Rosencrantz and Sclater, 1986). The clockwise apparent rotation of the kinematic axes of the Farallon plate from the Late Cretaceous to Paleogene (for example, Engebretson and others, 1985) is also consistent with this model. When detrital zircon populations are considered, two areas in southern México seem potential correlatives of the LOC: (1) the Zihuatanejo subterrane of the Guerrero composite terrane, and in particular its basement, which is represented by the Arteaga Complex of Triassic–earliest Jurassic age (for example Talavera-Mendoza and others, 2007; Centeno-García and others, 2008); and (2) the Cuicateco terrane (Pérez-Gutiérrez and others, 2009a; Mendoza-Rosales and others, 2010). Our geochronologic data indicates similarities between LOC to the Cuicateco terrane, sharing Jurassic, minor Triassic and Permo-Carboniferous zircon populations, preferred against the Zihuatanejo-Arteaga interpretation. Thus, for the Late Cretaceous, we propose that the LOC was located southwest of the Cuicateco terrane (fig. 7A). Only further dating will allow to better define which of the two potential Jurassic positions of the northern Chortís (the San Diego Phyllite) is more plausible.

The lack of Cretaceous zircons in the LOC, which are present in both the Zihuatanejo and Cuicateco terranes, suggests that the LOC did not receive input either by Cretaceous magmatism, or erosion of Cretaceous igneous rocks as those aforementioned crustal blocks. In this view, we propose to consider the LOC as a portion of a fringing Jurassic arc covered by Paleogene sedimentary units located in front of southwestern México, and removed during the early Tertiary by the docking of the northern Chortís Block represented by the San Diego Phyllite, and tentatively by similar units recognized in the central portion of the Chortís Block (Cacaguapa, Palacaguina, *et cetera,* see references above) in Honduras and Nicaragua (fig. 7B). Removal of the LOC from southern México would have occurred in a similar fashion as those units currently cropping out south of the Motagua Fault in Guatemala (southern Motagua mélanges, Harlow and others, 2004), but removed and docked by mid-Tertiary transpression (Pindell and others, 2012), together with those allochthonous blocks previously recognized, such as the El Tambor (for instance, McBirney, 1963) and the Late Jurassic Sanarate Complex (Ratschbacher and others, 2009). We envisage that metamorphism and deformation in LOC units could be a resulting consequence of that removal, sinistral stretching and tectonic transport. Such late Eocene–earliest Oligocene high-grade metamorphic event clearly has nothing to share with the Early Cretaceous migmatization of the Xolapa Complex of southern México (compare Ducea and others, 2004a; Pérez-Gutiérrez and others, 2009; Ratschbacher and others, 2009). The apparent absence of Grenvillian granulite-facies and of Paleozoic eclogite-facies metamorphic terranes in Chortís (for example Martens and others, 2007; Ratschbacher and others, 2009), possibly correlative with the Oaxacan and Acatlán complexes, respectively (for example Solari and others, 2003; Talavera-Mendoza and others, 2005; Nance and others, 2006; Keppie and others, 2006 and 2008), coupled with the apparent absence of late Paleozoic, low-metamorphic grade platform sediments in southwestern México, possibly correlative with the San Diego Phyllite (this work), preclude so far all pre-Mesozoic correlations between the Chortís Block and southern México.

Models that place the Chortís block in the Pacific widely separated from southern México by oceanic crust (for example, Keppie and Morán-Zenteno, 2005) and explain the truncation of the southern Mexican Pacific margin by subduction erosion in mid-Cenozoic times of a forearc up to 280 km wide (Morán-Zenteno and others, 1996; Keppie and others, 2009), are still under debate and validation and do not readily explain the intriguing stratigraphic correlations that suggest paleogeographic contiguity of the two blocks during most of the Mesozoic (for example, Venable, ms, 1994; Mills, 1998; Ortega-Gutiérrez and others, 2007).

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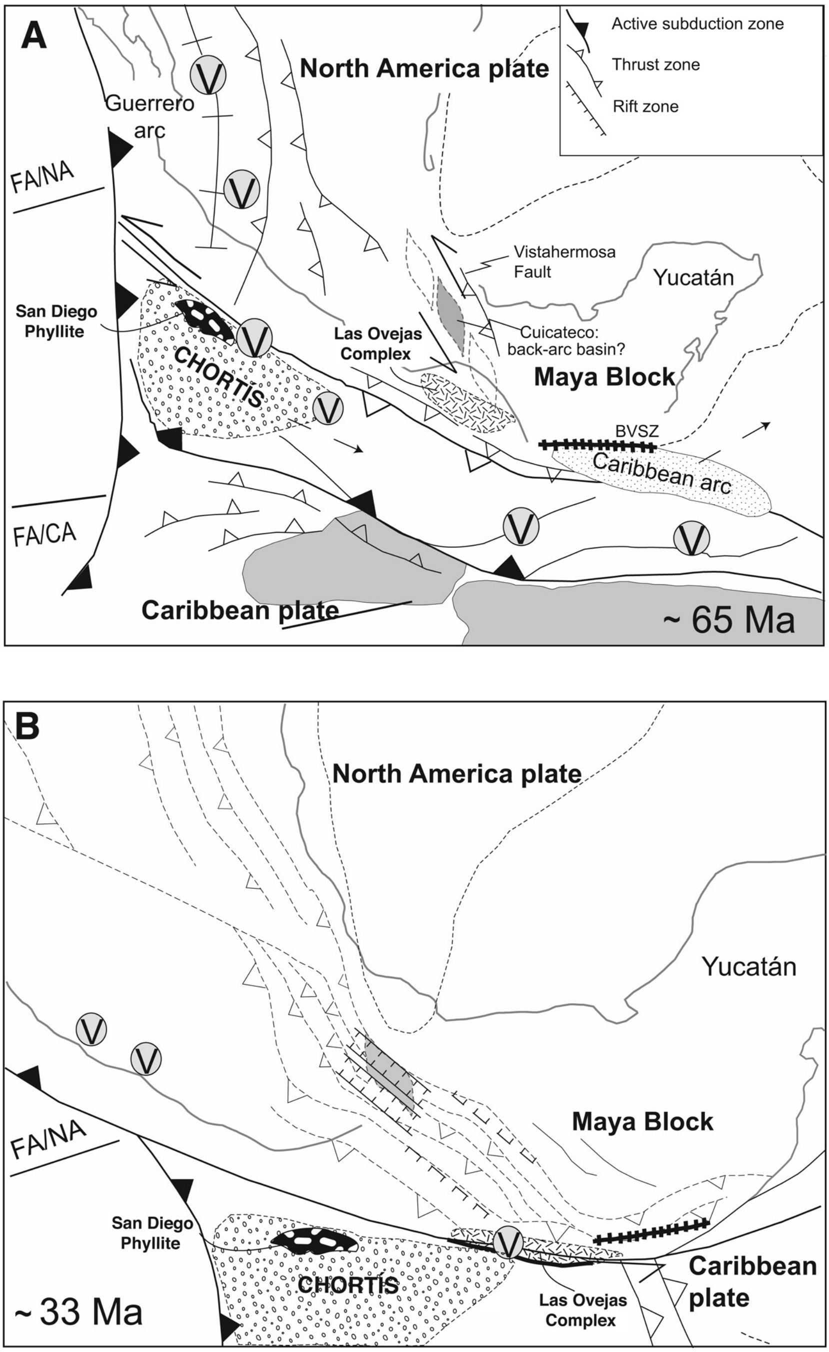

Fig. 7. Tectonic models at (A) *ca.* 65 and (B) *ca.* 33 Ma showing the proposed position of the northern Chortís Block, with the San Diego Phyllite, in front of southern México, as well as the Las Ovejas Complex (LOC). Modified from Cerca and others (2007), Rogers and others (2007b), and Pindell and Kennan (2009). Farallón/North America Plate and Farallón/Caribbean Plate relative displacement vectors are reported, for comparison. BVSZ stands for Baja Verapaz Shear Zone (compare Ortega-Obregón and others, 2008).

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References

Andersen T., 2002, Correction of common lead in U-Pb analyses that do not report ^{204}Pb: Chemical Geology, v. 192, n. 1–2, p. 59–79, http://dx.doi.org/10.1016/S0009-2541(02)00195-X

Barbeau, D. L., Jr., Ducea, M. N., Gehrels, G. E., Kidder, S., Wetmore, P. H., and Saleeby, J. S., 2005, U-Pb detrital-zircon geochronology of northern Salinian basement and cover rocks: Geological Society of America Bulletin, v. 117, n. 3–4, p. 466–481, http://dx.doi.org/10.1130/B25496.1

Blair, T. C., 1988, Mixed siliciclastic-carbonate marine and continental syn-rift sedimentation, Upper-Jurassic–lowermost Cretaceous Todos Santos and San Ricardo Formations, western Chiapas, Mexico: Journal of Sedimentary Petrology, v. 58, n. 4, p. 623–636, http://dx.doi.org/10.1306/212F8E09-2B24-11D7-8648000102C1865D

Bosc, E. A., ms, 1971, Geology of the San Agustín Acasaguastlán Quadrangle and Northeastern Part of El Progreso Quadrangle: Houston, Texas, Rice University, Ph. D. Thesis, 131 p.

Campa, M. F., and Coney, P. J., 1983, Tectono-stratigraphic terranes and mineral resource distributions in Mexico: Canadian Journal of Earth Sciences, v. 20, n. 6, p. 1040–1051.

Centeno-García, E., Ruíz, J., Coney, P. J., Patchett, P. J., and Ortega-Gutiérrez, F., 1993, Guerrero terrane of Mexico: its role in the Southern Cordillera from new geochemical data: Geology, v. 21, n. 5, p. 419–422, http://dx.doi.org/10.1130/0091-7613(1993)021⟨0419:GTOMIR⟩2.3.CO;2

Centeno-García, E., Guerrero-Suastegui, M., and Talavera-Mendoza, O., 2008, The Guerrero Composite Terrane of western Mexico: Collision and subsequent rifting in a supra-Subduciton zone, *in* Draut, A., Clift, P. D., and Scholl, D. W., editors, Formation and Applications of the Sedimentary Record in Arc Collision Zones: Geological Society of America Special Paper, v. 436, p. 279–308, http://dx.doi.org/10.1130/2008.2436(13)

Cerca, M., Ferrari, L., López-Martínez, M., Martiny, B., and Iriondo, A., 2007, Late Cretaceous shortening and early Tertiary shearing in the central Sierra Madre del Sur, southern Mexico: Insights into the evolution of the Caribbean–North American plate interaction: Tectonics, v. 26, TC3007, 34 p., http://dx.doi.org/10.1029/2006TC001981

Clemons, R. E., ms, 1966, Geology of the Chiquimula quadrangle, Guatemala, Central America: Austin, Texas, The University of Texas, Austin, Ph. D. thesis, 124 p.

Clemons, R. E., and Long, L. E., 1971, Petrologic and Rb-Sr Isotopic Study of the Chiquimula Pluton, Southeastern Guatemala: Geological Society of America Bulletin, v. 82, n. 10, p. 2729–2740, http://dx.doi.org/10.1130/0016-7606(1971)82[2729:PARISO]2.0.CO;2

Clift, P., and Vannucchi, P., 2004, Controls on tectonic accretion versus erosion in subduction zones: Implications for the origin and recycling of the continental crust: Reviews of Geophysics, v. 42, n. 2, RG2001, 31 p., http://dx.doi.org/10.1029/2003RG000127

Corona-Chávez, P., Poli, S., and Bigioggero, B., 2006, Syn-deformational migmatites and magmatic-arc metamorphism in the Xolapa Complex, southern Mexico: Journal of Metamorphic Geology, v. 24, n. 3, p. 169–191, http://dx.doi.org/10.1111/j.1525-1314.2006.00632.x

de Cserna, Z., 1965, Reconocimiento geológico en la Sierra Madre del Sur de México, entre Chilpancingo y Acapulco: Universidad Nacional Autónoma de México, Instituto de Geología, Boletín, v. 62, p. 1–77.

Dengo, G., 1969, Problems of tectonic relations between Central America and the Caribbean: Transactions of the Gulf Coast Association of Geological Societies, v. 19, p. 311–320.

Donnelly, T. W., Horne, G. S., Finch, R. C., and López-Ramos, E., 1990, Northern Central America; the Maya and Chortís blocks, *in* Dengo, G., and Case, J. E., editors, the Caribbean region: The Geological Society of America, The Geology of North America, v. H, ch. 3, p. 37–76.

Ducea, M. N., Gehrels, G. E., Shoemaker, S., Ruíz, J., and Valencia, V. A., 2004a, Geologic evolution of the Xolapa Complex, southern Mexico: Evidence from U-Pb zircon geochronology: Geological Society of America Bulletin, v. 116, n. 7–8, p. 1016–1025, http://dx.doi.org/10.1130/B25467.1

Ducea, M. N., Valencia, V. A., Shoemaker, S., Reiners, P. W., DeCelles, P. G., Campa, M. F., Morán-Zenteno, D., and Ruiz, J., 2004b, Rates of sediment recycling beneath the Acapulco trench: Constraints from (U-Th)/He thermochronology: Journal of Geophysical Research, v. 109, B09404, 11 p., http://dx.doi.org/10.1029/2004JB003112

Elías-Herrera, M., and Ortega-Gutiérrez, F., 1998, The Early Cretaceous Arperos oceanic basin (western Mexico): Geochemical evidence for an aseismic ridge formed near a spreading center—Comment: Tectonophysics, v. 292, n. 3–4, p. 321–326, http://dx.doi.org/10.1016/S0040-1951(98)00051-1

Elías-Herrera, M., Sánchez-Zavala, J. L., and Macías-Romo, C., 2000, Geologic and geochronologic data from the Guerrero terrane in the Tejupilco area, southern Mexico: new constraints on its tectonic interpretation: Journal of South American Earth Sciences, v. 13, n. 4–5, p. 355–375, http://dx.doi.org/10.1016/S0895-9811(00)00029-8

Engebretson, D., Cox, A., and Gordon, G., 1985, Relative plate motions between oceanic and continental plates in the Pacific basin: Geological Society of America Special Paper, v. 206, p. 1–64.

Escalona-Alcázar, F. J., Delgado-Argote, L. A., Weber, B., Núñez-Peña, E. P., Valencia, V. A., and Ortíz-

Acevedo, O., 2009, Kinematics and U-Pb dating of detrital zircons from the Sierra de Zacatecas, Mexico: Revista Mexicana de Ciencias Geológicas, v. 26, n. 1, p. 48–64.

French, C. D., and Schenk, C. J., 2004, Map Showing Geology, Oil and Gas Fields, and Geologic Provinces of the Caribbean Region: U.S. Geological Survey, Open-File Report 97-470-K.

Freydier, C., Martinez, R. J., Lapierre, H., Tardy, M., and Coulon, C., 1996, The Early Cretaceous Arperos oceanic basin (western Mexico): Geochemical evidence for an aseismic ridge formed near a spreading center: Tectonophysics, v. 259, n. 4, p. 343–367, http://dx.doi.org/10.1016/0040-1951(95)00143-3

Gehrels, G. E., Valencia, V. A., and Ruiz, J., 2008, Enhanced precision, accuracy, efficiency, and spatial resolution of U-Pb ages by laser ablation–multicollector-inductively coupled plasma-mass spectrometry. Geochemistry Geophysics Geosystems, v. 9, Q03017, 13 p., http://dx.doi.org/10.1029/2007GC001805

Gillis, R. J., Gehrels, G. E., Ruiz, J., and Flores de Dios Gonzaléz, L. A., 2005, Detrital zircon provenance of Cambrian-Ordovician and Carboniferous strata of the Oaxaca terrane, southern Mexico: Sedimentary Geology, v. 182, n. 1–4, p. 87–100, http://dx.doi.org/10.1016/j.sedgeo.2005.07.013

Godínez-Urbán, A., ms, 2009, Paleomagnetismo de la Formación Todos Santos, Chiapas, México: Querétaro, Mexico, Universidad Nacional Autónoma de Mexico, Posgrado en Ciencias de la Tierra, M. Sc. Thesis, 157 p.

Harlow, G. E., Hemming, S. R., Avé-Lallemant, H. G., Sisson, V. B., and Sorensen, S. S., 2004, Two high-pressure–low temperature serpentinite-matrix mélange belts, Motagua fault zone, Guatemala: A record of Aptian and Maastrichtian collisions: Geology, v. 32, n. 1, p. 17–20, http://dx.doi.org/10.1130/G19990.1

Herrmann, U., Nelson, B. K., and Ratschbacher, L., 1994, The origin of a terrane: U/Pb zircon geochronology and tectonic evolution of the Xolapa Complex (southern Mexico): Tectonics, v. 13, n. 2, p. 455–474, http://dx.doi.org/10.1029/93TC02465

Horne, G. S., Clark, G. S., and Pushkar, P., 1976, Pre-Cretaceous rocks of northwestern Honduras: basement terrane in Sierra de Omoa: American Association of Petroleum Geologists Bulletin, v. 60, n. 4, p. 566–583.

Hoskin, P. W. O., and Schaltegger, U., 2003, The composition of zircon and igneous and metamorphic petrogenesis, *in* Hanchar, J. M., and Hoskin, P. W. I., editors, Zircon: Reviews in Mineralogy and Geochemistry, v. 53, p. 27–62, http://dx.doi.org/10.2113/0530027

Ireland, T. R., and Williams, I. S., 2003, Considerations in zircon geochronology by SIMS, *in* Hanchar, J. M., and Hoskin, P. W. O., editors, Zircon: Reviews in Mineralogy and Geochemistry, v. 53, p. 215–241, http://dx.doi.org/10.2113/0530215

Keppie, J. D., and Morán-Zenteno, D. J., 2005, Tectonic Implications of Alternative Cenozoic Reconstructions for Southern Mexico and the Chortís Block: International Geology Review, v. 47, n. 5, p. 473–491, http://dx.doi.org/10.2747/0020-6814.47.5.473

Keppie, J. D., Dostal, J., Cameron, K. L., Solari, L. A., Ortega-Gutiérrez, F., and Lopez, R., 2003, Geochronology and geochemistry of Grenvillian igneous suites in the northern Oaxacan Complex, southern Mexico: tectonic implications: Precambrian Research, v. 120, n. 3–4, p. 365–289, http://dx.doi.org/10.1016/S0301-9268(02)00166-3

Keppie, J. D., Nance, R. D., Fernández-Suárez, J., Storey, C. D., Jeffries, T. E., and Murphy, J. B., 2006, Detrital zircon data from the eastern Mixteca Terrane, southern Mexico: evidence for an Ordovician-Mississippian continental rise and a Permo-Triassic clastic wedge adjacent to Oaxaquia: International Geology Review, v. 48, n. 2, p. 97–111, http://dx.doi.org/10.2747/0020-6814.48.2.97

Keppie, J. D., Dostal, J., Murphy, J. B., and Nance, R. D., 2008, Synthesis and tectonic interpretation of the westernmost Paleozoic Variscan orogen in southern Mexico: From rifted Rheic margin to active Pacific margin: Tectonophysics, v. 461, n. 1–4, p. 277–290, http://dx.doi.org/10.1016/j.tecto.2008.01.012

Keppie, J. D., Morán-Zenteno, D. J., Martiny, B., and González-Torres, E., 2009, Synchronous 29–19 Ma arc hiatus, exhumation and subduction of forearc in southwestern Mexico, *in* James, K. H., Lorente, M. A., and Pindell, J. L., editors, The origin and Evolution of the Caribbean Plate: Geological Society of London, Special Publications, v. 328, p. 169–179, http://dx.doi.org/10.1144/SP328.7

Lawrence, D. P., ms, 1975, Petrology and structural geology of the Sanarate–El Progreso area, Guatemala: Binghamton, New York, State University of New York, Ph. D. thesis, 255 p.

Ludwig, K. L., and Mundil, R., 2002, Extracting reliable U-Pb ages and errors from complex populations of zircons from Phanerozoic tuffs: 12th Goldschmidt Conference, Goldschmidt Conference Abstracts 2002, p. A463.

Malfait, B. T., and Dinkleman, M. G., 1972, Circum-Caribbean tectonic and igneous activity and evolution of the Caribbean plate: Geological Society of America Bulletin, v. 83, n. 2, p. 251–272, http://dx.doi.org/10.1130/0016-7606(1972)83[251:CTAIAA]2.0.CO;2

Mandujano-Velázquez, J. J., and Keppie, J. D., 2009, Middle Miocene Chiapas fold and thrust belt of Mexico: a result of collision of the Tehuantepec Transform/Ridge with the Middle America Trench, *in* Murphy, J. B., Keppie, J. D., and Hynes, A. J., editors, Ancient Orogens and Modern Analogues: Geological Society of London, Special Publications, v. 327, p. 55–69, http://dx.doi.org/10.1144/SP327.4

Manton, W. I., and Manton, R. S., 1984, Geochronology and Late Cretaceous–Tertiary tectonism of Honduras: Honduras, Dirección General de Minas e Hidrocarburos, 55 p.

Martens, U., Ortega-Obregón, C., Estrada, J., and Valle, M., 2007, Metamorphism and metamorphic rocks, *in* Bundschuh, J., and Alvarado, G. E., editors, Central America: Geology, Resources and Hazards: The Netherlands, Taylor and Francis, p. 489–526.

Martens, U., Weber, B., and Valencia, V. A., 2010, U/Pb geochronology of Devonian and older Paleozoic beds in the southwestern Maya Block, Central America: Its affinity with Peri-Gondwanan terranes: Geological Society of America Bulletin, v. 122, n. 5–6, p. 815–829, http://dx.doi.org/10.1130/B26405.1

Martini, M., Ferrari, L., López-Martínez, M., Cerca-Martínez, M., Valencia, V. A., and Serrano-Durán, L., 2009, Cretaceous-Eocene magmatism and Laramide deformation in southwestern Mexico: No role for terrane accretion: Geological Society of America Memoir, v. 204, p. 151–182, http://dx.doi.org/10.1130/2009.1204(07)

McBirney, A. R., 1963, Geology of a part of the Central Guatemalan Cordillera: University of California Publications in Geological Sciences, v. 38, p. 177–242.

McBirney, A. R., and Bass, M. N., 1969, Structural relations of pre-Mesozoic rocks of northern Central America, *in* McBirney, A., editor, Tectonic relations of Northern Central America and the Western Caribbean—The Bonacca Expedition: American Association of Petroleum Geologists Memoir, v. 11, p. 269–280.

Mendoza-Rosales, C. C., Centeno-García, E., Silva-Romo, G., Campos-Madrigal E., and Bernal J. P., 2010, Barremian rift-related turbidites and alkaline volcanism in southern Mexico and their role in the opening of the Gulf of Mexico: Earth and Planetary Science Letters, v. 295, n. 3–4, p. 419–434, http://dx.doi.org/10.1016/j.epsl.2010.04.020

Meschede, M., and Frisch, W., 1998, A plate-tectonic model for the Mesozoic and Early Cenozoic history of the Caribbean plate: Tectonophysics, v. 296, n. 3–4, p. 269–291, http://dx.doi.org/10.1016/S0040-1951(98)00157-7

Miller, B. V., Dostal, J., Keppie, J. D., Nance, R. D., Ortega-Rivera, A., and Lee, J. W. K., 2007, Ordovician calc-alkaline granitoids in the Acatlán Complex, southern Mexico: geochemical and geochronologic data and implications for tectonics of the Gondwanan margin of the Rheic Ocean, *in* Linnemann, U., Nance, R. D., Zulaf, G., and Kraft, P., editors, The Evolution of the Rheic Ocean: From Avalonian-Cadomian Active Margin to Alleghenian-Variscan Collision: Geological Society of America Special Papers, v. 423, p. 465–475, http://dx.doi.org/10.1130/2007.2423(23)

Mills, R. A., 1998, Carbonate detritus and mylonite zones in Guerrero, Mexico and northern Honduras: new evidence for detachment of the Chortis block from southern Mexico: Journal of South American Earth Sciences, v. 11, n. 3, p. 291–307, http://dx.doi.org/10.1016/S0895-9811(98)00016-9

Morán Zenteno, D. J., Corona Chávez, P., and Tolson, G., 1996, Uplift and subduction erosion in southwestern Mexico since the Oligocene: pluton geobarometry constraints: Earth and Planetary Science Letters, v. 141, n. 1–4, p. 51–65, http://dx.doi.org/10.1016/0012-821X(96)00067-2

Nance, R. D., Miller, B. V., Keppie, J. D., Murphy, J. B., and Dostal, J., 2006, Acatlán Complex, southern Mexico: Record spanning the assembly and breakup of Pangea: Geology, v. 34, n. 10, p. 857–860, http://dx.doi.org/10.1130/G22642.1

Ortega-Gutiérrez, F., Mitre-Salazar, L. M., Roldan-Quintana, J., Aranda-Gómez, J., Morán-Zenteno, D., Alaniz-Álvarez S., and Nieto-Samaniego A., 1992, Carta Geológica de la Republica Mexicana, escala 1:2 000 000, 5a edición: México, Universidad Nacional Autónoma de Mexico, Instituto Geología.

Ortega-Gutiérrez, F., Elías-Herrera, M., Reyes-Salas, M., Macías-Romo, C., and López, R., 1999, Late Ordovician–Early Silurian continental collisional orogeny in southern Mexico and its bearing on Gondwana-Laurentia connections: Geology, v. 27, n. 8, p. 719–722, http://dx.doi.org/10.1130/0091-7613(1999)027⟨0719:LOESCC⟩2.3.CO;2

Ortega-Gutiérrez, F., Solari, L. A., Ortega-Obregón, C., Elías-Herrera, M., Martens, U., Morán-Icál, S., Chiquín, M., Keppie, J. D., Torres-de León, R., and Schaaf, P., 2007, The Maya-Chortís boundary: a tectonostratigraphic approach: International Geology Review, v. 49, n. 11, p. 996–1024, http://dx.doi.org/10.2747/0020-6814.49.11.996

Ortega-Obregón, C., Solari, L. A., Keppie, J. D., Ortega-Gutiérrez, F., Solé, J., and Morán-Ical, S., 2008, Middle-Late Ordovician magmatism and Late Cretaceous collision in the southern Maya block, Rabinal-Salamá area, central Guatemala: implications for North America–Caribbean plate tectonics: Geological Society of America Bulletin, v. 120, n. 5–6, p. 556–570, http://dx.doi.org/10.1130/B26238.1

Ortega-Obregón, C., Keppie, J. D., Murphy, J. B., Lee, J. K. W., and Ortega-Rivera, A., 2009, Geology and geochronology of Paleozoic rocks in western Acatlán Complex, southern Mexico: Evidence for contiguity across an extruded high-pressure belt and constraints on Paleozoic reconstructions: Geological Society of America Bulletin, v. 121, n. 11–12, p. 1678–1694, http://dx.doi.org/10.1130/B26597.1

Page, B. M., 1981, The southern Coast Ranges, *in* Ernst, W., editor, The geotectonic development of California; Rubey Volume I: Englewood Cliffs, New Jersey, Prentice-Hall, p. 329–417.

Pérez-Gutiérrez, R., Solari, L. A., Gómez-Tuena, A., and Valencia, V. A., 2009a, El terreno Cuicateco: ¿cuenca oceánica con influencia de subducción del Cretácico Superior en el sur de México? Nuevos datos estructurales, geoquímicos y geocronológicos: Revista Mexicana de Ciencias Geológicas, v. 26, n. 1, p. 222–242.

Pérez-Gutiérrez, R., Solari, L. A., Gómez-Tuena, A., and Martens, U., 2009b, Mesozoic geologic evolution of the Xolapa migmatitic complex north of Acapulco, southern Mexico: implications for paleogeographic reconstructions: Revista Mexicana de Ciencias Geológicas, v. 26, n. 1, p. 201–221.

Pindell, J. L., and Kennan, L., 2009, Tectonic evolution of the Gulf of Mexico, Caribbean and northern South America in the mantle reference frame: an update, *in* James, K. H., Lorente, M. A., and Pindell, J. L, editors, The Origin and Evolution of the Caribbean Plate: Geological Society of London, Special Publications, v. 328, p. 1–55, http://dx.doi.org/10.1144/SP328.1

Pindell, J. L., Cande, S. C., Pitman, W. C., III, Rowley, D. B., Dewey, J. F., Labrecque, J., and Haxby, W., 1988, A plate-kinematic framework for models of Caribbean evolution: Tectonophysics, v. 155, n. 1–4, p. 121–138, http://dx.doi.org/10.1016/0040-1951(88)90262-4

Pindell, J. L., Maresch, W. V., Martens, U., and Stanek, K., 2012, The Greater Antillean Arc: Early Cretaceous origin and proposed relationship to Central American subduction mélanges: implications for models of Caribbean evolution: International Geology Review, v. 54, n. 2, p. 131–143, http://dx.doi.org/10.1080/00206814.2010.510008

Ranero, C. R., and von Huene, R., 2000, Subduction erosion along the Middle America convergent margin: Nature, v. 404, p. 748–752, http://dx.doi.org/10.1038/35008046

Ratschbacher, L., Franz, L., Min, M., Bachmenn, R., Martens, U., Stanek, K., Stübner, K., Nelson, B. K., Herrmann, U., Weber, B., López-Martínez, M., Jonckheere, R., Sperner, B., Tichomirowa, M., McWilliams, M. O., Gordon, M., Meschede, M., and Bock, P., 2009, The North American–Caribbean plate boundary in Mexico-Guatemala-Honduras, *in* James, K. H., Lorente, M. A., and Pindell, J. L., editors, The origin and Evolution of the Caribbean Plate: Geological Society of London, Special Publications, v. 328, p. 219–293, http://dx.doi.org/10.1144/SP328.11

Rogers, R. D., Mann, P., and Emmet, P. A., 2007a, Tectonic terranes of the Chortís block based on integration of regional aeromagnetic and geologic data, *in* Mann, P., editor, Geologic and tectonic development of the Caribbean Plate in northern Central America: Geological Society of America, Special Papers, v. 428, p. 65–88, http://dx.doi.org/10.1130/2007.2428(04)

Rogers, R. D., Mann, P., Scott, R. W., and Patino, L., 2007b, Cretaceous intra-arc rifting, sedimentation, and basin inversion in east-central Honduras, *in* Mann, P., editor, Geologic and tectonic development of the Caribbean plate in northern Central America: Geological Society of America Special Papers, v. 428, p. 89–128, http://dx.doi.org/10.1130/2007.2428(05)

Rosencrantz, E., and Sclater, J. G., 1986, Depth and age in the Cayman Trough: Earth and Planetary Science Letters, v. 79, n. 1–2, p. 133–144, http://dx.doi.org/10.1016/0012-821X(86)90046-4

Ross, M. I., and Scotese, C. R., 1988, A hierarchical model of the Gulf of Mexico and Caribbean region: Tectonophysics, v. 155, n. 2, p. 139–168, http://dx.doi.org/10.1016/0040-1951(88)90263-6

Schaaf, P., Morán-Zenteno, D. J., Hernández-Bernal, M. S., Solís-Pichardo, G., Tolson, G., and Köhler, H., 1995, Paleogene continental margin truncation in Southwestern Mexico: Geochronological evidence: Tectonics, v. 14, n. 6, p. 1339–1350, http://dx.doi.org/10.1029/95TC01928

Schwartz, D. P., ms, 1976, Geology of the Zacapa Quadrangle and vicinity, Guatemala, Central America: Binghamton, New York, State University of New York, Binghamton, Ph. D. Thesis, 191 p.

Sedlock, R. L., Ortega-Gutiérrez, F., and Speed, R. C., 1993, Tectonostratigraphic terranes and tectonic evolution of Mexico: Geological Society of America Special Papers, v. 278, 153 p.

Silva-Romo, G., 2008, Guayape-Papalutla fault system: A continuous Cretaceous structure from southern Mexico to the Chortís block? Tectonic implications: Geology, v. 36, n. 1, p. 75–78, http://dx.doi.org/10.1130/G24032A.1

Solari, L. A., and Tanner, M., 2011, UPb.age, a fast data reduction script for LA-ICP-MS U-Pb geochronology: Revista Mexicana de Ciencias Geológicas, v. 28, n. 1, p. 83–91.

Solari, L. A., Keppie, J. D., Ortega-Gutiérrez, F., Cameron, K. L., Lopez, R., and Hames, W. E. 2003, 990 and 1100 Ma Grenvillian tectonothermal events in the northern Oaxacan Complex, southern Mexico: roots of an orogen: Tectonophysics, v. 365, n. 1–4, p. 257–282, http://dx.doi.org/10.1016/S0040-1951(03)00025-8

Solari, L. A., Torres-de León, R., Hernández Pineda, G., Solé, J., Solís-Pichardo, G., and Hernández-Treviño, T., 2007, Tectonic significance of Cretaceous-Tertiary magmatic and structural evolution of the northern margin of the Xolapa Complex, Tierra Colorada area, southern Mexico: Geological Society of America Bulletin, v. 119, n. 9–10, p. 1265–1279, http://dx.doi.org/10.1130/B26023.1

Solari, L. A., Ortega-Gutiérrez, F., Elías-Herrera, M., Schaaf, P., Norman, M., Torres-de León, R., Ortega-Obregón, C., Chiquín, M., and Morán-Ical, S., 2009, U-Pb zircon geochronology of Paleozoic units in Western and Central Guatemala: insights into the tectonic evolution of Middle America, *in* James, K., Lorente, M. A., and Pindell, J., editors, Origin and evolution of the Caribbean Plate: Geological Society of London, Special Publications, v. 328, p. 295–313, http://dx.doi.org/10.1144/SP328.12

Solari, L. A., Ortega-Gutiérrez, F., Elías-Herrera, M., Gómez-Tuena, A., and Schaaf, P., 2010a, Refining the age of magmatism in the Altos Cuchumatanes, western Guatemala, by LA-ICPMS, and tectonic implications: International Geology Review, v. 52, n. 9, p. 977–998, http://dx.doi.org/10.1080/00206810903216962

Solari, L. A., Gómez-Tuena, A., Bernal, J. P., Pérez-Arvizu, O., and Tanner, M., 2010b, U-Pb zircon geochronology by an integrated LA-ICP-MS microanalytical workstation: Achievements in Precision and Aaccuracy: Geostandards and Geoanalytical Research, v. 34, n. 1, p. 5–18, http://dx.doi.org/10.1111/j.1751-908X.2009.00027.x

Steiner, M. B., and Walker, J. D., 1996, Late Silurian plutons in Yucatan: Journal of Geophysical Research, v. 101, n. B8, p. 17,727–17,735, http://dx.doi.org/10.1029/96JB00174

Stock, J. M., and Lee, J., 1994, Do microplates in subduction zones leave a geological record?: Tectonics, v. 13, n. 6, p. 1472–1487, http://dx.doi.org/10.1029/94TC01808

Talavera-Mendoza, O., Ruíz, J., Gehrels, G. E., Meza-Figueroa, D., Vega-Granillo, R., and Campa-Uranga, M. F., 2005, U-Pb geochronology of the Acatlán Complex and implications for the Paleozoic paleogeography and tectonic evolution of southern Mexico: Earth and Planetary Science Letters, v. 235, n. 3–4, p. 682–699, http://dx.doi.org/10.1016/j.epsl.2005.04.013

Talavera-Mendoza, O., Ruiz, J., Gehrels, G. E., Valencia, V. A., and Centeno-García, E., 2007, Detrital zircon U/Pb geochronology of southern Guerrero and western Mixteca arc successions (southern Mexico): New insights for the tectonic evolution of the southwestern North America during the late Mesozoic: Geological Society of America Bulletin, v. 119, n. 9–10, p. 1052–1065, http://dx.doi.org/10.1130/B26016.1

Vega-Granillo, R., Talavera-Mendoza, O., Meza-Figueroa, D., Ruiz, J., Gehrels, G. E., López-Martínez, M., and Cruz-Vargas, J. C., 2007, Pressure-temperature-time evolution of Paleozoic high-pressure rocks of the Acatlán Complex (southern Mexico): Implications for the evolution of the Iapetus and Rheic Oceans: Geological Society of America Bulletin, v. 119, n. 9–10, p. 1249–1264, http://dx.doi.org/10.1130/B226031.1

Venable, M. E., ms, 1994, A geological, tectonic, and metallogenic evaluation of the Siuna terrane (Nicaragua): Tucson, Arizona, University of Arizona, Ph. D. Thesis, 154 p.

Venegas-Rodríguez, G., Barboza-Gudiño, J. R., and López-Doncel, R. A., 2009, Geocronología de circones detríticos en capas del Jurásico Inferior de las áreas de la Sierra de Catorce y El Alamito en el estado de San Luis Potosí: Revista Mexicana de Ciencias Geológicas, v. 26, n. 2, p. 466–481.

von Huene, R., and Scholl, D. W., 1991, Observations at convergent margins concerning sediment subduction, subduction erosion, and the growth of continental crust: Reviews of Geophysics, v. 29, n. 3, p. 279–316, http://dx.doi.org/10.1029/91RG00969

Wadge, G., and Burke, K., 1983, Neogene Caribbean Plate rotation and associated Central American tectonic evolution: Tectonics, v. 2, n. 6, p. 633–643, http://dx.doi.org/10.1029/TC002i006p00633

Weber, B., and Köhler, H., 1999, Sm-Nd, Rb-Sr and U-Pb geochronology of a Grenville terrane in southern Mexico: origin and geologic history of the Guichicovi Complex: Precambrian Research, v. 96, n. 3–4, p. 245–262, http://dx.doi.org/10.1016/S0301-9268(99)00012-1

Weber, B., Schaaf, P., Valencia, V. A., Iriondo, A., and Ortega-Gutiérrez, F., 2006, Provenance ages of Late Paleozoic sandstones (Santa Rosa Formation) from the Maya block, SE Mexico. Implications on the tectonic evolution of western Pangea: Revista Mexicana de Ciencias Geológicas, v. 23, n. 3, p. 262–276.

Weber, B., Valencia, V. A., Schaaf, P., Pompa-Mera, V., and Ruiz, J., 2008, Significance of provenance ages from the Chiapas massif Complex (Southeastern Mexico): Redefining the Paleozoic basement of the Maya Block and its evolution in a Peri-Gondwanan Realm: The Journal of Geology, v. 116, n. 6, p. 619–639, http://dx.doi.org/10.1086/591994

Weber, B., Valencia, V. A., Schaaf, P., and Ortega-Gutiérrez, F., 2009, Detrital zircon ages from the Lower Santa Rosa Formation, Chiapas: implications on regional Paleozoic stratigraphy: Revista Mexicana de Ciencias Geológicas, v. 26, n. 1, p. 260–276.