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REGIONAL IMPLICATIONS OF THE JURASSIC–CRETACEOUS VOLCANOSEDIMENTARY CUICATECO TERRANE, OAXACA, MEXICO

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RESUMEN

El Terreno Cuicateco se ubica entre la margen oriental del Terreno Precámbrico Zapoteco y parte de la margen noroccidental del Batolito Pérmico de Chiapas. Se define como un cinturón orientado N-NW de 235 km de longitud y 20 km de anchura, formado por una secuencia volcanosedimentaria metamorfoseada en grado bajo. El área en estudio cubre 800 km cuadrados, ubicados en el extremo noroccidental del terreno.

La asociación de lavas y tobas de composición andesítica con rocas sedimentarias que varían hacia el oriente de grauvacas feldespáticas a grauvacas calcáreas y calizas se compara con un arco de islas que incluye pequeñas cuencas interiores. Las "raíces" de la provincia magmática afloran en el lado oeste del terreno y están formadas por rocas granodiorítico-monzoníticas, con segregaciones ultramáficas de piroxenitas y anfibolitas. Los cuerpos intrusivos presentan una deformación milonítica que decrece hacia las partes internas, donde dichos intrusivos son casi isotrópicos. En ausencia de intrusivos, la margen oeste del terreno está ocupada por metaandesitas con la misma textura milonítica. En la secuencia de metatobas está tectónicamente emplazado un gran cuerpo de serpentinitas y leucodioritas. En concordancia con el agua meteórica actual, el valor promedio de D/H del agua estructural de lizarditas y crisotilos es de -59 por mil, lo que atestigua su formación asociada con emplazamiento tectónico. Estructuralmente, la secuencia sedimentaria define un cinturón de pliegues y cabalgaduras con débil metamorfismo cuya vergencia es hacia el oriente.

Se considera que la zona de contacto entre los terrenos más antiguos, los cuales muestran una diferencia en espesor de aproximadamente 20 km, es un factor principal de litostática, responsable de la localización de la provincia magmática cuicateca.

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ABSTRACT

The 235 km long and 20 km wide Cuicateco Terrane is located between the eastern margin of the Precambrian Zapoteco Terrane and the northwestern margin of the Permian Batholith of Chiapas. The study area is about 800 sq. km, located in the northwestern limit of the terrane.

The association of andesitic lavas and tuffs with sedimentary rocks which grade eastward from feldspatic wackes, calcareous wackes to limestones is comparable to an island arc which includes small internal basins. The "roots" of the magmatic province are exposed in the western side of the terrane corresponding to granodioritic-monzonitic rocks showing ultramafic segregations (pyroxenites and amphibolites). The crystalline rocks show a strong mylonitic solid-state ductile flow fabric decreasing toward inner zones, where the intrusives are almost isotropic. Where the intrusives are absent, the western side of the magmatic belt is occupied by metaandesites showing the same metamorphic fabric. A large wedge of serpentinized ultramafics and leucodiorites are tectonically emplaced in the sequence of metatuffs. In accordance with the present-day meteoric water, chrysotile and lizardite structural water shows a D/H average ratio of -59 per mil, indicating its tectonically related formation. Structurally, the sedimentary sequence defines a thrust-faulted, folded and weakly metamorphosed belt verging eastward.

It is considered that the contact zone between the older terranes, which have a difference in thickness of about 20 km, is a major factor of lithostatics on the location of the Cuicateco magmatic province.

INTRODUCTION

The tectonic history of southern México is highly complicated by the apparent small scale of the different terranes and wide evolution time span. Some insights have been given from the tectonic point of view by using tectonostratigraphic terrane concepts (Ortega-Gutiérrez, 1981; Campa and Coney, 1983); however, they give little information about important structural and petrological aspects.

The Cuicateco Terrane (called Juárez by Campa and Coney, 1983), exposes a varied Jurassic-Cretaceous lithology which includes mylonitized crystalline rocks, a weakly metamorphosed volcanosedimentary sequence and a broad exposition of limestones and wackes (Mena-Rojas, 1960; Carfantan, 1981 (1984) and 1983; Delgado-Argote, in press).

The terrane is about 240 km long and 20 km wide. The area selected in this study comprises a 60 km long portion located on its northwestern extreme. Emphasis was given to the Cuicatlán-Concepción Pápalo and Teotitlán-Huautla sections, where the access is possible and the exposed geology is considered more representative.

The initial objective of this study was to define the tectonic setting and petrologic

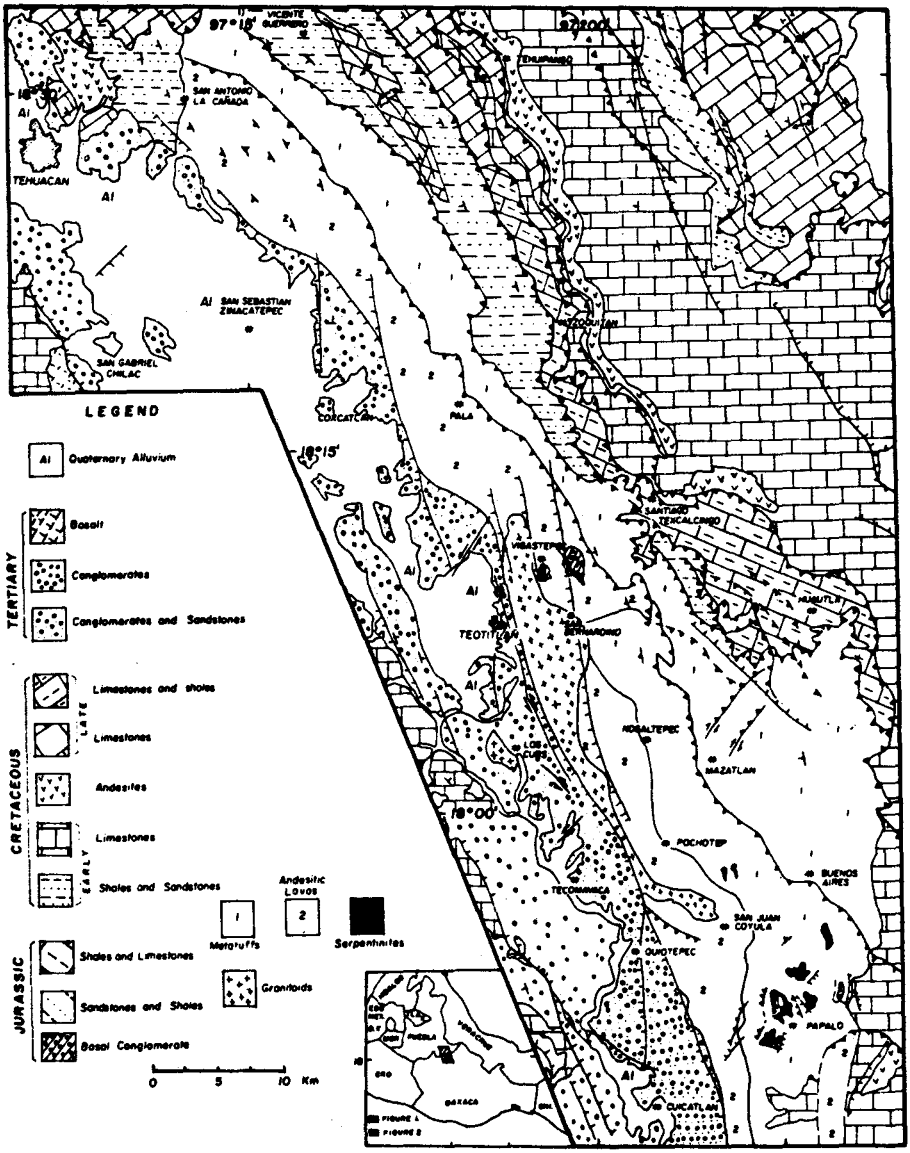


Fig. 1. Regional geologic map of the northern Cuicateco Terrane between Cuicatlán and Tehuacán. Geologic base data taken from INEGI (map scale 1:250 000), Mena-Rojas, 1960, and this study.

character of the ultramafic rocks of Concepción Pápalo (Delgado-Argote, in press) to follow with the structural and tectonic study of the northern part of the volcanosedimentary complex.

Following the criterium of Ortega-Gutiérrez (1981), the Cuicateco Complex is an epimetamorphic terrane which lies between the Precambrian Zapoteco Terrane and partially the Permian Batholith of Chiapas. This fact led Carfantan (1983) to propose an intercratonic volcanic arc where the ultramafics of Concepción Pápalo and a series of diabases, gabbros, etc. define a process of oceanization exposed as an ophiolite. A brief discussion on the ophiolite affinity of Concepción Pápalo is presented in Delgado-Argote (in press). Besides, the Cuicateco Terrane is particularly interesting with respect to the concept of accretionary tectonics of the southern cordillera, inasmuch as it lies between two older "suspect" terranes and it seems to be "native" (Gray, 1986). Following the same criterium, some facts suggesting a mantle uprising process in the limit of the two pre-Mesozoic terranes were presented in previous works (Delgado-Argote, in press; Delgado-Argote and Carballido-Sánchez, 1987). This study represents an advance in the understanding of the Cuicateco Complex due to the scarcity of both, published detailed geology and geochronologic data. Therefore, this study starts with a lithologic description and their stratigraphic relations within the Cuicateco basin.

LITHOLOGIC UNITS AND STRATIGRAPHIC RELATIONS

The lithology of the Cuicateco Terrane includes metamorphic igneous and sedimentary rocks which have been recognized to cover a time span ranging from Precambrian to Late Tertiary. The oldest rocks are graphitic paragneisses of the Zapoteco Terrane which are considered part of the local basement. Eastward, out of the mapped area, granitic and sedimentary rocks of probable Paleozoic-Jurassic age belonging to the Maya Terrane crop out (Campa and Coney, 1983; Grajales-N. *et al.*, 1985). The volcanosedimentary sequence of the Cuicateco Terrane crops out between these terranes and it is partially covered on its western margin by Oligocene red beds.

Because of their complex internal relations, the lithologic units, in decreasing order of apparent age, crystallinity and depth of emplacement (Figs. 1 and 2) are described as follows.

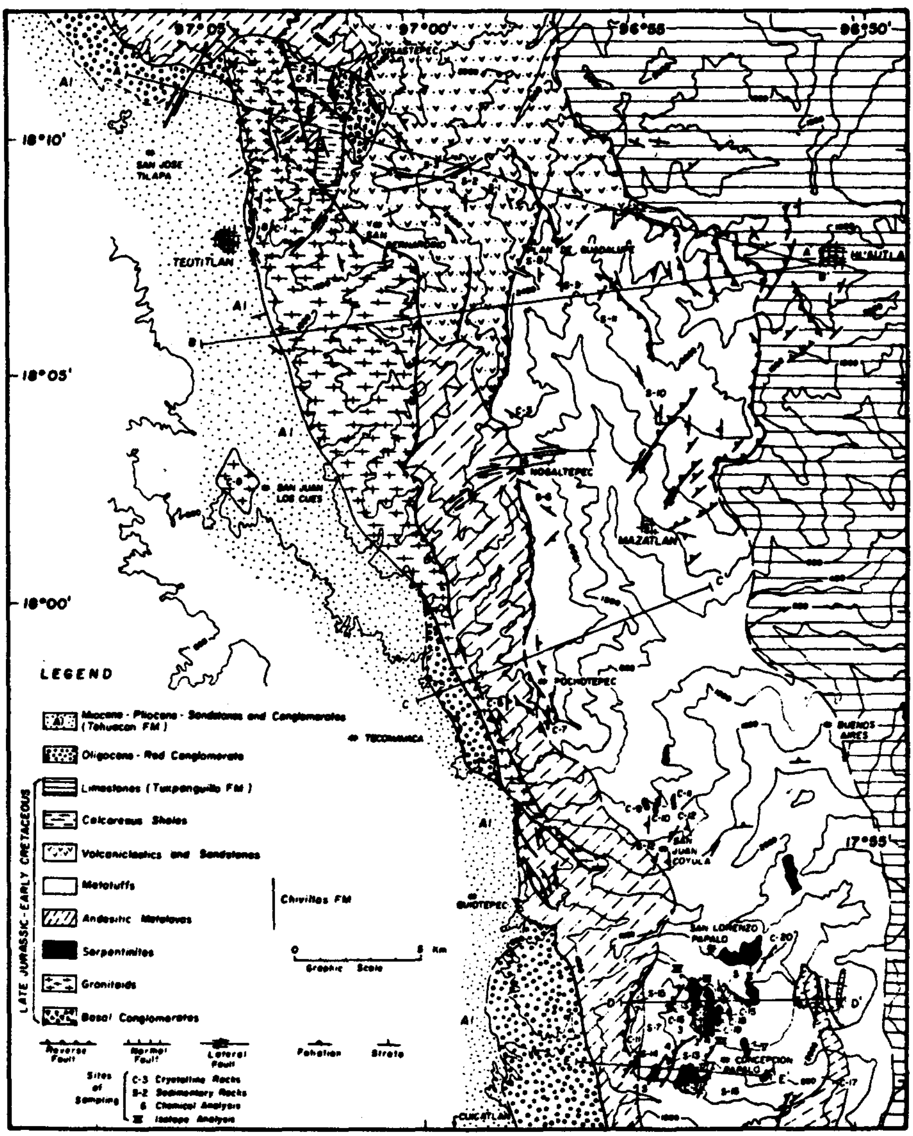


Fig. 2. Geologic map of the Cuicatlán-Teotitlán area.

Basement rocks

Rocks belonging to the metamorphic basement are observed as 15 cm long fragments included in a polymictic conglomerate near Vigastepec (Figs. 2 and 3); smaller fragments are also found in a conglomeratic sandstone underlying the Orizaba Formation (?), near San Antonio La Cañada (Fig. 1). On the way to Pala (north of Teotitlán, Fig. 1), its proximity is also inferred from the presence of grossular garnet and white mica found in peripheric granitoids which grade to granodiorites and diorites showing an original mineralogy low in alumina content. The high alumina is interpreted to result from the partial assimilation of the Precambrian gneissic basement just in the periphery of the intermediate intrusives which, on the western portion of the Sierra Mazateca, show an intense cataclastic deformation. In Vigastepec, in a minor scale, partially assimilated gneissic xenoliths are observed in subvolcanic andesitic rocks. Under the microscope, the gneissic rocks show triple junctions of quartz, Na-plagioclase and K-feldspar with ondulatory extinction. As in the paragneisses of the Zapoteco Complex, thin bands of graphite are clearly observed in hand specimen in both the conglomerate fragments and xenoliths.

Crystalline intrusive rocks

This group encloses all the phaneritic crystalline rocks located on the western margin of the Sierra Mazateca. Outcrops are continuous from San Juan Tilapa to Tecomavaca (Fig. 2). Also included in this section are the serpentinized masses of ultramafic rocks from Concepción Pápalo which, for a long time, caught the attention of miners because of their high chrysotile content of economic interest (Ramírez-Lozano, 1981; García-Calderón, 1978).

Serpentinites - The ultramafic unit of Concepción Pápalo is better defined as a completely serpentinized sill-like body 300 m thick. Its structural arrangement is concordant with the eastward verging regional structures. The body is only enclosed by metatuffs which show plastic deformation along the contacts. Internally, the flowage planes develop long fiber asbestos (chrysotile) and sporadically, blocks of peridotites as large as one meter long are rotated following the sense of deformation. The magnetic response associated with the generation of secondary magnetite after serpentinization of olivine tends to be low. In part, this permits to infer that the peridotitic protolith was probably olivine-poor (Wicks and Whittaker, 1977). Delgado-Argote (in press) pointed out that the ultramafic mass experienced at least two processes of general serpentinization. Firstly, the formation of lizardite under hydrothermal conditions allowed the mass to move up and be emplaced at shallower levels. Later, a second process of serpentinization took place during a general compressive disruption and chrysotile was formed under conditions of shearing stress at relatively constant temperature. A local heating effect associated to the Tertiary emplacement of basaltic dikes induced a partial loose of structural water from lizardite-chrysotile and subsequent formation of antigorite. Additional evidences for different processes of serpentinization are given by a cross-cutting geometry of veinlets of secondary magnetite (Delgado-Argote, in press). The general composition of the mass is inferred to be close to a harzburgitic or olivine pyroxenitic protolith, based on the absence of amphiboles after clinopyroxenes, the presence of bastites (after orthopyroxenes) as well as the poor magnetism shown by most of the serpentinites.

A synthesis of qualitative petrographic analyses on seven serpentinites is given in Table 1. The correlation between serpentinites, processes of serpentinization and isotopic behaviour is presented in a separate section.

Leucodiorites - Although leucocratic diorites are found all along the granitoid body, they are discussed separately, because, in Concepción Pápalo, they are invariably located on the upper part of the serpentinitic mass. Such position is interpreted to be associated to a dragging effect during the emplacement of the serpentinites, and are thought to be genetically related. Their internal structure is characterized by penetrative shearing which can derivate to a protomylonite or mylonite. Near San Juan Coyula, where the intrusive is less deformed, it shows schlieren-like textures.

Under the microscope, mineralogy is dominated by uralitized clinopyroxene (augite?), hypersthene (partially bastites), deformed and fractured plagioclase (oligoclase), and a matrix of shadowy quartz. Small proportion of talc, sericite and other hydrous silicates are also included in the matrix (samples OX-18 and OX-22, Table 1).

Metagranitoids - This unit includes a wide compositional range of intrusive rocks located on the western margin of the Cuicateco Terrane (Table 1, figure 2). Its exposure is continuous from Tilapa to Tecomavaca and, in Vigastepec, some outcrops are restricted to structural windows associated to subvolcanic dikes of andesitic composition, indicating a genetic relationship. Internally, the intrusive complex shows a strong primary anisotropy and, along its western margin, a penetrative shearing deformation defines a wide zone of mylonites and protomylonites. Both structural

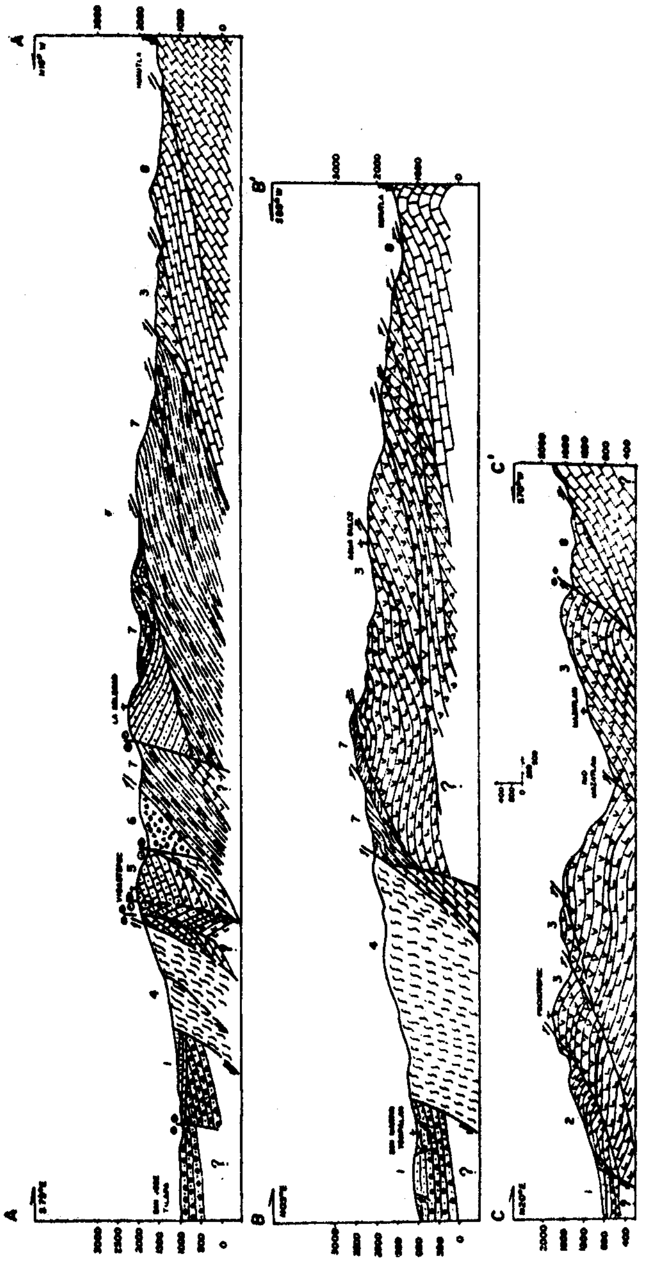


Fig. 3. Geologic cross sections. Sections D and E taken from Delgado-Argote (in press).

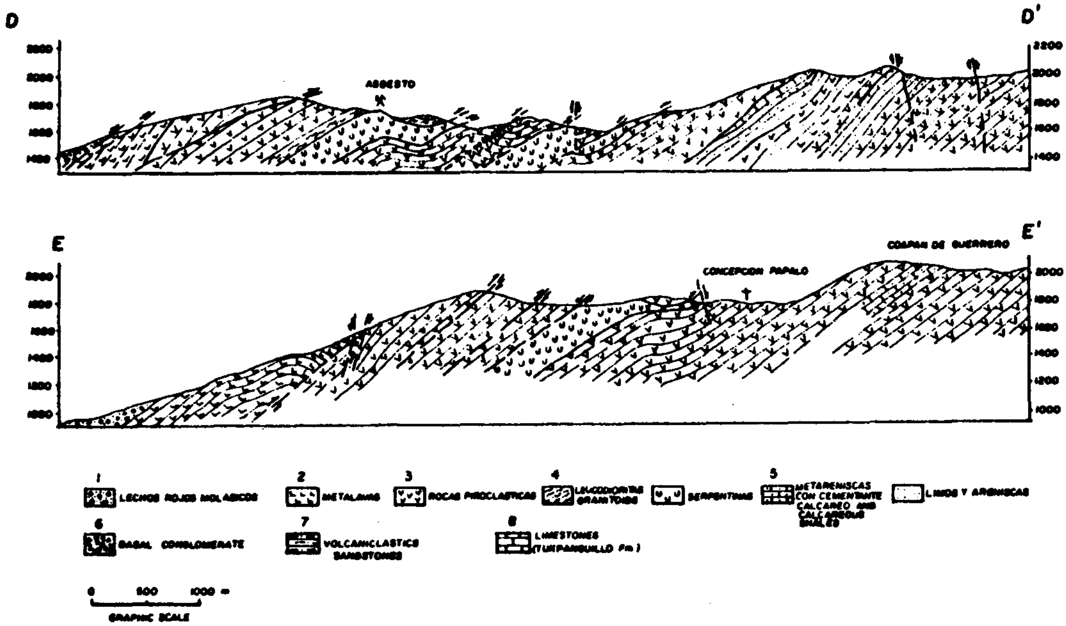


Fig. 3 D, E.

features coincide with an eastward vergence but, toward the central portions (SW San Bernardino), the intrusives tend to be isotropic and deformational features tend to be subvertical.

Petrographic and chemical data indicate a compositional range varying from monzonites to granodiorites (Table 1 and figure 4). Locally, large and continuous segregations (larger than several meters long) of hornblendites and other mafic rocks are important. Their mineralogy is mainly controlled by hornblende, clinopyroxene (diopside-augite), minor plagioclase and sometimes biotite. Matrix is commonly formed by serpentine and poor secondary magnetite when present, which partially indicates an origin after orthopyroxene. Details and petrographic classifications are given in Table 1.

Table 1

Petrographic synthesis of the crystalline sequence

Sample	Locality	Classification	Primary O	Cl	F	Hb	Px	Secondary Ch	Ep	Se	S	T-A	Remarks
X-86-1 C-1	Teotitlan del Camino	Hornblende monzonite	–	X	X	X	.	–	.	–	.	.	Calcite veinlets filling microfractures. Fe chlorite. Sericitized K-spar. Granular texture.
X-86-6 C-2	Vigastepec	Basaltic andesite	.	X	.	.	.	–	–	X	.	.	Hydrothermal calcite and Fe sulfides. Original microlitic matrix. Seriated hypocrystalline texture. Albilization-spilitization.
X-86-9 C-3	Vigastepec	Hornblende monzonite	X	X	–	–	–	–	–	X	.	–	Uralitized clinopyroxene. Selective silicification. Sericitized oligoclase.
X-86-10 C-4	Vigastepec	Pyroxene-rich hornblendite	.	.	.	X	X	–	–	.	X	X	S-matrix. Bastites. Interstitial magnetite. Uralite after clinopyroxene.
X-86-11 C-5	Nogaltepec	Metaandesite	.	–	–	.	.	X	–	–	.	–	Schistose texture. Probably autoclastic in part.
X-86-14 C-6	Tecomavaca	Diorite (cataclastic)	–	X	X	–	.	–	–	–	.	–	Andesine-oligoclase-microcline Secondary minerals fill microfractures. Solid-state ductil flow texture.
X-86-16 C-7	Tecomavaca	Mylonitized andesite	X	.	.	.	.	X	.	X	.	.	Coarse foliation. Flaser texture Magnetite-hematite present. Q-Se matrix.
X-86-23 C-8	Los Cúes	Quartz Monzonite	X	X	.	.	.	–	–	–	.	.	Cataclastic texture. Secondary quartz, 2 chlorite generation. Hydrothermal alteration.
X-86-25 C-9	San Juan Coyula	Serpentinite	.	.	.	.	–	–	.	.	X	–	S-showing interlocking and intergrowth textures (lizardite). Chrysotile along shearing planes Calcite + dolomite. Bastites + magnetite.
X-86-26 C-10	San Juan Coyula	Metagabbro ( )	.	–	.	.	–	X	X	.	–	–	Schistose texture. High epidote content (clinozoisite). Hypersthene relicts. Antophyllite. Fe-chl.

X-86-27 C-11	San Juan Coyula	Talc-chlorite schist	X	.	.	.	.	X	.	–	.	.	Secondary Q. Very high talc-content. Segregated magnetite. Original ultramafic rock hydrothermally altered.
X-86-28 C-12	San Juan Coyula	Talc-serpentine schist	.	.	.	.	–	X	–	–	–	–	High carbonate content. Segregated Q. Pervasive hydrothermal alteration.
08-10 C-13	Concepción Pápalo	Metabasalt	.	X	.	.	–	–	–	.	.	.	Cordierite, spinel, magnetite. Schistose texture.
OX-12 C-14	Concepción Pápalo	Metaandesite	X	X	.	.	.	X	X	–	.	–	Greenschist facies. Highly deformed by shearing.
OX-18 C-15	Concepción Pápalo	Hornblende Metadiorite	.	X	.	X	–	–	–	–	–	–	Secondary Q. S in bastites. Cpx-Uralite.
OX-22 C-16	Concepción Pápalo	Hornblende Diorite	.	X	.	–	–	–	–	.	–	–	Bastites and talc.Intense shearing.
OX-48 C-17	Concepción Pápalo	Andesite	–	X	–	–	.	X	–	–	.	.	Porphyritic texture. Selective propylitization.
OX-21 C-18	Concepción Pápalo	Serpentinite	.	.	.	.	.	X	.	.	X	.	Very high Ch content. High antigorite along veins in lizardite ( ). Low secondary magnetite.
OX-24 C-19	Concepción Pápalo	Serpentinite	.	.	.	.	.	.	.	.	X	.	Bastites. High secondary magnetite. Chrysotile along shearing planes. Interpenetrating antigorite.
OX-33 C-20	San Lorenzo Pápalo	Serpentinite	.	.	.	.	.	.	.	.	X	.	Similar to OX-24.
OX-39 C-21	Concepción Pápalo	Serpentinite	.	.	.	.	.	–	.	.	X	.	Extensional cracks filled by secondary magnetite. Primary oxides 10%. Some antigorite and chlorite.

Minerals: Q = quartz. Pl = plagioclase (mostly oligoclase-andesine). F = K-Spar. Hb = hornblende. Px = pyroxene. Ch = chlorite. Ep = epidote. Se = sericite. S = serpentine. T-A = tremolite-actinolite.
Abundances: X = more than 10%. – = less than 10%. . = traces or absent.

Crystalline extrusive rocks

Metavolcanic flows are spatially associated with granitoids. They are restricted to the western side of the Sierra Mazateca (Figs. 2 and 3). The thickness of the unit, between Cuicatlán and Concepción Pápalo has been estimated to be of about 500 m, but it can be thicker along the section between Coxcatlán and Zoquitán (north of the mapped area). Locally, where tectonic disruption is less accentuated, andesitic flows are interstratified with tuffs and tuffaceous sandstones. Also, in Vigastepec, andesites are present as sills and dikes intruding pellitic and calcareous rocks. Within strongly deformed zones, tuffaceous and sedimentary units are mechanically intruded by andesitic rocks making depositional features extremely difficult to distinguish.

In Coxcatlán, where deformation is less severe, andesites have a pillowed fabric, while near Concepción Pápalo they are massive. Here, leucocratic banding characteristic of zones of strong deformation and mylonitization is observed. Texturally they vary from equigranular to porphyritic when foliation is not penetrative. Subparallel microshearing is also a widespread texture and evolves to a mylonitic to protomylonitic texture. Near Vigastepec (Fig. 2) dikes of andesite intrude polimictic conglomerates and tuffaceous to calcareous sandstones. Locally they grade to porphyritic diorites showing close spatial, temporal and genetic relationships with respect to the granitoids.

Within this unit two small outcrops of metafelsites located on the road Cuicatlán-San Juan Coyula are considered. These rocks are intensely tectonized and they could correspond to late felsitic domes because of their apparent intrusive character with respect to mesocratic metalavas. These metafelsites show abundant secondary limonite after hydrothermal veins of Fe-Cu sulfides, and minor specularite, calcite and quartz. One chemical analysis of this leucocratic rock suggests a strong metasomatic effect (sample II-OX-5).

Under the microscope, most of the metalavas show a more mafic composition than the intrusives. All of them can broadly be classified as mafic schists, but the chemical analyses indicate a range of composition between basalt and basaltic andesite (Fig. 4). In general, metamorphism is considered to be isochemical.

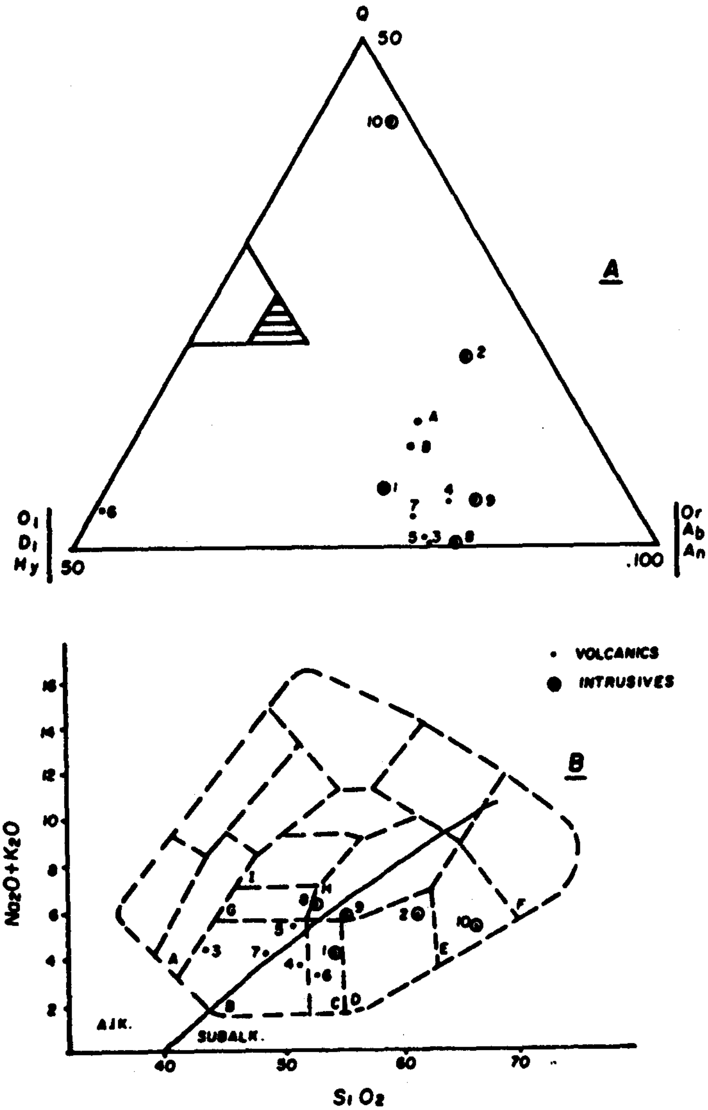


Fig. 4. *a)* Normative classification of volcanic and intrusive rocks after Le Maitre (1976). Points A and B represent average compositions of andesites and diorites, respectively.
b) Chemical classification of volcanic and intrusive rocks after Cox *et al.* (1979). Alkaline-subalkaline dividing line after Irvine and Baragar (1971). Rock fields are: A = basanite, B = basalt, C = basaltic andesite, D = andesite, E = dacite, F = rhyolite, G = hawaiite, H = traquiandesite, I = mugearite.

Volcanosedimentary sequence

Toward the western side of the complex the volcanosedimentary sequence is interstratified with the metalavic sequence, while clastic and calcareous rocks are widely distributed eastward. The last rocks gradually change to a volcaniclastic sequence closely associated to the metalavic unit. The association of metalavas and volcaniclastics seems to define volcanic edifices under regimes of intense erosion. Included into this ambit it is located the polimictic conglomerate which contains fragments of the Zapoteco complex. This association apparently corresponds to a foothill deposit related to a volcanic constructional zone under uplifting.

Metalavas, volcaniclastics, and part of the sedimentary sequences have been named Chivillas Formation since Pano (in Barrientos-Reyna, 1985). He assigned to Chivillas a Valanginian-Barremian age; that age is assumed as correct in this paper and temporarily correlated to the Tuxpanguillo Formation in the Tepexilotla area (Mena-Rojas, 1960).

The serpentinitic bodies of Concepción Pápalo and San Juan Coyula are enclosed in a thick metapyroclastic sequence overlying the metalavas. In the geologic map (Fig. 2 and 6) the volcanic rocks are arbitraryly named Chivillas Formation because of their stratigraphic position. Following the same criterium, the sequence of sandstones (greywackes) and shales, calcareous shales, and the local sequence of conglomerates and conglomeratic sandstones of Vigastepec are considered in the same stratigraphic order in spite of the absence of a detailed facies study. All these lithologic units gradually change to the more calcareous Tuxpanguillo Formation located eastward (Fig. 6 and Table 2). Compositional differences are attributed to local topographic changes and spatial distribution with respect to the volcanic edifices. It is considered that between each of the topographically elevated volcanic centers, local and small (about 10 km wide) basins developed, defining qualitatively distinct sedimentary regimes. An actual example of this situation is found in the Tonga Arc, where internal basins in the order of 30 to 10 km wide show complex sedimentary conditions (Lehner *et al.*, 1983). These types of sedimentary regimes have been documented in almost undisturbed cretaceous areas in Palmar Chico and San Pedro Limón, Estado de México (Delgado-Argote *et al.*, 1988). In Vigastepec and eastward, one of these basins shows little volcanic influence. However, interstratified flows are common in wackes showing high lithic and feldspatic content (samples X-86-3, X-86-7, X86-17, Table 2 and Fig. 2). Within this area, the large volume of clastics

Table 2

Petrographic synthesis of the volcanosedimentary sequence of the northwestern Sierra Mazateca

SAMPLE	LOCALITY	CLASSIFICATION	PRIMARY Q	F	RF	M	SECONDARY Ch	Se	Ep	Q	Ca	REMARKS
X-86-2 S-1	Puerto La Soledad	Conglomeratic sandstone	-	-	X	-	X	-	.	-	X	Volcanic RF (porphyritic andesites + tuffs) and shale fragments. Autigenic Q. Weak foliation.
X-86-3 S-2	Puerto La Soledad	Lithic arkose	-	-	X	-	-	-	.	-	X	Plagioclase + K-Spar. Volcanic metamorphic and sedimentary RF. Autigenic Q.
X-86-4 S-3	Puerto La Soledad	Grainstone	.	.	.	.	.	.	.	.	X	High porosity. Fe-oxides enrichment. Autigenic Q.
X-86-5 S-4	Vigastepec	Petromictic conglomerate	X	-	-	-	X	-	.	.	X	Plagioclase, K-Spar and Q fragments. Cemented by calcite.
X-86-7 S-5	Vigastepec	Arkosic greywacke	X	-	.	X	X	-	.	.	-	Fe chlorite and oxides up to 10%. Plagioclases. High M content.
X-86-13 S-6	Nogaltepec	Crystalline metatuff	X	-	.	-	X	-	.	.	.	Plagioclase showing polisynthetic twinning. K-Spar. Zr inclusions in Q, muscovite. Well defined foliation.
OX-8-15 S-7	Concepcion Papalo	Lithic metatuff	X	-	X	-	-	-	.	-	-	Well foliated. Andesitic RF. Some tremolite and Fe oxides.
X-86-17 S-8	Plan de Guadalupe	Quartzwacke	X	-	.	X	X	-	.	.	.	Plagioclase predominates over K-Spar. Ch and Q-rich matrix. Angular Q fragments
X-86-18 S-9	Plan de Guadalupe	Lithic greywacke	X	-	X	X	X	-	.	.	.	Twinned plagioclase. Volcanic and metamorphic RF.
X86-21 S-10	Plan de Guadalupe -Mazatlan	Crystalline tuff	X	-	.	X	-	X	.	.	.	Plagioclase-K-Spar. Absence of accidental fragments. Q is about 70%. High Se in M.
X-86-22 S-11	Plan de Guadalupe	Lithic greywacke	X	-	-	X	-	X	.	.	.	Volcanic lithics. Q-Se matrix. Fe-chlorite. Plagioclase-K-Spar.
X-86-24 S-12	San Juan Coyula	Metatuff	X	-	.	X	X	-	-	-	.	Ch-Se-Q matrix. Pyroxene and hornblende crystals partially tremolitized. Schistose texture.
OX-8-3 S-13	Concepcion Papalo	Metatuff	X	.	-	.	X	X	.	-	.	Schistose texture. Some biotite present. High Fe-oxides and limonite after sulfides.
OX-8-9 S-14	Concepcion Papalo	Metatuff	.	.	.	.	X	X	X	X	-	High clinozoisite content. Quartz-calcite veinlets. Schistose texture.
OX-8-14 S-15	Concepcion Papalo	Metatuff (Quartz-Sericite schist)	X	.	.	.	X	X	-	-	.	Schistose texture. Close banding of Ep-Se-Q.
OX-8-15 S-16	Concepcion Papalo	Lithic metatuff	X	.	X	-	-	-	.	-	-	Se-rich matrix. Volcanic RF. Schistose texture.

MINERALS: Q= quartz. F = feldspars. F = feldspars. RF = rock fragments. M = matrix. Ch = chlorite. Se = sericite. Ca = calcite. Ep = epidote.
ABUNDANCES: X = more than 10% ; - = less than 10% ; . = traces or absent.

permits to infer that the dimensions of paleobasins were considerably larger than at other places, as in Concepción Pápalo or Pala, where smaller basins were severely deformed. The environment of deposition is inferred to be closed and restricted to water supply as indicated by the presence of carbonaceous material associated with anomalous concentrations of volcanogenic sulfides (Delgado-Argote, in press). Exhalative horizons are made of chalcopyrite, pyrite and minor sphalerite (?) in tuffaceous rocks. Petrographic analyses of tuffaceous and volcanosedimentary rocks are summarized in Table 2.

Sedimentary sequences

This section deals with all the sedimentary units, which are mostly limestones, ranging from Neocomian to Maestrichtian, and are located out of the volcanic domain, east of the Cuicateco Terrane. From bottom to top, this sequence comprises the Neocomian Tuxpanguillo Formation which can be partially correlated to the Chivillas Formation, the Aptian Capolucan Formation, the Albian Orizaba Formation, and the Late Cretaceous Maltrata and Necoxtla Formations (Mena-Rojas, 1960; Barrientos-Reyna, 1985, and figure 6).

In order to show the regional distribution of lithology (a detailed revision on the stratigraphy of the region goes beyond the objectives of this work), the Cretaceous sedimentary units are schematized in figures 6 and 7. In that sense, Morán-Zenteno (1987) and Mossman and Viniegra (1976) are in good agreement with respect to the general paleogeography of the north and northwestern Cuicateco Terrane. The first author mentions a marine transgression on the Tehuacán-Orizaba region since Valanginian time, corresponding to the sedimentary portion of the lower part of the Chivillas Formation. During Barremian-Aptian time, Morán-Zenteno (1987) reports subaerial volcanism westward the Cuicateco region (Petlalcingo-Tlaxiaco), correlative in time to the Chivillas Formation, although this last formation is better defined as a reef-like unit. In both, the Mixteco and Cuicateco terranes, the same sedimentary regime was established since Albian time, related to an extensive transgressive event, which is evidenced by the San Juan Raya Formation in the Mixteco Terrane (Morán-Zenteno, 1987), and the Capolucan and Orizaba Formations, north and northeast of the Cuicateco Terrane (Barrientos-Reyna, 1985; Mossman and Viniegra, 1976). Finally, Mossman and Viniegra (1976) recognized in the states of Oaxaca and Veracruz a Middle Eocene structural disturbance which is correlated to the Tertiary red conglomerates exposed on the foothills of the Tehuacán Basin, mainly from Tehuacán toward San Juan Tilapa.

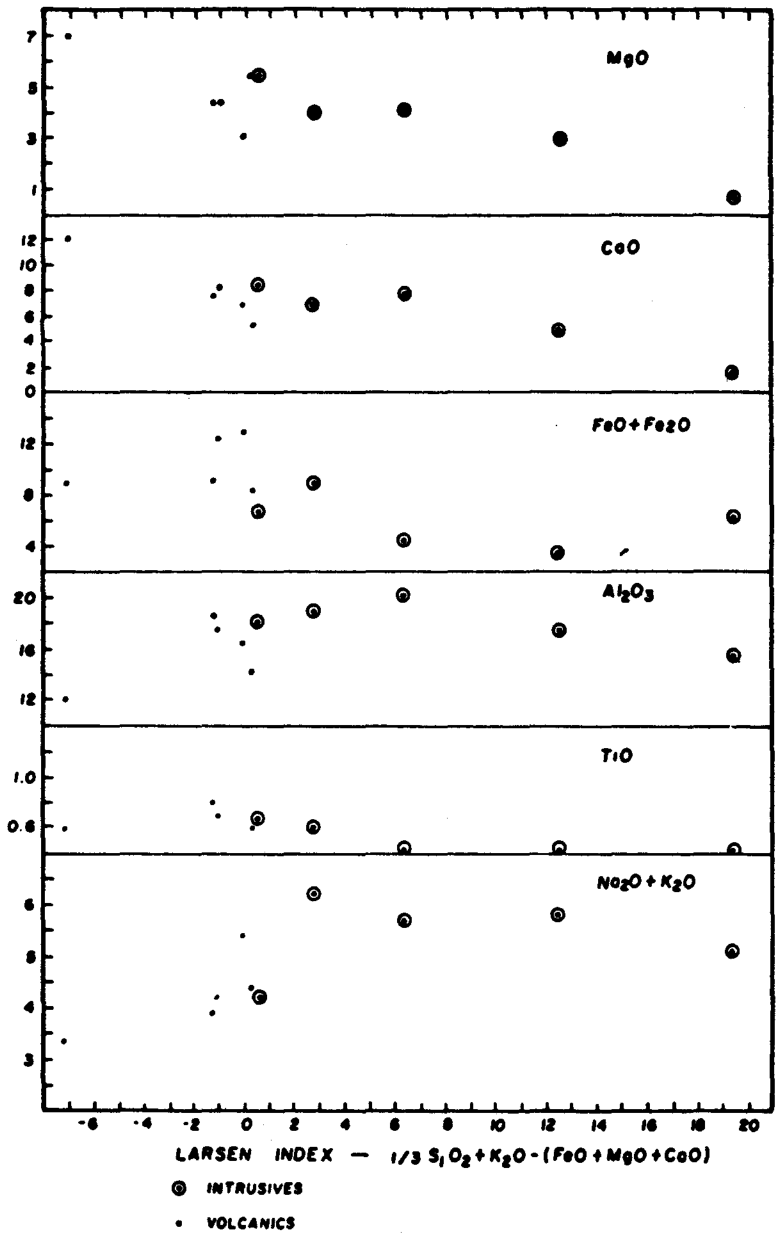


Fig. 5. Variation diagram of major oxides referred to the Larsen Index (1/3 $SiO_2 + K_2O - (FeO + MgO + CaO)$).

Eocene (?) - Oligocene red conglomerates

This unit is restricted to the western foothills (Oaxaca Fault) between San José Tilapa and Cuicatlán. In Cuicatlán, the conglomerates have their thickest expression (about 300 m). The unit is tilted due to continuous uplifting since Oligocene to probably Early Miocene time. It is formed by large subrounded to rounded boulders dominated by metaandesites corresponding to the underlying andesitic unit. As schematized in Fig. 7, its deposition is associated to the Eocene-Oligocene structural disruption which provoked the uplift of the western margin of the Cuicateco Terrane. It is important to notice that this kind of deposits, as well as the intense folding of the Mazateca region are absent in the Mixteco Terrane (Morán-Zenteno, 1987). Centeno-García and co-workers (1987) mention movements in the region of Cuicatlán as young as 100 000 y.b.p., evidenced by morphometric analyses.

Miocene - Pliocene sedimentary cover

The exposure of this cover is restricted to the Tehuacán Valley. It partially overlies the red conglomerates and, in San Gabriel Chilar (south of Tehuacán) it is locally intruded and interfingered by olivine basalts. In this paper, the whole sedimentary material filling the Tehuacán Basin is called Tehuacán Formation. Its age is assumed to range from Miocene to Pleistocene. During the deposition of the Tehuacán Formation along the so-called Oaxaca Fault, various restricted centers of volcanism developed and a series of celadonite-rich horizons are widespread.

DESCRIPTION OF STRUCTURES

The general structure of the Cuicateco Terrane follows a N20°W broad orientation. Both the Eocene compressive deformation as well as the Oligocene distensive disruption follow such tendency. During Eocene time the whole complex was overthrusted eastward, and deformation is particularly intense along the apparent core or nucleus of the magmatic arc. Crystalline units (both intrusive and volcanic rocks) locally show a pervasive cataclastic deformation and were uplifted with respect to the softer sedimentary cover located eastward. The last sequence is in turn partially overthrusted over the easternmost cretaceous platform. Geometrically an "alpha-like" structure (Link, 1949) is developed along the boundary of the main crystalline and sedimentary soft rocks. This structure is interpreted as shown in the cross sections of figure

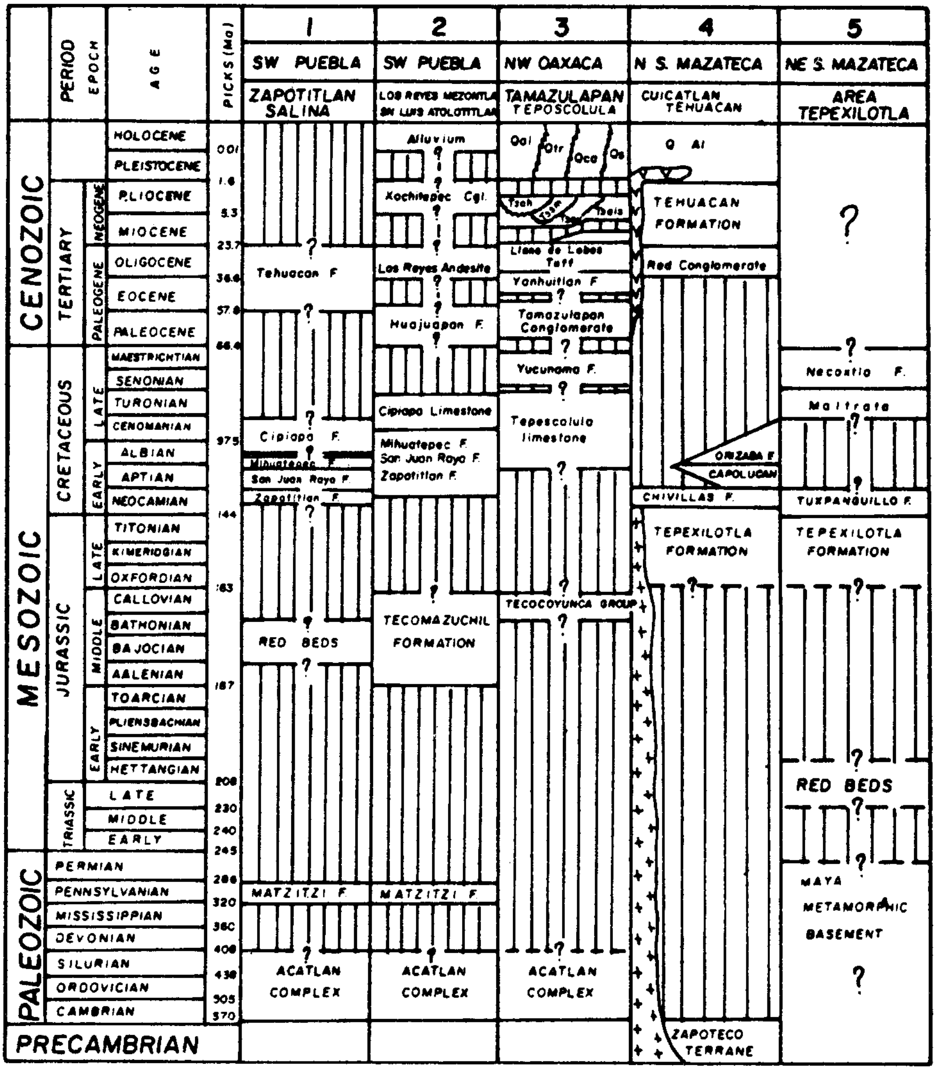


Fig. 6. Stratigraphic correlation between areas of the Mixteca Terrane (Morán-Zenteno, 1987) and Cuicateco Terrane (Sierra Mazateca). Tepexilotla area after Mena-Rojas (1960).

3, where the intrusive and subvolcanic rocks are better exposed. The uplift process is clearly observed in a 7 km wide area located between San José Tilapa and San Juan Los Cúes (Fig. 2), where a pervasive deformation indicated by secondary mineral anisotropy, strong shearing and yuxtaposed crystalline units change eastward, from almost horizontal to subvertical.

The most prominent structures in the Cuicateco Terrane are reverse faulting and foliation. They vary from subhorizontal showing wedge-like structures in soft sedimentary rocks to high angle reverse faults in crystalline rocks (figure 3). From Pochotepec to Concepción Pápalo the orientation of these features broadly change from N20°W to N10°E. The solution of 60 poles of foliation in Concepción Pápalo (Delgado-Argote, in press) indicates that deformation parallels the N10°E regional structures. Associated to the Eocene disruption short strike-slip displacements, oriented in the sense of maximum stress, were developed in the northernmost portion of the mapped area.

In Vigastepec, uplifting and high angle reverse faulting favored the exposure of a structural window composed of basal conglomerates showing fragments of the Zapoteco metamorphic complex. Also during the compressive event, serpentinites were plastically emplaced into the metatuffs along bedding planes (Delgado-Argote, in press); they follow the same structural style of the enclosing metavolcanosedimentary sequence, dipping about 30°W. Shearing and foliation are the most prominent features along which long-fiber asbestos develop. Nicolas and co-workers (1973) have shown through experimental observations that such structures follow the general trend of deformation that, for this area, is congruent with the observed regional style. Some exceptions to this tendency are observed where local crystalline barriers are identified. As it will be discussed later, the emplacement of serpentinites requires the ultramafic mass to be uprised to a certain level, mainly by a diapiric mechanism during the initial phase.

A regional normal faulting event is registered during Oligocene time corresponding to the deposition of the red conglomerates unit of the western margin. This deformation does not have an important expression in the interior of the Sierra Mazateca; however, some normal and local transcurrent faults are observed, and apparently, some fractures were later or contemporarily filled by basaltic dikes which decrease in abundance toward inner zones.

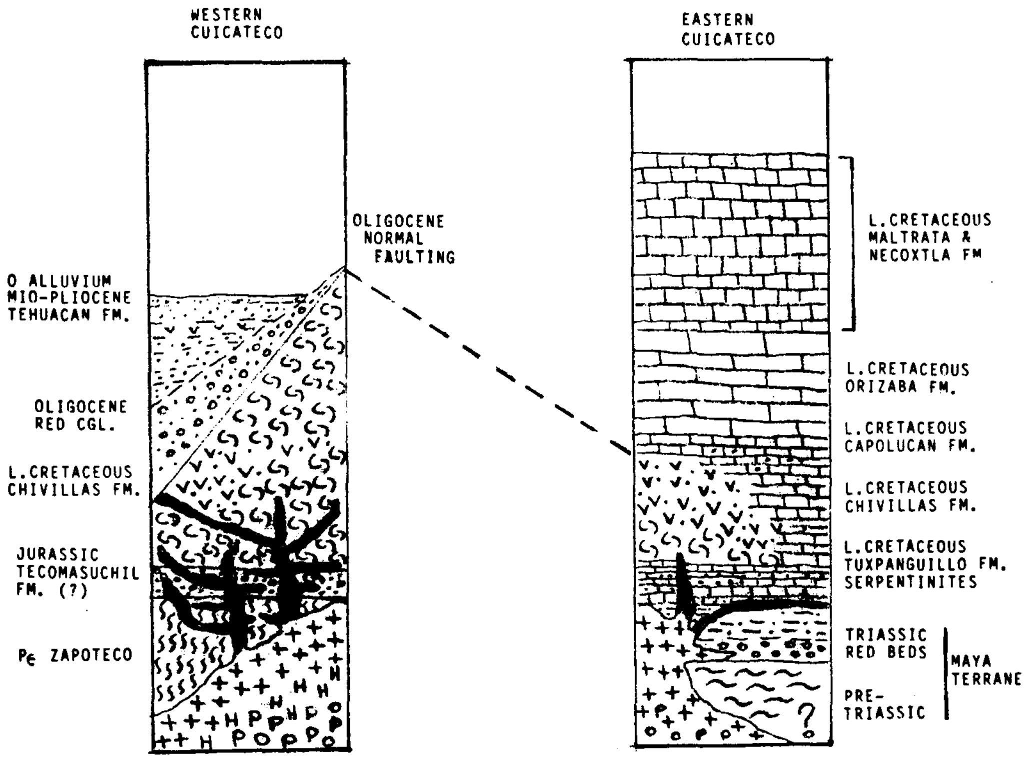


Fig. 7. Schematic correlation between eastern and western Cuicateco Terrane. See Barrientos-Reyna (1985) and MenaRojas (1960) for additional data.

As mentioned earlier, normal faulting and general uplift caused deformation of the Tehuacán Basin, which marks the boundary between the Cuicateco and Mixteco terranes (Figs. 2 and 7). The magnitude of this structure can be estimated from the presence of Pliocene-Pleistocene olivine basaltic flows interfingered with lake deposits. A correlation of main geologic events between the Mixteco, Cuicateco and Maya terranes is given in Table 5.

CHEMISTRY AND D/H ISOTOPIC DATA OF THE CRYSTALLINE SEQUENCE

Bulk chemistry analyses of ten samples on both intrusive and extrusive rocks indicate a wide dispersion in the chemical behaviour of this igneous suite. Chemical data and CIPW norms are given in Table 3; chemical classification of rocks and major oxides behaviour are presented in figures 4 and 5, respectively. A good agreement between chemical (Cox *et al.*, 1979) and petrographic-mineralogic classifications is observed. In the Cox and co-workers (1979) diagram (Fig. 4.b) the alkaline-subalkaline dividing line of Irvine and Baragar (1971) is included. Here four samples are plotted in the alkaline field (sample 3 represents a highly hydrothermally altered rhyolite). By using normative minerals and Le Maitre's (1976) classification diagrams (01-Di-Hy/Q/Or-Ab-An) it can also be observed that the rocks of this suite fall close to the average values of andesites and diorites (Fig. 4a). The lack of extreme composition rocks is a singular characteristic of the volcanic suite with the exception of the tuffaceous portion. In contrast, intrusives show a compositional range varying from granodiorite to diorite. Intrusives showing a high mica and/or garnet content were not included for chemical analyses because they probably involve a strong assimilation from the precambrian country rocks; the ultramafics were studied separately. It should be noted the impoverishment of MgO and normative quartz of this suite when compared with the chemical average andesites and diorites of Le Maitre's (1976).

Several diagrams were tested to define a chemical trend; however, no one was particularly informative to characterize the suite. A typical AFM diagram shows a wide dispersion with a slight tendency toward the tholeiitic field. This tendency is also observed in the FeO/MgO vs. SiO_2 diagram (Miyashiro, 1974). This characterization is considered inconclusive until a broader spectrum of analyses can be obtained. A Larsen Index-variation diagram proved to be more illustrative to show the chemical tendency of the crystalline rocks, with the exception of the volcanic rocks because of their poor compositional variety. In general, a decreasing tendency is observed for MgO, CaO and TiO_2 toward more positive indexes, while Na_2O+K_2O and $FeO+Fe_2O_3$ show a disperse character. Although the low-grade greenschist metamorphism can be considered isochemical, local hydrothermal alteration and/or interaction with marine water can explain the observed lack of chemical regularity, especially for the volcanic rocks.

D/H Isotopic data of serpentinites

Isotopic studies of structural water of chrysotile and lizardite made by Wenner and Taylor, Jr. (1973 and 1974) in North America, have shown a good correlation

Table 3

Whole rock chemistry of the crystalline sequence.
(Wet analyses were performed at the Instituto de Geología, UNAM)

SAMPLE	1	2	3	4	5	6	7	8	9	10
SITE	X-86-9a	X-86-9	II-OX-5	II-OX-7	08-10	X-86-11	II-OX-13	X-86-1	II-OX-7	OX-8-22
ROCK TYPE	DIOR.	MONZ.D.	ALT.RHY.	ANDES.	ANDES. BASALT	ANDES.	BASALT.	DIOR.	DIOR.	DIOR.
SiO_2	54.43	61.95	43.79	51.69	50.83	52.68	48.45	52.13	55.59	66.52
TiO_2	0.65	0.42	0.60	0.82	1.32	0.60	0.85	0.62	0.43	0.60
Al_2O_3	18.00	17.62	14.23	18.67	16.47	12.00	17.49	19.08	19.98	15.77
Fe_2O_3	1.85	0.90	4.52	2.07	5.43	3.18	6.42	3.37	1.54	3.56
FeO	4.73	2.85	4.42	7.14	7.64	6.30	6.00	5.48	2.77	2.65
MgO	5.40	2.88	5.48	4.30	3.08	6.99	4.49	3.90	4.08	0.59
CaO	8.60	4.62	5.17	7.64	7.04	12.16	8.36	6.85	7.84	1.85
Na_2O	3.10	3.60	3.60	3.30	4.80	2.70	2.70	4.60	3.20	2.87
K_2O	1.10	2.20	0.80	0.60	0.65	0.65	1.50	1.60	2.54	2.30
H_2O^+	2.07	2.36	16.72	3.49	2.59	2.53	3.62	2.26	1.99	3.15
H_2O^-	0.00	0.10	0.14	0.03	--	--	--	--	--	--
TOTAL	99.93	99.50	99.47	99.75	99.85	99.79	99.88	99.89	99.96	99.86
					CIPW NORM					
Q	5.60	17.38	0.16	3.99	0.31	3.44	2.78	0.0	4.50	34.31
C	0.0	1.91	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.97
OR	6.92	13.54	5.07	3.92	4.02	3.90	9.26	9.50	15.64	13.02
AB	27.93	31.73	32.65	30.85	42.49	23.22	23.88	39.12	28.22	23.28
AN	34.03	23.87	21.76	37.96	22.47	19.01	32.58	26.82	34.04	8.80
DI	9.85	0.0	3.01	3.31	11.89	36.53	9.33	6.27	5.67	0.0
HY	9.34	6.42	9.70	11.16	5.20	5.29	6.98	2.09	6.72	1.27
OL	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.72	0.0	0.0
MT	2.86	1.36	7.04	3.32	8.26	4.70	9.75	4.92	2.33	4.96
IL	1.32	0.83	1.22	1.72	2.63	1.16	1.69	1.19	0.85	1.10
TOTAL	97.86	97.04	82.61	96.23	97.26	97.26	96.26	97.63	97.97	96.71
LARSEN I.	0.51	12.50	0.29	-1.25	-0.16	-7.07	-1.20	2.74	6.38	19.38

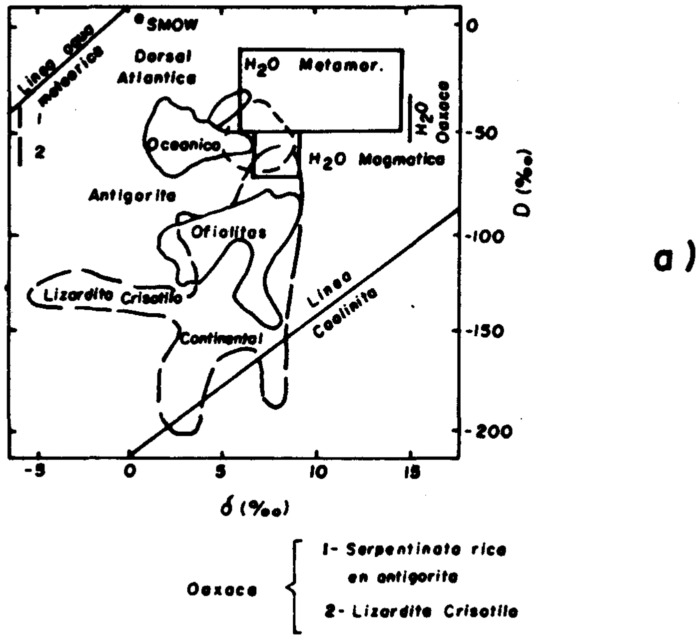
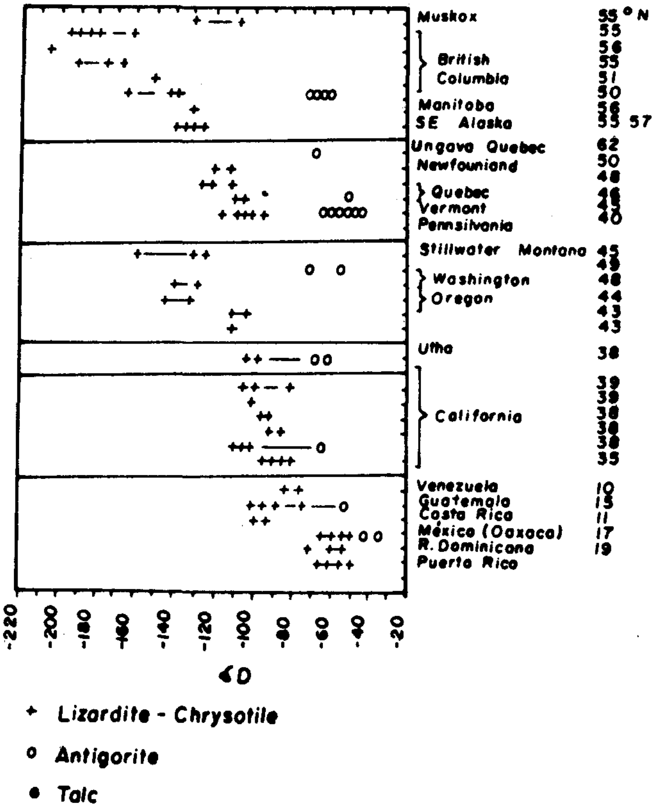


Fig. 8. *a)* D/H-180/160 diagram showing D/H composition of serpentinites from Concepción Pápalo, based on a diagram of Magaritz and Taylor, Jr. (1974).

between D/H ratios and latitude. By contrast, the same authors indicate that antigorite seems to show a closer association with metamorphic water at temperatures below the metamorphic climax. The association lizardite-chrysotile develops under relatively shallow environments at pressures of about 4 Kbars and temperatures less than 200°C (Wenner and Taylor, Jr., 1973). In general, such conditions are in good agreement with the mineralogical and textural criteria given by Wicks and Wittaker (1977) for processes of serpentinization. As mentioned, serpentinites in Concepción Pápalo are constituted mostly of chrysotile and lizardite and local and minor antigorite. It has been reported from structural and mineralogical data (Delgado-Argote, in press) that, to explain the abundance of asbestos, the main serpentinization process in Concepción Pápalo occurred under conditions of shearing stress at relatively constant temperature.

In a preliminary report by Casar-Aldrete *et al.* (1986) a series of analyses were



b)

Fig. 8.b) Correlation between latitude and D/H ratios in North America and Caribbean regions, after Wenner and Taylor, Jr. (1974) and Casar-Aldrete *et al.* (1986).

presented showing that lizardite and chrysotile from Concepción Pápalo correlates well with the D/H ratios expected for the latitude of Oaxaca by Wenner and Taylor, Jr. (1974). The isotopic data is shown in Table 4 and figures 8a and b, and sampling sites are located in figure 2. It can be seen that serpentinites yield D/H ratios of -67 to -53 per mil relative to one or two events of serpentinization, while antigorite-rich serpentines show a narrower range (-44.6 to -38 per mil) apparently related to a dehydration event involving water loss of about 25% of total water content. Details of the experimental analytical conditions are included elsewhere in a progress report.

It is considered that the first generation of serpentines was formed by introduction of meteoric water into the geothermal system and/or during the compressive deformation correlative to the serpentinitic emplacement, in such a way that an early serpentinizàtion and diapirism (involving shearing stress) took place. The whole process overprinted the ratios of the meteoric water that, at the latitude of Oaxaca, ranges between -30 and -50 per mil (Wenner and Taylor, Jr., 1974). The partial water loss involved during formation of antigorite correlates to a Tertiary regional thermal event and basaltic dike emplacement. The results are in agreement with the assumption that during recrystallization to antigorite, water fractionation by expulsion of light hydrogen with respect to deuterium is expected (Coleman, 1971).

Attending only to the isotopic data, formation of antigorite can be associated to metamorphic water (Fig. 8) at temperatures of about 300°C and, as well as metamorphic chlorites, D/H ratios have a restricted range between -39 and -66 per mil (Wenner and Taylor, Jr., 1974). In a preliminar manner, and coincident with textural analyses, hydrogen isotopic data indicate that at least two periods of serpentinization occurred in Concepción Pápalo, and meteoric water played an important role in the serpentinization process during the tectonic emplacement of the ultramafic mass (Casar-Aldrete *et al.*, 1986).

DISCUSSION AND REGIONAL TECTONIC RELATIONS

The tectonic significance of a complex as the Cuicateco Terrane can be discussed in terms of lithologic associations and paleogeography as indiçators of the type of terrane we are dealing with (Table 5). It was mentioned that the Jurassic-Cretaceous Cuicateco Terrane is located between two older crystalline massifs. To the East there are the Maya Terrane and the Permo-Triassic Chiapas Batholith; the western side is dominated by the Precambrian Zapoteco Terrane. Its limits with the Zapoteco are defined by the Tertiary N-S Oaxaca Fault; its Mesozoic cover (Mixteco Terrane; Morán-Zenteno, 1987) shows a substantially different tectonic and sedimentary history with respect to the Cuicateco. The eastern limits are not fully known because of its Upper Cretaceous-Tertiary sedimentary cover. In figure 7, the different rocks of the basement observed in the Cuicateco Terrane, as well as the relative masses of both crystalline and sedimentary rocks are schematically indicated. It is important to observe that the upper limit in the western side of the Cuicateco is drastically marked by the Oaxaca Fault, while its eastern side is interpreted to result from facies changes during Upper Cretaceous. Previous workers have considered

Table 4

Hydrogen isotope analyses and mineralogy of serpentinites from Concepción Pápalo.
(Analyses were performed at the Instituto de Física, UNAM)

	Sample	Mineralogy (1)	Time (2)	Weight (mg)	T°C	D/H (3)
I	OX-8-25	L+C	60	250	878	-53.49
			"	200	880	-58.10
II	OX-8-33	L+C	60	150	1017	-53.52
III	OX-8-36	L+C	60	200	980	-55.02
IV	PAP-16	L+C	60	150	936	-66.29
		"	"	100	967	-67.41
V	OX-8-43	L+C+A	60	100	837	-41.18
		"	"	"	916	-44.62
VI	PAP-14	L+C+A	60	150	967	-40.27
		"	"	100	936	-47.23
VII	PAP-5	L+C+A	60	150	941	-38.24
		"	"	100	1044	-38.01

(1) Mineralogy: L-lizardite, C-chrysotile, A-antigorite
(2) Time: minutes of dehydration
(3) Values given in per mil relative to SMOW

Roman numerals referred in geologic map

that the Cuicateco Terrane is tectonically overposed on the Maya and Gulf Coastal Plain (Campa and Coney, 1983), but no evidences were observed to support such idea. By contrast, the result of our mapping indicates that the more severe deformation is strictly located close to the Zapoteco Terrane and diminishes considerably eastward.

A reconstruction of the "native" Cuicateco Terrane should start with a major uplifting event during Triassic time of both the Mixteco (Morán-Zenteno, 1987) and Maya (Damon and Montesinos, 1974) terranes. Such event leads to a continental sedimentation on the eastern portion of the Cuicateco, and minor magmatism (andesitic to rhyolitic) in the eastern portion of the Mixteco. During Jurassic time, distinct geological regional events were experienced in the Maya and Mixteco terranes, at the same time that initial magmatism was taking place in the actual location of the Cuicateco. Ages of magmatism are supported from unpublished K-Ar data obtained in the Instituto Mexicano del Petróleo (C. Pacheco, personal communication, 1987). Hornblendes of both lava flows and different granitoids from areas close to Pala yield cooling ages ranging from Late Jurassic to Early Cretaceous. At that time, shallow marine sedimentation was taking place, associated to a general marine transgression which continued in several places until Early Cretaceous. During this epoch, general uplifting is reported for the Maya Terrane (Mossman and Viniegra, 1976), as well as a tensional disturbance in the Mixteco (Morán-Zenteno, 1987). Similar conditions were observed in the Sierra Mazateca, particularly in Vigastepec area, where during the construction of volcanic piles, normal faulting incorporated fragments of limestones of the Jurassic Tepexilotla Formation mixed with local volcanic debris and large blocks of graphitic pargneisses of the Zapoteco Terrane. This melange is interpreted to be formed in the borders of an andesitic edifice which was raised at the time of deposition of platform calcareous rocks. The uplifting process can also be inferred from the large size of pillow-like structures in association with marine sediments croping out in Pala, indicating low hydrostatic pressure. Moreover, many andesitic flows of the northern area, as well as the thick deposits of tuffs distributed in the southern portions of the mapped area are interpreted to occur in subaerial environments.

The presence of paragneisses and fragments of the Tepexilotla Formation indicates that the arc-like megastructure of the Cuicateco developed in the limits of the Zapoteco-Mixteco and Maya terranes. This condition defines the Cuicateco as a native terrane (Gray, 1986) and guides to infer the existence of a large cortical discon-

Table 5

Summary of main geologic events in the Mixteco, Cuicateco and Maya terranes

		T E R R A N E S			
		MIXTECO	CUICATECO	MAYA	REMARKS
C E	NIO	local olivine basalt			
N O Z	OLIGO	formation of the Tehuacán Basin	NORMAL FAULTING. UPLIFTING		Oligocene marks an intense episode of separation of the Mixteco-Cuicateco terranes with development of the Tehuacán Basin.
O I C	EOC-PAL	separation of terranes	LOCAL UPLIFTING AND EXPOSURE OF ZAPOTECO LITHOLOGY (BASAMENT) fold and thrust disturbance overthrusted terranes	MARINE SEDIMENTATION	Serpentine emplacement and formation of asbestos in Concepción Pápalo, and exposure of plutonic rocks.
M E S	CRET	ACIDIC TO INTERMEDIATE MAGMATISM. COMPRESSIVE DEFORMATION. GENERAL MARINE TRANSGRESSION.	MARINE TRANSGRESSION DEVELOPMENT OF ARC-LIKE MAGMATISM. UPLIFTING.	MARINE SEDIMENTATION	Main phases of magmatism and different sedimentary regimes in the Mixteco and Maya terranes.
O Z O	JURAS	TENSIONAL DISTURBANCE AND MARINE TRANSGRESSION.	SHALLOW MARINE SEDIMENTATION. RED BEDS SEDIMENTATION (?)	RED BEDS SEDIMENTATION	
I C	TRIAS	UPLIFTING AND BIMODAL VOLCANISM.		UPLIFTING OF GRANITIC BASEMENT. CONTINENTAL RED BEDS SEDIMENTATION	
P A L	PERM	MARINE SEDIMENTATION		UPLIFTING AND BATHOLITIC EMPLACEMENT.	Probable juncture of the Mixteco and Maya terranes before development of magmatism in the Cuicateco Terrane.
E O	PENN	UPLIFTING AND CONTINENTAL SEDIMENTATION			

DATA SOURCE: MIXTECO: Morán-Zenteno, 1987; MAYA: Mossman and Viniegra, 1976; Damon and Montesinos, 1974; CUICATECO: This study.

tinuity. In this respect, preliminar gravimetric data (M. Mena, personal communication, 1987), clearly indicate an important basement slope oriented parallel with respect to the Cuicateco Terrane and at the same time, marking the juncture between the Mixteco and Maya terranes. Crust thickness in the western Mixteco area averages 45 km, and the Maya Terrane, on the eastern part, is about 20 km thick. This west dipping slope is interpreted as a weakness zone where intraplate magmatism took place defining an arc-like system. Although the opening of the Gulf of Mexico had been playing an important role in the development of a wider fracturing zone in the brittle crust, large movements between terranes are not required to induce the diapiric penetration of magma through the lithosphere.

Two important problems to solve are the regional geometry of the Cuicateco magmatic belt and the evolution of a magma chamber capable of permitting differentiation of ultramafic products. In a previous study (Delgado-Argote, in press), it was assumed that the ultramafic rocks of Concepción Pápalo were "roots" of a magmatic arc. In a similar way, it is considered here that these rocks are differentiation products of a parental basaltic magma. Differentiation had to have taken place into the magma chamber and feeder conduits large enough to permit convection. The fact of having ultramafic rocks of deep origin in contact with superficial volcanic rocks, requires of a diapiric mechanism previous to the tectonic emplacement to rise the ultramafic mass to relatively high levels. Such mechanism has been documented in the ultramafic complexes of Guerrero (Delgado-Argote *et al.*, 1986; Delgado-Argote, 1986) where lizardite is the initial product of serpentinization, involving a density loss of about 25% and volume increase of about 30%, with respect to the original ultramafic mass. The depth and dimensions of magma reservoirs associated to andesitic volcanoes of Kamchatka and Alaska have been documented by Gill (1981). He mentions that detailed geophysical studies indicate the presence of magma chambers as large as 30 to 10 km diameter located at 8 to 30 km depth. According to Elder (1981) this type of reservoirs, which operates close to lithostatic equilibrium, can experiment fractional crystallization and conform a geothermal system where serpentinization at relatively high temperature can occur. After the diapiric movement, during the Eocene compressive disturbance, the serpentinitic body was emplaced following the NE structural grain, incorporating regional meteoric water in the structure of serpentinites of second generation (chrysotiles). Dealing with the formation of the ultramafic rocks, Wadge (1982) mentions that a great deal of evidences favor the injection and accumulation of hot basic magma into the bases of large, cooler and more siliceous magma bodies (granitoids). Such bodies are better defined as interconnected dendritic structures which develop a densely fractured permeable medium and, along the boundaries between both contrasting materials, the crystalline phases are deposited, favoring the formation of ultramafic rocks. Wadge (1982) remarks that the mentioned condition is controlled by properties of the whole crust, instead of particular volcanic regimes or local tectonics.

There is an additional problem in the interpretation of the Cuicateco Terrane: its oblique geometry with respect to both a Pacific convergent margin and other magmatic provinces (*i.e.* the Permian Batholith of Chiapas). This problem can be visualized as one of intraplate magmatism, where a process of lithospheric thinning plays an important role (Bonin, 1986). In Oaxaca, it is not easy to demonstrate such situation; however, the distribution of older terranes and the gravimetric slope they produce, seem to define an important lithospheric discontinuity. In addition, stress variations in the lithosphere must play an important role during the evolution of the different volcanic phases in Oaxaca. At this respect, Cloetingh (1986) has shown that major reorganization of plate boundaries (as the experienced in the southern portion of the North America Plate during Upper Jurassic-Lower Cretaceous time, evidenced from sea level fluctuations) can produce changes in stress level of more than 1 kbar, inducing the generation of a deep fracturing system.

In conclusion, it is considered that the processes of magmatism and formation of a series of basins in the Cuicateco Terrane is the result of lithospheric discontinuities instead of a direct subduction mechanism, or a process of oceanization. However, this conclusion remains as a working hypothesis because more chemical detail must be done for the crystalline sequence. Yet, a mechanism associated to subduction cannot be eliminated as a possible generator of a continental magmatic belt.

CONCLUSIONS

The Jurassic-Cretaceous Cuicateco Terrane, centered between Cuicatlán and Teotitlán is defined as a native terrane which developed almost parallel to the boundary between the two older Zapoteco-Mixteco and Maya terranes. The fact that the basal conglomerates of the Cuicateco contains graphitic paragneisses of the Zapoteco, testify their close association. Relationships with respect to the Maya Terrane are obliterated by a common cover of transgressive marine deposits.

Gravimetric data indicate a major cortical discontinuity along the boundary between the Zapoteco and Maya terranes, almost in the same site as for the Cuicateco. This terrane was considerably shortened during the Eocene compressive disturbance. The limits between different terranes are considered a major factor of lithostatics on the location of the magmatic province by a probable process of mantle uprising. The Precambrian terrane is about 40 km thick, in contrast with the Paleozoic Maya Terrane which is only about 20 km thick. An approximate separation of the terranes, prior to the compressive deformation, could be 20 km, equivalent to the width of the zone of vigorous magmatism in the Cuicateco Terrane.

During and after the diapiric ascent of original basaltic magmas, differentiation of ultramafic material took place in the base of magma chambers and along large feeder conduits. The ultramafic mass of Concepción Pápalo rose to upper levels as a consequence of serpentinization, to be tectonically emplaced later, during the Eocene fold and thrust disturbance.

The "roots" of the magmatic province are represented in the western portion of the Cuicateco Terrane by granodioritic to monzonitic rocks which include pyroxenitic to amphibolitic segregations. Almost the entire crystalline rocks show a mylonitic deformation which decreases eastward, indicating a more vigorous uplift along this western margin.

The association of andesitic lavas, tuffaceous and sedimentary rocks (feldspathic wackes grading eastward to calcareous wackes and limestones) defines an environment similar to an island arc with associated small basins (Tonga-like arc). The sequence of tuffs contains a large wedge of serpentinites which show a D/H average ratio of -59, in concordance with present-day meteoric water, indicating its tectonic related formation.

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