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Map and Database of Quaternary Faults in the Vicinity of Managua, Nicaragua

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U.S. Department of the Interior
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MAP AND DATABASE OF QUATERNARY FAULTS IN THE VICINITY OF MANAGUA, NICARAGUA

A project of the International Lithosphere Program Task Group II-2
"Major Active Faults of the World"

Data and map compiled by

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INTRODUCTION

As part of the International Lithosphere Program's "World Map of Major Active Faults," the U.S. Geological Survey (USGS) is assisting in the compilation of a series of digital maps of Quaternary faults and folds in Western Hemisphere countries. The maps show the locations, ages, and activity rates of major earthquake-related features such as faults and fault-related folds. They are accompanied by databases that describe these features and document current information on their activity in the Quaternary. The project is a key part of the Global Seismic Hazards Assessment Program (ILP Project II-0) for the International Decade for Natural Hazard Disaster Reduction.

The project is sponsored by the International Lithosphere Program and funded by the USGS's National Earthquake Hazards Reduction Program. The primary elements of the project are general supervision and interpretation of geologic/tectonic information (Michael N. Machette, Project Chief), data compilation and entry for the fault catalog (all personnel), database design and management (Kathleen M. Haller), and digitization and manipulation of data (Richard L. Dart) in [†]ARCINFO. For the compilation of data, we engage experts in Quaternary faulting, neotectonics, paleoseismology, and seismology. These experts are the primary authors of these reports, and questions about individual fault descriptions should be directed to them. Questions about the project, its status, and the GIS map should be directed to the USGS authors.

Prior to initiating this project, there were no digital maps of active or Quaternary faults for countries within Central and South America, even though understanding the extent and character of active and older Quaternary faults are critical elements of seismic-hazards analysis. Creation of this map and the accompanying database will help extend the relatively short record of instrumental and felt seismicity in the vicinity of Managua, Nicaragua by creating a paleoseismic record of surface deformation associated with large (M>6.5) earthquakes.

Although there have been limited fault studies in the Managua area (Woodward-Clyde, 1975; Dames & Moore-Lamsa, 1978; Cowan, 1998), basic fault data were not available for most of the country. The degree of completeness in the current database varies greatly and is a function the limited nature of previous studies, degree of remoteness and vegetation cover, and lack of critical facilities that often demand detailed fault studies. Information from a variety of sources was compiled by Hugh Cowan to ensure that the product was up to date and provided a fairly uniform coverage for the entire region. Nevertheless, the general state of knowledge for faulting is probably best described as being of a reconnaissance nature, especially outside of Managua. Only a modest amount is known about the overall rates of fault activity and fault chronology—information that is difficult to acquire but critical to seismic-hazard assessments.

STRATEGY AND PURPOSE

Given the limited time to produce the map (several years), the project was restricted to compilation of just those elements needed for ILP's Global Seismic Hazards Assessment Program (see database). We anticipate that the project will point out the shortcomings of past and current research on Quaternary faulting in the Managua area in terms of quantity, quality, scope, and regional coverage and should help promote new efforts to collect paleoseismological data in previously neglected or known critical areas. In many cases, seismicity is used to define some potentially active faults, especially along active plate margins. However, recent faulting events in the Western Hemisphere have shown that much of the faulting away from active plate margins occurs along faults with no significant level of seismicity and that only a fraction of active faults are characterized by ongoing seismicity. Thus, the information on Quaternary faulting included within this database should help extend the modern (past several hundred years) record of seismicity into prehistoric time, and allow better assessments of active and potentially active faults in the Managua area and other Western Hemisphere countries.

[†] Any use of trade names (such as this and others in the report) does not imply endorsement by the U.S. Geological Survey or Department of Interior.

PREPARATION OF THE MAP AND DATABASE

This compilation shows evidence for activity on Quaternary faults and folds in the Managua area, particularly in the region around metropolitan Managua and the western margin of Lago de Nicaragua. The map data were compiled by Hugh Cowan, partly in preparation for a paleoseismology workshop in Managua (Cowan, 1998). Hugh Cowan used available published and unpublished literature, recent geological investigations, and interpretation of aerial photographs to compile map and text data. The data and map were reviewed by Eugene Schweig (U.S. Geological Survey, Memphis, TN) and revised by the authors in September 2000. Machette edited the text and map and provided guidance for the project under the International Lithosphere Program's Task Group II-2 "Major Active Faults and Folds of the World," for which he is the Co-chairman (Western Hemisphere).

Digitization of the fault and fold data was accomplished by Karen Morgan and Richard Dart (USGS) using GIS (Geographic Information System) technology in May 2000. The traces of Quaternary faults and folds were digitized at 1:525,000 scale, attributed for age, sense of slip, and line type (continuous, discontinuous, and concealed or inferred). The maps were prepared with ARC/INFO version 7.1.2 running under Solaris version 2.5.1 on a Unix workstation and transformed using a Mercator projection. The GIS data are scale independent, but should not be used in more detail than about 1:250,000 scale (about 2 times the digitized scale). Data for the fault endpoints, length, and average strike were generated from the ARC/INFO files. The final map was prepared in Adobe Illustrator by Lee-Ann Bradley.

The base-map information for the map was taken from the Digital Chart of the World, which was created for use with ARC/INFO (copyright 1993 by the Environmental Systems Research Institute, Inc.). The Digital Chart of the World was compiled at a scale of 1:1,000,000, which is about one half the scale of the digitized fault map. The Digital Chart of the World was originally developed for the U.S. Defense Mapping Agency (DMA) and is primarily derived from the DMA Operational Navigation Chart (ONC) Series. Some place names were modified in accordance with usage in Nicaragua.

THE MAP

The map of Quaternary faults and folds of Nicaragua is based on a hand-drawn figure by Hugh Cowan and Xavier Amador at about 1:1,000,000 scale (Cowan, 1998, fig. 3). This data was enlarged and replotted by Cowan on the National Map of Nicaragua (1:525,000 scale, 1995 edition, UTM projection). The fault data were digitized from the national base map and imported into ARC/INFO. The scale of the digital source allows output as a single-country map (1:500,000 to 1:1,000,000 scale) using a 36-inch wide printer, while retaining all significant digital information. Output at more detailed scales, such as for various states (departments) or the Managua area (1:200,000 to 1:300,000 scale) magnifies errors in the location of structures, and should only be done with appropriate caution.

In addition to fault location and style, the map shows times of most recent movement and estimates of slip rate (as a proxy for fault activity). Although as many as five categories of Quaternary faults can be depicted on some of the Western Hemisphere maps, only three categories were used in Nicaragua:

Historic (generally <300 years),

Holocene and latest Pleistocene (post glacial, <15,000 years or <15 ka),

Quaternary (<1,600,000 years or <1.6 Ma).

Categories for late Quaternary (<130 ka) and late and middle Quaternary (<750 ka) time were not used owing to the general lack of stratigraphic and chronological control needed to make these age calls This categorical time scheme allows some flexibility in reporting between countries owing to the differing levels of investigation and abilities to date prehistoric faulting.

Three ranges of slip rates depicted by differing lines are shown on the map in order to differentiate known rates of fault activity:

>5 mm/yr—Plate-boundary faults and subduction zones (very high slip rates),

1-5 mm/yr—Lesser strike-slip and major extensional faults (medium to high slip rates)

<1 mm/yr—Most extensional and intraplate faults (low to very low slip rates)

Actual slip-rate determinations are sparse in the Managua area, but the senior author specified slip rate categories using the above guidelines as well as geomorphic and paleoseismic information. Thus, most faults in the Managua area with "unknown slip rates" are designated low or very low and drawn with the <1-mm/yr line thickness.

THE DATABASE

The purpose of the database is to provide a catalog of fault data that can be readily accessed using a variety of search parameters. For this database, we anticipate that the user would want search-and-retrieve capabilities from a personal computer. The user may want to sort the data by such parameters as fault name, time of most recent movement (one of three categories), slip rate (one of three categories), sense of movement, or by multiple parameters.

The process of data compilation starts with data acquisition and synthesis. In the case of faults, the compiler must determine if the structure is a simple one, or if it qualifies as having sections (increasing complexity of geometry or fault history). Then using the appropriate form, the compiler tabulates information on the fault's parameters. The forms were built in Microsoft Word for the Macintosh.

After this report is released, we will incorporate suggested changes and additions; then import the data to the computer database. Each of the fields is a potential search object. The use of a computer database program allows us to custom format the reporting of data and to collapse unused fields or notes. The basic fields are restricted to 256 characters, but we use the note option for more explanatory information (shown under comments in this report).

The fault and fold data will be released in several forms. This open-file report constitutes a traditional hard-copy catalog (database) and map for the Managua area of Nicaragua. The Nicaragua data will eventually be part of a larger relational computer database for Latin America that should be available on the World Wide Web (WWW). This interactive WWW product allows the user to browse, sort, and print the data.

TECTONIC SETTING OF QUATERNARY DEFORMATION IN NICARAGUA

Late Quaternary faulting in Nicaragua has been documented only at a few localities along the volcanic chain, at the Pacific margin of the Caribbean Plate. The regional tectonics is dominated by relative convergence of the Cocos Plate at a rate of about 8 cm/year (DeMets and others, 1994). The subducted Cocos slab (plate) descends of the northeast beneath the Pacific margin of Nicaragua at an angle of about 80° (see for example, Protti and others, 1995). Beneath the volcanic chain, the subducted slab is at a depth of 200 km (Hernandez and others, 1994) as shown by seismicity.

The volcanic chain is characterized by a NW-SE-trending alignment of stratocone and shield volcanoes located within the Nicaragua depression, which separates the interior highlands (to the northeast) from the coastal hills (to the southwest). The depression extends from El Salvador (on the north) to Costa Rica (on the south) and has been represented as a regional-scale graben bounded by long faults (Weyl, 1980). Recent studies have shown that only a short (30-50 km) portion of the depression is bounded by the Mateare fault, west of the capital city of Managua. Other, short (10 km) faults at the north margin of the depression show no evidence of recent movement (van Wyk de Vries, 1993).

The volcanic chain is superimposed on older igneous and marine sedimentary rocks of Tertiary (>1.6 Ma) age that crop out in the interior highlands and the Pacific coast, respectively (Instituto Geografico Nacional, 1972). The Nicaragua depression may reflect isostatic response (downdropping) to the emplacement of Tertiary volcanic and intrusive complexes in the adjacent highlands (Weinberg, 1993).

In the Managua area, the volcanic chain exhibits a pronounced offset of about 15 km to the south—from volcan Momotombo on the northwest shore of Lake Managua to the Masaya caldera southeast of the metropolitan area. The step-over region is associated with the Managua graben, which is defined by a closely spaced system of Quaternary strike-slip and oblique-normal faults that show evidence of mild east-west extension and strike-slip movement along north and northeast trends.

KINEMATICS

Stoiber and Carr (1973) proposed that the subducted Cocos Plate might be segmented beneath the arc (that is, divided into subplates), thus accounting for the lateral offset in the volcanic chain at Managua. Subsequent studies of seismicity in this region, however, have concluded that there is no evidence for sharp breaks in the geometry of the subducted Cocos Plate (Bevis and Isacks, 1984; Hernandez and others, 1994; Protti and others, 1995). Alternative models have been proposed by Malfait and Dinkelman (1972) and Manton (1987) that involve block rotations and eastward motion of the Caribbean Plate in response to movement along the Caribbean-North America plate boundary.

Many of the mapped faults in the Managua are have a left-lateral sense of movement. This movement seems anomalous in view of the right-lateral offset of the volcanic chain at Managua. Dewey and Algermissen (1974) suggested that relation might be resolved if the volcanic chain were associated with NE-SW directed rifting. The geometric offset across the Managua area would thus be analogous to an oceanic, ridge-ridge transform, accommodating left-lateral strike slip. However, no direct evidence of active extension has been reported from the Nicaraguan depression, and new geological and geodetic studies are clearly needed to resolve the regional kinematics.

DEFINITION OF DATABASE TERMS

The following terms, which are shown in Spanish and English in the fault descriptions, provide data for specialized fields that will be searchable when the computer database is released. In addition to the specialized fields, more detailed information is provided in the "Comments" section that follows some fields. If a field is empty, marked unknown, or has been deleted, no pertinent information was found in the published literature. The following description provides definitions of fields (in alphabetic order) and indicates where various information, if known, can be found. Citations of references are in USGS format, although foreign language citations are as provided by the compilers.

Average dip General down-dip direction of the structure, where known.

Average strike The length-weighted average strike of the fault trace is reported in the northwest and northeast quadrants of the compass (i.e., -30° is N30°W., versus 30° which is S30° E). The error limits that follow the strike describe the range for all vectors contained with the trace of that particular fault or collection of faults. These values are included only to provide a general impression of the sinuosity or variability in strike of the mapped structures. Some fault zones include a fault with a wide variety of strikes, and thus the error limits are large.

Compiler, affiliation and date of compilation The name and affiliation of the person(s) primarily responsible for compilation or update of data presented for the structure. Also shown is the date when data were compiled for this project (e.g., October 1998).

Fault geometry This heading includes geographic information pertinent to the fault or fault section being described. The data include length, average strike, average dip, and sense of movement.

Geomorphic expression General description of the structure's geomorphic expression including information on the presence or absence of fault scarps, offset streams, monoclines, shutter ridges, associated landslides, etc.

Historical surface faulting When the timing of most recent movement on a fault is historic, then this field(s) describes evidence for surface faulting associated with historical earthquakes. Also included is seismological information for the historical earthquake.

Length This field specifies the end-to-end length of the Quaternary-age fault (or fault section) as measured from the most distal ends of the trace. The ends of overlapping or echelon traces are projected to a line defined by the average strike and the length is then determined from those projected end points. Also shown (in parentheses) is the cumulative length of all surface traces included in the fault, fault zone, or collection of faults.

Name (**Fault name** or **Section name**) The earliest referenced name for a structure or fault section (where appropriate) generally is given preference, except in cases where a more commonly accepted name is widely used in the recent literature. "Comments" may also contain other names and references in which they are used, the geographic limits of the structure, north to south or west to east, as shown in this compilation; various geographic limits that are different than in other studies are also included. Minor changes in original name may have been made for reasons of clarity or consistency (such as segment to section) where appropriate. We have found no faults in Nicaragua that justify using the term "segment", owing to a lack of precise timing information.

Number

Structure number The structure (fault or fold) is assigned a number that is preceded by a two character abbreviation (Nicaragua fault number 1 is NE-01) that is unique to each of the countries in

the Western Hemisphere. References to the same structure shown in other compilations, such as CR-01 are included in "Comments".

Section number An alpha character is assigned to the northernmost or westernmost section of a fault; however, no faults in the Managua area have been sectioned (yet).

Number of sections (only used for faults with sections) Numeric value for number of sections (e.g., 2) defined in studies that do not meet the minimum requirements for segments established for this compilation. Comments include reference in which sections are discussed: if the term "segment" is used in the literature, an explanation of why "section" is used in the database is provided.

Recurrence interval Time interval in yr (based on historic data, calendric or calibrated radiocarbon dates), in ^{14}C yr (based on uncalibrated radiocarbon dates), or in k.y. (thousands of years, based on less precise dating methods, stratigraphy, or geomorphology). Unknown is shown if there is no published recurrence interval value. Alternative published recurrence intervals, starting with that which applies to the most recent time interval, are included in "Comments." No faults in Nicaragua have established recurrence intervals.

References A bibliographic citation is included for all references pertinent to each structure. Papers published in Spanish are cited in Spanish, and may not conform to USGS style.

Section A geographic, geometric, structural portion of a fault or collection of faults that appear(s) to have a different character than adjacent portions of the fault (or fold). Typically, not enough information exists to show that this portion of the fault acts independently of adjacent portions, and thus does not qualify as a bona fide "segment" of a fault in a paleoseismic sense. There are no known faults with proven segments or sections in Nicaragua. Further research is needed to document additional faults with sections or those with sections that may in fact be segments.

Sense of movement Includes thrust, less than 45° dip; reverse, greater than 45° dip; right-lateral strike slip (dextral); left-lateral strike slip (sinistral); or normal faults. For oblique slip, the principle sense of movement is followed by secondary sense (i.e., dextral, normal).

Slip rate The primary field shows an actual value or one of several slip-rate categories used for the map part of this compilation: <0.2 mm/yr, 0.2-1 mm/yr, 1-5 mm/yr, or >5 mm/yr. Very few faults in Nicaragua have established slip rates. “Unknown" precedes the suspected slip-rate or slip rate category if no published slip rate is known. "Comments" may include a synopsis of published slip rates and pertinent documentation. Generally speaking, there are two types of slip rates. The first type is termed a “Geologic slip rate” and is derived from the age and amount of offset of surficial geologic deposits. These rates are not precise, but allow one to place broad limits on possible slip rates, and hence characterize the fault in one of the above-mentioned categories. All slip rates from Nicaragua are geologically determined. The second type of slip rate is termed a “Paleoseismic slip rate” and is derived from times of faulting events and amounts of offset of geologic datums or piercing point. This type of slip rate is more precise, but are rare owing to the extensive amount of work involved (i.e., detailed paleoseismologic studies involving trenching and numeric dating).

Fault/fold name (see Name)

Fault/fold number (see Number)

Synopsis and geologic setting This field provides a short summary that describes the level of study, a snapshot of the scope of data that follows, and a generalized perspective of the fault in terms of its regional geologic setting, amount of total offset, and general age of offset strata. Not all faults in the database have a synopsis and discussion of geologic setting.

Timing of most recent event (faulting or folding event) The primary field shows one of the two prehistoric time categories: latest Quaternary (Holocene and latest Pleistocene, <15 ka) or Quaternary (<1.6 Ma). This field may document historic surface faulting, although details of the earthquake related to the faulting will follow.

Type of studies: This field briefly summarizes the types of studies conducted on the fault.

ACKNOWLEDGEMENTS

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DATABASE OF QUATERNARY FAULTS IN THE VICINITY OF MANAGUA, NICARAGUA

NI-01, LA PELONA FAULT ZONE

NUMERO DE LA FALLA/FAULT NUMBER: NI-01
NOMBRE DE LA FALLA/FAULT NAME: La Pelona (fault zone)
SINOPSIS Y AMBIENTE GEOLOGICO/SYNOPSIS AND GEOLOGIC SETTING: These short faults are oriented N10°E to N30°E, normal to the axial trend of the Nicaraguan volcanic chain, and cut across lava and tephra deposits associated with La Pelona caldera. No detailed studies of faulting have been made, but the volcanic deposits are of late Quaternary age suggesting young (late Pleistocene to Holocene movement).
COMPILADOR, AFILIACION Y FECHA DE COMPILACION/COMPILER, AFFILIATION, & DATE OF COMPILATION: Hugh Cowan, Instituto de Geociencias, Universidad de Panamá, Panamá City, Panamá; October 1998.
TIPOS DE ESTUDIOS/TYPE OF STUDIES: Air photo interpretation and limited volcanological field studies.
GEOMETRIA DE LA FALLA/FAULT GEOMETRY:
LONGITUD/LENGTH: 10.8 km (end to end); 19.9 km (cumulative)
RUMBO PROMEDIO/AVERAGE STRIKE: 22.6°±9° (N22.6°E±9°)
INCLINACION PROMEDIO/AVERAGE DIP: Unknown
SENTIDO DE MOVIMIENTO/SENSE OF MOVEMENT: Unknown
Comentarios/Comments: Absolute motion unknown, but a strong normal component is known.
EXPRESION GEOMORFOLOGICA/GEOMORPHIC EXPRESSION: Faults cut across late Quaternary lava and tephra deposits associated with La Pelona caldera. No information exists about the related scarps.
INTERVALO DE RECURRENCIA/RECURRENCE INTERVAL: Unknown
TASA DE MOVIMIENTO/SLIP RATE: Unknown, probably <1 mm/yr/
EDAD DEL ULTIMO MOVIMIENTO/TIME OF MOST RECENT OF MOVEMENT: Holocene and post glacial (<15 ka)
Probably latest Pleistocene or Holocene, based on preservation of scarps on weakly consolidated volcanic deposits of late Quaternary age.
REFERENCIAS/REFERENCES
Martinez, M., and Viramonte, J.G., 1971, Geologia de la Cordillera de los Marabios: Catastro e Inventario de Recursos Naturales, Managua, Nicaragua.
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NI-02, LA PAZ CENTRO FAULT ZONE

NUMERO DE LA FALLA/FAULT NUMBER: NI-02
NOMBRE DE LA FALLA/FAULT NAME: La Paz Centro (fault zone)
SINOPSIS Y AMBIENTE GEOLOGICO/SYNOPSIS AND GEOLOGIC SETTING:
These faults are oriented N45°W to N30°E, and located north of the town of La Paz Centro. The faults are mostly downthrown to the north and are associated with a shallow half-graben that is occupied by a northwestern arm of Lake Managua (Lago de Managua on map). The half graben is bounded to the north by the Monte Galan caldera and the active Momotombo volcanic stratocone. The longest element (strand) in the fault zone is El Recreo, which extends 17 km from El Recreo on the shore of Lake Managua, to Laguna Asososca on El Hoyo massif. Laguna Asososca is elongated northwest along strike and sub-parallel fractures have been documented on El Hoyo massif, including several fractures that opened during eruptions in 1953-54 (McBirney and Williams, 1965).
El Hoyo massif and Monte Galan caldera coincide with a change in the dominant fault trend, from northwest to north and northeast. Numerous craters and small volcanic cones are located in this area; most are aligned along a north-south trend (van Wyk de Vries, 1993). Several large (M>6.0)

earthquakes have been documented in this area during the past 300 years (Leeds, 1974). None have been correlated with surface faulting, but no studies of faulting have been made.

COMPILADOR, AFILIACION Y FECHA DE COMPILACION/COMPILER, AFFILIATION, & DATE OF COMPILATION: Hugh Cowan, Instituto de Geociencias, Universidad de Panamá, Panamá City, Panamá; October 1998.

TIPOS DE ESTUDIOS/TYPE OF STUDIES: Air photo interpretation and volcanological field studies.

GEOMETRIA DE LA FALLA/FAULT GEOMETRY:

LONGITUD/LENGTH: 22.6 km (end to end); 37.7 km (cumulative)

RUMBO PROMEDIO/AVERAGE STRIKE: -3.1°±33° (N3.1°W±33°)

INCLINACION PROMEDIO/AVERAGE DIP: Unknown

SENTIDO DE MOVIMIENTO/SENSE OF MOVEMENT: Unknown

Comentarios/Comments: Absolute motion unknown, but a strong normal component is obvious.

EXPRESION GEOMORFOLOGICA/GEOMORPHIC EXPRESSION: See comments in synopsis.

INTERVALO DE RECURRENCIA/RECURRENCE INTERVAL: Unknown.

TASA DE MOVIMIENTO/SLIP RATE: Unknown, probably 0.2-1.0 mm/yr

EDAD DEL ULTIMO MOVIMIENTO/TIME OF MOST RECENT OF MOVEMENT: Holocene and post glacial (<15 ka)

Comentarios/Comments: Probably latest Pleistocene or Holocene. Some of the faults offset the Malpaisillo ignimbrite deposits (<100 k.y.) and tephra deposits from the Momotombo stratocone that are possibly Holocene in age.

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van Wyk de Vries, B., 1993, Tectonics and magma evolution of Nicaraguan volcanic systems:, Unpublished Ph.D. thesis, The Open University, London, 276 pp.

NI-03, MATEARE FAULT ZONE

NUMERO DE LA FALLA/FAULT NUMBER: NI-03

NOMBRE DE LA FALLA/FAULT NAME: Mateare (fault zone)

SINOPSIS Y AMBIENTE GEOLOGICO/SYNOPSIS AND GEOLOGIC SETTING: The Mateare fault zone forms part of a prominent topographic escarpment that extends 30 km west from Sierras de Managua before passing beneath the western shore of Lake Managua, near the termination of El Recreo fault (La Paz Centro fault zone [NI-02]). The northeast-facing topographic escarpment is as much as 200 m high and is formed on ignimbrites deposits of Las Sierras Formation (late? Quaternary age). The escarpment is deeply dissected yet retains a steep, linear profile. West of the town of Mateare, the fault is composed of several smaller scarps. Brown and others (1973) suggested that the Mateare fault is active, although no evidence of late Holocene faulting has been reported and the area had been seismically quiescent during the previous 25 years of instrumental monitoring.

COMPILADOR, AFILIACION Y FECHA DE COMPILACION/COMPILER, AFFILIATION, & DATE OF COMPILATION: Hugh Cowan, Instituto de Geociencias, Universidad de Panamá, Panamá City, Panamá; October 1998.

TIPOS DE ESTUDIOS/TYPE OF STUDIES: Air photo interpretation and volcanological field studies.

GEOMETRIA DE LA FALLA/FAULT GEOMETRY:

LONGITUD/LENGTH: 36.5 km (end to end); 73.7 km (cumulative)

RUMBO PROMEDIO/AVERAGE STRIKE: -50.0°±18° (N50.0°W±18°)

INCLINACION PROMEDIO/AVERAGE DIP: Unknown

SENTIDO DE MOVIMIENTO/SENSE OF MOVEMENT: Unknown

Comentarios/Comments: Absolute motion unknown, but the fault has a strong down to the NE normal component.

EXPRESION GEOMORFOLOGICA/GEOMORPHIC EXPRESSION: The topographic escarpment is as much as 200 m high and is deeply dissected, yet it has a steep, linear profile. West of the town of Mateare, the fault is comprised of several smaller scarps.
INTERVALO DE RECURRENCIA/RECURRENCE INTERVAL: Unknown.
TASA DE MOVIMIENTO/SLIP RATE: Unknown, probably 0.2-1.0 mm/yr
EDAD DEL ULTIMO MOVIMIENTO/TIME OF MOST RECENT OF MOVEMENT: Unknown, probably Quaternary (<1.6 Ma)
Comentarios/Comments: The fault is probably as young as late or latest Pleistocene based on the age of offset ignimbrite deposits of late(?) Quaternary age
REFERENCIAS/REFERENCES
Brown, R.D., Ward, P.L., and Plafker, G., 1973, Geologic and seismologic aspects of the Managua, Nicaragua earthquake of December 23, 1972: U.S. Geological Survey Professional Paper 838, 34 pp.
McBirney, A.R., and Williams, H., 1965, The volcanic history of Nicaragua: University of California Publication Geological Sciences, v. 55, 65 pp.

NI-04, ASOSOSCA-ACAHUALINCA AND SAN JUDAS FAULTS (MANAGUA GRABEN)

NUMERO DE LA FALLA/FAULT NUMBER: NI-04
NOMBRE DE LA FALLA/FAULT NAME: Asososca-Acahualinca and San Judas (Managua graben)
SINOPSIS Y AMBIENTE GEOLOGICO/SYNOPSIS AND GEOLOGIC SETTING: The western margin of the Managua graben is defined by volcanic cinder cones and collapse pits that extend south from the Apoyeque caldera along a trend known as the Nejapa-Miraflores alignment (see for example Bice, 1980). The Asososca-Acahualinca and San Judas faults form east-facing escarpments along the western margin of the Managua graben. Woodward-Clyde Associates (1975) have documented Holocene displacement at several localities on these faults.
COMPILADOR, AFILIACION Y FECHA DE COMPILACION/COMPILER, AFFILIATION, & DATE OF COMPILATION: Hugh Cowan, Instituto de Geociencias, Universidad de Panamá, Panamá City, Panamá; October 1998.
TIPOS DE ESTUDIOS/TYPE OF STUDIES: Air photo interpretation and trenching following the 1972 Managua earthquake.
GEOMETRIA DE LA FALLA/FAULT GEOMETRY:
LONGITUD/LENGTH: 12.7 km (end to end); 14.4 km (cumulative)
RUMBO PROMEDIO/AVERAGE STRIKE: 6.3°±11° (N6.3°E±11°)
INCLINACION PROMEDIO/AVERAGE DIP: 60° east to vertical
SENTIDO DE MOVIMIENTO/SENSE OF MOVEMENT: Unknown
Comentarios/Comments: Absolute motion unknown, sinistral is suspected, but the fault has a strong down-to-east normal component.
EXPRESION GEOMORFOLOGICA/GEOMORPHIC EXPRESSION: Fault forms east-facing escarpments along the westerm margin of the Managua graben.
INTERVALO DE RECURRENCIA/RECURRENCE INTERVAL: Unknown.
TASA DE MOVIMIENTO/SLIP RATE: Unknown, probably 0.2-1.0 mm/yr.
EDAD DEL ULTIMO MOVIMIENTO/TIME OF MOST RECENT OF MOVEMENT: Holocene and post glacial (<15 ka)
Comentarios/Comments: Holocene movement inferred from offset of ash layers.
REFERENCIAS/REFERENCES
Bice, D.C., 1980, Tephra stratigraphy and physical aspects of recent volcanism near Managua: Unpublished Ph.D. Thesis, University of California at Berkeley, 422 pp.
Brown, R.D., Ward, P.L., and Plafker, G., 1973, Geologic and seismologic aspects of the Managua, Nicaragua earthquake of December 23, 1972: U.S. Geological Survey Professional Paper 838, 34 pp.
van Wyk de Vries, B., 1993, Tectonics and magma evolution of Nicaraguan volcanic systems: Unpublished Ph.D. thesis, The Open University, London, 276 pp.

Woodward-Clyde Associates, 1975, Investigation of active faulting in Managua, Nicaragua and vicinity: Final Report to Vice Ministerio de Planificacion Urbana, Gobierno de la Republica de Nicaragua, Woodward-Clyde Associates, Oakland, CA.

NI-05, ESTADIO FAULT

NUMERO DE LA FALLA/FAULT NUMBER: NI-05

NOMBRE DE LA FALLA/FAULT NAME: Estadio

Comentarios/Comments: Fault named after Estadio General Somoza (as shown on map by Brown and others, 1973), a large stadium on the western side of Managua.

SINOPSIS Y AMBIENTE GEOLOGICO/SYNOPSIS AND GEOLOGIC SETTING: This NNE-trending fault is located in the western portion of the Managua graben. Surface ruptures along a 2 km length were associated with a shallow moderate magnitude earthquake on March 31, 1931.

COMPILADOR, AFILIACION Y FECHA DE COMPILACION/COMPILER, AFFILIATION, & DATE OF COMPILATION: Hugh Cowan, Instituto de Geociencias, Universidad de Panamá, Panamá City, Panamá; October 1998.

TIPOS DE ESTUDIOS/TYPE OF STUDIES: Air photo interpretation and trenching following the 1972 Managua earthquake.

GEOMETRIA DE LA FALLA/FAULT GEOMETRY:

LONGITUD/LENGTH: 3.2 km (end to end); 3.2 km (cumulative)

Comentarios/Comments: Only 2 km on land, m extends unknown distance into Lake Managua.

RUMBO PROMEDIO/AVERAGE STRIKE: 26.2°±12° (N26.2°E±12°)

INCLINACION PROMEDIO/AVERAGE DIP: Subvertical

SENTIDO DE MOVIMIENTO/SENSE OF MOVEMENT: Left-lateral strike slip

Comentarios/Comments: Sinistral strike-slip with a minor normal component that is down to the east, based on reactivation during 1972 earthquake.

EXPRESION GEOMORFOLOGICA/GEOMORPHIC EXPRESSION: Little or no geomorphic expression; however, area is heavily built over.

INTERVALO DE RECURRENCIA/RECURRENCE INTERVAL: Unknown.

TASA DE MOVIMIENTO/SLIP RATE: Unknown, probably 0.2-1 mm/yr.

EDAD DEL ULTIMO MOVIMIENTO/TIME OF MOST RECENT OF MOVEMENT: Historic (1931)

FALLAMIENTO HISTORICO EN SUPERFICIE/HISTORICAL SURFACE FAULTING: Yes

NOMBRE DEL TERREMOTO/NAME OF EARTHQUAKE: 1931 Managua earthquake

Comentarios/Comments: The urban population of Managua in 1931 was around 40,000. About 1,000 people were killed and the central districts were severely damaged due to the collapse of buildings and by the fires that followed (Sultan, 1931).

FECHA/DATE: March 31, 1931

MAGNITUD O INTENSIDAD/MAGNITUDE OR INTENSITY: M_b 5.3-5.9

MOMENT MAGNITUDE: Unknown, probably <M6 owing to shallow depth.

LONGITUD DE RUPTURA/LENGTH OF SURFACE RUPTURE: > 2 km

Comentarios/Comments: Brown and others (1973) show the 1931 rupture as fault E on plate 1. This fault has an approximate on shore length of 2.0 km (Sultan, 1931), although its expression is poor and it may extend further NE beneath Lake Managa.

DESPLAZAMIENTO MAXIMO/MAXIMUM SLIP AT SURFACE: Unknown

SENTIDO DE MOVIMIENTO/SENSE OF MOVEMENT: Left-lateral

Comentarios/Comments: Sinistral strike-slip during 1972 earthquake.

REFERENCIAS/REFERENCESREFERENCIAS/REFERENCES

Brown, R.D., Ward, P.L., and Plafker, G., 1973, Geologic and seismologic aspects of the Managua, Nicaragua earthquake of December 23, 1972: U.S. Geological Survey Professional Paper 838, 34 pp.

Sultan, D.I., 1931, The Managua earthquake: Military Engineer, v. 23, p. 354-361.

Woodward-Clyde Associates, 1975, Investigation of active faulting in Managua, Nicaragua and vicinity: Final Report to Vice Ministerio de Planificacion Urbana, Gobierno de la Republica de Nicaragua, Woodward-Clyde Associates, Oakland, CA.

NI-06, TISCAPA FAULT

NUMERO DE LA FALLA/FAULT NUMBER: NI-06

NOMBRE DE LA FALLA/FAULT NAME: Tiscapa

Comentarios/Comments: Named for the faults location near Laguna Tiscapa, a volcanic crater lake on the south margin of the downtown area of Managua.

SINOPSIS Y AMBIENTE GEOLOGICO/SYNOPSIS AND GEOLOGIC SETTING: This relatively long (20 km or more) NNE-trending series of faults is located in the western part of the Managua graben. Surface rupture occurred along these faults during the December 23, 1972 earthquake. The 1972 earthquake ruptured four, NNE-trending faults (A-D, plate 1, Brown and others, 1973), of which the largest is the Tiscapa fault (fault C). The sense of displacement was left-lateral oblique, with aggregate horizontal movements in the range 2 to 38 centimeters, however, three of the four faults showed a minor vertical component of slip (Brown and others, 1973). Aftershocks defined a rupture zone that extended at least six kilometers offshore beneath Lake Managua, but not more than 8-10 km in depth.

COMPILADOR, AFILIACION Y FECHA DE COMPILACION/COMPILER, AFFILIATION, & DATE OF COMPILATION: Hugh Cowan, Instituto de Geociencias, Universidad de Panamá, Panamá City, Panamá; October 1998.

TIPOS DE ESTUDIOS/TYPE OF STUDIES: Air photo interpretation, documentation of surface faulting in 1972-73, and trenching following the 1972 earthquake.

GEOMETRIA DE LA FALLA/FAULT GEOMETRY:

LONGITUD/LENGTH: 20.8 km (end to end); 20.3 km (cumulative)

Comentarios/Comments: About one half of trace is on land; extends north into Lake Managua.

RUMBO PROMEDIO/AVERAGE STRIKE: 24.2°±7° (N24.2°E±7°)

INCLINACION PROMEDIO/AVERAGE DIP: Subvertical

SENTIDO DE MOVIMIENTO/SENSE OF MOVEMENT: Left-lateral

Comentarios/Comments: Left-lateral strike slip, with a minor down to east normal component.

EXPRESION GEOMORFOLOGICA/GEOMORPHIC EXPRESSION: The fault has little or no geomorphic expression in the former downtown area, but a clear left-lateral offset of several meters is evident on the northeast wall of Laguna de Tiscapa (crater lake). Southwest from Laguna de Tiscapa, the Tiscapa fault forms a prominent, east-facing topographic escarpment as much as 20 m high.

INTERVALO DE RECURRENCIA/RECURRENCE INTERVAL: Unknown.

TASA DE MOVIMIENTO/SLIP RATE: Unknown, probably 0.2-1 mm/yr.

EDAD DEL ULTIMO MOVIMIENTO/TIME OF MOST RECENT OF MOVEMENT: Historic (1972)

FALLAMIENTO HISTORICO EN SUPERFICIE/HISTORICAL SURFACE FAULTING: Yes

NOMBRE DEL TERREMOTO/NAME OF EARTHQUAKE: 1972 Managua earthquake

Comentarios/Comment: The urban population of Managua in 1972 was around 500,000. The western portion of the city, including the downtown area, was largely destroyed by structural collapse and fire; an estimated 11,000 people died, 20,000 were injured, and more than 200,000 people were left homeless. The economic cost of earthquake damage exceeded 40 percent of the gross national product (GNP) (Coburn and Spence, 1992).

FECHA/DATE: December 23, 1972

MAGNITUD O INTENSIDAD/MAGNITUDE OR INTENSITY: M_s 6.2, M_b 5.6

MOMENT MAGNITUDE: Unknown

LONGITUD DE RUPTURA/LENGTH OF SURFACE RUPTURE: >15.4 km

Comentarios/Comment: Movement occurred on 4 faults with lengths ranging from 1.6 to 5.9 km, plus perhaps another 6 km beneath Lake Managua based on aftershock (Brown and others, 1973). The minimum cumulative length of rupturing is 15.4 km.

DESPLAZAMIENTO MAXIMO/MAXIMUM SLIP AT SURFACE: Aggregate horizontal movements in the range of 2 to 38 centimeters.

SENTIDO DE MOVIMIENTO/SENSE OF MOVEMENT: Left-lateral strike-slip.

REFERENCIAS/REFERENCES

Brown, R.D., Ward, P.L., and Plafker, G., 1973, Geologic and seismologic aspects of the Managua, Nicaragua earthquake of December 23, 1972: U.S. Geological Survey Professional Paper 838, 34 pp.

Coburn, A., and Spence, R., 1992, Earthquake Protection: New York, Wiley Publishing, 355 p.

Woodward-Clyde Associates, 1975, Investigation of active faulting in Managua, Nicaragua and vicinity: Final Report to Vice Ministerio de Planificacion Urbana, Gobierno de la Republica de Nicaragua, Woodward-Clyde Associates, Oakland, CA.

NI-07, AEROPUERTO FAULT

NUMERO DE LA FALLA/FAULT NUMBER: NI-07

NOMBRE DE LA FALLA/FAULT NAME: Aeropuerto

SINOPSIS Y AMBIENTE GEOLOGICO/SYNOPSIS AND GEOLOGIC SETTING: The Aeropuerto fault is a north-south-trending structure associated with an east-facing topographic escarpment that bounds a deeper, eastern portion of the Managua graben. The surface trace of the Aeropuerto fault is slightly convex to the east and extends north from Las Jaguitas an unknown distance offshore beneath Lake Managua. The topographic escarpment of the Aeropuerto fault is formed on pyroclastic flows of Quaternary age. The fault is sub-vertical and its scarp has a maximum height of about 10-12 m at the western boundary of the International Airport. Recent field studies and trenching (associated with a paleoseismicity workshop) has revealed that the fault is active, with the last rupture being historic (but undated) sometime during the period from 1650 to 1880 A.D. (Cowan, 1998).

COMPILADOR, AFILIACION Y FECHA DE COMPILACION/COMPILER, AFFILIATION, & DATE OF COMPILATION: Hugh Cowan, Instituto de Geociencias, Universidad de Panamá, Panamá City, Panamá; October 1998.

TIPOS DE ESTUDIOS/TYPE OF STUDIES: Air photo interpretation, field mapping, and exploratory trenching.

GEOMETRIA DE LA FALLA/FAULT GEOMETRY:

LONGITUD/LENGTH: 15.2 km (end to end); 16.5 km (cumulative)

Comentarios/Comments: About two thirds of trace is on land; extends north into Lake Managua.

RUMBO PROMEDIO/AVERAGE STRIKE: 3.0°±6° (N3.0°E±6°)

INCLINACION PROMEDIO/AVERAGE DIP: Subvertical

SENTIDO DE MOVIMIENTO/SENSE OF MOVEMENT: Oblique-normal slip

Comentarios/Comments: Strike slip (unknown sense), with a normal component down to east

EXPRESION GEOMORFOLOGICA/GEOMORPHIC EXPRESSION: The fault scarp has a maximum height of about 10-12 m at the western boundary of the International Airport. Stream drainage north of the airport is strongly fault controlled, and late Holocene shorelines of Lake Managua are offset across the fault.

INTERVALO DE RECURRENCIA/RECURRENCE INTERVAL: Unknown.

TASA DE MOVIMIENTO/SLIP RATE: Unknown, probably 0.2-1 mm/yr.

EDAD DEL ULTIMO MOVIMIENTO/TIME OF MOST RECENT OF MOVEMENT: Historic (1650 to 1880)

Comentarios/Comments: Trenching revealed that faulted layers contain pottery fragments and pot rim sherds. Overlying unfaulted layers have been dated at 170±50 and 170±40 ^{14}C years B.P. Cowan (1998) concluded that the most recent event was historic and associated with a large earthquake sometime between 1650-1880 A.D., but probably before 1820 A.D.

NOMBRE DEL TERREMOTO/NAME OF EARTHQUAKE: Unnamed

FECHA/DATE: Not determined

Comentarios/Comments: Possible events include the 1765 or 1772 earthquakes (Leeds, 1974).

MAGNITUD O INTENSIDAD/MAGNITUDE OR INTENSITY: Unknown

MOMENT MAGNITUDE: Unknown

LONGITUD DE RUPTURA/LENGTH OF SURFACE RUPTURE: Unknown

REFERENCIAS/REFERENCES

Cowan, H. (compiler), 1998, Workshop in Paleoseismology, Managua, Nicaragua, March 16-22, 1998: Seismic Microzonation Project, Managua, Nicaragua, CEPREDENAC-NORAD-ILP-USGS, 33 pp., 7 figures, 5 appendices.

Leeds, D.J., 1974, Catalog of Nicaraguan earthquakes: Bulletin of the Seismological Society of America, v. 64, p. 1135-1158.

Woodward-Clyde Associates, 1975, Investigation of active faulting in Managua, Nicaragua and vicinity: Final Report to Vice Ministerio de Planificacion Urbana, Gobierno de la Republica de Nicaragua, Woodward-Clyde Associates, Oakland, CA.

NI-08, UNAMED FAULTS, EASTERN MANAGUA GRABEN

NUMERO DE LA FALLA/FAULT NUMBER: NI-08
NOMBRE DE LA FALLA/FAULT NAME: Unnamed (faults in eastern Managua graben)
SINOPSIS Y AMBIENTE GEOLOGICO/SYNOPSIS AND GEOLOGIC SETTING: These north-trending fault traces disrupt the floor of the eastern part of the Managua graben, extending north from Masaya caldera to Sabana Grande and continuing north to Lake Managua, passing east of the International Airport. In several places, these faults are associated with prominent surface trace escarpments that bound or are on young (possibly 1772) lava flows.
COMPILADOR, AFILIACION Y FECHA DE COMPILACION/COMPILER, AFFILIATION, & DATE OF COMPILATION: Hugh Cowan, Instituto de Geociencias, Universidad de Panamá, Panamá City, Panamá; October 1998.
TIPOS DE ESTUDIOS/TYPE OF STUDIES: Air photo interpretation
GEOMETRIA DE LA FALLA/FAULT GEOMETRY: Air photo interpretation
LONGITUD/LENGTH: 20.5 km (end to end); 25.4 km (cumulative)
RUMBO PROMEDIO/AVERAGE STRIKE: -4.5°±7° (N4.5°W±7°)
INCLINACION PROMEDIO/AVERAGE DIP: Subvertical
SENTIDO DE MOVIMIENTO/SENSE OF MOVEMENT: Strike slip
Comentarios/Comments: Strike slip (unknown sense), with a normal down to east component.
EXPRESION GEOMORFOLOGICA/GEOMORPHIC EXPRESSION: These north-trending fault traces disrupt the floor of Managua graben. In several places, these faults are associated with prominent surface trace escarpments that bound or are on young (possibly 1772) lava flows.
INTERVALO DE RECURRENCIA/RECURRENCE INTERVAL: Unknown.
TASA DE MOVIMIENTO/SLIP RATE: Unknown, probably 0.2-1 mm/yr.
EDAD DEL ULTIMO MOVIMIENTO/TIME OF MOST RECENT OF MOVEMENT: Holocene and post glacial (<15 ka)
Comentarios/Comments: Certainly Holocene, but possibly historic (1772 A.D.) (Cowan, 1998; Leeds, 1974).
FALLAMIENTO HISTORICO EN SUPERFICIE/HISTORICAL SURFACE FAULTING: Unknown
REFERENCIAS/REFERENCES

Cowan, H. (compiler), 1998, Workshop in Paleoseismology, Managua, Nicaragua, March 16-22, 1998: Seismic Microzonation Project, Managua, Nicaragua, CEPREDENAC-NORAD-ILP-USGS, 33 pp., 7 figures, 5 appendices.
Leeds, D.J., 1974, Catalog of Nicaraguan earthquakes: Bulletin of the Seismological Society of America, v. 64, p. 1135-1158.

NI-09, COFRADIA FAULT, EASTERN MANAGUA GRABEN

NUMERO DE LA FALLA/FAULT NUMBER: NI-09
NOMBRE DE LA FALLA/FAULT NAME: Cofradia (eastern Managua graben)
SINOPSIS Y AMBIENTE GEOLOGICO/SYNOPSIS AND GEOLOGIC SETTING: The eastern margin of the Managua graben and the eastern shore of Lake Managua are defined by the Cofradia fault, which forms a prominent escarpment as much as 15 m above the adjacent graben floor. The Cofradia fault extends south to the Masaya caldera as a series of en echelon scarps and is associated with numerous hot springs. At Tipitapa, previous studies have documented about six meters of post middle Holocene uplift of lacustrine deposits above the modern lake shoreline in the Cofradia fault zone (Dames and Moore-Lamsa, 1978).
COMPILADOR, AFILIACION Y FECHA DE COMPILACION/COMPILER, AFFILIATION, & DATE OF COMPILATION: Hugh Cowan, Instituto de Geociencias, Universidad de Panamá, Panamá City, Panamá; October 1998.

TIPOS DE ESTUDIOS/TYPE OF STUDIES: Air photo interpretation, trenching and mapping by Dames and Moore-Lamsa (1978).

GEOMETRIA DE LA FALLA/FAULT GEOMETRY:

LONGITUD/LENGTH: 39.8 km (end to end); 46.9 km (cumulative)

RUMBO PROMEDIO/AVERAGE STRIKE: 4.2°±13° (N4.2°E±13°)

INCLINACION PROMEDIO/AVERAGE DIP: 70°W to subvertical

SENTIDO DE MOVIMIENTO/SENSE OF MOVEMENT: Normal?

Comentarios/Comments: Significant normal down to west component.

EXPRESION GEOMORFOLOGICA/GEOMORPHIC EXPRESSION: The fault forms a prominent escarpment as much as 15 m above the graben floor. The fault extends south to the Masaya caldera as a series of en echelon scarps and is associated with numerous hot springs.

INTERVALO DE RECURRENCIA/RECURRENCE INTERVAL: Unknown.

TASA DE MOVIMIENTO/SLIP RATE: 1.2 mm/yr

Comentarios/Comments: Placed in the 1-5 mm/yr slip rate category based on about 6 m of relative uplift of lake deposits dated at 5±1 k.y. (1.2 mm/yr). If one uses the older date (on peat, see below), the rate is still about 1 mm/yr.

EDAD DEL ULTIMO MOVIMIENTO/TIME OF MOST RECENT OF MOVEMENT: Holocene and post glacial (<15 ka)

Comentarios/Comments: At Tipitapa, previous studies have documented lake deposits about six meters above the modern lake shoreline in the Cofradia fault zone (Dames and Moore-Lamsa, 1978). These deposits were dated at about 4000 C^{14} years (on shells) and 6000 C^{14} years (on peat).

REFERENCIAS/REFERENCES

Cowan, H. (compiler), 1998, Workshop in Paleoseismology, Managua, Nicaragua, March 16-22, 1998: Seismic Microzonation Project, Managua, Nicaragua, CEPREDENAC-NORAD-ILP-USGS, 33 pp., 7 figures, 5 appendices.

Dames & Moore-Lamsa, 1978, Informe final del Estudio Geologico de las Cuidades del Sistema Metropolitano, Vice Ministerio de Planificacion Urbana, Gobierno de la Republica de Nicaragua.

NI-10, OCHOMOGO FAULT ZONE

NUMERO DE LA FALLA/FAULT NUMBER: NI-10

NOMBRE DE LA FALLA/FAULT NAME: Ochomogo (fault zone)

SINOPSIS Y AMBIENTE GEOLOGICO/SYNOPSIS AND GEOLOGIC SETTING: This northeast-trending fault zone is located between the Mombacho and Zapatera volcanoes, about 25 km south of Granada. One of the faults is associated with about 500 m of apparent right-lateral offset of Eocene limestones. The faults pass offshore into Lake Nicaragua then reappear on Zapatera Island, where they exert a strong control on the volcanic structures. Faulted tephra layers have been reported and two local collapses of Volcan Mombacho are controlled by this fault system (van Wyk de Vries, 1993). The most pronounced geomorphic evidence of faulting is on Isla Zapatera, where a 150-m-high scarp bisects the northeast part of the island and controls several eruptive features.

COMPILADOR, AFILIACION Y FECHA DE COMPILACION/COMPILER, AFFILIATION, & DATE OF COMPILATION: Hugh Cowan, Instituto de Geociencias, Universidad de Panamá, Panamá City, Panamá; October 1998.

TIPOS DE ESTUDIOS/TYPE OF STUDIES: Air photo interpretation, field mapping by Hradecky (1988) and Cruden (1989).

GEOMETRIA DE LA FALLA/FAULT GEOMETRY:

LONGITUD/LENGTH: 22.3 km (end to end); 52.2 km (cumulative)

RUMBO PROMEDIO/AVERAGE STRIKE: 59.2°±27° (N59.2°E±27°)

INCLINACION PROMEDIO/AVERAGE DIP: Subvertical

SENTIDO DE MOVIMIENTO/SENSE OF MOVEMENT: Dextral

Comentarios/Comments: The southern fault in this elongate zone is shown as dextral (right lateral); sense for other faults unknown.

EXPRESION GEOMORFOLOGICA/GEOMORPHIC EXPRESSION: The most pronounced geomorphic evidence of faulting is on Isla Zapatera, where a 150-m-high scarp bisects the northeast part of the island and controls several eruptive features.

INTERVALO DE RECURRENCIA/RECURRENCE INTERVAL: Unknown.

TASA DE MOVIMIENTO/SLIP RATE: Unknown, probably 0.2-1.0 mm/yr

EDAD DEL ULTIMO MOVIMIENTO/TIME OF MOST RECENT OF MOVEMENT: Holocene and post glacial (<15 ka)

Comentarios/Comments: Holocene timing is based on age of volcanic deposits.

REFERENCIAS/REFERENCES

Cruden, A.R., 1989, The structure of southwestern Nicaragua: a preliminary assessment: Swedish Geological, SGAB International AB, Uppsala, Sweden, 28 pp.

Hradecky, P., 1988, Geologia del Volcan Mombacho y sus alrededores: INETER Archive, Managua, Nicaragua.

van Wyk de Vries, B., 1993, Tectonics and magma evolution of Nicaraguan volcanic systems: The Open University, London, unpublished Ph.D. thesis, 276 pp.

Table 1. Data for Quaternary faults in the vicinity of Managua, Nicaragua

Number	Name of fault	Sense of movement	Time of most recent movement	Slip rate (mm/yr)
NI-01	La Pelona fault zone	Unknown, normal component	<15 ka	Unknown, probably 0.2-1.0
NI-02	La Paz Centro fault zone	Unknown, normal component	<15 ka	Unknown, probably 0.2-1.0
NI-03	Mateare fault zone	Unknown, normal component	<1.6 Ma?	Unknown, probably 0.2-1.0
NI-04	Asososca-Acahualinca and San Judas faults (Managua graben)	Unknown, normal component	<15 ka	Unknown, probably 0.2-1.0
NI-05	Estadio fault	Left-lateral (sinistral)	Historic (1931)	Unknown, probably 0.2-1.0
NI-06	Tiscapa fault	Left-lateral (sinistral)	Historic (1972)	Unknown, probably 0.2-1.0
NI-07	Aeropuerto fault	Oblique-normal slip (lateral sense unknown)	Historic (1650 to 1880)	Unknown, probably 0.2-1.0
NI-08	Unnamed faults, eastern Managua graben	Oblique-normal slip (lateral sense unknown)	<15 ka, maybe historic (1772?)	Unknown, probably 0.2-1.0
NI-09	Cofradia fault, eastern Managua graben	Normal?	<15 ka	1.2 mm/yr
NI-10	Ochomogo fault zone	One right lateral (dextral), others not reported	<15 ka	Unknown, probably 0.2-1.0