Margins Volcanoes Field Trip July 2001 Nicaragua

Michael J. Carr

Image taken from INETER web site.

Note that lakes Managua and Nicaragua are missing.

Nicaraguan Volcanoes Field Trip

July 15 Sunday-Domingo Masaya-Las Sierras Volcanic Center
THEMES:
1. The Masaya-Las Sierras center is at the maximum in the $^{10}Be/^{9}Be$ subduction signal in Central America. It is just SE of the maximum Ba/La and U/Th subduction signals. From here to the Nicaragua/Costa Rica border (SE) there is a rapid decline in subduction signal, measured by several different ratios. Why? If you have a good idea, there is a further complication. The mid-late Tertiary mafic rocks on the NE side of the Nicaraguan Depression show the same southeasterly decline in Ba/La (Balzer, Plank, and Carr in progress). So, why the regional change in Ba/La and why has it apparently persisted for at least 15 my?

2. The Las Sierras exposures present an opportunity to infer the history and determine the rate of growth of a major volcanic center, thus providing constraints on geochemical fluxes out of the volcanic front. Also, to what extent is this a silicic center?

3. Las Sierras-Masaya is a highly explosive shield volcano/caldera complex with the world's highest $^{10}Be/^{9}Be$. Its volume of about 180 km^3 makes it the largest volcanic center in Nicaragua and sixth largest in Central America. It consists of a broad flat ignimbrite shield, Las Sierras, that is broken by old caldera(s) and two recent ones, the smaller, silicic Apoyo caldera and the larger, mafic Masaya caldera.

The Apoyo Caldera erupted dacitic pumice and ash in a sequence of fall and flow deposits that began about 23,000 years ago. Sussman (1982) estimates a volume of about 7 to 11 km^3 DRE, which is roughly the same as the volume of the caldera. The Apoyo caldera may have been preceded by a low shield volcano (Sussman (1982). Geographically, it appears to be part of the Las Sierras-Masaya massif.

Masaya is a puzzling volcano, famous in volcanology for having mafic Plinian eruptions and mafic ignimbrites and surges (Williams, 1983) and famous in geochemistry for having the highest $^{10}Be/^{9}Be$ found at an arc volcano. Using the U/La-Ba/Th plot of Patino et al (2000), Masaya apparently received a full dose of subducted components- altered MORB, carbonate and hemipelagic muds. Both volcanology and geochemistry argue that a volatile rich source feeds Masaya, making this an extremely hazardous volcano; especially so, given it's location adjacent to major population centers.

Petrologically, Masaya has a tholeiitic (low pressure) fractionation pattern, where SiO_2 is near constant, total Fe goes up and MgO goes down. It has relatively high K_2O and other LILs because of open-system mixing/fractionation processes in a large, long-lived chamber (Walker et. al., 1993). We may see some red glow from the shallow, long-lived chamber magma chamber that controls the major element variations.

Las Sierras is described as a mafic-felsic ignimbrite shield and it certainly looks like that on the section exposed in the Mateare fault scarp west of Managua. At the section we will visit, on the road to Masachapa on the Pacific coast, an upper thin section is clearly mafic-felsic, but the lower part looks more silicic. This needs work.

Head to Tipitapa and take the Tipitapa-Masaya road.

Stop 1 at overlook. (UTM ^{13}29 N and ^{5}97.5 E) View of Masaya from about 7 km to NE. We may recognize a N-striking graben coming from Masaya. The Cofradia fault is about 3 km west of us. Behind us is a quarry of slightly welded or indurated mafic tuff. The tuffs are pyroclastic surge deposits that extend up to 20 Km from the caldera. This is the uppermost volcanic layer in the region, Williams (1984) called this the Masaya pyroclastic surge member of the El Retiro Tuff.

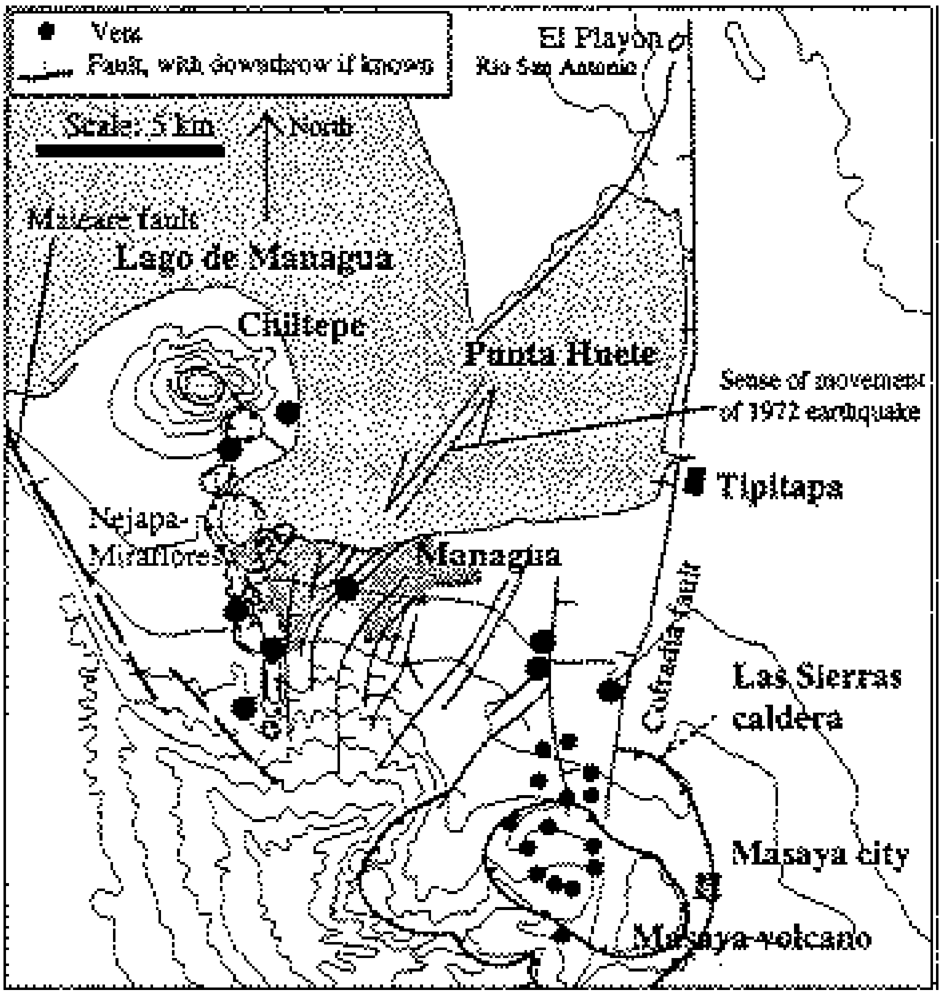
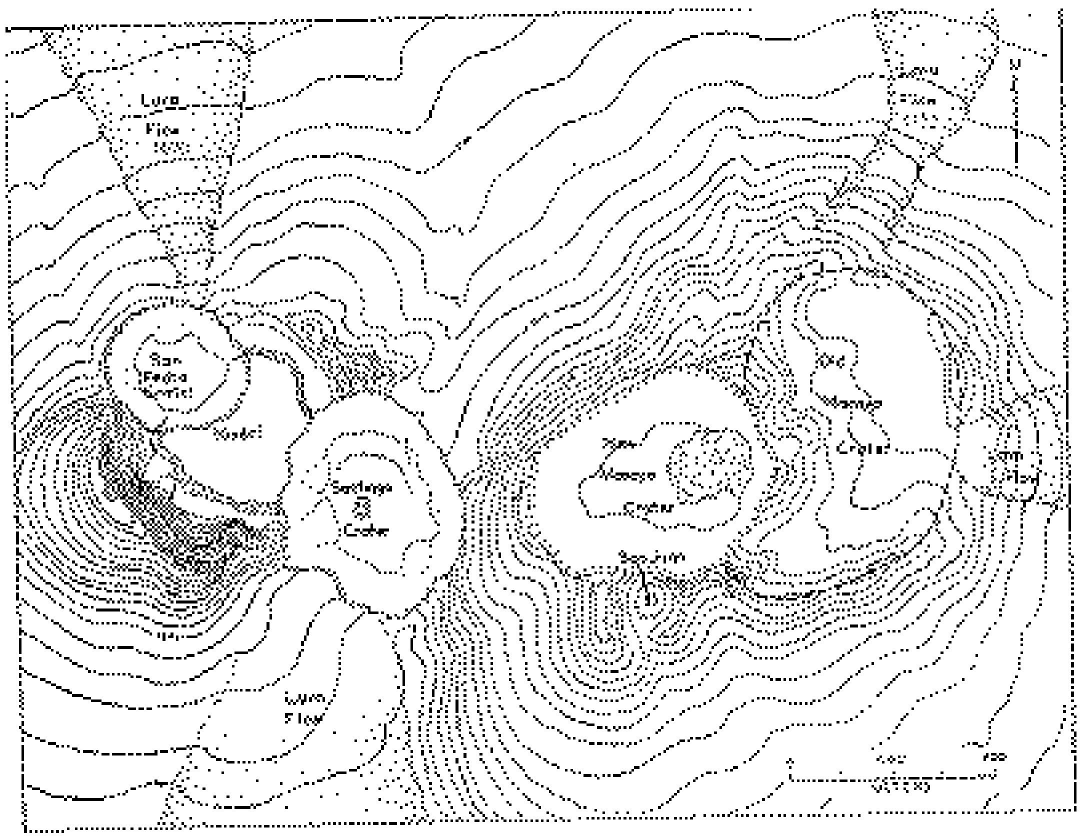


Figure 2.1.9. Structural map of the Managua Graben using data from aerial photography, field mapping and the Fault Map of Managua (INETER archives 1974). Figure from de Vries thesis

Stop 2 Masaya Volcano National Park. The Masaya Caldera has many vents, as shown in the map below modified from McBirney (1958). The active vent, Santiago, emits tons of gas every day, 1000's of tons/day in vigorous periods. The active crater has a frozen lava lake at its floor. Gas and, recently, bombs erupt from collapse pits in the frozen lake. A red glow is often visible. We will approach with care, following the advice of INETER experts.



Much new work is being done by European groups. Rymer et al. (1998) argue that the present degassing phase that started in 1993 is associated with changes in density (from microgravity data) but not necessarily with a fresh influx of magma. They include excellent maps and sections of the pit craters and their structures.

Researchers from Nicaragua (INETER), the United Kingdom (The Open University & Cambridge University), Belgium (Université Catholique de Louvain), and Canada (McGill University & UQAM) are currently studying the origin and impact of extended unrest at Masaya volcano. Their goals are to characterize the types and amounts of volcanic gases being emitted into the atmosphere, evaluate the dispersion and deposition of the gas plume downwind from Masaya and understand the extent and structure of the magmatic plumbing system. For info go to :http://exodus.open.ac.uk/williamg/Masaya/Masaya.html

Photo below is from Roche, et al. (2001). Sub-surface structures and collapse mechanisms of summit pit craters JVGR Volume 105, Issue 1-2.

Note:View looks roughly SE, so the road into the overlook comes from the left.

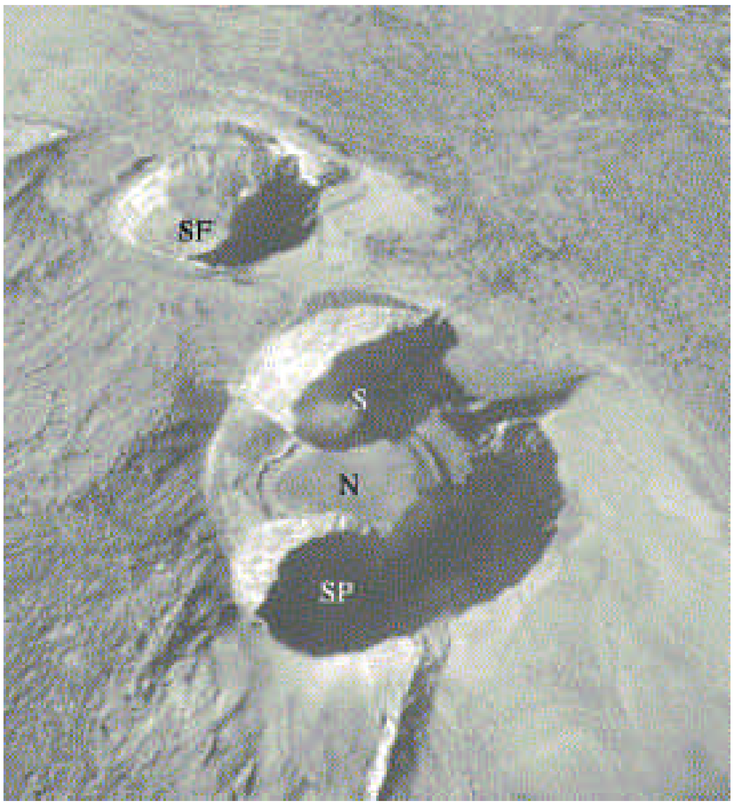
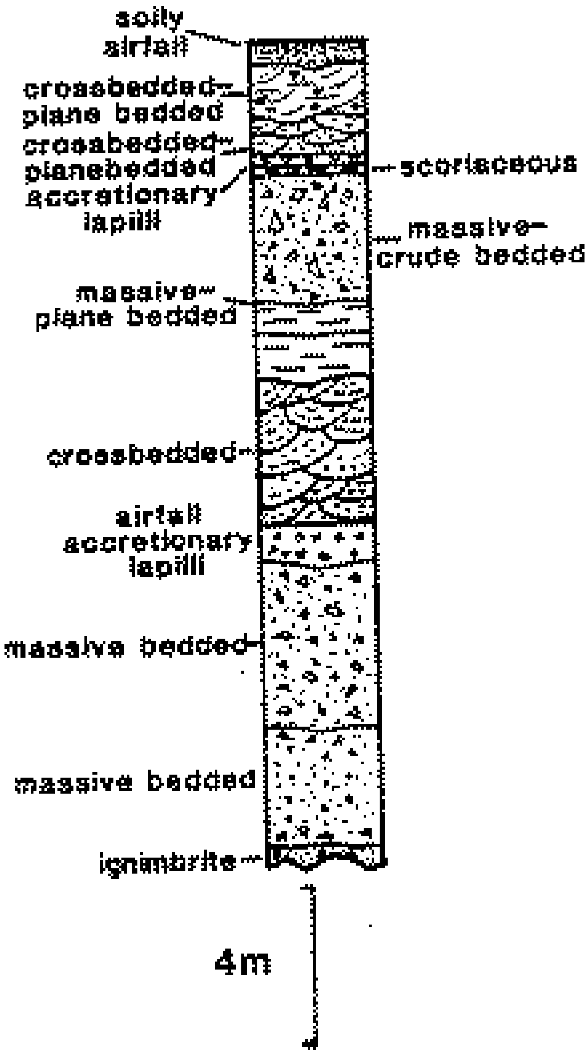


Fig. 1. Oblique aerial view from the west of the Masaya Volcano pit crater complex. The photograph shows San Pedro (SP, foreground) and Santiago (S) pits cutting the post 1670 Nindiri crater (N, with a conspicuous concentric tensional fissure). Further in the distance is the San Fernando (SF) crater and an infilled earlier crater. For scale, San Pedro pit is 400 m across, Santiago is 600 m in diameter, and San Fernando about 900 across and 200 m deep.

Stop 3 (optional) A lava sampling stop, probably in the area across the highway from the park, but possibly at the lake shore)

One interesting lava to sample is the 1772 flow. It is the source of NIC-MS4, the lava with the highest $^{10}Be/^{9}Be$ ratio yet found. However, on the field trip in 2001 we stopped a short distance down from the overlook to sample the 1670 Nindiri flow for ^{10}Be and other short-lived isotopic analyses.



Stop 4 Overlook above Masaya Lake and caldera just below Nindiri.

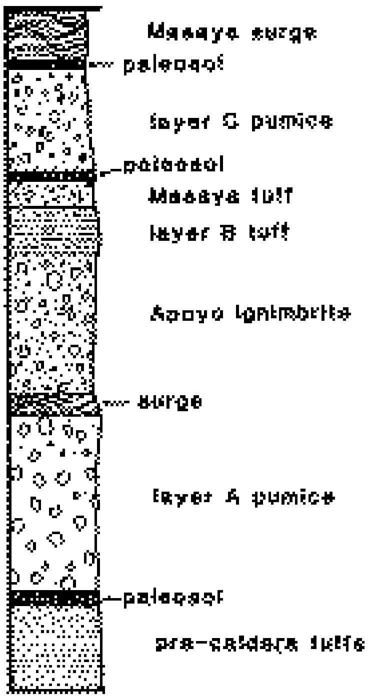
Admire the view, then descent into the caldera and examine outcrop of mafic surge layers erupted from Masaya about 6,000 yr bp. This is the uppermost volcanic layer in the region, the Masaya pyroclastic surge member of the El Retiro Tuff (Williams, 1984; his Nindiri section is reproduced to the left.). The road from Nindiri down the caldera wall to the lake passes a number of small quarries and several fine roadcuts. We took the bus half way down and walked up the section, starting with a mafic ignimbrite. A variety of pyroclastic deposits are exposed, including many layers of accretionary lapilli (ACLAPs) which are strong evidence of a wet eruption sequence.

The volume of the ignimbrite and surge comes to 8 to 9 km^3, similar to the volume of the Masaya caldera about 15 km^3. Williams (1984) concluded that the present caldera formed during this eruption.

The main point of this stop is to reiterate the highly explosive nature of Masaya. Mafic ignimbrites and surges are found at other volcanoes but Masaya has also erupted thick mafic plinian deposits, the Fontana Lapilli (age>20,000 yr bp [Bice, 1985]) and the San Judas formation (age 6500 yr bp [Bice, 1985]).

Now take highway that goes between Masaya and Apoyo and turn left into Catarina. This is a delightful town with a splendid overlook onto the Apoyo caldera and lake with a clear view of Mombacho in the distance. Excellent lunch stop.

Stop 5 (optional-not done in 2001) Road cut exposing silicic tephra from Apoyo.



The composite section to the left is from Sussman (1982). Carbon from the base of the Apoyo ignimbrite gave and age of 23,000 yr bp. Thus the major sequence at Apoyo appears to be a normal large silicic sequence of fall (Layer A pumice), flow (surge and Apoyo Ignimbrite, and co-ignimbrite (layer B tuff?).

The layer C pumice is a younger smaller Plinian fall deposit. The silicic deposits sum to about 11 km^3 DRE, about the same as the volume of the caldera.

Whole pumices have about 66 wt. % SiO_2 and a dacitic composition. It is clear that Nicaragua has some young silicic eruptions. It is not all basalt and andesite.

Proceed to road on west flank of Volcan Mombacho and go left toward Granada.

Stop 6 (optional-not done in 2001) Quarry exposing Granada volcanics, mostly scoria but plenty of large blocks for a solid sample. This quarry is at the SW (seaward) end of a N-S trending zone of vents that erupted mafic basalts.

The abundant N-S extensional structures in Nicaragua provide many minor vents that erupt lavas that bypass the large chambers that churn everything together and erupt rather uniform basalts and andesites. The relatively primitive (high MgO 7-12 wt %) and possibly parental magmas at Granada and Nejapa (a parallel zone of mafic vents on the NW side Managua) provide a different and more complex perspective on magma genesis. . This particular quarry provided NIC GR 101, the only low Ti basalt I sampled at Granada. Although this vent is the one nearest the trench, it is not clear that there is a geographic correlation with the chemistry of these lavas. Most of the Granada lavas have distinct REE and isotopic signatures accompanying normal HFS element contents (very high HFS contents for an arc)

Return to the Granada-Rivas Highway. Go right at next main intersection to take highway that circles Masaya-Las Sierras and takes us to Masachapa highway. Go just beyond the Masachapa turn and take new road to Guiterez on the left. Stop just beyond the first road cut and walk down the section.

Stop 7 Upper part of Las Sierras section that has mafic basaltic layers (scoria and glass), ash layers ACLAP layers. They are primarily fall deposits.

Hazardous place because of traffic! Use good sense.

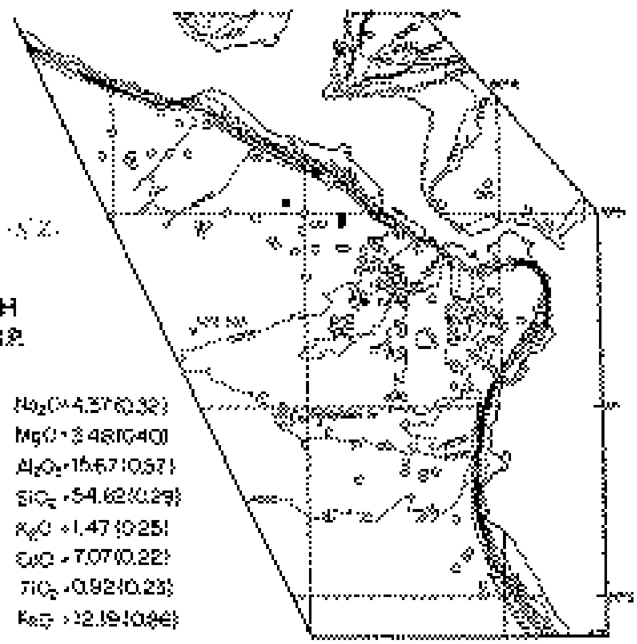
The scorias and glass here have about 54% SiO_2. They are Fe-rich and similar to recent Masaya lavas but slightly more evolved. The mafic end member of the upper part of the Las Sierras is clearly chemically similar to modern Masaya. The thick scoria band has fresh melt inclusions that had about 1.5% H_2O (Fara Lindsay, unpublished). This section is not as mafic as modern Masaya and may be less mafic than the mean of the recent Masaya and Apoyo sections.

Go to road to Masachapa and head toward coast. The Masachapa road goes down slope and the tephra section is roughly parallel to the road for a while. Below the fall deposits are what look like large silicic ignimbrites. In my one brief visit I found only one quarry in this and it was a scraping that left no useful surfaces in place.

Stop 8 Stop at quarry in town of Los Rizos.

The outcrop is either a couple of cycles of reworked volcaniclastic sediments or a couple of pyroclastic flows. You tell me. We are now near the base of the Las Sierras deposits, about 3 km from the El Salto frm, a Pliocene-Pleistocene marine near shore deposit with lots of fossils and some tephra. Of interest to me in this quarry were the black scoria boulders/cobbles in the predominantly silicic deposits. Analysis however, revealed these to have 56-62% SiO_2. The bottom line, between this stop and the Las Banderas stop tomorrow, is that the mafic part of Las Sierras is andesitic not basaltic. Overall, the lower part of the Las Sierras appears more silica rich than the upper section and considerably more silica rich than the modern volcanoes.

Stop 9 (optional)
There is marine terrace topped by Las Sierras near the coast.



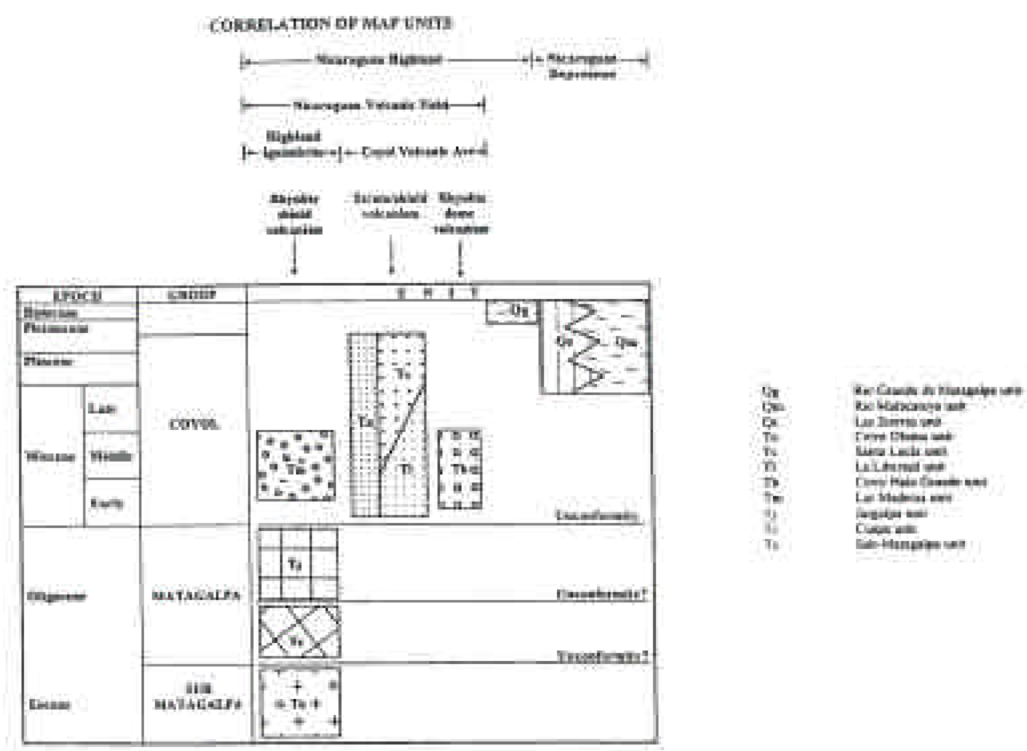
July 16 Monday Tertiary volcanics of Nicaragua. (recent volcanics at start and end).

THEMES:
1. Ehrenborg (1996) describes a new approach to Tertiary stratigraphy in Central America. Although he maintains the basic stratigraphy, based on pulses or volcanic outbursts separated by less active periods, he stresses the utility of identifying volcanic centers of different types, rhyolite shields (made mostly of pyroclastic flows), rhyolite domes, and mafic strato-shield complexes. In the Coyol area the constructional morphology of Tertiary volcanoes is reasonably well preserved and a facies approach, based on type of volcano and distance from the center, works well.

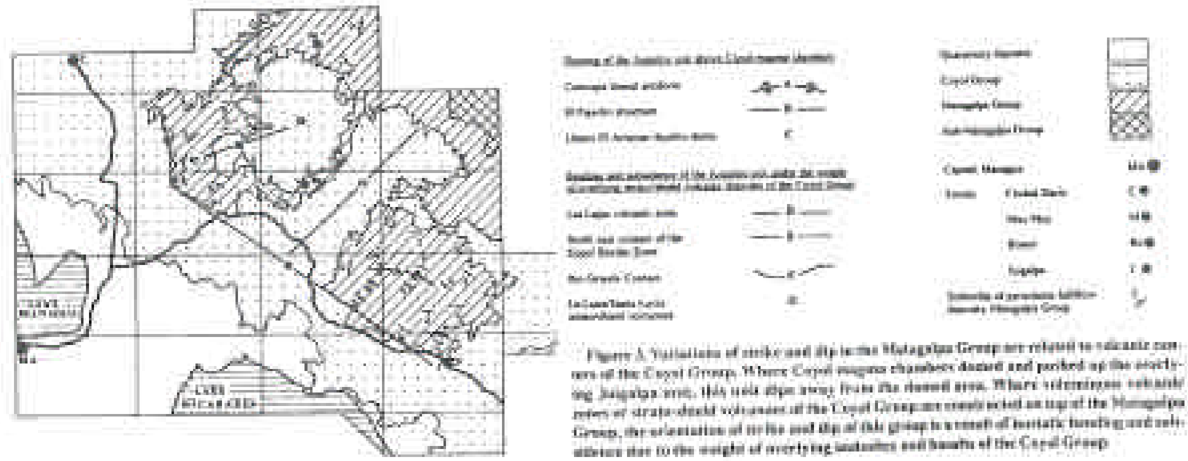
Here is an oversimplified Tv stratigraphy for the Nicaraguan highlands and other areas.

Time	**Group/Frm**	**Rock**	**Honduras/El Salvador/Guatemala**
Pliocene	Santa Lucia	Bas.-Andes.	Mafic Padre Miguel/Balsamo/Cuilapa
Miocene	Coyol	Ignimbrites	Padre Miguel/Chalatenango/Chalatenango
Oligo-Eocene	Matagalpa	Ignimbrites	Matagalpa/Morazan/Morazan

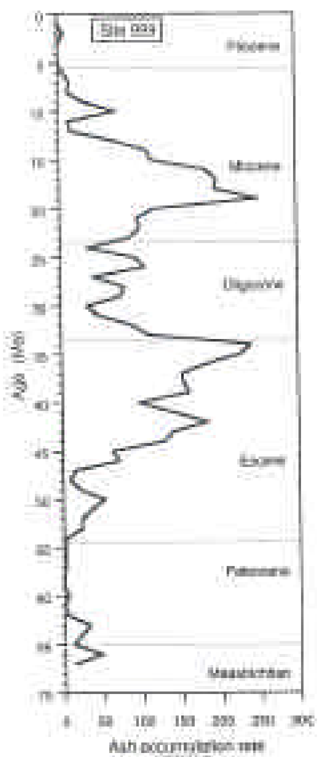
Ehrenborg's more realistic stratigraphy (below) for the Nicaraguan highland allows the three main volcano types, rhyolite shields-ignimbrites, mafic strato-shields, and rhyolite domes, to overlap in time and occur in separate areas.



An aspect of the stratigraphy not on any diagram is the progression of Tv and Qv from inland to the coast. In Nicaragua, McBirney, Weyl and Ehrenborg all cite a large seaward shift of the volcanic axis from Tertiary to present.



2. Sigurdsson et al. (2000) measured ash accumulation rates in the western Caribbean using ODP cores. Marine deposits just east of Central America have abundant ash layers, often 10 to 20 cm thick. The large amount of ash raining out east of Central America is consistent with predominantly westerly winds found today in altitudes of 10 20 km. The lower, tropospheric winds in Central America are dominated by trade winds that generally blow from east to west. Most tephra dispersal maps of historic eruptions have major axes extending to the west, following the trades. These relatively small eruptions rarely were energetic enough to penetrate into the stratosphere. The huge silicic tephra eruptions common in the mid Miocene geology of Central America surely had much higher eruption columns that allowed ash to reach elevations where prevailing winds disperse the ash to the east.



The large peak in the Miocene, between20 and 13 my ago made the Coyol group. The earlier peak may turn out to be the marine record of the Matagalpa group. A team based at Univ. Rhode Island is currently trying to link the land and marine stratigraphies.

3. Balzer et al (1996) sampled the Coyol strato-shield volcanics to study regional geochemistry. They found a strong regional gradient in Ba/La, identical to the one seen in the Quaternary volcanoes. Their Fall AGU abstract follows.

Sediment Recycling Through Time in Nicaragua

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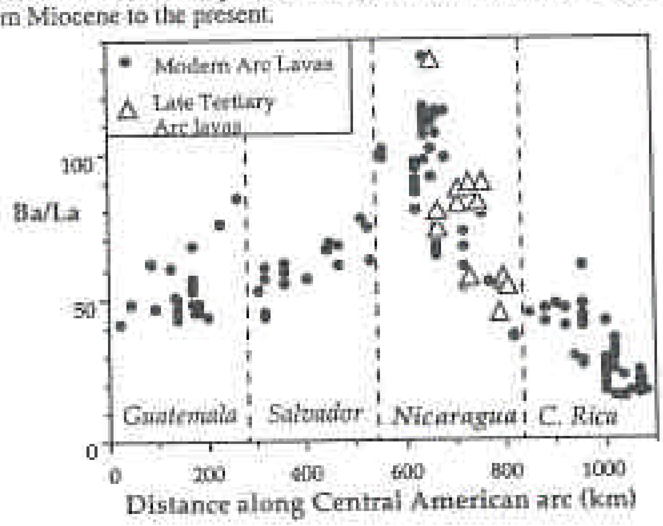
An important step in understanding geochemical recycling at subduction zones is quantifying element fluxes from the subducting plate to the mantle wedge. Calculating the volume and chemistry of the incoming crustal section at the trench is fairly straightforward; in many cases the bulk chemistry of trench sediments correlates well with the associated arc volcanics. However, modeling this process through time requires either an assumption that the system has been in steady state or independent evidence for temporal changes in the input. Current flux models typically assume steady-state to relate sediments at the trench to those at ~ 100 km depth, which are currently feeding the arc. In an effort to document the temporal variations (0-8 Ma) in subduction recycling, we analyzed 20 mafic lavas from the Late Tertiary volcanic arc in Nicaragua by ICP-MS.

The Central American arc provides an excellent opportunity to investigate recycling through time because the modern arc is very well studied and shows large along-strike variations in diagnostic slab tracers such as Ba/La (see Figure) and U/Th. Such a large gradient in these tracers, from a maximum at Nicaragua, to a minimum in Costa Rica, has been linked to greater off-scraping of the incoming sedimentary strata and/or less efficient delivery from slab to volcano beneath Costa Rica. An important test of a steady-state recycling model, then, is whether the large gradient in Nicaragua is also present in the Tertiary volcanics.

Sampling in May of 1996 focused on the Miocene? arc (dating is in progress), offset ~ 45 km to the NE of the present arc. Of the 20 samples we analyzed, 12 were low Ti basalts with MgO >3%, comparable to the modern lavas plotted. The Tertiary lavas preserve the same dramatic gradient in Ba/La as the modern arc; over-lap is virtually complete when the older samples are projected onto the line of the modern arc (perpendicular to strike). This remarkable similarity in Ba/La provides evidence for steady-state sediment compositions, supply and recycling efficiency along the Nicaragua margin during the Late Tertiary. In contrast, a similar U/Th gradient is not preserved in the older lavas, which have lower U than the extremely U-enriched modern lavas. The long-term sediment signal therefore is a mixture of continuity and change. The sedimentary environment for U may have changed from normal to U-enriched from Miocene to the present.



Take highway past Tipitapa, go right on Rama road to Las Banderas. After a few Km stop at outcrop of mafic Tertiary lavas. We will do the 2^{nd} stop first to save turnarounds.

Stop 2. (first Tertiary stop) Mafic lavas of San Jacinto volcanic remnant. Coyol group subunit Tbu- Santa Lucia, Pleistocene- middle Miocene Strato/shield volcanoes with still recognizable morphology. Age about 5 my.

Stop 1. (last Las Sierras-Masaya stop) Turn right just after the bridge in Las Banderas.

Abandoned quarry at Las Banderas. The cut stone used in buildings and roads in Managua largely comes from a remarkable black ignimbrite, the Las Banderas formation. The black scorias have compositions of SiO_2 58 to 67 wt %, a lot more silicic than they appear. The pyroclastic flow that made this deposit very likely erupted from the Las Sierras center. It likely occurred near the top of the Las Sierras section and is probably linked to a major caldera collapse. Much more work is needed to accurately place this unit in the regional stratigraphy. For example, it may be equivalent to the deposit exposed at the edge of Masaya Lake, just below the pre-caldera Masaya lavas.

Continue NE and stop at outcrop of opportunity at west end of lake, Embalse las Canoas

Stop 3. (optional-not done in 2001) Rhyolitic ignimbrite Tru: Middle to lower Miocene Las Maderas group, silicic pyroclastic flow and fall deposits. We will see more of this unit at Cuesta Coyol.

Go further NE on Rama road looking for Matagalpa outcrop.

Stop 4. (optional) Find outcrop of Matagalpa frm north of Boaco.
The Matagalpa group is an early to mid Tertiary pyroclastic flow and fall sequence characterized by mildly metamorphosed/altered greenish-white silicic ignimbrites. There are also many interbedded lake sediments derived from volcanics and this is what is exposed here. Rain prevented examining these sediments

Return to Interamerican Highway and go north.

Stop 5 Outcrop on highway through Cuesta Coyol Tru (Las Maderas group) and Tbll, dacitic and andesitic lavas interstratified with Las Maderas pyroclastics.

Steve Carey of URI suggested a good Coyol locality, a road cut in Cerro El Coyol at UTM ^{13}81.70 N and ^{6}02.12 E. He reports that the "sequence includes a red soil at base, 70 cm of sandy ash (surge?), ~2 meters of vitrophyre (one of our sampling locales), and a thick ignimbrite on top". Prof Rogers will fill us in on Tv issues in Central America.

Continue on highway north through Sebaco to find the paved road to Leon. Go Left.

The trip back down to the Nicaraguan Depression cuts through a high relief terrain dominated by prominent welded tuffs. The La India gold mine is on RHS and many outcrops of welded tuffs occur throughout. Upon the reaching the Nicaraguan Depression, the highway becomes very straight as it cuts through a terrain of quaternary pyroclastic deposits.

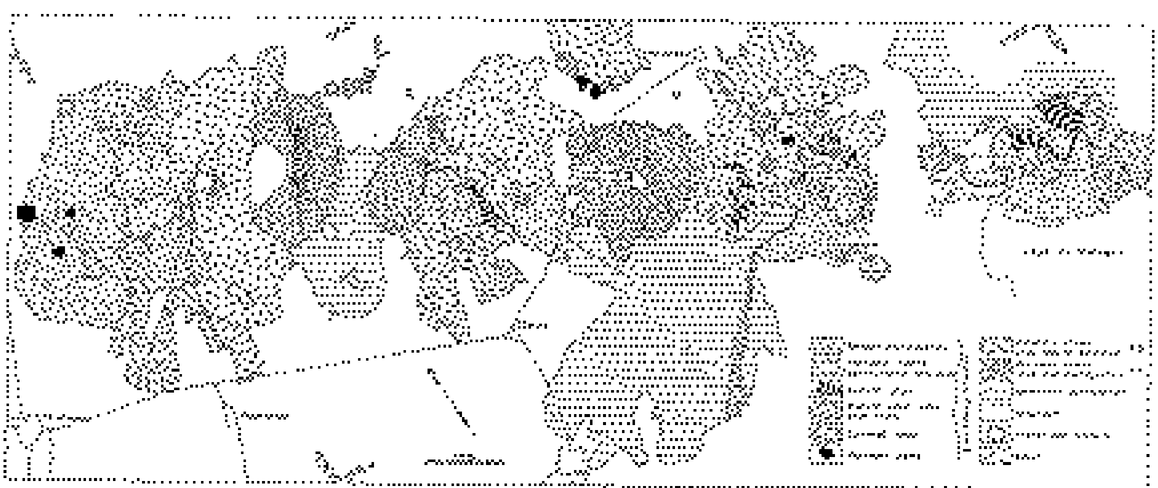
An old map (below) calls these reworked pyroclastics but the outcrop we stopped at and several others we drove past had primary depositional features. We stopped at a silicic fall deposit and drove past at least two different pyroclastic flow deposits. The obvious young structure here is the Mont Galan caldera, adjacent to Volcan Momotombo. However, van Wyk de Vries postulates a Malpaisillo caldera, possibly because the volume of silicic pyroclastics seems too large for the rather small Monte Galan caldera. Much work needs to be done here to clarify the source(s) of these white pumice deposits.

Stop 6. View Stop
Drive to nice view of Cerro Negro just through the town of Malpaisillo on the road to La Paz Centro. The very recent lava flow in the right foreground is a low-Ti lava from the Las Pilas complex (Nic LP 101). Admire Cerro Negro, speculate about origin of remarkable N-S gash to the left of Cerro Negro.

Stop 7. (optional-not done in 2001) time and weather permitting
The San Jacinto hot springs on the flank of Volcan Telica.
This is a tourist attraction with some nice bubbling mudpots and hissing vents, a variety of colors and smells. Child guides available whether you want them or not. I consider this very hazardous and stick to the beaten paths. Ongoing geothermal development will likely alter this field of hot springs, so be wary.

On to the Hotel Europa in Leon.

Loud explosions are common here, usually someone's birthday celebration. Leon is a really beautiful colonial city. The cathedral, with its Leones (lions) is a real treat. By all means walk to the main square. There are colonial buildings and churches everywhere. A useful supermarket too. The gas station near the hotel sells large water jugs, but the supermercado has more sizes.

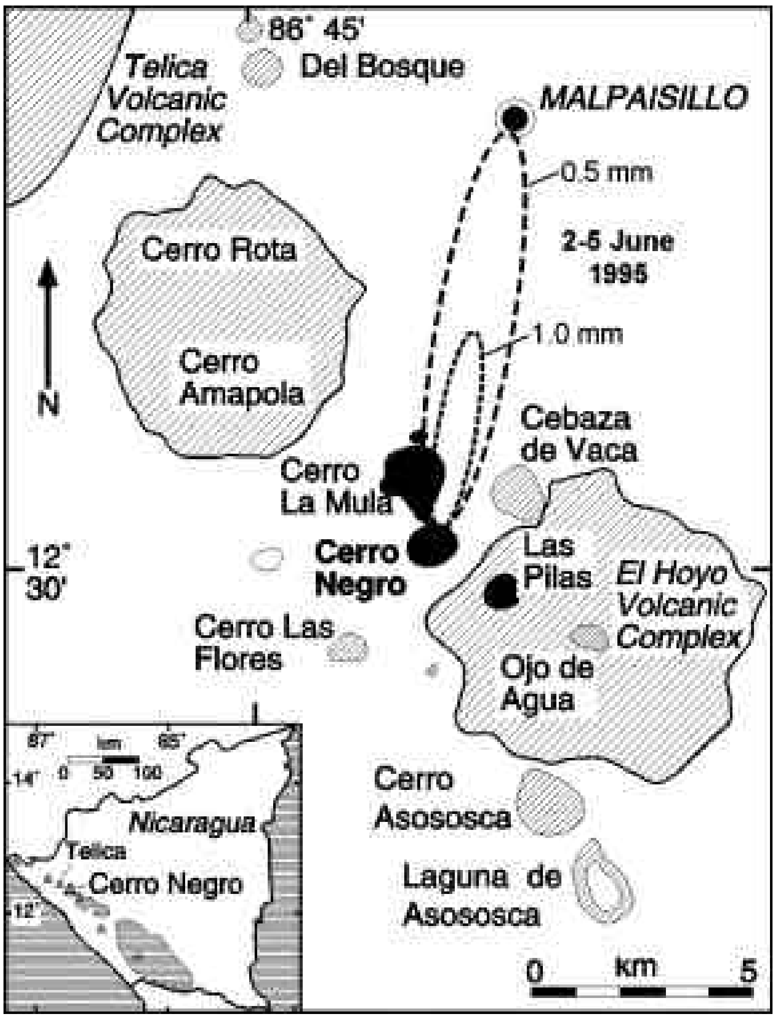


July 17 Tuesday Martes: Theme: Active volcanoes and volcanic hazards.

With luck, Cerro Negro will be still and Telica and San Cristobal will have weak ash explosions accompanying their vigorous degassing.

Stop 1 Spend a morning at Cerro Negro.

The diagram below is from the Smithsonian web and was created by Brittain Hill.



This is an excellent sketch of the relation between Cerro Negro and surrounding complexes. The Marabios range is wonderfully interesting because there are so many discrete vents (many more than can be shown in a sketch) with small eruptive volumes. As a result there is a high variety of magmas.

For a functioning way into the volcano see the last appendix.

Cerro Negro is a classic arc volcano with typical arc lavas, basalts with high subduction signature (Ba/La> 100, $^{10}Be/^{9}Be$ >20) and low HFS. The lavas are beautiful, with large plag and px phenocrysts and abundant magnetite and olivine (the typical POAM fractionation style plag oliv augite mag). Some lavas accumulated ol and px, especially some small flows with MgO contents of >10 wt %. The small 1999 flow largely filled the new vents that formed at the start of the eruption. This lava is phenocryst rich and may also be accumulative. It is notably brown and has a very vesicular surface.

On next page are some self explanatory figures from Hill and others (1998).

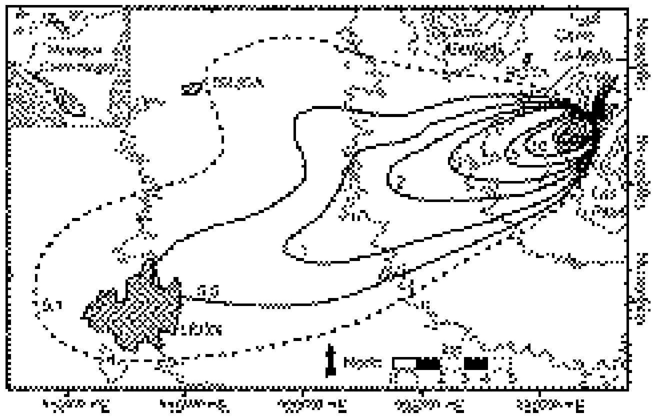


Figure 1. Distribution of tephra-fall deposits for November–December 1995 Cerro Negro eruption, based on field measurements by M. Kennedy (University of Geneva). Isopachs in centimeters. Dashed line indicates uncertainty in location of 0.5 cm isopach. Hatched pattern—older Cerro Negro lava flows; black—1995 lavas; stippled pattern—cone. Topographic contours (100 m) derived from 30-m-resolution digital elevation data. Coordinates in Universal Transverse Mercator, Zone 16, WGS 84 spheroid. Inset map shows locations of major Nicaraguan volcanoes (open triangles).

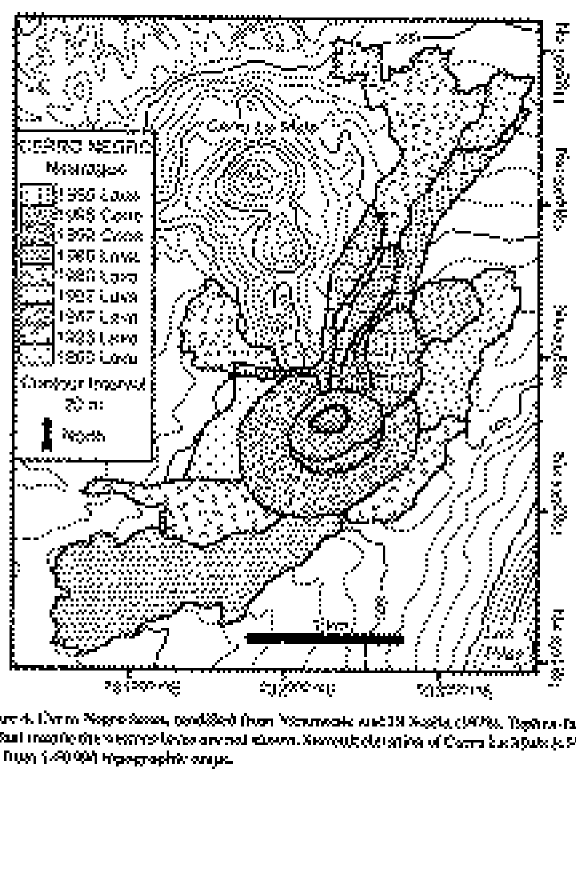
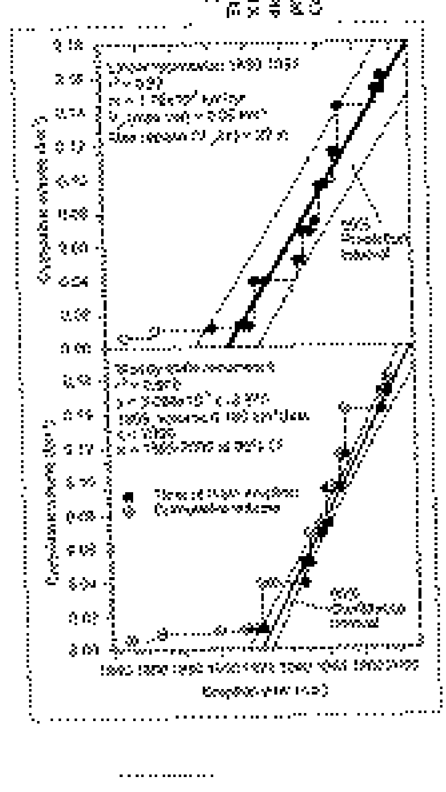


Figure 4. Cerro Negro lavas, modified from Viramonte and Di Scala (1970). Tephra-fall deposits that mantle the western lavas are not shown. Summit elevation of Cerro La Mula is 540 m, and is from 1:50 000 topographic maps.



What to do and see

First, **make sure you have a hard hat**, especially if you plan to climb the volcano.

Second, get from Carr a map with the route in and escape routes marked. (based on Chuck Connor's topo map of Cerro Negro post 1995). Within the last year (between July 2000 and July 2001) the municipality of Leon created a trail through the lava flows between the end of the road and the low, NE side of the cone. Where the trail ends, cairns begin, clearly marking the easiest route. This greatly facilitates climbing. The last few km of the road were also greatly improved, opening up Cerro Negro for tourists.

Third, gather at the base of the 1999 vents and lava plug. Carr will give a pitch on petrology and Pete La Femina will talk about geophysics.

Everyone should see: the bomb craters on the way to the base of the cone; the 1999 cones and the lava that covers them; and the beautiful volcanic rocks at the margins of the cone along the path along the cone-lava field intersection.

The Cerro Negro olivines are honey-brown rather than olive green. There are large phenocrysts of ol px plag and mag. A great sampling place for a petrology lab! I have found comagmatic troctolites and other gabbros here. The 1999 eruption left numerous large olivine crystals at the surface (a dilute olivine ash?) In 2000 we collected several for melt inclusion analysis, but they were not obviously present in 2001. Cerro Negro is famous for having a high volatile content (about 5% H_2O) in a mafic basalt (Roggensack et al., 1997). We sent our olivine samples on to Jim Walker and Kurt Roggensack.

Some will want to climb the cone, others may not.

Some may go to Cerro la Mula on the north side to look at low-T fumaroles and seek evidence of N-S faulting.

Others may climb the NW edge of the Las Pilas complex, which has a great view of Cerro Negro and some low-Ti bombs at the first summit, Nic LP 107 and 108.

Stop 2. Drive to San Cristobal-Casita to see the lahar deposits and scar caused by heavy rains during hurricane Mitch. INETER 4-wheel drive vehicles took us to the monument created above one of the largest villages destroyed by the floods and lahar.

A web reference on Casita is: http://volcanoes.usgs.gov/Hazards/What/Lahars/CasitaLahar.html

Kerle and van Wyk de Vries (2001) use using remote sensing to infer that structural deformation was the cause of slope instability. See their Fig 6. Below.

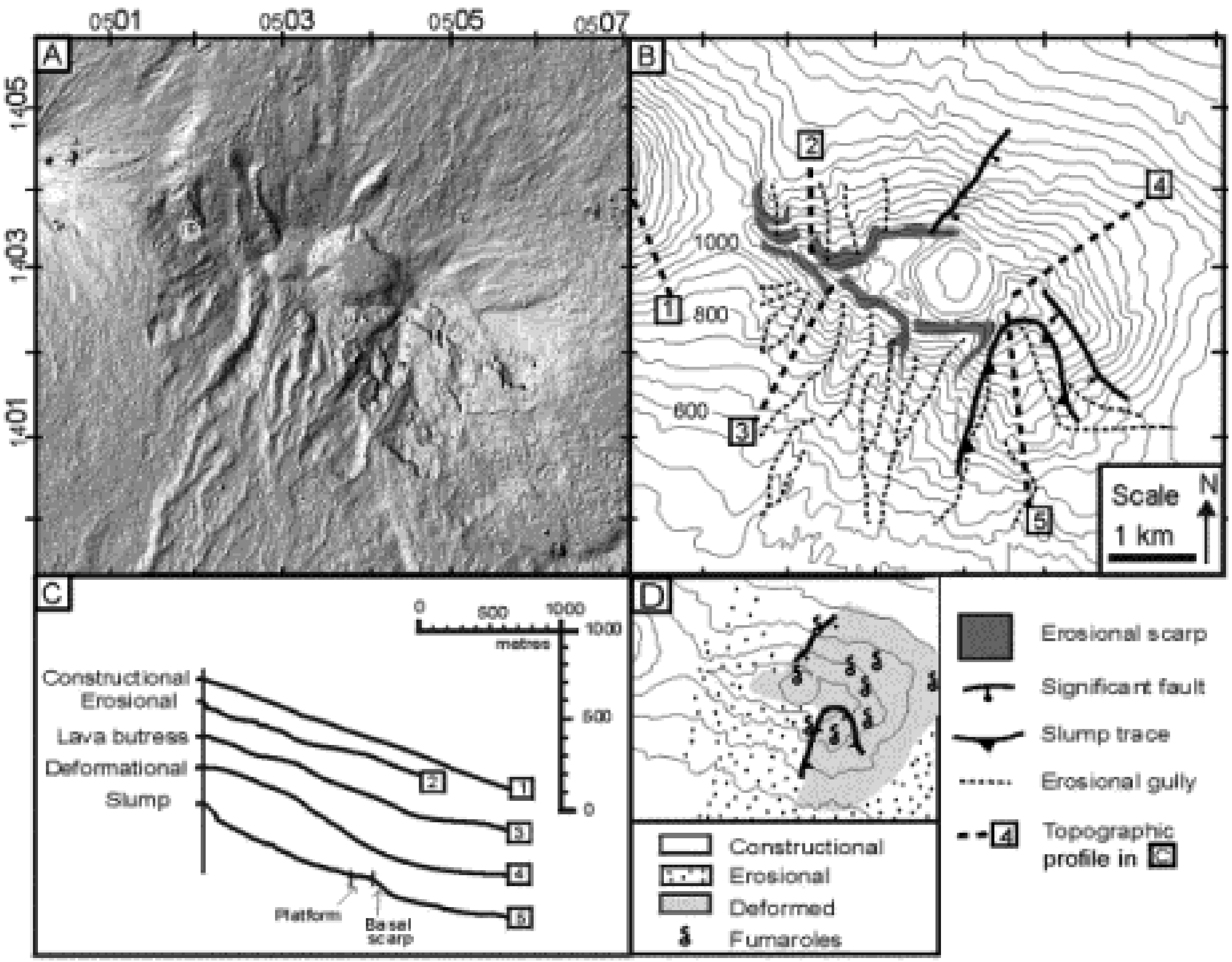


Fig. 6. (A) Digital elevation model; (B) topographic map of Casita volcano showing major morphological units: smooth, constructional morphology (Casita's west and northeast, as well as San Cristobal's eastern flank); strong erosion (Casita's northwestern and southwestern flanks); deformed (eastern flank), (B) also shows major faultlines and gullies, as well as the outline of the gravity slide; (C) Vertically exaggerated topographic profiles of Casita slopes as indicators of structural processes (locations marked in B): 1 constructional, smooth slope at San Cristobal; 2 erosional, irregular profile from northern flank of Casita; 3 lava buttress from one of the few flows on the southern flank of Casita; 4 deformed profile from northeastern flank of Casita showing a convex-concave slope; 5 profile through gravity slide, showing headwall, flatter interior, and steep basal scarp. D shows an overview of different morphologies.

Stop 3 (optional-not done in 2001)
Stop at the toes of a San Cristobal flow and a Telica flow. Both come right to the highway. Nic Te 124 is the only high Ti lava close to the road. Nic Sc 1 is a road cut Nic Sc 2 a quarry that may not be open. Nic Te 8 is a quarry also.

Other targets of opportunity or return to hotel

July 18 Wednesday Miercoles Theme Mafic and silicic tephras of western Nicaragua.

We will mosey back to Managua and stop at tephra opportunities and overlooks.

Stop 1 (not done in 2001) on road to Momotombo from La Paz Centro.
Quarry near La Paz Centro to see mafic pyroclastics from a N-S line of explosion pits and craters.

Stop 2 further down the road, near a bridge over a large wash. Just beyond this bridge is a picturesque farmhouse with a vista of Momotombo. We took a group photo here and walked back up the section before and after the bridge. Nearest the bridge are pyroclastic fall deposits, then a fault intervenes and a pyroclastic flow outcrops. The large pumices in the flow are distinctly more rounded than the pumices found in the fall deposits.
A silicic ignimbrite from Monte Galan (I think). Good view of Las Pilas-El Hoyo (usually smoking)

Stop 3 on Leon-Managua highway. (stopped at an overlook to take photos of Momotombo-Momotombito. We did not stop at the planned outcrop of Plinian deposit from Chiltepe peninsula (near Mateare)

Stop 4 (not done in 2001) Somewhere in Nejapa alignment to be worked out, possibly Cuesta del Plomo. Examine the Nejapa alignment of explosion/collapse pits, cinder cones and lavas.

Stop 4a (optional not done in 2001) Find a lava stop for the petrologists and geochemists. Geophysicists may need a little patience.

Stop 5 INETER in central Managua. This is the headquarters for geology and geophysics in Nicaragua. They have a fine seismograph network, a volcano monitoring program, superb maps etc., etc.

Return to Las Mercedes hotel for a swim (weather permitting).

July 19 Thursday Jueves
Fly out of Managua or return by bus to San Jose Costa Rica

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Appendix Sketch Maps of Nicaraguan volcanoes by Benjamin Van Wyk de Vries

A Cosigüina

B El Hoyo

C Telica and Rota

D Zapatera.

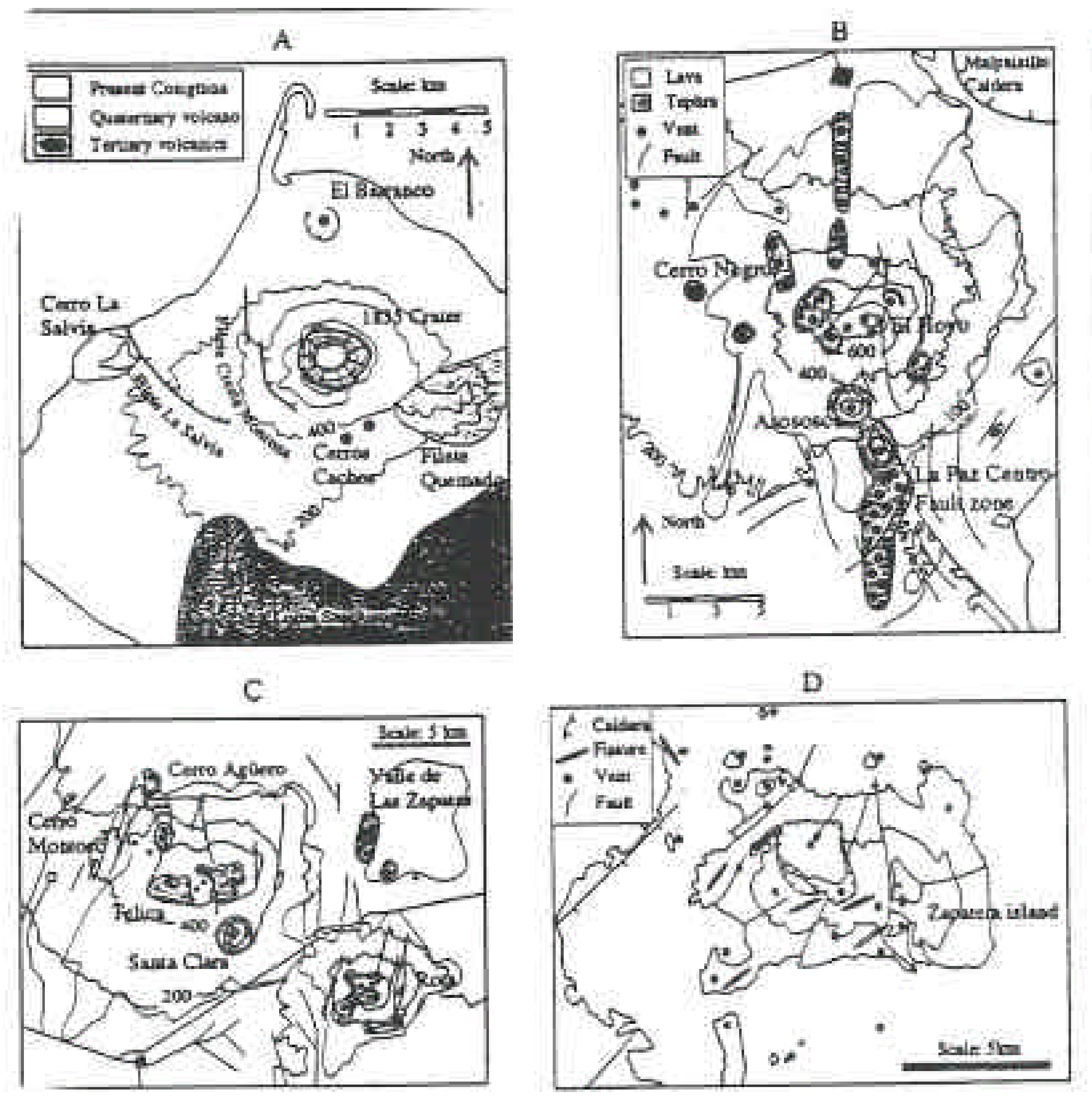


Figure 2.2.3. Topographic maps with simplified distribution of lava and tephra at shield volcanoes in Nicaragua made from aerial photography and field mapping. Previous maps for Cosigüina (Hradecky 1990), Telica and El Hoyo (Bice 1980) were consulted.

A Cosigüina   B El Hoyo   C Telica and Rota   D Zapatera.   Key in B applies to C.

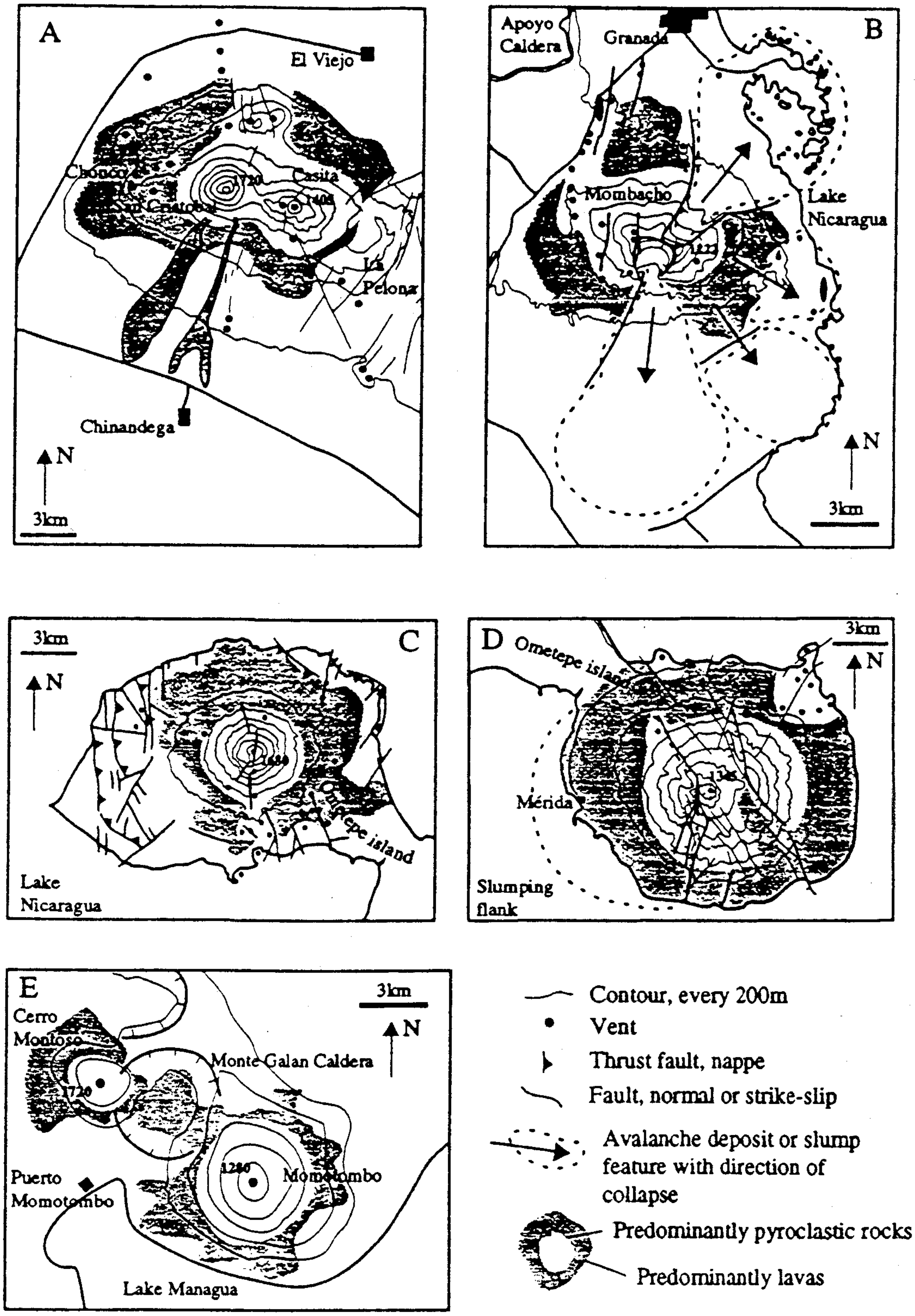
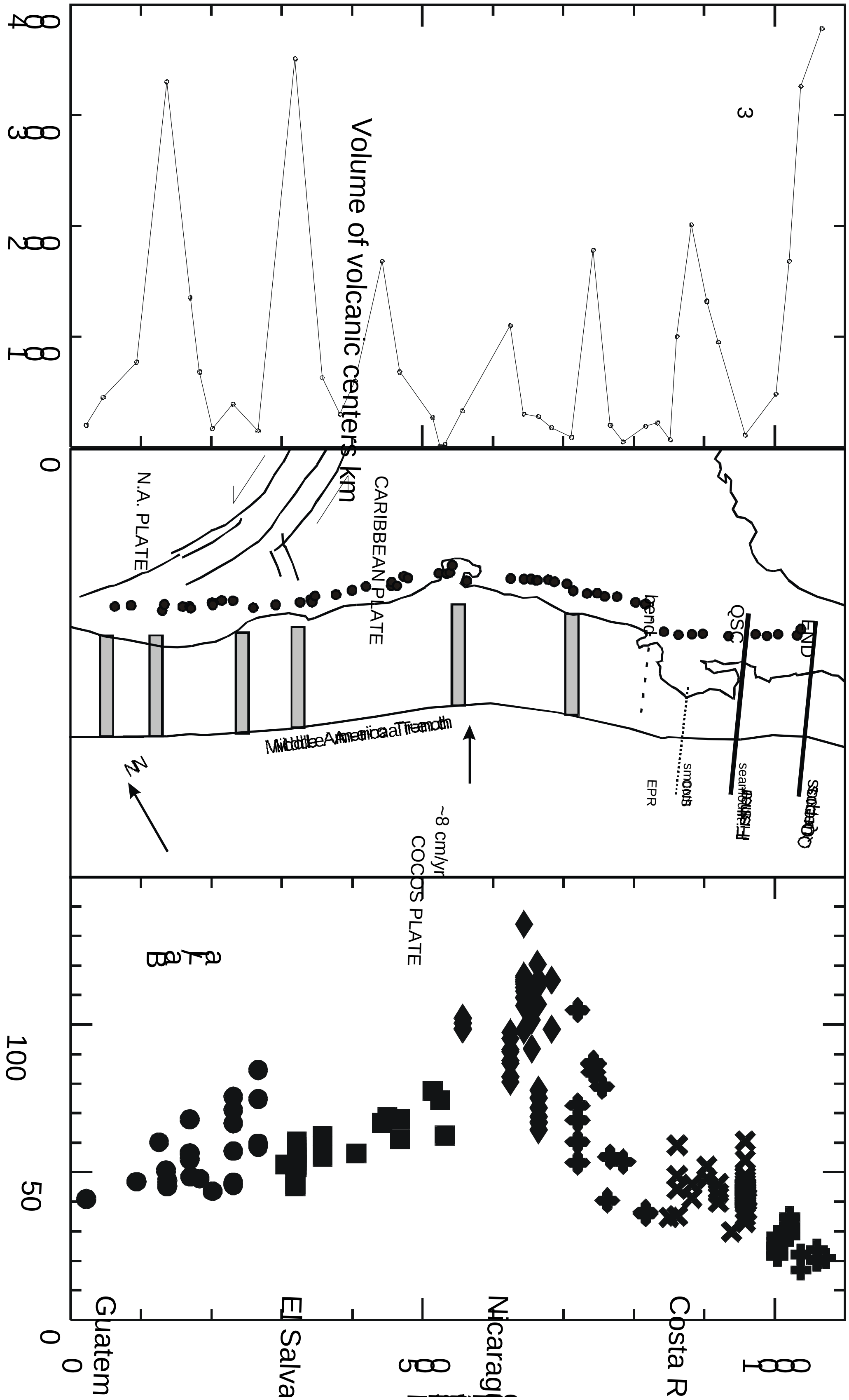
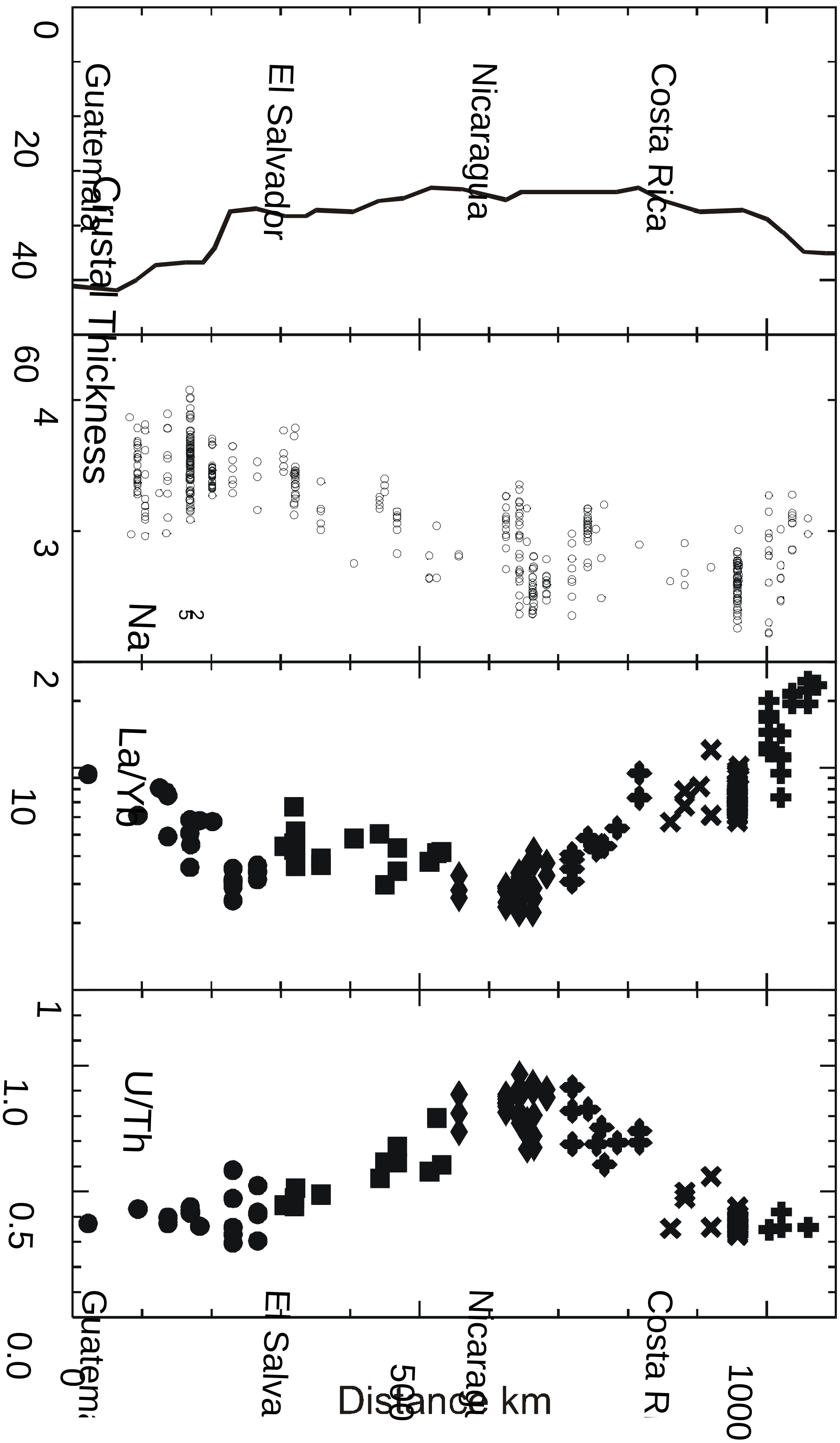


Figure 2.2.4. Topographic maps with simplified distribution of lava and tephra at stratocone volcanoes in Nicaragua made from aerial photographs and field mapping. A San Cristobal massif (after Hazlet 1987); B Mombacho (after Hradecky 1986); C Concepcion; D Maderas; E Cerro Montoso and Momotombo.

Some regional variation across Central; America from Carr et al. (in review)





Costa Rica
Nicaragua
El Salvador
Guatemala
Crustal Thickness
La/Yb
U/Th
Distance km
0
20
40
60
4
3
2
10
1
1.0
0.5
0.0
500
1000

One way to Cerro Negro and Las Pilas, from the Motel Europa in Leon.

The area around Cerro Negro is scrub with numerous woodcutters' trails. Thus, there are about a thousand and one paths to Cerro Negro. The notes below have served me well since I got them from Bill Rose sometime around 1973. INETER probably as a better way.

The first step (below) is finding the large unpaved road that heads in the general direction of Cerro Negro. Do this the evening before so you can find it at dawn. Try to be the last vehicle into the parqueo of the hotel, so you can exit cleanly in the madrugada.

Go east (right) on the road in front of Hotel Europa until you get to the major paved road. From there it is 0.35 km to the left (north) to where a large unpaved road crosses. Here you make a right turn. All further mileages are noted from this point.

0.0 km	Turn east off main road onto large unpaved road.
6.6	A major intersection, go straight.
7.8	Turn right.
8.2	Turn left.
8.3	White house (first aid or medical station) on left *NOTE by 1993 no longer white, closer to black*
8.3 con't.	Don't take the right turn.
9.0	Take left.
10.7	A small village.
11.3	Take left fork.
11.7	Take right fork.
11.9	Don't take left.
14.5	Don't take left and slightly farther, don't take right.
15.15	Take left fork.
18.15	Take left fork.
18.6	Take right fork.
19.8	Here you are coming in off the branch of a fork, when returning be sure to take the LEFT fork.
21.6	At fork take left , then go about1 km to get to Cerro Negro.

At this point the road was much improved in July 2001. The Municipality of Leon appears to be improving the road to Cerro Negro to facilitate tourism. They also built a path over the lava flows between the parking area and the easiest route to the crater rim (this route is now well marked). During our visit Fireman came to practice emergency procedures. There were accompanied by a large group of Spanish high school students. Tourism has begun.

NOTE: stop well before volcano, watch for large bomb craters near the repaired road.
Note the woodcutters path (a red-black scar) straight up one of the small cones making up the Las Pilas complex. This is a pleasant climb except for some sliding scoria. A good way into Las Pilas-El Hoyo. A great photo of Cerro Negro, especially with the low light angles at dawn.