3.3 Investigations of Volcanic Hazards (Task II)

Investigations of volcanic hazards have been focused in two specific geographic areas during the past year. Technical counterparts at UCR have concentrated their efforts on the volcanic stratigraphy of the western Valle Central, especially in the San Jose metropolitan area. Counterparts at UNA have continued their ongoing monitoring activity of the entire volcanic chain but have concentrated their monitoring and field investigation activities on Poas volcano. Poas has demonstrated increased activity in recent months; therefore, efforts have been dirrcted at this volcano over the other three bounding the Valle Central.

3.3.1 Investigations of Volcanic Hazards on the Flanks of Poas Volcano

Increased levels of phreatic ("geyser") activity, gas emission, deformation and seismic activity at Poas volcano have lead to a priority effort to identify potential hazards from a large phreatic event such as the one that took place at Poas in 1910 or a major Strombolian event such as the one at Poas in 1953-55. Historic records of activity at Poas indicate that relatively limited areas have been seriously impacted by such events. For that reason it was determined that volcanic mudflows or lahars represent the most significant hazard from a likely eruption at Poas in the near future. The UNA task group undertook a two-month effort aimed at identifying areas of present slope instability and past lahar activity utilizing aerial photo and map interpretation as well as field reconnaissance. The Counterparts from UCR and ICE have contributed to the UNA effort by providing recent reports on (1) a regional assessment of volcanic hazards, and (2) geologic studies of the Bajo de Toro Valley on the west flank of Poas. The interim product of the UNA assessment (shown in Figure 4) is a map-based analysis of the topography of the Poas summit, delineating probable lahar channels and areas of intermediate and high risk from lahars and airfall tephra. The UNA task group is currently preparing a more detailed assessment, including field checking of map and aerial photograph interpretations, of lahar hazards within a broader study area. This effort has pre-empted the previously defined MIRVYS tasks of field reconnaissance of Turrialba and Irazu volcanoes, but has not impacted UNA's ongoing volcanic monitoring effort.

3.3.2 Investigations of Volcanic Stratigraphy in the Valle Central

The investigation of the volcanic stratigraphy of the Valle Central by UCR Counterparts has assembled a bibliography of approximately 300 publications. This reference list consists of published and unpublished reports, including university theses and municipal water-well drilling logs. The Consultants provided a comprehensive list of publications generated by a computer search on the geology and geologic hazards of Costa Rica to the Counterparts. The Consultants are making copies of the more significant reports published in international journals.

During the June and September 1988 visits, the Consultants were able to identify and describe almost two dozen sites, and have now accompanied the Counterparts to several key sites to discuss both the stratigraphic units and a methodology for further refining the late Pleistocene/Holocene stratigraphy of the western Valle Central.

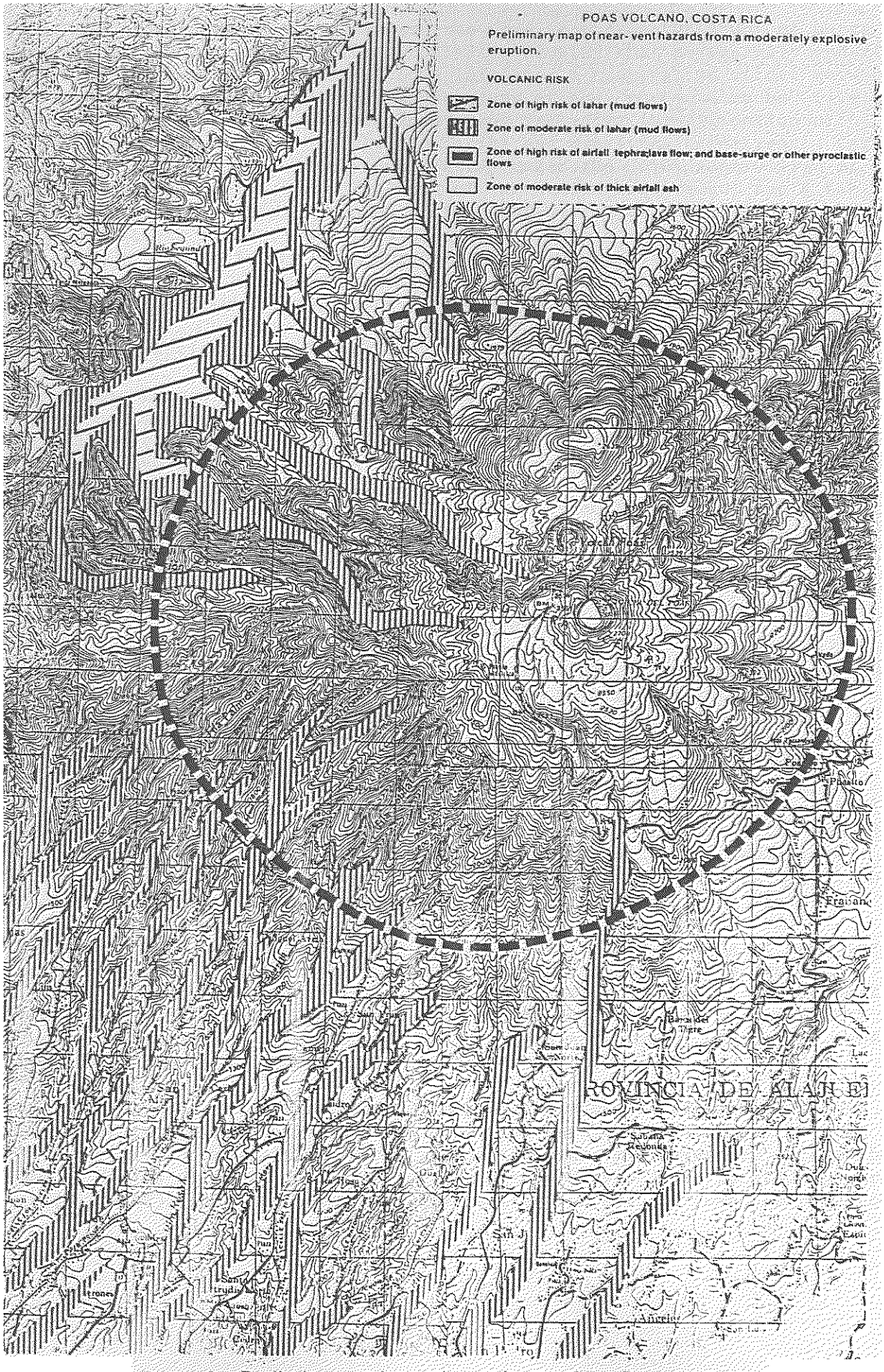

Figure 4. Preliminary volcanic hazard map of the Poas Volcano.

The UCR Counterparts have recognized the need to pursue the study of units overlying the thick grey Tiribi pyroclastic flow(s) that pervasively underlie the San Jose region. The Consultants initiated a cooperative effort between ICE and UCR to produce a stratigraphic study of the "post-avalanche" (i.e., post-Tiribi) deposits in the San Jose area, including identification of through-going faults that affect the Tiribi and overlying formations. Carlos Rodriguez (ICE), will conduct such a study under the joint supervision of ICE and UCR professionals, in fulfillment of the thesis requirement for a Lic. degree in Geology. Field samples of the post-avalanche deposit collected by the Consultants in September 1988 have been turned over to the UCR for laboratory preparation by C. Rodriguez. The Consultants will assist Rodriguez in the preliminary analysis of residual mineral and lithic fractions of washed samples during a subsequent visit scheduled in early November.

3.4 Investigations of Earthquake Hazards (Task III)

Earthquake hazard studies in FY88 focused on data integration, identification of seismic sources in the Valle Central, and discussion on a proposed seismic reflection study of the Valle Central and the western region of Costa Rica. The first two activities are a part of the original subtasks indentified in the MOU while the third activity (seismic reflection) is new; however, the Valle Central portion of this reflection line is considered to be important for understanding the structural relationships of the Valle Central and the behavior of future earthquakes in the Valle Central. These activities of FY88 are summarized in the following sections.

3.4.1 Earthquake Data Base Integration

A subcommittee of the MIRVYS Commission, consisting of representatives of UNA, UCR, ICE, and the Consultants, and referred to as the Data Integration Supervisory Panel (DISP), outlined a preliminary plan for integration of seismic data collected by the three Counterpart institutions. The outline of the plan is contained in the attached minutes of the June 21-22, 1988 subcommittee meetings (Attachment 3). Subsequent to that meeting and in accordance with the outlined plan, F. Guendell (UNA) prepared a more detailed plan which deals with the integration in two phases: (1) past data, and (2) future data. The first phase of this plan has, in part, been implemented. ICE seismologists met with the UNA technical committee to discuss details of the second phase, but the UNA technical committee was unable to agree to specific points of the plan, including equal acknowledgement of the institutions in the unified seismological bulletins and sharing of computer software. UNA is continuing to produce monthly and annual catalogs, and ICE/UCR is producing quarterly and annual catalogs. A proposal for network integration was prepared independently by UNA, and submitted to the MIRVYS Executive Committee. The proposal has not been accepted by UCR or ICE, and has not been available for review by the Consultants.

UNA has provided data from their seismograph network for the period 1984 - May, 1988 to UCR for inclusion in the unified earthquake data base for the Valle Central. These data are all the earthquakes that have been located by UNA at depths of 25 km or less using the standard hypocenter location program (HYPOINVERSE), and have been carefully checked for errors. UNA has produced

an epicenter plot of these data at small scale, which has been given to UCR. UNA is currently working on relocating these shallow events using a standard velocity model (Matumoto, 1978, modified by Morales and Montero) for the Valle Central.

ICE provided data from all the portable seismograph networks operated at ICE hydroelectric projects located within the Valle Central during the period 1980-1985 directly to UCR. ICE and UCR have not yet been able to locate the original phase data files from any of their networks that were in operation before 1984. Therefore, UNA has not begun to relocate pre-1984 events. Events located by the ICE/UCR network during the period 1984-1988 that were not located by UNA will also be included in the Valle Central data base. ICE and UNA are currently identifying such events, which will be relocated using the standard program and velocity model.

3.4.2 Identification of Seismic Sources in the Valle Central

UCR has reviewed and compiled data on shallow earthquakes that have occurred in the Valle Central during the period 1841-1988. This preliminary data base (or catalog) contains over 1200 earthquakes. In addition to data from regional networks discussed above, other sources of data include:

(a) Historic and world-wide seismicity data for the period 1841-1974, taken from international data sources (ISC, NOAA, USGS, etc.) and from national and international published and unpublished studies of specific earthquakes. Studies of pre-1841 earthquakes are, at present, insufficient for these earthquakes to be included in the data base.

(b) Data from the UCR Valle Central network for the period 1973-83.

(c) Data from various UCR portable networks that have been operated in the Valle Central.

UCR is presently examining the catalog for duplicate and/or incorrect entries. UCR has developed software to sort the data according to a variety of parameters, so that subsets of the data can be selected for plotting and analysis. This is necessary because the variety of data sources and the fact that, at present, the ICE and UCR data have not been relocated using a standard program, mean that the data base is not homogeneous. In addition to hypocentral parameters, each data base entry includes the data source and an indicator of the quality of the hypocentral solution, based upon the precision of the input data.

The software developed by UCR can be used to generate three-dimensional seismicity plots of the Valle Central at a scale of 1:500,000 and cross-sections at any selected azimuth. The three-dimensional plots are a very useful form of display, and the software is being further developed to "zoom" onto selected portions of the data and to view the three-dimensional seismicity distribution from any angle. At present, the plots can be displayed only on an IBM PC screen, since UCR does not have facilities for producing hard copies. However, the plot files can be stored on diskette and hard copies could be produced using a computer and peripherals with hard-copy capability.

The ICE Department of Geology has secured use of ICE's new Houston Instruments DMP-60 full-scale plotter to produce plots of the seismicity data to overlay maps at any desired scale. The plotter is linked to an IBM PC and runs AUTOCAD plotting software. The Consultants will develop the interface software necessary to produce the plots from the earthquake data base.

Much of the data is discussed and interpreted in the numerous papers and reports collected by the MIRVYS project. UCR has begun to synthesize these interpretations.

3.4.3 Seismic Refraction Shot

The proposal for the deep crustal refraction experiment was submitted to CNE for consideration by the MIRVYS Commission. The Consultants estimated the amount and cost of explosives for Phase I (Valle Central, on-shore). It is estimated that 4000 lbs of explosive charge will be needed plus boosters, detonators and primacord.

F. Guendell (UNA) met independently with Dr. W. Mooney of the U.S. Geological Survey (USGS) in August to discuss the possibility of a joint USGS/UNA refraction experiment, which would involve both offshore-onshore and the Valle Central profiles. Dr. Mooney has a great deal of experience in crustal profiling studies, and the USGS can make available a large amount of specialized equipment (about 120 radio-telemetered seismographs). However, it is not clear how long it would take to set-up such a joint experiment (probably at least 1-2 years), or how it would be funded. The MIRVYS Commission must evaluate the pros and cons of proceeding with Phase I of the proposal, based on its technical merit, application to the MIRVYS goals and objectives, and in consideration of the possible involvement of the USGS.

3.5 Geotechnical Engineering (Task IV)

The geotechnical engineering task consists of three subtasks. ICE is the lead counterpart for this task. The three subtasks consist of compiling existing data on the physical properties of the soil sequence(s) in the Valle Central (subtask I), field support (subtask II), and technical support in geology, seismology and engineering (subtask III). Subtasks I and III were initiated in September 1988; therefore there is very little to report on for FY 1988. Subtask II will not be initiated until Spring of 1989.

3.5.1 Geotechnical Data Compilation

The soil sequence in the Valle Central is relatively thick consisting of an upper organic section generally in excess of 0.5 m. The organic section overlies a highly weathered sequence of pyroclastics that are generally in excess of 5 m thick. An understanding of the extent and properties of these soils is important for evaluating expected ground response from both near and far source earthquakes. ICE has initiated a review of all existing data including drill logs and geophysical data of the Valle Central from various sources.

3.5.2 Technical Support

ICE has identified three major landslides in the Valle Central that are active and pose a threat to nearby population centers. Independent of the MIRVYS program, ICE is monitoring the San Blas landslide and is considering a monitoring program for the Tapesco landslide. The landslides hazards are summarized in the following descriptions.

San Blas Area - This slide is located in the Rio Reventado watershed which drains through western Cartago. The slide consists of a series of remobilized lahars whose source was the upper flanks of the Irazu volcano. Recent volcanic activity has resulted in oversteepened slopes of unconsolidated deposits on the upper flanks of Irazu. The lahars have partially filled the drainage basin. The estimated volume of this massive slide is 40 million cubic meters. The slide has been active for some time. The lower half is currently moving as a massive unit at a rate of between 15 and 25 m per year (according to personal communication from S. Mora of ICE). Heavy rainfall during 1988 has increased its activity. Concern has been expressed over the potential for damming of the Rio Reventado due to mass movement which could lead to breaching of the natural dam and catastrophic flooding of western Cartago, similar to the 1968 event.

Tapesco landslide - The Tapesco slide is a large slump block located in a drainage on the upper slope of Cerro Escazu. The block consists of seven to eight million cubic meters of rock and soil. With the heavy rains during 1988, the block has been destabilized and a well developed head-scarp up to 10 to 15 m exists. According to S. Mora (ICE), the estimated rate of movement is 5 m per year. The presence of numerous sag ponds and free flowing water suggest that the block is nearly saturated. The southern side of the block is drained by an active quebrada which empties into the drainage that passes through a number of communities including the small town of Santana. Concern has been focused on the potential that the river may be dammed below the slide. This natural dam could subsequently breach, causing flooding of the communities downstream.

Rio Chiquito landslide - This slide has not been observed by the Consultants; however, it is known to be active. It is located on the slopes of Irazu above the Town of Tres Rios.

3.6 Status of Strong Motion Network (Task V)

The Instituto Nacional de Investigaciones de Ingenieria (INII) of UCR has the primary responsibility for the seven subtasks of the strong motion task. The subtasks consist of an evaluation of the present strong motion network and additional equipment needs (Subtasks 1 and 2), an evaluation of the subsurface conditions at the accelerograph locations (Subtask 3), a review of the existing building code (Subtask 4), data analyses (Subtasks 6), and report preparation (Subtasks 5 and 7). Subtasks 1 and 2 were initiated in FY88; however, they are not scheduled to be completed until February, 1989. Subtask 6 is an ongoing activity. Subtasks 3 through 5 and Subtask 7 will be initiated in FY89.

3.6.1 Operation and Data Analysis

INII installed 18 accelerographs in the Valle Central and region during FY87. The accelerographs are located in a high rise buildings, (Holiday Inn Hotel), in other concrete structures, and in the field (both alluvial and rock sites). The accelerographs were installed by INII without direct Consultant assistance. INII is currently servicing both its network and the accelerograph stations of ICE. Data have been continually processed and analyzed. The Consultants will provide support in servicing the equipment and in data analyses.

4.0 PLANNED ACTIVITIES FOR FISCAL YEAR 1989

4.1. Planned Fault Hazard Evaluation (Task I)

During the first semester of FY89, studies will focus on refining the fault lineament of the Valle Central, on detailed mapping and exploratory trenching of selected lineaments believed to represent Quaternary faulting, and on identification of earthquake-induced landslides. Attachment 1 provides a schedule for this work. The second semester will focus on relating the microseismicity to the faults of the Valle Central and delineating the fault and landslide hazards.

An aerial reconnaissance will be conducted to select locations for exploratory trenching and detailed field mapping. Additional aerial photographs will be obtained from IGN to complete aerial photography coverage of the Valle Central. The photographs will be interpreted and any significant new lineaments identified will be added to the lineament map.

An exploratory trench will be excavated on one or more of the prominent west-trending lineaments south of the Cartago area. The trench(s) will be excavated under the direction of UCR geologists. It will be cleaned and logged by geologists from UCR in collaboration with the Consultants.

Field mapping and possible trenching will continue on other fault lineaments in the Cartago area, the lineament near Orotina, and the Alejuela Escarpment. UCR will prepare a detailed map of the quarry exposing the Alejuela fault near Grecia.
Strip maps of major exposures, natural or man-made (quarries and roadcuts) in the Valle Central will be made. This mapping will be done to verify the presence or absence of late Quaternary faulting. An analysis of the Holocene stratigraphy will be a component of this investigation. The work will be completed by UCR and ICE. The products of the work will be strip maps and a location map.

The air photograph interpretation work will include identification of landslides including possible earthquake-induced landslides in the Valle Central. This work will be done by ICE geologists.

4.2. Planned Volcanic Hazards Studies (Task II)

During the next six months, the Counterparts will focus on field activities necessary to complete MIRVYS Task II to produce a preliminary volcanic hazard zonation of the Valle Central. Published reports on the Holocene volcanic history of Poas, Irazu and Turrialba volcanoes will provide much of the basis for mapping the late Quaternary pyroclastic flow and lava flow hazard zones on the flanks of those three volcanoes. The Consultants intend to support the Counterparts in preparation of aerial photointerpretation-based maps of the volcanic complexes which will then be field checked to expedite progress on Barva, Irazu and Turrialba hazards assessment. In addition to field checking, the Counterparts will be asked to map late Quaternary deposits integrated onto a regional base map from published reports. Over the next three months, the Consultants intend to continue to invest their time in field investigations in coordination with the Counterparts.

4.3 Planned Earthquake Hazards Evaluation (Task III)

ICE is continuing to search for original earthquake phase data from its networks. S. Mora (ICE) indicated that his staff should be able to locate these data. L.D. Morales (UCR) will also continue to search for original phase data from the UCR and ICE networks. L.D. Morales is identifying the timing precision for each data source in the data base. Based on this, and once the original phase data have been located, the Data Integration Supervisory Panel (DISP) along with the Consultants will select those data sets that will be relocated by UNA. UNA will proceed with relocation of their 1984-1988 data set for the Valle Central using the shallow Valle Central velocity model, and will provide the updated data set to UCR. The final set of ICE/UCR events for the 1984-1988 period can then be selected, relocated by UNA, and included in the data base.

The preliminary data base listing will be supplied to ICE and UNA. These institutions will review the data base and suggest modifications, if necessary. The DISP is scheduled to meet at monthly intervals to achieve the objectives listed above, and to finalize the plan for future data integration. An agenda should be prepared in advance of each meeting. It will be important for the panel representative from each institution to participate in the development of the agenda. The recommendations of the DISP will be submitted to the MIRVYS Executive Committee.

The historical seismicity data base will continue to be refined in FY89. However, the final form of the data base, including entries for data quality and with errors and duplicates eliminated, should be completed in October 1988. The initial product from the data base will be epicenter plots to overlay base maps at a scale of 1:100,000. Plots will be available of subsets of the data, sorted according to date, latitude/longitude, depth, magnitude, data source, and data quality. Different symbols will be used to indicate instrumental or macroseismic (intensity) locations, and symbol size will be proportional to magnitude (or maximum intensity). Initial plots should be available in January 1989, at which time correlation of the seismicity data with geologic and lineament analyses can begin. The preliminary analyses will form the basis of selection of areas for detailed study.

Design of the portable microearthquake (MEQ) seismograph network(s) will be based on the initial correlation analyses. Commitment of portable seismographs from the 3 institutions were confirmed during December 1988. The plan is to deploy the MEQ network(s) in January, 1989. Figure 5 identifies a suggested configuration of possible areas for the portable network that provides coverage of the major faults in the Valle Central. A workshop will be organized in January or February involving all field and data processing personnel from the 3 institutions to set standardized MEQ survey field and data processing procedures.

ICE has indicated that R. Barquero (ICE) will start on the volcanic seismicity study immediately, using the ICE's existing volcanological and seismicity data base. Some waveform characterization studies will also be included. A preliminary report will be submitted on this subtask by ICE in February, 1989.

It will be important to set the investigation of Valle Central faulting and seismicity within the regional tectonic framework. For example, possible relationships between faulting and earthquakes in the vicinity of San Isidro and Buena Vista (1983 M_s 6.1) and along the Range Front Fault with those in the Valle Central will be investigated to examine the possible existence of regional tectonic structures related to oblique subduction, the Panama Fracture Zone, and the subduction of the Cocos Ridge.

Seismic network integration, i.e., reduction of duplication of instrument locations among the regional seismic networks of the participating organizations (see Figure 6 for comparison of UNA and ICE/UCR sites), is a major task confronting the MIRVYS Commission in FY89. Upon achieving integration of the earthquake data bases between the Counterparts, the Consultants will focus on integration of the networks. The Consultants will evaluate the integration issue and provide recommendations on the use of the networks and the possible relocation of instruments, if integration is concluded to be the best approach.

Discussions will continue with F. Guendell (UNA) concerning the probability and time-scale of a joint UNA/USGS deep profiling experiment. The MIRVYS Commission must decide whether or not to continue with the original proposal. This decision should be made early in FY89. If the MIRVYS Commission elects to go ahead with the proposal, the availability and cost of explosives in Costa Rica should be investigated. I. Boschini and S. Mora of ICE have identified LODINSA (tel: 27-0652) in San Jose as a possible supplier.

4.4 Planned Geotechnical Engineering Activities (Task IV)

During FY89, ICE will focus on compiling data and preparing a report on the physical properties of the soils of the Valle Central, and will provide geotechnical support to the landslide, seismic and volcanic hazards programs. S. Mora (ICE) is also considering a more active roll in the landslide studies. The equipment budget identified for ICE may be used for purchasing equipment designed for monitoring landslides. The landslides of interest are those discussed in Section 3.5.2 of this report.

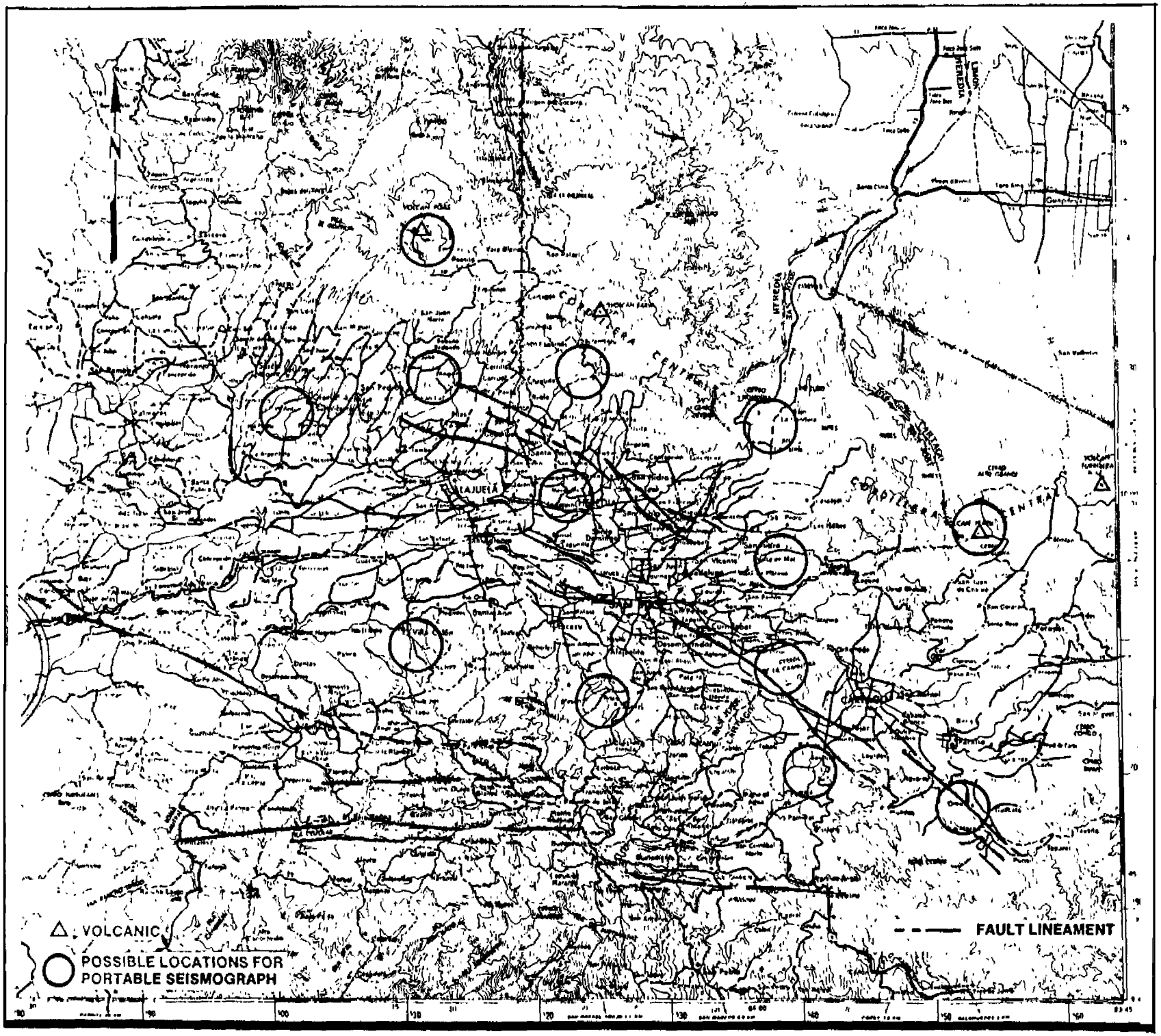

Figure 5. Preliminary fault lineament map with proposed seismograph network

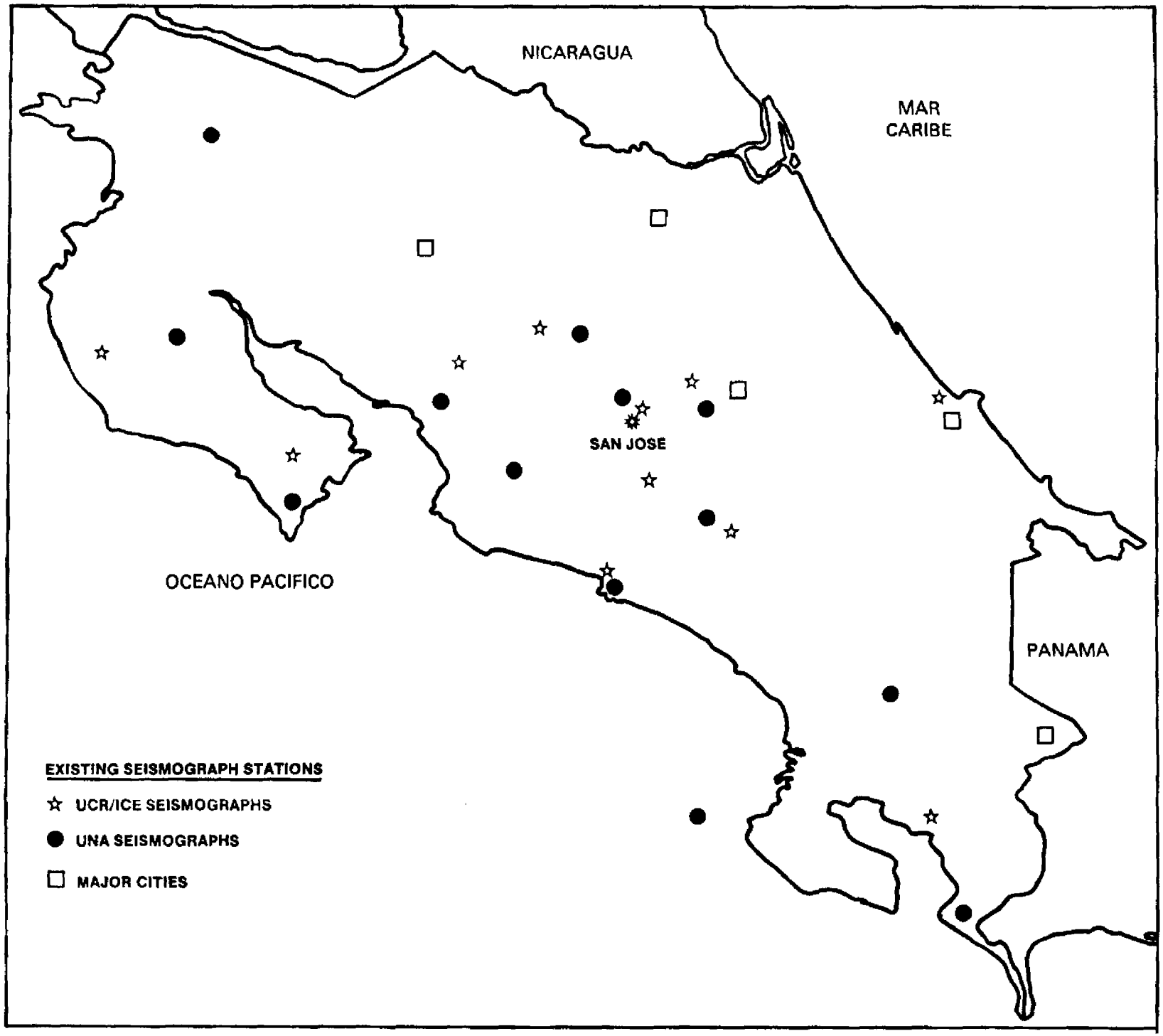

Figure 6. Existing Seismagraph network in Costa Rica

4.5 Planned Activities for the Strong Motion Task (Task V)

During FY89, the equipment identified will be purchased and shipped to Costa Rica. The majority of the components are spare parts. This will help assure the continued operation of the accelerograph network.

In addition to analyzing data, INII will initiate a program to evaluate the physical properties of the soils in the Valle Central to assess their anticipated behavior in earthquakes (both far and near source earthquakes). This investigation will result in a preliminary ground response map for the Valle Central. The Consultants will provide technical assistance to INII to train the investigators in making preliminary evaluations and to prepare a map.

To properly interpret accelerograms for local and regional earthquakes, INII will also run geophysical lines at the sites of their instruments to have specific site information. The data collected will then be more meaningful in terms of site specific ground response and refining the preliminary ground response map of the Valle Central. With the assistance of the Consultants, INII will provide input to the Colegio de Arquitectos y Ingenieros for possible revision of the building code currently in use for Costa Rica.

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