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TITLE: CENTRAL AMERICAN RESOURCE STUDIES

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Introduction

Los Alamos National Laboratory has been working with five Central American countries to assist in the development of their energy and mineral resources. Since 1985, mineral resources in Costa Rica, peat resources in Costa Rica and Panama, geothermal energy resources in Honduras and Guatemala, and geothermal field development in El Salvador and Costa Rica have been topics of study. This paper presents an overview of this work--within these proceedings are papers that deal with specific aspects of each topic, and these will be duly noted.

The studies described herein were funded by the U. S. Agency for International Development (USAID), and were administered through its Regional Office of Central American Programs (ROCAP), in Guatemala City. Mr. Carl Duisberg was the project manager. Due credit for assistance on much of this work must go to our counterparts in Central America: in Costa Rica, the Instituto Costarricence de Electricidad (ICE) (for the geothermal work), Minera Nacional, S. A. (MINASA) and the University of Costa Rica (UCR) (for the minerals work), and the Refinera Costarricence de Petroleo, S.A. (RECOPE) (for the peat studies); in El Salvador, the Comisión Hidroeléctrica del Río Lempa (CEL); in Guatemala, the Instituto Nacional de Electrificación (INDE); in Honduras, the Empresa Nacional de Energía Eléctrica (ENEE); and in Panama, the Instituto de Recursos Hidraulicos y Electrificacion (IHRE). Many personnel from these organizations helped greatly in our efforts. Thanks must also be given various contractors that worked on these projects: the U. S. Geological Survey (USGS), Lawrence Berkeley Laboratory (LBL), and various private consultants.

Los Alamos involvement in the region dealt first with mineral assessment in Costa Rica and peat assessment in Costa Rica and Panama. We later became more heavily involved in geothermal resource assessment in Honduras and Guatemala, and geothermal field development at Miravalles in Costa Rica and Ahuachapán in El Salvador. For the purposes of this paper, it is convenient to discuss these four "components" (mineral resource assessment, peat resource assessment, geothermal resource assessment, and geothermal field development) in the order mentioned above.

Mineral Resource Assessment

A major metallic mineral resource assessment was initiated in Costa Rica by Los Alamos, the USGS, MINASA and personnel from the UCR. The USGS and Los Alamos utilized two different approaches in assessing the mineral potential of a large part of the country. Los Alamos concentrated on the generation of geochemical atlases based upon the analysis of stream sediment samples while the USGS produced a mineral resource assessment folio for Costa Rica.

The USGS folio (Mineral Resource Assessment of the Republic of Costa Rica, USGS Misc. Inv. Map I-1865) is comprised of three parts. In the first part are a series of newly compiled country-wide maps for mineral resource assessment. Considerable

new data was collected to generate the physiographic, geologic, mineral occurrence and a variety of geophysical maps which are included in this section. Accompanying text describes the geology of Costa Rica, the more prominent geophysical anomalies and identifies areas that are of interest in exploring for various types of mineral deposits. In the second part of the folio the supporting data used to generate the mineral resource assessment maps are presented. These data include additional maps, figures and explanatory text. In the third part of the folio, the results of detailed investigations of the Costa Rican "gold belt" by the USGS and the counterpart organizations are given.

Los Alamos has published two geochemical atlases for Costa Rica (LA-10965-MS and LA-10965MS Addendum 1) which cover the San José, Golfito and Quepos guadrangles. Work is in progress on the atlas for the southwestern portion of the Talamanca quadrangle. These atlases are based on the analytical results of stream sediment sampled at a density of 1/20 km^2 over the four quadrangles.

Before beginning the stream sediment sampling program, Los Alamos conducted a pilot study in the San José and Talamanca quadrangles. This study, which became a M.Sc. thesis project for a Costa Rican geology student at the Colorado School of Mines (Arauz, 1986), determined the best sampling procedures and density for a tropical environment. Wet sieving techniques were developed to maximize sampling efficiency and the sample density of 1/20 km^2 was selected as optimal. Upon completion of the pilot study Los Alamos trained the counterpart geologists and students in the newly adopted sampling procedures and the field work began.

After collection, the stream sediment samples were dried and shipped to Los Alamos for analysis. The Los Alamos nuclear reactor was used to determine the abundances of 46 elements by neutron activation analysis, and a commercial geochemical laboratory was used for four additional elements.

The combined results of the USGS and Los Alamos assessments indicate that the Costa Rican "gold belt" is much larger than previously thought, extending a considerable distance to the southeast (see Fig. 1). The results also indicated a high potential for hot spring-type gold deposits. At the request of the Costa Rican government all results of the assessments were made public at an international gold conference held in San José in the fall of 1987. Specially prepared promotional brochures giving geochemical and geological data on the most promising prospects were distributed at this conference as were the USGS folio and the Los Alamos atlases. Releases of this vast amount of new data has greatly stimulated interest in gold development in Costa Rica and MINASA has received several proposals for more detailed evaluations of the prospects.

insert Fig. 1

Training of counterpart geologists and students has been an important part of the

entire assessment program. The USGS taught two formal courses in economic geology and both Los Alamos and the USGS performed on-the-job training in all aspects of modern mineral assessment and exploration. Over 150 geologists or students received some type of training.

Peat Resource Assessment

Los Alamos initiated an effort to find and evaluate peat deposits in Costa Rica and Panama, and were successful in identifying world class deposits in both countries. A detailed discussion of this work is contained in Thayer et al. (this volume). Suffice it to say that certain prospects were identified that would certainly be of interest to the counterparts involved. Those prospects are noted in Fig. 2.

insert Fig. 2

Geothermal Resource Assessment

Geothermal resource assessments have also been an important part of the Los Alamos Central American Program. Assessment work began in Honduras in 1985 and has continued there until the present time; in Guatemala it began in 1988.

Assessment work in Honduras began with a reconnaissance investigation of six previously identified areas that appeared to have geothermal potential. Results of these geological and geochemical investigations are reported in Eppler et al. (1986) and Goff et al. (1987, 1988a). The major conclusions of these reconnaissance-scale investigations were that three sites, Platanares, Azacualpa and San Ignacio, appeared to have the highest potential for electricity generation and that a fourth site, Pavana, had high potential for direct-use of the geothermal resource. Detailed geologic investigations were consequently focussed on these four sites. Results of these detailed studies are given in Heiken et al. (1987), Eppler et al. (1987a), Aldrich et al. (1987) and Eppler et al. (1987b) for Platanares, Azacualpa, San Ignacio and Pavana, respectively. Detailed geochemical work was also done at the four sites and these results are presented in Goff et al. (1987, 1988a). Based upon the results of these studies Platanares clearly had the highest potential for electricity generation with a calculated reservoir temperature of 225° C. Surface flow rates were also high at Platanares.

The encouraging results at Platanares lead to the decision to proceed with geophysical surveys and gradient drilling at this site. Telluric profiling and gravity and self-potential surveys were performed and three gradient wells were drilled. Results of the drilling are given in Goff et al. (1988b). Two of the three gradient wells encountered 160° C water at relatively shallow depths (< 650m) and the third, non-flowing well yielded a geothermal gradient of 139° C/km (Fig. 3 shows the artesian flow encountered at one well). All data from Platanares were integrated and a recommendations report (Laughlin, 1988) and an economics report (Trocki, 1989) submitted to ENEE. These reports concluded that it is economically very attractive to

begin the immediate development of the shallow reservoir while funding is sought for development and testing of the deeper 225° C reservoir. Los Alamos is now working closely with ENEE in seeking these funds. A more detailed discussion of the Honduras work is given by Goff et al. (this volume).

insert Fig. 3

In Guatemala, Los Alamos and the USGS have been working closely with INDE to complete a geothermal prefeasibility study of the Tecuamburro area in the eastern part of the country. Two field trips have been made and numerous rock and fluid samples have been collected for geology, geochronological studies and reservoir geothermometry. To date, results have been very exciting: reservoir temperatures as high as 298° C have been calculated and the geochronological results indicate that volcanism has continued as recently as 3000 years before present. Gradient drilling at Tecuamburro will begin in late 1989.

Geothermal Field Development

Los Alamos efforts under this category have concentrated on development of existing geothermal fields, well logging, geochemical brine sampling and analyses, reservoir engineering, and geophysics. The geothermal fields receiving attention to-date include Miravalles, in Costa Rica, and Ahuachapán, in El Salvador.

A large share of the funding was used to purchase a state-of-the-art well logging truck and downhole tools for the region. This equipment is patterned after the equipment developed by Los Alamos for the Hot Dry Rock Project in United States, which allows the monitoring of downhole temperatures, pressures, flows, and well diameters, plus the collection of brine samples at depth. These tools are calibrated for use in temperatures up to 300 °C in very caustic environments. One of these tools, a caliper tool, is shown in Fig. 4. Calcite buildup in certain wells at Miravalles (Dennis et al., 1989b) and recharge zones at Ahuachapán (Dennis et al., 1989a) are typical results observed. This equipment is being provided to the region and will be operated and maintained by a consortium involving CEL, ICE, INDE, ENEE, Los Alamos, and USAID. The details of this consortium are currently being worked out.

insert Fig. 4.

A second aspect of this component, geochemistry brine sampling and analysis, is linked to the well logging (downhole samples are collected as part of the well logging program). Analyses to-date have yielded interesting conclusions on recharge scenarios at Miravalles (Grigsby et al., 1989) and surface water encroachment at Ahuachapán (Dennis et al., 1989a).

A third aspect of this component, reservoir engineering, has been performed principally by a sister national laboratory, LBL, and has been concentrated at Ahuachapán. The focus of this effort has been to build a data base of past temperatures, pressures, drawdown, and geology in the field and then model various scenarios for development. This study will show how best to handle the current trend of dropping temperatures in the field (by perhaps using reinjection) and the direction of future drilling efforts. This work is on-going and initial results were presented at the Fourteenth Geothermal Reservoir Engineering Conference at Stanford in January 1989 (proceedings to be published).

The final aspect, geophysics, has dealt primarily with DC resistivity studies at Ahuachapán. Special equipment was built to extend the commercially available depth ranges so that the geologic structure could be seen better. The results of this work are still being analyzed and should be forthcoming soon.

Training has also been an important part of this component. Los Alamos and its contractors have made great efforts to transfer the ability to perform and analyze each of the aspects mentioned above to Central American counterparts. Several training sessions have been held, and certain personnel within the organizations of CEL, ICE, INDE, and ENEE have been trained in the techniques used.

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KNOWN GOLD DISTRICTS BEFORE LOS ALAMOS WORK

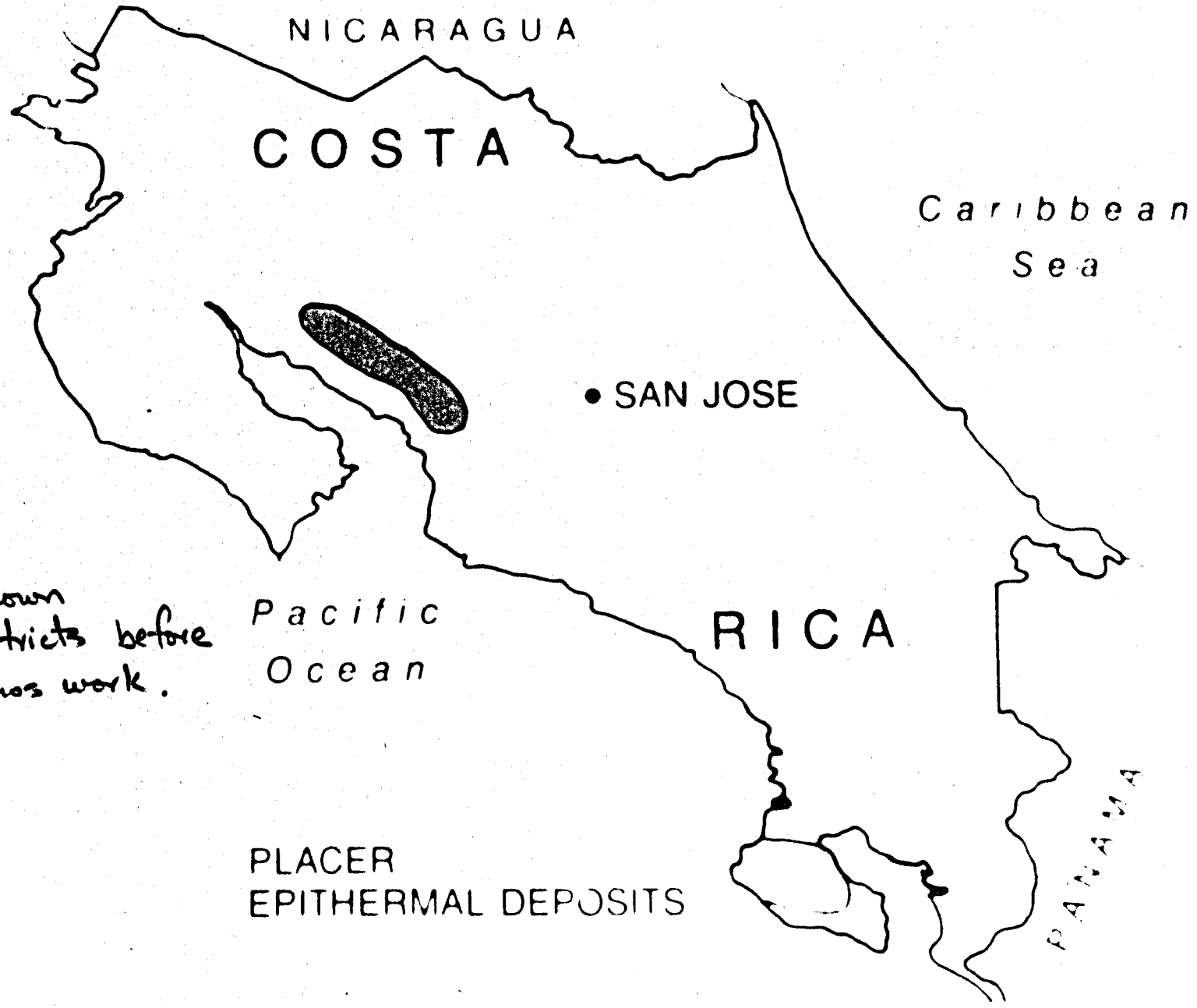

Fig. 1(a) Known gold districts before Los Alamos work.

POTENTIAL AREAS FOR GOLD AFTER LOS ALAMOS STUDY

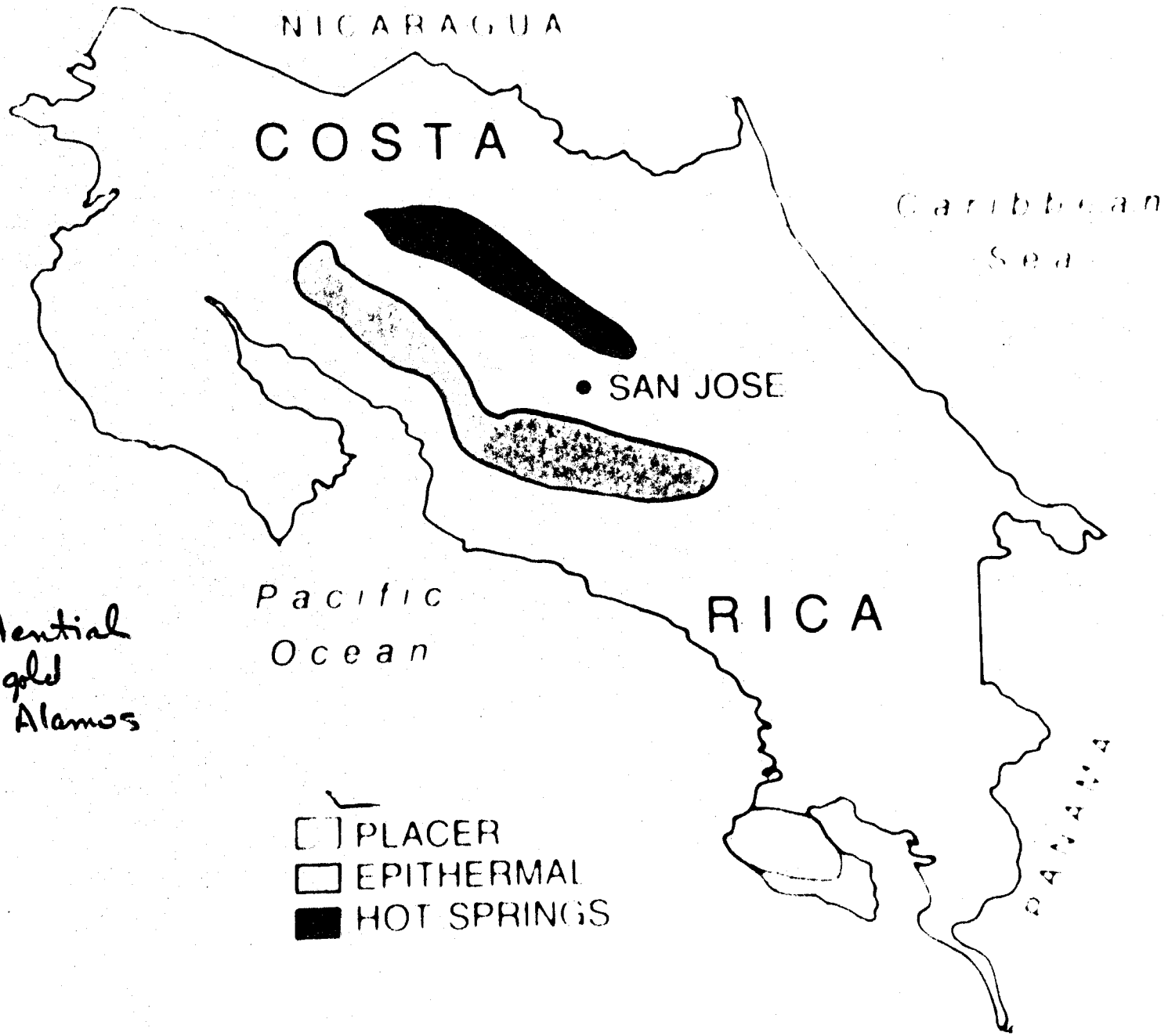

Fig. 1(b) Potential areas for gold after Los Alamos work.

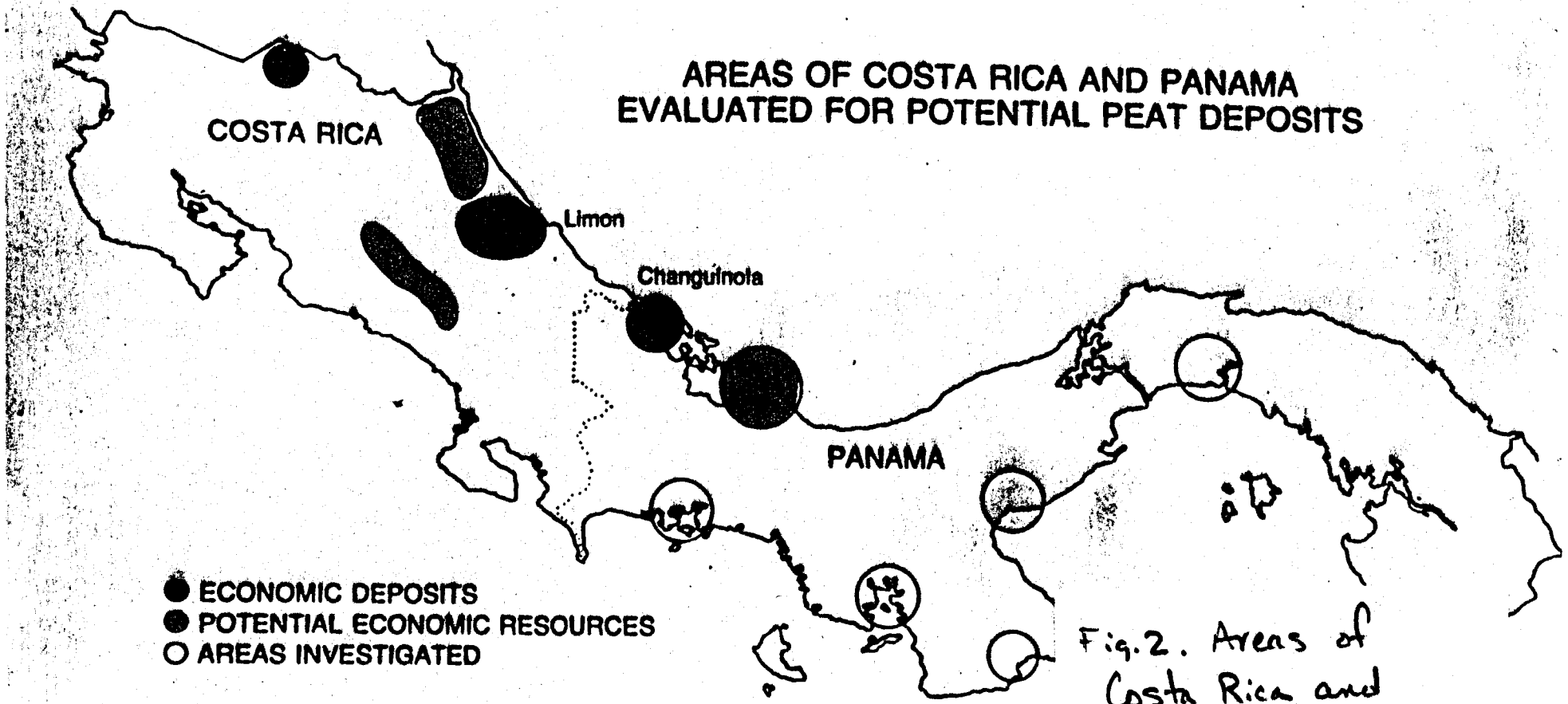

Fig. 2. Areas of Costa Rica and Panama evaluated for potential peat deposits.

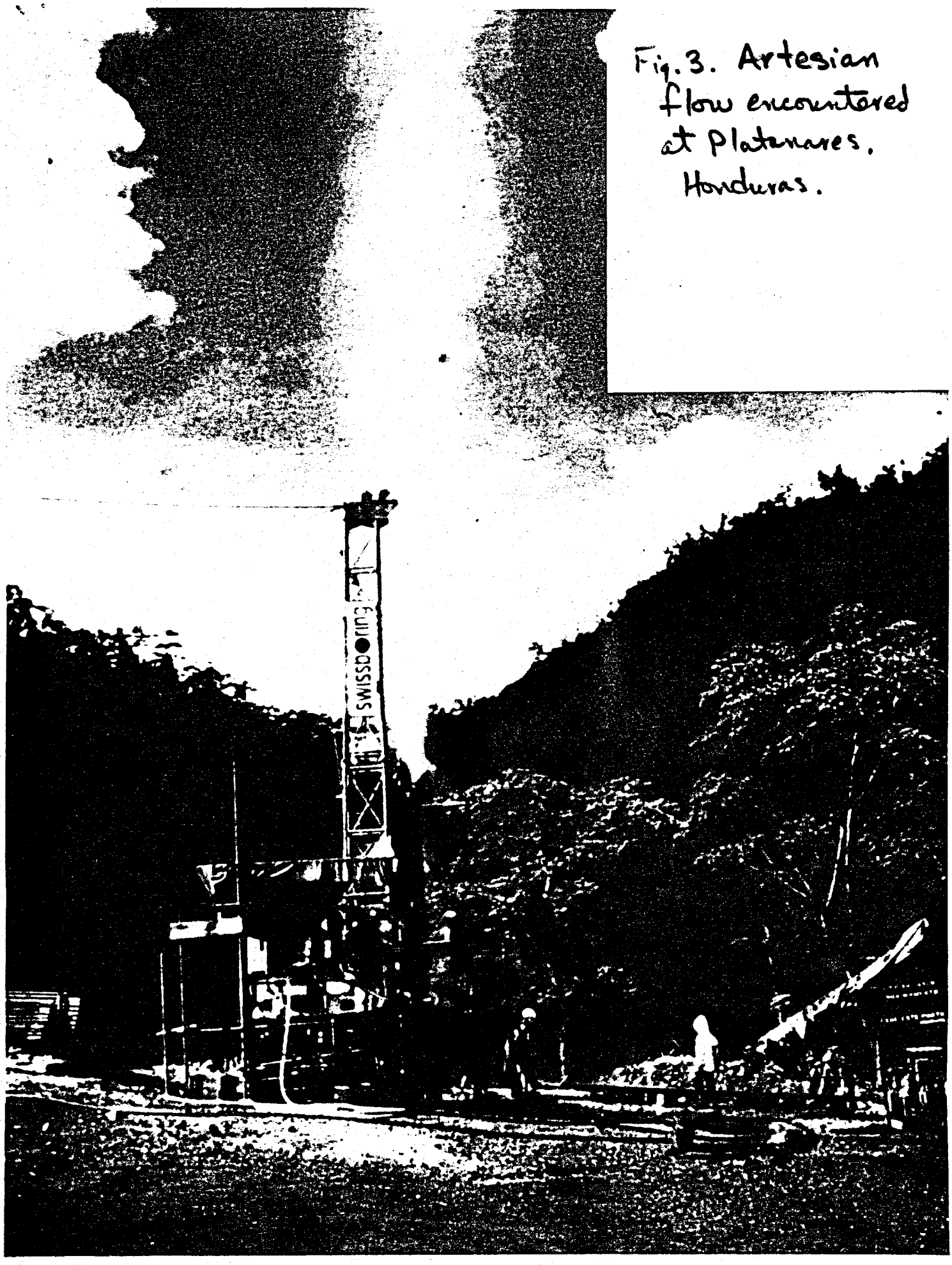

Fig. 3. Artesian flow encountered at Platanares, Honduras.

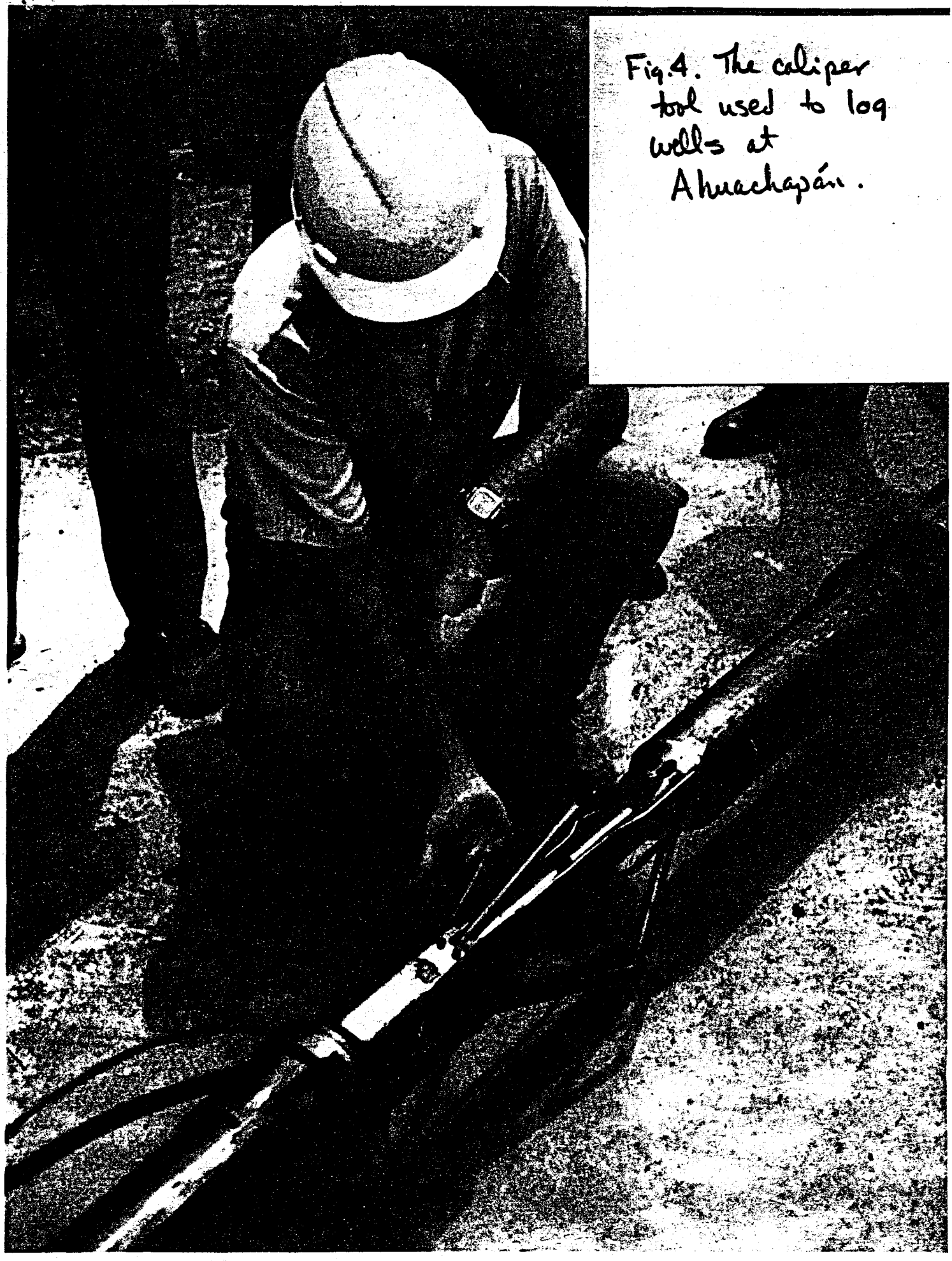

Fig. 4. The caliper tool used to log wells at Ahuachapán.