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Studies of Hydrothermal Processes in Crater Lake: A Preliminary Report of Field Studies Conducted in 1987 for Crater Lake National Park

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Summary.

Evidence from the 1987 field season strongly suggests the presence of hydrothermal input to the bottom of Crater Lake. The exact nature of the thermal discharge, however, is still uncertain. We observed many locations with hydrothermal precipitates and saw evidence of diffuse flow at two sites. These observations are compatible with dispersed flow through sediments from a number of vent sites. With this type of discharge the absolute temperature of the vent waters may be relatively low. Alternatively, there may be localized inputs of hotter water which follow conduits created by the faulting in the region. The observed variations of temperature with increasing depth are compatible with this interpretation. In either case it is clear that thermal waters, which carry elevated concentrations of dissolved metals and other salts, are entering the lake. These hydrothermal waters may significantly affect the rate at which the deep lake mixes with the upper levels of the lake, and in doing so, could have an important bearing on the biological productivity maintained by the lake. Future studies, which would allow more thorough mapping of the thermal features of the lake and actual sampling of the venting fluids, will be necessary to understand the full significance of this hydrothermal acitivity on the chemistry, biology and physics of the lake.

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* Subagreement No. 22 to Cooperative Agreement No. CA-9000-3-0003 "Crater Lake Hydrothermal System, Crater Lake National Park".

Introduction

The morphology and structure of Crater Lake provide dramatic evidence of a volcanic origin and history. It is also very likely that this igneous foundation controls the composition of lake water as well as the types and abundance of life found in the lake. For example, the extraordinary clarity of the lake and the resulting intense blue color may largely be the result of the volcanic terrain which limits the input of nutrients to the lake and biological productivity in the upper water column. Moreover, there has been a growing awareness that the volcanic root of the lake may generate thermal springs which define a distinctive water composition and influence the overall mixing characteristics of the lake. Given the igneous beginnings of the lake, the presence of thermal springs is not unexpected. It is probable that hot springs have been an important feature of the lake evolution throughout its 6900 year history.

During the summer of 1987 we began a focused study of the thermal spring input to Crater Lake. The timing of this study was influenced by two factors: (1) a recent need on the part of the National Park Service to document which parks have significant thermal features; (2) a growing awareness that hot spring input could explain a number of physical and chemical features of the lake. Results of chemical and isotopic studies we made during 1984 -86 provide the most recent evidence of hot spring input to the lake (Dymond and Collier, 1987). These results support the earlier thermal studies of Williams and von Herzen (1983) which suggested the presence of thermal springs in the bottom of the lake.

Our research group spent 20 days at the lake in 1987. The field portion of the current study was completed September 11, 1987, a week prior to preparation of this document. Consequently, this report is quite preliminary. A second report,which will be completed before February 15, 1988, will include results from extensive laboratory analyses on lake samples.

Instrumentation and Science Plan

The field portion of the program involved a mix of innovative and proven instrumentation used to locate sites of hot spring influx to the lake. The most innovative approach involved the use of a *remotely operated vehicle* (ROV), which provided live video for viewing and recording at the lake surface. Seven separate deployments of the ROV provided 12 hours of video imagry covering more than three kilometers of lake bottom (figure 1). In addition, a highly accurate device to measure the temperature, dissolved solids concentration (conductivity), and depth known as a *CTD probe* was used to explore the bottom water. The CTD was also outfitted with an instrument (*transmissometer*) to measure the water clarity since precipitation of hot spring fluids could decrease the clarity of bottom waters. Twenty nine CTD deployments ("casts") were made (figure 2), and some of these casts were transects that provided real-time, ship-board recording of the data over considerable distances of the lake bottom . Finally, an extensive *water sampling program* provided material to test the influence of hot springs on the composition of the lake. Water samples were collected from 11 "hydrocast" stations (figure 3). These will be analyzed for their isotopic compositons, major element contents, minor element abundances, trace gas contents, and physical chemical properties. Collaborators in these chemical measurements include: J.Lupton, University of California at Santa Barbara (helium isotopes); M. Lilley, University of Washington (methane); J. Thompson, US Geological Survey (sulfate, chloride, oxygen isotopes).

The basin south east of Wizard Island was chosen for intensive study (figures 1-3) because our preliminary studies of water samples from the lake revealed that this region appeared to have the clearest evidence of hydrothermal activity. Again, this was consistent with the work of Williams and von Herzen (1983). Samples and measurements from other basins were also obtained to compare with the region thought to have the greatest hydrothermal input. In addition, we briefly investigated Miriam Cone and the shallow platform east of Wizard Island. Both are relatively recent volcanic features that may have formed after filling of the lake.

All sampling was carried out using a highly-accurate and precise radar range-triangulation navigation system. Positions of the research boat on the lake surface could be relocated to within a radius of about 5 meters and with an overall accuracy consistent with the available USGS topographic maps.

Results

ROV

A remotely operated vehicle built by Deep Ocean Engineering was the most innovative portion of the 1987 field program. Although there were technical difficulties, operation was highly sucessful, especially considering that it was a significant extension of the instrument's design capability. The instrument was designed to operate at depths shallower than 1000 feet; however, we deployed it at the end of 1700 feet of cable in water 1600 feet deep. The video images obtained from this portion of the study provided the first visual evidence of hydrothermal venting on the lake floor. Electronic noise was present in the recorded images during the first two days (ROV 1-4). This degraded the visual record of some of the most impressive thermal sites. Figures 4-10 are prints made from the original tape included to illustrate specific points. The very distinctive patches of hydrothermal precipitates offer the clearest visual evidence of venting on the lake floor. These areas are in marked contrast to the smooth sediments that cover most of the lake bottom. The precipitates are distinctly coarser than the sediments and do not remain in suspension when disturbed by the ROV. The colors of the precipitates are various shades of red and brown, which are consistent with iron and manganese oxides, the expected solids which precipitate when metal-bearing thermal fluids contact oxygenated bottom waters. At two areas discovered during the ROV 3 deployment, diffuse flow was observed. Very fine, light-colored precipitates appeared to emanate with the flow. In addition, the coarse precipitates which were present at a number of sites, covered the bottom around the areas of diffuse venting. The regions of hydrothermal precipitation were only observed within the detailed study area southeast of Wizard Island, however, the observations in other parts of the lake were too limited to preclude wider distribution. In figure 10 we have mapped the locations of observed hydrothermal influence. The known area affected stretches over a distance of 300 meters. A fault zone was observed from the ROV with rocks that penetrated the sediment surface at the southern margin of the basin. Because hydrothermal fluids will follow conduits resulting from fracturing and faulting, this may be the source of the warmer waters (discussed below) which appear to fill the basin.

The CTD was attached to the ROV after the first three deployments demonstrated the vehicle could reliably operate in the great depths of the lake. With this device temperature perturbations as large as 0.4 degrees Celsius above the normal bottom temperature were observed in the detailed study area. Unfortunately, the ROV deployments where the CTD was used (ROV 4 and ROV 6) did not encounter areas of diffuse flow which were observed during ROV 3. Consequently, we could not document the temperature of the venting fluids. Nonetheless, the small temperature anomalies in association with clear visual evidence of deposition from thermal springs indicates the present-day influx due to venting at the lake bottom.

CTD Casts and Water Sampling.

The collection of temperature, conductivity and light transmission data was very successful. The CTD ("Seacat Profiler", SeaBird Electronics), is a state-of-the-art oceanographic instrument capable of highly precise temperature (±0.001 °C) and conductivity measurements (±0.0005 mmho/cm, about 5% of the conductivity of Crater Lake water) at depths down to 600 meters (±0.5 meters). Attached to the CTD was a light "transmissometer" (SeaTech Inc.) which measures the clarity of water. This instrument package was lowered from the research boat to within 0.5 meters of the lake floor using an accoustic depth sounder which displayed both the CTD and the bottom. The instrument package could record data on a self-contained computer or it could transmit the data to the research boat using a conducting hydrographic wire. Both configurations were used during our study.

The presence of warmer water at the bottom of the lake has been noted for many years. More recently, Williams and Von Herzen (1983) demonstrated systematic increases in bottom water temperatures near regions of high "heat-flow" through the sediments in the South basin. The minimum temperature in the lake, ~3.50°C, occurs everywhere at approximately 320 meters depth. From this point to the bottom, the temperature slowly increases by approximately 0.05°C. Our CTD data, which focused on this basin, frequently shows a significant temperature increase on top of this warming trend. This "temperature anomaly" was more than 0.1°C in the east end of the south basin and, during one ROV tow, we detected at least one temperature spike which was more than 0.4°C above the "background" water temperature. Although these temperature differences may appear small, they are analogous to temperature differences seen in the ocean very near to known hot springs since the heat is rapidly dilluted by the large volume of cold deep water. Horizontal sections of these temperature profiles running across the basin (Fig. 11) clearly show this warm water. Some of these vertical profiles are "stepped" or actually turn over at the bottom suggesting proximity to the active source of venting. We have integrated and contoured the "excess heat" associated with these anomalies (Fig. 12) and this distribution shows two main features in the south basin. These thermal areas are well correlated with the location of hydrothermal precipitates seen with the ROV (Fig. 10).

The warm water is also associated with an increase in conductivity which suggests an increase in dissolved solids in the hot springs. This is not surprising since one of the features of Crater Lake which has always suggested the presence of hot springs is its anomalously high salt content. This conductivity increase can be seen in a vertical profile shown with the temperature sections in Fig. 11. The magnitude of the increase would correspond to an increase of about 10% in dissolved ions.

There was relatively little decrease in light transmission associated with the warm water at the bottom of the south basin. This probably suggests that the spring water does not precipitate large amounts of dissolved solids within the water column after venting (unlike the "black smoker" hydrothermal vents in the Pacific Ocean). Small amounts of precipitate such as seen in the video tape at the hydrothermal sites, would be quickly diluted below the detection limit.

In summary, we were able to demonstrate the presence of thermal waters in the south basin. The location and characteristics of the inputs are still unknown although we have significantly narrowed down the target for the proposed submersible work. The venting fluid appears to be warmer and more saline such that it may be denser than the surrounding bottom water. This could actually allow it to "run down" the south east basin wall (as it appears to in Fig. 11) filling the rest of that basin with anomalous hydrothermal water. A small amount of thermal water was seen "over the saddle" between the south and northeast basins which may suggest some amount of overflow and/or and vent location at or above the depth of the basin connections.

Summary

The available data from the 1987 field season strongly support the presence of hydrothermal inputs to the bottom of Crater Lake. Detailed studies in the South Basin of the lake suggest this region is the focus of active venting. Video images of hydrothermal precipitates and diffuse flow in concert with anomalously warm water and higher salinity in the overlying water all point to a relatively large input of heated waters in this region. The exact nature of the discharge, however, is still uncertain. It could be in the form of diffuse flow from a number of sites over a large region. The observed diffuse flow at two sites and precipitates within the sediments are compatible with this interpretation. With this type of discharge the absolute temperature of the vent waters may be relatively low. Alternatively, there may be localized inputs of hotter water which follow conduits created by the faulting observed in the region. The variability in the temperature vs depth profiles from rather closely spaced sites is compatible with this interpretation. In either case it is clear that thermal waters, which carry elevated concentrations of dissolved metals and other salts, are entering the lake. These hydrothermal waters may significantly affect the rate at which the deep lake mixes with the upper levels of the lake, and in doing so, could have an important bearing on the biological productivity maintained by the lake. Future studies, which would allow the more thorough mapping of the thermal features of the lake and actual sampling of the venting fluids, will be necessary to understand the full significance of hydrothermal activity on the ecology of the lake.

<u>References</u>

Dymond, J. and R. W. Collier, 1987, Geochemistry and Limnology of Crater Lake, Final Project Report, Cooperative Agreement No. CA-9000-3-000, subagreements #13a&c.

Williams, D.L. and R.P. von Herzen, 1983, On the terrestrial heatfloe and physical limnology of Crater Lake, Oregon. J.G.R., 88:1094-1104.

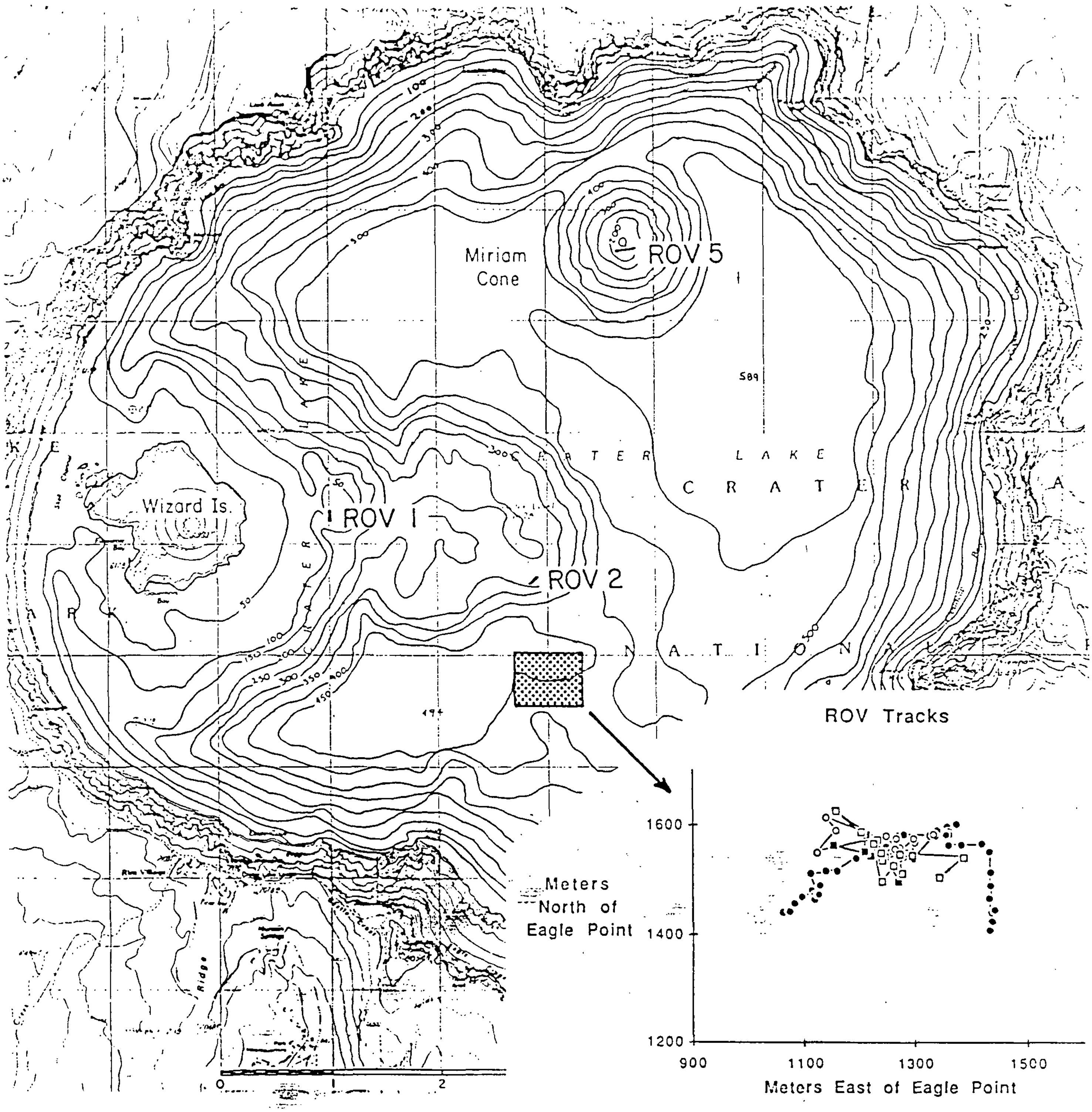


Figure 1. ROV track lines. ROV 1 was at the site of the dacite cone, which is believed to be a site of relatively recent volcanism (Charles Bacon, USGS, pers. comm.). ROV 2 is located on the edge of the Wizard Platform, which may be synchronous with Wizard Island. ROV 5 is near the summit of Miriam Cone, also believe to be a late-forming volcanic feature. The other four ROV deployments are located inside the box outlining the detailed study area. Open squares are ROV 3; filled squares are ROV 4, open circles are ROV 6; filled circles are ROV 7.

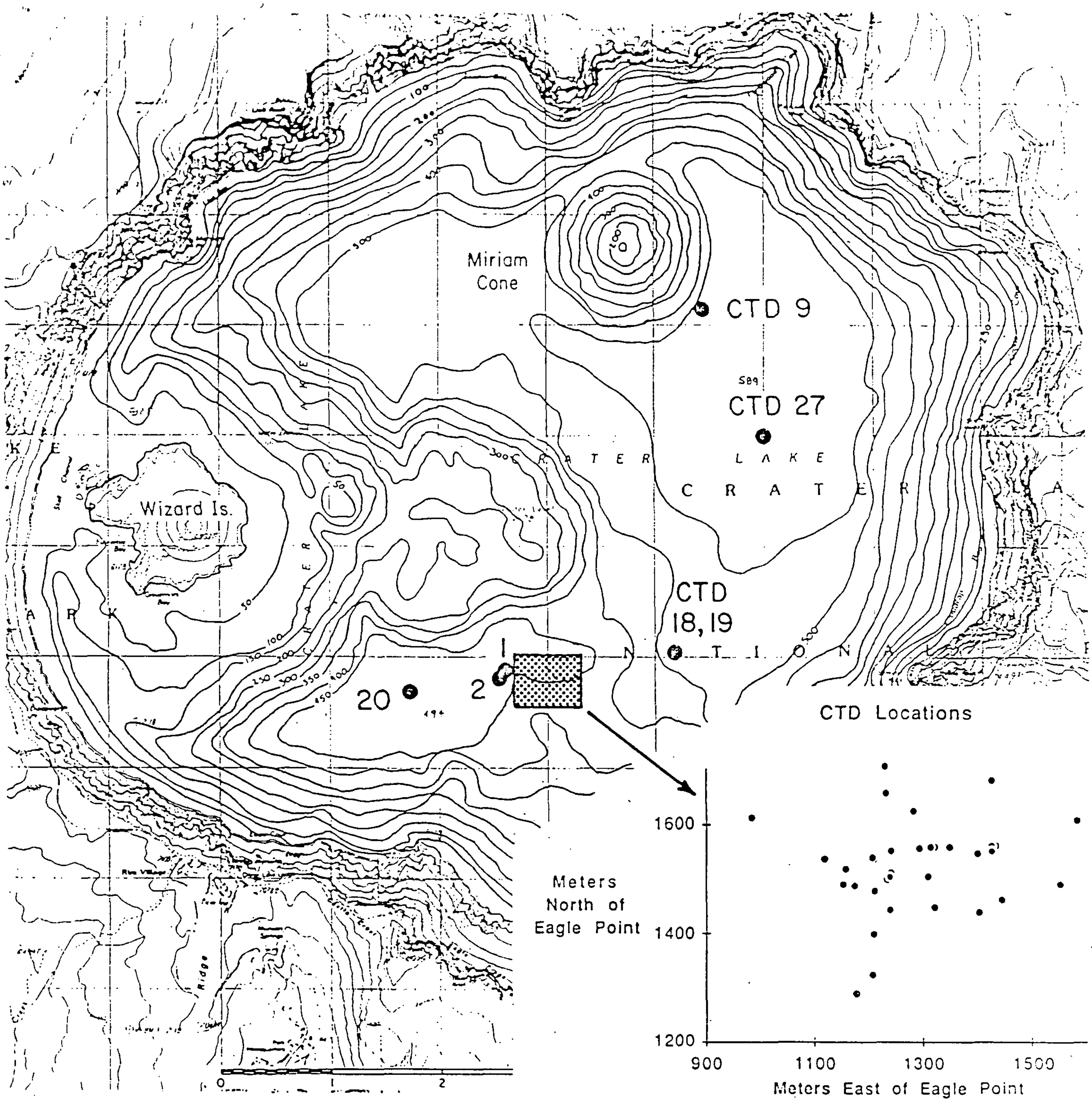


Figure 2. CTD locations showing the box outlining the detailed study area.

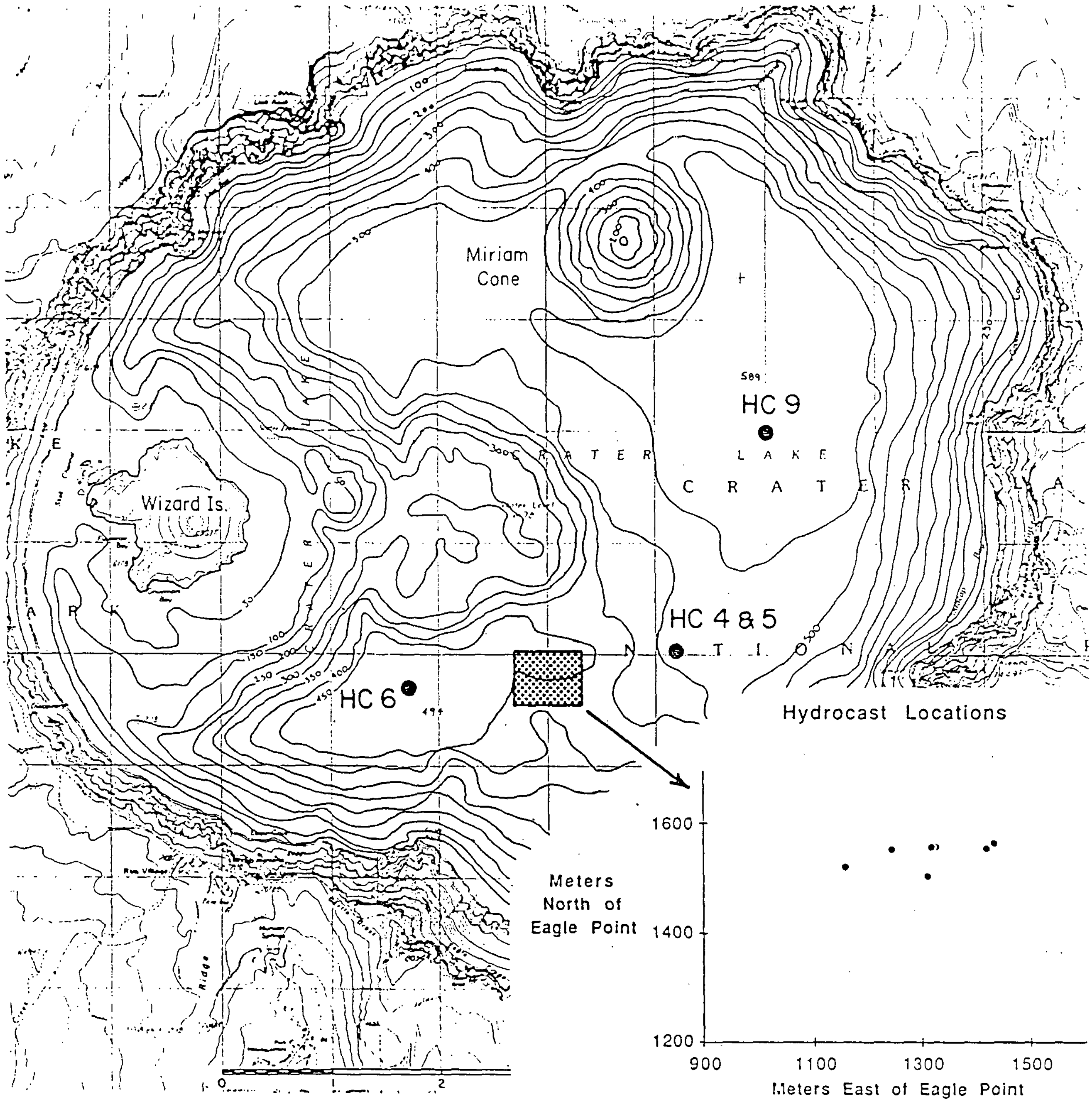


Figure 3. Watercast locations where water was recovered at different depths for laboratory analyses. The box outlines the detailed study area.

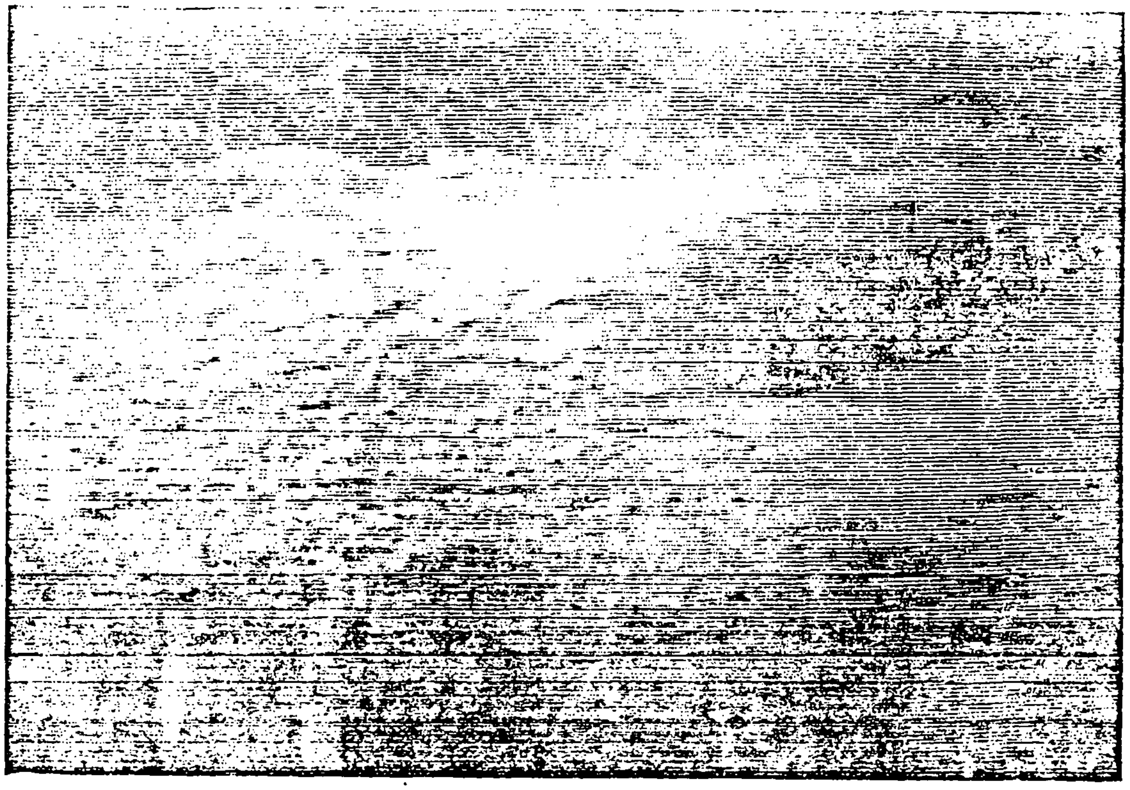


Figure 4. Video image of one of lava flows from the dacite cone east of Wizard Island. This region of the lake is believed to be relatively recent, and the flow structure shown in this image indicates that the lava was erupted under water. Consequently, the vulcanism must be subsequent to filling of the lake with water. Because of the depth (~100 m), this video was recorded under ambient light and the quality contrasts strongly with the deeper sites that require artificial lighting.

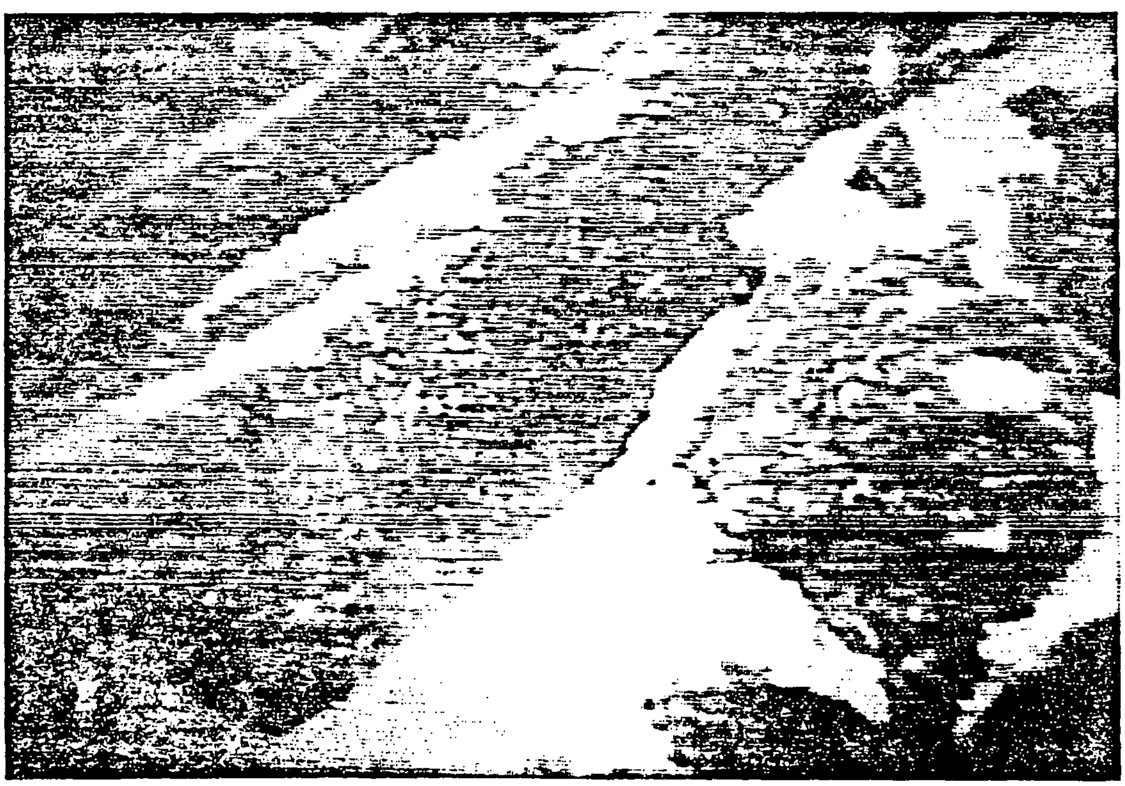


Figure 5. Video image from near the summit of Miriam Cone. The blocky nature of the rocks does not confirm an eruption beneath the lake surface. The very thin covering of sediment, however, either indicates a very recent origin or that significant currents at this relatively shallow depth exist which prevent the accumulation of sediments.

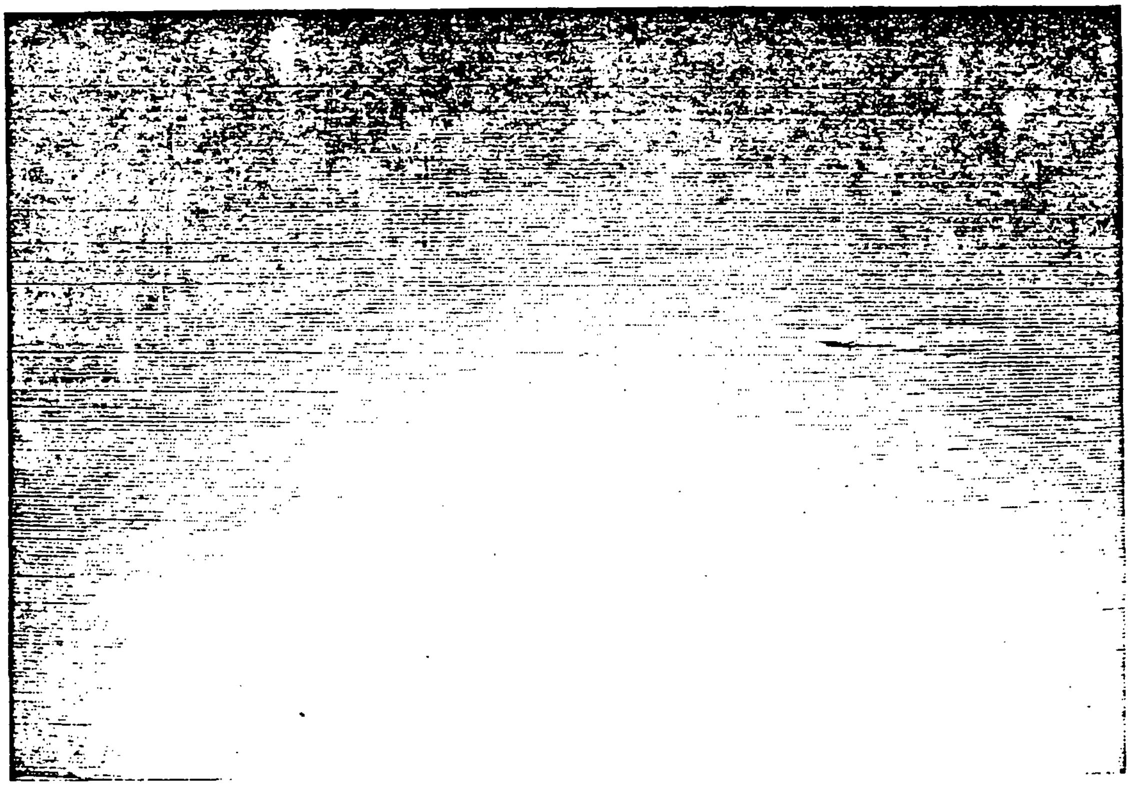


Figure 6. Typical Crater Lake bottom. The smooth buff-colored sediments cover most of the lake floor. They are relatively fined grained and are easily stirred up.

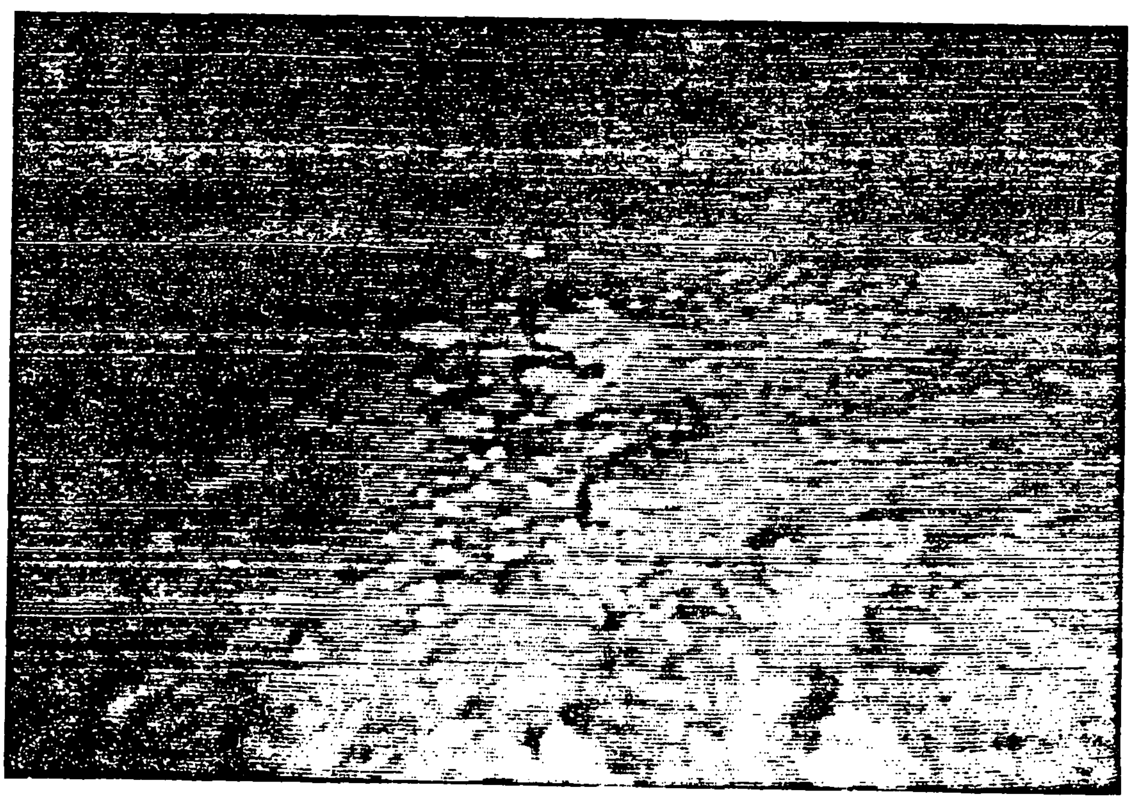


Figure 7. A site of hydrothermal precipitate deposition from the basin south east of Wizard Island. The dark and red colored pieces are most probably manangese and iron oxides. One sediment core collected in this region in the past contained these precipitates. These metals are greatly enriched in hydrothermal fluids and are very insoluble in cold, oxygenated water.

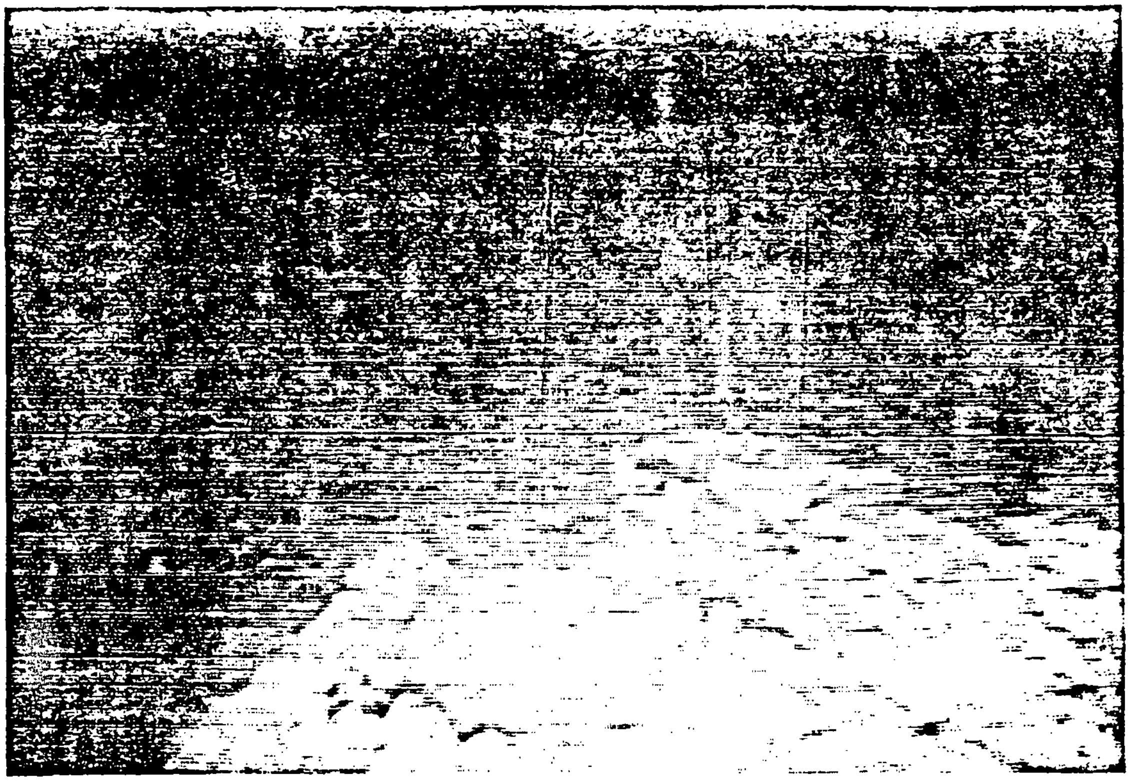


Figure 8. Hydrothermal layering within the sediment. The break in the sediment reveals banding that is consistent with diffuse flow of hydrothermal fluids through the sediment. The reddish-brown band in the center is probably iron oxides. Overlying that band is a thin, dark layer which is probably manganese oxides. The underlying buff material is the typical Crater Lake sediment. Because of the different solubilities of iron and manganese in oxygenated water, iron would be expected to precipitate first, followed by manganese, thereby producing the color sequence shown here. Similar deposition has been observed in hydrothermal systems which flow through sediments in the deep ocean.

Figure 9. A hydrothermal vent which revealed diffuse flow and very fine precipitates. Because of the degradation of quality caused by copying the original video the flow and fine precipitates are not visible in this photograph. The relatively coarse hydrothermal precipitates are scattered on the lake floor around the vent.

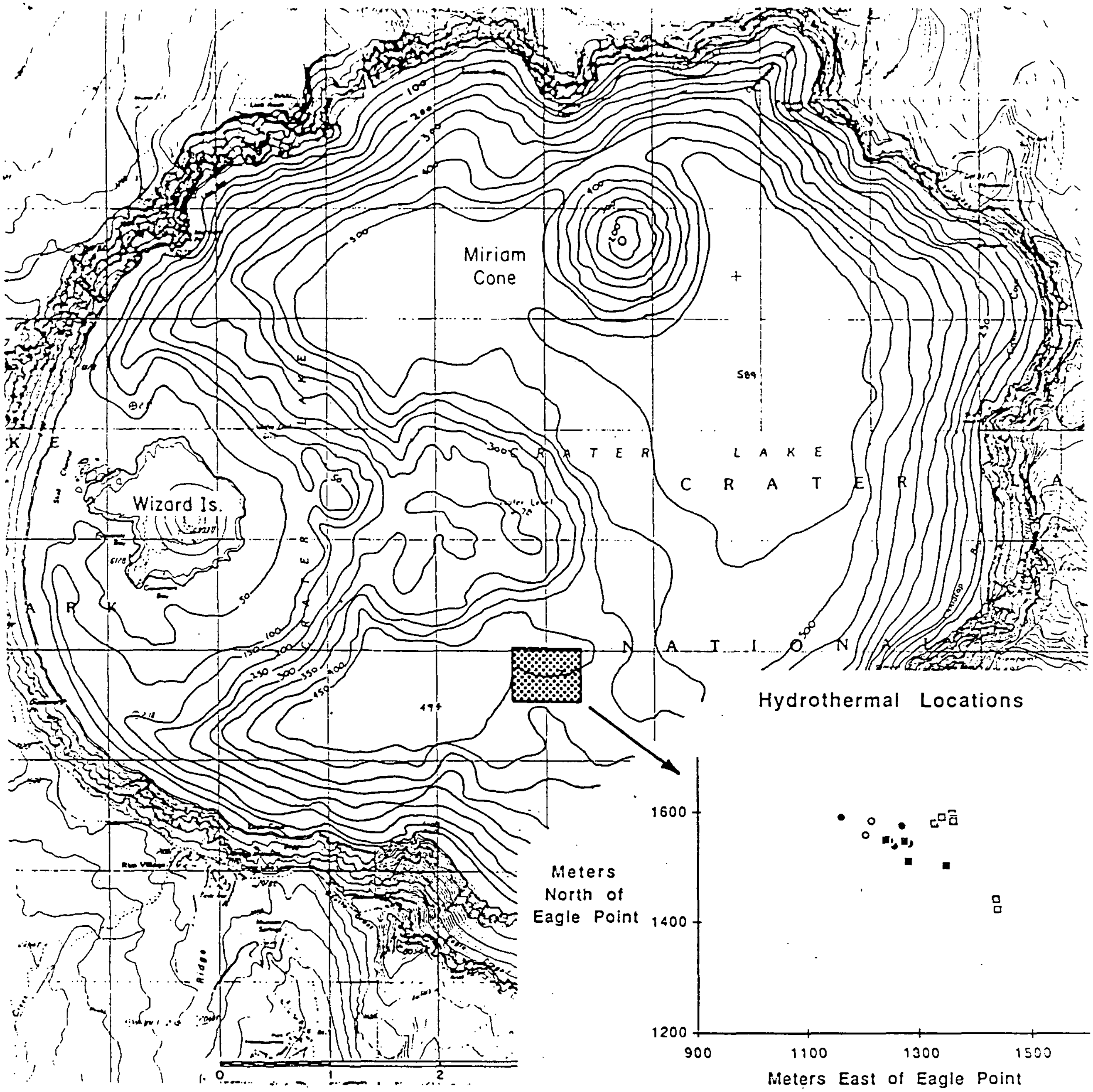
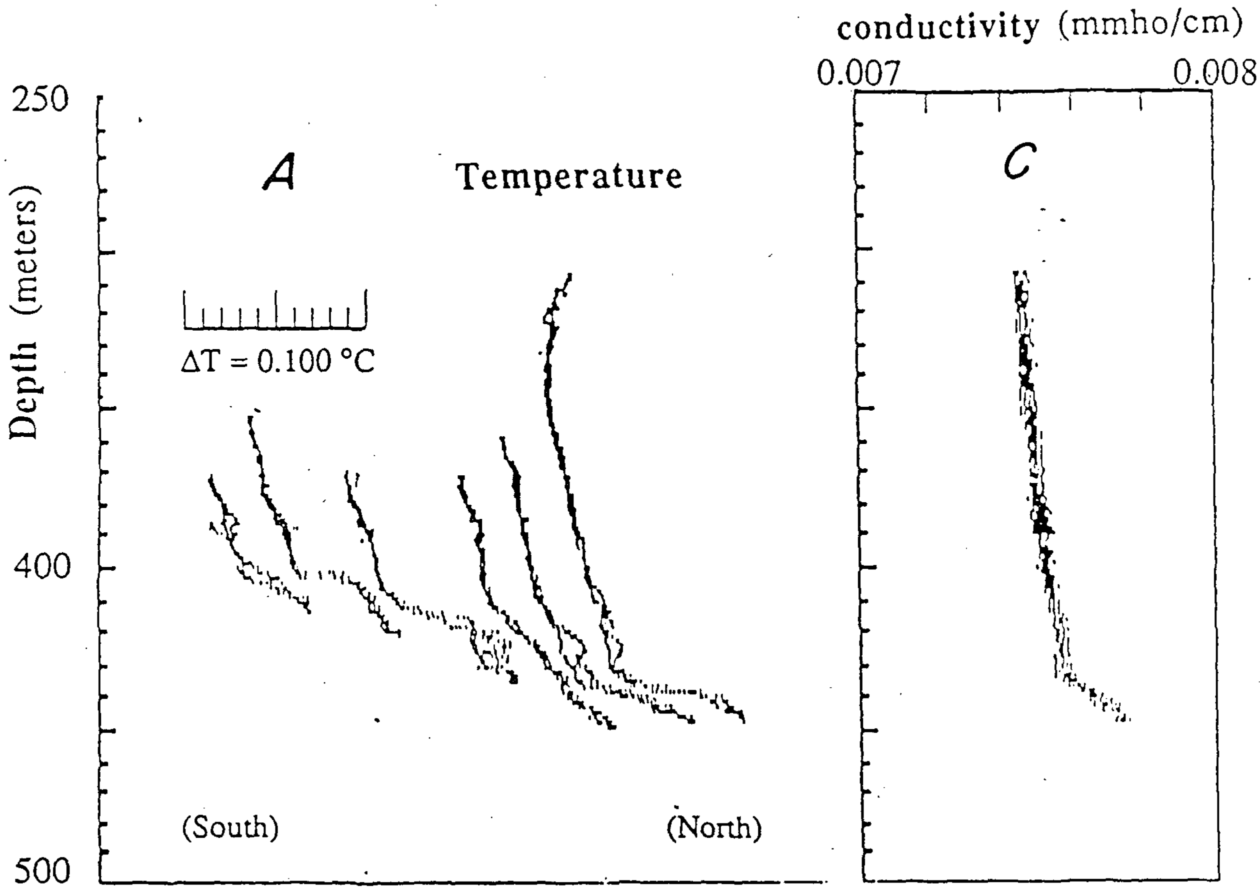


Figure 10. Hydrothermal locations defined by the video observations using the ROV. The sites marked are locations where patches of hydrothermal precipitates cover the bottom. The symbols represent the four different ROV dives in the area.



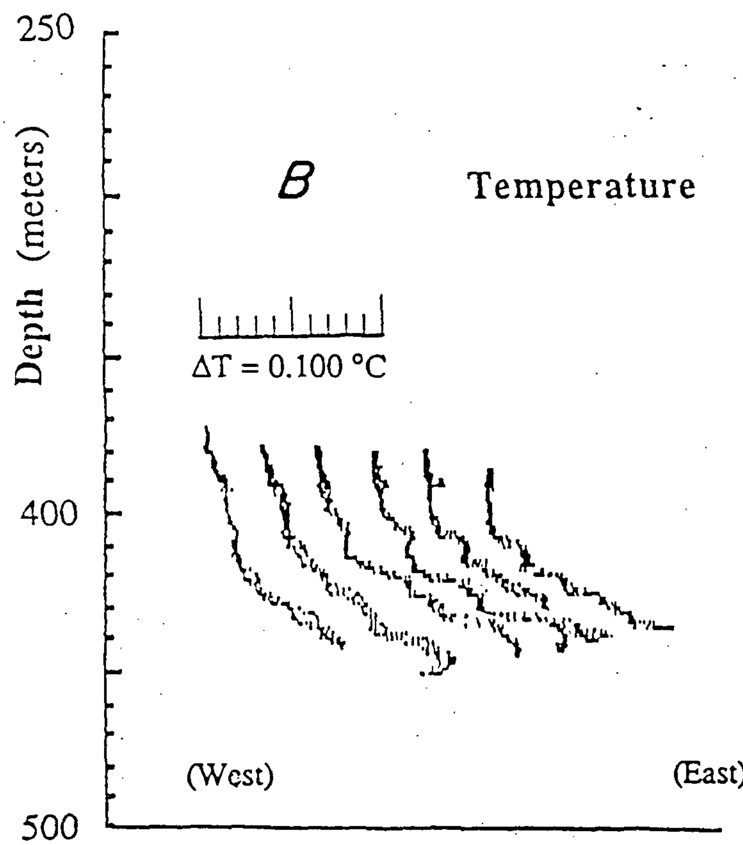


Figure 11. (A) A series of six vertical profiles of temperature near the bottom of the southern "hydrothermal" basin. The profiles are arrainged in a horizontal section running from the south (left on the graph) to the north (right on the graph), covering approximately 300 meters - the observer is looking to the west. These data are within the group of CTD stations shown in Fig. 2. Each profile has been offset to the right (in temperature) for clarity - all temperatures shallower than 380 meters are essentially identical (3.515 °C). The data in each profile ends at the lake bottom. It can be seen that the thermal anomaly appears to move down the slope (south-to-north) into the basin suggesting the possibility that it might be denser than the surrounding water. (B) Horizontal section of profiles moving from west (left) to east (right) - the observer is looking north. Notice that the temperature "turns over" near the bottom in several of these profiles suggesting the possible injection of a hydrothermal "plume" over the colder bottom water. (C) A vertical profile of conductivity corresponding to the northern-most profile in (A).

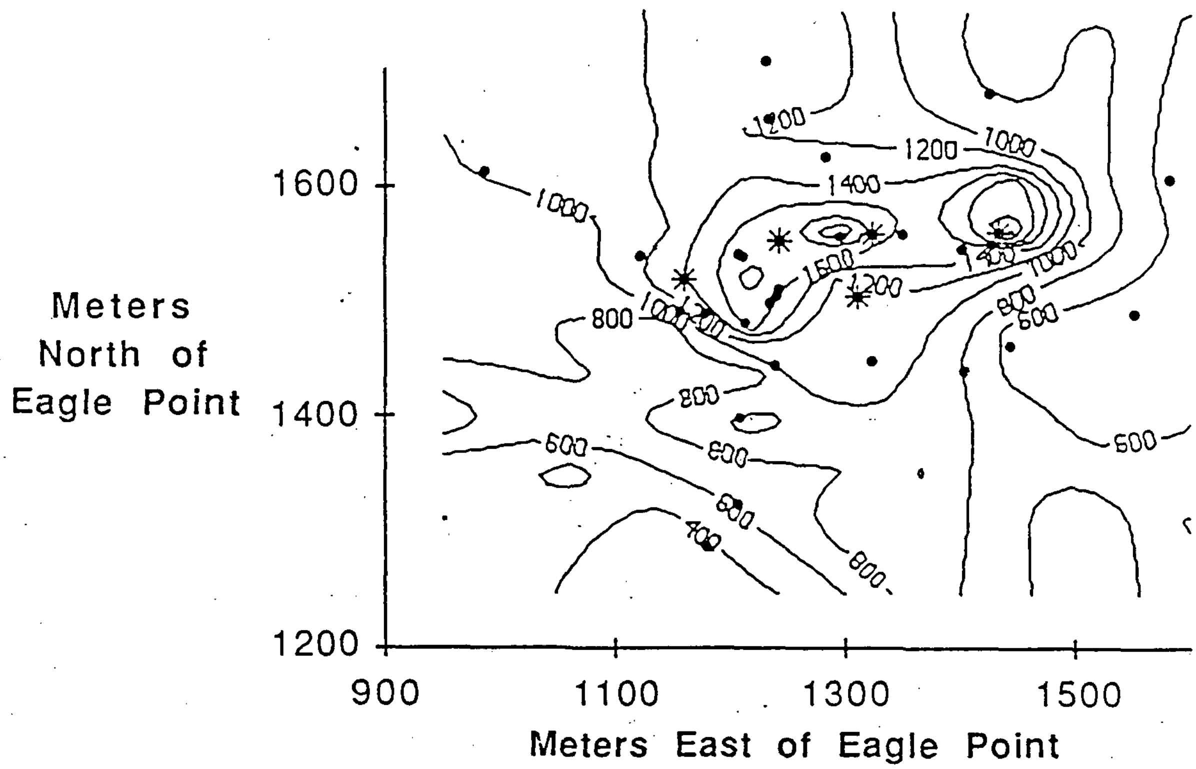


Figure 12. Contour plot of total water column heat "anomaly" (integrated vertically, $kcal/m^2$) within the hydrothermal basin. Points on the graph are the same CTD station locations shown in Figure 2. The major central region containing most of the hot water (some values over 2000 $kcal/m^2$) coincides with the zones of hydrothermal precipitates observed from the ROV videos (Figure 3).

FOR IMMEDIATE RELEASE
July 25, 1988

CONTACT: JOE LA FLEUR
(503) 593-2414

JIM MOORE
(707) 526-1000

Geothermal Simulation Coincides with Crater Lake Submarine Launching

July 25, 1988 . . . On the first of August, 1988, the National Park Service (NPS) will launch a one-man submarine into Crater Lake to continue their search for hot springs hypothesized to exist on the deep lake floor. The NPS has expressed concern that if these hot springs are found to exist they might somehow be impacted by geothermal drilling activity on the Winema National Forest, seven and one-half miles away and down hill from the lake surface. It has also been suggested that these hypothesized hot spring vents enhance lake water clarity.

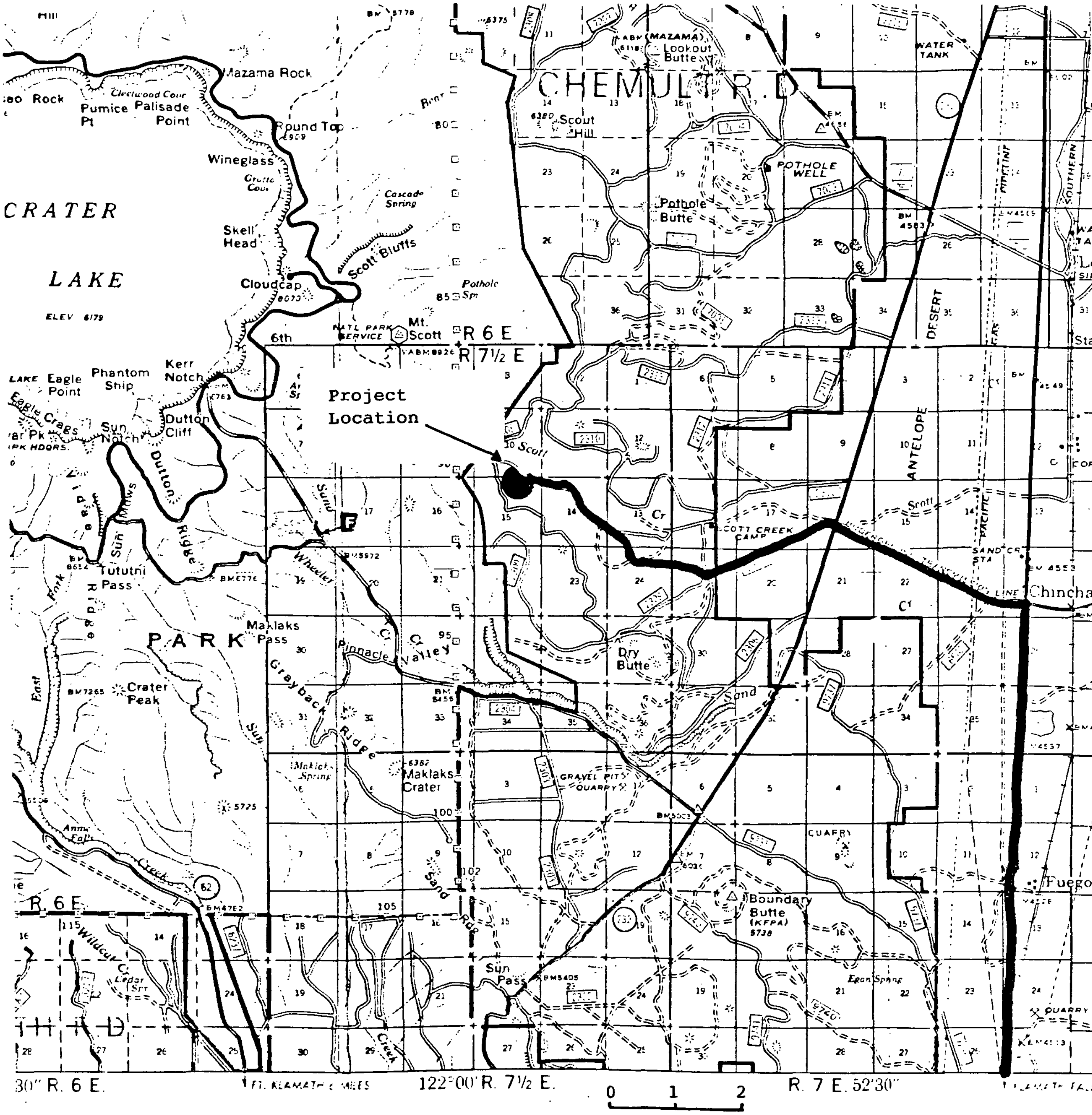
At a February scientific symposium concerning Crater Lake, scientists generally agreed that these contentions are physically impossible. This has been helpful in drawing attention to the real issue of concern at Crater Lake, i.e., lake clarity and the possibility of pollution emanating from park facilities.

The potential geothermal development on Winema National Forest has been the focus of environmental groups concerned about the impact, if any, on the aesthetics of the park. The geothermal developer, CECI, is taking tremendous steps to facilitate public understanding of the projected program. Charles Condy, Chairman of CECI stated: "Our number one concern is the environment and impact which our developments would have upon it. In fact," Condy continued, "our leases with the federal government stipulates that any unacceptable impact would cause a suspension of the project at any stage of exploration, development or production."

As part of its public education program, CECI will sponsor a week long plant simulation in the area of the potential plant site (see attached map) from August 1-6, 1988. Environmental impact consultants will reproduce the sound of an operating 120 megawatt geothermal power plant while also raising several helium-filled weather balloons above tree level at the site. The public is being invited to the site to experience first-hand how far the plant's sound would carry, as well as using park vistas to assess possible visual impacts. Specialists will be on-site to answer questions on the potential project and/or geothermal energy development in general.

-30-

C A L I F O R N I A E N E R G Y C O M P A N Y
2455 BENNETT VALLEY ROAD, SUITE 214-B □ SANTA ROSA, CA 95404 □ (707) 526-1000 □ FAX: (707) 526-0504



POTENTIAL GEOTHERMAL PROJECT LOCATION MAP

7/18/88

NEIL GOLDSCHMIDT
GOVERNOR

OFFICE OF THE GOVERNOR
STATE CAPITOL
SALEM, OREGON 97310-1347

January 19, 1988

The Honorable Donald P. Hodel
Department of Interior
Interior Building
Washington, D.C. 20240

Dear Don:

Geothermal development proposed near Crater Lake National Park is an issue critical to Oregon. The unique beauty of Crater Lake and its caldera are of importance to the State of Oregon economically and as part of our natural heritage.

While geothermal power will play a role in Oregon's energy future, conflicting uses may preclude particular locations. This clearly is the case on the flanks of Crater Lake National Park.

The Park Service is currently studying whether hot water at the geothermal drilling site may affect the lake water of Crater Lake. It may be a long time before we know whether there is direct linkage or not. Recent research results from Oregon State University identify thermal vents in the lake. This certainly suggests a linkage is possible.

Of greater concern to me is the major industrial development a geothermal power plant on the flanks of the Crater Lake caldera would represent. It would adversely impact the beauty and serenity of the Park, especially the experience of East Rim Drive and Mount Scott. Steam plumes, noise, and the visual impacts of a major power plant should not be allowed this close to the Park.

I urge you to cease further leasing in the vicinity of Crater Lake National Park. I further urge you to limit new drilling on current leases to areas removed as far as possible from the Park.

Fairness to the geothermal industry dictates that clear signals of areas off-limits to development ought to be sent before large exploration expenditures are made. Now is the time for such direction.

Sincerely,

Neil Goldschmidt
Governor

NG:tjp/7361o(f3)

cc: Oregon Congressional Delegation

United States Department of the Interior

GEOLOGICAL SURVEY

Office of Earthquakes, Volcanoes and Engineering
Mail Stop 910
345 Middlefield Road, Menlo Park, California 94025

30 October 1987

MEMORANDUM

To: Pamela A. Matthes, Policy and Regulations Section, National Park Service

From: Robert L. Christiansen *Terry C.C. Keith for RLC*
Coordinator, Geothermal Research Program

Subject: Response to request for comments on the preliminary Collier-Dymond report on Crater Lake

The U.S. Geological Survey has reviewed the report "Studies of Hydrothermal Processes in Crater Lake: a Preliminary Report of Field Studies Conducted in 1987 for Crater Lake National Park" authored by Robert Collier and Jack Dymond of Oregon State University. The report is a carefully written document that outlines the observations and data obtained by Oregon State University in 1987 and presents reasonable interpretations. The report adds support to the hypothesis of thermal features at the bottom of Crater Lake but does not provide unequivocal proof of their existence.

The new Oregon State University data can be explained either by a small inflow of hot water or by a larger inflow of water at temperatures too low to qualify as a thermal feature as defined by the U.S. Geological Survey (10°C above mean annual temperature).

Additional data needed to resolve this uncertainty are fluid samples and temperatures from several of the discharging vents observed visually.

cc: Herrmann
Klick ✓

December 22, 1987

J. Steven Griles, Assistant Secretary
Land and Minerals Management
Department of the Interior
C and 19th Streets
Washington D.C. 20240

Re: Senate Bill S. 1006 and "Significant Thermal Features" determination for Crater Lake

Dear Mr. Griles:

Thank you for your letter of November 19, 1987, responding to my letters of September 24, 1987 and October 20, 1987, regarding my concerns about draft Senate Bill S.1006 and "Significant Thermal Features" determination for Crater Lake (pursuant to Section 115 of Public Law 99-591).

I would appreciate being kept informed of any significant progress or new developments regarding the above-referenced issues.

With respect to S.1006, has the Department had the opportunity to address any of our concerns regarding certain provisions of the Bill relating to the "Significant Thermal Features" issue? Please inform me if and when any provisions of the Bill are either eliminated or modified which would have any potential effect on Section 115 of Public Law 99-591, as proposed in the draft which I previously submitted to you for review.

In your recent letter to me you mentioned that the additional studies conducted last summer at Crater Lake were intended to facilitate a final determination by your department whether a significant thermal feature is present. Your letter informed us that a summary report of those studies was being reviewed by your department and the USGS, and that the USGS, Division of Water Resources, Portland, Oregon would also be providing review input. We have received from the Department of Interior a copy of the summary report and a brief memo of comment from the USGS, Menlo Park, but we have not received copy of comments from the above mentioned field office. If comments from that branch agency of the USGS is available, we would appreciate a copy for our files. We believe that the Portland Office of the USGS can provide highly qualified expertise through personnel who are intimately knowledgeable of the geochemistry of waters in the region and we applaud your decision to involve them in this issue.

We do regret that our senior geologist, Joe La Fleur, cannot be involved in the review process as he has a highly qualified background in geothermal systems as well as in low temperature geochemical processes and has been studying Crater Lake specifically for six years. In light of this omission, we would like to take this opportunity to attach a few comments from our in-house review of the Oregon State University Summary Report (enclosed).

Very truly yours,

Phillip H. Essner
V.P. Land & Permitting

Enclosure

cc: Dalas Peck, U.S. Geological Survey, Ms 101, National Center, Reston, Va 22092
Karl Duscher, BLM, Branch Chief, Leasing Management and Resource Evaluation

CALIFORNIA ENERGY COMPANY
3333 MENDOCINO AVENUE, SANTA ROSA, CA 95401 (707)526-1000 TELEX II: 510-744-2088

CALIFORNIA ENERGY COMPANY, INC.
COMMENTS ON
OREGON STATE UNIVERSITY SUMMARY REPORT and USGS REVIEW

Our in-house review of the summary report has impressed us with the fact that an intense search of the suspect area (see Attachment No. 1) failed to identify or locate any hydrothermal vents. Although a highly sensitive thermometer and video camera were deployed repeatedly, the maximum reported temperature was about 3.6°C and the magnitude of anomalous temperature reported was again about 0.1°C. This temperature variation is two orders of magnitude lower than the USGS definition of thermal (10°C above annual mean temperature). Although the summary report was considered by USGS, Menlo Park to add support to the hypothesis of thermal features at the bottom of Crater Lake, it should be recognized that the negative results of such an intensive (and costly) search provides negative evidence regarding the factual existence of such features. The minor water temperature increase (0.1°C) on the lake bottom was uniform along the whole 300 meter length of profile across the suspect area (see Attachment No. 2). Williams and Von Herzen, 1983, observed this small temperature increase on the same area of lake bottom, to be essentially uniform over the distance of approximately 3km (3,000 meters). This uniformity does not support the concept of thermal fluids flowing away from a vent site. It does support the concept of conductive heating to the lake bottom. We are puzzled why the USGS has never addressed that more reasonable interpretation.

This approximately 0.1°C temperature increase on bottom has been observed in other deep areas of the lake (Williams, and Von Herzen, 1983, and Thornton, E.B., 1965). Thorton, 1965, attributed the slight deep water temperature increase to adiabatic compression and also suggested that terrestrial heat flow might contribute to the observation.

The summary report repeatedly mentions that "hydrothermal deposits" were observed, and describes the observations as precipitates of iron. Since iron mineralization is more common in cold ground waters we believe it inappropriate to arbitrarily attribute these observations to thermal water input without accompanying temperature measurements. We are confident that the Portland branch office of the USGS can advise you on the significance of iron deposition.

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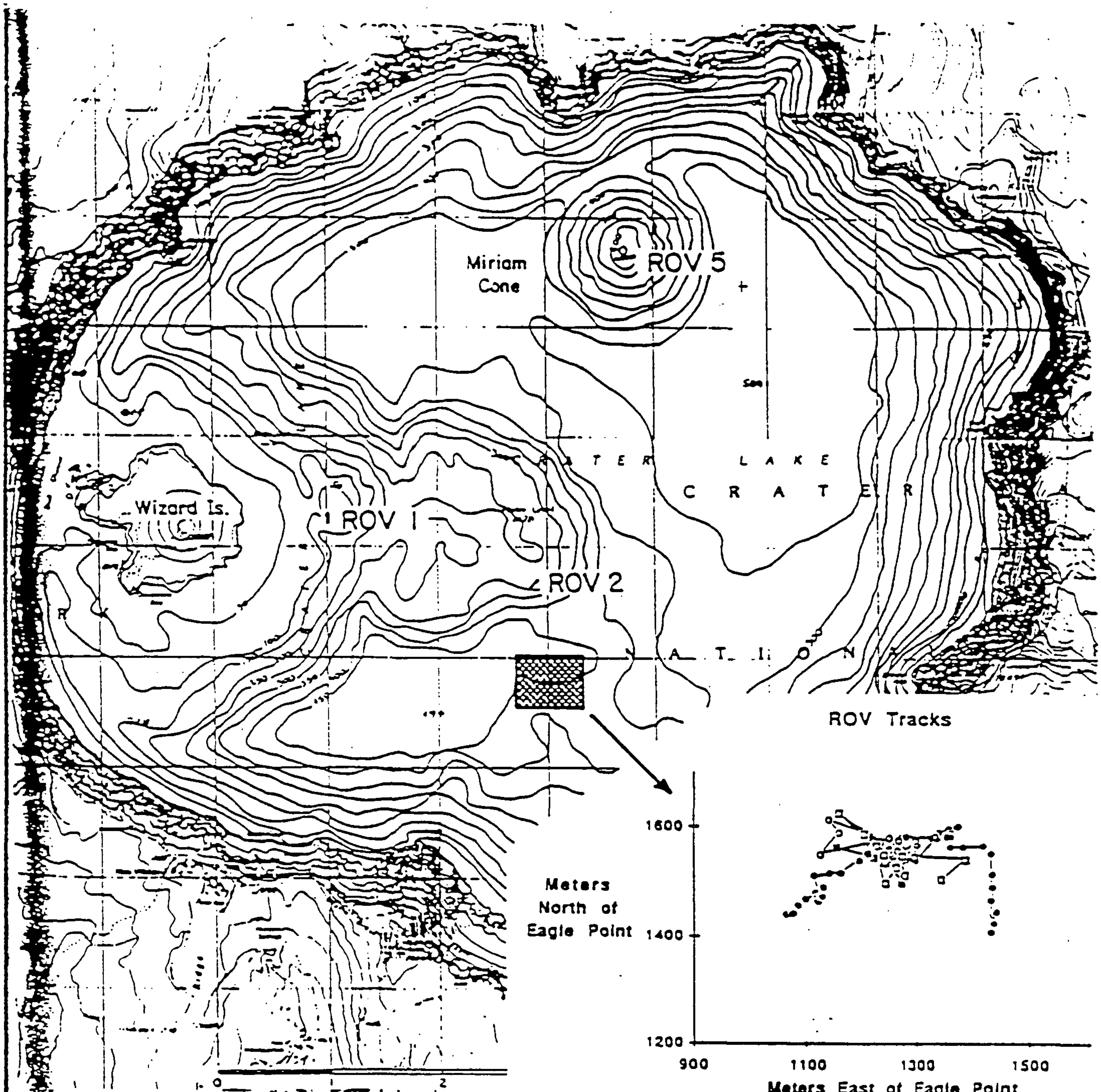

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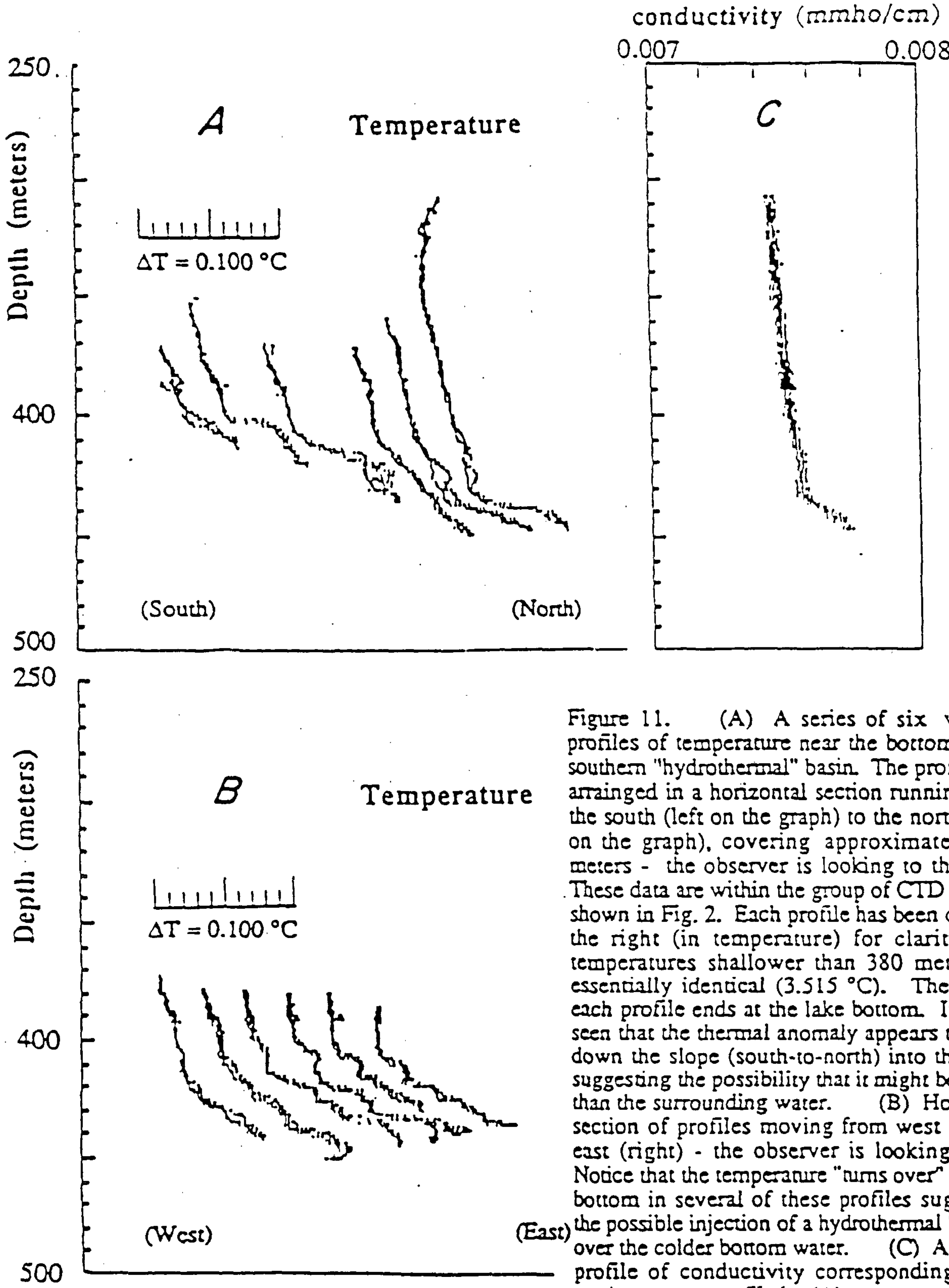
Attachment No. 1

(from Summary Report)



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THE OREGONIAN, THURSDAY, AUGUST 13, 1987

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of The Oregonian staff

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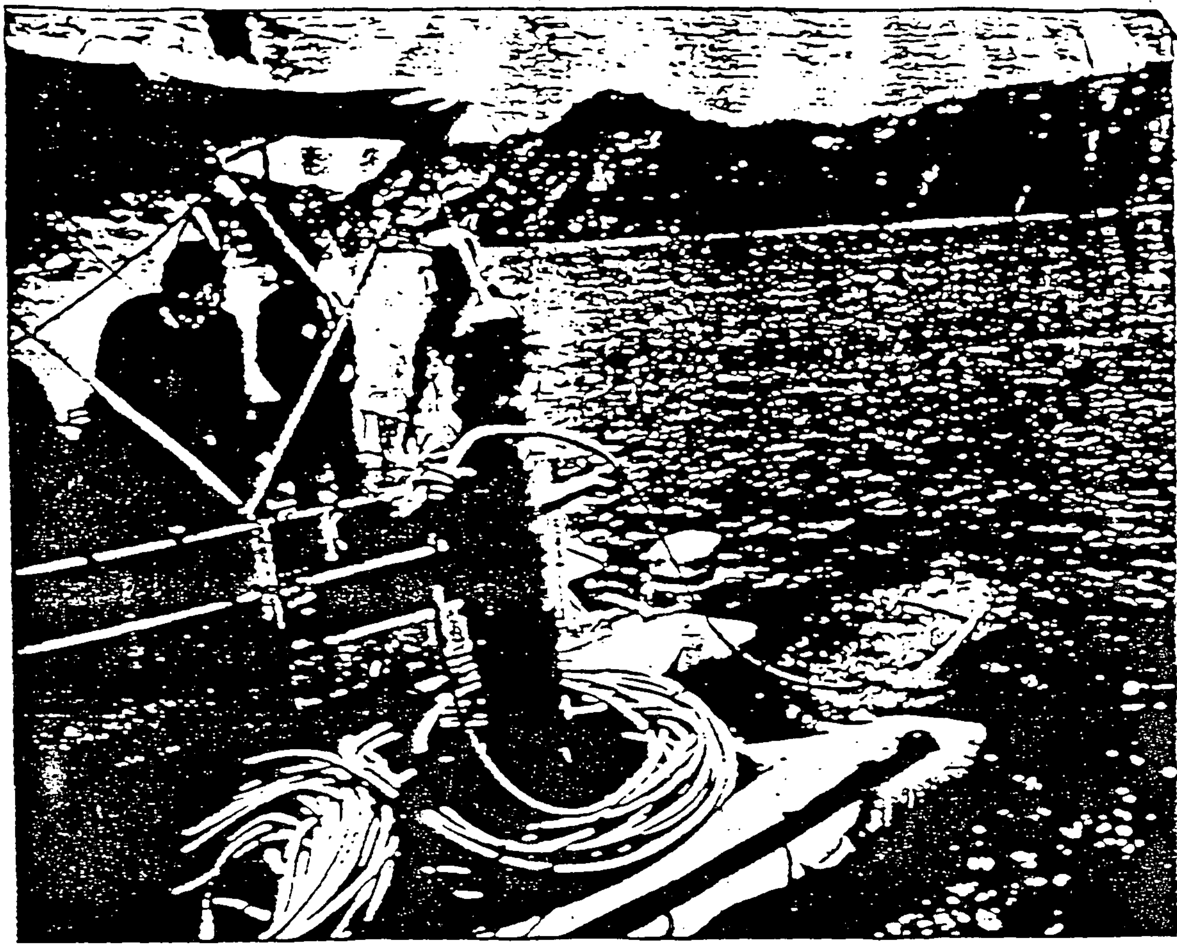

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Scientists photograph what they think are hot springs in Crater Lake with video camera

Hot springs seen in Crater Lake

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Attachment No. 4

Form 1120-7
(January 1983)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

PUBLICITY RECORD

Newspaper and Location	Section and Page Number	Date of Publication
Medford Mail Tribune, Medford, OR	3 A	8/13/87
Submitting Office		**Date sent to WO-130**
OR-010		

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Associated Press Writer

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Bob Benton points to spot that may be the site of geothermal venting.

Attachment No. 5

December 22, 1987

J. Steven Griles, Assistant Secretary
Land and Minerals Management
Department of the Interior
C and 19th Streets
Washington D.C. 20240

Re: Senate Bill S. 1006 and "Significant Thermal Features" determination for Crater Lake

Dear Mr. Griles:

Thank you for your letter of November 19, 1987, responding to my letters of September 24, 1987 and October 20, 1987, regarding my concerns about draft Senate Bill S.1006 and "Significant Thermal Features" determination for Crater Lake (pursuant to Section 115 of Public Law 99-591).

I would appreciate being kept informed of any significant progress or new developments regarding the above-referenced issues.

With respect to S.1006, has the Department had the opportunity to address any of our concerns regarding certain provisions of the Bill relating to the "Significant Thermal Features" issue? Please inform me if and when any provisions of the Bill are either eliminated or modified which would have any potential effect on Section 115 of Public Law 99-591, as proposed in the draft which I previously submitted to you for review.

In your recent letter to me you mentioned that the additional studies conducted last summer at Crater Lake were intended to facilitate a final determination by your department whether a significant thermal feature is present. Your letter informed us that a summary report of those studies was being reviewed by your department and the USGS, and that the USGS, Division of Water Resources, Portland, Oregon would also be providing review input. We have received from the Department of Interior a copy of the summary report and a brief memo of comment from the USGS, Menlo Park, but we have not received copy of comments from the above mentioned field office. If comments from that branch agency of the USGS is available, we would appreciate a copy for our files. We believe that the Portland Office of the USGS can provide highly qualified expertise through personnel who are intimately knowledgeable of the geochemistry of waters in the region and we applaud your decision to involve them in this issue.

We do regret that our senior geologist, Joe La Fleur, cannot be involved in the review process as he has a highly qualified background in geothermal systems as well as in low temperature geochemical processes and has been studying Crater Lake specifically for six years. In light of this omission, we would like to take this opportunity to attach a few comments from our in-house review of the Oregon State University Summary Report (enclosed).

Very truly yours,

Phillip H. Essner
V.P. Land & Permitting

Enclosure

cc: Dalas Peck, U.S. Geological Survey, Ms 101, National Center, Reston, Va 22092
Karl Duscher, BLM, Branch Chief, Leasing Management and Resource Evaluation

CALIFORNIA ENERGY COMPANY, INC.
COMMENTS ON
OREGON STATE UNIVERSITY SUMMARY REPORT and USGS REVIEW

Our in-house review of the summary report has impressed us with the fact that an intense search of the suspect area (see Attachment No. 1) failed to identify or locate any hydrothermal vents. Although a highly sensitive thermometer and video camera were deployed repeatedly, the maximum reported temperature was about 3.6°C and the magnitude of anomalous temperature reported was again about 0.1°C. This temperature variation is two orders of magnitude lower than the USGS definition of thermal (10°C above annual mean temperature). Although the summary report was considered by USGS, Menlo Park to add support to the hypothesis of thermal features at the bottom of Crater Lake, it should be recognized that the negative results of such an intensive (and costly) search provides negative evidence regarding the factual existence of such features. The minor water temperature increase (0.1°C) on the lake bottom was uniform along the whole 300 meter length of profile across the suspect area (see Attachment No. 2). Williams and Von Herzen, 1983, observed this small temperature increase on the same area of lake bottom, to be essentially uniform over the distance of approximately 3km (3,000 meters). This uniformity does not support the concept of thermal fluids flowing away from a vent site. It does support the concept of conductive heating to the lake bottom. We are puzzled why the USGS has never addressed that more reasonable interpretation.

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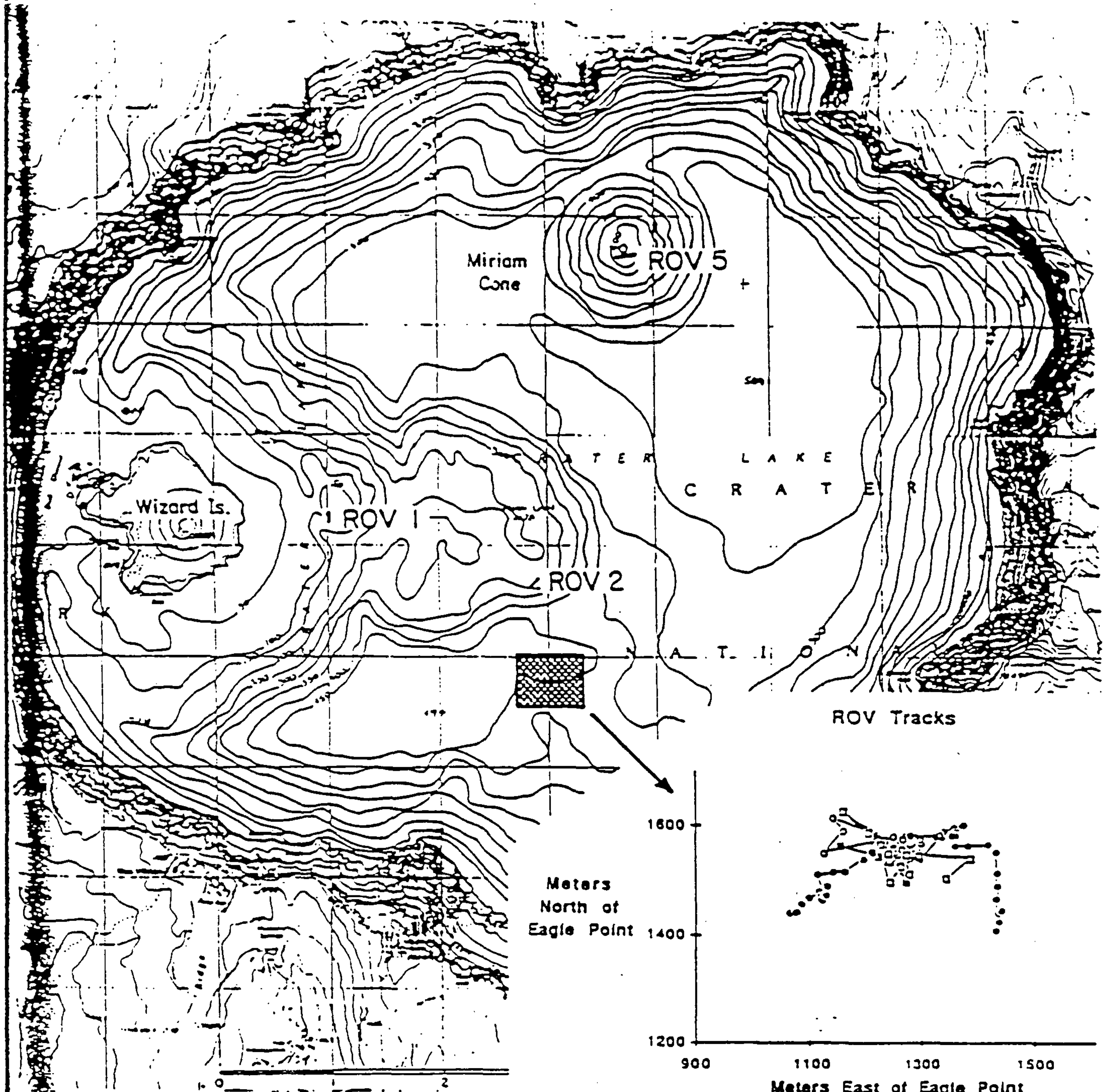

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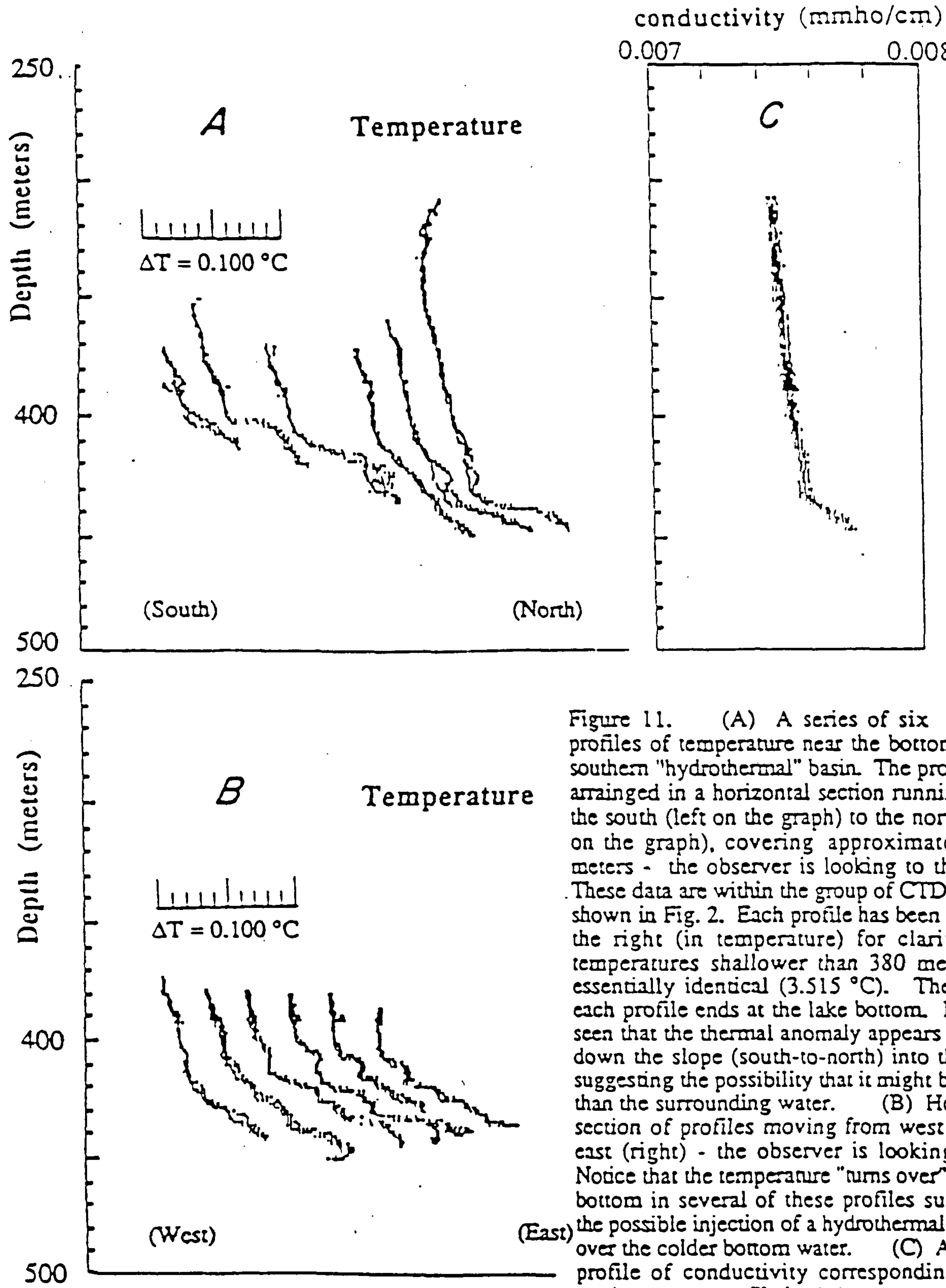

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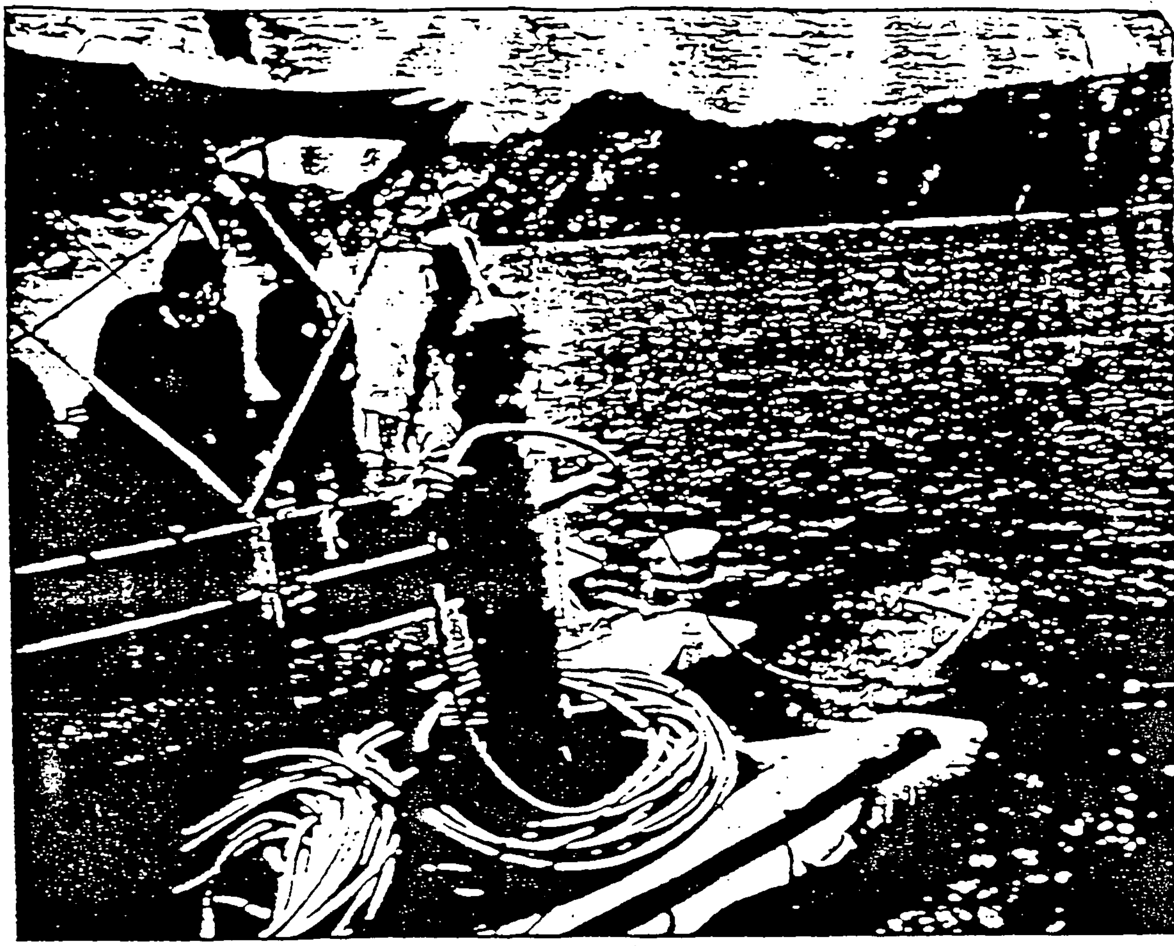

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Form 1120-7
(January 1983)

UNITED STATES
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Newspaper and Location	Section and Page Number	Date of Publication
Medford Mail Tribune, Medford, OR	3 A	8/13/87

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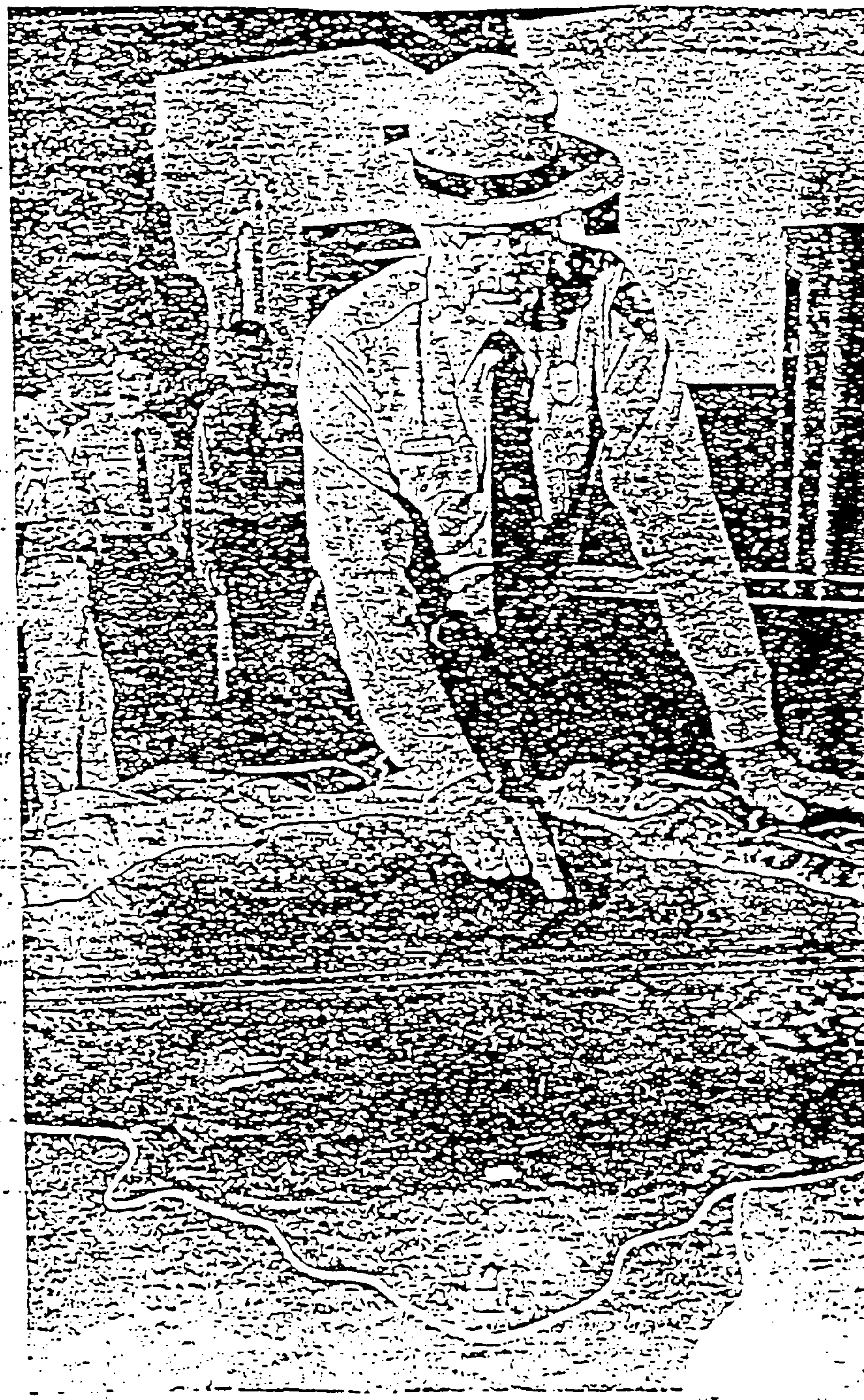

Bob Benton points to spot that may be the site of geothermal venting.

Attachment No. 5

Minisub to Explore Crater Lake Depths In Effort to Halt Geothermal Testing

By Tom Towslee
United Press International

CRATER LAKE, Ore. — The National Park Service is bringing in a minisub as part of a high-tech search for scientific evidence to thwart development of geothermal wells near one of the world's natural wonders — the nearly 7,000-year-old Crater Lake.

Beginning Monday, a scientific expedition financed by the Park Service will use the one-man minisub Deep Rover to probe the bottom of the volcano-created lake — the deepest in North America — for "vents" they hope will end geothermal exploration just outside Crater Lake National Park.

The vents, the scientists believe, pump hot water into the bottom of the lake and are connected to surrounding underground reservoirs of hot water by an elaborate subterranean plumbing system that would be thrown out of kilter by extensive commercial development.

"I feel the existence of hot springs is the only hypothesis that answers all the questions," said Jack Dymond, a Oregon State University oceanography professor, who will take turns piloting the submersible on a series of 20 dives during August.

Last year, Dymond and fellow scientist Robert Collier used an unmanned, remote-control camera similar to the one used to explore the wreck of the Titanic to comb the lake bottom.

They found a vent emitting a milky-white substance, but were unable to measure the temperature of the water coming out of the vents or take samples.

If the minisub substantiates that the lake bottom and hot springs outside the park are connected, it will give the Park Service ammunition to have the Interior Department add Crater Lake to a list of national parks where geothermal development should be restricted.

"We don't know if what they [geothermal developers] have planned will affect the lake," said park superintendent Bob Benton, "but the law orders us to protect the park and we view with concern anything that might screw it up."

Crater Lake was created 6,850 years ago when Mount Mazama exploded in a fiery volcanic eruption that collapsed the top into a caldera that filled with water, forming a lake 1,932 feet deep that has the clarity of distilled water.

It was discovered by gold miners in the 1850s and designated a national park — the only one in Oregon — in 1902. Each year, 500,000 tourists visit the 160,000-acre park on the southern Cascade Range, 200 miles southeast of Portland.

The geothermal activity around the lake is the result of underground springs of water turned boiling hot by molten rock deep beneath the Earth's surface.

California Energy Co. of Santa Rosa, Calif., has leased more than 76,000 acres of state and federal land on three sides of the park, with plans to drill test holes to determine the extent of the area's geothermal resource.

The interest by California Energy prompted Congress to pass legislation to protect the lake from any ill effects of geothermal drilling. The measure is now in a House-Senate conference committee.

Also, Gov. Neil Goldschmidt has called on the Interior Department to halt geothermal leasing on federal forest land around Crater Lake.

"The evidence that we have in hand indicates that we are on a resource that is focused on that part of the forest and not tied to something that is part of the lake," said Joe LaFleur, chief geologist for California Energy Co.

He said the company's ultimate plan is to build production wells that feed a geothermal plant to produce electricity to ease an energy deficit predicted to hit the Pacific Northwest early in the next century.

The size of the wells and the extent of the development will depend on the results of nearly two dozen test wells. So far, they have drilled half of one test well.

LaFleur discounts the "plumbing system" theory and claims differences in the ages of the rock and the elevation of the lake make it impossible for the proposed wells and the lake to be connected.

Nevertheless, he believes the Parks Service and the Oregon State University scientists already have made up their minds that the connection exists.

"I'm sure that if they can find the bottom of the lake, they will claim they have evidence of hot springs, but I don't think they could verify it to an objective third party," he said.

"The Park Service has stated to the press that they hope to use this evidence to shut down our projects," he said.

To present its side of the case, LaFleur's company will spend a week conducting demonstrations designed to coincide with the arrival of the minisub and show that geothermal wells are neither loud nor obtrusive.

Minisub to Explore Crater Lake Depths In Effort to Halt Geothermal Testing

By Tom Towslee
United Press International

CRATER LAKE, Ore. — The National Park Service is bringing in a minisub as part of a high-tech search for scientific evidence to thwart development of geothermal wells near one of the world's natural wonders — the nearly 7,000-year-old Crater Lake.

Beginning Monday, a scientific expedition financed by the Park Service will use the one-man minisub Deep Rover to probe the bottom of the volcano-created lake — the deepest in North America — for "vents" they hope will end geothermal exploration just outside Crater Lake National Park.

The vents, the scientists believe, pump hot water into the bottom of the lake and are connected to surrounding underground reservoirs of hot water by an elaborate subterranean plumbing system that would be thrown out of kilter by extensive commercial development.

"I feel the existence of hot springs is the only hypothesis that answers all the questions," said Jack Dymond, a Oregon State University oceanography professor, who will take turns piloting the submersible on a series of 20 dives during August.

Last year, Dymond and fellow scientist Robert Collier used an unmanned, remote-control camera similar to the one used to explore the wreck of the Titanic to comb the lake bottom.

They found a vent emitting a milky-white substance, but were unable to measure the temperature of the water coming out of the vents or take samples.

If the minisub substantiates that the lake bottom and hot springs outside the park are connected, it will give the Park Service ammunition to have the Interior Department add Crater Lake to a list of national parks where geothermal development should be restricted.

"We don't know if what they [geothermal developers] have planned will affect the lake," said park superintendent Bob Benton, "but the law orders us to protect the park and we view with concern anything that might screw it up."

Crater Lake was created 6,850 years ago when Mount Mazama exploded in a fiery volcanic eruption that collapsed the top into a caldera that filled with water, forming a lake 1,932 feet deep that has the clarity of distilled water.

It was discovered by gold miners in the 1850s and designated a national park — the only one in Oregon — in 1902. Each year, 500,000 tourists visit the 160,000-acre park on the southern Cascade Range, 200 miles southeast of Portland.

The geothermal activity around the lake is the result of underground springs of water turned boiling hot by molten rock deep beneath the Earth's surface.

California Energy Co. of Santa Rosa, Calif., has leased more than 76,000 acres of state and federal land on three sides of the park, with plans to drill test holes to determine the extent of the area's geothermal resource.

The interest by California Energy prompted Congress to pass legislation to protect the lake from any ill effects of geothermal drilling. The measure is now in a House-Senate conference committee.

Also, Gov. Neil Goldschmidt has called on the Interior Department to halt geothermal leasing on federal forest land around Crater Lake.

"The evidence that we have in hand indicates that we are on a resource that is focused on that part of the forest and not tied to something that is part of the lake," said Joe LaFleur, chief geologist for California Energy Co.

He said the company's ultimate plan is to build production wells that feed a geothermal plant to produce electricity to ease an energy deficit predicted to hit the Pacific Northwest early in the next century.

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May 22, 1986

Dr. John C. Eichelberger
Geochemistry Division 1543
Sandia National Labs
Albuquerque, New Mexico 87185

Dear John:

In light of some of the comments at the LBL meeting concerning the level of information on the Cascades Drilling Program that is available to the scientific community, I have prepared the attached description for publication in EOS. I have also sent a copy to AGU Headquarters. Please contact me with any comments.

Regards,

Dennis L. Nielson
Associate Director

cc: S. M. Prestwich
M. J. Reed
P. M. Wright

DLN:leo

DEPARTMENT OF ENERGY CASCADES GEOTHERMAL GRADIENT DRILLING

The U. S. Department of Energy has established a program of cooperative drilling with industry to investigate the geothermal potential of the Cascades volcanic province. Young volcanism and the association of high-temperature geothermal systems with similar geologic environments on a world-wide basis have focused preliminary exploration efforts on the province. However, few deep holes have been drilled, and much of the data accumulated is not in the public domain. This program is designed to provide fundamental scientific data on the Cascades which will be of use for both industry and basic science. At the present time, one 4000 foot corehole has been drilled on the southern flank of Newberry volcano, in Deschutes County, Oregon. Another corehole is planned for the northern flank of Newberry, and it will also be cored to a depth of 4000 feet. The third hole under the present program will be cored to a depth of 5000 feet near Breitenbush Hot Springs in Marion County, Oregon. A fourth hole will be drilled at Blue Lake to the east of Santiam Pass in Jefferson County. This hole will be drilled to a depth of 4000 feet with core collected between 3000 feet and 4000 feet. Altogether, these holes will provide a sampling of a shield volcano, the High Cascades province, and the boundary between the High Cascades and the Western Cascades provinces.

N-1, drilled by GOE Operator Corp., is the fourth hole into the Newberry volcanic pile for which all data are in the public domain. The corehole is located along the southern rift about three kilometers south of the summit caldera. It was drilled to test the depth of the "rain curtain", the downward and lateral flow of meteoric water which is thought to obscure thermal anomalies associated with Cascade volcanos. The thermal profile of the hole shows that the downward flow of meteoric water depresses the temperature profile to a depth of 1000 meters. Below this zone the temperature gradient is high to the bottom of the hole. The well has achieved its objective of documenting the extent of cold water overflow and the efficiency with which it masks the thermal anomaly of the Newberry magma-hydrothermal system. The well has been cased and is available for scientific measurements for one year.

Persons interested in this project should contact either Mike Wright or Dennis Nielson at the University of Utah Research Institute, (801) 524-3422 or Susan Prestwich at DOE/Idaho Falls, (208) 526-1147 or Marshall Reed at DOE/Washington, D.C. (202) 252-8076. Core and data from these holes will be open filed at the University of Utah Research Institute.