UNITED STATES
NUCLEAR REGULATORY COMMISSION
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SUBJECT: TRIP REPORT ON INFORMAL MEETINGS WITH DOE AND CVTS VOLCANOLOGISTS, AND YUCCA MOUNTAIN SITE VISIT

On February 8-10, 1993, I travelled to Las Vegas, Nevada for informal meetings with the leading researchers on volcanism in the Yucca Mountain area. In addition, I was given a tour of the Yucca Mountain vicinity by Phil Justus of the On-Site Representatives Office. Dr. Justus accompanied me during the two days of informal meetings, as did Charles Connor of the Center for Nuclear Waste Regulatory Analyses (CNWRA). The primary purposes of this trip were to gain an understanding of the status of site characterization activities related to volcanism in the southern Basin and Range, and to familiarize myself with the Yucca Mountain site. The two days of discussions with DOE and Center for Volcanic and Tectonic Studies (CVTS) scientists were largely interactive, though informal presentations were made by these scientists for the benefit of NRC and CNWRA participants.

This trip was extremely beneficial to my understanding of the volcanic history surrounding Yucca Mountain. It was truly an ideal situation being able to discuss, in a small group setting, some of the scientific questions surrounding Yucca Mountain. The trip highlights are as follows:

- Bruce Crowe indicated he will carry multiple geochronologic and tectonic models forward to licensing.
- Crowe stated that secondary, or hydrothermal effects, may be the most serious volcanism-related consequence to a repository.
- On behalf of Greg Valentine, Crowe stated the opinion that it is impossible to constrain the issue of eruption explosivity.
- In the forthcoming technical exchange on volcanism, Crowe wants to see if DOE's logic will stand on certain volcanism questions so efforts can be shifted to more important issues.

- Chuck Connor discussed his preliminary calculations of repository disruption probability, and he stressed the importance of constraining volatile contents in Crater Flat magmas.

- CVTS research staff believe that Crater Flat magmas originated in the lithospheric upper mantle.

- CVTS staff believe many cinder cones are polycyclic in nature, and they are making their foray into the Lathrop Wells chronology controversy.

Monday, February 8th was spent at the Los Alamos National Laboratory (LANL) site characterization office in Las Vegas. Bruce Crowe of LANL, the primary investigator in DOE volcanology studies, and Jean Cooper of DOE had planned to guide us on a field trip to the Lathrop Wells cone and cinder cones in Crater Flat, but heavy rain prevented such a trip. Dr. Crowe spoke with us about Yucca Mountain volcanism research all day, allowing plenty of time for our comments and questions. A summary of this interaction follows.

Crowe began by outlining the three study plans relating to volcanism on which LANL is working. This summary was extremely beneficial to Connor and myself, who are newcomers to the high-level waste program. Crowe first addressed study plan 8.3.1.8.5.1, Characterization of Volcanic Features, which is the primary data-gathering study plan. The discussion of task 2 of this plan, geochronology, was most interesting. Crowe outlined the multiple techniques being used to determine the eruptive age(s) of the Lathrop Wells cone (K-Ar, U-Th, He, ^{36}Cl, geomorphology). He suggested that the geochronology community is approaching agreement on the ages of the lava flows surrounding Lathrop Wells (~80,000 years), but the younger cone age is not so well defined. Crowe recognizes the substantial differences in models for Lathrop Wells (monogenetic versus polycyclic), so he plans to carry multiple models through to the license application. Risks will be calculated for all models. On the subject of Lathrop Wells, it was reported in a recent LANL monthly report that the name was changed to the Cind-R-Lite cone. Crowe informed us that the USGS disallowed this change; Lathrop Wells has become the common usage so this name stands.

Task 4 of 8.3.1.8.5.1 looks at the geochemistry of eruptive sequences, particularly sequences such as Lathrop Wells where there is debate over the monogenetic versus polycyclic nature. Crowe reported that Frank Perry of the University of New Mexico is finding geochemical evidence to support a polycyclic origin for Lathrop Wells.

While discussing task 5, evolutionary cycles of basaltic volcanic fields, Connor brought up his ongoing concern that Greg Valentine's (of LANL) models for Crater Flat basalt assume rather low volatile contents. Such assumptions could underestimate the explosiveness of an ascending magma. Magmas can effuse rather passively when volatile content is low, but they erupt explosively when driven by abundant volatile exsolution. As a general rule, more volatiles lead to more violent eruptions, which disrupt a greater volume of surrounding rock near the surface.

The second study plan on which LANL researchers are working is 8.3.1.8.1.1, Probability of Magmatic Disruption of the Repository. Task 1, location and timing of volcanic events, is basically a data analysis which has not begun.

Task 2 is an evaluation of the structural controls of basaltic volcanic activity. Crowe argues for a northwest structural control of volcanic centers near Yucca Mountain, while Gene Smith and coworkers at UNLV support north-northeast structural control. One of the reasons for this disagreement on structural models is the lack of data points (volcanic centers) in this data set. During this discussion Crowe and Cooper gave the NRC and CNWRA representatives advance copies of three figures showing the distribution of volcanic centers and lava volume through space. These preliminary drafts are attached; final copies will appear in DOE's forthcoming volcanism technical report.

Chuck Connor described his calculations which indicate a clustering of volcanic vents within the Crater Flat Volcanic Zone defined by Crowe. Connor said that if one considers only the clusters, the northwest trend is not evident while the north-northeast trend is. As a closing to the discussion on structural control, Crowe stated that in the end no model will be proven as correct. The best DOE can hope for is to compile a catalog of models which cover a reasonable range of possibilities, and carry all of these models forward to licensing.

Task 3 of 8.3.1.8.1.1 investigates the possible presence of molten material at depth. Teleseismic tomography is a useful geophysical tool for this investigation, and previous work by Evans and Smith (1992) of the USGS reveals a low velocity zone in the upper mantle beneath southern Nevada. A plausible scenario, one favored by Evans and Smith, is that this low seismic velocity represents a zone of partial melt. If such is the case, then it implies a potential source of magma lies beneath the Yucca Mountain area. However there are legitimate non-partial-melt interpretations of the low velocity zone. Crowe warned that false positives are common in the realm of seismic tomography, so different data sets and interpretations must be considered and weighed. No mention was made of a supporting document, an appendix to the study plan, which would describe additional geophysical studies to resolve the crustal magma source issue. The study plan states that such a document will be prepared if geophysical data presents evidence for crustal magma bodies.

The discussion turned toward the issue of magma transport and storage, and Connor asked what Crowe sees as the difference between the explosive nature of cinder cones such as Cerro Negro in Nicaragua (chemically quite similar to Crater Flat basalts) and the hypothesized low explosivity of Crater Flat vents. Crowe responded that Crater Flat lavas spent no time residing in crustal-level magma chambers; they came straight from the mantle. There was more discussion about whether explosiveness is restricted to the earliest phases of eruption, those phases most difficult to document. Crowe stated that Greg Valentine feels it is impossible to constrain the issue of eruption explosivity.

Our discussion of task 4, probability calculations and assessment, began with Crowe summarizing the work already published. Connor informed us of his preliminary calculation of disruption probability, which provides a spatial probability map. His probability of site disruption over 10,000 years ranges from 10^{-3} to 10^{-7}, similar to others' previously published work. For reference, Margulies et al. (1992) calculated a value of 1.7×10^{-4}. Again,

Crowe stated that DOE will not rely solely on his own homogeneous Poisson model; this is just one model which will help present a range of values for licensing. No mention was made of weighting models based on expert opinion. The study plan indicates that models will be weighted, but NRC comment 12 on this study plan suggests weighing may not be appropriate.

The third study plan we discussed was 8.3.1.8.1.2, Physical Processes of Magmatism and Effects on the Repository, on which Greg Valentine is the principal investigator. This study plan has not yet been received by the NRC. In short, this investigation will examine possible releases from repository disruption by volcanic activity. The tasks within this study plan differ from those listed in the SCP. The three tasks are 1) eruptive processes, 2) intrusion processes, and 3) magma dynamics. The first two tasks will look at the near-surface physical processes associated with volcanism which could lead to disruption, and the third will investigate magmatic processes all the way from the mantle to the surface. This last task will be accomplished largely through a literature search. Crowe stated DOE's intention to consider the effects of both direct and indirect magmatic hits on a repository. An indirect hit can be considered a magmatic event, either intrusive or extrusive, occurring close to (but not intersecting) a repository such that any attendant hydrothermal activity affects the repository.

After our lunch break, the group reconvened for a less structured discussion about volcanology. Crowe began by presenting in some detail his evidence for polycyclic volcanism at Lathrop Wells. One important question we discussed is the depth, or range of depths, at which a tabular feeder dike reduces aspect ratio to become a cylindrical feeder beneath a cone. Connor reiterated his concern with the issue of volatiles and explosivity. He wondered whether DOE has plans to examine melt inclusions in individual mineral grains to better constrain magma volatile contents. Crowe said there are no such plans. Crowe stated a belief that the secondary, or hydrothermal effects on a repository from indirect hits may be the most serious consequence to consider when assessing performance. It was encouraging to hear this, since an NRC comment on study plan 8.3.1.8.1.1 notes a deficiency of attention to secondary effects. Finally, as a prelude to the DOE/NRC volcanism technical exchange on June 9th, 1993, Crowe said that at that time he wants to see if DOE's logic will stand on certain (unnamed) issues so DOE's efforts can be concentrated on what they feel are more important issues.

As a programmatic note, Crowe plans to return to Los Alamos in August 1993 after serving five years at the Las Vegas office. LANL plans to add another volcanology investigator, and this new hire, Crowe and Greg Valentine will serve as co-principal investigators on the volcanism project. Each will be in charge of one study plan.

On Tuesday, February 9th, Justus, Connor and I spent the day at the CVTS in the geology department of UNLV. In attendance were Gene Smith of UNLV and two new post-doctoral researchers working with Smith at CVTS: Tim Bradshaw and Jim Mills. Much like the previous day, the presentations were informal with interspersed discussion. Tim began by presenting his work on the geochemistry of volcanics in an extensional corridor near Lake Havasu City, south of Las Vegas. He distinguished two types of basalts: those with a lithospheric

(upper mantle) source and those with an asthenospheric (deeper in the mantle) source. The distinction is seen in tantalum and niobium contents; magmas with a lithospheric origin show less enrichment in these elements. Red and Black cones in Crater Flat mimic the lithospheric geochemical signature seen near Lake Havasu, leading Bradshaw to believe Crater Flat melts originated in the lithosphere. There was an extensive group discussion on Crater Flat geochemistry and magma evolution. This served more than just academic purposes, for magma volatile contents and the presence or absence of mid-crustal magma chambers are important factors in understanding eruptive processes.

We engaged in the monogenetic versus polycyclic cinder cone debate, and all present agreed that some cones clearly demonstrate a polycyclic origin. No one had a satisfying answer as to why batches of magma separated by tens of thousands of years erupted from essentially the same location, when such magmas apparently passed directly to the surface from their places of origin in the mantle. Crustal magma chambers probably did not play a role in the Crater Flat and Lathrop Wells eruptions.

Smith presented his reasoning for north-northeast structural control of basaltic vents in the Yucca Mountain area, then Connor explained that his heterogeneous model of spatial distribution does not show a northeast trend to the distribution. Connor suggested that Smith abandon the Area of Most Recent Volcanism (AMRV) concept because the AMRV is nothing more than a series of clusters. Smith cautioned that Lathrop Wells could be the beginning of a new cluster, in which case future eruptions would likely be along a northeast trend from Lathrop Wells- toward Yucca Mountain. Justus raised the point that structural geologists are beginning to investigate the possibility that deep-seated, unseen structures trending northwest may control magma location at a deep level, then upper-level, northeast-trending structures may control the location of volcanic features at the surface. All agreed there are many unknowns about the role of structure in transporting basalt to the surface.

After our lunch break, Mills spoke about his dissertation work on the evolution of the Timber Mountain Tuff. He then discussed the geology of the Hoover Dam quadrangle. Within this quad lies the Black Canyon Dacite, in which Mills found a mantle xenolith. This is significant, for it is believed to be the only mantle xenolith found in Basin and Range lavas south of the Lunar Crater volcanic field. Also within the Hoover Dam quad lie the Fortification Hill Volcanics, 50-60 thin basalt flows which appear to originate from the same vent and feeder dike. These basalts are believed to be about 6 millions years (Ma) old. Fortification Hill is considered by some to be analogous to Crater Flat volcanism, and CVTS staff will continue to work there.

Smith closed out the day discussing strontium and neodymium isotopes in basalts of the southern Basin and Range. These isotopes indicate that prior to 9 Ma, basalts throughout the region were derived from mantle lithosphere. Since 9 Ma, basalts south of the Lake Mead Fault System (LMFS) display an asthenospheric mantle signature while those to the north maintain a lithospheric character. The LMFS is a northeast-trending fault zone passing along the north shore of Lake Mead. Chemical changes south of the LMFS at 9

Ma indicate a thinning of the lithospheric mantle to the south, leading Smith to postulate that the LMFS is a crustal manifestation of a mantle boundary.

In the future, CVTS staff will continue their detailed geochemical analyses of eruptive centers in Crater Flat. They wish to determine the chemical variability within individual centers. The Fortification Hill work will continue, as will isotopic analyses to search for more mantle boundaries (lithospheric versus asthenospheric sources). CVTS will also make its foray into Lathrop Wells chronology by applying uranium-series dating methods to feldspar grains. Connor stated that the absence of historically active volcanoes in the Basin and Range requires research outside this province. He believes active analogs must be investigated for clues to the degassing and hydrothermal processes associated with Crater Flat-type volcanic vents.

In addition to these discussions of the CVTS research, I gave a more formal 20 minute presentation on some of my dissertation work. This talk was given to an audience of approximately 20 people from the UNLV geology department. Crowe and Cooper also attended. The title of the talk, unrelated to NRC work, was "Differentiation within intermediate composition igneous sheets: Costilla Reservoir Sill, New Mexico, and Pine Valley Mountain Laccolith, Utah." There were several questions after the talk.

On Wednesday, February 10th, Phil Justus guided me on a tour of the DOE Field Operations Center and the Yucca Mountain site. Upon our arrival at the FOC we sat in on a portion of an ESF status meeting. We entered late, so there were no formal introductions. The most significant information I received in this meeting is that there is a 75% chance the Tunnel Boring Machine will be built for a 25 foot diameter tunnel. Apparently the tunnel diameter will be uncertain until June 1993.

Justus and I left the meeting before its adjournment and proceeded to the sample management facility. Here we were given a 30 minute tour and briefing on sample management practices by Chris Lewis of SAIC. Justus and I next visited the USGS hydrology facility, where we were hosted by Alan Flint. The staff at this laboratory are gathering vast amounts of data and performing myriad experiments. Their natural infiltration experiments are quite interesting; Phil and I viewed the location for their future experiments adjacent to Fortymile Wash. After a stop at the Yucca Crest lookout, we proceeded to Trench 14 for an examination of the controversial calc-silicate deposits. This was followed by a visit to the LM-300 drill rig. On the way back to the FOC, we examined the fresh-cut face of the future ESF portal. The Tiva Canyon Member is highly fractured here. There are some large lithophysae in the rock at this location, and they often contain zeolites and an unidentified clay. We also noticed at least one minor fault plane extending in a general east-west direction into the cliff face. The cliff face is 20-30 feet high at this time. This was the final stop of the day.

If there are questions regarding this report, I can be reached on 504-3460.

Stephen McDuffie

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Attachment: As stated

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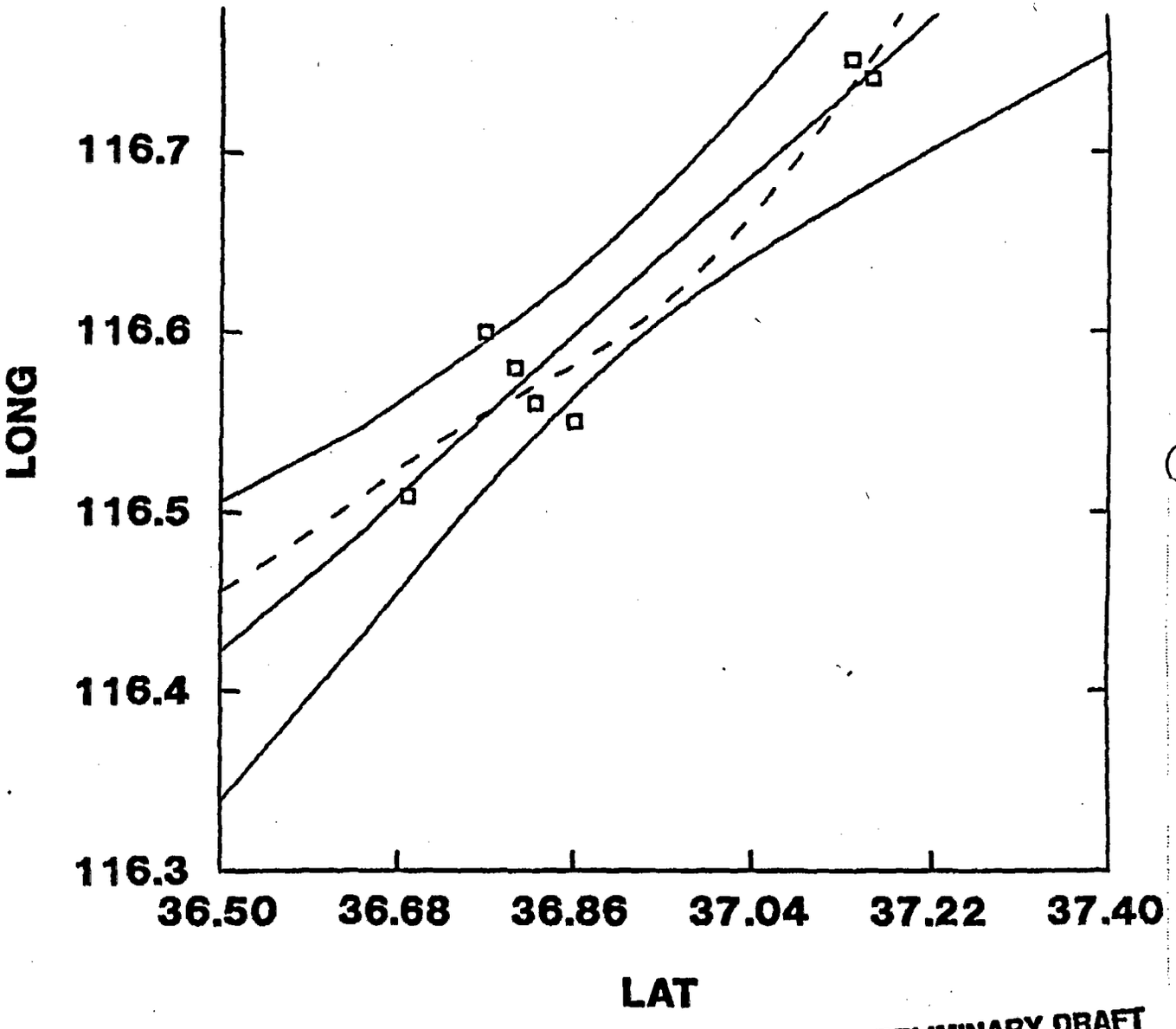

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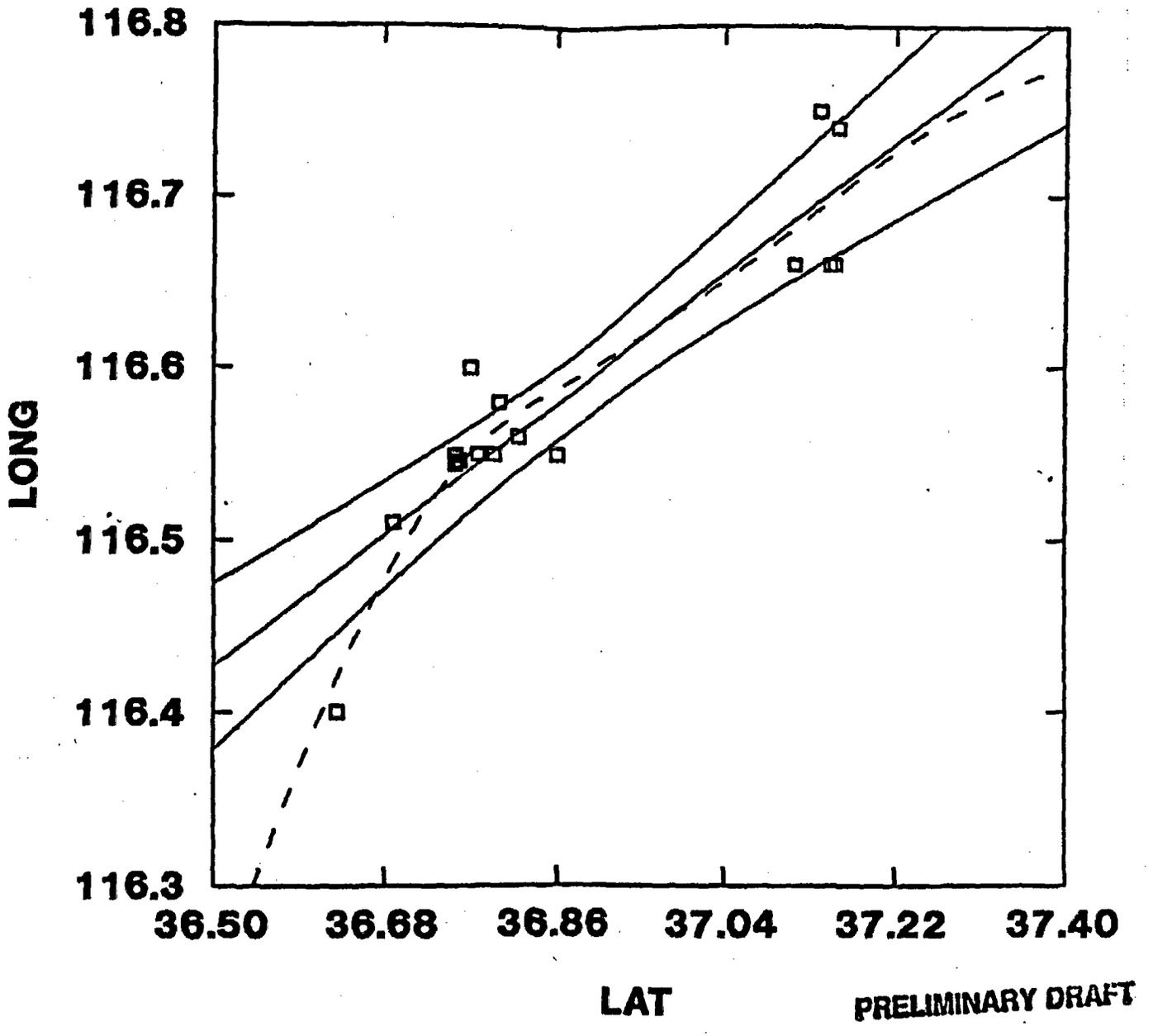
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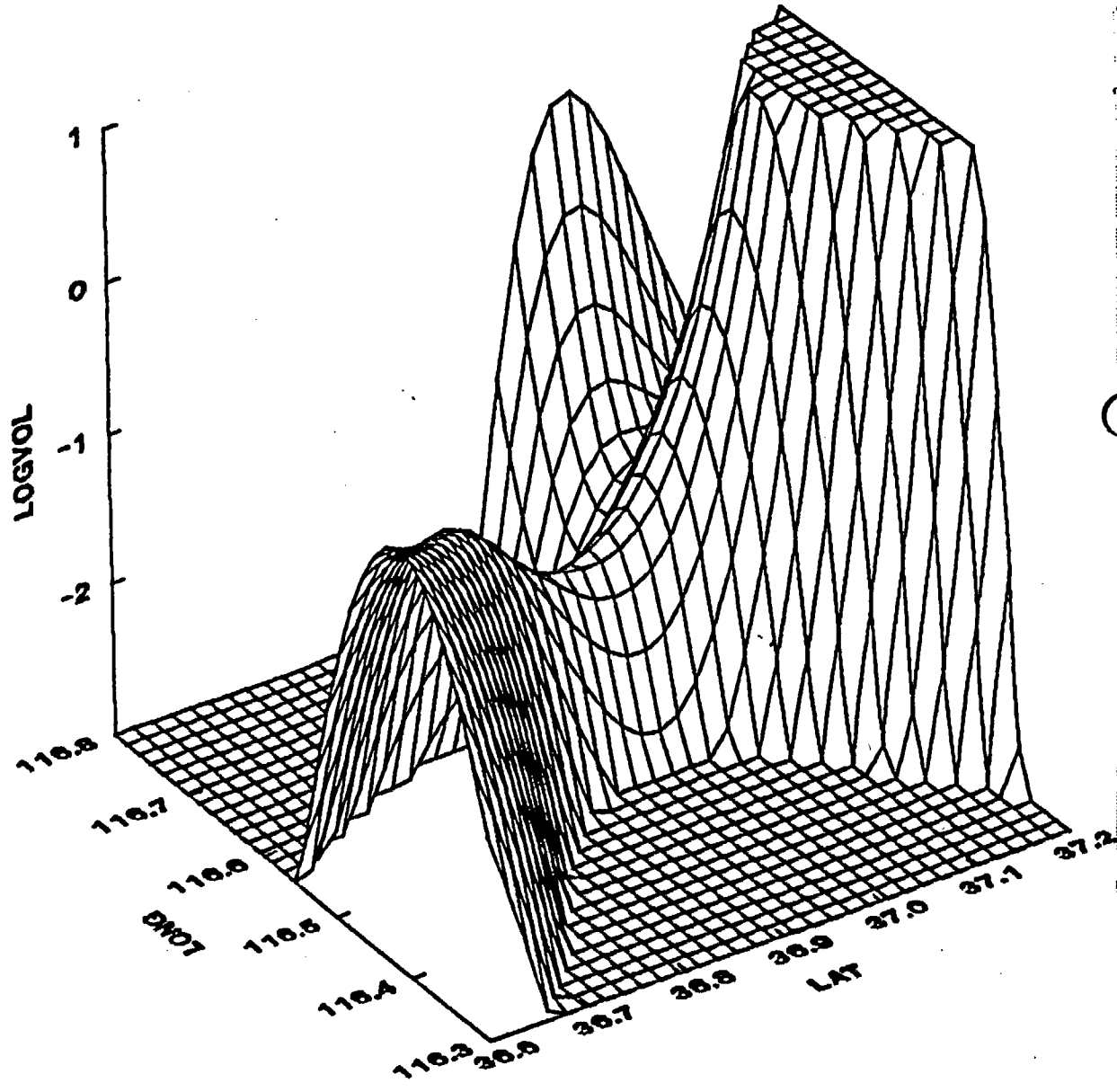

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