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CENTER FOR NUCLEAR WASTE REGULATORY ANALYSES

TRIP REPORT

SUBJECT: Attend the NRC-sponsored workshop on Quaternary Geochronology and Seismic Hazards Assessments. 20-5704-123

DATE/PLACE: March 22, 1994, Holiday Inn, Denver, Colorado

AUTHORS: Brittain E. Hill

PERSONS PRESENT: CNWRA: B.E. Hill; NRC: H. Lefevre. Attendance list attached as appendix A.

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BACKGROUND:

The U.S. Nuclear Regulatory Commission (NRC) currently is reviewing the state-of-the-science in Quaternary geochronology in anticipation of revisions to Federal regulations governing the licensing of nuclear facilities. William Lettis & Associates (WLA) is conducting this review for the NRC, with the goal of producing a detailed report on Quaternary geochronlogic methods at the end of 1994. The workshop was convened to assemble a panel of 10 expert geochronologists to discuss current techniques of Quaternary geochronology and their application to paleoseismology.

SUMMARY OF THE MEETING:

The meeting agenda is attached as appendix B. Discussions of the details for many of these dating techniques can be found in Hill et al. (1993) and Geyh and Schleicher (1990). After introductory remarks by Bill Lettis and Jay Noller (WLA), participants were divided into seven different groups to discuss the state-of-the-science in one of seven major categories of Quaternary geochronology. The groups focused on recent advances that may not be common knowledge, advances possible during the next 5-to-10 years, and the level of confidence assigned to the dating techniques. I participated in the group on thermoluminescence dating, which was headed by Dr. Steven Forman. After about an hour of discussion, the conclusions of each group were presented as follows:

I) ^{14}C dating (S. Trumbore): Recent advances focused on accelerator mass-spectrometry, in which a particle accelerator is used to measure ^{14}C abundances on small samples. Future improvements in the technique will likely involve more specific pre-treatment procedures to isolate the organic material being dated, and a better understanding of the sources of organic C in the sample. Many problems in this technique arise because different labs have different sources of error, which are rarely discussed in detail. In addition, careful sampling is needed in the field, because there are many sources of extraneous organic material which will affect the accuracy of the date. The material being dated also needs to be strongly linked to a seismic event, which is often difficult to determine.

II) K-Ar dating (P. Renne): Most recent advances have been the used of incremental heating on small samples. Instrumentation has improved significantly in the last decade, permitting the analysis of single crystals with high potassium content. Under the best possible conditions (high potassium content, abundant material, no alteration or loss of argon), dates as young as 50 ka are possible. For typical basalt samples, dates of < 500 ka are generally a problem and require especially clean extraction lines and sensitive calibrations. Problems still remain with ^{39}Ar recoil effects during sample irradiation, and proving that the sample was completely degassed of ^{40}Ar prior to closure. Incremental Ar-Ar heating can alleviate the problems of inherited ^{40}Ar.

III) U-series (R. Ku): Recent advances have focused on treating and analyzing carbonate samples with impurities. For the $^{230}Th/^{234}U$ technique, date errors commonly are about 10% for 10^5 year dates, and about 1-3% error for 10^2-10^3 dates. The most common source of error is that the sample inherited some amount of ^{230}Th during formation. By using an internal isochron technique, this problem can be accounted for.

IV) Cosmogenic Isotopes (J. Poths): Recent developments include the in-situ production of ^{14}C in appropriate samples, but this method remains to be tested in detail. Critical sources of error remain in the estimation of isotopic production rates, which vary with latitude, elevation, and sample geometry. For dates < 20 ka, the uncertainty is about 10%, but these dates can generally be calibrated with the ^{14}C time-scale. For dates > 20 ka, production rate uncertainties are about 20-30%. Reducing this uncertainty is a likely goal for the next 5 years. Other errors occur if there is any disturbance of the sample surface, which generally results in an additional 10-20% error. Surficial erosion or burial also is a complicating factor. Basalt samples in the < 100 ka range generally give reasonable ages, but tuffs can be accurately dated to about 10 ka. It is important to remember that these dates are exposure dates, which may not relate to the formation of the deposit or process under investigation.

V) Thermoluminescence (S. Forman): TL dating is a time-consuming technique and only done in a few labs, which has limited the number of tests for the method. TL dates are often controversial, which necessitates presentation of all analytical data. Problems remain in sample selection criteria, particularly in ensuring that the sample has been reset by the process being dated. Exposure to sunlight and heating to above about 300 C are effective ways to reset the TL signal. Samples from soil B-horizons generally yield inaccurate dates. Future work is likely to focus on Optically Stimulated Luminescence, which uses monochromatic light instead of heat to excite electrons to ground-states.

VI) Correlation and Chemical-Biological techniques (J. Noller): Multiple techniques need to be applied before a sample is accurately dated. Most of these techniques rely on calibration with known-age samples, which requires that the samples and calibrations occur in the same geological system. Numerous variables, such as temperature effects, differences in rock chemistry, and microenvironmental regimes, need to be adequately considered. Again, sample selection criteria and analytical data must be presented before the date can be related to a geological age.

VII) Soils and Geomorphology (T. Rockwell): Most recent advances have focused on the ability to accurately quantify soil properties, such as the profile mass of clays, iron and carbonate content, and development indices. Many of these dating techniques are critically dependent on calibration with samples of known age, which are rarely available. Errors generally occur because of important local and regional differences in time-sensitive processes. Soil development is especially sensitive to local effects, such as climate and geomorphology. However, soil development remains a fairly low-precision but high accuracy technique when variables are considered correctly.

The afternoon session focused on more general discussions about the application of these dating techniques to paleoseismology, and on general applications and limitations of these techniques. Some of the more general conclusions of these discussions were:

- Ideally, geochronologists should be involved in the planning and initial stages of the research. Too often, samples are simply submitted to a lab for analysis, with little of the information necessary to optimize the dating technique. It is also preferable that the sample site can be revisited after analysis, in order to resolve potential ambiguities in the dates. This is often difficult in paleoseismology, because sampled trenches rarely remain open for more than a couple of months.

- Geochronology is rarely a simple, isolated study. Ideally, researchers should plan on doing an initial characterization, the main study, and a follow-up study to resolve ambiguities. If appropriate, multiple dating methods should be employed to assess the precision and accuracy of the techniques.

- The appropriate dating technique needs to be used on the deposit or process under investigation. Researchers need to know the strengths, assumptions, and limitations of the dating techniques, in order to accurately sample the deposit and provide all the information necessary for dating analysis.

- There is a universal need to provide the appropriate analytical information, such that a knowledgeable reader can independently assess the precision and accuracy of the reported date and evaluate the relationship between the date and geologic age of the deposit. The assumptions used to relate the date to a geological process also need to be explicitly stated. This is especially true in paleoseismology, when the unique relationship between a seismic event and ensuing marker deposit is not always obvious.

- Peer review is critical towards the general acceptance of many developmental dating techniques. In addition to review by in-house experts and experts in the geochronological technique, generalists also should review the chronologic and geologic data to assess if the date reasonably reflects the age of the process under investigation.

- The Uranium-trend dating technique, which involves the open-system accumulation of U and Th in fine-grained sediments, was not supported by anyone present at the workshop. There are few proponents of this technique, and dates produced by this technique are rarely thought to represent a meaningful age.

IMPRESSIONS AND CONCLUSIONS:

The workshop was an excellent forum for the discussion of modern methods of Quaternary geochronology. Geochronology experts and experienced users were well represented, and the discussion sessions focused on the appropriate topics. Unfortunately, the workshop was only one day long, which was too short a time to discuss many of these topics in detail. However, the goal of this program is to produce a detailed report on these techniques, which will expand upon the topics discussed in the workshop and investigate additional dating techniques that were not generally discussed at the workshop, such as fission-track, rock varnish chemistry, and paleontology.

PENDING ACTIONS:

A final report, which includes the information discussed in the workshop, is planned for December, 1994.

RECOMMENDATIONS:

Participation in geochronology workshops and meetings such as this provides information that is critical to many of the research and technical assistance projects at the CNWRA. Informal interactions with dating experts and experienced users permits frank discussions on the utility and limitations of different dating techniques. Such information is often difficult to glean from the available literature.

PROBLEMS ENCOUNTERED: None significant.

REFERENCES:

Geyh, M.A., and H. Schleicher. 1990. *Absolute Age Determination*. New York, NY: Springer Verlag.

Hill, B.E., B.W. Leslie, and C.B. Connor. 1993. *A Review and Analysis of Dating Techniques for Neogene and Quaternary Volcanic Rocks*. CNWRA 93-018. San Antonio, TX: Center for Nuclear Waste Regulatory Analyses.

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Quaternary Geochronology and Seismic Hazards Assessments

- An NRC-WLA-sponsored workshop

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3/21/94

Quaternary Geochronology and Seismic Hazards Assessments

- An NRC-WLA-sponsored workshop

March 22, 1994 Denver, Colorado

AGENDA

7:30 WARM-UP. Coffee, tea, donuts available. Check in with member of WLA staff to receive workshop materials.

8:00 **INTRODUCTORY REMARKS**

Bill Lettis
- Background and perspective.
- Introductions.

Jay Noller
- Report on status of technical manual and proposed field program.
- Summary of workshop proceedings.

9:00 **WORKSHOP I**

Janet Sowers and Jay Noller
- Introduction of format.
- Group assignments.

Issue One: What is the state-of-the-science in our specialties of Quaternary geochronology?

Suggestions for discussion:
- Identify methods or techniques: standard, new, experimental, and no longer practiced.
- Identify problems: theoretical and practical.
- What advances do you foresee in these methods or techniques in the next 5-10 years?

Issue Two: What level of confidence do we have in age determination for our method?

Suggestions for discussion:
- Identify sources of error.
- Identify most appropriate means of determining and expressing error.
- How does level of confidence vary with age range?

10:00-10:10 BREAK. Refreshments available.

10:10 Reporting I: Each representative presents the groups conclusions and ideas.

11:00 **WORKSHOP II**

Janet Sowers and Jay Noller
- Introduce format.
- New group assignments.

Issue One: What are the major problems in the application of Quaternary geochronologic methods to seismic hazards assessments?

Suggestions for discussion:
- Consider misapplications of methods, misinterpretations of age estimates, and problems in assessment of confidence.
- Are users familiar with the assumptions of the method?
- Are there problems associated with costs and turnaround time?

Issue Two: What solutions can you suggest to the problems identified in Issue 1?

12:00-1:00 LUNCH. In the Aspen/Vail Room.

1:00 Issue Three: What criteria should the NRC use to evaluate geochronologic studies in seismic hazards assessments?

1:30 Reporting II: Each representative presents the groups conclusions and ideas.

3:00 BREAK. Refreshments available.

3:10-5:00 GROUP DISCUSSION.

Bill Lettis and Jay Noller - Discussion leaders
- Informal discussion over refreshments on findings of Workshops I and II.